Empirical modelling: a development methodology for reactive systems?

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The Empirical Modelling Project (EMP) is a programme of research that has been under development at Warwick over the last ten years [3, 14, 4, 8, 2, 6, 5, 9]. Two primary themes in the research are dependency and agency. The aspects of agency that have been the main focus of attention are rather primitive in comparison with those generally considered in connection with symbolic AI. A closer connection may be established with the work of Brooks [10, 11], whose approach eschews explicit symbolic representations, and emphasises the essential role of situatedness in any account of intelligence. There are two ways in which the ideas outlined in this short abstract can be construed: as contributing towards a development methodology for reactive systems (cf [17]), or - paradoxically - as discrediting the very concept of such a methodology in any conventional sense

A major focus of concern in the EMP is on understanding agency in a very general sense, without specific emphasis on agents as programming artefacts. Our research has involved the development of software tools to assist us in constructing agent-oriented models, but perhaps our most relevant contribution to agent-oriented analysis is the development of a notation for describing agents (the LSD notation [1]) that has no formal operational semantics. The most controversial - but potentially most significant - feature of our research is that it aims to lay a principled foundation for non-linguistic, pre-articulate representations arguably beyond the scope of symbolic AI. This involves the use of the computer to create physical artefacts that explicitly imitate phenomena in a manner that is similar to that involved in the development of a scientific instrument or an engineering prototype. The semantics of such a physical artefact is defined by interaction, rather than circumscription, and so lends itself to open-ended use and interpretation that is not necessarily preconceived prior to its construction. The underlying principles exploited in constructing such artefacts resemble spreadsheet development and use.

In simple terms, we regard agency as a conceptual device fundamentally associated with how a phenonemon is construed. As has been argued by McCarthy, an animistic view is most useful when applied to a phenomenon that is incompletely understood [13]. By making use of our new methods of representation mentioned above, we believe it is possible to construct computer models of n-agent systems ($n \geq 1$) in which the roles of agents with a degree of autonomy can be played by the modeller in the guise of superagent. Phenomena that are comprehensively understood can be represented either by animistic models in which the agents have a preconceived and limited degree of autonomy, or by mechanistic (0-agent) models. This latter category of models comprises those that are formal in the conventional sense.

The relationship between 0-agent models - as realised by formal (typically computer-based) models with an unambiguous operational interpretation, and n-agent models - as realised by physical artefacts (possibly but not necessarily computer-based), resembles the relationship between a scientific theory and the physical apparatus and experimental protocols used to establish and corroborate the theory. As discussed by Gooding in [12], this relationship is far more subtle than is sometimes acknowledged in the philosophy of science; we attribute the difficulty of giving a satisfactory formal account of agency to a similar failure to pay sufficient attention to the empirical foundations upon which agent-oriented analysis relies. The essence of our development method is the systematic incremental construction of n-agent models by an empirical process that conceptually involves experimentation with the evolving model and with the external phenomenon to which the model refers. The open-ended and situated character of this development process is consonant with Wavish and Graham's observation that, in a reactive architectural paradigm, each system must be individually hand-crafted through a potentially lengthy period of experimentation [16]. It also explains why it may be inappropriate to describe empirical modelling as a development methodology

A more detailed account of the LSD notation, and of the definition-based ("definitive") modelling principles used to represent state, is beyond the scope of this abstract. A large number of agent-based models, representing several different potential applications, can be found in our previous papers. Engineering simulations developed using our approach include a vehicle cruise controller, a sailboat, and an inverted pendulum [3, 14]; concurrent systems modelled include extended railway and digital watch animations [4, 2], interactive environments have been developed for primitive jigsaw construction and combinatorial geometric investigation [8, 9], and computer models have been constructed for billiards, cricket and OXO-like games [5, 6]. Of particular interest is the complementary research that has been directed at circumscribing agency within our models, so as to transform relatively large and inefficent computer models in which the modeller has exceptionally powerful privileges into more efficient models with much more limited functionality. This research indicates clear potential for semi-automatic translation to derive conventional programs from an agent-oriented model of a system requirement.

Our philosophical stance on agent-oriented modelling is not logicist. In the spirit of Cantwell-Smith [15], it aspires to principles based on foundations more general than conventional computational theory admits, in which physical realisibility has an essential role. This is not to argue that there is no place for the development of a belief, desire and intention framework for agent-based reasoning, but to suggest that such considerations are only one aspect (and possibly a relative minor aspect) of human intelligence, and that such a framework has to be built upon explicit and well-established empirical foundations. It is commonly supposed that logic represents the most primitive foundation for description of phenomena, and cannot be underwritten by yet more fundamental principles. The primary characteristics of logic as a medium for public communication, concerned with generalisations and the formalisation of absolute knowledge, are in complete contrast to our primary experience of agency, which originates in personal and private perceptions of specific situations, and has an experimental quality. An archetypal example of the fundamental activity to which our empirical modelling appeals, that we believe to be much more primitive than logic in its essence, is the process by which an optician diagnoses the characteristics of another person's sight through the systematic use of artefacts. In our view, a satisfactory foundation for multi-agent systems has to accommodate the empirical, private and specific as well as the rational, public and general elements in human understanding, and explicate the relationship between the two [7].

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