# A train traffic operation and planning simulator

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## Abstract

The objective of the project presented in this paper has been to develop a new simulator system that can contribute to improved methods for train traffic planning and operation and to create an experimental environment for development of new control support systems and operator user interfaces. The new simulator system is based on a previously developed simulation kernel, SIMON/TTS, which has been used by the Swedish National Rail Administration for off line planning experiments. The SIMON/TTS system has now been redesigned into an interactive, real-time simulator where external control and presentation systems can be connected via a communication module. The simulator system will be used for different purposes. Some of the most important experimental scenarios are to perform experiment with new user interfaces for train traffic control operators, to test the usefulness of decision support systems for train dispatchers, to evaluate alternative strategies for solving conflicts in train traffic control and to provide a simulator environment for education and training of train traffic operators.

## 1 Introduction

In the future we will face increasing demands concerning high efficiency in planning and operation of train traffic systems. Present methods for planning and control of traffic operation can normally not support optimality and are not sufficient development of new control and decision support systems. The objective of the project has been, firstly, to develop a new simulator system which can contribute to improved methods for train traffic planning and operation and, secondly, to create an experimental environment for development of new control support systems.

The new simulator system is based on a previously developed simulation kernel, SIMON/TTS [1,2,3], which has earlier been used by the Swedish National Rail Administration for off line planning experiments. The SIMON/TTS system has now been redesigned into an interactive, real-time simulator where external control and presentation systems can be connected via a communication module.

There are different reasons for developing a simulator system like the one presented here. Some of the most important experimental scenarios that have been considered here are:

- to perform experiment with new user interfaces for train traffic control systems. We have designed new types of user interfaces, which efficiently integrates complex and dynamic information sets. Through simulator experiments the practical usefulness of the interfaces can be tested and evaluated.
- to test the usefulness of different types of decision support systems for train dispatchers. This includes experiments with automatic control systems and decision support containing algorithms for optimisation of dispatching actions.
- to provide a simulator environment for education and training of traffic operators. Here new dispatchers can be trained and experienced dispatchers can be tested in simulated critical traffic situations.
- to evaluate alternative strategies for solving conflicts in train traffic control. This include tests of alternative strategies in today's traffic systems, but also completely new high level control organisations that must be completely evaluated in a simulated environment before being implemented into the real infrastructure.

Simulator systems have earlier been developed for different purposes in connection with train traffic simulation. In this project we have, as mentioned above, based our work on the SIMON/TTS system. Other research groups have earlier published related work. In [4] Ostermeyer and Osburg present a system that consist of a railway operation control technique simulator and a vehicle simulator. This TCSim-system provides research facilities for investigating existing and future traffic control systems. A fundamental element of this simulator system is the integration of a vehicle simulator. This means that it is possible to carry out realistic and inexpensive experiments that can support development of control systems as well as human machine interfaces. Cheung and Anderson reports on a study where a computer based training facility to enhancing railway operational training has been developed [5].

## 2 Development of user interfaces and decision support systems

### 2.1 New operator interfaces

A basic question that must be answered when new control systems are being developed is how the user interface for the operators should be designed. As a part of a research project [6,7], a set of different interface prototypes have been developed. The design of the prototypes is mainly based on the present Swedish train traffic control systems. The prototypes are being designed and evaluated in close co-operation between human factor experts and train dispatchers. The skills of the operators can only be fully utilised and incorporated into the design process if the dispatchers are part of the analysis and design team. So far, the interface prototypes have been tested in evaluation sessions together with train dispatchers. The functionality and design of the interface have been analysed following scenarios of different train control situations. The subjective comments from the dispatchers have been recorded and analysed. However, in order to evaluate the usefulness of the interfaces, we need a full-scale simulator system, where prototypes of future control systems together with their interfaces can be tested and evaluated during the execution of simulated traffic scenarios.

### 2.2 Decision support systems

All railway companies try to reach more regular and reliable train services, in order to be able to offer their customers higher reliability and flexibility. The present, expensive, strategy is increasing "physical" capacity. A more cost-effective alternative is to improve quality in the train control process itself. The most important factor in this process is the train dispatcher, who from a control centre supervises the movements of trains. The dispatchers chances to, in an active way, plan and control the train traffic is often crucial for how different disturbances effect train delays. Within this research area, one focus has been on development of algorithms and systems, which support optimal computer-aided train dispatching in real-time (CATD-RT) [8]. Also here, we must be able to study and evaluate the efficiency and usefulness of the prototype support systems in a realistic simulated environment.

## 3 Methodology

The developed simulator system, called TOPSim (Train Operation and Planning Simulator) is based on an already existing product. The Swedish National Rail Administration has since the early 1990ies used a simulator system called SIMON/TTS (see above) for long term and strategic planning activities, e.g. for the development of infrastructure and for construction and verification of time tables. The TOPSim-system is based on the experiences from the SIMON/TTS system, and SIMON/TTS's model kernel has been directly incorporated into the TOPSim system. However, since the SIMON/TTS system was designed for off line batch-wise experiments, some major changes have been made.

The basic kernel of the simulator model, the train traffic simulator (TTS), has been further developed into a real-time and interactive model. This has been achieved by including a run-time control function into the model, so that the model execution speed can be adjusted from real-time to maximum execution speed. The original traffic control algorithms in the old batch simulator have been removed, so that external operators, e.g. the dispatchers, can interact directly with the model during run-time.

It must be possible to configure the system in different ways depending of how it is going to be used. The TTS model must first be able to interact with an "outside" traffic control centre connected via a communication module, CM. The next step in adding functionality to the simulator system is to connect new operator interfaces, HMI (human machine interface), to the simulator. When testing different approaches to design of decision support systems, DSS, the model must also be able to communicate with different such modules.

## 4 Simulator specification

### 4.1 Basic configuration

The basic configuration of TOPSim consists of the TTS kernel with three windows for dialogue, results and messaging and a presentation module that displays the simulated course of events. The new modules that are added are the communication module (CM) and the present control module (PCM) for simple model control using existing command systems. The communication module enables this functionality. In figure 1 this basic system structure is visualised. Basic input is obtained from existing track and timetable databases.

### 4.2 Interaction with external user interface modules

Here the purpose is to connect the simulator system with an external operator user interface. The interface module will get information about the timetable, the real position and speed of the trains etc., and display this in the interface window, HMI window. Information about the timetable and the track information are read from a file when the simulation starts. A parser interprets the information in this set-up file since the modules do not use the same language; the interfaces are normally implemented in Java. By using the parser the interface will get a necessary subset of information from the file in order to display the timetable and the simplified track information. Other data that the interface will need is the dynamic information from the TTS. The same problem as in the static case occurs here since each message string from the TTS has to be interpreted and passed to the correct presentation object in the graphical interface. The structure of the simulator system when an external user interface module is implemented is shown in figure 2.

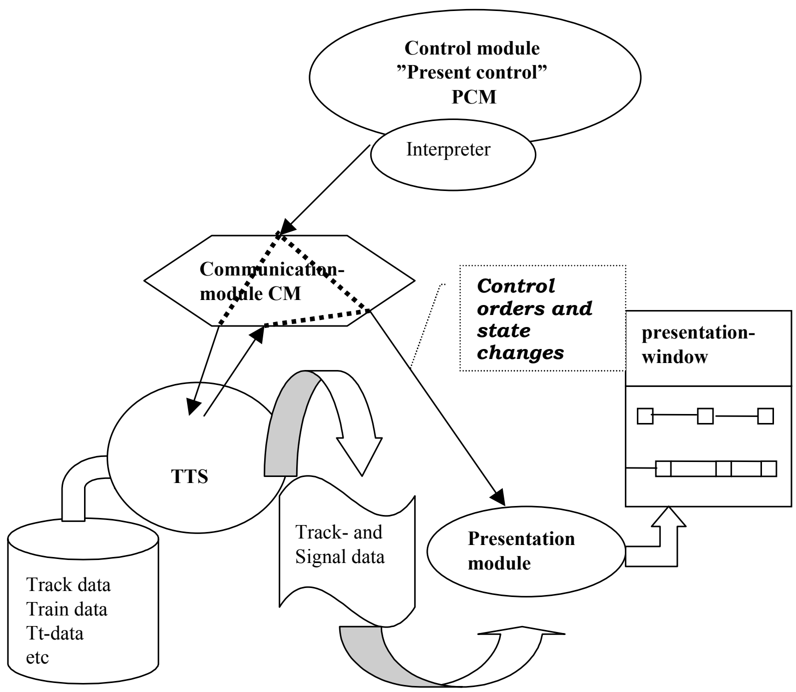


Figure 1: The basic simulator configuration

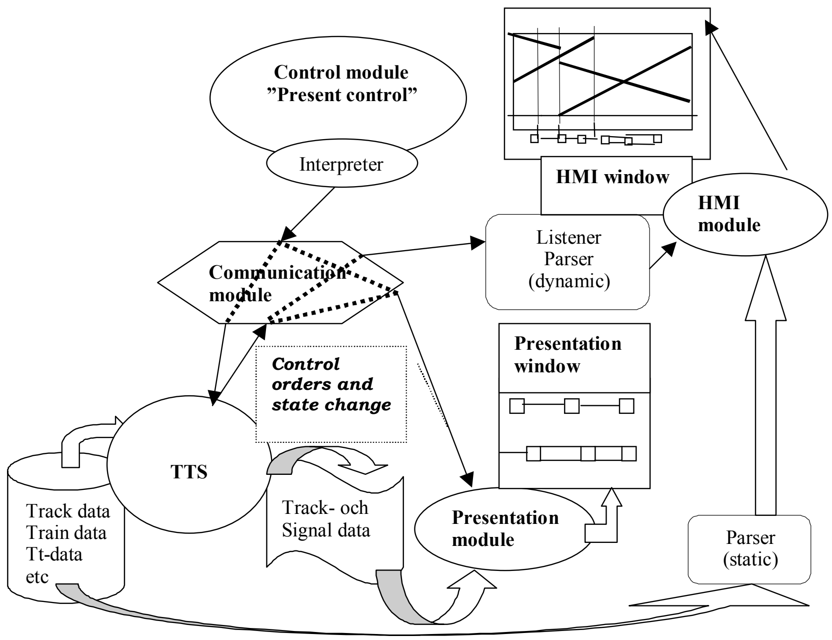


Figure 2: The basic TOPSim configuration completed with an HMI-module

### 4.3 Interaction with external decision support systems

The basic configuration must now be completed with a decision support system that will use the properties of the dynamic graph to display different alternative timetables suggested by the algorithms of the support system. The operator uses the DSS window to communicate with the DSS module when she or he want the DSS module to produce a new timetable, alter something in a proposed timetable and to select one of the proposed plans for effectuation. The DSS module will, to begin with, not send information back to the TTS module, but when the different configurations are fully integrated into the TOPSim system, it is necessary to apply a two-way communication. Static and dynamic data are passed to the DSS module in the same way as to the HMI module. The decision support algorithm often needs further information, e.g. additional time for the train's start and stop, to be able to calculate optimal timetables. A more detailed description of the DSS experimental set-up is out of the scope of this paper.

## 5 Implementation

The basic simulation kernel, the TTS module based on the SIMON/TTS system, is today implemented in Simula and running on a UNIX platform. Since the train traffic simulator runs on a UNIX machine, and the applications runs on a Windows NT machine, it is necessary to establish a socket connection between the machines. The UNIX machine will work as a server and every operator's NT platform will be a client. Every message between the train traffic simulator (server) and the train traffic control module (client) will be done by the use of sockets, i.e. read/write connections to specified client ports.

It is also necessary to interpret the source file that the TTS reads, since the new modules (HMI, DSS) are implemented in Java. The interpreter, or parser, is implemented with ANTLR 2.7.0 and reads the static data from the input source file. ANTLR is a language tool that provides a framework for constructing recognisers, compilers, and translators from grammatical descriptions containing Java or C++ actions. The parser will take an input source file and the output will be a package of Java objects. This description can be broken down into different tasks. A header section containing source code must be placed before any ANTLR-generated code in the output parser. In Java, this can be used to specify a package for the resulting parser, and any imported classes.

The dynamic parser is supposed to interpret the strings of tokens that are sent by the train traffic simulator during simulation execution. These messages contain dynamic data from simulated objects and describe the state of signals, routes, position and speed of the trains etc. It is possible to make changes in the TTS, i.e. to extend the traffic simulator model, in order to get access to more information that is needed for the new user interface.

## 6 Conclusions

When new train traffic control systems, or components of such systems, are developed, it is necessary to be able to perform realistic evaluation experiments. This is especially important when we use a user centred development model where we need the evaluated response from experiences users. The main purpose of the TOPSim project has been to create such a test bench to support the development process. The focus has been on the design and evaluation of new operator user interfaces and on decision support systems for train dispatching.

In the continuation of the project we will also focus on other goals. Examples of such goals are the evaluation of different ways to organise the control activities, development of new automatic control systems and the communication between these and the human operators, facilities for training of dispatchers in complex control situations etc.

In order to be useful as a R&D test bench, where we have to continuously implement new versions of control system components, user interfaces, decision support systems etc., it is necessary to design the system in a very general way. This is the reason why we have carefully separated the TTS model kernel from the presentation, control and decision support modules. The use of generated parsers that compile the communication between the modules, makes it easy to change the contents of the exchanged information, e.g. to include completely new traffic parameters in the user interface.

## 7 Acknowledgement

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