Object-Oriented Ecosystem Modelling

A Case Study: SALMO-OO

A thesis submitted for the degree of Master of Science

Byron He Zhang
Discipline of Environmental Biology
School of Earth and Environmental Sciences
The University of Adelaide

January 2006

Copyright ©2006 Byron H. Zhang.

Abstract

Object-oriented ecosystem modelling was introduced in the early of 1990s (Silvert, 1992). From that time on, ecosystem models using object-oriented programming (OOP) has earned significant achievements with increasing upgraded information technology. The common purposes of ecosystem modellers are to build a model with flexible structure, which allow continuous modifications on the model content. In last decade, ecosystem modellers have put a large number of efforts to practice the OOP approaches in order to implement a true object-oriented ecosystem model. However, these previous work have not fully take advantage of object-orientation because of misusing more or less this technique. This paper explains the shortcoming of these previous endeavours therewith points out a practical solution that using the methodology of object-oriented software engineering and some relative novel information techniques. A case study SALMO-OO will be presented in this paper to prove Silvert's assumption that OOP play an important role on ecosystem modelling approaches. Moreover, the results of SALMO-OO convince that object-oriented ecosystem modelling can be achieved by using object-oriented software engineering associating with a true object-oriented programming language (Java in this case).

Statement of Originality

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Libraries, being available for photocopying and loan.

Byron Zhang

Acknowledgements

I would like to thank my supervisors, Prof. Friedrich Rechnagel and Dr. HongQing Cao. Friedrich, my principal supervisor, offers this wonderful opportunity for me to engage in the interdisciplinary project between ecology and software engineering. His instruction benefits me to deepen my understanding of the difference and similarity between the scientific research and the software development. Also he has spent lots of precious time to teach me the knowledge of freshwater ecology with his advice, knowledge, even patience. Likewise, HongQing, my co-supervisor, reinforce my knowledge in software engineering area, and she instructs me one of her intelligent Genetic Algorithms, which make me feel that I have more strength for my future career.

This work would not have been done so quickly without the collaborations of Ms. Lydia Cetin. As my key colleague, she has prepared most of the materials that involve in the software development, and sometimes plays a role during I type source code as a peer programmer, especially thanks for her proofreading my thesis.

I also would like to thank my IBP teacher, Ms. Margaret Cargill. She helps me go through my first taste of writing a scientific paper.

Finally, I must thank my parents, QingZhi and DeJun, for their love, support, and financial aid. None of this work would have been possible without their continuous efforts on me.

Contents

1 Introduction 1

1.1 Literature Review 3
1.1.1 Introduction of Object-Oriented History 3
1.1.2 Previous Efforts of Object-Oriented Ecological Modelling 6
1.1.3 Ecosystem Models Using Object-Oriented Design 10
1.1.4 The Object-Oriented Ecosystem Models 13
1.2 Ecological Modelling vs. The Complexity of ecosystems 15
1.3 The Description of SALMO 19
1.3.1 The Structure of The model SALMO 20
1.3.2 Possible Improvements Of Lake Ecosystem Modelling In General And The Model SALMO In Particular By Means Of Object-Oriented Programming 22

2 Proposal: Objectives, Hypotheses and Expected Outcomes 25

3 Materials and methods 28

3.1 Materials 28
3.2 Methods 29
3.2.1 Object-Orientation 29
3.2.2 The Choice of Programming Languages – Using Java 31
3.2.3 Object-Oriented Software Engineering 33
3.2.4 Prototyping 42
3.2.5 Web Tier Techniques 43

4 Results 45

4.1 Prototypes 45
4.2 The SALMO-OO Database 51
4.3 The SALMO-OO Class Library 53
4.4 Web-Enabled Applications 56
4.5 The SALMO-OO Documents 58
4.5.1 The SALMO-OO Requirement Statement Document 58
4.5.2 The SALMO-OO Specification 59
4.5.3 The SALMO-OO Use-Case Diagrams 62
4.5.4 The SALMO-OO Class Diagrams 67
4.5.5 The SALMO-OO Sequence Diagrams 70
4.5.6 The SALMO-OO Communication Diagrams 74
4.5.7 The SALMO-OO UML diagrams for deployment 77
4.6 The SALMO-OO API Specification 80

5 Discussion 81

5.1 SALMO-OO can be implemented by Object-Oriented programming using Java 81
5.2 Users can access SALMO-OO via Internet as well as friendly GUI 85
5.3 Object-oriented technology allows for developing an algal model library 97
5.4 The implication of the SALMO-OO documents 100

6 Conclusions 102

7 Recommendations 104

List of Figures

Figure 1.1 An aquatic ecosystem class diagram (Ferreira 1994).....12

Figure 1.1 The structure of the ODE of SALMO (after Recknagel 1989).....21

Figure 1.2 The input and output variables of the model SALMO 21

Figure 2.1 The components of the EIS.....25

Figure 3.1 The map of Bauzten and Saidenbach reservoir.....29

Figure 3.2 UML use-case diagrams for illustrating the relationship between algae and algal growth 35

Figure 3.3 A UML class diagrams for phytoplankton and blue-green algae class 38

Figure 3.4 A UML sequence diagram for phytoplankton and zooplankton.....39

Figure 3.4 A UML communication diagrams for top-level value passing.....39

Figure 3.5 Data pre-processing 41

Figure 4.1 A UML use-case diagram for food web in the Parker model 46

Figure 4.2 A UML class diagram for Runge-Kutta calculations in the Parker model.....46

Figure 4.3 A UML class diagram for GUI in the Parker model.....46

Figure 4.4(a) The first prototype - the Parker model results 47

Figure 4.4(b) The original Parker model results ((Parker 1968).....49

Figure 4.5 (a) Data table structure ..... Figure 4.5 (b) Profile table structure

Figure 4.6 The SALMO-OO component view 54

Figure 4.7 Visualisation of validation results for concentrations of phosphate PO4-P, chlorophyll a, total algal biovolume and zooplankton biovolume simulated by SALMO-OO for the Bautzen Reservoir in 1978. 56

Figure 4.8 Web tier structure for SALMO-OO 57

Figure 4.9 UML diagrams for use-case for the interaction between the user and SALMO-OO 63

Figure 4.10 UML diagrams for use-case for the structuring of SALMO-OO by means of the model library and user selections 64

Figure 4.11 UML diagrams for use-case for the structure of the model SALMO 66

Figure 4.12 UML class diagrams for the model components of SALMO-OO . 68

Figure 4.13 UML class diagrams for the mathematical operation of SALMO-OO 69

Figure 4.14 UML class diagrams for the graphical user interface of SALMO-OO 69

Figure 4.15 UML class diagrams for the lake database of SALMO-OO 70

Figure 4.16 UML sequence diagrams for the application of SALMO-OO 73

Figure 4.17 UML communication diagrams for the application SALMO-OO ... 74

Figure 4.18 A UML communication diagrams for the relationships between the objects and the shard variables 76

Figure 4.19 UML diagrams for deployment for the stand-alone version of SALMO-OO 78

Figure 4.20 UML diagrams for deployment for network version of SALMO-OO 79

Figure 4.21 Suites file hierarchy of SALMO-OO 80

Figure 5.1 Simulation results by the FORTRAN IV version of SALMO for the Lake Stechlin 1975, Saidenbach Reservoir 1975 and Bautzen Reservoir 1978 81

Figure 5.2 Simulation results by SALMO-OO for Saidenbach Reservoir 1975 82

Figure 5.3 Simulation results by SALMO-OO for Bautzen Reservoir 1978 83

Figure 5.4 Initial GUI of the stand-alone version of SALMO-OO 86

Figure 5.5 Example for the selection of lake ‘Bautzen’ by means of the GUI stand-alone version of SALMO-OO 87

Figure 5.6 Example for the selection of year ‘1978’ of lake ‘Bautzen’ by means of the GUI stand-alone version of SALMO-OO 88

Figure 5.7 Visualisation of validation results for concentrations of phosphate PO4-P, chlorophyll a, total algal biovolume and zooplankton biovolume simulated for the Bautzen Reservoir in 1978 by the stand-alone version of SALMO-OO (page No. 1) 89

Figure 5.8 Visualisation of validation results for concentrations of phosphate PO4-P, nitrate NO3-N, dissolved oxygen and detritus simulated for the Bautzen Reservoir in 1978 by the stand-alone version of SALMO-OO (page No. 2) 90

Figure 5.9 Visualisation of validation results for the concentrations of total algal biomass, diatom biuomass, green algae biomass and blue-green algae biomass simulated for the Bautzen Reservoir in 1978 by the stand-alone version of SALMO-OO (page No. 3) 91

Figure 5.10(a) Modelling selection page .... Figure 5.10(b) 1st result page 92

Figure 5.10(c) 2nd result page Figure 5.10(d) 3rd result page 92

Figure 5.11(a) Selection of the scenario ‘artificial mixing and phosphate load reduction’ for the Saidenbach Reservoir in 1975 by means of the GUI of the stand-alone version of SALMO-OO 93

Figure 5.11(b) Specification of the phosphate load reduction by 90% for the selected the scenario ‘artificial mixing and phosphate load reduction’ for the Saidenbach Reservoir in 1975 by means of the GUI of the stand-alone version of SALMO-OO 94

Figure 5.12 Simulation result of the scenario ‘artificial mixing and phosphate load reduction’ for the Saidenbach Reservoir in 1975 visualised by the GUI of the stand-alone version of SALMO-OO.....95

Figure 5.13(a) Lake selection web page Figure 5.13(b) Year selection web page 96

Figure 5.13(c) Scenario selection web page Figure 5.13(d) 1st result web page 96

Figure 5.13(e) 2nd result web page Figure 5.13(f) 3rd result web page.....97

Figure 5.14 Selection of the algal growth model 3 from the model library for the simulation of the Bautzen Reservoir in 1978 by means of the GUI of the stand-alone version of SALMO-OO 98

Figure 5.15 Selection of the algal grazing model 3 from the model library for the simulation of the Bautzen Reservoir in 1978 by means of the GUI of the stand-alone version of SALMO-OO 99

Figure 5.16 Illustration of the simulation results for the Bautzen Reservoir in 1978 by different model structures of SALMO-OO selected from the model

library of the stand-alone version of SALMO-OO (from Cetin, Zhang and Recknagel 2005) 100

List of Tables

Table 3.1 Choice of programming languages.....32

Table 4.1 Examples of the naming list of SALMO-OO.....60