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Real-Time Mapping: Contemporary Challenges and the Internet of Things as the Way Forward

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Abstract. The Internet of Things (IoT) is an emerging technology that was conceived in 1999. The key components of the IoT are intelligent sensors, which represent objects of interest. The adjective 'intelligent' is used here in the information gathering sense, not the psychological sense. Some 30 billion sensors that 'know' the current status of objects they represent are already connected to the Internet. Various studies indicate that the number of installed sensors will reach 212 billion by 2020. Various scenarios of IoT projects show sensors being able to exchange data with the network as well as between themselves. In this contribution, we discuss the possibility of deploying the IoT in cartography for real-time mapping. A real-time map is prepared using data harvested through querying sensors representing geographical objects, and the concept of a virtual sensor for abstract objects, such as a land parcel, is presented. A virtual sensor may exist as a data record in the cloud. Sensors are identified by an Internet Protocol address (IP address), which implies that geographical objects through their sensors would also have an IP address. This contribution is an updated version of a conference paper presented by the author during the International Federation of Surveyors 2014 Congress in Kuala Lumpur. The author hopes that the use of the IoT for real-time mapping will be considered by the mapmaking community.

Keywords: Internet of Things, real-time mapping

1. Introduction

The ultimate goal of cartography is to prepare a map — a quantitative model of reality — to be used to develop information and knowledge. For a map to fulfil this role, data used for its construction must be current. Since real-world objects continuously change by altering their location and attributes, each map is always, to varying degrees, an historic document. The currency of a map's content has always been a problem for cartographers and map users. Over the centuries, various methods have been used to ensure maps are current or up-to-date, including severely punishing mapmakers, maintaining a master map to record changes noted on the ground, keeping an 'army' of mapmakers on a payroll, disclaimers warning users that a map may contain errors and omissions, and metadata standards and requirements. However, none of these measures resolve a map's currency problem; the problem remains and has gradually become a determinant of contemporary socioeconomic development.

Real-time mapping is gradually becoming a focal point for cartographers as a way to mitigate a map's currency issue. This is despite cartographers still having problems related to visualisation of three/four dimensional space, including the time dimension.

The aim of this paper is to help fellow mapmakers to develop an awareness that there is an emerging art and technology that, in our view, could be instrumental in resolving a map's currency issue. This art and science is known as the Internet of Things (IoT). The contents of this paper include a short introduction to the IoT, a proposed solution for a map's currency problem using the IoT approach, specification of some key questions, and the challenges associated with the adoption of this innovation to cartography and the geosciences.

This paper is a developmental version of a conference paper presented by the author during the International Federation of Surveyors (FIG) 2014 Congress, Kuala Lumpur. It was presented at the International Cartographic Conference in Rio de Janerio, Brasil in 2015.

2. Real-Time Mapping

2.1. Maps

Many definitions of a map have been developed over the centuries (e.g. Kraak and Ormeling, 2002; Pickles, 2003). Here we present another attempt to define a map. This definition indicates what a map is made off, and is generic enough to cover current trends and innovations in cartography (Becek, 2010).

A map is a collection of spatially related data presented for use by the human visual perception system in order to extract information.

According to the above definition, there are three fundamental elements that constitute a map:

- A collection of spatially related data must be on hand to create a map. The collected spatially related data defines the spatial extent of the map.
- This data collection must be presented to humans in a suitable way for visual perception and comprehension. This element includes all technical details of the presentation, such as medium, file format, symbology, and annotations. For visually impaired people, other forms of inspecting the data are available, i.e. the Braille alphabet and a verbal channel.
- The presentation of the collection of spatially related data must be made in a way that the user is able to make informative decisions based on the data.

This means that a map, among other things, must be up-to-date or current; the collection of data must be timely to reflect location and attributes of objects being mapped.

Spatially related data represent objects both abstract and physical by defining their location, type, and attributes. Considering time as one of the independent variables, location and attributes may not be fixed. This rather obvious observation determines the above-mentioned historical characteristic of made maps. Table 1 shows traditional (using surveying, photogrammetric, and remote sensing methods) mapping options of objects with various 'behavioural' properties with respect to their location and attributes; 'A' and 'N/A' indicate '*available*' and '*not available*', respectively. Three options with respect to the spatial behaviour and attributes of objects have been identified: 'Fixed' indicates that locations/attributes of objects remain stable over sufficiently long periods of time; 'Variable' indicates locations/attributes are time dependent; 'Catastrophic' means locations/ attributes may alter in a very short period of time to an unpredictable level.

Table 1. Contemporary available mapping options. Key: A, available mapping; N/A, not available mapping

Location Attributes	Fixed	Variable	Catastrophic
Fixed	A	N/A	N/A
Variable	N/A	N/A	N/A
Catastrophic	N/A	N/A	N/A

Table 1 indicates that using current mapping methods is not possible for making maps that fit all human activities, monitoring the environment, and discovering natural events. For example, there is currently no way to prepare a map of a landslide or a volcanic eruption event in progress. The major obstacle in the preparation of maps for situations as stipulated in Table 1 is the time required for acquisition and processing of spatially related data.

The limitations of cartography as identified above may lead to the marginalisation of mapmakers as a profession. This is because of the growing demand for visual tools to support decision-making processes in many areas of human activities, for example, monitoring environmental processes, security operations, public safety, logistic, and others (Schneider, 2013).

Therefore, increasing demands for current maps on one hand, and the fast growing availability of new acquisition methods of spatially related data on the other should stimulate the evolution of cartography through the adoption of technological innovations. Neglecting this reality should not be an option for cartographers. The recent development in making seamless interactive maps that integrate disparate data sources to show current and historical events in real time (Intergraph, 2015) is a prominent example of processes that should be considered by cartographers.

2.2. Real-time map

For many people, real-time mapping means preparing maps in a short time using data stored in a database. The spatially related data may be stored in several databases located on servers controlled by custodians of specific layers. The Internet or Intranet is a key component that provides easy access to these databases to extract required layers for a map being composed. This approach was discussed and researched some fifteen years ago; however, various issues restricted this type of infrastructure from becoming widespread. One of the issues in implementing this strategy was the currency of the spatially related data stored in databases. A map produced using this approach was up-to-date to the degree as the data stored in databases were reflecting situation on the ground.

In this contribution, a 'real-time map' means a map that is prepared in a very short time using spatial data that are gathered on demand in near real time. A good illustration of a real-time map in this broader sense is shown in Figure 1. The web service Flightradar24.com displays the up-to-date location and some of the attributes of planes in near real time on the background of a GoogleMap®. This is one of the few real-time maps that fulfil the requirements of the 'V–V' type of maps. The V–V abbreviation stands for: Location–Variable and Attributes–Variable as per Table 1.

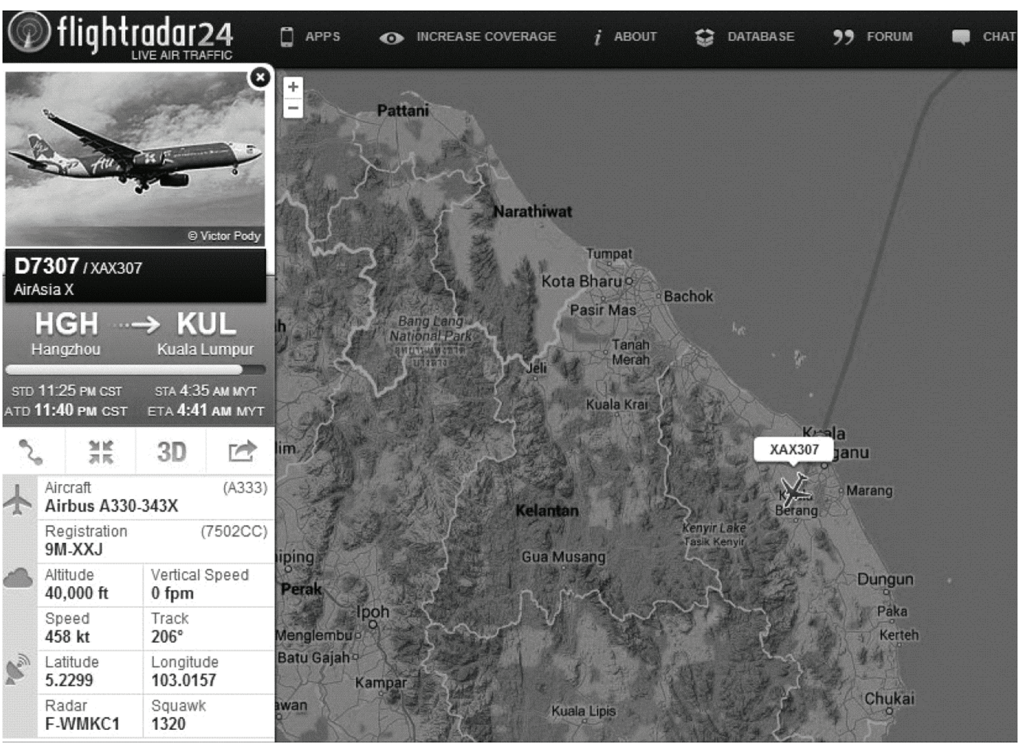

Fig. 1. Real-time maps that fulfil the requirements of the 'V–V' type of maps

3. What Is the Internet of Things?

The IoT is a network designed to collect and exchange data on objects or 'things' connected to the network via sensors representing their position and status (Ashton, 2009). Each object possesses its unique network identifier, possibly an IP address. Depending on the functionality of the sensor the object is equipped in, data exchange could be bi-directional. The sensor could be queried and the sensor could be querying the network for data 'needed' by the object to operate. Initially, the IoT was designed to supply manufacturers with data on objects, such as cars and home appliances, to increase the effectiveness of their maintenance and monitor their performance. However, a myriad of possible applications and benefits from the interconnected things has been conceived. The rapidly increasing number of objects, including mobile devices, and the growing supply of low-power interconnectivity options are factors stimulating the IoT revolution.

Some of the components of this emerging technology are already available. According to the global provider of market intelligence for the information technology markets (the International Data Corporation (IDC)), there are already some 30.1 billion 'things' installed worldwide (IDC, 2013). Forecasts for 2020 indicate that the number of 'installed and connected things' should reach a staggering 212 billion. Spending related to the IoT should grow to $8.9 trillion by 2020 (IDC, 2013).

Despite the continuing IoT revolution still many of us has never heard of the IoT. It appears that cartographers are part of this rather large community. A concise introduction to the IoT may be found, for example, in a paper by Becek (2014).

4. Innovation

Real-time mapping requires real-time data. Traditional methods of spatial data acquisition, including land surveying, photogrammetry, remote sensing, and use of public records, are able to produce spatially related data with a considerable time lag. In order to reduce this delay, an IoT-based solution has been proposed (Becek, 2014) that involves the acquisition of relevant spatially related data by querying sensors representing geographical objects and that are connected to the IoT. This process of data acquisition is performed at the time of map creation to ensure that the data are up-to-date. (An assumption is made that the sensors reflect up-to-date location and attributes of objects.)

While a sensor attached to an aeroplane and transmitting its location and some attributes is easy to imagine, how to connect a sensor to an abstract geographical object is less obvious. A virtual sensor has been proposed as a way to include abstract objects into the IoT. For example, a physical sensor attached to a land parcel is hard to imagine; however, a virtual sensor may be the solution to represent an abstract object. A virtual sensor is a data record stored on the Internet resources. This means that a virtual sensor is passive; it does not have the ability to update itself. Therefore, an external mechanism must be associated with the sensor that will automatically update the sensor. A crawler-type of software has been suggested as a record-updating facility (Becek, 2014).

Figure 2 shows the proposed arrangement of the key elements and data flow between reality (geographical objects) through a virtual sensor and a map. A web-based application — a 'crawler' — searches IoT resources for data on a particular sensor (geographical object) in order to update the location data and attributes of that object. This is a passive case applicable for abstract objects, e.g. a land parcel. An active case is when a geographical object is equipped with a sensor that is able to communicate current location and attributes of the object. The 'point of web presence (URL)' in Figure 2 indicates an access point of the mapping software requesting data on the current status and location of objects within areas of interest.

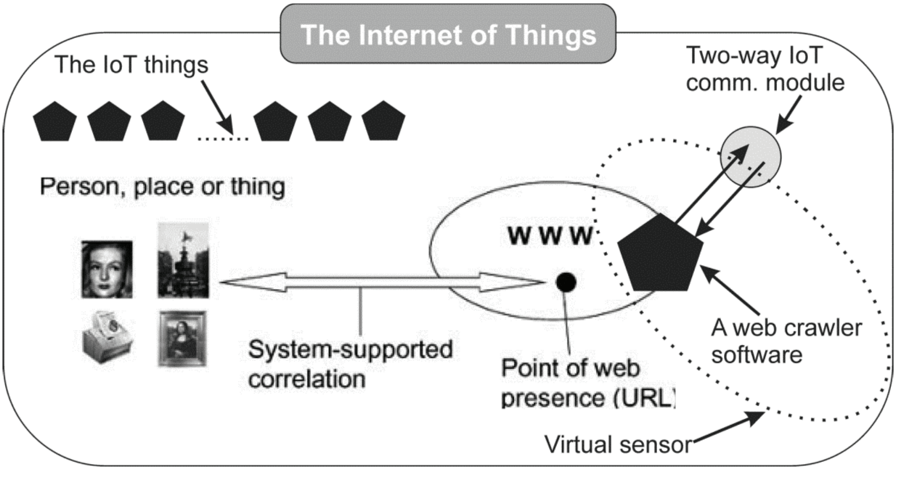

Fig. 2. Arrangement of the key elements and data flow between reality through a virtual sensor and a map

Referring to Table 1, there is a large class of geographical objects that do not change their location but may change their attributes (F-V/C means Fixed-Variable/Catastrophic). In that case, the location of these objects could be stored in a database and attributes would be produced by the sensor.

It was noted that geographical objects will be assigned with the IP version 6 address (Koistinen et al., 2013; Ziegler et al., 2015). To ensure that a geographical object can be found using a spatial query, its geographical location must be embedded in its IP address. Similar work has already been done by a British company offering an easy addressing service (http://what3words.com/).

There are many other technical issues to be resolved before IoT mapping becomes operational; however, it is just a matter of time and imagination before all these obstacles will finally be overcame. Some plans to adopt operationally the IoT-related approach has been outlined in Carpenter et al. (2015).

5. Challenges

According to the IDC (2013), the most important problem to solve for the IoT to work is creating a free and open data flow between sensors and applications. Studies on this issue have been stimulated by the incredible popularity of mobile communication devices, the development of Web 2.0 software, social media, and social networking. Business models are also evolving towards adopting mobile and out-of-office field work (e.g. http://www.terragotech.com/), which require effective communication between remote devices and the network.

Some important baseline projects that are 'compatible' with the IoT for cartography are already underway. They include the European Commission's INSPIRE directive, which aims to standardise the spatial industry across the European Union. These standards could be helpful in streamlining IoT mapping development.

A set of new standards relevant to IoT mapping within the open geospatial consortium are needed. Privacy and security issues are important factors to be addressed during development of the IoT (Lillington, 2015) and IoT mapping. Optimal ways to communicate real-time spatially related data using cartographic methods must also be studied and new problems resolved.

6. Conclusion

The number of situations has increased, in which a current and quantitative model of spatially related objects interacting amongst each other is essential for securing the sustainable management of societal affairs. For example, a topographic map for firefighters trying to extinguish a rapidly progressing forest fire does not provide enough data to manage resources and maintain safety of the crew because there is a lack of data on the up-to-date fire front on the map. As this example indicates, the problem is how to acquire rapidly changing spatially related data.

In this paper we attempted to draw the attention of mapmakers to the emerging technology of the IoT. The IoT has been proposed as a solution to real-time data acquisition of objects that change their location and attributes over time. These data transactions are facilitated by 'intelligent sensors'. This unfortunate name is a source of ambiguity related to 'intelligence' — a term used in psychology.

The IoT has been proposed as a method for gathering data for mapmaking processes. This can be achieved by assigning to each geographical object a sensor that is discoverable in the web. Current location and attributes of a geographical object would be achieved by querying their sensors. Adopting the proposed solution would facilitate map preparation in a very short time and would include current location and attributes of all objects within the area of interests. Obviously a lot of ground work and many challenges, including privacy restrictions, lie ahead. Mapmakers should take part in these processes as a myriad of people who have nothing to do with cartography have been working hard to address many of the problems (EU Commision, 2009).

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