Empirically Modelling a Fire Control System

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Abstract

This paper briefly considers the application of the principles of Empirical Modelling to an analog mechanical computer of WWII, and puts forward the theory that this primitive early computer, that followed such different principles to today's all-purpose computers, had properties of its design in common with EM models. The computer and system in question are related briefly to the principles of Human Computing, and the outcome of the modelling exercise itself is critiqued.

1. Introduction

This paper is a study of the application of the principles of Empirical Modelling to the creation of a model of an electro-mechanical gunnery control system in place on United States Naval Vessels around World War II.

The Ford Instruments Mk37 gunnery control system was a significant step in the development of the modern computer, as it incorporated as its core component the Ford 'Mark I Computer,' (not to be confused with the better-known *Harvard* Mark 1 Computer,) an ingeniously designed electro-mechanical analog computer which addressed the complex real-time mathematical problem of naval gunnery.

The Mk37, and specifically the Mark 1, are an appealing subject for the application of Empirical Modelling. Most significantly, the principles behind the Mark 1, though it was built long before the field existed, strongly correlate to those of Empirical Modelling. This paper briefly makes this argument and examines the significance of it.

Secondly, it is of interest to EM in its capacity as an embodiment of an alternative computing philosophy - analog mechanical computing - lying outside the current dominant paradigm of digital Von Neumann machines executing procedural code.

This paper considers the value of the model as an instructive demonstration both of Empirical Modelling and of the Mk 37.

Finally, it is freely admitted that the Mk 37 model is not in any sense 'complete.' This paper considers the considerable remaining potential for further work on the topic.

2. The Mk 37 Model

The Mk 37 (and environment) model is extensively documented, so a full discussion of its nature and capabilities is not necessary here. However, a brief introduction seems appropriate.

The model includes of a simple mathematical model of the environment in which the Mk 37 is situated – namely, a naval battle. As a system that has 'sensors' and 'effectors' for 'perceiving' and 'affecting' its environment, to look at it as a single entity, it is effectively meaningless out of its intended context.

The model of the Mk 37 itself consists of three components, each of which has an interface which allows the user to place themselves in the role of the human operator. These are the 'director' or observation tower, the central computer (in version 2,) and the gun turret. A fourth, 'god's eye view' interface is provided to allow the modeller/user to overview the simulation's current state.

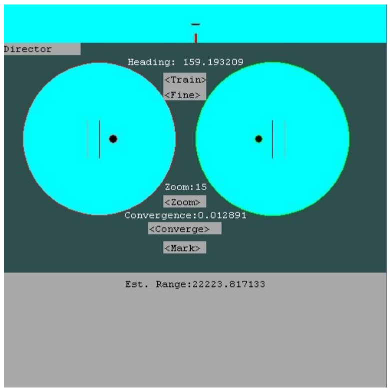

Figure 1: The interface for the 'director' including the rangefinder 'eyepieces.'

3. The compatibility of EM and analog mechanical computing

'Modelling,' the act of creating a representation of something that preserves at least some of the subject's properties, meaning or function, is *not* a recently developed human behaviour, and the power of today's digital computers means that sophisticated mathematical models of all manner of things are always being constructed. Naturally, the most common approach is that of using the techniques of conventional computer science – usually procedural programming, and often employing layers of abstraction such as object orientation. Thanks to the power of modern computer hardware and the ease of use provided by abstractions such as Object Orientation, great things have been achieved in modelling using these conventional, procedural techniques.

However, even with abstractions such as O.O., achieving anything in this mode usually requires the problem to be expressed in procedural code, whether this suits the problem or not. It is worth remembering that the dominance of procedural methods is in large part due to historical and economical reasons.

Empirical Modelling is concerned with permitting the use of today's computers to construct models more freely, concentrating upon the nature of the subject, in terms of dependencies, observables and agency, rather than having always to work in the terms dictated by procedural programming.

The Mark 1 Computer is of interest to the field of Empirical Modelling as, as alluded to above, the principles of its design mirror those of Empirical Modelling to a degree. More specifically, the Mark 1 may be regarded as a physically embodied model in itself, albeit an abstract one. Examined on a 'black box' level, the Mark 1 is typical of what we today refer to as a computer – it accepts input and produces results based upon them. However, what makes it interesting is the manner in which it works; the Mark 1 is totally dedicated – it is not a stored program computer, and does not 'execute' a program using a general purpose centralised architecture as modern digital computers do.

Rather, it consists primarily of mechanical components- rotating cams, gears and shafts, the rotation and interaction of which result in the 'output' of results. The machine has no 'thread of execution,' as all of its components are in operation at all times.

Observables of the 'real' world outside the vessel, such as the range of the target vessel, are represented physically by, for example, the rotation of a shaft. The mechanical components which enable the machine to perform its task are graceful physical embodiments of the dependencies between these properties. For example, two rotating shafts represent the components of two vessels relative to a straight line drawn between them. A differential gear causes another shaft to rotate with a speed that represents, the difference between the two, which happens to be the rate at which the range between the two vessels is currently changing.

Due to the nature of the Mark 1, it has been possible to construct a model of the Mk 37 using definitive scripts, implemented in a far more graceful and 'natural' manner than conventional procedural programming would allow. Indeed, many of the definitions in the model, especially those contained within '*computer.e*' in the second model directly correspond to physical components of the original machine. Thus, this model may be considered a 'truer' or 'purer' representation of the original than a standard procedural simulation. This 'structural accuracy' also permits experimenting with and developing the model in an easy and intuitive manner.

An illustration of the 'algorithm' of the Mark 1 exists, which is *both* a diagram of the internal dependencies *and* a diagrammatic (i.e. not truly physically accurate) illustration of the physical components of the system. Sadly, this diagram cannot be reproduced here, but it is available in Appendix A of Mindell's *Between Human and Machine*. [1]

The above argument stands as evidence that that there is a high degree of compatibility between Empirical Modelling and the practices of analog/mechanical computation. Readers are referred also to Charlie Care's model of a Planimeter, or mechanical integrator, at [2].

4. The Mk 37 and Human Computing

The Human Computing subfield of Empirical Modelling aims to address certain criticism of, to repeat the phrase, the 'currently dominant paradigm' of computing. As discussed above, for a variety of reasons contemporary computing is fixated upon procedural programming, and the formal concept of computation as the algorithmic application of a function or process to some input. EM Human Computing hopes to promote 'New Ways of Using Computers' where computation is 'not only evaluation of a function, but presentation of something in the world.' [3] A human 'user' should be an essential *participant in* the computation itself.

Hopefully at this point in the discussion it is evident that again, the Mark 1 Computer, though very primitive by the standards of today's all-purpose computers, foreshadowed these principles to a small extent.

The 'symbiotic' nature of the Ford Rangekeeping systems varied over time. The original Mk 1 Ford Rangekeeper was essentially simply a calculator, which assisted but could not replace a gunnery officer. This was actually part of the key to the adoption of the Ford machines – the Naval gunnery insitution was conservative and resisted any apparent attempt to reduce the control or prestige of the gunnery officers.

As the systems progressed through the baffling array of Mark numbers, the machine took over more of the calculation, yet the system was never entirely automated, providing a degree of the 'symbiosis' later called for by Licklider.

However, the Mk 1 and its siblings were totally inflexible; the machine was dedicated to its task, and attempting to adjust its mechanically realised 'internal model' to unforseen circumstances would, self-evidently, have been ludicrous. In this sense, it represents all that Human Computing seeks to amend.

4. The Mk 37 Model as an Educational Demonstration

The definitive scripts that make up the Mk 37 model do not stand alone. Documentation is included that not only explains the use of the model, but actively encourages and guides hands-on interaction with it, not simply 'using' the model but also altering it in order to obtain desired behaviours. It is hoped that with appropriate guidance, this model could serve as a worthwhile demonstration of both Empirical Modelling and of the Mk37 system itself.

5. Outcomes and Further Work

This model represents only a beginning upon the task of modelling the Mark 37 and its context, and as such there is considerable scope for expansion of this work, which is briefly considered below.

5.1. Corrective Feedback

This exercise was begun with the aim of modelling the Mk 37 to the best level of detail, (if not necessarily accuracy) feasible. Sadly not everything wished for was achieved, and it lacks a number of the features of the real thing. Perhaps the most significant failure of this model is the lack of the feedback correction mechanisms present in the original Mark 1 Computer.

The innovation of the Mark 1 in comparison to its peers was its inclusion of feedback loops enabling error to be corrected for, and a solution to be converged upon. Despite considerable effort, the modeller has been unable to incorporate this feature into the model. It seems likely, though not certain, that the failure stems from an inadequate comprehension of the Mark 1, rather than of writing with definitive scripts.

The explanation of the Mark 1's operation in [1], while detailed, is neither totally comprehensive nor entirely unambiguous, making the task of attempting to model one from it rather difficult. The potential is here in this model, however, for a modeller of better understanding to integrate this ability.

5.2. Environment Model

The component of this model which represents the environment in which the Mk 37 is situated is highly simplified. Matters of air resistance, wind, 'drift' (caused by the rotation of the airborne shell,) the 'navigational' movement of the own vessel, and the constant rotational movement of both vessels on unsteady seas have all been omitted in order to keep the problem manageable.

Extending the model to three dimensions would permit the use of the Sasami notation to replace the quite abstract interface that currently exists (most notably the rangefinder views,) rendering the model more appealing, accurate, intuitive and easy to understand.

5.3. Distribution

The Mk37 is a distributed, concurrent system that acts as a single agent, yet consists of multiple entities, many of which are human agents. Consequently, a model using *distributed* empirical modelling tools was considered, but rejected as too ambitious. Due to the natural suitability of EM methods for modelling this system posited above, a distributed extension may prove valuable for examining the distribution of a complex computing system that does not fall within conventional computer science.

Acknowledgements

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References

[1] Mindel, David A. *Between human and machine : feed-back, control, and computing before cybernetics*, The Johns Hopkins University Press, 2002.

[2] Care, C. *Planimeter Models*, http://empublic.dcs.warwick.ac.uk/projects/planimeterCare2005/

[3] Russ, S. Human Computing lecture notes