Game-Based Modeling of Human-Driven Geographic Systems

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Abstract

Agent-Based modeling demands controversial inference on human behavior in unobserved circumstances. We argue that these circumstances can be created using Virtual Reality games and suggest merging between Serious Games and Agent-Based modeling into a Game-Based Modeling (GBM) framework. Human players and autonomous agents simultaneously participate in the GBM and human behavior is analyzed and transferred to autonomous agents until a Turing-like Interrogator is unable to distinguish between them. We illustrate the approach with a Cruising for Parking GBM.

Keywords: Agent-Based modeling; Serious Game; Virtual Reality; Game-Based Modeling

1. The insurmountable problem of Agent-Based modeling

Numerous spatial systems are driven by humans and during the last two decades Agent-Based (AB) modeling became the major approach to modeling them. It's now the time to admit that, despite reaching a mature technical state, the AB modeling approach has not become an *operational* tool of geographic enquiry. If so, what do we, the professional modelers, do wrong?

Three "rough guidelines for future modeling efforts" from the timeless "Requiem for Large-Scale Models" of Douglas B. Lee (1973) immediately come to mind. Lee calls upon:

- A balance that should be obtained between theory, objectivity and intuition;
- Starting with a particular policy problem that needs solving, not a methodology that needs applying;
- Building only very simple models.

Many of us follow Lee's recommendation and, nonetheless, our success in modeling and, especially, forecasting, socio-spatial phenomena remains very limited. The reason is clear - we fail to model human behavior, especially in situations that were not yet observed in the past. However, the forecast of system's dynamics in unobserved situations is the major motivation why we model in the first place. Is our modeling therefore just a Caucus Race, where we get prizes only for complicating the tools but not for explaining reality?

Technically speaking, the step from compartment modeling of the 80s to the ABM of the 21st century made geographic modeling lively, but did not resolve the inherent problem of interactions between model's components and its complicatedness, in Lee's (1973) terms. Actually it made things even worse: in addition to the standard model parameters, AB models demand parameterization of behavioral heuristics. More than 400 "sciencedirect.com" hits for "Schelling segregation model" clearly manifest that even conceptually simple models that involve agents' decision-making have enormous variety of dynamics (Hatna and Benenson, 2015).

The AB modeler that aims at the operational modeling of a particular policy problem does not have the luxury of a Schelling model student and has to assign to the model agents a specific set of behaviors. And then she must infer about the AB model dynamics in the circumstances that are qualitatively different from those observed in reality. Such circumstances demand modifying behavioral heuristics. Thus, the circle becomes vicious.

On the eve of AB modeling we were hoping that choice theory and stated preferences survey will supply the clues on human decision-making in yet unobserved situation. However early on in the 21 century this hope appears to have diminished (Klein and Ben-Elia, 2016). Choice models suffer from acute hypothetical bias and the more remote a situation or innovation is from everyday life the more difficult it becomes to capture human preference. Moreover, even if preference is captured without bias, few situations on which the human respondents were asked about cannot cover the spectrum of states the model agents are attempting to contend with.

The problem of modeling human behavior in unobserved circumstances is directly related to the problem of AB model validation (Ngo, See 2012; Sargent 2013). Exact science employs a predictive paradigm: use historical data for estimating model parameters and compare model outputs to the later reality. Circumstances that did not yet exist cannot fit to this paradigm. Can we rationally decide on agents' behavior in our models though? Are we able to validate AB models?

2. From stated preferences to virtual reality and serious games

The virtue of Virtual Reality (VR) is in the possibility of creating, with the computer, *any* circumstances. Development of the computer game software (e.g., www.unity3d.com), together with low latency 3D tracking Head Mounted Displays (HMD) makes the development of a realistic, dynamic and immersive VR almost a routine procedure comparable to development of standard AB model.

Let the VR represent the non-existing reality, let humans be immersed, with a HMD, into this VR and perceive it, and let's ask them to imitate activities they would perform in reality when choosing the apartment in the city or travelling to work. In other words, ask humans to play a Serious Game. Different from reality, in VR we can possess a full log of human actions in the serious game and, thus, could infer about players behavior in all possible aspects, including their learning, competition, cooperation or more complicated form of social interaction (Helbing et al., 2005; Bainbridge, 2007). Dynamic, realistic and immersive VR can be populated with many actors and in this way the game becomes a social game.

3. From games to game-based modeling

Under the name of Artificial Life, serious multiplayer social games have become very popular towards the end of 20th century. The Well-known 'Second Life' (www.secondlife.com), 'The Sims' (www.thesims.com), or 'SimCity' (www.simcity.com) have millions of users and, visually, are highly realistic. Should we use or reproduce these games as an environment for the future AB models?

According to Lee's guidelines, the Artificial Life games are yet too complicated for being a tool of socio-economic geographic enquiry. Riensche and Whitney (2012) were the first who merged between games and Lee's limitations specifying Serious Analytic Games (SAG) within the serious games, as "focusing on tapping into the knowledge and ability of players". At the micro-level, players' actions in SAG are evaluated for realism and potential for real-world occurrence. At the macro-level, these games generate a library of histories, which can be used for calibration of the ABM (Riensche, Whitney, 2012) and can serve for establishing behavior of autonomous agents in this model.

We argue that we must go beyond and fully fuse the ABM and SAG into a Game-Based model (GBM). GBM considers VR of SAG and involves both humans and computer agents who react to each other without knowing who is who. Human participants see GBM as a serious VR game where they will pursue their residential or travel objectives while competing or cooperating with other players and agents. Agents react, according to their behavior heuristics, to the collective dynamics of the GBM.

By comparing game/model outcomes for human and autonomous agents, we are able to learn whether our formalization of behavior is good enough to make agents similar to humans. We follow Turing's Interrogation Test (Turing, 1950) concept for this comparison.

4. Turing-like validation of behavior within game-based model

Let us interpret Turing's Interrogation Test (TIT) for the GBM as follows: An external observer of the Game-Based Model should not be able to recognize who of the players is human or autonomous agent. TITs of several kinds can be suggested:

At a global level:

- estimate game outcomes for human players and agents and analyze the differences;
- vary parameters of agents' behavioral heuristics and investigate differences in game outcomes;

At a level of game player/agent:

- Analyze human's/agent's decision-making in one-to-one interacts with another human player or agent and compare those for different composition of a pair;
- Analyze human and agent's decision when interacting within larger groups, depending on the group human/agent composition;

At a level of game progress:

- Based on the game log, restore the game that lasted time T, and $t < T$. Substitute, all human players by agents, let the game continue until T and compare games outcomes;

At a level of interrogation:

- Interview human players and ask who of the other players were humans and agents;
- Present players' outcomes to external observer and ask who are humans and agents.

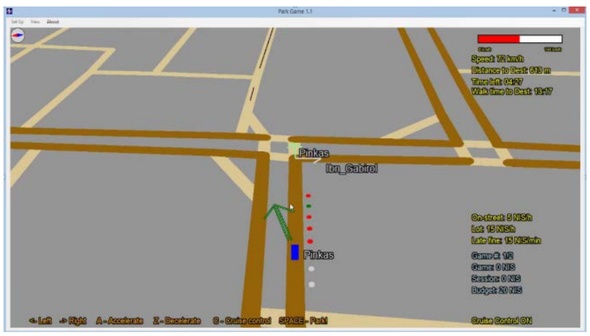
Various research tools can be employed in the TIT tests, including visual and statistical analysis of behavior of every participant and game outcomes. Being not able to distinguish between the "human player" and "model agent" behaviors in any respect, we could claim that agents' behavior rules satisfactorily represent behavior of human players.

TIT-based validation enables iterative development of the GBM. We become able to respond to the gaps between human players and agents by altering or updating the rules, and resubmit the model to TIT tests.

5. Pilot GBM of parking search in the city

To investigate the concept of GBM we have chosen the phenomenon of urban parking. Urban parking perfectly satisfies three of Lee's criteria: We possess essential theoretical and empirical knowledge of the parking phenomenon; congestion is an acute problem for almost every large city; the parking problem can be seen as "simple". Even though, our knowledge on drivers' parking behavior is limited and the consequences of parking regulations or prices are still a mystery.

Our "Cruising for Parking" GBM merges extensive field research (Levy et al., 2013), Serious Analytic Park Game in its 2D form (Ben Elia et al., 2015) and a new VR version (Figures 1a,b,c) and Levy et al (2013) ParkAgent AB model of parking search in the city (Figure 1d). We employ "Cruising for Parking" for illustrating principles, outcomes and problems of the GBM.



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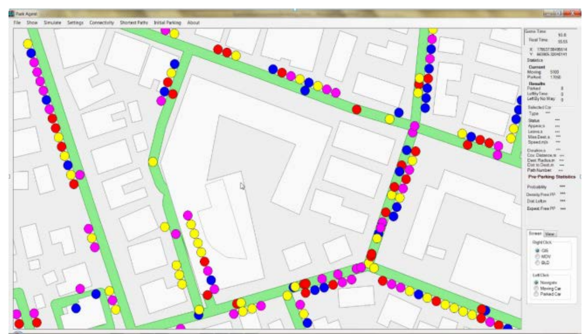

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Figure 1. Components of the Cruising for Parking GBM: (a) 2D version of the Park Game; (b) Human player using Oculus Rift HMD for playing Park Game; (c) VR version of the Park Game as observed by the human player; (d) ParkAgent AB simulation model

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