Smart Innovation, Systems and Technologies 74

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Agent and Multi-Agent Systems: Technology and Applications

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Vilamoura, Algarve, Portugal, June 2017
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Preface

This volume contains the proceedings of the 11th KES Conference on Agent and Multi-Agent Systems—Technologies and Applications (KES-AMSTA 2017) held in Vilamoura, Algarve, Portugal, between June 21 and 23, 2017. The conference was organized by KES International, its focus group on agent and multi-agent systems and University of Zagreb, Faculty of Electrical Engineering and Computing. The KES-AMSTA conference is a subseries of the KES conference series.

Following the successes of previous KES Conferences on Agent and Multi-Agent Systems—Technologies and Applications, held in Puerto de la Cruz, Tenerife, Spain (KES-AMSTA 2016), Sorrento, Italy (KES-AMSTA 2015), Chania, Greece (KES-AMSTA 2014), Hue, Vietnam (KES-AMSTA 2013), Dubrovnik, Croatia (KES-AMSTA 2012), Manchester, UK (KES-AMSTA 2011), Gdynia, Poland (KES-AMSTA 2010), Uppsala, Sweden (KES-AMSTA 2009), Incheon, Korea (KES-AMSTA 2008), and Wroclaw, Poland (KES-AMSTA 2007), the conference featured the usual keynote talks, oral presentations, and invited sessions closely aligned to the established themes of the conference.

KES-AMSTA is an international scientific conference for discussing and publishing innovative research in the field of agent and multi-agent systems and technologies applicable in the digital and knowledge economy. The aim of the conference was to provide an internationally respected forum for both the research and industrial communities on their latest work on innovative technologies and applications that is potentially disruptive to industries. Current topics of research in the field include technologies in the area of mobile and cloud computing, big data analysis, business intelligence, artificial intelligence, social systems, computer embedded systems, and nature-inspired manufacturing. Special attention is paid on the feature topics: business process management, agent-based modeling and simulation, and anthropic-oriented computing.

The conference attracted a substantial number of researchers and practitioners from all over the world who submitted their papers for main track covering the methodologies of agent and multi-agent systems applicable in the digital and knowledge economy, and three invited sessions on specific topics within the field.

Submissions came from 12 countries. Each paper was peer-reviewed by at least two members of the International Programme Committee and International Reviewer Board. Twenty-three papers were selected for oral presentation and publication in the volume of the KES-AMSTA 2017 proceedings.

The Programme Committee defined the main track entitled Agent and Multi-Agent Systems and the following invited sessions: Agent-based Modeling and Simulation (ABMS), Business Process Management (BPM), and Anthropic-Oriented Computing (AOC).

Accepted and presented papers highlight new trends and challenges in agent and multi-agent research. We hope that these results will be of value to the research community working in the fields of artificial intelligence, collective computational intelligence, robotics, dialogue systems, and, in particular, agent and multi-agent systems, technologies, tools, and applications.

The Chairs' special thanks go to the following special session organizers: Dr. Roman Šperka, Silesian University in Opava, Czech Republic, Prof. Salvatore Distefano, University of Messina, Italy, and Kazan Federal University, Russia, Max Talanov, Kazan Federal University and Innopolis University, Russia, Prof. Jordi Vallverdú, Universitat Autònoma de Barcelona, Spain, and Evgeni Magid, Kazan Federal University, Russia, for their excellent work.

Thanks are due to the programme co-chairs, all programme and reviewer committee members, and all the additional reviewers for their valuable efforts in the review process, which helped us to guarantee the highest quality of selected papers for the conference.

We cordially thank all authors for their valuable contributions and all of the other participants in this conference. The conference would not be possible without their support.

April 2017

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Robert J. Howlett
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KES-AMSTA 2017 Conference Organization

KES-AMSTA 2017 was organized by KES International—Innovation in Knowledge-Based and Intelligent Engineering Systems.

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Jordi Vallverdu	Universitat Autonoma de Barcelona, Spain
Evgeni Magid	Kazan Federal University, Russia
Max Talanov	Kazan Federal University, Russia

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Personalized HealthCare and Agent Technologies

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Abstract. Remarkable gains in life expectancy and declines in fertility have led current society to an ageing global population. Different stakeholders, researcher communities and policy makers invest serious efforts to develop intelligent and smart environments that have to support as much as possible independent living of old population. As necessary prerequisite for these efforts rapid and fascinating development in ICT offers wide range of new technologies including wearable, 3D sensors and smart environments. These new technologies provide rich complex data from living environment and give the opportunity to learn and analyze them in order to discover the patient's preferences, traits, and states. Further research efforts are oriented to personalized healthcare and development of sophisticated e-coaching facilities to obtain proper recommendations and advices to patients in order to increase their wellbeing.

Among different artificial intelligence methods and techniques agent technologies significantly influence and support different medical domains. The use of agents and multi agent systems in healthcare has also opened the ways to find out new applications like personalized and socialized healthcare platforms and systems with tailored recommendation capabilities. In this paper opportunities and challenges that agent technologies offer in personalized healthcare are discussed and presented.

1 Introduction

Remarkable gains in life expectancy and declines in fertility have led current society to an ageing global population. Life expectancy has increased to 70 years or more in many countries. The ageing of populations has led to changes in the prevalence of disease and disability.

Consequently in last decade there is growing need to supply constant healthcare monitoring and adequate support of elderly and disabled people.

Different platforms and tools for monitoring, smart support and making personalized recommendations to old people and patients have been developing. One of emerging research and application area is Ambient Intelligence (AmI). Ambient

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Intelligence for healthcare monitoring and personalized support is a promising research direction to provide efficient medical services for old and disabled patients.

New ICT technologies including wearable technologies (health watches and smartphones), 3D sensors and smart environments provide rich complex data and give the opportunity to learn and analyze them in order to discover the patient's preferences, traits, states and context.

Concepts and techniques of artificial intelligence (AI), data mining, and agent technology are unavoidable in AmI applications and platforms where sensors technology to monitor patient in the home and community settings are used.

The main objective of AmI is to try to adapt the technology to the patient's needs by different omnipresent devices which mutually communicate in a ubiquitous way. Various architectures and platforms of AmI application for health and wellness, home rehabilitation, assessment of treatment have been developing (Salih and Abraham 2013).

During usual patient activities wide range of data has been collected and later it must be processed, analyzed and later intelligent reasoning and proper decision making can help patients in everyday activities.

Software (and intelligent) agents represent one of widely applicable technology in different areas and domains. Agent technologies provide the right architecture for two major computing areas widely used in medical systems and environments: artificial intelligence (AI) and pervasive (seamless) computing.

In literature, the use of intelligent software agents has been proposed to deal with a variety of medical and health related problems: patient and treatment information access, community care, decision support systems (DSS), patient scheduling, training, hospital management, elder citizen care, self-care and automatic health monitoring (Iqbal 2016).

In this paper a quick overview of several contemporary trends in development of medical and healthcare systems will be presented. The rest of the paper is organized as follows. Section 2 is devoted to basic characteristics of personalization in medicine and healthcare. E-coaching in medical domains is presented in Sect. 3. Section 4 discusses some possible roles of agents in personalized medicine and e-coaching. Last section brings some concluding remarks.

2 Personalization in Medicine and HealthCare

Rapid increase of use smartphones and 3G and 4G networks has triggered expanded use of health devices and influenced a lot of different medical aspects like healthcare of aging people. Low-cost sensors have led to their integration into a wide range of wearable devices. So through smartphones and tablets patients can access different health data and monitor their daily activities. In fact the patients are moving into different technological interconnected worlds.

Healthcare wearables are those wearables for measuring metrics that are assumed to provide an indication of a patient's health and state of wellbeing. Recently there has been the emergence of wearables that are able to monitor detailed clinical metrics, such as blood pressure, heart function, glucose and insulin levels, and medicine intake and so on.

Additional advantage of use of ICT devices in everyday life is that patients can share their results and behavior through social networks and engage in lifestyle improvement games with their peers. Such hyper-connected patients open the new opportunities and directions of research that can help ageing population to cope with everyday activities smoothly and independently: ubiquitous and smart environments, personalized medicine, healthcare e-coaching.

In fact a lot of platforms developed to boost patients in their leaving space function as AmI environments. AmI puts together several crucial resources to provide flexible and intelligent services to patients acting in their environments: Pervasive Ubiquitous Computing and Artificial Intelligence (AI), Networks, Sensors and Unobtrusive Human Computer Interfaces (HCI). Complex context data can be collected by distributed sensors throughout the environment. When analyzing sensor data two strategies can be recognized: distributed or centralized. In the distributed model, each sensor has onboard processing capabilities and performs local computation before communicating partial results to other nodes in the sensor network (Salih and Abraham 2013). In the centralized model data is transmitted to a central server, which fuses and analyzes the received data.

Nevertheless which approach is adopted in analyzing sensors data it is possible to create a computational challenge for modeling several AI and data mining methods. But there exist another slightly different research direction that is based on and incorporate agent technologies in creating platforms for healthcare support.

Personalization in different e-services and systems is trend that exists for more than a decade. Personalization consists of tailoring a service or a product to accommodate specific individuals or groups. Personalization in different medical systems is newest trend. Personalized medicine and healthcare promise prediction, prevention and treatment of illness that is targeted to patients' needs. Personalized medicine is oriented towards the collecting of information from the patient in order to better tailor his/her needs. So to raise quality of life especially for elderly people it is necessary to orient research and activities towards more targeted prediction, prevention and treatment of illness. New technologies for detailed biological profiling of patients at the molecular level have been crucial in initiating the move to personalized medicine. To obtain more reliable mechanisms and support for patients it is necessary to continuously develop new technologies for collecting and properly analyzing complex medical, personal, environmental and behavioral data (Harvey et al. 2012).

There is also demand for qualitative increase: new types of data such as data on the patient's everyday leaving environment (nutrients, the microbiome, toxin exposure) are being seen as important for understanding biological functioning. More information is required in both the research setting, and in healthcare practice and also development of tools to monitor and manage patient's health status as part of their everyday life as a form of self-monitoring. Novel technologies and devices are being employed to facilitate health monitoring and they are becoming more sophisticated, capable of tracking several physiological variables and communicating them to a mobile smartphone or other computerized device. A step further represent the new technologies and gadgets that will allow the ongoing monitoring of functional status in real time, allowing fine tuning of therapy or adjustment of lifestyle to achieve the patient's health goals. Within self-monitoring and collected data from different devices it is necessary to obtain efficient ways of analyses of the data to identify areas for improvement,

provide education on how to achieve desired health goals, and gamification to increase engagement, as well as encouraging individuals to share their achievements with friends, compete and collaborate; providing further motivation to continue improving (usually via social network sites).

Presence of the diverse needs of an ageing society with use of wide range of ICT platforms, tools, and intelligent data mining algorithms is a key challenge in achieving following demands (PwC Global 2015):

1. Help older people to stay independent and healthy for as long as possible
2. Help older people to manage simple chronic conditions
3. Help older people that complex co-morbidities remain independent
4. Help older people to minimize the time they have to spend in hospital.

Technology, including telehealth, wearable devices, and sensor driven detection software in homes, are increasingly helping older people and their relatives to engage and communicate with service providers on their own terms. New technology, including different smart devices and wearables connected to the internet, collects more and more data (big and complex data), increasingly outside existing care providers. As such, the individual becomes the central node in the use of his or her own data, and therefore involved in the seamless delivery of the personalized services they need.

So personalized approach to care of elderly patients has to include different interconnected components, which will be incorporated in unique platform and obtain efficient and prompt support:

- Self-rated quality of life
- Family, community & peer support
- Smart homes
- Health apps and remote wellbeing monitoring.

Agent technologies play important role and can significantly help in developing higher-quality services.

3 E-coaching in Medical Domains

Coaching is new trend in different areas and aspects of human everyday activities. It generally can promote relationships, feedback, care, conversation, collaboration, answers, and bonding between different persons, groups, and communities. Great coaches are motivators, tending to boost individual's confidence and other emotional and behavioral issues. Extensive use of the internet advanced different aspects of coaching and introduced so called e-coaching. E-coaching performs the process online and greatly expands the possibilities. So online experiences are the essential way of supporting the coaching relationships (Rossett and Marino 2005). One important component of e-coaching is reducing costs, while providing encouragement, information, and connection to networks of people and content.

Experts from different disciplines and areas agree that there is a strong link between behavior and health. Healthy lifestyle can prevent many diseases. Personalizes e-coaching can play significant role in supporting people to achieve their health goals

and properly maintain their healthy behavior. This shift towards more personalized healthcare is reflected in the change of focus from a disease-centered approach towards a patient-centered approach. This obtains empowering patients to take an active role in the decisions about their own health. There are different sources of data for a patient starting from rather traditional ones like electronic healthcare records towards completely new types and forms of data like as data obtained from the patient's environment (nutrients, the microbiome, toxin exposure, gait and more others). Artificial intelligent techniques, effective data mining algorithms can help to separate relevant from irrelevant information and discover significant cognitive, emotional and behavioral patterns. From this point of view (Rutjes et al. 2016) e-coaching includes many aspects, e.g. persuasion, behavior change, personal contact and a type of recommendations.

Personalization, contextualization and frequent adaptation are necessary prerequisites of the e-coaching process. According to that seems that agent technologies are perfect candidates to take a role of an e-coaches that supports automated self-help therapies (Beun et al. 2016).

Important aspect of e-coaching in the area of personalized medicine is oriented to emotional and cognitive technologies and includes following essential components:

- Wearables
- Cognitive Health (that are based on Cognitive Enhancement and Cognitive Assistance)
- Remote Patient Monitoring (for Activity Detection)
- Medication adherence (that incorporates: Different Devices, Reminder Systems, Coaching and Advising, Coordination Systems)

4 Agents and Their Role in Personalized and E-coaching Medicine

The most popular application of wearable technology recently has been in the area of health and wellness. Different wearable devices collect a pile of data about patient and his/her environment. All the data from the different devices set in the environment are collected but it is necessary to apply AI and Machine Learning (ML) techniques to analyze this data comprehensively. Also the patient is able to view the instant and historical data on their mobile devices. Such platforms and systems also have to provide the real-time hands-free feedback and instructions through the sophisticated user interfaces (visually, acoustically and tactilely). Sophisticated user interfaces that facilitate HCI more and more are realized as different personal virtual and visual agents (avatars).

The development of AmI-based software requires creating increasingly complex and flexible applications. Autonomous decision making agents that incorporate learning mechanisms, and are able to respond to events by (pre)planning in execution time are excellent mechanisms to be incorporated and support activities in AmI healthcare environments. With good reasoning and planning mechanisms agents facilitate acquiring data from different devices that patients use but also the data from their everyday living environment. They are also good mechanisms that support straight coordination and communication among wireless medical devices.

The successful use of intelligent agents in healthcare has attracted researchers to apply this emerging software engineering paradigm in more advanced and complex applications. The multi agent systems have been applied from single healthcare activity like knowledge-based medical system to complex, multi-component based systems. The use of multi agent systems in healthcare domain has also opened the ways to find out new applications like personalized and socialized healthcare systems with tailored recommendation capabilities.

Agents and Multi-Agent systems are good entities and concepts in abstraction tools, but predominantly for modeling devices and their interactions, to serve as personal assistants and recently as virtual e-coaches and advisors in patients' emotional and cognitive activities.

Full potential of AmI cannot be realized without sophisticated knowledge representation, reasoning, and AI and agent-oriented technologies.

In last two decades development of new theories, methods and technologies is emerging in order to support adaptive and personalized dialogues between a human and a (intelligent) software agent. Software agents can be incorporated in different health platforms and applications: supporting an expert's decision making (based on big and complex data collected from wearable devices and environmental sensors), accessing and making use of distributed data sources or the coordination of the execution of assistive technology for healthcare activities. Assistive technology can be supportive, preventive or responsive (Baskar 2014).

Apart from different practical challenges and possibilities software agents are essential facilitators in handling everyday queries about health that are perceived as meaningful and useful to the patients. The agent needs to have wide range of data and knowledge about the patient, the particular topic of the dialogue, and also necessary data about the physical and social environment in which patient is living. Moreover, the agent has to know how to be cooperative and be able to recognize patient's emotions and cognitive status and behave and express with empathy while conducting a dialogue activity. In some situations, it needs to approach to the decisions together with the patient and give him/her adequate recommendations and advices. The dialogue activities must be based on straightforward argumentation schemes and trust. The agent can adapt its moves to the patient's trail of reasoning, goals, and behave in an empathic way and adapt to the human's emotional state.

General structure of cognitive agent architecture (Baskar 2014) that could be used in personalized medical e-coaching as well is presented in Fig. 1.

The knowledge about the patient's activities involves observation of both personal and environment activity, obtained by the seamlessly integrated sensors as a part of a ubiquitous computing environment in which patient lives.

Different kinds of dialogues and e-coaching between virtual agent (e-coach) and patient could be performed, but some highly important in personalized medicine could be (Baskar 2014):

1. **Information-seeking dialogues**, where patient seeks the answer to some medical and health questions from virtual e-coach realized as intelligent software agent.
2. **Inquiry dialogues** when the patient collaborates with virtual e-coach to obtain an answer to specific question and to validate a claim about particular topic.

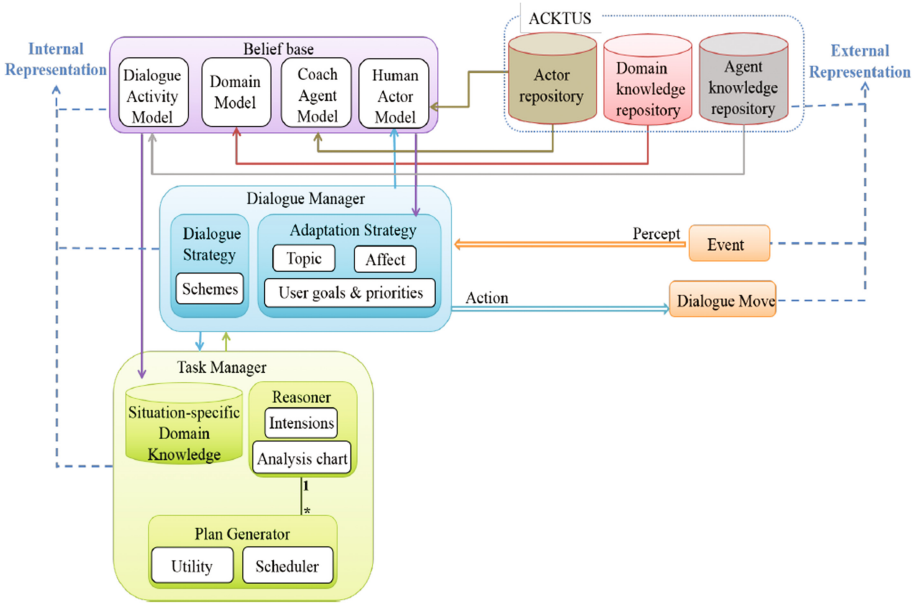

Fig. 1. Cognitive agent architecture (Baskar 2014)

3. **Deliberation dialogues**, in this dialogs both participants collaborate to decide what course of action should be adopted. For example in the healthcare, it could be the decision about interventions aimed at improving a patient's daily medical conditions.
4. **Persuasion dialogues** involve virtual e-coach seeking to guide and persuade patient to perform some activities and solve some situations adequately in accordance with his health state.

Software agents also can be used in other medical domains and to support different tools and platforms in patient-centered environments. Different sub-domains include ambient medical intelligence, medical data harvesting and collection, medical data management, knowledgebase and decision support systems, operational systems for healthcare, healthcare resource planning and management and so on (Iqbal 2016). A very brief description of these additional possibilities of use agents in medical systems is given below:

1. **Planning and resource management** - These systems focus on planning medical processes, monitoring of staff and performance measurement, patient health monitoring, hospital and clinical resources management.
2. **Decision support systems/knowledge base systems** - Such systems utilize knowledgebase and apply some type of data analysis techniques (using AI or machine learning), pattern recognition algorithms, and also might often use knowledge inference techniques.

3. **Data management systems** - These systems focus mainly on health data extraction, representation, organization, storage, retrieval, and presentation.
4. **Remote care/self care systems** - This area includes systems designed for automated patient monitoring remotely, and patient self-care.
5. **Multifunction systems** – There exists various systems that perform multiple tasks related to a complete healthcare solution. These systems are usually complex and may be composed of two or more sub-domains.

5 Conclusion

Changes in the healthcare sector have to address the shift to an empowered patient and the potential of wearable sensing data to personalize health treatment. Future of wearable application lies in the support of the user to make sense of data and get contextualized personalized feedback for behavior changes (Hänsel et al. 2015).

Emergent and rapid development of wide range of ICT components has significant influence on personalized medicine and virtual e-coaching. It also directs research in the area in the following directions (Gemert-Pijnen et al. 2016):

1. **Health analytics** - advanced methods (machine learning) and models to analyze Big and Complex Data.
2. **Predictive modeling** - to set up smart models to predict behaviors, to prevent diseases and to personalize healthcare.
3. **Visualization of data** – different tools support and facilitate presentation of data in meaningful way to support reliable decision making.
4. **Integration of mobile (hardware and software) technologies** – integration of different devices with data-platforms is important to enable automated services and to tailor feedback and recommendations.
5. **Personal communication and recommendations between patient and virtual e-coach** - In these area agent technologies definitely could play extremely important role. Virtual Human Agents are suitable components (have been developed on the bases of knowledge representation, cognitive and emotional modeling, natural language processing) to support and empower communication, personalization and increase motivation of patients.

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Multiagent Environments for Dynamic Transportation Applications

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Abstract. Dynamic transportation applications have long been a domain of choice for the multiagent paradigm. Indeed, the presence of distributed entities, the highly dynamic character of these applications and the often presence of human actors in the system makes it very suitable for a multiagent design. This paper advocates for the primary consideration of multiagent environment design when dealing with such dynamic transportation applications. Transportation applications can greatly benefit from the use of the multiagent environment since most of them consider a dynamic geographical positioning of the system components. Indeed, the simultaneous consideration of the time and space dimensions makes the environment, which is shared and accessed by all the agents of the system, a candidate of choice to capture the dynamics of the application. The environment design can be envisioned at several levels of the system construction. It can be used as a medium for interaction between distributed entities. It could be used as a coordination entity of the system components. It can finally be designed as a mental model for the agents that they can use in their reasoning. We illustrate the possible uses of the environment with two transportation applications dealing with traveler information.

1 Introduction

The multiagent paradigm is proven to be a powerful model to design and implement transportation applications. Indeed, the multiagent approach deals with systems consisting of many physically or logically distributed interacting components that possess some level of autonomy. These components are able to perceive their environment and also react to changes in that environment in accordance to their goals. That is why the multiagent approach is adapted to the transportation domain since it facilitates an approach by analogy in a domain where the objective is the management of distributed entities. The authors in [1] list several reasons for the privileged use of multiagent systems in these applications, such as the natural and intuitive problem solving, the ability of autonomous agents for the modeling of heterogeneous systems, the ability to capture complex constraints connecting all problem-solving phases, etc. Indeed, the concept

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of an agent is well suited for the representation of travelers in transit or road traffic scenarios [2,3]. They are autonomous entities which are situated in an environment, adapt their behaviors to the dynamics they perceive and interact with others agents in order to achieve specific goals. For Parunak [4], "Agent-based modelling is most appropriate for domains characterized by a high degree of localization and distribution", which is the case for complex and dynamic transportation applications.

In the multiagent community, there is a growing conscience that the multiagent environment should be considered as a primary design abstraction, of equal importance as the agents. Models and architectures have been proposed in the literature for multiagent environments design, validated in a variety of application domains [5]. We believe that one of the domains of choice for the multiagent environment modeling is the transportation domain. Indeed, transportation applications always have some kind of representation for the environment, typically the transportation networks. The environment in transportation application has its own dynamics (e.g. traffic conditions, dynamic rules, weather, etc.), which advocates for its independent and explicit representation. Transportation systems are open, with entities joining and leaving the system (e.g. travelers, drivers, vehicles, regulators, etc.), generally in a nondeterministic way. The multiagent environment can also be the privileged interlocutor of the newcomer entities.

In this paper, we illustrate different design angles of the multiagent environment when dealing with transportation applications. The environment design can be envisioned at several levels of the system construction. It can be used as a medium for interaction between distributed entities. It could be used as a coordination entity of the system components. It can also be designed as a mental model for the agents that they can use in their reasoning. To illustrate the possible uses of the environment, two applications are considered: traveler information and information dissemination in disturbed transit networks.

The remainder of this paper is structured as follows. In Sect. 2, we present a generic design of multiagent environment, in the form of a specification language and the traveler information application built with the language, and using the environment to support agents interaction. In Sect. 3, we present a representation of the multiagent environment that is specific to transportation applications, based on space-time graphs. The chosen application example is information dissemination in disturbed transit networks. Section 4 concludes the paper and provides some future works.

2 Generic Environment Model

In dynamic transportation applications such as advanced traveler information or dial a ride systems, travelers, clients and vehicles join the system in a nondeterministic way, and might leave it anytime as well. When specifying such open systems, the designer has to define an architecture that allows for the integration of unknown agents. Newcomer agents have to be able to find the agents that