Kvintus.org - a choice based agent-based simulation model integrated with Google Maps

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Abstract — Kvintus.org is a new agent-based simulation tool especially constructed to model recreational behavior integrated with models of animal behavior. The entire model which is available as 'open source' is based on the generic software package REPAST [4]. Model configuration – in terms of base parameters, entry points, timetables, agent types and state/transitions – are established, manipulated, loaded and saved via XML-files which enables a high degree of flexibility and user interaction. At run time, agents can be displayed in Google Maps [1]. This way models can be applied in most regions of the World without access to base maps, aerial photos etc. Further – which is probably even more important – using a standard Internet platform like Google Maps it is possible to enable non-expert users to 'play with' the models and this way focus more on communicative and participatory aspects.

Index Terms — Agent-based simulation, choices, Google Map, recreation.

1 Introduction

Kvintus.org is an agent-based simulation system for modeling the impacts of recreation activities on ecological and socially related phenomena. An agent-based system – or Agent Based Model (ABM) - has the individual person or animal as its basic unit. 'Agents' have goals, abilities and preferences, and can perceive and comprehend their surrounding environment and accordingly make decisions about which action to take. Decisions include movement patterns, mood changes or modification to behavior. ABM's are executed in discrete time steps in real world time units (for instance one step per 30 seconds). In each step, all agents present in the model will perceive, comprehend and take action according to the environment, other agents, goals, abilities and preferences.

Further at each time step it is checked if the model has expired its endTime, if new agents should be created and if exiting agents has met their obligation and therefore has to be removed from the model. See fig. 1.

ABM's are in particular advantageous in situations where the behavior of individuals is assumed to be known and it is the overall performance of the 'system' that is of interest. We might know where a certain group of visitors would like to go. For instance we might know how many entries there are during a day, but we do not know where in the area problems related to congestion might occur, and we do not know what will happen if access points are added or changed, or what happens if the level of visitation is increased.

Further ABM's due to their resemblance with computer games are expected to be

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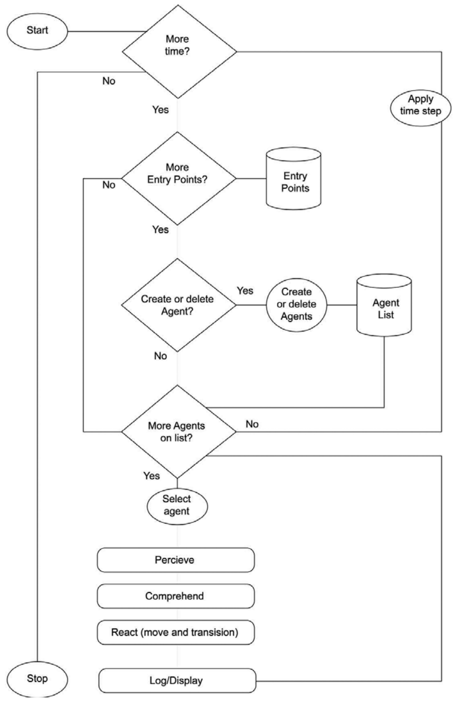

Fig. 1: Flow chart of the model.

more appealing to end users than other types of models and information systems. Accordingly it is expected that ABM's can be applied effectively in participatory planning and management processes [3].

2 Background

The Danish nature is a popular site for recreational activities. Is has been estimated that an annual average of 75 Mill. visits tales place in the nature [2] a level of visitation that is increasing. Accordingly there is a need for assessment of the distribution of recreational disturbance – both socially and in relation to biodiversity. The development of Kvintus.org was initiated by the Danish Forest and Nature agency (based on the revenue from game licenses) to facility such an assessment.

As a point of departure the model is applied in two Danish forests: Rude Skov north of Copenhagen and Hestehaven in the easternmost part of Jutland.

3 Kvintus.org

Kvintus.org is to some extent based on the generic package REPAST [4]. In its present form the main purpose of Kvintus.org is to simulate recreational behavior in natural environments and to a lesser extent the behavior of selected animal species. The simulation of visitor behavior is (in the models' present version) based on movement along the path network of the areas analyzed. Animal movement and associated behavior (at present only applied to roe deer) takes place freely across the landscape.

The model is programmed as a finite state machine. I.e. the behavior of the agents of the system is defined by a discrete number of possible states (types of behavior). An agent can only be in one state at a time. Each state defines the actual behavior and the transition rules that can make the agent change to another state. In Kvintus.org *transitions can also be issued as a function of time* (which is, strictly speaking, external to the state it self). For instance an agent type can be defined by three states: 'walk away from the car into the forest', 'walk around in the forest' and 'get back to the car'. Further transitions can also be *'tricked' by events* e.g. encountering a nice spot for mushroom picking or being scared by a dog. In relation to animal behavior, the temporal transition rules can include the periods an entire day spend on sleeping/resting/ruminating/sleeping and eating/foraging.

At each time step – as indicated in fig. 1 – agents are going through three behavioral stages: Perception, comprehension and action (PCA). During perception the agent senses its surroundings (type of network edges ahead, whether or not a choice has to be made, can other agents bee seen etc.). The sensory information is merged with the abilities and preferences of the agent in the comprehension stage, which leads to a decision of which action to take. An action will typically be movement to a new location, but can also include changes in mood or transition to a new state.

Simulation outputs can be produced in a number of ways including; statistics on the number of agents that has traversed individual network edges (most useful when modeling visitor behavior), the number of agents that have been 'locations' represented by cells of a predefined size (especially useful when modeling animal behavior), a comprehensive log where each agent's locations and mood is recorded for each time step. The comprehensive log can be used when the preset aggregations are not considered sufficient or replaying simulations that already have been executed.

4 Human agents (network)

Individual visitor-agents can either be directed towards a given point of interest (waypoints) or make their way according to choices made at every junction (node) of the network. An agent performing *waypoint behavior* is guided towards a given location in the network. At junctions choices are made between those of the optional edges that enable reaching the way point within the shortest possible path multiplied by a 'strayfactor'. I.e. alternatives to the single shortest path can be applied. During *choice-based behavior*, decisions are made at junctions based on a set of weighted parameters. Which parameters are included and how their present values are evaluated is part of the state a given agent. An example of such a choice parameter is the slope of the edges leading away from the actual node in which the decision is to be made. Different agent, in different states, will have different attitudes to the magnitude of the slope: Elderly people might prefer gentle slopes or flat terrain, whereas mountain bikers are expected to like the adventure and exercise of steeper path segments. In the present version of the system the parameters in table 1 are included. As can be seen some parameters are coded directly as (static) attributes on the edges of the network, whereas some (dynamic) parameters has to be gained from the model at run time.

5 Roe deer agents (raster)

Animals are guided by a set of polygon representing 'ranges' for different states – i.e. types of activities (e.g. eating or ruminating) and a set of selection criteria for land cover preferences. As for the choice parameter applied to choices made at network nodes, preferences (and accordingly choice parameters) are declared as part of the state definition. An event-driven transition rule is applied to the roe deer agent. When a roe deer 'observes' a visitor, it runs a specified distance directly away from the person it sees. After feeing (and hiding) it will regain the state dictated by the temporal transition schema.

6 Model configuration

The model is constituted by a range of components. Including:

- ❑ base settings and administration,
- ❑ logging, output and display environment,
- ❑ geographical environment,
- ❑ timetables and entry points,
- ❑ a set of agent types, and
- ❑ a set of stages (types behavior).

All components of a model are stated by the user in XML-format. This means that a model – including new locations, entry points, agent types, and states - can be set up without recoding.

6.1 Base setting

The base settings include the name of the model, start- and end- time and date of the simulation, the duration of the time steps, and configuration of the output/logging environment. In the present version the output is provided in three files: Gross statistics, Edge statistics, Location statistics and Comprehensive logging.

Gross statistics is the number and distribution of agent types over bands of time (e.g. hourly). Further also distribution of agent types over moods can be generated.

In edge statistics the number of agents that have traversed each edge of the network is written to a file. The information in the file can be joined to the network (in a GIS system) to visualize the load of the network during the simulation. In location statistics the number of agents that have been in cell-locations (cell size will be equal to the size of the land cover grid). Location-based statistics is in particular useful when non-network agents (for instance animals) are active. If comprehensive logging is activated type, mood, edge-id (if in network mode), and xy-coordinate will be logged for all agents, at all time steps. This file will obviously be very large if the duration of the simulation is long, the number of agents is high and the time step is short.

6.2 Environment

The environment is defined by a *network*, a *land cover grid* and a *digital elevation model* (DEM). The files representing the environment are stated in the model XML-file.The network is loaded from a file in ESRI Shape-format. The network topology (edge-node) will be generated at loading. Nodes will be snapped according to a used defined snap tolerance. All edge attributes are loaded with the shapes. The generated nodes (including statistics of use) are stored in separate files with the remainder output. The DEM and the land cover are loaded from ESRI ascii grid files. It is assumed that all environmental data are present in the same projection and datum. Overlap (if the data sets represent the same area) will be checked at loading.

6.3 Timetables and entry points

Entry points are identified by a name and XY-coordinates (which will be ‘snapped’ to the closest node of the network). Further – to control the order and amount agent creation – entry points are coupled to time tables (providing the average number of new agents in two hour intervals) and a list of agent types and their relative distribution.

6.4 Agent types and states

An agent type is defined by name and – in the case of visitor agents - the time available to the visit. Further an agent is defined by an ordered series of states it will traverse during its’ ’life’. The distribution of time, relative to the time available to the entire visit, will be given too.
A state is defining activity either on or off the network. At present the only off-network activities enabled are those related to animal behavior. A state is defined by a speed of movement, an optional waypoint (for network activities) and/or a set of choice parameters. When a waypoint is provided a ‘stray factor’ is given. The stray factor expresses how much longer than the shortest possible a route to the way point can be.
For network states choices are made every time an agent passes a node in the network. Choices are made between the edges that connect to the present node. The choice is based on weights put the possible values that characterizes the options (i.e. the edges). Characteristics can be both attributes to the edges (precoded before loading the network into the model) and values obtained by specified choice functions. Edge attributes can for instance be pavement type or aesthetic beauty along the edge. An example of a specified choice function can be the number of agent that can be seen or the Cartesian angle of the edge compared to the angle to the point of departure of the visit.

7 Kvintus.org on the Internet

Goggle Maps [1] is selected for displaying the movement of the agents at run time. While the simulation-engine itself will (and can) run off-line on a standalone PC, Mac or other type of workstation, displaying the agents’ movement requires Internet access. As an alternative to the workstation mode, the entire system is planned to be operational entirely from a web-browser, as a ‘thin’ client.

Figure 2: Screenshot of Kvintus.org at Google Maps.

While displaying the normal Google Maps functions of zooming, panning and changing background maps and aerial photos are enabled. Further a set of basic model parameters (the present model time, the number of active agents etc.) are displayed.

At run time agents can be 'tagged' and 'dragged' to a panel next to the map, so that their present information (including agent type, age, remaining time, stage, and mood) is displayed. Changes in mood are visualized as changes in color of the individual agent. Information about the agent (type, 'age' and mood) can be displayed by clicking the agent symbol.

In most cases the simulation itself will run much too fast to be displayed. Therefore the model has to be slowed down if displaying Is required. This is done interactively by a 'skater' in the GUI. Accordingly and because display itself is a time consuming process most model run will efficiently be performed without display. Never the less display is a very effective mean of debugging and model performance control. Further it could be expected that run-time display will help attracting the attention of lay persons and other non-scientific stake holders to the phenomena addressed by the simulation.

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