An Agent-Based Simulation Model of Visitor Behaviours for China Tourism Attractions[1]

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Abstract

In order to manage visitors in tourism attractions in a predicted rather than a reactive way, this paper proposed an agent-based simulation model for visitor management of China tourism attractions. The model integrated Repast Simphony (Repast S) modelling framework with geography information system ArcGIS's Shape data model and runs on Repast S running platform. Visitors were modelled as artificial Agents having their own decision making capabilities. Visitor data observed and tracked at "May 1" holidays of two years from the Summer Palace Beijing were used to do the verification and validation. Simulation results demonstration the model's ability to capture visitors' temporal and spatial distribution and provide decision making support for visitor management in tourism attractions.

Keywords: agent-based modelling; visitor modelling; simulation; tourism attraction;

1 Introduction

Recent years, in China Golden Weeks and even short holidays, many well-known China tourism attractions encounter large amount of visitors and continuous peak flows. This results in many challenges for sustainable development of attractions, such as visitor safety, experience quality, conflicts between uses and protection. It is urgent for China tourism attractions to eliminate such negative affections of use and environments, balance them and make a sustainable development of tourism attractions. Visitor management is critical to solve such problems.

Using computer simulation to study visitors' behaviours for park or protected area management has thirty-year history. However, they didn't clearly specify visitors' decision making algorithms or rules (Gimblet, 2005). This makes the interaction rules between visitors and the visiting environments undiscovered and thus the agent-based simulation of visitors' behaviours in tourism attractions unconvincing. This paper bases on an integrated agent-based simulation architecture to propose a visitors' behaviours simulation model. In this model, visitors' decision making is based on a

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dynamic decision making algorithm. The proposed model is validated in the Summer Palace, one of the famous China tourism attractions, visitor load increasing year by year. The validation experiment indicates the proposed model can reflect the real visitor distribution in the Summer Palace, Beijing. Analysis of the simulation data produced by the model running provides some critical visitor management implications for China tourism attractions.

2 The Visitor Behaviour Simulation Model

The architecture of the proposed simulation model integrates the elements of Repast Simphony (Repast S) 2.0. and ArcGIS 9.3. It consists of four kinds of key elements: various Agents， Agents' abstract organization Contexts and sub-Context, the interaction organization between Agents Projection and the geographic environmental elements in format of Shape documents (Howe, et al., 2006).

2.1 Contexts and projections

The visitor behaviour simulation model has three layers of Contexts. The highest layer is Tourism attraction Context; the second layer is Scenic Stop Context and Visitor Context; the third layer is Road Context, Stop Context, Junction Context and Area Context, which are sub-Contexts of Scenic Stop Context. All Contexts have such properties as Year, Season, Week, Time and Weather, etc. Stop Context has such properties as Altitudes, Weights and Heights of buildings, etc., as well. The Projection of Junction Context is Network. The Projections of other Contexts are all Geography because visitor behaviours closely relate to geographic data, such as roads, altitudes, natural and culture scenery, etc.

2.2 Agents

Visitor Agents. Visitor Agents represent the visitors in tourism attractions. Each Visitor Agent has static properties such as ID, Name, Visit types (Individual or Group), Age group, Preferences, Visit objective (sightseeing, recreation, exercise, etc.); and dynamic properties related to visitor behaviours such as Visiting directions, Visiting speed, Staying time at scenic spots, Sign of leaving tourism attraction etc. The values of dynamic properties change with the moving of visitors and the changes of time and space environments visitors are involved in. The values of both static and dynamic properties decide Visitor Agents' behaviours. Basic behaviours of Visitor Agents involve moving and stopping at a Stop (taking photos, resting, etc.).

Roads and Junction Agents. Road Agents and Junction Agents represent roads and junctions in geographic environments of tourism attractions, respectively. Road Agents have properties ID, Identifier, Junctions, etc. Junction Agents connect the edges of ArcGIS network graphs into roads. The interaction structure of Road Agents is Geography Projection. A Junction Agent has properties like ID, Geographic coordinates, Roads connected to itself. The interaction structure of Junction Agents is Network Projection.

Stops and Area Agents. Stop Agents represent the places where visitors could stay. Stop Agents have properties like ID, Geographic coordinates, Function, Attraction, Status, the Number of Visitors, etc. Functions could be Scenic Stops, Service Center, Parking Lot, Toilet, Shopping, Food, Resting, etc. Attraction refers to the extents the Stop could attract visitors, which could be related to some properties of Contexts like seasons, weathers, etc. Status refers to the service status of Stops, such as Normal, Full Repairing, Partially Repairing, etc. The numbers of visitors dynamically get values from Stops' Context. Area Agents refer to a congregation of close Stops, Roads and Junctions connected with the Stops (including water areas which can ship visitors or provide visiting service by ships).

2.3 Dynamic decision making of Visitor Agents

After a Visitor Agent arrives at a Stop and stays for a while, it needs to make a decision on where to go next. There are many factors that affect the choices of next Stops, such as properties of Contexts like time, seasons, weather, etc., and properties of the next Stop like function, attraction, status, etc., and even the routs leading to them. In this study, we choose the most effective factors to China visitors in China tourism attractions: (1) time cost to go to the next stop; (2) attractions of the next stops.

With regard to what a Visitor Agent also need to decide when it arrives at a Stop: how long it will stay in this Stop and by what a speed it will go to the next Stop, in current research stage this study applies statistic methods. The choices of stay time and visiting speed base on the statistic data of collected samples in terms of different time periods.

3 Simulation

This study takes the Summer Palace Beijing of China as case study. Two years of data collection focus on the Long Promenade area, one of the areas with heavy visitor load in the Summer Palace. The collected visitor behaviour data is used to configure running parameters of the model and validate the model.

3.1 Data Collection

Data was collected two times in two year. The first time is 3 days, 1st to 3rd of May, 2012 (China "May 1" holidays). The second time is 1 day, 1st of May, 2013. Each day data was collected from 8:00 to 17:00 in two ways: (1) Observing scenic spots: collect visitor types, visitor numbers in observed scenic spots, visitor numbers to different directions leaving the observed scenic spots, etc., in every 15 minutes; (2) Tracing visitors: trace visitor moving in the Long Promenade by following visitors (mainly groups) and collect visitor type, the numbers of visitors in each groups, time of entering and leaving the Long Promenade, how long visitors stay in the observed scenic spots.

3.2 Parameter Configurations

According to our collected data, most visitors in the Summer Palace in China "May 1" holidays are in a group organized by a Travel Agency. For such a group, visiting time of the Long Promenade is limited, up to one hour according to our survey. Let the time limit of one hour be Max_T. Then the three different time status (sufficient time, enough time and lack of time) is defined as time cost less than, equal to and more than $Max_T / 2$, respectively. When time status are sufficient time and lack of time, the values of W_T^t and W_A^t are random under the conditions of $W_A^t > W_T^t$ and $W_T^t + W_A^t = 1$, and $W_A^t < W_T^t$ and $W_T^t + W_A^t = 1$, respectively. For simplification, V_T^{ij} and V_A^j are defined as monotonic increasing functions with the same value range [10, 100]. The value of V_T^{ij} represents a ranking score of time cost from Stop i to j. Divide Max_T into 10 time periods and let T_i^j be the time cost form Stop i to j. When $Max_T - T_i^j$ is in the last divided time period $[9 * Max_T / 10, Max_T]$, the value of V_T^{ij} is 100; when in the first divided time period $[0, 1 * Max_T / 10)$, the value of V_T^{ij} is 10; when in the second divided time period $[1 * Max_T / 10, 2 * Max_T / 10)$, the value of V_T^{ij} is 20; and so on. Therefore, there are 10 possible values of V_T^{ij}. The value of V_A^j represents a ranking score of attraction of Stop j. Rank all effective Stops which Visitor Agents need to evaluate from 10 to 100 scores. There are 7 such Stops in the Long Promenade area. Let the lowest score be 10 and highest 100. Then the scores of the other 5 Stops are $10 + k * 90 / 6 (k = 1,5)$. Stay time and visiting speed are determined by statistical computing of the collected data.

3.3 Model Running

According to the collected data, given the number of visitors entering into the studied Long Promenade visiting area (from five directions) and the parameter configurations, the proposed model was implemented and running on our integrated Repast S and ArcGIS simulation platform. When the model is running, the simulation platform system will produce all the simulation data ready for analysis, such as visitor space distribution at a certain time in the studied visiting area, visitor time distribution at a given space (e.g., Stops, or Areas), etc. Basic simulation data can also be computed for further analysis, such as comparisons between two Stops' peak time or the numbers of visitors, or comparisons of a Spot' carrying capacity with its visitor load, etc. Such analyzing results can provide rich management implication for visitor management of China tourism attractions.

4 Management Implications

By analysis of the simulation data from the model running, we found the change curves of different Stops with time changes are different, each Stop's visitor peak appearing at different time. This means visitor number controlling at entrances of tourism attractions, which are applied by most China tourism attractions as visitor management measures, do not fully work to the inner places of tourism attractions. Not all Stops have the consistent visitor number changes with the overall visitor number changes of a tourism attraction in pace with time. Therefore, management of tourism attractions, especially those with heavy load of visitors need to pay attention to each Stop's visitor changes with time and then take corresponding management measures, especially where visitors stay longer and bottlenecks are often easy to appear.

We also found there was an obvious "following" relationship in terms of visitor numbers between more attractive Stops and bottleneck Stops. Simulation can know the direction of such "following" relationships by running data. Therefore, when overall visitor peaks appear, the corresponding management measures need not only to pay close attention to those important Stops but also make advantages of the time differences of each Stop's peaks and their "following" relationships, to effectively regulate and adjust visitor numbers and flows and control.

Given the area of Stops, based on the visitor numbers produced by the running system, momentary visitor density of each Stop at overall visitor peak time can be computed. According to the computing results, Stops have different closeness between their momentary visitor density at overall visitor peak time and carrying capacity per unit area. Carrying capacity management in tourism attractions in China needs not only to pay attention to the overall carrying capacity of whole tourism attractions and regulate the visitor numbers of entrances, but also the local carrying capacity of each Stop. This can avoid the situations that the visitor numbers of some Stops overload with crowd, congestions, etc., while the overall numbers of visitors are less than the overall carrying capacity.

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