Co-evolution of Language and Behaviour in Autonomous Robots

An MSc project proposal

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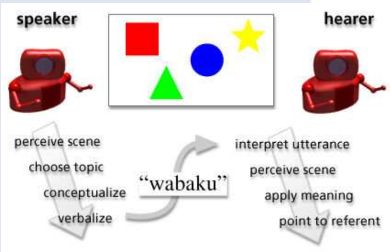
Abstract: I propose to set up an experiment for autonomous agents in order to study how the use of an evolved language can lead to intelligent behaviour in a realistic environment. The inspiration for this project stems from work on modelling the evolution of language in humans, where simplified models show how languages in terms of syntax, semantics and phonetics are created and transferred through learning, biological and cultural evolution. Results of this project will support the assumptions made in these models and will underline the importance of bottom-up design in the collective behaviour of robots and finally, it will show how the use of language can add flexibility and intelligence to cooperative behaviour, whether in humans or robots.

1. Modelling language evolution

a. The Iterated Learning Model [1] The setup of the Iterated Learning Model consists of two agents, an "adult" speaker who teaches the language to a learner by randomly choosing meanings represented in its "mind". It creates an utterance representing that meaning, which the learner perceives and interprets. After a number of these meanings have been uttered, the language learner has an internal representation of the language. The teacher is removed from the environment, the learner becomes an adult and a new agent is introduced into the cycle. After a number of generations, the language stabilises, showing how a language can be created, changed and maintained.



b. Language Games in robotics [3] A language game is played between two robots to coordinate some behaviour. If communication is successful the robots manage to achieve their task, receiving positive feedback from the environment, otherwise the language representation in both robots must be updated to increase the likelihood of success in the future.

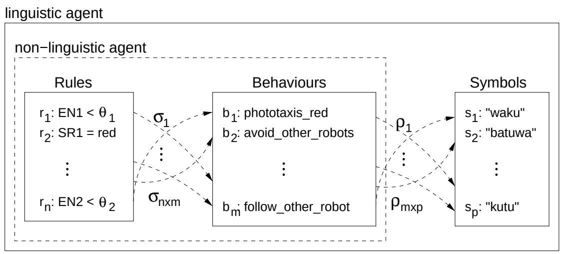
2. Evolving intelligent behaviour

Steels, 1996 [2]. In this work a selectionist mechanism is developed by which the agent can change its behaviour on-line without endangering its viability. For this purpose, an eco-system is designed, containing one agent, a lego robot, a charging station, and a number of competitors, which compete with the robot over the global energy of the system and can be dimmed by running against them (in which case the competitor will refrain from consuming energy for some time).

Proposed project

The aim of the project is to create a generation of agents (simulated robots) that will simultaneously learn a language and how to intelligently solve a "life-task" in their environment in order to survive. The Iterated Learning Model and the language games described above will be used to evolve a language for the agents to communicate and coordinate their collective behaviour.

- **The environment** should include only two agents to begin with, energy sources, competitors and a set of simple environmental rules [2].
- **The rules** could determine which station to avoid or which to charge from. Maybe if the robots' energy level is already above a certain threshold, they would have to visit the charging station together, etc.



- Each robot will be equipped with a set of rules R, behaviours B, and for the language-speaking robots also a set of symbols S associated with these behaviours. The connection weights σ, ρ determine how a robot behaves and/or communicates about its behaviour.

Three sets of experiments will be run and the results compared, where in order to solve their life-task the agents will use:

1. **Only language.** Behavioural rules are hard-coded; the agents must create and pass on a language over generations until the language stabilises. $f : R \times \sigma \to B$
2. **Only machine learning to learn behaviours.** Agents are not equipped with a language sub-system; traditional machine learning methods used to learn the correct behaviours through experience. $g : B \times \rho \to S$
3. **Language to learn behaviours.** Learner agents have no idea of either language or behavioural rules. We will observe whether they can learn behaviours through language learning. $f \circ g : R \times \sigma \to B \times \rho \to S$

Output of the project

Hopefully, the third experiment should outperform the other two in terms of how fast a behaviour is learned, the mean and variance of the energy level, the complexity/sophistication of the behaviours and the life-expectancy of the agents.

If this is the case, the results will confirm the idea that the use of language can enhance collective intelligence and behaviours and to what degree this is the case. It will not only support the work done in modelling language evolution and its biological plausibility, but will also accentuate the importance of language and its complexity for survival both in a biological environment, as well as in robotics, showing the potential of language to design complex behavioural systems from the bottom up.

References

[1] S. Kirby and J. Hurford. *The Emergence of Linguistic Structure: An Overview of the Iterated Learning Model*, chapter 6, pages 121–148. Springer Verlag, London, 2002.

[2] L. Steels. Discovering the competitors. *Adaptive Behavior*, 4(2):173–199, 1996.

[3] P. Vogt. Anchoring Symbols to Sensorimotor Control. In H. Blockdeel and M. Denecker, editors, *Proceedings of Belgian/Netherlands Artificial Intelligence Conference BNAIC'02*, 2002.