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Object oriented representation of signalling and train control system in railway operation

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Abstract

This paper presents the method of applying Object Oriented Technology (OOT)[1] in the modeling of Signaling and Train Control [6,7] devices in railway operation. By using Object Oriented Analysis (OOA)[2] and Object Oriented Design (OOD)[3], the attributes and behavior of the signaling devices are complied into objects and stored in a software library. These objects can be used to simulate the operation of Signaling and Train Control equipment in the railway system. Due to the high level of reusability, extendibility, and developmental efficiency of OOT, cost-effectiveness and time-efficiency can be achieved in conducting simulation studies.

1. Introduction

The main function of the signaling and train control system in railway operation is to regulate movement of trains such that operational objectives are achieved. Today, different types of signaling and train control devices are in operation. Although tasks performed by these equipment are similar, their characteristics and behavior vary. Hence, the ability to select the most appropriate signaling equipment for constructing a new railway system and the most suitable equipment for upgrading an existing system is a key success factor in operation.

Simulation of the operation of the signaling and train control system can be carried out to aid this selection process.

Although simulation provides an effective way in evaluating selection, construction of such a simulation model is a complicated task. Enormous amount of effort has to be put to understand railway operation, prepare study data, and construct simulation algorithm. Furthermore, to make a slight alteration on the existing simulation will require an exponentially large amount of work. Hence, a reusable, extendible, and developmental efficient software library containing attributes and behavior of the railway elements will enhance the cost-effectiveness and time-efficiency in conducting simulation studies.

Object Oriented methodology is used to model equipment in railway operation because each simulated 'object' can be mapped directly to a corresponding real-life element such as train, track, or station in railway operation. This feature allows high level of flexibility in conducting simulation studies.

2. Object Oriented Modeling and Design

'Object-oriented' means that information is organized as a collection of discrete objects that incorporate both data structures and behavior of the real world entities instead of procedures in conventional programming. The process of applying the object oriented techniques in the representation of signaling devices and elements in railway operation may be understood in 3 stages, namely the analysis stage, design stage and implementation stage[1].

During the object oriented analysis(OOA) stage, the problem space is studied carefully so that precise attributes and behavior of the desired system is identified, defined and compiled into objects. After the OOA, each object model holds attributes and behavior that correspond to a real life element in operation. The software library is made up of a collection of these objects.

The object oriented design (OOD) is an extension to the OOA. During this stage, externally observable behavior and additional details for the actual implementation such as human interaction component, task management component and data management component are specified.

Finally, the object classes and relationships developed in the OOA and the OOD are translated into programming language and implemented on a computer.

The object oriented technique provides many attractive features in the modeling of railway operation. Firstly, real life elements in railway operation such as trains, stations, depots, and tracks are represented by software objects that can be reused, extended, and developed for future applications. This feature improves the time-efficiency and cost-effectiveness in future simulation studies. Moreover, the state variables of objects change only with simulated events during simulation. These simulated events correspond to real life events in railway operation. Hence, every event can be tracked and evaluated during simulation.

3. The Software Library

The software library contains software objects that represent real life entities in railway operation. Objects involved in modeling the railway operation are trains, tracks, stations and depots. The signaling and train control system [6,7] can be classified into the Automatic Train Protection (ATP) system, Automatic Train Control (ATC) system, and Automatic Train Supervision (ATS) system. Some examples of the objects that model signaling and train control equipment are ATP block, ATP train-carried system, ATO train-carried system, and Local Processing Unit(LPU).

3.1 Railway Operation Elements

Track: The simulated object track contains the ATP block and the geographical block. Both the ATP block and the geographical block are simulated objects. The ATP block handles generation and transmission of ATP code whilst the geographical block holds information on the gradient of the geographical terrain. Object model of track is shown in figure 1(a).

Station: The simulated object of a station contains the object platform. Events such as the passenger loading and unloading occur at the platforms. The object model of station is shown in figure 1(b).

Train: The simulated object of a train contains the ATO system and the ATP system. The ATO regulates the movement of train while the ATP system provides the overspeed protection. Different version of the ATO and ATP objects can be stored in the library so that performances of different devices can be evaluated via simulation. The object model for a train is shown in figure 1(c).

Depot: The object model of a depot is shown in figure 1(d). The simulated object of a depot accommodates a train at the initial stage of operation.

3.2 Signaling and Train Control Devices

ATP Block: The ATP block generates and transmits the ATP code to train. The ATP code contains information on the maximum safe speed(MSS) and target speed(TS). These information is used for the overspeed protection. The object model of an ATP block is shown in figure 1(a).

ATP Train-carried System: The ATP train-carried system decodes the ATP code received from the track. The ATP code is then checked. If a violation of the overspeed protection occurs, the emergency brake will be applied. The object model of the ATP train-carried system is shown in figure 1(c).

ATO Train-carried System: The ATO train-carried system regulates the movement of a train. The object model of an ATO train-carried system is shown in figure 1(c).

Local Processing Unit (LPU): The local processing unit (LPU)[6] in real life is a self-contained processor within a 'distributed-processing' system. The LPU runs all the trains within its own area of control, and maintain communications with adjacent LPUs. The software library contains the object LPU, and performs the same function as the LPU in real life.

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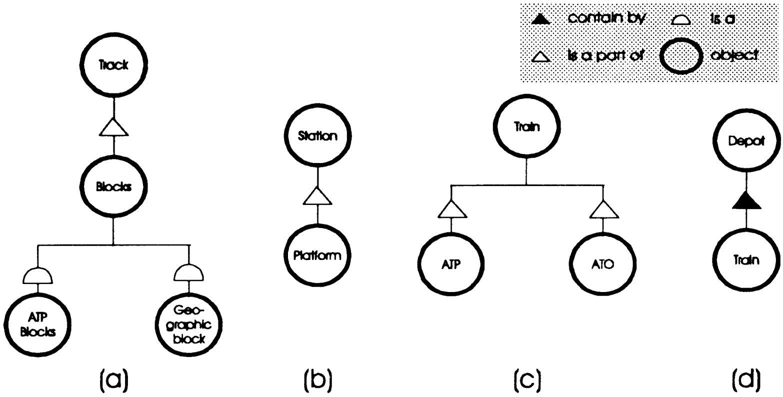

Figure 1: Object models for objects representing elements in railway operation. (a) Object model for track, (b) Object model for station, (c) Object model for train, (d) Object model for depot.

4. Discrete Event Simulation Of Railway Operation

The software library contains objects that correspond to real life elements in railway operation. Besides these objects, the 3 key elements that are needed in the discrete event simulation are the simulated clock, the time-driven event object and the movement-driven event object.

The simulated clock is a software object that simulates time sequence in real life. In the discrete event simulation[5], the statues of objects change only at discrete times when an event occurs.

Time event objects are software objects that correspond to real life events in railway operation. Some examples of these events are: train door open, train door closed, train departs from station, etc. The state diagram for the time event -- train door open, is shown in figure 2(a).

The movement-driven event objects are software objects that correspond to real life events in train movements such as: train starts coasting, train starts braking to station, etc. The state diagram for one such event -- train starts braking to station, is shown in figure 2(b).

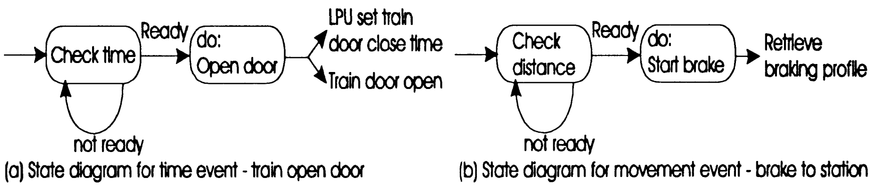

Figure 2: State diagram for (a)time event, and (b)movement event

The discrete event simulation is carried out with these software objects. The next section gives an example of the application of these objects in the software library.

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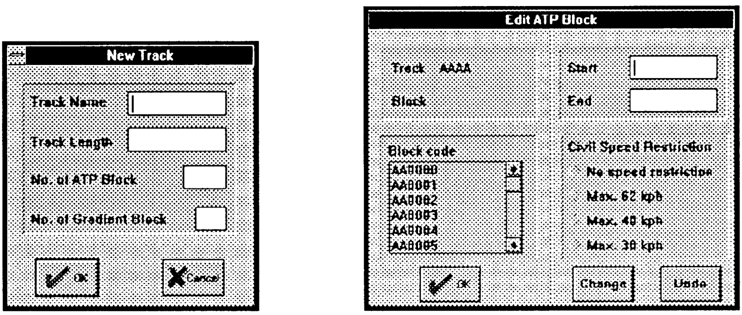
5. Example of Using the Software Library

In this example, the objects in the software library are used to conduct study for a disturbed railway operation[4]. The railway system has to be modeled to conduct studies on the metro system operating under disturbed condition. Two computer algorithms are constructed for this purpose. The first algorithm allows configuration of the railway system and the second algorithm handles simulation. These algorithms are written with Borland C++ 3.1 and operate in Microsoft Windows 3.1 environment

5.1 Configuration of a Flexible Railway System

The software objects need to be configured before simulation are the track, station, train, and the depot.

Configuration of a track: The dialog box for the configuration of a new track is shown in figure 3(a). The inputs include the name of the track, the length of track, the number of ATP block on the track and the geographical features of the track. Normally, the lengths of the ATP block and the geographical block are set to their default values. However, these default values can be altered via other dialog box as shown figure 3(b).



(a) Dialog box for adding new track, (b) Dialog box for editing ATP Block.
Figure 3: Dialog boxes for configuration of track

Configuration of Station: The station object can be configured by setting the names and the number of platforms with the dialog box as shown in figure 4.

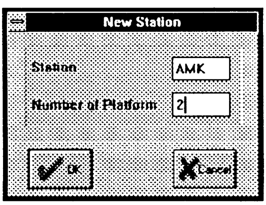
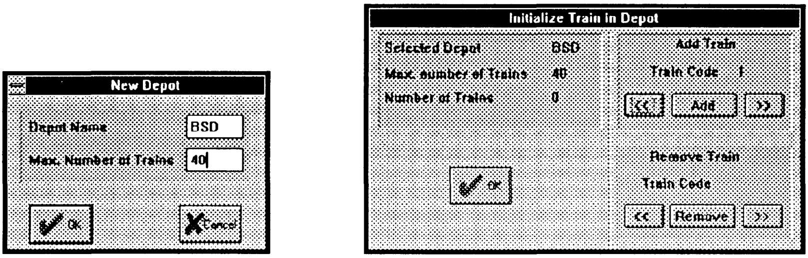


Figure 4: Dialog box for adding new station

Configuration of Depot: The depot object is configured by setting the names and the maximum allowable number of trains by the dialog box as shown in figure 5(a). The starting condition can be set by adding trains into the depot via the dialog box as shown in figure 5(b).



(a) Add new depot (b) Initialize starting condition for depot

Figure 5: Dialog boxes for configuration of depot

Defining a Train route: In normal railway operation, a train moves along a pre-defined route and visits pre-determined stations in a specific sequence. These information are defined via dialog box.

After configuration, the simulation is carried out. Since this configuration routine is very flexible, railway systems with different configurations may be simulated.

5.2 Running the Simulation

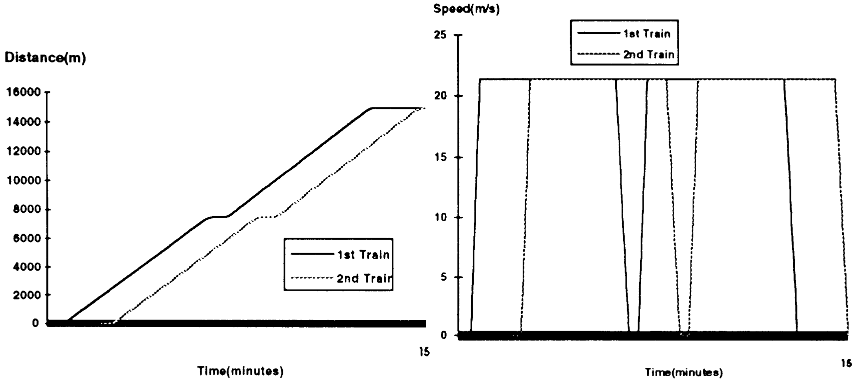
The simulation algorithm makes use of the configured objects, time-driven event objects, movement-driven event objects, and the simulated clock. During simulation, the simulated clock generates discrete time pulse. This time pulse is sent to the time event objects, the movement event objects, and some graphics objects. Status of these objects change only at discrete time interval, when a time pulse is received. Time events that are supposed to occur during the particular time, will enable a message to be sent to update the status of the simulated railway operation upon receiving of the clock pulse.

5.3 An Outline of The Simulation Methodology

The simulation test is conducted to evaluate the effect of a delay in train departure on railway operation. Configuration of the simulation model is:

Track Length	=	15000 m
No. of stations	=	3 (namely, STA, STB, and STC)
Train Route	=	STA $\rightarrow$ STB $\rightarrow$ STC
Normal dwell time	=	20 sec
Length of ATP block	=	200m

The distance-time curve and the speed time-curve of the trains moving with an 2 minutes headway initially are shown in figure 6(a) and figure 6(b) respectively.

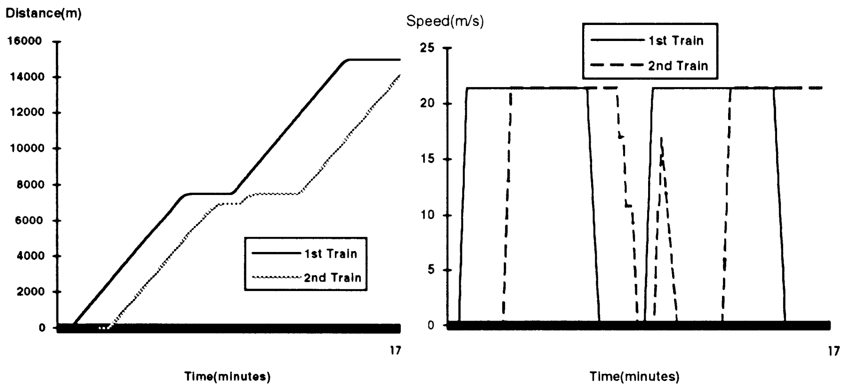


(a) Distance-time curve (b) Speed-time curve

Figure 6: (a) Distance-time curve and (b) Speed-time curve of trains operating in the simulated environment.

5.4 Effect of a Large Delay at Station

With the configuration given in section 5.3, a delay of 100 seconds is imposed on the train stopping at station STB. The distance-time curve and the speed-time curve under this disturbance are shown in figure 7(a) and figure 7(b) respectively.



(a) Distance-time curve (b) Speed-time curve

Figure 7: (a) Distance-time curve and (b) Speed-time curve for train operation in a disturbed condition

Comparing figure 6(a) with figure 7(a), the following features are observed:

1. The second train comes to a full-stop before the arrival at station STB.
2. Regularity of the second train deteriorate.

Figure 7(b) shows that the second train reduces its speed according to the following sequence.

21.4m/s(77 km/h)→17.5m/s(63km/h) →10.83m/s(39km/h)→0

This is due to the actions of the ATP and ATO. When the first train stops at station STB, the second train approaching receives ATP codes according to some sequence. The ATO in the second train will reduces the speed of the train according to the ATP code. As a result, although the large delay is imposed on the first train when it arrived at station STB, the regularity of the second train will also be affected.

Currently, fuzzy logic software objects in under development. In near future, simulated operation of the fuzzy controlled railway operation will be available.

6. Conclusions

Attributes and behavior of the elements in railway operation are analyzed and compiled into software objects applying object oriented techniques. These objects are stored in a software library, and simulated test for signaling and train control system can be carried out by retrieving objects from this library. In this paper, a simulated study on railway operation under disturbed condition is also carried out to demonstrate the application of the objects in the software library. Currently, this concept of object oriented representation is also used in the study of energy consumption in railway operation[8].

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