

An Empirical Modelling Approach to Boating

Stephen Brown 0712526

Abstract

Modelling moving systems is a complex task that traditional computer science is not ideal for. I intend to model the movement of a boat in moving water, taking into account its direction, current, power source and wind. This is a task for which empirical modelling is very suited, and is therefore ideal for solving the problem. The problem will be broken down into various sections, starting from a boat with no rudder, power or wind, and adding the various parts one by one to show the effect of each change. As a keen kayaker myself, I know how the various outside factors affect the movement of my boat and so will be able to translate my knowledge into the model in order to show others how the concept functions, and allow them to form their own construal of the problem.

1 Introduction

This paper studies the application to Empirical Modelling to the problem of modelling complex moving systems, and show that such an approach gives us a valuable resource for educating users on the subject of the model in an experiential way. We then look at the model produced and show the advantages of using Empirical Modelling over conventional Computer science approaches, including a discussion of the possibilities in the education field as a teaching tool for physics.

2 Moving Water Systems and Empirical Modelling

When shown a simple moving water system, such as a static unpowered vessel in a current, it is easy to see how the current affects the boat and where the boat is likely to end up. However, as we increase the complexity of the situation it becomes much more difficult to work out what is likely to happen, and what steps or changes to the environment would bring about a desired objective. This section discusses the problem in the real world and the various factors one would expect to encounter, as well as a discussion on the relevance of Empirical Modelling to this problem.

2.1 The Real World Problem

A vessel in moving water has several factors affecting it, and the pilot of such a vessel has to be trained to be able to understand those effects, and to change various controls such as engine power and rudder direction in order to successfully navigate. The common

factors affecting a vessel are the current of the water, the wind speed, and the momentum of the boat. These can be modelled mathematically (Nave). The current of the river will have an effect on the vessel by causing the boat to accelerate in the direction of the current. The acceleration on the vessel will never be larger than the difference in speed of the current and the vessel.

The wind will have an effect on the vessel by causing the boat to accelerate in the direction of the wind. The acceleration on the vessel will never be larger than the difference in speed of the current and the vessel, and because of the low "friction" between wind and vessel the wind will have a much smaller effect than that of the current.

The momentum of the boat is particularly interesting, and will cause the boat to move in the direction of the momentum. This cannot be changed by the modeller apart from through the EDEN command interface.

The boat power is similar to the current and the wind, except that it is dependent on the current rotation of the boat. Thus, if the current is nothing, the wind is nothing, and the rudder is set to an angle, the boat will turn around in circles. The movement becomes even more interesting when current and wind are again applied.

There are various internet games that attempt to model some of these factors, allowing the player to try to navigate around a river system. However, they do not model all the same factors, and not to the same degree, perhaps owing to the difficulty in using conventional software mechanisms to model the problem. This leads us onto the next section, the relevance of Empirical Modelling on this problem.

2.2 Use of Empirical Modelling Concepts

The most important and defining feature of this particular model and its implementation is the way that the Empirical Modelling tools give the modeller the opportunity not only to manipulate the model in the way designed through the Scout controls, but also by directly modifying the model in EDEN in an intuitive manner.

Empirical Modelling is defined by Meurig Beynon as "a body of principles and tools concerned with computing activity that is based on observation and experiment"(Beynon, 2010). Empirical Modelling offers the computer scientist a radically different perspective on Computer Science that gives a much broader view of computing, by introducing the powerful notion of a model that can affect a modeller or user's construal of the problem.

The problem of modelling moving systems is significant and complex. Computer models can only take into account a number of factors, but using Empirical Modelling to construct the artefact offers significant advantages, allowing us to model the problem effectively. Definition of observables in the EDEN language of objects in the real world allows the model to be designed and developed with a real opportunity for extensibility, and every part of the model can be shown to map directly back to real life objects and properties of these objects.

This gives us a large advantage for this particular problem as it allows me, the modeller, to construct the model in an evolutionary manner. This report is carefully structured to highlight the way that the model started off with some very basic definitions and agents, and was extended bit by bit as a result of real world empirical observations. The simple model quickly became more complicated and more realistic, and without the design and implementation of Empirical Modelling tools this would have been a much more difficult and less effective task.

Significant use was made in this model of features such as dependencies and observables in the model, and this gives it a real analogue flavour - the modeller and user can do almost anything with the model, and generally behaves in a way consistent with the modeller's mental model of the problem situation (their construal).

2.2.1 Assumptions

There are several assumption in the model that simplify the task of the modeller. First, we assume that the many factors modelled are complete and full - and

that no other factors exist in the real world. This is not true - real rivers may have obstructions, counterflows, eddies, whirlpools and a myriad of complex factors that are simply out of the scope of this report and model.

Secondly, we assume that the size of the vessel has no difference on the effect of the various factors. In the real world this would have an effect on the vessel, but might confuse a modeller extending this model in other directions.

Thirdly, the actions of some of the factors do not completely match the real world factors. For instance, wind in the real world will come in bursts, and may increase and decrease almost randomly. This would have been possible and easy to implement in EDEN, but for consistency with the modeller's mental model of a static wind set through a variable, this was removed from the model.

3 Empirical Model

The Empirical model described below is designed to give pilots an accurate model of the conditions a vessel will be in, and the standard basic controls for that vessel, in order to educate the pilot and pass on the knowledge that I have as the designer of the model, through the container of the model.

3.1 The First View of The World

We start by constructing the basic building blocks of the world upon which the modeller can expand. We will later look at how this model was expanded to meet the observation of the modeller when comparing the behaviour of the model to the behaviour of the real world objects.

3.1.1 The River

The river is modelled in EDEN as a rectangular body of water with variable width (and length if desired). The river has a current, which moves at a particular speed and will have an effect on artefacts within the river area. The banks of the river will cause a crash if collided with.

3.1.2 The Boat

The boat is modelled as a simple shape in EDEN (see Figure 1), but can be easily modified depending on what type of boat the modeller is trying to simulate. The width and length of the boat can be changed through variables, as well as the length of the bow

on the vessel. The vessel has a position and rotation, and various factors and objects within the model will affect these properties.

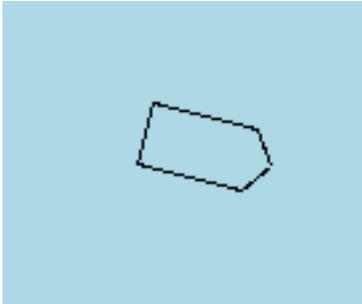


Figure 1: Simple Rendering of a Vessel

3.2 Modelling Factors

After modelling the basic objects within the model, the next step and stage in the model was to recognise that there are other factors affecting the behaviour of the boat, both external to the boat and internal to the boat. The way in which all of the factors are modelled adds a real analogue flavour to the model. The controls for changing many of these are shown below in Figure 2.

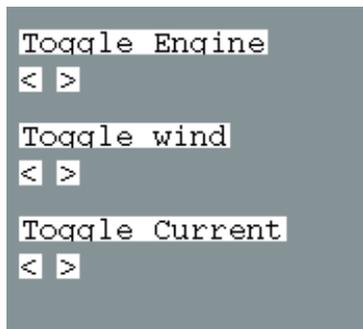


Figure 2: Scout Controls for using the model

3.2.1 The Wind

The wind is modelled in a very similar way to the current of the river, except that it has a variable direction as well as a variable speed. This is then applied as movement to the boat. The force can be modified by the Scout controls.

3.2.2 The Engine

The engine is modelled as a force coming out of the back of the boat and propelling the boat in the direction it is facing. The force can be modified by the Scout controls. This is particularly interesting as the force of the engine is described as a dependency on both engine power, and boat rotation.

3.3 Progression using EM

Empirical Modelling then allowed the progression onto more advanced modelling, using the concepts of acceleration and friction. These are described in the subsections below.

3.3.1 Acceleration

In the previous models, the forces such as wind, current and engine power simply affected the position of the boat at a speed given by the variables such as windSpeed and speedOfCurrent. However, simple experiments in the real world showed me that the model did not match up to these observations. Applying a wind (hairdryer) to a boat (rubber duck) showed that the boat actually accelerated up to the speed of the wind, instead of immediately being moved at the speed of the hairdryer airflow. The model was therefore extended to introduce the property of momentum to the boat. Additionally, my real world tests showed that the acceleration on a boat was smaller if the boat was already moving in that direction, and so a wind speed of 1 in the same direction of a current going at a speed of one will result in a real speed for the boat of 1, when fully accelerated.

3.4 Friction

The real world tests showed that acceleration was not the only factor missing, as even after the additional of acceleration into the model, it still didn't quite match up with the real world. Given a current of speed 1, and a wind of speed 1, putting a boat (kayak) into a moving water system (river in north wales), the current speed accelerated the boat much faster than the wind did. To accurately model this, I further extended the model to give each force a "friction" property. The lower the friction, the slower the boat will accelerate up to the speed of the force.

4 Evaluations

We now move onto a critical evaluation of the success of the project, split up into four areas; the model,

the tools used, potential use as a teaching tool, and extensions to the model. In these sections, both my model and the tools I used are analysed and critiqued, showing areas of great promise as well as areas for improvement.

4.1 Model

The Empirical model constructed for this report is finished, tested, and realistic. It provides a good model to for people to be able to form a construal of the problem, or to extend and adapt to a particular situation. It does simplify the situation in that some potential factors on a river such as still parts of water are ignored, however these are not necessary for the model to function as a useful tool. Areas the model could be extended in are discussed later in Section 4.4, Possible extensions to the model.

4.2 EDEN

EDEN has been an invaluable tool in the modelling of the situation. It has allowed the author to extend the model as noted in the several sections, and has allowed easy iteration of the force properties in order to better match the model to the empirical evidence.

However, some parts of the tool were certainly lacking. The ability to create n different objects and manipulate them all with the various different forces is not possible in EDEN in the way needed, and this could have provided a very interesting opportunity.

However, a solution to this in the field of Empirical Modelling does exist. The Cadence notation and tool developed by Nick Pope allows this type of use, and so could have provided a way to add several boats into the vessel, and allowed more expansion in that area of research. However, at the time the model was proposed and created the tools for simple drawing were immature, and so using EDEN was less risky and more proven.

4.3 Use as a teaching tool

It is obvious that this model has a great potential for use as an educational tool. There are two potential uses for it: as a teaching tool for vessel pilots, and as an educational tool showing the forces of physics present within the river environment. As noted in the section on the Real World problem, various mathematical models already exist for calculating speed and direction given "engine speed" and current speed, but none actually model them as real forces acting on vessels.

Effort was thus made during development of the model to represent theoretical physics such as friction and acceleration as accurately as possible, thus enabling a user to themselves learn about the concepts in a more real world setting, and to allow my model to give much greater flexibility to the modeller. Potential learning tasks could include adding small changes such as wobble on a faulty rudder, or an intermittent engine. The model has been designed with unlimited future modelling in mind, and the Empirical Modelling tools fully support this objective, perhaps unlike conventional computer science.

4.4 Possible extensions to the model

There are a number of potential extensions to the model that I consider useful extensions to the current model, but not required for full use of the model.

1. Multiple Vessels. This might require the model to be ported to Cadence. Once this has been done, crash detection between vessels would be possible
2. Scout Interface for changing more variables, such as wind direction. Currently, wind direction is a crosswind, but this can be changed by the modeller.
3. Shaped Rivers. Currently the river is a rectangular shape. A real river will normally have curves and bumps on the sides. Adding this would allow real river situations to be modelled.
4. A rudder on the boat. Currently the boat just spins around at a speed given by the modeller. It would be useful to attach a rudder in order to model the effects of the engine and rudder together on the rotation, and then the effects of that rotation on the effects of the engine.

5 Conclusion

This report has conclusively shown that Empirical Modelling can be used as a powerful tool to model moving water systems with a greater ease and potential for expansion and education than conventional software tools. We have shown the way that the real world properties of a vessel map easily to EDEN variables, and the way that a model can evolve at the same rate as a modeller's knowledge. This forms a very significant part of this report, as the author felt it was an area among many where Empirical Modelling

tools were unmatched by their conventional programming counterparts.

The model produced has significant future potential and current value and shows this in practice. It has areas in which further research and modelling could improve the accuracy and usefulness, but the fundamental work produced in my model has many uses already. We have discussed in this report the potential for use as a teaching tool, and most importantly the way that Empirical Modelling uniquely supports this philosophy.

6 Acknowledgements

I would like to thank Meurig Beynon for his groundbreaking work on Empirical Modelling, without which this project would have never come into existence. I also thank the Canoe club at Warwick University, for their assistance in evaluating the performance of the model and input on the fine-tuning of various factors. Finally, I thank my coursemates, David Smith and David Deacon, for their encouragement and deep discussion of the analogue flavour of the model.

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