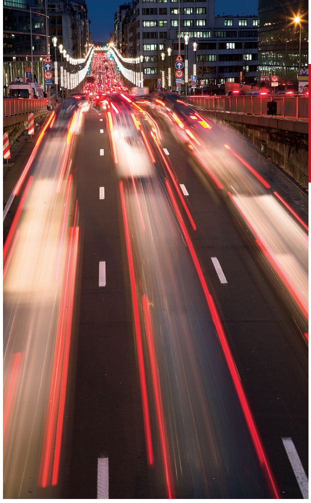



Editor: **Rosaldo J.F. Rossetti,** University of Porto, rossetti@fe.up.pt

# Playing Transportation Seriously: Applications of Serious Games to Artificial Transportation Systems

**Rosaldo J.F. Rossetti, João Emílio Almeida, Zafeiris Kokkinogenis, and Joel Gonçalves,**
*University of Porto, Portugal*

Serious games have gained a great prominence in the last decade and contributed a great deal for digital games to become an important discipline in their own right. According to Michael Zyda, in his systematic and elucidative discussion on the term, serious games might be defined as "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives."[1] Basically, Zyda focuses on the potential role of digital games for use in nonentertainment purposes, in diverse domains, in a wide variety of applications—and this naturally includes transportation systems.

Whereas serious games have been largely investigated within the context of education and training, there's a growing effort to explore other characteristics and applications. In this article, we discuss the potential integration of serious games into the conceptual framework of artificial transportation systems (ATSs), whose essence heavily rely on agent-based modeling and simulation. However, capturing behavior characteristics of transportation users so as to grow and breed appropriate artificial societies of agents is a laborious task. Even though massive data can be easily acquired through current sensor network technology, cognitive characteristics and decisional semantics aren't conveyed as easily. We believe serious games might help in that way; as far as the behavior of players is concerned, we identify three important purposes and abilities of such games:

- *Behavior assimilation*. This is in line with the primary purpose of gaining new skills, training, and improving certain player abilities. This is the basis for edutainment, and the game can act as a coach that instructs players in the fundamentals of a certain activity and directs learning strategies.
- *Behavior elicitation*. This isn't solely related to monitoring players during the game and generating usage statistics. Elicitation here implies adequate means to capture the semantics of decisional processes as an attempt at disclosing players' cognitive abilities. This is of ultimate relevance to the proper understanding of decision-making mechanisms and the implementation of persuasion strategies.
- *Behavior persuasion*. Contrary to behavior assimilation, persuasion has to do with the ability of the game to evolve behavior and influence certain patterns in the long-term. This mechanism relies on incentive-based policies that aim to induce (not enforce) players to perform certain actions that are more appropriate from the system's point of view.[2] In the case of sociotechnical systems, such as transportation, this might well serve as an instrument to improve social awareness.

Assimilating behaviors by the players is a straightforward concept behind serious games; whereas elicitation and persuasion need further clarification, stir up many issues, and pose important realization challenges. In our view, behavior elicitation is a suitable instrument toward a proper


1541-1672/13/$31.00 © 2013 IEEE
*Published by the IEEE Computer Society*

representation of the decisional mechanisms and cognitive abilities of agents forming the artificial society underlying ATSs. We thus integrate serious games into the conceptual framework of ATSs by combining behavior elicitation with the peer-designed agents (PDAs), allowing players to feature their peer agents with their own idiosyncrasy.

## Games in Transportation

The history of digital games in the transportation domain isn't new. Before going further into our discussion, let's consider the interface between digital (serious) games and transportation systems. Transportation has been a great application domain for so-called simulation games. Driving simulators have been used for a long time, together with other similar examples, such as flight simulators. They usually rely on heavy computer graphics and virtual reality techniques to resemble the operation environment as realistically as possible and provide players with full immersion. In the case of driving simulators, for instance, games have been largely used for studying inherent psychological aspects of the primary task of driving and the likely interference of other secondary tasks. Another useful application of such simulators includes accreditation, as flight pilots need to complete their training with simulator hours, for instance. Even Formula 1 race drivers now complement their training with simulator hours, as it's quite expensive to perform track practices and those are also limited by championship regulations.

A classic simulator among teenagers in the early 1980s was *Enduro*, available for the Atari game console. Albeit mainly entertaining, it conveyed an educational dimension as players were compelled to drive cautiously through snow or in the dark. *SimCity* is another masterpiece among desktop computer games. Since its *Micropolis* version, in the mid-1980s, this game genre has evolved tremendously, emphasizing managerial and planning abilities that are essential for urban planners and social scientists. Even entertaining games can thus be used for educational purposes. Now, with the proliferation of mobile computing and the worldwide reach of the Internet, a vast variety of game genres are available, not only for commodity computers and traditional game consoles, but for tablets, smartphones, and other portable devices.

A couple of years ago, more or less inspired by the same genre of games as *SimCity*, IBM released an online serious game devised to help city leaders, businesses, and students realize ways to make cities work better. The free game, *CityOne* (see www-01.ibm.com/software/solutions/soa/innov8/cityone), simulates different dimensions—including transportation, environment, business, and logistics—and challenges players to complete missions involving, for example, energy, water, banking, and retailing. Also concerned with efficient and sustainable mobility issues in metropolitan settings, the European-funded project Superhub (see http://superhub-project.eu) also devised a serious game called *Eco-dealers*, offering the players a series of missions that take into account their normal or occasional movements within the city and raffle Eco-money rewards. Exploring the symbiotic potential of social games in combination with location-based games, *Waze* (see www.waze.com) is a nice example of a serious game implemented as a community-based traffic and navigation app.

As far as the teaching and training of intelligent transportation systems (ITSs) are concerned, Jeffrey Adler and his colleagues[3] envisage potential benefits of game technology as an educational aid to leverage ITS awareness, and assist transportation stakeholders in identifying and analyzing ITS deployment issues. In the specific field of ATSs, Qinghai Miao and his colleagues[4] have developed a game-engine-based approach to improve the modeling of artificial societies in which agents are designed similarly to actors in games. This approach features an artificial-population module with design capabilities that allow individuals of the population to be modeled in detail.

## Integrating Serious Games into ATSs

Because of the high complexity and uncertainty of contemporary transportation systems, traditional traffic simulation fails to capture in detail all the dynamics that characterize them. For example, travelers can choose whether to travel; can change at any moment their planned itinerary; and their choices might be affected by any social, economic, or environmental phenomena. Also, new performance measures brought about by an extensive future urban transport agenda and the implementation of the smart-cities concept pose additional requirements to which the user is central, and these aren't as easily integrated in traditional modeling approaches. To appropriately represent, test, and analyze transportation control and management strategies, Fei-Yue Wang devised and introduced the concept of ATSs.[5–7] Basically, the ATS goes beyond traditional simulation methodologies and integrates the transportation system with other socioeconomical urban systems with real-time information, resulting in a tool appropriate for transportation analysis, evaluation, decision making, and training. Coupling physical and virtual systems on an integrated basis, it's possible to make real entities to interact with simulated counterparts in a seamless manner. The foundations of ATSs are grounded on the paradigms of multiagent systems, social simulation, and artificial societies, as well as distributed computing, which provide adequate tools to represent interacting entities of complex domains such as transportation. The main characteristics featured by an ATS wrapper are the massive field data collection from sensor networks, the application of simulation-based control and management strategies back to the physical system and the human-in-the-loop interaction for decisional support and analysis.

Whereas ATSs heavily rely on the paradigm of multiagent systems, growing and breeding an artificial society of autonomous entities is far from easy. This process, which is quite laborious, is generally based on the discretization of highly aggregated social data, psychological-based behavior analysis, and other similar studies. In another work, the authors provide a brief overview of contributions in ATSs' development along three dimensions: modeling issues and metaphors for ATS models, architectures for ATSs, and practical applications of ATSs.[8] However, there has been little advancement in appropriately representing users and their behavior in the various dimensions of ITSs. In this article, we suggest the use of serious games as a PDA technique to bridge the gap between behavior observation techniques and the practical implementation of agents in simulated artificial societies.

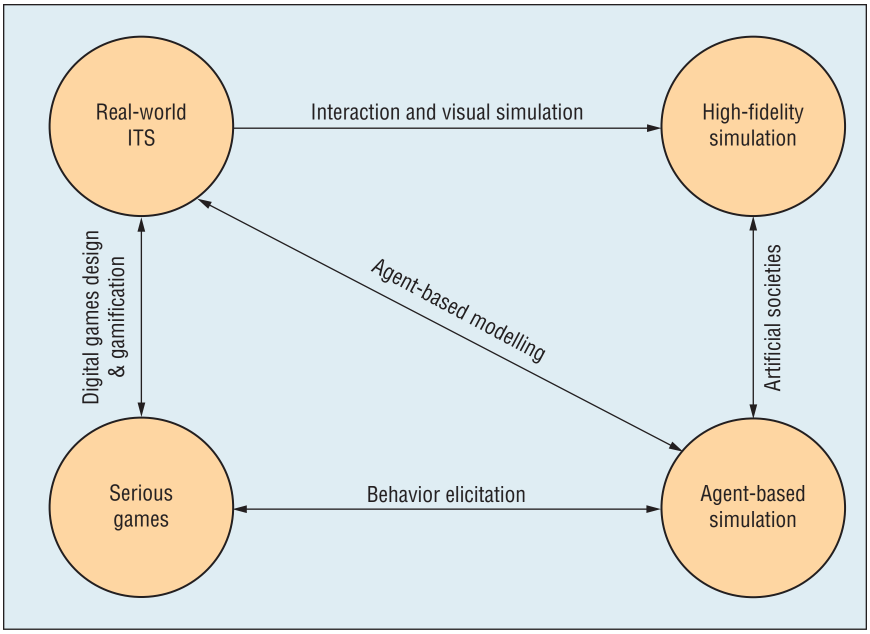


**Figure 1. Methodological perspective for the serious game and artificial transportation system integration. Our approach takes serious games, agent-based simulators, virtual reality simulators, and real-world transportation systems as first-class abstractions.**

## Serious Games in ATSs

In our methodological perspective of ATSs, we use the metaphor of digital ecosystems to identify distributed, adaptive, open sociotechnical systems whose entities, either physical or artificial, interact with other entities and their environment, exhibiting properties such as self-organization, scalability, and sustainability. Albeit not disposed in the same structure, this is consistent with initial discussions on the concept of ATSs. We transcend the training and educational abilities of serious games to consider them as one such ecosystem, through which we implement behavior elicitation. We then make serious games a first-class abstraction in our methodology alongside agent-based simulators, virtual reality simulators, and real-world transportation systems (see Figure 1).

The identification of a real-world ITS ecosystem follows the same abstraction as other work.[9,10] According to this view, real transport systems are seen as a common environment where physical components and actors such as traffic control and management systems (either physical or artificial), travelers, and other ITS solutions live and interact. The observation of traffic and transportation systems has been traditionally performed through surveys and questionnaires, video-streaming cameras, and sensors installed in the infrastructure. This process has benefited enormously from rapid advancements in sensor network technologies. Alternative sources of information—such as crowdsourcing, social networks, and other forms of crawling cyberspace using cloud computing—are also gaining some relevance. From observations in the real-world ITS ecosystem, scientists, practitioners, and decision makers build abstraction models and analytical tools with diverse purposes. Each such tool, following the integrative perspective of ATS, can also be considered ecosystems in the same abstraction dimension.

Through rich graphics with a high degree of detail and virtual reality techniques allowing countless interaction forms, the high-fidelity simulation ecosystem recreates the real domain. While trying to preserve the same level of immersion, high-fidelity simulations allow observation of other system facets on a controllable basis, which wouldn't be possible through experimentation with the real system. Different psychological experiments are carried out in such simulation environments, such as using driving simulators and similar environments. Insightful analysis of intrinsic decisional mechanisms of subjects, either individually or in groups, might be performed with relatively high accuracy. However, these sorts of simulators are built on complex and expensive infrastructures, and gathering subjects to participate in the experiments is another issue that could limit the studies' scope.

The agent-based simulation ecosystem is actually where artificial societies (as a means to represent human behaviors and social interactions) grow and breed. The multiagent system underneath the ecosystem takes into account the real-world society's evolving behavior and interactions with other ITS entities in the real world. This is a core component of ATS. The agent model underlying the simulated artificial society can easily result from resorting to a systematic and consistent use of appropriate methodologies for agent-oriented analysis and design. However, testing, verifying, and validating such models are nontrivial tasks.

Certainly, insightful knowledge originating from high-fidelity simulations is of paramount importance to the formulation of sound validation routines; a drawback, however, is the expensive apparatus they demand. Applying inference mechanisms to big data so as to identify behavioral patterns is now being widely investigated with promising potential; whether they convey appropriate cognitive characteristics and decisional semantics is still an issue to be addressed. Nonetheless, the design and validation of artificial societies are expected to be continuous and iterative processes. Accounting for the integrative perspective of ATS, in fact, agents evolve through learning as they become the virtual entities interacting both with humans in the real-world ITS and with subjects in the high-fidelity simulation, as well as with players in the serious games.

As for the serious games ecosystem, it can't be seen merely as a technological system through which entities, either physical or artificial, interact. Serious games can be seen as interaction artifacts interfacing the real-world ITS and the artificial society in the multiagent simulation, as well as ITS users toward participative simulation (for example, implemented as Web-based multiplayer games), letting us capture the system's collective intelligence.

This extended account of the concept of serious games in accordance with the integrative perspective of ATSs stirs up many application potentials, as well as practical implementation issues. Here, we use serious games to reveal the decision processes behind the course of action people perform to achieve certain goals and respond to stimuli, or during deliberation. We call this behavior elicitation. This process isn't just a matter of collecting data through logs of different and successive interactions of the player during the game for postprocessing. Rather, we make use of the intrinsic nature of serious games to impel the player to add semantics to every decision and action performed during the game that might better clarify the sequence of cognitive states that resulted in or triggered certain actions. In other words, we ask the player to model his/her own agent, in a process that's known by PDAs.

Although the PDA paradigm has been practically used in certain situations, empirical investigation of the level of similarity observed between agents and the people who designed them is inconclusive. Nonetheless, PDAs are an important instrument that can alleviate the evaluation process of mechanisms (replacing people) and facilitate their design.[11] One practical example of PDAs is reported by Michal Chalamish and colleagues, in which the authors conduct parking simulations of PDA-based driver agents, implementing strategies designed for parking lot users.[12] In their development process, users were provided with PDA skeletons, which albeit fully functional were missing their strategic layer. We believe this method will be largely enhanced if PDAs become a constitutive part of the serious game structure, and this would be mutually beneficial both to the agent-based simulations and to serious games.

Considering now that PDAs reflect idiosyncrasies of players that designed them, then agents' native decision mechanisms can be better analyzed and understood. Such a setting can promote the symbiotic relationship between players and agents in the artificial society, and constitute a proper ground to implement incentive-centered instruments as an attempt at persuading agents to act toward the benefit of the whole system. Social awareness could then be conveyed through the behavior persuasion means of serious games, possibly resulting in wonderful gains to the real-world ITS in various dimensions.

## Instantiating the Concept

Just for the sake of illustration, we mention two ongoing projects to exemplify how serious games and ATSs can be practically integrated. Although the prototypes are in their initial stages, they incorporate aspects mentioned in our discussion.

***Simulation of Pedestrians and Elicitation of their Emergent Dynamics (SPEED).*** The Speed framework aims to study pedestrian dynamics and interactions, which concern reasoning processes, (path) planning, and all other aspects associated with pedestrian movement

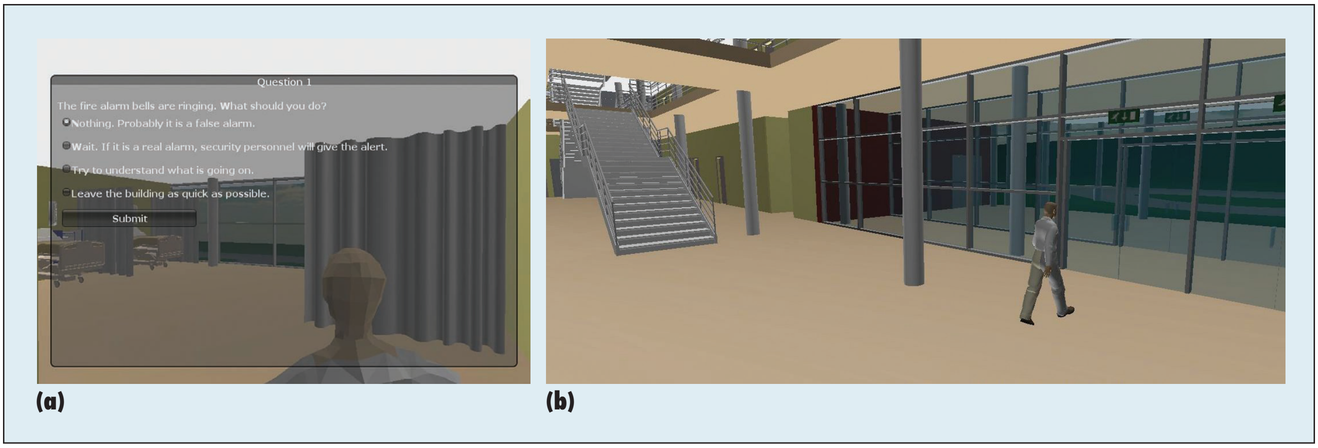


**Figure 2. Simulation of Pedestrians and Elicitation of their Emergent Dynamics (SPEED). (a) In certain key instances during the game, the player must answer questions that try to capture the rationale motivating their actions. (b) In evacuation scenarios, one important aspect to study is how quickly individuals can find exits following standardized signs, especially when people are unacquainted with the space.**

in a variety of mobility settings, both indoors and outdoors. This kind of tool is important for urban planners as an aid for designing and evaluating urban spaces regarding comfort, safety, and other important issues, such as accessibility of public buildings (see Figure 2).[13]

When modeling pedestrians, researchers and social scientists usually rely on data from questionnaires, direct observation, photos, and videos. More recently, high-definition virtual reality simulators such as CAVEs are used. Although empirical experimentations on such simulation infrastructures can be relatively expensive and are mostly laborious and time-consuming, they're an integrative part of the methodological approach proposed, providing immersion and realism in the representation of the application domain.

The behavior elicitation part integrates agent-based modeling, social simulation, and serious games, which is used both as a training tool and an important observation aid. PDAs capture players' behavior during the game and are used to form a synthetic population upon which social simulations reproducing various situations and what-if scenarios can be performed. We implement the serious game component in Unity3D (see www.unity3d.com), and the agent-based social simulation in NetLogo (see http://ccl.northwestern.edu/netlogo).

***In-Car Driver Ergonomics Evaluation Platform (IC-DEEP).*** In-vehicle information systems and advanced driver assistance systems are used during the context of driving, where the objective is to deliver a better driving experience by providing infotainment functionalities and enhancing safety, respectively. As the inherent complexity of such systems in the safety-critical context of driving increases, the role of ergonomics and human-computer interactions must be carefully analyzed and understood.

Traditional approaches for evaluating these interactions use high-fidelity driving simulators to safely perform empirical studies using human subjects. While effective, this approach generally implies high-cost maintenance of the simulator, integration issues for deploying prototypes in the simulator, and data collection from one subject at a time. Nonetheless, driving simulators are also an integrative part of our methodological approach for their ability to provide realism and immersion in the driving environment.

The IC-DEEP framework was created to meet the demand for rapid design-prototype-evaluate cycles in the development of in-vehicle information systems and advanced driver assistance systems, as well as to improve driver modeling in microscopic simulation (see Figure 3).[14] This low-cost platform is composed of commodity hardware, game accessories, and a serious game (*Serious Driving*) developed in Unity3D. The PDA concept is used to collect driver-performance statistics in both primary and secondary tasks and elicit their behavior during the game, allowing the generation of a synthetic population of PDA-based driver agents whose interactions are simulated in an agent-based microscopic simulator for further analysis and other studies with different purposes.

In both examples, players become active participants of the artificial society simulation through PDAs. With this methodological approach we aim to ease development, allowing rapid prototyping and enabling meaningful data collection, while the ability of serious games to implement behavior assimilation, elicitation, and persuasion can be explored to their full extent.

## Challenging Issues and Opportunities

While envisioning applications of serious games in the context of the integrative perspective of ATSs, we


**Figure 3. Evaluating advanced driver assistance systems and information system ergonomics for the In-Car Driver Ergonomics Evaluation Platform (IC-DEEP). (a) Visual alerts show up on the screen whenever the player fails to keep a vehicle's trajectory within the lane, for instance, and driving metrics are logged for further analysis. (b) In addition to the primary task of driving, players must perform secondary tasks such as reading e-mails on the dashboard screen. These secondary tasks might affect the player's ability to keep a vehicle's trajectory.**

identify some interesting and stimulating challenges that are also research opportunities.

Whereas behavior elicitation seems to be a feasible instrument leveraging the design of agent behaviors in the simulation of artificial societies, further research is still necessary to evaluate the effectiveness of the PDA approach. Including the PDA concept in test, verification, and validation methodologies is also essential. Featuring PDAs with learning abilities as they continuously interact with their designers also might be an extension to consider.

Gamification is an important instrument toward behavior persuasion. This concept builds upon the market vision of digital games as a means to stimulate consumer loyalty by incentivizing users with points, badges, and special offers for performing positive actions. New performance measures of future transportation systems are dependent on the effective implementation of social awareness, and serious games can certainly help in that way through gamification. This demands appropriate instruments to implement correct incentive-based schemes to promote user loyalty to the application, and to evaluate how behavior evolves and changes in the short- and long-term.

The educative and informative capabilities of serious games offer a great potential to leverage ITS awareness. We believe game technology might be included in the implementation of forthcoming ITS educational tools, promoting ITSs in a fun and entertaining way. Infotainment applications envisioned in the vehicular network infrastructure could also be explored in this way.

Apart from other technological and integration issues not herein discussed, we believe that a combined appreciation of serious games and ATSs will foster useful knowledge in both areas and must be seen as a cross-fertilization opportunity.

In the past few years, serious games have gained a recognized prominence, with many potential applications to diverse fields, naturally including ITSs. In our view, the integration of serious games into the conceptual framework of ATSs builds up an exciting arena of research on how game technology can leverage the principles of participative simulation. This perspective turns ITS users into active actors in the integrative loop of ATSs. The ability of serious games to foster behavior assimilation, elicitation, and persuasion allied to PDAs facilitates the formation of the artificial society underlying the concept of ATSs. Also, the philosophy behind the concept of gamification, realized through social and location-based games, implementing appropriate incentive-centered mechanisms, can further promote social awareness toward future smarter and sustainable transportation systems.

## Acknowledgment


This work has been partially supported by Fundação para a Ciência e a Tecnologia, the Portuguese Agency for R&D, under grants SFRH/BD/67202/2009 and SFRH/BD/72946/2010.


## References


1. M. Zyda, "From Visual Simulation to Virtual Reality to Games," *Computer*, vol. 38, no. 9, 2005, pp. 25–32.
2. R. Centeno, H. Billhardt, and R. Hermoso, "Persuading Agents to Act in the Right Way: An Incentive-Based Approach," *Engineering Applications of Artificial Intelligence*, vol. 26, no. 1, 2012, pp. 198–210.
3. J.L. Adler et al., "Advanced Educational Technologies and Intelligent Transportation Systems Training: State of the Practice," *Transportation Research Record 1729*, Nat'l Academy Press, 2000, pp. 65–74.
4. Q. Miao et al., "A Game-Engine-Based Platform for Modeling and Computing

Artificial Transportation Systems," *IEEE Trans. Intelligent Transportation Systems*, vol. 12, no. 2, 2011, pp. 343–353.
5. F.-Y. Wang, "Integrated Intelligent Control and Management for Urban Traffic Systems," *Proc. IEEE Intelligent Transportation Systems Conf.*, vol. 2, IEEE, 2003, pp. 1313–1317.
6. F.-Y. Wang and S.M. Tang, "Concepts and Frameworks of Artificial Transportation Systems," *Complex Systems and Complexity Science*, vol. 1, no. 2, 2004, pp. 52–59.
7. J. Li et al., "A Software Architecture for Artificial Transportation Systems—Principles and Framework," *Proc. IEEE Intelligent Transportation Systems Conf.*, IEEE, 2007, pp. 229–234.
8. R.J.F. Rossetti, R. Liu, and S. Tang, "Guest Editorial: Special Issue on Artificial Transportation Systems and Simulation," *IEEE Trans. Intelligent Transportation Systems*, vol. 12, no. 2, 2011, pp. 309–312.
9. R. Rossetti, E. Oliveira, and A. Bazzan, "Towards a Specification of a Framework for Sustainable Transportation Analysis," *Proc. 13th Portuguese Conf. Artificial Intelligence*, APPIA, 2007, pp. 179–190.
10. R.J.F. Rossetti et al., "Towards an Artificial Traffic Control System," *Proc. 11th Int'l IEEE Conf. Intelligent Transportation Systems*, IEEE, 2008, pp. 14–19.
11. A. Elmalech and D. Sarne, "Evaluating the Applicability of Peer-Designed Agents in Mechanisms Evaluation," *IEEE/WIC/ACM Int'l Joint Conf. Web Intelligence and Intelligent Agent Technology*, vol. 2, IEEE CS, 2012, pp. 374–381.
12. M. Chalamish, D. Sarne, and R. Lin, "Enhancing Parking Simulations Using Peer-Designed Agents," *IEEE Trans. Intelligent Transportation Systems*, vol. 14, no. 1, 2012, pp. 492–498.
13. J.F. Silva et al., "EVA: A Serious Games for EVAcuation Training," *Proc. IEEE 2nd Int'l Conf. Serious Games and Applications for Health* (SeGAH), CD-ROM, IEEE CS, 2013.
14. J. Goncalves, R.J.F. Rossetti, and C. Olaverri-Monreal, "IC-Deep: A Serious Games Based Application to Assess the Ergonomics of In-Vehicle Information Systems," *Proc. 15th Int'l IEEE Conf. Intelligent Transportation Systems*, IEEE, 2012, pp. 1809–1814.

**Rosaldo J.F. Rossetti** is an assistant professor in the Department of Informatics Engineering and a senior researcher in the Artificial Intelligence and Computer Science Laboratory, Faculty of Engineering, University of Porto, Portugal. Contact him at rossetti@fe.up.pt.

**João Emílio Almeida** is a PhD student in informatics engineering and a researcher in the Artificial Intelligence and Computer Science Laboratory, Faculty of Engineering, University of Porto. Contact him at joao.emilio.almeida@fe.up.pt.

**Zafeiris Kokkinogenis** is a PhD student in informatics engineering and a researcher in the Artificial Intelligence and Computer Science Laboratory, Faculty of Engineering, University of Porto. Contact him at zafeiris.kokkinogenis@gmail.com.

**Joel Gonçalves** is a PhD student in informatics engineering and a researcher in the Artificial Intelligence and Computer Science Laboratory, Faculty of Engineering, University of Porto. Contact him at pro12009@fe.up.pt.

cn *Selected CS articles and columns are also available for free at http://ComputingNow.computer.org.*