Information systems modeling

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MODELING OF OBSERVATION IN THE MOUNTAIN TERRAIN DEPENDING ON NUMBER OF SUPERVISORY SYSTEMS

Abstract. The various types of electron-optical supervisory systems (SCS) have been used in the border stations of border zones in the Armed Forces of many countries. The mission of these SCS is to supervise the possible activities of smugglers, the illegal movement of enemy troops, the technics and weapon systems, the frontier intruders. In the paper, there has been offered a method which, on the basis of the developed mathematical model and Geography Information System technology, allows modeling of observation in mountain terrain depending on the number and location of SCS. The developed software module allows: 1) to generate the investigated terrain based on Digital Terrain Elevation Data file, 2) to input the possible observation points and the controlled zone via an interface, 3) to simulate and visualize the observed areas for both single and group observation devices located in the possible observation points. The developed method had been applied to one of the selected terrains of the Azerbaijan Republic and demonstrated efficiency of the offered method. Based on the developed model and GIS technology the visual modeling in mountain terrain depending on a number and a location of the SCS has been carried out.

Keywords: modelling; observation; mathematical model; supervisory system; software module.

Introduction

The various types of electron-optical supervisory control systems (SCS) have been used in the border stations of border zones or/and in the Armed Forces of many advanced countries. The mission of these SCS is to supervise day and night the possible activities of smugglers, the illegal movement of enemy troops, technics and weapon systems, frontier intruders with high precision a great and middle distance [1,2,3].

With the goal of optimal SCS deployment in mountain terrain by using the digital altitude model of terrain the views held analysis is possible to carry out [4]. This views held analysis helps to select optimal points (posts) on the terrain. The SCS optimal deployment in mountain terrain makes the possibility to use rationally SCS number because SCS has very much costs. Using the rationally SCS number we can reduce the necessity of the specialist number. Also, it accelerates the commander's correct decision making. The correct SCS deployment makes possibilities to take into account during monitoring such dead zones as runways or ravines. The correct SCS's posts selection increases the visible areas and, at the same time, decreases invisible areas. The correct post's points and rational number deployment help to observe and to detect many targets and movements on the terrain. Also, it helps us to reveal and to prevent enemy subversive actions.

Taking into account above, in [5–7] papers the mathematical model of the rational deployment of technical observing systems in mountainous terrain has been developed and offered. The determination method of visibility level between selected terrain points has been developed. The assessment criterion of rationally deployment and the algorithm of the fast solution have been offered. For task solution the below method has been offered:

1) it is offered a net of terrain, the net point junctions are heights of the terrain;

2) it is adopted that around of each height all point junctions are a SCS deployment set;

3) we determine the visible and invisible point's sets for each selected SCS deployment point;

From the set of the deployment point junctions, the deployment points were selected for minimal SCS number determined maximum visible zones.

In the presented paper, the task of development of the software module has been formulated and solved on the basis of the developed mathematical model and Geography Information System technology. The developed software module allows:

- to generate investigated terrain based on Digital Terrain Elevation Data (DTED) file;
- to input the possible observation points and the controlled zone via the interface;
- to simulate and visualize observed areas for both single and group observation devices located in possible observation points.

Methods. Mathematical model of deployment of the electroptıcal supervısory systems

Early, the mathematical model of the rational deployment of electron-optical SCS in mountain terrain has been developed and offered [5,6,7]. The determination method of visibility level between selected terrain points has been developed. The assessment criterion of rationally deployment and the algorithm of the fast solution have been offered.

The optimal deployment of SCS on terrain is one of the important tasks of military reconnaissance. Such a task has its own specific character and can be solved by the application of appropriate mathematical methods. The specific character of such tasks is that the necessity for continuing surveillance and control objects can be located in specific zones of terrain (for example, in canyons, along with rivers, etc.). Accessible places of SCS set are situated on some distance from these zones. The number of SCS is limited, therefore, it is impossible to distribute theirs on all set points. Therefore, it is necessary to select such SCS set points that the zone observation range would be the largest.

In the paper, the task of optimal SCS deployment in mountain terrain has been considered by using the digital altitude model and knots of the regular net of terrain. Neighbor's points are connected by straight lines, and as a result, the 3D digital vector model of relief of the terrain is generated. These segments are called relief lines and their projections on the side plane are called edges.

Let the searching terrain's zones are known and connected to knots. Let us consider that the possible knots of SCS installation are marked. It is obvious, in the range of each observation place the most suitable observation point can be selected. For example, if the observation of the nearest lowland is a priority then the observation point can be placed nearer to observed points. However, if the observation of far lowland is priority then the observation point can be placed at the highest point, etc. Therefore, we can adopt that the observation set of points is grouped around of N separate high-altitude knots. Let them are called initial knots. In real conditions usually $N \leq 10$.

It is required to deploy n ($n < N$) SCS on the terrain that they would provide the maximum observation zone. Not intersection the line segment connecting A and B points on the relief plane is condition of visibility B point from A point. That is if AB segment is placed above all incidental edges then B point is seen from A point.

The next method to solution this task is offered:

● Development of $\wp$ procedure for each other visibility checkup of two given knots;

● By application of $\wp$ procedure for each A knot from the set of possible SCS deployment places to determine the set of visible and invisible points in the range of technics possibilities of SCS;

● Assessment of visibility level of zone and determination of the most suitable SCS deployment in the set of initial knots;

● Improvement of the computed solution by variation of knots in the range of group.

Let denote the set of points of under obligatory observation terrain zones by V_0. As stated above, the observation set of points will be grouped around separate altitude knots of A_m (m=1,2,…,N), which are taken as initial knots. Let V_m are set of knots, which can be observed from A_m knot in the case of ideal flat relief, the ranges of which only are depended on technical characteristics of observation devices. By use $\wp$ procedure for each initial knot of A_m we will get $U_m \subseteq V_m$ sets. As the assessment criterion of zone observation range for the task of SCS deployment such a way that to embrace the widest zone observation, we can take a following:

$$\Im(m_1, m_2, ..., m_n) = mes\left(V_0 \setminus \bigcup_{k=1}^{n} U_{m_k}\right) \to \min .$$

Thus, first of all, by application of $\wp$ procedure all sets included in functional are described. Then, by the method of $m_1, m_2, ..., m_n$ exhaustion, $\Im$ is calculated and the most suitable is determined. Further, by varying knots in the range of $m_1, m_2, ..., m_n$ groups we can improve the obtained solution.

It is obvious, that from the point of view of mathematics it is possible to prove that in common case such an algorithm not leads to an optimal solution. However, in practice such a solution is satisfactory. Therefore, this solution is called rationally.

Experiments

One area in the mountain terrain of the Azerbaijan Republic was taken as an investigated zone. The mountain terrain is higher than the surrounding zones. The absolute height of such areas is more than 500 m. The mountain terrain has a complex and diverse colored relief, a characteristic nature. The mountains, steep slopes of the mountain chain and narrow canyons are the main relief forms of this area. The characteristic features of mountain terrain are input-output and difficult relief, the poor road network and few settlements, varying level and rapid flow rivers, diversity of climate, stone land. The mountainous terrain is closed and split area.

The combat operations in mountain terrain demand especial combat training, a detailed and maximum precise evaluation of the condition. The level of cross-country ability of mountain roads is depended on the season. In winter the roads are covered by snow and ice. The difficult relief of mountain area leads to form the unobservable zones. It makes a worse condition for observation and fire, but it provides conditions for security deployment and movement of troops, fortification construction, masking and easing antitank defense. Depending on the absolute height the mountain terrains are low (500÷1000 m), medium (1000÷2000 m) and high (> 2000 m).

For investigations, the topographic maps with 1:50000 scale had been used. First of all, by using of ESRI company ArcGIS program package and Global Mapper software [8,9] the DTED [10] format of terrain has been obtained. Then, for the purpose of investigation of observation conditions of terrain, the program module has been developed in Delphi package. Purposely construction of the model and algorithms testing, there had been had below:

- the investigated zone had 5.5 km x 5.5 km area;
- WGS84 coordinate system was taken [11, 12];
- in the investigated zone (x, y, h) coordinates of 21 483 points were measured;
- the distance between knots of regular graticule of the (x, y) coordinate was 115 m;
- the maximum height was 1730 m, the minimum height was 920 m.

Results and discusions

The models of terrain have been made at three steps: data obtaining, developing and models making. At the step of data obtaining, for the purpose of the showing possibility of the topography surface with any precision, the local topographic contours on the topographic maps of the investigated area have been digitized in ArcGIS 10.4 program software of ESRI company (Fig. 1).

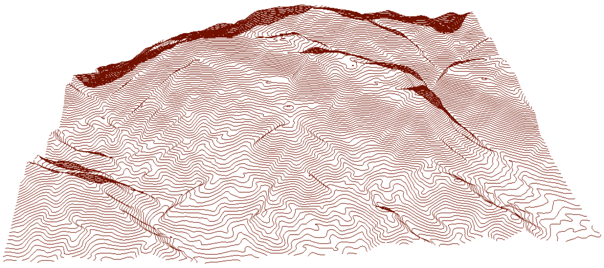


Fig. 1. Digitized topographic contours

The height difference between the topographic contours is 10 m. Then, by using ArcGIS 10.4 program software on the topographic contours at every 50 m one point had been indicated. As a result of this, 21 483 points had been obtained. The values of rectangular (x,y) coordinates of obtained points had been calculated.

One of the tasks of observation system organization on the terrain is an optimal number of observation devices and the correct choice of their deployment. As it was indicated above, in [7] the mathematical model for determination the visible zone of terrain from the given point based on the relief map in DTED format was offered [10,13]. DTED file is the value of heights of terrain relief and is set in the knots of the regular rectangular graticule. Such a format is suitable for visualization on the computer screen by using various software. For instance, the generated shape of the above-indicated area of terrain (see fig. 1) by Excel program is presented in Fig. 2.

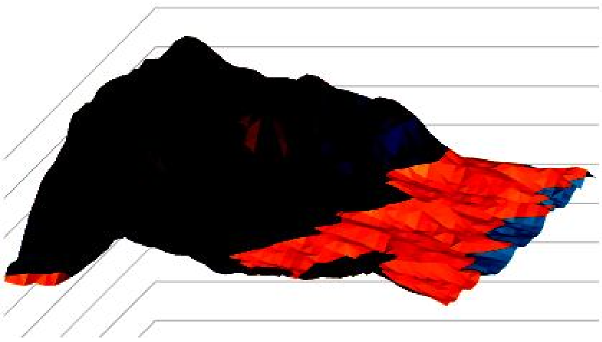


Fig. 2. Investigated area heights classification. Visualization terrain by Excel program

However, it should be noted that in such kind realization of the offered model demands many computational resources in the case of numerous data value. On the other side, the percentage evaluation of the area of observation zone by supervisory devices towards all controlled zone formulated in [7], it is not an adequate extent of task solution. Due to security, it is conditional on demand of the view of some "continuous line" along the whole length of the observation zone. So, the sufficient reasons are raised for the development of the software module, which allows the commander to calculate a view zone both for single observation's device allocated in the suitable observation point and for the group of devices. At this time, the commander chooses more suitable versions.

So, the task of development of such a software module have been postulated for:

- generation investigated zones on the basis of DTED data file;
- input the possible observation points and controlled zone via the interface;
- visualization view zone both for the single and for group (one, two, etc.) observation devices allocated in the suitable observation points.

By using this software module, the commander can choose more suitable versions for the allocation task solution. Such a software module had been developed with the above-indicated characteristics. The functional block-chart is presented in fig. 3.

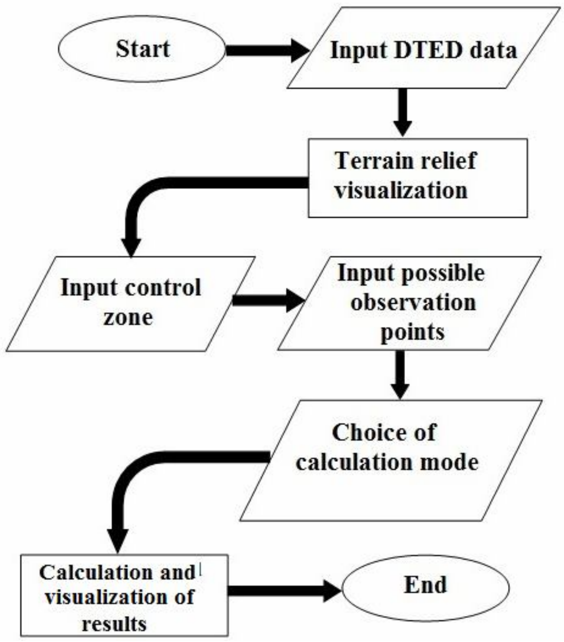


Fig. 3. A software module block-chart

Using this software module, the relief map of the terrain, shown in Fig. 1 and 2, is presented in Fig. 4. In accordance with the indicated size of terrain, the relief is presented by 45x45 squares painted by colors of the middle height. There are six colors in these figures, each of them include the alternate fields with height difference of 135 m. It is obvious, in depending on necessary precision, other parameters of detailing relief can be chosen.

The simulation program had been written on the Turbo-Pascal programming language in the Delphi package. Let us demonstrate the operation of a software module of the developed program. The electron-optical supervisory systems (devices) were put in points 1 and 2 (Fig. 5). There have been carried out the investigation and analyzing of the calculated visible zones (blue color) from the view of selected point 1, from point 2 and from jointly 1 and 2 (Fig. 5). There is the more dark color the higher mountain terrain in Fig. 5.

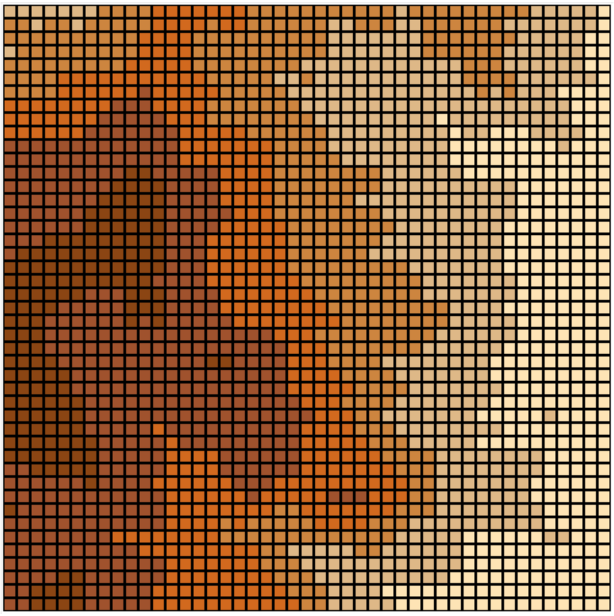


Fig. 4. A relief map of terrain

From an analysis of simulated images on Fig. 5 (a, b, c), it can be concluded that:

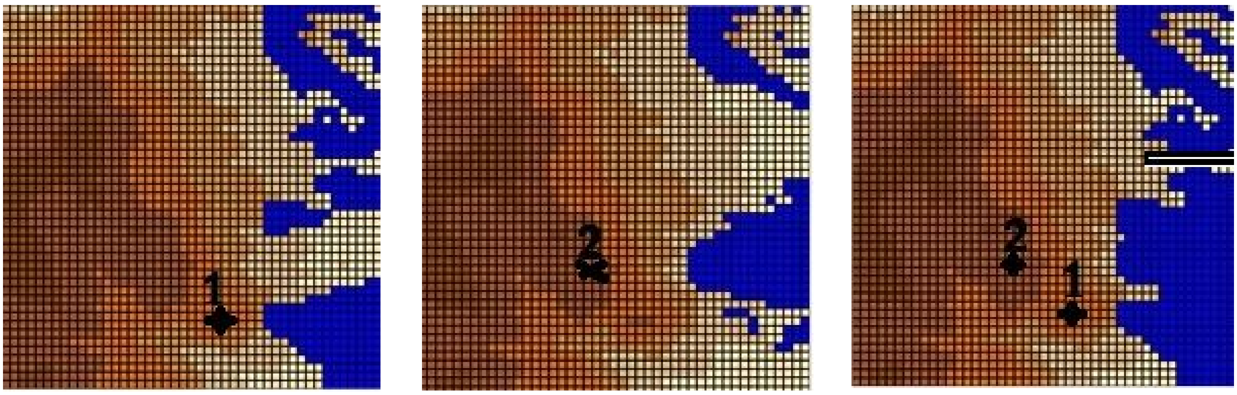
- the areas of visible zones are differed depending on the selection of viewpoint;
- the higher mountain terrain does not create a possibility of more area of the visible zone;
- even simulate observation from two selected viewpoints, then there is an invisible strip area on the terrain.
- if there are several viewpoints (electron-optical supervisory systems), there is some area of the invisible zone.

So, it can be concluded that when even the several electron-optical supervisory systems are used, then in all of the same cases there is an invisible zone, where the enemy can cross the border (frontier). In this case, there appear to be sufficient reasons for the use of Unmanned Aerial Vehicle for controlling (monitoring) invisible zones.

Conclusions

Thus, by analysis of obtained results, the next conclusions can be made:

- based on the developed model and GIS technology there has been carried out visual modeling in mountain terrain depending on a number and a location of the electron-optical supervisory systems;
- the developed software module allows visually analyze of developed mountain terrain and find the hidden zones from viewpoints;



a b c

Fig. 5. Visible zones (blue color) from the view of point 1 (a), from point 2 (b) and from jointly points 1 and 2 (c) – crosses; Tthe black strip in fig. 5, c is invisible zone

- the developed method allows efficiently to investigate the dependence of hidden zones area on a number and a location points of the electron-optical supervisory systems;
- by using the given method it can be to determine exactly a minimum number of electron-optical devices that to carry out observation for maximum area zones for given mountain terrain.

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Моделювання огляду в гірській місцевості в залежності від кількості систем спостереження

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Анотація. Різні види електронно-оптичних систем (ЕОС) використовуються Збройними Силами в прикордонних зонах різних країн. Призначення цих ЕОС полягає в спостереженні за можливою активністю контрабандистів, нелегальними пересуваннями військ, техніки і систем озброєння противника, порушників кордону. У статті пропонується метод, який на основі математичного моделювання і технології Географічної Інформаційної Системи дозволяє моделювати огляд спостереження в гірській місцевості в залежності від кількості та місця розташування ЕОС. Розроблений програмний модуль дозволяє: 1) генерувати досліджувану ділянку на основі Digital Terrain Elevation Data file, 2) вводити через інтерфейс можливі точки огляду і контрольовану зону, 3) симулювати і імітувати області спостереження для одиночних і групових пристроїв спостереження, розміщених в можливих точках спостереження. Розроблений метод застосований на обраній місцевості Азербайджанської Республіки і показав ефективність даного методу. На основі розробленої моделі і технології ГІС проведено візуальне моделювання в гірській місцевості в залежності від кількості та розташування ЕОС.

Ключові слова: моделювання; спостереження; математична модель; система спостереження; програмний модуль.

Моделирование обзора в горной местности в зависимости от числа систем наблюдения

А. А. Байрамов, Э. Н. Сабзиев, Я. А. Насибов

Аннотация. Различные виды электронно-оптических систем (ЭОС) используются Вооруженными Силами в пограничных зонах различных стран. Предназначение этих ЭОС заключается в наблюдении за возможной активностью контрабандистов, нелегальными передвижениями войск, техники и систем вооружения противника, нарушителей границы. В статье предлагается метод, который на основе математического моделирования и технологии Географической Информационной Системы позволяет моделировать обзор наблюдения в горной местности в зависимости от числа и места расположения ЭОС. Разработанный программный модуль позволяет: 1) генерировать исследуемый участок на основе Digital Terrain Elevation Data file, 2) вводить через интерфейс возможные точки обзора и контролируемую зону, 3) симулировать и имитировать области наблюдения для одиночных и групповых устройств наблюдения, размещенных в возможных точках наблюдения. Разработанный метод применен на выбранной местности Азербайджанской Республики и показал эффективность данного метода. На основе разработанной модели и технологии ГИС проведено визуальное моделирование в горной местности в зависимости от числа и расположения ЭОС.

Ключевые слова: моделирование; наблюдение; математическая модель; система наблюдения; программный модуль.