Morpheus: a User-friendly Modeling Environment for Multiscale and Multicellular Systems Biology

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Introduction

Modeling and simulation are rapidly becoming indispensible tools to understand the regulatory interactions driving tissue formation. Yet, model construction typically requires considerable computational expertise, in particular for the development of multiscale models that may involve feedbacks between signaling, gene regulation, cellular behavior and tissue-wide gradients. Here we present Morpheus, a dedicated modeling environment for multiscale and multicellular systems that allows rapid model development in a user-friendly fashion [Starruß et al., 2014].

Modeling formalisms

Morpheus implements various model formalisms to facilitate the modeling and simulation of processes at different spatiotemporal scales. Intracellular processes such as signaling pathways and gene regulatory networks can be represented using the well-established methods of ordinary, stochastic and delay differential equations. Cellular behaviors including cell motility, cell-cell adhesion and proliferation can be modeled using the cellular Potts model. Extracellular processes including morphogen gradients and reaction-diffusion systems can be modeled using partial differential equations.

Domain-specific language

A key benefit of Morpheus is that it supports the construction of complex multiscale models without requiring programming. Instead, models are described using a domain-specific language that uses familiar biological and mathematical terminology. By providing symbolic names for morphogens, cell-bound variables or genes, their interactions and dynamics can be directly specified in mathematical expressions using conventional infix notation. When relating variables belonging to different modeling formalisms, model integration is performed automatically and transparently.

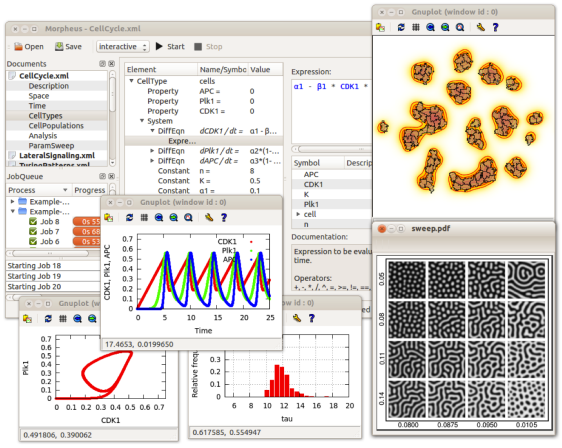

Figure 1: Morpheus graphical user interface with editor, result visualization and analysis panels.

Graphical user interface

Morpheus' graphical user interface (fig. 1) provides a number of tools enhancing the typical modeling workflow including an advanced model editor, a browseable result archive and tools for parameter exploration, batch processing and high performance computing.

Availability

Morpheus software is available as binary executables for all major operating systems (Linux, MS Windows and Mac OSX). Download, documentation and example models are available on the website:
http://imc.zih.tu-dresden.de/wiki/morpheus

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References

J. Starruß, W. de Back, L. Brusch, A. Deutsch, Morpheus: a user-friendly modeling environment for multiscale and multicellular systems biology. *Bioinformatics*, 2014 (in press).