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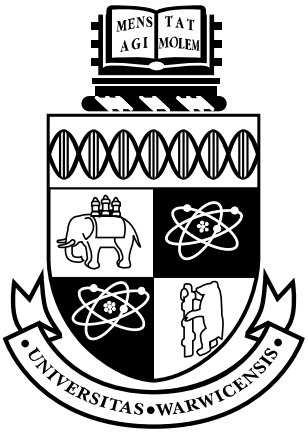

Interaction with Meaningful State: Implementing Dependency on Digital Computers

by

Ashley Thomas Ward

Thesis

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THE UNIVERSITY OF
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To Uncle Adam, Uncle Colin,
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Declaration

This thesis is presented in accordance with the regulations for the degree of Doctor of Philosophy. It has been composed by myself and has not been submitted in any previous application for any degree. The work in this thesis has been undertaken by myself except where otherwise stated. All quoted text remains the copyright of the original attributed author. I have taken the liberty of correcting typographical errors, spelling and grammar where necessary. All trademarks are acknowledged.

None of the material in this thesis has been previously published, but some of the motivating ideas have appeared in joint work published in [BCSW99, BWM+00, BCH+01, BRWW01, BBRW03].

Interaction with Meaningful State:
Implementing Dependency on Digital Computers

Abstract

A perception of an agent as follows — that the act of changing the value of one observable indivisibly entails a predictable accompanying change in that of another — can be termed a *dependency*. Indivisibility in change allows us, as agents, to make our experience of interaction with the 'world' meaningful.

Empirical Modelling (EM) is the name we have given at Warwick to the activity of building artefacts to embody patterns of observables, dependencies and agent actions that are encountered in experience. EM involves the progressive development of understanding through interaction, whereby meaning is continually refined in the light of additional experience. An EM artefact can be physical (*cf.* the Phillips machine [Phi00]) or computer-based (*cf.* spreadsheets).

This thesis investigates how dependency can be effectively implemented on a digital computer through the critical evaluation of three contrasting tools to support EM developed at Warwick over the last 16 years. The thesis contribution has three aspects: conceptual insight; critical, historical and empirical review; and technical and practical development.

Slade's original Abstract Definitive Machine (ADM) concept [Sla90] and its implementations are reviewed and linked to the original motivation for its development — animating LSD accounts. The main emphasis of the ADM is on agency. Subtleties and inconsistencies in the way in which the ADM concept has developed over time are exposed and an algorithm for an 'Authentic' ADM (AADM) is proposed.

Cartwright's design and implementation of the Definitive Assembly Maintainer (DAM) machine [Car99] is analysed and critiqued. The DAM machine emphasises only dependency. The DAM machine is extended to allow lower-level interaction using a special-purpose code and to exploit the video hardware to create dependency at a very low level.

The primary tool of the EM research group, EDEN [Yun93, Yun90], successfully combines both dependency and agency. Its development is reviewed in its historical context and various extensions, including novel interfacing, are described. The first exposition of EDEN's internal operation is given.

The analysis of existing EM tools motivates the examination of some problematic issues regarding concurrency, moding and higher-order dependency. Some proposals for design and implementation to address these issues are described.

Throughout the thesis, consideration of technical issues is motivated by the possibility that human engagement with computers can have qualities similar to engagement with 'real-world' artefacts, manifest in interaction with meaningful state that is at all times intelligible to the human interpreter, unlike the typically meaningless intermediate states that are generated in the execution of a conventional program. The insights that exploring this possibility brings may be significant in producing programs that are more robust under change.

Abbreviations

AADM	Authentic ADM
ADM	Abstract Definitive Machine [Sla90]
AOP	Agent-Oriented Parser [Har02, Bro01]
ARCA	A definitive notation named after Arthur Cayley (1821–1895), which "might be charitably regarded as 'An Aid for the Realisation of Combinatorial Artefacts'" [Bey83]
BRA	Block Redefinition Algorithm [Car99] (my abbreviation)
CADNO[1]	Computer-Aided Design Notation ([Bey89b], first named in [Bey89a])
DAM machine	Definitive Assembly Maintainer machine [Car99]
DAMscript	A type of Low Level Definitive Notation used to program the DAM machine
DM	Dependency Maintainer
DMM	Dependency Maintainer Model [Car99]
!Donald	An implementation of DoNaLD running on the DAM machine
DoNaLD	Definitive Notation for Line Drawing [BABH86]
`dtkeden`	An implementation of EDEN that allows distributed communication [Sun99]
EDDI	Eden Definition Database Interpreter [Tru96]
EDEN	Engine for DEfinitive Notations [Yun90] — in this thesis, upper case 'EDEN' denotes an implementation
Eden	The language implemented by EDEN [Yun89]
EM	Empirical Modelling

[1] Also Welsh for "fox".

empublic	A local directory containing our tools installation and collected archive of models, partially accessible via the web [WRB]
FV	Formula Variable [Yun90] (in Eden)
HOD	Higher Order Dependency/Definition
ISM	Interactive Situation Model [Sun99]
LLDN	Low Level Definitive Notation [Car99] (my abbreviation)
LSD	Language for Specification and Description [Bey87a]
RWV	Read-Write Variable [Yun90] (in Eden)
S, $S*$, S' states	States before, during and after a transition
Sasami	A definitive notation for EDEN allowing use of 3D graphics, implemented using OpenGL [Car00]
SCOUT	SCreen layOUT — a definitive notation [Yun93]
`tkeden`	An implementation [Yun93] of EDEN with a graphical user interface implemented using Tcl/Tk [Ous94]
`ttyeden`	An implementation of EDEN with a terminal-based 'curses' interface
UNITY	Unbounded Nondeterministic Iterative Transformations — a computational model and proof system [CM88]
VM	Virtual Machine