A multi-agent model for the estimation of passenger waiting time in public transportation networks

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Abstract

Several efforts have been focused on the improvement of new services of an urban transport network in order to face the increasing of the demand. In this paper, we present a methodology based on a meta-model to design and simulate multi-agent systems. This methodology allows to build a multi-agent model of public transport network in order to estimate the passenger waiting time at connection stops. This will provide the basis for minimization of the waiting time when transferring between buses.

Keywords : Transportation system, Multi-agent, Agent-oriented methodology, Design patterns and components, UML.

1 Introduction

Due to different factors such as the congestion of urban roads caused by a constant increase of the number of cars in many cities, public urban transport has become an indispensable transportation mode. This justifies the need of efficient methods for designing an attractive public transportation services. One of the most important quality of service requirements is to minimize the waiting time in line connections. A principal step towards the achievement of this goal consists of evaluating the performance of transportation networks.

We use the agent technology to describe the behaviors of different entities that constitute the transport network. We choose this approach for two reasons. In first, an urban transport network is distributed over a large geographical area. It is composed of autonomous entities which can be well modelled by the agent paradigm. The second reason for our choice of agent technology is that the global system behavior is composed of several emergent phenomena that result from the behavior of the physical entities and their interactions. In fact, the multi-agent approach leads to the description of the global behavior by message exchanges based on the local interactions between agents.

The multi-agent approach has already been used in the transportation domain [7,8]. Some works use agent technology for the transportation planning [11]. Indeed, the agent paradigm helps to design the microscopic models and to predict the behavior of the individual elements of the transportation infrastructure such as, traveller, traffic light, intersection. Other projects aim to simulate the traffic flow [2] or to schedule some activities in the transportation domain [6].

This paper deals with an agent based modelling approach aimed to estimate the waiting time at connection stops. Several approaches have been proposed to study the problem of transferring passengers. For example, stochastic Petri nets have been used in [1] to evaluate the waiting time which is represented by a random variable with exponential distribution. However, this distribution function does not allow to specify all timing events which can occur from the environment. In this paper, we take into account the following considerations which are more realistic :

- the passengers arrivals at stops are exponentially distributed over time;
- the movement of a vehicle over links is normally distributed over time;

- the passengers leave the bus randomly at any bus stop.

The rest of this paper is organized as follows. Section 2 introduces the RIO (i.e. Role, Interaction, Organization) approach and their main concepts. Section 3 presents the use of RIO approach to design a model for evaluating the waiting time at connection stop and gives some elements of the implementation. Conclusion is given in section 4.

2 The RIO approach

In this section, we explain how an organizational model can be used to design Multi-Agents System (MAS) and we present the main concepts of the RIO approach.

2.1 Organizational concepts

The RIO approach introduces three interrelated concepts : role, interaction and organization [5]. Roles are generic behaviors that can interact mutually according to interaction patterns. An organization groups the roles and their interactions. Organizations are thus the descriptions of coordination structures. The coordination occurs between roles when the interactions take place.

In this context, an agent is only specified as an active communicative entity which plays roles. In fact, the agents instantiate an organization (roles and interactions) when they exhibit the behaviors defined by the organization's roles and when they interact following the organization interactions. An agent may instantiate one or more roles and a role may be instantiated by one or more agents. The playing relationship between roles and agents is dynamic.

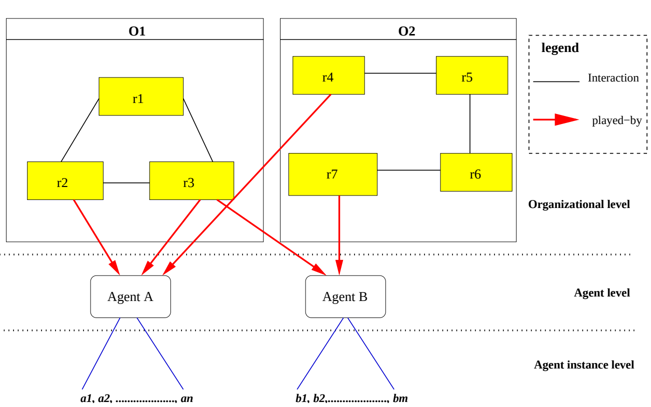

Figure 1. RIO Meta-model

The behavior of a MAS is the result of role playing by agents. Figure 1 gives a graphical representation of the RIO concepts. A box represents an organization that encloses a set of boxes representing its roles. An interaction is materialized by a line connecting two roles.

2.2 Methodology description

In the RIO approach, the system is modelled according to three layers [4]:

- The organizational level contains a set of organizations and roles. Each organization results from distributing some behaviors according to different perspectives.

- The agent level contains a set of agent models which may instantiate a set of roles within each organization. Each agent is specified as an active communicating entity which plays one or more roles. In fact, the agents instantiate an organization when they exhibit behaviors defined by the organization's roles and when they interact following the organization interactions.

- The agent instance level is defined by a set of agents instantiated from agent models.

The next section presents a RIO model which is intended to simulate a bus transportation network in order to evaluate the waiting time at connection stops.

3 Modelling the public transport network

3.1 RIO model

Based on the approach described above, we introduce two organizations. Each organization is composed of a set of generic roles and their interactions as shown in figure 2. The line organization handles the traffic simulation within normal conditions. Four roles are assembled in this organization : *Bus*, *Link*, *Bus stop* and *Clock*. The *Bus* role represents the abstract behavior of any bus that moves along a line of the network. The *Link* role represents a connection between two stations. Eventually, the *Bus stop* role defines what happen in stops. The environmental role *Clock* measures the simulation time and the duration of any action that can be performed by an active agent.

The second organization deals with the point of view of transporting passengers from one location to another. Three roles are assembled in connection organization :

the *interchange station* role is a set of actions assigned to bus stop that permits a passenger to transit from one bus to another. The *inbound bus* role implements a bus behavior that transports passengers towards the connection stop. The *outbound bus* role implements the same behavior as the *inbound bus* role but the direction of the transportation is taken from the connection stop to an other stop.

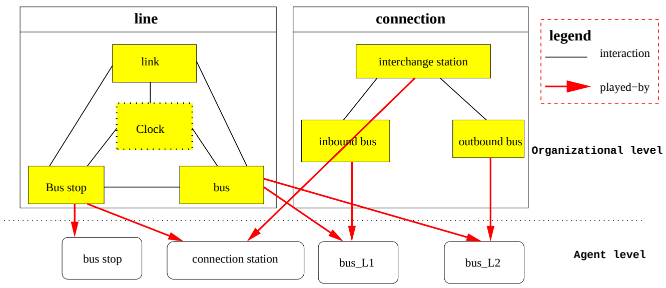

Figure 2. Modelling the autonomous agents of public transport network

In the agent level, four agents play the previous roles. The **bus stop** agent plays the *Bus stop* role (figure 2). While the **connection station**, **bus_L1** and **bus_L2** agents play two roles in different organizations. The **bus_L2** agent plays the *bus* role from the line organization and also plays the *outbound bus* role from the connection organization. Both of these roles are combined together to form the sequence of roles that can be played by **bus_L2** agent. We model the generic roles by black boxes and the agents that play these roles by white boxes. With this approach, we take advantage of reusing the role models. Additionally, we can define a complex behavior from simple role models.

In the next section, we introduce some interaction patterns which are defined in the organizational level.

3.2 Interaction protocol

The interaction between two roles in the organizational model is refined as an interaction pattern between agents. When the agents instantiate an organization, they exhibit the behaviors defined by this organization and they interact with other agents following the interaction patterns. Figure 3 shows a simple interaction scenario between bus agent and other agents. We used Agent Unified Modelling Language (AUML)[10] to model this interaction. AUML is an extension of UML by a graphical notation to model the interaction protocols between agents. The sequence diagram is used to model the sequence of messages that can be exchanged by the agents. Each message is represented by an arrow between the lifelines of two agents. The order in which these messages occur is shown top to bottom on the diagram.

An agent may send a message to an agent (or group of agents) to inform or to request about it's desired requirements. The interaction between agents can trigger the activation of several receiver methods. Different agents may execute their actions in parallel. We can note that the almost of agents which constitute the transport network are pro-active. They act in response to their environment and they are able to exhibit goal-directed behavior by taking the initiative.

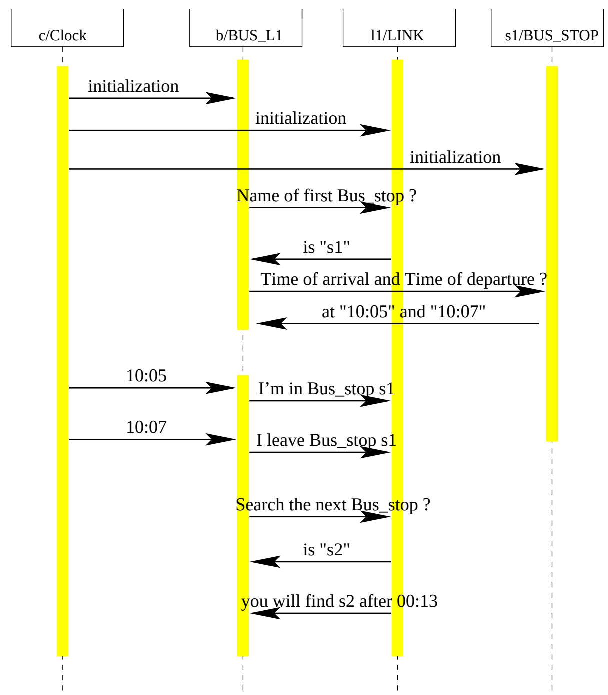

Figure 3. scenario of interaction between agents

3.3 Implementation

In figure 4, we show a screen-shot of a typical simulation run. The graphic window plots two lines of transport network and their bus stops. The continuous movement of all bus and their arrival time is listed in textual format on the bottom of the screen. Some simulation parameters can be modified by placing them in a numeric entry box at the right of the screen. This simulator has several functionalities. We can obtain either the detailed statistics of the network components and we can see the movement of buses in graphical window.

The simulator has been implemented using the Mad-

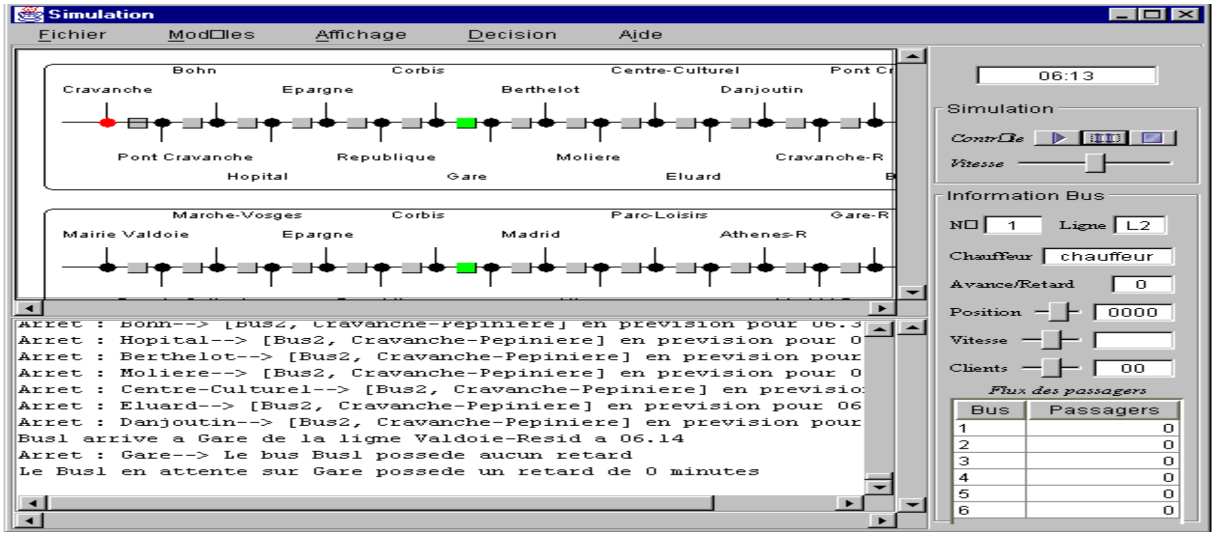

Figure 4. Screen of simulation

Kit tool. MadKit [3,9] is a Java multi-agent platform built upon an organizational model. It provides agent facilities such as lifecycle management, message passing and allows high heterogeneity in agent architectures. Using this tool, the estimation obtained by simulating the bus network with two lines, connected by a single connection is depicted in figure 5. In this simulation, the variation of the passenger waiting time can dramatically change when the outbound bus frequency vary. We can deduce from this figure that to reduce the waiting time at connection stop, we must increment the frequency of the outbound bus. This information may help the transport enterprise to evaluate the quality of transport services.

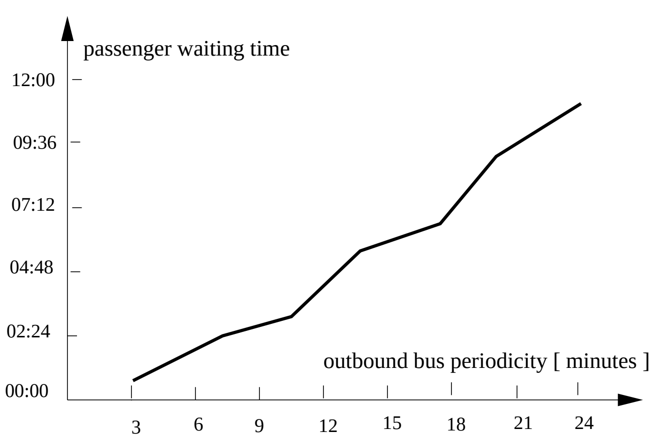

Figure 5. statistics of passenger waiting time at connection stop

4 Conclusion

In this paper, we have presented a methodology for designing a multi-agent system intended to simulate the transfer of passengers between buses. It constitutes the first step toward the modelling and simulation of public transport networks.

The multi-agent approach seems to be well suited for this study. The simulation shows the impact of some parameters assumed to play an important role in public transportation networks. Actually, we plan to extend the model presented in this paper in order to simulate a real public transport network and to reuse it for an intermodal transportation network.

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