The Pennsylvania State University

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Department of Philosophy

PICTURES OF THOUGHT:
THE REPRESENTATIONAL FUNCTION OF VISUAL MODELS

A Thesis in

Philosophy

by

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Abstract

Scientific inquiry makes use of visual models to represent empirical systems. Many philosophers claim that models function only as analogies, and that their role is limited to a didactic or heuristic role. I analyze four families of visual models: maps, graphical images from the study of turbulence, fractal images, and strange attractors. I show that these models are projected from data; that they are dynamic pictures, which can be manipulated by the researcher; that they are necessary for the theories in which they function; and finally that they interact at many levels with the theory. I call models possessing these qualities generative, because they contribute to the elaboration and formulation of theories. Strange attractors, visual models produced in the study of dynamical systems, are the best example of generative models.

I show the limitation of conceiving of models as analogies, and restrict the scope of concepts such as similarity, resemblance, correspondence, and analogy. The study of generative visual models shows that visualization takes us beyond the perceptively visible, but that the representational function of the model is retained. Visual models represent the world, even if they do not resemble or

look like the world. The objects of scientific inquiry are represented through our constructed worldview. This position sides with a constructivist account of reality.

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"And yet I have constructed in my mind a model city from which all possible cities can be deduced," Kublai said. "It contains everything corresponding to the norm. Since the cities that exist diverge in varying degree from the norm, I need only foresee the exceptions to the norm and calculate the most probable combinations."

"I have also thought of a model city from which I deduce all the others," Marco answered. "It is a city made only of exceptions, exclusions, incongruities, contradictions. If such a city is the most improbable, by reducing the number of abnormal elements, we increase the probability that the city really exists. So I have only to subtract exceptions from my model, and whatever direction I proceed, I will arrive at one of the cities which, always as an exception, exist. But I cannot force my operation beyond a certain limit: I would achieve cities too probable to be real."

Italo Calvino, <u>Invisible Cities</u>

Introduction

The sense of sight has been the major paradigm in philosophical discussion of knowledge. This is evident in our use of language to describe the nature, acquisition and relevance of knowledge, which includes many metaphors of light and brilliance. Michel Serres writes: "The theory of knowledge has never ceased to take the emission or expansion of light as its primary model" (1991, 247 [my translation]).[1]

The principal role of the sense of sight is reflected in the "organizational system" through which we represent our knowledge; in every discipline, theories make use of visual representations to display and order data. We think of Bohr's model of the atom, or the tree-diagrams used in the taxonomy of species in evolution theory, but also of other visual systems of representation, for example geographical maps or classical music notation. Although these visual models are part of theories, they function differently from linguistic descriptions or mathematical formalisms. The meteoric rise of the computer as a universal tool for simulation and graphic imaging over the

[1] Serres' work Les Cinq Sens (1985) seeks to defuse the prominence of sight by examining knowledge attained through our other senses.

last few decades has made it possible to represent visual models with a complexity, accuracy and sophistication previously unthinkable.

The relationship between words or sentences as units of meaning and objects in the world has been the subject of intense philosophical debate in this century, and has served to defend competing metaphysical conceptions of reality. But the relation of thought to the world is not limited to words alone or to the epistemological consequences of our use of language. Images and pictures in the fine arts are non-linguistic statements about how we perceive and conceptualize our world. In the sciences, visual models are representations of the perceived or measured world, and as such representations of our knowledge about the world. The use of visual models constrains and alters the reality we perceive and measure through the images we create. This formulation strikes at the heart of the realist-constructivist controversy.

Recent work in philosophy has offered only partial concepts of representation to explain representation in language, in the arts, or for scientific models. The concept of representation offered by the philosophy of language is not adequate for non-linguistic representation. Aesthetics provides several concepts of representation,such as mimesis or semiosis. In the philosophy of science, we find an over-reliance on the concept of analogy in otherwise erudite explanations of the role of scientific models; but analogy does not work very well for specifically visual models.

This work proposes a number of shifts in our understanding, characterization and description of the function of visual models in order to rethink the categories of representation and its complex, manifold, inexhaustible mechanisms. By saying that images, pictures or models represent reality, our perception of reality, or our theories, we assume a representational link between two ontological realms. Two questions govern the work: What is representation, and by what mechanism do images, pictures and models represent?

More specifically, how do we represent our knowledge to ourselves by means of images? What are the defining characteristics of pictorial representation? How does pictorial representation differ from other modes of representing knowledge? What are the limits imposed and the opportunities afforded by pictorial representation?

How does visualizing a set of phenomena contribute to understanding them? What is the function of the visual model in theories? What is the epistemological status of a visual model?

In Chapter 1, I briefly discuss two theories of representation and the linguistic tropes of analogy and metaphor. I introduce the most important findings of the current philosophical research on models in the philosophy of science, and define the relation between visual models and the empirical system.

In the three middle chapters I present four families of visual projection models: maps, graphical images of turbulence, fractal images, and strange attractors.

Chapter 2 examines the concept of projection by reducing it to formal operations and analyzing its function in the development of all kinds of maps. Formal concepts used in mathematics, like isomorphism and similarity, are contrasted with the more general meaning they have acquired in everyday language. The central question is how a mathematical transformation can effect the transformation from data into image.

Chapter 3 extends the concept of projection model beyond maps to include dynamic, interactive graphical imaging. The example chosen is the analysis of boundary-layer turbulence in fluids. A distinction is made between a perspective- and transformation-specific image, and a manipulable image which involves a whole domain of visualization. The difficulty presented by a whole matrix of manipulable visual models is that of providing meaning for the constructed picture.

Chapter 4 examines the fantastic world of fractal images, which are produced by very simple iterated mathematical equations but need the number-crunching and graphic power of sophisticated computers to reveal their full complexity. In some cases, fractals do resemble images projected from empirical systems, while in others, they are visual models of systems without in the least looking like them. Visual models represent empirical systems even when they do not resemble them.

Chapter 5 describes the production and use of strange attractors in the study of a variety of dynamical systems. The example explored here is the "Lorenz butterfly" produced by a simple mathematical simulation of cellular convection, and which has staggering consequences for the ability to make predictions. Strange attractors are visual models produced by the analysis of dynamical systems; they are necessary, dynamic and interactive. These three properties make them generative models; they influence the construction and elaboration of theories.

Chapter 6 examines the theory that models are analogies. The study of visual models brings out the limitations of analogies and shows the hidden assumptions of using terms such as correspondence in theories of linguistic representation. I propose a generative theory of representation to explain the construction and function of visual models in scientific theories.

Chapter 7 shows how generative models lead to a reevaluation of the concept of visible by extending our capacity for visualization beyond the perceptively visible and conceivable. I examine the influence of visual models in the creation of a worldview and the resulting constructivism.