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# CoSMoS: Complex Systems Modelling and Simulation Infrastructure

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**Abstract** CoSMoS is a four year EPSRC-funded project to develop a modelling and simulation process and infrastructure specifically designed to allow complex systems to be explored, analysed, and designed within a uniform framework. Here we outline the components of CoSMoS, and report on the current state of the process and infrastructure.

**Keywords** complex systems · modelling · simulation · validation · CSP

The CoSMoS project is developing a modelling and simulation process and infrastructure specifically designed to allow complex systems to be explored, analysed, and designed within a uniform framework. CoSMoS has a **a modelling and analysis process**, based on computational concepts such as class, process, state, and communication, and on complex system emergent behaviours, expressed in part as rich argumentation, modelling, analysis, and refactoring Pattern Languages. It also has a **massively parallel and distributed simulation environment**, based on CSP, the $\pi$-calculus, and system modelling technologies that encompass a wide range of process granularities, targeted to the specific properties of complex systems: vast numbers of (relatively) simple agents interacting and communicating in dynamic parallel networks, in a dynamic and often stigmergic environment. The development of CoSMoS is **case study driven** across a wide range of domains, to ensure that it contains the necessary generic components.

We have identified requirements for the engineering of scientifically rigorous simulations (Polack et al, 2008). We are developing **pattern languages**, covering: abstract computational representations suitable for modelling complex systems; analyses of their collective and emergent properties; refactorings, both of composed models, and for targetting simulations; argument structures, to reason about validity. Initially, we have started to identify various simulation patterns, particularly to do with modelling space (Andrews et al, 2008b).

We are building **a simulation framework** for massively parallel and distributed systems, as instantiatable code frameworks in occam-$\pi$, targetting multiple processors. The current

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implementation infrastructure supports mobile communications (Bonnici and Welch, 2009), multi-core processors (Ritson et al, 2009), and distribution over a cluster of Linux nodes (Sampson et al, 2009).

We are developing an **integrated process** that guides the tasks of probing a complex system in order to build suitable abstract domain models with the help of domain experts, mapping a domain model to the simulation framework, instantiating the framework to produce a simulation, and using the simulation in an analytic and a predictive manner (Andrews et al, 2009). A key aspect of the process is **validation**: building a structured argument of the validity of the various process steps (Andrews et al, 2008a; Ghetiu et al, 2009).

We are using **case studies**, and building models and simulations of a range of complex systems, both for driving the initial development and for performing the eventual validation of the entire CoSMoS process (modelling, mapping, instantiating, validating, predicting). The case studies include "textbook" examples of complex systems, such as flocking and pheromone trails (Bonnici and Welch, 2009), and models and simulations of biological processes built with the help of domain experts (Andrews et al, 2008a; Read et al, 2009). We will shortly be starting a social science based case study of modelling a city as a complex system.

We have run two international workshops on complex systems modelling and simulation (Stepney et al, 2008, 2009), and will be running further workshops in 2010 and 2011. More information about the project can be found at http://www.cosmos-research.org/

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