

**TITLE: DEVICE FOR SIMULATING A RAILWAY SYSTEM AND ASSOCIATED
SIMULATION METHOD**

5 The present invention relates to a device for simulating a railway system, in particular with the aim of optimizing the operation of this system and improving its energy efficiency.

 A railway system, in particular a railway system for urban trains, is a complex system made up of many systems and subsystems cooperating with one another.

10 Using known simulation technologies, it is either not possible to predict the effects on the entire railway system of a local change (for example affecting a subsystem), or not economically viable to develop and maintain suitable software, or not conceivable to obtain, with an acceptable simulation time, relevant information on the behaviour of such a system.

15 The invention aims to address this problem.

 To that end, the invention relates to a device for simulating a complete railway system, the device including: a member for storing a model of the railway system, said model associating a unitary component with each agent resulting from a functional breakdown of the railway system to be simulated, each unitary component incorporating a
20 model of the behaviour of the associated agent, having input parameters and delivering output parameters, the output parameters of at least one unitary component being able to make up input parameters of another unitary component, each unitary component being characterized by a running period of the model of the behaviour that it incorporates; and a computing member, able to simulate an evolution over time of the model of the railway
25 system from an initial state, by running the behaviour model of each unitary component with a periodicity corresponding to the running period that characterizes it, using current values of the input parameters to calculate updated values of the output parameters.

 According to specific embodiments, the device includes one or more of the following features, considered alone or according to any technically possible
30 combinations:

 - the modelling includes one or several of the following unitary components: a infrastructure unitary component describing the network; a unitary component of the power supply system; a rolling stock unitary component describing the configuration of a train; a train kinematic unitary component describing the dynamic behaviour of a train; a
35 regulating unitary component of the traffic; a unitary signalling component; a control

unitary component of the trains; and a environment unitary component describing the outside parameters affecting the railway system;

- each running period is chosen as a multiple of a minimum reference period;
- the computing member incorporates an import module capable of configuring the initial state of the model by loading an initial state file from the storage member;
- the computing member is configured to evaluate operating properties of the railway system simulated from values of the output parameters;
- the computing member is configured to evaluate an energy consumption of the railway system simulated from values of the output parameters;
- the device includes a publishing unit allowing an operator to define the model;
- the device includes a unit for interpreting a results file generated by the computing member at the end of the simulation; and
- the computing member comprises an engine of the holistic type.

The invention also relates to a method implemented by a device according to the preceding device, characterized in that it comprises the following steps: storing a model of the railway system, said model associating a unitary component with each agent resulting from a functional breakdown of the railway system to be simulated, each unitary component incorporating a model of the behaviour of the associated agent, having input parameters and delivering output parameters, the output parameters of at least one unitary component being able to make up input parameters of another unitary component, each unitary component being characterized by a running period of the model of the behaviour that it incorporates; and simulating an evolution over time of the model of the railway system from an initial state, by running the behaviour model of each unitary component with a periodicity corresponding to the running period that characterizes it, using current values of the input parameters to calculate updated values of the output parameters.

The invention and its advantages will be better understood upon reading the following detailed description of one particular embodiment, provided solely as an illustrative and non-limiting example, this description being done in reference to the appended drawings, in which:

[Fig 1] figure 1 is a schematic block illustration of a computer platform as simulation device able to perform the simulation method according to the invention; and

[Fig 2] figure 2 is a functional illustration of a model in unitary components of the complete railway system to be simulated, this model being used by the simulation device of figure 1.

Figure 1 is a schematic illustration of a computer platform 100, also called "simulation device" hereinafter.

The latter includes computing means 101 and storage means 102.

5 The storage means in particular store computer program instructions, which are able to be run by the computing means to implement said programs.

Among these programs, there is a simulation software application 120, the running of which makes it possible to implement the simulation method according to the invention for the behaviour of a complete railway system.

10 This railway system is for example a railway network for urban trains, made up of a plurality of lines and a plurality of trains traveling on these lines.

The simulation software application 120 is based on a model M of the railway system. This model M is stored in the storage means 102.

15 The model is based on a breakdown of the railway system into a plurality of functional blocks, also called elementary agents, an elementary agent corresponding to the smallest functional entity of the railway system.

The model M then associates, with each functional block/elementary agent, a unitary component C_i .

20 According to the invention, each agent is described through a set of deterministic behaviours, a behaviour being triggered by identified inputs and producing identified outputs. The unitary component C_i associated with a functional block/elementary agent incorporates a model reflecting the deterministic behaviours/operation of the corresponding block/agent, this model including input parameters E_i and output parameters S_i . The output parameters therefore represent the effect of the input parameters on the operation/behaviour of the unitary component, that is to say, of the
25 corresponding block/agent.

Each model for example comprises a plurality of programming software instructions able, when they are run by the computing means 101, to be determined as a function of the corresponding input parameters, output parameters.

30 The outputs of certain unitary components are exposed to all of the unitary components. Some of these outputs constitute inputs of other unitary components of the model of the railway system whose behaviour is sensitive to the properties in question.

Additionally, the unitary components can have several behavioural laws representative of the operating cycles of the railway system or of the laws of evolution of the environment of the railway system.

35 In a manner known in itself, the railway system comprises a network of railroad tracks, at least one power supply device, at least one railway vehicle, at least one traffic

regulating unit, at least one signalling device and at least one control member of the railway vehicle(s).

As shown in figure 2, the model M of the complete railway system for example includes:

- an infrastructure unitary component C1 describing the network: the topology of each line; the current position and state of each switch; the local gradient; the position of each station and depots; etc.

- a model unitary component of the power supply device C2 in particular modelling: the type ("reversible" or not) of each supply substation; the presence of energy storage means; the injection and return points of the current along the tracks; the electrical characteristics of the components; etc.

- a railway unitary vehicle component C3 describing the configuration of the railway vehicle: number of cars; weight; auxiliary systems (air conditioning of the cars, lighting, etc.; electricity consumption/generating model on board the train; an energy model of the traction system; an energy consumption model of the auxiliary devices on board the train; etc.

- a railway vehicle unitary kinematic component C4 [describing] the dynamic behaviour of the railway vehicle: acceleration in traction and breaking; speed; etc.

- a unitary traffic regulating component C5 describing: the regulating mechanisms for managing the traffic of the trains on the modelled network (along the tracks and depots); the timetables; etc.

- a signalling unitary component C6 describing: the signalling device of the network and its operating dynamic for the use of the network; the speed limits; the switch protection constraints; etc.

- a control unitary component C7 of the trains describing: the ATP/ATS systems implemented; the generation of movement authorizations for the trains; etc.

- an environment unitary component C8 describing outside parameters affecting the railway system, that is to say, outside parameters relative to an environment in which the railway system evolves: outside air temperature; desired temperature inside a car; number of passengers; etc.

It should be emphasized that a system can in turn be broken down into subsystems, and that as a result, many models are conceivable as a function of the breakdown level of a system of the railway system and models implemented by each elementary component.

The simulation device 100 includes a publishing unit 122 for publishing the model M, such as a man-machine interface, to allow an operator to build such a holistic depiction

of the entire railway network, including all of the interconnected systems and subsystems that make it a complex system.

The simulation software application 120 includes an engine 124, preferably of the holistic type, making it possible to cause the state of the railway system depicted by the model to evolve. The engine 124 is able to be run by the computing means 101.

To that end, the simulation is based on time scales. Each unitary component C_i is associated with a life cycle, which is defined by the data for a running period.

The running period is a unitary component, and in particular of the model that it incorporates, is a multiple of a minimum period.

When the engine 124 is run by the computing means 101, each unitary component, and in particular the model that it incorporates, is run periodically according to the value of the running period associated with it.

Thus, the unitary components having a reduced running period are run more often than the components having a high running period. The output parameters of a unitary component having a short life cycle will therefore be refreshed more often than those of a unitary component having a long life cycle.

Thus for example, a life cycle of 100 ms is assigned to the training kinematic unitary component, of 1 s to the rolling stock unitary component in particular describing the energy behaviour of a train, and of 3600 s to the environment unitary component relative to the heat balances.

When it is run, the engine 124, which is associated with an import module 125, loads, via said module, the model M as well as an initial state file E_i .

The engine 124 begins by initializing the state of the model M . The initialization data are read in the initial state file E_i .

Then, when the engine 124 is run by the computing means, the simulated railway system evolves, at the rhythm of its life cycle, each unitary component reacting to the evolution of its input parameters caused by the rest of the model, outside the considered unitary component. In other words, the computation of the output parameters of each unitary component at a specific instant is obtained from a known state at that instant of the complete railway system.

After a certain running time of the engine 124, equivalent to an operating time of the railway system, the engine 124 produces a final state file E_f and a results file R , corresponding to properties of interest evaluated during the running of the simulation. These files are stored in the storage means 102 via the module 125.

In particular, the results file R includes an estimate of the energy consumption of the railway system and/or properties relative to the working of the railway system.

The energy consumption is for example obtained from an output parameter of the unitary component of the power supply device.

The simulation software application 120 includes an interpretation unit 126 for interpreting the results file R able to be run by the computing means 101.

5 One skilled in the art will note that the invention consists of a virtualization of the operation of an entire railway system using a multi-agent/multi-time scale technology, which makes it possible to determine a state of the system after a running duration with a manageable effort and running time.

10 With such an approach, it is in particular not necessary to know the effect of a downgraded mode to be able to model it.

CLAIMS

1. A device for simulating (100) a railway system, characterised in that the device includes:

5 - a memorisation member (102) for storing a model (M) of the railway system, said model comprising a plurality of unitary components (C1 to C8) resulting from a breakdown into functional blocks of the railway system to be simulated, each unitary component incorporating a model of the behaviour of the associated functional block, having input parameters (E1 to E8) and delivering output parameters (S1 to S8), the output parameters
10 of at least one unitary component being able to make up input parameters of another unitary component, each unitary component being characterised by a running period (p1 to p8) of the behaviour model that it incorporates; and

- a computing member (101), able to simulate an time evolution of the model (M) of the railway system from an initial state, by running the behaviour model incorporated into
15 each unitary component with a periodicity corresponding to the running period that characterises it, using current values of the input parameters to calculate updated values of the output parameters;

wherein the railway system comprises a network of railroad tracks, at least one power supply device, at least one railway vehicle, at least one traffic regulating unit, at least one
20 signalling device and at least one control member of the or each railway vehicle, the model (M) including the following unitary components:

- an infrastructure unitary component modelling the power supply device and able to determine each running period of electrical properties of the network in particular from position and electrical power values called by each railway vehicle; and

25 - a railway vehicle unitary component modelling the configuration of the railway vehicle and/or a kinematic railway vehicle unitary component modelling the dynamical behaviour of the railway vehicle and/or a control unitary component of the or each railway vehicle; and

30 - a signalling unitary component able to model the security devices of the railway system relative to the travel and switching of each railway vehicle; and

- a traffic regulation unitary component able to model the algorithms used by railway supervision systems to manage delays and the movement of each railway vehicle; and advantageously

35 - an environment unitary component describing outside parameters affecting the railway system.

2. The device according to claim 1, wherein the running period associated with each component is a multiple of a minimum reference period.

3. The device according to any one of the preceding claims, wherein the computing member is able to run an import module (125) capable of configuring the initial state of the model by loading an initial state file (Ei) from the memorisation member, the initial state preferably comprising values of the input parameters for each unitary component.

4. The device according to any one of the preceding claims, wherein the computing member is configured to evaluate operating properties of the railway system simulated, from values of the output parameters.

5. The device according to any one of the preceding claims, wherein the computing member is configured to evaluate an energy consumption of the railway system simulated, from values of the output parameters.

6. The device according to any one of the preceding claims, wherein the device includes a publishing unit (122) allowing an operator to define the model.

7. The device according to any one of the preceding claims, wherein the device includes a unit (126) for interpreting a results file (R) generated by the computing member (101) at the end of the simulation.

8. The device according to any one of the preceding claims, wherein the computing member is able to run an engine of the holistic type to simulate the evolution over time of the model.

9. A simulation method carried out by a simulation device according to any one of the preceding claims, characterized in that said method includes the following steps:

- storing a model (M) of the railway system, said model associating a unitary component (C1 to C8) with each agent resulting from a functional breakdown of the railway system to be simulated, each unitary component incorporating a model of the behaviour of the associated agent, having input parameters (E1 to E8) and delivering output parameters (S1 to S8), the output parameters of at least one unitary component

being able to make up input parameters of another unitary component, each unitary component being characterized by a running period (p1 to p8) of the behaviour model that it incorporates; and

- 5 - simulating an evolution over time of the model (M) of the railway system from an initial state, by running the behaviour model of each unitary component with a periodicity corresponding to the running period that characterises it, using current values of the input parameters to calculate updated values of the output parameters.