Evaluation of decision support modules and human interfaces using the TopSim simulator .

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Abstract
The quality of the command and control processes in the railway business will be of outmost importance in the creation of new products and services, which are competitive in the traffic markets. To increase the quality and flexibility of the online control of train movements there are two ongoing interdependent projects in Sweden named TOPSim and CATD respectively. The main objective of the TOPSim project is to create a Train traffic Operation and Planning SIMulator that is intended to be the used in the development and evaluation of new train control and decision support systems (DSS). On the other hand the objectives of the CATD project (Computer-Aided Train Dispatching) are to formulate and communicate the requirements for the simulator as well as develop, implement, test, and evaluate new decision support tools and human-machine interfaces.

The new simulator system TOPSim/TTS is an interactive, real-time simulator. It has a modular architecture making it possible to connect external control and presentation systems via the central communication module. It is based on a redesign of the kernel of the previously developed simulation system, SIMON/TTS, which for several years has been used by the Swedish National Rail Administration for off-line planning experiments.

In the short run the aim of developing the simulator system is to create a laboratory environment, where it is possible to experiment with and evaluate, new methods and technologies within the areas of Decision Support Systems and Human-Machine Interaction . Taking the long view there are also plans of providing a simulator environment for education and training of train dispatchers. Here new dispatchers can be trained and experienced dispatchers can be tested in simulated critical traffic situations. It will also be possible 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 thoroughly evaluated in simulated environments before being implemented into the real infrastructure.

This paper will present the TopSim/TTS system concept as well as the first DSS prototypes that will be tested and evaluated. Some preliminary results of using the TopSim/TTS as a test bench or "laboratory environment" for traffic control experimentation and making experiments with the new DSS and HMI prototypes will finally also be described.

Introduction

In Sweden, like many other countries where the railway net is dominated by mixed traffic on single and double track lines, and the train control to a high degree is centralised, there are a couple of interesting questions concerning train dispatching not yet answered, see also [7,8,9]. First, to what extent is it possible to reduce the spread of delays when a disturbance, effecting one or more trains has occurred, i. e. to minimise the so called "secondary delays"? Secondly, to what degree is it possible to improve the quality in the train control process itself by introducing different kinds of decision support tools and/or improving the human-machine interfaces? A third question is whether there is a need for a change in the organisation of the work in the train traffic control centre? Changing work load, roles, or just make changes in the actual work tasks.

As you can see, the issues involved are complex and often inter-related, making it both difficult and expensive to study them in the "real world"-environments. Therefore we have found, that in order to start answering these questions and others alike we must create a "laboratory environment", wherein it is possible to simulate a train traffic that is controlled by a human "dispatcher". And where it at the same time is possible to install and test new DSS modules and HMI´s.

Two interdependent projects, named TOPSim and CATD respectively, are currently running in Sweden. The main objective of the TOPSim project is to create a Train traffic Operation and Planning SIMulator that is intended to be used in the development and evaluation of decision support systems (DSS) and human-machine interfaces (HMI) for future train control systems. The aim of the CATD project (Computer-Aided Train Dispatching) are to formulate requirements for the TOPSim simulator as well as develop, implement, test, and evaluate new decision support tools and human-machine interfaces.

The new simulator system TOPSim/TTS is an interactive, real-time simulator. It has a modular architecture making it possible to connect external control and presentation systems. It is based on a redesign of the kernel of the previously developed simulation system, SIMON/TTS, which for several years has been used by Banverket, the Swedish National Rail Administration, for off-line planning experiments, see e. g. [1,2].

In the long run there are also plans of expanding the described system into a simulator environment for education and training of train dispatchers. Here new dispatchers can be trained and experienced dispatchers can be tested in simulated critical traffic situations. In this environment it will also be possible to evaluate new alternative train traffic control strategies. This include tests of alternative strategies in the traffic systems of today, but also completely new high level control organisations that must be thoroughly evaluated in simulated environments before being implemented into the real infrastructure. See also [3,4,5].

The emphasis in this paper is on decision support in the train traffic control centre. The goal has in the short run been to develop simple, easy to use, and practicable support tools. Which here means that they must fit within the limitations of the actual system, the budget, and have the potential to be of practical use. The first version of the decision support prototypes will therefore probably only be used to learn more about the control process and the tasks involved.

Within the framework of the CATD project a first analysis and description of actual and possible decision support tools has been made. From this work we have chosen two decision support tools to be implemented. They are more thoroughly presented later in this paper.

Role of the decision support system

Why is it difficult to make good decisions? Clemen [11] points out four determining factors. First and foremost is the complexity of the task. A human being has a limited ability to perceive and solve complex problems, and therefore builds simplified mental models of the real situations. And even if these models are used in a rational way, all simplifications leads to less good decisions being made. It is for example, almost impossible for a dispatcher to keep a check on all trains moving around in the net and predict and control their future behaviour. The second factor is the uncertainty in the situation. How fast is that particular train running? A third factor that the decision-maker has to consider is that there often are several different goals involved. A decision that is correct in the short view may be wrong in the long term and vice versa. Finally, different perspectives may lead to different conclusions, especially when several people are involved in the decision process. Lenior [12] has given examples of the influence of the last two factors in the train control process, but see also [5,7,9].

The decision-maker must be informed, have access to good models, and also have access to the "right" information in order to be able make good decisions. Here model ranges from simple, implicit ones to sophisticated mathematical models or computer programs. One way to reach this goal is to introduce a DSS. A DSS is in general terms a computer-based, interactive system that collects the necessary information from different sources and gives the user assistance in the organisation and utilisation of the information. Often it also makes it possible for the user to analyse and evaluate the different decision alternatives by using built-in models.

In the DSS research society it is generally agreed that a DSS has three main components, namely the DBMS (Database Management System), the MBMS (Model-base Management System), and the UI (User Interface). The DBMS collects, organises, and gives the user access to the data . The MBMS handles the use of the models that is part of the system. Finally the UI, which to the user "is" the actual DSS, takes care of all interaction between the user and the other parts of the system.

The DSS that we propose is to be used to support the dispatcher in the decision-making processes that exists in the train traffic control task. To start with we concentrate on the conflict solution and timetable replanning stages.

In short, the main purpose of a decision support system (DSS) is to aid a decision-maker to gain a greater understanding of his tasks and thereby help him to find a solution that is good enough.

The TOPSim-DSS system architecture

According to the requirement specification that was produced in the beginning of the two projects, the first version of the TOPSim/TTS system is completed and ready for use. It consists of three parts or subsystems. First, the so called "TOPSim, basic configuration", which – stand alone - is the first prototype of an interactive, real-time train traffic simulator.

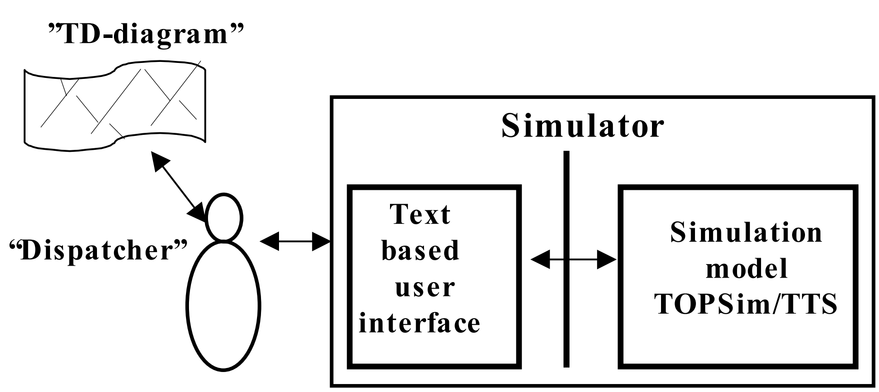

Figure 1: The TOPSim simulator, the basic configuration.

See Figure 1. The aim of the basic configuration is to be the base for different types of systems. It should be possible to build a "new" TOPSim-XXX system for some special purpose just by connecting a new module. As a stand-alone system it will primarily be used as a reference system in connection to different experiments and tests with the enhanced TopSim configurations, but also for separate train control experiments.
Second there is one of the enhanced configurations, the TOPSim-DSS, in which the actual DSS module is implemented. See Figure 2. The third part and the other of the enhanced configurations is TOPSim-HMI, in which the new interface module is implemented. This part has the same structure as TOPSim-DSS.

With the first version of TOPSim/TTS it is possible to – interactively and in real-time – control the simulated train traffic for every track layout in a way that resembles the way it is done in the traffic control centre today. The control commands are normally given as text commands in the user interface window. In the current version of TOPSim-HMI it is also possible to give the control commands by "mouse clicking".
A more thorough description of the TOPSim/TTS system can be found in [6].

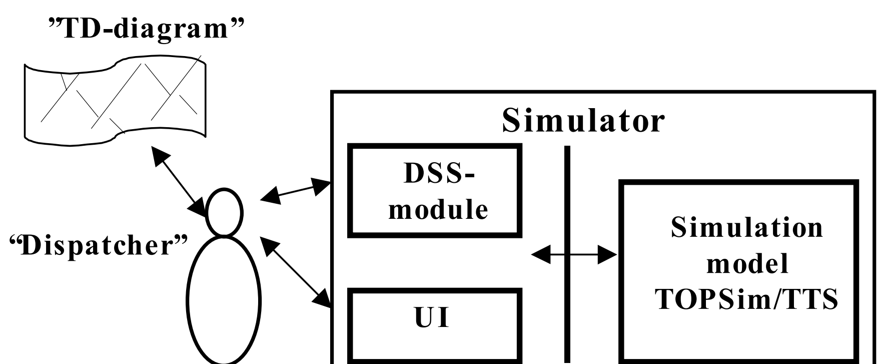

Figure 2: The TOPSim-DSS simulator.

DSS modules chosen for implementation

Functions for the TopSim-DSS system can be developed and implemented in different ways, depending on how complex the system is meant to be, necessary data input, and how the module should be implemented into the system. Our effort has been to find and implement support functions with the potential to be of practical use. This work is essentially based on experience from previously performed work, see [9,10], but also with direct links to an ongoing project called FTTS, in which train drivers, dispatchers, and people responsible for time-table planning are directly involved.

During the analysis phase we found five different candidates of DSS-functions that could be chosen for further development and implementation. These are hereunder listed in order of complexity:

1. “Simple prognosis simulation”. A function that makes a simple prognosis over the trains behaviour during the next one or two hours based on the actual runtimes of the trains. And in a graphic TD-diagram shows were future conflicts might occur.
2. “Simple interactive prognosis simulation”. Based on alternative 1, but adding the possibility to choose, in time order, how to solve the different conflicts detected.
3. “Prognosis simulation SIMON/TTS”. Similar to alternative 1, but a SIMON/TTS Kernel here calculates the prognosis for the nearby future, using its “built-in dispatcher” to solve the conflicts.
4. “Prognosis simulation TopSim/TTS”. Similar to alternative 2 but instead using a TopSim/TTS Kernel to perform an interactive prognosis for the nearby future.
5. “Timetable-Optimisation”. A function based on an optimisation algorithm like the ones described by Jovanovic or Higgins, see [9], that from a given situation calculates the most optimal timetable for the near future.

Within the given frames, concerning time and money, we realised that during the first development round it would not be possible to implement neither alternative 4 nor alternative 5 because both alternatives are too complex and time consuming and involves to many unknown components. Alternative 2 was decided to be our main task to develop, as it was judged to be of great interest to evaluate. Alternative 3 was (and still is) of great interest to us because we think we would be able to learn a lot about the dispatching process itself through this function, even though the behaviour of the built-in dispatcher within the SIMON Kernel sometimes is far from optimal. At that point it was decided to become our second choice for further development.

The “simple interactive prognosis simulation” has been designed to give the dispatcher a possibility to quickly evaluate a set of possible solutions to a conflict problem. It is primarily designed to deal with conflicts on single-track lines, but future developments will also involve detection of conflicts on double-track lines.

The following example will give you an idea of how the module acts when called upon by the user: If, for instance, a sudden disturbance occurs, causing a train to be delayed, then the dispatcher can “consult” the DSS-module. The module interface will then show an overall prognosis of the near future (1 to 2 hours) by constructing a prognosticated timetable in a graphic TD-diagram where all detected conflicts – collision or overtake situations – are marked by flashing rings.

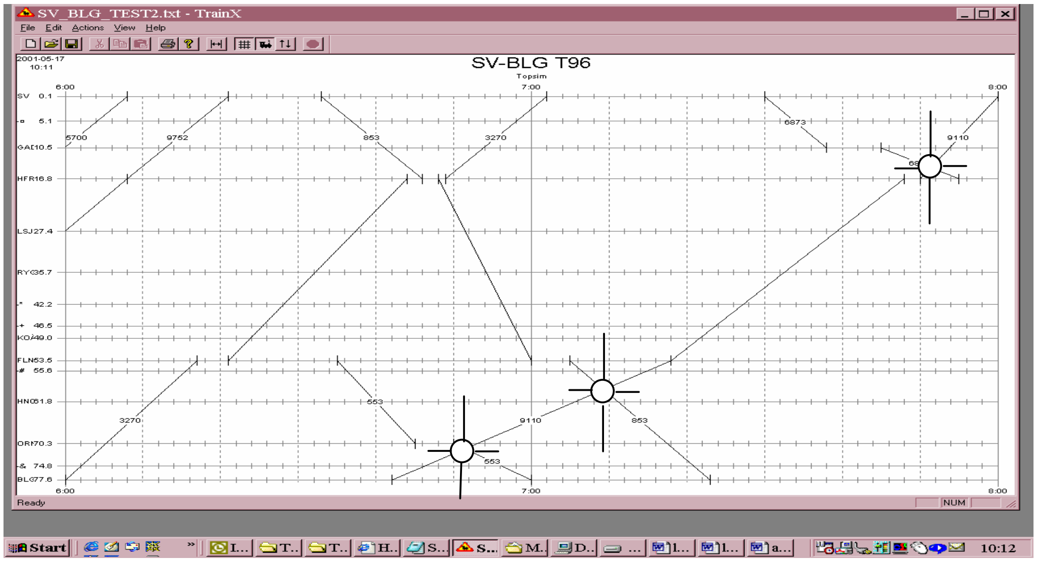

Figure 3: Train 9110 is estimated to be 15 minutes late and the DSS-module presents a prognosis in a TD-diagram.

The dispatcher will now be able to, in order of time, select a detected conflict and “solve” it. To solve a conflict the dispatcher simply choose were a meeting, or an overtake, is to take place, by parallel-moving the time table line of one or both trains involved or perform changes directly in the Timetable. This is done by a “drag and drop” option within the DSS user interface, or by calling a dialog box where one specify what train one want to effect and in what way, i.e. change of arrival/departure time(s). Once one conflict is “solved” the DSS-module will perform a recalculation and present a new prognosis for the further development of the traffic. All subsequent conflicts, including the newly detected ones will be shown.

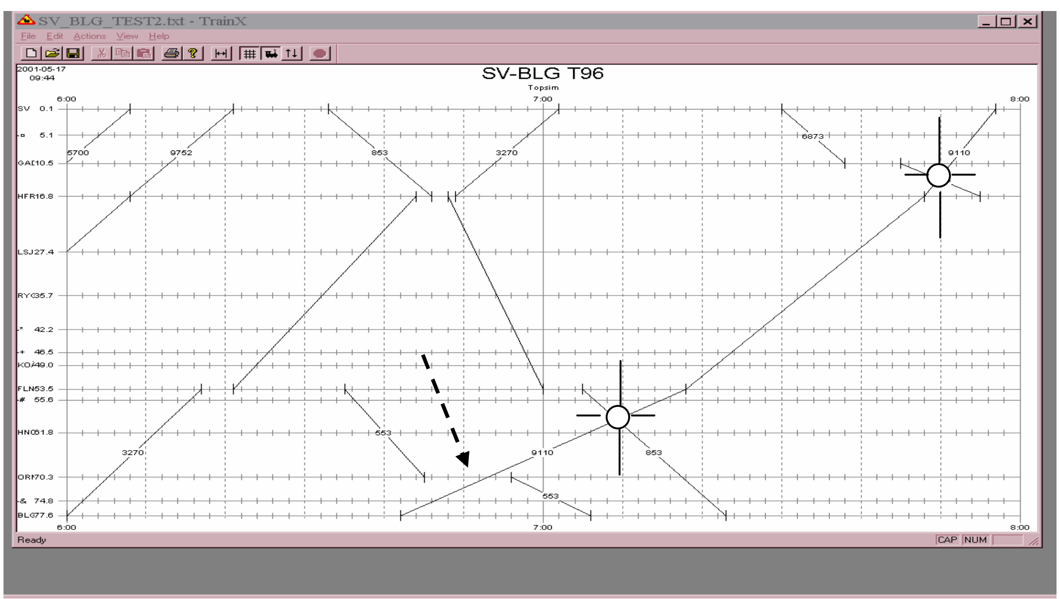

Figure 4: The first conflict in order of time has been solved and a new prognosis is shown in the TD-diagram with remaining and/or new conflict zones. (The solved area is marked by a dotted arrow).

If the dispatcher will find (by own judgement) that the prognosticated scenario did not look optimal, he can go back to the beginning and start all over again by solving the conflicts, again by order of time, but in an alternative way. Once the dispatcher is satisfied with a solution he can decide that the prognosticated time table will run as the current timetable and replace the original one.

Note: When we say, “solve a conflict”, that does not mean one have to solve it within a discrete, marked, conflict zone. The dispatcher is free to manipulate with all, in the TD-diagram occurring, trains in such manner that an “optimal” solution to the current conflict will be obtained.

Conclusions

Our efforts have, and will be, to make this experimental environment behave and “look” as close to the real world as possible, even though there are limitations within the SIMON/TTS system and its model, that narrows our possibilities. One of the most important factors when developing DSS modules for future train dispatching is the skill of the professionals. The FTTS project has been, and will continue to be, a most important reference group to us during the development and evaluation of DSS tools. Their mix of participating professionals from all levels of the train dispatching area gives us an outstanding base of knowledge to refer to, especially when it comes to questions about how to formulate detailed scenarios of future traffic and control systems. These scenarios play an important role in the ongoing research work.

Experiments performed so far have been concentrated on the TopSim/TTS basic configuration, trying to dispatch the traffic under real time conditions. The next step will be to use the basic configuration in combination with the first developed DSS module and evaluate its usefulness with the help of professional dispatchers. The near future will also include the implementation of the second DSS alternative and its evaluation in the same manner as for the first DSS function. It will be most interesting to see the outcomes of these DSS experiments and what they will bring for future developments.

Acknowlegements

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