An Evolutionary Robotics Simulation of Human Minimal Social Interaction

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This abstract introduces an evolutionary robotics simulation of experimental results on minimal human social interaction. Such simulation experiments play an important role in a minimal enactive approach that aims to combine experiential, empirical and theoretical results to generate an explanation for cognitive behaviour without reducing behavioural phenomena (macro level) to constituent parts of the agent–environment system (micro level). The results of this study are interesting in three different ways: Firstly, such an enactive account of social interaction that does not focus on individual capacities, but on the dynamical interaction process, is able to account for emergent phenomena that are difficult to understand otherwise. Secondly, the evolutionary robotics simulation uncovers a number of surprising aspects of the task, which allow a different view on the data. Thirdly, the presented work is an example of how the gap between minimal artificial life simulations and the empirical study of human level cognition, involving human conscious experience, can be bridged – not by scaling up the complexity of robotics models, but by scaling down the complexity of the aspects of human behaviour under investigation.

1 Experiments in minimal perceptual crossing

Auvray, Lenay and Stewart ([1], personal communication) have investigated the dynamics of human perceptual crossing in a minimal shared virtual environment. Each subject could move a cursor left and right on a onedimensional virtual tape that wraps around and was asked to indicate the presence of the other. The subjects were blindfolded, all they sensed were on/off tactile stimulations when crossing an entity on the tape. Apart from each other, subjects could encounter a static object on the tape, or a displaced 'shadow image' of the partner, which is strictly similar as regards movement characteristics (see Fig. 1). The problem is therefore not only to distinguish moving and static entities along the tape, but to distinguish two entities that move exactly the same way, only one of which represents the other subject, who can sense the subject's presence and respond to its actions.

How is this task solved? Initially, subjects oscillate around any entity they sense on the tape and can even be fooled into mistaking the shadow image for the inter-

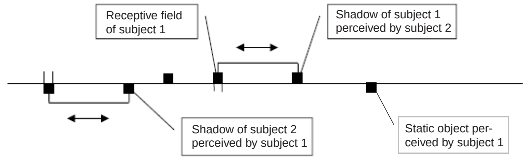

Figure 1: Schematic diagram of the onedimensional environment

acting partner. However, the scanning of an entity encountered will only stabilise in the case that both partners are in contact with each other – if interaction is only one–sided, between a subject and the other's shadow, the shadow will eventually move away, because the subject it is shadowing is still engaged in searching activity. The only globally stable condition is two–way interaction. Therefore, the solution to the task does not rely on individuals performing the right kind of perceptual recognition between different momentary sensory patterns, but emerges from the mutual perceptual activity that is oriented towards each other.

Interesting as these results may be as they stand alone, their minimalist and closed–loop nature also renders them a very suitable domain for evolutionary robotics modelling. We think of evolutionary robotic models as tools for thinking, which "will not tell us how real cognitive systems work but [. . .] provide us the proofs of concept and exploratory studies that can challenge existing views and unwritten assumptions in a healthy manner" [3]. The simulation experiments presented in the following paragraphs have been conducted in this spirit and point out interesting aspects of the task that help to generate new hypotheses to be tested and new perspectives on the data already obtained.

In our model, populations of artificial agents were evolved in simulation to solve the task in the described set–up (Fig. 1). The genetic algorithm (GA) used is a generational GA with truncation selection, the real valued $\in [0, 1]$ genotype is mutated with vector mutation. The agents (size 4, tape size 600) are controlled by CTRNN controllers that have four input neurons, corresponding to four neighbouring binary touch sensors, up to 5 hidden neurons and two motor neurons for left and right movement. The network structure is partially evolved. Agents are tested against clones of themselves using a weighted fitness average over six trials. The fitness criterion is the average distance from the other ($F = \frac{1}{T}\sum_0^T 1 - \frac{d(t)}{300}$).

2 Results

Our first experiments were not successful, the GA could not find a satisfactory solution to the task, it remained in a local minimum where agents stop on top of any object first encountered. This strategy is successful, if agents first encounter each other or if one agent runs into its waiting partner, however, in all other cases, fitness is devastatingly bad. A term to punish closeness to the static object was included in the fitness criterion, but is in itself not sufficient to help evolution.

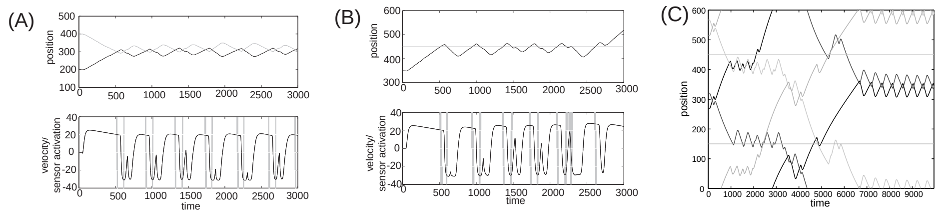

Figure 2: (A) Stabilised perceptual crossing (trajectories and sensorimotor values). (B) Scanning of a fixed object (trajectories and sensorimotor values). (C) The trajectories are very similar to those generated by human subjects (lighter lines: shadows/static objects). All diagrams include motor noise.

Only when introducing a time delay between a crossing on the tape and the agent's sensation, this minimum could be overcome. Also, only then, the agent's behaviour started to resemble the human subject's scanning movements. Even though not very strong in themselves, these findings raise the question: Why do subjects keep oscillating around each other, rather than to just 'stand on top of each other' after recognition? A hypothesis derived from our model and to be tested is that sensory delays play a role for this behaviour and that the amplitude of the scanning oscillations around a target is positively correlated with the amount of sensorimotor delay.

The general result from our experiments is that agents evolved to perform the task successfully, generating trajectories similar to those generated by human subjects (Fig. 2 (C)). Interestingly, while the capacity to distinguish between the shadow image and the other subject evolves quickly, it is very hard to evolve agents that can distinguish another agent from a fixed object. If we take a closer look at the data, we find a striking similarity between sensorimotor patterns for coordinated mutual scanning and for scanning a fixed lure (Fig. 2 (A) and (B)), which explains the difficulty of this distinction. Encountering any stimulus makes the agent revert its direction of movement, which leads to another encounter followed by another inversion of velocity, and so forth. When we inspect the duration of the stimulus upon crossing a fixed object, we realise that it lasts longer than when crossing a moving partner. This is because the fixed object does not move itself. The agent seems simply to rely on integrating sensory stimulation over time, which is longer for a static object, to make the distinction. This can be confirmed with the fact that the agent is quite easily tricked into making the wrong decision if the size of the fixed lure is varied.

What is interesting about these findings is that the smaller perceived size in the case of perceptual crossing depends on encounters remaining in anti–phase oscillation (figure 2 (A)), which is an *interactionally coordinated property*[2]. A systematic distinction between objects having the same objective size is therefore *co–constructed* by the agents during coordinated interaction. In turn, individuals respond to this emergent coordination by staying in coordination with the apparently smaller object. Similar anti–phase oscillatory trajectories are generated in human–human–experiments.

3 Conclusion

These findings do not tell us anything about the strategy humans employ in this task, so what do they imply? They demonstrate that an approach that does not just look at the individual capabilities, but also at the phenomena emerging during embodied and situated interaction sees things that are not seen otherwise. A task that intuitively seems difficult, i.e. to distinguish two entitites with identical movement characteristics (the partner and the shadow image), becomes almost trivial, if the effects emerging from the mutual search for each other are taken into consideration. This finding already results from the minimal closed loop experiments by Auvray, Lenay and Stewart [1]. On the other hand, the intuitively easy task of distinguish a moving entity (the partner) from a static one is indeed non–trivial, if the emergent effects of interaction, i.e. anti–phase coordination, are taken into consideration. This issue was uncovered with the help of our evolutionary robotics simulations, it had not previously been recognised by the authors, and they have signalled their interest to have a closer look at the empirical data in response to our results. This achievement, along with the hypotheses generated from our experiences with sensory delays, demonstrates how evolutionary robotics, as a tool for thinking, cannot just be inspired by empirical results, but can also enrich the experimental scientific praxis. This enriching role is not limited to “low level” insect cognition or navigation behaviour, but can play a role in the study of human behaviour that involves an experiential component, which can also be integrated into the picture through first person methods. You can do justice to the rich dynamics of reciprocity in human–human interaction that are left outside in traditional agent–centred or explicit–desing–based approaches, without trying to imitate human level complexity.

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