A MULTI-AGENT SIMULATION OF
THE EVOLUTION OF LANGUAGE

Dimitar Kazakov, Mark Bartlett
Department of Computer Science
University of York
Heslington, York YO10 5DD, UK
Tel: +44 1904 43 4775/3378; fax: +44 1904 432767
e-mail: kazakov, bartlett@cs.york.ac.uk

ABSTRACT
This paper discusses the evolution of language as an emerging phenomenon with both genetic and social components that are shaped under evolutionary pressure. Communication is seen as an act of kinship-driven altruism and is analysed from a Neo-Darwinist perspective. The paper provides motivation for the use of multi-agent systems in the simulation of the evolution of language and describes one setup investigating the above-mentioned issues.

1 INTRODUCTION
In recent years, there has been much research carried out in attempting to model the evolution of language through computer simulation. Within this field, there are two somewhat disjoint problems being tackled. One set of researchers are investigating communication systems that are stored and passed between entities genetically [1, 9], while others are approaching the problem of learned communication systems [3, 7].

Our research is based within the domain of simulating learned communication systems and focuses on why any creature should develop or choose to use such a system to speak. More specifically, we present a framework in which the urge to use language is seen as an inherited feature selected by evolution, while language itself is a social phenomenon that is passed on through interaction rather than genetically inherited.

2 ALTRUISM AND NEO-DARWINISM
Clearly an entity that is able to use a learned communication system to understand the meanings of others' speech is at an advantage, as it can gain information through the work of other entities rather than its own toil. However, it is less apparent why a creature should choose to speak, when this will clearly give other creatures an advantage, which this one has had to work hard to gain. In Darwinian terms, by helping other creatures with no obvious benefit to itself, the creature acts altruistically, decreasing its own fitness relative to that of others, and therefore we would expect such behaviour to be selected against by nature. However, the existence of human language shows that in at least one case natural selection has acted opposite to this expectation.

Several researchers [5, 10] have looked at similar problems in the domain of innate communication systems and we look to this work for possible approaches. They have found that communication does indeed seem to be selected against if an agent can choose not to speak without penalty. However, there are possible modifications to these systems that seem to encourage communication to occur. A spatial distribution is one such modification that can be applied, with agents interacting more with those adjacent to them. This promotes reciprocal altruism, in which both entities benefit by cooperating rather than competing. Another possible explanation is to look at the issue of altruism from a Neo-Darwinian perspective. Hamilton [2] shows us that if we view the basic element of evolution not as the individual, but as the gene, we find that natural selection may actually favour selfless acts in the form of kinship-driven altruism. This form of altruism involves helping relatives proportionally to their degree of kinship to the altruistic entity. Through this mechanism, a hypothetical gene promoting altruism would be able to spread itself. We propose to investigate whether either form of altruism can be used to explain the existence of learned language.

3 EVOLUTION OF LANGUAGE IN MULTI-AGENT SYSTEMS
We have chosen to simulate the evolution of language within a multi-agent system (MAS) setting as this allows us to simulate with ease many of the potentially relevant phenomena, such as the spatial distribution of agents (language speakers) and resources. The MAS framework also permits us to study the behaviour and social acts (both verbal and non-verbal) of individuals.

Simulations of the evolution of language using the multi-agent paradigm can be also of interest to the designer of any general-purpose agent-based applications. In a dynamic environment that is expected to change considerably during an agent's lifetime, the faculty of learning could be essential to its success. Machine learning techniques could be used for this purpose [4]. Learning biases that specify the range of possible hypotheses are essential in machine learning, and their choice is crucial to the success of any algorithm. In an evolutionary MAS setting, sexual reproduction and
mutation can be used to explore a range of possible learning biases, from which natural selection would choose the best. One would expect advances in small steps, and selection of only very general concepts that are relevant to most of the population for many generations.

Evolution in the MAS is not limited to following Darwinian principles: One could also implement Lamarckian evolution, that is, use a MAS in which the parents’ individual experience can be reflected in the genes inherited by their offspring. Lamarckian evolution is faster, but brings the risks of inheriting too specific concepts based on the parents’ personal experience.

There is yet another way of evolving a learning bias that is open to populations of agents. Language uses concepts that are specific enough to be useful to a variety of aspects of the agent’s environment, yet general enough to correspond to shared experience. In this way, the concepts of a language serve as a bias used to describe the world that is inherited socially rather than genetically. To preserve the advantages that the use of language brings about in the case of a changing environment, the MAS designer should allow the language to evolve.

4 OUR APPROACH
Our approach (set in a multi-agent environment) is to assume that kinship-driven altruism has already been selected for in the population, as demonstrated in previous work [8], and to allow the agents to choose between the altruistic acts of sharing physical resource (food, water, etc.) or sharing information about the location of that resource.

Information about resource location is communicated in the form of paths, consisting of sequences of landmarks that are to be seen along the way to the target destination. Landmarks are identified by the non-descriptive names that the speaker uses for them. Initially, these names are arbitrarily chosen by individual agents. Since the names used by the speaker and the receiver may be different, linguistic games similar to those described by Steels [7] are used to evolve a common lexicon of landmark names. Whether a path is discovered by exploration or described by another agent, it is stored internally in the form of a set of rules of the form:

\[ \text{goto} \text{(Resource)} \rightarrow \text{goto} \text{(Pos,)} , L_1, L_2, \ldots, L_n \]

where \( L_i \) are landmark names, and \( \text{Pos,} \) is the current position of the listener defined by the snapshot of its surroundings. Rules of the above form can be interpreted either as procedural rules guiding the agent from a location to a resource or as grammar rules of a regular language. The description of path chosen is a relatively impoverished one. So, for instance, no absolute or relative co-ordinates of landmarks are used, neither is the direction to follow or distance between landmarks described. It is assumed that each landmark would be visible from the previous.

If in a given environment, these descriptions prove useful, i.e., storing and exchanging them promotes the survival of the agents involved, one would expect to observe the following two phenomena. Firstly, agents possess sets of rules describing paths, which ultimately lead to a useful resource, and secondly, this set of rules can be seen as a proto-language, the grammatical structure of which copies the structure of the landscape.

5 CONCLUSION
We intend to study the languages that occur in two ways. One could measure the similarity between the languages used by each pair of agents and (hierarchically) cluster all agents accordingly. If agents are split into a set of mutually exclusive clusters, all agents within the same cluster can be seen as speakers of the same language. In this case, language is seen as a social artefact that only exists in the community of its speakers. Alternatively, all rules used by the agents can be clustered by using as a measure of similarity a pair of rules the number of agents sharing both rules. Again, any partitioning of the resulting hierarchy of rules would correspond to a set of languages, where each language is defined by the set of its rules.

References