Selecting locations for landing of various formations of helicopters using spatial modelling

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Abstract. During crisis situations such as floods, landslides, humanitarian crisis and even military clashes there are situations when it is necessary to send helicopters to the crisis areas. To facilitate the process of searching for the sites suitable for landing, it is possible to use the tools of spatial modelling. The paper describes a procedure of selecting areas potentially suitable for landing of particular formations of helicopters. It lists natural and man-made terrain features that represent the obstacles that can prevent helicopters from landing. It also states specific requirements of the NATO documents that have to be respected when selecting the areas for landing. These requirements relate to a slope of ground and an obstruction angle on approach and exit paths. Creating the knowledge base and graphical models in ERDAS IMAGINE is then described. In the first step of the procedure the areas generally suitable for landing are selected. Then the different configurations of landing points that form the landing sites are created and corresponding outputs are generated. Finally, several tactical requirements are incorporated.

1. Introduction
The thematic maps showing locations suitable for landing of helicopters belong to common products within geospatial support of operations. Their production can be a lengthy process and requires verification in the terrain. When searching large areas it can be convenient to predict where the suitable locations might be and also to reduce the number of places to be verified. This can be achieved by using applications such as the one described in this paper. These applications can be tailored specifically to particular types of helicopters and to their specific formations.

The paper describes an application employing spatial modelling for selecting locations that are suitable for landing of various helicopter formations. Still, such an application will always serve as an auxiliary tool supporting the decision where to land. The ultimate decision concerning a particular landing site depends on a current situation in the terrain.

2. Backround
A solution of the task can be divided into two parts: (1) selecting areas potentially suitable for landing of a helicopter and (2) searching for locations suitable for landing of particular formations of helicopters.

2.1. Selecting areas suitable for landing
To carry out an analysis of locations suitable for landing of a helicopter in a given area, both natural and man-made terrain features that can represent obstacles have to be determined. This procedure is similar to that which is used for specifying the obstacles of movement considering other means of transportation [1,2]. There are features that can act as obstacles due to their height such as forests, power lines, or communication towers. Other features can impede landing by their nature such as vineyards, lakes, or swamps. All the features included in the analysis were classed to categories and they are listed in Table 1.

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Table 1. Selected obstacles impeding landing of helicopters.

Vegetation	Water	Transportation	Utilities	Terrain	Other objects
forest	lake	road	pipeline	rocks	chimney
wood strip	river	railroad	power line	cliffs	power station
nursery	canal	aerial cableway		crevasse	cemetery
orchard	ditch	pipeline		depression	oil rig
vineyard	swamp	power line		fault	tower
hop-garden	aqueduct			landslide	windmill
reed grass	water tower			karst	transformer yard

In addition, there are specific requirements, such as in the NATO Standardization Agreements (STANAG), which also have to be respected when selecting the areas for landing. The STANAG 2999 "Use of Helicopters in Land Operations - ATP-49(E)" setting criteria for selecting helicopter landing sites for day and night operations was used as a guideline [3]. This document does not specify the types or nature of the obstacles but it describes the selecting criteria for locations suitable for tactical or non-permanent landing sites. From a variety of conditions only the following two conditions were selected for further analysis: (1) slope of ground and (2) obstruction angle on approach and exit paths. These criteria can be formulated as follows:

- Slope should not exceed 7° or 3° in any direction by day or night, respectively.
- Within the selected approach and exit paths, the maximum obstruction angle to obstacle should not exceed 6° to a distance of 500 m by day and 4° to a distance of 3000 m by night.

2.2. Searching for locations suitable for landing of particular formations

Knowing all the areas suitable for landing with respect to natural and man-made obstacles and with respect also to requirements for a slope of ground and for the maximum obstruction angle, searching for locations suitable for landing of particular helicopter formations can be started. It is not expected to search for locations allowing landing of a single helicopter. Firstly, a single helicopter can land almost anywhere, and secondly, the geospatial data possessing sufficient spatial resolution, precision, and reliability enabling selecting such small sites will rarely be available in the operational reality.

The landing sites are usually composed of several landing points having specific dimensions. The STANAG 2999 specifies the minimum dimensions for landing points. The size of the landing point used is affected by numerous considerations such as helicopter type, unit proficiency, nature of loads, climatic conditions and day or night operations. When these parameters are not known, the largest landing point size is chosen. In this case, it is the size 5 landing point which is either circular (diameter of 100 m) or rectangular (dimensions of 100 m × 100 m).

The number of landing points determines the size and the shape of the landing site that is searched for. Two, three, four, and five landing points were taken into consideration during the analysis. To find the smallest possible space where the indicated number of helicopters can land, various configurations of landing points can be considered. The areas suitable for landing can then be analysed with the aim of selecting locations where particular configurations of landing points in any position can fit.

Apart from finding locations matching particular shapes, sizes, and orientation of landing point configurations, various tactical tasks or requirements can be modelled. These can be requirements for a maximum distance between landing sites and roads; proximity to specific corridors, dead ground or areas of interest; avoidance of minefields; and so on.

3. Study area and data

The study area is the vicinity of the city of Kosovska Mitrovica located in the northern part of Kosovo. The size of the study area is 40 by 60 km. The standard VMap 1 (Vector Map Level 1) and DTED 1 (Digital Terrain Elevation Data Level 1) databases were used.

The VMap 1database contains digital geospatial data in a vector format with resolution, accuracy and level of generalization relating to the map scale of 1:250,000. Data is separated into the thematic levels including boundaries, elevation, hydrography, industry, physiography, population, transportation, utilities and vegetation. The data stored in the VPF (Vector Product Format) format were transformed into the shapefiles and finally into the raster IMG format.

The DTED 1database provides a uniform latitude/longitude based matrix of terrain elevation values. These values are recorded approximately every 100 metres (for longitude from 0° up to 50° north or south the spacing is 3 by 3 arc seconds, for other areas the spacing is different). The elevation data were also transformed into the raster IMG format.

4. Method

The spatial modelling tools provided by ERDAS IMAGINE software suite were used. This software suite offers three different techniques of building the models: (1) creating the knowledge base using the Knowledge Engineer module, (2) creating the graphical models using the Model Maker module, or (3) creating the custom algorithms and script models directly in the Spatial Modeler Language (SML) [4]. In case of works presented in this paper a combination of a knowledge base and graphical models was used for the analysis of all areas potentially suitable for landing. Then a combination of graphical models and SML scripts was used for analysis of locations suitable for landing of various formations of helicopters.

4.1. Selecting areas suitable for landing

Firstly, the hypotheses were formulated for creating the information classes representing parts of the terrain that are not suitable for landing due to a slope of ground exceeding the requirements of STANAG 2999, separately for day and night operations [5]. Then the hypotheses were defined for creating the information classes representing either individual obstacles shown in Table 1 or certain groups of obstacles of a similar type. Within all these hypotheses the rules for selecting and visualizing of obstacles were created. Some hypotheses relate to the terrain features impeding landing by their nature, such as all water features, swamps, vineyards, railroads, etc. Other hypotheses create the information classes representing the buffer zones around certain obstacles so as to meet the requirement of STANAG 2999 for the maximum obstruction angle within the approach and exit paths.

4.2. Searching for locations suitable for landing of particular formations

Prior to searching, a total of eight landing point configurations were created. They were labelled accordingly to their shapes: I for two landing points; I and A for three landing points; I and O for four landing points; and finally I, H and W for five landing points (Figure 1).

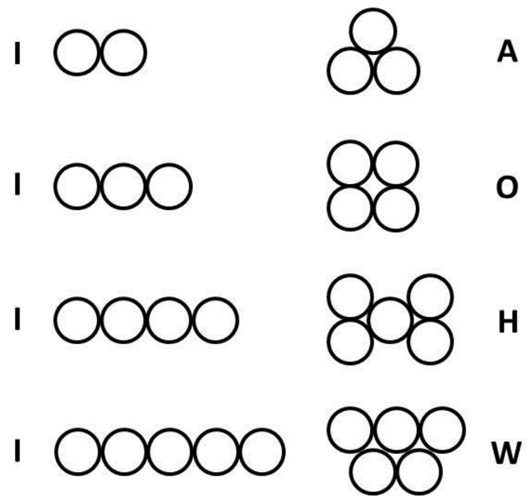

Figure 1. Configurations of landing points for two, three, four, and five helicopters.

The convolution kernels of these shapes were created and then applied in the neighbourhood analysis to the layer resulting from the previous step. The FOCAL SUM function returning sum of pixels in a convolution kernel around each pixel of the layer mentioned above was applied. If the sum equalled the pre-defined value the current position of the convolution kernel was recorded. That meant one position of a particular landing point configuration that complied the requirements for landing. All eight kernels were applied and corresponding results for the whole study area were generated. The example of a portion of a graphical model searching for locations suitable for landing of four helicopters is shown in Figure 2.

Finally, the two tactical requirements were added: (1) the maximum distance of 200 metres between landing sites and roads for the purpose of loading and unloading by vehicles, and (2) an exact position of the specified area of interest that was represented by a given overlay. That has further reduced the number of potential landing sites that would be necessary to verify in the terrain.

5. Results and discussion

From all of the possible combinations of data processing only the day operations requirements and the default size of landing point, i.e. the size 5, were considered in computations. The flowchart showing the procedure of data processing is shown in Figure 3.

The results for landing of two, three, four, and five helicopters were generated and compared. As it was expected, when searching for landing sites comprising more landing points less locations within the study area were selected. The examples of results of locations complying with requirements for landing of two, three, and four helicopters are shown in Figure 4.

The experience from this phase of the work can be used for refining both the knowledge base and the models. The results described in this paper were not verified in the terrain yet, because it was not the aim of the study. However, testing using different datasets covering various landscape types should be performed in the following phases of the work. Apart from the field inspection there are other methods that can be used for verification of the results of modelling. For example, it is possible to use the tools of constructive simulation with a different aggregation level [6]. This method is often used during the preparation of the staffs before their deployment to the operations.

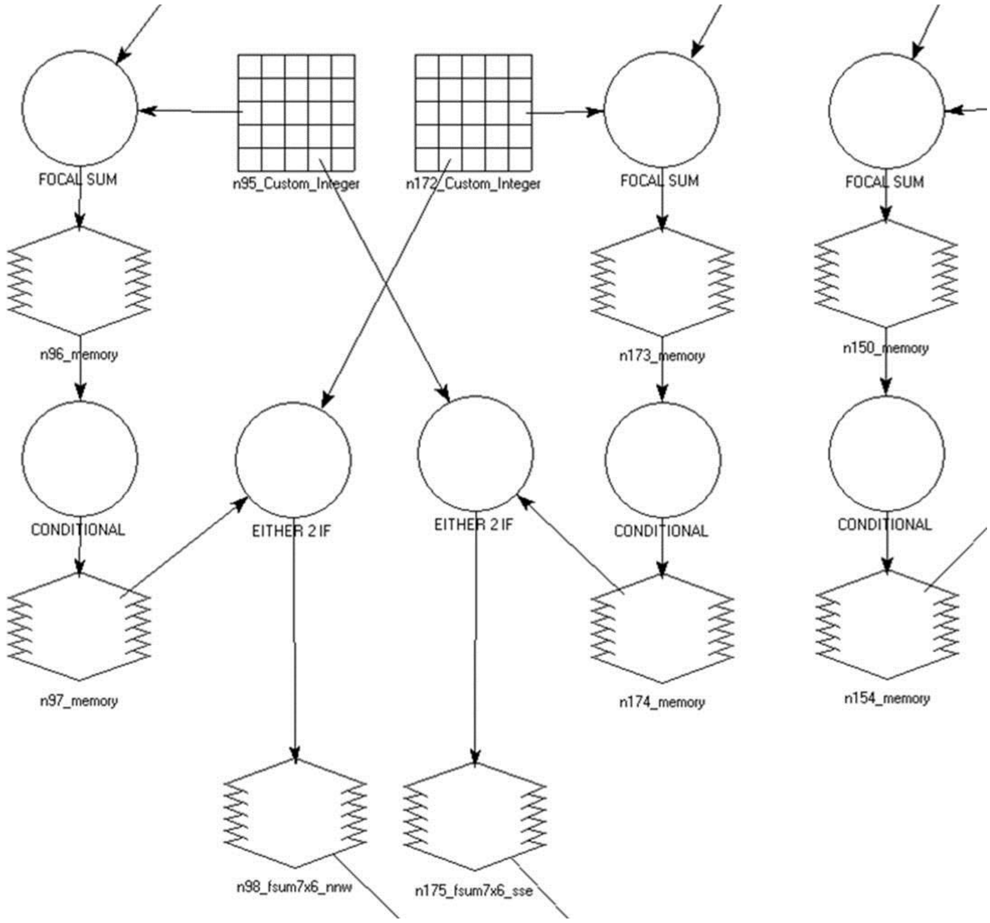

Figure 2. The example of a graphical model.

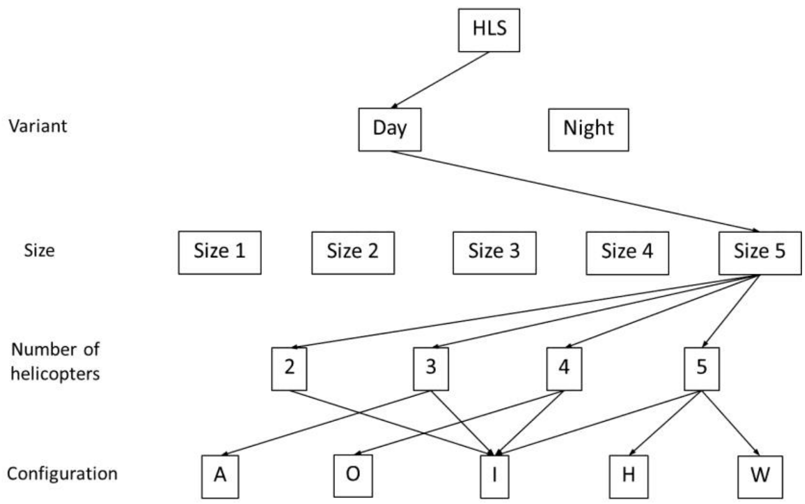

Figure 3. Flowchart showing the procedure of data processing undertaken in this study.

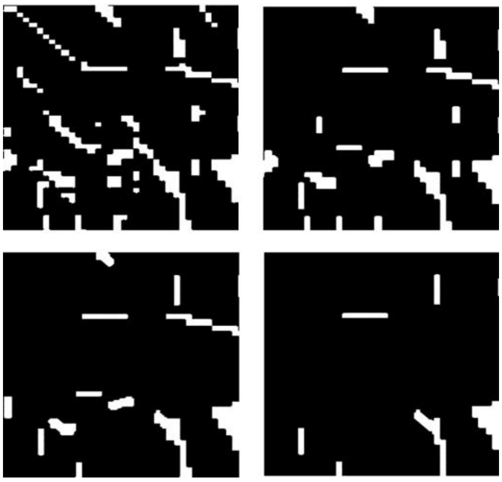

Figure 4. Examples of the results showing locations suitable for landing generally (upper left) and for landing of two (upper right), three (lower left), and four (lower right) helicopters.

6. Conclusions

It is necessary to emphasize that whatever accuracy and reliability of the knowledge base and the models can be reached, this method would always be an auxiliary planning tool only. It will always depend on accuracy and reliability of the datasets and it can never portray the real situation in the terrain. The local conditions, such as snow, sand, dust, vegetation, etc. are very difficult to predict. The ultimate decision whether and where to land or not will always rest with a helicopter commander or a formation leader. However, the results of this method can reduce significantly the extent of the area to be searched for landing sites. It can be used for generating the products showing the locations suitable for landing of specific helicopter types in day or night operations and for a given number of helicopters. Also specific tactical tasks can be included into the solution.

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