Emergence of Congruent Behaviour by Implicit Coordination of Innate and Adaptive Layers of Software Agents

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Thesis submitted for partial fulfilment of the requirements for the Degree of Doctor of Philosophy

University of Colombo, Sri Lanka.

2008

Abstract

The emergence of behavioural and structural congruence based on simple local interactions of atomic units is a fascination to the scientific community across many disciplines. The climax of behavioural congruence and emergence of behaviour is exemplified by the community life-style of ants. Each individual ant possesses the capability to solve only part of the overall puzzle while aggressively communicating in primitive methods with the spatially related neighbours to produce emergent behaviour. Hence, ant colonies have evolved means of performing collective tasks, which are far beyond the capabilities of their individual structures. The consensus is that comprehension of emergent complexity in insect colonies such as ants would serve as a good foundation for the study of emergent, collective behaviour in more advanced social organisms. As evidence of structural congruence, the realisation of a phenotype from a single genotype during the embryonic development, and some theories of the human mind that describe intelligence as a synergy of mindless constituents provide insight to the emergence theories. These facts argue that there exists a fundamental theory for structural and behavioural congruence that is yet to be discovered.

The primary hypothesis of the research is that the constituent atomic actions of a complex behaviour could be successfully coordinated by collaborative and autonomous agents that are loosely coupled through implicit communication to demonstrate emergent congruent behaviour in dynamic environments. The resulting congruent behaviour could be further optimised by using a hybrid learning approach that models adaptive behaviour on a static foundation of innate elementary behaviour.

The AAANTS model was conceptualised and implemented as a platform to represent the biologically inspired learning model to test the research hypothesis. The model encompasses aspects related to coordination, knowledge representation and adaptation by reinforcements. Two experimental domains were implemented on this platform, related to foraging in a grid-world and robotic arm movements to grab and push an object. The experiments demonstrated relative improvements in achieving behavioural congruence using the AAANTS model in relation to the traditional Monte-Carlo based methods. The research has also identified further improvements to the model that would enhance the capabilities in achieving higher levels of behavioural congruence in heterogeneous application domains.