Agent Based Bridges

Abstract

This paper uses the medium of bridge modelling to present a critique of the methods of Empirical Modelling and those of the AgentSheets approach. The construction and modelling of bridges is interesting in the context as it presents some common challenges and points of interest within the field of EM. The individual bridges are constructed form similar elements however the elements must interact with each other in a manner which can be described in a number of ways which are relevant to the concepts of Agency and Dependency. The subject also invites application in the area of education and the use of such models in the context is considered.
Keywords: Empirical Modelling, Agency, AgentSheets, Bridge

1 Introduction

The problem of modelling systems in which there are many interacting elements is one which in various forms is common. It is often interesting or necessary to model the emergent behaviour of these interacting systems. If we are to approach the needs of modelling these systems through the use of computer based artifacts it is necessary to have both tools and a conceptual framework which will facilitate this. There are a number of options available for this and and each have different strengths. The two main methods of model building that are considered in this paper are Repenning's AgentSheets (**?**) and the empirical modelling framework using the EDEN tool. The modelling of bridges is used as an example of this practise as these are relatively simple systems which involve the modelling of the effects of multi-element structures, in which each element effects every other it is connected to.

AgentSheets and EM share the idea of basing some of the concept of interaction with the artifact on model of a spreadsheet. AgentSheets takes the concept most literally and considers the visual element of the spreadsheet to represent a grid of individual squares which may each contain multiple agents. Each of these agents can sense and interact with the contents of the squares immediately adjacent to them. This is done through the use of procedures which are guarded by both the internal states of the agents and the states of the immediately adjacent agents.

Empirical modelling also uses a underlying idea which is based off a spreadsheet model of interaction however there are key differences in the focus. Empirical modelling has several themes which include the modelling of dependency and state, agency and observation, and a human focused attitude to the artifacts. The values of state and dependency mean that it is important to consider how a model represents the state, the dependent relations, and elements of agency the modeller perceives within the system. Human focus means that the role of the modeller as an experimenter and a agent within the system should be considered. Empirical modelling is generally put into practise through the creation of definitive scripts which can be done within EDEN (**?**) which are used to define the state of systems, their dependencies and changes of state.

2 AgentSheets Model

In the standard AgentSheet package there is included several example models of the use of the environment to create models. The model of a bridge within this can therefore be seen as a reasonably representative sample of the use the technique for a task.

In the AgentSheets model the structure of the bridge is modelled by considering how the each brick can hold itself and other bricks into the structure. Each brick is considered to be one of the agents which form an AgentSheets model and reside uniquely in a single square. The support of the bridge is passed up the structure of the bridge via the consideration for every brick of an UP value. This represents whether the brick will fall from the structure. The UP values are defined relative to the UP values of the surrounding squares. Bricks next to one another will hold each other up, a load placed on the top of the structure will reduce the UP value of the square immediately below.

This model is aimed at use in education and works in this fashion through a constructivist manner of learning through the construction or destruction to show how particular bridge designs may be formed. The model is successful in creating simple rules which will allow the creation of a number of different bridges with arches of varying span. This allows users to see some of the progression of designs of arch and beam spans over time as the builders from Greeks to Romans became more sophisticated.

2.1 Implementation

There are a number of interesting points about this model from a Empirical Modelling perspective. The use of AgentSheets has had the effect that the model is locked into the paradigm of interacting agents which concurrently evaluate the situation. In the description of each type of agent which can make up the simulation the focus is on a procedural script of actions which will be repeated implemented during each step of the simulation. Within this explicit modelling of behaviour there is also a consideration of the state of the support agent at an instance in time, the UP value. The concept of the state of an individual support is used largely for the communication of what are modelled to be the forces exerted upwards in the structure.

Although they are defined in each agents script to be calculated on the basis of the surrounding squares variable the evaluation of the model as a whole relies on the procedural implementation of the model. Since each brick is modelled on a simple formula for the up value it would seem that this could easily be converted to be a dependency based model of each bricks up value. This however reveals two aspects of the AgentSheets model. It is acceptable to repeatedly approximate to a value through circular definitions, this is limited by the fact that the UP value have a maximum value of one. The second point of interest is the fact that there is no mechanism to define the initialisation of the agent network. Naively considering the action script controlling the bricks results in the first bricks to have their script implemented results in the brick falling if there is a space below. This does not occur when the simulation is started therefore it must be assumed that the simulation uses implicit knowledge about the execution environment to create the model.

2.2 Semantics

Considering the Semantics of the AgentSheets model is to a certain degree attempting to take it beyond the scope that it was created in. It is interesting to consider as it illustrates the effects of the design methodology.

The decision to model the state of the bricks as being dependent on the UP values from below is a reasonably simple one and one which is explained in the model's description as designed to simplify the dynamics of the bridge. This is largely to make the design quick and to be complex enough to allow the creation of 'realistic' structures. However there are several consequences to this firstly as a tool for teaching the concepts which hold bridges up it allows the creation of bridges which rely on the fact that the bricks have no weight and thereby relies somewhat on the users own semantics of how a bridge will work. This can be relied upon in most situations it is not necessarily the best if someone was to know nothing about bridge shapes, however it is still true that the classic shapes are the most material efficient.

The second consideration of the bridge is the fact that although it is possible and helpful to make bridges that appear similar to arches, the model is only really modelling the bridges as being beam bridges which narrow in thickness towards the centre. It is possible to partially show this by the shape of the resulting bridges and it would be more obvious if this was expanded onto a larger grid. This has fairly large disadvantages for teaching the mechanisms for physical bridges' operation since in the simple cases of Greek beam versus Roman arch that it is necessary to show the conceptual change of an arch placing all the elements in compression. This also misses a crucial point that an arch needs to be supported at the sides as well as below since it will tend to push outwards.

3 Bridges with EM

To consider the use of the Empirical modelling technique and the EDEN tool kit it is best to consider the task of creating the models of bridge structure. Initially attempting to create to replicate the conceptual model of the AgentSheets model will constitute a test of the usability of the tools and how well a definitive environment will allow for exploration of the conceptual model. As has been noted in the critique of the agent sheets model there are implicit failings of it as a construal of the mechanics which result in bridge stability. If we are to move beyond the most simple level of consideration shapes of arched bridges it is necessary to use a more complicated evaluation scheme to assess the structure.

3.1 First Model

The most immediate advantage of creating the simple bridge model using AgentSheets is the easy of use of the grid agent description model. This means that it is only necessary to create the actual system of interacting agents rather than the framework with which they reside. Creating a 'grid' within EDEN is possible however creating such a grid requires greater sophistication as it is necessary to manually create structure more as part of the artifact than of the construal.

Creating the agents in Eden to exist within the model presents a number of considerations of how to model their functions, in common with the model in Agentsheets the agents will have to move down the grid if they are unsupported. The support can be measured by the UP value of the brick in question. Since it is not clear in the Agentsheets model the control flow of evaluations of the UP value it would be intuitive to define the UP value of a brick be defined to be the set proportion of the surrounding values. Using the is operator in Eden to do this means that the evaluation engine will attempt to find the value of each at a since time and then update the surrounding values when these change. This results in a circular definition error which would need to be finally evaluated and presumably (if not caught) would continue until the maximum level of recursion was reached.

A similar effect to the AgentSheets model can be achieved by using the procedural elements of Eden to iterate the UP values until their values are static. This could be thought of as a modelling conceit similar to the manner in which real structure would settle into a position as loads are applied to them, and it would be the case that the forces within the structure move. This utilising Eden for this model also has the advantage that it would be simpler to create metrics for judging the UP value in a more non-local manner, such as considering a line of flow of forces up and down the structure, or merely having a higher level perception of the structure's shape.

3.2 Second Model

The Second model was created with reference to the empirical modelling principles of state dependency and agency. The first consideration in creating a model of the bridge system is how is the forces will move and be measured within each element in the bridge. To model this is complicated in the real world as there are many forces which would need to be considered even internally to a single homogeneous element. The methods in actual engineering modelling can be excessively complex for a educational model. In common with the AgentSheets model the intention is to create a model of the principles rather the the physics of real world bridges. With this in mind the most basic but functional physics model for the forces was used - rigid one dimensional rods governed by gravity and Hooke's Law connected at points. This simplifies the mechanics in a similar way to the initial teaching these concepts in education. The conceptual

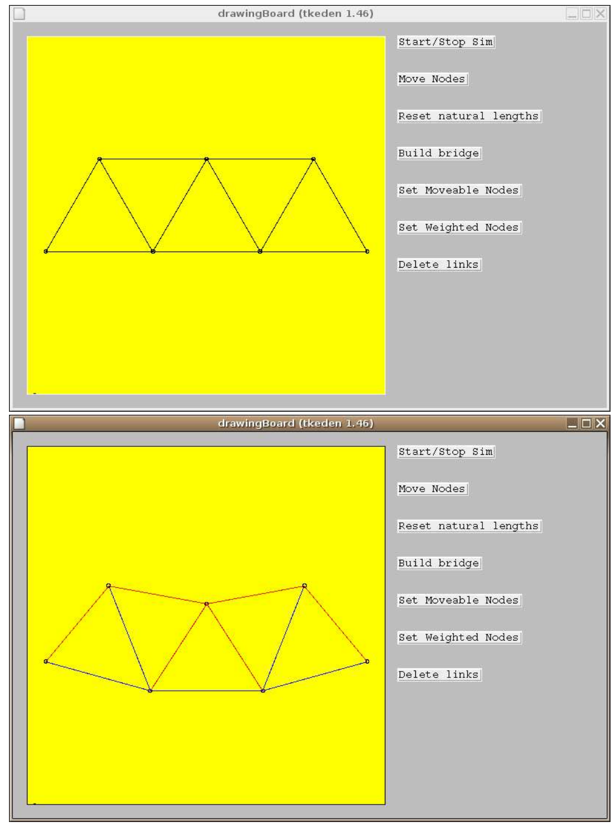

Figure 1: An example bridge design before and after animation in the second model

model outlined would easily form a construal of their interaction as each rigid strut of the bridge, and joining point of the structure as an agent. This fundamental model of each of the elements of the bridge of as a point force would have an impact on the usefulness of the the model to create bridges as simply as the AgentSheets model. One of the nice features of the AgentSheets model is the ability of the bridge to be deconstructed as well as constructed, allowing without an understanding of the design principles a gradually more efficient bridge to form. This is unfortunately one of the aspects lost in the creation of a model based on the chosen physics model. However in its place there are several advantages to the creation of a model with considers the forces on and in the structure more closely. Firstly the concepts of compression and tension have been made directly accessible by causing the colour of the element to depend on the ratio of its length to its natural length (red for compression, blue for tension). Secondly the dependency based nature of the construal there is the latent ability to both refine and play with the model for a user. There are a variety of refinements which could be added to the model, for instance: Internal forces of the elements could use a more realistic model of the force extension relationship; Loads could move across the bridge rather than needing to be statically defined to be at individual points. There is also scope for playing with the mechanics of the situation to gain an appreciation of the advantages of strengthening and weakening of individual components.

Although it is possible to create bridges which implement the ideas of either a suspension bridge or an arched bridge it is not necessary to do so. This is because internal forces within the elements are not considered making a beam. This would seem to be nonsense and defeat the rational behind the model. It is either necessary to consider the flexing of the beams. Choosing to maintain the simplicity of the model and considering that it should have states which are a consistent construal of the real world at this point conflict, in the real world we know that it is possible for flexing and breaking to happen within beams. The target of the construal is the principles of bridge design rather than an engineering model of a real bridge. This means that it can either be chosen through by the user as an agent with implicit knowledge of the various manners in which to use the artifact. In an educational environment it may be useful to force the use of complex structures by setting a maximum natural length for any element.

3.3 Comments on the use EM technique

In producing the models has raised issues when they are considered in the light of the techniques. These are largely focused on the how both the tools and their implementation effected the implementation of a construal of the bridge structures.

One of the areas of empirical modelling that was not utilised fully was the aspect of experimentation as a means to create interesting construal. This was due to both the fact the both the models involved were based on a definite concept and the tools available. The known models meant that there was relatively little experimentation of a 'thinking with computers' nature, although the implementation of a close model to the AgentSheets model enabled the less obvious issues of that model to be considered more easily. The tools of Eden and the other definitive notations felt in many ways unhelpful for the creation of artifacts with numerous similar components. This is mainly because there are only ad hoc methods for high level definition of scripts, through the use of procedural scripts to automate definition. This has a number of flaws from the point of view of a modeller. The main effect of this is that it returns the modeller to a paradigm similar to the programmer of write the script then test a run through of the script. Having a dual layer of scripts and strings of scripts requires more of the skills of a traditional programmer, and will increase the time to create and effort to debug the models created.

The largest problem with this lack of hight level definition is the amount that it constrains experimentation with the model, as it requires that such things as agents must either the laboriously manually constructed or relatively inflexibly procedurally created. This could be solved in a number of ways. It might be possible to in a similar way to the notion of class inheritance in Object Orientated design definite high level specifications of agents which could be linked by dependency to change based of both changes to the high level and low level instances.

Issues of dependency versus agent action were also made prominent by the modelling tasks most obviously in the case of the UP values which were an intrinsic part of the agents and had pseudo dependence in the AgentSheets model. These issues are discussed to a certain degree in Ashley Ward's PhD dissertation (**?**) where he cites various others (**?**) (**?**) that dependency 'guarantees' the currently valid nature of a variable using the 'is' operator. However this guarantee only holds true in certain situations. In building the model it seems conceptually obscure in some cases beacause it considers the variable defined variable to be functionally linked only to the symbols which are directly within the defining statement (as the arguments to implicit or explicit function calls). This meant that confusingly setting an UP value calculator to be calculated from a function that took its location as its parameter would result in it only being updated if the agent was moved. Conversely in the second model the value of the Vertical and horizontal forces exterted at a point by a link may be defined as the result of a function. This will always be correct as the function takes the location of the end points of the link in its parameters.

As a modeller from a programming background there is a tendency to wonder if the methods of handling some types of action is within the underlying concepts of the model, or merely a programmer's attitude to what can be considered to be equivalent. The handling of such things as the synchronisation of the actions within the animation of the model, and the gathering of the forces from each agent by summing them before each move raised the question of what fits within the larger concept of the model and in the larger context of an educational product does this fit within non-programmers view of the world. Intuitively the used 'leapfrog'[1] method of integrating the movement of the of the structure seems reasonable, as it would be the way in which one might explain the effect of acceleration. It is however important to realise that this has problem is alway going to exist if attempting to truly model the action of the real world as a simplication of the integration problem using a discrete system in some ways this is always going to be a comprise solution. However this need not be conceptually so on a system designed to support this.

4 Conclusions

In looking to compare the two approaches of the creation of a educational models of this type it is important to realise that both are designed to have change and interaction with the model within the scope of the modellers. This means that both the user and creating modeller as agents in the system should be considered, although within both paradigms the roles are interwoven.

4.1 User

Considering the use of the various models in an educational context it is probably the case that the second EM model is more apropriate for a more sophisticated lesson on bridge design. The brick based models have as their key advantage a simple method of construction and the support can easily be constructed and deconstructed which would facilitate a constructionist understanding of the problem. However this would be a shallow understanding and mainly be based on the geometry of a plausible solution.

The second eden model is less intuitive to use as the bridge does not appear without the users interaction and suitable for a more sophisticated audience, allowing for the modelling of structures comprised of any combination of rods. It does however have several flaws in this. The techniques used for both the animation of the model and for calculation of the internal forces in the rods are not realistic and result in behaviour which is obviously inaccurate. This is largely an area in which improvements could be made through experimentation to determine the action which is expected and to make the action of the model conform to the modellers expectations. The second model is equally capable of demonstrating the importance of careful use of geometric shapes in structural design. It is superior for teaching the concepts of compression and tension through the simple colour coding to those who are not familiar enough with the mathematics to approach it directly.

[1] updating the speed by the current acceleration and then adding the speed to the current location

4.2 Creating Modeller

From the modeller's perspective the strengths and limitations of the AgentSheets approach are much the same as it presents the user with an interface which highly circumscribes the interaction and modelling possible. The main strength of the interaction is its familiar grid structure, and the clearly understandable methods for creating and placing agents within a system. This enables the swift creation of agents and a surrounding environment, however leaves the models constrained to only considering their local environment, although additional message passing between agents may solve this.

Within Eden the situation is largely the reverse and the freedom of creation is one of the strengths. The tools while allowing for the creation of almost any type of interaction, however this is to a degree limited in that the interaction while open is not necessarily well supported, although it is always possible to create additions through the use of such tools as the Agent Oriented Parser. The aproach is particularly useful for investigating the conceptual modelling of existing systems. In considering the conceptual model of definitons and state of the possibly the largest advantages of the methodology are the ease with which due to the focus on meanings within the artifact it is possible to modify the models as the modellers understanding of the concept changes.

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