Meeting 0: Paradoxes

Philosophy of Computation at Berkeley
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1   Computation and Information

To start talking about computation, we need to know what computation *does*. The boy kicks *the ball*; the wind carries *the seeds*; so what does computation *act upon*? The answer: information.[1] Here is an adapted excerpt from *The Information: A History, A Theory, A Flood*, an excellent introduction to the topic:

> *The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have meaning.*
>
> – Claude Shannon (1948)

> By 1948 more than 125 million conversations passed daily through the Bell System's 138 million miles of cable and 31 million telephone sets. But what, exactly, did the Bell System carry, counted in what units? Not *conversations*, surely; nor *words*, nor certainly *characters*. Perhaps it was just electricity...
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> A few engineers, especially in the telephone labs, began speaking of *information*. They used the word in a way suggesting something technical: quantity of information, or measure of information...
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> An invention profound and fundamental came in a title both simple and grand – "A Mathematical Theory of Communication" – and the message was hard to summarize. But it was a fulcrum around which the world began to turn. The *bit* now joined the inch, the pound, the quart, and the minute as a determinate quantity – a fundamental unit of measure.
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> But measuring what? "A unit for measuring information," Shannon wrote, as though there were such a thing, measurable and quantifiable, as information...
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> For the purposes of science, *information* had to mean something special. Three centuries earlier, the new discipline of physics could not proceed until Isaac Newton appropriated words that were ancient and vague – *force*, *mass*, *motion*, and even *time* – and gave them new meanings. Newton made these terms into quantities, suitable for use in mathematical formulas... It was the same with information. A rite of purification became necessary. And then, when it was made simple, distilled, counted in bits, information was found to be everywhere... It led to compact discs and fax machines, computers and cyberspace, Moore's law and all of the world's Silicon Alleys. Information processing was born, along with information storage and information retrieval. People began to name a successor to the Iron Age and the Steam Age. "Man the food-gatherer reappears incongruously as information-gatherer," remarked Marshall McLuhan in 1967.
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> We can see now that information is what our world runs on: the blood and the fuel, the vital principle. It pervades the sciences from top to bottom, transforming very branch of knowledge. Information theory began as a bridge from mathematics to electrical engineering and from there

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[1] A paradox, already: information is computation is information; the object of computation can simultaneously become the subject of the computation. But I'm getting ahead of myself.

to computing. What English speakers call "computer science" Europeans have known as *informatique*, *informatica*, and *Informatik*. Now even biology has become an information science, a subject of messages, instructions, and code. Genes encapsulate information and enable procedures for reading it in and writing it out. Life spreads by networking. The body itself is an information processor. Memory resides not just in brains but in every cell. No wonder genetics bloomed along with information theory. DNA is the quintessential information molecule, the most advanced message processor at the cellular level – an alphabet and a code, 6 billion bits to form a human being. "What lies at the heart of every living thing is not fire, not warm breath, not a 'spark of life,'" declares the evolutionary theorist Richard Dawkins. "It is information, words, instructions....If you want to understand life, don't think about vibrant, throbbing gels and oozes, think about information technology." Evolution itself embodies an ongoing exchange of information between organism and environment.

"The information circle becomes the unit of life," says Werner Leowenstein after thirty years spent studying intercellular communication. He reminds us that *information* means something deeper now: "It connotes a cosmic principle of organization and order, and it provides an exact measure of that." The gene has its cultural analog, too: the meme. In cultural evolution, a meme is a replicator and propagator – an idea, a fashion, a chain letter, or a conspiracy theory.

Money is completing a developmental arc from matter to bits, stored in computer memory and magnetic strips, world finance coursing through the global nervous system...

Increasingly, the physicists and the information theorists are one and the same...

As scientists finally come to understand information, they wonder whether it may be primary: more fundamental than matter itself. They suggest that the bit is the irreducible kernel and that information forms the very core of existence. John Archibald Wheeler, the last surviving collaborator of both Einstein and Bohr, put this manifesto in oracular monosyllables: "It from Bit." Information gives rise to "every it – every particle, every field of force, even the spacetime continuum itself."... The laws of physics are algorithms. Every burning star, every silent nebula, every particle leaving its ghostly trace in a cloud chamber is an information processor...

In the long run, history is the story of information becoming aware of itself.

Some ideas of discussion:

- What is intuitively meant by information and how does this differ from what is formally meant by information (if at all)?

- "Shitposting is powerful and meme magic is real" is a sentence that has been uttered by a very rich man who donated a lot of money to help Donald Trump get elected[2]. Based on this and ideas in the above excerpt, devise a startup with a focus on memes to earn millions of dollars while also contributing to social good, by spreading *good* memes, not *bad* memes.

- Do you think UCBMFET is a conscious organism?

- When one says that "everything is information", it frequently has the reductionist connotation of "everything is *just* information". Is it necessarily reductionist to say that everything is information? Let's assume that our world, call it world A, may or may not be entirely information. If in world A' everything really *were* information, would there exist something intangibly valuable in A which does not exist in A'? Can you prove so?

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[2]https://www.theguardian.com/technology/2016/sep/23/oculus-rift-vr-palmer-luckey-trump-shitposts

2 Strange Loops

The undisputed bible in this scene is *Gödel, Escher, Bach* by Douglas Hofstadter. As the story goes, he graduated from Stanford with a math degree, came to Berkeley as a graduate student in math, got his hopes and dreams crushed, dropped out, went to Orgeon, traveled the country in a van for long stretches of time, and, sleeping on the grass one starry night, had an epiphany and wrote the 800-page tome. Eventually he got a doctorate in physics and now teaches at Indiana University in Bloomington.

There are probably few people more imaginative, radical, poignant, precise, and thought-provoking as Hofstadter. His most famous book is also widely misunderstood, because it is as much literature as it is science, and most of the points he wants to get across he hides behind coy metaphors. Frustrated, he wrote *I Am a Strange Loop* thirty years later, a book about the exact same topics except explicitly spelled out and much shorter at 300 pages. If you don't have the patience for Hofstadter's pile of musings, you may want to read that book instead. The point of *Gödel, Escher, Bach* is this notion of *Strange Loops*, and how the three thinkers – mathematician, musician, artist – independently interrogated this topic. Hofstadter's unyielding belief is that we *are* Strange Loops: "In the end, we self-perceiving, self-inventing, locked-in mirages are little miracles of self-reference."

But what *is* a Strange Loop? Here are some excerpts from the introduction to *Gödel, Escher, Bach*:

An Endlessly Rising Canon[3]

There is one canon in the Musical Offering which is particularly unusual. Labeled simply "Canon per Tonos", it has three voices. The uppermost voice sings a variant of the Royal Theme, while underneath it, two voices provide a canonic harmonization based on a second theme. The lower of this pair sings its theme in C minor (which is the key of the canon as a whole), and the upper of the pair sings the same theme displaced upwards in pitch by an interval of a fifth. What makes this canon different from any other, however, is that when it concludes-or, rather, seems to conclude-it is no longer in the key of C minor, but now is in D minor. Somehow Bach has contrived to modulate (change keys) right under the listener's nose. And it is so constructed that this "ending" ties smoothly onto the beginning again; thus one can repeat the process and return in the key of E, only to join again to the beginning. These successive modulations lead the ear to increasingly remote provinces of tonality, so that after several of them, one would expect to be hopelessly far away from the starting key. And yet magically, after exactly six such modulations, the original key of C minor has been restored! All the voices are exactly one octave higher than they were at the beginning, and here the piece may be broken off in a musically agreeable way. Such, one imagines, was Bach's intention; but Bach indubitably also relished the implication that this process could go on ad infinitum, which is perhaps why he wrote in the margin "As the modulation rises, so may the King's Glory." To emphasize its potentially infinite aspect, I like to call this the "Endlessly Rising Canon". In this canon, Bach has given us our first example of the notion of Strange Loops. The "Strange Loop" phenomenon occurs whenever, by moving upwards (or downwards) through the levels of some hierarchical system, we unexpectedly find ourselves right back where we started. (Here, the system is that of musical keys.) Sometimes I use the term Tangled Hierarchy to describe a system in which a Strange Loop occurs. As we go on, the theme of Strange Loops will recur again and again. Sometimes it will be hidden, other times it will be out in the open; sometimes it will be right side up, other times it will be upside down, or backwards. "Quaerendo invenietis" is my advice to the reader...

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[3]http://www.youtube.com/watch?v=nsgdZFIdmeo&t=0m52s
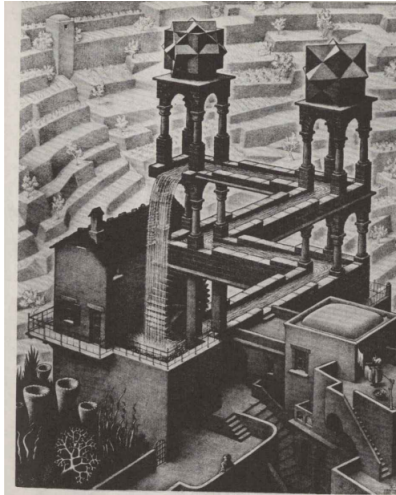
Escher

To my mind, the most beautiful and powerful visual realizations of this notion of Strange Loops exist in the work of the Dutch graphic artist M. C. Escher, who lived from 1902 to 1972. Escher was the creator of some of the most intellectually stimulating drawings of all time. Many of them have their origin in paradox, illusion, or double-meaning. Mathematicians were among the first admirers of Escher's drawings, and this is understandable because they often are based on mathematical principles of symmetry or pattern ... But there is much more to a typical Escher drawing than just symmetry or pattern; there is often an underlying idea, realized in artistic form. And in particular, the Strange Loop is one of the most recurrent themes in Escher's work. Look, for example, at the lithograph Waterfall, and compare its six-step endlessly falling loop with the six-step endlessly rising loop of the "Canon per Tonos".

Gödel

In the examples we have seen of Strange Loops by Bach and Escher, there is a conflict between the finite and the infinite, and hence a strong sense of paradox. Intuition senses that there is something mathematical involved here. And indeed in our own century a mathematical counterpart was discovered, with the most enormous repercussions. And, just as the Bach and Escher loops appeal to very simple and ancient intuitions-a musical scale, a staircase-so this discovery, by K. Gdel, of a Strange Loop in mathematical systems has its origins in simple and ancient intuitions.

In its absolutely barest form, Godel's discovery involves the translation of an ancient paradox in philosophy into mathematical terms. That paradox is the so-called Epimenides paradox, or liar paradox. Epimenides was a Cretan who made one immortal statement: "All Cretans are liars." A sharper version of the statement is simply "I am lying"; or, "This statement is false". It is that last version which I will usually mean when I speak of the Epimenides paradox. It is a statement which rudely violates the usually assumed dichotomy of statements into true and false, because if you tentatively think it is true, then it immediately backfires on you and makes you think it is false. But once you've decided it is false, a similar backfiring returns you to the idea that it must be true. Try it! The Epimenides paradox is a one-step Strange Loop, like Escher's Print Gallery. But how does it have to do with mathematics? That is what Godel discovered. His idea was to use mathematical reasoning in exploring mathematical reasoning itself. This notion of making mathematics "introspective" proved to be enormously powerful, and perhaps its richest implication was the one Godel found: Godel's Incompleteness Theorem.

- Consider the following: you see a sequence of black dots and white dots on a table, presumably placed by some person or some machine (or dog). Based on what you see, you want to predict what the next dot in the table will be: will it be black, or will it be white? How would you go on making such a prediction?

- Will it be easier to predict if a person, or a machine, or a dog placed the dots? A rat? A germ?

- Could it ever be the case that no matter what you do, you will *never* be able to predict with better than 50% probability what the next dot will be? If you think the sequence you are looking at embodies just such a case, how would you prove it?

3   Culture and Contradiction

Philosophy of Computation is a niche domain. Philosophy of Computational Culture is an even more niche domain, and unjustfiably so – it explores how infrastructure such as information, computation, and incompleteness could be used to explain different cultural ways of thinking. So our discussion today will end with a paper by professor Kaiping Peng, who taught here at Berkeley and at Peking and Tsinghua for over thirty years. His research, represented well in the paper, "Culture, Dialectics, and Reasoning about Contradiction" [4], begins with that pertinent topic – paradox – and describes how different cultures think about paradox using absolutely different strategies.

Consider the following statements about recent scientific discoveries:

Statement A. Two mathematicians have discovered that the activities of a butterfly in Beijing, China, noticeably affect the temperature in the San Francisco Bay Area.

Statement B. Two meteorologists have found that the activities of a local butterfly in the San Francisco Bay Area have nothing to do with temperature changes in the same San Francisco Bay Area.

What would be your intuitive reaction to these statements? Do you see an implicit contradiction between the two pieces of information? What strategy would you use to deal with such contradictions? What is the rationale for using such a strategy? Does your cultural background affect your reasoning and judgments about contradiction? If so, how?

Theoretically, there are four possible psychological responses to apparent contradiction. The first, and perhaps easiest, is not to deal with contradiction at all or to pretend that there is no contradiction, a psychological stance that could be labeled denial. A second approach is to distrust or discount both pieces of information because they seem to contradict each other, a stance that could be called discounting. However, both of these stances can be counternormative because the full set of information might have important implications for behavior. A third response involves comparing both items of information, then deciding that one is right and the other is wrong. Psychologists have found that in group decision making, people exposed to opposing propositions often increase their preference for the proposition they were inclined to believe initially and decrease their preference for the less favored proposition (for reviews, see Isenberg, 1986; Kaplan, 1987). Psychologists have also found that people sometimes change opinions to reduce the cognitive dissonance caused by two contradictory cognitions. Such polarizing strategies could be characterized as differentiation. Theoretically, however, a fourth response to contradiction is possible: A person might retain basic elements of the two opposing perspectives and believe that both perspectives might contain some truth, even at the risk of tolerating a contradiction. Such an approach would not regard the two statements about the association between the activities of a butterfly and temperature changes as a contradiction, but would rather attempt a reconciliation, with the result that both are believed to be true. This cognitive tendency toward acceptance of contradiction could be defined broadly as dialectical thinking.

Chinese ways of dealing with seeming contradictions result in a dialectical or compromise approachretaining basic elements of opposing perspectives by seeking a "middle way." On the other hand, European-American ways, deriving from a lay version of Aristotelian logic, result in a differentiation model that polarizes contradictory perspectives in an effort to determine which fact or position is correct. Five empirical studies showed that dialectical thinking is a form of folk wisdom in Chinese culture: Chinese participants preferred dialectical proverbs containing seeming contradictions more than did American participants. Chinese participants also preferred dialectical resolutions to social conflicts and preferred dialectical arguments over classical Western logical arguments. Furthermore, when 2 apparently contradictory propositions were presented, American participants polarized their views, and Chinese participants were moderately accepting of both propositions. Origins of these cultural differences and their implications for human reasoning in general are discussed.

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[4]https://culcog.berkeley.edu/Publications/1999AmPsy_DT.pdf