GENERIC SIMULATION MODELLING OF STOCHASTIC CONTINUOUS SYSTEMS

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Summary

The key objective of this research is to develop a generic simulation modelling methodology that can be used to model stochastic continuous systems effectively. The generic methodology renders simulation models that exhibit the following characteristics: short development and maintenance times, user-friendliness, short simulation runtimes, compact size, robustness, accuracy and a single software application.

The research was initiated by the shortcomings of a simulation modelling method that is detailed in a *Magister* dissertation. A system description of a continuous process plant (referred to as the Synthetic Fuel plant) is developed. The decision support role of simulation modelling is considered and the shortcomings of the original method are analysed. The key objective, importance and limitations of the research are also discussed.

The characteristics of stochastic continuous systems are identified and a generic methodology that accommodates these characteristics is conceptualised and developed. It consists of the following eight methods and techniques: the variables technique, the iteration time interval evaluation method, the event-driven evaluation method, the Entity-represent-module method, the Fraction-comparison method, the iterative-loop technique, the time "bottleneck" identification technique and the production lost "bottleneck" identification technique. Five high-level simulation model building blocks are developed.

The generic methodology is demonstrated and validated by the development and use of two simulation models. The five high-level building blocks are used to construct identical simulation models of the Synthetic Fuel plant in two different simulation software packages, namely: Arena and Simul8. An iteration time interval and minimum sufficient sample sizes are determined and the simulation models are verified, validated, enhanced and compared. The simulation models are used to evaluate two alternative scenarios. The results of the scenarios are compared and conclusions are presented.

The factors that motivated the research, the process that was followed and the generic methodology are summarised. The original method and the generic methodology are compared and the strengths and weaknesses of the generic methodology are discussed. The contribution to knowledge is explained and future developments are proposed. The possible range of application and different usage perspectives are presented. To conclude, the lessons learnt and reinforced are considered.

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Martin Albertyn
October 2004
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"Zen and the art of the lean, mean simulation model"

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LIST OF ABBREVIATIONS

BPR	:	Business Process Re-engineering
c.	:	*circa* - about, approximately (used in the references)
ED	:	event-driven
eq.	:	equation
ERM	:	Entity-represent-module
et al.	:	*et alii*, *et alia* - and others
etc.	:	*et cetera* (also *etcetera*) - and the rest; and similar things or people
EUROSIS	:	European Simulation Society
FC	:	Fraction-comparison
FMCG	:	Fast-moving Consumer Goods
GTL	:	Gas-to-liquids
i.e.	:	*id est* - that is to say
INT	:	Integer function that drops the fractional portion of a variable to return its integer value
ITI	:	iteration time interval
LP	:	Linear Programming
Ltd.	:	Limited
m^3/h	:	cubic metres per hour (used for the liquid phase)
MBA	:	Master of Business Administration
MTBF	:	Mean Time Between Failure
MTTR	:	Mean Time To Repair
MW	:	megawatt
nm^3/h	:	normalised cubic metres per hour (used for the gas phase)
No.	:	number
no.	:	number (used in the references)
OR	:	Operations Research
Pty.	:	Proprietary
p.	:	page (used in the references)
RAM	:	Random Access Memory

LIST OF ABBREVIATIONS
(CONTINUE)

Sapref	:	South African Petroleum Refinery
S.l.	:	*sine loco* - without a place (used in the references)
sic	:	used, spelt, *etc.*, exactly as written in the work that is quoted
SPD	:	Slurry Phase Distillate
ton/h	:	tons per hour (used for the solid phase)
VBA	:	Visual Basic for Applications
VL	:	Visual Logic (the logic building environment of Simul8)
vol.	:	volume (used in the references)
WSSD	:	World Summit on Sustainable Development

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INTRODUCTION

The key objective of this research is to develop a generic simulation modelling methodology that can be used to model stochastic continuous systems effectively. Simulation models that are developed with the generic methodology have the following characteristics: short development and maintenance times, user-friendliness, short simulation runtimes, compact size, robustness, accuracy and a single software application.

The first chapter provides detail about the origins of, and the motivation behind, the research that is presented in this document. The origins of the research can be traced back to the development of a simulation model of the Sasol East plant. The simulation modelling method of this simulation model, which is the subject matter of a *Magister* dissertation, is used as the point of departure for the development of a generic simulation modelling methodology. A system description of an imaginary continuous process plant is developed. This plant represents the Sasol East plant, is referred to as the Synthetic Fuel plant and is used to demonstrate the generic methodology. The role of simulation modelling as a decision support tool is considered and the shortcomings of the original simulation modelling method are analysed. The key objective, importance and limitations of the research are also discussed.

The generic simulation modelling methodology is conceptualised in the second chapter. The key characteristics of stochastic continuous systems are identified and discussed. Seven methods and techniques are developed to solve the unique simulation modelling problems that are posed by these characteristics. The seven methods and techniques are integrated into, and form the "toolbox" of, the generic methodology. In Chapter 3 the two simulation models that are developed with the generic methodology are enhanced and another method is developed and integrated into the generic methodology. Therefore, the "toolbox" of the generic methodology contains the following eight methods and techniques: the variables technique, the iteration time interval (ITI) evaluation method, the event-driven (ED) evaluation method, the Entity-represent-module (ERM) method, the Fraction-comparison (FC) method, the iterative-loop technique, the time "bottleneck" identification technique and the production lost "bottleneck" identification technique. The generic methodology is divided into two separate parts, namely: an iterative-loop technique part (that determines the governing parameters) and a simulation model part. The simulation model itself is divided into a "virtual" part (represented by the logic engine high-level building block) and a "real" part (represented by the four different high-level building blocks of the ERM method). The five high-level building blocks can be used to construct simulation models of stochastic continuous systems.

In the third chapter the generic simulation modelling methodology is demonstrated and validated by the development of two simulation models. Different simulation software packages are evaluated and a simulation model breakdown is derived from the system description of the Synthetic Fuel plant. The five high-level building blocks are used to construct two identical simulation models of the Synthetic Fuel plant in two different simulation software packages, namely: Arena and Simul8. An iteration time interval and minimum sufficient sample sizes are determined and the simulation models are verified, validated, enhanced (by the inclusion of an additional evaluation method option) and compared. The strengths and weaknesses of Arena and Simul8 are discussed.

In the fourth chapter the two simulation models are used to evaluate two alternative scenarios. The scenarios are used to identify the "bottlenecks" and to determine how additional capacity impacts on the throughput of the Synthetic Fuel plant. The results of the scenarios are compared and conclusions are presented.

The last chapter provides a synopsis of the research. The factors that motivated the research are identified and discussed. The process that was followed is detailed and a concise summary of the generic simulation modelling methodology is provided. The original simulation modelling method and the generic methodology are compared and the strengths and weaknesses of the generic methodology are discussed. The contribution to knowledge is explained and possible future developments are proposed. The possible range of application and three different usage perspectives are identified. To conclude, a few of the lessons learnt and reinforced during the completion of the research are presented.

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