Empiricism in Computer-Based Modelling

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Agenda

What have we been doing?

What do we make of it?

What is its relationship to TCS?

What implications does it have for TCS?

What have we been doing?

10 year Empirical Modelling Project ...
- approach to computer modelling
- applications
  - interactive graphics (cf Wyvill)
  - concurrent systems modelling (BT / MSc)
  - software development (IBM)
  - CAD / concurrent engineering (EPSRC)
  - history / philosophy

Edward & Simon Yung
Mark Norris & Mike Slade
Alan Cartwright

MOTIVATION.

SPECIFICATION OF REACTIVE SYSTEMS

cf. NO SILVER BULLET — BROOKS
BITING THE SILVER BULLET —HAREL

- THEORY APPROACHES VIA COMPLEX MATHEMATICAL MODELS WITH WELL-DEFINE OPERATIONAL SEMANTICS
- "REAL-WORLD SEMANTICS": CORRESPONDEN BETWEEN MATHEMATICAL MODEL AND STATE-CHANGING DEVICES IN CONTEXT OK. FOR TRADITIONAL COMPUTER ✓ PROBLEMATIC IN REACTIVE SYSTEM
- HAREL ADVOCATES VISUALISATION AND INTERACTIVE INCREMENTAL SPECIFICATION

ISSUE: CAN WE MAINTAIN CLOSE CORRESPONDENC MODEL ⟷ REAL-WORLD SEMANTICS AND ACHIEVE THE BENEFITS OF FORMAL MODEL

Empirical Modelling

state-based

interactive

agents and viewpoints

definitive scripts: indivisibility

[definitive = definition-based]

"PROGRAMMING AS MODELLING"

REVISITED

Essential concepts

... consider the spreadsheet

cell ↔ observable

redefinition ↔ action

effect of redefinition

↔ state-transition associated with action

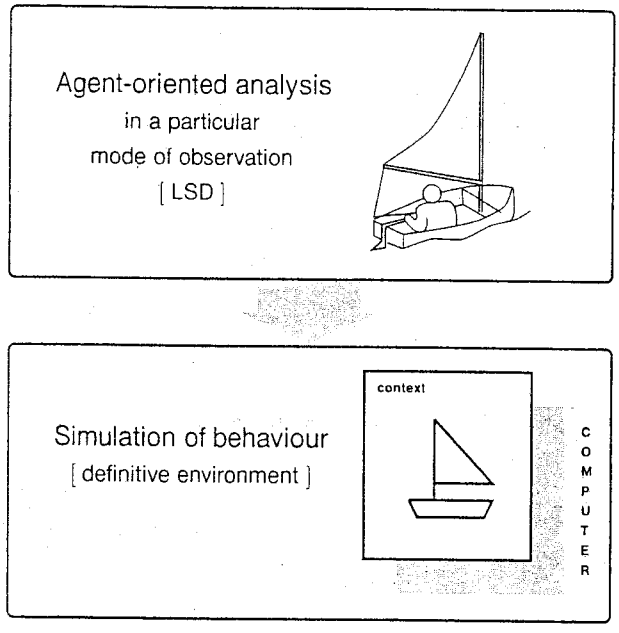
... generalisation via **definitive notations**

computer-generated observable ↔ observable

computer-interpreted stimulus ↔ action

... illustrated by the sailboat model

Agent-Oriented Modelling



Agent-Oriented Analysis

observables in

activity Identifying and classifying observations of a system with respect to state-changing agents

notation LSD

extract

```
agent sail {
state
  sail_dir      // sail direction as bearing [rad]
  driving_dir   // sail driven anti/clockwise [1/-1]
  driving_force // driving force of sail [N]
  sheet_angle   // angle between keel and sail [rad]
  sail_area     // effective sail area [m^2]
oracle
  rel_wind_dir  // wind dir. experienced by the sail
  rel_wind_speed  // wind speed experienced by the sail
  sailAvel
derivate
  sail_area = boom_len * mast_len * cos(list)
  sail_dir = heading + pi + sheet_angle
  ...
}
```

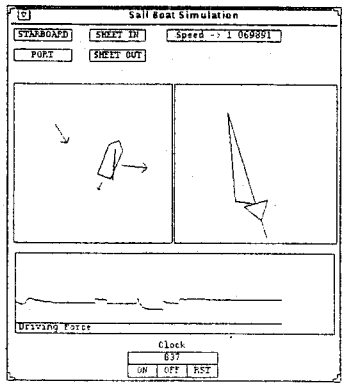
Simulation of Behaviour

activity Providing a context for execution & interaction

notation Definitive environment

	A	B	C	
1	sail_dir	driving_dir	mast_len	
2	driving_force	sheet_angle	heading	
3	sail_area	boom_len	list	
4				

A.3 = B.3 * C.1 * cos(C.3)
A.1 = C.2 + pi + B.2



What do we make of it?

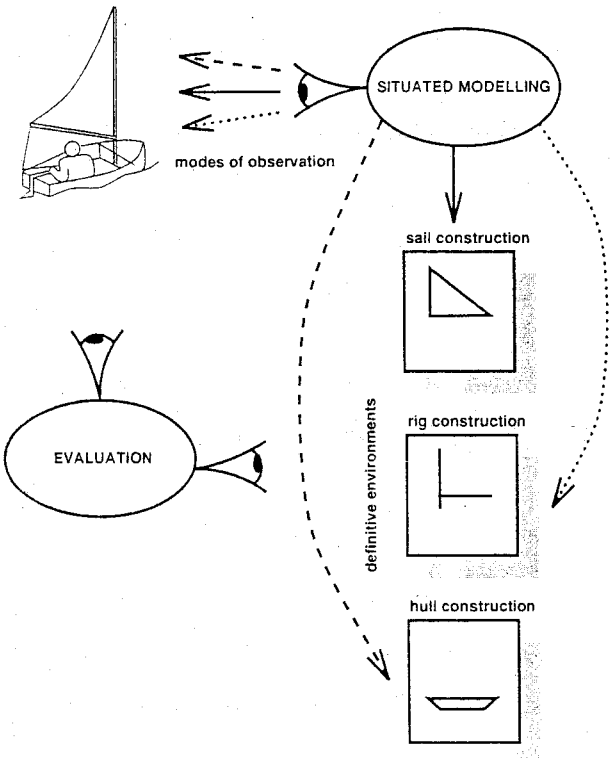
Characteristics of our models

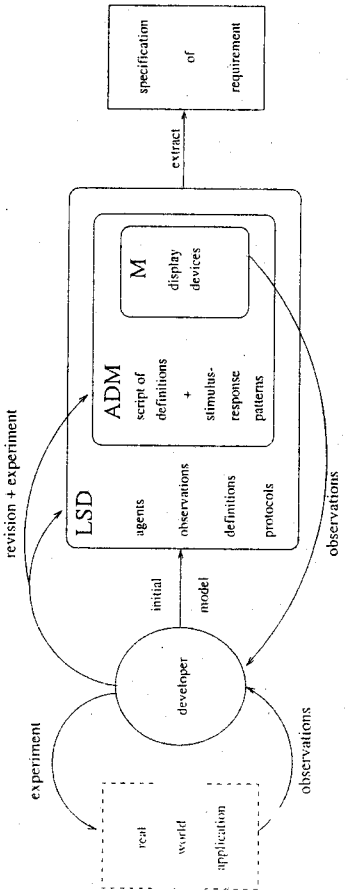
- models non-circumscribed behaviour
  invokes an agent concept
  supplies basis for definition of agent action

- corr. between state-based models; "situated"
  models how each agent affects state of others
  environment not a document

- presumes only a reliable state-changing device
  cf computer as scientific instrument
  cf engineering model

Modes of Observation





The "Good Experiment" Paradox

A Good Experiment is one in which we really don't know what to expect ...

BUT

... must be some preconception of what to expect

A Good Experiment is one in which we know exactly what will happen ...

BUT

... must be some possibility of being confounded

Essence of Empirical Modelling process

Conviction based on empirical evidence converts experimental activity from 1st to 2nd category

Only a change of **perspective** is involved

NOT

a change in the experimental activity

What is its relationship to TCS?

Our models vs theoretical models

	private	public
expt	private experiment personal experience	public experiment phenomenological
theory	private theory private conviction	public theory science

experiment -> *conviction* -> theory

private -> *communication* -> public

experimental method: from expt to theory

convention, consensus:

from private experience to shared knowledge

Illustrative example

Computer-assisted jigsaw solving

identification and classification of pieces
by puzzler is personal and pre-articulate

ingredients can't be preconceived
e.g. solve by turning the jigsaw upsidedown

formal specification of the solution
formal description of a class of pieces
(e.g. the RHS of the jigsaw)
is inappropriate in process of solution

Empiricism and the Sailboat Model

cf sailboat: windforce = F(wind_vector)

... what is F? ... there are three answers:

- PN's personal experience of sailboat
- spurious theoretical model (WMB+SY)
- Experimentally derived (sailboat authority)

Empirical ingredients in this context

- PN's experiences of sailing
- SY + WMB's recourse to theory
  (influence of theory on modelling)
- correlation between
  experience of boat & predictions of model
- knowledge informing kind of model

[use of Newtonian dynamics & decomposition *together with* empirical windforce model]

Bifurcation of concepts ↔ transition to theory

time

... as timely response to stimulus

... as clock

language

... as reference to identities: mere symbols

... as structural conventional pattern

lexation vs patternment

environment vs document

[clarification through interaction vs names]

theory

... as conviction

... as public knowledge, consensus

reality

... as directly perceived

... as accepted by common consensus

What implications does it have for TCS?

What is TCS? cf what is Theoretical Engineering?

Theory has empirical roots ... so what?

Claim *can't abstract from empirical roots*

Classical theory of computation:

presumes reliable devices

discount interaction conventions

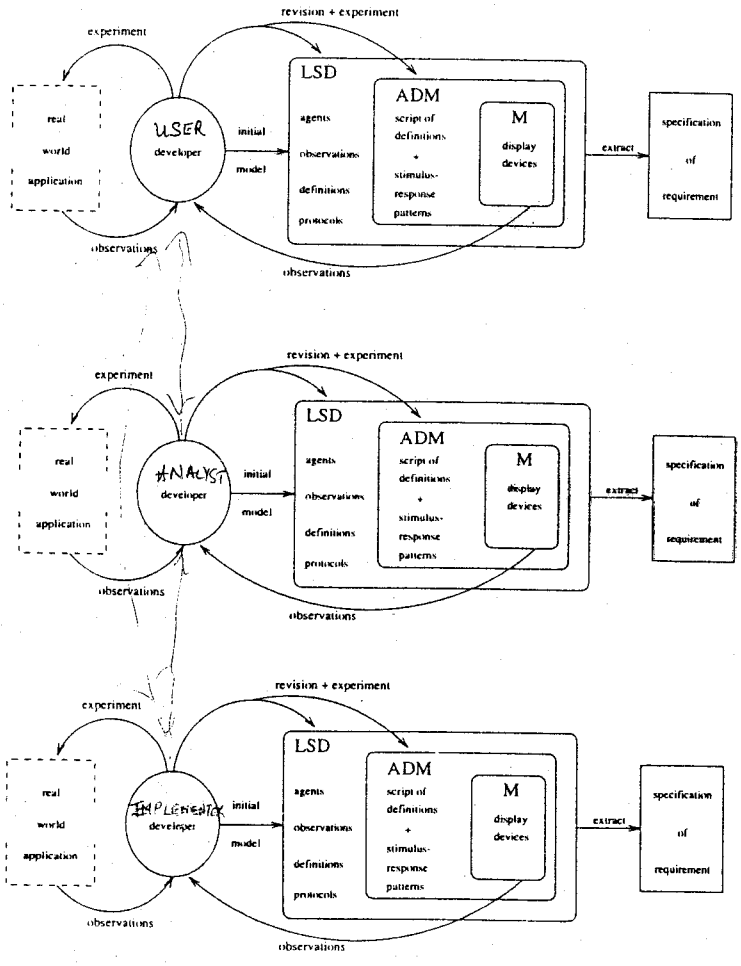
essence of problem not in interaction media

BUT ... what is directly experienced transcends any given abstract formal model of communication

.. theory is available only in fragments eg Newton

... don't disparage these (cf naive physics stance) but must set in the context of empirical knowledge

..empirical modelling for ignorance representation



Closed World *vs* Open Development

circumscribed *vs* immediately experienced behaviours

logical *vs* phenomenological variables

preconceived reliable response *vs* experiment

abstract *vs* situated modelling

computer = calculator *vs* computer = state representer

computer = machine *vs* computer = instrument

theoretical *vs* empirical

form *vs* process

theory-oriented *vs* agent-oriented

declarative *vs* procedural

consistency + completeness *vs* conflict + singularity

encapsulated *vs* open to interaction

abstract general universal *vs* concrete specific personal

Empirical Modelling Concepts ... Definitive Scripts

..... *alogical* relationship between form and content

- spreadsheet principle

  situated modelling
  viewpoint oriented
  indivisible relationships
  fastidious not *promiscuous* modelling

- definitive scripts

  metaphorical representation of state
  dependencies between viewpoints
  representation of agent interface

- cognitive artefacts

  state-based computer model
  society of mind
  specification of agent views
  phenomenological variables