Computational Monadology

Eric Steinhart

1. Computational Methods in Metaphysics

Philosophers have used computers to model theories in the philosophy of science (Thagard, 1988, 1992; Shrager & Langley, 1990; Slezak, 1989), ethics (Danielson, 1992), logic (Grim, Mar, St. Denis, 1998) as well as in philosophy of mind and language. Yet it appears that the computer has not been used to model metaphysical theories.[1] Such application should not seem odd: scientists regularly use computers to model sophisticated and highly speculative cosmological theories (Hut & Sussman, 1987). Likewise, philosophers can cast their metaphysical views in computational form.[2] To illustrate computational modeling of a metaphysical theory, I propose to demonstrate such a model of Leibniz's *Monadology* (1965).

2. Modeling with Object-Oriented Programming

One reason philosophers have not been inclined to model their metaphysical theories computationally is undoubtedly the lack of adequate computational tools. It has not been immediately apparent to philosophers how they might program directly with the logical categories that are the metaphysician's stock-in-trade, categories such as types, individuals, properties, relations, and processes. Recent advances in computer languages and programming paradigms, however, stand to equip the metaphysician with exactly the computational tools needed. *Object-oriented programming* (Khoshafian & Abnous, 1990) facilitates programming directly in terms of types, properties, relations, and processes. It provides metaphysicians with the logical categories they need.

Smalltalk (Digitalk, 1993) is a computer language which implements the object-oriented approach. Our model of the *Monadology* is written in Smalltalk. Smalltalk provides the programmer with a *hierarchy of classes*, much like the Aristotelian genus-species hierarchy. To program, one defines classes. Each class has *instances*. The properties and relations of the instances of a class are defined by the class's instance variables. For example, one might define the class *Human*, giving it instance variables *name*, *weight*, and*gender*. Then one might define two instances of *Human*, giving the first the name "Bob", weight 150, and gender "male", and the second the name "Sue", weight 110, and gender "female". Processes associated with the instances of a class are defined by the *methods* of the class. For example, one of the processes of instances of *Human* is that they eat. Hence *eat* is a method of *Human;* when an instance of *Human* eats, its *weight* is increased. In continuing this example, one might define a class *Food*. This class would then have subclasses: the

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[1]Henry & Geertsen (1986) have indicated that PROLOG can be used to represent certain concepts from Whitehead's cosmology, though they have not done any modeling. Goldman (1999) has suggested that metaphysics can learn from cognitive science, but he has not done any modeling either.

[2]By *metaphysics* we mean the attempt to understand existence categorially at the most abstract level. For a materialist, the basic categories of existence are the kinds of material objects; for an idealist, the basic categories of existence are the kinds of minds. Besides dealing with the categories themselves, metaphysics also deals with the properties, relations, and processes of their objects. The result is a metaphysical theory. For the materialist, such a theory describes the properties, relations, and processes of material objects.

different types of *Food*. For instance, one might define *Fruits*, *Vegetables*, and *Meat* as types of *Food*. The result is a *class hierarchy*. The *eat* method of *Human* would then be defined so that an instance of *Human* always eats some instance of *Food*.

3. Modeling Leibniz's *Monadology*

3.1 Computational Interpretations of the *Monadology*

To show how object-oriented programming can be used to model metaphysical theories, I offer a simple computational model of Leibniz's *Monadology*. It should be clear that this model is finite, discrete, and partial. Compared with the rich complexity of Leibniz's thought, this model is trivial indeed. Many interesting aspects of Leibniz's thought are ignored for the sake of brevity, and certain aspects of his thought must be modified to render them computable. But the result is still clearly Leibnizian. It is a first approximation that can be elaborated and refined. In modeling the *Monadology*, I focus on perception, perspective, and harmony.[3]

I am not the first to interpret Leibniz's thought computationally. Rescher (1991) conceives of monads as computational automata running perspectivally coordinated programs. Mac Donald Ross (1984: 98) suggests a similar model of the monadic system:

> Computer graphics can be used to create animated film sequences representing the changing shapes and positions of imaginary objects from particular perspectives. We can imagine an infinity of such films, each from infinitesimally different viewpoints, all being run simultaneously. Even though the objects and their interactions are entirely fictional, it will be as if there had been infinitely many cameras filming one and the same scene from different points of view. The simplest way of describing what they portrayed would be by adopting that fiction, even though its only reality would be as a formula in a comptuer program. But although this formula would not be real in the sense of having a physical embodiment outside the computer, it would be objective.

3.2 The Logical Structure of the World

To model the monadology, we first define a class *Monad*. According to Leibniz, monads have qualities (properties and relations; M 8, 13), but not parts (M 1).[4] So the class *Monad* has an instance variable for each quality. One important monad is God (M 38-48); God is an instance of God's own class, so the class *God* is a subclass of *Monad*. Besides God, Leibniz also posits a class hierarchy of created monads: spirits are types of souls, which are types of bare monads (M 18, 19, 29). For us, spirits are simply human egos. We treat bare monads as the sensations perceived by such egos. Every monad is the dominant monad of some set of subordinate monads (M 70); thus the world has a recursive, hierarchical structure (M 64-69). Each monad has an instance variable *subordinates* which is the set of its subordinate monads.

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[3]We cannot deal with the *Monadology's* theological aspects, such as the notion of the best of all possible worlds, nor with the more subtle psychological aspects.

[4]The abbreviation M denotes the *Monadology;* NE denotes *New Essays on Human Understanding* (Leibniz, 1981); G denotes *Die philosophischen Schriften von G. W. Leibniz* (Gerhardt, 1875-90).

For Leibniz, perception is an important relation (M14-19). Each monad percieves other monads, and perceives those in its own body most clearly (M 62); hence the body of a monad is a composite (M 2) of those sensible things it perceives. But these sensible things are not material things; they are phenomenal: the body of a monad is the totality of appearances it perceives (G II, 450; G III, 623; NE, 146; NE, 374-375; Jolley, 1986). A Leibnizian analysis of the body of a monad is a phenomenalist analysis of appearance. To assist us in carrying out this analysis, we use an extremely simplified version of Carnap's *The Logical Structure of the World* (1967) and Goodman's *The Structure of Appearance*. (1951).

We distinguish between spirits, visible worlds, and sensations. Our model contains 4 spirits: m_1, m_2, m_3, m_4. Each spirit at each time perceives one of 16 visible worlds. Visible worlds are analogous to Carnap's elementary experiences. Each visible world has a body composed of four positions, each of which can be occupied exclusively by either a black or white sensation. These sensations are our bare monads. The architecture of our model is adumbrated in Figure 1.

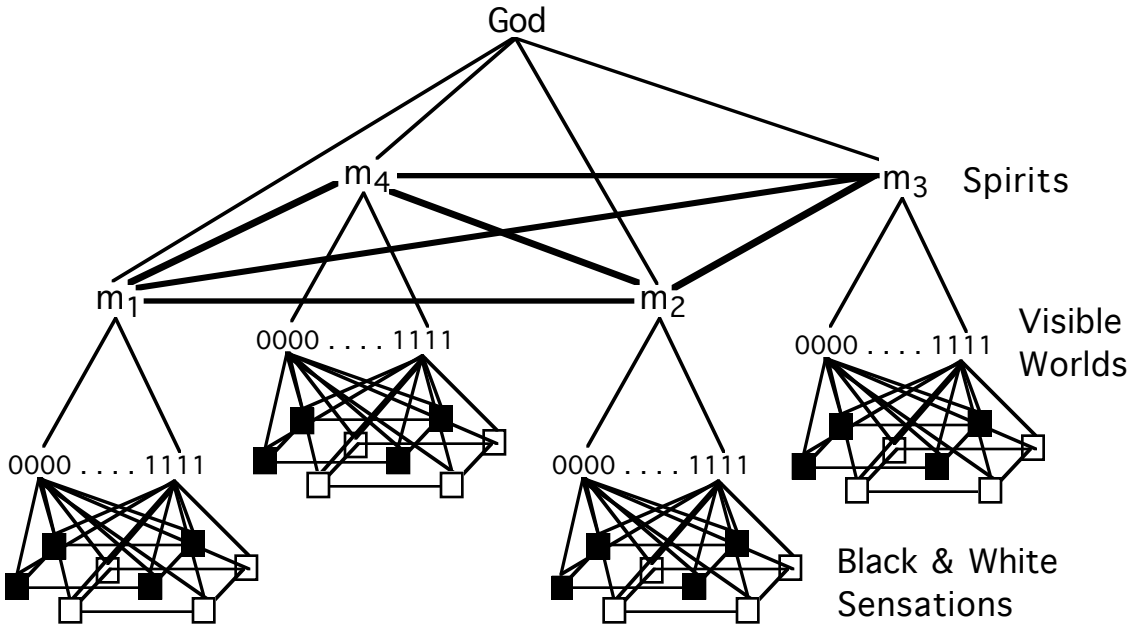


Figure 1. Rough architecture of the monadic hierarchy.

3.3 Visible Worlds as Patterns of Sensations

Each spirit in our model percieves something like a black and white TV screen, on which different patterns of sensations appear. These patterns are described by binary numbers: each position on the screen is numbered from 1 to 4; the i-th digit in a binary number is 0 if that position is occupied by a white sensation and 1 if by a black sensation. Each distinct pattern is a distinct visible world. Each of these visible worlds is composed of the same 4 black and 4 white sensations. Figure 2 shows the 16 visible worlds percievable by a spirit.

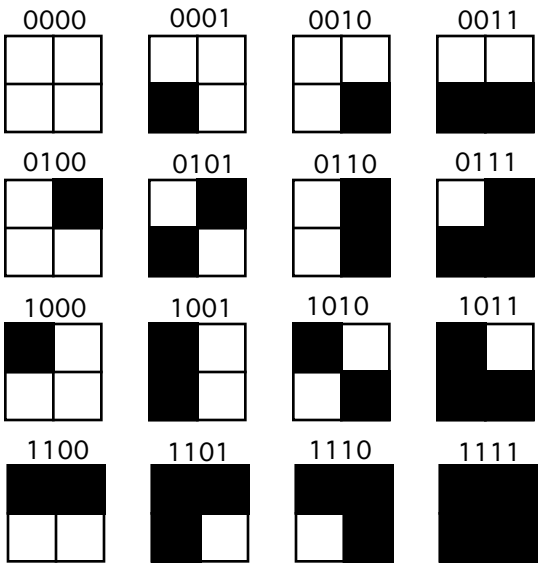


Figure 2. Visible worlds over a 2 by 2 visual field.

3.4 Relations of (In)compossibility

The Leibnizian cosmos is structured by relations of (in)compossibility (Loemker, 1074-77; to Bourguet [1714]). Two monads are compossible if both must be actualized together; they are incompossible if the actualization of one excludes that of the other. Since one spot can have only one color at one time, black and white sensations in the same position are incompossible. Lines terminated by balls in Figure 3 show the relations of incompossibility among black and white sensations; lines between sensations of the same color are successor and predecessor relations organizing these sensations into a spatial array.

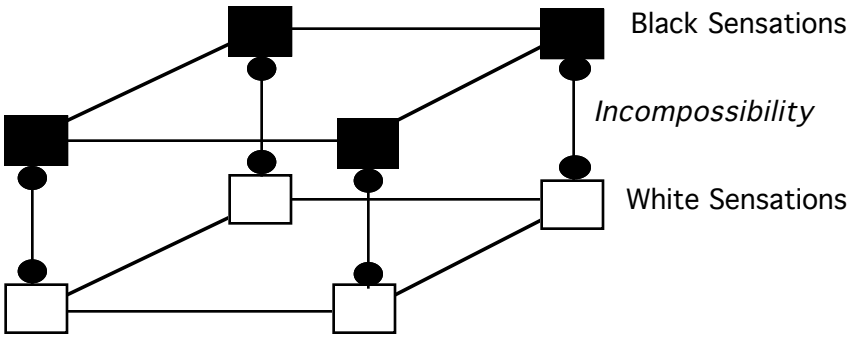


Figure 3. Relations among sensations.

Since only one visible world can be perceived at one time, all visible worlds in the body of a spirit are mutually incompossible. Each visible world is compossible with the sensations that occur in its body, and incompossible with those that do not. Figure 4 shows the relations of (in)-compossibility between the visible world 0101 and the sensations in its body. When we consider perspective, we will explain how each visible world in the body of a spirit is (in)compossible with those in the bodies of others.

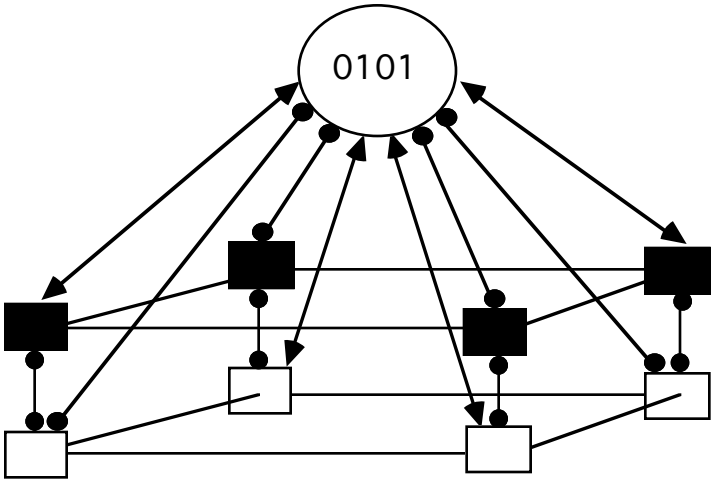


Figure 4. Relations of (in)compossibility between a visible world and the eight sensations in its monadic body.

3.5 Perspectives

Spirits take up different *perspectives* on the world (M 57); since the world is just other monads, each monad is like a *mirror* reflecting other mirrors (M 56). There are exactly four perspectives on a 4 by 4 grid; each perspective is adopted by one of the four spirits. The easiest way to see these perspectives is to think of each spirit as looking at a single, public 4 by 4 black and white grid. Figure 5 shows the four different perspectives on this grid. Since there are no perspectives besides the four shown in Figure 5, our model implements Leibniz's notion of a *plenum* (M 8, 61, 62). Figure 6 shows the visible worlds actually seen by the spirits in Figure 5.

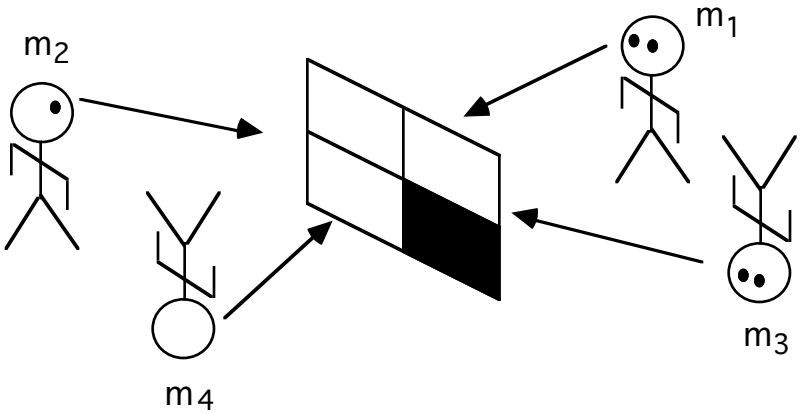


Figure 5. Spirits with 2 by 2 black & white visual fields.

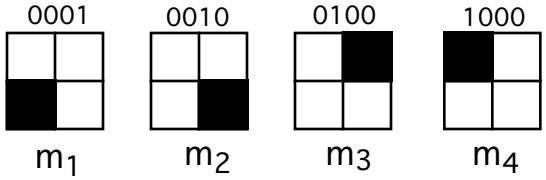
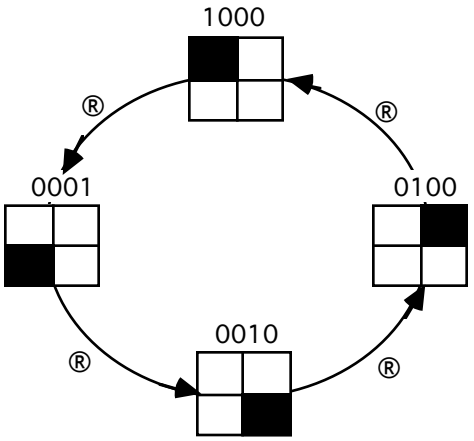


Figure 6. Visible worlds seen by the spirits in Figure 5.

Each different perspective in Figure 5 is a rotation by some multiple of 90 degrees of other perspectives. Figure 7 shows the rotations of the pattern 0001. It is easy to define a

rotation operator ® over the set of visible worlds W in the body of a spirit. Figure 8 defines the rotation operator.



0010 = ® 0001
0100 = ® 0010
1000 = ® 0100
0001 = ® 1000

Figure 7. The rotations of a visible world.

®: W → W	®: W → W
0000 → 0000	1000 → 0001
0001 → 0010	1001 → 0011
0010 → 0100	1010 → 0101
0011 → 0110	1011 → 0111
0100 → 1000	1100 → 1001
0101 → 1010	1101 → 1011
0110 → 1100	1110 → 1101
0111 → 1110	1111 → 1111

Figure 8. Definition of the rotation operator.

3.6 Apperception and Harmony

The visible worlds perceived by a spirit are distinguished as apperceived or not (M 20-24). If a monad appercieves a perception, it is conscious of the monad that perception represents. Apperceptions of spirits are harmonious (M 59, 78-80). Told that some spirit appercieves a particular visible world, we can determine the visible world that must be appercieved (to preserve harmony) by any other spirit using the rotation operator. Thus we define relations of (in)compossibility among the visible worlds in the bodies of spirits in terms of rotations. If $W_A(m, t)$ is the visible world percieved by monad m at time t, and if "≡" denotes compossibility, then we have $W_A(m_1, t) \equiv ®W_A(m_2, t) \equiv ® W_A(m_3, t) \equiv ® W_A(m_4,t)$. Two visible worlds in distinct spirits are incompossible if they are not compossible. If the visible worlds appercieved by all spirits at time t are compossible, then the apperceptions of the spirits are *harmonious*.

3.7 Algorithmic Description of the World-Process

Change in the Leibnizian cosmos is change in the apperceptions of monads (M 20-24). In our model, God always apperceives all spirits. If a spirit is appercieved by God, it is conscious; otherwise it is swooning. Thus all spirits are always conscious in our model. At any time, each spirit apperceives exactly one visible world. If a spirit appercieves a visible world, that visible world is conscious; otherwise, it is swooning. At each time, each spirit appercieves exactly one visible world. Each conscious visible world appercieves just those sensations that are compossible with it. If a visible world apperceives a sensation, that sensation is conscious; otherwise, it is swooning. If we let consciousness be denoted by an

activation of 1 and swooning by 0, we can describe the entire world sequence as a sequence of patterns of activations over all the monads in the world.

In our model, God and spirits are always conscious; we interpret God's "continual fulgurations" (M 47) as clock-ticks which drive the world-process. Only the activations of visible worlds and sensations change. The activations of sensations can be derived from the activations of visible worlds via relations of (in)compossiblity. So we are concerned only with the changes in the activations of visible worlds. Though each spirit could calculate which visible world it appercieves at any moment, we prefer to distribute this computation over the visible worlds themselves. Each visible world contains an *internal principle of change* (M 12). This *appetition* (M 15) is a transition function that determines its successor (i.e. the visible world that a spirit will appercieve next). The next visble world appercieved by a spirit is a function of the last visible world it appercieved (M 22); thus if F is the transition function, then $W_A(m,t) = F(W_A(m,t-1))$.

Spirits of the same species (e.g. human) each compute a token of the same type of transition function; these functions must be harmony-preserving. An obvious choice of a harmony-preserving transition function is just the rotation operator itself. Thus, $W_A(m,t) = ®W_A(m,t-1)$. The result is that each spirit appercieves a rotating pattern of sensations (i.e. it appercieves one visible world after another, much as in a movie, and the sequence seems to be a rotating pattern of sensations). Because the rotation operator itself is harmony-preserving, the changing patterns of sensations are coordinated across distinct spirits, so that at any time what the four spirits appercieve preserves their perspectives and consequently the harmony of the world.

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