Enhancing Self-similar Patterns by Asymmetric Artificial Potential Functions in Partially Connected Swarms

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Extended Abstract

The control of mobile robotic agents is required to be highly reliable. Artificial potential function (APF) methods have previously been assessed in the literature for providing stable and verifiable control, whilst maintaining a high degree of non-linearity. Further, these methods can, in theory, be characterised by a full analytic treatment. Many examples are available in the literature of the employment of these methods for controlling large ensembles of agents that evolve into minimum energy configurations corresponding in many cases to regular lattices [1-2]. Although regular lattices can present naturally centric symmetry and self-similarity characteristics, more complex formations can also be achieved by several other means. In [3] the equilibrium configuration undergoes bifurcation by changing a parameter belonging to the part of artificial potential that couples the agents to the reference frame. In this work it is shown how the formation shape produced can be controlled in two further ways, resulting in more articulated patterns. Specifically the control applied is to alter the symmetry of interactions amongst agents, and/or by selectively rewiring inter-agent connections. In the first case, the network of connections remains the same, and may be fully connected. In the second some links are rewired with possible changes of APF parameters, this can be better understood considering a group of 5 mobile agents interacting through Morse-like potentials, which C_a, C_r, l_a, l_r to defined the potential shaping parameters and $\left|x_{ij}\right|$ as the inter-agent distance is defined as; $U_{ij} = -C_a \exp\left(-\left|x_{ij}\right| / la\right) + C_r \exp\left(-\left|x_{ij}\right| / lr\right)$. When all the agents are subjected to the same APF the swarm will relax into the minimum energy configuration, a circle. This configuration can be modified by tuning the attraction or repulsive scale distance, l_a or l_r, in one agent. Consider a change in the l_r parameter for a agent and say that for this agent the parameter takes value $l_{rr}<l_r$, creating an asymmetry in the global potential field. As the difference between the two increases, the minimum energy level corresponding to a circle formation turns to be higher, and hence less favourable, than the one corresponding to a cross formation which the swarm will then naturally evolve into. This can be better understood by looking at Figure 1 where the global artificial potential $U = \sum_{i,j} U_{ij}$ as function of a characteristic distances and of the free parameter l_{rr} is shown. Consider now the case of 5 groups, each as the one just discussed, giving 25 agents in total. Linking the centres of all the groups together

with the same attraction-repulsion function coefficients would lead again to 5 groups (each one cross shaped) self arranging into a circle.

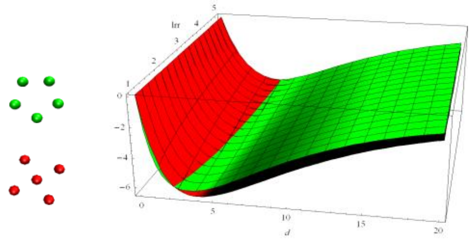

Figure 1 - Global artificial potential as function of the inter-agent characteristic distance and of the free parameter l_r for the circle configuration (green) and the cross configuration (red). The characteristic distance considered is the radius (from the centre to a peripheral agent) for both configurations

On the other hand, once again adjusting the same free parameter as previously shown, one group will move to the centre, surrounded by the other 4, however this will not guarantee that all the groups keep the same relative orientation. It is otherwise possible to organize the 5-agent groups into a cross formation as the agents in the groups spontaneously relax. This can be achieved by adding links between each of the four other agents of one group (that will be the central one) to an agent other than the central one belonging to the other groups. This will guarantee that 5 groups of 5 agents organize amongst them in exactly the same way as the agents which they are composed of do amongst themselves. The final outcome is a self-similar pattern at both agent and group level, as seen in Figure 2. Furthermore, as the second level agents are connected in couples, the separation distance corresponding to the minimum energy configuration can be calculated exactly from the analytic expression of the Morse potential, giving fully verifiable swarm shape and size control.

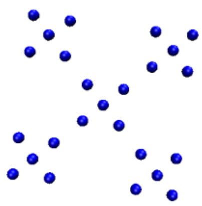

Figure 2 - 25 agent self-similar formation obtained by linking the central agents of each group amongst them plus one agent for each side group to one "arm" of the central group.

References

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