Software Tools for Movement Visualization in Agrarian Sector

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Anotace

Rozvoj informačních a komunikačních technologií přispěl k rozvoji metod vizualizace dat. Existuje mnoho nástrojů, které umožňují monitorování pohyblivých objektů v agrárním sektoru a řada způsobů využití polohových dat a přístupu k nim. Jejich použití závisí především na uživatelských požadavcích. Každá skupina uživatelů má jiné nároky a jiné kompetence k ovládání softwarových nástrojů. Hlavním cílem tohoto článku je analýza cílových skupin uživatelů a určení vhodnosti jednotlivých GIS (geographic information system) pro různé uživatelské skupiny.

Experimentálně byly ověřeny tři způsoby užití a to: desktop, server a developer. Byly zhodnoceny jejich možnosti s ohledem na cílovou skupinu a požadovanou funkcionalitu. Testování využívalo standartní úlohy vizualizace pohybu, například zobrazení bodů, tras pohybu, polygonů a heat map výskytu. Použitá datová základna byla získána v rámci dlouhodobé spolupráce Katedry informačních technologií a Katedry myslivosti a lesnické zoologie.

Klíčová slova

GIS, Google Maps ,vizualizace pohybu, geolokace, mapové služby, uživatelské skupiny.

Abstract

Development of information and communication technology also led to development in data visualization methods. There are many tools for monitoring of moving objects in agrarian sector, and also many different approaches on how to access and utilize location data. The suitability of given solution depends mostly on user requirements. Every user group has different demands and rights when operating software tools. The main objective of this article is to analyze different user groups and suitability of various GIS (geographic information system) for them.

Three different approaches were experimentally evaluated: desktop, server and developer. Possibilities of these GIS solutions were ascertained with the target user group and required functionality in mind. Software was tested using standard movement visualization tasks, such as point location, movement paths, occurrence boundaries, and occurrence heat maps. Data used for the evaluation was procured from a long-term cooperation between Department of Information Technology and Department of Game Management and Wildlife Biology.

Key words

GIS, Google Maps, movement visualization, geolocation, map services, user groups.

Introduction

GIS originated in 1960s and its development is closely linked to the evolution of computer hardware and aeronautics (Rhind and Coppock, 1991). Computers were necessary for automated processing of large amount of information and satellite imagery provided previously unavailable data. Development of GIS started in academic environment in USA and Canada, and penetrated to government and private sector during the 70s and 80s. The two most commonly used GIS today by ESRI and Intergraph have its origins in those decades. With the wider spread of the internet, GIS development focused mainly on standardization during the 90s. In the new millennium, thanks to the boom of personal computer technology, GIS transformed from being a tool used by a handful of specialists to a ubiquitous system that is commonly used by many users, whether they need to find a closest bus stop on their mobile phone or plan a family vacation using interactive map on their desktop computer.

GIS are specialized systems for geographic data management, storage and processing (Heywood et al., 2011). They are capable of solving wide array of tasks and spatial calculations regarding the position, relationships and trends of spatial data using maps, globes, reports and charts to visualize the results (Klimešová and Brožová, 2010). One subset of these tasks comprises of movement monitoring, which models the dynamics of real world objects by capturing data about their movement and running further spatial calculations upon the data. Movement monitoring includes scenarios such as animal movement in open air, cars inside traffic, packages or containers within storage halls or during transit (Dimitrova et al., 2013), or people in city environments such as shopping malls. Using buoy with GPS locator, it is also possible to measure river stream speed, depth or water temperature in sections of the river without the need of multiple costly measurements (Hooge et al, 2001). Processing movement data helps to better understand the behavior of objects within the observed system and aids analysis and categorization of the given space, which in turn provides crucial information for tasks such as construction planning or public space organization (Koshak and Fouda, 2008).

In agrarian sector it is often required to monitor moving objects, such as animals or agricultural machinery. Positional data need to be stored and accessed in an optimized form. Various types of GIS can achieve these tasks. The specific requirements depend mostly on type of users, which access the data. Each user group has different needs and competence to handle the software tools.

Main objective of this article is to analyze different user groups and the suitability of various GIS software types for these user groups. Analysis is specifically focused on visualization of object movement. Several GIS solutions were experimentally tested with the target group and its needs in mind.

Materials and methods

According to Bonham-Carter (1994) working with GIS can be divided into three fundamental phases. Firstly, the used data has to be gathered. Then the actual GIS software is used to process the data and perform tasks and calculations. In the last phase, results are analyzed, visualized and conclusions are reached. In the area of movement monitoring, the data acquisition is usually done using GPS or other location tool, which is attached to moving objects. In case of small and closed environments such as storage halls or shopping malls, CCTV (closed circuit television) can be used instead. Movement monitoring is highly specific in the data processing phase, since it uses calculations that are tailored for visualization of movement and can be hardly used for stationary objects. The most common tasks in agrarian sector are calculation of movement paths, their occupancy, traffic density in individual nodes or routes, or the expected occurrence of an object in given area. GIS also allows additional object properties to be attached, so that multidimensional queries using various object attributes are also possible. Lastly, the output of these tasks usually comes in form of graphical representation, such as point and line for paths, polygons for significant areas or heat maps to categorize observed space. Processed data can be also used for further non-GIS calculations, such as statistical analysis.

Majority of GIS software is capable to handle these task with relative ease, but every type of GIS solution has certain specifics which can lead to different levels of performance and usability. Every individual case can therefore have different GIS solution that is most suitable. Sometimes, the basic personal version of GIS using a desktop computer is enough, other times it might be necessary to employ a more robust solution using server GIS alongside smaller hand-held clients. Some problems may require a more tailored solution developed specifically for them. This article classifies GIS and ascertains suitability of different types of GIS with respect to the user group and its needs.

GIS software categories

GIS encompasses all software that deals with geographical data in any manner or form. It is possible to separate GIS software into categories based many different criteria. Longey et al (2005) divided GIS software into five categories based on its main purpose and type of deployment:

- **Desktop GIS software** is targeted for personal computers. Software in this category can be divided by the type of operating system, or it can be separated into sub-categories based on its functionality and overall scope. There are software ranging from basic map viewers, to more complex mapping and editing systems, and very high-end systems for professional users with high demands.

- **Server GIS** processes requests from clients in the network. Those can be lightweight versions of desktop application or field devices such as mobile phones. Server GIS can usually also accommodate service using web browser interface. Its deployment is best suited for problems that involve a network of multiple users and allows every user to access full functionality capabilities of the server GIS using only a "thin" client.
- **Developer GIS** are toolkits for programmers to create highly customized and optimized applications. These can be either stand-alone applications or embedded inside another piece of software. Web applications with integrated GIS capabilities can also fall into this category.
- **Hand-held GIS** operates on a smaller machine, like mobile phone or tablet. This type of GIS generally does not provide the same capabilities as desktop version due to the limited hardware capacity. Some most common and easy to process functions are usually included, but for the more complex calculations, hand-held devices often need to access GIS server.
- **Other GIS types** besides the main four also exist. They usually provide some very specific functionality. Most of software in this category does not feature the full GIS core but rather focuses on a certain aspect of geographical related problems and offers a precise solution. Usual specializations include geographical data management, image processing, visualization and modelling tools.

Each software type comes with a specific set of possible uses and applications. Some problems can be addressed with multiple types of GIS software, while others require the usage of certain software category.

Software requirements

According to Eldrandaly (2007) there are five major criteria when selecting the appropriate GIS software: cost, functionality, reliability, usability and vendor support. However in this article we will focus mainly on the first two. The main priority is to choose a solution that is functionally capable of solving the problem. After eliminating software that is missing the required functionality, the overall cost of solution has to be determined in order to select the most suitable software.

Total cost of a GIS solution is comprised of multiple expenditures which can be divided into three main groups. Firstly, the cost of hardware which depends on the technical requirements. Desktop GIS can be generally run on any personal computer, while server GIS may require a designated engine with nonstop runtime and sometimes also requires additional hand-held client devices. Second part are software costs. This includes the price of the actual GIS software as well as any other required licenses / permits. Lastly, there are costs embedded in human resources. These can involve the training needed for users to operate the GIS software, or the cost of hiring new employees to create, use and maintain the software solution.

The above mentioned costs can further be separated into two groups based on time. One is the initial price and other is long term upkeep and maintenance (Idrizi et al, 2014). The initial hardware cost includes the purchase of any equipment while the upkeep cost encompasses the price of keeping the machines running. Software costs can be separated into those two groups as well, since GIS software licenses can have a yearly based character. Any costs for support from the software vendor can be also considered as a long term software cost. Costs in human labor can be divided like this too. There can be a higher initial cost, for instance when deploying a developer type based solution. But once created the costs in human resources will drop significantly. No matter the type of solution, someone will be always required to operate it. Salary of administrators or other involved personnel constitutes the long term human resources costs.

Moving object visualization

According to Jarolímek et al (2014) the following graphic representations are most crucial in visualization of moving objects in agrarian sector, specifically animals:

- **Point** holds the information where the object was at a given time. Every point can contain additional information such as conditions at the time, object status or activity being performed.
- **Path** connects points based their succession in time. Path allows for the movement of object to be captured and easily displayed. The shorter the interval

between measurements, the more accurate the path will be.

- **Occurrence boundaries** is a polygon shaped space which determines where the object is commonly located. Overall or time specific boundaries can be calculated. When dealing with animal movement this area is usually called “home range”.
- **Occurrence heat map** uses colors to distinguish areas based on how often the object was present there. This allows to model the probability of occurrence at each possible location. Illustration of this type of visualization is illustrated on figures 2 and 3 in the Results and discussion section of this article.

GIS software user groups

GIS application users can be divided based on various criteria. Two important categorizations are based on the type of user access and user environment.

Type of user access determines the authorization that the user will be given, limiting the extent of control over the application and data. The four main types of user access are:

- **Main administrator/s** is a group of users that has the most control over the software. This group has the absolute authority and generally includes only people with good knowledge of the actual GIS environment. Users in this group manage the system, determine rights for other users, manage the data sources and also create outputs.
- **Regular user** is usually someone from the wider range of people who work on a given project. These can also be associates or business partners that are allowed to access the core GIS functionality. Users in this group perform common tasks and operate the software. They generally have lower rights than the main administrators.
- **Professional public** comprises of academic, business or government administration users who are not directly involved in the project, but may require access to it for various reasons. Users in this group are expected to have at least basic knowledge of GIS. They usually do not have access to the source data, but may be given access to outputs generated by the application or limited rights to operate the software.
- **General public** has the same rights as professional public, but users in this group do not possess any special training or knowledge about the project. They usually access the application by chance or by using a mediator. These users generally do not operate GIS much and only require to view the most basic and plain outputs. Projects that focus on this user group specifically are generally trying to popularize the issue in question.

Second categorization is based on the environment where GIS is initially being used and therefore determines the general purpose of its application. The four main categories are:

- **Science** where GIS is used to analyze research data and create outputs for research results publishing.
- **Business** environment where GIS is used to optimize business processes and achieve better profit or other company goals.
- **Government administration** which uses GIS application to effectively govern and share important data with citizens.
- **Personal** usage can for instance include individuals that use GIS for their hobby or various clubs and non-profit organizations that need GIS because of the focus of their activity.

Results and discussion

Based on the analyses of different GIS types and user groups in the previous chapter, the following three main types of GIS deployment were selected to be included in the experimental evaluation:

Desktop GIS

Solution based on desktop GIS is suitable mostly for smaller teams, regardless of the user environment. One or few users can be selected to serve as the main administrators who also operate the GIS while the rest of the team does not use it often or at all. This can make the overall management much easier. This solution can also be the cheapest. Software licenses are generally expensive but when it necessary to purchase only one or few copies for couple of personal computers, the overall cost is not that high. The costs of hardware are usually negligible, since in general, no new machines have to be purchased. Desktop GIS is robust enough to contain the required functionality for movement visualization. The main disadvantage of this approach is that the outputs have to be manually created. Desktop GIS does not have high level of automation and the outputs are not interactive. After each data update, processing and creation of outputs has to be done over again.

Server GIS

Server GIS solution is best used in business environment, government administration or larger research groups. It allows for centralized data management and presentation of results using report modules that can directly feed the output to web interface. This type of solution is however too robust for movement monitoring which is only small sub-section of server GIS capabilities. Therefore the costs (both software and hardware) may be unnecessarily too high. If the software can be used for other purpose within the company or research team, the investment might be worth it, but it can also lead to the server being overloaded. Processing calculations in batches can decrease the server traffic but introduces a delay and reduce the solution interactivity. The basic schema of server GIS solution is illustrated on figure 1.

Developer GIS

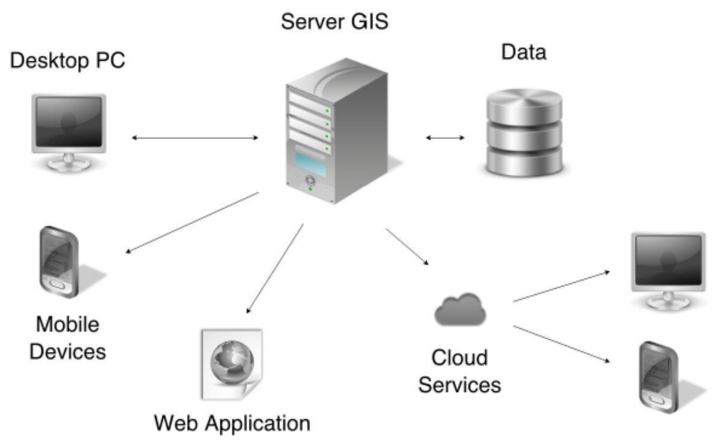
Using GIS developer tools it is possible to create own solution for the project. It does not have to be very costly since open-source software can be used. The main issue of this solution is its time consumption, because the entire application has to be written first. It requires a significant time investment and an experienced programmer or team. After its development the application can be usually maintained easily by an administrator with proper training. Another major disadvantage is the application low flexibility. When new functionality, updates or upgrades to the application are needed an extensive overhaul has to take place, which produces more time delays and additional costs. GIS application can be developed to be integrated inside a web application which makes the outputs more accessible and interactive. This type of solution is therefore most suitable for situations where the entirety of required functionality is known beforehand or if results have to be published online.

Table 1 summarizes the aspects of different GIS solutions with regards to the extent of their functionality, output publishing, costs and user groups.

Experimental verification

To verify defined requirements and limitations, each of the three types of deployment was tested. Used data depict animal movement and was obtained from a long-term conjoint research of Department of Information Technology, faculty of Economics and Management and Department of Game Management and Wildlife Biology, faculty of Forestry and Wood Sciences. The results of the three experimental solutions follow:

- **Desktop GIS:** ArcGIS software, version 10.2.1 was used. Data about animal movement were transferred from Microsoft SQL database server to Microsoft Excel format and uploaded into the ArcMap application. Thus the base data layer was created upon which the visualization tasks were computed (see figure 2). This solution provided high level of control over the calculation processes, but had little to no automation and provided only static outputs.



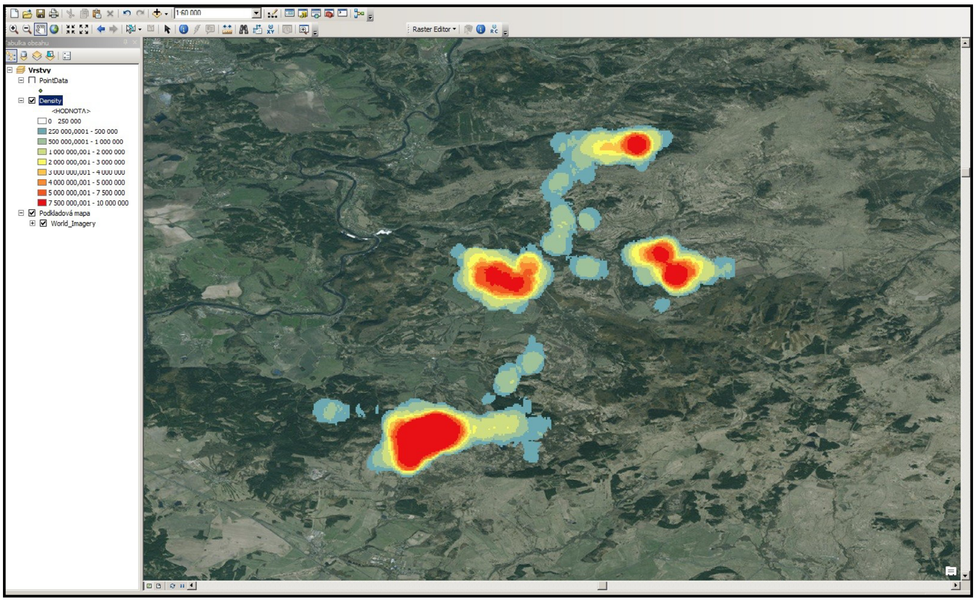
Source: Author; general structure of the schema is taken from ARCDATA, 2015

Figure 1: Server GIS schema.

	Functionality extent	Output publishing	Costs	User groups
Desktop	can handle common tasks, additional modules can be purchased if needed	manual output creation, static outputs	low hardware costs, medium software costs	small teams, business, science, personal use, usually has only one main administrator
Server	very robust, can handle almost everything	easy outputs using report modules, utilizes web interface	hardware and software both very costly	government, business and research, larger teams, many regular users
Developer	functionality has to be determined beforehand, difficult to change	can be highly automated, interactive outputs via web application	costly to develop (programmer salary), time consuming	any environment and user access, tailored to fit the actual needs

Source: Author

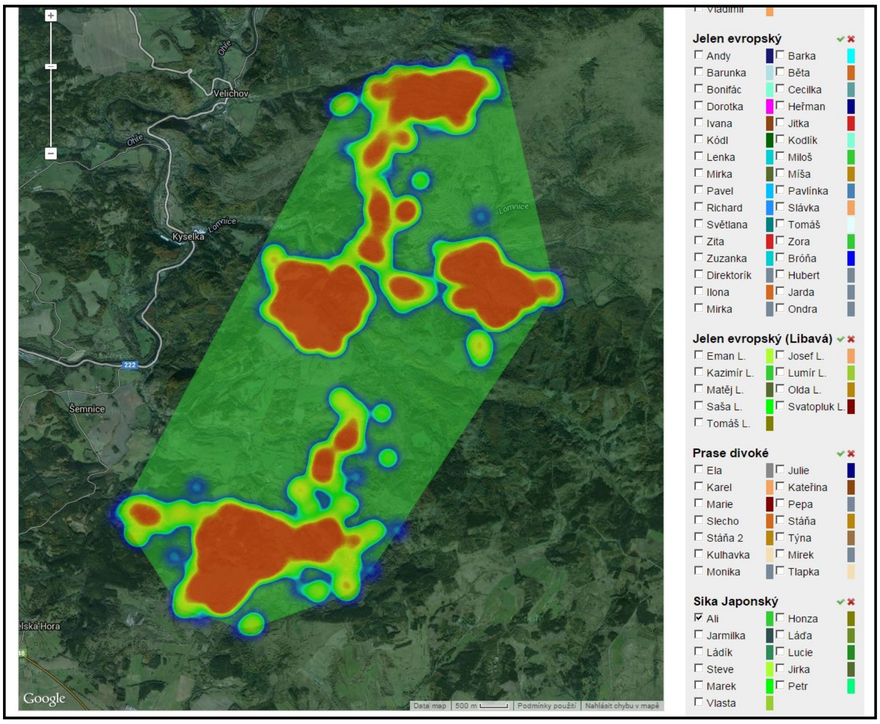
Table 1: Comparison of different GIS types.



Source: Author

Figure 2: Animal movement heat map – solution in desktop ArcGIS.

- **Server GIS:** This solution was created using open source platform GeoServer. This software uses XML (Extensible Markup Language), more specifically SLD (Styled Layer Descriptor) documents to control the calculations and resulting visualizations. Commercial server software generally uses the usual point-and-click interface similar to desktop GIS. This solution was highly complex and because of the small team of authors working on this article, it was actually very demanding to deploy. But it provided better functionality than desktop solution and more importantly it allowed for automation and somewhat interactive outputs.
- **Developer GIS:** This solution was already created from previous research projects (Masner and Stočes, 2013) in web application Game Online (zver.agris.cz). Google Maps Javascript API v3 (application programming interface) was used to integrate maps and calculations into the web application. Animal movement data is continuously updated within Microsoft SQL database using Ground Station Harvester 1.0. The application accesses the data directly and no conversion is therefore needed. Developer GIS solution had the highest demands to implement, since it required knowledge of all used languages (HTML, SQL, javascript). But significant time investment lead to a solution that is highly tailored to the required task, does not contain any excess functionality and allows for high level of output interactivity, which can be seen on figure 3. Easy to control web interface makes this solution very suitable for general public.



Source: Author

Figure 3: Animal movement heat map and home range polygon – solution in GoogleMaps.

Conclusion

Based on analysis and synthesis of available source material, essential properties of movement visualization solutions were compared. Three main GIS deployment types (desktop, server, developer) were experimentally tested. Theoretical knowledge was verified, using sample animal movement visualization project. Desktop GIS proved to be very scalable and inexpensive, but with shortages in output and automation. Therefore desktop GIS should be used mainly in scientific, small business and personal environments. Server GIS solution is very robust and in turn expensive and is too strong of a tool for movement visualization which is only a small subset of possible performed tasks. Its use is recommended in government and large business environments, or in the field of science, provided it can be used for multiple different projects. Developer GIS solution turned out to be highly effective thanks to being crafted accurately according to the project needs. Time consumption and demand for programming prowess of developers can be compensated by higher level of automation and interactivity when integrated inside web application. This solution is therefore most suitable for project that require bigger involvement of public user groups.

Summary of apt conclusions for different GIS types with regards to defined user group access type and environment is depicted in tables 2 and 3 respectively.

Experimental verification was conducted within the area of agriculture using animal movement data. Similar approach can be used for other agrarian tasks such as movement of agricultural machinery. In many cases, reached conclusions can be in effect in other areas of human activity as well.

	Desktop	Server	Developer
Main administrator	+ high level of control - no automation	- difficult to manage if administrator team is small	- time demanding to change or add functionality
Regular user	- expensive if there are many users	+ multiplatform access + easy data sharing	+ easy to operate - single platform access
Professional public	- static outputs	+ access through web interface	+ easy data sharing if required
General public	- no web integration	- traffic can cause server overload	+ possibility of web integration

Source: Author

Table 2: GIS comparison for defined user group access type.

	Desktop	Server	Developer
Science	+ scalability - no extensive publication	- only for large projects	- need to specify functionality beforehand
Business	- no data sharing outside of company	+ suitable for big companies with many users	+ cheaper for IT companies who already employ programmers
Government Administration	- no automation	+ can handle many simultaneous agendas	- difficult to keep up to date with changing legislature
Personal	+ some vendors provide major discounts for personal use	- too costly	+ can be tailored to accommodate unusual requirements

Source: Author

Table 3: GIS comparison for defined user group environment.

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