Abstract (30)
We discuss on the potential integration of Serious Games into the conceptual framework of Artificial Transportation Systems, focusing on behaviour elicitation through peer-designed agents to model and simulate artificial societies on a participative basis.

Introduction
Serious Games (SG) have gained a great prominence in the last decade and contributed a great deal for digital games to become an important discipline on their own right. According to Michael Zyda [1], in his systematic and very 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.” Basically, Zyda stresses on the potential role of digital games for non-entertainment purposes, in diverse domains and a wide variety of applications – and this naturally includes transportation systems!

Whereas SGs have been largely investigated within the context of education and training, there seems to be a growing effort to explore other characteristics and applications of the concept. In this article, we discuss on the potential integration of SGs into the conceptual framework of Artificial Transportation Systems (ATS), whose essence heavily rely on agent-based modelling and simulation. However, capturing behaviour characteristics of transportation users so as to grow and breed appropriate artificial societies of agents is a very laborious task. Even though massive data can be easily acquired through current sensor network technology, cognitive characteristics and decisional semantics are not conveyed as easily. We believe SGs might help in that way; as far as the behaviour of players is concerned, we identify three important purposes and abilities of such games, as defined below.

Behaviour assimilation: this is very much in line with the primary purpose of gaining new skills, training, and improving certain abilities of the player. This is the basis for edutainment, and the game can act as a coach, who instructs the players in the fundamentals of a certain activity and directs learning strategies.

Behaviour elicitation: this is not solely related to monitoring the players during the game and generating usage statistics. Elicitation here implies adequate means to capture the semantic of decisional processes as an attempt at disclosing the cognitive abilities of the player. This is of ultimate relevance to the proper understanding of decision-making mechanisms and the implementation of persuasion strategies.

Behaviour persuasion: contrary to behaviour assimilation, persuasion has to do with the ability of the game to evolve behaviour 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 appropriated from the system’s point of view [2]. In the case of social-technical systems, such as transportation, this might well serve as an instrument to improve social awareness.

Assimilating behaviours by the players is perhaps a straight forward concept behind SGs, whereas elicitation and persuasion need further clarification, stir up many issues and pose important realisation challenges. In our view, behaviour elicitation is a suitable instrument towards a proper representation of the decisional mechanisms and cognitive abilities of agents forming up the artificial society underlying ATSS. We thus integrate SGs into the conceptual framework of ATSS by combining behaviour elicitation with the peer-designed agents (PDA), allowing players to feature their peer agents with their own idiosyncrasy.
Games in Transportation

The history of digital games in the transportation domain is not at all new. Before going further into our discussion, it is nice to have a short account of the interface between digital (serious) games and the transportation systems. Transportation has been one great application domain for the so-called simulation games. Driving simulators have been used for a long time, together with other similar examples, such as flight simulators, and other counterparts. They usually rely on heavy computer graphics and virtual-reality techniques to resemble the operation environment as realistically as possible to provide players with full immersion. In the case of driving simulators, for instance, they 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 is quite expensive to perform track practices and those are also limited by championship regulations.

A classic among teenagers, in early 1980’s, was “Enduro”, available for the Atari™ game console. Albeit mainly entertaining, it conveyed an educational dimension as players were compelled to drive cautiously under snow or in the dark. SimCity is another masterpiece among desktop computer games. Since its “Micropolis” version, in mid-1980’s, this game genre has evolved tremendously, emphasising 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 the 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, smart phones, and other portable devices to a great extent.

A couple of years ago, more or less inspired in the same genre of games as SimCity, IBM released an on-line serious games devised to help city leaders, businesses, and students realise ways to make cities work better. The free game, coined CityOne (http://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 e.g. energy, water, banking, and retailing. Also concerned with efficient and sustainable mobility issues in metropolitan settings, the European-funded project SUPERHUB (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 (http://www.waze.com/) is a nice example of gamification implemented as a community-based traffic and navigation app.

As far as ITS teaching and training are concerned, Adler et al. [3] envisage potential benefits of game technology as an educational aid to leverage ITS awareness, and assist transportation stakeholders in identifying and analysing ITS deployment issues. In the specific field of artificial transportation systems, Miao et al. [4] developed a game-engine-based approach to improve the modelling 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 modelled in detail.

Integrating SG into ATS

Overview of ATS

Due to 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, travellers can choose whether to travel or not, can change in any moment their planned itinerary, and their choices may 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 concept of smart cities pose additional requirements to which the user is central, not as easily integrated in traditional modelling approaches. In order to appropriately represent, test, and analyse transportation control and management strategies, Fei-Yue Wang devised and introduced the concept of Artificial Transportation Systems [5, 6, 7].
Basically, ATS goes beyond traditional simulation methodologies and integrates the transportation system with other socio-economical urban systems with real-time information resulting in a powerful tool for transportation analysis, evaluation, decision-making and training. Coupling physical and virtual systems on an integrated basis, it is possible to make real entities to interact with simulated counterparts in a seamless manner. The foundations of ATS are to be searched on the paradigms of multi-agent 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 ATS heavily rely on the paradigm of multi-agent systems, growing and breeding an artificial society of autonomous entities is far of being easy. This process, which is quite laborious, is generally based on the discretisation of highly aggregated social data, psychological-based behaviour analysis, and other similar studies. Rossetti et al. [8] provide a brief overview of contribution in ATSs development along three dimensions: modelling issues and metaphors for ATS models, architectures for ATS, and practical applications of ATS. However, it results that very little has been advanced in what concerns the appropriate representation of users and their behaviour, in the various dimensions of Intelligent Transportation Systems. In this article, we suggest the use of SGs as a peer-designed agent technique to bridge the gap between behaviour observation techniques and practical implementation of agents in simulated artificial societies.

**The role of SG in ATS**

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

![Methodological perspective for the SG-ATS integration.](image)

The identification of a **real-world ITS** ecosystem follows the same abstraction as presented by Rossetti et al. [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), travellers and other ITS solutions “live” and interact. The observation of traffic and transportation systems has been traditionally performed through surveys/questionnaires, video-streaming cameras and other type of sensors installed in the infrastructure. This process has benefitted enormously from rapid advancements in sensor network technologies. Alternative sources of information are also gaining some relevance, such as crowdsourcing, social networks and other forms of crawling the new frontiers of the cyberspace redefined by cloud computing. From the observations in the real-world ITS ecosystem, scientists, practitioners, and decision-makers build abstraction models and analytical tools with diverse purposes. Each of such tools, following the integrative perspective of ATS, can also be considered ecosystems in the same abstraction dimension.

Through rich graphics with 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 other facets of the system to be observed on a controllable basis, which would not be possible through experimentation with the real system, though. Different psychological experiments are carried out in such simulation environments, such as those using driving simulators and similar environments. Insightful analysis of intrinsic decisional mechanisms of subjects, either individually or in groups, may be performed with relatively high accuracy. However, such sort of simulators is
built on very complex and expensive infrastructures, and gathering subjects to participate in the experiments is another issue that may limit the scope of the studies.

The agent-based simulation ecosystem is actually where artificial societies (as a means to represent human behaviours and social interactions) grow and breed. The multi-agent system underneath takes into account the real-world society's evolving behaviour 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 non-trivial tasks.

Certainly, insightful knowledge originated 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 behavioural patterns are 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 cannot be seen merely as a technological system through which entities, either physical or artificial, interact. SGs can be seen as an interaction artefact interfacing the real-world ITS and the artificial society in the multi-agent simulation, as well as ITS users towards participative simulation (e.g. implemented as Web-based multi-player games), allowing us to capture the collective intelligence of the system.

This extended account of the concept of serious games in line with the integrative perspective of artificial transportation systems stirs up many application potentials, as well as practical implementation issues. Here SGs are used to disclose the decisional processes that are behind the course of actions people perform in order to achieve certain goals, to respond to stimuli or during deliberation. We call this behaviour elicitation. It is not just a matter of collecting data through logs of different and successive interactions of the player during the game for post-processing. We rather make use of the intrinsic nature of serious games to impel the player add semantics to every decision and action performed during the game that may better clarify the sequence of cognitive states that resulted in or triggered certain (course of) actions. In order words, we "ask" the player to model his/her own agent, in a process that is known by peer-designed agents (PDA).

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 not conclusive. Nonetheless, PDAs are found to be an important instrument that can alleviate the evaluation process of mechanisms (replacing people) and facilitate their design [11]. One practical example of peer-designed agents is reported by Chalamish et al. [12], in which authors conduct parking simulations of PDA-based driver agents, implementing strategies designed by users of the parking lot. 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 simulation and to SGs.

Considering now that PDAs reflect idiosyncrasies of players that designed them, then agents’ native decisional mechanism can be better analysed 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-centred instruments as an attempt at persuading agents to act towards the benefit of the whole system. Social awareness could then be conveyed through the behaviour 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 on-going projects to exemplify how SG and ATS can be practically integrated. Although prototypes are in their initial stages, they contemplate the aspects mentioned above.

**SPEED: Simulation of Pedestrians and Elicitation of their Emergent Dynamics**

The SPEED (Simulation of Pedestrians and Elicitation of their Emergent Dynamics) framework was conceived to study pedestrian dynamics and interactions, which concern reasoning processes, (path) planning, and all other aspects associated with the pedestrian movement in a variety of mobility settings, both indoors and outdoors [13]. This kind of tools 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 regarding emergency evacuation plans (Figures 3 and 4).

As long as modelling pedestrians is concerned, researchers and social scientists rely on data from questionnaires, direct observation, photos and video analysis their inherent dynamics. More recently high definition virtual-reality simulators such as CAVEs (cave automatic virtual environments) are used. Although empirical experimentations on such simulation infrastructures can be relatively expensive and are mostly laborious and time consuming, they are an integrative part of the methodological approach proposed, providing immersion and realism in the representation of the application domain.

The behaviour elicitation part integrates agent-based modelling, social simulation, and serious games, which is used both as a training tool and an important observation aid. PDA-based agents capture players’ behaviour during the game and are used to form up a synthetic population upon which social simulations reproducing various situations and what-if scenarios can be performed. The SG component is implemented in Unity3D (http://www.unity3d.com/), whereas the agent-based social simulation is accomplished in NetLogo (http://ccl.northwestern.edu/netlogo/).

Figure 2: Behaviour elicitation in SPEED

Figure 3: Analysing emergency evacuation plans in SPEED

**IC-DEEP: Simulation of Pedestrians and Elicitation of their Emergent Dynamics**

In-Vehicle Information Systems (IVIS) and Advance Driver Assistance Systems (ADAS) are systems used during the context of driving, where the objective is to deliver 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 analysed 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 usually data can only be collected 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 (Simulation of Pedestrians and Elicitation of their Emergent Dynamics) framework was created to meet the demand for rapid design-prototype-evaluate cycles in the development of IVIS and ADAS, as well as to improve driver modelling in microscopic simulation [14] (Figures 4 and 5). It is a low-cost platform composed of commodity hardware, game accessories, and a serious game (coined Serious Driving) developed in Unity3D (http://www.unity3d.com/). The concept of PDA is used to collect statistics of drivers’ performance in both primary and secondary tasks and elicit their behaviour 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 SGs to implement behaviour assimilation, behaviour elicitation and behaviour persuasion can be explored to their full extent.

**Challenging Issues and Opportunities**

While envisaging applications of SGs in the context of the integrative perspective of ATS, we identify some very interesting and stimulating challenges that are also research opportunities, as briefly discussed below.

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

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

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

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

**Conclusion**

In the past few years, Serious Games has gained a recognised prominence, with many potential applications transversally to diverse fields, naturally including ITS. In our view, the integration of SGs into the conceptual framework of ATS 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 ATS. The ability of SGs to foster behaviour assimilation, elicitation and persuasion allied to peer-designed-agents facilitates the formation of the artificial society underlying the concept of ATS. Further, the philosophy behind the concept of gamification, realised through social and location-based games, implementing appropriate incentive-centred mechanisms, can further promote social awareness towards future smarter and sustainable transportation systems.

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References


About the Authors

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. Dr. Rossetti’s research interests include multi-agent systems, agent-based modelling and simulation, artificial transportation systems, and spatial-temporal inference methods. Contact him at rossetti@fe.up.pt.

João Emilio 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.

**FIGURES**

Figure 1: Methodological perspective for the SG-ATS integration.
Figure 2: Behaviour elicitation in SPEED: in certain key instants during the game, the player must answer to questions trying to capture the rationale motivating their actions.

Figure 3: Analysing emergency evacuation plans in SPEED: In evacuation scenarios, one important aspect to study is how quickly individuals can find exits following standardised signs, especially when people are not acquainted with the space.
Figure 4: Evaluating ADAS in IC-DEEP: visual alerts show up on the screen whenever the player fails to keep vehicle’s trajectory within the lane, for instance; driving metrics are logged for further analysis.

Figure 5: Evaluating ergonomics of information systems in IC-DEEP: In addition to the primary task of driving, players must perform secondary tasks such as reading e-mails on the dashboard screen; secondary tasks may affect the player’s ability to keep vehicle trajectory.