Magic

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"Any sufficiently advanced technology is indistinguishable from magic"
Arthur C. Clarke
Profiles of the Future

For the purposes of this essay we will assume an obverse version of Clarke's insight. "If a technology is not magical it is insufficiently advanced." Computing and software development are clearly not magical even though some applications, especially in cinema special effects, certainly convey magical impressions.

The central question of this essay – can we use magic as a metaphor to re-evaluate and redefine the theory and practice of computing? Or, stated slightly differently, can magic provide a metaphor for opening a new frontier in the investigation and solution of the core problems confronted by software developers and computing professionals in today's world?

Along the way to answering this question we will explore, for just a bit, the appeal of the metaphor and make two side trips to examine potential insights from other disciplines.

The Appeal of Magic

Magic is not a new metaphor for computing. Adept practitioners have long been referred to as 'wizards." In 1981, Vernor Vinge published a novella, *True Names*, using magic as a key metaphor. Twenty years later, Vinge wrote about why magic seemed so appropriate for his fictional account of networked computing in a place he called "The Other Plane" but which today most people call cyberspace.

> *"…. Even in serious commercial programming, the magic metaphors are very common, partly as humor, partly because they provide useful terminology to hang reasoning on. … So the magical terminology fit with some things that go on in real programming. … The magic metaphor was a powerful guide in the choosing of terms …"* (Frenkel 2001, pp 18-20)

Vinge's work resonated with numerous computer scientists, both at the time it was first published and today. Marvin Minsky wrote an afterword that accompanied the first publication and he was joined by the likes of Pattie Maes, Danny Hillis, and Richard Stallman in writing essays about the influence of *True Names* in the world of computing.

The use of magical metaphor in True Names is mostly at the human-computer interface.

> *"Protected now against traceback, Mr. Slippery set out for the Coven itself. He quickly picked up the trail, but this was never an easy trip, for the SIG members had no interest in being bothered by the unskilled.*

In particular, the traveler must be able to take advantage of subtle sensor indications, and see in them the environment originally imagined by the SIG. The correct path had the aspect of a narrow row of stones cutting through a gray-greenish swamp. The air was cold but very moist. Weird, towering plants dripped audibly onto the faintly iridescent water and the broad lilies. The subconscious knew what the stones represented, handled the chaining of routines from one information net to another, but it was the conscious mind of the skilled traveler that must make the decisions that could lead to the gates of the Coven, or the symbolic 'death' of a dump back to the real world.

There was much misinformation and misunderstanding about the Portals. Oh, responsible databases like the LA Times and the CBS News made it clear that there was nothing supernatural about them or the Other Plane, that the magical jargon was at best a romantic convenience and at worst obscurantism.

A typical Portal link was around fifty thousand baud, far narrower than even a flat video channel. Mr. Slippery could feel the damp seeping through his leather boots, could feel the sweat starting on his skin even in the cold air, but this was the response of Mr. Slippery's imagination and subconscious to the cues that were actually being presented through the Portal's electrodes. The interpretation could not be arbitrary or he would be dumped back to reality and would never find the Coven; to the traveler on the Other Plane, the detail was there as long as the cues were there. And there is nothing new about this situation. Even a poor writer - if he has a sympathetic reader and an engaging plot - can evoke complete internal imagery with a few dozen words of description. The difference now is that the imagery has interactive significance, just as sensations in the real world do. Ultimately, the magic jargon was perhaps the closest fit in the vocabulary of millennium Man." (Frenkel 2001, pp. 251-252)

Although interface issues are critical, and although HCI designers have yet to apply all the insights available in True Names and subsequent science fiction works like William Gibson's *Neuromancer* and Neal Stephenson's *Diamond Age*; this essay is more concerned with looking at magic as a metaphor to redefine the very essence of computing itself.

To accomplish the main goal we need a better understanding of what is meant by magic and what referents we want to associate with the metaphor when we apply it to the world of computing. Then we need a basis (a theory or at least an ideational framework) for applying the metaphor. For the first we will turn briefly to anthropological framings of magic and for the second a superficial examination of one aspect of Hindu philosophy.

Magical Essentials

A belief in the supernatural is a cultural universal - all cultures of which we are aware, even prehistoric ones exhibit some kind of belief in forces or spirits that transcend the material world. It is useful to make a relatively clear distinction between a belief in "forces" and in "spirits." Spirits usually have qualities like bodily form, personality, predictable responses to human beings, etc.

Supernatural forces, on the other hand, usually have no will of their own and cannot refuse humans who know how to invoke, command, and manipulate them. Forces, can be used for 'good' or for 'bad,' by humans who know the proper rites and spells - i.e. who know magic.

The popular conception of magic incorporates both spirits and forces. Readers of J. K. Rowlings popular "Harry Potter" novels confront spells that affect forces and inanimate objects as well as a

collection of supernatural creatures ranging from house elves to 'veela.' As entertaining as such things might be, we will confine ourselves to the realm of forces and leave Hagrid to be responsible for the care of magical creatures.

In 1890, Sir James Frazer proposed two logical principles or assumptions common to all forms of magic: the imitative principle (like causes like), and the contagious principle (contact based). A "voodoo" doll is an example of imitative magic. Spells performed on hairs, nail clippings, jewelry, associated with the target of the spell are examples of contagious magic.

Rituals are organized performances of behaviors intended to influence or manipulate supernatural forces. Rituals are stereotyped - the same behaviors in the same order, the same speech patterns, the same places, the same language, the same objects of magical manipulation. Rituals may be as simple as a single word (uttered in exactly the correct way and at the correct time in the correct place, addressed to the correct object); or, they may involve a cast of thousands, be extra-ordinarily complex and take many days to complete. Rituals range in their intended outcome from manipulations intended to invoke an immediate result, to those that have no direct result, but merely re-establish balances or harmonies among natural and supernatural forces.

From this exceptionally brief examination of the anthropological notion of magic we extract the following ideas that we will apply to computing later in the essay.

- Users of magical things invoke responses that are intrinsic to the magical object, they do not concern themselves with the nature of the force (what the Polynesians called *mana*) that enables the magical thing to respond. (Reminiscent of objects and black-box design, but stricter in its application - there is no "inside" of a magical thing like there is of a black-box or object.)
- All interaction between users and magical objects is of the form, stimulus-response. The stimulus is the ritual, the response the action of the invoked force (hopefully the desired outcome of the invocation). If the ritual was faulty there is no response or an undesired response. (Superficially similar to message passing, if messages are restricted to unary imperatives.)
- User interface design will conform to limitations derived from the two principles of magical invocation - contagion and imitation.
- Magical objects are limited to a specific set of responses. You must find the correct spirit and use the correct incantation if you want a result. But, this limitation is also, at least partially, a benefit - providing a way to categorize ritual-object-response triads in order to form 'indices' that will allow us to find the one we need. (Again, some surface similarity to ideas of classes and class hierarchies but only in terms of taxonomic organization and classification - not inheritance.)

Metaphysics for Magicians

Vedic (Hindu) philosophers posited an ethereal dualism - separate realms of pure "mind" (*purusa*) and pure inert matter (*prakrti*). Some kind of cosmic accident caused the two realms to infuse one another giving rise to the phenomenological universe of which we find ourselves. Fundamental tenets of Hinduism and Buddhism - reincarnation, enlightenment, Karma, among others - are grounded in this basic metaphysics.

A corollary of this philosophy is the assertion that every bit of *prakrti* - from subatomic particles to complex organisms - has some measure of *purusa* associated with it. *Purusa* establishes the combined entity's nature, its characteristics, and its behavioral possibilities. For example, an electron knows how to orbit (I am using the Bohr metaphor for atomic structure with full awareness that it is inaccurate. But it is illustrative in its own right) a nucleus because the entangled bit of *purusa* both knows how to do so and wills to do so. Although rare, it is possible for an electron to "act incorrectly" and thereby incur karmic consequences.

In more complex entities, especially biological organisms and very especially in human beings, the quantitative accumulation of purusa yields far more interesting behavioral possibilities. (Also greater potential for attached action and accumulation of karma.)

This kind of philosophy is not unique to Hindu and Buddhist cultures. Resonant ideas can be found in many cultures and philosophical traditions. Brigham Young, the colonizer and first Governor of Utah, advanced a very similar philosophy of matter infused with "intelligence." (As far as I am aware, without any contact with Hinduism.)

Christopher Alexander (of software engineering and, later, patterns fame) espouses parallel ideas in his newest works on the Nature of Order. His vocabulary uses "Life" instead of intelligence or purusa but, for him, Life infuses everything to one degree or another, the lesser the degree the lesser the "Quality Without A Name" and the greater the 'ugliness' of the construct.

The fact that purusa infuses all matter, at all levels - quantum to sentient, is justification for using a single invocation method (simple signals) regardless of the apparent complexity of the magical entity that is the target of the invocation. In fact, the apparent complexity of an entity (a human being, perhaps) is exactly that - apparent. Metaphysically speaking, nothing exists except Purusa and Prakrti so all invocations to apparent "purusa-prakrti" constructs are illusory.

Stimuli - intoning the Aum sound for example - utilize the imitative principle of magic to generate a single, simple, stimulus directed to the unary Purusa of an apparently complex entity (a human being). If the stimulus is correct, all the 'purusa' in the target attunes itself (vibrates sympathetically) with the stimulus resulting in a response of self-recognizing-Self.

Tantric sexual ritual (a kind of contagious magic) uses juxtaposition, physical contact, as the stimulus mechanism. Because the male and female entities involved in the ritual appear to be complex constructs a lot of simultaneous juxtapositions are required - but the ritual is nothing more than an aggregate of simple stimuli.

The relevance of this philosophy to our goal of seeking an alternative approach to computing is threefold:

- It adds a dimension of respectability and elaborates extensively on the simpler magical concepts of animism. The extensive exploration of the basic idea of *purusa* infused *prakrti* and how to interact with *purusa* is a fertile field for secondary metaphors within the umbrella of the Magic metaphor.
- It sets a constraint on how we conceive of "computing." Specifically, "computations" can be nothing more than the juxtaposed responses of an amalgamation of stimulated "purusa-prakrti-entities."
- Similarly, apparently complex stimuli (polyphonic instead of monotonic chants, yoga postures, Tantric sexual congress) must be simple aggregations of signal-stimuli.

Some development of the third point is in order. Purusa is akin to a "magical force" in that it has no "inside" - no intrinsic nature or structure. (Some Vedic philosophers might argue this point, but such esoterica is not relevant to our purposes here.) Purusa has nothing in common with our typical conception of a computer program. We cannot, therefore, think of magic in terms of a command line invocation of a stored and compiled program where that program can be arbitrarily complex in its function. We must think instead along the lines of stimulus and response mechanisms and conceive of programming only in terms of assembling an appropriate set of signals addressed to an appropriate set of forces resulting in an appropriate set of responses that, collectively, have the apparent structure of the ultimately desired result.

A variety of alternative illustrations of this stimulus-response concept are available to us. Consider but one, sympathetic vibration - a sound inducing a response in a properly constructed medium. Within the context of magic, an example might be the intonation of the Aum in an attempt to create a tonal stimulus that will resonate with the basic "frequency of the Universe" and therefore invoke a kind of harmony with that Universe. There is nothing programmatic about a tone and any resulting sympathetic vibration.

The constraint might be seen as overly restrictive - mandating creation of only the most basic and simple atomic responders or components. This is not the case. Complicated and multi-part stimuli are possible and are needful for many types of invocation. But the construction of these stimuli is not based on anything analogous to modular program design. Instead, they are analogous to music - the creation of a chord, or the polyphonic chants of Tibetan monks. Others are based on juxtaposition, like a sequence of notes, harmonies, or a well-turned poetic phrase. In all cases, the invocation has an evocative nature only - there is no element of representation, of computation or calculation, or of declaration (as understood in Lisp or Prolog programming). In all cases the response is reflexive with almost no element of reflection. (Some element of reflection does exist - hence the possibility of Karma, which requires willful action - but this subtlety is not essential to the main discussion at hand.)

Our discussion of magic and Vedic philosophy yields five points that will be revisited in our discussion of software development as "magic." In summary form, they are:

1. Users of magical things invoke/evoke responses that are intrinsic to the magical object.

2. All interaction between users and magical objects is of the form, stimulus-response.

3. Magical objects are limited to a specific set of responses.

4. Basic stimulus-response is completely dependent on the intrinsic nature of object being stimulated.

5. Arbitrarily complex responses can be evoked with comparably complex stimuli and that on both sides of the invocation, all apparent complexity results from juxtaposition (spatial or temporal) and not hierarchical decomposition.

At this point we have a metaphor and a philosophical position that can be used to support that metaphor. Before we can discuss application we need one additional element - a possible physical substrate to which we can apply the metaphor. For this last foundational piece, we will briefly examine current research in nano-technology - the concept of "Smart Matter."

Smart matter: bridging the mundane and the magical

> "*Smart Matter is one of Xerox PARC's three cross-laboratory research themes. Smart Matter aims to exploit trends of miniaturization and integration of both computer hardware and micro-mechanical systems to build new kinds of machines. The idea is to trade computation (which is getting cheaper very fast) for physical or mechanical complexity. Some of its tenets are:*
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> - *Trading off computational and physical resources.*
> - *Integrating sensing, actuation, and computation at fine granularity.*
> - *Co-locating mechanical, computational, and electronic functions.*
> - *Building systems with complex behavior from many simple pieces.*
>
> *As a research area, Smart Matter explores the "white spaces" among a wide range of disciplines: distributed computing, active control, robotics, software engineering, wireless communication, low-power electronics, smart materials, and MEMS.*"
>
> John Gilbert, Principal Scientist
> Xerox PARC

Xerox PARC (now PARC, Inc.) started the smart matter project at a fairly gross level of matter - a perforated board large enough to support a sheet of paper in need of alignment. At each hole in the board a jet of air could be used to create a force to align a sheet of paper. Also at each jet: a sensor to detect if the paper was above the jet. The sensors and jets were coupled to a computing device that digested the sensor input and output instructions to the jets to exhale, or not.

Subsequent and future efforts focused (will focus) on moving the computation closer to the sensor-jet dyads, perhaps with an analog of a neural net like connectivity so that the computation will be distributed across, and be a function of, multiple dyads.

A question asked by scientists engaged in this project, "how low (small) can you go?" At least one researcher anticipates nanometer scale smart matter. The nanytes of science fiction might very well be a commercial product, indispensable to your children and grandchildren.

Most of the research in the area of smart matter seems to make a basic assumption about the nature of computing in this type of environment. That assumption: essentially a replication at smaller and smaller scales of the typical computing environment in the macro-world. Specifically, creating small (perhaps special purpose) embedded computers communicating with each other via wired and wireless networks. Software for these environments would likely be familiar to any programmer of desktop and palm type applications and certainly to any embedded systems programmer.

In *Diamond Age: A young woman's primer*, Neal Stephenson writes of a world where the economy is based on nano-technology. Taking a cue from researches associated with Drexler, Stephenson assumes that nanytes will possess on-board mechanical (nanometer scale rods and springs) computers. A lot could be accomplished with this kind nano-scale device, but even more might be possible if we rethought how computing might (should) be accomplished in a radically new environment like a nanyte.

There is also an inherent limit to the scale at which you can still replicate anything like a computer and communication network. You certainly could not have computation occur at the level of a single atom or elementary particle following the prevailing notions of computing. In all fairness, it probably is not necessary to seek even nano-level computing. (And many people at PARC doubt it is possible.) However, a different approach to thinking about computing might make even gross scale smart matter simpler (and therefore much cheaper) at the same time it enables continued reduction in the scale of smart matter devices.

Smart matter research is exciting, not because it offers new insights into the possible nature of computing, but because it can create an environment - a kind of ultimate ubiquitous computing - that might be exploited by a new approach to computing arising from another area - or metaphor, like magic.

Smart matter provides a potential medium for applying the magic metaphor - one that is consistent with the Vedic metaphysics used to extend that metaphor. We are not ready to introduce some presuppositions or "first principles" that will provide a framework, or 'theory,' upon which a discipline of magical computing can be based.

A Theory of Magic

One principle, four premises, and three corollaries comprise, at present, a theoretical framework or foundation for magical computing. Additions to this foundation are likely (if anyone is captivated enough by the metaphor to explore it in more depth) but the elements presented here must be considered as a mandatory set. Consistency and conformity to these elements - in their entirety - is prerequisite to making any claim to be a "magical software technology."

Principle One: Ward Cunningham's, "The simplest thing that could possibly work." William of Occam proposed a very similar principle as a tool for deciding among competing theories. Ward's formulation is better suited to dynamic decision-making. Whenever we confront alternatives - theoretical or applied - we will opt for the simplest choice possible. This will become particularly relevant when we work on "casting spells" (programming) and we are confronted with temptations to introduce complications in order to achieve "flexibility" or "compatibility." Adherence to Principle One mandates resistance to such temptations.

Premise one: Intelligence (purusa / spirit / life / computing) can be distributed across the entire spectrum of potential platforms, from atoms to von Neumann architecture computers to human beings if, and only if, two conditions are met:

One, the same mechanisms and principles apply at all levels, micro to macro, and that mechanism is simple stimulus – response. Stimuli and responses are simple signals, no information content (remember principle one). This does not mean that a stimulus or a response cannot have complicated form. It merely means that, however complicated, stimuli and responses are never anything other than aggregations of stimuli juxtaposed in space or time.

For example: It is easy to think of a single tone as a signal with no content. It is tempting, however to see an orchestral performance as being somehow qualitatively different. Obviously it is not. A performance is nothing more than a collection of single tones juxtaposed in time (simultaneous or sequential) and, to a lesser degree, space - origin points

are arranged in a prescribed manner. The purpose of the amalgam of notes is the evocation of a response in the listener(s).

Two, responses are totally dependent on local resources – the entity receiving the stimulus can respond only on the basis of its own state, its own intrinsic nature. You cannot coerce a magical entity to respond differently than its nature allows by passing arguments (signals only, remember). A magical entity cannot supercede its own nature by collaborating with other entities. No magical entity is dependent (especially in the sense of dependency familiar to modular software developers) upon any other magical entity.

The purpose of these restrictions is easier to see when one thinks of computing at the level of a single atom, but seem unnecessarily restrictive at macro levels. For the moment, the only rebuttal arguments are: Ward's first principle; and, "we are looking to redefine computing, not merely rehash some aspect of that discipline."

Corollary one: Representation – one of the two Cartesian (Rationalist) foundations for computation as we currently understand it – is not our friend! Neither stimuli nor responses 'represent' anything – they just are. Again, this is easier to see at a micro-level but much harder at, say, a human level where we like to believe that we are symbol processors in addition to being subject to stimulus-response behavioral patterns. Whatever the case of humans might actually be (an there are reasons to believe that stimulus-response plays a far larger role in cognition that most are willing to believe) – magical computing will be restricted to the evocative, not denotative, realm.

Corollary two: stimulus-response is as simple as computing based on binary logic without being as simplistic. Stimuli and responses can be arbitrarily complicated but remain non-parsable, hence without losing their status as signals. (Parsing, in this context, means you cannot decompose a complicated signal into components with differing semantic meaning. A complicated signal can be separated into discrete simple signals but that separation provides no additional meaning, since it is the combined signal that is the stimulus that is required to invoke a response.)

This gives us a much more varied and interesting set of 'building blocks' from which to construct computation without incurring any of the costs associated with Turing machines. (One example of such costs: in theory, it is possible to construct a representation of the universe as a string of 1s and 0s. Also theoretically, a program – itself a sting of 1s and 0s, could be constructed and applied to the first string to simulate the dynamics of the Universe. But, construction of either string and execution of the program – all would take longer time than the Universe itself has existed. Something more direct is required if we are to achieve magical computing.)

Corollary three: although much of the language of stimulus-response implies some kind of media-based exchange [like a flow (stimulus) of electronic voltage (medium) evoking a tone (response)] there are other categories of stimulus and response. Geometry, for example, can be a stimulus and a response – like the docking of molecules or biological organisms based strictly on the geometry of their structure. Stimuli and responses need not be in the same category in order to participate in any given stimulus-response construct. Consider the guitar chord where a given response is determined by three stimuli: length of string (geometric), tension (static-force), and stroke (dynamic-force) synthesized despite being of different categories.

Premise two: Intelligence (purusa / spirit / life / computing) implies "willful being-ness." Another way of stating this, "everything has a motive to exist and to participate in existence." This premise is primarily metaphoric. Whether or not it is literally true is irrelevant for our purposes. When we discuss design of magical entities and incantations (spells) we will want to use an anthropomorphic principle (as was the case in behavior driven objects) as a constraint on our thinking. Premise two is therefore a basis for mental discipline.

Premise three: complicated stimuli and complicated responses come about from the application of two mechanisms: synthesis and juxtaposition.

Synthesis is the seamless integration of multiple stimuli (or responses) into one. Perhaps the best example is a chord that produces a single tone (response) via the simultaneous application of three stimuli – tension, length, and stroke – to a single entity (a guitar string perhaps).

Synthesis is important because it allows us to create intermediaries - magical entities that respond to stimuli by producing an output that we can use as a stimulus to some other magical entity.

Juxtaposition is nothing more than the congruence of stimuli and responses in terms of space and/or time. A chord is an example of synthesis because the stimuli are integrated to evoke a specific single response. The sound of an orchestra at a discrete interval of time is the result of juxtaposition of discrete notes produced during that interval. A musical phrase is an example of juxtaposition in that its overall evocative power (its ability to function as a stimulus) results from the sequencing of discrete stimuli over a time interval.

A special case of juxtaposition would be the combination of two or more magical entities in order to modify the responses of one or both the conjoined entities. Juxtaposing a volume of water and a container (a jug perhaps) changes the "value" of the response evoked by the passage of air over the mouth of the container. (Of course, it is important to juxtapose the inner surface of the container with the volume of water rather than the outer surface if the desired result is to be achieved.)

Synthesis and juxtaposition provide a means to achieve complicated structure without the concomitant implication that such structures can be pre-determined or "engineered." The success of a musical phrase, the ability of a chord to evoke a response is not determinable except via experimentation and after-the-fact analysis.

Premise four: It is possible for multiple entities to instantiate systems of cooperation and coordination (via juxtaposition and synthesis), but control is both infeasible and undesirable. It is also possible for an environment to provide coordination and enhance cooperation by existing as a patterned or persistent 'stimuli zone."

An example of absence-of-control cooperation would be the "structural coupling" described by Maturana and Varela in their "new biology" based on autopoiesis.

An example of environment-based coordination would be a magnetic field that provides a consistent and persistent stimulus to which iron atoms respond by changing their spatial orientation. "Field" type environments could be as simple as magnetic fields or as *outré* as

Rupert Sheldrake's morphogenetic fields, or as complicated as David Bohm's and Karl Pribram's quantum and holographic fields, respectively.

Practical Magic

At this point we have a metaphor, "magic," a kind of theory or explanation of how to think about magic, and a substrate or physical platform, nanotech, which can be "enchanted." We can also summarize the main points discussed so far:

- Magic is an evocative process – a kind of stimulus-response mechanism. A "spell" is the evocative stimulus.
- The ability of an "enchanted" object to respond to stimulus is not algorithmic or programmatic in nature.
- Enchanted objects can have complicated structure, as can spells, but that structure reflects nothing more than the juxtaposition of responses, or stimuli, in space and/or time. Synthesis – juxtaposition that results a qualitatively different thing (like hydrogen and oxygen juxtaposed in a specific way to create water) – is a possible consequence of juxtaposition.
- Enchanted objects are totally and absolutely autonomous. Even when aggregated or synthesized, there is no organization and there is emphatically no control of one object by another.
- Enchanted objects can cooperate with each other by a process of autopoietic organization based on the exchange of stimuli and responses. (Maturana's and Varela's *Tree of Life: a New Science of Biology* provides insights into how this simple mechanism can generate complex cooperative communities of objects.)
- 'Fields,' analogous to magnetic fields can result from the aggregate responses of a collection of enchanted objects (the atoms in a copper winding) to a common stimulus (application of an electrical current) and such fields can provide a common stimulus to a collection of enchanted objects.

The value of any new metaphor derives from its utility. Utility can arise from some kind of implementation – a new language, library, or artifact, for example – or, as in this case, by suggesting some concrete topics for further exploration. If such explorations prove to be fruitful in any kind of pragmatic manner then the metaphor is a good one. Some research topics:

1. Is there a finite and enumerable set of "primitive" enchanted objects from which everything else comes into existence via juxtaposition and synthesis? Remember that everything in the Universe results from the juxtaposition and synthesis of a finite and pretty small number of elements. (Or a still smaller number of fundamental particles, or a smaller yet number of quanta.)
2. Is there a way for these primitive enchanted objects to interact with each other with resulting complicated (perhaps complex) macro-objects whose enchantment is qualitatively different from the enchantments of any individual primitive? Autopoiesis and biology suggest the answer is yes. Using the magic metaphor as a lens for exploring biological metaphors of computing will likely yield quite different results than current efforts to frame computing in biological terms or biology in computational terms.
3. Can we devise a "science" of enchanted object juxtaposition and synthesis? The goals of such a science would be to create new and useful enchanted objects capable of providing a response desirable for human beings. Such a science would be much more analogous to

chemistry and the culinary arts than it our current understanding of computational science.

4. Can we discover patterns in the autopoietic organization of enchanted objects that would offer insights and shortcuts to support our new science of juxtaposition and synthesis. It seems likely given the work of researchers as diverse as D'Arcy Thompson and Christopher Alexander.
5. To what extent can geometry provide a formalism in support of our science of juxtaposition the way that algebra, logic, and various calculi have provided for contemporary computer science.
6. Can we think of user interfaces in terms of "amulets" – magical objects that exist primarily to translate stimuli created by humans into stimuli that can evoke behavior in magical objects? An analog for this kind of translation – the way that rubbing the rim of a crystal bowl (an stimulus that a human can provide) evokes a tonal response that is beyond the capability of a human voice to produce directly.
7. How would be go about enchanting ordinary objects (doors for example) so that they would respond to simple incantations like, "open sesame?" (Perhaps, by juxtaposing a thin layer of magical objects that reverse some kind of polarity in response to the sound vibrations of our voice.)
8. Can we think about "demons" (somewhat similar to those found haunting operating systems) as a special kind of mediator between humans and the magical world? A demon would be capable of responding to a simple, human generated stimulus, by finding other magical objects and uttering appropriate incantations to them on our behalf. Demons would be a magical way to encapsulate our current understanding of algorithmic computing in the sense that a program is just the juxtaposition of a set of discrete imperatives (spells).
9. Can we devise an enchanted world where everyone can create the auditory or kinesthetic stimuli that evoke appropriate everyday responses in support of human activities? Wizards would be specialists that had memorized more complex spells necessary to evoke sophisticated and special purpose responses from that world. Shamans would be the most advanced magical practitioners – capable of creating as well as manipulating magical objects.

Conclusion

"Papers in the Onward! Track are not aimed at advancing the state of the art - they're aimed, instead, at altering or redefining the art by proposing a leap forward - or sideways - for computing."

Hopefully this paper provides some ideas curious enough and sufficiently 'sideways' that they will magically evoke more and better ideas completely outside the framework provided by contemporary computer science and software development paradigms.