GEOINFORMATION TECHNOLOGIES POSSIBILITIES FOR WEB-BASED MAPS AND NAVIGATION APPLICATIONS DEVELOPMENT

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Abstract
At present geoinformatics usage has got global penetration in many industries and areas, including, spatial and environmental modeling, urban planning and land use management, agriculture, healthcare, insurance, military sector, automotive sector, transport and logistics, telecommunications and media, economic and business analysis, and many others. However, navigation systems developments are one of the benchmark aspects of the geoinformatics, used by billions of peoples every day via different apps and screens. At the very core of a navigation system stays a digital map. Focus of the article is the map making process in digital environment by the example of HERE Technologies, as well as the digital maps usage as a base for some of the HERE Technologies derivative products in the areas of automotive, transport and logistics, supply chain and infrastructure planning. Special attention is given to the initial source of information and data quality. Separately it will be presented the HERE Bulgarian map in the context of the HERE global map.

Keywords: geoinformation, digital maps, navigation systems

INTRODUCTION

The scientific problems related to organization and understanding of space are developed during the last fifty years. The process started with classical mapping and cartographic modeling and develop with the integration of the technologies in geographical knowledge and spatial modeling. In theoretical aspects it is projected in the works of Salistev (1982), Robinson et al. (1984), Berliant (1986, 1988), Aronoff (1989), Bartels, Ketellapper (1979), Konecny, Rais (1985), Burroughs, Macdonell (1998), Foote, Lynch (1990), Kirkley et al. (1987), Knox (1964), Smyth (1998), Tomlin (1990), Ziegler, Kim. (2000) etc. The natural evolution of this process is the interaction and implementation of remote sensing and web-based technologies.

The other aspect related to the models and modelling in geography and optimization of the spatial analysis is based on the research of Haggett, Chorley (1967), Haggett (1990), Harvey (1969, 1996), Hägerstrand (1967, 1983).
GEOINFORMATION TECHNOLOGIES AND WEB-BASED MAPS

Geoinformation technologies and web-based maps

One of the challenges of classical cartography is the transition from analogue to digital or web maps. With the development and ubiquity of geoinformation technologies in the scientific, socio-economic and social world, this transition is a natural consequence and development in the creation of cartographic products. Geoinformation technologies allow the collection, processing, and visualization of huge data sets obtained from different sources. Nowadays, there are many open-access web-based programs for adding, processing, and sharing information of different nature on a cartographic basis. Crowdsourcing, or in the context of cartography, volunteered geographic information (VGI), which falls under the Big Data phenomenon and with the help of geoinformation technologies, leads to the creation of new spatiotemporal patterns in web cartography in both quantitative and qualitative aspects. Such models are web maps with different thematic focuses and various mobile applications. Participants in crowdsourcing are both information providers and users of the added information, and geoinformation technologies enable this to happen in real-time. On the other side, business organisations, public and non-governmental sectors, use geoinformation technologies, through the so-called Application Program Interface (API), and allow the connectivity of mapping platforms with providers of other types of processed information, again in real-time. For example, real-time information on the weather, traffic, the concentration of people in certain places, air pollution, the level of water bodies, the stage of development of agricultural products, etc. At the height of the Covid epidemic, many mobile applications were developed to locate Covid-19 vaccination centers and hospitals with vacant beds for treatment. Within the widespread use of geoinformation technologies, one of the most used applications are web-based maps.

HERE Technologies is a global leader and pioneer in the production and delivery of mapping databases, Location-based products and services (LBS) for a variety of industries, and public and non-governmental sectors. The main thematic focus of the maps is related to the development of navigation applications for the automotive industry. In 1985 the company was established under the name Karlin & Collins, Inc. as a small start-up providing “door-to-door” maps through kiosk utilities for specific areas in San Francisco, California in the USA. The company later grew and changed its business model from one for end users to a business model aimed at hardware manufacturers. In the early 1990s, Philips Electronics acquired Karlin & Collins, Inc., and together the two companies began developing map databases for embedded navigation systems for automobiles. This led to the development of the first navigation system for the BMW 7 Series in 1994 and the first web-based map in 1995. In the meantime, the company’s name changed to NavTech and later to NAVTEQ. In 2000 NAVTEQ provided map databases to 2/3 of the automotive industry. In 2007 NOKIA acquired NAVTEQ. A new era in the development of maps for cellular and smartphones has begun. The name of the company changed to HERE. In 2015 followed a new acquisition by a consortium of German automotive companies - Audi, Mercedes & BMW.

Methods and technologies in HERE map development.

From the very beginning and to this day, the primary method for collecting baseline data for the development of the HERE map has been the field method. Initially, field data were collected manually on paper plates. Later, data collection was done using portable hardware devices connected to GPS, of the personal navigation device (PND) type. As a result of the increasing spatial coverage, data collection requires the use of more efficient technologies. In the 1990s, the first NAVTEQ field cars were developed, equipped with a GPS receiver, a front camera, and a computer with special software that controls the peripherals or a so-called single-camera kit Fig. 1.
Fig. 1 Vehicle equipment for terrain data acquisition. Top left PND

Specially trained employees describe additional environmental information. The additional information includes data on street names, addresses, adjacent objects, and horizontal and vertical road markings. The volume of GPX and MP4 data collected by this type of vehicle, over an 8-hour working day amounts to approximately 10-12 GB. The next generation of data collection vehicles is the so-called multi-cam vehicles. What is new about these is the presence of 4 to 7 cameras mounted on the roof of the car that capture the surroundings up to 315°, as well as a more powerful computer and server in the trunk of the car (Fig. 2).

Fig. 2 Multi-camera equipment of a terrain vehicle - server on the left, set of cameras mounted on the roof of a car on the right

In 2010 NAVTEQ, being a part of NOKIA, developed together with Microsoft the technology for NAVTEQ True cars, fig. 3.
The equipment includes one set of 6 high-resolution front cameras that capture 270° in front of the vehicle and 1 rear camera. The second set of 8 cameras captures 360° horizontally and two vertical cameras (Figure 4).

LiDAR sensor containing 64 horizontally positioned lasers with a laser radius range of 100 m, which collect 1.3 million points per second from the surrounding environment (Figure 5).
Z-coordinate precision distance measurement unit (internal measurement unit, IMU), GPS receiver, etc. Figure 5 illustrates the elevation variation in road gradient processed from the IMU data. Fig. 6 illustrates processed data from a fragment of terrain captured with the HERE True car.

Today, the HERE True fleet consists of over 400 vehicles. On an average day, the vehicles drive over 100,000 km on pre-planned routes in different countries and cities and collect 28 TB of LiDAR data, with centimeter accuracy.
Maintaining an up-to-date digital map with global coverage is an ambitious and resource-intensive task. The length of all classes of roads suitable for road transport around the world is estimated at just over 64 million km. In the HERE map, the road length is 63.7 million km. If we assume that a HERE True vehicle can travel and capture per day an average of 300 km, then it would take 640 days to fully capture the world's roads with the available fleet. The very next day, however, there will have been changes on the earth's roads that will not be registered and the information on the map will not fully correspond to reality. This means that the capabilities of the field method alone are currently too limited to maintain an actual map of the world, even just the roads.

**Remote sensing method**

The possibilities of the remote sensing method for capturing the territory of the earth compared to the field method are incomparably greater. According to the Union of Concerned Scientists (UCS), in 2022, there are over 4,850 satellites in orbit around the earth, imaging the earth's surface for various purposes, 150 of which are navigational. For example, according to the European Space Agency (ESA), the two satellites of the Sentinel-2 mission, located in a polar orbit at 180° to each other, can cover a 290 km wide area at the equator in 5 days and at mid-latitudes in 2-3 days. This undeniably proves the advantage in scale and time of the remote method compared to the field method.

Maxar Technologies is HERE's partner in providing satellite images. Satellite images have global coverage without Antarctica. Processed in WGS84 projection with a resolution of 50 cm, with 30 cm resolution for certain areas, such as larger cities. Deviation in these images is between 3 and 5 meters. Loading a high-resolution layer on a cartographic substrate allows the addition of roads, including markings, the addition of 2D and 3D polygons of buildings, and the detection of incompleteness and gaps in the map content, especially in a park and suburban terrain where access to motor vehicles is prohibited. (Fig. 8).

**Key study areas**

To achieve better generality of the methods applied in this study, two key regions for modelling, evaluation, and analysis have been identified.

Both regions are in urbanized areas.

In the first case, a park area with close parameters to natural landscapes was selected, including forest formations, grass formations, wetlands, etc. - the region of the South Park of Sofia City (fig. 8).

The second territory is defined because it has a long historical period of anthropogenic impact - the town of Nessebar (fig. 9).
Third-party data

Despite the great opportunities provided by field and remote methods, a global map cannot be kept sufficiently up-to-date by collecting data from the field using remote methods. Data from the public sector and other data providers are an integral part of the content in the HERE map and the volume and type of data are continuously expanding. Examples of public sector data are cadastral data, data from post offices, national road maintenance agencies, data from various ministries and institutes, municipal data, and data from academic institutions and business organisations. Most of this type of data, e.g. administrative boundaries, postcodes, building plans, etc., cannot be collected by field or remote methods (Fig. 8)
Fig. 8 The administrative boundary of the Sofia city region is outlined with a white and blue dotted line. In the centre is the enclosed Sredets district. In the upper right, the postcode 1000 is visible.

In addition to data from the public and non-governmental sectors, the HERE map also contains data from providers of various types of real-time information. The capabilities of geoinformation technologies to share, process, and display data in real-time is what builds on and defines the direction of development of end products and mobile and web-based maps in particular. Such data are, for example, data from car navigation or mobile applications connected with GPS. During movement, the devices emit a signal and leave a trace with geographic coordinates, the data are stored on a server or in a cloud, they are processed by software and made available in real-time via API connectivity at intervals between 30 and 60 seconds to HERE servers. The processed data provides real-time traffic information as an additional layer in the map content (Fig. 8)

Fig. 8 WeGo HERE fragment of the web map, Sofia City, business day, about 9:00 a.m. with a loaded real-time traffic layer
The information contained in the data from the related attributes such as the direction of travel, speed, etc. are further analysed and processed and are also used to build and maintain the content in the map (Figure 9).

**Fig. 9 HERE Map Creator, map fragment, town of Nessebar with loaded data layer from connected GPS devices**

**VGI / Crowdsourcing**

Voluntary provision of map information (VGI) is a widespread phenomenon in the context of web mapping on the Internet. The contribution of end-users is enormous and growing. Thanks to geoinformation technologies, end users are providers and, depending on the platform used, could also be users of map content, almost in real-time. For the efficient use of VGI for HERE map maintenance, a dedicated web-based open-access program was developed - HERE Map Creator. In HERE Map Creator users can add and make changes to some of the attributes of the map content. These are: roads, objects, street names, addresses, attributes of the vertical and horizontal road markings, 2D polygons, etc. The specificity of HERE Map Creator to maintain the highest possible data quality in HERE end products is based on the fact that before being integrated from HERE Map Creator into HERE WeGo every change is subject to a strict quality control system and is integrated only after successful validation. For this reason, there is a time lag between adding data to HERE Map Creator and it appearing or not appearing in HERE WeGo.

**HERE WeGo web map and mobile application**

The collected output data are processed on an ongoing basis in the production centres and in over 50 representative offices of HERE Technologies in different countries. The map provides different degree of coverage for over 200 countries (fig. 10).
Every day more than one million changes are made in the HERE map. Implicitly, the map content, arranged in a hierarchic structure, includes almost 1000 attributes and more than 120 categories of objects (fig. 11 and 12).
In addition to the map content can also be loaded layers of satellite images, real-time traffic and weather information (only for the mobile application).

**HERE WeGo web map of Bulgaria**

In 2009 the content of the HERE map for Bulgaria included a part of the National road network, the first and the second class of roads and partial coverage of the road network in Sofia and in other regional cities. The Bulgarian branch of HERE was established in 2010 with main business activities related to development and maintenance of the data in the map. Today, the HERE map for Bulgaria is the web navigation map with the richest content (fig. 13). Some of the content is:

- National and municipal road network - 110 000 km.
- Addresses – 620 000
- Street names in 2500 settlements
- Horizontal road marking on the National road network plus all cities
- Attributes designated for truck navigation
- Advanced Driving Assistance Systems (ADAS) on the National road network
- Digital Terrain Model (DTM)
- Hydro layer
- Forest polygons
- Real Time Traffic
- Etc.

**CONCLUSIONS**

For the development and maintenance of web maps, the key methods for extracting output data are the field method and the remote method, as well as the use of data available from third-party – public sector and private sector. VGI has supplemental effect with a huge potential. The quality of the output data rather than the technology used is the key component of developing the end products. The human factor still plays a key role in data processing and collection; however, the increasing use of artificial intelligence, 5G technologies for data exchange from connected devices and communication through a cloud space, soon will reduce to the minimum the human participation in the digital cartographic process.

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**BIOGRAPHY**

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