Combat model with Finnish terrain parameters

Tactical military simulation model for Finnish terrain

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Abstract. Predicting result of a combat and using all data and information available is crucial for planning campaings in war. We develop a planning tool which takes into account terrain information in more detail than is usual in similar combat models. Geographical information is used in the form of terrain parameters like cross country mobility, visibility and cover against fire. Parameters represent terrain information in the simulation model. In the user interface terrain information is used in the form of several maps, both topographic and thematic analysis result maps. These maps need also to be designed for this special purpose. One of the most challenging problems in the project is to define the way of implementing the movement of the military unit, company and inteligence required for moving and fighting in the terrain. An experimental prototype is developed on the application in ArcEngine environment. ...

1 Introduction

Predicting the result of a combat is a crucial part of planning campaigns in war. Mathematical models have been developed for this purpose, and the state-of-the art is to use computer simulation packages for this purpose [1] [2]. These models rely on data and analysis of historical battles, and their use in planning is based on intelligence data. Models of this kind are used in Finland but the experience is that especially the effect of land-cover and terrain, which are often very varying and detailed in Finland and typified by lakes and ridges, are underestimated [3].

There is an on-going research and development project in the Institute of Cartography and Geoinformatics of Helsinki University of Technology in which a new combat model is developed in cooperation with the Finnish Defence Forces. Jaakola [4] analyzed the existing combat models, available geographical information, the effect of fire on a unit, and the movement of a unit. Hurme [5] developed a campaing model and studied combat simulation games. Recently the impact of terrain and land-cover on detection and visibility has been studied along with issues related to the campaign planning tool to be developed. This paper concentrates on the architecture and on the user interface of the planning tool.

The paper is organized as follows. First we very shortly explain what are multi-agent simulation models, and describe the geographical information that is used to create the virtual environment for the agents, which represent combating units in the system. Then the existing software and the analytical methods, which are used in the project are described. An architectural design, a simulation algorithm, a model of a combating unit, and guidelines for the user interface are presented as results. The paper concludes with a discussion of the findings.

2 Materials and methods

A multi-agent simulation model [6] is based on an implementation of agents in a programming language, on a virtual environment for the agents created by the same programming language possibly from some input data, and on simulation control code written also in the selected programming language. An agent exists and acts in the virtual environment. An agent is an extension of the well-known concept of an object, in that it has some self-inflicted communication and action capabilities and tendencies. In the combat simulation model being developed, a combating unit is an agent.

The combating unit in the model is a company. A company has a spatial structure (Fig. 1). It has five subunits that are positioned depending on their function. These units represent maintenance, reserve and combating platoons. Each subunit consists of one fifth of the soldiers of the company. Area occupied by a company can be up to three kilometres wide and several kilometres long depending on the terrain and the mission the company is carrying out. When marching on a road the company is in a line formation. In terrain the company should keep a spread out formation.

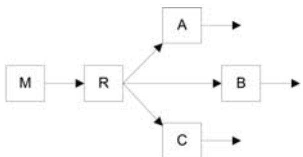

Fig. 1. Spread out combat formation of a company.

The application uses the following source data sets: Topographic map in 1:50 000, topographic map in 1:250 000 for background map purposes; Topographic data base information (National Land Survey), soil maps (Finnish Geological Survey), vegetation information (Forest Research Institute), environmental information about snow and frost (Finnish Environment Institute), climate and weather (Finnish Meteorological Institute) in computing the terrain parameters. Some analyses like cross country analysis are ready made applications developed earlier at the Finnish Defence Forces, and this data set is available as such from the Topographic Map Service which acts as the geographic information service unit at Finnish Defence Forces.

2.1 Software

The selected programming language for the system is Java. The GIS engine[1] from ESRI will provide the required capability for handling terrain information and ability to run spatial analytical methods. Engine also has utilities to handle map presentation in the user interface.

Esri ArcGIS Engine is a component library that provides developer with a selection of geographical information handling mechanisms that can be used withing normal program code. We will use map control facilities for user's map interface, visualizing map layers, and companies' locations on the map.

Spatial analysis functions include cost weighted path analysis and visibility analysis which are in the component library. ArcMap is used for other analyses that provide precalculated data for the planning tool.

3 Terrain parameters

The combat model needs terrain parametres to take into account land forms and other terrain features that have substantial impact on the battle outcome. These parametres are calculated from existing terrain data. A short description of each follows.

3.1 Cross country mobility

Cross country mobility is a terrain analysis application developed at Finnish Defence forces. Cross country mobility shows the possibility of a specified vehicle to advance in the terrain. The major source data set in the analysis is soil map data. Other data sets in the model are amount of vegetation, depth of snow, depth of frost and steepness of slope. The analysis result is a classified variable that gives a mobility value for a vehicle in question. The value is now given as a value between 1...7 (no go ...go). For this model the cross country mobility result in received as a ready computed map layer in raster form, havin resolution of 25m x 25m. The problem of the analysis is the reliability of the result because not enough information is available about the uncertainity of the source data sets. Another reseach has been made on this topic [7]. The cross country analysis is described in details in [8].

3.2 Speed

The combat model needs a speed parameter that tells how long it takes for the reserves to get to a certain point in the company's area. This is calculated from cross country mobility by finding the shortest path.

[1] http://www.esri.com/software/arcgis/arcgisengine/

3.3 Cover

Cover was not a ready defined parameter and a brief study on the topic was made by Mr. Seppnen [10]. Cover against the enemy fire can be defined as the probability that the bullets and fragments are halted by the obstacles of the terrain and vegetation. In the cover analysis model the following terrain information is taken into account: vegetation, buildings, forms of the terrain and specially the main openness of the terrain (whether the terrain is open land or not). The worst problem in this analysis is lack of suitable source information. The resolution of vegetation information as well as the elevation model is not detailed enough. In order to make a real model about cover against fire also rock and bushes should be taken into account. The analysis gives the result now in the mentioned resolution 25 m x 25 m as continuous variable. The analysis is received as a ready computed map layer to the model.

3.4 Visibility

Visibility is a different parameter compared to the previous one in the sense that it can not be ready computed but needs to be computed in real time. Thus the efficiency on the algorithm is a crucial issue. Visilbility has been studied by Mr. Hannes Seppnen in his M.Sc thesis [9]. In calculation of visibility elevation model is of course the major source data set, added by buildings, vegetation information as well as information about the weather, time of the year and time of the day. Different visibility types are line of sight (LOS), radial line of sight and viewshed. LOS show whether the given target can be seen from the given point. Viewshed is the polygon that shows the area which can be seen from sa given point. Radial line of sight is a part of the viewshed. Simple algorithms for visibility analysis can be found as ready made functions in GIS software but a more detailed model must be defined and implemented. The same problem is evident that in the computation of cover, especially vegetation information is not available in such details and also so updated than would be necessary. Manual interpretation can be used in addition to algorithms. For example, vegetation information can be visualized on the top of the computed result and the user may do his/her decision about the effect of the forest in question [10].

3.5 Impact area

Impact area is the intersection of visibility and a weapon type's range. It tells the area that can be targeted by the company's weapons from the company's current location. This is also a decision support function for the user.

4 Prototype Structure

The main architectural elements of the planning tool to be developed are the pre-processing tool, the simulator, and the post-processing tool. These elements share a single graphical user interface but each have a different emphasis. The pre-processing tool puts emphasis on dialogs and tools for defining the units, their location, mission, and other information related to the units. A design goal for the simulator is that it should require as little user intervention as possible. The user interface of the post-processing tool should have tools for examining the results of the simulation and comparing two or more simulations.

All the main elements share also the model of the combat units (agents) and that of the virtual environment. In the pre-processing tool a view is generated into the model consisting of the multi-agent system.

4.1 Pre-processing tool

Pre-processing tool consists of controls to define a situation from which the simulation starts and thus of controls for modifying and creating troops and missions. The user interface also has raster analysis based tools to support decision making.

Companies should be controlled just by activating them and clicking a next destination. This will prompt the user with a dialog including the mission details.

To support tactical decisions the user is provided with several different kinds of map views. Troops can be controlled on a regular topographical 1:50 000 scale map. In addition to this the user also has a smaller scale map of 1:250 000 and views based on analyses. The user can choose elevation model, cross country mobility, cover, or other relevant views based on precalculated analyses. In addition the user has ability to examine analysis results relevant to some chosen company. These include visibility based on the elevation model and the fire region. These are calculated from a selected location and also based on the range of the weaponry type's in the latter case.

We also plan to implement a function to visualize the expected moving speed of a company. User could point a destination and give an approximate moving area. The map view would then show route with time labels at milestone locations.

There is a dominating map view in the user interface on which the user can choose to view these different layers or they can be contemplated on smaller helper map boxes as in Figure 2.

The speculative opinion of military users is that one map view is enough. So in our design the user has the ability to open helper map boxes if preferred.

4.2 Simulation logic

The combat model's idea is to estimate battalion or brigade level battle by calculating outcomes when companies confront. Changes in company strength during a battle are calculated using company's state, weaponry and terrain parametres.

Companies cover some area which is used to calculate different parametres that quantify certain characteristics of the area.

Simulation logic calculates combat proceeding one step at a time. It also holds information on companies, e.g. their state, location and missions. The

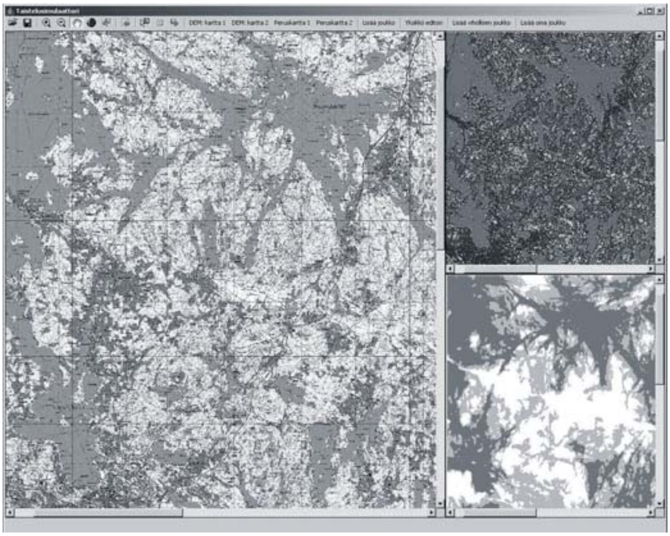

Fig. 2. One version of the planned grafical user interface.

simulation computes a new location for each company and calls a method that chooses combat actions and calculates losses according to the combat model. This way the combat model can be changed by only modifying the method in question.

The simulation algorithm computes the battle simulation at one minute steps. Every step a new location is calculated for each company. This is followed by calculating locations receiving indirect fire and possible losses caused by indirect fire. To estimate the possibility of any new enemy contacts the line of sight calculation is used. If this is the case or if there are any troops already engaged in a battle the method performing combat calculation is called. Figure 4 illustrates the simulation algorithm as a flow diagram.

The route calculation is based on the terrain, the destination, the present company location and the mission type. First a simple approach is taken by simply using a cost weighted path search provided by the spatial component library. This is a heavy method and more efficient algorithms are considered.

Line of sight is calculated every simulation step for every company's all five platoons and three additional lookout points. These lines of sight are used to determine whether the company has an enemy contact and what part of it can be under direct fire.

Pseudo code presentation of the simulation algorithm

```
simulate(){
foreach company
  handle destination and mission
```

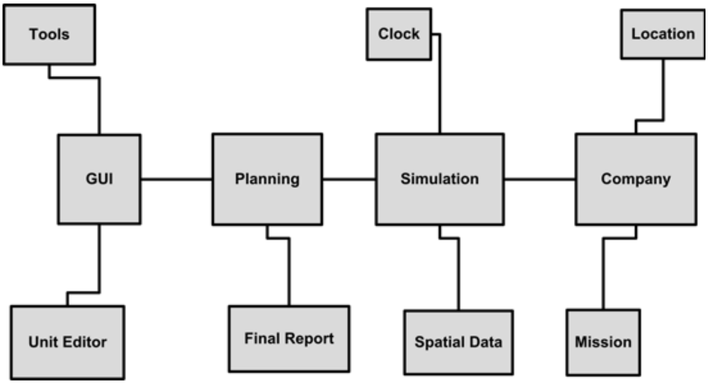

Fig. 3. This is the basic structure of the architecture of the combat model prototype. It contains map tools and unit editor related to graphical user interface and planning module between gui and simulation part.

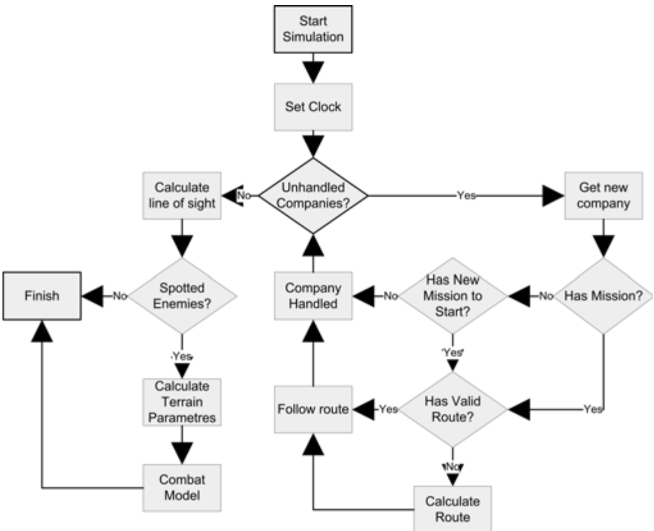

Fig. 4. Simulation algorithm

```
    if mission complete
       start a new one
    else continue mission

  calculate the route

  calculate line of sight
     if visibility !=0 and distance to companies < visibility
        calculate using DEM
if seen
  calculate terrain properties
  if terrain contains forest -> drop
     return list of seen enemy troops

  check indirect fire
     if hits
calculate losses

  if some troop sees enemy troops
     simulateCombatStep(troops involved in battle, LOSs, cover)

}
```

Interface to combat model. The combat model uses companies' locations, strength and missions to calculate companies actions and losses during a simulation step. In addition to this state related information, the combat model also needs some terrain dependent data to take the impact of the terrain into account. Cover, visibility, line of sight and speed in companys area are passed to the combat model.

4.3 Company

A company is the basic unit for this simulation. Each company moves in the landscape as an independent unit following its own route. The terrain parametres are computed for the area occupied by the company. The line of sight is not calculated for the company but for eight points representing platoons of the company.

Each company's weaponry is expressed by strengths in about 10 weaponry classes. Also losses are relevant to these classes.

Mission. Every company has a list of missions that the company will try to fill during the simulation. These missions are given by the user at the beginning of the simulation. Mission types can be march, attack, defend, or special type. Every mission has an attached location which is the destination of a march, target of an attack or a location to be defended. The mission also contains time of start, allowed moving area and a method of proceeding including one of the choices of march on a road, ready for battle on a road, and ready for battle on terrain.

5 Discussion

Applications data is divided in three classes: scenario, company, and spatial environment data. Each of these has a spatial aspect. Scenario's season data and company's form both influence the results of spatial analysis calculated from the spatial environment.

The simulation runs in two levels. The simulation algorithm shown handles the movement of units and prepares the information for the combat model. The combat model which is based on Jaakola's [4] work is currently being developed further at the technical research center of the Finnish Defence Forces. This model will be linked to this application as an independent algorithm.

The spatial analyses needed by the simulation algorithm are the route computation, the line of sight calculations and the computation of the terrain parameters for the combat model. The last analysis could for example be a simple averaging operation.

The result of the line of sight calculation tells whether two units can detect each other or not.

The route computation is based on the mission of the unit and cross country mobility information. However, it should be noted that the cross country mobility of the terrain depends on weather, time of day, and effects of warfare, such as mine fields and destroyed bridges. The route computation may also include tactical military decision making and in that case require user intervention.

The goal of this work is to produce a working prototype of a tactical prediction tool based on simulating the designed combat model. User interface is an essential part of the tool when usefulness is weighted. The user has to have the possibility to easily control troops and the results of the simulation should be presented in an understandable way.

A good model for the GUI to plan the campaing might be that found in many modern image manipulation programs. In these programs the user can draw with a free hand and use transparent layers. The user interface functionality which is required from the GIS Engine may be limited to using background maps. A lot of detailed functionality which supports military planning still needs to be researched and tested.

6 Conclusion

In this paper we have presented an architecture for linking a combat model into a spatial simulation model. The architecture clarifies some issues regarding how different elements are linked to each other. Military knowledge can separated from GIS engineering also in the architectural level.

The essential parts of this application are the terrain analyses as well as the terrain parameters. By them it is possible to take into account the detailed forms of the Finnish terrain and also receive more realistic results of the simulation of the battle. Thew worst problem seems to be, however, not to develop efficient algorithms but to receive updated and detailed source data about the environment. This might be a solved problem in the future when the data collection methods for example by different laser technologies have been take into operative use.

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