A new tool for railway planning and line management

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Abstract

Nowadays a trend focused on developing new tools in order to ease the decision making process in traffic central post facilities is clearly demanded by railway administrations. Also, hardware and software technical improvement allows new and more complex control and planning systems to be developed.

In this paper a new tool developed for railway planning and traffic regulation is presented. Intelligent planning and traffic regulation is carried out with the help of a simulation tool that provides very valuable information to the planning and regulating tools of the way the railway line will react to the control orders. This simulator gives information of both mechanical and electrical behaviour of the system so electrical consumption can be taken into consideration in order to obtain an operational plan.

The way the line planning is carried out can be described this way: First, planning tool gets the operator inputs to the tool that are mainly the starting position of the train units in the line, the interval between circulations throughout the day or the departure time of the train. Then the planning tool calculates the optimal theoretical schedule and the routing list for each station in the line according to the inputs, conditions and restrictions of the line. This theoretical planning is tested using the simulator and if it fulfils line operational requirements is stored as a valid plan. Finally, a traffic regulation tool is in charge of executing the theoretical plan. This tool compares the theoretical plan with the result of the operation of the railway line, calculates the deviation from the theoretical plan (conflict detection) and sends orders to the traffic control system trying to lessen the deviations from the theoretical plan (conflict resolution). If deviations can't be reduced, a new planning taking into consideration the actual state of the line is obtained in order to operate the line while a degraded situation is taking place. Then, once the degraded situation is overridden, the first theoretical plan is recovered if possible.

Keywords: railway planning, decision making, train control, simulation tool.

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1 Introduction

Railway management has become more and more complex since decision making more powerful tools have been developed during last two decades. Central posts are nowadays a commodity where general line decisions are taken, but up to date solutions do not include interaction between these central modules. Information is not shared between them. Energy trackside system information is not considered when schedule planning is being carried out or when critical situations occur.

The use of simulation tools is widely spread in control tools. It has become feasible to integrate electrical trackside systems simulations with operational – dynamical simulators. This allows control tools to take into account the electrical results of the planned line schedule and use parameters like feeder station instant power demand or contact wire voltage to build a better line plan. It also allows the control tool to take actions when degraded line conditions happen.

A new tool for railway planning and line management has been developed by CITEF (Research Centre on Railway Technologies). This tool has advanced knowledge management modules that are in charge of the decision processes and advanced simulation tools that allow the integration of electrical, dynamical and operational modules.

As it is defined in EU Commission's interoperability principia, railway systems are divided into infrastructure administration and operation of the railway line as two different issues. So, railway management can be split up in these topics:

- Railway planning: whose main purpose is to obtain a strategy of resources allocation, limited by the infrastructure, in order to face operational programming tasks.
- Railway traffic control: that is in charge of the tactical execution of the obtained planning strategy.
- Train control: who considers trackside equipments and devices status to operate the line according to the requirements of the Railway Authority.

Considering this, planning, line management and operation tools should not be designed considering train control, as long as this is achieved by railway safety facilities and the electrical trackside system.

In order to describe the management of a railway line describing the facilities, their management and train operations is a necessity.

Thus, the development of an intelligent tool to help in the decision making process of a CTC system must be made into two stages [2]: first, planning process which will lead to obtaining the optimum schedule based on the number and variety of train unit circulations and the facilities of the line; and, secondly, train regulation process that will define the orders to be sent to each train unit depending on the circulations, the status of the facilities and the evolution of the circulations.

A railway line operative architecture could be basically made by two kinds of processes:

- A central process that is in charge of the line traffic management.

- A series of elementary processes as interlockings or stations are placed along the line that are in charge of the execution of train routes according to the strategy for the line set by the central process.

Besides, line planning and operation are affected by track profile restrictions (maximum speed, maximum number of trains in a station, number of block sections between stations…) and line restrictions like electrical trackside facilities limits or interlocking restrictions.

Decision making process in railway traffic management is 'event driven'. Decisions are made according to events that arise when managing train units such as train delay, or a train passing (either train heading in the same direction or opposite direction), or according to train operation such as train stops, shunting routes or train coupling.

2 Planning and regulation operations

Planning and regulation are tasks that must be carried out by the train operator [3]. As said before, planning and regulation are the two steps to follow in order to control the system. This control process can be split into these main tasks:

- Planning process: searching and obtaining an optimal control law according to the functional aspect during the off-line stage.
- Traffic regulation process: adjusting the obtained control law when the environmental condition forces a change in the operating point.

The first searching process (planning) is obtained off-line considering ideal conditions for the railway line. The availability of test bench scenes provides the best conditions in order to obtain the results of the search, mainly due to the possibility of evaluate the results of the rules found along the search process.

The second searching process (regulation) is held on-line. The process is controlled according to the laws (rules) obtained in the previous step. New obtained rules are tested in the process simulator before obtaining the optimal action to perform. A matter of great importance is to avoid wrong decisions to be taken when failures are present in the process and also to get the appropriate variations in the base of rules for the actual state of the process variables.

Regulation task is helped by management oriented tools based on train tracking inputs obtained from the infield facilities like track circuits and interlockings. Thus operator has to face two different problems: the first one refers to train routing and the second one refers to train location.

A routing order must allow the management of available unlocked resources that are compatible with all the routes already set in the station. Interlocking is in charge of informing the dispatcher of the current state of the facility.

A train must be located in order to perform the convenient routes in the station. Train dispatcher is aware of the train description, of its delay, of schedule information (space vs. time graphs), and the train set (number of coaches, locomotive unit…). Train dispatcher assigns the available resources (entrance route, station track and exit route) in order to control the train unit movement in a defined lapse of time.

Train dispatcher's routing selection is made following these principia [4]:

- Avoid collisions and incompatibilities: Safety system is in charge of avoiding collisions, exception made of emergency situations. Safety's main goal is to avoid accident threats. This safety interference can affect the setting of train units and unit assignment that can propagate forwards, this means that the following trains could be affected by this decision. Therefore a bad assignation can provoke future delays.
- Minimize train delay: if a train delay has already occur and, for example, there is no way that a train unit enters the station; human expert must dispatch trains creating a new theoretical assignment.
- Respect train priority: Train units are classified according to their services –passengers or freight– and also according to their trip distance (long distance, regional services, and proximity services) and as well according to their services and facilities (cafeteria, video, berth service…) and different fares. Experts prioritize trains as avoiding delays and keeping schedule commitment is more important in certain trains. Train priorities change dynamically according to the accumulated delay of each train.
- Schedule controls the traffic: Schedule contains information about train number, arrival time, departure time, train platform, etc. There are events that can change the expected timetable somehow. Expert must solve these situations trying to keep platform number and stopping time so train connections can be made. Thus, depending on the train delay a decision is made in order to keep this connection or not.
- Dispatching train exit: Train sequence must be permitted either in routes divided into block sections or between stations. Train speed during the section must be known in order to assign outgoing priorities. Therefore, it is an issue of great importance to set the outlet of the trains from the station dispatching the faster ones before the slower ones. This situation is usually referred in the schedule. On the contrary, a train can be reached by a faster one and it will stop to let the other pass by only if it has no delay. This is an important issue in order to defining train connections in the stations.

These dispatching principia considers that line management is centralized in the traffic central post which is the place where traffic routes are set for train routing to the interlockings that are the facilities where these routing orders are executed. Central post trails train position and, therefore, timetable fulfilment.

2.1 Obtaining the set of rules

Once planning and regulation tasks are described a deeper look at how the searching process is carried out is detailed next.

The main parts of the management system are the generator of rules and the simulation tool. In order to obtain the set of rules to control the system heuristics and genetic algorithms are used and the outlets of this process are tested using a simulator that validates the resulting control actions. As a result of this simulated process the tool can evaluate how good the solution proposed is and try to obtain a better one. Once this iterative searching process is accomplished the best obtained set of rules according to system constraints and operational parameters is proposed for acceptance by the planning operator. Figure 1 shows the way this searching process is carried out.

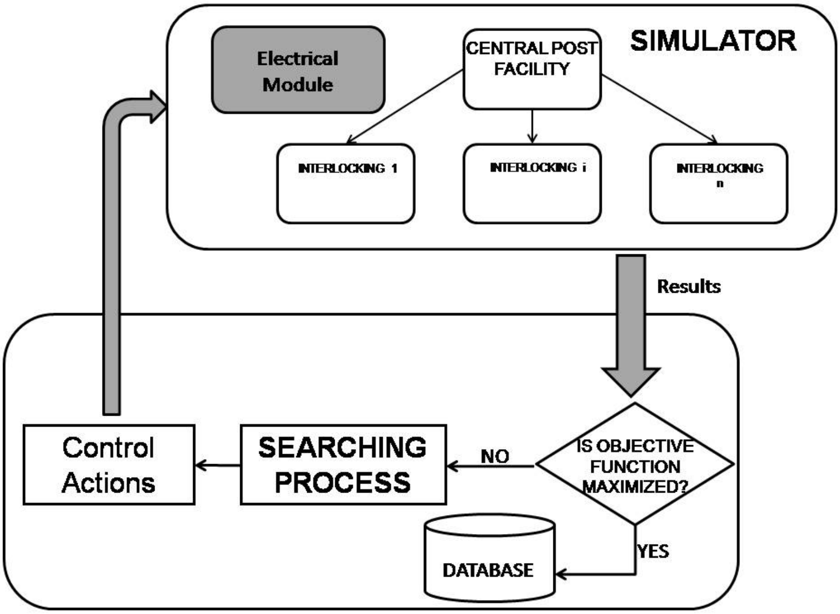

Figure 1: Schema of the searching process to obtain the set of rules.

2.2 Traffic Regulation

Once the 'theoretical' or off-line working point is obtained, regulation process is in charge of the system to follow this working point defined off-line. Traffic regulation process registers the events of the line and detects deviations from the desired working point. Then it takes the actions to lead the system to the established working point. In order to do so traffic regulation tool uses the simulator to contrast the effects of the actions and obtain additional learned knowledge. Figure 2 shows a schema of the traffic regulation procedure.

This working method relies in a proper simulator workout. Simulator has to be aware of the current railway line state. This implies that the simulation tool has to know the position of every train in the line, the working state of all the elements of the line (signals, sidings, track circuits, feeder stations, overhead wire, automatic control systems like ATO/ATP or ERTMS, interlocking, etc.). The simulation time is compromising in real systems so simulator is built as a set of modules (electrical system, interlocking, train units, ATO/ATP, ERTMS, etc.) so partial simulations can be performed if the regulation tool considers that no major problem is taking place. For example, if a delay in a train unit is detected the traffic regulation tool tries to solve it increasing the maximum speed of the unit or reducing its stopping time. A simulation can be skipped. If the delay persists, a simulation can be carried out involving adjacent train units and control facilities. This is a 'lighter' simulation. If the conflict keeps unsolved a whole system simulation can be carried out and new control actions performed and if this does not solve the conflict, a new plan is obtained considering a new working point for the line.

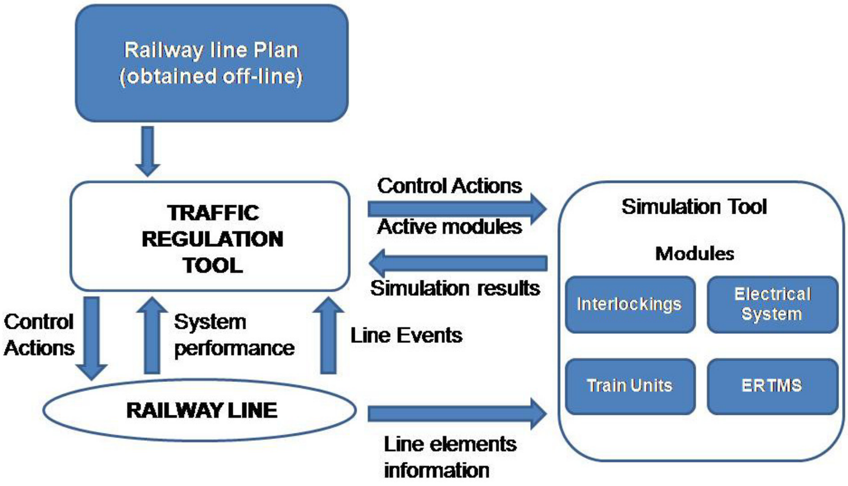

Figure 2: Regulation tool working procedure.

3 Conflict detection

Identifying conflicts in the line is a main task in traffic control facilities. These conflicts can affect line management. There are two main sets of conflicts: one involves train delay and the other involves trains preceding and succeeding current train unit.

A conflict can be defined as an event that modifies the scheduled train running. It can be noticed as a deviation from scheduled trip time in a space vs. time graph.

Most common train operations which take part in the process of conflict detection and resolution are shown next [4]:

- Train delay: A delay is a temporal increase over scheduled time.
- Train crossing: This event takes place when two facing trains have to share a train station. This usually happens in a single track railroad line where traffic in both directions shares the same track.
- Train reaching: This event happens when a slower train must be passed by a faster one. The slower one must wait in a station for the faster train to pass.

- Closed track: This is a track that can't be used. If this event takes place between stations, a train can't use it to get to the adjacent station; if it occurs inside the station it affects the train capacity of the station.
- Conflicting routes: This event happens when two trains want to occupy the same track at the same time.
- Train setting: this event takes place when a train has to arrive to its destiny to form another train set. This happens when a T1 train set has to get to the terminal station and come back being train set T2. The delay of train set T1 unables T2 from leaving the station at scheduled time.

Therefore planned space vs. time graphs define crossing points, reaching points, connections and destinations for all the train units in the managed line. Depending on the cumulative delay only crossing and reaching points can be modified. Train setting depends on available material in the initial station.

4 Advanced time conflict detection and resolution

An issue of special interest is developing tools that are able to detect conflicts as soon as possible or even before they occur. In order to do so an advanced simulation tool is a must.

4.1 Simulation tool

As said before in this paper a proper simulation tool is an important part in order to obtain valid knowledge in the off-line stage and to obtain on-line predictions of the railway line behaviour.

CITEF has developed its own railway line and train simulator. This simulator considers a wide range of parameters and start up values [5]. Most important are listed next.

- Train data: Weight, traction and braking power limits, resistance coefficients, curve resistance, maximum train speed, train set length.
- Railroad data: cross section and raised view section of the line, maximum speed sections, train station positions in the line.
- Electrification trackside system: feeding voltage, frequency, overhead wire topology as seen in Figure 3 (catenary and overhead wire, returning feeders, reinforcement feeders). This figure belongs to an electrical simulator and is represented to give an idea of the complexity of the system. The simulation tool used in the planning and traffic regulation tool has no user interface since it gets data from database. Other important parameters are section of wires, feeder station positions, neutral zone position and position of autotransformers facilities. These last two only in 2x25 kV systems.
- Signalling system: track circuits, signals (aspects), points, interlockings, routing table, incompatibilities, block sections, ATP/ATO modules, ERTMS.

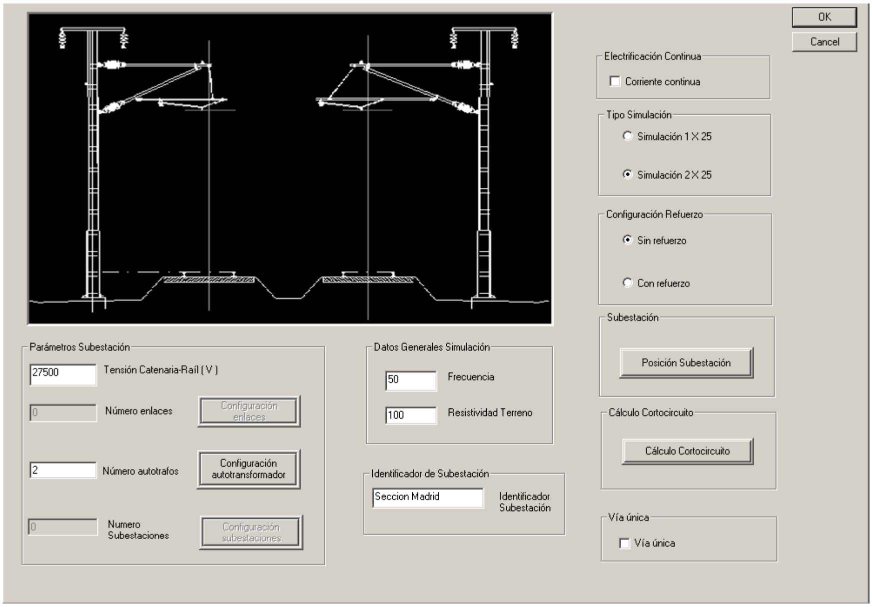

Figure 3: Electrical trackside facilities parameters.

The more railway line knowledge can be transferred to the simulation tool the more real-like simulations will be obtained.

4.2 Conflict detection and resolution

Once a reliable simulation tool is built it can be used in order to predict how the railway line will react to the control commands obtained by the traffic regulation tool. Line malfunctioning can be even foreseen as long as simulation tool reliably represents line behaviour. Traffic regulation tool can detect conflicts and solve them using the simulation tool and also can simulate each determined amount of time if the tool has a low work rate (i.e. weak traffic lines) and can detect time-ahead conflicts.

The traffic regulation tool is the one that detects changes in the working point of the line and generates the control actions in order to correct diversions from this working point. This tool is the one that decides whether or not the simulation tool is called and which modules of the tool should perform the simulation and provide results to the traffic regulation tool. This tool uses heuristics. Genetic Algorithms are use both in the planning phase and when a new plan has to be made due to line conditions when the older one was proven useless. This is because time restrictions do not allow using the developed GAs in real time.

5 Conclusions

Two new tools for planning and traffic regulation tasks are presented. These tools are being developed by CITEF and they are not yet working in a real central post facility but test are being performed against a simulated model. Other tools with less simulator requirements have being developed and provided excellent results. It is expected to have a prototype working in a real facility by the end of the current year.

The use of railway decision-making oriented helping tools is a promising area for new developments.

System integration in the simulation tool provides information for both electrical and operational systems. This integration provides valuable information when planning task is carried out.

The use of modular simulation tools provides great adaptability to obtain the requested performance of the whole system or only partial. This depends on the kind of railway line events to be solved and the time requirements of the traffic regulation tool.

A control strategy allows obtaining the desired strategy off-line using the planning tool and to carried it out detecting line events and solving them. When this is no longer possible a new plan is obtained to work in the degraded railway line.

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