Systems Theory: Synchronicity, Indeterminacy and Doubt

DARLA LINDBERG
Pennsylvania State University

Synchronicity

The idea of systems presented here will be more like the theme in a canon or fugue. Douglas Hofstadter in *Godel, Escher, Bach: an Eternal Golden Braid* describes the musical canon as a puzzle game made popular in the day of Frederick the Great, King of Prussia. Johann Sebastian Bach wrote ten canons in the *Musical Offering* for King Frederick. The canon lends itself to this kind of system/puzzle because the theme is played against itself. The canon introduces its single theme along with some tricky hints and the canon theme is to be "discovered" by someone else. A round is a canon. "Three Blind Mice" and "Row, Row, Row Your Boat" are simple canons (Hofstadter, 1999). Canons use time (staggered copies) and pitch (harmonic when voices overlap) and complexity (to invert the original theme below the copy), yet all the information about the original theme is always recoverable from any of the copies. This kind of transformation is called an isomorphism and contributes significantly to our understanding of similarities in form, structure or correspondences in identity of systems.

A more complex musical puzzle is a fugue. The Tallis Scholars directed by Peter Phillips present "Spem in alium," a 40-voice motet (Gimell Records, 2001). The telltale sign of this fugue is the way it begins: a single voice sings the theme. When the first voice is done, it continues with a secondary theme while the second voice and then the third, the fourth, and so on, until full 40 voices, enter in harmony with some accompaniment of the *countersubject* in some other voice. You cannot compose a fugue by formula. When all 40 voices have arrived in "Spem in alium," the piece is magical, living well beyond its end because we have been introduced to an indeterminate "theme," not a song. The fanciful and generative accomplishment of the canon or fugue theme as a system is that it uses the countersubject to provide rhythmic, harmonic and melodic contrasts to the subject. Unlike a point/counterpoint deterministic system to expose difference, the canon and the fugue are opportunistic in their intent to align similarities. The system as theme is played against itself making diversity into harmonic sustainability.

Early work contributing to thinking about systems in this way can be traced to Ludwig von Bertalanffy (1901—1972), an important theoretical biologist researching comparative physiology, biophysics, cancer, psychology and philosophy of science. Working from a humanistic worldview, he developed a kinetic theory of stationary open systems (perhaps like the canon and the fugue) and a holistic epistemology keenly critical of the machine metaphor (deterministic if-then statements) for explaining existence. His main goal was to unite metabolism, growth, morphogenesis, and sense physiology in his research toward a methodology of science known as the General Systems Theory (GTS). Based on observations that organic systems progress towards a steady state, he reasoned that a non-equilibrium state was not only possible but that it actually created opportunities for the generative and systemic processes necessary for adaptation.

GTS represents a set of interrelated components - could be social, biological, situational - but existing in a complex spacetime relation to one another. The important point here is not that a relation exists but that the structural similarities for expression, metabolism and interacting, like the basic and fundamental processes of the human cell, are not lost in the transformation from one realm to the next. So, like the Human Genome Project with its long string of simple Ts, As, Cs and Gs, and like the isomorphism or the canon and the fugue, the basic theme is recoverable from one copy to the next. But if we are to learn anything from the HGP, the isomorphism or the canon and the fugue, we cannot be impressed with how simple things are but how complex they must become in order to produce life, meaning and beauty. Von Bertalanffy's work with GTS revealed these similarities exist even more importantly between living organisms and social systems. Institutions, economies, laws and mores regulate practice and frame values. They can be as destructive to human existence and the planet as any hurricane or biological pandemic. Based on these understanding one can then begin to imagine a similar approach to understanding the basic and fundamental processes critical to sustainability and natural systems design. Taking cues from the fugue, which aligns data thematically, this is made possible with technology. Complexity thinking depends on vast amounts of information made physically possible because of the advances available to us through search and knowledge aggregation technologies that allow co-evolutionary feedback, evolving probability, asset mapping, parallel processing and indeterminacy in the study of true complexity.

Ironically, in the early 1950s, when von Bertalanffy shifted his research from the biological sciences to his seminal work on the General Systems Theory, computers had already sparked our imaginations, and we believed that mechanized intelligence was just around the corner. A seeming paradox then becomes simply synchronicity. Computers are by their very nature the epitome of rational thought - far from the borderless characteristic of intelligent behavior and complexity thinking. Yet, logic is simply systems that factor in change or create rules for inventing new rules. So it is possible to imagine the computer and technology as a critical and interacting part of a paradigm shift essential to von Bertalanffy's work. Equipped to manage enough information, with rules about turning inflexible systems of thought into intelligent and flexible systems of being, complexity thinking is made possible because of technology. Values characteristic of vulnerable ecosystems are framed by the most comprehensive collection of data making significant biodiversity possible. Recalling the fugue, complexity thinking finds rhythmic, harmonic and melodic contrast in the informational possibility because of the technology made available to us in the voice of Modernism and enhanced by multiple harmonic voices to follow.

Indeterminacy

Marcel Proust puzzled over the self-satisfaction felt by "busy men" at not having time to do what they needed to do. Poets and musicians express the spectacular gaps in understanding created with the unexpected and hurtful behavior of another. Accountants and lovers might possibly agree the letter that needs to be written holds far more truth and affection than the letter that gets sent. De Botton wrote in his delightful *How Proust Can Change Your Life*, "Afraid of losing her, we forget all the others. Sure of keeping her, we compare her with those others whom at once we prefer to her." (de Botton, 1997). Similarly, Adam Smith set out to be a moralist but became an economist instead (Levitt and Dubner, 2005). Upon seeing how economic factors shaped the way a person thought or behaved it became apparent the incentives, the innocuous choice, and the friction between individual desire and societal norms were the more significant stuff of the modern moral life. In nature and society, systems of probability and indeterminacy are realistic. Many of life's most compelling puzzles are indeterminate, riddled with approximation, probability and chance. Stochastic systems become even more realistic as they apply chance to the structure of probability. Entries can be added, changed or removed in a stochastic system creating mutations. A Markov Chain is a stochastic system, a transition or transformation table made up of a matrix of probability. While it takes longer for a condition of probability to achieve equilibrium and even a final result of stability is uncertain, over time the behavior of the system can be analyzed and predicted statistically (e.g., a coin toss has a 50% probability of being heads and a 50% chance of being tails). Marchov Chains are a significant part of Game Theoretic analysis to consider choice and consequence. Metamorphosis is a stochastic mutation over time and influence. Larger systems increase variety and with it probability. World economies, natural resources, population dynamics, disease spread and ecological relationships are complicated and intricate legacies of the "what if?" of probability and chance. De Certeau's observation that "The imaginary landscape of an inquiry is not without value, even if it is without rigor...(I)t thus keeps before our eyes the structure of a social imagination in which the problem constantly takes different forms and begins anew" (de Certeau, 1988). For example a deeper look at the root causes of world hunger reveal a different problem - that of access to land and economical farming practices. And researchers show a high probability that the same industrial practices that force tens of millions of farmers off the land by growing primarily high-profit exports also creates a production model for crop acreage that contributes to a loss of biodiversity in the natural systems ecologies and species - fundamentally our first line of defense in disease-spread threats.

Fortunately, the brain is designed to work well with enormous amounts of synchronous information, probability and indeterminacy. A single channel can contain multiple messages without mutual interference. Multiple signals or sine waves can be bundled together and transmitted as one (often referred to as 'many-to-one') and then separated again at the receiving end. In brain terms, a single neuron can process not only one signal but also multiple complex ideas about the world presented to it at any one time. If a signal is too complex for one neuron, then like the canon and the fugue, the brain can distribute the signal among many neurons dealing with one (harmonic) feature of the signal.

C. E. Shannon's work on the signal-to-noise ratio intensified the interest in Information Theory. He believed that:

> "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; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one selected from a set of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design." (Shannon, 1948)

This was possible as a logarithmic function. Time, bandwidth and number of relays tend to vary logarithmically, doubling or squaring the possible messages with each addition. Likewise, the logarithm measures by linear comparison with common standards - $\log_{10}$ or X^2. So, a base 2 gives us resulting units called binary digits, *or bits*. If the base of 10 is used, the resulting units may be called decimal digits. Work like Shannon's contributed to the notion that systems consist of vast amounts of interrelated parts; engineering that problem means operating in terms that can be scalable and random. This is not the process of a determinate system.

Doubt

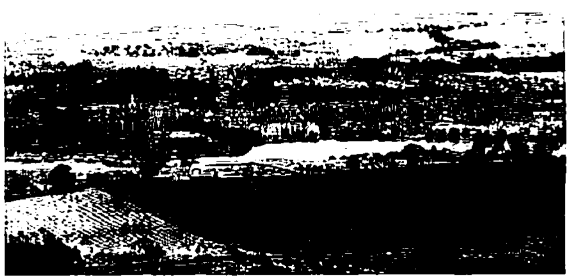
The crisis of culture and agriculture is an example that would benefit from complexity thinking as a visionary paradigm for sharing vast amounts of useful information from a wide range of wise people across increasingly porous borders. And it precedes any discussion of architecture, urban design, fabrication, and corresponding visionary sciences and economies. *Without a paradigm shift in how we approach the natural systems of living on the planet, any other vision veils reality.* Fundamentally, the cost and scope of maintaining biodiversity against increasing threats on local ecosystems by invading migratory species is global and enormous, in both ecological and economic terms. Alien invasive species result when the natural barriers of oceans, mountains, rivers and deserts lose their isolative quality essential for unique species and ecosystems to evolve. In just a few hundred years, these barriers have been rendered ineffective by the major global forces of tourism, globalization, and an emphasis on free trade. Global climate changes have also significantly assisted the spread and establishment of alien invasive species because increasing temperatures enable disease-carrying insects to extend their range beyond natural predators into new territories. Ecologist Andrew Kimbrell argues that:

> Our conversion from agrarian, local, fully integrated food systems to industrialized, monocultured agricultural production has brought a staggering number of negative side effects, many of them unanticipated. Throughout the entire food system, we can trace this crisis as it manifests itself in soil erosion, poisoned ground waters, food-borne illnesses, loss of biodiversity, inequitable social consequences, toxic chemicals in foods and fiber, loss of beauty, loss of species and wildlife habitat, and myriad other environmental and social problems. To make the crisis even worse, we continue to export this destructive industrial system of food production around the earth. (Kimbrell, 2002)

Critical information that could alert management agencies to the potential dangers of new species introductions is not shared. More likely, information sharing in an appropriate format for many countries and to appropriately trained staff keeps countries from taking prompt action. Complexity thinking on a subject like biodiversity is critical at three diversity levels: genetic, phenotypic and ecosystemic. Its importance supports both the value of its components to sustain flagship species including tigers, rhinos, bears, turtles, sharks, elephants and chiru and builds a first line of defense for disease threats to our existence. Without biodiversity, disease can sweep through a homogenous species or crop creating a world health pandemic. Void of complexity thinking about the larger systems at risk, blind emphasis on productivity and consistency standards (certified Grade AA eggs) breeds a poultry herd that is virtually the same animal. The current Avian Influenza spread from Turkey to Romania is more about a contiguous herd than poorly regulated agriculture. Complexity thinking provides a paradigm to include critical search and knowledge aggregation that would improve the capacity of governments to act responsibly to prevent the arrival of alien invasive species. This demands improved laws and greater management capacity, backed by quarantine and customs systems that are capable of identifying and intercepting alien invasive species in order to sustain an essential biodiversity.

To support a sustainable ecosystem, complexity thinking is predicated on the assumption that in order to be successful we need to be able to seek out and construct useful information about what Nature would require of us. That's a huge leap of faith emphasizing Nature's wisdom over human cleverness or disciplinary confidence. Faith in doubt, then, as Nature applies it, is the genome of diversity and interdisciplinarity. There are 'no guarantees in life,' and Nature understands that truism well by storing up reserves, recycling, hedging against circumstance and patiently waiting to exercise an option. The never-plowed native prairie features this kind of faith in its diversity of species, nearly all of which are perennial. Because their roots do not die as annual roots do, they hold soil through all seasons, even when drenched by rain. Moreover, perennial roots build soil as new roots form and others decompose. This ecosystem thus maintains its own health, runs on the sun's energy, and recycles nutrients, and at no expense to the planet or people.

In order to do this, four synchronous groups are featured: warm-season grasses, cool-season grasses, legumes, and composites. Other species are present, but these groups are featured. Different species fill different roles. Some thrive in dry years; others in wet ones. Some provide fertility by fixing atmospheric nitrogen. Some tolerate shade while others require direct sunlight. Some repel insect predators. Some do better on poor, rocky soils while others need rich, deep soil. Diversity provides the system with built-in resilience to changes and cycles in climate, water, insects and pests, grazers, and other natural disturbances.



Conclusion

The challenge is to feature species diversity and perennialism when we work to construct the theme for a natural system. We must work to have all four functional groups represented in our mixture or polyculture, and it must produce harvestable products for direct human use. Our primary strategy, then, is to understand the theme--the structure of the prairie ecosystem,--in order to model the functions described above. Properly designed, the system itself should virtually eliminate the ecological degradation characteristic of conventional till agriculture and minimize the need for human intervention.

This sounds idyllic, but is it possible? Researchers in the area of "natural systems agriculture" have proven the functions of a natural system can be achieved by replicating its structure or theme. The implications and potential impact of this work are global. By demonstrating underlying principles along with practical applications, "natural systems" approaches can be transferable worldwide. Since it is not a formula but a harmonic theme, developing species and mixtures of species appropriate to specific environments can contribute to co-evolutionary biodiversity, producing healthy and sustainable practices. With additional research, agriculture and an accompanying knowledge economy that is resilient, productive over the long-term, economical, ecologically responsible, and socially aligned is just within reach.

When we move away from till agriculture to put together several plant species in a rough structural analog of the prairie, that prairie we are imitating is a complex polyculture, similar to the fugue. In our domestic prairies, which would feature grain, the corn or wheat fields are no longer large acreages of a single crop (nor the urban place cut off from agriculture). The wheat field must have interactions with other crops we have chosen to ignore over the 10,000 years to develop industrial till agriculture. We need ways of thinking about agriculture, biodiversity and co-evolutionary systems that are as complex as necessary. Calling for a trust in "natural systems" as a sustainable ecology is the product of complexity thinking. The industrial or materials sector has no such discipline. As progress is made, we can begin to reconfigure human endeavors, knowledge engines, and all other building and living economies and cultures to Nature's image, letting her be our ultimate teacher.

James Gleick wrote, "Where Chaos begins, classical science stops. For as long as the world has had physicists inquiring into the laws of nature, it has suffered a special ignorance about disorder in the atmosphere, in the turbulent sea, in the fluctuations of wildlife populations, in the oscillations of the heart and the brain. The irregular side of nature, the discontinuous and erratic side - these have been puzzles to science, or worse, monstrosities." (Gleick, 1987)

References

De Botton, Alain. 1998. *How Proust Can Change Your Life*. New York: Vintage Books. 172.

De Certeau, Michel. 1988. *The Practice of Everyday Life*. Berkeley and Los Angeles: University of California Press. 41.

Gleick, James. 1987. *Chaos: Making a New Science.* New York: Penguin Books. 3.

Hofstadter, Douglas. 1999. *Godel, Escher, Bach: an Eternal Golden Braid.* New York: Basic Books. 8.

Kimbrell, Andrew, editor. *Fatal Harvest: the tragedy of industrial agriculture*. Sausalito: The Foundation for Deep Ecology by arrangement with Island Press. xi.

Levitt, Steven, and Stephen Dubner. 2005. *Freakonomics: a rogue economist explores the hidden side of everything*. New York: HarperCollins Books. 14-15.

Shannon, C. E. "A Mathematical Theory of Communications." Reprinted with corrections from *The Bell System Technical Journal.* Vol. 27, p. 1. July, October, 1948.

Smith, Steve and Peter Philllips, producers. 2001. *Thomas Tallis Spem In Alium*. Oxford, Merton College Chapel: Gimell Records.