Managing Temporal Data in Military Historical GIS

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Abstract. This paper discusses the main experiences and findings in managing temporal data of military historical reconstruction using GIS. This paper could be considered as continuation of a previous publication of 2007 [1]. Besides GIS-based reconstruction of several defense lines in Hungary, managing and handling the time issue in GIS have been analyzed through the example of the defense system of Budapest (Attila-line, 1944-45). The temporal data have a highlighted function in military history especially in event reconstructions; therefore this issue had to be carefully considered.

Firstly, the existing concepts and methods for handling temporal data in geographical information systems have been investigated from the beginning to nowadays’ spatiotemporal data models and object-oriented approaches. An overview has been prepared, which summarizes the advantages and disadvantages of these methods and the general difficulties in understanding, formalizing and integrating time data. It was also important to examine the functions of the temporal data bases, especially focusing on their representation.

Secondly, these concepts have been adapted to military historical reconstructions. Change and modification of functions according to this special application have also been investigated. The most exciting part was the issue of data relevance. Which information could be used as relevant data in the case of a past event? A terminology has been defined to group the data sources according to this aspect. The data presentation, as an important function has also been considered as a highlighted issue. Finally, it was declared that none of the existing methods are suitable for military reconstructions alone, but the combination of the concept parts could provide a feasible solution.

Keywords. GIS, time, military history

1. Introduction

The application of geographical information system and remote sensing in military historical reconstruction was researched in the last few years. A methodology was developed to manage this type of data in GIS based on the experiences of previous investigations. These investigations comprised the reconstructions of various Hungarian military historical events, (XIX. and XX. century) and the connected defense objects. There are three basic parts during these processes. Firstly, the reconstruction of the period environment, then the defense objects and finally, the military historical events [2]. It is necessary to take into consideration the temporal data in addition to the spatial data at least in the last part of the process. In connection with this issue I reviewed the known GIS concepts for modeling temporal data. Besides, the possible problems were also investigated. The military historical data managing in GIS is a special task; none of the known methods are suitable to solve the possible difficulties. However, if we can utilize the positive characteristics of the various methods in a composite solution, the results will suit the requirements of this special task.
2. The characteristics of the temporal data

According to the well-known definition, the GIS is concerned with the spatial data acquisition, process, handling and visualization. Nowadays it is applied in almost every segment of our life. On the other hand, there are many applications, where it is not sufficient to consider only one snapshot or map of the environment or the relevant objects. It is often required to compare various snapshots which represent the statements in different dates and to analyze the changes. Handling the time, as the fourth dimension means a new challenge for the geographical information system, because new approaches are needed in most cases, in contrary with the spatial data. There are two basic causes of these differences. Firstly, the uncertainties in the definition of time, which are basically belonging to philosophy. I would not like to deal with this part of the problem in this paper. Secondly, the legacy of the geographical information system, which comes from the traditional topography and cartography. According to this legacy the information stored in the databases in static form to describe the statements of the environment and generally it is impossible to investigate the changes along time. The most obvious difficulties of the temporal data handling in GIS databases are:

- There are snapshots connected to each date \( (T_0, T_1, T_2 \ldots) \). The changes and the unchanged objects are also stored in every snapshot thus the redundant information storage can provide unmanageable data amount.
- It seems logical to create these snapshots in a regular time intervals, however, there can be short events which happen between two sequential statements represented in the database. This phenomenon may causes incompleteness.
- Only the statements are represented in databases in many cases, not the changes.

According to these incompletion and the main functions there are atemporal (traditional) and temporal databases distinguished and mentioned in the literature [3]. The major aim is to handle, to analyze the temporal data like the spatial ones. If we review the existing GIS methodologies for temporal data managing, we can declare that none of them are suitable for military reconstructions alone. The general and complex solution, which provides appropriate results in most cases, is still missing. The existing methodologies are mostly task-specific approaches. The temporal data as the third component completes the original two components (the position and the attributes) in these applications. Generally one of the components is fixed the second one is controlled and the third one is measured (Table 1.). The images of a typical application are presented in Fig. 1, where the attributes (mobile phone ID) are fixed, the time is controlled and the positions are defined by measurements.

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<th>Application</th>
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<td>Soil data</td>
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In the next section I review the difficulties of temporal data integration and process into geographical information system. The investigation of time intervals is more complicated than the analysis of a single snapshot, as it is already mentioned in this chapter. In addition, there can be problems in the definition or in the understanding of the task because of the differences between temporal and spatial data in terms of orientation and navigation. For example it is possible to step forward (scenario planning or analysis) or back in time. Besides, we have to manage in GIS database such concepts like evolution, duration, periodicity or termination. The formalization of these concepts can be difficult. Finally, the matter of the practical realization of the complex data management: the resolution in time and space, the scale dependence, the modeling of the changes and possibilities of the temporal analysis.

2.1. Handling and grouping temporal data and applications

After the problems and difficulties let us investigate the existing solutions, which are developed to handle the temporal data in geographic information system. Before the review of the particular methods and data models, it is necessary to group the applications based on their basic characteristics. The first grouping aspect is the relation between the spatial objects and time. This type of grouping can be defined as a philosophical approach. In the first group the temporal and spatial data have different extension. An individual object has various statements in time and these statements as organic parts, compose the object. Thus we can define the objects as a temporal composite. Like the caterpillar and the butterfly, the different statements of the same living being. According to the other approach, the temporal extension is the same as the spatial, so the time is “only” another dimension. The temporal changes of the spatial objects can be described, for example with sequenced snapshots. The second grouping aspect in the case of temporal GIS data models is their application. The three basic components (position, attribute, time) create different parts (fixed, controlled, measured) in various applications, as it is previously represented in Table 1. Comparing the importance of time and position components in the applications, different subcategories can be defined. Thus the domi-
nancy of certain components also has to be taken into consideration (Fig. 2.). Investigating this figure from left to right, the dominancy of the temporal data increases and this obviously results in the decrease of the importance of the spatial information. The particular applications are grouped into three subcategories based on the change of the time-space emphasis.

![Figure 2: Spatial and temporal dominancy in various applications](image)

Grouping the applications based on their functions is the third option. Here are the most important grouping aspects [3]:

- Two major groups are distinguished according to the duration of the applications. The “ad hoc” type takes place generally in the case of unique projects and always finishes after the solution of the certain task. On the other hand, the applications in the second group, called “permanent”, operate continuously from the starting date and process more and more new information.
- There is also a major difference in the temporal GIS database updating methods. The old information are deleted or overwritten by the new ones in some cases, but there are solutions, where the old data are stored and replaced by the new information.
- An interesting point of view is the data representation methodology as a grouping possibility. There are diverse methods in various applications: modification or completion of the data with graphics or texts, thematic symbology usage, application of time sequences or animation.

2.2. Temporal data models

In this section I review the most known concepts for spatiotemporal GIS data modeling, including their advantages and disadvantages. The sequence of the review is equal to the sequence of evolution. Obviously there are more spatiotemporal applications known (in particular in the last few years) than the ones are mentioned here, but I deemed them too task-specific and furthermore I skipped them because of the limited extension of this paper.
2.2.1. Space-time cube:
In this concept the two dimensional events are simply represented as a function of time. The data acquisition can be carried out by defining a reference point or a vector, or setting out a profile or a smaller cube (Fig. 3.).

![The space-time cube](image)

Figure 3: The space-time cube

2.2.2. Sequential snapshots:
This is an ordered sequence of snapshots created in given dates. This concept is based on the traditional mapping and generally analogue to the moving film frames. The major disadvantage of this method is the lack of the change representation, because only the statements of given dates (\(T_0, T_1, T_2, \ldots\)) are stored in the database. The investigation of the differences or the changes between two certain statements can be difficult. Besides, the hidden data structure and the redundant data storage are also disadvantageous (Fig. 4.).

![Sequential snapshots](image)

Figure 4: Sequential snapshots (city of Kunmadaras, Hungary)

2.2.3. Base statement with amendments:
Similar to “Sequential snapshot” concept, there are also certain statements stored in this type of solution. However, as opposed to the previous concept, the changes are highlighted in this method. While in the “Sequential snapshot” concept it is necessary to store the objects from the whole investigated area in each and every statement; here it is enough to store them one time and process only the changes. This is the major advantage in this case. The type, the timing and the sequence of the changes are realizing practically the temporal data management. Compared to the previous method, it seems more logical to store only the changes in the database. Further advantage in addition to the obvious temporal data structure is the minimal possibility of redundancy (Fig. 5.).
2.2.4. Space-time composite:

This concept is based on the “Base statement with amendments” method and is a step forward basically considering the data storage. The certain entities can be described by their entire history. The important temporal data are stored in the attribute data base. The reduction of the temporal sequenced data from three dimensions to two dimensions is the essence of the space-time composite generation. This process provides facilities to manage temporal data with the exception of the spatial data and obviously the spatial data handling with the skip of temporal information. The basic disadvantage of this concept is the possibility of entity fragmenting. There will be more and more entities in the database with decreasing size after a certain period, thus this solution operates efficiently in case of relatively short time periods and on small areas (Fig. 6.).
2.2.5. Object-oriented system:

This new type of data modeling is also adapted to the temporal geographical information system in the last few years. There are different data structures developed, which apply this kind of concept. I highlight only a typical one in this paper to represent this kind of database structure. The name of this particular concept is “Feature Evolution Model (FEM)” [4]. A base statement has to be created also in this method like in the previous ones, and the versions of the objects, which are connected to given dates, are stored in the database. The statement of each object is described by attribute data. The changes are also stored as objects in this type of solution. These change objects can be defined as “Event” or “Process” and both have attribute data. The events are connected to individual date and the processes connected to a time interval. The new statement of an object is created by the way of attribute changing. As a matter of fact, a change object defines the connection between two versions of an object (Fig. 7.a). There is a second level in this concept, where the individual object and change objects are organized into “Complex object” and into “Transition” (Fig. 7.b). And finally, there are two overall object types on the third level: the “Evolved object” and the “State descriptor”. These overall objects have direct connections with the individual objects and also with the complex objects, thus obviously contain the entire history of these objects (Fig. 7.c). Although this level results in some redundancy, it is necessary. There can be special events like an object termination, when this is the only way to store the terminated object.

![Feature Evolution Model, Level 1](image1)

![Feature Evolution Model, Level 2](image2)
In conclusion, it is declared that there are several possibilities to manage temporal data in GIS environment, but almost all of them have some disadvantages. There are four well separated levels of the various temporal GIS applications according to their evolution. The simplest solution totally avoids temporal data handling, since the objects are connected to a single and given date. These kinds of applications are generally consisting of static maps. The real temporal data structure is also missing in the next level. However, some simple comparing analysis can be carried out with time-sequenced snapshots. The changes are represented as an entity or an object first time on the third level. This solution is already a real temporal data structure. On the other hand only the applications on the highest level are suitable to carry out individual or complex analysis of the events (Fig. 8.).

Figure 7.c: Feature Evolution Model, Level 3

Figure 8: Levels of the temporal GIS applications
There is one more important characteristic I have to mention in connection with these concepts. The careful and right selection of the appropriate time intervals has a great influence on the correct data analysis. Actually, the data sampling is achieved through this selection. The understanding of the data sampling methods has always a great relevance; since the drawn conclusions are basically depend on this [5]. Unfortunately there are several research topics, where the possibilities and circumstances of data sampling are not ideal. Also the military historical reconstruction is belonging to this special category as reviewed in the next chapter.

3. Military historical reconstruction

The use of the geographical information system in military historical reconstruction is a very special application, but a few international papers in this topic have been published in the last years. The specialty of the topic is caused by the limited data sources, the various durations of the events and the need of multidisciplinary knowledge. I would like to review only the part of the process which is connected to the temporal data management. There are three major levels of a complete reconstruction: the modeling of the period’s environment, the defense objects and finally, the military historical events. It is logical to integrate the data from archive sources (maps, aerial photographs), which were created sometime around the given date, thus the environmental features in the database are also connected to this date. It is the same situation in the case of the reconstructed defense objects. However, there can be various versions connected to certain objects, like the statement at the date of built or the renewal date. Considering the temporal data handling, the most interesting part is the reconstruction of the military historical events.

First of all, it is important to investigate the reconstruction considering data sampling. The two major parameters are the duration and the time interval of the sampling. The definition of the duration generally does not cause any problem, because the investigated events are started and finished in the past. However, there is much more obstacle in data sampling. Unfortunately, there are only limited numbers of archive data that can be found in connection with the particular events. According to this fact, it is always necessary to integrate all of the collected information into the database. It is important to take a note here. To achieve an objective and reliable result, the source criticism is very useful in the process, mostly in the case of written documents. From the reviewed concepts, the “Sequenced snapshots” and the “Space-time cube” methods and additionally simple graphics and symbology were applied in my previous researches. The data representation is one of the most important functions of the reconstruction GIS databases. The military events have been designed and presented on maps for centuries, so there is traditional symbology on these paper maps. Therefore, it is useful to apply the same representation in the GIS database, too. Hereinafter I discuss one of my achieved reconstructions; the Attila-line.

The Attila-line was built in 1944 when the soviet attack reached the Hungarian border from south-eastern direction. The major aim of this defense line was to protect Budapest and to stop further attacks. The defense line consists of three parts which run around the Pest side like a horseshoe. The battle lasted for weeks and it was one of the biggest sieges in the WW II. To reconstruct the military events I had to represent the particular defense lines, the position and the movements of the front lines and the corps. There was point features (bunkers, artillery, corps…), line features (front line, defense line…) and polygon features (arrow, front…) defined in the database. The important dates were connected to the certain features as attribute data (Fig. 9.). The representation of the defense objects and the events in connection with different dates is already very informative. Similarly, the possible attribute and spatial queries are also supporting the analysis of this event.
Figure 9: Representation of the military movements in the reconstruction of the Attila-line
(1944-45, Budapest, Hungary)

4. Conclusions

The geographical information system is already “discovered” and used by the archeology and the military history. The highlighted GIS functions are the data storage, the registration and the representation for these human disciplines, thus the temporal data have to be integrated in the databases considering these functions. The most important characteristics of the military historical reconstructions are the lack of information and necessity of source criticism. The GIS database enables not only the uniform data management of the information with various geometry and attribute but also can be used for different analyses and queries. Generally, considering temporal data handling the low leveled concepts are to be applied in the reconstruction processes.

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