Using Models in Complex Systems Simulation

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Engineering Simulations

The **CoSMoS project** is developing tools and techniques to enable the construction and exploration of simulations across all fields of science.

Case-studies in immunology, ecology and sociology have focussed on **complex systems** and **emergence**.

Simulation construction is interdisciplinary: **domain experts** (the scientists), and **developers** (software engineers).

Engineered simulation platform is a **bespoke tool** to run simulations for theory exploration, hypothesis generation, and design of domain experiments.

Domain knowledge must be captured by computer source code, often the only **explicit representation** of the target simulation domain.

Building a simulation platform involves **assumptions** about the **accuracy** of the model and the **correctness** of the implementation.

Model Use

Use a range of primarily diagrammatic modelling approaches to **capture**, **communicate** and **reason** about simulations.

Models are generated and updated throughout simulation-based research: **identification** of the scientific basis, **development** of the simulation platform, and **use** of the simulation platform to explore the domain.

The appropriate models are **annotated** with scientific or engineering assumptions.

Simulation Confidence

We need to show **how** the simulation has been engineered and **why** it is a good **scientific instrument** to enhance our domain knowledge.

A series of **explicit modelling steps** help expose how the scientific facts are translated into the simulation and helps mitigate inappropriate assumptions.

Rigorous calibration of the simulation platform is required to understand how the simulation outputs relate to the real-world domain of study.

Confidence in simulations results can be enhanced through presentation of structured **validation arguments**.

The CoSMoS Approach

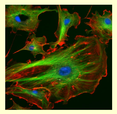
Our use of **simulations for science** is driven by the five concepts represented here.

Arrows denote a **flow of information** from one concept to the next.

Development of the models and simulation platform shaped by a **research context**: e.g. motivation, research questions, requirements for validation and evaluation.

DOMAIN

The **real-world system** (or part of) being investigated.



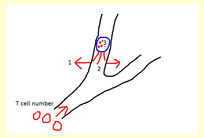
DOMAIN MODEL

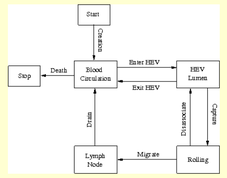
A model about the **subject of the simulations** based on the domain science.

Identifies and describes domain **structures**, **behaviours** and **interactions**.

Free from simulation platform **implementation bias**.

Communicates domain understanding between developers and domain experts.





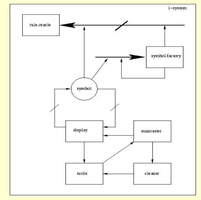
PLATFORM MODEL

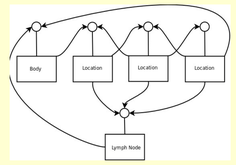
A **software engineering** model towards development of the simulation platform.

Describes **how** domain model concepts will be **encoded** into simulation platform.

May **remove** domain model concepts such as emergent behaviours.

Add instrumentation to observe, record and interact with simulations.



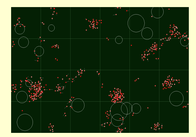


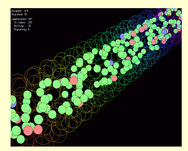
SIMULATION PLATFORM

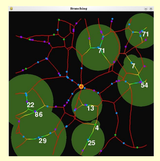
A **software** and **hardware** platform on which many simulations can be run.

Implements the platform model and provides variables to **manipulate** the encoded model.

Variables have a **traceable** link back to the domain though platform and domain models.







RESULTS MODEL

Captures understanding of the simulation platform extracted from simulation experiments.

Provides the **basis for interpretation** of what the simulation results show.

Comparison with domain model establishes whether simulation platform provides a suitable representation of domain.

Provide details to **drive new experimentation** in the real domain.