Empirical Modelling for Education: Modelling the Routing Information Protocol (RIP-1)

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Abstract

Teaching of the principles and operation of complex systems (particularly in science-based subjects) often demands that students be presented with a simplified model of a system, with irrelevant details omitted so that only those relevant to a particular educational objective remain. This paper suggests problems that may be encountered by teachers in such cases, and proposes that when combined with traditional teaching methods, Empirical Modelling provides an effective solution that can be utilised by both teachers and students. Teaching of the Routing Information Protocol (RIP-1) is used as an example to demonstrate the strengths and limitations of creating educational models with the EDEN software tool.

1. Introduction

The process of academic teaching often involves helping a student to construct a consistent mental model of some concept or system in order to understand it at some level. Traditional teaching methods, such as lectures, textbooks and set exercises can be sufficient where the subject matter involves some degree of connection to real-world observables (such as teaching the significance of historical events or cultural awareness). However, one might question whether such widely accepted teaching methods are still as effective when the subject matter becomes abstract or intangible in nature.

This question particularly applies to teaching of science-based subjects, where it is often necessary to simplify a concept in order to emphasise a particular aspect of the properties and behaviour of a complex system (such as electron orbits around an atom, or magnetic storage on a hard disk). Such simplification necessarily involves a degree of removal from the complex system that exists in the real world – in effect, partitioning a complex system into multiple levels of understanding and complexity, where only a single level is presented to a student at any one time[6]. This can result in a student having to accept certain properties and behaviours of such systems without understanding the more fundamental concepts than underpin the processes involved.

This presents a problem for a teacher using purely traditional methods because it is quite possible that students will have an entirely different way of construing the system to that of the teacher[1]. The teacher cannot achieve direct transference of his or her own mental model to a student because it will most likely rely on an understanding of some more complex or fundamental principles that the student is currently unfamiliar with. How, then, should one represent an intangible or abstract system to a student that is unfamiliar with its structure and mechanisms in a way that is useful from an educational perspective?

This paper discusses the suitability of the Empirical Modelling approach to education, with particular focus on teaching of the Routing Information Protocol (RIP-1) as an example of how Empirical Modelling can be used to aid a teacher in dealing with more abstract systems.

2. Empirical Modelling in Education

Empirical Modelling involves creation of computer models based on observation of their real-world counterparts, definitions of dependency between observables and agency. The process of forming a model inevitably involves deciding which observables are relevant to the model and which are not – in effect lifting the thing being modelled out of its environment (unless the environment forms part of the model itself), and presenting the model at some level of abstraction without irrelevant details or complexities. Such a model, therefore, makes no presumptions about how it is to be interpreted; rather a student's construal of the system that it represents is formed after experiencing personal interaction with the model.

The fact that a model can represent a simplified abstraction of “what needs to be learned about” without necessarily dictating the way in which one should understand the model makes Empirical Modelling ideally suited to aiding teachers in dealing with more abstract subject areas where it is not feasible for a student to construe a complex system in the same way that the teacher does.

A teacher can use this property of a model to their advantage by providing some background or introductory lesson by more traditional means, and then integrating interaction between students and a model into their teaching, enabling students to form their own construal of a particular representation of a complex system.

3. Model Building

3.1 Related Model

The model of the IGMP protocol[2] (created by R. Boyatt) provides an example of a model for a networking protocol.

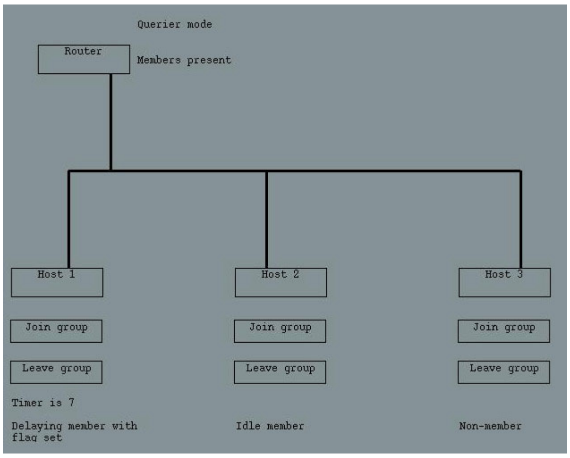

Figure 1: The IGMP model

IGMP (Internet Group Management Protocol) is used by IP hosts to register membership to multicast groups, and by routers to discover group members[3]. Although the model only represents a single scenario, the principles and operation of IGMP become apparent after some interaction with the model’s user-interface. Messages between a router and network hosts are output to the console, and the state of the model is represented graphically on-screen. An advantage of the RIP-1 model over the IGMP model is that it makes use of the more recent clocks feature in the tkeden software tool, allowing the clock in RIP-1 to be dealt with automatically. From an educational perspective, it is useful to have automatic clocks in a protocol simulation because it enables a model to exactly mirror the coordination and timing of protocol instructions.

3.2 Empirical Modelling Tools

The model of the Routing Information Protocol (RIP-1) that accompanies this paper was created using EDEN, the Engine for DEfinitive Notations. The graphical interface was implemented with DoNaLD (Definitive Notation for Line Drawing) and SCOUT (Definitive Notation for SCreen LayOUT)[5].

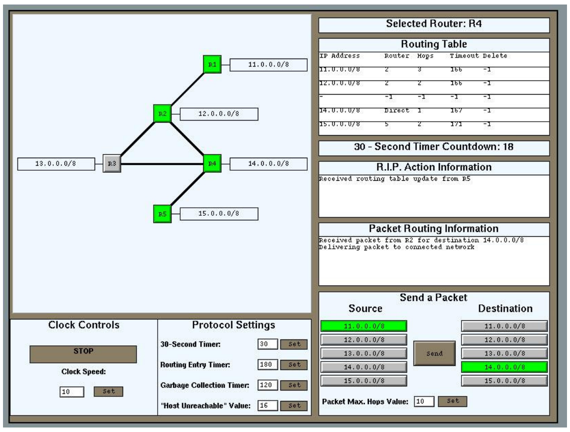

Figure 2: The RIP-1 model

These tools were sufficient for modelling the specific scenario of five interconnected routers and networks. The fact that EDEN variables and dependencies can be manipulated at runtime meant that the ability to alter protocol settings could be built directly into the GUI with any changes having immediate effect. This property of EDEN makes it desirable as a tool for creating educational models, where students can explore the model freely as it runs (rather than have to restart some aspect of the simulation every time a change is made)

As EDEN does not provide support for object-orientation, one can experience a degree of difficulty when attempting to generalise a model from a specific scenario to a set of possible scenarios. In the case of the RIP-1 model, each of the five routers needs a whole set of variables to represent aspects of its state. While such limitation is not detrimental to such a small model, modelling, for example, one hundred interconnected routers in this way would not be feasible. This restricts extension of the model to specialisation, where features are modified or added to the existing framework (rather than generalising the existing framework to cope with a broader range of scenarios).

EDEN's issues with generality are more likely to be problematic when dealing with large-scale business-oriented models than educational models because educational models normally illustrate small-scale examples of some concept or system, and are seldom much more complex than necessary for educational purposes.

3.3 Modelling RIP-1

The Routing Information Protocol (version 1) facilitates the exchange of routing information between connected routers in an autonomous system[4]. The RIP-1 model illustrates how something as abstract as a set of rules for operating on data can be simplified and graphically represented in a way that preserves the fundamental principles of the protocol's operation while omitting irrelevant implementation details (such as message headers).

Once a level of simplification and abstraction has been decided upon, protocols are relatively easy to model accurately because they rely on well-documented rules (rather than subjective observations). This does not mean that teaching their operation is also easy. Although the rules themselves can be memorised, the way in which the protocol's elements work together as a system can be difficult to visualise. By interaction with the model, a student can immediately visualise the way in which protocol rules produce the desired behaviour of routing messages to their destination.

The RIP-1 model has potential educational benefit to a student at several levels:

Given a working model with no background, context or instructional exercises, a student will be able to learn about the basic principles that form the behaviour of the model. They will be able to interact with the model and observe changes in behaviour. The problem with this is that the student will have interacted only with the model – an abstract simplification of a real-world implementation. The student will not gain appreciation of the context in which the protocol operates, and may miss some interesting features or behaviours that can occur.

Given a working model together with some traditional introductory lesson, background information on RIP-1 and suggested avenues for exploration of the model, a student will be able to explore the model to a deeper level, perhaps steering the model into unusual or interesting states by following suggestions for exploration. The key difference here is that the student uses the traditional teaching to gain a breadth of knowledge about the protocol, and then through interaction with the model, forms a construal of the protocol's behaviour that is consistent with its real-world implementation.

In the same way that design and implementation of the model was a learning exercise for the modeller, a student can also learn constructively by looking deeper into the dependencies and ultimately modifying or extending the model. Although constructivist learning is often favoured over instructionist learning, computer model building currently depends on prior knowledge of some specialised notation, and as a result such modelling exercises can initially be overshadowed by the amount of learning required to reach an adequate standard in some particular modelling notation, particularly for students that are not computer specialists.

4. Conclusion

Teaching of science-based subjects often involves simplification and abstraction of complex real-world systems so that they are fit for educational purposes. This presents a problem to a teacher because they cannot simply impose their construal of a complex system upon a student. Empirical Modelling enables a teacher to represent "what needs to be learned about" while letting a student form his or her own construal of the system from interaction with a model.

Learning by interaction with a model alone is not always sufficient, and a deeper understanding of the model can be achieved if a teacher were to complement such interaction with traditional teaching to provide context and breadth of knowledge concerning the thing being modelled. Construction and extension of a model helps to form an even deeper understanding of the system being modelled, although knowledge of specialised modelling notation is currently required in order to do this, making such modelling exercises less accessible to students that are not computer specialists.

References

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