Symmetry: Art and Science
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THE FORM OF LOGIC, THE LOGIC OF FORM: KUTACHI

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Abstract: *The intersection between mathematics and art has captured the imagination of many; it underlies the energy that keeps ISIS-S going. We propose one area of interdisciplinary study across math and science, inspired by the Society. The goal is to provide a usable visualization system for a next generation of intelligent, computerized systems. Doing so properly will require a true interdisciplinary collaboration among a variety of disciplines, very much in the spirit of ISIS-S.*

This paper starts with the general idea that there is great value in seriously studying art and mathematics together in terms of form and logic. Then in Part 2, we propose an activity as an online project to host a focused interdisciplinary collaboration. Finally in Part 3 one specific approach within this project is suggested, something we call *kutachi*.

1 THE BIG IDEA, SOME INSPIRATIONS

Early in my career, I was privileged to get advice from Eugene Wigner. At the time, I was working on some difficult problems that seemed to me well beyond my capabilities. It was already well known in my community that any problem seems difficult if you approach it with the wrong abstractions. The challenge is not to hammer away at the problem with old tools, but to gently work with the problem to let it advise you of its nature so that you can meet it on its own terms.

“But how?“ a young investigator under pressure would ask.

Wigner’s advice was obvious in hindsight; good advice always is. He suggested that early in my intellectual life I find a set of abstractions through which to think about the nature of abstractions. In other words, what I needed was a way of knowing when I was starting to get close to seeing the problem the way it wanted to be seen. The meta tools I was to develop and reuse were to evaluate what the right tool for a job was.

In Wigner’s case, those metatools were based on symmetry. If the way he was thinking of a problem had elegant symmetry then it was more promising than if it did not. That is not to say that *more* symmetry or more perfect balance is better. This notion of elegance is what matters. When you go to report your insights to colleagues, it has to be correct of course but what matters is how elegant it is. Wigner had the ability to evaluate the elegance of the symmetry in the abstractions used against a problem space.

He was fascinated by the dynamics of these metatools and wrote a provocative paper on the subject; the speculation still is controversial. Quite apart from whether the theory a scientist works on is invented or discovered, he speculated that the metatools were invented. In this, he followed squarely in the camp of Hilbert who had himself written something similar about the utility of thinking (he said “imagining”) in geometric terms. A shorthand for this was claiming that the world was inherently geometric.

Great wars broke out in the scientific (primarily physics) worlds, dividing those whose metatools were based on symmetry or some other notion of form or geometry, and those who were not. Einstein, von Neumann, Oppenheimer, Gödel, and Feynman joined Wigner and Hilbert in this belief. Nobel prizes were doled out in careful balance between the two camps.

“Symmetry” in that case occupied a zone between mathematical principles and the tendency for us to think of natural things in terms of form. That is to say that it bridges the math-art divide. It allows us to extend our reasoning of form into the most primitive and trustworthy parts of our brain, the limbic region. That part of the brain is shared among all higher animals and is where our best notions of beauty and rightness come from. The evidence is that protohumans were reasoning in this way for dozens of millions of years, and that a gesture language directly evolved from the limbic brain existed for one or two million of those years. Only 100,000 or possibly 25,000 years ago did speech appear (allowing Cro-Magnon Man to eliminate his competitors).

I have come to believe that if we wanted to build metatools based on elegance and beauty, the likely candidates are symmetry and form. Over the years, I have affirmed this, beyond the fact that it works for me. The first ISIS-S Congress had many amazing speakers, but one, Nicholas Toth, presented the archeological evidence for a language of symmetry that predates speech by orders of magnitude.

In the second ISIS-S Congress, I encountered Kodi Husimi, arguably the most brilliant Asian physicist of his time. He showed me how constant exercise with origami, and considering and stretching the rules of origami in his mind informed all of his advances in physics. (In an endearing sidenote, all this folding was done with his wife as a deep intuitive sharing. They wrote on this together. There is a relevant tradition of Shinto prayer knots.)

At the third Congress, Yuval Ne'eman gave an impassioned talk, by some measures the talk of a lifetime. He made an impassioned plea for us to invest in the conceptual tools of form. The future of not only science depends on it, he averred, but all problems in the world that required clean thinking and collaborative agreement.

The fourth international Congress was when I first became aware of the Katachi Society. This is a Japanese society whose name translates as "the Society for Science on Form." The society consists of scientists who believe that a better understanding of the laws of form and how they work across sciences will make them better scientists. There are deep cultural traditions that advise this view and the work.

Wigner, Ne'eman and Husimi were all patrons of ISIS-S, believing in the promise of some results deeper than occasional gatherings. The Katachi Society has long and deep association with ISIS-S. It is in that spirit that we propose a project here.

2 THE FORM OF LOGIC, THE LOGIC OF FORM

My work is in the area of what is often called artificial intelligence. The biggest challenge of that field is how to model reality as we experience and think of it. This includes the easy stuff: all the laws of the world and the more difficult stuff: how we relate and feel. How we dream and love. What we fear and do about it. It is a daunting challenge, one that has successfully eluded us, hundreds of thousands of us for fifty years now.

My belief is that the metatools for this will also be based on symmetry and form, and bridge formal systems and human art, most centrally in the areas of *narrative*. I propose here a project to create these tools, metatools.

In the computer world, the mathematical formalisms used are captured in "logic," which can be seen as a humanization of mathematics. Logic is supposed to model the way we think, whether rationally or not. The basic abstractions in logic are concepts and how we understand them. The basic problem in humanizing computers is the challenge of devising new logics and logical tools.

As it happens, in the last two decades the world of possibilities for new logics has exploded because of the work of imaginative mathematicians. That is the good news. We now have the chance to build things that are more human. The bad news is that we have little idea how to use the new tools or even which tools to select. We need metatools;

the range of possibilities has grown so fast and become so powerful that our ability to formally find good options must be based on intuition.

Our general proposal is we that take advantage of the fact that logic is already a potential bridge between human experience and mathematical formalisms. Practically speaking, it is on the cusp of the art and science divide mentioned in the charter of ISIS-S. If we can make some headway in this area, significant benefit could accrue in many fields. It is just the sort of interdisciplinary project envisioned by the founding sponsors of the society.

What would the *form of logic* look like? Well, that is the key; it is all about what you would see. Today, if you look at raw logic as written on a page, you will see something rather incomprehensible. There is no way to bring intuition to this; if you have the decades of training required to read this notation naturally, you likely have had all the intuition bled out of you.

If we were successful in this project, you might be able to look at different shapes that are associated with a complex argument and judge certain qualities about it. Depending on the forms you see, you might know something about the truth or correctness of the reasoning, about directness and cleanliness — about elegance. You might know something about the situations, attitudes and beings involved.

There are already some ways of getting logical statements into visual representations; many, most of them begin with drawing graphs with lines and nodes. Our project proposes a different approach. Some ISIS-S members have developed or explored visualization techniques that go in the other direction. They can be thought as studies in bringing order to space, bringing a “logic” to “form.”

A great many ISIS-S members work in this area. One of the most exciting things about the members is the array of approaches. Members work in the “logic” of knots, tiles, sponges, dance, architecture, textiles, literature, calligraphy, music, painting, foams, bubbles, and natural formations like trees shells clouds and mountains. We presume in this project that the relationship between formal order and visualization from that work can be “flipped,” providing an immediate way of visualizing mathematical and logical systems.

For example, many members are developing different ways of characterizing the laws of dividing space in space frames, tessellations, minimal surfaces, historical buildings and so on even to the level of ornaments and building plans. These are clever linkages between visual things and formal expressions. It is entirely conceivable that some of these experts can use their skills to work the other way. For example, the knot theory used to understand Islamic patterns has a direct connection to the theories that underlay logic. There is a distinct possibility that knots can be used as a visualization language

for some elements of logic without much extension to the work done in "the other direction."

Because the natural mathematics of symmetry is group theory, we find many members using group theoretic formalisms in their studies of architecture and crystals for example. A probable task within the project will be to show how the insights from group theory apply to logical expressions.

We expect that the project will begin via web-enabled technologies and migrate to more formal projects, some of them funded. Web infrastructure has been established for this.

3 ONE APPROACH: KUTACHI

We are committed to managing this project, and helping with the logistics and seeking of sponsorship. We also have a specific approach within the larger project that we will be exploring. We expect to have the significant involvement of Japanese members of the society who also are sensitive to the philosophy of the Katachi society. While the larger project is "Form of Logic, the Logic of Form," our special thrust is something we call "kutachi."

Our starting point makes several assumptions.

On the logic side, we have created a system that is friendly to this problem. It is based on something called *situation theory*. Mathematical logicians, primarily based at Stanford, developed this as a way of making logic "softer," meaning more like the way we really think. A way of supporting this new logic is by developing the mathematics that builds a separate but integrated logic just for the meta-tools area.

While this system of logic has been around for some time, we have been the first to actually implement it in a way that works on a computer. The implementation leverages the extraction of topology from the logic. That topology informs the metalogic, the very stuff we want to visualize. So it is no surprise that our approach to this project relies on this extended, more human-friendly approach to logic.

We call our implementation *topoiesis*.

Somewhat independent from topoiesis, we sponsored a series of workshops on something we call *semantic distance*. Simply stated, this is a collection of techniques that can translate semantic qualities to spatial ones.

Combined, topoiesis and semantic distance gives us a way to project whole worlds from logical models to spatial ones. We can make what we have available to others, but the "form of logic" project is open to anyone with any workable notion of logic or mathematical models.

We have ideas on the visualization side that we want to implement in animated three dimensional displays that allow *haptic* manipulation. (Haptics is based on special gloves that allow you to reach into the virtual objects and handle them as if they were physical.)

Our idea is to base the visualization on the intuitive metaphor of ink flows through fluid media. Narrative progression is denoted by the flow from left to right. The shape of the flows, branching, vortices, texture, color, scintillation and so on would all have some metatool quality.

We would have the flows conform directly to the laws of physics, but have the fluids inherit their characteristics from the properties of the story or logical statements. We envision that viewers would not have many specific rules for kutachi evaluation. Users would have to learn from masters. This is why we need to include culturally-informed masters.

The kutachi mode is the "read-only" mode. A complementary mode we call *kunji*, where an expert could write in a new set of ink-flow characters. As with Japanese kanji, the calligraphic nature will be significant. But these would be colored, three-dimensional, animated, morphing characters, designed on kutachi principles.

Our contributions are expected to heavily favor developments in film narrative as indicators to cognitive structures.

We intend to host the *Form of Logic, Logic of Form* project on

http://www.kutachi.com

http://kutachi.symmetry-us.com

http://www.sirius-beta.com/Kutachi.html

References

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