Project title: System Reduction and Error Analysis for Complex Systems

Project leader: Dr. Pieter Collins

Function: Universitair Docent

Collaborators: Prof. Ralf Peeters, Dr. Ronald Westra, Prof. Paul Volders (CARIM)

Proposal (250 words):

Introduction: A complex system is a dynamic system formed by many interacting subsystems. The main challenge in the study of complex systems is to understand and predict the behaviour of the composite system based on knowledge of how the components behave in isolation and their direct interactions. Since direct simulation using detailed mathematical models of each component and interaction is infeasible, simplified or reduced component models are used instead.

Hypothesis and Objectives: A fundamental difficulty with current methods for analysis via systems reduction is the errors introduced in the simplification process are unavailable, so it is unclear whether subsequent predictions are reliable. In this project, we propose to develop a new computational methodology for systems analysis, in which rigorous bounds are provided for the approximation errors made in the reduction process, and the effect of these errors on computations of higher-level behaviour are analysed.

Setting and Methods: The main innovation is in the application of recent numerical tools for working with sets and functions in a rigorous and efficient way to model-order reduction of nonlinear systems, and to the solution of the resulting differential inclusions.

Impact: The long-term vision is to be able to reliably validate properties of a complex system by performing successive reductions with error control. The theoretical research will be guided by a case study aimed at deriving a simplified model of the electrophysiology of a human heart cell from a detailed model of the cell's ion transport processes.

Requirements candidate: Highly motivated student with good English communication skills and proactive and resolute attitude. Background knowledge in differential equations or control theory, and in numerical methods. Interest in complex dynamic systems and reliable computation.

Keywords: Complex multiscale systems, system reduction, disturbance analysis.

Top 5 selected publications:

1. Michael Clerx, Pieter Collins, Enno de Lange, and Paul G.A. Volders. "Myokit: A simple interface to cardiac cellular electrophysiology." *Progress in Biophysics and Molecular Biology (Special Issue on Recent Developments in Biophysics & Molecular Biology of Heart Rhythm)*, 120(1):100–114, 2016.
2. Sanja Živanović Gonzalez and Pieter Collins. "Computing reachable sets of differential inclusions." In *Coordination Control of Distributed Systems*, pages 357–365. Springer, 2015.
3. Luca Benvenuti, Davide Bresolin, Pieter Collins, Alberto Ferrari, Luca Geretti, and Tiziano Villa. "Assume-guarantee verification of nonlinear hybrid systems with Ariadne." *International Journal of Robust and Nonlinear Control*, 24(4):699–724, 2014.
4. Pieter Collins. "Model-checking in systems biology-from micro to macro." In *Formal Methods in Macro-Biology*, pages 1–22. Springer, 2014.
5. P Collins, and DS Graça. "Effective Computability of Solutions of Differential Inclusions: The Ten Thousand Monkeys Approach." *Journal of Universal Computer Science,* 15 (6), 1162-1185.