Influence of a collective behaviour on the Naming Game

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Abstract

Language games are models that have been developed for the study of self-organised natural language evolution. They are used to study the emergence of a shared vocabulary through a self-organisation process. One instance of language games is the Naming Game, which models the emergence of conventions in a population using a simplistic communication protocol between agents. In its original configuration, this game is played by two agents who have to agree on a word to name a predetermined topic. In order to reach this goal, the agents take two different roles; the speaker, who proposes a word, and the hearer, who accepts or refuses the word on the basis of whether it had already heard it. The game is deemed successful if the speaker proposes a word already in the hearer's lexicon, in which case they both forget all other words. Later revisions of the naming game allow simultaneous games in larger populations: here, the speaker can broadcast words, and thus does not update its lexicon according to the success of the game. This version of the Naming Game has the same consensus dynamic as the original. The Naming Game has been used to study the emergence of social conventions in various settings such as linguistics, culture, or economy. The dynamics of this model has been thoroughly characterised with various static topologies of agents' interaction. Only recently, this model has been ported in the context of swarm robotics, the study of the design of collective behaviours in large populations of robots using only local interactions and local communication. The goal of this study was to understand effect of embodiment and random agent mobility on the evolution of language in large populations. These results have shown that, even in that setting, the naming game exhibits the same outcome as in simpler simulations: all agents achieve consensus on a single word.

Our work aims at studying the consensus dynamics of the Naming Game in the case where a swarm of robots is exhibiting a collective behaviour. Our goal differs from those of previous studies, which focused on the dynamics of the Naming Game in settings with static topologies of agents' interactions or having dynamic topologies induced by agents following an individual random walk. To this end, our intention is to bring the Naming Game to swarm robotics and initiate a systematic study of the interaction between this model and the numerous collective behaviours that characterise this field.

Apart from approaches that include communication implicitly as a component of the individual behaviour leading to the desired collective behaviour, other studies have more explicitly focused on the emergence of communication itself within a swarm, focusing on questions such as: "When is communication needed in the first place?", "How does language emerge?", and "Which form should communication take in order to be most effective?". Moreover, most of the work done in the above direction has focused on the biological evolution of language (biolinguistics): They belong to the framework of evolutionary swarm robotics, which studies the application of biological evolutionary models to swarm robotics. Thus, the cultural evolution of language (evolutionary linguistics) has mostly been overlooked in swarm robotics; a gap we propose to bridge.

So far, our work has focused on the interaction effect between the naming game and one of the simplest, yet most important collective behaviour studied in swarm robotics: self-organised aggregation. Self-organised aggregation is a decision-making process whereby agents need to gather all around the *same* area, without relying to global information, global communication, or any kind of centralised information or decision.

In our work, the aggregation behaviour of the robots is modelled by a probabilistic finite state automaton (PFSA), inspired from observations of cockroach larvae, which decides whether to leave or join an aggregate. In this PFSA, the probability to join an aggregate is complementary to the probability to leave it and increases with the size of the aggregate, i.e. larger groups are more attractive for settling. Moreover, we anchored the Naming Game into this behaviour by making successful games a condition to join–or even stay–in aggregates. This new algorithm can be understood as robots having to collectively decide on a new place to swarm, but being able to do so only if they can agree on a name for this place.

Experiments in simulated environments reveal that this combination influences the dynamics of the Naming Game as well as of aggregation: it allows aggregation to form a controllable number of groups and, more importantly, each emerging group converges on a different word. This is a brand new feature as previous studies all showed an eventual consensus on a single world. This new model we propose could be useful to represent competing ideologies, identities, or cultural conventions: It could be used to understand how they can be bound to a geographical place (as it happens for languages) and how they spread according to the displacements of their proponents.

Keywords

Evolutionary linguistics, language game, naming game, self-organised aggregation, swarm robotics.

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