The Evolution of Cultural Resilience and Complexity

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Abstract The study of memetics has thus far mostly applied a reductionist view of genetics to describe the pathogenic infectivity and transmission dynamics of ideas/memes. In this position paper, we take a first look at some of the distinctive attributes of cultural evolution through the lens of complexity science and theoretical biology. The article comments briefly on connections between memetics and complex biological systems. First, we describe some basic roles that self-organization and selective processes play in the integration of memes into personal mental constructs and the consequences this has on the complexity of these constructs (meme networks). Using the concept of an attractor landscape, we propose that the fitness of an idea may have consistent and predictable influences on attractor basin attributes for pre-existing mental constructs. We compare these ideas with findings reported on the evolution of attractor landscapes for gene regulatory networks and particularly, we consider whether insights from GRN studies can be translated into testable hypotheses on the evolution of cultural complexity. We also consider how the attractor landscape metaphor could facilitate a better understanding of how good ideas can paradoxically both reinforce existing beliefs yet also construct the very conditions that make new sets of beliefs possible.

1 Introduction

“Most of what is unusual about man can be summed up in one word: 'culture'…Cultural transmission is analogous to genetic transmission in that, although basically conservative, it can give rise to a form of evolution.”
– Dawkins, The Selfish Gene (Ch. 9)

Culture is an emergent property that must be viewed from a holistic perspective, i.e., as having both a micro level of interactive components (individuals with shared and divergent beliefs that are situated and interact within a social network), and a corresponding macro level (a self-organized society with persistent cultural artifacts that emerge through the integration of ideas and beliefs that propagate through a social network). This perspective allows us to formulate aspects of cultures that operate over distinct temporal and spatial scales into a tangible complex systems problem. A complex systems perspective of culture has been explored in our previous work, [4], through the development of a seven-dimensional model for describing culture and the stabilization of beliefs, and an agent-based simulation and visualization of cultural emergence in an organization. We introduced a method of understanding cultural emergence via social interaction, (meta-stable) equilibrium of ideas, and evolution of beliefs in a culture.

Cultural simulation models provide a useful tool for understanding the impact of culture on societal as well as inter and intra- organizational dynamics. In particular, modeling can be useful for understanding behavioural trends within a society or organization. It can also be useful for understanding the consequences of cultural alignments and in some cases can help to isolate and understand the causes of conflicts between cultural groups. While the limitations of models should be recognized and kept in mind when interpreting simulation results, such models enable the study of organizations within unique scenarios and varied organizational structures, norms, and environments that would not be possible to evaluate in the real world.

While culture modeling can be used to help understand the impact of human factors on organizational norms and policies, there are limitations to what can be achieved with models that focus solely on a social network. Social network models can be used to explore how a communication network influences certain facets of idea propagation, but it does not necessarily capture the equally important role played by the interpretation and integration of ideas within personal mental constructs, i.e. an individual’s interpretation network, [13]. Both types of networks are important to understanding cultural resilience, evolution, and complexity. Culture is a complex system that changes over time through both self-organized (emergent) and selective (evolved) forces making it difficult to understand cultural development using reductionist principles alone. Thus, non-reductionist multi-agent simulation models may provide a unique tool and opportunity for untangling complex relationships within cultures.

In this work we begin to explore biological parallels for understanding how replicable yet flexible/malleable ideas can influence the evolution of cultural complexity and resilience. We start with Dawkins' analogy of ideas as memes, or single units of cultural transmission (see Dawkins chapter in "The Selfish Gene", [3], for more). These 'idea memes' are replicators of a certain kind that, like genes in DNA, are dependent upon a network for their transmission. For instance, just as the expression of gene products can regulate the future expression of other genes, ideas similarly participate in forming complex mental constructs that regulate the expression of future ideas and thoughts. Furthermore, robust expression patterns emerge in both systems through the self-organization of activating and suppressing interactions amongst genes/memes. Here we begin to explore the possibility that a roughly analogous Memetic Regulation Network – a model for the dynamic construction of personal mental constructs – can provide a richer conceptual framework for understanding: (1) how ideas are accepted, modified, and integrated into a person's belief system, (2) how the requirements of meme survival within an individual's belief system influence the transmission and infectivity of ideas over longer periods of time across a social network and (3) how individual ideas can contribute to the evolution of complex cultures across a population.

Importantly, a memetic network conceptual framework may help to focus the study of ideas towards a computationally solid foundation where complex systems theories and dynamic systems theories may be employed to understand memes, their influences, and their effects on other memes and culture as a whole. Because of the numerous specific parallels that can be drawn between memes and genes, it is the view of these authors that advances in understanding genetic evolution and biological complexity can be translated into new hypotheses and systems principles for understanding challenging facets associated with the emergence and evolution of complex cultures.

The conceptual similarities between memes, genes and culture are substantial. However it is important to emphasize that this paper is concerned with conceptual similarities only and not the relationships of these topics in the real world. In particular, this paper does not address the actual influence that genetic selection has on behavioral traits, the influence that memetic evolution can have on genetic selection, or the influence that genetic evolution can have on culture.

Section 2 briefly reviews some of the literature regarding culture modeling, cultural evolution, social networks, biology and culture, attractors, and memes. Section 3 describes earlier work on the relationship between culture and genetics. Section 4 proposes an extension of regulation networks from genes to memes. Section 5 promotes the use of attractor landscapes for theorizing about changes to the thought processes of individuals. Section 6 highlights an example of how attractor landscapes might also be used to understand and predict cultural resilience. Section 7 concludes the paper.

2 Literature Summary

The literature pertaining to culture modeling is large, and covers research on social network modeling, agent based systems, norm-governed system dynamics, mathematical modeling, and multi-dimensional approaches as discussed in [4], [15], [16]. Cultures evolve, and an evolutionary framework has mostly thus far been employed to consider some of the philosophical underpinnings of cultural evolution, e.g. see [11], [10]. The relationship between culture and genetic evolution was first explored in great detail by Dawkins and Sharov, see [3], [13], and [14]. While research on gene regulatory networks is vast, it is rarely considered in the study of memetics. See [8], [1], [2], [6], and [7] as examples. Here we explore the possibility that new insights into the dynamics of GRN could be useful for understanding cognitive dynamics and macro-level changes in culture. We also suggest in this paper that complementary research on the relationships between resilience, evolution, and complexity in attractor landscapes may also provide useful guidance for the development of cultural theories [1], [14], [5], [12].

3 The Biological Analogy: Memes, Genes, and Culture

Before introducing the memetic regulatory network concept, we first present earlier work on a similar concept: the *interpretation system*. According to Sharov, [13], memes are mental codes which are transferred across a communication system, interpreted by a recipient interpretation system and transformed into functions/actions. Communication systems transfer memes between two components in a social network, and can be either self-communication (communication with future states through memory), or horizontal communication between agents (e.g. acoustic/verbal transfer). Interpretation systems are described as "network pathways that convert encoded functional information into phenotype and behavior," [13]. Cultures emerge as persistent patterns within a human-communication system with sufficiently compatible interpretation systems.

Sharov proposes four levels of genetic selection and three levels of habit selection that can influence both interpretation systems and cultures. These build on each other, and we repeat them here and then expand on the highest level. Level 1 is the intracellular molecular processes and gene functions. Level 2 is the assembly and modification of cell structures. Level 3 is the tissue growth, differentiation, cell migration, and assembly of larger extra-cellular structures. Level 4 is the growth and development of organs controlled by signals. Level 5 is the neural system of behavior encoding and somatic functions.

Beyond this level is where the selection of habits and behavioral traits takes place with behavioral adaptability often seen as a defining characteristic of selected traits.

First is habit selection which is encoded in brain memory based on continued reinforced behavior. This gives rise to, secondly, short term adaptations for survival that are selected for through reinforcement. Thirdly, long-term adaptability is selected for as new functions arise and are used or abandoned. Sharov notes that higher levels of adaptation and selection may exist, but does not expand on these. This higher level, however, might arise where adaptability for meme selection takes place. In this level would exist cohorts of various sizes and their associated traditions/trends that are motivated by and also reflected in technology and lifestyle. Selection may also take place at these levels, evolving in the direction of higher complexity [13].

4 Regulatory Networks for Genes and Memes

There are important and fundamental similarities between genes and memes/ideas. Both can be replicated and infect other gene/meme carriers and both undergo types of variation that are subject to selection. For instance, ideas are frequently added to, mixed, and modified as they are integrated with an individual's belief system; thus providing divergent effects that are somewhat similar to the non-functionalism (silencing), neo-functionalism (new ideas), sub-functionalism (complementary ideas), of gene theory, [1]. Both genes and memes exist within and are transmitted by complex carrier systems containing other genes/memes and environmental artefacts. In biology, these artefacts include RNA and numerous structural, regulatory, and enzymatic proteins which combine to construct and regulate diverse molecular assemblies, membranes, and subcellular compartments.

For memes, somewhat similar artifacts are seen in language rules and writings, written or spoken language, linguistic phonemes in speech and hearing, and environmental influencing factors. Such a memetic-biology analogy might be particularly useful when considering research into gene regulatory networks ([2], [1]) where properties of the network determine which gene gets expressed, the degree of expression, and also regulate properties of the cellular environment, [2]. A gene regulation network conceptualization of ideas/memes may facilitate connections to features of cognitive models that are well understood in the literature but that are typically ignored in discussions of memetics. Examples include the flexibility of ideas and the co-activation of ideas during the development of complex mental models. Furthermore, just as gene expression results in RNA and protein formation that through feedback loops can regulate future gene expression, so too does the expression of ideas/memes regulate the future thought patterns of an individual.

For illustration purposes, we can break down features of a GRN model into a parts list, topology, control logic, and simulation routines for system dynamics [6]. The parts list represents collections and descriptions of network elements in GRN's. Topology refers to the network connections and interactions as represented by graphs. Control logic refers to the effects of regulatory signals, whether inhibiting (down-regulating), or activating (up-regulating) for each particular gene. Dynamic routines simulate real-time behaviors of the network model. These modeling attributes can be directly applied to Meme Regulation Networks and, over larger temporal and spatial scales, the modeling of cultural evolution within a larger social network.modeling. Other related modeling frameworks might also be applicable [6], such as Boolean networks, finite state linear models (FSLM), petri nets, and even soft-computing with fuzzy sets, neuro-computing, and evolutionary algorithms, [2].

The question remains as to whether additional parallels exist between GRN's and networks of meme expression, and whether these systems will be useful for better understanding the primary determinants of meme interpretation and propagation across a social network. Such a parallel would be an important one however as the GRN modeling framework comes with considerable established connections to *in silico* and *in vivo* biological research.

5 Attractor Landscapes for Cultures

Attractor landscapes could also be useful to conceptualize the behavior of culture and its evolution into different states, as well as its associated properties of resilience, fitness, and evolvability. The attractor landscape concept has been applied to the study of gene regulatory networks whereby the developmental paths of a particular genotype is defined by movement over an attractor landscape. Attractors are stable solutions of a dynamic system, and are sometimes encoded as equations that determine the time series of system state transitions, [5]. These attractors represent static, periodic, and quasi-periodic state patterns that the system may reach according to its transition functions. Attractor basins define the sets of initial conditions, or states, that a system can take on yet still lead to a particular attractor, according to the system dynamics. These basins of attraction may vary in size, and thereby represent the system's resistance or robustness to changes from one state solution to another. Additionally, a basin may contain sub-attractors representing definite sub-patterns that the system may be in at a particular time (see [5] for more details).

Attractor landscapes can illustrate the connectivity between basins of attraction and thus can allow one to visualize the robustness and transition probability between different attractors. In some cases, this can be visualized as hills and valleys on a surface. A system moves like a (zero mass) ball through these various depressions according to its rate equations, and the presence of noise and perturbations from the environment, which results in shifts in either the system state, or sometimes the landscape itself. The system may settle into a single attractor or may be pushed out by perturbations, or it may oscillate between attractors. Aldana *et al*, [1], reported evidence that there is a critical regime in which some instantiations of gene regulatory networks exist. Within the critical regime, the properties of the attractors for that system indicate that the system is in a state of maximum resilience and maximum evolvability. Attractor landscapes can also change through structural or compositional modification of a system, thus the set of stable system expression patterns can also change over time, deepening the basins of attraction, widening the basins, or removing the basins [8], [1].

At present, the attractor landscape metaphor has not been considered for understanding how ideas become co-actived/entangled and in this manner drive the thought patterns of an individual. Attractors can be used to define stable expression patterns of thought that are sometimes perturbed by environmental cues. On the other hand, changes in the attractor basin, or perturbations in the interpretation system of a person may instead be driven by new ideas/memes. Memes with high fitness may cause significant and predictable changes in an attractor landscape, and thereby lead to subsequent shifts in cultural attributes similar to those reported by Aldana *et al* [1]. Given that genetic regulation networks and memetic regulation networks are both interpretation systems, universal principles may apply. However, it is important to first ascertain whether there are sufficient similarities between network models of gene and meme expression.

Attractor Landscapes for Genes and Memes:

Gene regulation forms an attractor basin, whereby many genes are turned on and off over time to form a stable expression pattern. Alternative stable expression patterns can also sometimes be induced through state changes brought about by the environment, e.g. signaling cascades, thus resulting in movement of gene expression into another attractor basin. Together, these attractor basins connect to form an attractor landscape that can fully describe the dynamical behavior of a particular genotype. Similarly, external forces such as social interactions can bring about a series of transitions in the thought processes of each individual involved. However unlike genetic systems, memes can be transmitted very rapidly during social interactions, resulting in small changes in the attractor landscapes of each person's belief system and leading sometimes to the propagation of memes and altered thought processes across multiple socially connected individuals.

6 Understanding and Cultivating Cultural Resilience

While the spreading of ideas can directly alter certain attributes of a culture, it is also interesting to consider what features of a culture allow it to resist change. Resilience refers to the capacity of a system to tolerate disturbances without shifting into qualitatively different patterns of states controlled by different sets of processes. Resilience and complexity are important cultural attributes that can be studied through cultural modeling and simulation. It is demonstrated in [1], that genes with maximum resilience and evolvability are found in a "critical zone" of the evolutionary landscape. Similar relationships may apply to cultural memes as well and may shed new light onto sources of resilience for cultural artifacts.

Conversely, these concepts might be also useful for understanding the prerequisites for individual and cultural change. In particular, memes might modify an attractor landscape by widening, flattening, and deepening a basin of attraction in a manner that is predictably correlated to meme *fitness*, i.e. a meme's success in becoming integrated into the belief system of the individual. Some predictable correlations have been reported in gene regulatory networks [1].

Most of this paper's discussion has focused on how ideas alter the properties of an individual's belief system. However in future research we aim to explore in greater detail how this conceptual framework might be used to understand the propagation of ideas across a social network and the evolution of complex cultures within a population. As a simple but illuminating example, consider a two state culture that is oriented towards a political position (dictatorship). This state can be either reinforced or destabilized by ideas regarding the abilities of the dictator to successfully govern the country. The fitness of the meme, determined by its ability to spread and integrate with the belief systems of many individuals, would result in either reinforcing public belief in the dictator, or in weakening the public belief, or have a neutral effect. The public belief represents one aspect of the culture en-masse and it is influenced by ideas injected from external sources such as the media or other cultural groups, as well as internal sources such as individual observation and reflection on the dictator's actions. A case for this is presently seen in the revolutions occurring in countries such as Egypt, Tunisia, Syria, Libya, and Yeman in 2011. Now consider the possibility that the influence of memes on an attractor landscape will predictably fall into one of a small set of outcome classes as found by Aldana *et al* for gene regulatory networks [1]. The application of a meme regulation network and attractor landscape framework could then, in principle, allow one to infer statistical properties of meme influence on the attractor landscapes of individual belief systems and thereby make predictions about the possible reinforcement or destabilization of extant cultural beliefs. While considerable work is needed, memetic regulatory networks arguably present a promising path of cultural and social analysis whereby new ideas may be traced from their origins all the way through to their effects on culture at a global scale.

7 Conclusion

Resilience, evolvability, and complexity are important properties of any culture and are interesting topics to study using cultural models. This paper has made some first steps in considering the use of evolutionary and biological theories in order to ask new questions about culture. Our proposal of a memetic regulation network, similar to the gene regulation network, presents an opportunity to apply standard techniques from genetics and dynamic systems theory to less standard and fuzzy ideas about culture. Memes and genes both exist within regulatory interpretation systems, which are useful for theorizing about, and experimenting with, the behavior of these systems. Present day cultures present a host of possible modeling opportunities. Future work will aim to develop a memetic regulation network to explore the evolution of cultural properties in a simulated organization. This will be used to evaluate whether idea driven changes in the attractor basins and landscapes of memetic networks have any similarities with those seen in gene regulatory networks. If sufficient similarities exist, this may then allow one to determine whether analogous critical regimes exist that enable both resilience and evolution of ideas.

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