KICKER: A DECISION SUPPORT TOOL FOR MULTI-MODAL TRAFFIC BASED ON MULTI-AGENT SYSTEMS

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Abstract: KICKER is a joint project between the Information Systems Division of Italian Railways (FS S.p.A.) and the Computer Science Department at the University of Genova, Italy. It is based on the results of the EuROPE-TRIS project (Guida, 1998) and its aim is to realize a decision support system to be used by train control co-ordinators, working along European lines, in the management of freight trains traffic towards multi-modal centres of shipment.
The realization of KICKER is carried out using CaseLP, a prototyping environment for software applications modelled as Multi-Agent Systems. CaseLP combines well established prototyping techniques, based on traditional software engineering approaches with the innovative paradigm of Multi-Agent Systems, that suits very well the realization of distributed, dynamic and heterogeneous software applications.
The paper outlines the KICKER project, presents the principal features of CaseLP and summarizes the results that have been obtained till now.

Keywords: Agents, Decision support systems, Prototyping, Traffic control

1. INTRODUCTION

Freight traffic is becoming a key factor of development for both social and economical reasons. In particular, the creation of an European global freight market forces railway companies to direct their efforts towards an efficient and co-operative management of freight train traffic, mainly in a multi-modal perspective. Thus, automatic tools for freight traffic optimization are playing a growing role, in order to support human operators with decisions which are becoming more and more time constrained.

Such kind of systems have to incorporate very sophisticated technologies, in order to provide a wide range of operative solutions. One of these technologies is certainly *Multi-Agent Systems* (MASs) (Jennings *et al.*, 1998). A MAS is a distributed system whose components can act autonomously, are able to react to external stimuli, can take the initiative to reach their goals and can communicate with other components in order to exchange knowledge useful to accomplish their tasks.

The adoption of a multi-agent approach on the domain of freight trains traffic management gives several advantages:

- MASs allow a decompositional approach to software development that optimally suits the inherent distribution of the domain, in which several modules and entities exist and have to exchange information and to be co-ordinated.

- The decision support is given in a highly dynamic environment, under a high degree of information incompleteness and uncertainty. The adoption of MASs help in developing entities which perceive the environment and react to the changes occurring in it, also dealing with incomplete information.
- The agents in a MAS are autonomous, so their behaviour is mainly independent from the behaviour of other agents. For example, modifying the way an agent manages an incoming message has no impact on the description of the behaviour of other agents.
- One of the main features of MAS is to provide interfaces towards legacy software, allowing its integration and reuse, taking advantage of the best features of existing application.

CaseLP is a logic programming-based prototyping environment for software applications modelled ad MASs. KICKER aims to apply CaseLP to the complex domain of multi-modal transportation of goods, in particular to the management of freight trains traffic.

The rest of the paper is organized as follows. Section 2 gives an overview of the KICKER project focusing on its background, current status of realization and work in progress. Section 3 outlines the prototyping method and tools that are included in CaseLP. Section 4 concerns some final considerations about the project.

2. THE KICKER PROJECT

KICKER (*Keep Informed Controller Knowledge on Events about Railways*) is a project that aims to realize a tool that gives decisional support to European co-ordinators of train movement, especially in the management of freight traffic. These traffic operators are mainly responsible for train dispatching and scheduling of freight transports. KICKER takes into particular account decisions about short-term train scheduling, that consists in dynamic creation and dispatching of unscheduled trains along railway lines.

2.1 *The EuROPE-TRIS project*

KICKER originates from the EuROPE-TRIS project (Guida, 1998), funded by the European Commission within the 4th EU-RDT programme. EuROPE-TRIS is a telematics-oriented project composed by three sub-systems.

- The module TCM (Traffic Capacity Management) provides telematic tools that, according to EU Directives, support procedures for accessing railway infrastructures. Procedures rule the interactions between railway companies and track providers.
- The module TTC (Timetable TeleConference) provides a telematic environment that allows rail planners in different countries or national sites to reach agreements on validation of train timetables, without organizing traditional physical timetable meetings.
- The module F-TTM (Freight-Timetable Tele-Marketing) improves the activity of contingent planning, namely short-term train scheduling. It also provides functionalities like communication among transport companies and data exchange, agreements and co-operative decision making between transborder traffic co-ordinators.

In particular, the F-TTM sub-system provides a set of demonstration tools, presented below.

TRAIN: Train Real-time Automatic Information. This tool helps traffic operators in updating the status of train circulation in case that contingent dispatching decisions (e.g., fitting special or delayed trains with the scheduled ones) have to take place.

REMUS: Rail Electronic Mailer Unified System. This tool provides a guide schema to compose multi-lingual structured messages to be exchanged between transborder co-ordinators, working for different national railway companies.

VIDES: VIdeo-conferencing Dispatcher Electronic Set. This tool upgrades the functions provided by REMUS with multi-media teleconferencing. It allows sharing of documents that can be co-operatively read and eventually modified by traffic operators. It also provides interactive messaging and ultimately is able to subsume the facilities of the electronic mailing system.

ITHACA: Inter-modal Train Haulage As Cargo Arrives. This tool provides a telematic infrastructure to connect traffic operators, placed at inter-modal centres and yards, to traffic co-ordinator offices. This infrastructure facilitates the demand and reservation of new trains, and the management of the authorization for wagons to be loaded.

MIDAS: MIning DAta Server. This tool provides a link between the traditional rolling stock management information systems (legacy architecture) and open, user friendly, interfaces. It also completes the knowledge of co-ordinators about yard capacity status and incoming flow of freight trains, in order to facilitate dispatching decisions.

ODOS: Operational Dispatching On-line Scheduler. This tool provides a graphical workstation to support the co-ordinators in making decisions about new transport requests or re-dispatching of delayed trains, in particular at country-borders.

2.2 *Operative scenario*

The tools included in F-TTM provide traffic operators with several functionalities but they are stand alone applications and thus they are not able to really support operators' decisions. KICKER overcomes this limit and realizes a full integration among F-TTM sub-modules, providing an unique decisional framework.

As a case study, the railway line connecting Bern (Switzerland) to La Spezia (Italy) represents a suitable environment where to demonstrate KICKER features, because of its key role in multimodal traffic from inside Europe to Mediterranean destinations. The line (see Figure 1) is divided into *sections*, each co-ordinated by a different operator and delimited by *nodes*, which represents the entry points of freight trains from inside freight *terminals*. The node of Chiasso corresponds to the border between Switzerland and Italy, where trains coming from abroad access the Italian network and begin to be subjected to Italian regulations.

Figure 2 sketches the general structure of the prototype of KICKER currently under development. A terminal operator can submit to KICKER the three kinds of requests described below. In the picture, solid lines represent the flow of information among KICKER components corresponding to a request of a new train. Dashed and dotted lines corresponds instead to requests of loading authorization and dispatching authorization. In order to manage these requests, some components are assumed to have slightly different functionalities with respect to the F-TTM modules previously described.

New Train. Terminals submit to KICKER the request for a not scheduled train, (i.e. a train not programmed within the static timetable). The request may be *accepted*, *refused* or *accepted with variations* by the system. In the latter case, the terminal operator can *accept* or *refuse* the counterproposal.

Terminal operators request a new transport via ITHACA, supplying all the necessary information, such as destination, technical features (typology of goods, weight, etc..), or departure and arrival time constraints. ITHACA interacts with ODOS, that acquires from the static timetable necessary information about programmed trains. MIDAS is active part of the decision process, especially in case of special goods typologies, such as dangerous goods, for which railway stations may have special constraints. The retrieval of human and traction resources for the requested transport, performed by the responsible Transport Operator via ITHACA, is necessary in order to the request is accepted. Decision processes result in customized messages forwarded via REMUS to all the involved operators.

Loading Authorization. Freight traffic regulations require terminals to obtain an authorization for the loading of wagons directed to yards connected with harbours (e.g. La Spezia). This authorization can be *accepted* or *refused* by KICKER. The procedure of loading authorization is required before train dispatching and permits a careful management of destination yards, in order to optimize the wagons flow towards harbour terminals.

Authorization requests are collected by ITHACA, which replies to requesting terminals on the basis of the information retrieved by MIDAS on capacity status of the destination yard.

Dispatching Authorization. This function decides about the dispatching of scheduled or unscheduled trains along the railway line. Dispatching can be *accepted*, or *refused* by KICKER.

A request of this kind is submitted to ODOS and can be accepted or refused according to the dynamic status of trains running along the railway line. This information is collected from TRAIN and permits to maintain an updated index of line congestion (number of trains per kilometer) which is the crucial parameter in order to accept or refuse a train dispatching request. MIDAS provides instead information about the capacity status and incoming freight flows of nodes along the train route.

2.3 *Status of implementation and work in progress*

The implementation of KICKER is currently in progress. At the moment a simplified prototype that includes ODOS and ITHACA has been successfully modelled. This first prototype concerns the railway line between the Italian stations of Milano and La Spezia and do not deal about problems that concerns international traffic and co-ordination between operators of different countries. The implementation of the prototype has been illustrated in (Cuppari *et al.*, 1999).

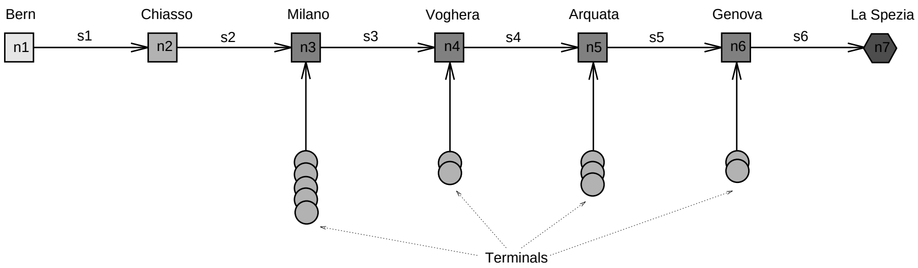

Fig. 1. Railway line between Bern and La Spezia.

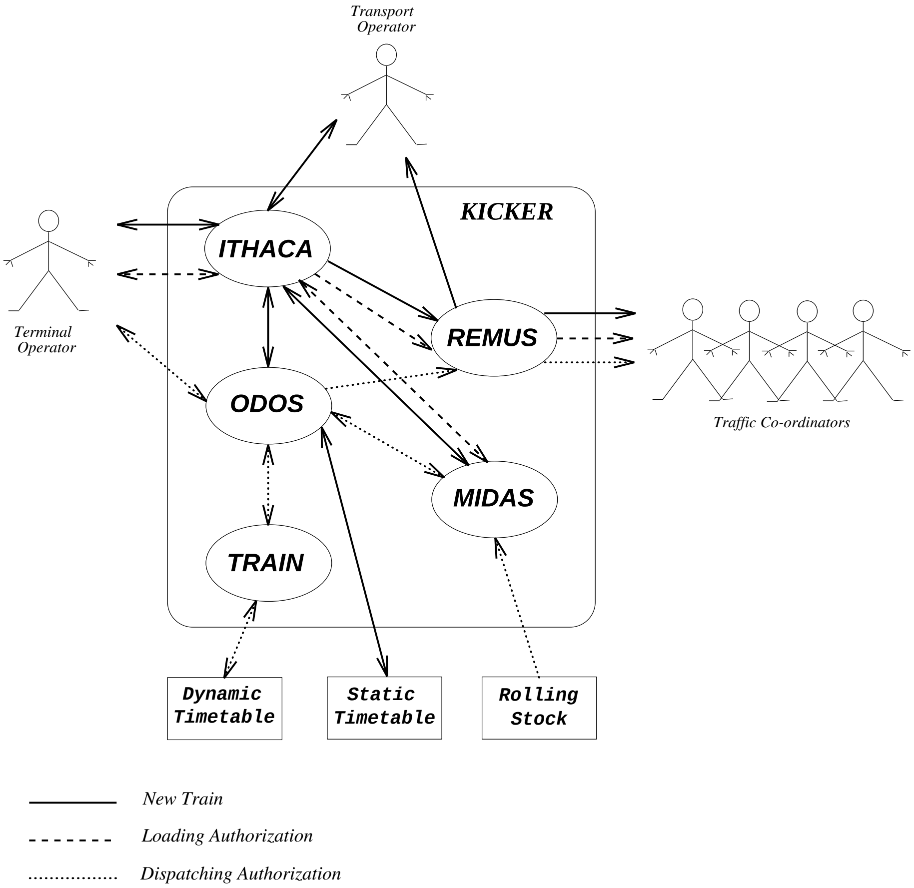

Fig. 2. KICKER.

Current work concerns extending the MAS implementation of KICKER integrating the other F-TTM modules shown in Figure 2. More precisely, new versions of KICKER will include the TRAIN module, that supplies real time information about the status of train circulation along the considered line and the MIDAS module that provides the system with information about yard capacity status and incoming freight flows, in order to facilitate dispatching decisions. Moreover, the prototype will use the communication module (REMUS), in order to provide traffic operators with information about the process of decision making. The other communication module (VIDES) will be integrated in the near future.

3. THE PROTOTYPING ENVIRONMENT

The realization of KICKER is carried out using CaseLP (*Complex Applications Specification Environment based on Logic Programming*), an environment for rapid prototyping of agent-based software (Martelli *et al.*, 1998) (Martelli *et al.*, 1999). CaseLP provides an iterative method for specification, implementation, execution and testing of MAS-based prototypes, and a set of tools that are used to develop the prototype. The method allows to build the prototype following a sequence of clear steps, progressively refining it against the initial or subsequent requirements.

In CaseLP agents have different kinds that diversify their role in the MAS. For instance, *logical agents* provide control and coordination among MAS components thanks to their complex reasoning capabilities, whereas *interface agents* provide interface between external modules and the agents in the MAS. CaseLP agents are characterized by a purely reactive, purely proactive or hybrid architecture. Agents of different kinds and with different architectures may coexist in the same MAS, thus allowing a great flexibility in the prototype definition.

All the agents share some main components: an updatable set of *beliefs* defining the agent's *state*, a *mail-box* for incoming messages and a fixed set of rules that defines the *behaviour*. Reactive interface agents embed an *interpreter* for accessing external software. Agents communicate via point-to-point asynchronous message passing.

The realization of a MAS prototype is driven by a method composed by 6 steps, in which the architecture of the needed prototype is first described in terms of classes and instances of agents, the services that they provide and the communication links among them. Subsequently, each agent is given a behaviour that express the way it provides its services and semi-automatic tools are used to obtain a working prototype implemented into the target logic programming language. The developer has at his/her disposal a set of languages and tools to execute the various steps of the method. For example, the architectural description of the system is given using MAS-adl (a customized architectural description language for MAS) and agents' behaviour can be specified using ACLPL (a rule based logical language).

In addition to the advantages of MAS technology presented in Section 1, the choice of CaseLP as prototyping tool gives another advantage, the execution and simulation of the specification. CaseLP allows to model the application in a quite easy way. Once the prototype has been specified, its its behaviour can be simulated. Therefore, increasingly wider scenarios can be simulated and tested by means of CaseLP.

CaseLP has been profitably used to develop prototypes in variegated areas. For example, an application was related to a problem of transport and logistics and involved the planning of goods transportation in a European context. It has been realized in co-operation with Elsag S.p.A., an international company which provides service automation. Another application concerned the retrieval of medical information contained in distributed databases. In this case CaseLP has been successfully adopted for a reverse engineering process. Finally, the combination of agent-oriented and constraint logic programming techniques have been applied to the management of distributed database transactions.

4. CONCLUSIONS

Automation of decisional processes in the management of freight trains traffic is an urgent priority that railway companies have to face. Technology based on Multi-Agent Systems is a good candidate for dealing with the inherent distribution and heterogeneity of this application domain. The KICKER project is an application oriented contribution to a very interesting and important field. It has two main goals. On one hand it aims to demonstrate that agent-based technology can be successfully applied to real-world non trivial problems. On the other hand, the application of CaseLP to this problem can be an extremely useful feedback to be exploited for enhancing the CaseLP design choices.

5. REFERENCES

Cuppari, A., P.L. Guida, M. Martelli, V. Mascardi and F. Zini (1999). Prototyping Freight Trains Traffic Management Using Multi-Agent Systems. In: *Proc. of IEEE International Conference on Information, Intelligence and Systems.* IEEE. Washington, DC.

Guida, P.L. (1998). EuROPE–TRIS Project. 4th European Union RDT Program Telematics Applications Programme. Transport (Rail) Contract DGXIII - TR 1022 (TR), Specifications and System Design, Deliverable D04.2. Web page: http://www.srd.it/TRISprj.

Jennings, N.R., K. Sycara and M. Wooldridge (1998). A Roadmap of Agent Research and Development. *Autonomopus Agents and Multi-Agent Systems* **1**, 7–38.

Martelli, M., V. Mascardi and F. Zini (1998). Towards Multi-Agent Software Prototyping. In: *Proc. of The Third International Conference and Exhibition on The Practical Application of Intelligent Agents and Multi-Agent Technology (PAAM'98)* (H.S. Nwana and D.T. Ndumu, Eds.). London, UK. pp. 331–354.

Martelli, M., V. Mascardi and F. Zini (1999). Specification and Simulation of Multi-Agent Systems in CaseLP. In: *Proc. of Appia–Gulp–Prode 1999: Joint Conference on Declarative Programming* (M.C. Meo and M. Vilares-Ferro, Eds.). L'Aquila, Italy. pp. 13–28.