Self-organising synchronisation in a robotic swarm

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Synchrony is a pervasive phenomenon: examples of synchronous behaviours can be found in the inanimate world as well as among living organisms (Strogatz, 2003, Sync, Hyperion Press). The synchronisation behaviours observed in Nature can be a powerful source of inspiration for the design of swarm robotic systems, where emphasis is given to the emergence of coherent group behaviours from simple individual rules. Much work takes inspiration from the self-organised behaviour of fireflies or similar chorusing behaviours. Here, we present a study of self-organising synchronisation in a group of robots based on minimal behavioural and communication strategies. We follow the basic idea that if an individual displays a periodic behaviour, it can synchronise with other (nearly) identical individuals by temporarily modifying its behaviour in order to reduce the phase difference with the rest of the group. In other robotic studies, synchronisation is based on the entrainment of the individual internal dynamics through some form of communication (see for instance Wishmann et al., Adaptive Behaviour, 14(2), p.113). In this paper, instead, we do not postulate the need of internal dynamics. Rather, the period and the phase of the individual behaviour are defined by the sensory-motor coordination of the robot, that is, by the dynamical interactions with the environment that result from the robot embodiment. We show that such dynamical interactions can be exploited for synchronisation, allowing to keep a minimal complexity of both the behavioural and the communication level. In order to define a robot controller able to exploit such dynamical agent-environment interactions, we use artificial evolution (Nolfi and Floreano, 2000, Evolutionary Robotics, MIT Press). The obtained results are analysed under a self-organising perspective, evaluating their scalability to large groups of robots.

The main contribution of this work consists in the analysis of the evolved behaviours, which is brought forth exploiting a dynamical systems approach: We introduce a dynamical system model of the robots interacting with the environment and among each other. This model offers us the possibility to deeply understand the evolved behaviours, both at the individual and collective level, by uncovering the mechanisms that artificial evolution synthesised to maximise the user-defined utility function. Moreover, we show how the developed model can be used to predict the ability of the evolved behaviour to efficiently scale with the group size. We believe that such predictions are of fundamental importance to quickly select or discard obtained solutions without performing a time-demanding scalability analysis, as well as to engineer swarm robotic systems that present the desired properties.