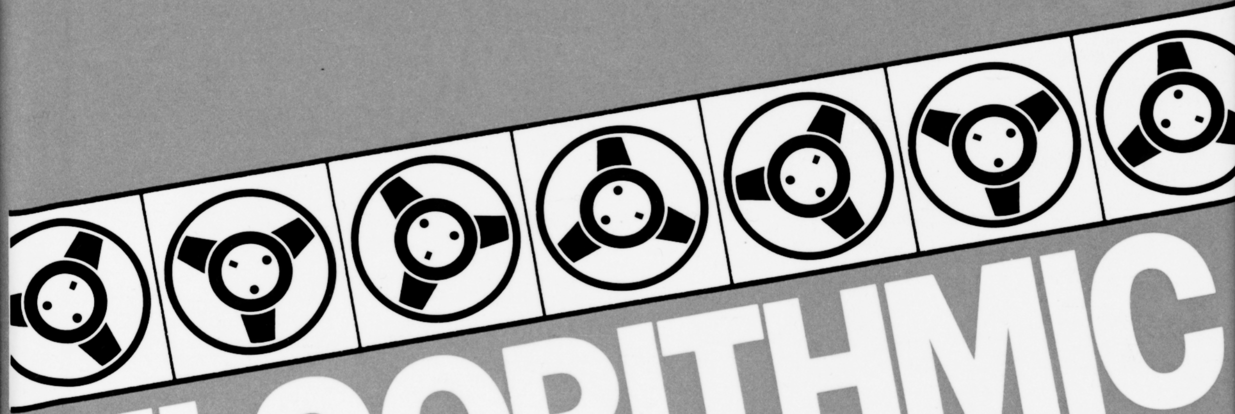

ALGORITHMIC AESTHETICS

COMPUTER MODELS FOR CRITICISM & DESIGN IN THE ARTS

By George Stiny and James Gips

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Computer Models for Criticism and Design in the Arts

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PART I: INTRODUCTION

1
Introduction

Aesthetics is concerned with questions about how existing works of art can be described, interpreted, and evaluated and with questions about how new works of art can be created. The description, interpretation, and evaluation of an existing work of art is called *criticism*. Criticism is taken to include the efforts of any observer to understand and evaluate a work of art, whether or not the observer considers himself a professional critic. The creation of a new work of art is called *design*. Design is taken to include the efforts of any person to produce a work of art, whether or not the person considers himself a professional artist. In this sense, aesthetics is concerned with the philosophy of criticism and design, with the foundations of criticism and design, with questions arising from criticism and design.

This conception of aesthetics is similar, in many respects, to Beardsley's conception of aesthetics as "metacriticism."[1] However, Beardsley conceives aesthetics to be just the philosophy of criticism; we conceive aesthetics to be the philosophy of both criticism and design. Indeed, an important goal of this study is to investigate the relationships and common foundations of criticism and design.

Our approach to aesthetics is novel in that it makes extensive use of the idea of an *algorithm*. An algorithm is an explicit statement of the sequence of operations needed to perform some task. A brief introduction to algorithms is given in the Appendix.[2]

[1] M. Beardsley, *Aesthetics* (New York, 1958), pp. 3-4.
[2] See also D. Knuth, "Algorithms," *Scientific American* (April 1977).

We begin our investigation of aesthetics by postulating a structure for algorithms for criticizing or designing works of art. This structure fixes both the basic components of criticism algorithms and design algorithms and the relations of these components. Issues in aesthetics are investigated in terms of the structure postulated for criticism algorithms and design algorithms.

The main aesthetic concepts used in the postulated structure for both criticism algorithms and design algorithms are description, interpretation, and evaluation. Each of these concepts is given a precise definition in terms of the components of the algorithms.

Description, interpretation, and evaluation also play a central role in more traditional investigations of aesthetics such as Beardsley's. Beardsley is concerned with the classification of statements made by critics about works of art as "critical descriptions," "critical interpretations," and "critical evaluations,"[3] the analysis of these statements, and their justification. In contrast, we are concerned with how algorithms that generate descriptions, interpretations, and evaluations of works of art can be constructed and with how these algorithms can be used to investigate issues in aesthetics.

The postulated structure for criticism algorithms and design algorithms is used in three ways to formulate and investigate questions in aesthetics.

First, the components of these algorithms are considered as black boxes or (mathematical) functions. Here, only the input-output relations of the components are important and not the specific content of the inputs and outputs or the actual internal workings of the components. Questions in aesthetics that are investigated in this way pertain to, for example,

> the logical nature of the description, interpretation, and evaluation of a work of art in criticism and design and their relationships,
>
> the distinguishability of multiple copies or performances of a work of art or of the original and forgeries of a work of art,
>
> the basic tasks of criticism and design and their relationships, and

[3] M. Beardsley, *Aesthetics*, pp. 7-10. Beardsley uses the terms "description" and "interpretation" somewhat differently than we do. In particular, he uses "description" to cover some aspects of what we take to be "interpretation."

> the very conditions under which an object is called a work of art and their implications.

Second, the specific content of the inputs and outputs of the components of criticism algorithms and design algorithms is also taken into account. Here, what these inputs and outputs say about a work of art is important. Questions in aesthetics that are investigated in this way pertain to, for example,

> general approaches to understanding works of art, such as expression, representation, and form, and
>
> general approaches to evaluating works of art, such as unity and variety.

Third, possible internal workings of the components of criticism algorithms and design algorithms are also taken into account. Here, the actual way an output is produced by a component for a given input is important. Sometimes only broad suggestions for internal workings are given, sometimes detailed accounts. Questions in aesthetics that are investigated in this way pertain to, for example,

> the detailed and specific nature of different conventions and criteria for describing, interpreting, and evaluating works of art proposed in the literature of aesthetics and the arts and their relationships.

In this study, we certainly do not provide the complete specifications for an algorithm for looking at any work of art in, say, the Vatican and giving an original, cogent critique of the work of art. Nor do we give the complete specifications for an algorithm for turning a blank wall in the Vatican into another *School of Athens.* We believe it is theoretically possible to specify such algorithms. We do not believe that such algorithms ought not be specified in any moral or ethical sense. It is simply that the specification of such algorithms is not a project for 7 man-years of work but for 7,000 man-years or for 7,000,000 man-years or for a civilization. The amount that must be learned before such algorithms could be fully specified is enormous.

The process of criticizing or designing a work of art can be very complicated and can involve a full range of mental abilities. The ability to specify a criticism algorithm or a design algorithm may well presuppose the ability to formalize a wide range of perceptual and cognitive skills and a wide range of knowledge. For example, a criticism algorithm which allows for the interpretation and evaluation of *School of Athens* may involve the ability to recognize painted shapes as people, the ability to recognize those people as representations of Greek philosophers as well as portraits of Italian artists of the fifteenth and sixteenth centuries, the ability to associate these people into groups in terms of their philosophical points of view as Greek philosophers as well as their spatial locations in the picture, the ability to treat the picture as part of art history, the ability to relate the ideas associated with the picture with the ideas in some cultural context, the ability to identify the emotions evoked by various aspects of the picture, among many. Specifying an algorithm with even the first of these abilities would be an extremely difficult task at the present time.

What we do attempt in this study is to suggest, in very broad strokes, what an algorithm for criticizing or designing works of art might look like. In the process, we attempt to show how various approaches to art might be modeled using this structure and we investigate some traditional issues in aesthetics in terms of this structure.

We believe the algorithmic approach to aesthetics taken in this study is important for two main reasons. First, the postulated structure for criticism algorithms and design algorithms provides a common framework in which a number of central issues in aesthetics, which traditionally are treated separately, can be investigated uniformly and can be related. Second, just the attempt to represent aesthetic ideas or specific approaches to understanding and evaluating works of art in terms of algorithms is salutary. Algorithmic representations require an explicit awareness of underlying assumptions and details that may remain hidden using less rigorous methods. Further, completed algorithmic representations of ideas provide a test of their consistency and soundness and a means of identifying their consequences: completely specified algorithms can be run on a computer. As Knuth points out,

> It has often been said that a person doesn't really understand something until he teaches it to someone else. Actually a person doesn't really understand something until he can teach it to a

> computer, i.e., express it as an algorithm. . . . The attempt to formalize things as algorithms leads to a much deeper understanding than if we simply try to understand things in the traditional way.[4]

[4] D. Knuth, "Computer Science and Mathematics," *American Scientist,* 61, 6 (1973), 709.

2
The Structure of Criticism Algorithms and Design Algorithms

In *The Nature of Explanation,* Kenneth Craik proposes a general model of the process of thought. This model provides the basis for the structure postulated for criticism algorithms and design algorithms. Craik's model consists of three essential processes:

> (1) "Translation" of external process into words, numbers or symbols.
>
> (2) Arrival at other symbols by a process of "reasoning," deduction, inference, etc., and
>
> (3) "Retranslation" of these symbols into external processes....[1]

These three processes are represented in the schema of figure 2-1. Systems having the form of this schema have three basic parts:

(1) A receptor that allows the system to sense the outside world. The receptor contains a transducer(s), shown schematically by an "eye," that is sensitive to light, sound, or pressure, etc. The receptor encodes some aspects or facets of the outside world as a sequence of symbols. The receptor is the input device for the system.
(2) A processor that transforms the sequence of symbols produced by the receptor into another sequence of symbols. The processor is the "brain" of the system.

[1] K. Craik, *The Nature of Explanation* (Cambridge, 1943), p. 50.

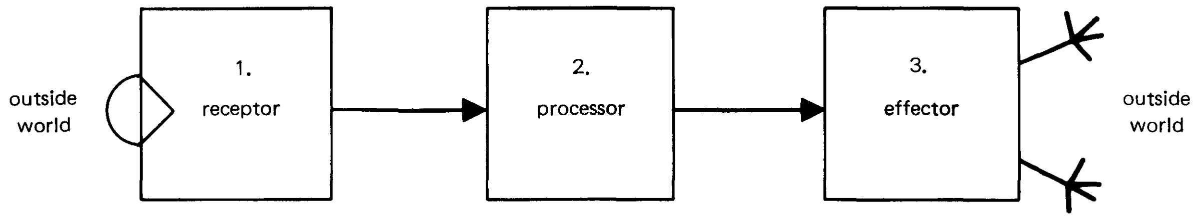


Fig. 2-1

Basic schema for Craik's general **model of the** process of thought.

(3) An effector that allows the system to respond to or affect the outside world. The effector contains a transducer(s), shown schematically by "hands," that might produce light, sound, or pressure, etc. The actions of the effector are determined by the sequence of symbols produced by the processor. The effector is the output device for the system.

The schema of figure 2-1 is commonly assumed in psychology and computer science. The schema is used as the starting point for our investigations. We proceed from this schema to obtain the postulated structure for criticism algorithms and design algorithms by specifying the inputs and outputs of the components of this system and more fully elaborating the structure of the processor.

2.1 The Structure of Criticism Algorithms

The task of a criticism algorithm is taken to be: produce a response to an object as a work of art. Typically this response will be a statement containing a description, interpretation, and evaluation of the object. The postulated structure for criticism algorithms is shown in figure 2-2. This structure consists of:

(1) An object as a possible work of art. The notion of "object" is used in its widest possible sense to include, for example, musical or theatrical performances as well as paintings or novels.

(2) A *receptor* consisting of a transducer(s) and a linked algorithm. For example, the transducer might be a color television camera or a microphone, or a combination of these. The linked algorithm uses the output of the transducer to produce a sequence of symbols that encodes the essential facets or aspects of the object.

(3) The output of the receptor: the description of the object. For music, drama, literature, or architecture, the description could resemble a score, script, text, or plan.

(4) An *aesthetic system.* The aesthetic system consists of four algorithms that encode the conventions and criteria that are to be used to interpret and evaluate the object in terms of its description. The structure of aesthetic systems is given in chapter 4.

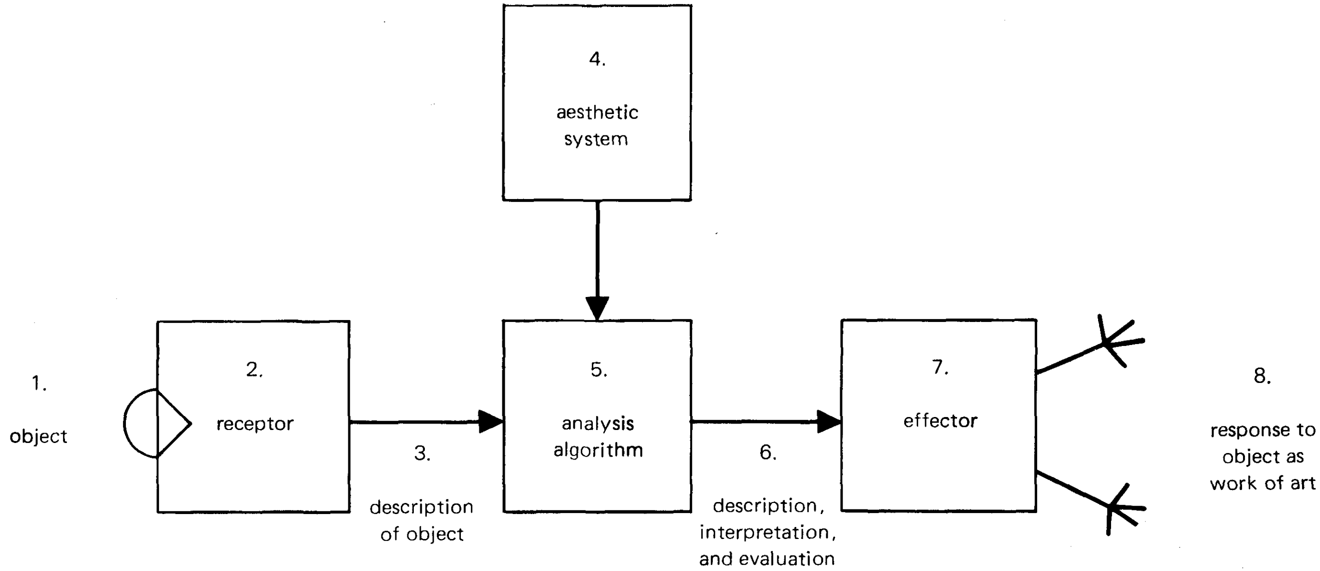


Fig. 2-2

Postulated structure for criticism algorithms.

(5) An *analysis algorithm.* The analysis algorithm uses the algorithms in the aesthetic system to find the best interpretation and evaluation of the object as described.
(6) The output of the analysis algorithm: the description, interpretation, and evaluation of the object.
(7) An *effector* consisting of a transducer(s) and a linked algorithm. As envisioned here, an effector is typically a printing device for printing the description, interpretation, and evaluation of the object, but it could also be, for example, mechanical hands for clapping or an artificial voice box.
(8) The response to the object as a work of art. Typically this response consists of the description, interpretation, and evaluation of the object.

2.2 The Structure of Design Algorithms

The task of a design algorithm is taken to be: produce an object as a work of art in response to some initial conditions. The postulated structure for design algorithms is shown in figure 2-3. This structure consists of:

(1) Some initial conditions, for example, a person whose portrait is to be painted or the injunction "Write music for the royal water-party between Whitehall and Limehouse to be held on August 22, 1715." The initial conditions might be null, for example, "Paint a picture."
(2) A *receptor* consisting of a transducer(s) and a linked algorithm. For example, the transducer might be a color television camera, a microphone, the keyboard of a computer terminal, or some combination of these. The linked algorithm uses the output of the transducer to produce a sequence of symbols that encodes the initial conditions.
(3) The output of the receptor: the specification of the initial conditions.
(4) An *aesthetic system,* as in criticism algorithms.
(5) A *synthesis algorithm.* The synthesis algorithm uses the algorithms in the aesthetic system to find the description of the object which has the best possible interpretation and evaluation and at the same time which satisfies the initial conditions.

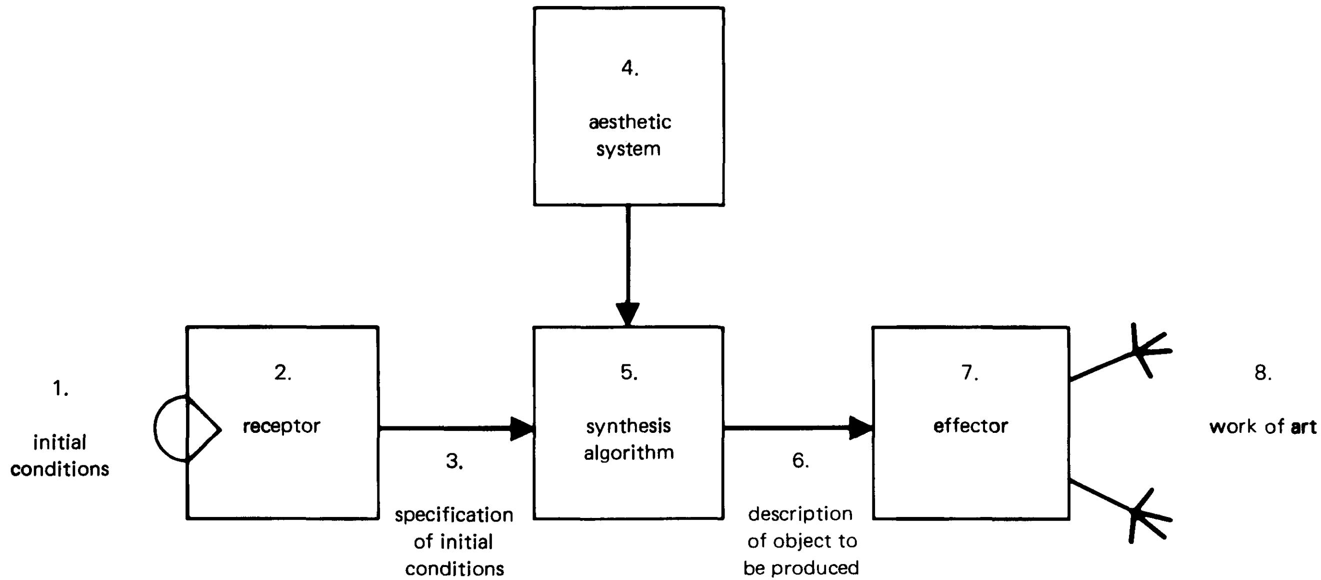


Fig. 2-3

Postulated structure for design algorithms.

(6) The output of the synthesis algorithm: the description of the object to be produced.
(7) An *effector* consisting of a transducer(s) and a linked algorithm. For example, the transducer might include a color television display, a loudspeaker, or a printing device. The effector produces the object described in the output of the synthesis algorithm.
(8) The object produced by the effector. This object is the work of art produced by the design algorithm.

2.3 Discussion

The structures postulated for criticism algorithms and design algorithms are essentially the same. The difference between them is reflected in the role played by the description. In a criticism algorithm, the description is the output of the receptor; in a design algorithm, the description is the input to the effector. It is important to notice that the same aesthetic system can be used in a criticism algorithm and in a design algorithm. That is, the same conventions and criteria for interpretation and evaluation can be used for the criticism of existing works of art and for the design of new works of art.

The criticism algorithms and design algorithms envisioned here are static. The conventions and criteria encoded in these algorithms for describing, interpreting, and evaluating objects do not change over time. Each criticism algorithm or design algorithm corresponds to some specific, fixed approach to criticism or design.

2.4 Approaches in Criticism and Design

Criticism and design in the arts can be approached in many different ways. The variety of actual approaches in criticism is apparent when two different observers understand and evaluate the same object as a work of art in two different ways. For example, consider the disparity among opening night reviews of a given Broadway play. A telling collection of differing critiques for the same works of art (*The Alexander Mosaic, The Laocoon, The Mona Lisa, Guernica*) is given by Osborne.[2] These critiques show

[2] H. Osborne, *The Art of Appreciation*, (London, 1970), pp. 250-271.

that the same work of art is often understood and evaluated in a variety of ways. The variety of actual approaches in design is apparent when two different artists produce two different works of art in response to identical initial conditions. For example, consider the disparity between the commissioned portraits of L. B. J. or the differences in the submitted plans for St. Peter's.

The aim of our work is not to produce any single, authoritative criticism algorithm or design algorithm. We consider any approach to art to be legitimate. Rather, we postulate a structure for criticism algorithms and design algorithms in which a variety of, and we believe all, approaches to art can be represented. Criticism and design in the arts can be done in many different ways and still be modeled using this fixed structure.

Each different approach in criticism or design would correspond to a different criticism algorithm or design algorithm. Different approaches in criticism or design might result in differences in any or all of the components of criticism algorithms or design algorithms. For example, aesthetic systems corresponding to several different approaches to nonrepresentational, geometric pictures are suggested in chapter 9. Each of these aesthetic systems would encode different conventions and criteria for interpreting and evaluating pictures. Using one of these aesthetic systems, a picture would be interpreted in terms of the shapes in the picture, using a second in terms of the colors in the picture, using a third in terms of the associations attached to the picture, and so on. Of course, there can be many different aesthetic systems which provide for pictures to be interpreted in terms of shape, color, or associations. Similarly, using each of these aesthetic systems a picture would be evaluated in a different way. If these aesthetic systems were used in criticism algorithms, then different statements of how a given picture is interpreted and evaluated would be produced. If these aesthetic systems were used in design algorithms, then different pictures would be produced in response to some given initial conditions. None of these aesthetic systems is taken to be definitive. Again, any approach to art is considered legitimate.

The range of objects with which a criticism algorithm or a design algorithm can deal can be very broad or narrow. For example, a criticism algorithm or a design algorithm may deal with only pictures, only representational pictures, only representational pictures of a certain period or style, only one picture, and so on.

A basic underlying assumption of this study is that there is no single, correct way to describe, interpret, and evaluate any given object as a work of art. Which objects are considered works of art and how these objects are understood and evaluated as works of art is purely a matter of convention. For a given culture the conventions used to understand and evaluate objects of a particular type as works of art may be commonly agreed upon. This does not preclude the possibility that in some other culture the same objects may be understood and evaluated as works of art in an entirely different way or may not even be considered works of art. Similarly, for different people within a culture the conventions and criteria used to describe, interpret, and evaluate an object as a work of art may differ.

This study is organized in terms of the structure postulated for criticism algorithms and design algorithms. In the subsequent chapters, the components of criticism algorithms and design algorithms are discussed in more detail. In particular, the structure of aesthetic systems is elaborated as are the tasks of analysis algorithms and synthesis algorithms. Issues in aesthetics are treated in these chapters as they arise.

PART II: RECEPTORS

3
Receptors

In a criticism algorithm or in a design algorithm, the receptor provides the sensory connection between the algorithm and the outside world. A receptor consists of two parts: a transducer(s) and a linked algorithm.[1] Generally, the transducer would be sensitive to electromagnetic or mechanical energy. For example, the transducer could be a television camera, an optical character reader, a microphone, the keyboard of a computer terminal, or some combination of these. The algorithm linked to the transducer produces a finite sequence of symbols as output. This sequence of symbols is based on what the transducer has sensed. In a criticism algorithm, this sequence of symbols is the description of an object that is to be interpreted and evaluated. In a design algorithm, this sequence of symbols is the specification of initial conditions that are to be used to make an object.

3.1 Receptors in Criticism Algorithms

In a criticism algorithm, the receptor produces the description of an object that is to be interpreted and evaluated. The *description* of an object specifies the aspects of the object that are of interest, the aspects that are to be considered in interpreting and evaluating it. Usually, the description of an object lists its essential and relevant features and properties one-by-one. In general, an object is described in terms of some canonical and minimal representation of these features and properties. For example, the description of a picture might enumerate all the areas of uniform

[1] For a discussion of how transducers can be linked to algorithms in both receptors and effectors, see B. Raphael, *The Thinking Computer* (San Francisco, 1976) pp. 9-14.

color in the picture by shape, color, and place of occurrence. The description of a musical piece might enumerate the tones in the piece by pitch, duration, and order of occurrence. In principle, given the description of an object, the object can be reproduced in all its "essential and relevant" aspects.

3.2 Examples of Receptors and Descriptions

The nature of receptors and the descriptions they would produce in criticism algorithms is illustrated by some simple examples.

3.2.1 Written Literature

For written literature, such as novels, short stories, or poems, the standard description is the text. A receptor that produces the text of a piece of written literature as the description could have an optical character reader as its transducer. Optical character readers are commercially available devices that given a page of text automatically specify the sequence of characters that would be encountered in reading the page. The algorithm linked to the optical character reader would be essentially null, merely having as output an encoding of the linear sequence of characters scanned.

3.2.2 Oral Literature

By oral literature, we mean some speech performance such as the telling of a folktale or the reading of a poem. Here, the object is taken to be a sequence of sounds produced in some limited period of time.

A receptor for oral literature would naturally contain a microphone as its transducer. Various algorithms could be linked to a microphone to produce various descriptions of oral literature. In the simplest case, the description could be a sequence of numbers indicating the amplitude of the acoustic signal, sensed by the microphone, at small, discrete, uniform intervals of time. Here, the algorithm linked to the microphone would be essentially null, merely having as output a digital encoding of the output of the microphone. A much more complicated description to produce would be a specification of the sequence of phonemes determined to be uttered by the speaker. A yet more complicated description to produce would be a specification of the sequence of words determined to be uttered by the speaker. This description would correspond to a text of what is being said by the speaker. The specification of an algorithm linked to a microphone which would produce a sequence of phonemes or a text for some speech performance is a very difficult task. Recently there has been a multimillion dollar effort to specify such algorithms.[2]

The appropriateness of these descriptions for oral literature depends on the aspects of a speech performance which are of interest. If the text of a speech performance is used as its description, information on the recitation itself would be lost. The text of the recitation would be an appropriate description for a critique of what is said independent of how it is said. The text of the recitation would not indicate the speaker's intonation, inflection, timing, accent, and so forth. Hence, use of the text as the description of a speech performance would be inappropriate for critical comment on the recitation. A description of the speech performance as a sequence of phonemes uttered by the speaker would be more appropriate for critical comment on the recitation itself. Depending on the aspects of the recitation that are of interest, there may be other more appropriate descriptions. In general, the appropriateness of a description for criticism will vary and depend on the aspects of the object that are to be considered in interpreting and evaluating it.

3.2.3 Performances of Instrumental Music

Performances of instrumental music, such as symphonies, can be described in a variety of different ways. Here, the object consists of a collection of sounds produced by instruments, such as pianos, violins, trumpets, and synthesizers, over time. (The visual aspects of musical performances, e.g., the motions of the conductor, are ignored in this discussion.)

A receptor for musical performances would naturally contain a microphone as its transducer. Various algorithms could be linked to a microphone to produce various descriptions of musical performances. In the simplest case, the description could be a sequence of numbers indicating the amplitudes of the acoustic signal, sensed

[2] A. Newell et al., *Speech Understanding Systems* (Amsterdam, 1973). G. M. White, "Speech Recognition: A Tutorial Overview," *Computer*, vol. 9, no. 5 (1976).

by the microphone, at small, discrete, uniform intervals of time. Here, the algorithm linked to the microphone would be essentially null, merely having as output a digital encoding of the output of the microphone. A variety of other possible descriptions for musical performances are possible. For example, a description might consist of a sequence of numbers indicating the dominant frequencies of the acoustic signal over time.

Of course, the score is a possible description of a musical performance. An algorithm has been developed[3] which, linked to a microphone, automatically obtains the score for simple, two instrument musical performances.

The appropriateness of a particular kind of description for musical performances depends on the aspects of the performance which are of interest. For example, the score of a musical performance would be an appropriate description if only the compositional aspects of the piece performed were of interest and not the details of its actual performance. Interpretation and evaluation of different aspects of the performance itself might require specialized descriptions.

3.2.4 Pictures

For pictures, for example, paintings, a receptor might contain a high resolution color television camera as its transducer. The nature of the output of a color television camera leads directly to a simple type of description for pictures. Here, a picture would be described by indicating the color occurring at each "point" in the picture. The picture is considered to be subdivided into a fine, discrete, square grid. Each cell in the grid is called a "pixel" (picture element). The color at each pixel ("point") is indicated by three numbers. A color is uniquely determined by three coordinates. Traditionally, these coordinates are hue, chroma, and value. Using a color television camera as transducer, it would be natural for the coordinates to be the intensities of the red, blue, and green components of the color.

The description of a picture would consist of a linear sequence of the numbers representing the colors at each pixel of the picture. For example, the description could consist of the sequence of

[3] J. A. Moorer, "On the Transcription of Musical Sound by Computer" (Tokyo, 1975).

colors encountered at each pixel by beginning with the top left pixel, listing each pixel in the top row from left to right, and repeating this left to right listing for each successive row in the grid. This sequence would correspond to the sequence of characters encountered when reading a page of English text. Pixel descriptions seem similar to Goodman's "elementary pictorial characterization" for specifying the pictorial properties of a picture.[4]

Sometimes it is important to describe a picture from multiple views, for example, full view, from the side, close up, or under different lighting conditions. A description of a picture could consist of a sequence of pixel descriptions of the picture from different views, under different illuminations, and so on.

Other descriptions of pictures besides pixel descriptions and sequences of pixel descriptions are possible. That is, other algorithms can be linked to color television cameras to produce descriptions of pictures. For example, a picture might be described by specifying the areas of uniform color occurring in the picture. In a description of this type, the shape of a uniformly colored area is specified together with the color of the area and its location in the picture. Beardsley and Cavallius, among others, have suggested that pictures be described in this basic way.[5] This type of description is used in the example given in chapter 9.

3.2.5 Multimodality Art Forms

Thus far, we have discussed the description of objects in a single sensory modality, that is, either audio or visual. Some art forms, for example, drama, opera, ballet, film, are most suitably described in terms of both audio and visual modalities.

In these cases, a receptor would naturally contain both a microphone and a television camera as its transducer. The algorithm linked to the transducer could produce a description of an object consisting of the concatenation of an audio description and a visual description of the object. For example, the description of the performance of a play could be the combination of an amplitude over time description of the acoustic signal and a sequence of pixel

[4] N. Goodman, *Languages of Art* (Indianapolis, 1968), p. 42.

[5] M. Beardsley, *Aesthetics* (New York, 1958), p. 10 and G. Cavallius, *Velazquez' Las Hilanderas* (Uppsala, 1972), pp. 12-17.

descriptions over time. This description would be a direct symbolic encoding of the outputs of the microphone and the television camera.

More complicated receptors for multimodality art forms can be imagined. For example, the description of the performance of a play might be the script (including stage directions) of the play.

3.3 Detail in Descriptions

Theoretically, it is always possible to obtain a description of an object that contains at least as much sensory detail about the object as is available to a human observer. There are physical and psychophysical limits on the amount of detail that can be observed by a person in any sensory modality. Thus, there are computable limits on the amount of detail that must be included in a description in order for it to contain all the detail possibly observable by a person.

For example, a television camera of extremely high resolution could be used as the transducer of a receptor that produces pixel descriptions of pictures that contain all the visual detail possibly discernible by a person. For a given picture, this description would be very long. The length of the description would depend on the size (number) of the pixels and the amount of information recorded for each pixel. The size of the pixels would depend on the maximum spatial resolution (visual acuity) of a human observer; the amount of information recorded would depend on the number of colors that can possibly be distinguished by a human observer. Since there are bounds on the spatial resolution of and number of colors distinguishable by a person, there are bounds on how long this description need be to capture the detail of the picture discernible by a person. Of course, the use of visual aids, for example, a magnifying glass or a microscope, by a human observer presents no problem, as these aids could be incorporated in the transducer of the receptor. Neither does viewing a picture from multiple locations or under multiple lighting conditions, as these can be handled as discussed in section 3.2.4.

Similarly, an extremely sensitive microphone could be used as the transducer of a receptor that produces descriptions of musical pieces that contain all the audio detail possibly discernible by a person.

In criticism, the problem is not whether a description of sufficient detail can be produced. Rather, the problem is how to produce a description that is appropriate for our critical interests and purposes. It is easy to construct receptors that produce descriptions of objects that contain a flood of detail, most of which would be irrelevant. What is difficult is to construct receptors that produce descriptions that contain only information that is essential and relevant for interpretation and evaluation. The basic problem is to develop sophisticated algorithms to link to transducers to form receptors.

3.4 The Conventionality of Description

The way an object is described is a matter of convention. The same object can be described in different ways using different conventions.

Different descriptions of the same object might result because different aspects of the object are physically sensible. Obviously, a performance of a ballet observed visually only (e.g., by a receptor containing just a television camera as its transducer) would have a different description than the same performance observed aurally only (e.g., by a receptor containing just a microphone as its transducer). A deaf man and a blind man attending the same ballet would not describe it in the same way. The sensory modality or modalities in which an object is observed is a matter of convention.

More interestingly, different descriptions of the same object might result because different aspects of the object which are physically sensible are of interest for interpreting and evaluating it.

> What we see when we look at a picture depends on the nature of the interest with which we approach it and the habits of appreciation which we have formed. These things determine in a large degree the features of the picture which each observer notices and attends to.[6]

For example, some of the audio aspects of a musical performance – the tuning of the orchestra, the tapping of the conductor's baton, coughs, the rustling of programs – may or may not be included in its description. If the performance is to be

[6] H. Osborne, *The Art of Appreciation* (London, 1970), p. 250.

interpreted and evaluated in some "standard" way, then these aspects would not be included in its description; if the performance is to be interpreted and evaluated in some "avant-garde" way, then it may be appropriate for these aspects to be included in its description. Indeed, when the performance begins and when it ends as well as what sounds between the beginning and the end are part of the performance are purely a matter of convention. Of course, how these sounds are represented, for example, as an amplitude over time description or as a score, as discussed in section 3.2.3, is also a matter of convention.

Similarly, some of the aspects seen in viewing a picture – the picture frame, shadows on the picture – may or may not be included in its description. If the picture is to be interpreted and evaluated in some "standard" way, then only those visual aspects of the picture that are inside the frame and independent of shadows, and so forth would be included in its description; if the picture is to be interpreted and evaluated in some "avant-garde" way, then it may be appropriate for some other visual aspects (perhaps environmental or transient) to be included in its description.

There are aspects of written literature that may or may not be included in its description. For example, if a poem is to be interpreted and evaluated in some "standard" way, then its description would consist solely of the sequence of characters forming the text of the poem. If the poem is to be interpreted and evaluated in some "avant-garde" way, for example, as concrete poetry, then the position, orientation, and size of the actual characters as printed on the page would also be included in its description.

It should be clear that how objects are described varies with different conventions. The same object may be described in different ways in different cultures and by different people in the same culture. For example, as Dickie points out,[7] the prop man in traditional Chinese theater appears on stage among the actual actors but is not considered part of the performance. When a naïve Westerner views a traditional Chinese play, he may well include the actions of the prop man in his description of the performance.

How an object is described depends not only on the physical nature of the object but also on the conventions used in describing it.

[7]G. Dickie, *Art and the Aesthetic* (Ithaca, 1974), p. 166.

3.5 Copies, Performances, and Forgeries

Internally, a criticism algorithm deals with the description of an object produced by the receptor and not with the object itself. The receptor produces a single description of an object. No sensory aspect of an object which must be gleaned directly from the object that is not in its description can affect how the object is interpreted and evaluated.

Usually in criticism, different objects are considered aesthetically different. A receptor would usually produce different descriptions for different objects. In a criticism algorithm, only when two different objects have two different descriptions can they be interpreted and evaluated differently.

Sometimes in criticism, different objects are considered aesthetically the same. For example, multiple copies of a novel, performances of a symphony or play, or prints of a lithograph may be considered indistinguishable for critical purposes and, hence, may be treated identically. A receptor sometimes produces identical descriptions for "different" objects. Because a criticism algorithm deals with objects in terms of their descriptions, two objects that have the same description are indistinguishable for that criticism algorithm. Thus, two objects having identical descriptions in a criticism algorithm are always interpreted and evaluated identically.

The way multiple copies of a novel, performances of a symphony or play, or prints of a lithograph are treated by a criticism algorithm depends on the receptor, that is, on how they are described. If the descriptions of, for example, two performances of a symphony are identical, then the performances are indistinguishable and are treated identically by the criticism algorithm. This case might result when the score is produced as the description of the performance. If the descriptions of two performances of a symphony are not identical, then they are distinguishable and may be treated differently by the criticism algorithm. This case might result when an amplitude over time description of the performance is produced. Two performances may be described identically in one criticism algorithm and may be described differently in another criticism algorithm. Hence, the two performances may be interpreted and evaluated identically by one criticism algorithm and differently by another.

This discussion for copies, performances, and prints applies equally well to the problem of forgery in painting. Is there an aesthetic difference between the original of a picture and a forgery? For a criticism algorithm, there may or may not be an aesthetic difference between the original and a forgery. If the original and a forgery have identical descriptions, then they are indistinguishable for the criticism algorithm and, hence, they are interpreted and evaluated identically. If the original and a forgery have different descriptions, then they are distinguishable and, hence, they may be interpreted and evaluated differently. As with copies, performances, and prints, whether an original and a forgery are aesthetically different for a criticism algorithm is determined by their descriptions in that algorithm.

The problem of forgery in painting is raised by Goodman:

> Suppose we have before us, on the left, Rembrandt's original painting *Lucretia* and, on the right, a superlative imitation of it. We know from a fully documented history that the painting on the left is the original and we know from X-ray photographs and microscopic examination and chemical analysis that the painting on the right is a recent fake. Although there are many differences between the two – e.g., in authorship, age, physical and chemical characteristics, and market value – we cannot see any difference between them; and if they are moved while we sleep, we cannot tell which is which merely by looking at them. Now we are pressed with the question whether there can be any aesthetic difference between the two pictures; and the questioner's tone often intimates that the answer is plainly *no*, that the only differences here are aesthetically irrelevant.[8]

As Goodman suggests, this question would often be answered in the negative, that only directly perceivable aspects would count in in determining whether the pictures are aesthetically different. Beardsley advocates this view:

> And I will say that if a perfect imitation of a bronze statue be carved from cheese, so that to sight and touch no difference could appear – let us ignore the smell – then as an aesthetic object the imitation is exactly similar to the original.[9]

[8] N. Goodman, *Languages of Art*, pp. 99-100.

[9] M. Beardsley, *Aesthetics*, p. 52. See also Beardsley's discussion of neo-gothic buildings on pp. 50-52. A similar view is advocated by A. Lessing in "What is Wrong with a Forgery?," *Journal of Aesthetics and Art Criticism* (1965), in discussing Van Meegeren's false Vermeers.

The opposite view seems to be taken by Goodman. Goodman argues that knowledge about the pictures which is obtained by means other than "merely looking" at them, especially knowledge about the authenticity of the pictures, is important aesthetically.

> My knowledge of the difference between the two pictures . . . instructs me to look at the two pictures differently. Now, even if what I see is the same . . . [this knowledge] indicates to some extent the kind of scrutiny to be applied now, the comparisons and contrasts to be made in imagination, and the relevant associations to be brought to bear. It thereby guides the selection, from my past experience, of items and aspects of use in my present looking. Thus . . . the unperceived difference between the two pictures is pertinent to my visual experience with them.[10]

An examination of Goodman's question in terms of criticism algorithms leads to the conclusion that whether the two pictures are identical for a criticism algorithm depends on the receptor of the criticism algorithm. Again, there can be no aesthetic difference between two objects for a criticism algorithm without differences in the descriptions of the objects used in the algorithm. Any of a variety of receptors can be used for describing objects of a given art form. The description of a picture produced by the receptor of a criticism algorithm can contain a variety of information about the picture, not all of which must be gleaned by "merely looking" at the picture. For example, the transducer of the receptor might contain machinery that allows for X-ray, microscopic, or chemical analysis of a picture as well as a television camera for merely looking at the picture. Information about the picture gleaned by any of these means could be included in its description. The original of a picture and a forgery might be indistinguishable by "merely looking" at them, but they may be aesthetically different for a criticism algorithm. Thus, we disagree with Beardsley because he would insist that two pictures that are indistinguishable by merely looking at them can have no aesthetic differences. However, a receptor might construct the descriptions of the two pictures by "merely looking" at them. In this case, their descriptions would be the same and there would be no aesthetic difference between them for the criticism algorithm. Whether or not the original of a picture and a forgery are considered aesthetically the same depends on the conventions used to describe them.

[10] N. Goodman, *Languages of Art*, pp. 104-105.

Usually, two different objects will have two different descriptions in a criticism algorithm. However, any two objects may have identical descriptions in a criticism algorithm and, hence, be indistinguishable for the algorithm. For example, two performances of Bach's Partita Number 2 in C Minor would be considered the same if they have the same description, performances of any two Bartok pieces would be considered the same if they have the same description and, for that matter, a performance of Bach's Partita and a performance of a Bartok piece would be considered the same if they have the same description.

Just as different objects are sometimes indistinguishable for criticism algorithms, different objects are sometimes indistinguishable for human observers. For example, two performances of Bach's Partita might be indistinguishable, all Bartok pieces might be indistinguishable, or (to a non-Western observer) all Western music might be indistinguishable.

3.6 A Note on the Use of Descriptions in Design Algorithms

In a design algorithm, the description of an object is the input to the effector (see fig. 2-3) rather than the output of the receptor as in a criticism algorithm. In a design algorithm, the description specifies the object to be produced. The effector uses the description to produce an object having the description. Clearly, the types of descriptions given as examples in section 3.2 can be used in this way. The use of descriptions to specify objects to be produced is common in the arts. For example, in music, drama, and architecture, a score, script, or plan is frequently used to specify a musical piece, a play, or a building for its production. A more extended discussion of the use of descriptions in design algorithms is given in chapter 14.

3.7 Receptors in Design Algorithms

The receptor of a design algorithm produces a specification of the initial conditions that are to be satisfied by the object to be produced by the design algorithm.

Initial conditions impose constraints on the object to be produced by a design algorithm. These constraints may pertain to the physical characteristics of the object. For example, the initial conditions may constrain the physical size of and the range of colors in a picture or the duration of and the instruments available for a musical piece. The constraints imposed by the initial conditions may also pertain to the way the object is to be interpreted. For example, the initial conditions could specify the subject matter of a picture or the emotions that are to engender or be evoked by the picture or the theme to be developed into a musical piece.

The initial conditions for a design algorithm could correspond to external events perceived by an artist, for example, a scene to be painted. In this case, the transducer of the receptor could include, for example, a television camera. The initial conditions for a design algorithm also could correspond to an internal event in the artist, for example, to an emotion or the recall of some specific knowledge. In this case, the transducer of the receptor could include a computer terminal that would be used to type these initial conditions into the design algorithm.

PART III: AESTHETIC SYSTEMS

4
The Structure of Aesthetic Systems

Aesthetic systems provide the basis for interpreting and evaluating objects in criticism algorithms and design algorithms.

An aesthetic system consists of four algorithms – an *interpretation algorithm*, a *reference algorithm*, an *evaluation algorithm*, and a *comparison algorithm*. The input-output relations of these algorithms in an aesthetic system are shown in figure 4-1. Specification of these algorithms completes the formal structure postulated for all criticism algorithms and design algorithms.

The interpretation algorithm and the reference algorithm are used to interpret objects in terms of their descriptions. These algorithms embody the interpretative conventions of the approach to art used in a criticism algorithm or design algorithm. The interpretation algorithm has as input a sequence of symbols and produces as output a sequence of symbols. Each input-output pair of the interpretation algorithm is called an *interpretation*. All interpretations in an aesthetic system are input-output pairs of the interpretation algorithm. The reference algorithm has as input the description of an object and an interpretation. The output of the reference algorithm is "yes" if the interpretation is an interpretation of an object having the input description and "no" otherwise. The properties and uses of the interpretation algorithm and reference algorithm in an aesthetic system are investigated in detail in chapters 5, 6, and 7.

The evaluation algorithm and comparison algorithm are used to evaluate objects in terms of their interpretations. These algorithms embody the evaluative criteria of the approach to art used in a criticism algorithm or design algorithm. The evaluation algorithm

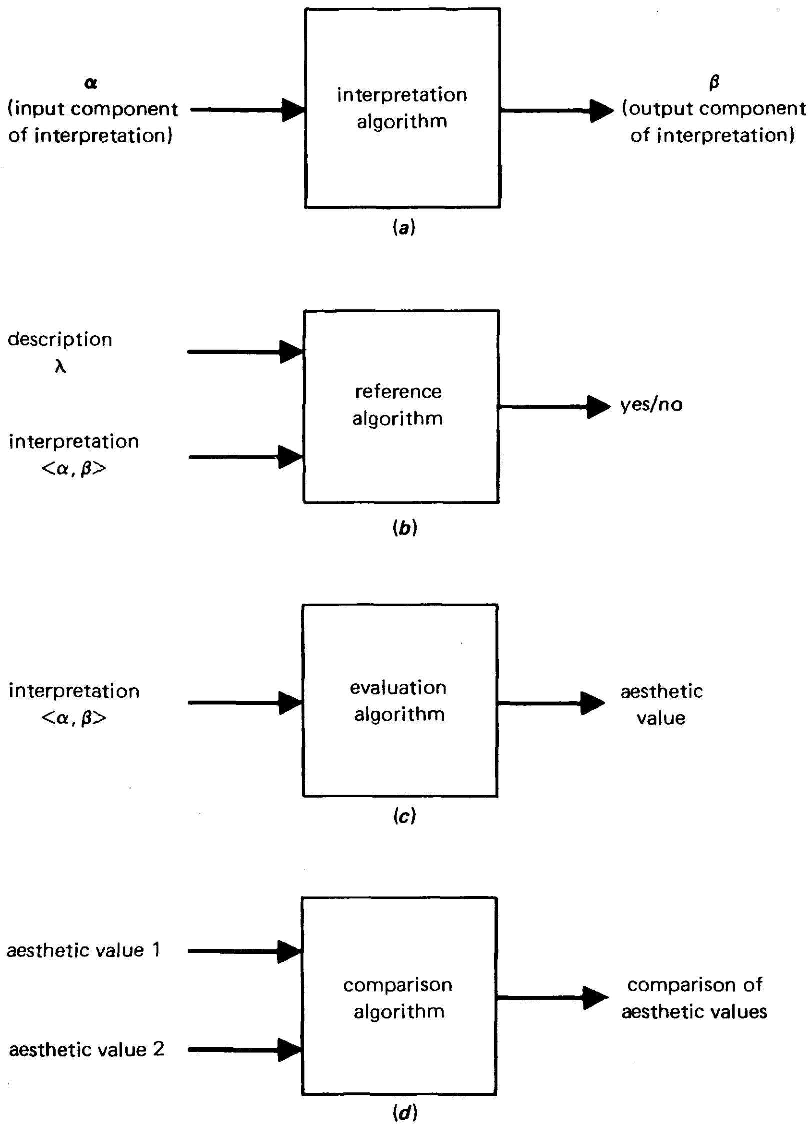


Fig. 4-1

The four components of an aesthetic system.

has as input an interpretation and produces as output the *aesthetic value* assigned to that interpretation. The comparison algorithm has as input two aesthetic values and produces as output a *comparison* of these values. The properties and uses of the evaluation algorithm and comparison algorithm in an aesthetic system are investigated in detail in chapter 8.

Any four algorithms which satisfy the input-output relations given in figure 4-1 form an aesthetic system. Hence, there are many possible aesthetic systems, just as there are many possible interpretative conventions and evaluative criteria for art. Each different approach to art would be modeled by a different aesthetic system. The algorithms constituting each of these aesthetic systems would be different but would satisfy the input-output relations required of algorithms to form an aesthetic system.

5
Interpretation

> Hence it is legitimate to say that all the cognitive processes which have been considered, from perceiving to thinking, are ways in which some fundamental "effort after meaning" seeks expression. Speaking very broadly, such an effort is simply the attempt to connect something that is given with something other than itself.[1]

Interpreting (understanding) objects in terms of their descriptions is the key task performed by both criticism algorithms and design algorithms. Understanding objects using these algorithms is analogous to Bartlett's "effort after meaning." Bartlett suggests that understanding something that is given consists of connecting it with something other than itself. For example, as Bartlett points out, a geometrical pattern is often understood by finding a rule for its construction or by associating it with something familiar from past experience.[2] Similarly, in a criticism algorithm or design algorithm, understanding an object in terms of its description is assumed to consist of connecting the description of the object with an interpretation of the object. The description of an object specifies the aspects of interest of the object, the aspects of the object that want understanding. An interpretation of the object tells how the object is understood in terms of its description. An interpretation of an object says what there is to say about the object as described. Basic to this notion of understanding are (1) the mechanism by which interpretations are defined and (2) the mechanism

[1] F. C. Bartlett, *Remembering* (Cambridge, 1932), p. 227.

[2] Ibid., pp. 18-28. Bartlett cites an abundance of interesting and suggestive examples of just this sort for verbal as well as visual material.

by which the description of an object is connected with an interpretation of the object.

The aesthetic system in a criticism algorithm or a design algorithm provides the basis for interpreting or understanding objects in terms of their descriptions, that is, for defining interpretations and for connecting descriptions of objects with interpretations. An interpretation of an object tells how the object is understood in terms of its description using the assumptions and knowledge comprising some given interpretative conventions. These conventions are modeled by the first two components – the interpretation algorithm and the reference algorithm – of the aesthetic system. The interpretation algorithm encodes the conventions that define what are possible interpretations. The reference algorithm encodes the conventions for deciding whether the description of an object can be connected with a particular interpretation.

Each aesthetic system contains an interpretation algorithm and a corresponding reference algorithm. These algorithms vary from aesthetic system to aesthetic system depending on the interpretative conventions modeled, but have common input-output relations in all aesthetic systems. These invariant relations are specified now.

The interpretation algorithm of an aesthetic system encodes the conventions that define what are possible interpretations. The interpretation algorithm has a sequence of symbols as input and produces a sequence of symbols as output. An input sequence of symbols usually is denoted by α; an output sequence of symbols usually is denoted by β. As with all algorithms, the interpretation algorithm produces a unique output sequence of symbols β for each input sequence of symbols α. Formally an interpretation in an aesthetic system is an input-output pair $<\alpha, \beta>$ for the interpretation algorithm (see fig. 4-1*a*). That is, an interpretation always has the structure <input sequence, resulting output sequence>. In an aesthetic system, all input-output pairs for the interpretation algorithm are interpretations.

In an aesthetic system, interpretations are defined independent of actual objects. Whether a pair of sequences is an interpretation depends only on the interpretation algorithm. The reference algorithm of the aesthetic system encodes the conventions that determine whether a particular interpretation refers to (that is, is an interpretation of) a particular object.

The reference algorithm in an aesthetic system determines whether an interpretation refers to an object in terms of the description of the object. It is the aspects of the object that are specified by the description of the object that are understood in an interpretation of the object. The reference algorithm has two inputs: (1) the description λ of an object and (2) an interpretation $<\alpha, \beta>$. The output of the reference algorithm is "yes" if the interpretation $<\alpha, \beta>$ is an interpretation of the object having the description λ and "no" otherwise (see fig. 4-1*b*). The interpretation is an interpretation of an object having the description if and only if the reference algorithm determines that the description is connected with the interpretation. In general, in an aesthetic system, there may be many interpretations that do not refer to objects and many objects that do not have interpretations that refer to them.

A rough analogy between English sentences about events and interpretations of objects helps elucidate the role of the interpretation algorithm and the reference algorithm in an aesthetic system. In much the same way that an English sentence about an event can be said to satisfy two sets of conditions, an interpretation of an object must satisfy two sets of conditions. First, the sentence satisfies the general conditions fixed for all English sentences by the rules of English grammar. Analogously, the interpretation satisfies the general conditions fixed for all interpretations in the aesthetic system by the interpretation algorithm. Namely, the interpretation must be an input-output pair for the interpretation algorithm. Second, the sentence satisfies the specific conditions fixed for just those sentences about the event by an observer of the event in conjunction with the nature of the event. Analogously, the interpretation satisfies the specific conditions fixed for just those interpretations that refer to the object by the reference algorithm in conjunction with the description of the object. Namely, when given the description of the object and the interpretation as input, the reference algorithm must produce as output "yes." All those interpretations that refer to an object are analogous to all those sentences about an event. Just as an event may be talked about in a variety of ways, an object may have a variety of interpretations in an aesthetic system. Just as a sentence need not be about any actual event, an interpretation need not refer to any actual object. This analogy breaks down somewhat in that it seems that any event can be talked about in English, but for a given object there may be no interpretation in an aesthetic system that refers to the object. The reason for this difference is that while the conventions of English usage seem universally applicable, the interpretative conventions encoded in an aesthetic system may be applicable only to, say, paintings of a certain type or style.

The range of objects with which an aesthetic system can deal can be very broad or narrow, depending on the applicability of the interpretative conventions encoded in the interpretation algorithm and reference algorithm of the aesthetic system. For example, an aesthetic system may deal with only paintings, only representational paintings, only representational paintings of a certain period or style, only paintings of one particular artist, only one painting, and so on. Whether an aesthetic system can deal with a particular object depends on whether the object has an interpretation in the aesthetic system. For example, only representational paintings may have interpretations in a particular aesthetic system.

In an aesthetic system, the interpretation algorithm and the reference algorithm model some given interpretative conventions. The interpretation algorithm determines the potential scope of these conventions by providing for the definition of allowable interpretations. The reference algorithm determines the empirical extent of these conventions by deciding when an interpretation refers to an object.

6
Interpretation: Constructive and Evocative Modes of Understanding

Types of aesthetic systems can be characterized in terms of the ways objects are understood in their interpretations. Two basic types of aesthetic systems are fundamental. In aesthetic systems of each type, an interpretation of an object explicitly contains the description of the object as one of its components.

In aesthetic systems of the first type, objects are interpreted based on a *constructive mode of understanding*. Here, objects are understood by telling how they can be constructed or generated. In an interpretation of an object in an aesthetic system of this type, the description of the object is the output component of the interpretation.

In aesthetic systems of the second type, objects are interpreted based on an *evocative mode of understanding*. Here, objects are understood by telling what associations, emotions, or ideas they evoke. In an interpretation of an object in an aesthetic system of this type, the description of the object is the input component of the interpretation.

Aesthetic systems based on the constructive mode of understanding and aesthetic systems based on the evocative mode of understanding play a central role. Other types of aesthetic systems, in which the interpretation of an object does not contain the description of the object, will be constructed by combining aesthetic systems of these two basic types.

It is important to stress that any aesthetic system can be used in criticism algorithms or in design algorithms. In particular, criticism algorithms or design algorithms can contain aesthetic systems based on the constructive mode or evocative mode of understanding. Understanding objects in terms of how they can be constructed or generated or in terms of what they evoke can provide the basis for doing either criticism or design.

6.1 Aesthetic Systems Based on the Constructive Mode of Understanding

Using the constructive mode of understanding, an object is understood in terms of how the object is put together. Paradigmatic of this mode of understanding is the way number sequences are understood in mathematics. A number sequence is understood by giving rules to generate it.[1] For example, the number sequence 1, 4, 9, 16, 25 . . . can be understood by giving the rule "$f(i) = i^2$." Implicit in this way of understanding this number sequence are the aspects of the number sequence which want understanding, namely the sequence of numbers as opposed to, say, the type face or size of the numerals, and the conventions for applying the rule that generates the sequence, namely that "$f(i) = i^2$" means "the i-th term of the sequence is the square of *i*." This paradigm can be used for understanding any object. Intuitively, an object is understood by giving the information, for example, rules, that can be used to generate the aspects of the object that are of interest, that tells how the object is put together in terms of those aspects. To apply this paradigm precisely, it is necessary to (1) specify the aspects of the object which are of interest and (2) specify the conventions by which the information is used to generate the specification of those aspects. In criticism algorithms and design algorithms, the specification of the aspects of an object which are of interest is given by the description of the object. The conventions by which the information is used to generate the description of the object are encoded in the interpretation algorithm of an aesthetic system. Here, the object is understood by giving information that can be used to generate its description in terms of the conventions embodied by the interpretation algorithm. Using the

[1] For a compendium of rules that have been used to generate sequences of numbers, see N. J. A. Sloan, *A Handbook of Integer Sequences* (New York, 1973).

constructive mode of understanding, an object is understood by telling how the description of the object can be constructed or generated.

In an aesthetic system based on the constructive mode of understanding, an interpretation of an object contains the description of the object as its output component. An interpretation of an object has the form $\langle \alpha, \lambda \rangle$, where λ is the description of the object. The sequence of symbols α is an input to the interpretation algorithm of the aesthetic system which results in the description λ of the object as output. The input α supplies the information the interpretation algorithm needs to construct or generate λ. Hence, the interpretation has the form <information for construction, description>. (See fig. 6-1.)

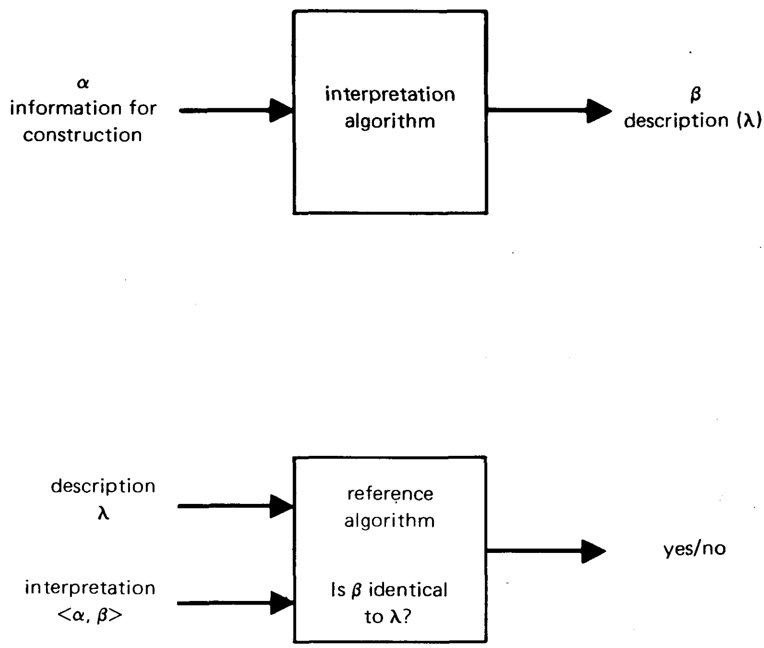


Fig. 6-1

The interpretation algorithm and reference algorithm in an aesthetic system based on the constructive mode of understanding.

The information given by the input may be considered in two ways. An input to an algorithm may be regarded as a list of instructions to be followed or as data to be acted upon. There is no formal difference between inputs as instructions and inputs as data. Considering an input as instructions and considering an input as data are merely two different intuitive ways of looking at the same thing. Looking at the input α in these two ways is helpful in understanding interpretations based on the constructive mode of understanding.

In an aesthetic system based on the constructive mode of understanding, the input component α of an interpretation may be regarded as a list of instructions or rules of construction that can be followed to produce the description λ of an object. Here, the interpretation algorithm of the aesthetic system encodes the conventions that determine the nature of acceptable instructions and the way these instructions are executed. The input α may specify the description λ in terms of rules based on the underlying syntactic or semantic structure, on the recurrence of motifs or themes, implicit in the description of the object. Just as in the example given for number sequences, here an object is understood or interpreted by giving rules to construct the description of the object. An example of an aesthetic system dealing with geometric pictures in which the input components in interpretations of objects are most naturally considered as instructions or rules of construction is presented in detail in chapter 9.

Alternatively, in an aesthetic system based on the constructive mode of understanding, the input component α of an interpretation may be regarded as data to be acted upon to produce the description λ of an object. Here, the interpretation algorithm of the aesthetic system encodes a schema for a large class of descriptions of a certain type. The input α gives the details that particularize this schema so that a unique description is specified. In this case, the general rules for constructing descriptions are encoded in the interpretation algorithm. These rules in conjunction with the input α specify a unique description λ. An interpretation of an object tells how the object is put together by stating the data or details needed to construct the description of the object using the schema or rules embodied in the interpretation algorithm. All objects that have interpretations in the aesthetic system are understood in terms of the same underlying schema or rules, and hence in the same general way.

For example, the interpretation algorithm in an aesthetic system of this kind might embody a schema for drawings of faces.[2] Each drawing specified using this schema would be in the same style. The schema would contain general rules by which the drawing of a particular face can be obtained when given certain details about the face. The input α would give these details. Different inputs would result in drawings of different faces, but each drawing would fit the schema.

The analogous situation in mathematics for understanding number sequences occurs when sequences are understood using some fixed formula or rules. Here, a number sequence is understood by giving the initial conditions that particularize the fixed formula so that the sequence is specified. For example, the fixed formula might be the formula for Fibonacci sequences. The initial conditions needed to specify a particular sequence would be the first two terms of the sequence. All sequences of numbers that can be understood (and there are an infinite number of these) are understood in terms of this one formula.

The use of aesthetic systems based on the constructive mode of understanding in which input components in interpretations of objects are most naturally considered as data is discussed for expression and representation in sections 7.1.1 and 7.2.1.

In aesthetic systems based on the constructive mode of understanding, the input component of an interpretation of an object may be considered as instructions or as data. When the input component is considered as instructions, the conventions encoded by the interpretation algorithm are usually very general. Here, the interpretation algorithm has the flavor of a universal computing algorithm.[3] When the input component is considered as data, the

[2]For a classic discussion of how schemata of this type are used in art see E. H. Gombrich, *Art and Illusion* (Princeton, 1960). A computer program which generates drawings of faces based on a fixed schema is described in M. Gillenson et al., "Computer-Assisted Facial Sketching," *Leonardo*, vol. 9, no. 2 (1976).

[3]A universal computing algorithm is an algorithm that accepts as input a specification of any algorithm and an input to the specified algorithm. The output of the universal computing algorithm is the output of the specified algorithm for the given input. For an introductory exposition of universal computing algorithms see M. Minsky, *Computation: Finite and Infinite Machines* (Englewood Cliffs, N. J., 1967), pp. 132-145 or B. Trakhtenbrot, *Algorithms and Automatic Computing Machines* (Boston, 1963), pp. 80-85.

conventions encoded by the interpretation algorithm are usually narrow. Here, the interpretation algorithm has the flavor of an algorithm that performs a restricted task. In both cases, the input component gives the information that can be used by the interpretation algorithm to construct the description of the object.

The reference algorithm determines whether an interpretation refers to an object in terms of the description of the object. In an aesthetic system based on the constructive mode of understanding, the reference algorithm makes this decision by checking to see if the output component of an interpretation is identical to the description of the object. That is, an interpretation $<\alpha, \beta>$ refers to an object having the description λ if and only if β is identical to λ (see fig. 6-1). Here, the reference algorithm simply makes a comparison between two sequences of symbols and, hence, is easily constructed.

Aesthetic systems based on the constructive mode of understanding are characterized by their reference algorithms. Any aesthetic system in which reference is determined as stipulated in the previous paragraph is based on the constructive mode of understanding.

Example

We now give the interpretation algorithm and reference algorithm of a simple aesthetic system based on the constructive mode of understanding. This aesthetic system contains interpretations of sequences of sixteen tones. Interpretation algorithms and reference algorithms of similar aesthetic systems based on alternative modes of understanding are given in subsequent sections. The evaluation algorithms and comparison algorithms of these aesthetic systems are given in chapter 8.

These aesthetic systems are presented for pedagogical reasons only. They are purposefully as simple as we can imagine. Even so, the details of specifying the algorithms of these aesthetic systems are fairly complicated. This complexity, however, does not begin to reflect the complexity that would seem to be needed to specify completely the algorithms of aesthetic systems that would model traditional approaches to the arts.

For all these aesthetic systems, sequences of sixteen tones are described following the method used in Parson's *The Directory of*

Tunes and Musical Themes.[4] Here, a sequence of sixteen tones is described by giving the "up-and-down" pattern of the tones occurring in the sequence. The first tone in the sequence is encoded by an asterisk (*). Each subsequent tone is encoded by U, R, or D, depending on whether it is higher than the preceding tone, repeats the preceding tone, or is lower than the preceding tone. Descriptions of this type are here called "URD-descriptions." For example, the URD-description of the first sixteen notes of "God Save the Queen" is *RUDUUURUDDDUDDU. The URD-description of the opening sixteen notes of Beethoven's Symphony No. 5 in C Minor is *RRDURRDURRDURRD. This method of describing sequences of sixteen tones is well defined but is rather coarse in the informational sense. As Parsons points out, "apart from the shape of the melody, all other features – key signature, rhythm, phrasing, pitch, and note intervals – are ignored" in the descriptions of sequences. Nevertheless, as Parsons demonstrates, this simple method of description is rich enough to distinguish almost all of over ten thousand classical musical themes.

The interpretation algorithm of the aesthetic system based on the constructive mode of understanding considered here encodes a schema for generating URD-descriptions of sequences of sixteen tones. The input to the interpretation algorithm provides the data or details that particularize the schema so that a unique URD-description is produced as output. The input to the interpretation algorithm is a sequence of at least two characters and as many as sixteen characters beginning with an asterisk and followed by a sequence consisting of Us, Rs, or Ds. For example, allowable inputs to the interpretation algorithm include *D, *RR, and *RRDURRDURRDURRD. The schema encoded in the interpretation algorithm applies the following "productions" or "rewrite rules"

$$U \rightarrow UUR$$
$$R \rightarrow RDU$$
$$D \rightarrow DUD$$

to an input to generate an URD-description. The production "U→UUR" means "Replace the occurrence of a U with UUR." That is, a tone that is a move upward from its predecessor is

[4]D. Parsons, *The Directory of Tunes and Musical Themes* (Cambridge, 1975).

developed into two up-tones followed by a repeating tone. The meaning of the other productions is similar. The productions are applied simultaneously to each occurrence of U, R, or D in an input to the interpretation algorithm and then to each successively generated sequence until a sequence containing at least sixteen characters is generated. The first sixteen characters of this sequence is the output of the interpretation algorithm. Intuitively, the interpretation algorithm begins with a simple sequence that is developed into successively more complicated sequences.

For example, consider the input *D to the interpretation algorithm. This sequence has fewer than sixteen characters. Hence, the productions encoded in the interpretation algorithm must be applied. The application of the productions to the input results in the sequence

*DUD

That is, D is replaced by DUD. The sequence *DUD has fewer than sixteen characters. Hence, the productions must be applied again, to this sequence. That is, in the sequence *DUD, the first occurrence of D is replaced by DUD, the U is replaced by UUR, and the second occurrence of D is replaced by DUD. The application of the productions to the sequence *DUD results in the sequence

*DUDUURDUD

The sequence *DUDUURDUD has fewer than sixteen characters. Applying the productions to each of the characters in this sequence results in the sequence

*DUDUURDUDUURUURRDUDUDUURDUD

This sequence has more than sixteen characters. Hence, the sequence generation process terminates. The interpretation algorithm now outputs the first sixteen characters of the sequence, namely the URD-description

*DUDUURDUDUURUUR

Recall that an interpretation is an input-output pair of the interpretation algorithm. Thus, the aesthetic system contains the interpretation <*D, *DUDUURDUDUURUUR>.

Now consider the input

*RR

to the interpretation algorithm. Applying the productions to this sequence results in the sequence

*RDURDU

Applying the productions again results in the sequence

*RDUDUDUURRDUDUDUUR

This sequence is the first sequence produced that has at least sixteen characters. The output of the interpretation algorithm is the first sixteen characters of this sequence, namely the URD-description

*RDUDUDUURRDUDUD

Thus, the aesthetic system contains the interpretation <*RR, *RDUDUDUURRDUDUD>.

Finally, consider the input

*RRDURRDURRDURRD

to the interpretation algorithm. This input has sixteen characters. Hence, the productions are not applied. The output of the interpretation algorithm is the URD-description

*RRDURRDURRDURRD

Thus, the aesthetic system contains the interpretation <*RRDURRDURRDURRD, *RRDURRDURRDURRD>.

In an aesthetic system based on the constructive mode of understanding, an interpretation is determined by the reference algorithm to be an interpretation of an object if and only if the description of the object is identical to the output component of the interpretation. For example, in this aesthetic system, a sequence of sixteen tones having the URD-description *DUDUURDUDUURUUR has the interpretation <*D, *DUDUURDUDUURUUR>.

Notice that in this aesthetic system if λ is an URD-description of a sequence of sixteen tones, then the interpretation $\langle\lambda, \lambda\rangle$ is an interpretation of the sequence. For example, the interpretation <*DUDUURDUDUURUUR, *DUDUURDUDUURUUR> is an interpretation of the sequence of sixteen tones having the description *DUDUURDUDUURUUR. Consequently, every sequence of sixteen tones has an interpretation in this aesthetic system.

Finally, notice that a sequence of sixteen tones can have more than one interpretation in this aesthetic system. For example, the sequence of sixteen tones having the description *DUDUURDUDUURUUR has the interpretations

<*D, *DUDUURDUDUURUUR>
<*DUD, *DUDUURDUDUURUUR>
<*DUDUURDUD, *DUDUURDUDUURUUR>
<*DUDUURDUDUURUUR, *DUDUURDUDUURUUR>

in this aesthetic system.

In this aesthetic system, an interpretation of a sequence of sixteen tones tells how the sequence is understood by giving the data or details that can be used to generate the URD-description of the sequence using the schema encoded in the interpretation algorithm of the aesthetic system. The schema encoded in the interpretation algorithm incorporates three productions that are fixed for this aesthetic system. Hence, each sequence of sixteen tones is understood in terms of these productions. That is, a sequence of sixteen tones is understood by giving an initial sequence (the data) which when developed using the productions results in the URD-description of the sequence.

Of course, similar aesthetic systems can be defined which have interpretation algorithms incorporating other productions. For example, an interpretation algorithm might incorporate the productions

$$\begin{aligned} U &\rightarrow URU \\ R &\rightarrow DU \\ D &\rightarrow DRD \end{aligned}$$

In an aesthetic system having this interpretation algorithm, all sequences of sixteen tones would be understood in terms of these particular productions. The same sequence of sixteen tones could be understood differently in aesthetic systems having interpretation algorithms incorporating different productions.

An aesthetic system that is a generalization of aesthetic systems of the type just discussed can be defined. In this new aesthetic system, the productions would be given explicitly as part of the input component of an interpretation. For example, an interpretation of a sequence of sixteen tones having the description *DUDUURDUDUURUUR might be <*D#U→UUR#R→RDU#D→DUD, *DUDUURDUDUURUUR>. The input component of this interpretation gives the initial sequence *D and the three productions that develop the initial sequence into the URD-description given in the output component. The sharp signs (#) in the input component are used as separators. The interpretation algorithm in this aesthetic system would encode the conventions that determine how the productions are applied. In this aesthetic system, a sequence of sixteen tones can be understood in terms of a variety of productions. Here, it is most natural to consider the input component of an interpretation as instructions or rules of construction.

6.2 Aesthetic Systems Based on the Evocative Mode of Understanding

Using the evocative mode of understanding, an object is understood in terms of the evocations of the object. These evocations might include associations, emotions, or ideas. To use our analogy with number sequences, a ten digit number sequence might be understood by listing its evocations as a telephone number, for example, associations involving the person whose telephone number it is. To make this mode of understanding precise, it is necessary to (1) specify the aspects of an object which are of interest and (2) specify the conventions by which those aspects evoke associations, emotions, or ideas. In criticism algorithms and design algorithms, the specification of the aspects of an object which are of interest is given by the description of the object. The conventions by which the description of an object is used to evoke associations, emotions, or ideas are encoded in the interpretation algorithm of an aesthetic system. Here, an object is understood by listing the associations, emotions, or ideas that are generated by the description of the object using the conventions embodied in the interpretation algorithm. In the evocative mode of understanding, an object is understood by telling what evocations are produced by its description.

In an aesthetic system based on the evocative mode of understanding, an interpretation of an object contains the description of an object as its input component. An interpretation of an object has the form $<\lambda, \beta>$, where λ is the description of the object. The sequence of symbols β is the output of the interpretation algorithm of the aesthetic system which results when the description λ of the object is given as input. Hence, the output β may be considered a statement of the evocations of the object having the description λ. An interpretation has the form <description, evocations>. (See fig. 6-2).

In the previous section, it was pointed out that the input to an algorithm may be treated as instructions or as data. In aesthetic systems based on the evocative mode of understanding, it is more natural and instructive to consider the input component, that is, the description of an object, of an interpretation as data. Here, the interpretation algorithm encodes a particular schema for responding to objects. The description of an object provides the data or

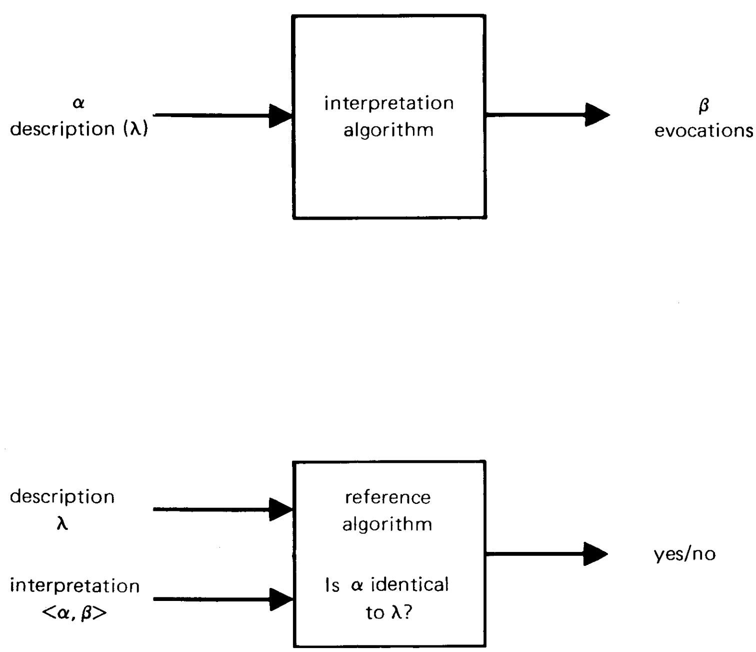


Fig. 6-2

The interpretation algorithm and reference algorithm
in an aesthetic system based on the
evocative mode of understanding.

details that particularize the schema so that the output produced by the interpretation algorithm is the response to that particular object. General rules for generating associations, emotions, or ideas from an object are embodied in the interpretation algorithm. The description of an object provides all the data needed to attach specific associations, emotions, or ideas to the object using these rules.

For example, the interpretation algorithm might encode a schema for the emotions aroused by the colors and their arrangement in a picture. This schema might be based on, say, Goethe's characterizations of the emotional effects of colors.[5] The description of a picture would give data about the colors and their arrangement in the picture. This data in conjunction with the schema would specify the emotions aroused by the picture. Using a fixed schema, different pictures could arouse different emotions because different pictures have different descriptions. Of course, there are many different schemata that may be used to determine what emotions are aroused by a picture. Each of these schemata would correspond to a different interpretation algorithm. A given picture may evoke different emotions in aesthetic systems using different interpretation algorithms because the algorithms embody different schemata.

In an aesthetic system based on the evocative mode of understanding, the interpretation algorithm embodies the conventions that determine what is evoked by the object in terms of the description of the object. The conventions could include a large complex of knowledge about the outside world and mechanisms for attaching parts of that complex to the description of the object. Formalization of this complex of knowledge and of the mechanisms for accessing the knowledge may be straightforward as in the following example or may be very complicated as in the example of the *School of Athens* discussed in chapter 1.

The reference algorithm in an aesthetic system based on the evocative mode of understanding determines whether an interpretation refers to an object by checking to see if the input component of the interpretation is identical to the description of the object. That is, an interpretation $<\alpha, \beta>$ refers to an object having

[5]Goethe, *Theory of Colours* (London, 1810, 1967), Part VI. See also J. Albers, *Interaction of Color* (New Haven, 1963), pp. 66-68.

the description λ if and only if α is identical to λ (see fig. 6-2). Here, the reference algorithm simply makes a comparison between two sequences of symbols and, hence, is easily constructed.

Aesthetic systems based on the evocative mode of understanding are characterized by their reference algorithms. Any aesthetic system in which reference is determined as stipulated in the previous paragraph is based on the evocative mode of understanding.

Example

The interpretation algorithm and reference algorithm of an aesthetic system based on the evocative mode of understanding are now considered. This aesthetic system contains interpretations of sequences of sixteen tones having URD-descriptions (see the example of section 6.1).

The interpretation algorithm of the aesthetic system considered allows for the generation of the evocations of sequences of sixteen tones from their URD-descriptions. The input to the interpretation algorithm is an URD-description. The interpretation algorithm includes an encoding of the classical portion of Parson's *The Directory of Tunes and Musical Themes*. This portion of *The Directory* lists in alphabetical order the URD-descriptions of the first sixteen notes of themes from classical musical works. For each URD-description listed, the title of the work having a theme with that URD-description is given along with the composer of the work, and the place in the work where the theme occurs. For example, the entry in *The Directory* for the URD-description *RRDURRDURRDURRD is "Beethoven Symphony/5 in Cmi 1m 1t." This entry associates the URD-description with the first theme of the first movement of Beethoven's Symphony No. 5 in C Minor. We assume that also included in the interpretation algorithm is an encoding of some additional information about certain of the works given in the directory. For example, the entry for the URD-description *RRDURRDURRDURRD might also include Berlioz's commentary on the first movement of Beethoven's Symphony in C Minor:

> The Symphony in C minor (the Fifth), on the other hand, appears to come directly from Beethoven's genius. His own intimate thoughts are developed there; as well as his secret sorrows, his pent-up ranges, his dreams filled with melancholy oppression,

> his nocturnal visions, and his bursts of enthusiasm furnish its entire subject; whereas the melodic, harmonic, rhythmic, and orchestral forms are delineated with an essential novelty and individuality also giving them considerable power and nobility.
>
> The first movement is devoted to the expression of the disordered sentiments filling a great soul when it is preyed upon by despair. It is not the calm and concentrated despair bearing the outward look of resignation; or the grief so similar and silent shown by Romeo when hearing of Juliet's death. Rather it is the terrible fury of Othello when hearing from Iago's mouth the poisoned calumnies persuading him of Desdemona's crime.
>
> Sometimes it is an excessive depression, expressing itself only in accents of regret, and appearing to hold itself in pity. Listen to those orchestral gasps; to those chords in the dialogue between woodwinds and strings, coming and going while gradually growing weaker like the painful breathing of a dying man.
>
> These finally give place to a phrase full of violence where the orchestra seems to rise again as if animated by a spark of fury. Look at that quivering mass, hesitating for an instant, and then precipitating itself bodily divided into two ardent unisons resembling two streams of lava. And, having done this, say whether this passionate style is not beyond and above anything yet produced in instrumental music.
>
> The movement presents a striking example of the effect produced by the excessive doubling of parts under certain circumstances, and of the wild aspect of the chord of the fourth on the second note of the scale, sometimes described as the second inversion of the chord of the dominant. It is often encountered without preparation or resolution, and even occurs once without the leading note and on an organ point; the D forming the bass of the strings while the G forms the discordant summit of a few parts assigned to the woodwinds.[6]

The output of the interpretation algorithm would indicate that the URD-description given as input (1) is not the URD-description of any theme listed in *The Directory* (indicated by "na"), (2) is the URD-description of a theme listed in *The Directory* by giving the entry associated with that description, or (3) is the URD-description of a theme listed in *The Directory* by giving the entry associated with that description and some additional information about the musical work in which the theme occurs.

[6] H. Berlioz quoted in *Beethoven by Berlioz*, compiled and translated by R. DeSola (New York, 1975), pp. 27-28.

Recall that an interpretation is an input-output pair of the interpretation algorithm. Interpretations in this aesthetic system include <*DUDUURDUDUURUUR, na>, <*RDUDUDUURR-DUDUD, Handel Concerto Grosso in F op6/2 2m>, and <*RRDURRDURRDURRD, Beethoven Symphony/5 in Cmi 1m 1t. [Berlioz's commentary]>. Here, "[Berlioz's commentary]" means Berlioz's commentary quoted above.

In an aesthetic system based on the evocative mode of understanding, an interpretation is determined by the reference algorithm to be an interpretation of an object if and only if the description of the object is identical to the input component of the interpretation. For example, in this aesthetic system, the opening sixteen notes of Beethoven's Symphony in C Minor has the URD-description *RRDURRDURRDURRD and hence has the interpretation <*RRDURRDURRDURRD, Beethoven Symphony/5 in Cmi 1m 1t. [Berlioz's commentary]>. Notice that all sequences of sixteen tones have interpretations in this aesthetic system.

In this aesthetic system, an interpretation of a sequence of sixteen tones tells how the sequence is understood by giving the evocations of the sequence generated from the URD-description of the sequence using the interpretation algorithm of the aesthetic system. The interpretation algorithm of this particular aesthetic system is based on Parson's *Directory* augmented with some additional information about certain musical works. Of course, other similar aesthetic systems with interpretation algorithms based on other directories or other additional information are possible.

6.3 Aesthetic Systems Based on Both the Constructive and Evocative Modes of Understanding

In an aesthetic system based on the constructive mode of understanding, an interpretation of an object has the form <information for construction, description>. In an aesthetic system based on the evocative mode of understanding, an interpretation of an object has the form <description, evocations>. The explicit occurrence of the descriptions of objects in interpretations of objects in aesthetic systems of these types allows for the construction of aesthetic systems based on both the constructive and evocative modes of understanding. In aesthetic systems of this new type, an interpretation of an object has the form <information for construction, evocations>. Here, an interpretation of an object tells how the object is understood by giving information that can be used to generate its description and by listing the evocations generated from its description.

Consider any aesthetic system based on the constructive mode of understanding and any aesthetic system based on the evocative mode of understanding. Call the interpretation algorithm of the first aesthetic system A_1, of the second aesthetic system A_2. A new aesthetic system can be constructed having an interpretation algorithm A_3 which is the composition (see the Appendix) of the algorithms A_1 and A_2 as shown in figure 6-3. The reference algorithm of this new aesthetic system is constructed using either the algorithm A_1 or the algorithm A_2 as indicated in figure 6-3.

For an object having the description λ, there is an interpretation $\langle\alpha, \beta\rangle$ of the object in the new aesthetic system if and only if there is an interpretation $\langle\alpha, \lambda\rangle$ of the object in the first aesthetic system and an interpretation $\langle\lambda, \beta\rangle$ of the object in the second aesthetic system.

In the interpretation $\langle\alpha, \beta\rangle$ of the object, α is the input component in an interpretation $\langle\alpha, \lambda\rangle$ of the object in the aesthetic system based on the constructive mode of understanding. Hence, α gives the information needed to construct the description λ of the object. β is the output component in an interpretation $\langle\lambda, \beta\rangle$ of the object in the aesthetic system based on the evocative mode of understanding. Hence, β gives the associations, emotions, or ideas evoked by the description λ of the object. So, the interpretation $\langle\alpha, \beta\rangle$ has the form <information for construction, evocations>. The two components of the interpretation are linked by the description of the object, which is constructed internally in the interpretation algorithm A_3.

Example

An aesthetic system based on both the constructive and evocative modes of understanding is now considered. This aesthetic system contains interpretations of sequences of sixteen tones having URD-descriptions.

The aesthetic system given as an example in section 6.1 and the aesthetic system given as an example in section 6.2 are combined to form this new aesthetic system using the construction shown in figure 6-3. Given a sequence of sixteen tones, for an interpretation

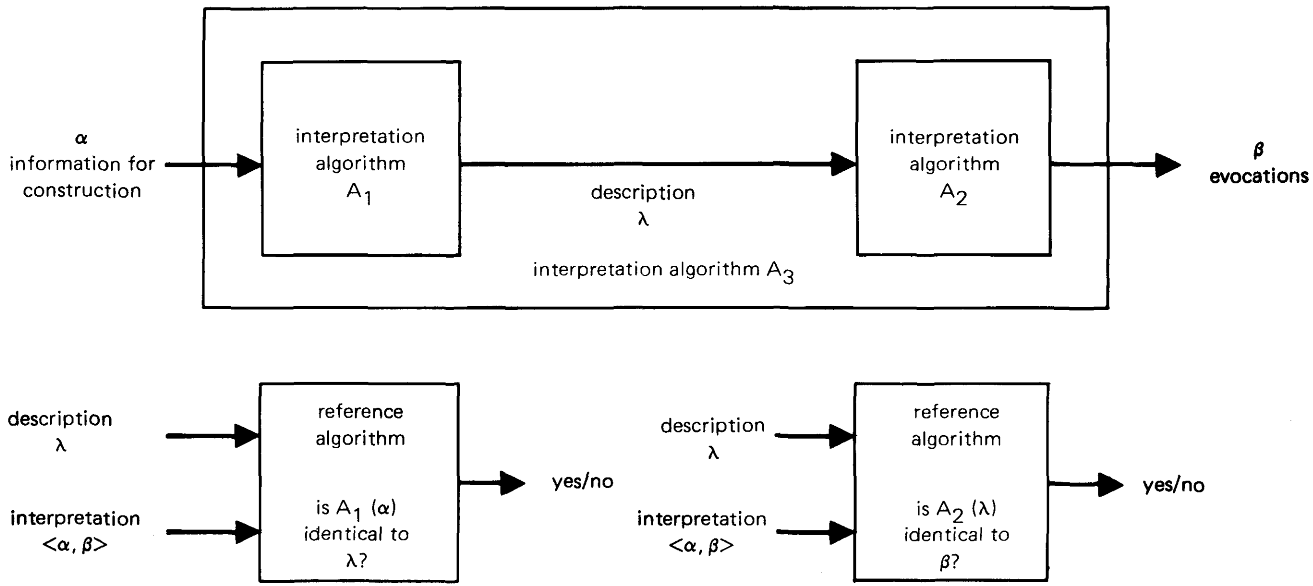


Fig.6-3

The interpretation algorithm and the two possibilities for the reference algorithm in an aesthetic system based on both the constructive and evocative modes of understanding.

of the sequence in the first aesthetic system and an interpretation of the sequence in the second aesthetic system, there is a corresponding interpretation of the sequence in the new aesthetic system. The input component of this interpretation is the input component of the interpretation in the first aesthetic system. That is, the input component gives an initial sequence (data) that can be developed into the URD-description of the sequence using the three productions encoded in the interpretation algorithm of the first aesthetic system. The output component of this interpretation is the output component of the interpretation in the second aesthetic system. That is, the output component gives the evocations that are generated from the URD-description of the sequence using the portion of Parson's *Directory* augmented with some additional information encoded in the interpretation algorithm of the second aesthetic system.

A sequence of sixteen tones having the description *DUDUURDUDUURUUR has the interpretation <*D, *DUDUURDUDUURUUR> in the first aesthetic system and the interpretation <*DUDUURDUDUURUUR, na> in the second aesthetic system. Thus, the sequence has the interpretation <*D, na> in the new aesthetic system.

A sequence of sixteen tones having the description *RRDURRDURRDURRD has the interpretation <*RRDURRDURRDURRD, *RRDURRDURRDURRD> in the first aesthetic system and the interpretation <*RRDURRDURRDURRD, Beethoven Symphony/5 in Cmi 1m 1t. [Berlioz's commentary]> in the second aesthetic system. Thus, the sequence has the interpretation <*RRDURRDURRDURRD, Beethoven Symphony/5 in Cmi 1m 1t. [Berlioz's commentary]> in the new aesthetic system.

A sequence of sixteen tones having the description *RDUDUDUURRDUDUD has the interpretation <*RR, *RDUDUDUURRDUDUD> in the first aesthetic system and the interpretation <*RDUDUDUURRDUDUD, Handel Concerto Grosso in F op 6/2 2m> in the second aesthetic system. Thus, the sequence has the interpretation <*RR, Handel Concerto Grosso in F op 6/2 2m> in the new aesthetic system.

In this aesthetic system, an interpretation of a sequence of sixteen tones tells how the sequence is understood by giving information that can be used to generate the URD-description of the sequence and by giving the evocations generated from the URD-description of the sequence using the conventions encoded in the interpretation algorithm of the aesthetic system.

6.4 Summary

An aesthetic system provides the basis for interpreting objects in terms of their descriptions. The interpretation algorithm of the aesthetic system encodes the conventions that determine what are possible interpretations. The reference algorithm of the aesthetic system encodes the conventions for deciding whether the description of an object can be connected with a particular interpretation. An interpretation of an object is an input-output pair of the interpretation algorithm that is determined by the reference algorithm to be connected with the description of the object.

Three main types of aesthetic systems are characterized:

In an aesthetic system based on the constructive mode of understanding, an interpretation $\langle \alpha, \lambda \rangle$ of an object having the description λ tells how the object is understood by giving the information (instructions or data) α that can be used by the interpretation algorithm of the aesthetic system to generate the description λ.

In an aesthetic system based on the evocative mode of understanding, an interpretation $\langle \lambda, \beta \rangle$ of an object having the description λ tells how the object is understood by listing the evocations β generated from the description λ using the interpretation algorithm of the aesthetic system.

In an aesthetic system based on both the constructive and evocative modes of understanding, an interpretation $\langle \alpha, \beta \rangle$ of an object having the description λ tells how the object is understood by giving the information α that can be used to generate the description λ and by giving the evocations β generated from the description λ. An aesthetic system of this type is constructed by combining an aesthetic system based on the constructive mode of understanding and an aesthetic system based on the evocative mode of understanding.

7
Interpretation: Expression, Representation, Transparency, and Form

Traditionally, works of art are interpreted in a variety of ways. Typical of these are interpretations of works of art in terms of expression, representation, and form. In this chapter we show how these different approaches to art could be modeled by aesthetic systems. We examine the possible contents of input-output pairs of the interpretation algorithms in such aesthetic systems.

7.1 Expression

Discussions of works of art frequently deal with expression. In these discussions, works of art are considered in terms of emotions or feelings that are in some way connected with them. Various types of expression have been distinguished on the basis of who has the emotions or feelings and how these emotions or feelings are connected to the work of art.

Four types of expression are distinguished here: In the first, the artist has emotions or feelings that are embodied or translated into a work of art. In the second, the observer has emotions or feelings that are aroused by a work of art. In the third, the artist has emotions or feelings that are embodied or translated into a work of art which arouses (ideally the same) emotions or feelings in the observer. In the fourth, neither the artist nor the observer has the emotions or feelings.

In this section, it is not our intention to argue for the validity of any one of these types of expression. To reiterate an underlying theme of this study, no single approach to art is advocated as no single approach to art is considered absolutely correct. The four types of expression examined all have something to say about art and have been advocated at various times. Our intention is to show that these different types of expression can be profitably treated in terms of aesthetic systems.

7.1.1 Expression and the Artist

Expression can be examined in terms of the emotions or feelings of the artist.

> Sometimes when people talk about musical expression, we can see that they are really talking about the state of mind of the composer; to them "The scherzo of Beethoven's *A Major Symphony* expresses joy" means "Beethoven felt joy when composing that scherzo, and was impelled by that emotion to compose it."[1]

In this sense, the emotions or feelings of the artist provide the basis for the generation of a work of art. The work of art follows from the artist's emotions or feelings.

Expression of this type seems most naturally modeled by aesthetic systems based on the constructive mode of understanding. In an aesthetic system based on the constructive mode of understanding, an interpretation has the form <information for construction, description>. For an aesthetic system for this type of expression, the input component, information for construction, of an interpretation of an object would be a specification of emotions or feelings. This specification could be an English statement, for example, "gentle melancholy tinged with doubt."[2] The output component would be the description of the object. The interpretation algorithm of the aesthetic system would translate the

[1] M. Beardsley, *Aesthetics* (New York, 1958), p. 326. See also J. Hospers, "The Concept of Artistic Expression," *Introductory Readings in Aesthetics* (New York, 1969), pp. 142-150 and R. Collingwood, *The Principles of Art* (Oxford, 1938). Beardsley and Hospers reject this notion and the notions in the next two sections as the meaning of "expression." Here we are not interested in defining the term "expression" but rather in the different interpretative conventions that have sometimes gone under the heading "expression."

[2] Hospers, "The Concept of Artistic Expression," p. 164.

specification of emotions or feelings into the description of the object (see fig. 7-1). The interpretation algorithm would embody a schema for generating descriptions of objects from emotions. The input component of the interpretation would give the specific details of emotions or feelings which particularize the schema to produce a unique description. Here, the interpretation of the object would tell how the object is understood by stating the emotions that caused the production of the object.

Of course, there can be many schemata for translating emotions into descriptions of objects. Different schemata would be embodied in different interpretation algorithms. Thus, there can be many aesthetic systems that model this type of expression. In the same way, given that you accept this type of expression, different artists translate their emotions into works of art in different ways.

Even though aesthetic systems modeling this type of expression deal with the emotions or feelings of the artist, they could be used for criticism as well as design. When an aesthetic system of this kind is used in a design algorithm, an object would be produced in direct response to emotions or feelings. When an aesthetic system of this kind is used in a criticism algorithm, the response to an object would be based on an inference about the emotions or feelings of the artist when the object was produced. The use of aesthetic systems in criticism algorithms and design algorithms is examined in detail in chapter 12.

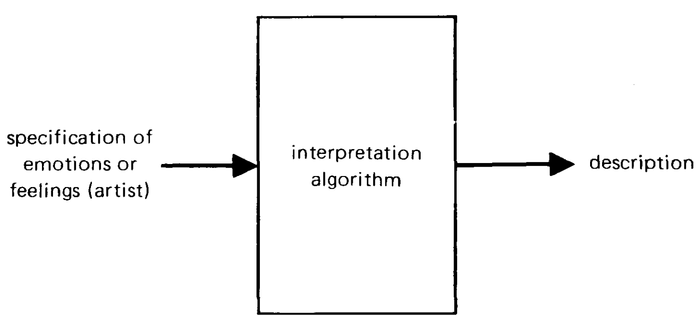


Fig. 7-1

Interpretation algorithm in an aesthetic system based on the constructive mode of understanding for expression (in terms of the artist).

7.1.2 Expression and the Observer

Expression can be examined in terms of the emotions or feelings of the observer.

> Other critics who talk about musical expression are really talking about their own state of mind when they listen to the music; to them, "The scherzo of Beethoven's *A Major Symphony* expresses joy" means "The scherzo makes me feel joy when I hear it. . . ." In this second sense, "express" is synonymous with "arouse"; the music makes the listener experience joy or sorrow, calmness or uneasiness.[3]

In this sense, a work of art evokes emotions or feelings in the observer. The emotions or feelings of the observer follow from the work of art.

Expression of this type seems most naturally modeled by aesthetic systems based on the evocative mode of understanding. In an aesthetic system based on the evocative mode of understanding, an interpretation has the form <description, evocations>. For an aesthetic system for this type of expression, the input component of an interpretation of an object would be the description of the object. The output component would be a specification of the emotions or feelings evoked. The interpretation algorithm of the aesthetic system would translate the description of the object into the specification of emotions or feelings (see fig. 7-2). The interpretation algorithm would embody a schema for generating specifications of emotions from descriptions of objects. The input component of the interpretation would give the specific details of the object which particularize the schema to produce a specification of particular emotions. Here, the interpretation of the object would tell how the object is understood by stating the emotions that result from the object.

Of course, there can be many schemata for translating descriptions of objects into emotions. Different schemata would be embodied in different interpretation algorithms. There can be many aesthetic systems that model this type of expression. In the same way, given that you accept this type of expression, a given work of art could evoke different emotions in different observers.

[3]Beardsley, *Aesthetics,* pp. 326-327. See also Hospers, "The Concept of Artistic Expression," pp. 150-156.

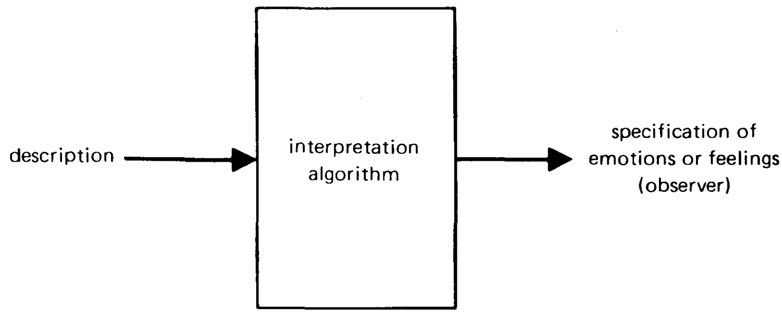


Fig. 7-2

Interpretation algorithm in an aesthetic system based on the evocative mode of understanding for expression (in terms of the observer).

Even though aesthetic systems modeling this type of expression deal with the emotions or feelings of the observer, they could be used for design as well as criticism. When an aesthetic system of this kind is used in a criticism algorithm, an object would be responded to directly in terms of emotions or feelings. When an aesthetic system of this kind is used in a design algorithm, an object would be produced on the basis of an inference about the emotions or feelings that would be evoked in the observer by the object.

7.1.3 Expression as Communication

Expression can be examined in terms of the emotions or feelings of both the artist and the observer.

> To evoke in oneself a feeling one has once experienced, and having evoked it in oneself, then, by means of movements, lines, colors, sounds, or forms expressed in words, so to transmit that feeling that others may experience the same feeling – this is the experience of art.
>
> Art is a human activity consisting in this, that one man consciously, by means of certain external signs, hands on to others feelings he has lived through, and that other people are infected by these feelings and also experience them.[4]

[4] L. Tolstoy, *What is Art?* (Indianapolis, 1896, 1960), p. 51.

> The typical kind of view here is one hallowed by tradition; we might describe it roughly as follows: The artist feels a powerful emotion which he expresses by creating a work of art, in such a way that we, the audience, on reading or seeing or hearing the work of art, feel that same emotion ourselves.[5]

In this sense, the artist has emotions or feelings that are embodied or translated into a work of art which arouses (ideally the same) emotions or feelings in the observer. The emotions or feelings of the observer follow from the emotions or feelings of the artist through the work of art. Clearly, this type of expression is a combination of the first two types.

It should be obvious that expression of this type is naturally modeled by aesthetic systems based on both the constructive and the evocative modes of understanding. An aesthetic system of this type is constructed by combining an aesthetic system based on the constructive mode of understanding and an aesthetic system based on the evocative mode of understanding (see section 6.3). An aesthetic system modeling expression as communication would be constructed by combining (1) an aesthetic system modeling expression from the artist's point of view and (2) an aesthetic system modeling expression from the observer's point of view. In the first aesthetic system, the input component of an interpretation of an object would be the specification of the emotions or feelings that result in the description of the object. The output component would be this description. In the second aesthetic system, the input component of an interpretation of an object would be the description of the object. The output component would be a specification of the emotions or feelings that result from this description of the object. In the aesthetic system modeling expression as communication, both the input component and the output component of an interpretation of an object would be specifications of emotions or feelings. The input component would be a specification of emotions or feelings that result in the description of the object. Intuitively, this specification would give the emotions or feelings of the artist. The output component would be a specification of the emotions or feelings that result from the description of the object. Intuitively, this specification would give the emotions or feelings of the observer. The description of the object is

[5]Hospers, "The Concept of Artistic Expression," p. 157.

constructed internally in the interpretation algorithm of the aesthetic system (see fig. 7-3).

Ideally, in an aesthetic system modeling expression as communication, the input component of an interpretation of an object would be identical to the output component. In this case, there would be perfect communication. The two interpretation algorithms used in the construction of the interpretation algorithm of this aesthetic system would mesh perfectly. The conventions used to translate a specification of emotions or feelings into the description of an object would be symmetric with the conventions used to translate the description of the object into a specification of evoked emotions or feelings. Intuitively, the emotions or feelings of the artist when producing a work of art would be identical to the emotions or feelings of the observer when observing the work of art. The conventions of an artist used to translate emotions or feelings into a work of art would be symmetric with the conventions of the observer used to translate a work of art into emotions or feelings.[6]

Of course, in an aesthetic system modeling expression as communication, the input component of an interpretation of an object could be different than the output component. In this case, there would be imperfect communication. The two interpretation algorithms used in the construction of the interpretation algorithm of this aesthetic system would embody conventions that do not mesh. Intuitively, the conventions of the artist and the conventions of the observer would be different. For example, an artist might produce a work of art out of suicidal desperation and the observer might find the work of art maudlin.

An aesthetic system modeling expression as communication could be used in both a criticism algorithm and a design algorithm. When used in a criticism algorithm, an object would be responded to both in terms of an inference about the emotions or feelings of the artist when the object was produced and directly in terms of the emotions or feelings evoked by the object. When used in a design algorithm, an object would be produced both in terms of a direct response to emotions or feelings and on the basis of an inference about the emotions or feelings that would be evoked in the observer by the object.

[6] See the postage stamp game in E. H. Gombrich, "Expression and Communication," *Meditations on a Hobby Horse* (London, 1963), pp. 68-69.

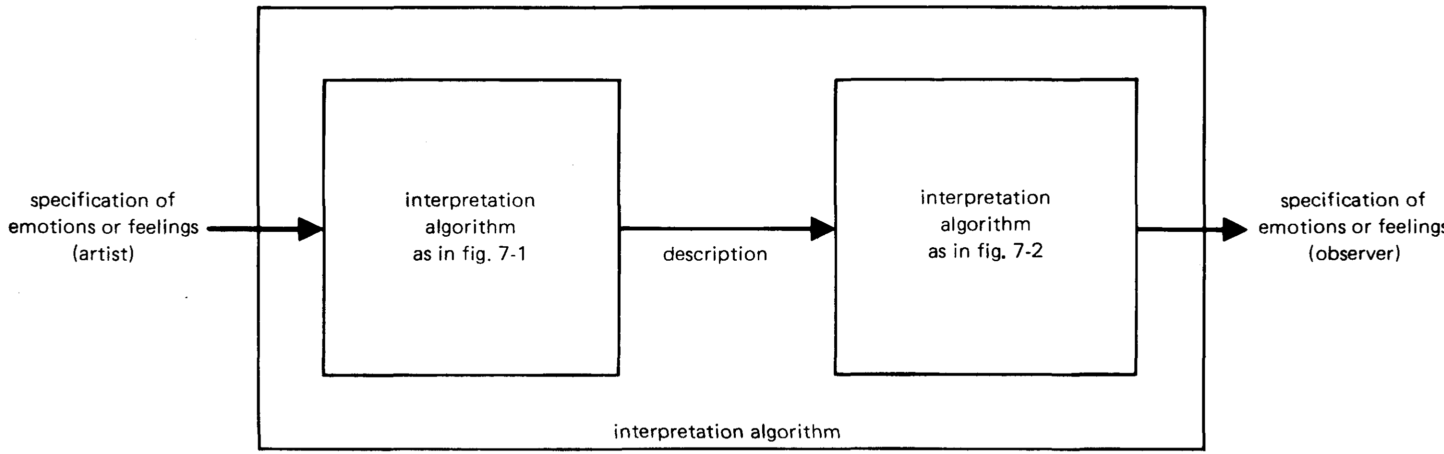


Fig. 7-3

Interpretation algorithm in an aesthetic system based on both the constructive and evocative modes of understanding for expression (as communication).

7.1.4 Expression in Terms of the Work of Art Itself

Sometimes a work of art can be interpreted in terms of emotions that are felt neither by the artist nor the observer. Two main cases of this type of interpretation are possible.

In the first case, the work of art is representational and is perceived to contain representations of people. Here, the work of art can be understood in terms of the emotions or feelings perceived in the people represented. For example, emotions or feelings can be ascribed to Mona Lisa that are not felt by the observer and, presumably, were not felt by Leonardo. Similarly, *King Lear* can be understood in terms of emotions ascribed to Lear independent of whether his emotions are felt by the audience or were felt by Shakespeare.

The interpretation of representational works of art in this way is a matter of convention. That is, ascribing emotions to people on the basis of their facial expressions or behavior are to some extent culturally dependent.

As Goodman writes,

> When the first fine Japanese films reached us, Western audiences had some difficulty in determining what emotions the actors were expressing. Whether a face was expressing agony or hatred or anxiety or determination or despair or desire was not always instantly evident; for even facial expressions are to some extent molded by custom and culture. What the insular and amateur spectator may take to be instinctive and invariable, the professional actor or director knows to be acquired and variable.[7]

In the second case, the work of art is not perceived to contain people. Here, the work of art can be understood in terms of emotions used, metaphorically or figuratively, to characterize the properties of the work of art.

> It is neither the artist nor the audience that matters here; it is the work of art itself. It is *the music* that is expressive; and the music may be expressive even if the artist had no emotions when he wrote it, and even if the audience is composed of such dull, insensitive clods that they feel nothing when they hear it. . . . We may take pains to define the music's expressive character in terms of certain configurations of tones or rhythmic patterns in the

[7]N. Goodman, *Languages of Art* (Indianapolis, 1968), p. 48.

> music. We may say, for example, that music is expressive of sadness if it falls within a certain range of (rather slow) tempo, is in the minor key, has more than a certain proportion of descending notes, a certain proportion of sixths or diminished thirds among its intervals, etc.[8]

> Suppose from "This music expresses joy," we extract the statement, "This music is joyful," which is a description of the music. It is a metaphorical description, to be sure, but it is no less a description for being metaphorical.[9]

In this sense, emotions or feelings are used to characterize properties of a work of art. No one need have these emotions or feelings. Rather, the emotions or feelings are used in metaphorical or figurative statements, linking qualities of a work of art with human qualities.[10] As an extreme example, "sad music has some of the characteristics of people who are sad. It will be slow, not tripping; it will be low, not tinkling. People who are sad move slowly, and when they speak, they speak softly and low."[11]

The interpretation of works of art in this way is also a matter of convention. For example, a given object might be understood as expressing joy by one observer and understood as expressing feigned joy but real sadness by another. It may seem at first sight that what an object expresses is innate in the object, that only certain emotions or feelings could possibly be expressed by an object. The conventions by which an object can be said to express emotions or feelings are not fixed and constant but relative and variable. These conventions may vary for different people, different cultures, or different historical contexts. What a person believes an object expresses depends on the person's assumptions and preconceptions as well as on the object itself.

Both cases of this type of expression seem most naturally modeled by aesthetic systems based on the evocative mode of understanding. In such aesthetic systems, an interpretation of an object would have the description of the object as its input component and a specification of emotions or feelings as its output component.

[8] Hospers, "The Concept of Artistic Expression," p. 163.

[9] Beardsley, *Aesthetics,* p. 328.

[10] Ibid., pp. 328-332.

[11] O. K. Bouwsma, "The Expression Theory of Art," in *Aesthetics and Language* (Oxford, 1952), p. 99.

In an aesthetic system for the first case, the interpretation algorithm of the aesthetic system would contain conventions for determining the people in a work of art from its description and conventions for ascribing emotions to these people. The output component could list the people perceived in the work of art and the emotions ascribed to them. In an aesthetic system for the second case, the interpretation algorithm would contain conventions for associating emotions with properties of a work of art, where these properties are determined from the description of the work of art. The output component of the interpretation could list the properties of the object and the emotions associated with them. (See fig. 7-4.)

Of course, different conventions for ascribing emotions to people or associating emotions with properties would correspond to different interpretation algorithms.

As with all aesthetic systems, aesthetic systems for this type of expression could be used in both criticism algorithms and design

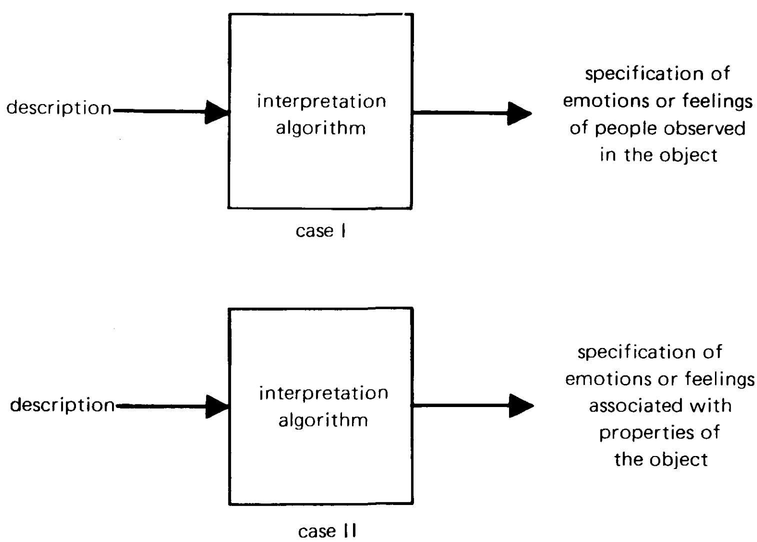


Fig. 7-4

Possible interpretation algorithms in aesthetic systems based on the evocative mode of understanding for expression (in terms of the work of art itself).

algorithms. An object can be responded to in terms of the emotions or feelings it is perceived to express or an object can be produced with the intention that it express some emotions or feelings.

7.2 Representation

In painting, representation is concerned with the two-dimensional portrayal of three-dimensional scenes. The scene represented in a painting may be actual, idealized, or imagined.[12] Representation has been a central interest of Western art.

> . . . twice on this globe, in ancient Greece and in Renaissance Europe, have artists striven systematically, through a succession of generations, step by step, to approximate their images to the visual world and achieve likenesses that might deceive the eye. . . . The ancient world certainly saw the evolution of art mainly as a technical progress, the conquest of that skill in *mimesis*, in imitation, that was considered the basis of art. Nor did the masters of the Renaissance differ here. Leonardo da Vinci was convinced of this value of illusion as was the most influential chronicler of Renaissance art, Giorgio Vasari, who took it for granted that in tracing the evolution of a plausible rendering of nature he was describing the progress of painting towards perfection. It goes without saying that in Western art this evolution did not come to an end with the Renaissance. The process of the conquest of reality through art continued, at a varying pace, at least as far as the nineteenth century, and the battles fought by the Impressionists were fought over this issue.[13]

Understanding a picture in terms of representation rests on a relation between the two-dimensional picture and a three-dimensional scene. In an aesthetic system dealing with representation, the two components of an interpretation of a picture would be the description of the picture and a specification of a three-dimensional scene. Intuitively, this interpretation would say "The picture having the description given in one component 'represents' the scene specified in the other component." The description of the picture could be given using a two-dimensional coordinate

[12] For a discussion of this point see H. Osborne, *Aesthetics and Art Theory* (New York, 1968), pp. 79-80.

[13] E. H. Gombrich, "Visual Discovery Through Art," *Arts Magazine* (November, 1965), p. 215.

system, the specification of the scene using a three-dimensional coordinate system. Included in the specification of the scene might be the coordinates and orientation of the viewer of the scene. For example, in the description it might be stated that there is a gray quadrilateral located at a certain place in the picture. In the specification it might be stated that there is a rectangular solid (or building) located at a certain place in the scene. The interpretation algorithm of the aesthetic system would provide the mapping between the gray quadrilateral and a face of the rectangular solid.

Two general types of aesthetic systems dealing with representation are possible: (1) those in which the input component of an interpretation of a picture is a specification of a three-dimensional scene and the output component is the description of the picture and (2) those in which the input component of an interpretation of a picture is the description of the picture and the output component is a specification of a three-dimensional scene. Aesthetic systems of the first type are based on the constructive mode of understanding, aesthetic systems of the second type on the evocative mode of understanding.[14] It is unclear which of these two general types of aesthetic systems for representation is more appropriate. Both are interesting and instructive.

7.2.1 Representation Based on the Constructive Mode of Understanding

In an aesthetic system based on the constructive mode of understanding for representation, an interpretation of a picture would have as input component a specification of a three-dimensional scene and as output component the description of the picture. The interpretation algorithm of this aesthetic system would encode a schema for obtaining descriptions of two-dimensional pictures from specifications of three-dimensional scenes (see fig. 7-5). A given specification of a scene would provide the data that particularize the schema so that a unique description of a picture would be produced. The interpretation algorithm would map specifications of three-dimensional scenes into descriptions of two-

[14] Aesthetic systems for representation based on both the constructive and evocative modes of understanding are, of course, mathematically possible, but their aesthetic relevance is not investigated.

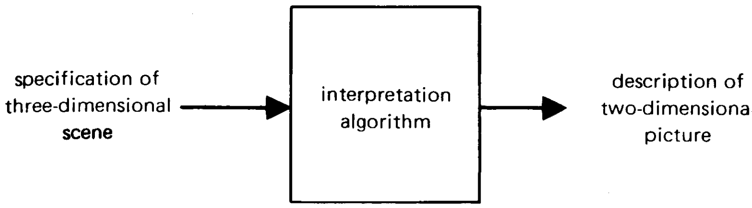


Fig. 7-5

Interpretation algorithm in an aesthetic system based on the evocative mode of understanding for representation.

dimensional pictures. This mapping could be based on certain laws of perspective.

As a simple example, the interpretation algorithm in an aesthetic system of this type might model a specific camera with a specific lens and specific settings. The input to the interpretation algorithm would be a specification of a three-dimensional scene, including the exact location and orientation of the camera. The output of the interpretation algorithm would be a description of the photograph of the scene taken by the camera from the indicated location and orientation. Different cameras with different lenses or settings would be modeled by different interpretation algorithms in different aesthetic systems.

An aesthetic system based on the constructive mode of understanding for representation need not have an interpretation algorithm based on a mapping implicit in some camera, that is, on "true geometrical perspective." Sometimes, true geometrical perspective is modified to incorporate perceptual cues such as drawing distant objects larger than they would appear in a photograph (size constancy)[15] or drawing parallel vertical edges of an object parallel rather than converging as they would appear in a photograph.[16] A wide variety of different conventions for mapping three-dimensional scenes into two-dimensional pictures have been used in art, for example, in Egyptian, Greek, Chinese, Japanese, Renaissance, and Cubist art.[17] Different conventions for mapping

[15] R. L. Gregory, *Eye and Brain* (New York, 1966).

[16] P. Klee, *Pedagogical Sketchbook* (New York, 1925, 1953), p. 41. Goodman, *Languages of Art*, pp. 15-16.

[17] For an interesting discussion of some of the different mappings used in representational art see F. Dubery and J. Willats, *Drawing Systems* (London, 1972).

three-dimensional scenes into two-dimensional pictures could be embodied in different interpretation algorithms in different aesthetic systems. Each of these aesthetic systems would deal with representation. A given specification of a three-dimensional scene would occur in a different interpretation in each of these aesthetic systems. That is, the input component of each interpretation would be the same, namely the specification of a three-dimensional scene, but the output component would be different. Each output component would be the description of a different picture. For example, pictures of the same scene drawn using conventions from Egyptian, Chinese, Renaissance, or Cubist art would be different. For a given aesthetic system, whether a picture "represents" a scene would depend on the conventions embodied in the interpretation algorithm.

As a short digression, an interesting controversy in aesthetics is whether or not there is one mapping from scenes to pictures that is most natural for people. Gombrich has argued[18] that there is a most natural mapping and that the history of much of Western art is a record of progress in the search for that mapping. Goodman has countered[19] that there is no most natural mapping, that the naturalness of mappings is relative, "determined by the system of representation standard for a given culture or person at a given time."[20] Here, we are not specifically concerned with this controversy. Rather, we are interested in the range of possible mappings and in how those mappings might be embodied in aesthetic systems.

Recent work in computer graphics[21] suggests possibilities for interpretation algorithms in aesthetic systems based on the constructive mode of understanding for representation. A number of programs (algorithms) exist for mapping specifications of three-dimensional scenes into descriptions of two-dimensional pictures. The specifications given as input to these programs indicate the three-dimensional coordinates of the vertices and identify the edges and faces of the objects in a scene. Here, objects normally

[18] E. H. Gombrich, *Art and Illusion* (Princeton, 1960). See also the quote at the beginning of section 7.2.

[19] Goodman, *Languages of Art*.

[20] Ibid., p. 37.

[21] W. Newman and R. Sproull, *Principles of Interactive Computer Graphics* (New York, 1973).

are treated as polyhedra. The descriptions produced as output by these programs are pixel descriptions of pictures. These descriptions give the gray value at each point in the picture. The pictures are displayed on a television connected to a computer.

7.2.2 Representation Based on the Evocative Mode of Understanding

In an aesthetic system based on the evocative mode of understanding for representation, an interpretation of a picture would have as input component the description of the picture and as output component a specification of a three-dimensional scene. The interpretation algorithm of this aesthetic system when given the description of a picture would produce a specification of the three-dimensional scene evoked by the description.

> We have to consider a double reality. The painting is itself a physical object, and our eyes will see it as such, flat on the wall, but it can also evoke quite other objects – people, ships, buildings – lying in space.[22]

In an aesthetic system based on the evocative mode of understanding for representation, the interpretation algorithm would encode a schema for obtaining specifications of three-dimensional scenes from descriptions of two-dimensional pictures (see fig. 7-6). A given description of a picture would provide the data that particularize the schema so that a specification of a scene would be

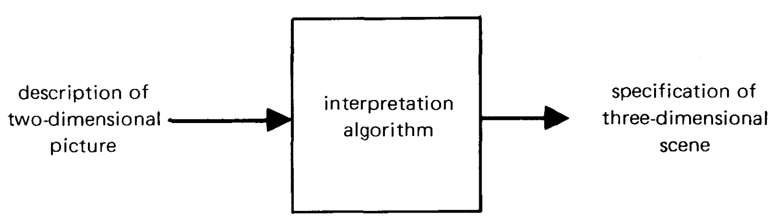


Fig. 7-6

Interpretation algorithm in an aesthetic system based on the evocative mode of understanding for representation.

[22] Gregory, *Eye and Brain*, p. 169.

produced.[23] The interpretation algorithm would map descriptions of two-dimensional pictures into specifications of three-dimensional scenes.

Here, the interpretation algorithm would perform a perceptual task. This task consists of identifying the objects and their arrangement in a scene from a picture of the scene. People perform this task all the time in a seemingly automatic way. But the process of performing this task remains one of the most difficult to specify algorithmically.

Recently, a large amount of effort has been expended in developing computer vision programs.[24] Various programs exist which map descriptions of two-dimensional pictures into specifications of three-dimensional scenes. These programs have only rudimentary perceptual capabilities but suggest possibilities for interpretation algorithms in aesthetic systems based on the evocative mode of understanding for representation. Generally, these programs work for pictures of simple arrangements of polyhedra. The descriptions given as input to these programs are pixel descriptions of pictures. These descriptions give the gray value at each point in a picture. The descriptions of pictures are obtained from a television camera. The specifications of three-dimensional scenes produced as output by these programs consist of the identification of the objects in a scene by name, for example, a cube, and their three-dimensional coordinates or statements about their relative positions, for example, that a wedge is located on top of a cube.

7.2.3 Discussion

Both general types of aesthetic systems for representation are feasible. In fact, rudimentary computer programs exist that can be used as interpretation algorithms in aesthetic systems of either type. The development of interpretation algorithms for representation with capabilities on a par with those of people is an extremely

[23] It might sometimes be the case that a picture evokes more than one scene, i.e., that it is ambiguous. Simple examples of such pictures are the Neckar cube and the infamous "duck-rabbit." In this case, the output component of the interpretation of the picture could contain specifications of all of the scenes evoked. For example, the output component might have the form "[specification of scene 1] or [specification of scene 2]."

[24] See P. Winston, *The Psychology of Computer Vision* (New York, 1975), and the second half of R. Duda and P. Hart, *Pattern Classification and Scene Analysis* (New York, 1973).

difficult task. Currently, a considerable amount of research is focused on the development of computer graphics programs and computer vision programs. Computer graphics programs can be used as interpretation algorithms in aesthetic systems based on the constructive mode of understanding for representation; computer vision programs can be used as interpretation algorithms in aesthetic systems based on the evocative mode of understanding for representation. Aesthetic systems of the first type seem more compelling mathematically. Aesthetic systems of the second type seem more compelling psychologically. Both types seem instructive.

Aesthetic systems based on the constructive mode of understanding for representation seem most natural for design; aesthetic systems based on the evocative mode of understanding seem most natural for criticism. Even so, either type of aesthetic system for representation can be used in a criticism algorithm or in a design algorithm.

In an aesthetic system of the first type, an interpretation of a picture has as input component a specification of a three-dimensional scene and as output component the description of the picture. When this aesthetic system is used in a design algorithm, a picture would be produced in direct response to a three-dimensional scene. When this aesthetic system is used in a criticism algorithm, the response to the picture would be based on an inference about the three-dimensional scene from which the picture could be produced.

In an aesthetic system of the second type, an interpretation of a picture has as input component a description of the picture and as output component a specification of a three-dimensional scene. When this aesthetic system is used in a criticism algorithm, a specification of a three-dimensional scene would be produced in direct response to a picture. When this aesthetic system is used in a design algorithm, a picture would be produced on the basis of an inference about the picture that would evoke the scene to be represented.

7.3 Transparency

In representation, a picture is understood solely by identifying the scene depicted by the picture. Sometimes, a picture is understood not only by identifying the scene represented but also by indicating the evocations of the scene. For example, Goya's painting *3 May 1808* is often understood in terms of evocations of the scene, a firing squad executing a group of citizens (hooligans?), represented in the picture. These evocations could include the emotions or feelings perceived in the people in the scene, inferences about the events leading up to the scene, political associations of the scene, lessons to be drawn from the scene, as well as the emotions or feelings aroused in the observer of the scene. Representation plays a basic role in understanding pictures in this way, but additional ways of understanding are involved as well.

Understanding a picture in terms of evocations of the scene represented is here said to deal with "transparency." Transparency occurs when one "looks through" the picture to the scene or event represented. In this case, the scene or event represented is considered as if it were real. The picture is understood solely in terms of aspects of that scene or event. (See section 7.1.4.)

Transparency is a very common way of understanding pictures. When the man in the street asks "What does this picture mean?" he is usually interested in understanding the scene represented in the picture. Much of the popular puzzlement over modern art has resulted because this art cannot be understood in terms of transparency. It is understanding art in terms of transparency that Bell (who advocates understanding art in terms of "significant form") rails against:

> Representation is not of necessity baneful, and highly realistic forms may be extremely significant. Very often, however, representation is a sign of weakness in an artist. A painter too feeble to create forms that provoke more than a little aesthetic emotion will try to eke that little out by suggesting the emotions of life. To evoke the emotions of life he must use representation. Thus, a man will paint an execution, and, fearing to miss with his first barrel of significant form, will try to hit with his second by raising an emotion of fear or pity. But if in the artist an inclination to play upon the emotions of life is often the sign of a flickering inspiration, in the spectator a tendency to seek, behind form, the emotions of life is a sign of defective sensibility always.[25]

[25] C. Bell, *Art* (London, 1913; reprinted New York, 1958), pp. 28-29. See also Bell's discussion of Frith's picture *Paddington Station* on pp. 22-23.

Understanding a picture in terms of transparency can, as discussed above, involve the second type of expression – the evocation of emotions or feelings in the observer – characterized in section 7.1.2.[26] Transparency can also involve the evocation of associations or ideas. Understanding pictures as didactic or propagandistic are extreme ways of understanding pictures in terms of transparency. A very wide range of associations, emotions, or ideas can be attached to a picture in terms of the scene it represents.

7.3.1 Transparency in Pictures

Aesthetic systems dealing with transparency can be constructed using aesthetic systems for representation. There are several ways that aesthetic systems dealing with transparency can be structured.

In constructing aesthetic systems dealing with transparency, the following types of sequences of symbols are used: pixel descriptions of pictures, specifications of three-dimensional scenes, and specifications of associations, emotions, or ideas. The following types of algorithms are used to relate these types of sequences of symbols: interpretation algorithms for representation which when given specifications of scenes as inputs produce pixel descriptions of pictures as outputs, interpretation algorithms for representation which when given pixel descriptions of pictures as inputs produce specifications of scenes as outputs, and algorithms that when given specifications of scenes as inputs produce specifications of associations, emotions, or ideas as outputs. Here, these types of algorithms are called computer graphics algorithms, computer vision algorithms, and evocation algorithms, respectively (see fig. 7-7).

As was pointed out for computer graphics algorithms and computer vision algorithms in section 7.2, evocation algorithms can embody a wide variety of different conventions. That is, different evocation algorithms would consider a given scene to evoke different associations, emotions, or ideas. Further, as with computer graphics algorithms and computer vision algorithms, evocation algorithms that match the capabilities of people would be difficult to construct.

[26] In this section we only consider transparency in terms of the evocations of the scene represented. Transparency can also be considered in terms of the constructive mode of understanding and both the constructive and evocative modes. In particular, transparency can involve the other modes of expression characterized in section 7.1.

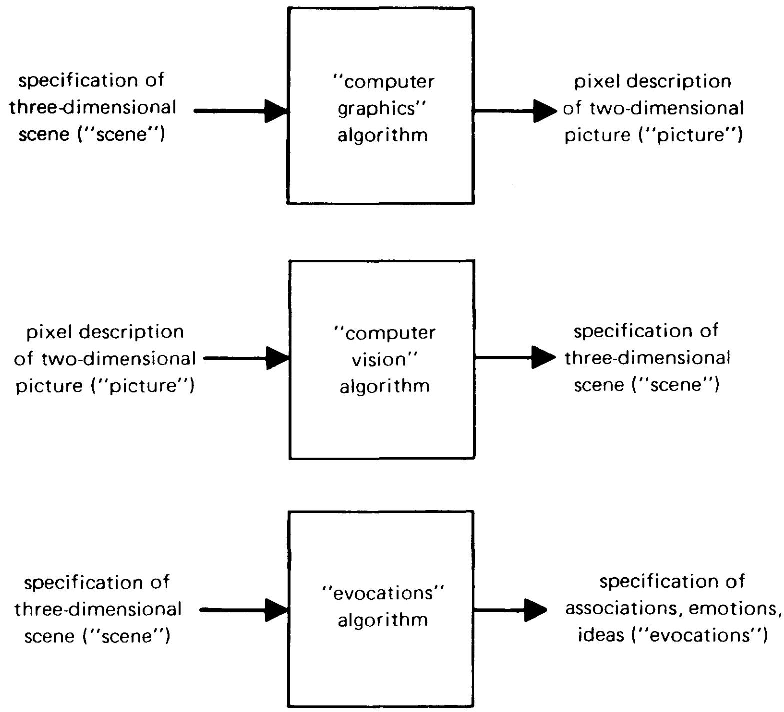


Fig. 7-7

The three algorithms used to construct interpretation algorithms and reference algorithms in aesthetic systems for transparency.

Three ways of constructing aesthetic systems dealing with transparency are now considered. These three constructions are presented both to investigate the nature of transparency and to illustrate some of the ways interpretation algorithms can be manipulated.

In the first way of constructing aesthetic systems dealing with transparency, the interpretation algorithm of an aesthetic system is formed by the composition of a computer vision algorithm and an evocation algorithm. This interpretation algorithm has the form shown in figure 7-8*a*. In this aesthetic system, descriptions of pictures would be pixel descriptions. An interpretation of a picture would have as input component the description of a picture and as output component a specification of associations, emotions, or

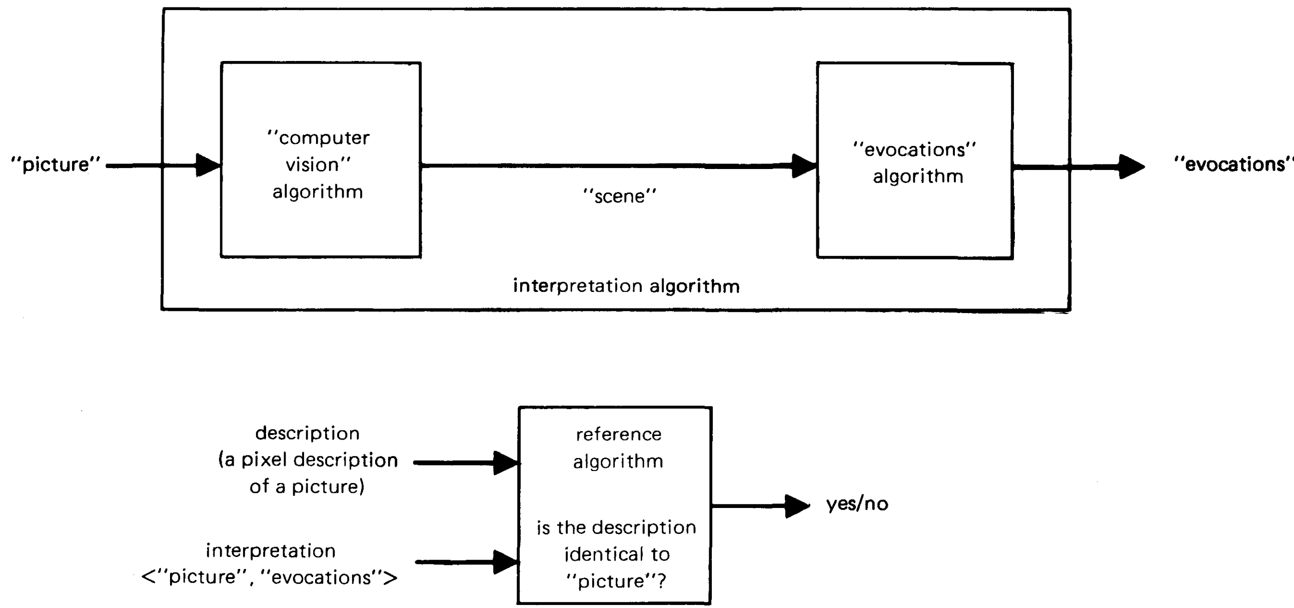
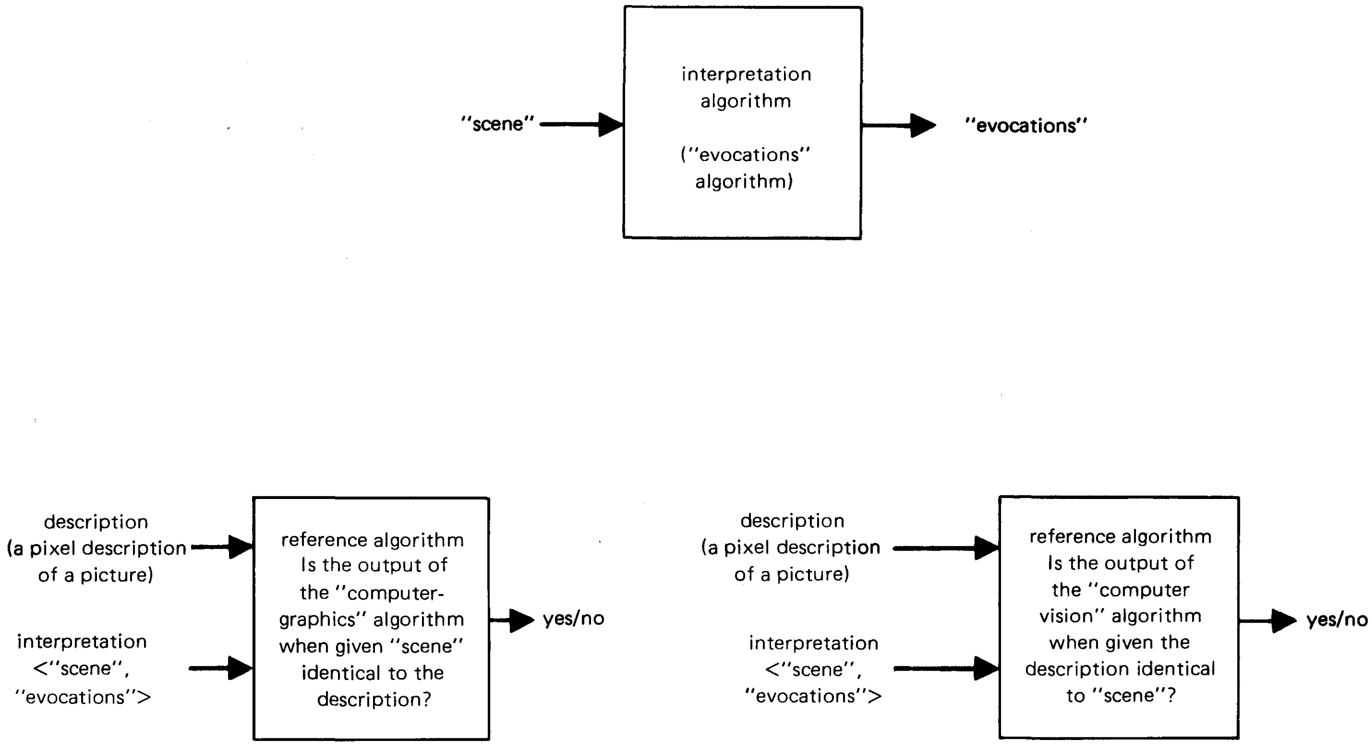

"picture"
"computer vision" algorithm
"scene"
"evocations" algorithm
"evocations"
interpretation algorithm
description (a pixel description of a picture)
interpretation <"picture", "evocations">
reference algorithm
is the description identical to "picture"?
yes/no

Fig. 7-8*a*

ideas. The scene that directly evokes those associations, emotions, or ideas would be produced internally in the interpretation algorithm. In the interpretation algorithm the picture would be considered to evoke a scene and the scene would then be considered to evoke assocations, emotions, or ideas. The reference algorithm of this aesthetic system is also shown in figure 7-8*a*. An interpretation would refer to a picture if and only if the input component of the interpretation is identical to the description of the picture. Aesthetic systems dealing with transparency constructed in this way fit the paradigm for the evocative mode of understanding given in section 6.2.

In the second way of constructing aesthetic systems dealing with transparency, the interpretation algorithm of an aesthetic system is simply an evocation algorithm (see fig. 7-8*b*). An interpretation of a picture would have as input component a specification of a scene and as output component a specification of associations, emotions, or ideas. In this aesthetic system, descriptions of pictures are pixel descriptions. Notice that here the description of a picture neither would occur in an interpretation of the picture nor would be produced internally in the interpretation algorithm. The two alternatives for the reference algorithm of this aesthetic system are shown in figure 7-8*b*. A computer graphics algorithm is used in the first alternative. An interpretation would refer to a picture if and only if the output of the computer graphics algorithm when given the first component (the specification of a scene) of the interpretation as input is identical to the description of the picture. In this case, pixel descriptions would be compared. A computer vision algorithm is used in the second alternative. An interpretation would refer to an object if and only if the first component of the interpretation is identical to the output of the computer vision algorithm when given the description of the picture as input. In this case, specifications of scenes would be compared. In either alternative, whether a picture represents the scene specified in an interpretation would be determined by the reference algorithm. An interpretation of a picture would tell how the picture is understood by specifying the scene depicted by the picture and specifying the associations, emotions, or ideas evoked by that scene. Aesthetic systems dealing with transparency constructed in this way would fit neither the paradigm for the con-



"scene"
interpretation algorithm ("evocations" algorithm)
"evocations"
description (a pixel description of a picture)
interpretation <"scene", "evocations">
reference algorithm Is the output of the "computer-graphics" algorithm when given "scene" identical to the description?
yes/no
description (a pixel description of a picture)
interpretation <"scene", "evocations">
reference algorithm Is the output of the "computer vision" algorithm when given the description identical to "scene"?
yes/no

Fig. 7-8*b*

structive mode of understanding nor the paradigm for the evocative mode of understanding.

In the third way of constructing aesthetic systems dealing with transparency, the interpretation algorithm of an aesthetic system is also simply an evocation algorithm (see fig. 7-8*c*). An interpretation of a picture would have as input component a specification of a scene and as output component a specification of associations, emotions, or ideas. Unlike the first two ways of constructing aesthetic systems dealing with transparency, here, descriptions of pictures would be specifications of scenes. That is, a picture would be described by specifying the scene depicted in it. The reference algorithm of this aesthetic system would compare the first component of an interpretation with the description of a picture (see fig. 7-8*c*). An interpretation would refer to a picture if and only if the

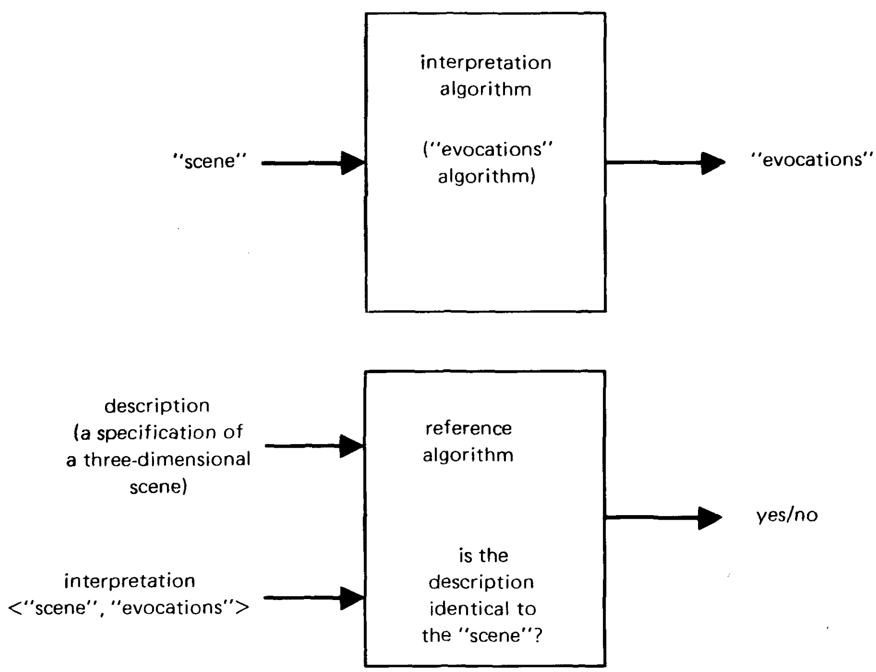


Fig. 7-8*c*

Possible interpretation algorithms and reference algorithms in aesthetic systems for transparency.

input component of the interpretation is identical to the description of the picture. An interpretation of a picture would tell how the picture is understood by specifying the scene depicted in the picture and specifying the associations, emotions, or ideas evoked by that scene. Aesthetic systems dealing with transparency constructed in this way fit the paradigm for the evocative mode of understanding.

Notice that neither computer graphics algorithms nor computer vision algorithms are used in aesthetic systems dealing with transparency constructed in the third way. However, when an aesthetic system constructed in this way is used in a criticism algorithm or a design algorithm, a computer graphics algorithm or a computer vision algorithm may be used in other components of the criticism algorithm or the design algorithm. In particular, when this aesthetic system is used in a criticism algorithm, a computer vision algorithm will usually be embedded in the receptor. In this case, a pixel description of a picture would be produced internally in the receptor, which would then produce a specification of the scene depicted in the picture. This specification would be the description of the picture and would be used by the aesthetic system. When this aesthetic system is used in a design algorithm, a computer graphics algorithm will usually be embedded in the effector. In this case, the description of a picture (specification of a scene) is used to produce a pixel description of the picture internally in the effector. This pixel description would provide the basis for displaying or making the picture.

Each method of construction results in aesthetic systems that treat transparency in a different way. Intuitively, in understanding a picture in terms of transparency, there is a sense in which the picture as two-dimensional object is replaced by a three-dimensional scene. Information about the picture as two-dimensional object is given in the pixel description of the picture, information about the scene in the specification of the scene. The extent of this replacement varies for each of the methods of construction and is reflected in the role played by pixel descriptions and specifications of scenes in the constructions. In aesthetic systems constructed in the first way, the pixel description of a picture is both the description of the picture and the input component of the interpretation of the picture. The specification of the scene is produced internally in the interpretation algorithm. In aesthetic systems constructed in the second way, the pixel description of a picture is the description of the picture. The specification of the scene is the input component of the interpretation of the picture. In aesthetic systems constructed in the third way, the specification of the scene is both the description of the picture and the input component of the interpretation of the picture. The pixel description of the picture is not used in the aesthetic system; it has vanished into a receptor or effector. In each successive construction, the role played by the pixel descriptions of pictures becomes less and less important, while the role played by specifications of scenes becomes more and more important.

Intuitively, a picture is understood in terms of transparency by "looking through" the picture to the scene it represents and reacting to that scene. Aesthetic systems constructed in the three ways given above all deal with transparency. That is, in these aesthetic systems, a picture would be understood in terms of associations, emotions, or ideas evoked by the scene represented in the picture.

7.3.2 Transparency in Literature

Transparency frequently occurs for a variety of art forms. In particular, literary works are often understood in terms of transparency. Here one "looks through" a work, for example, a novel, to the characters, scenes, and events depicted and reacts to those characters, scenes, and events as if they were real. Intuitively, the literary work is "transparent" – the text "vanishes" and is replaced by the characters, scenes, and events depicted. Understanding a literary work as social commentary or on the basis of a Freudian analysis of the characters depicted are examples of understanding a literary work in terms of transparency.

Aesthetic systems dealing with transparency in literature can be constructed in the same way as aesthetic systems dealing with transparency in pictures (see fig. 7-8). Recall that the key components of these constructions are specifications of three-dimensional scenes, algorithms that map pixel descriptions into specifications of scenes, and algorithms that map specifications of scenes into pixel descriptions of pictures. In order to construct aesthetic systems for transparency in literature what is needed are "linguistic" components analogous to the "visual" components of figure 7-7.

A possible candidate for each of these "linguistic" components is suggested by the recent work of Schank and others on conceptual dependency.[27] At the center of this work is the notion of a conceptual structure. A conceptual structure is an abstract representation of the semantic content of a sentence. An example of the conceptual structure for a sentence is given in figure 7-9. For transparency in literature, a conceptual structure could play the same role as a specification of a scene plays for transparency in pictures. Algorithms have been developed which map English sentences (of a restricted type) into conceptual structures and which map conceptual structures into English sentences. For transparency in literature, algorithms that map English sentences into conceptual structures could play the same role as do computer vision algorithms in transparency for pictures. Algorithms that map conceptual structures into English sentences could play the same role as do computer graphics algorithms in transparency for pictures (see figs. 7-7 and 7-8).

In addition to the three components discussed above, an analog would be needed for the algorithm that has as input a specification of a scene and as output of associations, emotions, or ideas (the evocations algorithm). For transparency in literature, this algorithm

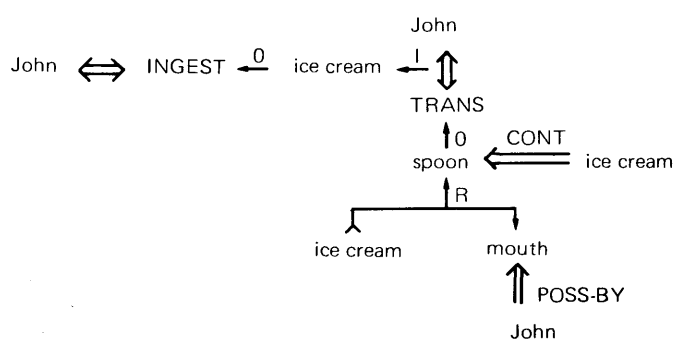


Fig. 7-9

Conceptual structure for the sentence "John ate the ice cream with a spoon." (From R. Schank, "Identification of Conceptualizations Underlying Natural Language" [1973].)

[27] R. Schank, "Identification of Conceptualizations Underlying Natural Language," in *Computer Models of Thought and Language* (San Francisco, 1973) and R. Schank, *Conceptual Information Processing* (Amsterdam, 1975).

would have as input a conceptual structure and as output a specification of the resulting evocations. A text description of a literary work would be the analog of the pixel description of the picture. A text description gives the sequence of letters and punctuation occurring in a text.

Of course, interpreting a picture or a literary work in terms of transparency is a matter of convention. The same picture or literary work is often interpreted in a variety of ways. For example, Durer's *Knight, Death and Devil* has been given one interpretation, in terms of the scene represented, by Panofsky and quite another by Gombrich. Panofsky interprets the Knight as an Erasmus-like "Knight of Christ," on the long, steep, winding road to the "Fortress of Virtue," resolutely ignoring the specters of Death and Devil.[28] Gombrich interprets the Knight as being warned by Death "that he might move across his path at any moment." Gombrich says "the message of the print is one not of proud defiance but of the need for contrition."[29] In literature, a given text is often taken to have different meanings. Indeed, Steiner argues that each person must construct the meaning of a text for himself and that in many respects this meaning can be individual and idiosyncratic.

> No two historical epochs, no two social classes, no two localities use words and syntax to signify exactly the same things, to send identical signals of valuation and inference. Neither do two human beings. Each living person draws, deliberately or in immediate habit, on two sources of linguistic supply: the current vulgate corresponding to his level of literacy and a private thesaurus.[30]

There can be many interpretation algorithms embodying different conventions for interpreting pictures or literature in terms of transparency.

7.4 Form

In the preceding sections, expression, representation, and transparency have been examined using aesthetic systems. Each of

[28] E. Panofsky, *The Life and Art of Albrecht Durer* (Princeton, 1943, 1955), pp. 151-154.

[29] E. H. Gombrich, "The Evidence of Images," *Interpretation: Theory and Practice* (Baltimore, 1969).

[30] G. Steiner, *After Babel* (London, 1975), pp. 45-46.

these ways of understanding an object has been based on the relation of the object to some aspects of the outside world. Specifically, in expression an object is understood in terms of its relation to feelings or emotions. In representation, a picture is understood in terms of its relation to some three-dimensional scene. In transparency, an object is understood in terms of its relation to some scene and the connection of that scene to some complex of associations, emotions, or ideas. Understanding an object need not be based on the relation of the object to aspects of the external world, but rather can be based on the internal relations holding among parts or components of the object.[31]

Understanding objects in terms of the internal relations holding among their parts or components is here said to deal with form. A useful definition of "form" is given in *Webster's Third International Dictionary:*

> [1] Form . . . 10c: the structural element, plan, or design of a work of art; *specif:* the combinations and relations to each other of various components (as lines, colors, volumes in a visual work of art or themes and elaborations in an aural work of art) . . .

Understanding a picture in terms of its composition, a fugue in terms of its organization, a sonnet in terms of its structure – all deal with the form of works of art. In understanding an object based on its form, the object usually is treated as a coherent whole that can be divided into several parts, each bearing a relation to the other parts and each bearing a relation to the whole. Here, an object is understood by identifying patterns, regularities, and structure in the object. For example, the text of a poem might be understood in terms of regularity of rhythm and rhyme.

Aesthetic systems dealing with form can be constructed using either the evocative or the constructive mode of understanding. When the evocative mode is employed, form is considered in terms of a type of directly observable properties or attributes of an

[31] The distinction between understanding an object in terms of internal relations and understanding an object in terms of external relations has been ubiquitously but variously discussed. For example, see Frye's distinction between "inward or centripetal" and "outward or centrifugal" understanding (N. Frye, *Anatomy of Criticism* (Princeton, 1957), p. 73), Beardsley's distinction between "critical description" and "critical interpretation" (*Aesthetics,* pp. 9-10), and Meyer's distinction between "absolute" and "referential" meaning (L. Meyer, *Emotion and Meaning in Music* [Chicago, 1956], p. 1).

object. When the constructive mode is employed, form is considered in terms of underlying rules of construction or principles of organization for the object.

7.4.1 Form and the Evocative Mode of Understanding

An interpretation of an object in an aesthetic system based on the evocative mode of understanding has as input component the description of the object and as output component a specification of the evocations of the object. In an aesthetic system of this type for form, these evocations would consist of associations or ideas pertaining to the form of the object.[32] The output component of an interpretation of the object would be a statement about the patterns, regularities, or structure of the object as derived from the description of the object. This statement would characterize those patterns, regularities, or structure in terms of "formal" attributes of the object, for example, symmetry or balance. The interpretation algorithm of the aesthetic system would embody the conventions or encode a schema that would determine those patterns, regularities, or structure from the description of the object (see fig. 7-10).

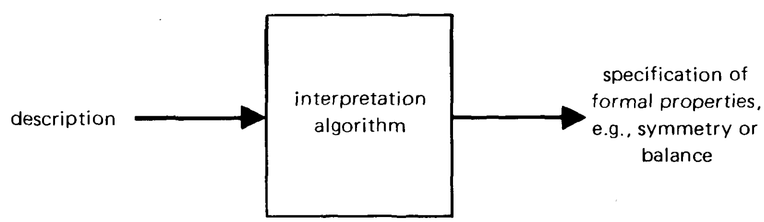


Fig. 7-10

Interpretation algorithm in an aesthetic system based on the evocative mode of understanding for form.

[32] Notice that emotions have been excluded as possible evocations. A possible reading of Bell's *Art* suggests that the evocations of an object in terms of its form could include an emotion, the "aesthetic emotion." In this case, the description of an object would be used to determine whether the object has "significant form" and hence evokes the "aesthetic emotion." An alternative reading of Bell's *Art* is discussed in section 7.4.4.

For example, in an aesthetic system of this type dealing with the form of pictures, the output component in an interpretation of a picture might be a statement about the balance, equilibrium, symmetries, color harmonies, and so on, of the picture.[33] In an aesthetic system of this type dealing with the form of music, the output component of an interpretation of a piece of music might be a statement about the themes and their elaborations, the chordal structure, the overall form (e.g., whether it is a sonata, etc.) of the music. In an aesthetic system of this type dealing with the form of poetry, the output component of an interpretation of a poem might be a statement about the regularities of rhythm and rhyme, the sound patterns (e.g., alliteration, assonance, consonance, and so on) of the poem.

In an aesthetic system dealing with form based on the evocative mode of understanding, an object is understood by pointing out patterns, regularities, or structure perceived in the object. Here, form is treated as an evocation of the object, as a constellation of certain kinds of directly observable attributes of the object. Most traditional discussions of form[34] seem to be based on the evocative mode of understanding.

An aesthetic system for form based on the evocative mode of understanding that is derived from Birkhoff's aesthetic measure is given in section 10.1.

7.4.2 Form and the Constructive Mode of Understanding

An interpretation of an object in an aesthetic system based on the constructive mode of understanding has as input component information needed to construct the description of the object and as output component the description of the object. In an aesthetic system of this type for form, the information given in the input component might indicate the primitive parts of an object and how those parts are developed or arranged to produce the object. These primitives might be shapes, colors, tone sequences, rhythmic formats, and so on.

There is a tradition in aesthetics of looking at form in this way. Here, the object is considered to result from the application of

[33] See, e.g., R. Arnheim, *Art and Visual Perception* (Berkeley and Los Angeles, 1954).

[34] E.g., Ibid.; Beardsley, *Aesthetics;* G. Cavallius, *Velazquez' Las Hilanderas* (Uppsala, 1972).

rules of construction or principles of organization to some primitive elements, for example, to some motif or theme. In this sense, the object is seen to grow from or be determined by the primitive elements together with the rules of construction or principles of organization, much as a plant is seen to grow from or to be determined by its seed.[35] This notion has been discussed in a variety of ways.

> Nothing is more tempting – and in certain cases nothing is better warranted – than to show how forms comply with an internal, organizing logic. In the same way that sand spread out upon the diaphragm of a violin would fall into different symmetrical figures in response to the strokes of a bow, so does a secret principle, stronger and more vigorous than any possible creative conceit, summon together forms which multiply by mitosis, by change of key, or by affinity.[36]

> A motive tend to engage in motivic play, which is repetition of a motive by exchange between several voices or sequence in the same voice, further characterized by constant tonal flux and irregular rhythm. This process tends in turn to generate a form that is monothematic and cursive.
>
> As a "classic" and exceptionally pure example of this motivic process, a short Baroque work may be cited. Bach's four-voice "Praeludium XVI" in G Minor from The Well-Tempered Clavier, II, "grows out" of a four-note motive.[37]

In an aesthetic system based on the constructive mode of understanding for form, the input component of an interpretation of an object would give the information needed to construct the description of the object using the interpretation algorithm of the aesthetic system (see fig. 7-11). As pointed out in section 6.1, this information may be treated as instructions or as data.

When the input component is treated as instructions, it gives explicitly the primitive elements and rules of construction or principles of organization which when applied to those primitive elements result in the description of the object. For example, an interpretation of the Bach piece cited in the previous quote would

[35] Cf. L. Sullivan, *A System of Architectural Ornament* (New York, 1924, 1967).

[36] H. Focillon, *The Life of Forms in Art* (New York, 1948), p. 8.

[37] W. S. Newman, "Musical Form as a Generative Process," *Journal of Aesthetics and Art Criticism* (1954), reprinted in Beardsley and Schueller, *Aesthetic Inquiry* (Belmont, Calif., 1967), p. 70.

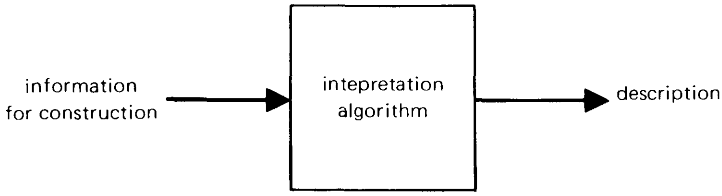


Fig. 7-11

Interpretation algorithm in an aesthetic system based on the constructive mode of understanding for form.

have as input component the four-note motive and the rules for generating the piece from that four-note motive and as output component the score of the piece. The interpretation algorithm of an aesthetic system of this type would encode the conventions by which the rules of construction or principles of organization are applied. An example of an aesthetic system of this type for pictures is given in detail in chapter 9.

When the input component is treated as data, it gives explicitly the primitive elements that are developed or arranged to produce the description of the object. Here, the interpretation algorithm would encode the rules of construction or principles of organization which are applied to the primitive elements to produce the description of the object. In this case, the same rules of construction or principles of organization are always involved in the understanding of objects using a given aesthetic system. For example, an interpretation of the Bach piece cited above could have as input component the four-note motive and as output component the score of the piece. The rules for generating the piece from that four-note motive would be encoded in the interpretation algorithm of the aesthetic system. The aesthetic system given as example in section 6.1 is of this general type.

7.4.3 Discussion

Treating form in terms of the evocative mode of understanding and treating form in terms of the constructive mode of understanding are complementary.

In an aesthetic system for form based on the evocative mode, the formal attributes of an object are given explicitly in the interpretation of the object. The rules of construction or principles of organization which result in the object are not given explicitly in the interpretation but may be implied by the formal attributes given. For example, that a painting has certain symmetries may imply certain types of rules of construction.

In contrast, in an aesthetic system for form based on the constructive mode, the formal attributes of an object need not be given explicitly in the interpretation of the object. Rather, the use of certain types of rules of construction or principles of organization (whether in an interpretation or in an interpretation algorithm) might tend to result in objects that are perceived to have certain formal attributes. For example, the use of rules that characterize "motivic play" would tend to generate music that is "monothematic and cursive." Similarly, the laws of physics cause the generation of patterns of sand on a vibrating diaphragm which are symmetric.

In aesthetic systems for form based on either mode of understanding, an object is understood in terms of patterns, regularities, or structure observable in it. In the evocative mode, these patterns, regularities, or structure are characterized descriptively in terms of formal attributes of the object, for example, symmetry, balance, or cursiveness. In the constructive mode, these patterns, regularities, and structure are encoded as rules of construction or principles of organization.

7.4.4 Significant Form

Bell is a critic who believes that works of art should be interpreted solely in terms of their form.[38] He argues that the single property that all works of art have in common is "significant form" and further that the only way to view works of art is in terms of their "significant form." Bell maintains that the perception of "significant form" gives rise to a peculiar emotion, the "aesthetic emotion."

> For a discussion of aesthetics, it need be agreed only that forms arranged and combined according to certain unknown and mys-

[38] See, e.g., the quotation in section 7.3.

> terious laws do move us in a particular way, and that it is the business of an artist so to combine and arrange them that they shall move us. These moving combinations and arrangements I have called. . . "Significant Form."[39]

How might Bell's notion of significant form be looked at using aesthetic systems?

By form, Bell means, for example, the arrangement and combination of colors and lines in a painting. An aesthetic system dealing with Bell's notions would deal with form as just discussed. In fact, Bell is notorious for denying that significant form has anything at all to do with expression, representation, transparency, and so on.

Form can be treated in aesthetic systems based on either the constructive mode or the evocative mode of understanding. Bell states that significant form results when forms are "arranged and combined according to certain unknown and mysterious laws" and that "it is the business of an artist so to combine and arrange them." Bell's notion of significant form can be considered in terms of either mode of understanding.

For Bell, the task of an artist is to produce an object with significant form, that is, to produce lawful arrangements or combinations of forms. The artist can be considered to do this in two ways. First, the artist can be considered to apply laws, either consciously or unconsciously, to construct arrangements or combinations of forms. Here, lawfulness is taken literally to mean that the artist actually uses laws to arrange or combine forms. A design algorithm that operates in this way would use an aesthetic system for form based on the constructive mode of understanding. The laws applied to construct an arrangement or combination of forms either would be given explicitly as the input to or would be encoded in the interpretation algorithm of the aesthetic system. Alternatively, the artist can be considered to arrange or combine forms so that they evoke or are indicative of lawfulness. Here, lawfulness is taken figuratively to mean that an arrangement or combination of forms need not be produced using laws but need only give the impression of lawfulness. At an extreme, forms can be arranged or combined at random and yet appear to be lawful as

[39] Bell, *Art*, p. 17.

in, for example, some of the work of Arp.[40] A design algorithm that operates in this way would use an aesthetic system for form based on the evocative mode of understanding. The interpretation algorithm of this aesthetic system would encode a schema for determining when forms appear to be arranged or combined lawfully.

For Bell, a "sensitive" observer is capable of perceiving significant form, that is, perceiving lawfulness in certain arrangements or combinations of forms. An observer, just as an artist, can be considered to do this in two ways. First, the observer can be considered to perceive, either consciously or unconsciously, actual laws that can be used to construct the arrangement or combination of forms. This may well be what Bell has in mind.

> The pure mathematician rapt in his studies knows a state of mind which I take to be similar, if not identical. He feels an emotion for his speculations which arises from no perceived relation between them and the lives of men, but springs, inhuman or superhuman, from the heart of an abstract science. I wonder, sometimes, whether the appreciators of art and of mathematical solutions are not even more closely allied. Before we feel an aesthetic emotion for a combination of forms, do we not perceive intellectually the rightness and necessity of the combination?[41]

Just as a mathematician can be considered to see the laws underlying a solution before he feels an emotion similar to the aesthetic emotion, an observer can be considered to see the laws underlying an arrangement or combination of forms before he feels the aesthetic emotion. A criticism algorithm that operates in this way would use an aesthetic system based on the constructive mode of understanding. The laws perceived to underly an arrangement or combination of forms either would be given explicitly as the input component of the interpretation of the object or would be encoded in the interpretation algorithm of the aesthetic system. Of course, these perceived laws need not have been used by the artist. Alternatively, the observer can be considered to have the impression of lawfulness in the arrangement or combination of forms but not to perceive any actual laws that can be used to

[40] See the pictures of Arp's *Three Constellations of Same Forms* and the discussion of this work in R. Arnheim, *Entropy and Art* (Berkeley, Los Angeles, London, 1971).

[41] Bell, *Art*, p. 27.

construct this arrangement or combination of forms. Here, the laws are truly "unknown and mysterious" to the observer. A criticism algorithm that operates in this way would use an aesthetic system for form based on the evocative mode of understanding. The interpretation algorithm of this aesthetic system would encode a schema for determining when forms give the impression of lawful arrangement or combination.[42]

We would have liked to have given a more detailed characterization of the types of laws or schemata for lawfulness that could be used in aesthetic systems modeling Bell's notion of significant form. However, Bell is not too helpful here. He is content merely to point to examples of significant form – the windows at Chartres, Giotto's Frescoes at Padua – rather than characterizing the laws or notions of lawfulness involved.

The question of how an object might be evaluated for significant form naturally arises. When significant form is modeled by an aesthetic system based on the constructive mode of understanding, the evaluation algorithm E_Z, defined in the next chapter, seems a reasonable candidate. Here, the aesthetic value assigned to an interpretation would correspond to the amount of significant form in the object, that is, to use Bell's definition, the intensity of the aesthetic emotion produced by that object.

[42] Of course, an interpretation algorithm in an aesthetic system based on the constructive mode of understanding for significant form can be composed with an interpretation algorithm in an aesthetic system based on the evocative mode of understanding for significant form. This new interpretation algorithm would determine the impressions of lawfulness produced using particular laws.

8
Evaluation

In this chapter, we examine the two components – the evaluation algorithm and the comparison algorithm – of an aesthetic system which provide the basis for evaluating objects in terms of their interpretations. These algorithms encode the evaluative criteria used in a criticism algorithm or design algorithm.

8.1 The Evaluation Algorithm and the Comparison Algorithm

Each aesthetic system contains an evaluation algorithm and a comparison algorithm. The evaluation algorithm assigns aesthetic values to interpretations. The comparison algorithm compares aesthetic values assigned to interpretations (see fig. 4-1). The evaluation algorithm and the comparison algorithm usually provide for the ranking of interpretations in terms of their aesthetic values.

The evaluation algorithm of an aesthetic system has as input an interpretation and produces as output a statement of the aesthetic value assigned to that interpretation (see fig. 4-1). This output may be any normative statement:

> Normative statements are critical evaluations. You are evaluating a work of art when you say it is good or bad, ascribe it beauty or ugliness, recommend it as an object to be sought after or avoided.[1]

For example, the evaluation algorithm may produce statements like "not so good," "more or less good," "good," "very good,"

[1] M. Beardsley, *Aesthetics* (New York, 1958), p. 9.

and so on, for input interpretations.[2] The evaluation algorithm may also assign numerical values, such as "1.414," as the aesthetic values for input interpretations. In this chapter, we are concerned mainly with evaluation algorithms that assign numerical values to interpretations.

Objects are evaluated in terms of how they are understood, not independently of how they are understood. In an aesthetic system, an object is evaluated in terms of its interpretation. The aesthetic value of an object is the aesthetic value assigned to the interpretation of the object. Objects cannot be evaluated if they cannot be understood. Only objects that have interpretations in an aesthetic system can be evaluated in the aesthetic system.

Aesthetic values assigned to interpretations by the evaluation algorithm are compared for relative aesthetic merit by the comparison algorithm. The comparison algorithm of an aesthetic system has as input two aesthetic values and produces as output a statement of the relative merits of these aesthetic values (see fig. 4-1). Normally, the output of the comparison algorithm indicates which of the two input values is greater.

In an aesthetic system, the relative aesthetic merit of two objects is determined in terms of the aesthetic values assigned to the interpretations of the objects. Whether one object is aesthetically superior to a second object depends on whether the aesthetic value assigned to the interpretation of the first object is greater than the aesthetic value assigned to the interpretation of the second object. Only objects that have interpretations in an aesthetic system can be compared for relative aesthetic merit in the aesthetic system.

An object may have more than one interpretation in an aesthetic system. In this case, the evaluation algorithm and the comparison algorithm of the aesthetic system provide the means for selecting the best interpretation of the object, the best way of understanding the object. Namely, the best interpretation of the object is that interpretation assigned the greatest aesthetic value.

8.2 Possible Evaluation Algorithms

The evaluation algorithm and comparison algorithm of an aesthetic system usually reflect the interpretative conventions modeled

[2]When normative statements of this type are used, aesthetic value can be considered a "linguistic variable" in the sense of L. Zadeh, "The Concept of Linguistic Variable and Its Application to Approximate Reasoning," *Information Sciences*, vol. 8, no. 3 (1975).

by the interpretation algorithm and reference algorithm of the aesthetic system. Just as there are many possible interpretative conventions for art, there are many possible evaluative criteria for art. Different evaluative criteria would be modeled by different evaluation algorithms and corresponding comparison algorithms. Given evaluative criteria may be used appropriately with some particular interpretative conventions or with a variety of interpretative conventions. Further, a variety of evaluative criteria may be used appropriately with some given interpretative conventions. Different evaluative criteria may be discussed in terms of the ways their corresponding evaluation algorithms assign aesthetic values to interpretations.

In assigning an aesthetic value to an interpretation, an evaluation algorithm may consider the content of an interpretation. Here, the evaluation might be based on the occurrence of specific symbols or specific sequences of symbols in either or both components of the interpretation.

For example, if an aesthetic system deals with expression based on the evocative mode of understanding, then the evaluation algorithm might determine the intensities of the specific emotions listed in the output component of an interpretation in assigning an aesthetic value to it. Here, the aesthetic value of an object would depend on the intensity of the emotions it evokes.

If an aesthetic system deals with expression as communication, that is, is based on both the constructive and evocative modes of understanding, then the evaluation algorithm might determine the degree of correspondence between the emotions listed in the input component and in the output component of an interpretation in assigning an aesthetic value to it. An interpretation in which the input component and output component are identical, that is, indicating perfect communication, would be assigned greatest aesthetic value. Here, the aesthetic value of an object would depend on how well it communicates emotions.

If an aesthetic system deals with transparency, then the evaluation algorithm might determine the "correctness," in terms of some political ideology, of the specific associations, emotions, or ideas listed in the output component of an interpretation in assigning an aesthetic value to it. Here, the aesthetic value of an object would depend on how strictly it follows a party line.

If an aesthetic system deals with form based on the evocative mode of understanding, then the evaluation algorithm might determine the degree to which certain formal properties, for example, balance or equilibrium, are listed in the output component of an interpretation in assigning an aesthetic value to it. Here, the aesthetic value of an object would depend on the degree to which it has, say, balance or equilibrium.

Alternatively, in assigning an aesthetic value to an interpretation, an evaluation algorithm may consider the general characteristics of the interpretation, for example, the lengths of the two components of the interpretation. An interesting evaluation algorithm of this type is now investigated.

8.3 The Evaluation Algorithm E_Z

An interesting evaluation algorithm for aesthetic systems is given by

$$E_Z\ (\langle\alpha, \beta\rangle) = L(\beta)/L(\alpha)$$

where $\langle\alpha, \beta\rangle$ is an interpretation, $L(\alpha)$ is the length of the input component α of the interpretation, and $L(\beta)$ is the length of the output component β of the interpretation. The length of a sequence of symbols is defined to be the number of symbols in the sequence. The aesthetic value assigned to an interpretation by the evaluation algorithm E_Z is the ratio of the length of the output component of the interpretation to the length of the input component of the interpretation. An interpretation in which the input component is short relative to the output component is assigned high aesthetic value.

The comparison algorithm C_Z naturally associated with the evaluation algorithm E_Z embodies the total order less than or equal to ($\leqslant$). That is, for input values V_1 and V_2, the comparison algorithm C_Z has as output 1 if $V_1 > V_2$ and 0 if $V_1 \leqslant V_2$. Using the evaluation algorithm E_Z and the comparison algorithm C_Z, it is understood that one object is aesthetically superior to a second object if the aesthetic value assigned to the interpretation of the first object is greater than the aesthetic value assigned to the interpretation of the second object.

The use of the evaluation algorithm E_Z and the corresponding comparison algorithm C_Z in aesthetic systems based on the constructive mode of understanding, the evocative mode of understanding, and both the constructive and evocative modes of understanding has many interesting ramifications.

8.4 The Evaluation Algorithm E_Z and the Constructive Mode of Understanding

In an aesthetic system based on the constructive mode of understanding, an interpretation of an object has the form <information for construction, description>. If the evaluation algorithm of the aesthetic system is E_Z, then the aesthetic value assigned to the interpretation is the ratio of the length of the output sequence of symbols giving the description of the object to the length of the input sequence of symbols giving the information used to construct or generate that description. If the length of the input component (information for construction) of the interpretation is small relative to the length of the output component (the description of the object), then the interpretation is assigned high aesthetic value.

Recall that the input component of an interpretation of an object in an aesthetic system based on the constructive mode of understanding can be considered as instructions or as data, as discussed in section 6.1.

When the input component of an interpretation of an object is considered as instructions, the interpretation is assigned high aesthetic value by the evaluation algorithm E_Z if those instructions or rules of construction are small in number and simple in substance relative to the length of the description of the object. In order for this to occur, the description of the object must have regularities that have been identified and used to formulate the instructions.[3] These instructions might be based on the syntactic or semantic structure or the recurrence of motifs or themes in the description of the object. Few of the aspects of the object specified in its description are seen to be ad hoc or contingent. That is, few of the aspects must be given explicitly in the instructions given to gener-

[3] For an informal discussion of this idea, see H. Simon, *The Sciences of the Artificial* (Cambridge, Mass., 1969), especially pp. 109-111. A more formal treatment has been given in terms of algorithmic information theory (see section 8.4.2).

ate the description of the object. The interpretation is assigned high aesthetic value by E_Z if the object is seen to be tightly organized. In contrast, the interpretation is assigned low aesthetic value by the evaluation algorithm E_Z if the instructions are as complicated (lengthy) as the description itself. Here, no regularity has been identified in the description of the object or the little regularity that has been identified has not been helpful in formulating the instructions. Most of the aspects of the object specified in its description are seen to be ad hoc or contingent. That is, most of the aspects must be given explicitly in the instructions given to generate the description of the object. The interpretation is assigned low aesthetic value by E_Z if the object is not seen to be organized.

When the input component of the interpretation of an object is considered as data, the interpretation is assigned high aesthetic value by the interpretation algorithm E_Z if a small amount of data is given relative to the length of the description of the object. In order for this to occur, the description of the object must naturally fit the schema encoded in the interpretation algorithm defining the interpretation. That is, only little data or few details are required to particularize the schema to produce the description. Almost all of the aspects of the object specified in its description are accounted for by the schema. In contrast, the interpretation is assigned low aesthetic value by the evaluation algorithm E_Z if the amount of data given is as lengthy as the description itself. Here, the description does not naturally fit the schema encoded in the interpretation algorithm defining the interpretation. That is, considerable data or details are given to particularize the schema to produce the description. Few of the aspects of the object specified in its description are accounted for by the schema. Almost all of the aspects are considered ad hoc or contingent and must be given explicitly in the input component of the interpretation.

Notice that if an object has multiple interpretations in an aesthetic system based on the constructive mode of understanding, then selecting the best interpretation of the object in terms of the aesthetic values assigned to these interpretations corresponds to an application of Occam's razor or the law of parsimony. All interpretations of the object have identical output components, namely the description of the object. The aesthetic values assigned to these interpretations by the evaluation algorithm E_Z are inversely proportional to the lengths of their input components. That is, of these interpretations, the interpretation assigned highest aesthetic value has the shortest input component. This interpretation gives the most parsimonious way to generate the description of the object. Hence, this interpretation gives the most parsimonious way to understand the object in terms of the interpretative conventions of the aesthetic system.

Example

We now examine the use of the evaluation algorithm E_Z in the aesthetic system based on the constructive mode of understanding for sequences of sixteen tones given as an example in section 6.1. The aesthetic value assigned by E_Z to an interpretation of a sequence of sixteen tones is the ratio of the length of the URD-description of the sequence to the length of the initial sequence used to generate the description. The length of the URD-description of a sequence of sixteen tones is always 16. The length of the initial sequence may be as small as 2 and as large as 16. Hence, the aesthetic value assigned to an interpretation may be as large as 8 and as small as 1.

In the example of section 6.1, six specific interpretations are exhibited. The aesthetic values assigned to these interpretations by the evaluation algorithm E_Z are given in table 8-1. The interpretations are listed in the table in order of decreasing aesthetic value as determined by the comparison algorithm C_Z.

TABLE 8-1
AESTHETIC VALUES ASSIGNED TO INTERPRETATIONS BY THE EVALUATION ALGORITHM E_Z.

Interpretation	*Aesthetic Value*
<*D, *DUDUURDUDUURUUR>	8.0
<*RR, *RDUDUDUURRDUDUD>	5.33
<*DUD, *DUDUURDUDUURUUR>	4.0
<*DUDUURDUD, *DUDUURDUDUURUUR>	1.6
<*DUDUURDUDUURUUR, *DUDUURDUDUURUUR>	1.0
<*RRDURRDURRDURRD, *RRDURRDURRDURRD>	1.0

The higher the aesthetic value assigned to an interpretation of a sequence of sixteen tones, the better the sequence is seen to fit the schema, the productions for generating URD-descriptions, encoded in the interpretation algorithm of the aesthetic system. An interpretation of a sequence of sixteen tones is assigned a high aesthetic value if a short initial sequence is given in the input component of the interpretation to particularize the schema to produce the URD-description of the sequence of sixteen tones.

A sequence of sixteen tones having the URD-description *DUDUURDUDUURUUR has four different interpretations, namely the first, third, fourth, and fifth interpretations listed in table 8-1. Selection of the best interpretation on the basis of highest aesthetic value assigned by E_Z corresponds to an application of Occam's razor or the law of parsimony. That is, the best interpretation is the most parsimonious interpretation, the interpretation that gives the smallest amount of data in its input component that results in the URD-description of the sequence.

In most interesting aesthetic systems based on the constructive mode of understanding using the evaluation algorithm E_Z, the number of distinguishable objects, that is, possible objects having different descriptions, with interpretations having high aesthetic value, is very small. For example, the number of different URD-descriptions of sequences of sixteen tones is $3^{15} = 14{,}348{,}907$. That is, for the aesthetic system there are 14,348,907 different sequences of sixteen tones. Of these possible sequences, only $3^5 = 243$ have interpretations with aesthetic value greater than 1, the lowest possible value. Only 9 sequences have interpretations with aesthetic value greater than 5. Three sequences have interpretations with aesthetic value equal to 8, the highest possible value.

8.4.1 Unity and Variety

Probably no notion is more frequently suggested as the basis for aesthetic value in the arts than the canon of "unity and variety" (or "order and complexity"). Unity and variety has been variously, and usually vaguely, characterized in the literature.[4] Typically, variety is characterized as the multiplicity and diversity of the perceptual aspects of an object; unity is characterized as the

[4] A comprehensive survey of "unity and variety" in the arts is given in T. Emond, *On Art and Unity* (Lund, 1964).

coherence, organization, or relatedness of those aspects. The relationship of aesthetic value to unity and variety was stated by Hutcheson as follows:

> What we call beautiful in objects, to speak in the mathematical style, seems to be in a compound ratio of uniformity and variety: so that where the uniformity of bodys is equal, the beauty is as the variety; and where the variety is equal, the beauty is as the uniformity.[5]

In an aesthetic system based on the constructive mode of understanding using the evaluation algorithm E_Z, the aesthetic value assigned to an interpretation of an object can be looked at as a measure of the unity and variety of the object.

The output component of the interpretation is the description of the object. The length of the description is a measure of the number and richness of the aspects of interest of the object, of the multiplicity and diversity of the perceptual aspects of the object. Hence, the length of the description of the object can be considered a measure of the variety of the object.[6] For example, according to Emond

> "Variety" as applied to painting would thus primarily imply diversity of colour, differences in appearance and attitudes of shapes, variations in direction and qualities of lines.[7]

When the description of a picture is given by shape-color-occurrence tables, as in the aesthetic system of the next chapter, the length of the description of a picture is precisely a measure of this type of variety.

The input component of the interpretation gives the information that can be used to generate the description of the object. The length of the sequence of symbols specifying this information is a measure of the amount of information given. When only a small amount of information is needed to generate the description of the object, the aspects of interest of the object (as specified by its description) are coherent, organized, and strongly related. Hence, the length of the sequence of symbols specifying the infor-

[5] F. Hutcheson, *An Inquiry into the Original of Our Ideas of Beauty and Virtue* (Farnborough, 1725, 1969).

[6] Of course, the variety of an object, when measured in this way, is relative to the conventions used to describe the object. Different descriptions of the object could result in different measures of the variety of the object.

[7] Emond, *On Art and Unity*, p. 54.

mation that can be used to generate the description of the object can be considered an inverse measure of the unity of the object.[8] For example, when this information is given by a generative specification, as in the aesthetic system for pictures of the next chapter, the length of the generative specification can be considered an inverse measure of the unity of the picture specified. When the length of a generative specification is small, the shapes and their colors and occurrences in the picture specified are coherent, organized, and highly related. The generative specification gives explicitly how the shapes and their colors and occurrences are organized and related.

When the length of the input component (information for construction) is considered an inverse measure of the unity of an object and the length of the output (description of the object) is considered a measure of the variety of the object, the aesthetic value assigned to the interpretation of the object by the evaluation algorithm E_Z can be considered a measure of the unity and variety of the object. It should be obvious that the assignment of aesthetic values by E_Z follows Hutcheson's rule.

8.4.2 Algorithmic Information Theory

In the late 1950s, there were several attempts to link information theory, and related earlier work on thermodynamics, with aesthetics.[9] It was suggested that the aesthetic value of an object (typically a musical piece) is somehow connected with the entropy of the object. Here, the notion of the entropy of an object is based on concepts from statistical information theory[10] and is defined in terms of the probability of occurrence of the object in some universe of possible objects. More recently, there has been some disillusionment over the profitability of treating aesthetic value in

[8]The unity of an object, when measured in this way, is relative to the way the object is interpreted. Different interpretations of the object, even in the same aesthetic system, could result in different measures of the unity of the object, as different interpretations could have input components of different lengths.

[9]See, for example, R. Pinkerton, "Information Theory and Melody," *Scientific American* (February 1956); L. Hiller and L. Isaacson, *Experimental Music* (New York 1959); L. Meyer, "Some Remarks on Value and Greatness in Music," *Journal of Aesthetics and Art Criticism*, vol. 17, no. 4 (1959); F. Attneave, "Stochastic Composition Processes," *Journal of Aesthetics and Art Criticism*, vol. 17 (1959).

[10] C. Shannon and W. Weaver, *The Mathematical Theory of Communication* (Urbana, 1949).

terms of information theory.[11] Our belief is that the troubles encountered have resulted not because aesthetic value and entropy cannot be connected but because of the statistical nature of the definition of entropy employed.

When the entropy of objects is determined using statistical techniques, it is required that one have knowledge about the distribution of probabilities of occurrence of possible objects. To determine the entropy of a given object, it is not sufficient to just have knowledge about the object itself. Knowledge about the place of the object in a universe of possible objects, that is, about the probability of occurrence of the object, is also required. Usually, it is unreasonable to expect that this knowledge can be obtained. For example, how can one reasonably determine the probability of occurrence of Bach's Partita No. 2 in C Minor? What is needed is a definition of entropy that allows for the entropy of an object to be determined without knowledge about the probability of its occurrence. As pointed out by Kolmogorov,

> The ordinary definition of entropy used probability concepts, and thus does not pertain to individual values, but to random values, i.e., to probability distributions within a given group of values. . . . By far, not all applications of information theory fit rationally into such an interpretation of its basic concepts. I believe that the need for attaching definite meaning to . . . [entropy], in the case of individual values . . . that are not viewed as a result of random tests with a definite law of distribution, was realized long ago by many who dealt with information theory.[12]

In the past fifteen years, information theory has been reformulated in terms of algorithms.[13] The definition of entropy used in this reformulation allows for the entropy of an individual object to be determined solely in terms of knowledge about the object

[11] See, for example, R. Green and M. Courtis, "Information Theory and Figure Perception: The Metaphor that Failed," *Acta Psychologita* vol. 25 (1966); R. Arnheim, *Entropy and Art* (Berkeley, Los Angeles, London, 1971).

[12] A. Kolmogorov, "Logical Basis for Information Theory and Probability Theory," *IEEE Transactions on Information Theory*, vol. IT-14, no. 5 (1968).

[13] R. Solomonoff, "A Formal Theory of Inductive Inference," *Information and Control*, vol. 7 (1964); Kolmogorov, "Logical Basis for Information Theory and Probability Theory"; G. Chaitin, "On the Length of Programs for Computing Finite Binary Sequences," *Journal of the Association for Computing Machinery*, vol. 13, no. 4 (1966). The most intuitive presentation of these ideas is given in G. Chaitin, "Randomness and Mathematical Proof," *Scientific American* (May 1975).

itself. No knowledge about the probability of occurrence of the object is needed.

The *entropy* of a sequence of symbols is defined to be the length of the shortest input to a universal computing algorithm which results in the sequence as output.[14] An input to the universal computing algorithm may be considered as the instructions that can be used to generate a sequence of symbols. The universal computing algorithm follows or executes these instructions to produce an output. Intuitively, the entropy of a sequence of symbols is the length of the shortest rule, procedure, or method that can be used to generate the sequence.

Any sequence of symbols $a_1a_2 \ldots a_n$ can be generated using the rule "write out $a_1a_2 \ldots a_n$." Here the sequence itself is given explicitly in the rule used to generate it. For long sequences, the length of this rule is slightly greater than the length of the sequence.

For some sequences of symbols, there are no methods for generating them that are much shorter than giving them explicitly. For a sequence of this type, the entropy of the sequence – using the algorithmic definition of entropy – is approximately the length of the sequence itself. Sequences of symbols with entropy approximately equal to their lengths are called *random.*[15] This formal definition of randomness fits well with the intuitive notion of randomness. There are no rules for generating a random sequence that are much shorter than giving the sequence itself. For a sequence to be random there is little or no pattern, regularity, or structure observable in it. The occurrence of each symbol in the sequence seems independent of occurrences of other symbols and, hence, must be given one-by-one. The occurrences of symbols in the sequence are seen to be contingent or ad hoc. All that can be said about the sequence is "This is the sequence." The shortest way to generate the sequence is essentially to give the sequence itself.

For some sequences of symbols there are methods for generating them that are much shorter than giving them explicitly. The entropy of a sequence of this type is substantially smaller than its

[14] The input and output sequences are usually defined over a binary alphabet. However, this point is not important for the following discussion.

[15] P. Martin-Löf, "The Definition of Random Sequences," *Information and Control*, vol 9 (1966); G. Chaitin, "Randomness and Mathematical Proof", 1975.

length. Sequences of symbols with entropy much smaller than their lengths are non-random. These sequences have patterns, regularities, or structure that can be used to formulate relatively short rules to generate them. It can be shown that few sequences of symbols have entropy much smaller than their length, that almost all sequences of symbols are random.[16]

An elucidating application of the algorithmic definition of entropy to science has been suggested by Chaitin. (In the following quotation the term "complexity" is synonymous with the term "entropy" and the term "program" means "computer program" and is synonymous with "rule, procedure, or method.")

> . . . the concept of complexity might make it possible to precisely formulate the situation that a scientist faces when he has made observations and wishes to understand them and make predictions. In order to do this the scientist searches for a theory that is in agreement with all his observations. We consider his observations to be represented by a binary string, and a theory to be a program that calculates this string. Scientists consider the simplest theory to be the best one, and that if a theory is too "ad hoc," it is useless. How can we formulate these intuitions about the scientific method in a precise fashion? The simplicity of a theory is inversely proportional to the length of the program that constitutes it. That is to say, the best program for understanding or predicting observations is the shortest one that reproduces what the scientist has observed up to that moment. Also, if the program has the same number of bits as the observations, then it is useless, because it is too "ad hoc." If a string of observations only has theories that are programs with the same length as the string of observations, then the observations are random, and can neither be comprehended nor predicted. They are what they are, and that is all; the scientist cannot have a theory in the proper sense of the concept; he can only show someone else what he observed and say "it was this."
>
> In summary, the value of a scientific theory is that it enables one to compress many observations into a few theoretical hypotheses. There is a theory only when the string of observations isn't random, that is to say, when its complexity is appreciably less than

[16] G. Chaitin, "Randomness and Mathematical Proof." This fact can be used to show the general difficulty of criticism and design when based on aesthetic systems using the evaluation algorithm E_Z.

> its length in bits. In this case, the scientist can communicate his observations to a colleague much more economically than by just transmitting the string of observations. He does this by sending his colleague the program that is his theory, and this program must have much fewer bits than the original string of observations.[17]

It should be obvious from the above discussion that the algorithmic definition of entropy is based precisely on the constructive mode of understanding. This notion of entropy can be applied directly in aesthetic systems based on the constructive mode of understanding.

Consider an aesthetic system based on the constructive mode of understanding in which the interpretation algorithm is a universal computing algorithm. If the entropy of an object is assumed to be the entropy of its description, then the entropy of an object having description λ is the length of the shortest input α to the interpretation algorithm that results in the description λ as output. That is, the entropy of the object is the length of the input component α of the interpretation $<\alpha, \lambda>$ of the object that has the shortest input component. Of course, the entropy of an object having description λ is never much greater than the length of the description λ, as there is always the interpretation <write out λ, λ> of the object.

If the evaluation algorithm E_Z is used in an aesthetic system of this type, then the interpretation of an object having the shortest input component is the interpretation of the object assigned highest aesthetic value. Let this interpretation be $<\alpha, \lambda>$, where λ is the description of the object. The length of the input component α is the entropy of the object. The length of the description λ is approximately the entropy of a random sequence of symbols of the length of λ. The aesthetic value assigned to the interpretation $<\alpha, \lambda>$ is approximately equal to the entropy of a random sequence of the length of λ divided by the actual entropy of the description λ. This expression can be considered the reciprocal of the relative entropy[18] of the object. If no interpretation of an object is assigned aesthetic value greater than a little more than 1,

[17] G. Chaitin, "Some Philosophical Implications of Information-Theoretic Computational Complexity," *SIGACT News*, vol. 5, no. 2 (1973).

[18] Shannon and Weaver, *The Mathematical Theory of Communication.*

then the object as described is random. Here, the best that can be said about the aspects of interest of the object is "These are the aspects of interest." If there is an interpretation of an object assigned aesthetic value much greater than 1, then the object as described is non-random.[19] In general, in a universe of possible objects, few objects have descriptions that are non-random. For example, if pictures are described by pixel descriptions, few pictures in the universe of possible pictures are non-random.

It is often the case that the interpretation algorithm in an aesthetic system based on the constructive mode of understanding is not a universal computing algorithm. Here, it is reasonable to talk about the entropy of an object relative to the interpretation algorithm of the aesthetic system. The entropy of an object relative to the interpretation algorithm is the length of the shortest input to the algorithm that results in the description of the object, that is, the length of the input component in the interpretation of the object with the shortest input component. This interpretation is the interpretation of the object assigned highest aesthetic value by the evaluation algorithm E_Z in the aesthetic system. Notice that the entropy of an object (relative to a universal computing algorithm) is less than or equal to the entropy of the object relative to the interpretation algorithm plus the length of the specification of the interpretation algorithm.

In practice, one may not know whether a given input to an algorithm that results in a desired sequence of symbols is the shortest input that results in the sequence.[20] In this case, it is reasonable to talk about the "perceived entropy" of the sequence. The perceived entropy of a sequence is the length of the shortest known input to the algorithm that results in the sequence. In terms of aesthetic systems based on the constructive mode of understanding using the evaluation algorithm E_Z, the perceived entropy of an object is the length of the input component of the known interpretation of the object assigned highest aesthetic value.

The algorithmic definition of entropy can be applied in aesthetic systems based on the evocative mode of understanding and in

[19] Of course, an object may have different descriptions in different criticism or design algorithms. Thus, the object may be considered random in one case and non-random in another.

[20] In fact, this is formally undecidable in general.

aesthetic systems based on both the constructive and evocative modes of understanding in a similar way. Here, however, the entropy considered is the entropy of the evocations of an object.

8.5 The Evaluation Algorithm E_Z and the Evocative Mode of Understanding

In an aesthetic system based on the evocative mode of understanding, an interpretation of an object has the form <description, evocations>. If the evaluation algorithm of the aesthetic system is E_Z, then the aesthetic value assigned to the interpretation is the ratio of the length of the output sequence of symbols giving the evocations of the object to the length of the input sequence of symbols giving the description of the object. If the length of the output component (evocations) of the interpretation is large relative to the length of the input component (the description of the object), then the interpretation is assigned high aesthetic value. Here, the description of the object is connected with multiple, lengthy evocations. The object is seen to evoke a large complex of associations, emotions, or ideas. The interpretation is assigned low aesthetic value when the length of the output component (evocations) is small relative to the length of the input component (the description of the object). Here, the object is seen to have few or no evocations.

Example

We now examine the use of the evaluation algorithm E_Z in the aesthetic system based on the evocative mode of understanding for sequences of sixteen tones given in section 6.2. The aesthetic value assigned by E_Z to an interpretation of a sequence of sixteen tones is the ratio of (1) the length of the evocations of the sequence as determined using the classical portion of Parson's *The Directory of Tunes and Musical Themes* augmented by additional information to (2) the length of the URD-description of the sequence. The length of the evocations of a sequence of sixteen tones is at least 2 (i.e., the length of the sequence "na" is 2). The length of the URD-description of a sequence of sixteen tones is always 16. Hence, the aesthetic value assigned to an interpretation is greater than or equal to 0.125. The longer the evocations of a sequence of sixteen tones, the higher the aesthetic value assigned to its interpretation.

In the example of section 6.2, three specific interpretations are exhibited. The aesthetic values assigned to these interpretations by the evaluation algorithm E_Z are given in table 8-2. Each aesthetic value in the table is determined by counting the number of symbols (including spaces) in the output component of an interpretation and dividing this number by 16, that is, the number of symbols in the input component of the interpretation. For example, the output component in the second interpretation listed in the table has 37 symbols and hence an aesthetic value of 2.3125. The interpretations are listed in the table in order of decreasing aesthetic value as determined by the comparison algorithm C_Z.

TABLE 8-2
AESTHETIC VALUES ASSIGNED TO INTERPRETATIONS BY THE EVALUATION ALGORITHM E_Z.

Interpretation	*Aesthetic Value*
<*RRDURRDURRDURRD, Beethoven Symphony/5 in Cmi 1m 1t. [Berlioz's commentary]>	94.0
<*RDUDUDUURRDUDUD, Handel Concerto Grosso in F op 6/2 2m>	2.3125
<*DUDUURDUDUURUUR, na>	0.125

Parson's *Directory* contains entries for approximately 10,000 URD-descriptions. These entries range in length from approximately 16 characters to approximately 64 characters. Assume that additional information is supplied for 1,000 of these URD-descriptions. The additional information for an entry can be assumed to be at least 50 characters long. Just as for the aesthetic system discussed as an example in sections 6.1 and 8.4, there are 14,348,907 distinguishable sequences of sixteen tones for the aesthetic system examined here. Of these possible sequences, only 10,000 have interpretations assigned aesthetic value greater than 0.125. That is, only these sequences have nontrivial evocations as determined by entries in Parson's *Directory*. Of these sequences, only 1,000 have interpretations assigned aesthetic value greater than 4. That is, there are 1,000 sequences having evocations that include additional information to that given in Parson's *Directory*.

8.6 The Evaluation Algorithm E_Z and Both the Constructive and Evocative Modes of Understanding

In an aesthetic system based on both the constructive and evocative modes of understanding, an interpretation of an object has the form <information for construction, evocations>. If the evaluation algorithm of the aesthetic system is E_Z, then the aesthetic value assigned to the interpretation is the ratio of the length of the output sequence of symbols giving the evocations of the object to the length of the input sequence of symbols giving the information used to generate the description of the object. If the length of the input component (information for construction) is small relative to the length of the output component (evocations), then the interpretation is assigned high aesthetic value. For example, when a small amount of information is used to generate the description of the object and the description of the object is connected with multiple, lengthy evocations, the interpretation is assigned high aesthetic value.

Recall that an aesthetic system based on both the constructive and evocative modes of understanding is formed by combining an aesthetic system based on the constructive mode of understanding and an aesthetic system based on the evocative mode of understanding. If there is an interpretation $\langle\alpha, \beta\rangle$ of an object in the combination aesthetic system, then there is an interpretation $\langle\alpha, \lambda\rangle$ of the object in the aesthetic system based on the constructive mode of understanding and an interpretation $\langle\lambda, \beta\rangle$ of the object in the aesthetic system based on the evocative mode of understanding, where λ is the description of the object. Assuming the evaluation algorithm E_Z is used in the three aesthetic systems, the aesthetic value assigned to the interpretation $\langle\alpha, \beta\rangle$ is the product of the aesthetic values assigned to the interpretations $\langle\alpha, \lambda\rangle$ and $\langle\lambda, \beta\rangle$. When the aesthetic values assigned to the interpretations $\langle\alpha, \lambda\rangle$ and $\langle\lambda, \beta\rangle$ are high, the aesthetic value assigned to the interpretation $\langle\alpha, \beta\rangle$ is high. That is, the amount of information used to generate the description of the object is small relative to the length of the description and the evocations of the object are large relative to the length of the description.

Example

We now examine the use of the evaluation algorithm E_Z in the aesthetic system based on both the constructive and evocative modes of understanding for sequences of sixteen tones given as an example in section 6.3. The aesthetic value assigned by E_Z to an interpretation of a sequence of sixteen tones is the ratio of the length of the evocations of the sequence as determined using the classical portion of Parson's *The Directory of Tunes and Musical Themes* augmented by some additional information to the length of the initial sequence used to generate the URD-description of the sequence using the productions given in the example of section 6.1. An interpretation of a sequence of sixteen tones in which the URD-description of the sequence is seen to be generated from a short initial sequence and in which the URD-description of the sequence is seen to generate long evocations is assigned high aesthetic value.

In the example of section 6.3, three specific interpretations are exhibited. The aesthetic values assigned by the evaluation algorithm E_Z to these interpretations and to three additional interpretations formed from interpretations given in tables 8-1 and 8-2 are given in table 8-3. The interpretations are listed in the table in order of decreasing aesthetic value as determined by the comparison algorithm C_Z. Notice that the interpretation in table 8-3 assigned highest aesthetic value is formed from an interpretation in table 8-1 assigned lowest aesthetic value and the interpretation in table 8-2 assigned highest aesthetic value. The interpretation in table 8-3 assigned second highest aesthetic value is formed from the interpretation in table 8-1 assigned second highest aesthetic value and the interpretation in table 8-2 assigned second highest aesthetic value. The interpretation in table 8-3 assigned third highest aesthetic value is formed from the interpretation in table 8-1 assigned highest aesthetic value and the interpretation in table 8-2 assigned lowest aesthetic value.

It should be obvious that the number of distinguishable sequences of sixteen tones having interpretations assigned high aesthetic value is very small. In fact, fewer than 11,000 of the 14,348,907 possible sequences have interpretations assigned aes-

TABLE 8-3
AESTHETIC VALUES ASSIGNED TO INTERPRETATIONS
BY THE EVALUATION ALGORITHM E_Z.

Interpretation	*Aesthetic Value*
<*RRDURRDURRDURRD, Beethoven Symphony/5 in Cmi lm lt. [Berlioz's commentary]>	94.0
<*RR, Handel Concerto Grosso in F op 6/2 2m>	12.33
<*D, na>	1.0
<*DUD, na>	0.5
<*DUDUURDUD, na>	0.2
<*DUDUURDUDUURUUR, na>	0.125

thetic value greater than 0.125, the lowest possible aesthetic value in this aesthetic system.

As a closing observation on the use of the evaluation algorithm E_Z, it is expected that in almost all interesting aesthetic systems using E_Z, almost all interpretations are assigned close to minimal aesthetic value.

8.7 Evaluation Algorithms Based on Time and Space Complexity

A well known definition of "the Beautiful" is given by Hemsterhuis as "that which gives the greatest number of ideas in the shortest space of time."[21] This definition suggests that the aesthetic value of an object can be measured by the extent of the evocations of the object and by the amount of time it takes to generate these evocations. In terms of aesthetic systems, this definition suggests that the aesthetic value of an interpretation of an object in an aesthetic system based on the evocative mode of understanding is high if the output component (the evocations of the object) is long and the time taken by the interpretation algorithm to generate the evocations from the description of the object is short. This definition requires some notion of time of computation.

[21] F. Hemsterhuis, *Lettre sur la sculpture* (1769). Quoted in *Encyclopedia Britannica*, vol. 11 (1946).

In the past several years, interesting measures of computational complexity in terms of the amount of time an algorithm takes to produce an output and the amount of space or auxiliary memory an algorithm requires to produce an output have been developed by Blum and others.[22] These measures could be used in constructing evaluation algorithms, based on notions of beauty such as that of Hemsterhuis, for aesthetic systems. In particular, if $T_A(\alpha)$ is a measure of the time required for an interpretation algorithm A to compute β given α, then one could define an evaluation algorithm E_H based on Hemsterhuis's definition of beauty by

$$E_H(\langle\alpha, \beta\rangle) = L(\beta)/T_A(\alpha)$$

where $\langle\alpha, \beta\rangle$ is an interpretation and $L(\beta)$ is the length of β.

As a technical aside, it is interesting to note that the evaluation algorithm E_Z depends on the input and output components of interpretations and not on the internal workings of the interpretation algorithm that defines those interpretations. If two aesthetic systems having different interpretation algorithms but both using the evaluation algorithm E_Z contain the same interpretation, then the aesthetic values assigned to that interpretation are identical in the two aesthetic systems. In contrast, evaluation algorithms, such as E_H, based on measures of time or space complexity would depend both on the input and output components of interpretations and on the internal workings of the interpretation algorithms that define those interpretations. If two aesthetic systems having different interpretation algorithms but both using evaluation algorithms based on the same measure of time or space complexity contain the same interpretation, then the aesthetic values assigned to that interpretation may be different in the two aesthetic systems.

8.8 Transitivity and Comparability in Aesthetic Systems

Two important open questions can be asked about comparison algorithms of aesthetic systems.

[22] J. Hartmanis and J. Hopcroft, "An Overview of the Theory of Computational Complexity," *Journal of the Association for Computing Machinery*, vol. 18, no. 3 (1971).

First, should the comparison of aesthetic values assigned to interpretations in an aesthetic system be transitive? That is, if one interpretation is determined to have greater aesthetic value than a second interpretation and the second interpretation is determined to have greater aesthetic value than a third interpretation, should it necessarily be implied that the first interpretation has aesthetic value greater than the third interpretation? McCulloch discusses this question in terms of what is sometimes called the "value anomaly."

> By this we mean that an animal or machine, successively offered his choice between each two of three incompatible ends, A, B, C, sometimes chooses A rather than B, B rather than C, C rather than A, and does so consistently. I have myself encountered this in experimental esthetics, when examining by paired comparison three rectangles divided into two, three, and five equal rectangles. Animal psychologists have discovered that, say, a hundred male rats all deprived of food and sex for a specified period will all prefer food to sex, sex to avoidance of shock, and avoidance of shock to food. That this happens is of theoretical importance to ethics. [And, we might add, to aesthetics.] We commonly suppose that ends, or goals, can be arranged in a hierarchy of value, increasing *ab infimo malo ad summum bonum* (whether or not we conceive one or both limits actual), and enable ourselves thereby to answer the insistent casuistical query about conflicting goods by forcing the lesser to bow to the greater.[23]

In an aesthetic system using a comparison algorithm, such as C_Z, which embodies an order, value anomalies do not occur. However, there is nothing in the definition of aesthetic systems, and in particular in the definition of comparison algorithms, which would disallow the possibility of aesthetic systems in which value anomalies do occur. It is an open question whether value anomalies should or should not be allowed. Our belief is that the case for value anomalies can be overstated. For the remainder of this study, it is assumed that comparisons of interpretations in terms of aesthetic value in an aesthetic system are transitive. More precisely, it is assumed that all comparison algorithms embody or are based on orders.

[23] W. McCulloch, "Toward Some Circuitry of Ethical Robots or an Observational Science of the Genesis of Social Evaluation in the Mind-Like Behavior of Artifacts," *Acta Biotheoretica*, vol. 11 (1956).

Second, should the aesthetic values assigned to any two interpretations in an aesthetic system be comparable? That is, should a comparison algorithm be allowed to output a statement such as "These two values can not be compared"? For a comparison algorithm that embodies an order, the answer to this question is affirmative if the order is partial, and negative if the order is total. Comparison algorithms that embody partial orders seem natural in some aesthetic systems. For example, an aesthetic system formed by combining two aesthetic systems based on different interpretative conventions using the technique given in section 11.1 has a comparison algorithm which embodies a partial order. However, except for section 11.1, for the remainder of this study it is assumed that aesthetic values assigned to any two interpretations in an aesthetic system are comparable. More precisely, it is assumed that all comparison algorithms embody total orders.

9
An Aesthetic System for Nonrepresentational, Geometric Pictures

In this chapter, we present an aesthetic system for nonrepresentational, geometric pictures. By a picture, we mean any colored, two-dimensional object. Typical examples of pictures are paintings, photographs, and even computer graphics displays. Because pictures are considered in terms of their descriptions and the descriptions used in this aesthetic system are independent of media, the medium in which a picture is realized is not important for this aesthetic system. The description, interpretation, and evaluation of nonrepresentational, geometric pictures using this aesthetic system are examined. Examples of pictures and their descriptions, interpretations, and evaluations in this aesthetic system are given.

The aesthetic system is based on the constructive mode of understanding. That is, an interpretation of a picture has as input component a specification of the information (rules) that can be used to construct or generate the description of the picture and as output component the description of the picture. In this aesthetic system, the input component of an interpretation of a picture is a *generative specification*[1] for the picture. Generative specifications provide a method for generating pictures in terms of their form, in

[1] G. Stiny and J. Gips, "Shape Grammars and the Generative Specification of Painting and Sculpture," in C. V. Freiman, ed., *Information Processing 71* (Amsterdam, 1972; reprinted Princeton, 1972).

terms of combinations and relations of shapes and colors. Generative specifications are described below. In this aesthetic system, the description of a picture lists one-by-one the shapes, colors, and occurrences of the distinct areas of the picture. Descriptions of pictures are given by *shape-color-occurrence tables*, which are described below. The conventions for using the generative specification of a picture to construct or generate the shape-color-occurrence tables of the picture are encoded in the interpretation algorithm. The reference algorithm is the reference algorithm shown in figure 6-1. The evaluation algorithm is the evaluation algorithm E_Z. The comparison algorithm is the comparison algorithm C_Z. The four algorithms of this aesthetic system are summarized in figure 9-1.

We now describe this aesthetic system in more detail. The reader unfamiliar with generative and/or computer graphics techniques may find parts of this material difficult. The level of detail presented is indicative of the amount of work required to specify an aesthetic system that is to deal with real works of art in even a very simple way. While we do not want to discourage the reader from going over this material, which is of interest in itself, we do not wish the reader to be discouraged by its difficulty. An understanding of this chapter is not required for an understanding of the remainder of the book.

9.1 Generative Specifications

A generative specification gives all the information needed to construct a picture in terms of rules for generating the picture.

A generative specification consists of four parts: a shape grammar, a selection rule, coloring rules, and a limiting shape. The shape grammar gives rules for generating a set of shapes. The selection rule determines which of those shapes is to be used in the picture. The coloring rules specify how the areas in the shape selected are to be colored. The limiting shape determines how the colored shape is to be located on a canvas or displayed, for example, on a computer display.

An example of a generative specification is shown in figure 9-2. This generative specification gives all the information necessary to construct the bottom picture shown in figure 9-3.

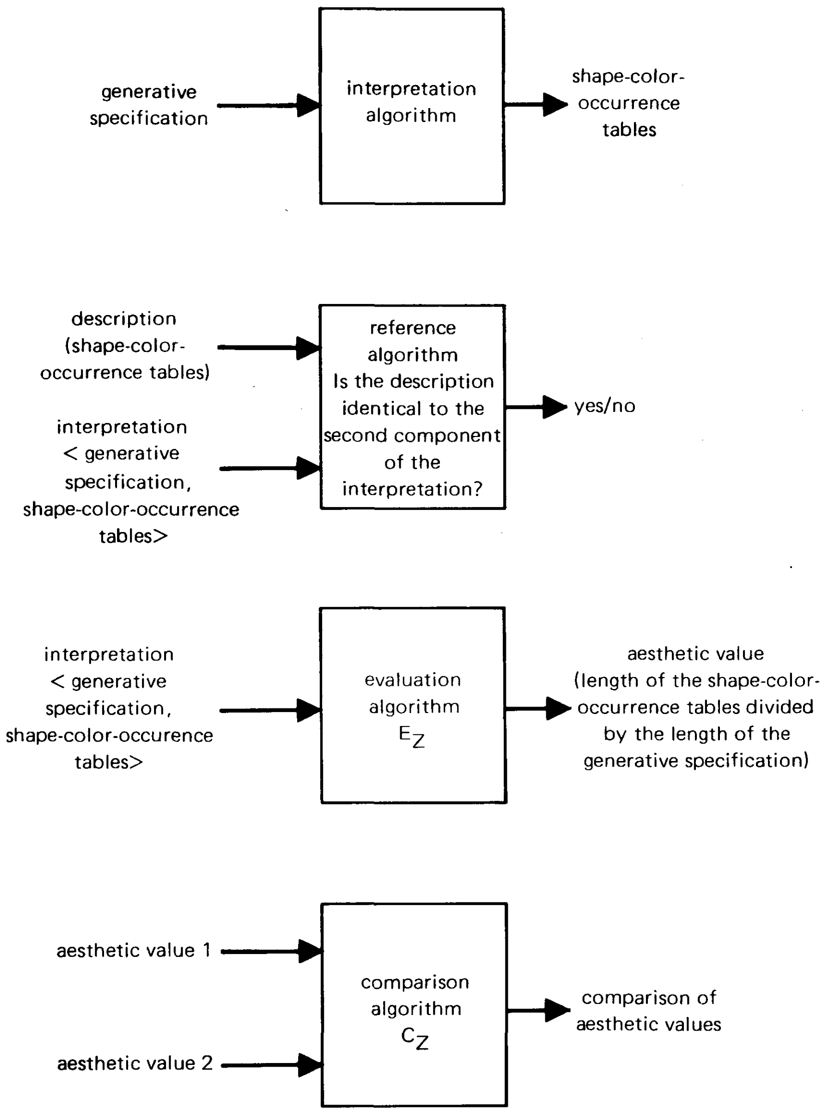


Fig. 9-1

The four algorithms in an aesthetic system for nonrepresentational, geometric pictures.

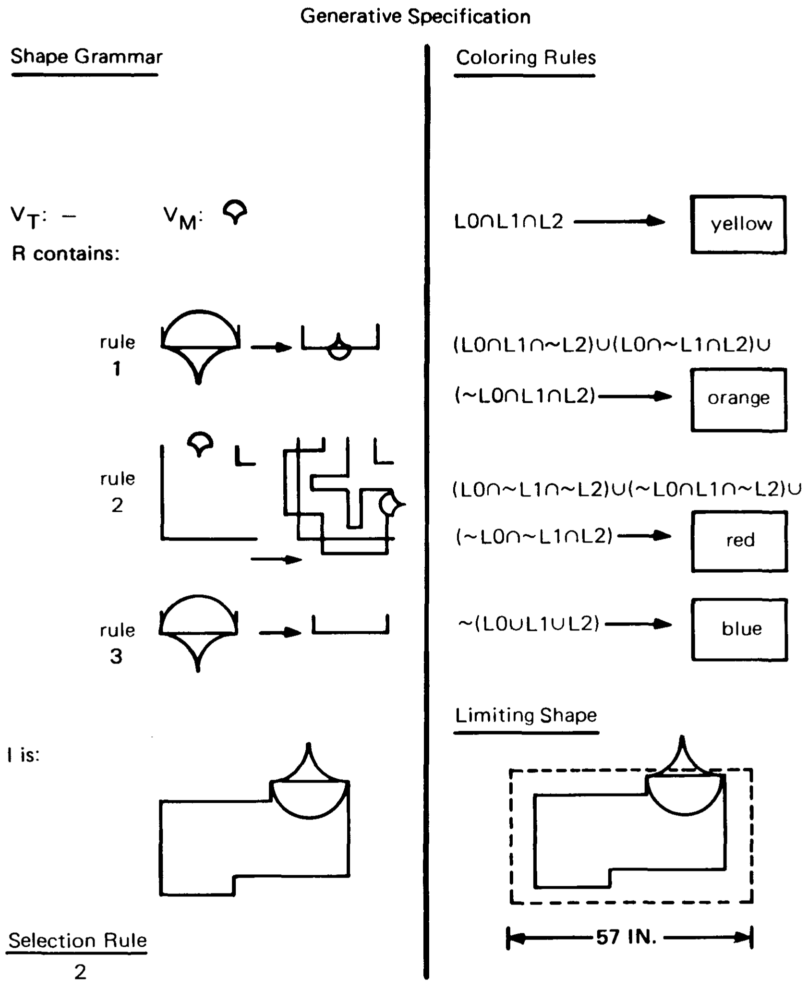


Fig. 9-2

The generative specification for the picture Urform III.

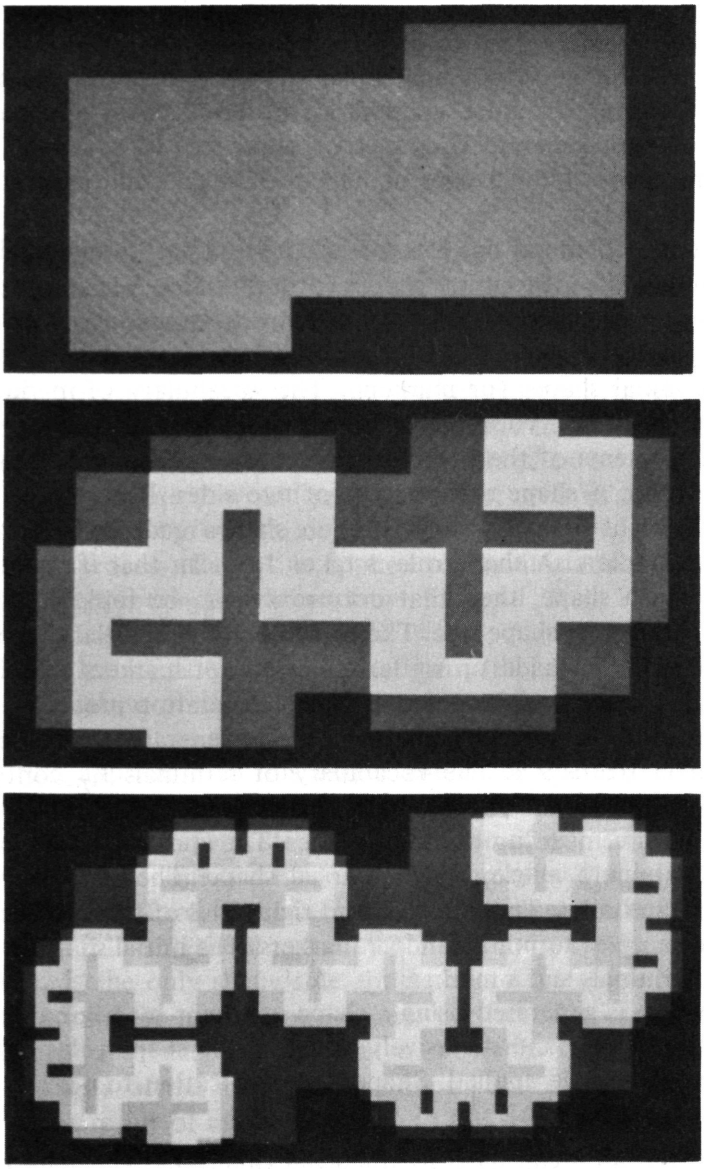


Fig. 9-3

The pictures Urform I-III.
(Black in this figure is blue in the pictures, dark gray is red,
gray is orange, and light gray is yellow.)

9.1.1 Shape Grammers

Shape grammars[2] provide a recursive method for generating shapes. Shape grammars are similar to phrase structure grammars. Where phrase structure grammars are defined over alphabets of symbols and generate languages of sequences of symbols, shape grammars are defined over alphabets of shapes and generate languages of shapes.

A shape grammar has four parts. The first part is an alphabet or vocabulary V_T of terminal shapes (or terminals). A shape grammar defines a language of shapes made up of terminals or parts of terminals. The second part is an alphabet or vocabulary V_M of nonterminal shapes (or markers). The vocabulary of markers together with the vocabulary of terminals provide the primitive shape elements of the shape grammar. The third part is a set R of shape rules. A shape rule consists of two sides. Both the left side and the right side of a shape rule are shapes made up of terminals and/or markers. A shape rule is taken to mean that if its left side occurs in a shape, then that occurrence can be replaced by the right side of the shape rule. The fourth part is an initial shape. The initial shape is made up of terminals and/or markers. The initial shape is the starting shape for the shape generation process.

Consider the shape grammar of the generative specification shown in figure 9-2. The vocabulary of terminals V_T contains a single straight line. Shapes in the language defined by this shape grammar are made up of straight lines. The vocabulary of markers V_M contains a single closed, curved shape. The set R contains three shape rules. The left sides and right sides of these shape rules are made up of terminals and/or markers. The initial shape is made up of terminals and a marker.

A shape is generated using a shape grammar by beginning with the initial shape and recursively applying the shape rules until no shape rule can be applied. Shape rule application to a given shape proceeds as follows:

(1) Find a subshape of the given shape that is geometrically similar to the left side of a shape rule.
(2) Find the Euclidean transformations (translation, rota-

[2] G. Stiny, *Pictorial and Formal Aspects of Shape and Shape Grammars* (Basel, 1975). J. Gips, *Shape Grammars and Their Uses* (Basel, 1975).

tion, scale, mirror image) that make the left side of the shape rule identical to the corresponding subshape of the given shape.

(3) Apply these transformations to the right side of the shape rule.

(4) Substitute the resulting shape for the occurrence of the subshape in the given shape.

The generation of a shape using the shape grammar just shown is given in figure 9-4. Step 0 shows the initial shape. Recall that a shape rule can be applied to a shape when its left side can be made identical to a subshape of the shape. Either rule 1 or rule 3 is applicable to the initial shape. Application of rule 3 would result in the removal of the marker and, hence, the termination of the generation process as no shape rules would then be applicable. Application of rule 1 would reverse the direction of the marker, reduce it in size by one-third, and force the continuation of the generation process. Rule 1 is applied to the initial shape in this generation to obtain the shape shown in step 1. Rule 2 is the only shape rule applicable to the shape in step 1. Application of rule 2 would add terminals to the shape, advance the marker, and force the continuation of the generation process. Rule 2 is applied to the shape in step 1 to obtain the shape in step 2. Rule 2 is the only shape rule applicable to this shape. The shape resulting from the application of rule 2 is shown in step 3. Either rule 1 or rule 3 is applicable to the shape in step 3. Application of rule 3 would erase the marker and terminate the generation process. The application of rule 1 would force the continuation of the generation process. Rule 1 is applied to the shape in step 3 to obtain the shape in step 4. Rule 2 is the only shape rule applicable to the shape in step 4. Rule 2 applies to the shape because its left side can be made identical to a subshape of the shape shown in step 4. This subshape consists of the marker and some of the terminals added in step 3. The result of applying rule 2 to the shape in step 4 is the shape in step 5. Rule 2 is the only shape rule that applies to the shape in step 5 and to the resulting shapes in steps 6 through 17. Either rule 1 or rule 3 is applicable to the shape in step 18. Rule 3 is applied to this shape to produce the shape in step 19. No shape rules are now applicable so the generation process is halted. If rule 1 were applied, rule 2 would have to be applied an additional 98

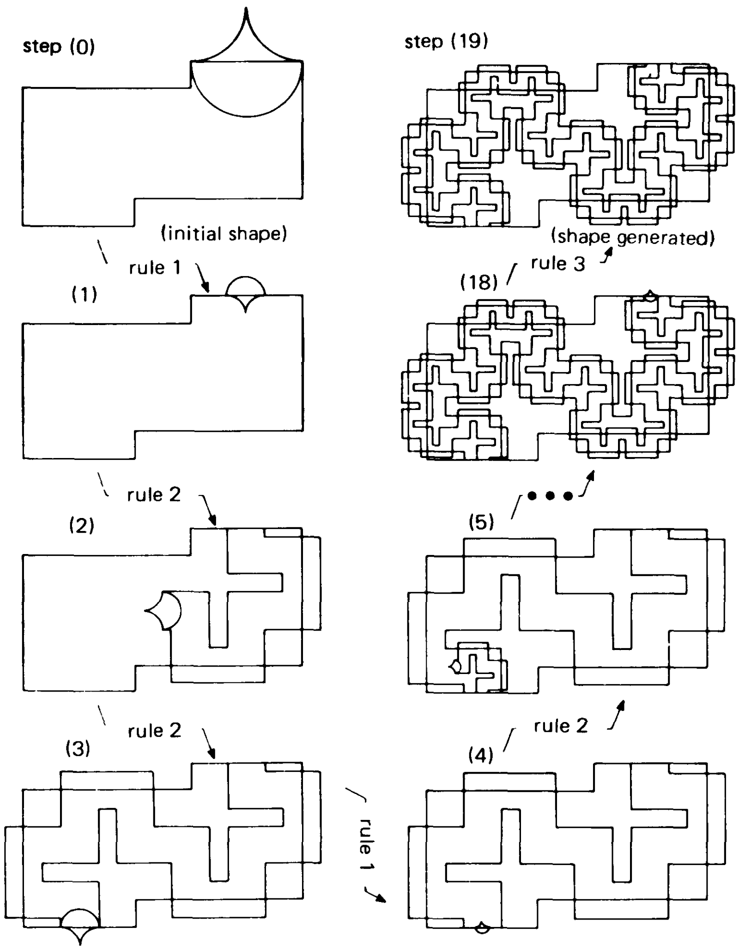


Fig. 9-4

Generation of the shape used in Urform III using the shape grammar given in the generative specification of fig. 9-2.

times before rule 3 could next be applied to terminate the generation process. Of course, the shape generation process can be continued indefinitely.

Shape generation using this shape grammar may be regarded in this way: The initial shape contains two occurrences of the shape shown in figure 9-5*a*, which we will refer to as an "L." Additional shapes are formed by the recursive placement of the arrangement of seven smaller L's shown in figure 9-5*b* on each L, as shown in figure 9-5*c*. All L's of the same size are connected.

The language defined by a shape grammar contains all those shapes generated by the shape grammar that are made up of terminals or parts of terminals only. Three shapes in the language defined by the shape grammar given in figure 9-2 are shown in figure 9-6. The most complicated shape in this figure is generated as shown in figure 9-4.

9.1.2 Selection Rules

The language defined by a shape grammar may contain more than one shape, as in the example just given. Only one of these shapes is used to make a picture. Hence, a mechanism, a selection rule, is required to determine which of the shapes in the language

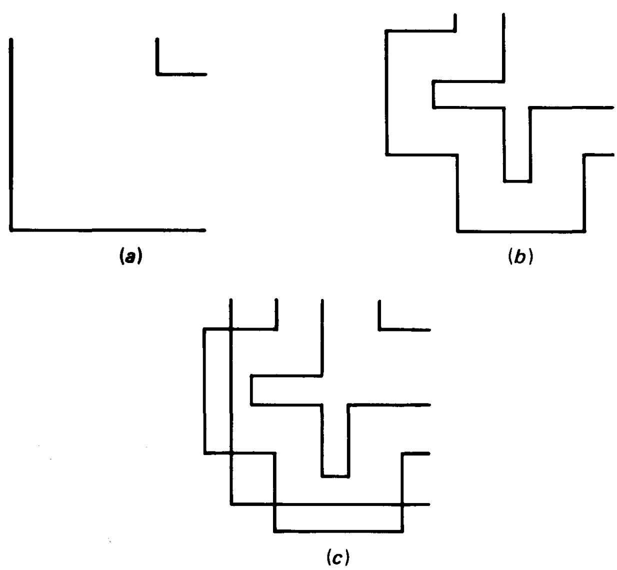


Fig. 9-5

Formation of the second shape rule in the shape grammar used in the generation of Urform III.

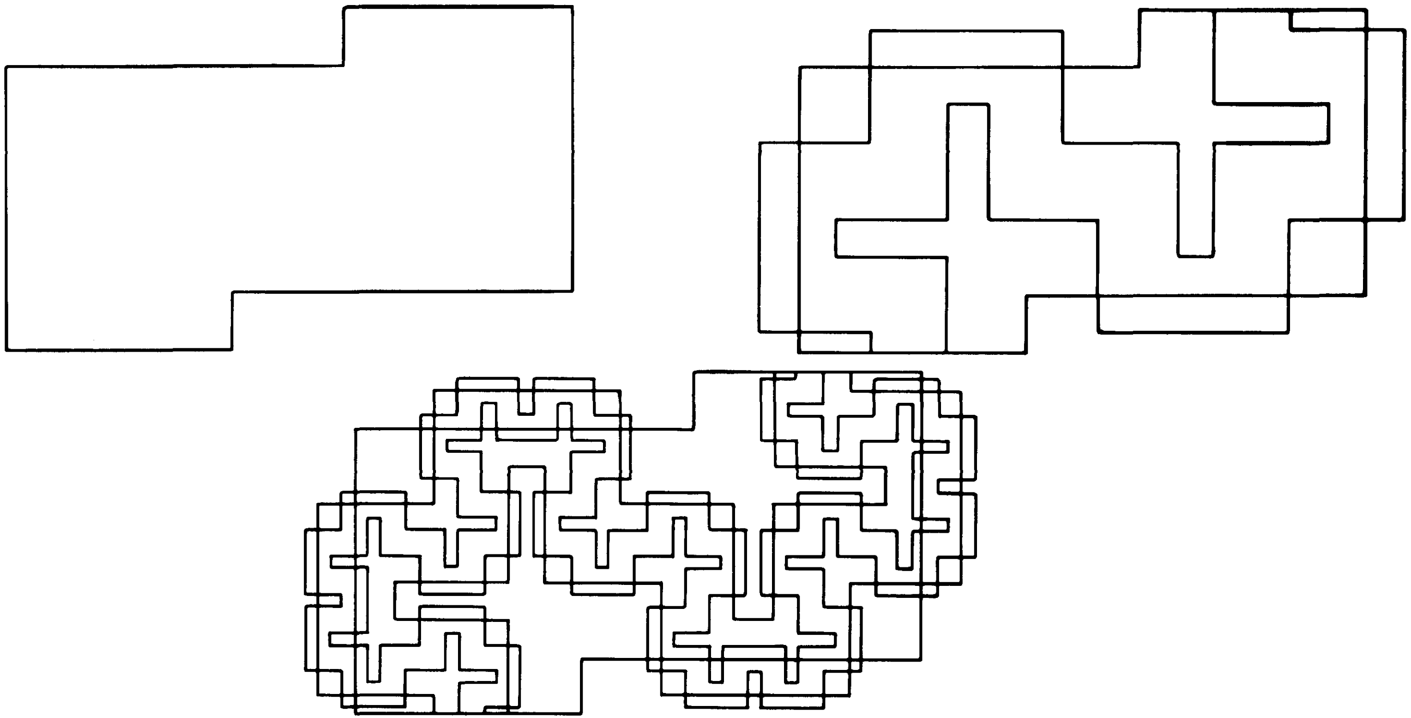


Fig. 9-6

Three shapes in the language defined by the shape grammar used in the generation of Urform III.

defined by the shape grammar is used. The selection rule acts as a halting criterion for the shape generation process.

The concept of "level" provides the basis for selection rules and for coloring rules, as discussed in the following section. The level of a terminal in a shape is analogous to the depth of a node in a tree. Level assignments are made to terminals during the shape generation process. Terminals in the initial shape are assigned level 0. Terminals added to a shape by the application of a shape rule are assigned higher levels. Basically, if the highest level assigned to any terminal in the subshape that corresponds to the left side of the shape rule is n then the terminals added by applying the shape rule are assigned level n + 1. For example, level assignments for the shape generated in figure 9-4 are shown in figure 9-7. The terminals in the initial shape are assigned level 0. The terminals resulting from the applications of rules in steps 1 through 3 are assigned level 1. The terminals resulting from the applications of rules in steps 4 through 19 are assigned level 2.

The selection rule is an integer. The selection rule determines when a shape rule that has fewer markers in its right side than in its left side (e.g., shape rule 3 in the example given) can be applied. Such a shape rule can only be applied if the highest level assigned to terminals in the subshape corresponding to the left side of the shape rule is exactly the integer of the selection rule. In the generative specification of figure 9-2, the selection rule is 2. This selection rule allows shape rule 3 to be applied only to the shape in step 18 and not to the shapes in steps 0, 2, 117, and so forth. Thus the shape in step 19 is the shape selected by the selection rule from the language defined by the shape grammar. If the selection rule were 0, the top shape shown in figure 9-6 would have been selected. If the selection rule were 1, the middle shape shown in figure 9-6 would have been selected. The generative specifications for Urform I and II, shown in figure 9-3, contain the selection rules 0 and 1, respectively.

9.1.3 Coloring Rules

The coloring rules in a generative specification determine how the areas in the shape determined by the shape grammar and selection rule are colored.

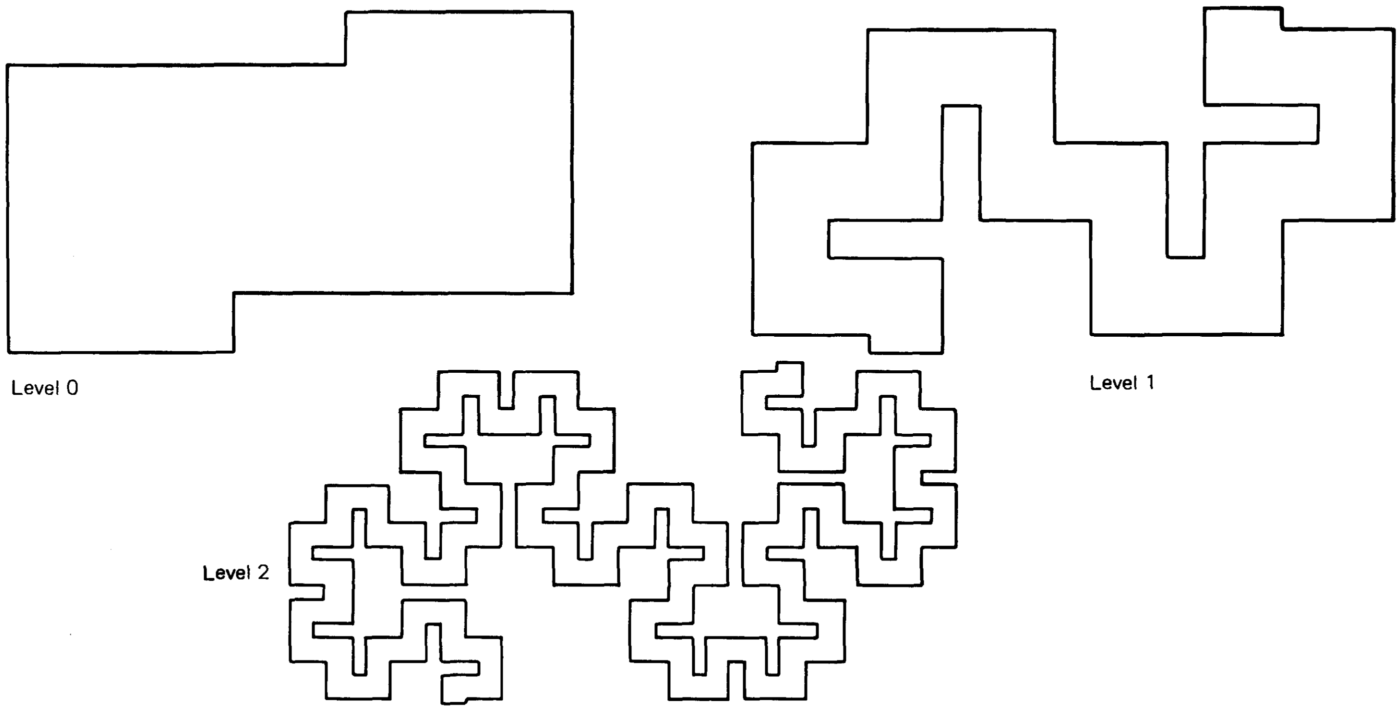


Fig. 9-7

Level assignments to the shape used in Urform III.

Coloring rules indicate how the areas contained in a shape are colored by considering the shape as a Venn diagram. The terminals of each level in the shape are taken as the outline of a set in the Venn diagram. Levels 0, 1, 2, . . . n are said to define sets L0, L1, L2, . . . Ln respectively, where n is the selection rule.

A coloring rule has two sides. The left side of a coloring rule defines a set using the sets determined by level assignment and the usual set operators, for example, union, intersection, and complement. The right side of a coloring rule indicates the color given to the set defined by the left side of the rule. The coloring rules specify one color for each possible area of the shape.

The effect of the coloring rules in the generative specification of figure 9-2 is to count set overlaps. Areas with three overlaps are painted yellow, two overlaps orange, one overlap red, and no overlaps blue.

9.1.4 Limiting Shapes

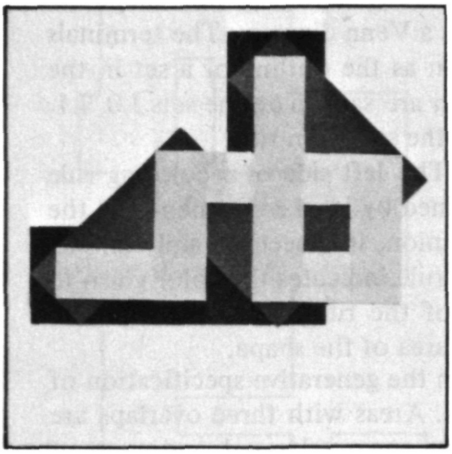
The limiting shape of a generative specification determines how the colored shape is to be located on a canvas or computer display. The limiting shape is designated by broken lines, and its size is indicated explicitly. The initial shape of the shape grammar is located with respect to the limiting shape. Informally, the limiting shape acts as a camera viewfinder or cookie cutter. The limiting shape determines what part of the colored shape is represented on a canvas or display.

The limiting shape in the generative specification of figure 9-3 is a rectangle.

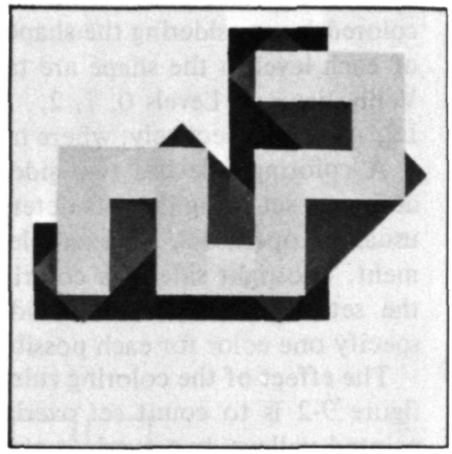
9.2 Shape-Color-Occurrence Tables

The description of a picture is given by three tables: a shape table, a color table, and an occurrence table. Shape-color-occurrence tables describe a picture in terms of the shapes and colors of the distinct areas occurring in the picture. This method of describing pictures is similar to methods typically suggested in the literature of aesthetics. (See chap. 3, n.5.) The shape-color-occurrence tables for the picture Anamorphism I, in figure 9-8, are shown in figure 9-9.

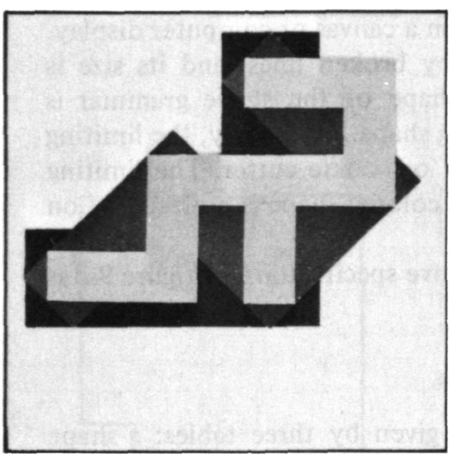
The shape table specifies the different shapes of the distinct areas of the picture. There is one entry in the shape table for each



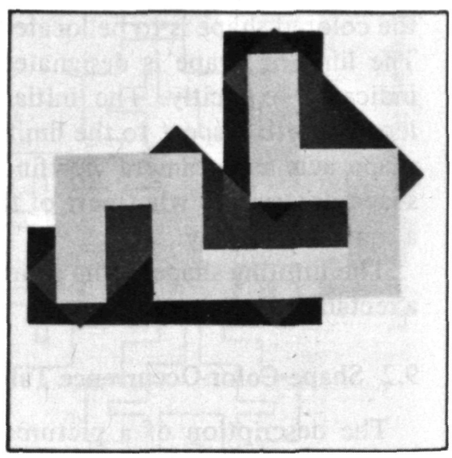
Anamorphism I



Anamorphism II



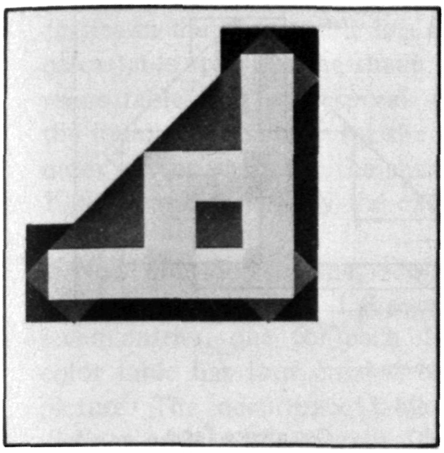
Anamorphism III



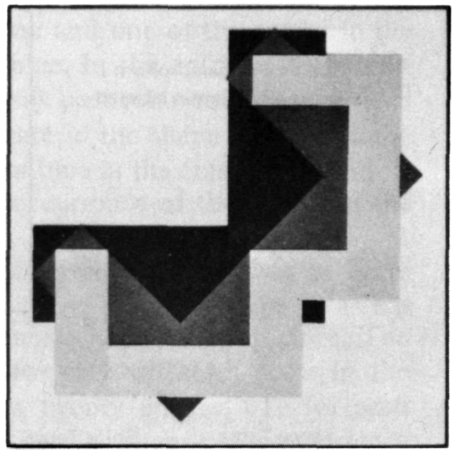
Anamorphism IV

Fig. 9-8

The pictures Anamorphism I-VI.
(Black in this figure is blue in the pictures, dark gray is red,
light gray is green, and white is light blue.)



Anamorphism V



Anamorphism VI

Fig. 9-8

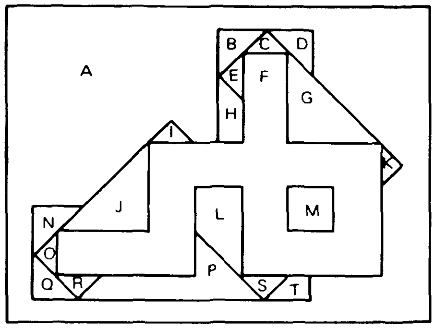
The pictures Anamorphism I-VI. (Cont.)

different shape. Two shapes are different if and only if they are not geometrically similar. For example, if several of the areas in the picture are squares, exactly one entry in the shape table would be a square.

The color table specifies the different colors of the distinct areas of the picture. There is one entry in the color table for each different color. For example, if some of the areas of the picture are colored a certain shade of blue, exactly one entry in the color table would be that shade of blue.

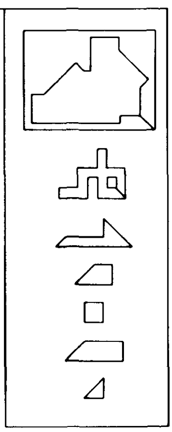
The occurrence table specifies the occurrences of the distinct areas of the picture. Each entry in the occurrence table corresponds uniquely to a distinct, colored area in the picture. Each entry has seven parts: i_s is the index of a shape entry in the shape table and specifies the shape of the area: i_c is the index of a color entry in the color table and specifies the color of the area; X, Y, θ, S, and M are parameters that are used to map the shape indexed by i_s from the shape table coordinate system to the picture coordinate system, where X and Y determine translation, θ determines rotation, S determines scale, and M determines if the mirror image of the shape is used. For example, assume a blue square occurs in

Outline of Anamorphism I
with colored areas lettered



β constructed for Anamorphism I:

Shape Table

i_s	Shape
1	
2	
3	
4	
5	
6	
7	

Color Table

i_c	Color
1	grn
2	red
3	blue
4	lt. blu

Occurrence Table

i_s	i_c	X Y θ S	M
1	4	param's for area	A
7	3	"	B
7	2	"	C
7	3	"	D
7	2	"	E
2	1	"	F
7	2	"	G
6	3	"	H
7	2	"	I
7	2	"	J
7	2	"	K
4	2	"	L
5	2	"	M
7	3	"	N
7	2	"	O
3	3	"	P
7	3	"	Q
7	2	"	R
7	2	"	S
4	3	"	T

Fig. 9-9

The shape-color-occurrence tables for Anamorphism I.

the top right corner of the picture. Consequently, one of the entries in the shape table is a square and one of the entries in the color table specifies the shade of blue. In the entry of the occurrence table that corresponds to this particular colored area, i_s is the index of the entry for the square in the shape table, i_c is the index of the entry for the shade of blue in the color table, and X, Y, θ, S, and M specify the exact occurrence of the square in the picture.[3]

Now consider the shape-color-occurrence tables given in figure 9-9 for Anamorphism I shown in figure 9-8. The shape table has seven entries, one for each different shape in the picture. The color table has four entries, one for each different color in the picture. The occurrence table has twenty entries, one for each distinct area in the picture. Together the shape-color-occurrence tables specify all of the aspects of the picture relevant to the aesthetic system. Given the shape-color-occurrence tables, the picture can be reproduced in all these essential or relevant aspects.

9.3 The Four Algorithms of the Aesthetic System

The interpretation algorithm of the aesthetic system has as input a generative specification of a picture and as output the shape-color-occurrence tables of the picture. An interpretation algorithm has a sequence of symbols as input and a sequence of symbols as output. Both the generative specifications and shape-color-occurrence tables are encoded as sequences of symbols for the interpretation algorithm. The conventions for mapping a generative specification encoded as a sequence of symbols into a trio of shape-color-occurrence tables encoded as a sequence of symbols are embodied in the interpretation algorithm (see fig. 9-1).

The interpretation algorithm has been implemented as a computer program for a class of generative specifications and corresponding shape-color-occurrence tables. The program is written in SAIL and runs on a PDP-10.[4] The class of generative specifications and corresponding shape-color-occurrence tables for which the program operates is astronomical in number but still constitutes

[3] In general, entries in the shape-color-occurrence tables are represented in some canonical form and listed in some canonical order so that each picture is described by exactly one trio of shape-color-occurrence tables.

[4] A description of the program is given in Gips, *Shape Grammars and Their Uses*.

only a restricted class of the possible generative specifications and corresponding shape-color-occurrence tables. This program, particularly the symbolic encodings used for generative specifications and shape-color-occurrence tables, provides the basis for the remaining discussion of the aesthetic system.

The reference algorithm of this aesthetic system is simply the reference algorithm given in figure 6-1. That is, given the shape-color-occurrence tables that constitute the description of a picture and an interpretation, the reference algorithm determines that the interpretation refers to the picture if and only if the output component (shape-color-occurrence tables) of the interpretation is identical to the description of the picture. Implementation of the reference algorithm on a computer would be trivial.

The evaluation algorithm of the aesthetic system is the evaluation algorithm E_Z (see sections 8.3 and 8.4). Given an interpretation, the evaluation algorithm measures the length of the generative specification, the input component of the interpretation, and the length of the trio of shape-color-occurrence tables, the output component of the interpretation. The output of the evaluation algorithm is the ratio of the length of the trio of shape-color-occurrence tables to the length of the generative specification.

The evaluation algorithm has also been implemented on the computer. For this program, the lengths of each of the components of an interpretation are the number of words of computer memory used in their encoding, in their computer representation. The encoding used for generative specifications is rather involved and is not discussed here.[5] The encoding used for shape-color-occurrence tables can be given simply.

The computer representation of each shape (each must be closed and rectilinear) in a shape table is constructed by fixing two of the vertices of the shape and listing the angles and distances encountered in a counterclockwise trace around the boundary of the shape. A hole in a shape requires the construction of a straight line (actually two lines, one superimposed on the other) between a vertex on the inner boundary and a vertex on the outer boundary of the shape so that the trace around the shape is continuous (see, e.g., shapes 1 and 2 in the shape table of fig. 9-9). The number of words of memory used to represent each shape is given by 2L-3,

[5] See Gips, *Shape Grammars and Their Uses.*

where L is the number of straight line segments determing the shape. The computation of the length of the shape table of figure 9-9 is shown in figure 9-10. Each entry in a color table is represented by three words of memory denoting the intensities of the red, blue, and green components of the color. Each of the seven items in each entry in an occurrence table is represented by a word of memory. The length of each table is the sum of the lengths of each entry in the table plus one additional word of memory used to specify the number of entries in the table. The length of a trio of shape-color-occurrence tables is just the sum of the lengths of each of the three tables in the trio.

The comparison algorithm of this aesthetic system is the comparison algorithm C_Z. Given two values assigned to interpretations, C_Z determines that the interpretation assigned higher aesthetic value is aesthetically superior. The comparison algorithm C_Z would be trivial to implement on a computer.

Also implemented on the computer is a program that allows pictures having interpretations in this aesthetic system to be automatically displayed on a color television attached to the computer. We now present two examples of the application of the aesthetic system to classes of pictures.

9.4 Anamorphism I-VI

Consider the six pictures, Anamorphism I-VI, shown in figure 9-8.

The generative specification for Anamorphism I is given in figure 9-11. The generative specifications for Anamorphism II-VI can be obtained by substituting the shape rules shown in figure 9-12 for the first shape rule in the shape grammar in the generative specification for Anamorphism I. The generative specifications of these six pictures differ only in the location of the markers (circles) in the right side of the first shape rule in their shape grammars.

The shape-color-occurrence tables for Anamorphism I are given in figure 9-9. The shape-color-occurrence tables for Anamorphism II-VI are not shown but are constructed similarly.

The tabulation of aesthetic values for Anamorphism I-VI using these interpretations in this aesthetic system is given in table 9-1. In the given interpretations for Anamorphism I-VI, the lengths of the generative specifications (number of words of memory used to

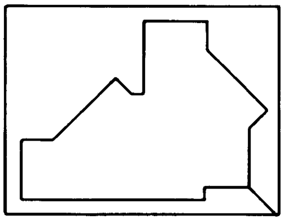
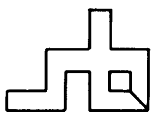
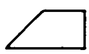
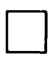
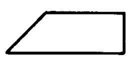
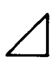
i_s	Shape	No. of Edges L	Length 2L − 3
1		20	37
2		20	37
3		5	7
4		4	5
5		4	5
6		4	5
7		3	3
Total			99
Length of Table (Total +1)			100

Fig. 9-10

Computation of the length of the shape table for Anamorphism I.

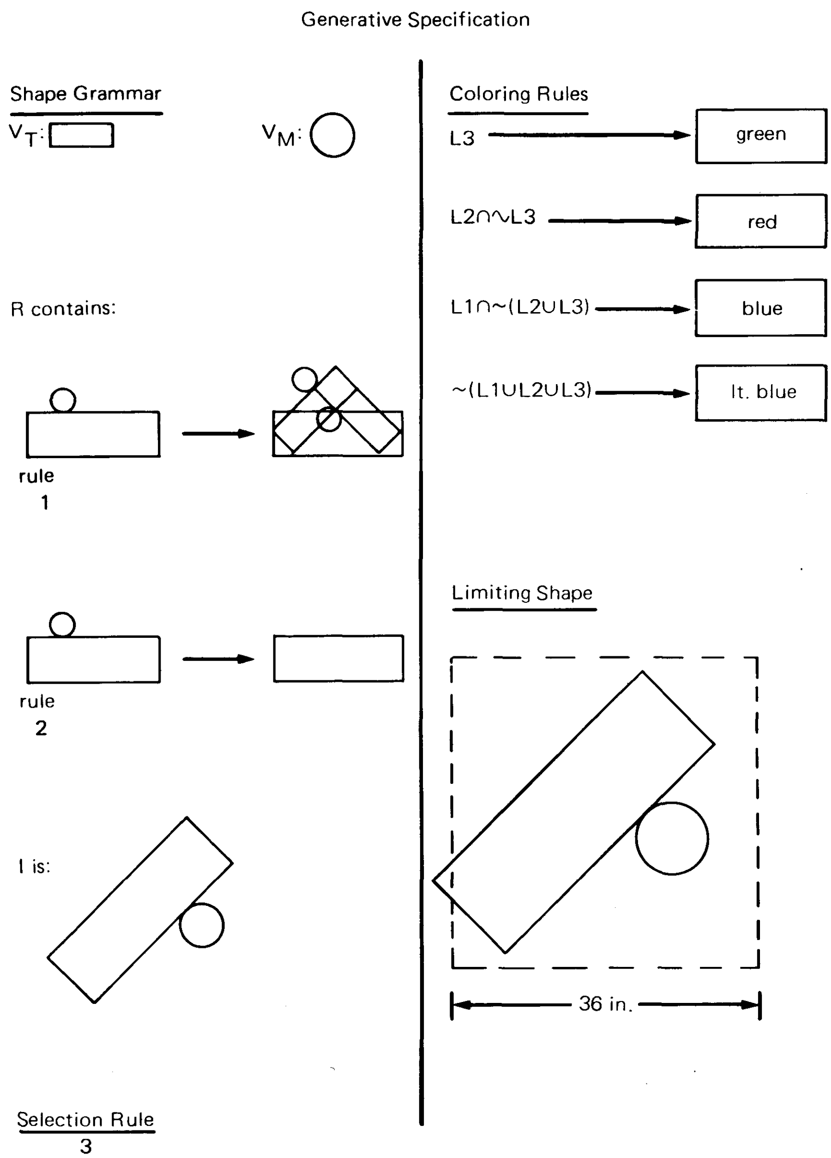


Fig. 9-11

The generative specification for the picture Anamorphism I.

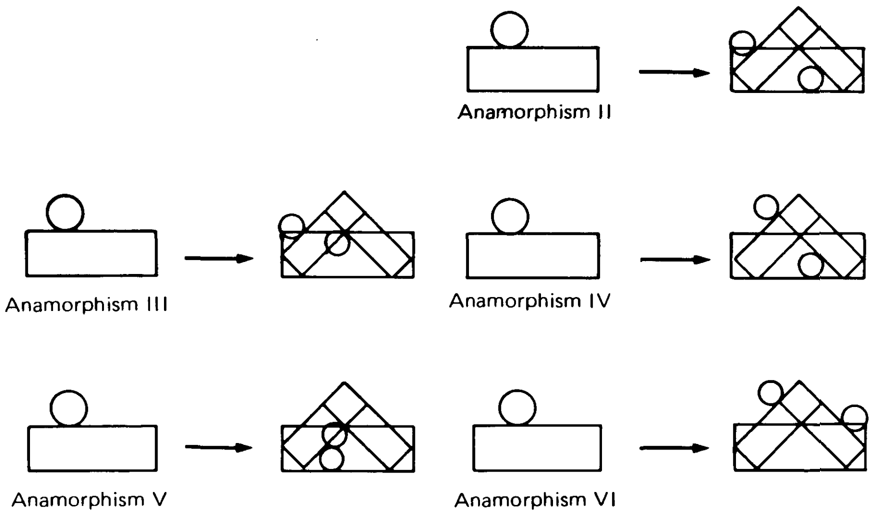


Fig. 9-12

Shape rules for Anamorphism II-VI.

TABLE 9-1
TABULATION OF AESTHETIC VALUES FOR
ANAMORPHISM I-VI.

Anamorphism	$L(\alpha)$	*Shape table*	*Color table*	*Occur. table*	$L(\beta)$	$E_Z(\langle\alpha,\beta\rangle)$
I	41	100	13	141	254	6.20
II	41	95	13	141	249	6.07
III	41	82	13	141	236	5.76
IV	41	98	13	141	252	6.15
V	41	62	13	127	202	4.93
VI	41	95	13	113	221	5.39

represent them in the computer) are equal because these generative specifications differ only in the location of the markers in their respective shape grammars. Since the lengths of the generative specifications are the same in each of these interpretations, the relative aesthetic values of these interpretations depend only on the relative lengths of their shape-color-occurrence tables. In the aesthetic system, the ordering of the aesthetic values of the given interpretations for Anamorphism I-VI is, in order of decreasing aesthetic value, Anamorphism I, IV, II, III, VI, and V. That is, using the interpretative conventions and evaluative criteria of the aesthetic system and using the given interpretations, Anamorphism I is considered aesthetically superior.

9.5 Bridgework I-VI

As another example, consider the six pictures, Bridgework I-VI shown in figure 9-13.

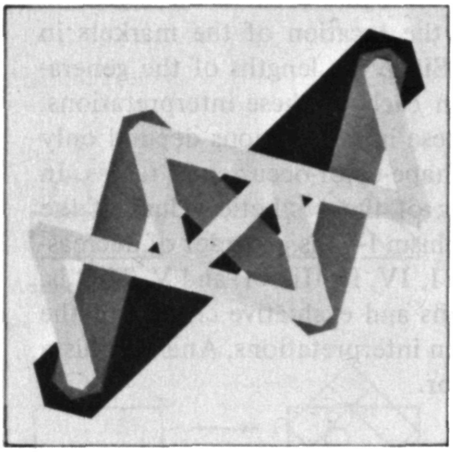
The generative specification for Bridgework I is given in figure 9-14. The generative specifications for Bridgework II-VI can be obtained by substituting the shape rules shown in figure 9-15 for the first shape rule in the shape grammar in the generative specification for Bridgework I. The generative specifications of these six pictures differ only in the locations of the markers (circles) in the right side of the first shape rule in their shape grammars.

The shape-color-occurrence tables for Bridgework I-VI are not shown but are constructed in the straightforward way described above.

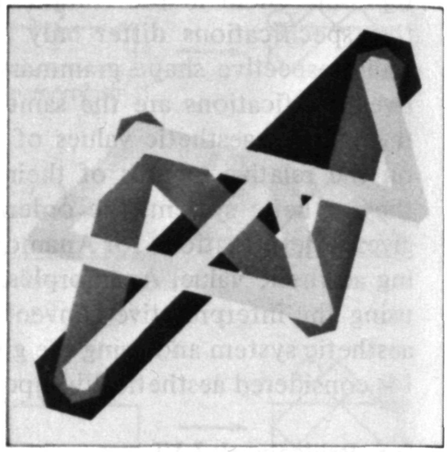
The interpretation considered here for each picture has the given generative specification of the picture as its input component and the shape-color-occurrence tables for the picture as its output component. The tabulation of aesthetic values for Bridgework I-VI using these interpretations in this aesthetic system is given in table 9-2. The aesthetic ordering of Bridgework I-VI using these interpretations is, in order of decreasing aesthetic value, Bridgework II, IV, I, V, VI, and III.

9.6 Discussion

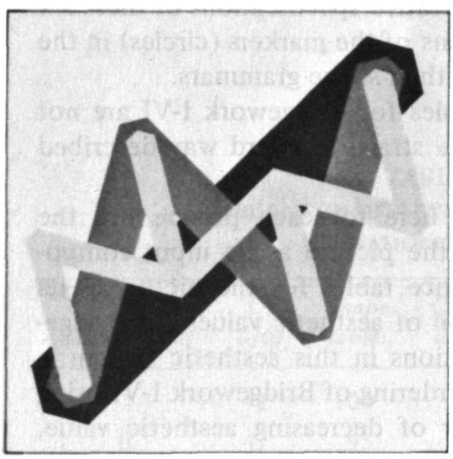
The aesthetic system examined here is based on the constructive mode of understanding and deals with the form of pictures. More



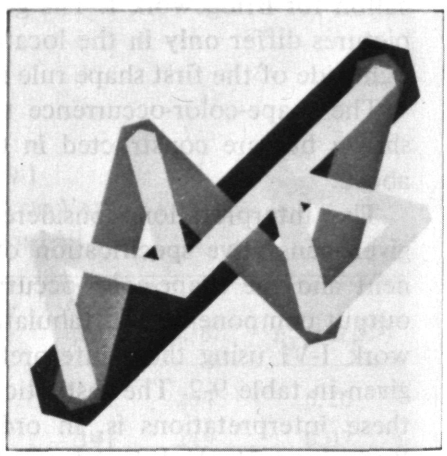
Bridgework I



Bridgework II



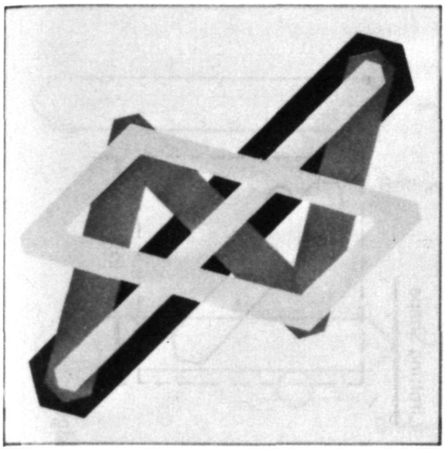
Bridgework III



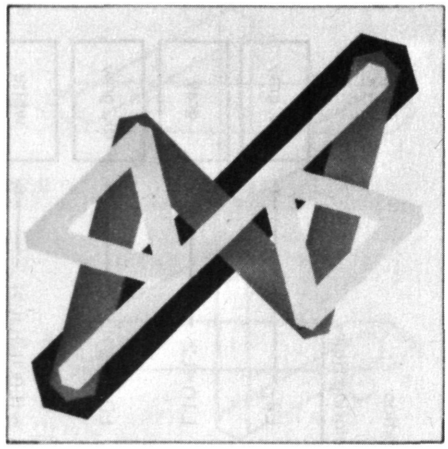
Bridgework IV

Fig. 9-13

The pictures Bridgework I-VI.



Bridgework V



Bridgework VI

Fig. 9-13

The pictures Bridgework I-VI. (Cont.)

specifically, the aesthetic system deals primarily with the shapes and the arrangement of shapes in a picture. A picture is understood by giving the rules for generating the shapes and their arrangement in the picture. A picture is evaluated in terms of the number and complexity of the shapes in it and the economy of the rules given to generate it. A picture with a large number of complex shapes that is seen to be generated by a small number of simple rules has high aesthetic value in this aesthetic system. This aesthetic measure can be related to the standard canon of "unity and variety" as discussed in section 8.4.1.

Discussions of pictures in terms of form often utilize concepts such as "balance," "proportion," and "symmetry." In this aesthetic system, these concepts are not dealt with explicitly. These properties are not identified in the interpretation of a picture. However, these properties can be examined indirectly in terms of the interpretation of a picture and the interpretative conventions and evaluative criteria of the aesthetic system. For example, there is an implicit bias in the aesthetic system against symmetric pictures. The bias results because asymmetric pictures tend to have a larger variety and more occurrences of shapes than symmetric

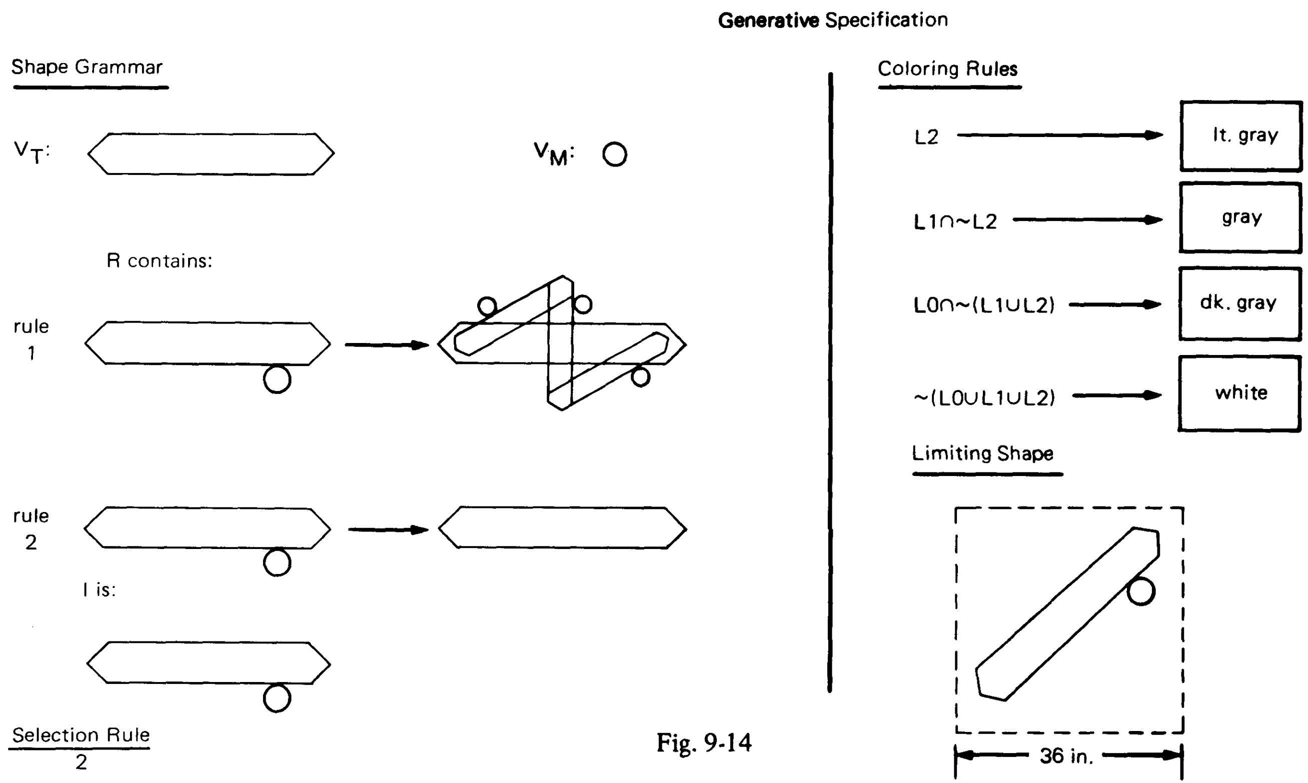


Fig. 9-14

The generative specification for the picture **Bridgework I.**

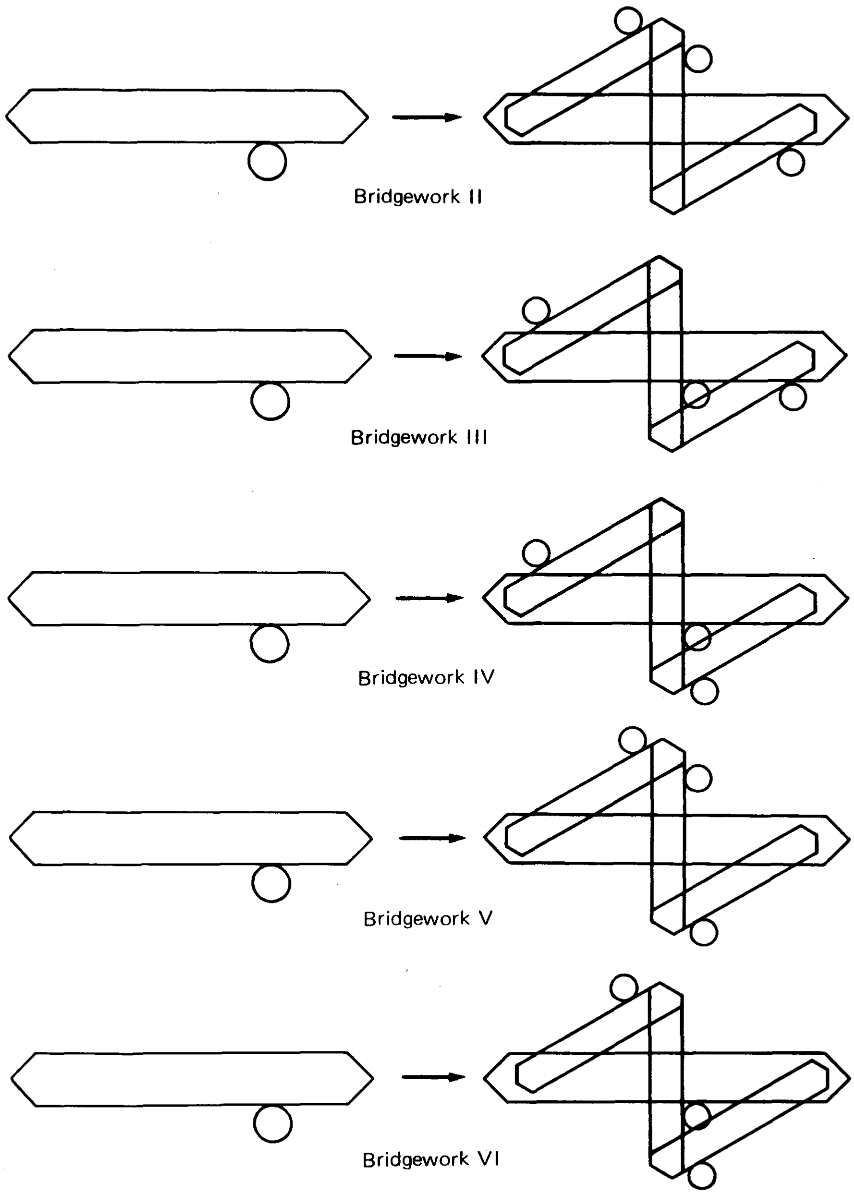


Fig. 9-15

Shape rules for Bridgework II-VI.

TABLE 9-2
TABULATION OF AESTHETIC VALUES OF
BRIDGEWORK I-VI.

Bridgework	$L(\alpha)$	*Shape table*	*Color table*	*Occur. table*	$L(\beta)$	$E_Z(<\alpha,\beta>)$
I	50	177	13	169	359	7.18
II	50	226	13	162	401	8.02
III	50	168	13	127	308	6.16
IV	50	211	13	141	365	7.30
V	50	183	13	155	351	7.02
VI	50	181	13	155	349	6.98

pictures. The shape tables and occurrence tables of asymmetric pictures tend to have more entries than the shape tables and occurrence tables of symmetric pictures. Hence, the descriptions of asymmetric pictures tend to be longer than the descriptions of symmetric pictures. As a result, the aesthetic values assigned to asymmetric pictures tend to be higher. The aesthetic values assigned to the interpretations given for Anamorphism I-VI and the aesthetic values assigned to the interpretations given for Bridgework I-VI illustrate this bias.

The aesthetic value of a picture in this aesthetic system can also be examined in terms of its invariance under certain changes or operations to the picture. In this aesthetic system, the aesthetic value of a picture is invariant under changes of color and/or under the Euclidean transformations of translation, rotation, scale, and/or mirror image. More precisely, if two pictures are the same except for the colors occurring in them and/or their position, orientation, size, and/or reflection, then for any interpretation of the first picture there is an interpretation of the second picture in the aesthetic system which is assigned the same aesthetic value.

For example, consider two pictures that are the same except that one is a rotation of the other. For any generative specification of the first picture there is a corresponding generative specification for the second picture which differs only in the orientation of its limiting shape. Consequently, the lengths of these two generative specifications are the same. Similarly, the descriptions of the two pictures differ only in the specific parameters given in their occurrence tables. Hence, these descriptions have the same lengths. Thus for any interpretation of the first picture, one can give an interpretation of the second picture that is assigned the same aesthetic value in this aesthetic system.

Each of the generative specifications given in this chapter can be modified to define a picture with an interpretation assigned an arbitrarily high aesthetic value in this aesthetic system by simply increasing the selection rule and adding the appropriate coloring rules. Increasing the selection rule increases the number of levels generated by the shape grammar. This has the effect of greatly increasing the lengths of the shape tables and occurrence tables of the description of a picture but only minimally increasing the length of its generative specification. Consequently, the aesthetic value increases in this aesthetic system as the selection rule increases.

In theory, aesthetic value can become arbitrarily high in this aesthetic system as the selection rule becomes arbitrarily high. However, there are practical bounds on possible aesthetic value when the aesthetic system is used in a criticism algorithm or design algorithm. As the selection rule increases, the number and complexity of the distinct areas in the picture increase while the size of the picture remains constant. Thus the spatial resolution or acuity required to distinguish the areas in the picture also increases. For any criticism algorithm the receptor would have some maximum resolution or acuity. That is, areas smaller than some specifiable fraction of the size of a picture cannot be distinguished. Pictures containing areas smaller than the resolution of the receptor in a criticism algorithm cannot be described in detail in the criticism algorithm. Similarly, for any design algorithm, the effector would have some maximum resolution. That is, areas smaller than some specifiable size cannot be produced and pictures larger than some specifiable size cannot be produced. Pictures with descriptions requiring resolution beyond the capability of the effector in a design algorithm cannot be produced by the design algorithm. Consequently, the receptor in a criticism algorithm and the effector in a design algorithm provide physical limits to the aesthetic value of pictures using this aesthetic system. The selection rule in any of the generative specifications given in this chapter can be increased only to a certain limit before the picture specified either cannot be described as specified by a given criticism algorithm or cannot be produced as specified by a given design algorithm.

9.7 Alternative Aesthetic Systems

Some alternative aesthetic systems for nonrepresentational, geometric pictures such as those shown in this chapter are now suggested. For each of these aesthetic systems, the description of a picture would be given by shape-color-occurrence tables. These aesthetic systems differ mainly in the way a picture is understood in terms of its shape-color-occurrence tables.

In an aesthetic system based on the evocative mode of understanding and dealing with form, a picture might be understood in terms of properties such as balance, proportion, and symmetry. The interpretation of a picture would have the description (shape-color-occurrence tables) of the picture as its input component and an enumeration of the formal properties of the picture as its output component. The interpretation algorithm of the aesthetic system would embody conventions for determining these properties from the shape-color-occurrence tables of a picture. A similar aesthetic system for polygons based on Birkhoff's aesthetic measure is given in the next chapter.

In an aesthetic system based on the constructive mode of understanding and dealing with color, a picture might be understood in terms of rules for generating the colors and how they go together in the picture. The interpretation of a picture would have rules for generating the colors in the picture encoded in its input component and the shape-color-occurrence tables of the picture as its output component. The interpretation algorithm of the aesthetic system would embody conventions for applying these rules. Work on color such as that of Albers[6] might provide the basis for formulating an aesthetic system of this type.

In an aesthetic system based on the evocative mode of understanding and dealing with color, a picture might be understood in terms of the feelings and emotions evoked by the colors of the picture. The interpretation of a picture would have the shape-

[6] J. Albers, *Interaction of Color* (New Haven, 1963).

color-occurrence tables of the picture as its input component and a specification of the feelings and emotions evoked by the colors and their arrangement in the picture as its output component. The interpretation algorithm of the aesthetic system would embody conventions for determining these feelings and emotions from the shape-color-occurrence tables of the picture. The interpretation algorithm might be based on, for example, Goethe's color triangle.[7]

In an aesthetic system based on the evocative mode of understanding and dealing with symbols, a picture might be understood in terms of the associations of shapes in the picture taken as symbols. The interpretation of a picture would have the shape-color-occurrence tables of the picture as its input component and an enumeration of the associations of the symbols found in the picture as its output component. The interpretation algorithm of the aesthetic system would embody conventions for identifying symbols in a picture and specifying their associations from the shape-color-occurrence tables of the picture. The interpretation algorithm might utilize a catalog of symbols.[8]

Of course, any of these aesthetic systems based on the constructive mode of understanding could be composed with any of these aesthetic systems based on the evocative mode of understanding because shape-color-occurrence tables are used as descriptions in all these aesthetic systems. For example, the aesthetic system using generative specifications could be composed with an aesthetic system based on the evocative mode of understanding and dealing with form. In this new aesthetic system, a picture would be understood in terms of the rules used to generate the shapes and their arrangement in the picture and the formal properties (balance, symmetry, proportion) exhibited by these shapes and their arrangement. A general method for combining any of these aesthetic systems is given in section 11.1.

[7]Goethe, *Theory of Colours* (London, 1810, 1967).

[8]For example, H. Dreyfuss, *Symbol Sourcebook* (New York, 1972).

10
Some Other Possible Aesthetic Systems

Many diverse interpretative conventions and evaluative criteria have been suggested for the arts. Our belief is that any interpretative conventions and evaluative criteria for the arts can, in principle, be represented as an aesthetic system.[1] The specification of the four algorithms of an aesthetic system for some given interpretative conventions and evaluative criteria requires that these conventions and criteria be formulated in every detail. Most interpretative conventions and evaluative criteria suggested for art are very loosely and vaguely formulated. Traditional expositions of these conventions and criteria merely hint at the general principles and specific details for the interpretation and evaluation of objects. Because of the imprecision with which most interpretative conventions and evaluative criteria are given, the amount of effort involved in representing them as aesthetic systems could be monumental. We believe this effort would be salutary. By attempting to specify imprecise conventions and criteria rigorously enough that they can be represented as algorithms, we are forced to make explicit any underlying assumptions implicit in these conventions and criteria. Further, inconsistencies in these conventions and cri-

[1]The theoretical limitations on algorithms identified by Turing and others (see M. Minsky, *Computation: Finite and Infinite Machines* (Englewood Cliffs, N.J., 1967) for an introductory discussion) in no way affect the possibility of representing people's interpretative conventions and evaluative criteria as algorithms in aesthetic systems. It has been proved that there are certain mathematical tasks that algorithms cannot perform. However, people cannot perform these tasks either. Thus these limitations are not relevant here.

teria would be exposed and we would be forced to resolve them. The process of representing interpretative conventions and evaluative criteria as algorithms in an aesthetic system, then, leads to a more complete and rigorous understanding of those conventions and criteria.

The most likely interpretative conventions and evaluative criteria for straightforward representation as aesthetic systems are those that have been worked out in considerable detail. In this chapter, we examine some of these interpretative conventions and evaluative criteria and discuss how they might be represented as aesthetic systems. As in the previous chapter, the reader is encouraged to notice the amount of detail that is required to represent even the simplest interpretative conventions and evaluative criteria as an aesthetic system.

10.1 Birkhoff's *Aesthetic Measure*

A well-known measure of aesthetic value was given by Birkhoff[2] by the formula $M = O/C$, where M is the aesthetic measure, O is the order of an object in a certain class of objects, and C is the complexity of the object in that class. Birkhoff applies this formula to several classes of objects – polygons, ornaments and tilings, vases, simple musical pieces, poetry – by giving explicit conventions for measuring the order and complexity of objects in each of these classes.

The conventions Birkhoff gives for measuring the order and complexity of objects of each class together with the relationship of order and complexity given by the formula $M = O/C$ provides the basis for constructing an aesthetic system for each class of objects. Basically, the conventions for measuring order and complexity are used to specify an interpretation algorithm; the formula $M = O/C$ is used to define an evaluation algorithm. Each class of objects has a different aesthetic system. We now give the details of Birkhoff's formulation of his aesthetic measure for polygons and of how this formulation can be represented as an aesthetic system.

In applying his formula to polygons, Birkhoff gives conventions for determining the order and complexity of any given polygon.

[2] G. D. Birkhoff, *Aesthetic Measure* (Cambridge, Mass., 1933).

The order O of a polygon is defined as $O = V + E + R + HV - F$, where V is a measure of vertical symmetry, E is a measure of equilibrium, R is a measure of rotational symmetry, HV is a measure of the relation of the polygon to a horizontal-vertical network, and F is a general negative factor which takes into account, for example, angles too near 0 degrees or 180 degrees or vertices too close together. The complexity C of a polygon is defined as the number of indefinitely extended straight lines required to contain all of the sides of the polygon.

More precisely, the conventions for determining the properties of a polygon are summarized by Birkhoff as follows:

> The formula is:
>
> $$M = \frac{O}{C} = \frac{V + E + R + HV - F}{C}$$
>
> with the following definitions.
>
> *C*
>
> C is the number of distinct straight lines containing at least one side of the polygon.
>
> *V*
>
> V is 1 or 0 according as the polygon is or is not symmetric about a vertical axis.
>
> *E*
>
> E is 1 whenever V is 1.
>
> E is also 1 if the center of area K is situated directly above a point D within a horizontal line segment AB supporting the polygon from below in such wise that the lengths AD and BD are both more than 1/6 of the total horizontal breadth of the polygon.
>
> E is 0 in any other case when K lies above a point of AB, even if A and B coincide.
>
> E is -1 in the remaining cases.
>
> *R*
>
> R is the smaller of the numbers $q/2$ and 3 [where $360°/q$ is the least angle of rotation which rotates the polygon into itself] in

the case of rotational symmetry, provided that the polygon has vertical symmetry or else that the minimum enclosing convex polygon has vertical symmetry and that the niches of the given polygon do not abut on the vertices of the enclosing polygon.

R is 1 in any other case when q is even (i.e., if there is a central symmetry).

R is 0 in the remaining cases.

HV

HV is 2 only when the sides of the polygon lie upon the lines of a uniform horizontal-vertical network, and occupy all the lines of a rectangular portion of the network.

HV is 1 if these conditions are satisfied, with one or both of the following exceptions: one line and the others of this type may fall along diagonals of the rectangular portion or of adjoining rectangles of the network; one vertical line and one horizontal line of the portion, and the others of the same type, may not be occupied by a side. At least two vertical and two horizontal lines must be filled by the sides however.

HV is also 1 when the sides of the polygon lie upon the lines of a uniform network of two sets of parallel lines equally inclined to the vertical, and occupy all the lines of a diamond-shaped portion of the network, with the following possible exceptions: at most one line and the others of the same type may fall along diagonals of the diamond-shaped portion or of the adjoining diamonds of the network; one line of the diamond-shaped portion and the others of its type may not be occupied by a side. At least two lines of either set of parallel lines in the network must, however, be occupied by the sides.

HV is 0 in all other cases.

F

F is 0 if the following conditions are satisfied: the minimum distance from any vertex to any other vertex or side or between parallel sides is at least 1/10 the maximum distance between points of the polygon; the angle between two non-parallel sides is not less than 20°; no shift of the vertices by less than 1/10 of the distance to the nearest vertex can introduce a new element or order V, R, or HV; there is no unsupported reentrant side; there is at most one type of niche and two types of directions, provided that vertical and horizontal directions are counted together as one; V and R are not both 0.

F is 1 if these conditions are fulfilled with one exception and one only.

F is 2 in all other cases.[3]

Birkhoff applies these conventions and his formula for aesthetic value to 90 polygons. Three of these polygons are shown in figure 10-1. A summary of the properties of these polygons and their aesthetic values, according to Birkhoff, is given in table 10-1. Of the polygons Birkhoff considers, the square has the highest aesthetic value.

Birkhoff's conventions and formula provide the basis for specifying an aesthetic system based on the evocative mode of understanding and dealing with certain formal properties of polygons.

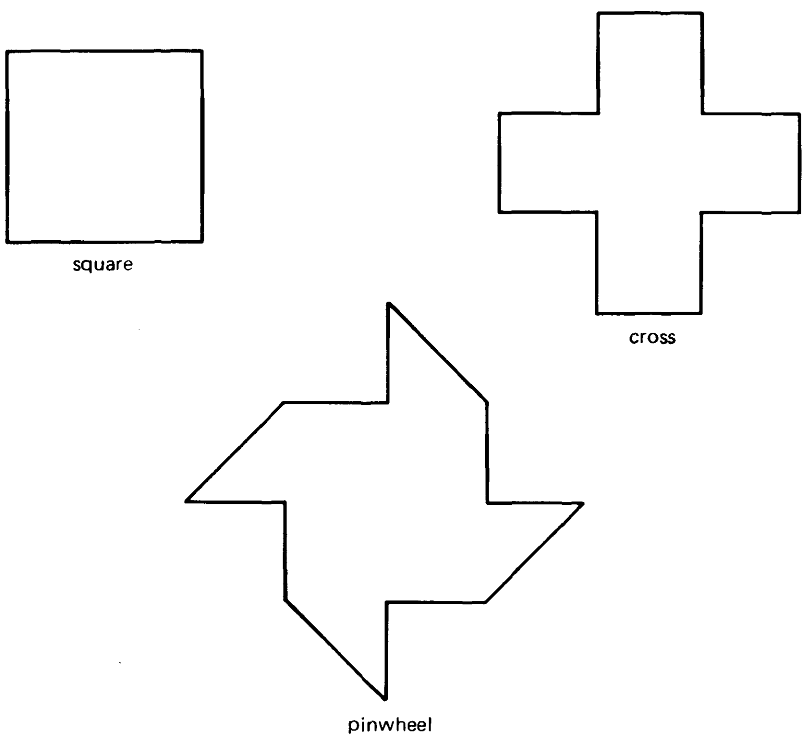


Fig. 10-1

Three polygons.

[3] Ibid., pp. 42-44.

TABLE 10-1
COMPUTATION OF AESTHETIC VALUE FOR THREE POLYGONS
USING BIRKHOFF'S AESTHETIC MEASURE.

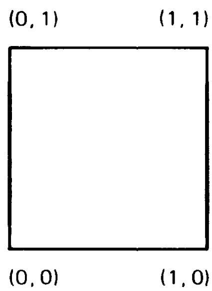
Polygon	*Factor*							
	C	V	E	R	HV	F	O	M
square	4	1	1	2	2	0	6	1.5
cross	8	1	1	2	2	0	6	0.75
pinwheel	10	0	0	1	1	0	2	0.2

The interpretation of a polygon would have as input component the description of the polygon and as output component a specification of the formal properties of the polygon. The interpretation algorithm of the aesthetic system would embody the conventions for determining the properties of the polygon from its description. The evaluation algorithm of the aesthetic system would be Birkhoff's formula.

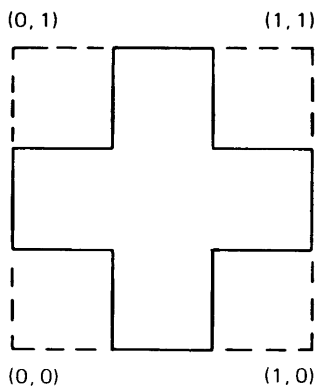
A specific method for describing polygons is not given by Birkhoff. The following method is consistent with the conventions Birkhoff gives for determining the properties of polygons: Circumscribe the least horizontal-vertical rectangle around the polygon. Let the lower left vertex of the rectangle be the point (0,0). Let the longest side of the rectangle be of length 1. The description of the polygon consists of a list of the coordinates of the vertices of the polygon encountered in a counterclockwise trace around the polygon beginning with the vertex of the polygon located on the lower horizontal side of the circumscribed rectangle and closest to the point (0,0). The description of each of the three polygons shown in figure 10-1 is given in figure 10-2.

The output component of an interpretation of a polygon would be a list of the properties of the polygon. Interpretations for the polygons shown in figure 10-1 are given in table 10-2. It is important to notice that the values given in the output components of these interpretations are not just numbers but are encodings of specific properties of the polygons. For example, when the value given for E is 1, the property of the polygon is that it has optical and mechanical equilibrium. When the value for E is 0, the property of the polygon is that it has just mechanical equilibrium.

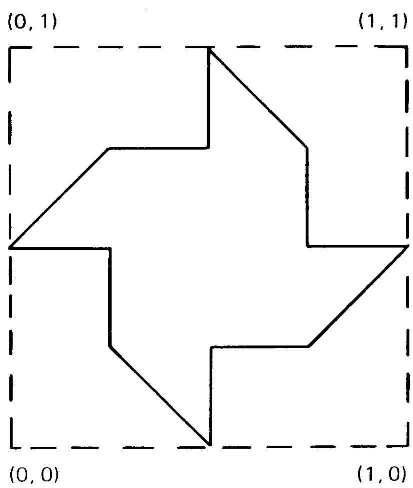
Polygon — **Description**



(0, 0) (1, 0) (1, 1) (0, 1)



(1/3, 0) (2/3, 0) (2/3, 1/3) (1, 1/3)
(1, 2/3) (2/3, 2/3) (2/3, 1) (1/3, 1)
(1/3, 2/3) (0, 2/3) (0, 1/3) (1/3, 1/3)



(1/2, 0) (1/2, 1/4) (3/4, 1/4) (1, 1/2)
(3/4, 1/2) (3/4, 3/4) (1/2, 1) (1/2, 3/4)
(1/4, 3/4) (0, 1/2) (1/4, 1/2) (1/4, 1/4)

Fig. 10-2

Descriptions of the polygons shown in fig. 10-1.

TABLE 10-2
INTERPRETATIONS FOR THREE POLYGONS.

Polygon	*Interpretation*
square	<(0,0) (1,0) (1,1) (0,1), C = 4 V = 1 E = 1 R = 2 HV = 2 F = 0>
cross	<(1/3, 0) (2/3, 0) (2/3, 1/3) (1, 1/3) (1, 2/3) (2/3, 2/3) (2/3,1) (1/3,1) (1/3,2/3) (0, 2/3) (0, 1/3) (1/3, 1/3), C = 8 V = 1 E = 1 R = 2 HV = 2 F = 0>
pinwheel	<(1/2, 0) (1/2, 1/4) (3/4, 1/4) (1, 1/2) (3/4, 1/2) (3/4, 3/4) (1/2, 1) (1/2, 3/4) (1/4, 3/4) (0, 1/2) (1/4, 1/2) (1/4, 1/4), C = 10 V = 0 E = 0 R = 1 HV = 1 F = 0>

When the value for E is -1, the property of the polygon is that it has neither optical nor mechanical equilibrium.[4] Similarly, values given for other variables in the output component of an interpretation encode specific properties of the polygon to which the interpretation refers.

Reference would be determined in this aesthetic system by comparing the description of a polygon with the input component of an interpretation. In particular, the reference algorithm of this aesthetic system would be the reference algorithm of figure 6-2.

The evaluation algorithm of the aesthetic system would embody Birkhoff's formula $M = O/C$ for polygons. That is, the evaluation algorithm would be $M = (V + E + R + HV - F)/C$. The evaluation algorithm has as input an interpretation. The evaluation algorithm uses only the output component of the interpretation to determine aesthetic value.

Given two aesthetic values, the comparison algorithm would determine that the interpretation assigned the higher value refers to the polygon that is aesthetically superior.

This aesthetic system for polygons has some interesting properties. The aesthetic value of a polygon is invariant under the Euclidean transformations of scale and/or of reflection about a vertical

[4] Ibid., pp. 35-36.

axis. That is, changing the size of a polygon or reflecting it about a vertical axis results in a polygon that has the same aesthetic value. In contrast, the aesthetic value of a polygon can change under the Euclidean transformations of rotation and/or of reflection about a horizontal axis. These changes result because the properties V, E, and HV of a polygon can change under rotation and the property E can change under reflection about a horizontal axis. For example, the square shown in figure 10-3*a* has aesthetic value 1.5 in this aesthetic system while the squares in figures 10-3*b* and 10-3*c* have aesthetic values 1.25 and 0 respectively.

An alternative aesthetic system based on Birkhoff s conventions for determining the properties of polygons is suggested by some work of Eysenck.[5] Eysenck proposes the formula $M = O \times C$ as a measure of the aesthetic value of polygons where O and C are the order and complexity of polygons as defined by Birkhoff. Eysenck arrived at this formula after experimentation on subjects' aesthetic preferences for polygons.

Birkhoff's application of his formula to other classes of objects provides the basis for specifying aesthetic systems for each of these classes of objects. Each of these aesthetic systems would have the same general form as the aesthetic system given for polygons.

10.2 Schenker's Theory of Tonality

Schenker's theory of tonality gives an interesting and detailed treatment of Western musical compositions between 1600 and 1900. Kassler's formalization[6] of Schenker's theory, especially as given in Schenker's *Der Freie Satz* (Vienna, 1935), provides the basis for the specification of the interpretation algorithm in an aesthetic system based on the constructive mode of understanding and dealing with tonality.

Kassler writes,

> The essence of Schenker's theory is a claim that every composition that is an instance of tonality – and no other composition –

[5]H. J. Eysenck, "An Experimental Study of Aesthetic Preference for Polygonal Figures," *Journal of General Psychology* (1968).

[6]M. Kassler, "Proving Musical Theorems I: The Middleground of Heinrich Schenker's Theory of Tonality," (August 1975). For a description of related work, see R. Frankel, S. Rosenschein, and S. Smoliar, "A Lisp-Based System for the Study of Schenkerian Analysis," *Computers and the Humanities* (1976).

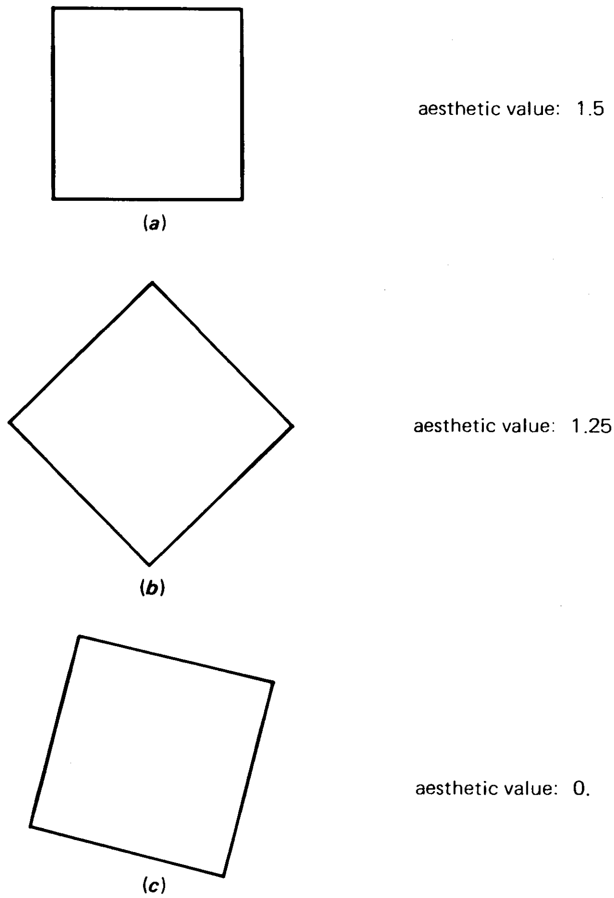


Fig. 10-3

Variations in aesthetic value for congruent polygons using Birkhoff's aesthetic measure.

can be derived from one of three *Ursatze* – primitive musical compositions which Schenker regarded as axioms – by successive application of a small number of rules of inference called "prolongation techniques." Three stages are distinguished in the derivation of a composition (or of a movement in a multi-movement composition): the background, which comprises essentially just one *Ursatz*; the middleground, wherein the large-scale structure of the composition – e.g., its principal sections and their tonal "centres" – is specified; and the foreground, wherein the harmonic, melodic, and rhythmic "details" are specified that must be added to the large-scale structure to yield the composition itself. The middleground, accordingly, comprises a sequence of compositions that starts with an *Ursatz* and proceeds so that each subsequent composition in the sequence is derivable from its predecessor by application of one or another of the prolongation techniques that Schenker designated for the middleground. And the foreground thus comprises a sequence of compositions that starts with a final composition of some middleground sequence – i.e., a composition representing a possible large-scale structure for some instance of tonality – and proceeds so that each subsequent composition in the sequence is derivable from its predecessor by one or another of the prolongation techniques that Schenker designated for the foreground. The class of final compositions in one or another foreground sequence will coincide – if Schenker's theory is valid – with the class of compositions instancing tonality.[7]

The interpretative components of an aesthetic system based on the constructive mode of understanding can be specified in terms of Schenker's theory of tonality as it is being formalized by Kassler. The interpretation algorithm of the aesthetic system would embody the prolongation techniques postulated by Schenker. The input to the interpretation algorithm would consist of a symbolic representation[8] of one of the three possible *Ursatze* (or "axioms"), shown in figure 10-4, and the sequence of prolongation techniques to be applied. Given an input, the interpretation algorithm would begin with the *Ursatz* specified in the input and successively apply the indicated sequence of prolongation techniques to obtain the score of a musical composition. The score would be generated in three stages as indicated by Kassler. The output of the interpretation algorithm would be the score of the musical composition derived. This score would be the description of the musical composition. An interpretation of a musical composition would have as input component an *Ursatz* and a sequence of prolongation techniques and as output the score of the composition. In this aesthetic system, an interpretation of a musical composition would tell how the composition is understood by giving

[7]Kassler, "Proving Musical Theorems I," pp. 4-5.

[8]A symbolic representation for the three *Ursatze* and for any other scores has been developed by Kassler. The specifics of the symbolic representation are not pertinent to this discussion. For details see Kassler's paper.

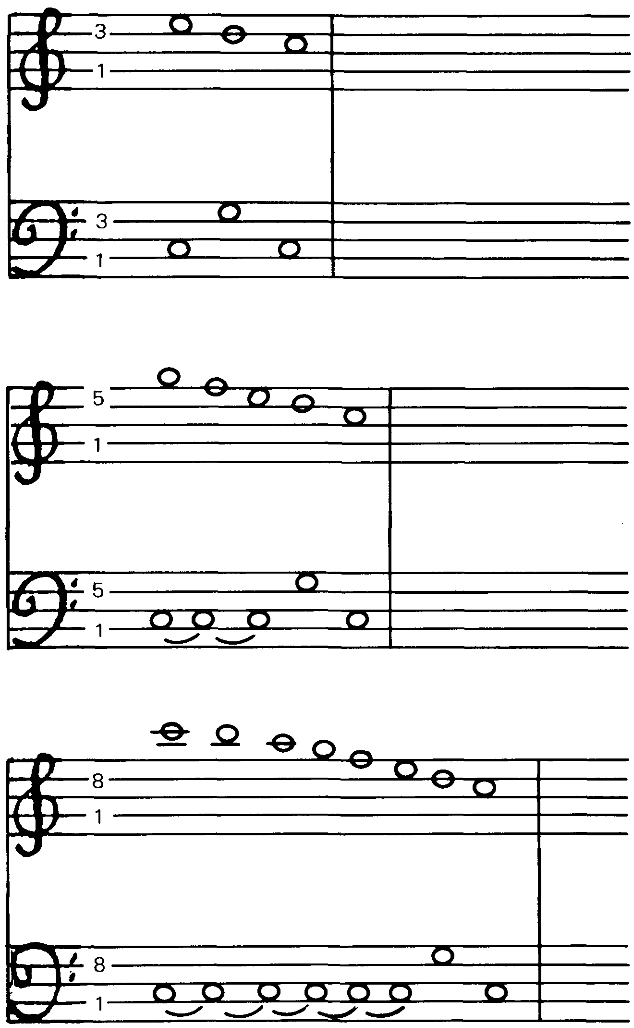


Fig. 10-4

The three possible *Ursatze*. (From M. Kassler, "Proving Musical Theorems I" [1975].)

the *Ursatz* and the prolongation techniques which when applied to the *Ursatz* generate the score of the composition.

The reference algorithm of this aesthetic system would, of course, be the reference algorithm of figure 6-1.

It is interesting to note that Kassler is working on the specification of the equivalent of a criticism algorithm for music in terms of Schenker's theory of tonality. Given the score of a musical composition, Kassler's algorithm would determine whether the musical composition is an instance of tonality and, if so, would output the *Ursatz* and sequence of prolongation techniques from which the score can be generated. This amounts to finding an interpretation of the musical composition in the sense discussed above.

10.3 Propp's *Morphology of the Folktale*

Propp's analysis[9] of the structure of Russian fairy tales could well provide the basis for an aesthetic system based on the evocative mode of understanding for fairy tales.

Propp's goal is to provide a morphology of the fairy tale, "i.e., a description of the tale according to its component parts and the relationship of these components to each other and to the whole."[10] Propp considers the fairy tale in terms of the actions or functions taken or performed by the characters in the tale. Characters in each tale are considered to have certain roles, for example, hero, villian, donor, seeker, independent of whether they are animals, human beings, or mythical beings. Propp asserts that

> (1) Functions of characters serve as stable, constant elements in a tale, independent of how and by whom they are fulfilled. They constitute the fundamental components of a tale.
>
> (2) The number of functions known to the fairy tale is limited.[11]

Propp enumerates and labels the different actions and functions known to the Russian fairy tale. For example, one action possible in a tale is "one of the members of a family absents himself from home." This action is called "absentation" and is labeled "β." Actions in this category are further divided into three types. If the family member leaving is a member of the "older generation" the action is labeled β^1. If parents leave home because they die this is

[9] V. Propp, *Morphology of the Folktale* (Austin, 1968). Translation of *Morfologija Skazki* (Leningrad, 1928).

[10] Ibid., p. 19.

[11] Ibid., p. 21.

"an intensified form of absentation" and is labeled β^2. If children leave home the action is labeled β^3.[12]

Propp has analyzed each fairy tale in Afanas'ev's collection of Russian folk tales[13] in terms of the sequence of actions or functions occurring in them. For example, an adumbrated form of tale 131 (an especially simple tale) with Propp's analysis indicated in parenthesis is

> 131. Tsar, three daughters (α). The daughters go walking (β^3), overstay in the garden (δ^1). A dragon kidnaps them (A^1). A call for aid (B^1). Quest of three heroes ($C\uparrow$). Three battles with the dragon (H^1 - I^1), rescue of the maidens (K^4). Return ($\downarrow$), reward (w^o).[14]

Thus, Propp's analysis of the tale is the sequence of symbols "$\alpha\beta^3\delta^1A^1B^1C\uparrow H^1 - I^1K^4\downarrow w^o$".

Propp's analysis of the structure of fairy tales suggests an interpretation algorithm based on the evocative mode of understanding for fairy tales. This interpretation algorithm would deal with fairy tales in terms of the actions or functions taken or performed by the characters in the tale. The input to this interpretation algorithm would be the full text of a fairy tale. The text is taken as the description of the fairy tale. The output of the interpretation algorithm would be the sequence of symbols giving the structure of the fairy tale in terms of Propp's conventions. The interpretation algorithm would contain a table of the functions identified by Propp as being possible in a fairy tale and methods for determining which of those functions occur in a tale given the text of the tale. Because "the number of functions known to the fairy tale is limited," such a table can always be encoded in an algorithm. The interpretation of a fairy tale would have the general form <text, sequence of symbols specifying the functions in the tale>. For example, the interpretation of tale 131 would be <[text of tale 131], $\alpha\beta^3\delta^1A^1B^1C\uparrow H^1 - I^1K^4\downarrow w^o$>. This interpretation would tell how the tale is understood in terms of the functions and actions of the characters in the tale. The output components of the interpretations in this aesthetic system for forty-six Russian fairy tales are given in Appendix III of Propp's book.

[12] Ibid., p. 26.
[13] A. N. Afanas'ev, *Russkie Narodnye Skazki* (1855-1864).
[14] Propp, *Morphology of the Folktale*, p. 128.

10.4 Cavallius's Analysis of Velazquez's *Las Hilanderas*

Cavallius's very detailed analysis[15] of the painting *Las Hilanderas* by Velazquez is suggestive for an interpretation algorithm for an aesthetic system for painting. Cavallius considers *Las Hilanderas* in terms of its "general properties," its "structure," and its "associations."

Cavallius begins by identifying the "general properties" of a picture and its elements.

> The general relationships are definable with respect to four groups of properties. Besides *colour* and *shape* we will be referring to the properties of *magnitude* and *position.*[16]

Essentially, an enumeration of the general properties of a picture and its elements corresponds to the shape-color-occurrence tables (see section 9.2) of the picture. Cavallius examines *Las Hilanderas* by identifying and naming the distinct colored areas, the "first units," of the painting and their general properties.

Cavallius considers the "structure" of a picture to be

> concerned with the relationships between the visual elements of the picture and with an exposition of the prevailing system or order.[17]

In examining the structure of *Las Hilanderas,* Cavillius determines the relationships of the distinct areas of the picture both as painted areas and as objects represented. For example, the heads of two of the figures in the picture are compared. The head of the first figure ("aP1") is characterized in part as dull, bareheaded, spheroid, voluminous, and a 3/4 view of a light brown face (pp. 42 and 44). The head of the second figure ("aP2") is characterized in part as shiny, covered, ovoid, somewhat flat, and a quasi-frontal full view of a reddish brown face (pp. 43 and 47). Characterizations and comparisons such as these are made for all of the distinct areas of the picture and many of their combinations.

Cavallius considers the associations of a picture as

> having to do with basic human experience independent of time and place, and . . . with such experience which in a more precise

[15] G. Cavallius, *Velazquez' Las Hilanderas – An Explication of a Picture Regarding Structure and Associations* (Uppsala, 1972).

[16] Ibid., p. 12.

[17] Ibid., p. 11.

> manner is historically and geographically confined or which presupposes specific learning.[18]

For Cavallius, the associations of a picture pertain mostly to the relationships of the picture to the outside world. These relationships are determined by the scene represented by the picture and the structure of the picture as well as by independent knowledge about the outside world. For example, some of the associations of the two figures ("aP1" and "aP2") mentioned above are given by Cavallius in this way:

> The repose, calm and strictness combined with the greater physical skill and mental order of aP2 may, if combined with her age and somewhat admonitory gesture and attitude toward aP1, suggest an elder-younger, teacher-pupil relationship. . . . The interaction between the two women is clearly expressed in the structure. The idea that aP2 is influencing or admonishing aP1 has its structural equivalent in Head-aP2's leftward inclination and Kerchief's protrusion into aP1 via Tulipshape.[19]

Further, the figure aP2 is seen by Cavallius as reminiscent of "Fortune playing the part of Destiny and Fate" (p. 167) and of Pallas in Ovid's tale of Pallas and Arachne (pp. 159-160), among other associations.

Cavallius's examination of *Las Hilanderas* suggests an interpretation algorithm for pictures based on the evocative mode of understanding. The input to this interpretation algorithm would be the description of a picture. This description would be a list of the "general properties" of the picture in terms of its "first-units." The description would correspond more or less to the shape-color-occurrence tables in the picture. The output of the interpretation algorithm would have two parts. The first would be a specification of the structure of the picture; the second, a specification of the associations of the picture. The interpretation algorithm would embody the conventions for determining the structure and associations of pictures from their descriptions. The structure of a picture would be determined directly from its description. The associations of a picture would be determined from both its description and its structure. The interpretation of a picture would have the general form <description, structure # associations>. One could

[18] Ibid., p. 11.
[19] Ibid., pp. 137-138.

imagine Cavallius's monograph *Velazquez' Las Hilanderas* as the output component of the interpretation that refers to *Las Hilanderas* in an aesthetic system using this interpretation algorithm. One could imagine similar monographs written by Cavallius about other pictures as the output components of interpretations of these pictures in this aesthetic system.

Certainly, the interpretation algorithm suggested here is the least well defined of all of the interpretation algorithms suggested in this chapter. However, of the interpretative approaches we have seen for representational pictures, Cavallius's seems the most detailed and methodical and, hence, the most suggestive for an interpretation algorithm.

10.5 Computer Art and Music

In the past twenty years there have been numerous attempts to use a computer to generate visual art and music. Systems for generating visual art or music using the computer generally have the logical structure shown in figure 10-5. These systems have two components: (1) an algorithm which when given an input of a certain type generates the description of the visual art or music to be produced, and (2) an output device or effector which when given the description produces the visual or musical work of art having that description. The first component in such a system is an algorithm that has the structure of the interpretation algorithm of an aesthetic system based on the constructive mode of understanding. Hence, the first component from one of these systems can be used as the interpretation algorithm in an aesthetic system based on the constructive mode of understanding for visual art or music. Similarly, the second component of one of these systems can be used as the effector in a design algorithm for visual art or music.

We now discuss a system that has been developed for generating visual art using a computer and a system that has been developed for generating music using a computer. The structure of interpretations in aesthetic systems based on these systems is characterized.

10.5.1 Knowlton's MINI-EXPLOR

Knowlton's MINI-EXPLOR[20] is a system for generating visual patterns using a mini-computer. MINI-EXPLOR consists of a col-

[20] K. Knowlton, "MINI-EXPLOR, A FORTRAN-Coded Version of the EXPLOR Language for Minicomputers," *Computer Graphics*, vol. 9, no. 3 (1975).

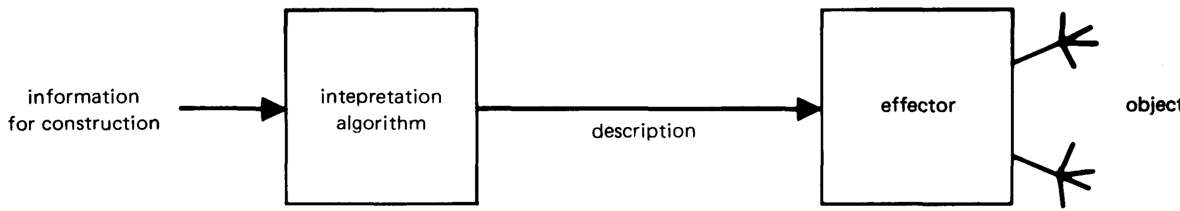


Fig. 10-5

Structure of programs in computer art and music.

lection of nine FORTRAN functions and subroutines which can be used in FORTRAN programs to generate two-dimensional visual patterns. Thus, MINI-EXPLOR can be considered a specialized programming language, based on FORTRAN, for specifying two-dimensional patterns.

The net result of using MINI-EXPLOR on a computer is a system that has the logical structure of figure 10-5. The input to the system is a MINI-EXPLOR program. The program is followed to generate the pixel description of a two-dimensional pattern (see section 3.2.4). The description of the pattern specifies the shade of gray of each pixel of the pattern. The description is a 140 by 140 array of values, where each value is a number between 0 and 3. Each value indicates whether the corresponding pixel is white (0), light gray (1), dark gray (2), or black (3). The description is used as input to a printer that produces the pattern. A pattern and the MINI-EXPLOR program that generates it are shown in figure 10-6.

An aesthetic system defined using MINI-EXPLOR would be based on the constructive mode of understanding. The interpretation of a pattern would have the form <MINI-EXPLOR program, pixel description>. In this aesthetic system patterns would be understood in terms of how they can be generated by MINI-EXPLOR programs.

10.5.2 Mathews's Music V

Mathews's Music V[21] is a system for generating music using a computer. Music V is a computer program that allows artificial musical instruments to be specified, musical compositions to be specified, and these compositions to be performed on the specified instruments. Instruments are specified in terms of various acoustic characteristics, in particular in terms of the wave forms they produce. Musical compositions are specified by programs. In these programs, notes may be specified explicitly by listing their frequency, amplitude, time of occurrence, duration, and instrument on which they are played. More interestingly, notes may be specified by FORTRAN routines that generate sequences of notes and their parameters. Music V allows a collection of artificial instru-

[21] M. Mathews, *The Technology of Computer Music* (Cambridge, Mass., 1969).

```
DO 8 K = 1, 18
IY = 8 + 3 * K
IX = NE (15, 105)
IF (NUM (IX, IY) .NE. 0) GO TO 3
IW = 18 - K
IH = K - 1
DO 8 J = 1,9
CALL CHANJ (IX, IY, IW + 2 * J, IH + 2 * (10-J), 100, 3012)
CALL SHOW (60, 40, 120, 80)
```

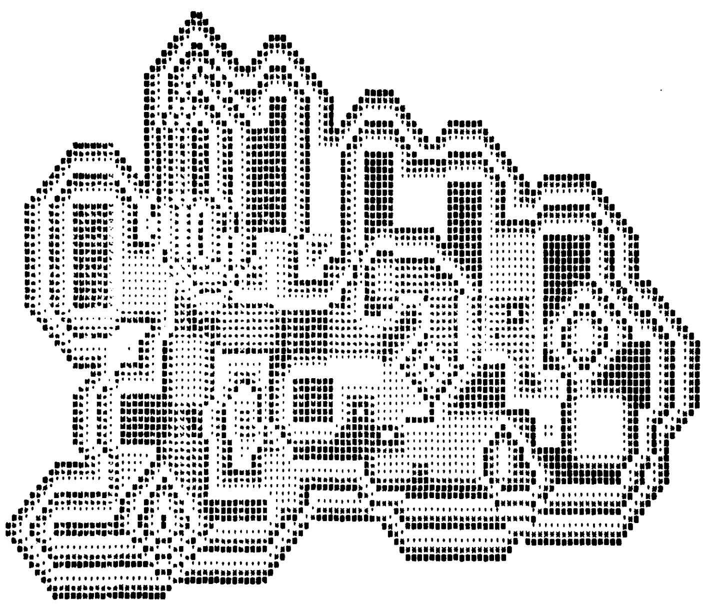


Fig. 10-6

A MINI-EXPLOR program and the resulting picture.
(From K. Knowlton, "MINI-EXPLOR" [1975].)

ments, that is, an orchestra, and the corresponding score for each of these instruments to be determined for the orchestra to perform a certain musical composition.

The net result of Music V is a system that has the logical structure of figure 10-5. The input to this system is a specification of an orchestra and the music the orchestra is to perform. Given the input, the Music V program generates the score of the piece and then generates the amplitude over time description (see section 3.2.3) of the performance of the piece by the orchestra. The amplitude over time description is a sequence of numbers that indicates the amplitude of the acoustic signal produced by the orchestra at each of small discrete units of time, for example, at every fifty microseconds. This amplitude over time description can then be used as input to an effector containing a digital-to-analog converter connected to a speaker.

An aesthetic system defined using Music V would be based on the constructive mode of understanding. The interpretation algorithm of the aesthetic system would have as input a specification of both an orchestra and a score and as output the amplitude over time description of the orchestra's performance of the musical piece. The interpretation of the performance of the musical piece would have the form <specification of orchestra and score, amplitude over time description>. In this aesthetic system, the performance of a musical piece would be understood in terms of how the instruments in the orchestra can be specified and how the score the orchestra performs can be generated using Music V.

10.6 Discussion

It is our belief that future work in algorithmic aesthetics should be focused on formalizing interpretative conventions and evaluative criteria for various art forms as algorithms. Indeed, the purpose of this chapter was to suggest that there is an abundance of work in aesthetics and criticism which is ripe for such formalization.[22]

[22] Recently, the generative mechanisms for interpretation algorithms in aesthetic systems based on the constructive mode of understanding have been developed for Palladian villa plans (G. Stiny and W. J. Mitchell, "The Palladian Grammar," *Environment and Planning B* [1978]) and for traditional Chinese lattice designs including the seemingly irregular patterns called "ice-rays" (G. Stiny, "Ice-Ray: a Note on the Generation of Chinese Lattice Designs," *Environment and Planning B* [1977]).

11
Combining Aesthetic Systems

Many of the aesthetic systems discussed so far have allowed for objects to be interpreted and evaluated only in one particular way. Aesthetic systems, each of which allows for objects to be treated in a variety of ways, can be constructed by combining aesthetic systems. One technique for combining aesthetic systems by the composition of their interpretation algorithms was given in section 6.3. In this chapter, two additional techniques are characterized. Each of these techniques is of aesthetic interest and is important in different contexts. Various other interesting techniques for combining aesthetic systems are also possible.

11.1 Combining Aesthetic Systems by Concatenating Interpretations

It is often the case that an object is understood and, hence, evaluated in more than one way, for example, in terms of representation and form or transparency and form. Aesthetic systems that deal with objects in different ways can be combined to form a new aesthetic system. For example, an aesthetic system for transparency can be combined with an aesthetic system for form to produce an aesthetic system for transparency and form. More precisely, consider a picture having a pixel description. Suppose that this picture has an interpretation in an aesthetic system for transparency and an interpretation in an aesthetic system for form. Let the interpretation of the picture in the first aesthetic system be of the type <specification of scene represented, specification of evocations of scene>. The aesthetic system for transparency is assumed to be of the second type discussed in section 7.3.1. Let the interpretation of the picture in the second aesthetic system be of the type <pixel description, specification of formal properties>. The aesthetic system for form is assumed to be based on the evocative mode of understanding as discussed in section 7.4.1. For this picture to be understood in terms of both transparency and form, it would be desirable to have an aesthetic system with an interpretation of the picture with the structure <specification of the scene represented # pixel description, specification of the evocations of the scene # specification of formal properties>. This new interpretation has as input component the concatenation of the input components of the two given interpretations separated by a sharp sign (#). The new interpretation has as output component the concatenation of the output components of the two given interpretations separated by a "#." Intuitively, this new interpretation would give the two ways of understanding the picture. Given the first two aesthetic systems, the construction of an aesthetic system having an interpretation of this kind is straightforward.

In what follows, a general method for combining any two aesthetic systems by concatenating components of interpretations is given. In special cases, for example, when the description of an object appears as a component in interpretations of the object in both aesthetic systems, more specialized techniques may be more appropriate.

Consider any two aesthetic systems. Let the first aesthetic system consist of interpretation algorithm A_1, reference algorithm R_1, evaluation algorithm E_1, and comparison algorithm C_1. Let the second aesthetic system consist of interpretation algorithm A_2, reference algorithm R_2, evaluation algorithm E_2, and comparison algorithm C_2. Assume that $<\alpha_1, \beta_1>$ is an interpretation in the first aesthetic system, that is, $A_1(\alpha_1) = \beta_1$, and that $<\alpha_2, \beta_2>$ is an interpretation in the second aesthetic system, that is, $A_2(\alpha_2) = \beta_2$. A new aesthetic system can be constructed from the two given aesthetic systems such that $<\alpha_1 \# \alpha_2, \beta_1 \# \beta_2>$ is an interpretation in the new aesthetic system.

The interpretation algorithm of the new aesthetic system is given by

$$A_3(\alpha_1 \# \alpha_2) = A_1(\alpha_1) \# A_2(\alpha_2) = \beta_1 \# \beta_2$$

The interpretation $<\alpha_1 \# \alpha_2, \beta_1 \# \beta_2>$ is an interpretation in the new aesthetic system if and only if $<\alpha_1, \beta_1>$ is an interpretation in the first aesthetic system and $<\alpha_2, \beta_2>$ is an interpretation in the second aesthetic system.

The reference algorithm is given by

$$R_3(\lambda, <\alpha_1 \# \alpha_2, \beta_1 \# \beta_2>) = \begin{cases} \text{yes}/\ R_1(\lambda, <\alpha_1, \beta_1>) = \text{yes } \textit{and} \\ \qquad R_2(\lambda, <\alpha_2, \beta_2>) = \text{yes} \\ \text{no/otherwise} \end{cases}$$

where λ is the description of an object. The interpretation $<\alpha_1 \#\alpha_2, \beta_1 \#\beta_2>$ refers to an object having the description λ if and only if the interpretation $<\alpha_1, \beta_1>$ refers to the object in the first aesthetic system *and* the interpretation $<\alpha_2, \beta_2>$ refers to the object in the second aesthetic system.

The evaluation algorithm is given by

$$E_3(<\alpha_1 \#\alpha_2, \beta_1 \#\beta_2>) = (E_1(<\alpha_1, \beta_1>), E_2(<\alpha_2, \beta_2>))$$

The aesthetic value assigned to the interpretation $<\alpha_1 \# \alpha_2, \beta_1 \# \beta_2>$ is an ordered pair of aesthetic values (V_1, V_2), where V_1 is the aesthetic value assigned to the interpretation $<\alpha_1, \beta_1>$ in the first aesthetic system and V_2 is the aesthetic value assigned to the interpretation $<\alpha_2, \beta_2>$ in the second aesthetic system.

The comparison algorithm is given by

$$C_3((V_1, V_2), (V_1', V_2')) = \begin{cases} 1 \ / \ V_1 >_{C_1} V_1' \textit{ and } V_2 >_{C_2} V_2' \\ 0 \ / \ V_1 \leqslant_{C_1} V_1' \textit{ and } V_2 \leqslant_{C_2} V_2' \\ \text{no comparison/otherwise} \end{cases}$$

where (V_1, V_2) is the aesthetic value assigned to one interpretation and (V_1', V_2') is the aesthetic value assigned to another interpretation in the new aesthetic system. The aesthetic value (V_1, V_2) is greater than the aesthetic value (V_1', V_2') if and only if the aesthetic value V_1 is greater than the aesthetic value V_1' in the first aesthetic system *and* the aesthetic value V_2 is greater than the aesthetic value V_2' in the second aesthetic system. Similarly, for less than or equal to. Notice that the comparison algorithm defined here embodies a partial order given that C_1 and C_2 embody orders, either partial or total. Of course, other comparison algorithms could have been defined instead, for example, a comparison of weighted averages.

In general, an arbitrary number of aesthetic systems can be combined using this type of method. An interpretation in an aesthetic system so constructed would have the basic structure $<\alpha_1 \# \alpha_2 \# \ldots \alpha_n, \beta_1 \# \beta_2 \# \ldots \beta_n>$.

11.2 Combining Aesthetic Systems by Universalization

It is sometimes the case that a review of a work of art contains not only a statement of how the work of art is understood but also a statement of the interpretative conventions used in the understanding of the work of art. Here, some theoretical ground rules for understanding works of art as well as a specific instance of the application of those ground rules are given. Interpretations where both statements about how a work of art is understood and a statement about the interpretative conventions underlying that understanding occur when aesthetic systems are combined by universalization.

Consider a class of aesthetic systems that are identical except for their interpretation algorithms. A new aesthetic system can be constructed which combines all aesthetic systems in this class by letting the interpretation algorithm be a universal computing algorithm. For an aesthetic system in the class of aesthetic systems which has an interpretation algorithm A and which contains an interpretation $<\alpha, \beta>$ of an object, the interpretation $<\alpha \# A, \beta>$ would be an interpretation of the object in the new aesthetic system. The interpretation algorithm of this new aesthetic system would apply the algorithm A to the sequence of symbols α to produce the sequence of symbols β. In general, for each interpretation in an aesthetic system in the class, there is a corresponding interpretation in the new aesthetic system. This new interpretation would be identical to the original interpretation except that a specification of the original interpretation algorithm would be included in its input component. Intuitively, this new interpretation would tell how an object is understood by giving a specific statement of how the object is understood and a statement of the interpretative conventions underlying that understanding. The reference algorithm in the new aesthetic system would be identical to the reference algorithm used in all aesthetic systems in the class except that it would ignore the specification of an interpretation algorithm in the input component of an interpretation. Similarly, the evaluation algorithm in the new aesthetic system could be identical to the evaluation algorithm used in all aesthetic systems in the class except that it would ignore the specification of an interpretation algorithm in the input component of an interpretation. The comparison algorithm could be identical to the comparison algorithm used in all aesthetic systems in the class.

Less general methods similar to universalization may also be useful for combining aesthetic systems. The idea here is to generalize over certain aspects or parts of interpretation algorithms instead of over entire interpretation algorithms. This generalization is accomplished by specifying those aspects or parts in the input components of interpretations.

For example, in section 7.2.1 the possibility of defining an aesthetic system based on the constructive mode of understanding for representation that models a specific camera with specific lens and specific settings was discussed. Here, an aesthetic system would correspond to a single camera with a given lens and given settings. In this aesthetic system, an interpretation would have the structure <specification of three-dimensional scene, description of two-dimensional picture>. The interpretation algorithm defining this aesthetic system would encode the properties of a specific camera, lens, and settings. Generalizing over cameras, lenses, and settings would result in a single aesthetic system that allows for the modeling of more than one camera with a variety of lenses and settings. In this new aesthetic system, an interpretation would have the structure <specification of scene # specification of camera-lens-settings, description of picture>. In this new interpretation, the specification of camera, lens, and settings has been added to the input component of an interpretation in the aesthetic system corresponding to that camera with lens and settings. The interpretation algorithm of the new aesthetic system would use the properties of the specified camera, lens, and settings to produce the description of a picture from the specification of the scene.

This technique of generalization can be applied to classes of aesthetic systems that differ only in certain specifiable aspects or parts of their interpretation algorithms. A variety of classes of aesthetic systems of this type have been discussed in previous chapters. For example, aesthetic systems of the type used in the example in sections 6.1 and 8.4 can be combined in this way.)

PART IV: ANALYSIS AND SYNTHESIS ALGORITHMS

12
Analysis and Synthesis Algorithms

The task of a criticism algorithm is to produce a response to an object as a work of art. Typically, this response is a statement of how the object is described, interpreted, and evaluated. The task of a design algorithm is to produce an object as a work of art in response to some given initial conditions.

12.1 The Task of Analysis Algorithms

The task of an analysis algorithm in a criticism algorithm is to determine how an object with a given description is interpreted and evaluated in terms of the interpretative conventions and evaluative criteria encoded in the aesthetic system of the criticism algorithm.

The input to the analysis algorithm is the description of an object; the output of the analysis algorithm is the description, interpretation, and evaluation of the object having that description.[1] This interpretation and evaluation tells how the object is understood and evaluated in terms of the interpretative conventions and evaluative criteria of the aesthetic system.

It is natural to desire that the analysis algorithm produce the best way of understanding the object. That is, the goal for the analysis algorithm is that it output the interpretation of the object that is assigned highest aesthetic value.

[1] It may be the case that the analysis algorithm can find no interpretation of the object. Here, the algorithm would merely output the description of the object and a statement that no interpretation and, hence, no evaluation can be given.

The task of the analysis algorithm is defined precisely in terms of its input and the components of the aesthetic system: Given the description of an object, find an interpretation defined by the interpretation algorithm which refers to the object using the reference algorithm and which is assigned an aesthetic value by the evaluation algorithm which is greater than or equal to, in the sense of the comparison algorithm, the aesthetic value assigned to any other interpretation of the object.

For example, consider a criticism algorithm that contains the aesthetic system described in chapter 9. When presented with a picture, the receptor of the criticism algorithm would produce the shape-color-occurrence tables for the picture as its description. The analysis algorithm of the criticism algorithm would receive these shape-color-occurrence tables as input. The task of the analysis algorithm would be to find the best interpretation of the picture described by the shape-color-occurrence tables. This interpretation would be that interpretation of the picture assigned highest aesthetic value in the aesthetic system. Because in this aesthetic system the output component of an interpretation of the picture is the description of the picture and the evaluation algorithm E_Z is used, the task of the analysis algorithm amounts to identifying the shortest generative specification for the picture. This generative specification, together with the shape-color-occurrence tables, gives the best way of understanding the picture in terms of the interpretative conventions and evaluative criteria of the aesthetic system.

12.2 The Task of Synthesis Algorithms

The task of a synthesis algorithm in a design algorithm is to determine the description of an object that fulfills some given initial conditions. The description produced by the synthesis algorithm is used by the effector to construct the object. The object as described in the design algorithm can be interpreted and evaluated in terms of the interpretative conventions and evaluative criteria of the aesthetic system of the design algorithm.

The input to the synthesis algorithm is a specification of initial conditions. The output of the synthesis algorithm is the description of an object which would satisfy the specified initial conditions and which has an interpretation and evaluation in the aesthetic system.[2]

It is natural to desire that the synthesis algorithm produce the description of the best possible object which satisfies the initial conditions. That is, the goal for the synthesis algorithm is that it output the description of an object which satisfies the initial conditions and which has an interpretation assigned highest possible aesthetic value.

The task of the synthesis algorithm is defined precisely in terms of its input and the components of the aesthetic system: Given a specification of initial conditions, find the description of an object (1) which would satisfy the initial conditions and (2) for which there is an interpretation defined by the interpretation algorithm that refers to the object using the reference algorithm and which is assigned an aesthetic value by the evaluation algorithm which is greater than or equal to, in the sense of the comparison algorithm, the aesthetic value assigned to any interpretation of any other object that would satisfy the initial conditions.

For example, consider a design algorithm that contains the aesthetic system described in chapter 9. The receptor of the design algorithm would output a specification of initial conditions.[3] The initial conditions might be that the picture cannot be larger than a certain size, that no edge of an area in a picture can be shorter than an eighth of an inch, that only certain colors can be used in the picture, and that the picture be generated using rectangles. The synthesis algorithm of the design algorithm would receive a specification of these initial conditions as input. The task of the synthesis algorithm would be to find the description, that is, shape-color-occurrence tables, of the picture that satisfies the initial conditions and has an interpretation assigned highest aesthetic value. The task is to find the description of a picture which satisfies the initial conditions and which has a generative specification that is as short as possible relative to the description. The picture thus described is the best picture, in terms of the interpretative conventions and

[2]It may be the case that the synthesis algorithm can find no description of an object that satisfies the initial conditions. Here, the synthesis algorithm would output a statement to this effect.

[3]For example, the receptor could be the keyboard of a computer terminal. In this case the initial conditions would simply be typed in.

evaluative criteria of the aesthetic system, which satisfies the initial conditions.

Of course, in the formulation of the task of a synthesis algorithm, "objects" are objects that might be constructed rather than objects that already exist. Objects that might be constructed are dealt with easily by a synthesis algorithm because they are dealt with in terms of their descriptions and interpretations. Synthesis algorithms manipulate sequences of symbols, that is, descriptions and interpretations, and not physical objects. A synthesis algorithm decides whether an object would satisfy given initial conditions in terms of the description and interpretation of the object.

Recall that the initial conditions can pertain to the physical characteristics of an object or to the way an object is understood or both. Initial conditions that constrain the physical characteristics of an object generally pertain to the description of the object. For example, restrictions on the size of a picture, the fineness of detail that can be rendered, or the range of colors available pertain to the description of a picture. Restrictions on the length of a musical composition, the range of performable notes, or the instruments available pertain to the description of a musical piece. Initial conditions that constrain how an object is understood generally pertain to the interpretation of an object. For example, the emotions that engender an object to be produced or which are to be evoked by an object or the theme or subject matter to be portrayed in an object pertain to the interpretation of the object. An object satisfies the initial conditions when its description and interpretation satisfy the initial conditions.

12.3 Analysis and Synthesis as Search Problems

The task of an analysis algorithm and the task of a synthesis algorithm can be viewed as search problems. A search problem can be formulated in terms of (1) a universe of possible solutions and (2) criteria for determining the best solution in the universe.[4]

For analysis, the universe of possible solutions consists of all possible interpretations defined by the interpretation algorithm of the aesthetic system. The selection criteria are that the interpreta-

[4]For an extended discussion of search problems see N. Nilsson, *Problem Solving Methods in Artificial Intelligence* (New York, 1971).

tion identified as the solution (1) refers to the object having the description input to the analysis algorithm and (2) has greatest aesthetic value. The universe of possible solutions consists of all possible interpretations. Of these, only those interpretations that refer to the object to be interpreted and evaluated are of interest. Of these, that interpretation with the highest aesthetic value is the one to be selected. In this sense, the task of the analysis algorithm can be viewed as a search through the possible ways of understanding objects for the best way of understanding the given object or as a search through the possible ways of understanding the given object for the best way of understanding the object.

For synthesis, the universe of possible solutions consists of all possible descriptions.[5] The selection criteria are that the description identified as the solution (1) satisfies the initial conditions that pertain to descriptions, (2) is connected with an interpretation that satisfies the initial conditions that pertain to interpretations, and (3) that the interpretation is assigned greatest aesthetic value. The universe of possible solutions consists of all possible descriptions. Of these, only those descriptions that satisfy the initial conditions pertaining to descriptions are of interest. Of these, only those descriptions connected with interpretations that satisfy the initial conditions pertaining to interpretations are of interest. Of these descriptions and connected interpretations, that description connected with the interpretation assigned greatest aesthetic value is the one to be selected. In this sense, the task of the synthesis algorithm can be viewed as a search through possible descriptions for the description of the best object which would satisfy the initial conditions or as a search through possible descriptions of objects which would satisfy the initial conditions for the description of the best object.[6]

The characterization of design as a search task is not especially novel. Several important artists have viewed design in this way. Stravinsky writes

> All art presupposes a work of selection. . . . To proceed by elimination – to know how to discard, as the gambler says, that is the

[5]Possible descriptions are just those finite sequences of symbols defined over the alphabet of symbols used for descriptions.

[6]Other possible ways of considering synthesis might be drawn from the growing literature on engineering and architectural design. See, e.g., W. Spillers, ed., *Basic Questions of Design Theory* (Amsterdam, 1974).

> great technique of selection. And here again we find the search for the *One* out of the *Many*.[7]

Valéry states

> It takes two to invent anything. The one makes up combinations; the other one chooses, recognizes what he wishes and what is important to him in the mass of the things to which the former has imparted to him.[8]

In both of these cases, the act of creating a work of art is viewed as involving the selection of one candidate out of many possible candidates.

12.4 Discussion

The internal workings of an analysis algorithm in a criticism algorithm or of a synthesis algorithm in a design algorithm generally will depend on the internal workings of the algorithms in the aesthetic system with which it is linked. It is not feasible to formulate precisely an analysis algorithm or synthesis algorithm that works reasonably well in conjunction with every aesthetic system. The computational methods and tricks that are appropriate for an analysis algorithm or a synthesis algorithm, if it is to perform its task efficiently, depend on the nature of the algorithms in the aesthetic system with which it is connected. All that can be said about analysis algorithms and synthesis algorithms in general concerns the tasks they are to perform.

It is often suggested (especially by artists) that criticism is easier than design. A casual comparison of criticism algorithms and design algorithms could suggest that this observation is true. At first glance, the task of the analysis algorithm in a criticism algorithm seems easier than the task of a synthesis algorithm in a design algorithm. The analysis algorithm has the description of an object to guide it. For example, in terms of the search paradigm, the analysis algorithm need only search through interpretations of the given object while the synthesis algorithm may need to search through the interpretations of many objects. On closer examination, however, no characterization of the relative ease of criticism

[7] I. Stravinsky, *Poetics of Music* (New York, 1947), p. 70.

[8] P. Valéry, *Nouvelle Revue Francaise*, quoted in J. Hadamard, *The Psychology of Invention in the Mathematical Field* (Princeton, N.J., 1945), p. 30.

and design is warranted for criticism algorithms and design algorithms. The difficulty of the task of an analysis algorithm or a synthesis algorithm depends in large part on the nature of the aesthetic system with which it is connected. For example, it seems that an analysis algorithm need only search through the interpretations of a given object, but, in some cases, it may be necessary for the analysis algorithm to search through many interpretations just to find the interpretations of the object. In many instances, the task of an analysis algorithm may be more difficult than the task of a synthesis algorithm.[9]

[9] It should be noted that in some cases the task of an analysis algorithm or a synthesis algorithm is trivial. For example, the task of an analysis algorithm or a synthesis algorithm connected with any of the aesthetic systems given as examples in chapters 6 and 8 would be straightforward.

13
What is a Work of Art?

An important issue in aesthetics is the definition of "work of art." Various definitions of this term have been suggested.

For example, for Tolstoy a work of art is an object that is produced by an artist as an embodiment of his emotions or feelings and evokes those emotions or feelings in an observer of the object.

> . . . it is art if a man, having experienced either the fear of suffering or the attraction of enjoyment (whether in reality or imagination), expresses these feelings on canvas or in marble so that others are infected by them. And it is also art if a man feels or imagines to himself feelings of delight, gladness, sorrow, despair, courage, or despondency and the transition from one to another of these feelings, and expresses these feelings by sounds so that the hearers are infected by them and experience them as they were experienced by the composer.[1]

As another example, for Bell a work of art is an object that has "significant form."

> For either all works of visual art have some common quality, or when we speak of "works of art" we gibber. Everyone speaks of "art", making a mental classification by which he distinguishes the class "works of art" from all other classes. What is the justification of this classification? What is the quality common and peculiar to all members of this class? . . . Only one answer seems possible – significant form. In each, lines and colours combine in

[1] L. Tolstoy, *What is Art?* (Indianapolis, 1896, 1960), pp. 50-51. See also section 7.1.3.

> a particular way, certain forms and relations of forms, stir our aesthetic emotions. These relations and combinations of lines and colours, these aesthetically moving forms, I call "Significant Form"; and "Significant Form" is the one quality common to all works of visual art.[2]

It is clear that Tolstoy's view and Bell's view of art conflict. An object may transmit emotions such as suffering or joy yet lack significant form. An object may have significant form yet not transmit such emotions. Bell himself raises this possibility. For example, a picture of an execution that infects observers with the emotions and feelings of the artist about the execution would be considered a work of art by Tolstoy. The same picture would not be considered a work of art by Bell if it lacked the requisite formal elements and relations.[3]

Of course, Tolstoy's criterion and Bell's criterion are not the only criteria that are possible or that have been suggested for defining "work of art." How is this multiplicity of criteria to be reconciled?

First, one of these criteria could be taken as correct. For example, one could accept Bell's criterion as being veridical. The trouble with this solution is that it only satisfies those people who agree with Bell. Reasonable men do disagree on what objects are works of art and what the criteria are for so deciding.

Second, some combination of these criteria could be given as the definition of work of art. For example, an object could be considered a work of art if it satisfies Tolstoy's criterion, or if it satisfies Bell's criterion, or if it satisfies both criteria. An approach similar to this has been suggested by Stevenson. Stevenson proposes a definition of "poem" that is based on a weighted average of criteria. Stevenson first identifies six properties – rhythms, rhymes, word sounds, manner of printing, subject matter, and figures of speech – that may be exhibited in a poem. Each of these properties is associated with a column in a diagram. The columns are of varying width. The width of the column corresponds to the importance of the property in defining "poem."

> Given any sequence of words that is a candidate, as it were, for being called a poem, we must estimate the degree to which it has

[2] C. Bell, *Art* (London, 1913; New York, 1958), pp. 17-18. See also section 7.4.4.
[3] See Bell, *Art*, p. 29.

> each of the constituent properties in question and must shade in each column to the corresponding height. If the total shaded area exceeds a certain percentage (say 30 percent) of the area of the whole diagram, then the given sequence of words that it represents is a poem; otherwise it is not.[4]

Stevenson points out that this definition of poem is related to Wittgenstein's notion of "family resemblance."[5] No single property is found in all poems, but rather poems are defined using a combination of properties. Stevenson further suggests that the same technique can be used to answer the question "What is a work of art?"

An interesting definition of work of art that seems to be based on a combination of criteria is given by Dickie.[6] Under Dickie's "institutional" definition, an object is a work of art if and only if some member of the art world has conferred the status "work of art" on the object. Here, the art world consists more or less of artists, critics, curators, and any interested member of the public. In particular, any person who believes he is a member of the art world is a member. Dickie views this definition as a unit criterion, namely whether the status "work of art" has been conferred by someone in the art world. The definition can also be viewed as a combination of criteria, namely as a combination of all those criteria used by different members of the art world to confer the status "work of art." Dickie's definition can be viewed as a disjunction of all criteria that have ever been used by members of the art world.[7]

A third possibility is to maintain that no final definition of "work of art" can be given. Weitz has advocated this position.[8] Weitz maintains that the concept "work of art" is "open."

[4] C. L. Stevenson, "On 'What is a Poem?,'" *The Philosophical Review,* vol. 66 (1959).

[5] L. Wittgenstein, *Philosophical Investigations* Part I, Sections 66 and 67 (Oxford, 1953).

[6] G. Dickie, *Art and the Aesthetic* (Ithaca, 1974).

[7] Dickie's definition has the unfortunate consequence that it can easily be made vacuous. Namely: (1) We declare ourselves members of the art world; (2) We confer the status of "work of art" on all objects. Now that we have committed this dastardly deed, all objects are now works of art under Dickie's definition. Not just for us, but for everyone.

[8] M. Weitz, "The Role of Theory in Aesthetics," *Journal of Aesthetics and Art Criticism* (September 1956).

> A concept is open if its conditions of application are emendable and corrigible; i.e., if a situation or case can be imagined or secured which would call for some sort of *decision* on our part to extend the use of the concept to cover this, or to close the concept and invent a new one to deal with the new case and new property.[9]

Here, for any criterion for work of art, new objects can come into being which we would like to call works of art but which are not covered by the criterion. Hence, the definition of work of art must remain open; we must be able to add to it.

> . . the very expansive, adventurous character of art, its ever-present changes and novel creations, makes it logically impossible to ensure any set of defining properties.[10]

A fourth possibility is argued here. We believe that the multiplicity of ways of looking at art precludes the possiblity of a single, all-encompassing definition of "work of art" that satisfies everybody. There are people who have different ways of looking at art, who disagree on whether a certain object is a work of art. No single definition of work of art could ever satisfy these people.

The position taken here is that an object is a work of art only in terms of some way of looking at art. No object is in and of itself a work of art. No object is a work of art in any absolute sense. Whether an object is a work of art is purely a matter of convention. Thus, the question to ask is not "What is a work of art?" but rather "Given the conventions of a certain approach to art, what is a work of art under those conventions?"

Clearly, different ways of looking at art give rise to different definitions of work of art. Each definition can be logically consistent and coherent. Yet, the class of definitions may well be inconsistent. In Bell's terms, within some approach to art all works of art may have some "common quality." Yet across different approaches to art "when we speak of 'works of art' we gibber."

Each criticism algorithm or design algorithm embodies a particular approach to art, a particular way of looking at art. Because criticism algorithms and design algorithms have a definite structure,

[9] Ibid., p. 7. The notion of open concept is derived from Wittgenstein, *Philosophical Investigations,* Part I, Sections 65-75.

[10] M. Weitz, "The Role of Theory in Aesthetics," 1967, p. 8.

a common format for definitions of work of art can be posited in terms of this structure:

> For a given criticism algorithm or design algorithm, an object is a work of art if and only if it has an interpretation and that interpretation is assigned aesthetic value greater than some threshold.

Intuitively, this criterion states that an object is a work of art for a criticism algorithm or design algorithm if it can be reasonably well understood in terms of the interpretative conventions and evaluative criteria encoded in the algorithm. How an object is understood is given by its interpretation. How well an object is understood is determined using the aesthetic value assigned to its interpretation. An object is *reasonably well understood* if its interpretation is assigned aesthetic value greater than some threshold.

We now examine the role of the threshold in a definition of work of art for a criticism algorithm or design algorithm. Three cases are considered.

First, consider the case where the threshold is lower than the aesthetic value assigned to any possible interpretation. In this case, the threshold essentially plays no role in the definition. That is, an object is a work of art if and only if it has an interpretation. This corresponds to a "classificatory" definition of work of art.[11] Here, an object is a work of art independent of its aesthetic value. If there is any way of understanding an object in terms of some approach to art, then it is a work of art for that approach.

The problem with this definition is that for some criticism algorithms or design algorithms, an interpretation of an object may give only a null understanding of the object. For example, consider a criticism algorithm or a design algorithm containing an aesthetic system based on the constructive mode of understanding. Often, using an aesthetic system of this type, all objects that can be described have interpretations. Of these objects, some may only have interpretations of the general form <write out λ, λ>, where λ is the description of the object. That is, the information used to construct the description of the object explicitly contains the description itself. This interpretation essentially says that the object is what it is and offers a null understanding. The aesthetic system

[11] See, e.g., T. Emond, *On Art and Unity* (Lund, 1964), or G. Dickie, *Aesthetics* (Indianapolis, 1971).

developed as an example in sections 6.1 and 8.4 is one for which this problem arises.

An interpretation may also give a null understanding of an object in an aesthetic system based on the evocative mode of understanding. Using an aesthetic system of this type, all objects that can be described have interpretations. Of these objects, some may only have interpretations of the general form $<\lambda, \text{ne}>$, where λ is the description of the object and "ne" indicates "no evocations." That is, the object as described evokes no associations, emotions, or ideas using the interpretative conventions embodied in the aesthetic system. This interpretation essentially says that the object is what it is and offers a null understanding. The aesthetic system developed as an example in sections 6.2 and 8.5 is one for which this problem arises.

Of course, aesthetic systems of diverse types may have interpretations of objects which give only null understandings of the objects. The question is whether one wants to consider objects with only such interpretations to be works of art. If one does, then the threshold may be set below any aesthetic value assigned to any possible interpretation as discussed above. For example, for the aesthetic systems developed as examples in sections 6.1 and 8.4 and in sections 6.2 and 8.5, the threshold could be set at 0. If one does not want such objects to be considered works of art, then the threshold may be set at some point that separates those interpretations giving null understandings from those interpretations giving nontrivial understandings. In this second case, the threshold acts as a filter or sieve. Those objects that can be understood nontrivially are considered works of art. For example, for a criticism algorithm or a design algorithm using either of the example aesthetic systems just cited, the threshold might be set at 1.

In general, for a criticism algorithm or design algorithm using an aesthetic system containing the evaluation algorithm E_Z, the value 1 is a reasonable point at which to set the threshold. Using an aesthetic system based on the constructive mode of understanding, the threshold 1 separates objects that are considered random from objects that are considered nonrandom using the interpretative conventions and evaluative criteria embodied in the aesthetic system (see section 8.4.2). Using an aesthetic system based on the evocative mode of understanding, the threshold 1 separates objects that have shorter evocations than descriptions from objects that have longer evocations than descriptions.

In the third case, the threshold may be set at some very high value. Here, an object is a work of art for a criticism algorithm or a design algorithm if and only if it has an interpretation assigned aesthetic value greater than this (very high) value. This can be considered a definition for "masterpiece." That is, a masterpiece for a criticism algorithm or design algorithm is a work of art with very high aesthetic value using the interpretative conventions and evaluative criteria of that criticism algorithm or design algorithm. Using this definition of "work of art" with the threshold set at some very high value, only "masterpieces" are considered works of art.

The criterion that we have posited for deciding whether an object is a work of art for some criticism algorithm or design algorithm is that the object be understandable in the algorithm. This general criterion is perfectly consistent with definitions of "work of art" such as those given by Tolstoy or Bell. For Tolstoy, objects are understood as works of art in terms of the emotions they communicate and are works of art if they can be so understood. With a criticism algorithm or a design algorithm based on Tolstoy's approach to art, objects would be understood in terms of the emotions they communicate and would be works of art if they could be so understood. For Bell, objects are understood as works of art in terms of "significant form" and are works of art if they can be so understood. With a criticism algorithm or a design algorithm based on Bell's approach to art, objects would be understood in terms of signficant form and would be works of art if they could be so understood. Works of art for a criticism algorithm or a design algorithm incorporating Tolstoy's (or Bell's) approach to art would be exactly those objects that are works of art for Tolstoy (or Bell).

Our position concerning the definition of "work of art" is very close to that of Weitz, but with a difference in emphasis. We agree with Weitz that there can be no single meaningful, all-inclusive definition of "work of art." However, Weitz looks at the definitions that have been proposed and finds them wanting because they are not all-encompassing. We look at the definitions that have been proposed and find them valid in and of themselves. Weitz goes on to suggest that proposed definitions of "work of art" are valuable, even though incomplete, because they suggest interesting ways of understanding and evaluating objects as works of art. We see each of the ways of understanding and evaluating objects proposed in art and aesthetics as providing the basis for a definition of "work of art." Just as we do not require that each way of looking at art be all-inclusive, we do not demand that each definition of "work of art" be all-inclusive. We are satisfied if each way of looking at art, and each corresponding definition of "work of art," is internally consistent and coherent.

PART V: EFFECTORS

14
Effectors

The effector of a criticism algorithm or a design algorithm is the output device of the algorithm. In, general, an effector consists of an algorithm and linked transducer. Given some sequence of symbols as input, the effector performs some action or produces some object in the external world.

In a criticism algorithm, the effector has as input the description of an object and the interpretation and evaluation found by the analysis algorithm for the object. The output of the effector is the response of the criticism algorithm to the object in terms of its description, interpretation, and evaluation. In criticism algorithms, we would be content to have a printer as the effector. That is, given a description, interpretation, and evaluation of an object, the effector writes out the description, interpretation, and evaluation. One could imagine an effector that transforms the description, interpretation, and evaluation into English prose. One could also imagine an effector that has hands for clapping or tear ducts for crying based on the description, interpretation, and evaluation, but we won't.

In a design algorithm, the effector has as input the description of the object that is to be produced. The effector produces the object using the input description. The nature of the transducer in the effector would depend on the art form for which the design algorithm is constructed.

In literature, the transducer would typically be a printer. Namely, the description of a literary work would be its text. The effector would simply print the text. If a literary work is to be presented orally, then the transducer could be an artificial voice box. (Output devices that enable computers to produce speech are now commercially available.) The description of a literary work could be a sequence of phonemes to be uttered or it could be the text of the literary work. In the latter case, the algorithm in the effector would transform the text into some phonemic representation which would then be articulated by the artificial voice box.

In the visual arts, there are several possibilities for the transducer. Many techniques for producing visual images using a computer have been developed. The transducer could be a computer graphics terminal or color television. In this case, the object produced would be the picture displayed on the terminal or television screen. Alternatively, the transducer could be a device for producing a separable, physical object. There are numerous ways of producing such objects involving, for example, microfilm devices, printers, cameras, or plotters. Finally, one could imagine an effector containing artificial hands and eyes that could actually paint pictures.[1] For the visual arts, the description input to the effector could be of any of the types discussed in chapters 3 and 9. The algorithm of the effector would transform the given description into a specification suitable for the transducer. For sculpture, the effector could contain, for example, numerically controlled machine tools.

In music, there are several possibilities for the transducer. Various techniques for producing musical sounds using a computer have been developed. The transducer could contain analog signal generators, such as those in a Moog synthesizer, which are directly controlled by the linked algorithm of the effector. Alternatively, the transducer could contain electronics and speakers that enable the output of the algorithm of the effector to be directly transformed into sounds. The description of a musical piece could be its score or any of the other types of descriptions for music mentioned in section 3.2.3. If necessary, the algorithm of the effector would transform the description into a representation suitable for the transducer. The transducer would produce the appropriate musical sounds.

As discussed above, the design of music is considered a one stage affair. That is, the design algorithm would produce actual

[1] For an introductory discussion of computer systems with artificial hands and television cameras as eyes, see B. Raphael, *The Thinking Computer* (San Francisco, 1976).

musical sounds in response to some given initial conditions. Except for instances such as jazz, the design of music usually is considered to consist of two stages.[2] The first stage corresponds to the composer and results in a score. The second stage corresponds to a performer(s) and results in the production of musical sounds from a score. Both the composer of a score and the performer(s) of that score may be considered artists. Music as a two stage art can be modeled naturally as the composition of two design algorithms, as shown in figure 14-1.[3]

The first design algorithm corresponds to the composer. This design algorithm would respond to some given initial conditions by producing the score of a musical work. The aesthetic system of the design algorithm would embody interpretative conventions and evaluative criteria suitable for composing music. The effector of the design algorithm would contain a printer as transducer which prints the score.

The second design algorithm corresponds to the performer. This design algorithm would be given the score as initial conditions and would produce as output a performance of the score. The aesthetic system of the design algorithm would embody interpretative conventions and evaluative criteria suitable for performing music. The aesthetic system would determine how the score is to be "interpreted" in its performance. Of course, the performance produced by the design algorithm need not strictly follow the score in the same way that human performers sometimes alter the score. Indeed, the design algorithm could augment the score, for example with a cadenza. The description of the performance would be finer than the score and would give all the nuances of the performance. The effector of the design algorithm would contain devices for actually producing sound.

[2]For a discussion of one-stage and two-stage arts, see N. Goodman, *Languages of Art* (Indianapolis, 1968), pp. 114-115.

[3]Other similar combinations of criticism algorithms and design algorithms can be envisioned to model the interaction between critic and artist, artist and critic, critic and critic, or artist and artist. Networks of these algorithms are conceivable.

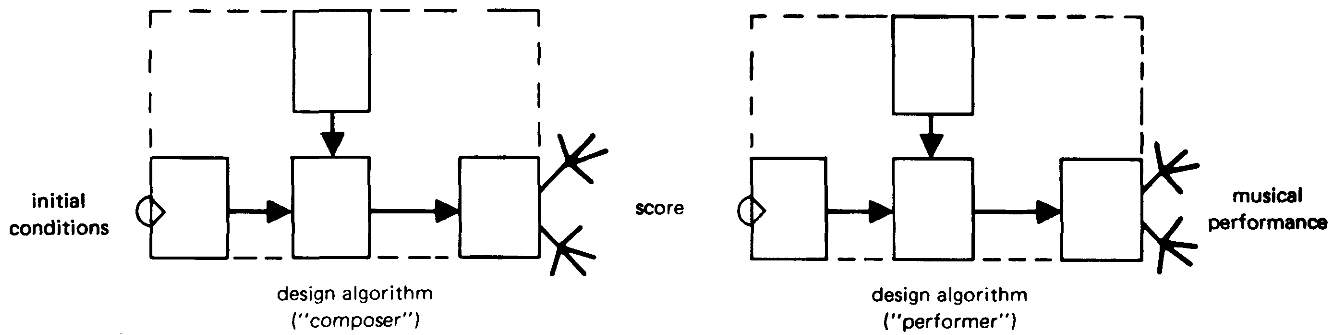


Fig. 14-1

Music as a two stage art.

Appendix
Introduction to Algorithms

An algorithm is a finite list of instructions that can be followed mechanically. An algorithm is applied to an input to produce an output. An algorithm has the following properties:

(1) The input to an algorithm is a finite sequence of symbols. Any symbol occurring in an input to a particular algorithm is a member of a fixed, finite alphabet. For example, the alphabet for an algorithm could be the English alphabet, the numerals, and some punctuation marks. A possible input using this alphabet is some particular English text.

(2) Each algorithm consists of a finite number of instructions. Each instruction is itself finite and can be executed or performed in a finite amount of time. Each instruction is unambiguous and rigorous in the actions it specifies. The instructions of an algorithm can be executed or followed mechanically by some computing agent, for example, a person with a pencil and paper.

(3) The output of an algorithm is a finite sequence of symbols. Any symbol occurring in an output of a particular algorithm is a member of a fixed, finite alphabet.

(4) For each given input, an algorithm produces a unique output. That is, each time an algorithm is given a particular input, the algorithm always produces the same output. Further, the sequence of instructions executed when a particular algorithm is applied to a given input is always the same, as is the result of executing each instruction.

As a very simple example, consider the following algorithm:

```
INPUT N
SET X TO 0
SET Y TO 0
OUTPUT (X, Y)
DO THE FOLLOWING SEQUENCE OF 4 INSTRUCTIONS N TIMES
   INCREASE X BY 1
   OUTPUT (X, Y)
   INCREASE Y BY 1
   OUTPUT (X, Y)
STOP
```

For this algorithm, the input alphabet contains the numerals 0,1,2, . . .9. An input is a sequence of numerals designating a number. The output alphabet contains the numerals and the punctuation marks left parenthesis, right parenthesis, and comma. A possible output is (0,0)(1,0)(1,1). The instructions of the algorithm determine the specific output produced for a given input.

Consider what happens when the input to the algorithm is 2. In the first instruction, N becomes 2. In the second instruction, X is set to 0; in the third, Y is set to 0. The first five symbols of the output of the algorithm are determined in the fourth instruction. These symbols are (0,0). The fifth instruction determines that the succeeding sequence of four instructions is to be performed twice, as N is 2. In the first time through the sequence, X is increased from 0 to 1, the symbols (1,0) are added to the output, Y is increased from 0 to 1, and the symbols (1,1) are added to the output. So far, the cumulative output of the algorithm is (0,0)(1,0)(1,1). In the second time through the sequence, X is increased from 1 to 2, the symbols (2,1) are added to the output, Y is increased from 1 to 2, and the symbols (2,2) are added to the output. So far, the cumulative output of the algorithm is (0,0)(1,0)(1,1)(2,1)(2,2). This is the complete output of the algorithm as the next instruction is STOP.

Figure A-1 shows the outputs produced by the inputs 0,1,2, and 3. These outputs can be considered as descriptions (see chap. 3) of the shapes shown in the figure by considering the output as a sequence of (X,Y) coordinates to be sequentially connected. It should be noted that instructions in algorithms are certainly not restricted to arithmetic operations on numbers.

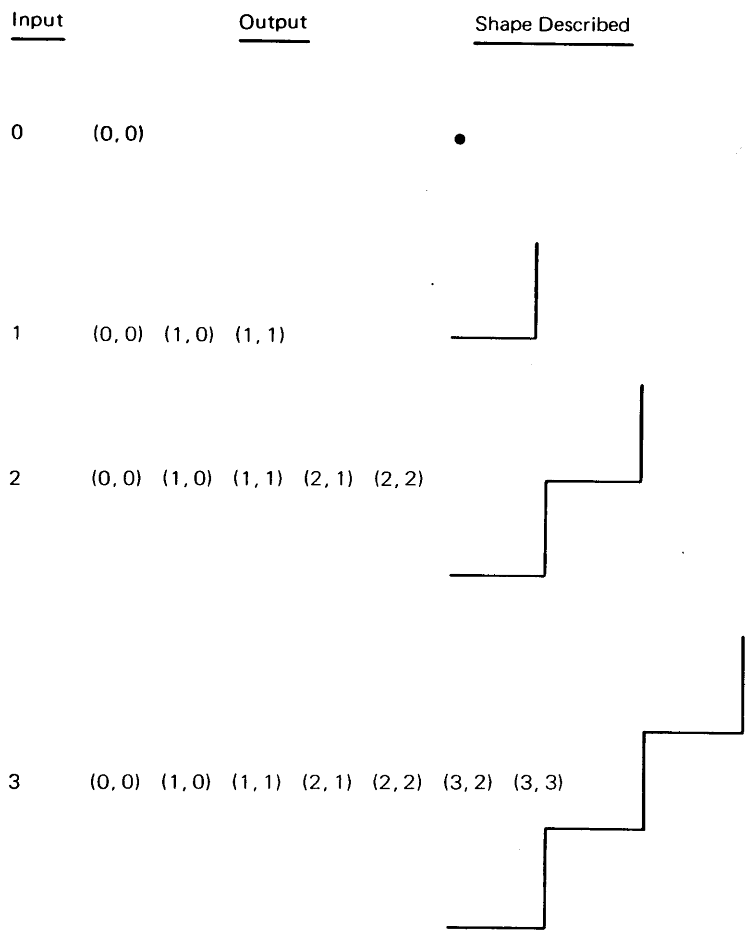


Fig. A-1

Inputs and outputs for a simple algorithm.

In this study the input-output structure of an algorithm is represented schematically by a box. An input to the algorithm is indicated by an arrow pointing into the box; and output is indicated by an arrow pointing out from the box (see fig. A-2). Sometimes, in this study, the input to an algorithm is considered to have two parts. In this case, there will be two arrows pointing into the box (see fig. A-3).

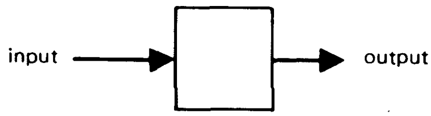


Fig. A-2

Schematic representation of an algorithm with one input.

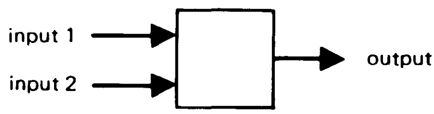


Fig. A-3

Schematic representation of an algorithm with two inputs.

Two algorithms can be combined to form a new algorithm by composition. That is, the output of the first algorithm is used as the input to the second algorithm. The input to the new algorithm is the input to the first algorithm; the output of the new algorithm is the output of the second algorithm. A schematic representation of the composition of two algorithms is shown in figure A-4.

The computing agent that applies an algorithm can be a person with pencil and paper, but more typically is a computer. There are special computing languages or programming languages for representing algorithms in a way that can be automatically followed by computers. An algorithm that is represented in one of these languages is called a (computer) program.

In order to specify an algorithm that performs some process, it is necessary to specify unambiguously and deterministically every step in the process. Nothing about the process can be left to chance or the imagination of the computing agent. Because an algorithm must be specified in such detail, just the attempt to construct an algorithm for a given process provides an excellent means of exploring the process in all its aspects and features.

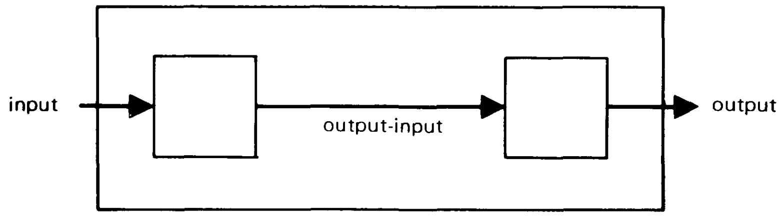


Fig. A-4

Schematic representation of the composition of two algorithms.

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