Spatial Analyses to Support Decision-Making with Focus on Radar Systems

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Abstract: - Many decisions in professional and personal life of people are spatially oriented. Identification of radar protection zone and its intersection with surrounding buildings is an example of a spatial analysis which can support many different decisions in public administration and personal life of people. The paper shows a possible way how to model radar protection zone, buildings in its surrounding, how to identify their intersection and how to visualize obtained results. ArcGIS Desktop and Google SketchUp are used as software tools.

Key-Words: - Spatial Analyses, Visibility Analysis, Radar, Decision-Making, GIS

1 Introduction
People run many activities in their environment. Most of the activities are somehow located [1]. Location of an activity, object or phenomena can be crucial information which can significantly influence further decision-making process. In the case of wrong information, the following decisions can be incorrect and they can cause damages, lives losses, etc.

A suitable system which allows people to identify both fixed and moving objects is for example radar. History of the radar systems began in the very beginning of the 20th century [2], [3].

GIS represent a very suitable tool which allows identification of real and potential conflicts and calculate limits of area development. In this paper, at first a very brief description of radar systems is provided. Then, it is described how to identify and visualize intersects of buildings (mostly houses) with radar protection zone by means of ArcGIS Desktop, ArcScene and Google SketchUp. Some emphasis is put on the possible ways of the visualization of the results because of the sophisticated nature of the used software tools.

2 Radar and its Protection Zone
Radar is a tool (or system) which is able to detect objects by means of electromagnetic (radio) waves. Of course, only selected parts of electromagnetic spectrum are suitable, i.e. only selected frequency bands (wavelength ranges) are used. Only frequencies from 1.3 GHz to 24 GHz are used by radar systems [4]. Radars have been explored and used since the beginning of 20th century. The first operating device was built in 1904; World War II speeded up its further development [2], [3]. The acronym RADAR was proposed by the U.S. Navy in 1940; it comes from “radio detection and ranging” [3].

One of the contemporary utilization of radars is to control air traffic [5] or airport traffic [6]. Airports are today situated close to the cities and villages so some problems connected to conflict of radar protection zone and surrounding urban area may occur. Radar protection zone should protect people from health impacts of non-ionizing radiation (e.g. [7]) so it is quite important to correctly calculate it. For the further development of region it is very important to identify limits caused by radar protection zone.

GIS can be used to analyse visibility, i.e. to analyse exposure to the Sun light [8] or to calculate lines of sight in the case of wireless networks [9]. Analyses and visualisation of radar data of lightning strikes [10] or satellite tracking [11] are other examples of joint GIS and radar utilization. Adaptive Kalman procedure can be used for synthetic aperture radar (SAR) data resolution improvement [12].

Final visualization of an area of interest by means of maps, 3D models and animations can provide easily understandable outputs. For example Yang et al. [13] proposed utilization of ArcObjects.
3 Spatial Analyses to Identify Objects Interfering with Radar Protection Zone

The study is focused on a real area of interest. It was initiated by citizens and public administration authorities. The whole procedure proposed for this purpose consists of the following steps:

1. Problem identification: detection of conflicts of airport radar protection zone and buildings in surrounding
2. Area of interest – its description
3. Data collection and pre-processing:
   - Collection of topographical data, setting the coordinate system. Data modelling should be included in the more complex cases
   - Precise localisation of radar
   - Estimation of height of objects of interest – estimation/measurement during field research or identification from existing documentation
   - Preparation of the digital terrain model (DTM), in the TIN (triangulated irregular network) structure
4. Particular analyses:
   - Modelling radar protection zone according to its documentation
   - Placement of buildings into DTM
   - Visualisation of the situation, i.e. terrain, buildings and protection zone should be visualised; in 2D and 3D
   - Finding intersection of protection zone and buildings
5. Visualisation and interpretation of results
   - 2D visualisation of results by means of maps
   - 3D visualisation of results by means of ArcScene and Google SketchUp
   - Animation of results

All the proposed steps are further described in the following chapters.

3.1 Problem Identification
Detection of conflicts (intersection of airport radar protection zone and buildings in the surrounding is the main goal of the whole study. Airport radar is located close to inhabited places. The distance from the radar to the closest houses is approx. 700 m. It is necessary to model radar protection zone and signal spreading to identify places where it is impossible to build new houses and to set height limits for buildings in the surrounding.

3.2 Area of Interest
The area of interest of this study covers municipalities Trébosice and Staré Jesenčany – see Fig. 1. The municipalities are located close to the city of Pardubice, more precisely they are located to the south of the city. The area of interest is situated to the south from the international airport with the mixed operation – it provides both military and civil services. In the north of the airport there is the city of Pardubice located. In the south, only small villages are situated. Trébosice and Staré Jesenčany are less then 1 km distant from the airport, namely from its runway. The surrounding terrain is flat and the land is mostly used as cultivated fields. The situation is shown in the Fig. 1.

![Fig. 1 – Area of interest (Source: Authors)](image)

3.3 Data Collection and Pre-processing
At first, an overview of all available data in both digital and paper form must be done. In the case of more national coordinate systems, one of them must be selected for the further work. Some comments
and the most important requirements on the data follow:

- Topographic data including elevation in a high level of precision are required. In the case of this study, input data were in the scales 1 : 10 000 and 1 : 2 880 (parcels).
- Radar has to be precisely located within used topographical data. The coordinates can be verified e.g. by comparison with ortophotomaps.
- Assessed houses must be correctly located. A plan view of all houses must be covered by the data too. The data were in the scale 1 : 10 000
- Information about buildings height can be estimated during field research, if it is not available from existing documentations. This approach was used during our study.

During the pre-processing phase, DTM was prepared from contours (scale 1 : 10 000) by means of Create TIN tool in ArcGIS Desktop. It means triangulated irregular network data structure was used. Utilization of TIN allows users to create a model of surface which will correctly model buildings and their heights.

### 3.4 Particular Analyses

ArcGIS Desktop 10 was used to run all the following steps described in this chapter. The whole procedure is shown in the Fig. 3. Only tool and the most important inputs/outputs are drawn.

The first step is adding buildings (including their heights) into DTM. AddBuildingsToTIN script was used to add buildings to DTM and consequently create the digital model of the surface.

Modelling of radar protection zone – a gradient angle of a radar signal spreading and the distance of the beginning of gradient must be known to model signal spreading. Then, trigonometric function can be used to model protection zone. The main principle of radar protection zone calculation and parameters used in this study are shown in the following Fig. 2.

![Fig. 2 – The most important parameters for radar protection zone calculation [15]](image)

![Fig. 3 – The proposed analysis procedure (Source: Authors)](image)
The first visualisation of results on the screen and by means of cartographic outputs takes part at this moment to allow the first visual interpretation.

Identification and visualisation of buildings intersecting with radar protection zone is possible by means of Viewshed tool. This tool determines visibility of target cells by means of the calculation of difference between elevation of one cell (the observer point) and the next cell (the target cell). It requires input data in a form of raster (grid). So, TIN To Raster tool was used to convert the previously obtained TIN model of surface into raster. Radar was set as an observer point. Add Surface Information tool was used to automatically add elevation to the radar point from DEM. Both azimuth and radius values were set to limit the analysis in the space. Parameter Vert2 was set as well to limit the lower horizontal angle.

Utilization of Intersect 3D lines with multipatch tool is the next step. Set of points of intersect of surface model and radar protection zone is an output. This analysis consists of several steps. TIN surface model (i.e. the one including buildings) is used as an input data layer in the beginning. Output polygon data layer is created by means of Interpolate Polygon To Multipatch tool. The output layer bears information about elevation. Next, point layers containing radar coordinates and representing protection zone in the selected distances were created. Again, all data layers contain elevation. The data were used in the next step. The tool Construct Sight Lines was used to create lines from the points – it created lines between each of the observer points and each of the target points. Intersect of the lines with radar protection zone was calculated by means of the Intersect tool. Elevation values were added to the resulting points. The sight lines were converted to the point data layer and the tool Construct Sight Lines was used once more to create the final lines representing radar protection zone. Next, the tool Intersect 3D lines With Multipatch was used to obtain the new point data layer containing all points of intersection of the surface model and radar protection zone (multipatch was obtained during the first step of this analysis. Finally, the tool Add Z Information was used to add the elevation to each point.

Identification of the intersecting parts of buildings and calculation of their size is the next step. At first, elevation obtained during the previous analysis, must be added to the polygon layer representing buildings. This step is based on the location of buildings and points of intersection. Then, the Polygon To Raster tool is used to transform polygons representing buildings into raster. Elevation must be set as a cell value. Very fine resolution was chosen (cell size = 0.5 m) to keep shapes of the buildings as precisely as it is possible. The next step is based on a simple subtraction. Map algebra allows us to subtract altitudes of the surface model and points of intersection to get only parts of buildings which are inside the protection zone. Back transformation to polygons (Raster To Polygon) and calculating their area (Calculate Areas) provides the required results.

Fig. 4 – Secure heights of new buildings (units: meters) [15]

The next step is a calculation of acceptable heights of new buildings (with respecting this height a building will not intersect with a protection zone (see Fig. 4). In this case, cadastral data in the scale 1 : 2 880 were used too. The secure heights were calculated as a difference between terrain elevation and radar protection zone. The 41 % of polygons (from 778 polygons in total) belong to the interval 6 – 10 m, i.e. it is the most suitable height for buildings. It is followed by the interval 10 – 12 m (12 %) [15].

3.5 Visualisation and Interpretation of Results

Visualisation by means of maps, in ArcScene, Google SketchUp and using both ArcScene and Google SketchUp together is the final step of this study. Outputs clearly show situation in the area of interest. The final output, created in ArcScene and using models from Google SketchUp, is shown in the following Fig. 5 to provide one example of possible outputs.

It is good to remember that digital surface model should be visualized, i.e. terrain including all buildings, trees and all other landscape features should be covered.
4 Conclusion

GIS can significantly help with solving many various spatially-oriented problems. Identification of buildings which intersect protection zone of radar is an example. By means of suitable tools it is possible to find out intersecting buildings and sizes of the parts of buildings which are inside the protection zone. Next, it is possible to calculate in advance height of newly planned buildings to don’t let them intersect the protection zone.

It is obvious that results of this kind of analyses can be very interesting for many people. From the above described procedure it can be concluded that most of the analyses and visualizations must be run by GIS specialists and by means of special software tools. Anyway, GIS applications provide an environment to make the workflow easier and repeatable – visual programming languages [14].

Only the last step – selection of a house of interest can be easily implemented in user-friendly software tools, like Web-based GIS applications. Thus, GIS specialists have to focus on the good quality of results visualization and suitable ways of their publishing.

In the paper, at first the suitable analysis procedure for the Czech conditions was proposed. It means, official Czech data sources were used. The complete way of data processing and analysis in ArcGIS Desktop is described. In the end, utilization of Google SketchUp is newly proposed to highly improve the visual quality of outputs.

Optimization of outputs for their publishing by means of Web applications is the planned for the future work.

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References:


