Language as Generative of Culture

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Abstract

SISTER (Symbolic Interactionist Simulation of Trade and Emergent Roles) simulates the coevolution between emergent symbol systems and social structure. This article demonstrates the active role that language has in creating ontologies of complex social relations, and in reproducing these relations despite the deaths of the individuals. In SISTER, new agents acquire the language of an already existing society through the pressure of other agent's expectations. When a new agent displays a sign, it experiences selective pressure to behave according to other agent's expectations of the behaviors that go along with the sign displayed. The emergent language of SISTER agents is grounded in the practical utility of everyday economic actions. SISTER agents follow the principles of interpretive social science, perceiving only through signs and taking feedback only through utility. Each SISTER agent has its own private genetic algorithm through which it learns the ontology and structure of society. Both the ontology and the social structure are created in the simulation: SISTER agents start our homogeneously, but differentiate into a division of labor as a result of their symbolic interaction. SISTER offers a solution to the hermeneutic paradox of how meanings are learned individually, and yet come to be shared.

Hermaneutics for Agent Societies

Current studies of the emergence of language are often separated from studies of the emergence of culture. Most often these studies show what words come to be popular when competing with other possible words, to denote parts of a preexisting ontology (Perfors 2002). Sometimes these words are guessed and confirmed, as in Steels language games (Steels 1999), and sometimes they are simply copied (Werner and Dyer, 1992, Oliphant and Batali, 1997). However, 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 hold and spread new concepts is not. SISTER (a Symbolic Interactionist Simulation of Trade and Emergent Roles) 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 this article 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 (Duong 1995, Duong 1996, Duong and Grefenstette 2005), A Symbolic Interactionist Simulation of Trade and Emergent Roles, follows the principles of hermeneutics as does Steel's models (Steels 1999). It offers a solution to the hermeneutic paradox, of how it is that people can only interpret the meaning of signs from the context of their individual life experiences, and yet they come to share meaning. SISTER agents 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). Other works in the emergence of language have a direct connection to survival (Oliphant and Batali, 1997), however, agents in these are not closed with respect to meaning, as they all are part of the same genetic algorithm, which by nature converges. It is not scientifically sound to explain why meaning is shared, with an algorithm that forces the sharing of meaning.

The combination of a direct connection to utility and hermeneutic closure with respect to meaning turns out to be important. Most models of the emergence of language and culture often violate these principles. According to Conte and Dignum, imitation is the central method of modeling social phenomena: "conventions, norms regularities, social structures and patterns of any sort (segregation, discrimination, opinion formation) are said to emerge from agent's imitation of either the most successful, the most frequent, or simply the closest behaviors" (Conte and Dignum, 2003). However, when imitation is emphasized, we lose the point at which utility

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enters the picture. People invent meaning as it makes sense to their lives: as Piaget said, "to understand is to invent" (Piaget 1972). In other words, language and concept acquisition which goes along with it, do not happen by imitation as much as by making sense in the context of ones life experiences. 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 is 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.

This paper will show 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, depending on the individual perceiving the sign. These expectations have a role in language acquisition: they serve to train newcomers into the society into the proper behaviors of the role. Each sign for a role is a contract, which means different things for different perceivers of the sign. A sign is the focal point of a set of social behaviors in a social network. 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 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 is a simulation of the basic social process: the emergence of macro-level social institutions from micro-level symbolic interactionism (Duong and Grefenstette, 2005). SISTER was the first program to address the hermeneutic paradox, that people learn only from their own experiences, and yet share meaning on the social level (Duong 1995). SISTER outputs a division of labor and social structure that increases the utility 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. A rudimentary communication system based on "tags" or "signs" associated with each agent is a key component of the model. 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 and distance. SISTER shows how a complex endogenous communication system can develop to coordinate a complex division of tasking, in which symbols and roles are maintained despite distance and the deaths of individual agents.

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. Figure 1 illustrates evolved tags indicating agent roles. 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.

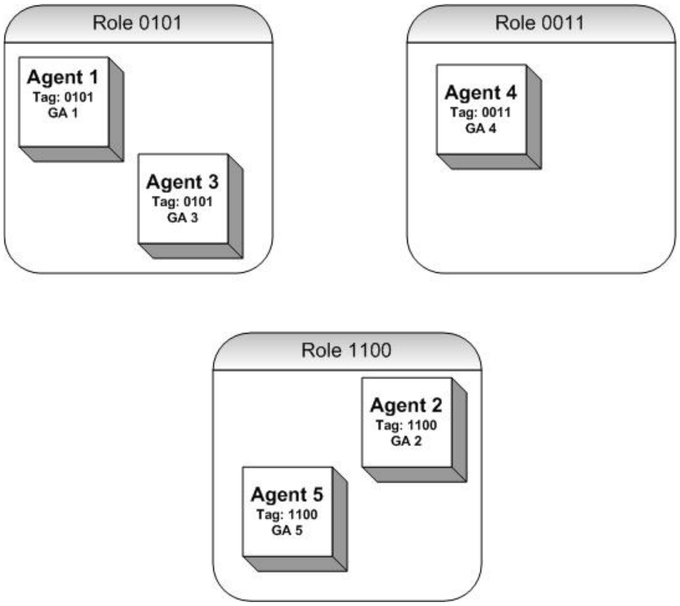

Figure 1. Agents that evolve the same tags in their separate GAs and have the same behaviors are in the same roles.

How SISTER Works

SISTER simulates a differentiation into the roles of a division of labor in an economic system (Duong, 1996, 2005). In SISTER, initially homogenous agents differentiate into the heterogeneous agents reflecting a division of labor. Roles solve the problem of how agents may work together to increase their utility. Every "day" of the model, agents harvest goods in the morning according to their production plans, trade in a market in the afternoon according to their trade plans, and consume their food at night, judging a single chromosome of plans for the day by their satisfaction in consumption (according to a Cobb-Douglass utility function). Agents are free to devote their efforts to harvesting goods or trading them. The simple economic assumption of economy of scale is built in (it is more efficient to produce a single good than to diversify production), as is a utility function that rewards accumulation of multiple goods. These combine to encourage trade among agents.

SISTER focuses on how agents determine who to trade with. Agents seek trading partners based on a displayed sign. Signs are induced both by the wearer, and by the agent seeking trade. See figure 2 for an example of a trade plan. This "double induction" of a sign is a simulation of Parson's "double contingency" (Parsons, 1951), and facilitates the emergence of a shared symbol system. Signs have no meaning in the beginning of the simulation, but come to have a shared meaning. Agents come to agree on what a sign implies about behavior. As they come to a consensus, a system of roles is developed.

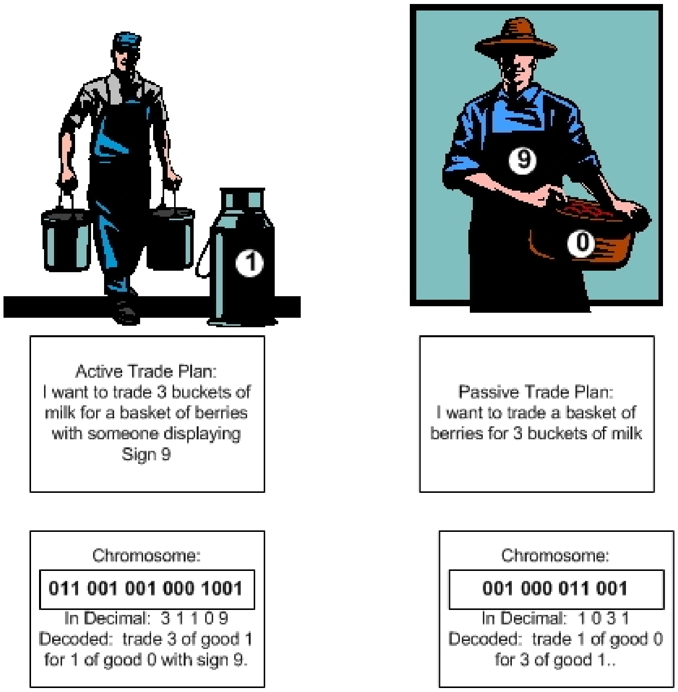

Figure 2. Agents must have a corresponding trade plan encoded in their genetic algorithms for a trace to take place. Each chromosome has all the plans of trade and production for a single day, and the plan to display a sign as well (the Passive trader's chromosome tells him to display sign 9, in a section that is not illustrated).

For example, suppose the goods of a simulation run include *berries* and *milk*. Suppose agents coincidently have the trade plan in figure 2, and each agent benefits from the trade. Both agents are satisfied with the trade and the sign: they remember this sign, and repeat it in future trades. The more the trade is repeated in the presence of the original sign, the more it becomes a stable element in the environment and therefore something that other agents can learn. Since an agent with an active trade plan is looking for any agent who displays a particular sign, any agent can get in on the trade just by displaying the appropriate sign. The agents come to believe that the sign means "milk," in the sense that if an agent displays the sign, then other agents will ask him to sell milk. This puts selective pressure on that agent to make and sell milk. If a random agent displays the sign for a composite good (a good composed of other goods, like "berry-flavored milk"), it learns the recipe for the composite good from marketers trying to sell the ingredients for the composite good. Over time, the society divides into roles, with groups of agents displaying the same sign and having the same behavior.

The signs are Berger and Luckmann's "objectivations" that become coercive: if a new agent is inserted into the simulation, then to participate in trade he must learn the sign system already present (Berger and Luckman, 1966). 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 Parson's ideas of double contingency and Luhmann's model of mutual expectations (Parsons, 1951; Luhmann, 1984). 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 inflexible: what they do is ultimately connected to their utility. They can reject a trade if it is not to their advantage. Thus SISTER agents have the flexibility needed to complexify.

Figure 3 illustrates a role based society that is advanced enough to make composite goods, with a relatively high mutual information.

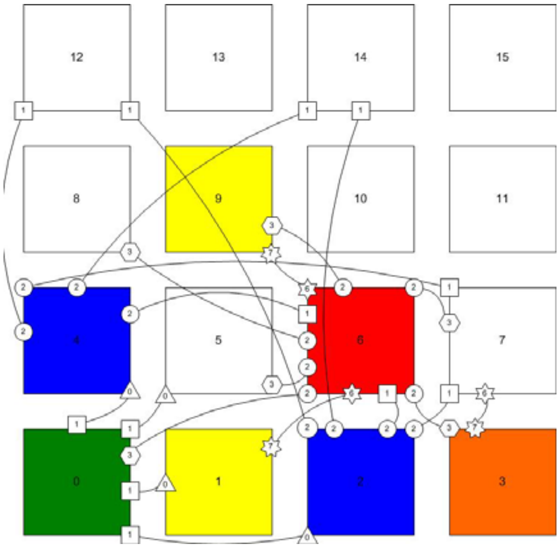

Figure 3. A scenarios from SISTER representing the trades made in a single day of the simulation. Agents with the same color square have come to have the same role: that is, the same trading behaviors and same sign. The smaller shapes represent goods traded. An arc connecting shapes represents a trade.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

Experiment

In this experiment, agents which display induced signs are compared to a control in which agents are forced to display a unique ID. The use of an ID prevents the formation of a system of roles denoted by the induced signs. We refer to a society where agents read and display signs freely as a "role recognition treatment" and a society where agents are forced to display a unique ID as an "individual recognition treatment." Whether the sign is arbitrary or an ID, an agent seeking a trade has to induce the sign to seek in trade. However, in the role recognition treatment, the displayer of a sign induces the sign it should display at the same time that the agent seeking a trade induces the sign to read. This double induction allows a system of arbitrary symbols to come to have meaning, but there is no double induction in the control. Duong and Grefenstette (2005) contains an experiment where individual recognition is compared to role recognition in the ability to create complex goods. The experiment of this article has both treatments making complex goods, and compares their ability to make them when there is a complete turnover in their population as a result of death and rebirth of agents. Death and birth is added to test the ability of new agents to acquire the language of the existing agents and achieve cultural continuity that is greater than the individual behaviors of members of the culture. The individual recognition treatment and the role recognition treatment are run twenty times each.

In this experiment, three different death rates are applied to each treatment. The average utility of the agents (the number of goods and the evenness of the spread of the goods, measured with a Cobb-Douglas utility function) is compared in each treatment, as well as the mutual information in the symbol systems that have evolved. The higher the correspondence between behavior and the sign displayed, the higher the information content, or mutual information, in the symbol system. Although the signs of the individual recognition treatment are not modifiable by the displayers of the signs, there is still a symbol system whose information may be measured. The individual recognition treatment can reach high values of mutual information if agents displaying different ID's have different behaviors. If a treatment has a higher utility value, then the agents are more successful in trading with each other. If they have higher mutual information, which is correlated with that utility, then it is likely that they are trading better as a result of the information contained in their symbol systems. Thus language makes knowledge and culture possible. They develop a language that is practical for the purposes of setting up networks of trade. If this language can carry these practical recipes for interaction on even through a complete turnover of the population, then language has reproduced culture, and expectation of the meanings of signs have spread knowledge to new members, so that culture continues despite the deaths of members.

The hypothesis of this experiment is: When birth and death are introduced into agent societies, those with role recognition (arbitrary signs) have greater continuity of knowledge of how to make complex goods than societies with only individual recognition.

While the number of agents remains at 16, agents are periodically killed and replaced by randomizing the chromosomes of the private genetic algorithms in each of their heads. When an agent is replaced, it is given a new unique id. The death rate is tested at several values, a 0.001 chance of death resulting in a complete turnover of agents in about every 1000 cycles, a 0.002 chance of death resulting in a turnover of agents in about every 500 cycles, and a 0.005 chance of death resulting in a turnover of agents in about two hundred cycles. A cycle is defined as a period of 1000 days of trade, after which reproductions in the GAs take place (learning). The tests are all on how well an agent does after one turnover, so the cycle lengths tested are different. Additionally, a 5 bit sign is used to represent the 16 agents rather than a 4 bit sign, in order to give new "names" to the new agents that arise in the system. A 5 bit sign represents 32 different unique names for the individually recognized agents, who must display their unique name in their sign. 32 unique names are needed if all of the agents will die and be replaced about once.

Results

For the parameters of this experiment, 130 is the level of utility where agents have no trade, but have become good at making everything for themselves. Any utility over that level indicates trade, and under that level indicates new agents are having difficulty learning. The average utility is significantly greater in the role recognition treatment, at over the 99% confidence level, than in the individual recognition treatment. Average utilities of the role treatments, for death rates 0.001, 0.002, and 0.005 are 145, 133, and 125. Average utilities of individual treatments are 127, 121, and 115. These show that increasing death rates are harder on both individual and role utilities at above the 99% confidence level. Figure 11 shows these results in tabular format.

Treatment	Death Rate	Avg Utility	Death Treatment Mutual Info	No Death Control Mutual Info	Correlation Utility and Mutual Info
Role	.001	145	0.715	0.665	0.43
	.002	133	0.858	0.794	0.36
	.005	125	0.575	0.65	0.5
Individual	.001	127	0	0.14	N/A
	.002	121	0.04	0.27	N/A
	.005	115	0	0.34	N/A

Figure 11. Results for the death scenario. Utility is higher in the role treatment than in the individual treatment. Role mutual information actually increases under the stress of death.

Death flattens the trade and mutual information in all of the treatments for the individuals. The control run (with no death) for the individual treatment does not have much trade, but has more than zero. This is reflected in the average mutual information scores of the 1000 cycle control, 0.14, as compared to the death rate 0.001 treatment, 0; the 500 cycle control , 0.27, as compared to the death rate 0.002 treatment, 0.04; and the 200 cycle control, 0.34 as opposed to the death 0.005 treatment, 0. These decreases in mutual information from the control are all significant above the 98% confidence level. In contrast, the average mutual information in the role recognition runs actually increased from the control; however this increase is not significant. This is reflected in the average mutual information scores of the 1000 cycle control, 0.665, as compared to the death rate 0.001 treatment, 0.715; the 500 cycle control 0.794, as compared to the death rate 0.002 treatment, 0.858; and the 200 cycle control, 0.65 as opposed to the death 0.005 treatment, 0.575. The increase in the average mutual information of the role recognition treatment over the individual recognition treatment is significant above the 99% level.

In the role treatment, average utility is correlated with average mutual information in death rates 0.001, 0.002 and 0.005 at values 0.43, 0.36 and 0.50. These results are significant above the 95% level except for the 0.36 value, which is significant above the 90% level. Individual recognition values are too low to have correlations.

Discussion

This experiment supports the hypothesis that use of arbitrary symbols help to preserve the knowledge in society even though individual knowers die. When an agent dies in an individual based recognition society, all the social coordination associated with its place in society is lost. If an agent dies in a role recognition society, even if there is only one agent in that role at a time, other agents in the society or new agents may adjust their sign and receive the selective pressures to adjust their behaviors to the dead agent's niche. The role system exists because of an emergent symbol system to denote it, and is reproduced through the expectations that these symbols bring to mind in the agents. Language acquisition occurs along with concept acquisition, as a result of the pressures of these expectations.

This finding contributes to artificial intelligence, because it shows a way to keep a coevolving society of agents learning new things. When new agents are brought into a society, they can bring change to the society more readily than old agents that have already-converged genetic algorithms directing them. Thus, death is a type of macro level mutation for coevolving systems. Death enables roles in the society to readjust to each other, change as the need arises, and complexify. If role recognition makes agents robust in the face of death, then it can help keep the diversity up in a coevolving system when used in concert with death. This finding further contributes to artificial intelligence in that robot agents in the real world will die by accident, and role based recognition is a way to keep the knowledge that they have accumulated alive socially despite their accidental death.

Role recognition is superior to individual recognition of agents in preserving knowledge because the agents serve as replacements for each other. Roles form robust replacement classes of agents, which enable the preservation of the knowledge of society, even when individual members of a class die. Role classes also promote the creation of knowledge, not only because agents within a role class may learn from each other's experiences. This experiment has shown that role recognition, in conjunction with death, facilitates the creation of knowledge through the diversity that death and birth bring to a society. Roles coordinate knowledge across generations. These roles are indicated by an ontology in a symbol system, that coevolves with them, and that regenerates them by bringing to mind expectations of behavior, which pressure agents to behave accordingly. Thus, language is generative of culture, and can regenerate it to recover from the deaths of individual members.

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