Modelling tools for environmental systems analysis in the Gauja National Park

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Abstract: - The Gauja National Park (Latvia) was established in 1973. The Gauja National Park focuses mainly on nature protection, but it is also used for educational and leisure tourism. Therefore, one of the tasks is intelligent planning of exploiting of the nature resources using situation analysis and forecasting by use of the structural modelling (LISTechnology) and the set of the simulation tools (EXTEND, NetLogo). The current article deal with some aspects of the modelling of the environmental protection tasks in the Līgatne Nature Trails at the micro processes level.

Key-Words: - Agent-based simulation, Discrete event systems simulation, Environmental protection, EXTEND, LISTechnology, NetLogo, Sociotechnical systems

1 Introduction

The Gauja National Park (Latvia) was founded in 1973 [1]. The park includes the primeval valley of the Gauja River with its tributaries forming a particularly original 91745 ha landscape. On the banks of the rivers and brooks, there are the biggest Devonian outcrops in Latvia – sandstone cliffs, rocks, and caves. The Gauja National Park focuses mainly on nature protection but it is also used for educational and leisure tourism. Important task is intelligent planning of exploiting of the nature resources using situation analysis and forecasting.

The modelling can be done at static and dynamic stages (LISTechnology). The infological modelling can be implemented in the static stage to recognise the main tourist flows. The functioning of the tourism system firstly can be analysed at macro process level granting possibilities for transparency of the all processes carried out in the tourism object.

At this level, the tourism system can be simulated as discrete event system (EXTEND) for determination of the throughput of the system. Other question is the influence of the tourist flows intensity on the regenerating capabilities of nature resources.

To analyse and forecast the critical situations in ecosystem at the micro process level another approach based on agent-based simulation (NetLogo) can be used.

2 Environmental Systems vs. Technical Systems

Simulation professionals have significant experience in simulation of the technical systems due invested serious funding into development of the simulation environment, because any upgrade or optimisation of the manufacturing operations ensure appropriate increase of the profit or competitiveness.

The technical systems mostly cover mechanisms, processes, procedures, and systems operating in conformity with predefined algorithms. The simulation tools oriented to such a system modelling are prevalent. Many tools and environments existing, which are oriented to discrete, continuous and hybrid systems simulation: Arena, EXTEND, Witness, AutoMod, Promodel, Simul8, and other.

Social systems involve people with their manner, values, behaviour, style and relations, laws and rules or other like biologic and environmental systems. These are systems for which changeable algorithm of functioning is typical and controling of the external perturbations is very significant unlike technical systems simulation, where human factor is respected minimally.

Sociotechnical systems are manageable systems respecting human and/or biologic and/or environmental factor role, mutual assistance and influence on joint functioning of the both systems.

The Ligatne Nature Trails was established in 1975 in order to acquaint visitors with nature, mammal, and plant species characteristic for Latvia, nature diversity, and protection. It is located in the territory of the Gauja National Park. On the banks of the Gauja River and in the middle of wooded glens, trails of more than 5 km are arranged.

By choosing the trail along the Gauja River, wild nature trail, or the route for visitors with cars, it is possible to get to know landscapes characteristic for the Gauja River valley and to see the animals have been brought from various places of Latvia [2].

In this case are two kind resources, which are critical for operating of the tourism object. Firstly, those are the parking places along trails and scenic routes. Each route has their throughput (cars or tourists per time unit). Functional model in this case can be described as discrete event system and can be simulated in EXTEND environment for instance. Other critical resource is capacity and quality of the sight place. Under the quality we understand the capabilities of regenerating of the nature resources (lawn, for instance) in given area influenced by the flow of the tourists with predefined intensity. In this case would not be so easy to create a useful model in EXTEND environment, therefore agent based approach can be used.

The tourism system mentioned above is a typical sample of the sociotechnical system.

3 LISTechnology – methodology and tool for the systems structural modelling

Due to the development of distributed and complicated tourism systems, designing of which requires remarkable financial and time resources, the necessity for designing methodologies in order to ensure the transparency of the project, is becoming topical. After all, the persons who pay for the project wants also to understand what is going on in this project. For this reason the systems structure analysis and designing methodology LISTechnology some years ago was created [3].

The methodology named LISTechnology was developed to promote a clearness and transparency of the project for the customer's administration and serves for both systems' analysis and designing needs. One of the typical application fields of LISTechnology is logistics, therefore it well suited for the tourist, and cars flow description in the Ligatne Natural Trails.

Analysis of the system by means of LISTechnology consists of three stages: STATIC, DYNAMIC, and EXPERTISE stage (see Fig.1).



Fig. 1. The architecture of the LISTechnology

Splitting of the goal system into sets of the objects and the important information links is implemented at the STATICS stage, where the logical structure of the goal system is described in the form of the infological model. The main task at the current level is determination of important objects and describing of an initial structure of the goal system. The graphical representation is accomplished in the forms of *Communication Diagrams (CD)* and *Data Diagrams (DD)*. Communication Diagrams are used for graphical and structural presentation of the goal system model with a necessary level of abstraction. Data Diagrams reveal precise hierarchical subordination of the objects that is important to analyse the tourist flows. The representation of the goal system by the set of typical processes is implemented at the second, DYNAMIC stage of analysis, where the dynamic or processes form of the logical structure is presented. The graphical representation mostly is performed using *Macro Processes Level Diagrams (MPLD)*, but in case, if more detailed description is required, the *Processes Diagrams (PD)* are used. It is the main level at which the overall goal system model functioning is described.

At the EXPERTISE level a quantitative parameters of the structural elements are estimated, and it would be done, if necessary, using simulation means. Usually in such a way the quantitative analysis some of resources or contours, which are critical for some of criterions: expenses, capacity, dimensions, viability, service time, and other parameters are carried out.

4 Analysis of the critical resources at the macro process level

The architecture of the Ligatne Nature Trails system at STATIC level can be described as $S = \langle R, L \rangle$, where L - the set of trails and routes, which linked objects of the R set, but R - the set of parking places R_P^i marked by squares and sight places R_S^j marked by circles (see Fig.2).

The set of links L consists of Nature trail with wild animals 5.5km, Gaujmala trail 2.0km, Wild nature trail 1.3 km and Scenic route for visitors with cars 5.1 km.

In conformity with the Communication Diagram's created at the macro process level using Buhr notation the first task belonging to the logistics class is specified and completed [4]. Using this model the necessary capacity of the parking place R_P^i can be calculated, if intensity of the tourists flow (tourists per hour) is I^i . It can be recognized, how long the delay will be for waiting in queue to get on the Scenic route with the car. The same manner is possible to plan the size of the sight places.

For solving the task the discrete event system simulation model in EXTEND environment was elaborated. EXTEND is designed from the ground up to be a flexible, extendable simulation tool. It can be used to model every aspect of an organization at all levels of expertise - from manager to engineer/scientist and from novice to professional modeller [5, 6].



Fig. 2. Infological model of the Ligatne Nature Trails system

EXTEND has an interactive and graphical architecture that is combined with a robust development environment. EXTEND's modern, advanced design and rich feature set reduces the amount of time for developing, validating, verifying, and analyzing the simulation models. Model builders can use EXTEND's pre-built modelling components to quickly build and analyze systems with little or no programming. Simulation tool developers can use EXTEND's built-in, compiled language, ModL, to develop new reusable modelling components.

The current approach provides initial data for the second task formulated in previous chapters. It is the task related with forecasting of the regeneration capabilities of the nature resources of the sight place for instance. This simulation task is implemented at the micro process level. The intensity of the tourist

flow I^{j} , which affected the environmental situation in sight place R_{S}^{j} , serves as initial data for agentbased simulation.

5 NetLogo use for process simulation at the micro level

5.1 NetLogo Fundamentals

NetLogo is а programmable modelling environment for simulating natural and social phenomena. It was authored by Uri Wilensky in 1999 and is in continuous development at the Centre for Connected Learning and Computer-Based Modelling [7]. It is particularly well suited for modelling complex systems that are developing over time. Modellers can give instructions to hundreds or thousands of independent "agents" all operating concurrently. NetLogo is written in Java, so it can run on all major platforms. It running as a standalone application. Individual models can be run as Java applets inside a web browser.

Some basic NetLogo terms are explained below to understand the model description.

The NetLogo "world" is made up of agents. Each agent can carry out its activity, all simultaneously. In NetLogo, there are three types of agents: turtles, patches, and the observer. Turtles are agents that move around in the "world". The world is twodimensional and is divided up into a grid of patches. Each patch is a square piece of "ground" over which turtles can move. In NetLogo, commands and reporters tell agents what to do. A command is an action for an agent to carry out. A reporter computes a result and reports it. Variables can be a global, a turtle variable, or a patch variable. Buttons in the interface tab provide an easy way for interactive modelling. NetLogo plotting features let creating plots to promote understanding, what is going on during simulation. Set of primitives allows interacting with outside files, which is great advantage of NetLogo over StarLogo or Agentsheets for instance [8].

5.2 GRASS Logo – simulation model for decision-making support

An intensity of tourist flows I affected sight places R_S were determined as initial conditions for

current modelling level during previous steps of the modelling.

How high will be the grass during selected period if meteorological conditions will be given and tourist flows intensity will be predefined? That is the problem for decision-maker, who must plan the tourism object operating and work load of the service staff.

Simulation model GRASS Logo utilizes three basic meteorological factors – temperature,

humidity, and trample, which is the function of I. All conditions are average values. The model notices the following basic relations:

- Higher temperature and lower humidity grass height reduces fast;
- Higher temperature and higher humidity grass grows fast;
- Temperature below zero grass does not grow;
- The natural grass growth is affected by trample, which always reduces grass growth.

The GRASS Logo model starts with variables and "world" initialization clicking button "Setup" (see Fig.3). During initialization optimal grass height is given, the "world" is drawn and values to the basic variables are assigned.

Further, by clicking the "Start/Stop" button, is possible to launch or to stop the iteration of the simulation. The "Start/Stop" button calls the procedure "go". Procedure "go" describes main simulation process. During this process the speed and the density of the rain are calculated, which are related with given humidity. A new drops are made on the modelling desktop by calling the procedure "new_drop". Then all "drop" agents are moved forward and the drops gained the ground are erased. The growth calculation is done and the colour of the sun. which depends of air temperature, is determined. Changes of all factors (temperature, humidity, trample, growth progress) are shown on the plots. To continue the simulation this procedure can be looped. Button "Print Char1" exports "Chart 1" to the output file. Curve "Chart 1" shows values of "temp", "humidity", "trample", and all growing progress. Curve "Chart 2" - shows value of the variable "factor" representing growing.



Fig. 3. Simulation desktop of the GRASS Logo model

Sliders "temp", "humidity", and "trample" ensure manual changes of the variables assigned during iteration. The picture in the middle of simulation desktop is "world", where the agent's live.

Such a simple interactive simulation model is easy for operation, but sometimes very useful for decision-making.

During validation of the GRASS Logo model the chi-square and Kolmogorov-Smirnov tests given satisfactory results, which approves that the model of course is not absolute precise, but can be used for forecasting credible enough.

6 Conclusion

Sociotechnical systems are manageable systems respecting human and/or biologic and/or environmental factor role, mutual assistance, and influence on joint functioning of the both systems – technical and social.

Tourism systems are typical samples of the sociotechnical systems.

To select suitable modelling environment some requirements must be respected. Those are the transparency of the project designing and running for non-programmers and applicability for analysis not only classic logistics processes, but also social phenomena or tasks of environmental protection.

Selected tools LISTechnology, EXTEND and NetLogo correspond to the requirements mentioned above and allow elaborating the multi-level simulation model for tourism objects operation analysis at the Ligatne Natural Trails.

7 Acknowledgement

The presented activity is supported by the grant No.2006/11 of the Latvian Ministry of Education and Science "Simulation Tools EXTEND and NetLogo use for Ecosystems Analysis".

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