A COMPUTER SCIENTIST'S PERSPECTIVE ON CHAOS AND MYSTERY

by Stuart A. Kurtz

Abstract. James E. Huchingson's *Pandemonium Tremendum* draws on a surprisingly fruitful analogy between metaphysics and thermodynamics, with the latter motivated through the more accessible language of communication theory. In Huchingson's model, God nurtures creation by the selective communication of bits of order that arise spontaneously in chaos.

Keywords: algorithmic information theory; communication theory; finite; James E. Huchingson; infinite; Maxwell's demon; thermodynamics.

James E. Huchingson's *Pandemonium Tremendum* constructs a distinctive and surprising model of God based on scripture, philosophy, theology, and communication theory. Communication theory? Huchingson defends a seemingly odd choice by invoking the desirability of a starting point that is grounded in the culture of time: "Questions about God, creation, sin, and salvation best find expression when articulated faithfully within the experience of a historical period" (2001, 24).

To this end, Huchingson identifies in the ongoing cultural and intellectual revolution based on computers the distinctive characteristic of our times. He argues that computers are novel objects that transcend the traditional categories of tools, machines, and automata and that from their radical newness has emerged an information era discontinuously different from the preceding, modern era of the Protestant Reformation, the Scientific Revolution, and the Renaissance.

This is all well and good—but a bit misleading. Huchingson's model has more to do with thermodynamics than computing, and communication

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theory serves his purposes by providing a familiar language in which he can introduce unfamiliar concepts. For the purposes of this review, we largely dispense with the veil of communication theory and deal directly with the metaphor behind the veil.

Let us start with a standard example from thermodynamics. You can cool a cup of hot coffee by adding a bit of cold water or ice. Stirring it hastens the process, but it isn't necessary. But what if you want, instead, to separate a cup of tepid water into its hot and cold components? You can't unstir the water, separating it thereby into hot and cold. Instead, you must expend energy, for example by pouring the water into two cups and putting one in the icebox and the other in the microwave oven. Even so, this is cheating, because the water is not truly separated into hot and cold but rather into two equally tepid cups, with energy then expended to impose either heat or cold onto the tepid water. Thermodynamics explains this everyday situation. The original state of the system (a cup of hot coffee and a bit of ice) is more highly ordered than the ending state (tepid coffee). Systems progress spontaneously from more-ordered to less-ordered states. But systems cannot move from less-ordered to more-ordered states without the expenditure of energy.

The cup of tepid water consists of many, many molecules of water, and these vary in energy (that is, temperature). Suppose we were not allowed to cheat by using energy. Instead, let's suppose that we could somehow sort the molecules into two cups, putting the faster (more energetic, or hotter) molecules into one cup and the slower molecules into another. In this case one cup would be hotter than the other, although the temperature difference might not be so large as before we mixed them. Even so, random collisions will redistribute the energy among the molecules in each cup, and soon there will be a few molecules in the hot cup that are colder than tepid and likewise a few molecules in the cold cup that are hotter than tepid. This suggests that repeating the process of separating the molecules of hot and cold water into separate cups would result in a greater difference of temperature (and it would) and that by repeating this process enough times we could successfully recover hot and cold water from tepid water. This sorting process seems not to require energy, and physicists have named the hypothetical agent who could do this sorting "Maxwell's demon." The "Maxwell's" part is to honor the physicist who thought of this, and the "demon" part reflects the discomfiture of physicists over not being able to rule out the existence of an agent able to evade laws otherwise thought to be universal.

Maxwell's demon gains its advantage because disorder contains variation. A disordered system will contain little bits and pieces of order that arise spontaneously and are destroyed equally spontaneously. The demon accomplishes his magic by selectively choosing little bits of order that serve his purposes and placing them where he wants them before they can be destroyed.

Huchingson's model contains three entities: chaos, creation, and God. Chaos is infinite, containing unlimited potential but unconstrained direction. It reflects no history and imposes no future. Being both limitless and maximally disordered, local bits of order arise and are destroyed spontaneously. God observes chaos and selects from it bits of order out of which to assemble and sustain creation according to divine purposes.

The analogical map is direct: the disordered cup of tepid water maps to chaos, the organized system of cups of hot and cold water maps to creation, and finally Maxwell's demon maps to God.

This is not how we are accustomed to thinking about God, yet Huchingson notes with pregnant purpose that Genesis portrays God creating an ordered creation by acts of separation—the waters above from the waters below, light from darkness. In effect, the poetic vision of creation is elevated not merely to contingent historical truth (this is the way it happened to happen) but to necessary truth (it could not have happened any other way). And this is exactly the way Maxwell's demon creates order from disorder.

Perhaps the most striking feature of Huchingson's approach is his vision of the primordial chaos, the Pandemonium Tremendum of the title of his book. Chaos is neither evil nor good. As water to a garden, the admission of chaos into ordered creation follows the Goldilocks principle: too little chaos, and creation stagnates and dies; too much chaos, and order is destroyed. The richness of human existence as we experience it depends on variety and commonality. If we were all philosopher kings, none of us would eat. Yet without a shared society, without a nearly universal understanding that the other has rights that limit our own, we would have anarchy, and the last person standing would merely be the last one to die. And so it is with all creation.

I now step out of the shadows and talk about how Huchingson both delights and frustrates me, a computer scientist trained as a mathematician. I am delighted by the creative surprise of Huchingson's model: Who would have thought that a creative and useful understanding of God could be built upon a paradox of thermodynamics, and even more surprising, that God would be placed in analogy with a demon? Who could have dreamed that this sophisticated analogy based on statistical physics could allow a literal reading of Genesis? Who could have imagined a model in which chaos is the foundation of creative variation in the world? Huchingson did—and we enjoy the benefits.

I am delighted that Huchingson's model is fully reconciled to an evolutionary understanding of biology. Evolution functions much like Maxwell's demon does, preferring the most fit individuals of a varying population. Huchingson identifies in this variety the creative aspect of chaos and celebrates it as a part of God's plan. He writes, "The human body, including the brain, is a stratified historical record of the negotiations made over billions of years by the multitude of kybernetai inhabiting the earth" (2001, 182). This is a refreshing change from most of the theologizing I see, which takes a formally agnostic position on issues such as evolution in public contexts where scientists are present but often takes an unreconstructed creationist position in venues where no scientists are present to contradict it.

I was delighted by the little lemma, "If love is an essential ingredient of divine life, creation is necessary" (p. 187). I was bothered, however, by Huchingson's use of communication theory, in which he established a metaphor between the terminology of communication theory and his model of God but then essentially ignored the actual technical content of that theory. Claude Shannon defined such conditions as noise, entropy, and communication, in particular, in order to state and prove a couple of very specific theorems: (1) that any communication channel has a finite bandwidth and (2) that codes exist that enable one to obtain essentially error-free transmission at any speed less than the limiting bandwidth. Shannon's first theorem is theologically inconvenient in that limits on the channel bandwidth would, metaphorically, be limits on God's ability to act in the world. It is difficult to conceive of any analogical counterpart to Shannon's second theorem. Thus, although Huchingson uses the language of communication theory to describe and motivate a particular model of God, it cannot truly be said that he establishes an analogy. This connection seems superficial, but it is emphasized in the text and dominates its early chapters.

The mapping of thermodynamic concepts to his model is far more successful in that more than just words are involved. In the thermodynamic case, the concept of Maxwell's demon rests on but is not a part of the base lexicon, and this transfers over to the theological model in a very satisfying way. This connection seems deep, but it is hidden until the latest possible moment.

I was frustrated by Huchingson's frequent use of the words *finite* and *infinite*. To a mathematician these words have technical meaning. If I am to judge the theological understanding of these words from Huchingson's use, *finite* means "within the realm of potential creaturely understanding," and *infinite* means "outside the realm of potential creaturely understanding." The mathematician's uses of these words are not consistent with the theologian's uses, and I find that the mathematician's uses are more insightful and possibly more fruitful as a source of theological inspiration. Let me develop the mathematical side, briefly and informally.

The natural numbers are the familiar counting numbers: 0, 1, 2, and so on. A set is finite if we can associate with every element of the set a unique natural number, all below some common bound. Thus, the set of all American workers is finite (because in principle each is assigned a unique Social Security number), but the set of all natural numbers is not finite, it is infinite.

Huchingson writes, "God is beyond words, and finally beyond ideas, because being infinite, the divine boundlessness would be compromised by any association with the finite, creaturely world. . . . Words and concepts that work well in ordinary conditions fail miserably and even result in falsehood and distortion when applied to the infinite" (p. 97). The latter sentence is not entirely false, because mathematicians have in fact learned that careless application of words and concepts associated with finite sets can result in paradoxes when extended to the infinite. The thing is, though, that mathematicians have learned to be careful about their use of words and concepts and routinely reason about infinities. Indeed, the job description of a set theorist is essentially to be someone who uses finite languages to reason about infinities.

For the mathematician, there is not just one infinity, there are infinitely many. There are more real numbers (measurement numbers, like 2.567) than counting numbers (like 7). And there are delightful surprises: an infinite set can contain the same number of elements as a proper subset of itself. For example, there are just as many even natural numbers (0, 2, 4, etc.) as there are natural numbers (0, 1, 2, etc.).

For the mathematician, there is no greatest infinity. For Huchingson, all infinities are the same. The variation that Huchingson loves in creation can be found in the mathematician's infinities but not in his own.

I found myself very frustrated by Huchingson's brief discussion of algorithmic information theory, and for several reasons. Algorithmic information theory formally ties the notion of computability to information theory and so seems like a particularly fruitful source of analogies upon which to construct models of God.

The first reason has to do with scholarship. The principal inventor of algorithmic information theory was the Russian mathematician A. N. Kolmogorov, and the measure of complexity that theory defines is usually called Kolmogorov complexity. Gregory Chaitin, another significant figure in the history of algorithmic information theory, has the unfortunate habit of presenting "cleaned-up" versions of the history of the subject that fail to acknowledge Kolmogorov's priority and instead present himself as the sole originator of the foundational concepts of algorithmic information theory. In this case the failure of scholarship is not Huchingson's, it is Chaitin's, but it is to be regretted that Huchingson's brief account of the field reflects only Chaitin's revisionist history and terminology.

A second reason for frustration is that Huchingson seems unaware of a particularly fruitful creative extension of algorithmic information theory: Charles Bennett's theory of logical depth. To describe Bennett's contribution, I'll have to develop a bit of algorithmic information theory.

For a computer scientist, a *string* is a finite sequence of characters. For example, *aabba* is a string of length 5, containing the characters *a, a, b, b,* and *a* in that order. Algorithmic information theory is based on the notion that not all strings of a given length have the same information content. For example, the Declaration of Independence contains 8,150 characters (at least as transcribed by the National Archives and counted by my Macintosh computer). This document contains much more information, intuitively, than a string of 8,150 *a*'s. To formalize this: The information content of a string is defined as the length of the shortest program that produces that string. It turns out that (within reason) the particular choice of programming language does not affect the development of the theory. In one commonly used programming language (Python), we can produce a simple program that produces a string of 8,150 *a*'s: "print 8150 * 'a'". This program has length 16. No program this short can produce the full text of the Declaration of Independence, at least so far as I know.

The connection with communication complexity is through compression. Using program length as a measure of information theory amounts to using an optimal compression algorithm—a fact that Kolmogorov proved. From the algorithmic information theory point of view, strings with relatively low Kolmogorov complexity are uninteresting, whereas strings with relatively high Kolmogorov complexity are the most interesting. Bennett makes the point that random strings have maximal Kolmogorov complexity (this is in fact the definition of randomness), and as a practical matter we learn very little by having a random string communicated to us.

So, what communications are actually useful? Bennett notes that Kolmogorov's theory is nonconstructive in important ways. There is no computational means for establishing the Kolmogorov complexity of a string, only ways to give upper bounds (such as by demonstrating a program that prints the string in question). The issue is that, with at most a small number of exceptions, we never know that the program we have generated is minimal. His point is that it is often very useful to know that a long string has a short description—for example, when Tycho Brahe's observations of the positions of the planets were explained by Johannes Kepler's laws of planetary motion. In Bennett's theory, finding a short description for a long string is tantamount to "understanding." Communication, ideally, is a means of increasing our understanding, and therefore the most interesting communications have low Kolmogorov complexity, but for deep algorithmic reasons. These strings of short length and high complexity seem to fit nicely within Huchingson's worldview, as they combine in essential ways order (short description length) and variety (deep computational time).

Huchingson's *Pandemonium Tremendum* is interesting and challenging reading. I was impressed by the breadth of his vision and scholarship, and many of his examples and insights commanded immediate reflection and reevaluation of long-held beliefs. This is a strikingly creative book and one that holds the power to surprise deep into its final chapters. I will be very interested to see how these ideas develop.

Reference

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