Metaphors in Design: 
An Experiment with a Frame, Two Lines and Two Rectangles

Josep Fargas and Pegor Papazian
Massachusetts Institute of Technology

The research we will discuss below originated from an attempt to examine the capacity of designers to evaluate an artifact, and to study the feasibility of replicating a designer's moves intended to make an artifact more expressive of a given quality. We will present the results of an interactive computer experiment, first developed at the MIT Design Research Seminar, which is meant to capture the subject's actions in a simple design task as a series of successive "moves". We will propose that designers use metaphors in their interaction with design artifacts and we will argue that the concept of metaphors can lead to a powerful theory of design activity. Finally, we will show how such a theory can drive the project of building a design system.

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When trying to understand how designers work, it is tempting to examine design products in order to come up with the principles or norms behind them. The problem with such an approach is that it may lead to a purely syntactical analysis of design artifacts, failing to capture the knowledge of the designer in an explicit way, and ignoring the interaction between the designer and the evolving design. We will present a theory about design activity based on the observation that knowledge is brought into play during a design task by a process of interpretation of the design document. By treating an evolving design in terms of the meanings and rules proper to a given way of seeing, a designer can reduce the complexity of a task by focusing on certain of its aspects, and can manipulate abstract elements in a meaningful way.

The design experiment

In order to try to capture some of the mechanisms of interpretation involved in design activity, we devised an experiment in which designers are asked to manipulate a set of simple graphic elements in order to give them some abstract quality, such as "stability". In presenting the results of the experiment, our aim is not to engage in an objective protocol analysis where "in choosing data for transcription, and in transcribing and encoding them, the theoretical commitments that are made should be kept as small and weak as possible" [Ericsson and Simon 1984]. Rather, we use the experimental data as material for developing, testing and fine tuning a generative model of certain kinds of design processes. Below, we will present the details of the experiment and its results, the theory of metaphors derived from them, and a design generation system based on that theory.

In the experiment different designers are shown, on a computer screen, randomly generated pictures consisting of a 5 by 3 inch frame, two lines and two rectangles. The design task is to make the picture "more stable" or "more dynamic" only by moving the rectangles dragging them with a mouse. No clarification is given about the meaning of the terms "stable" and "dynamic". The computer records the designers' moves, and later produces a real time replay and an account of the process as a succession of snapshots. Each snapshot shows the state of the picture where the subject paused for more than four seconds, or switched from moving one rectangle to moving the other, with all intermediate positions shown in gray.

The subject of the experiment is presented with an initial picture, generated by the computer, in which the sizes and positions of the rectangles and the positions of the lines are random. The rectangles do not intersect each other or go out of the frame, and each of the lines is either
horizontal or vertical and goes from one edge of the frame to the other. The subject is asked to produce a final picture in which the rectangles are inside the frame and do not overlap. After the subject decides to stop modifying the picture, a replay of the process is shown, and the experiment is repeated starting with the final state of the previous process. Throughout the experiment, any comments that the subject makes are informally recorded.

Figure 1 shows a session of the experiment where the task given to the subject is to make the picture more stable.

![Figure 1](image)

Our interpretive theory is based on the observation that the subjects of the experiment use metaphors in order to give meaning to the elements of the picture and to motivate their actions. The use of metaphors can be very explicit, such as in a particularly telling session in which the task was to make the picture more dynamic. The subject referred to the two horizontal lines of the picture as “the river”. Her aim was to place the smaller rectangle on the band formed by the upper line and the top of the frame which she called the “far side” and the larger on “this” or the “near side”, meaning the band formed by the lower line and the bottom of the frame. The

final picture shown in figure 2 consisted of two objects on either banks of a river in a kind of oriental perspective composition.

![Figure 2](image)

Obviously, the use of the term “river” to refer to the lines can be seen as metaphorical. The figure of the river is itself embedded in the more general context of a perspective composition. Thus, the subject’s actions are guided by a particular way of treating pictures which we call the perspective view metaphor.

Often, the metaphorical character of the subjects’ interaction with the picture is more implicit. In many sessions where the task was to make the picture stable, different subjects tended to drag the rectangles down to the bottom line of the frame, or to stack them on top of each other. The rectangles were treated as blocks having a certain weight, and were placed on horizontal lines as if to rest. This way of treating the picture seems to be based on what we call a gravity metaphor. Figure 3 shows an excerpt from a
session where such a metaphor plays a dominant role.

![Figure 3](image)

There is, of course, a strong correspondence between the mechanisms of metaphor in speech, and those of metaphors used in a designer's interaction with a design document. An interesting aspect of this parallel has to do with the degree to which metaphors used in design can be treated as literal rather than figurative. In language a "dead metaphor" is a potentially metaphorical figure of speech which has lost its figurative value and is taken literally. In the term "leg of the table", the metaphorical identification of the table with a legged animal is lost. In the visual aspects of designing, many architectural traditions take quite literally certain rules of visual composition which, upon closer examination, can turn out to be metaphorical in nature. Both classical and contemporary texts, for instance, recommend various rules of proportion in the design of facades. In fine arts, books such as Arneheim's "visual thinking" promote concepts such as "the power of the center" in paintings [Arneheim 1969], and countless manuals suggest normative theories of composition based on some assignment of meanings to certain aspects of figures, and on rules to be applied to them. Figure 4 shows an illustration taken from a photography manual [Heilbron 1939] where construction lines are used to create a "balanced" composition.

Our purpose here is not to show the metaphorical nature of certain normative theories in design, nor to develop a normative theory ourselves. Rather we will try to propose the idea of metaphor as a tool for modeling design activity. In The Metaphorical Process [Ricoeur 1979], Paul Ricoeur stresses the role of imagination in metaphor, saying that it does not merely picture the sense thanks to the display of images aroused and controlled by the cognitive process. Rather, it contributes to the projection of new possibilities of redescribing the world." It is this generative aspect of metaphor that we propose to exploit in our theory of designing.

As a general definition, we will say that a metaphor is the combination of a set of meanings assigned to graphic elements, and the rules used to relate those elements. By applying a metaphor to an arbitrary picture, the designer not only creates a mapping from the syntactic visual elements of the picture to a set of semantic elements, but also brings into play a set of rules governing the relationship between those semantic elements. Thus a gravity metaphor assigns the meaning of "floor" to the bottom line of the frame and "block" to the four lines of the rectangle, and invokes the rule that a block resting on the floor is "in equilibrium", and thus stable. We also apply this definition of metaphor in cases where the subject's interpretation of the graphic elements seems quite literal. Figure 5 is an excerpt from the session shown in figure 1. In snapshots a to c the subject's actions seem to be driven by the aim of centering the pair of rectangles between the two lines which form the left and right edges of the frame and centering each rectangle about the two horizontal lines. We will hypothesize that in snapshot b the subject starts moving the larger rectangle to the right in order to create some sort of balanced distribution of the two rectangles between the left and right sides of the frame.
In the process, the subject adopts a kind of centering metaphor in which the two horizontal lines and the left and right sides of the frame have the same semantic relationship with the two rectangles. Thus in snapshot c the rules of the active metaphor lead the subject to complete the process by moving the smaller rectangle to the right, and placing it between the two horizontal lines.

We have not yet dealt with the way in which a particular metaphor is chosen rather than another. Nor have we explained how more than one metaphor can come into play during a given session. In the next section we will argue that the way metaphors are put to use or discarded is based on an attitude which is fundamentally opportunistic.

Opportunism

The mechanism guiding the process of adopting a metaphor, switching from one metaphor to another, or returning to a previously used or sleeping metaphor seems to depend on the recognition of opportunities to improve the picture in terms of a new set of meanings and rules.

Figure 6 shows a very short session in which the role of opportunism is particularly clear. In snapshot a the subject notices that the smaller rectangle has proportions which are very similar to the lower right quadrant formed by the two lines. In b, a short move places the small rectangle in that quadrant. As a consequence, and with another opportunistic move, the larger rectangle is moved into the upper right quadrant, producing the final state shown in snapshot d.

Figure 6

Figure 7 shows snapshots d to f of the process shown in figure 1. Comparing snapshot d to the preceding one, namely snapshot c of figure 5, it is possible to see a radical change in the strategy used to transform the picture.

![Figure 7](image)

We will propose several opportunistic mechanisms involved in adopting a metaphor. One of them consists of exhausting the possibilities offered by a given metaphor, and initiating an exploration for another way of looking at the picture, that is a different metaphor, which offers new possibilities. The centering metaphor discussed above leads, in snapshot c, to a state of the picture where the implicit rules of centering are satisfied. The will to continue trying alternative arrangements leads to a search for opportunities which immediately results in the recognition that the larger rectangle may fit between the bottom of the frame and the upper horizontal line. In snapshot d the subject moves the larger rectangle towards the lower right corner of the frame in an attempt to fit it there. At this point the subject seems to have adopted a new metaphor which involves notions of fitting and gravity. The following snapshots confirm this fact, since in e the subject attempts to fit the smaller rectangle in the space between the top of the larger rectangle and the frame, and in f he moves it down, placing it adjacent to the larger one.

A similar phenomenon is that of distraction. A particular intermediate state of the picture reached while acting according to the rules of an initial metaphor can trigger the adoption of another metaphor due to the salience of certain visual clues. This phenomenon is similar to ones which occur in the famous Necker cube or duck/rabbit examples, where the same picture is seen in one of two different ways, but not as both at the same time.

Another common switch results from the partial compatibility of two metaphors. Two metaphors can assign the same or similar meanings to certain elements, or may impose compatible rules governing the relationship of certain elements. Consider the gravity metaphor which we have
already introduced, and another common metaphor which we will call the corners metaphor that, among other rules, has one requiring that rectangles be “tucked” into “corners” formed by the frame and the lines. These two metaphors are compatible in certain states of the picture, such as ones where both rectangles are placed in corners formed by the bottom of the frame and any vertical line. The rectangles are thus both “resting” on the bottom of the frame, and “tucked” into the corners.

In the excerpt shown in figure 8, the subject explores some possibilities offered by the gravity metaphor in snapshots f to h. In i, the subject first moves the smaller rectangle to the lower right corner, where it is still compatible with the rules of the gravity metaphor, then proceeds to move it up to another corner, thereby abandoning the gravity metaphor and switching to the corners metaphor.

Just as metaphors as we have defined them are analogous to metaphors in speech, there is a very close analogy between the choosing and switching of metaphors described above and the notion of belief and belief revision in the field of epistemology. Gilbert Harman writes in Change in View (Harman 1986) that “there is a difference between theoretical reasoning, which immediately modifies beliefs, and practical reasoning, which immediately modifies plans and intentions”. Similarly, in the context of our experiment, subjects sometimes change their strategy in transforming a picture by changing or adding some rules and assigned meanings, but without fundamentally changing the active metaphor.

Figure 8

Figure 9 shows an excerpt from a process in which the subject verbally describes the rectangles as rectangular tubes seen in section, and the lines as the edges of planes perpendicular to the field of view.

Bothered by the inconsistency of the intersection of the larger, vertical “tube” and the two “planes” the subject immediately takes the unprecedented action of moving the larger rectangle outside the boundaries of the frame. This does not imply a switching of metaphors, but it results in the breaking of certain rules associated with an implicit metaphor common to almost all the subjects, and which makes the frame to be seen as the physical boundary in which the rectangles are trapped. Once that relatively literal metaphor is abandoned, the subject is not inhibited, in snapshot c, from temporarily moving even the smaller rectangle outside the frame.

Equivalence and replication

In order to describe the results of the experiments, we have been giving names to the metaphors used by the subjects based on certain verbal or visual cues, and on the consistency we perceived in the subjects’ actions.

It is very likely that our interpretations do not exactly coincide with the explanations that the subjects would have given about their own actions. One might even claim that any explanations that the subjects themselves give, are nothing more than interpretations of their
own behavior. The observation that two different ways of seeing can both explain coherently a set of transformations of a picture, can be generalized in what we will call the concept of equivalent metaphors. Figure 10 shows a session in which the task is to make the picture more stable. In snapshot e, the vertical rectangle is placed in the center of the region between the vertical line and the right edge of the frame, where it is also centered along the horizontal line. In f, the horizontal rectangle is also centered along the horizontal line.

Watching the replay of this process clearly shows that in f, the subject first moves the horizontal rectangle to one position, pauses for a moment, and then moves it to its final position shown in g:

![Figure 10](image)

Figure 10

Figure 11 shows a breakdown of snapshot f into smaller intervals, where a pause of two seconds or more constitutes a snapshot. Note that in f', the subject moves the horizontal rectangle to the center of the region between the vertical line and the left edge of the frame (where he stops for a moment), and then slides it slightly to the left in f". We will argue that the subject's initial motivation is to center each rectangle in the region having a corresponding orientation (perhaps according to a kind of opportunistic "a is to b as c is to d" rule), and that once each rectangle is locally centered, the subject switches to a global view of the picture which leads him to complete the move of snapshot f by sliding the horizontal rectangle to the left.

![Figure 11](image)

Let us now pose the problem of finding an interpretation of the elements of the picture which leads to placing each rectangle in the center of the "corresponding" regions when each region is considered independently, but which also leads to placing the horizontal rectangle further to the left when the picture is considered as a whole. For the sake of argument, let us suggest a structural engineering metaphor as a possible solution. Imagine the two regions to the left and the right of the vertical lines as structural slabs seen in top view, and the rectangles as the top views of two pillars seen through the (transparent) slab. When each slab is considered locally, the most "stable" structural solution is to place the pillars in the middle of the slabs. Figure 12-1 shows the diagram of moments along a transversal section of the slab. But when the two regions are seen globally as one continuous slab, the diagram in figure 12-2 shows that the structure is more stable (that is the moments are minimized) when the left pillar is moved further towards the cantilever to the left.

![Figure 12](image)

This structural metaphor is almost certainly not the one used by the subject. However it has the property that it replicates the subject's moves at least for the snapshots of figure 10, and that it might be a valid replicator for a family of pictures which are variations of the one shown in this session. In that sense the structural metaphor and the one used by the subject are equivalent metaphors. Just as a metaphor can be relatively literal or figurative, two metaphors can be more or less equivalent, meaning that they produce the same actions in a larger or smaller number of cases. In A Cognitive Theory of Metaphor, Earl Mac Cormac writes "How can we discover that we have been victimized by a metaphor if
we have become so familiar with the metaphor that we believe it to be literally true? Often this can be done by extending the metaphor and by finding that such an extension produces absurd results” [Mac Cormac 1988].

Similarly, one can discover that two apparently equivalent metaphors are not identical by extending the variety of cases in which they are both applied and finding cases where the moves resulting from one metaphor are “absurd” in the context of the other. The concept of equivalent metaphors suggests a methodology for replicating design activity based on the interaction of a number of metaphors equivalent to ones used by a hypothetical (or particular) designer. In the following section we will briefly present two computational design systems based on such a methodology.

**Modeling design activity**

After completing the experiment described above, we went on to explore the possibility of using the metaphor model for a design generation system. As a first step, we developed a small computer program called EstheR, the Esthetics Replicant, which mimicked the actions of some of the subjects of the experiment, producing very similar processes of transforming the pictures.

We then built a more elaborate version of the mechanism used in EstheR, as a general-purpose shell applicable to different design tasks [Papazian 1991]. We will not describe the design generation system in detail here. We will therefore concentrate on its aspects which are most relevant to the metaphor model.

The system is composed of four main components: (1) the persona, (2) the forum, (3) the arbiter and (4) the focus manager. The persona is simply a collection of modules, each of which corresponds to a metaphor. Each module has a “seeing-as function” which is an independent way of representing the design artifact, a function for evaluating a given state of the artifact in terms of its criterion, and a small knowledge-based system for proposing design moves expected to improve the artifact with respect to its criterion. The persona interacts with the other three components in a see-move-see cycle: The persona "sees" the design document resident in the forum and produces a number of potential transformations. The arbiter chooses one of these transformations (or a composite of some of them) and applies it to the document as a design “move”. At each cycle, the focus manager tunes the attention of the persona, both in terms of the elements of the document and in terms of priorities of intentions.

One design task to which the system is applied consists of arranging three blocks of variable height and rectangular footprints of arbitrary dimensions, according to some formal principles of massing. These principles are quite simple. They favor the following features.

1. Maximum alignment and abutment of the blocks
2. Compactness of the massing
3. Some constant footprint-to-volume ratio
4. Visibility of all the blocks from some viewpoint

Figure 13 shows the initial condition of the document (in the upper left window) which contains seven blocks of arbitrary dimensions and location. The other windows show the document as seen by each of five modules, in terms of their metaphors.
Each module corresponds to one criterion in the design task. The Overlap module "sees" the document as the configuration spaces of the blocks, and tries to undo overlaps; the Number module sees the document simply as a number (the number of blocks) and tries to add or remove blocks to maintain a certain number (in this case 5); the Align module sees continuous lines and tries to make them coincide; the Corners module sees concave and convex corners and tries to match them; the Environ module sees the blocks in perspective from a specific viewpoint and adjusts heights to keep them all visible, and to maintain a fixed footprint/volume ratio. Figure 14 shows the first forty-nine moves made by the system in a typical session. The highlighted frames could be thought of as "solutions". Note that after 25 moves, the system reaches a spinwheel configuration which can be considered optimal in terms of a formal specification of the design criteria.

The dynamic behavior of the system is very different from the behavior of other systems, such as ones based on constraint models or shape grammars. Some of its characteristics, such as its exploratory behavior and its resistance to oscillation, are features due to the use of the metaphor model. In addition, the fact that design knowledge is represented in terms of independent
metaphores makes the system modular and insures that the principles on which its behavior is based are explicit.

One of the advantages of the system described above is that it replicates many of the typical characteristics of design activity such as exploration, opportunism, resolution of conflicting motivations and the ability to selectively ignore constraints. Another approach to exploiting these characteristics consists of using the system to model the interaction between different cooperating or conflicting designers. Thus each metaphor module can represent part of the goals and interests of one of the parties influencing the evolution of a design. As an example of such an application, we will present a system for simulating urban development using the metaphor model [Fargas 1991]. The system produces building envelopes in the Midtown Cultural District of Boston, Massachusetts by capturing, on the one hand, the knowledge implicit in the regulations of the District’s Zoning Plan and, on the other, the influence of different interests motivating urban development. One module, for instance, "sees" the exploitable sites in the District from the point of view of what we will call the "uncrushing developer" which tends to maximize the buildable area, trying to build the largest possible number of offices in each building. Another module represents the point of view of a "city hall planner" encouraging the preservation of certain traditional characteristics of development in the area such as limited heights and setbacks of buildings as specified in the zoning regulations. Figure 15 shows the development of the building envelope of a series of lots according to the criteria of two of these modules, without the intervention of the others. The interaction of the modules results in the gradual development of the area as dictated by a fine grained process of cooperation and compromise among the modules.

Figure 15
Figure 16 shows an intermediate state of development produced by the system.

Figure 16
Conclusion

We have presented a theory of design activity which takes into account the designer’s interpretation of an evolving design, and assigns to the act interpretation the basic generative force which guides the evolution of the design. We have proposed the concept of metaphors in order to capture the mechanism by which meanings are assigned to the components of a design and rules relating those elements are brought into play. We have shown how the metaphor model can be used to build a dynamic design generation system.

Indirectly, we have also suggested a methodology of research which we feel is particularly appropriate for design studies. This methodology consists of developing a theory based on the subjective interpretation of data such as the results of exploratory experiments, and fine tuning the theory by building generative systems based on it. Building the design system presented above is itself an act of design. The choice of relevant metaphors, as well as the rules constituting each metaphor module have an indirect but important bearing on the system’s behavior. We will claim that the act of designing the system is equivalent to designing the family of artifacts it produces. In that sense, the methodology of design research proposed above can also be a new method of designing.

References


Papazian, Pegor, “Principalles, Opportunism and Seeing in Design”. MIT Artificial Intelligence Laboratory Memo No.1309. Also presented at the IJCAI ’91 workshop on AI in Design, Sydney, Australia.


1 In general, no metaphor is an island. Although for the sake of convenience we will refer to metaphors as independent modules, in reality the space of metaphors is a continuous one, and there are many metaphors which share characteristics, elements and rules, and there are families of metaphors which can be organized as hierarchies. In addition, there are many basic ordering principles (such as an abstract notion of symmetry, or the principle of “a is to b as c is to d”) which are valid across metaphors.

2 The fact that two partially compatible ways of seeing a design document can “coexist”, is also important in the study of how different designers cooperate and communicate ideas about the same design.