ENHANCED ROAD TRAFFIC MODELLING USING DOSTE & EDEN

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ABSTRACT

Road traffic flow is a continuing area of research in both empirical and theoretical modelling. The proposal for this paper is to attempt an abstract model of real world traffic dynamics, based on representations of the relationships between objects. Previous work has demonstrated the possibility of modelling simplified examples of traffic systems, such as the T-junction model provided by Mendis (Mendis, 2002). It is hoped this project will expand upon the depth and visualization achieved by this projects, and empirically demonstrate unseen emergent behaviours. Traffic lights are designed as a method of traffic control; singularly they can be used to reduce traffic build-up at a junction. However, when used in conjunction, traffic light systems can produce complex flow networks – reducing or increasing traffic directly, or re-distributing traffic indirectly. Research into traffic control is important in our modern world, where our economic and social growth has become reliant on the existence of complex transportation systems. It is desirable to produce accurate models of such systems; to aid with improving existing road layouts and designing new traffic systems. As with the work of Mendis (Mendis, 2002), this project will focus on the same T-junction system. However, the overall aim of this research is to improve the model in terms of complexity, realism and graphics by using a combination of the EDEN and DOSTE empirical programming languages; and discussing the associated difficulties of doing so.

1 INTRODUCTION

In the United Kingdom, the increasing number of vehicles and the necessary expansion of connectivity have required the modification of existing road systems; such as the inclusion of additional traffic lights and roundabouts. This added stress, on systems that were not originally designed to handle such large quantities of traffic, has caused an increase in traffic congestion. Although, many of these new features are implemented with the aim of controlling and preventing congestion, without proper understanding of the propagation effects caused by these additions often more harm is done than good. Road traffic has a lot in common with network flow theory, whereby a small change at some point in a network can often have drastic and non-trivial effects elsewhere (Long JianCheng, 2008). As such, it is important to be able to study and model such systems, so that desired changes can be tested with some degree of certainty prior to their implementation; which is often costly.

Currently there are two established approaches used for modelling similar systems, as mentioned by Mendis (Mendis, 2002, pp. 1-2): This first: Agent based systems, whereby objects in a simulation are represented by competing agents, each with individual goals. Agents have a set of sensory inputs and use this information to determine an action to take. Although the decisions of agents can be related to the properties of other objects in the scenario, no “strict” (Patrick A.M.Ehlert, 2001) relationships are defined. The second approach focuses on a relational model, whereby the output of one agent is strictly governed by the actions of another. Relationships can be chained and circular. This project is more analogous to the later methodology. However, the combination of both the DOSTE and EDEN languages used allow it to populate a middle ground.

The overall aim of this project was to demonstrate how, by empirically modelling a road system, we can estimate the impact that changes would make to congestion. However, unlike Mendis who demonstrates how a traffic light system can be improved between two separate models, this study will focus on the changes observable in a single model when various parameters are adjusted.

2 Model Design

2.1 Previous Work

Most previous work encountered concentrates solely on how congestion is affected by the layout of road systems, or rather the ordering of the significant components in the system. For example Mendis' improved "Traffic Light Simulator" (shown in Figure 1) and in Gardner's "Town Planning" simulator (show in Figure 2).

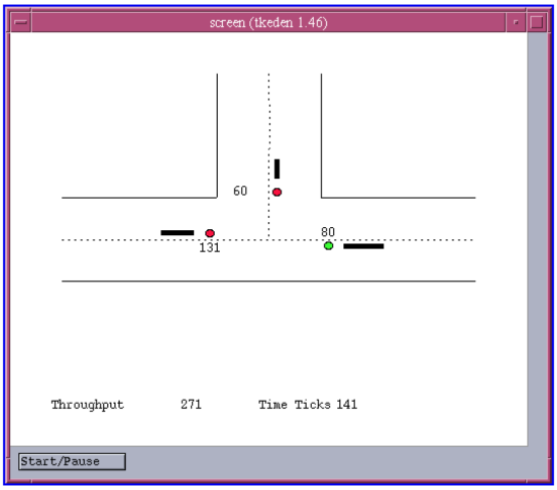

Figure 1 - (Mendis, 2002)

Often, as with Mendis, the movement of vehicles in these simulations is discrete or grid based. This ignores the effect that moving or adjusting a traffic control system may have on the potential velocity of vehicles in the system, and hence the congestion they will encounter.

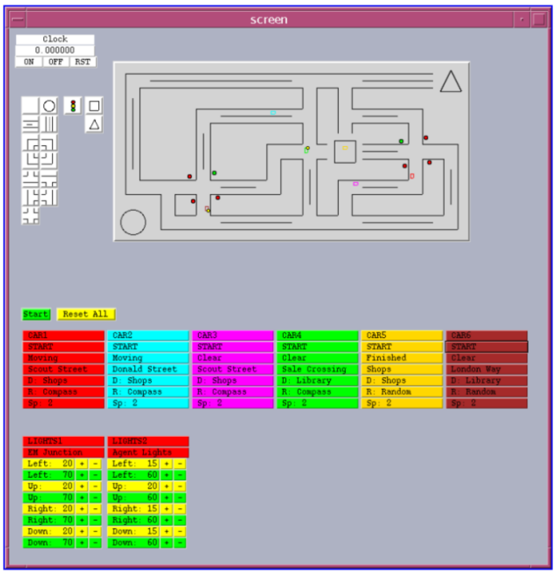

Figure 2 - (Gardner, 1999)

For example, the velocity of a car is defined by several properties, such as the length of the road it is travelling on and the maximum speed defined for that road. By positioning two traffic management systems side-by-side you may achieve an optimum throughput if movement is considered discrete. However, if you account for the time wasted during breaking and acceleration the real world effect may be less beneficial.

2.2 Choice of Languages

It was chosen to undertake the project in both the DOSTE and EDEN languages; available using the TKEDEN version 2.10 tool (Modelling, 2008). There were two main reasons for this decision. Firstly, DOSTE is a comprehensive relational language; allowing for the description of the core dependencies in the model, such as how the speed of one car is dependent on the speed of another. EDEN allowed for the programming of more traditional, procedural practices that were also required. Secondly, by programming some sections of the model in a traditional way it was hoped to maintain a greater analogy with how a similar system would operate in the real world. For example, real traffic lights are controlled by traditional, procedural programs. However, the dynamics of cars and their drivers can be more easily compared to a relational model. Although cars are reliant on the state of the lights, the lights are usually oblivious to the state of surrounding cars; it is describing how drivers react to changes in light state and surrounding that presents the interesting and difficult aspect of the modelling problem. As such, it was chosen to program the light switching algorithm in EDEN, whilst vehicles on the road are represented in DOSTE.

2.3 Objects & Relationships

The model is grouped by three main objects:

- Cars
- Traffic Lights
- Roads

Each of the three objects has a visual representation stored as a sprite. For cars and lights the sprite used dynamically changes depending on the current state of the object. For cars the sprite is dependent on its direction of travel and whether it has crashed. For lights the sprite is dependent on its current stage; red, green or orange.

The "Cars" object is then further divided into three groups depending on the starting location of the vehicle; "Car Left"; "Car Right" and "Car Bottom". Although vehicles of different types contain similar operational code, a split was introduced to allow for simplified definitions – rather than requiring long conditional statements to determine how a car should behave for each of the three starting directions.

A simplified overview of vehicle movement in the model is defined by a hierarchy of three properties:

- Current position (x, y)
- Current speed
- Current direction
- Current acceleration

The current position of a vehicle is dependent on its speed, which in turn is dependent on its acceleration and direction. Acceleration is then dependant on several other properties:

- Distance from the car ahead
- Speed of the car ahead vs. Current speed
- Distance from the target traffic light

Traffic lights in the model are controlled by an EDEN clock. Each light in the model has a current state, duration to stay green and duration to stay orange (including counters to store how long each light has been green or orange). The state of each light is dependent on the clock and the state of every other light.

Roads are static objects containing basic information regarding position, size and imagery.

For a more comprehensive definition of the relationships between objects in the model please see Appendix 5.1.

3 Demonstration of Model

Shown briefly in Figure 3 and Figure 4 is the functioning model. Currently users have the ability to restart the model, and pause or resume the traffic light sequence. The other interface controls do not currently work, as is discussed in section 4.2.1.

Figure 3 - Model Running 1

Figure 4 - Model Running 2

By adjusting certain parameters in the model it is possible to estimate the effect this would cause in the real world, for example by adjusting the maximum speed of an individual car it was possible to cause a crash, or to cause the car to run lights. Likely due to the increase in breaking distance required.

An iteration count / clock is also provided, by adjusting parameters it is also possible to determine how optimal some setup is based on the time required for all cars to pass the lights successfully. For example, reducing the lights "green" duration to only a few seconds allowed for only a single car to pass per stage. Due to the constant acceleration and deceleration, more time was wasted than with a longer "green" period. Please see the appendix for more examples of the model running.

4 Analysis

4.1 Benefits in Comparison

In comparison to previous projects several improvements have been made. Behaviour of cars in the model is now more realistic and dependant on additional properties, such as speed and distances.

The use of DOSTE has allowed for significantly improved graphics, in comparison to previous projects. Although this is not a necessary component for functionality, in line with the empirical view it allows the user to more naturally construe emergent relationships; which is an important factor when learning through empirical practices.

The incorporation of individual car objects with continuous movement means that not only can the model be used to learn about traffic congestion, but can also be used to empirically understand the likelihood of traffic accidents - dependant on factors such as stopping distances, speed limits and driver reaction time.

4.2 Current Limitations

4.2.1 Of Languages

The current model is limited by the relational structure of DOSTE, which means that the number of objects in the scene must be pre-defined and the only way to add additional objects is through console interaction rather than being able to instance multiple objects through code and the GUI itself. This could be compensated for by the ability to declare new DOSTE objects and relations in EDEN. However, given the timescale provided and level of integration from EDEN to DOSTE it was deemed not achievable within the scope of this project.

Several of the DOSTE interface components fail to function correctly or at all. In the model interface, edit boxes have been included with the intention of allowing the user to adjust model properties at runtime. However these, under admission of the language designer, do not currently work and there is no other suitable component to replace them with. If these components were to be fixed in future releases of DOSTE it would be a minor task to link the already included components.

4.2.2 OF MODEL

Because objects and relations have to be pre-defined it was not possible to program the model in a way to allow the addition of new vehicles at runtime. The same requirement, for pre-definition, means that aspects of the model, such as collision detection, are also limited. Within the scope of the project, it was not possible to integrate full collision detection. Currently, a given car can only collide with the car ahead of it, which is defined as one of its properties and can be null (for leading cars in queues).

A further criticism of the current model is that acceleration has been over simplified to ease implementation. Currently acceleration is in a discrete form, whereby a car can accelerate at one of four pre-defined levels, which is not realistic.

4.3 FURTHER WORK

More complex modelling of acceleration and braking, allowing for continuous changes in degree, would be an interesting and relatively easy addition.

On a larger scale, the implementation of the model into a scale town/city planner, as demonstrated by Gardner, would be an extremely useful development. Not only would this allow you to model behaviours over a single road intersection but would allow you to demonstrate the propagation and dispersal effects of traffic lights in a complete road system.

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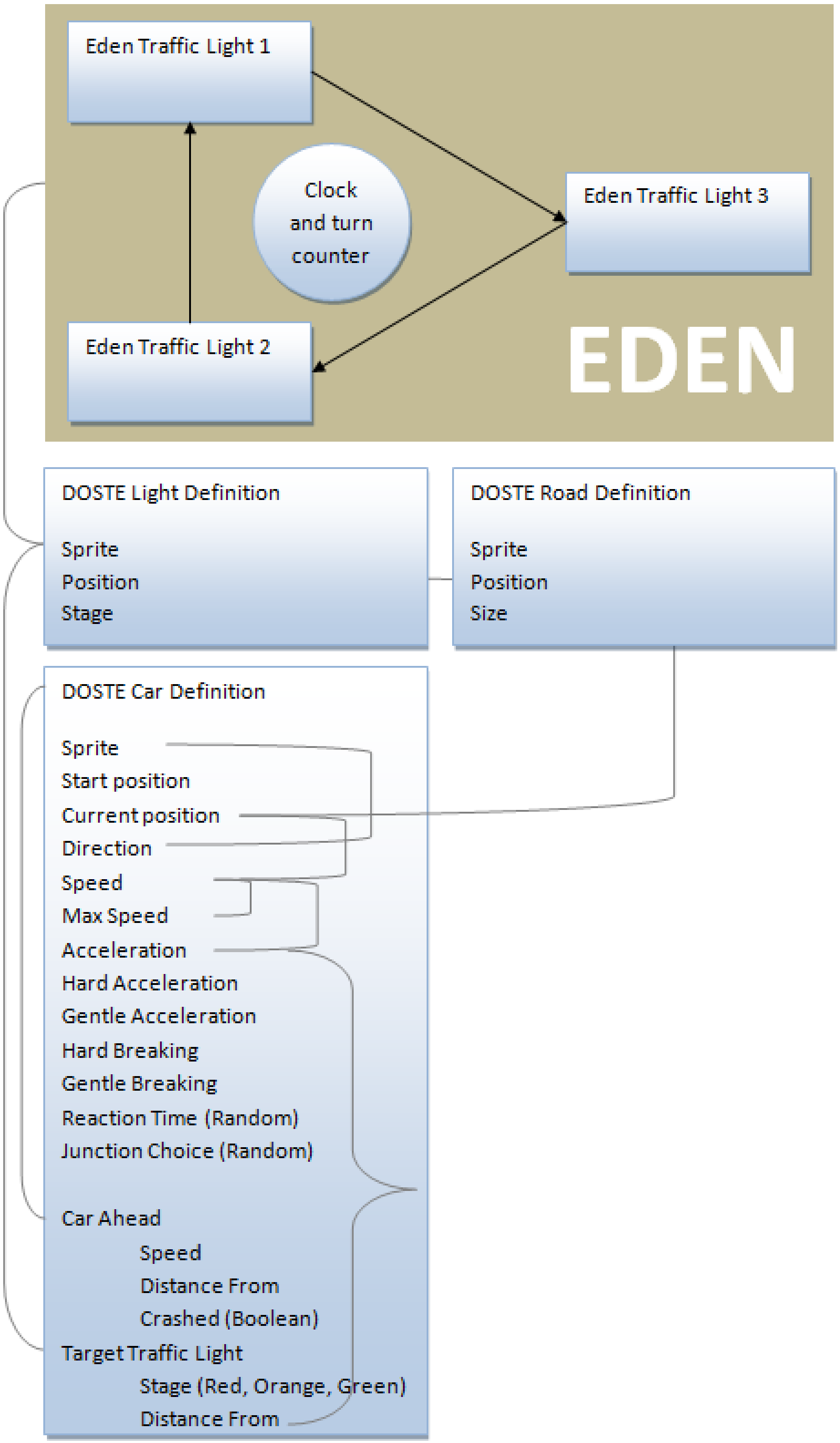
5 Appendix

5.1 DOSTE Dependency Diagram



5.2 Full Size Screen Captures

Figure 5 - Showing traffic lights on orange and queuing cars

Figure 6 - Showing traffic lights on green

Figure 7 - Showing a collision between two cars