The role of agent-based simulation in recreational management and planning

Hans Skov-Petersen

Abstract — It is expected that agent-based simulation models will be increasingly implemented during planning and management of visitor landscapes. This expectation is based on a) changes of recreation towards greater visitation levels and more complex settings in terms of stake-holder interests, recreational behavior types and a higher focus on protection of biodiversity, b) technological development of digital equipment, and c) a changing approach to nature planning and management to be more open, inviting and aimed at stake-holder and public participation. Based on these three lines of sight, the paper will discuss future trends in application of ABM's in recreational management and planning.

Index Terms — Agent based models, ABM, simulation, recreational management and planning

1 Introduction

This paper is about the present and future role of agent-based simulation models (ABM's) in recreational management and planning. A founding pillar of the paper is the work carried out during the compilation of the book 'Monitoring, Simulation and Management of Visitor Landscapes' [6] co-edited by Professor Randy Gimblett of the University of Arizona and my self. I want to express my gratitude especially to Randy and also to the contributing authors for a very inspiring collaboration.

In the paper I will assess a number of issues related to ABM's in the context of visitor landscapes. I will discuss observations and express views on the present state and provide some considerations of what will – or should – be the potential directions for the future development. I would like to stress that I do not see this as only including development of the technical capabilities of the software. Further development will to a very high extent also include focus on behavioral epistemology on one hand and the human and organizational context to which the models is intended to be applied to on the other.

It is expected that there will be an increasing interest in application of ABM's in relation to recreation. Drivers for such a future development include:

- Changes in recreation due to
  - Increased pressure on nature as a consequence of population growth and urban sprawl
  - Increased participation in recreation
  - Diversification and specialization of recreational activities
  - Environmental change, for instance in relation to global climate change
- Technological enhancements
  - Computer power (CPU speed, RAM and storage)
  - Software development frameworks (Object Oriented Programming, gener-

*Hans Skov-Petersen is with forest and landscape Denmark, University of Copenhagen. Email: hsp@*life.ku.dk

al purpose ABM-platforms and libraries, and Internet based visualization, interaction, cascading etc.)
  - Monitoring and sampling devises (GPS, automatic counting, CCTV, etc.)
- Changes in planning and management paradigms
  - Multi stake holder involvement
  - Public participation
  - Environmental education and awareness

After a brief review of motivations to apply models in general - ABM's in specific - in the following section, the paper will proceed with a discussion of these three main drivers (changes in recreation, technology and management/planning paradigms) and their possible implications on future development of ABM's in relation to recreational management and planning.

2 Why model at all?

One way to define the concept of 'models' – of which agent-based simulation models is a sub-category – is that they are idealized representations that takes up less 'space' than the phenomena they represent. The space can be in terms of concepts, data, processes, etc. Which components to include or excluded, and to which degree of detail they are represented will – of course – be a matter of the phenomena modeled and the issues in focus. A non-exhaustive list of reasons to embark on modeling includes:

- By simplification and idealization to focus on issues of interest and thereby gain knowledge and insight.
- To compensate for lack of data (for instance in situations where data from remote locations are hard or expensive to obtain)
- To test possible future situations (construction of scenarios)
- To use the models' idealized image of real-world phenomena as a platform for communication including environmental learning situations, behavior studies in cyber space, participatory planning processes etc.

A discussion of these broad motivations in more direct relation to recreation can be found in [10] and [18].

Agent-based models are constituted by the individual actors of the system represented. A premises is that it is the behavior, abilities, preferences and motivations of a set of individual components that is know and that it the 'reaction' of the 'system' that is of interest. For instance we assume to know the probability by which campsites will be frequented by visitors from a given entry point; the 'systems response' we are looking for could be at which locations of the path network a high frequency of encounters will take place.

3 Changes in recreation

Whereas the earliest recreational behavior models were aimed at fairly extensively used nature areas [21] several of present day systems are developed for and applied to more urbanized settings including high use nature areas [20], urban forests, city parks and even botanical gardens [11] [1]. These types of areas are often characterized by much higher visitation levels; more diversified types of recreational activities and a higher management level including more dens and sometimes more segregated path networks. Whereas earlier models designed for less intensively used environments were based on *probabilistic agents* precoded to follow specified tracks to predefined location, this complexity calls for more focus on the underlying behavioral processes of the recreational activities. This goes for both the motivations and preferences behind activity types and user groups [7]

[1] Here in fact development of recreational simulation models meets models developed for pedestrian simulation in urban settings including street festivals [2], train stations [4] and museums [2].

and the choice processes guiding the selection of recreational destination [8] and when moving around inside the recreational area [9 and 20]. Settling motivations and choice processes enables design of *rule-based agents* which will behave in accordance with their motivation and abilities on one hand and information perceived from the environment and other agents. Rule-based agents can be *goal-oriented*, striving to fulfill a given objective (for instance to shoot a bear [15]). Often recreation – at least as part of daily life activities – is not driven by achievement of specific goals in terms of locations to go to or utilities to obtain. Frequently the time spend as enjoyable as possible is the goal by itself. In that case the focus must be on the (spatial) choices made to enhance the appreciation of the trip in accordance with preferences of the agent type in question (see for instance [9] or [20]).

Choices are based on perceived local information (for instance characteristics of optional path segments connected to a junction to the path network) and global knowledge (for instance the approximate location of the trip's point of origin). It appears that the distinction between local and global knowledge still have to mature in the modeling community. An example could be application of a route between a point of origin in a path network and a destination. Applying a generic GIS-based search for the shortest route assumes perfect, global knowledge of the agent (from e.g. a map or by knowing the area). A newcomer would have to make choices based on what appears to be the most feasible looking at options from the present junction. Another example is the search of the most appreciably route based on global knowledge of the entire area is a different situation than choosing path segment one by one, based on local information from the immediate surrounds of the actual location of the agent. Without a distinction between perceived local information and global knowledge it will be impossible to assess situation where different attitudes of well acquainted locals and 'tourists' visiting an area for the first time. Further the effect of providing 'global knowledge' to visitors (for instance in the form of leaflets, maps etc.) will be hard to model.

Overall representing knowledge is rarely considered as a specific issue in relation to simulation of recreational behavior. How perceived information is compiled to knowledge, how it is stored, applied and communicated are topics that are intensively discussed in relation to general agent-based modeling and Artificial Intelligence [1], but – as observed above – rarely in relation to recreational ABM's. Cases where representation and handling knowledge about nature areas is important include effect of:

- different signage strategies
- maps and brochures
- knowledge exchange between visitors
- knowledge exchange between stake holders

The close relation between use and disturbance is an ever present core of planning and management of recreation in nature. Simulation models of wildlife behavior on one side and visitor behavior on the other have developed separately; both in terms of the applications developed and the scientific groups involved. A range of examples exists where animal and visitor models have been loosely coupled (for instance [16]), but models that dynamically and concurrently models both wildlife and visitor behavior is yet to be seen [20].

4 TECHNOLOGICAL ENHANCEMENTS

Following Moore's law (the number of transistors that can be crammed onto an integrated circuit is doubled every 2 year [14]) almost every capability of digital equipment is increasing dramatically. This goes for CPU speed, memory capacity, digital camera resolution etc. Accordingly the size and complexity of the applications (including ABM's) that can be executed will increase. Size in term of the number of agents that can exists concur-

rently in a model, the scale, geographic size, and the number of layers of the environment that can be included; complexity in terms of different agent types and perceptive/comprehensive/reactive capabilities agents can be given. Further more options will be given to program agent's learning/memory/communicative capabilities. The massive development of Internet applications – not the least in the direction of geographic capabilities (for instance GoogleMaps [22]) raises expectations of more communicative and end-user oriented development of ABM's.

The number of simulation systems or platforms for developing ABM's is still increasing; both in terms of toolkits and more or less complete applications. Toolkits include well known systems like SWARM and Repast, but also an incredible number of other options. The toolkits are supplied as libraries and API's and requires a substantial amount of programming knowledge and effort. The advantage is a much higher control over the systems capabilities, than in cases of more fully developed systems. Another advantage is that toolkits allow for further integration with other toolkits for instance GIS-packages. On the other hand a number of open source/freeware ABM packages, including StarLogo and NetLogo, are available serving as general purpose platforms, with limited development potentials.

For a more comprehensive discussion of available software options relevant to ABM development, refer to [3].

Packages/systems presently in use for recreational simulation include

- RBSim (Recreation Behavior Simulator) [5], developed by Randy Gimbeltt and Robert Itami, has in various versions been applied to a range of case studies throughout North America and Australia over the last decade.
- MASOOR (Multi Agent Simulation of Outdoor Recreation) [9] developed by Alterra of Wageningen University and Research Centre (Holland), has been used for studies of recreational behavior in high visited nature areas in a number of Western European countries.
- iRAS (Intelligent Recreational Agent Simulator) [11], based on the commercial software JACK™, developed by the University of Melbourne. Applications include a model of the Royal Botanical Gardens in Melbourne.
- Extend [10] has been used for modeling visitor behavior in North American parks. It is a commercially available, generalized simulation software, which in this case can be applied to ABM.
- Kvintus.org is developed by a team at the University of Copenhagen (Denmark) [20]. It is based on the simulation toolkit Repast and is a present applied to a number of Danish nature areas of high use levels.

All examples mentioned above are based on visitors' movement along a predefined transport network (which most frequently represents a path- or road network). In cases where animal behavior and/or off track visitor behavior is included in the model this vector-based core has to be extended to include a raster representation of the landscape in general. In Kvinuts.org raster-based behavior is applied to roe deer and will be developed further to enable visitors' off track movement. If wildlife disturbance is to be an issue in future simulation models such raster/vector integration is a mandatory point of development.

The technological development also includes a range of new equipment for monitoring/tracking: GPS both as dedicated devises and integrated in other electronic devises (for instance mobile telephones) appear to be among the most promising. In applications reported to date tracks obtained from GPS-equipment has been used entirely for qualification model results (i.e. visitor loads on path segments registered by GPS has been used to validate results of simulation models, see e.g. [9]). It can be expected in the future where a greater amount of tracks through visitor landscapes can be obtained, that e.g. choice

and preference parameters can be revealed and applied to ABM's. The expectation of access to greater volumes of tracking data is based on reduction of the price of equipment and/or data handling, or by access to 'tracks' of visitor' mobile telephones.

For a comprehensive assessment of devises and methods applied to visitor monitoring and simulation refer to [19] and [23].

5 CHANGES IN PLANNING AND MANAGEMENT PARADIGMS

Managing and planning nature is no longer just an endeavor of the legal managers or owners of the land. Nature conservation and public access to enjoy nature is a matter of great public interest. Further the way nature is managed often has a significant impact on other issues of physical planning including economy (timber production), ground water protection, CO_2 demobilization, protection of biodiversity, protection of indigenous peoples' right etc. Accordingly the tools applied to optimize resources and to resolve conflicts must be more than just deterministic 'machines', leaving no space for debate or alternative views. There is an expectation of ABM's to have a major potential in relation to planning processes. This is mainly due to this model types' transparency due to its basics on the individual agent. It is relatively easy to accept the models outcome if the behavior of the premises of the individual agent is accepted. Pröbst et al [17] lists 11 key factors that has shown to be important for the potential success of ABM application. Including (non exhaustive):

- Complexity of the management tasks
- Diversity of factors determining visitor behavior
- Size and type of area
- Number of anticipated/planned changes
- Planning process diversity

In general it is concluded that the more diverse a physical setting, the behavioral factors, planning themes and process, the more likely it is that the application of ABM's will be successful [17].

Model builders – including those constructing GIS-models for spatial decision systems – are often wondering why so few of the expected end-users are actually picking up the new 'toys'. Macmillan [12] for example, wonders why so few urban planners actually use the analytical capabilities of GIS while millions of copies of PC programs like SimCity can be sold. He concludes that 'It is a nice irony that as modelling has fallen out of favour with academic greybeards, children have taken up the challenge'. While focusing on individual behaviour commonly associated with ABM's, they closely resemble the functionality of computer games. Accordingly there is an expectation that the comprehensiveness of ABM's can be accepted to a higher extent than more aggregated models used in the past to support planning. Further it is apparent that ABM's could play a role in the future to aid learning processes – both in schools and colleges, and as part of professional training and public awareness campaigns[13]. Students or planning participants could be allowed to 'play' with the future and thereby not only search for solutions to present or future challenges, but also immediately see the 'global' effects of local actions. The agent-based approach would allow for assessment of global effects of individual actions. For instance school children could ask: 'What would this area look like in ten years, if I threw five pieces of litter every time I visited it, and everybody else the same?'. Or motor enthusiasts could ask: 'How many hikers will be disturbed if I and 10 other parties per weekend would be allowed to ride our ATV's on the AT?'.

6 CONCLUSIONS AND PERSPECTIVES

The technological capacity of computing is increasing at a breathtaking speed. Parallel to these rapid technological changes is our

growing understanding of the complexes of motivations, preferences, choices etc. behind visitor behavior in recreation settings. Finally key planning and management concepts – at least in the developed and democratic parts of the World – are openness and participation, especially in relation to local planning and management. Stake holders and laypersons are to a much higher extent than earlier invited to play an active role when management- and strategic plans are formulated.

Agent-based simulation models are highly capable of handling complex behavioral phenomena, and at the same time well suited for open and participatory problem solving and have been shown to lead to a more thorough understanding of ecological and social processes. Driven by these three concurrent forces there is a *tremendous opportunity now and in the near future* to further develop and apply ABM to facilitate recreational planning, management and protection of the natural resource. No matter how much our computational power will evolve, how much we invest in the understanding of complexities of behavioral psychological theory, and how much time is spent applying this technology, a measure of success will be achieved only if computer scientists, geographers, biologists, behavioralists, planning process specialists and of course planners and land managers work together towards a common goal.

It appears that assessment of the quality of ABM's to date has been focused on how well aggregate model results corresponds to real-world monitoring data. If – as expected – there will be an increased focus on the communicative and participatory potentials of simulation model, we must in research to come, set the scene to enable structured and systematic assessment of the quality of the systems in terms of benefits they provide to the planning processes they are applied to, and ultimately the quality of the resulting plans and management strategies.

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Hans Skov-Petersen Ph.D. Geography (2002), M.Sc. Horticulture (1989). County of Funen (1989-1990), CADPOINT inc. (1990-1992), Land Use Planning Project, Bhutan (1992-1995), Forest and Landscape Denmark (1995-date). Editor in charge: Perspektiv (Danish GIS-Magazine). 23 international papers (14 with review). Books: Visitor monitoring in nature areas – a manual based on experiences from the Nordic and Baltic countries (2007). Forest recreation monitoring – a European perspective (2008). Monitoring, Simulation and Management of Visitor Landscapes (2008). Interests: GIS, Spatial/temporal analysis, recreational monitoring and modeling.