1 Short ODD-Protocol

The description of the model is done in a shortened form according to the updated version of the ODD protocol.

Purpose

The aim of this model is to simulate touring companies in the Harz NLP in the defined study area around the Brocken. As a result, national park management is to be provided with key figures (for example, number of visitors to POIs, hikers on paths) for SOCMON.

Entities, state variables and scales

The data for the structure of the study area are loaded shapefiles. The study area has an extent of approximately 17,850 m (N-S) x 14,650 m (E-W). All data in the shapefiles are in meters (m), the speeds are given in meters per second (m / s). Numbers are given in units (pieces) and proportional values in percent (%). One cycle in the model corresponds to 300 s real time, the simulated time period per day is 07:00 to 19:00. The length of a year is assumed to be 365 days. In the model, 14 entities are used as agents, 2 of which serve pure representation (main roads and railway lines), 4 are designed for the determination of measured values (fishnet for the heatmap, count points, count polygons, total count area), 1 for both counting and presentation 1 represents the route network of the hikers (road network), 5 serve as start and finish points (parking lots, bus stops, cities, train stations and POIs) and 1 is responsible for the representation of the touring companies groups in the model. The model uses a global reduction factor MRF = 10, which reduces the number of hiker-agents to be simulated. It was chosen in such a way that no appreciable influence on model results takes place. A check of the exponentially increasing runtime of the model results in a value of $t_{MRF,10}$ = 8.076 ± 668 s for MRF ≥ 10.

Process overview and scheduling

The model structure obeys the sequences shown in Fig. 1 and is thus divided into the main areas of initialization, daytime running and completion. The daily run is cyclically repeated until the desired simulation year has ended.

Basic principles

Fig. 2 shows an Entity Relationship Diagram (ERD) to illustrate the relationships between the individual entities. Due to some entities serving the same purpose, they can be grouped into scopes.

Emergence

The spatio-temporal distribution of the touring companies in the study area represents the essential emergent variable in the model. From this, the use of the paths and the number of visitors encountered at the POIs are a further variable that can not be determined beforehand. The distribution of nature-oriented hikers is also not determined deterministically due to their behaviour of paths selection.

Adaption

The search for a free parking space is limited by the existing capacity of the parking lots located in the study area. Since in most cases several parking lots are located near a starting point, the arriving touring companies select from the remaining parking lots and thus deviate from these starting points already when choosing their parking lot. The weather also influences the hiking speed: In bad weather the urge to reach the goals (POI) is more prevalent. In contrast, hikers can spend more time in better weather conditions. Nature-oriented hikers perceive the prevailing conditions from a special point of view. The route selection takes place under optimizing conditions, so that more natural paths are chosen and paths with increased numbers of hikers are avoided.

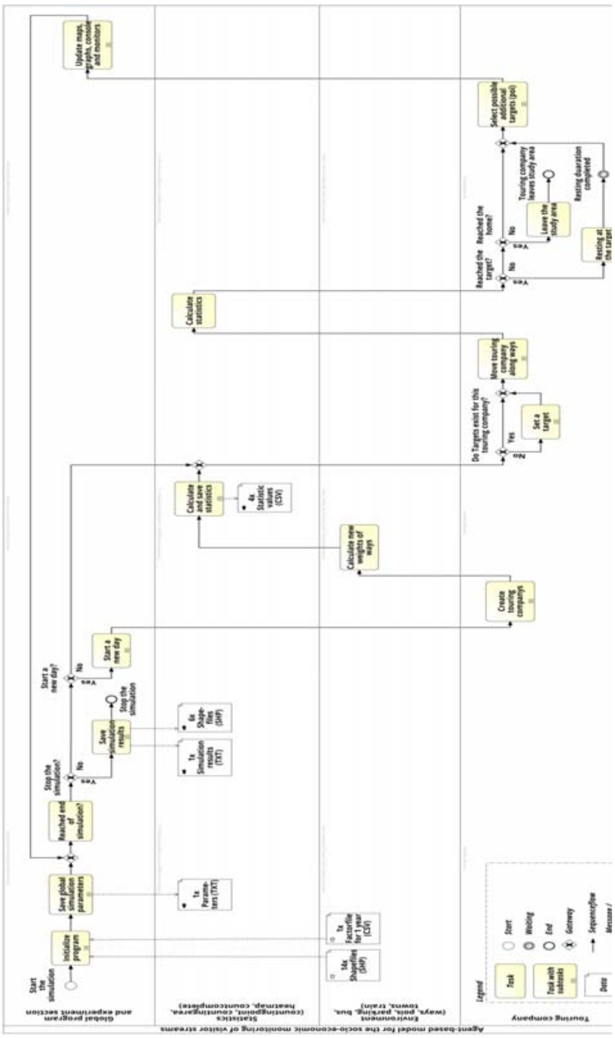

Fig. 1: Flow chart of the model at a higher level

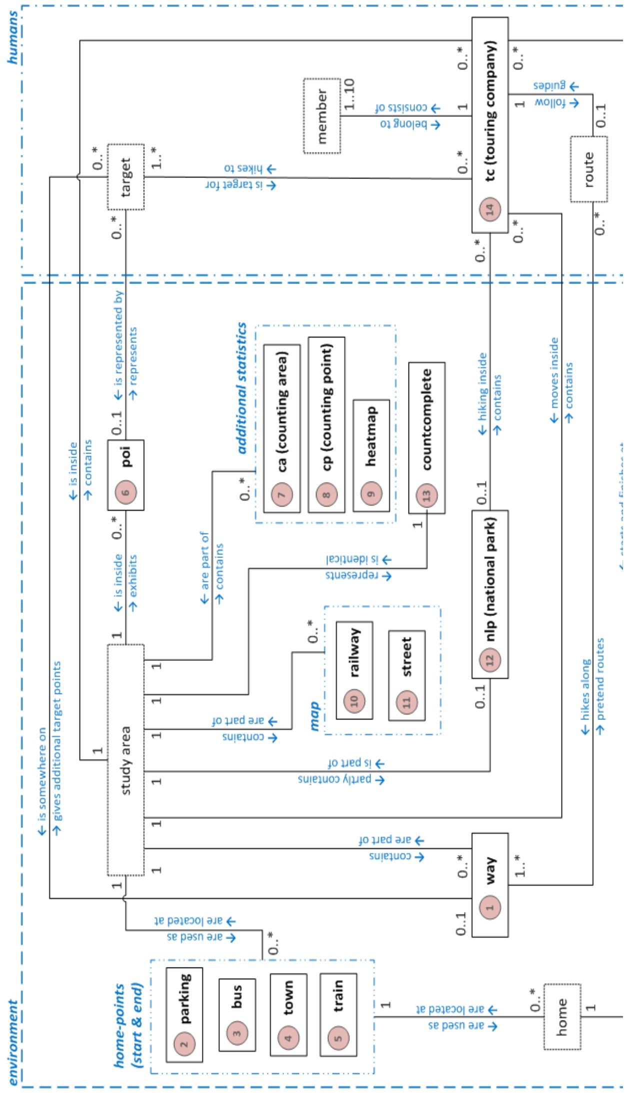

Fig. 2: ERD to represent the relationships between the entities

Objectives

The hikers follow several objectives in the model, which are also reflected in the state changes described below (see Fig. 3). First, every touring company wants to find a starting point. Then it selects a main POI within its available distance budget. On the way to their POI and back to the starting point, a number of secondary POIs are available, which can also be accessed as destinations. The return to the starting point before the onset of darkness is also an objective, taking into account the length of the route, the start time and the sunset time.

Prediction
When adding POIs as additional targets, the hiker agents estimate their actions using implemented restrictions. Thus no further additional targets are added to the tour, if thereby the permissible tour length is exceeded or the return time would be after sunset.

Sensing
Hiker-agents take values from their environment and let them influence them. These are (1) the weather conditions, (2) the number of hikers on footpaths, (3) the difficulty level of trails, (4) the category of trails, and (5) the state of the trail in winter.

Stochasticity
The model contains a multiplicity of variables, which exhibit a stochastic behaviour and for which a Gaussian normal distribution is assumed.

Collectives
Within the model there is no dynamic grouping of agents. Implicitly, the summary of hikers to touring companies is such an approach.

Observation
The simulations of the model include a full-scale outline map of the location of all stationary entities as well as the current location of the touring companies and advanced dynamic information. The simulation is equipped with 10 graph groups, which provide insights into the development of individual values within the model at runtime. In addition, there are a number of value monitors available with which the most important model results can be read. The 47 model outputs are grouped into (1) general values, (2) visitor numbers and shares, (3) visitor numbers of NLP facilities, (4) visitor flows in the Brocken area and (5) hikers share with Brocken visit (Brockenhikers).

Initialization
The number of touring companies is set at the beginning of a new day and is based on a so-called standard number, a random part and other seasonal factors. The number of groups to be simulated per day is approximately 875

$$standard\_number\_of\_tc = \frac{mb\_total\_nlp\_inside * k_{12to24h}}{\bar{x}_{members\_per\_tc} * \sum_{i=1}^{365} k_{season,i}} * k_{correction} \quad (1)$$

and is broken down as follows: car = 479, car stopover = 85, bus = 59 pieces, city = 32 pieces and train station = 221.

Input data
The total of 83 input variables with their starting values for the calibration of the basic model include the areas (1) model control, (2) standard numbers and factors, (3) model representation and output, (4) touring companies, (5) environment and (6) daily information. Additional values are required to load shapefiles with fixed entities, to control the program flow and to configure the GUI of the model. The day-dependent parameters are summarized as a CSV file and are loaded during the simulation run.

Submodels

The hikers can take 7 different status states. The status transitions are defined in accordance with Fig. 3, so that by means of this submodel a status-model (state-engine) is used for each individual traveling group. The route selection in the model is carried out by means of a Dijkstra shortest path algorithm. The division of the overall model into additional submodels is typical of a structured programming language.

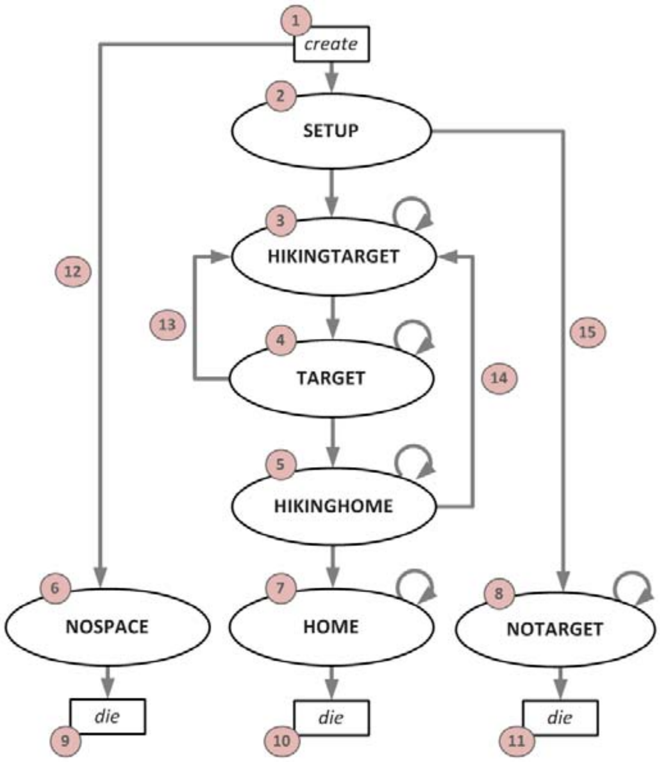

Fig. 3: Submodel of the state-transitions of touring companies