APPLICATION OF MULTIAGENT SYSTEMS IN TRANSPORTATION

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Summary: The paper provides a short survey of research on agent-based approaches to transportation. The authors present the problem domain of multi-agent systems and show the connection with the decision support systems (DSS) and distributed artificial intelligence (DAI). A general conclusion of this study is that agent-based systems are very suitable for transportation domain. Last chapter presents the conception of framework for agent-based traveler assistance decision support system based on European ITS Framework Architecture – FRAME. The general purpose of this framework is to create basis for interoperable real-time traveler information systems that are flexible and scalable in terms of adding new agents.

Keywords: traveller decision support systems, multiagent systems, distributed artificial intelligence

1. INTRODUCTION

An excellent transport system is vital for a high quality of life, making places accessible and bringing people and goods together. Information and Communication Technologies (ICT) helps to achieve this high level objectives by enhancing Transportation systems with intelligent solutions providing more reliable transportation services such as traffic management or traveler information services. Such smart transport solutions are already applied across the European Union – but in fragmented manner, geographically and technologically isolated domains, due to the lack of standards and framework architecture.

According to the statistics provided by The Office of Rail Transportation quality indicators of the passenger railway transport is still far below satisfactory level. The levels of punctuality (delay more than 5 minutes) differs from the carriers and for the fourth quarter is equal to: 80,44% (PKP Intercity), 89,76% (Przewozy Regionalne), 87,29% (Koleje Mazowieckie – KM). The mean time of delay is about 21-23 minutes depending on the quarter. This number shows that real-time information for travellers is the necessity.

This paper provides also a survey of existing research on agent-based approaches to transportation and presents the framework for development multiagent systems to traveler
assistance decision support system, based on European ITS Framework Architecture - FRAME.

2. FRAME ARCHITECTURE

European Framework ITS Architecture is the result from Framework Programmes funded by European Commission since 1998. For that time FRAME is continuously enhanced – with cooperative systems being added by the E-FRAME project (2008-11) [10]. FRAME Architecture covers 9 areas of ITS [3]. For each area the possible MAS application is presented in table 1.

<table>
<thead>
<tr>
<th>FRAME functional areas</th>
<th>MAS applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Electronic Fee Collection</td>
<td>Highway toll collection [11]</td>
</tr>
<tr>
<td>2 Emergency Notification and Response</td>
<td>Simulation of disaster response [12], coordination ambulances for medical services [13]</td>
</tr>
<tr>
<td>3 Traffic Management</td>
<td>Information for drivers about traffic situations, decision support system, reduction of traffic congestion, network demand simulations [2], [7]</td>
</tr>
<tr>
<td>4 Public Transport Management</td>
<td>Transportation management [8], simulation and evaluation of urban bus networks [9]</td>
</tr>
<tr>
<td>5 In-Vehicle Systems</td>
<td>Connected autonomous vehicles (capacity increase of 243%) [3]</td>
</tr>
<tr>
<td>6 Traveler Assistance</td>
<td>Multimodal trip planner [7]</td>
</tr>
<tr>
<td>7 Law Enforcement</td>
<td>Vehicle detection, automated number plate recognition [14]</td>
</tr>
<tr>
<td>8 Freight and Fleet Management</td>
<td>Logistics, dynamic multi-vehicle pickup and delivery problem [7]</td>
</tr>
<tr>
<td>9 Support For Cooperative Systems</td>
<td>Collective driving [7]</td>
</tr>
</tbody>
</table>

FRAME architecture can be modeled the same way as systems in system theory or systems engineering. The inputs are the stakeholder aspirations and the output is the result of the FRAME transformation process [18].
Inputs are a structure consisting of a set of Stakeholder Aspirations \(Sa=\{x_1, x_2, \ldots, x_n\}\). Outputs are a collection of results from FRAME Architecture \(Rs=\{S_b, D_p, O_i, C_s, C_r, C_{Ba}, R_a\}\), where: \(S_b\) – System boundary, \(D_p\) – Deployment programme, \(O_i\) – Organisational issues, \(C_s\) – Component specification, \(C_r\) – Communication requirements, \(C_{Ba}\) - Cost/Benefit analysis, \(R_a\) – Risk analysis.

Inside the FRAME Architecture key role plays Data Flow Diagrams which are a graphical representation of the "flow" of data through an Intelligent Transportation Systems. These diagrams consists of functions, dataflows, datastores and terminators/actors, creates a model of almost all ITS services within road transport area.

FRAME Architecture is intended to use within the European Union, that’s why consists only user needs, and functional viewpoint to not mandate any physical or organizational structures on its users. Within the scope of this paper FRAME is used as a tool for the first step for Traveler Assistance Decision Support Systems development. Within the physical viewpoint FRAME Architecture allows to multiply necessary functions which is very suitable for distributed systems. Those functions will play a role as an intelligent agents.

2. PROBLEM DOMAIN

The problem discussed here belongs to the fields of transportation, distributed artificial intelligence and decision support systems.

2.1. TRANSPORTATION

A transport is an activity where something is moved between the source and destination by one or several modes of transport. There are five basic modes of transportation: road, rail, air, water and pipeline [14]. Within the scope of this paper is the road transportation due to the big need of improvements in the field of traffic management, public transport management, traveler information, in-vehicle systems, and so on. Nowadays, transportation systems becoming much more complex. Real time data gathered from sensors such as inductive loops or ANPR cameras, humans and in-vehicle systems create the need for fast and reliable reaction to unpredicted events. Decisions need also be evaluated in terms of impact on the environment (i.e. traffic and travelers). That’s why the state-of-the art intelligent transportation services should encompass tools that support decision making on different levels.
2.2. DECISION SUPPORT SYSTEMS (DSS)

Everyone makes hundreds of decisions each day. These decisions range from the inconsequential to significant. “Good decision making” means we are informed and have relevant and appropriate information on which to base our choices among alternatives [4]. Decision Support Systems assist decision makers in semi-structured tasks, support rather than replace judgment, and improve the effectiveness of decision-makers rather than its efficiency. A DSS assumes that there is no single solution or answer to a problem, but allows users to bring their expertise to the solution of the problem [5].

2.3. DISTRIBUTED ARTIFICIAL INTELLIGENCE (DAI)

The modern approach to artificial intelligence is centered around the concept of an agent. An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives [6]. Distributed Artificial Intelligence is the study, construction, and application of multiagent systems (MAS). That is, systems in which several interacting, intelligent agents pursue some set of goals and perform some set of tasks [2]. The long term goal of DAI is to develop methods that allows agents to interact with each other or with humans as well as humans communicate (or even better). This goal raises a number of difficulties in terms of agents behavior and interaction between agents and humans. Multiagent Systems consists of a group of agents that can potentially interact with each other.

Agent architectures are the fundamental mechanisms underlying the autonomous components that support effective behaviour in real-world, dynamic and open environments. Thus agent architectures can be divided into four main groups: [1]

a) logic based architecture based on logic reasoning i.e. descriptions logic (ALC), distributed description logic (DDL) and default logic (introduced by Reiter) [16],

<table>
<thead>
<tr>
<th>constructor</th>
<th>first-order logic analogy</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A(x)</td>
<td>concept name</td>
</tr>
<tr>
<td>R</td>
<td>R(x, y)</td>
<td>role name</td>
</tr>
<tr>
<td>T</td>
<td>TRUE</td>
<td>top</td>
</tr>
<tr>
<td>⊥</td>
<td>FALSE</td>
<td>bottom</td>
</tr>
<tr>
<td>C ⊓ D</td>
<td>C(x) ∧ D(x)</td>
<td>conjunction</td>
</tr>
<tr>
<td>C ⊔ D</td>
<td>C(x) ∨ D(x)</td>
<td>disjunction</td>
</tr>
<tr>
<td>¬C</td>
<td>¬C(x)</td>
<td>complement*</td>
</tr>
<tr>
<td>∀R.C</td>
<td>∀y R(x, y) ⇒ C(y)</td>
<td>universal quantifier</td>
</tr>
<tr>
<td>∃R.C</td>
<td>∃y R(x, y) ∧ C(y)</td>
<td>existential quantifier</td>
</tr>
</tbody>
</table>

Fig. 2. ALC constructors
b) reactive architectures - do not include an internal symbolic world model of their environment and do not use complex symbolic reasoning processes. They gain their intelligence from interactions with their environment. The best-known reactive architecture is Brooks's subsumption architecture,

c) Belief, Desire, Intention (BDI) architectures – the most well-known BDI architectures is the Procedural Reasoning System (PRS) in which beliefs represents data (incomplete or incorrect), desires represents goals, and intentions represents current goals,

d) layered architectures – defines control horizontal and vertical data flows (one pass control or two pass control). One of the most well-known layered architectures is the Touring Machines.

Agents can take both the past and the future into account when choosing an actions. We can define function \( \pi \) that implements past observations \( \theta_t \) of an agent at time \( \tau \) and actions taken at time \( \tau \) to the new action \( a_t \), where \( \tau \leq t \) as \( \pi(\theta_0, a_0, \theta_1, a_1... \theta_t) = a_t \). If agents ignoring the past \( \pi(\theta_t) = a_t \). [17]

### 3. TRAVELER ASSISTANCE DECISION SUPPORT SYSTEM (TADSS)

This chapter presents the framework for agent based traveler assistance decision support system which aims to provide multimodal and interoperable search engine for public transport passengers. This engine will be based on metaheuristics algorithms and game theory with extensive games that allows agents to reconsider their plans during game.

#### 3.1. ARCHITECTURE

TADSS architecture is a hierarchical (master-slave). We can distinguish three types of agents:

a) Traveler agent – is responsible for receiving request for travel from traveler and sends the response back to the traveler. Traveler agent is a Human – Machine – Interface (HMI) between human entities and software agents. This agent allows to define trip planning criteria and stores the preferences of the user.

b) Coordinating agent – is responsible for coordinating the transportation agents, and suggests the optimal route or change of mode of transport for the traveler. Coordinating agent calculates and optimize the global goal based on the data from transportation agents. This agent will have a map of existing transportation agents.

c) Transportation agents - is responsible for getting information from the traffic management services and other traveler information systems to inform the coordinating agent about any adherence from normal situations.
Fig. 3. Graph based architecture for TADSS

The framework allows for tracking user wherever is within the network. This assumption requires real time information updates when situation changes. The experimental platform will be based on Java EE 6, Java SE 7 specification and Agent Object Programming (AOP) paradigm [1].

Fig. 4. FRAME Architecture area for Traveler Assistance DSS
4. CONCLUSION

This paper presented multi-agent approach to transportation problem solving. In particular FRAME architecture was used to map the DAI applications with the transportation functional areas. This study showed that optimization and coordination problems within FRAME functional areas could be solved using the agent-based approach.

The paper presented the conception of dynamic Traveler Assistance Decision Support Systems. TADSS is a hierarchical system with three types of agents which each type plays a different role with different optimization criterion. The one of the biggest benefit of approach presented in this paper is scalability and flexibility. Agent based approach is a natural method for development such systems with the possibility for adding new agents to the existing system and upgrading the necessary functionalities.

References

3. Tientrakool, P., Highway capacity benefits from using vehicle-to-vehicle communication and sensors for collision avoidance, Vehicular Technology Conference (VTC Fall), 2011 IEEE.
7. Klugl F., Bazzan A., Ossowski S., „Applications of Agent Technology in Traffic and Transportation
ZASTOSOWANIE SYSTEMÓW WIELOAGENTOWYCH W TRANSPORCIE

Streszczenie: Niniejszy referat przedstawia przegląd badań w zakresie zastosowania aplikacji agentowych w transporcie. Autorzy prezentują obszar naukowy, jakim są systemy wieloagentowe i wskazują na ich związek z innymi dyscyplinami naukowymi takimi jak systemy wspomagania decyzji (DSS) oraz rozproszonej sztucznej inteligencji (DAI). Ogólny wniosek jaki został wypracowany z niniejszego referatu jest taki, iż systemy wieloagentowe doskonale sprawdzają się w obszarze transportu. Przedstawiono koncepcję systemu wspomagania decyzji dla podróżujących, której bazą jest Europejska Ramowa Architektura Inteligentnych Systemów Transportowych FRAME, a implementacją usługa oparta o systemy wieloagentowe.

Słowa kluczowe: system wieloagentowe, systemy wspomagania decyzji, rozproszona sztuczna inteligencja, systemy informacji dla podróżujących