Computerised Modelling for Developmental Biology

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Computerised modelling for developmental biology
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An exploration with case studies

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus Prof. mr. P.F. van der Heijden,
volgens besluit van het College voor Promoties
te verdedigen op woensdag 12 september 2012
klokke 11.15

door

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geboren te Zeist, Nederland, in 1981

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To my dad

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INTRODUCTION

Many studies in developmental biology rely on the construction, simulation and analysis of models. These models vary from schematic drawings, representing *e.g.* regulatory pathways, to complex systems of equations, enabling accurate quantitative analyses of processes. New modelling techniques are constantly being developed, as well as new applications for already existing techniques. In particular, a growing interest can be observed in employing computational modelling approaches to biological phenomena, exemplified by the recently emerged field of computational biology.

This dissertation presents a broad view of modelling approaches for developmental biology. In the first chapter an overview is given of modelling properties, relevant when selecting a particular modelling approach, followed by a review of frequently used modelling techniques in the field of developmental biology.

The first chapter establishes a context for the subsequent chapters, 2 to 6, in which a series of case studies is presented for various modelling approaches. The approaches have been selected on the basis of their particular merits for developmental biology and each represents a different category from the review in chapter 1. Since computation is becoming increasingly important for developmental biology, the case studies presented in this dissertation make use of computational and/or computer-assisted techniques. In chapters 2 and 3, 3D reconstructions are used to study heart development in the turtle. Chapter 4 describes a general ontology system for vertebrate heart development, incorporating the use of 3D reconstructions. Finally, chapters 5 and 6 present a modelling solution for the formation of biological gradients, using the algorithmic approach of Petri nets, combined with the equation based approach of differential equations.

In each of the case studies, optimization of captured knowledge and functionality was strived after, by taking advantage of the specific characteristics of the modelling approach. As a result, new ways of utilizing the techniques were developed, in particular for ontologies and Petri nets (*cf.* chapters 4, 5 and 6), and new insights were gained into biological phenomena, in particular for the cardiac development of the turtle (*cf.* chapter 2 and 3). Furthermore, attention was paid to integration of modelling approaches, in order to extend the functionality of the resulting models. Chapter 7 addresses this aspect of integration, for each of the separate instances. In this way the dissertation presents a broad investigation of new approaches to modelling structures and processes in developmental biology.