

Autonomous Tags: Language as Generative of Culture

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Abstract. The first intelligent agent social model, created by the author in 1991, used tags with emergent meaning to simulate the emergence of institutions based on the principles of interpretive social science. This symbolic interactionist simulation program existed before Holland's Echo, however, Echo and subsequent programs with tags failed to preserve the autonomy of perception of the agents that displayed and read tags, as first program did. These subsequent tag programs include Epstein and Axtell; Axelrod; Hales; Hales and Edmonds; Riolo, Cohen and Axelrod, as well as the works on contagion originating in Carley, etc. The only exceptions are the author's 1995 SISTER program, and Axtell, Epstein, and Young's 2001 program on the emergence of social classes, which was influenced by the symbolic interactionist simulation program at George Mason University, and Steels' 1996 work. Axtell Epstein and Young's program has since been credited for strong emergence (Desalles et al). This paper explains that autonomy of perception is the essential difference in the symbolic interactionist implementation of tags that enables a strong emergence to occur, and that is why strong emergence has occurred in the works of Duong and of Axtell, Epstein and Young. This paper introduces no new model, but explains the important differences in existing tag models more clearly, pointing out the qualities that enable symbolic interactionist models to become social engines with strong emergence.

Keywords: Symbolic Interactionism, Interpretive Social Science, Emergent Language, Agent-Based Simulation, Tags, Autonomy

"In the beginning was the Word, and the Word was with God, and the Word was God. The same was in the beginning with God. All things were made by him; and without him was not any thing made that was made. In him was life; and the life was the light of men. And the light shineth in darkness; and the darkness comprehended it not." (John 1:1-5, KJV)

1 Introduction

Holland saw the creative power of the word as important in the formation of living systems when he included the tag as one of the three basic mechanisms of complex adaptive systems. A "tag" is simply a sign, such as a name or a physical trait, which is used to classify an agent. In the social world, a tag may be a social marker, such as skin color, or simply the name of a social group. A tag goes hand in hand with the other two mechanisms Holland thought important to complex adaptive systems: an internal model (whether tacit or explicit) to give meaning to tags, and building blocks to accumulate and recombine the structures that result from those meanings into hierarchical aggregates (Holland 1995). Holland's insight on the generative nature of signs was correct, however, his implementation of the sign, in his version of tags, failed to include perceptual autonomy, and as a result, did not have the generative power of signs. The Symbolic Interactionist Simulation program demonstrates that it is necessary to distinguish between the sign and the interpretation of the sign to create a full social engine. In accordance with interpretive social science, the keys to the engine lie in interpretation.

Holland is commonly thought to be the first to use tags to simulate social phenomena. However, there is another variation on tags, the symbolic interactionist simulation technique, that was developed before Holland's complex adaptive system research program, the Echo project (Duong 1991, Holland 1992). Like Echo, symbolic interactionist simulation recognizes the primacy of signs in the formation of living systems, but differs from Echo in that its agents have autonomous perception of the meaning of signs. The difference is understandable, because the principle of

autonomy of perception is more prominent from the social sciences standpoint than from the biological standpoint, even if it exists in biology as well (Maturana, Lettvin, McCulloch and Pitts, 1960). Many of the ideas in microsociology are inherited from phenomenology and hermeneutics, philosophies that contemplate the mysteries of autonomy, such as the paradox that human beings can only interpret meanings through their individual experiences with their senses, and yet they still come to share meaning (Winograd and Flores 1987). This “hermeneutic paradox” is the core issue of micro-macro integration in sociology from the angle of perception: to solve the hermeneutic paradox is to solve the mystery of the “invisible hand” by which autonomous, selfish agents synchronize their actions into institutions for the good of the whole. Since emergence in agent-based social simulation is fundamentally about solving the micro macro link, symbolic interactionist simulation seeks to solve the hermeneutic paradox. It is by virtue of the preservation of autonomy that symbolic interactionist simulations exhibit strong emergence and constitute minimal social engines.

In Holland’s Echo program and its successors that simulate the emergence of cooperation in iterated prisoner’s dilemma (IPD) programs, tags are implemented with replicator dynamics. Referring to the work of Riolo, Cohen, and Axelrod as well as the work of Hales and Edmonds, Hales discusses the tag implementation: “the models implement evolutionary systems with assumptions along the lines of replicator dynamics (i.e. reproduction into the next generation proportional to utility in the current generation and no ‘genetic style’ crossover operations but low probability mutations on tags and strategies).” (Hales, 2004). Replicator dynamics do not keep the principle of autonomy of perception: one agent interprets a sign the same way as another agent because they have a common ancestor, not because they both induced the sign separately based on their individual experiences. Simulations of the emergence of common meaning of tags using replicator dynamics exhibit high amounts of genetic linkage (biological or mimetic), so that the relation between the sign and the behavior is an artifact of the method, rather than emergent from the simulation.

Any simulation of contagion that explains macro level institutions with micro-level imitation does not exhibit strong emergence by definition. If we use a general definition of institutions as “Systems of established and prevalent social rules that structure social interactions” (Hodgson, 2006). then a model of simple contagion would explain the prevalence of institutions as an aggregate of copying behavior rather than as emergent phenomena which is more than the sum of its parts. Simulations of contagion, such as in the works of Carley, may involve homophilia that emerge fractious structures, however, these structures are faults in cohesion, explaining where institutional cohesiveness breaks down rather than explaining why social rules are prevalent. To the extent that they are prevalent in contagion/replicator dynamic simulations is the extent to which they are aggregate as opposed to emergent phenomena. Micro macro integration sociologist James Coleman challenges us to go farther than cohesion based theories of institutions, to theories based on (broadly defined) structural equivalence. In fact, cohesion vs. structural equivalence is a controversial divide in the theories of social homogeneity (Friedkin). Coleman believes that to explain institutions, we must explain the arise of a network of relations in a social system, that is, how institutions are different depending on roles, which together constitute a social system and not just an aggregate (Coleman, 1994). For example, Coleman claims Weber’s theory of capitalism as caused by the protestant work ethic is not a theory of emergence because it is an explanation of the propensities towards the same behaviors, rather than an explanation of how the different behaviors in the capitalist system came be. In other words, to explain Macro phenomena from Micro, we must explain how an entire system comes to form, and only this is “strong emergence”. In simulations with contagion, copying is one of the assumptions, and so is not explained by the simulation. In order to be emergent, phenomena can not be derived directly from the assumptions and starting conditions of the simulation, but must be of a higher order.

Bedau (2002) and other philosophers of emergence agree that “emergent properties have irreducible causal power on underlying entities “Downward causation,” or “Immergence” as Gilbert called it, is the result of the whole being more than the sum of the parts: the lower parts of the hierarchy are restrained and act in conformity to the laws of the higher level. The influence of the macro on the micro is irreducible in that it is directly downward as opposed to influencing via the micro properties. Thus, two way causation, upward because the macro is composed of the micro, and downward because there are upper level laws that limit the micro, is necessary for emergence in the strong sense. Desalles, Galam and Phan (2007) believe that for downward causation to occur in the case of social emergence, agents must be equipped to identify emergent phenomena before it can affect their behavior, and Muller adds autonomy of perception: that this

must be through the physical world (of physical signs coming to have new meanings), rather than by direct copying of other agent's perceptions (Muller 2004), so that agents may be free to interpret the world to achieve their individual goals.. According to Desalles et al, agents must describe the emergent phenomena they observe in a language other than the language of the lower level process itself, and agents must have a change of behavior that feeds back to the level of observation of the process. This insightful definition of strong emergence acknowledges the importance of autonomy of perception, that is, of not allowing agents to copy each other's internal states, in developing a new emergent language to describe emergent phenomena, that is different than the language of the lower level phenomena. To use the same language as the micro would be to use the same objects, relations, and patterns as the micro, but emergent phenomena requires an entirely new set of objects, relations and patterns, with new concepts to describe them. In agent-based systems, the first rudimentary language to describe un-preprogrammed, emergent phenomena, is the tag that comes to mean the macro level phenomena that emerges during the simulation. As institutions emerge, so should tags emerge to represent them, and to influence micro level behaviors. Immersion, or the ability of the lower level agent to change its behavior based on the emergent social phenomena, opens the door for generative feedback between micro and macro social levels. Such a generative engine, which some social scientists would call a dialectic, characterizes strong emergence.

Luc Steels' research program also addresses the hermeneutic paradox: his agent's signs come to have shared meaning, even though they have autonomous perception. However, his agent's signs were not tags related to social structure as in symbolic interactionist simulation. In Steel's work, arbitrary signs come to have meaning as agents use them to differentiate objects by their features. As individuals make distinctions based on their own perceptions and associations, they come to have shared words to refer to features and shared ontologies of what distinctions to make are important, in an emergence with upper lower feedback (Steels 1996). Ironically, even though these agents may be embodied as robots, they are not truly situated, as they are describing their environment but not applying this description to their utility, or in anyway changing their world with their language. The ontologies these agents use to cut up the world are arbitrary, whereas the ontologies of human languages cut up the world based on utility. Although language is reproduced, culture and the way that the world is manipulated is not.

2 Symbolic interactionist simulation

In symbolic interactionist simulation, the mechanism of autonomous emergence of the meaning of signs (tags) facilitates a strong emergence of practical ontologies that coevolve with practical behaviors.. Symbolic interactionist agents interpret signs based on utility, so that an interpretation makes sense given the background of the agent's individual experiences. In symbolic interactionist simulation, a sign is interpreted in a certain way because it makes utilitarian sense, and not because it is copied. Agents communicate solely through signs, inducing the meanings of both displayed and read signs. Inductions are based on economic and practical gain, and as a result of these utilitarian interpretations, symbol system and social institutions coevolve. The interpretation of the sign is more important than the sign itself because the individual, autonomous, interpretation causes cultural reproduction.

The first symbolic interactionist simulation (Duong, 1991, Duong and Reilly 1995) was a simulation of a workforce of employers and employees. In some of the runs, for example, there were 3 employers and 50 employees in a society. Each employee had either a high or low level of talent, which the employer could not see until after the employee was hired. However, the employer would look at the signs that an employee displayed to guess whether that it was talented. The prediction was based on the employer's individual past experiences with employees. The employee displayed a fixed sign (such as skin color, race or gender), a sign that costs money (such as a new suit) and a sign that is free (such as a fad). The fixed sign was made to be uncorrelated with talent. Employees obtained money through employment, and thus employees that could stay employed longer could make more money than employees that were fired frequently. A certain percentage of the workforce of each employer was laid off every cycle, but employees that were not talented were laid off in greater proportions. Thus, an employee that is talented has more of a capacity to make money, and the potential to differentiate itself from a non-talented employee using that money. The employees would choose a set of signs to display based on their prediction of whether they would be hired after an employer saw them. This prediction was based on their individual past interviews outcomes. Of course, employees could only display the purchasable

signs that they could afford. Both the employer and the employee agents had IAC neural networks to induce the meanings of the signs based on their private experiences with the signs. Even though the signs were arbitrary and autonomously perceived (employers did not consult each other on the meanings of signs, nor did employees), they came to have a shared meaning. Agents learned to buy expensive suits as status symbols, and race often became an issue despite the fact that race was uncorrelated with talent, because it sometimes became correlated with the suit. Races could get into a vicious circle where they could not afford a suit because they were not hired and were not hired because they did not wear a suit, at which time social classes based on race would form.

In this symbolic interactionist simulation, interpretation is generative of culture. Because individual employers are free to interpret the meanings of signs on the basis of individual experiences, individual interpretations may differ. An employer's discovery of talent in a race which he formerly believed to lack talent allows the talented members to afford suits, raising their esteem in the eyes of other employers. Individual interpretation allows self fulfilling prophecy to take effect as social change. Autonomous interpretation of tags is the means by which downward causation takes effect, the means by which upper level patterns change lower level behaviors based on individual utility.

Axtell, Epstein and Young's model of the emergence of social classes subsequently adapted the autonomy of the symbolic interactionist tag methodology (2000). Desalles et al (2007) took note of the strong emergence Axtell et al achieved by use of autonomously interpreted tags. Axtell et al achieved the emergence of social class based on fixed tags (such as skin color, race or gender) in a one shot bargaining model.

3 SISTER

Another symbolic interactionist simulation which uses a one shot bargaining model, SISTER (Symbolic Interactionist Simulation of Trade and Emergent Roles) was prior to and influential on Axtell, Epstein and Young's work on the emergence of social classes (The Economist 1997). SISTER also simulates the coevolution of symbol systems and social structure (Duong 1995, Duong 1996, Duong 2005, Duong and Grefenstette 2005). The role of interpretation in the reproduction of culture is even more important than in the 1991 Symbolic Interactionist model, as the self fulfilling prophecy of interpretation in SISTER causes roles and specific role knowledge to be reproduced. Diversity of interpretation through autonomous perception is vital to a distributed definition of roles and to the reproduction of cultural knowledge such as how to cook.

SISTER is a simulation not of a modern economy, but of a simple barter economy, where no wealth may accumulate from day to day. Agents produce in the morning, trade in the afternoon, and consume at night, leaving nothing for the next day. It is assumed that agents seek to have eight goods in equal amounts, and as much as they can get of them. Agents can produce some or all of the goods as they please, but these activities cost effort. An agent has only limited efforts to spend, but by concentrating efforts on a small number of categories of goods then more total units of good will be made. This simulates the benefits of specialization, also known as economies of scale. By this design the agents will be happier if they make lots of one good and trade it away for the others, however, it is up to the agents to learn how to trade. They develop institutions in the process of learning how to trade, and their institutions are solutions to the problem of how to trade. They start out the simulation completely ignorant of what to produce, what to trade, how much to trade, and whom to trade it with, and what sign they should present to others to tell who they are. The knowledge they come to have to get to the answer, the development of interlocked behaviors and shared meanings prerequisite to that answer, are the emergent institutions. This study focuses on just one of these institutions: the emergence of a division of labor. Other institutions that the agents develop are price and money.

The subjective micro-level rules come from the principles of interpretive social science as found in phenomenological and symbolic interactionist sociology. The agents follow a basic principle of interpretive social science: they are closed with respect to meaning. That is, they can not read the minds of other agents to learn how to interpret signs, but can only understand signs through associations with sensory phenomena that they experience in their individual lives. They each have their own private inductive mechanism with which they perform the symbolic interactionist task of inducing what signs they should display and the meaning of signs that they read. Their inductive mechanisms are autonomous in the sense that they are not seeded with information from other

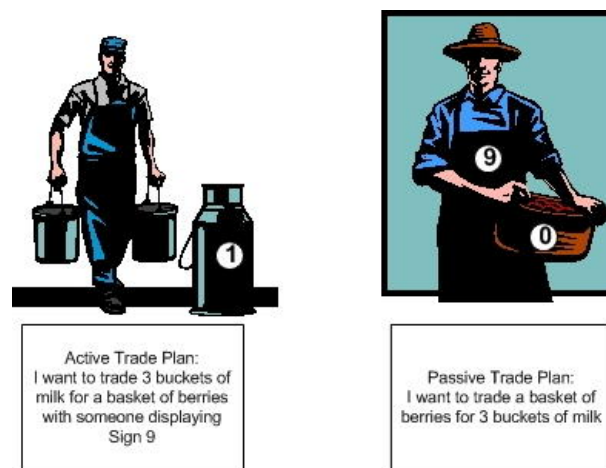
inductive mechanisms. With these inductive mechanisms, the agents interpret the signs they display solely from the context of their individual previous experiences, never copying another agent's sign, or another agent's interpretation of a sign. Yet despite this autonomy, the signs emerge shared meaning. This is in accordance with the hermeneutic paradox of our inventing our own meaning and yet sharing meaning. As in the symbolic interactionist paradigm, the signs come to have meaning as is pragmatic for the agents in the function of their "everyday life". The signs they learn to read and display are signs of whom to approach to make a trade with and what to display to attract trade. The meanings that the signs come to have are roles in a division of labor. This is in accordance with phenomenological sociologist Peter Berger's emphasis on the importance of roles and symbols of roles as a mechanism of organizing behavior. To learn how to trade, every agent must learn his role in terms of what goods to produce or assemble, and have general knowledge of the other roles in the society so that he may know who to trade with.

3.1 The Design of SISTER

SISTER is a simulation of daily habits of trade in a bartering society. Every agent learns a plan of harvesting, cooking, trade, and a sign to display for a single day of the simulation. Each agent has a limited number of "efforts" that it learns to allocate between harvesting, cooking and trading of goods. It allocates these efforts to specific goods to harvest or cook, and specific trade plans to perform. At the beginning of the day, agents harvest according to their production plans. They may harvest a few of each good, or more of some and less of others as their plans dictate.

Next, agents trade. All agents have both active and passive trade plans that are activated if agents devote the right amount of effort to them. Each trader follows its plans for active trading, by seeking out agents to trade with that display signs closest to the ones in their trade plans. If the passive trader has a corresponding trade plan and both the active and passive trader have the goods, then the trade takes place. See figure 1 for an illustration of corresponding trade plans. If the scenario simulates composite (cooked) goods, then an agent must have all the components of a good before it can trade that good ([Lacobie 1994](#)). An agent may trade to get the ingredients of a recipe, cook it, and trade it away.

Figure 1. Corresponding Trade Plans. Agents trade with agents who have corresponding trade plans and are wearing the correct sign



In the evening, the agents consume all of their goods, and judge their trade plans for the day solely on their satisfaction with what they consume that night.

The agents' motivation for trade lies in the encoded microeconomic rules. This simulation encodes two concepts from micro economics: the nature of the agent efforts and the nature of agent needs. The nature of agent efforts is that if agents concentrate their efforts on fewer activities, they are

able to be more productive than if they spread their efforts out over more activities. This simulates the benefits of specialization, or economies of scale. The nature of agent needs is that agents seek an even spread of several goods, and as much as they can get of them. It is as though each of the goods is one of the four essential food groups, and they seek a balanced diet of those goods.

Economies of scale are encoded by setting the efforts devoted to an activity to an exponent, whether that activity is a particular trade, the harvesting of a good, or the combining of goods (cooking):

$$activity = Kt^c$$

The number of specific activities an agent may complete is equal to a constant for that type of activity, K, times the efforts designated to that particular activity, e, raised to an effort concentration factor for that type of activity, c. For example, if the trade constant is 0.5 and the trade concentration factor is 3, and an agent devotes 2 efforts to trade 4 units of oats for 3 units of peas, then there are $0.5(2^3) = 4$ such trades it can make. If the activity is a trade, the concentration of effort might mean that the agent has invested in a cart to make an active trade, or in storage to make a passive trade. If the activity is harvesting, it might mean that the agent has put in the investment to harvest a particular good well. If the effort is composing goods (cooking), the agent may have invested in training to learn how to cook a particular type of food. Whatever activity it is, this equation means that putting a little more effort into the activity will make it much more productive.

The nature of an agent's desires are encoded with the Cobb-Douglas utility function. At the end of the day, each agent consumes all of its goods. How happy an agent is with its trade plans is judged solely by the Cobb-Douglas utility function of the goods an agent consumes:

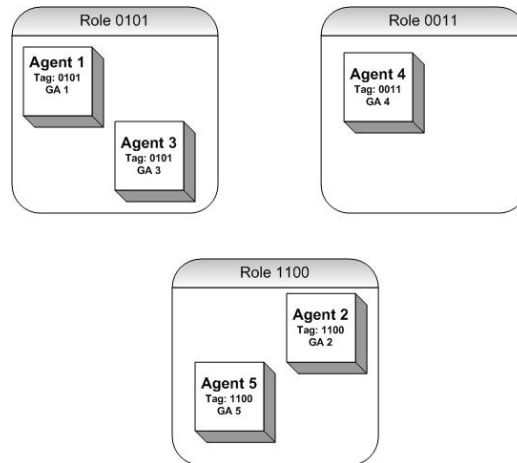
$$utility = \prod_{i=0}^n good_i^{weight_i}, \text{ where } \sum_{i=0}^n weight_i = 1.0$$

"Good" is the amount of a good that an agent consumes, n represents the number of different goods, and weight is a measure of how much each individual good is desired. All of the weights add up to one. Each agent has a minimum of one of each good given to it. This is a standard utility function in economics. If all of the weights are the same, it makes it so that agents want a spread of all different types of goods, and as much as they can get of them. The agents want a spread of goods in the same sense that people need some of each of the four food groups. For example, if an agent has eight units each of two of the four food groups, his happiness is $8^{0.25} \times 8^{0.25} \times 1^{0.25} \times 1^{0.25} = 2.82$. If the goods are more spread among the food groups, and the agent has four units of each of the four food groups, then its happiness is $4^{0.25} \times 4^{0.25} \times 4^{0.25} \times 4^{0.25} = 3.48$. The agent would rather have four of four goods than eight of two goods. With this equation both the spread of goods and the amount goods are important. In this study, the weight for each good is equal, so that differences in outcome can not be attributed to uneven utility values for individual goods.

The equations for effort and utility make it to the agents advantage to concentrate their efforts on making fewer goods so that they can make more of them, and then trading them for the rest of the goods, so that they can have an even amount of many goods. Agents may choose to make all of the goods for themselves until they learn how to trade them. In order to learn to trade the goods, the agents must learn to read each others signs and to display the correct sign. This is done according to the rules of interpretive social science. Agents never copy another agent's interpretation of a sign, but rather interpret and display signs solely according to its own utility. To simulate Parsons' double contingency, the sign is double induced: both the sign to seek for a trade and the sign to display on ones self are learned (Parsons 1951). These signs come to have common meaning as the agents differentiate themselves. As in Parsons' theory, the ordering of society comes through a shared symbol system, and as in Berger's and Coleman's theory, that ordering is a system of roles (Parsons 1951; Berger and Luckman 1966; Coleman 1994).

The passive trader displays a sign that its individual genetic algorithm has learned. The sign that an agent displays for its passive trades comes to represent that agent's role. That sign starts out random, but comes to signify a role when all the agents that have learned to display the same sign have similar behaviors. Figure 2 illustrates agents that have differentiated into roles denoted by a learned tag that they display in common. An endogenous differentiation of the agents occurs. This happens because the genetic algorithms are individual to each agent, and not seeded with information from other agents, in contrast to tag programs like Echo in which a single genetic algorithm is used for all agents. Rather, the SISTER genetic algorithms coevolve. Several individuals become replacements for each other in their behavior. An agent who wants to make an active trade can teach (that is, exert "selective pressure" on) many different agents who can replace each other to make a trade.

Figure 2. Agents differentiate into roles. Roles are designated by tags, learned from an agent's individual GA. Different agents which have the same tag are said to be members the same role if the agents who display the same tag also have the same behaviors. These tags are individually learned by each GA, but come to mean the same set of behaviors. The individual agents have autonomy of perception in that they learn the meaning of the tags with individual genetic algorithms that are not seeded from other agents.



For example, let's call the goods oats, peas, beans, and barley. Suppose an agent in the simulation has produced more oats and fewer beans. Suppose also that he displays a random sign to attract trade, and another agent with more beans and fewer oats guesses the meaning of that sign by coincidence while trying to trade his beans for oats. Both agents are satisfied with the trade and the sign: they remember this, and repeat it. The more the trade is repeated, the more it becomes a stable thing in the environment for other agents to learn. Since an agent with an active trade plan is looking for any agent who displays a particular sign, then any agent can get in on the trade just by displaying the sign. The agents come to believe that the sign means "oats," in the sense that if an agent displays the sign accidentally, the other agents will ask him to sell oats. This will put selective pressure on that agent to make and sell oats. At the same time, other agents who produce oats will benefit from learning the oat sign so as to attract trade. After a while, the society divides into roles, with groups of agents displaying the same sign and having the same behavior. If a new agent comes into the simulation, then to participate in trade he must learn the sign system already present. The signs are a guide to his behavior: when he displays a sign, the other agents pressure him to have the corresponding behavior. Thus a sign creates expectations of behavior, in accordance with Luhmann's model of expectation expectations. A system of signs represents a compromise between the interests of the agents who have put selective pressure on each other to behave in ways beneficial to themselves. These signs enforce evolutionary stable strategies of agent behavior.

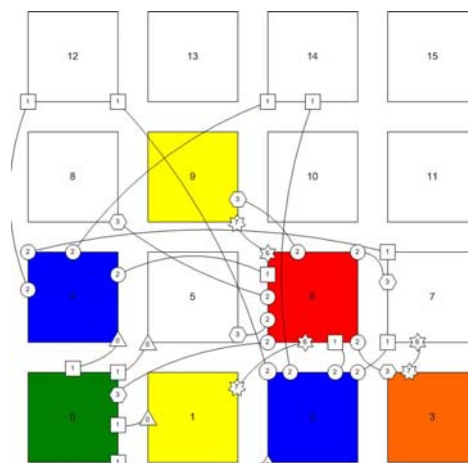
If composite goods or "cooking" is in the scenario, then agents must have all of the goods that a composite good is made of before it can trade that good. In a scenario with composite goods, agents have to know more to make trades in that good than they have to know in simple scenarios. They

have to know to either harvest or purchase the goods that a composite good is made of, in addition to having to know who would buy the composite good. If a newly inserted agent displays the sign of one who sells a composite good, then it learns the component parts of the good when other agents come to it to sell those components. An agent is thus trained in how to perform his roles by the expectations of the agents in roles that interact with that role. For example, suppose that in a SISTER society, the harvested goods were corn and lima beans, and the composite good was succotash, made from corn and lima beans. Suppose the agent who discovers succotash puts up a sign that she sells succotash. She buys lima beans and corn from lima bean and corn farmers, and finds that she has much business when she sells her succotash to the local diner, that uses her succotash to compose some of their dinner entrées. Through experience, our inventor of succotash has learned who sells the components of her good, lima beans and corn, as well as who buys the components of her goods, local diners. New agents who want to sell succotash now do not have to relearn all of that, because as soon as they put up a sign that says they sell succotash, lima bean and corn marketers start to call them. The new agent, because of the other agent's expectations, figures out how to make succotash if he didn't know before. If he only knows about the lima beans when he starts to display his sign, he will quickly learn about the corn. This is because he will feel selective pressure to buy corn. It will make the succotash better as far as the diners are concerned, and will give him more business. And it will be easy to buy because corn agents are constantly asking him to buy it. If it comes to be to his advantage, he will learn it. This is how the knowledge of how to make composite goods is held in the mutual expectations of agents. The mutual expectations that the agents have of the roles allows individuals to take advantage of what other individuals have learned in previous interactions. The knowledge of the society is held in the mutual expectations of the symbol system, as in Parsons' and Luhmann's theories ([Parsons 1951](#); [Luhmann 1984](#)).

The reason that role systems can hold more information about how to make cultural products is that agents can replace one another and can learn from the expectations that other agents have of their replacement class. This is how they become trained to do their role. However, this training is not all encompassing: what they do is ultimately connected to their utility. They can reject trades if it is not to their advantage, for example, if they find that succotash tastes better with tomatoes than with lima beans.

Thus, knowledge of how to make cultural products is reproduced through a variety of points of view, a variety interpretations of signs which ultimately come from individual utility perceived autonomously. These interpretations at first occur on an individual basis, but then become coercive because of the strength in numbers of interpretations. Signs come to have meaning only as new social institutions begin to form, and the individual interpretation of signs generates these institutions. Autonomy of perception preserves the different points of view needed to hold all of the role based knowledge, and preserves the connection to utility. Figure 3 illustrates the result.

Figure 3. A scenarios from SISTER representing the trades made in a single day of the simulation. Agents with the same color square have come to have the same role: that is, the same trading behaviors and same sign. The smaller shapes represent goods traded. An arc connecting shapes represents a trade. The stars are composite goods, or goods composed of other goods. Agents have developed complex roles and composite goods.



3.2 Discussion

SISTER is a study of the “free tags” of the original symbolic interactionist simulation of the emergence of social classes (Duong 1991). The free tags were the equivalent of words in a language, but applied to the identification of people. The dynamics involved in the emergence of meaning of tags are the same for the more general emergence of meaning of words. Symbolic interactionist simulation kept the principles of autonomy and hermeneutics in its study of the emergence of language that subsequent more well known works, such as Steels’, did. However, it also addressed critical issues that they did not. Steels and subsequent studies of the emergence of language are separated from studies of the emergence of culture. What is missing are models of language as coevolving with culture, models which capture the coevolutionary dialectic in which language and culture create each other and enable each other to grow. The dynamics of the propagation of signs which start out random is studied, but the dynamics of how they come to denote, hold, and spread new concepts needs more exploration. SISTER models the emergence of language as a dynamic creator of culture. If we define culture as the knowledge available to a society, both of the objects and the social structure, then SISTER shows how symbols emerge to hold culture and allow it to complexify, and how they enable culture to continue despite the deaths of individuals.

SISTER offers a solution to the hermeneutic paradox as do Steel’s models, of how it is that people can only interpret the meaning of signs from the context of their individual life experiences, and yet still come to share meaning. SISTER agents are autonomous because they are closed with respect to meaning: they each have their own private induction mechanisms, and do not copy one another’s signs or interpretations of signs, but induce the meanings of the signs from their own experiences alone. SISTER however, is different from Steels’ work in that the feedback is directly connected to the utility of the agent. A sign gets a particular interpretation based on what is good for the agent for it to mean, for its survival, rather than from the grunting approval of another agent. SISTER agents see “as the frog sees green” ... just as the frog does not observe reality as it is, but constructs it as is beneficial to its survival (Maturana, Lettvin, McCulloch and Pitts. 1960), so do SISTER agents interpret signs based on whatever it is that gets them the most food. The combination of a direct relation of interpretation to utility along with perceptual autonomy is what makes SISTER agents both embodied and situated. If we do not model the advantage to utility that an interpretation confers at every step, we lose the ability to model important social processes of what becomes popular.

One example of such a process to model is that of the legend. Legends hold deep cultural meaning, often so deep as to be universal. Legends are told and retold orally over many generations. Each time they are retold, the teller contributes to the creation of the legend in small ways. As all the authors of a legend recreate it to meet their needs, it comes to be very good at meeting needs, settling down on a compromise between all needs. Imitation without such modification does not promote cultural products which contribute to the needs of all, deeply intertwined with the rest of the culture. It is not a deep consensus.

The principles of hermeneutics are important to the study of the emergence of language because we can not separate language learning from concept learning, concept creation, and language creation. If we look at language as a passive thing, it does not matter if we include utility or not. If all a word is, is a random sign, and all we are explaining is how one random sign gets chosen over another random sign, then we need look no further than imitation. However, if we look at a word as a holder of a concept, a concept which serves to meet the needs of people within a web of other concepts, and which can only emerge as a word to denote it emerges, then it is appropriate to model the emergence of words in agents which interpret their meanings solely from their individual perspectives and usefulness to their lives. All the interpretations together create words and concepts which best serve the cultural needs of all the individuals. In the study of the emergence of language, it is not the sequence of phonemes that becomes popular that is important, but rather the capturing of the dynamic in which words make possible the ontologies that we use to construct our world. Studies in the emergence of language should address how words make the most practical ontologies, through the contributions of all utterers of words, rather than address the most practical sounds uttered.

SISTER shows that social systems with an emergent symbol system denoting an ontology of roles can enable cultural knowledge to continue despite the deaths of its individual members. The reason

that it can continue is that signs denoting roles create expectations of behavior in agents who interact with a role. These expectations serve to train newcomers to the society into the proper behaviors of the role. Each sign for a role is a focal point of a set of social behaviors in a social network, in that the sign means a different thing to different other roles in a social network, and agents of each role have a certain set of expectation for agents of other roles that they interact with. The signs and the set of relations they denote are emergent, and must be emergent if they are going to denote any arbitrary set of behaviors. The knowledge in the society is held in the expectations that signs bring to the different agent's mind. These meanings are all induced by the private inductive mechanisms of agents, and yet the meanings of the signs come to be shared.

SISTER outputs a division of labor and social structure that increases the utility (that is, "satisfaction") of agents. Agent ontologies of roles emerge that guide agents in complex social relations and behaviors needed for survival. SISTER captures the fundamental social process by which macro-level roles emerge from micro-level symbolic interaction. SISTER comprises a multi-agent society in which agents evolve trade and communication strategies over time through the use of tags. The knowledge in SISTER is held culturally, suspended in the mutual expectations agents have of each other based on the signs (tags) that they read and display. Language emerges and is maintained robustly, despite the stresses of deaths of individual agents. SISTER shows how a complex endogenous communication system can develop to coordinate a complex division of tasking.

SISTER employs coevolution, in which agents each have their own genetic algorithm (GA), whose fitness is dependant on successful interaction with other agents. These GAs evolve tags that come to indicate a set of behaviors associated with a role. Roles are nowhere determined in the simulation and exist in no one place, but rather are suspended in the mutual expectations of the coevolving agents. These mutual expectations emerge endogenously and are expressed through signs with emergent meanings. All institutional knowledge is distributed in these subtle mutual expectations.

4 Future Directions

When Desalles et al praised Axtell et al's strong (symbolic interactionist-style) emergence, Desalles et al noted an immergence, a downward irreducible causation that changed the behavior of the races by means of a tacit, rather than an explicit, understanding of the signs. The signs did not point to something outside of the agent, they point to utility alone as in Maturana et al's frog that sees green. Desalles et al noted that the (symbolic interactionist-style) agent's internal models were not reflexive, that they did not map to the agent's world. However, Desalles along with many other current theorists of "immergence" fail to realize that it is the tacit nature of the model that allows an entire social engine to form, an invisible hand that makes need-filling institutions out of individual selfish actions. Desalle et al proposed an improvement to Axtell et al in which agents can categorize their knowledge into a previously developed ontology. Rather than an improving upon the strong emergence this change would disable the autonomous social engine, because the previously developed ontology is an exogenous and static input. What is needed for true objectivity, the move from tacit as-the-frog-sees-green to explicit, more objective models of the environment that is entirely endogenous is a breakthrough in cognitive science. Since endogenous objectivation is beyond our technical knowledge, tacit knowledge is the only simulatable phenomena that can form an entire need filling engine at this time.

Of course, people cognate detailed models of the environment for their utility just as Maturana et al's frog did, and even though no one person has a complete explicit map of the entire world of thought, these models are more shared than the tacit knowledge of Maturana et al's frog. This objective knowledge is useful in society and to the symbolic interactionist practice of "taking the shoes of another." In order to go from one's own selfish functional perspective to someone else's selfish functional perspective, one must pass through an objective "hub" to see other functional "spoke" points of view first. The technology that could put an agent in the shoes of another would be a technology that could take in correlations that it an agent discovered through functional induction, and put out an objective model of cause. Until cognitive science is at the point where it can derive an objective causal simulation from subjective correlative data, programs which purport to simulate immergence must use tacit models. The alternative, considering the state of the science now, is to hard code a representation of the "emergent" property, losing the endogeny

necessary for the simulation's fidelity. In the mean time, it is best to, as Holland did, recognize that a tacit model is just as much an internal model as an explicit model.

Endogenously created cognitive maps would go a step farther in simulating the symbolic interactionist paradigm, as reflexivity at the level of getting into the other's shoes is required, and thus the ability to find an objective representation is needed. Further, symbolic interactionist simulations to this point have only covered the first two mechanisms in Holland's recipe for complex adaptive systems: tags and internal models. They have no building blocks, no dynamically recombinable signs that can mean new things to be interpreted during the interaction, as in Garfinkel's ethnomethodology in symbolic interactionism requires (Garfinkel 1967). Endogenous internal causal models from correlated relations and recombinable symbols that are in language are ambitious next steps for not only the symbolic interactionist paradigm, but for cognitive science in general. Maybe the techniques of cognitive science can benefit from the techniques of symbolic interactionism in these next steps for modeling emergent meanings.

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