Automatic conflict detection and advanced decision support for optimal usage of railway infrastructure
Prototyping and test results

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Abstract

The Netherlands Railways currently uses a computer-controlled route setting based on a route setting scheme. Route management has shifted from dispatching towards planning and supervising routes. Early conflict detection and decision support (CD/DS) is needed to support this new working method. The CD/DS system effectively adjusts the route setting scheme in advance when, for example, a delayed train will cause a conflict. This paper highlights prototyping results with this system, its architecture and purposes and results of real life tests. The tests were performed to ensure the feasibility, reliability and accuracy of train movement predictions and conflict detection. The purposes and concepts of the CD/DS are discussed by Stolk [2].

1 Introduction

The Netherlands Railways currently utilise computer-based systems for train control. These TRACE PSS systems (Renkema, Vas Visser [1]) are operated by a train process supervisor, who replaces the former train dispatcher. His main task is to ensure a short-term up-to-date route setting scheme, which enables the automatic route setting system to effectively handle incoming and outgoing trains.

When performing the new short-term planning task, it has become clear that there is a need for early conflict detection and advanced decision support.

Chapter 2 describes the CD/DS system architecture, including a short overview of the main entities.

After several studies, work began on the development of the functional specification of the CD/DS system. The functional requirements were established by a functional advisory board. Primarily as a result of the complexity, interaction and abstract level of the decision support system a prototype was developed. Experience with and results of the prototype are summarised in chapter 3.

The concept of early conflict detection is fully based on an accurate and reliable prediction of train movements. This was tested with a limited implementation of the CD/DS system during train operations at Eindhoven. The testing took place in the spring of 1996. The results provided confidence in the system and are presented in chapter 4.

The Netherlands Railways are currently finishing the implementation of the first release. In this release, the most important conflicts and accompanying measurements will be available for testing in a real life situation near Utrecht in late 1998. The purposes and evaluation criteria are listed in chapter 5 together with future developments.

2 System architecture

The CD/DS system comprises four main entities: 1) a man-machine-interface for interaction with the train process supervisor, 2) a running time calculation entity for the prediction of train movements, 3) a conflict detection entity for the detection and reporting of conflicts and 4) a decision support entity to solve reported conflicts. The system is integrated into TRACE PSS (Renkema, Vas Visser[1]). Figure 1 depicts the system architecture and is briefly explained below.

Running time calculations

One of the conditions for calculating future train movements is the availability of a detailed and accurately maintained data set. The running time calculation entity calculates the train movements based on the track layout, signals, signs, curves, (temporary) speed limits, train characteristics etc. The train movements are recalculated using the actual reported train positions. If the deviation between the prediction and the actual position/time measurement exceeds a threshold value, e.g. plus or minus 30 seconds, the train movement is recalculated from the reported position. The result of the calculations is a collection of time stamps for each train along the infrastructure.

Conflict detection

The conflict detection entity signals concurrent use of the infrastructure, based on the collection of time stamps along the infrastructure. Combined with the planning data, this results in various types of conflict. Non-infrastructure related conflicts are also included, e.g. a broken connection. All conflicts are reported to the Man-Machine-Interface (MMI). At the MMI the supervisor can select a conflict and request a solution.

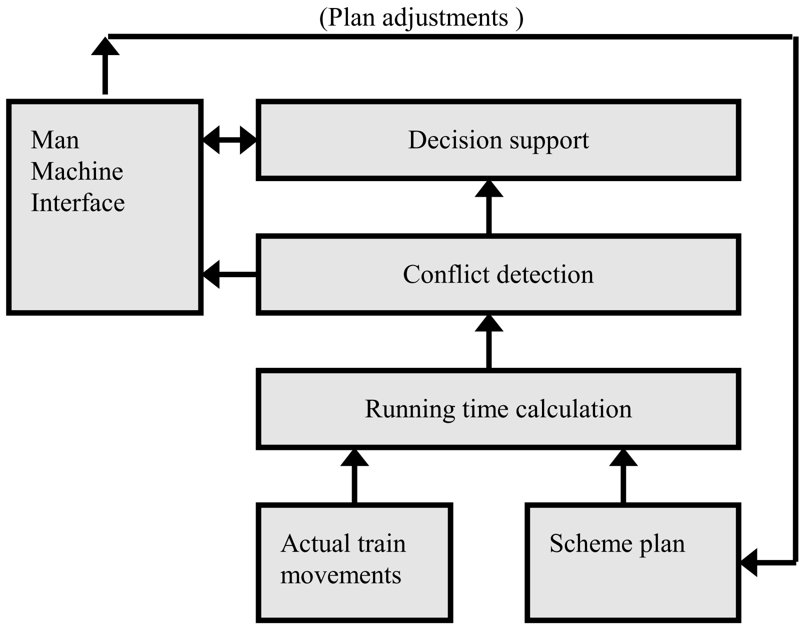


Figure 1. System architecture CD/DS system

Decision support

This entity uses operational research, decision trees and cost functions to solve the selected conflict. There are two operational modes, simple and advanced. In the simple mode the decision support system is controlled by the supervisor, who will interactively try to solve the conflict. Possible measures are presented and subsequent conflicts are calculated after selecting a measure. In the advanced mode the decision support system tries to solve the initial conflict by calculating the cost effects of each individual measure. With the help of heuristics the search area is limited and stops when a 'best' solution is found in comparison with other solutions.

Both modes will lead to a set of adjustments to the current scheme plan. The new scheme plan will be recalculated and the initial conflict will be removed from the MMI.

3 Prototype

Why a prototype

During the functional specification of the decision support entity, it became clear that a traditional software development approach was not applicable. The need for another approach was caused by the abstract level and complexity of the subject and contradictions between user requirements and technical possibilities. The project management and the functional advisory board decided in favour of the implementation of a prototype with realistic behaviour and the following goals:

- Functional specification of the decision support entity with such a level of detail that software engineers would be able to design, implement and test it.
- Defining the requirements of decision support for the supervisor in realistic situations with both slightly and heavily disrupted train processes.
- Ensuring functional requirements which are feasible with existing state-of-the-art technology.

Why was it successful

The prototype approach was very successful because the end users (supervisors), experts and designers acted as a team and were really committed to the specification. The specified functionality could be realistically demonstrated within cycles of two or three weeks. Such demonstrations provided immediate feedback to the team and purely theoretical discussions were avoided. The prototype demonstration and discussion sessions established clear functional requirements with a known impact.

Results

The functional requirements, alternatives and technical feasibility were much more clear and explicit as a result of prototyping than they would have been in writing only. After the prototyping phase, several aspects were no longer vague or incomprehensible and the functional specification was completely fixed. It also became clear that operational research techniques and heuristics could be used.

4 Feasibility test in Eindhoven

The overall ambition level of the CD/DS system requires accurate and reliable predictions of the train running times. A comparison between predicted and actually measured times was needed to provide confidence in the further system development. In the spring of 1996, actual train running times were predicted and measured over a period of 8 days in Eindhoven. The objective was to gain a quantitative insight into the following areas:

- Accuracy of the system's prediction algorithm, i.e. what are the deviations between the prediction and the actual execution. The effects of the various influencing factors.
- The time differences between the prediction and the related actual execution.
- Dynamic behaviour of the prediction algorithm. i.e. the number of adjustments of a specific prediction and the magnitude of the variations in these adjustments.

The test results in these areas and a few analysis results are shown below.

Accuracy of predicted signal passing times

Standard deviations of all predictions for a specific signal passing time were calculated. An example of the results is shown in Figure 2.

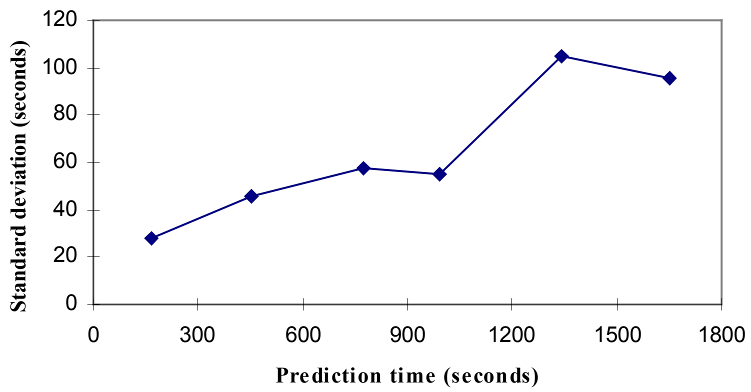
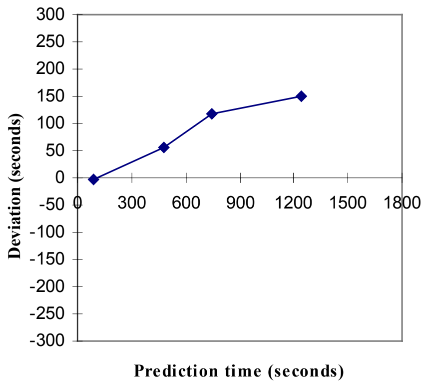


Figure 2. Example accuracy of signal passing time as a function of prediction times.

It was concluded that prediction times, which are less than 10 minutes, are reliable.

Stability of the predicted signal passing times

The stability of the predictions determines a yardstick for the fluctuations of a specific prediction as a function of the time. Conflict predictions will change where there are large fluctuations. This will lead to an unusable system.



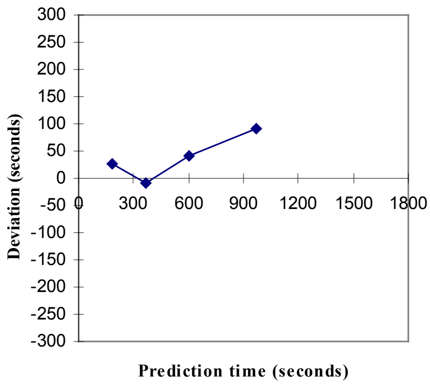


Figure 3. Two examples of deviations of actual and predicted signal passing times as a function of the prediction time

Fluctuations in measured running times

The fluctuations in the measured running times determine a *lower limit of the maximum achievable accuracy of predictions.*

Measurements were carried out of the running times of arriving trains (A), departing trains (B), nearly constant speed trains with short intermediate stops (C) and trains with temporary speed limits (D). The standard deviation values vary considerably according to the train type. Results are shown in Table 1.

Train types	Standard deviation values relative to running times.
Arriving (A)	21 - 44 %
Departing (B)	19 - 36 %
Nearly constant speed (C)	3 - 8 %
Temporary speed limit (D)	9 - 53 %

Table 1. Standard deviation values according to train type

Deviations from predicted running times

The predicted running times of *arriving* trains are systematically shorter than the actually measured running times. The train driver starts to brake earlier than predicted. The predictions are based on the (maximal) braking curves. This explains the deviation. Generally speaking, the predictions conform to the measured running times.

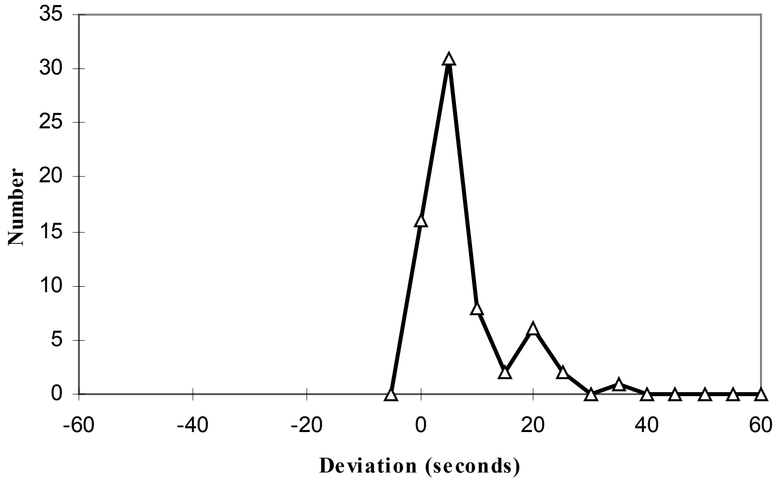


Figure 4. Example number of deviations actual/predicted running time as a function of the deviation.

Conclusions

General conclusions from the Eindhoven tests are as follows:

- Predictions made at less than 10 minutes before the actual occurrence provide sufficient confidence to form the basis for reliable conflict detection. Predictions at earlier times than 10 minutes before need to be treated with a greater degree of caution. This is mainly caused by systematic delays during arrivals and departures.
- Conflict detection for trains which are entering the control area is not reliable.
- Fluctuations in the predictions are generally limited.

The general result was that the Eindhoven measurements proved that the CD/DS system predictions are sufficiently accurate and reliable to provide confidence for further development.

5 Operational test in Utrecht

The first release of the CD/DS system will be used for testing purposes during normal train traffic control in Utrecht at the end of 1998.
The test is the next step in the system development process. The main goal is to prove the usefulness for the train process supervisor under operational circumstances. The goals and evaluation criteria of the test are as follows:

- Determining whether the CD/DS system is capable of sufficiently reliable predictions under operational circumstances to detect the relevant conflicts.
- Determining whether the supervisor gains sufficient insight into the detected conflicts.
- Determining whether the set of available solutions sufficiently covers the needs for rescheduling the scheme.
  The solution of a presented conflict, which would be chosen by the supervisor, shall be included in the list of suggested solutions with a 95 % score.

The tests will follow three chronological steps. First the predictions will be reviewed and conflicts will be judged, with the help of system diagnostics. The second step will focus on the integration of the system in the train process supervisor's work. Finally the system will be used during operation for longer periods of time.

It is understood that usual train traffic control may not be disrupted during the tests. The CD/DS system shall also co-operate and integrate smoothly with other train control systems for train traffic control and planning.

Future developments

The calculation of the running time is a deterministic process. However there are still influences that cannot be easily modelled. For example the number of passengers entering or leaving the train during a short stop is not known at the moment and therefore cannot be taken into consideration in the calculation. Diagnostics functionality and systematic fault correction, which will account for the non-deterministic factors, will be included in the CD/DS system. This represents a further step in the direction of a 'self-learning' system.

References

[1] Renkema, M. & Vas Visser, H. TRACE supervision system for dispatching and passenger information, *Proceedings of the COMPRAIL, pp 247-256, 1996*.

[2] Stolk, A. Automatic conflict detection and advanced decision support for optimal usage of railway infrastructure; Purpose and concepts, *Proceedings of the COMPRAIL 1998*.