The Internet of Things:
Are We at the Fringes of a Paradigm Shift in Geomatics?

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SUMMARY

The Internet of Things (IoT, proposed pronunciation iota) is an emerging technology which was introduced as a complimentary solution to the Internet in 1999. The difference between the Internet and IoT lies in the sources of data on which the networks rely. While the Internet is predominantly fed by data provided by humans, the data sources for IoT are signals from sensors attached to things or objects around us. Nowadays, the number and types of objects being equipped with sensors is growing rapidly. Modern cars, mobile phones, and many other instruments or objects are have sensors that produce a steady flow of data on the objects' internal status. Such add-ons to modern objects are very useful for both manufacturers and users of objects. The former use the data to develop better products, while the latter use the data for optimal management of their fleet of assets. Location is one of the most fundamental attributes of any object. Therefore, it is obvious that sensors must also be georeferenced. This georeferencing should also be applied to moving objects, meaning that that sensor needs to generate location data. In this presentation, we explore possible options to include the Internet of Things as a strategy/technology for geosciences of the future, that is, to build models of reality in real time. The demand for real-time maps (RTMs) is growing in many fields of human activity. Prominent areas in which RTMs are extremely useful are emergency response, disaster mitigation, and monitoring and assessment of rapidly developing events, both natural and anthropogenic. However, more "static" objects such as land parcels, transportation routes, buildings, and topographic features can also be represented with help of RTM. It is not difficult to imagine many economic and other types of benefits that the RTM representation of the real world could bring. Presently, real-time mapping already exists, at least in a relatively narrow sense and one that is far distant from the IoT strategy. For example, real-time logistic management requires maps showing the updated positions of assets for effective management. Still, the idea of IoT offers much more than that, because it would also allow for sensors to communicate independently from a central command post, as is the case with the current solution of logistic management. The Internet of Things has already been the subject of two European studies, specifically the IoT–Architecture (IoT-A) and IoT–Initiative (IoT-I) projects, as well as the Cluster of European Research projects on IoT (IERC). As far as the authors are aware, however, no geomaticians are participating in these projects. In our view such participation is desirable, and we suggest that interested colleagues would consider joining research efforts within these programs. This would bring to the field of geomatics a fresh wave of new thinking about our discipline.

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1. INTRODUCTION

There is a growing demand for the delivery of maps in real or near real time termed Real-Time Mapping (RTM). Real-time maps are used in a growing number of human activities, including disaster management and mass-market applications, such as navigation and location of goods and services. RTM must provide a quantified representation of a requested part of our reality, which in a timely manner depicts not only the position, but also the current value of attributes of objects of interest or 'things'. As we know, traditional space survey methods (land surveying, geodesy, photogrammetry, remote sensing and cartography) are not designed to deliver real-time mapping output. Maps that are produced these days represent in a majority of cases some historical snapshot of reality, except perhaps maps showing in real time the position of a vehicle or the extent and intensity of rainfall. This 'historical' character of maps is growing with the growing complexity of anthropogenic systems, including cadastre, buildings, transportation and hydrography. This is simply because the complexity of a system is always associated with the increasing number of states a system may be in at a particular point in time. Also, increasingly frequent and intense natural phenomena causing disasters contribute to the rate of alterations to objects, which causes maps to lose their currency. Therefore, it appears that objects in reality are changing faster than we can map them using traditional methods. This lag will grow in future, which suggests that a discussion on a new paradigm for geomatics in the area of spatial data acquisition and mapping should commence sooner rather than later.

We believe that one of the ways to minimise a time gap between timestamps of a change of the state and position of a geographical object and the moment when the change is reflected on a map may be narrowed down by harvesting the power of the Internet of Things (IoT) (Feki et al., 2013) which can be described as a "... general evolution of the Internet (...) from a network of interconnected computers to a network of interconnected objects." (EU Commission, 2009). The term the "Internet of Things" was coined in 1999 by Kevin Ashton (Ashton, 2009). However, Mark Weiser at XEROX PARC with John Seely Brown in the late 1980s conducted research on 'ubiquitous computing' as the third generation of computing, what is now called the Internet of Things (Weiser, 1991).

The aim of this contribution is to examine the application of IoT technology to increase the speed of the data flow about geographical objects from field to map. This requirement is increasingly valid as the demand for real-time mapping is growing, as it is related to overall technological and societal development. In addition, it appears that IoT technology can bring significant economic benefits to geospatial professionals and map users. This aim will be achieved by: introducing the key elements of Internet of Things technology; reflecting on geomatics as an art, science and technology of modelling of geographical reality with an emphasis on its limited capabilities for providing real-time mapping services; describing a vision of applying IoT technology to solve the main bottleneck of geomatics hindering the delivery of real-time mapping services.

2. WHAT IS THE INTERNET OF THINGS?

There is a range of valuable resources explaining the Internet of Things. The following brief introduction of IoT is based on an overview article by Professors F. Matter and C. Floerkemeier of ETH Zurich, Switzerland (Matter & Floerkemeier, 2010).

The Internet of Things is a vision according to which sensors that serve as sources of data about our reality are attached to things or objects, and linked into a network using a communication facility. This idea of connected and interconnected things supplying data and communicating through a network complements the modus operandi of the Internet: people are the source of data and subjects of interactions at the network level. At first glance, the vision of IoT connecting objects, which are communicating with each other may be considered a utopian concept, but the authors of the EU communication entitled "Internet of Things: An action plan for Europe" (EU Commission, 2009) explain that there are already clearly visible trends and elements in operation that may be considered to be parts of IoT development. They include the facts that: people are increasingly using web-enabled mobile phones equipped with cameras and other sensors and Bluetooth communication; manufacturers across the EU are starting to use unique IDs for their products; an increasing number of utility companies are introducing 'smart grids' to enable electricity consumption to be monitored in real time; and some industries, including logistics and manufacturing, already use 'intelligent things' to improve and speed up operations. It is expected that IoT will create countless possibilities for societies and individuals and can potentially resolve many problems (Matter & Floerkemeier, 2010). However, it also expected that IoT technology will require huge technical and technological investments in order to function (ibid).

To facilitate the functioning of IoT, a number of technologies must converge to provide a number of necessary capabilities, including:

- Communication. Things must be able to communicate with the network and each other. Technologies, including GSM, Wi-Fi and Bluetooth, are currently available to serve IoT;
- Addressability. A thing within IoT must be properly addressed, like objects in the Internet, using an IP address. This enables collaboration with objects via technologies including discovery, look-up and DNS. An extra, geography-based way of the addressability of things will also be required;
- Sensing. Things should be able to hold data on their current state or at least identify the location of a relevant record about their state;
- Actuation. Things should be able to execute certain procedures as described by their designated behaviour;
- Localisation. Already mentioned before. Things are spatially aware. They must be able to generate positioning, timing and navigation stamps (location, time, and direction and speed of movement);
- User interface. Things should be equipped in convenient interfaces for communication

with humans. Recent technological advancements, including grapheme, open a wide range of possibilities to also make these interfaces 'smart'.

As one can expect, not all things require all the above-mentioned capabilities. For example, things that are static by nature do not require a GPS for localisation. However, every object in IoT requires a unique number. This must be something more than a bar code or RFID (radio frequency ID) which are 'localised' identification systems. In the IoT technology, as in the case of the Internet, each thing or object must have a universal or global IP address. For that purpose, the IPv6 can be used. Version 6 of the IP system uses a 128-bit address. This allows for 2^{128}, or approximately 3.4×10^{38}, unique IDs. Putting this number in a geographical context, assigning an IPv6 address to every mm^2 of the Earth's surface area would utilise just 5.10072×10^{20} addresses (out of 3.4×10^{38} possible). So, some of the order 10^{18} free addresses would still be available.

The introduction of IoT will face a number of technological challenges, including:

- Scalability. The IoT technology must provide equal working conditions at all scales (local to global);
- Arrive and operate. The things in IoT configurations must work without any particular engagement by an operator. They must undertake their operation in a spontaneous manner;
- Interoperability. The things around us are extremely diversified; hence their modus operandi is also different. Extensive standardisation efforts will be required;
- Discovery. The things must be appropriately described in natural language to enable searching for them using a search engine;
- Software complexity. A new class of software management systems will be required to provide services to things both as individual items and as members of a network;
- Data volumes. It is understood that some things, in particular the image type of sensors, will require large data storage and transmission.
- Data interpretation. This will be required in order to put streams of data in their correct context, which needs to be diverse from diversified data sources.
- Security and personal privacy. One of the fundamental issues is how to make sure that both IoT and the things among themselves will work in a way that satisfies the requirements of privacy and data and information security.

Other elements of a specific nature include fault tolerance, power supply, interaction and short-range communications, and wireless communications (Mattern & Floerkemeier, 2010). The authors encourage the reader to fill out unavoidable gaps in the above framework-type presentation of the Internet of Things.

GEOMATICS IN THE INTERNET OF THINGS ERA

It is rather unavoidable that sooner or later a thing such as the Internet of Things will become a part of the data and information infrastructure at our civilisation's disposal. This could, at least, be reasoned from the fact that large bodies such as the European Commission and the world's largest professional association (IEEE) have decided to work on ways to put the idea of IoT into practice (Pretz, 2013; Schneider, 2013). In 2009, the European Commission published its Communication on IoT (EU Commission, 2009). Also, a research cluster on IoT has been formed called the "European Research Cluster on the Internet of Things (IERC)" that is working on preparations for the Horizon 2020 Programme on European Research and Innovation(Smith, 2012).

Considering the above, one may ask "how might the Internet of Things impact business processes within geomatics?" As one can imagine, the number of possible answers is large, considering the possible deep 'penetration' of many diverse domains of human activities by the new technology. In this contribution, we will demonstrate a possible application of IoT speeding up information flow from reality to a model of reality – a map. The proposal is so far-reaching that it could be considered a new paradigm in geomatics.

Methods used in geomatics are based on a 'passive' way of spatial and attribute data acquisition on geographical objects. The adjective 'passive' means that an object of interest is simply just a subject of measurements and observations. However, in the context of IoT technology, an alternative situation is imaginable, which could be described as 'active' data acquisition. In this scenario, the object of interest makes all relevant data on its position, navigation and attributes readily available to an inquiring agent. So, the role of a surveyor would be reduced from facilitating data flow from a field to a map to just quering objects in the area of interest for relevant data via an IoT-enabled interface. This kind of arrangement means that all geographical objects would need to possess sensors to represent them in the IoT network. Obviously, these sensors must also be able to keep the data and metadata records assigned to objects in an updated state at all times. A basic requirement for creating such an IoT-enabled sensor is that each geographical object must be assigned a unique IP address. As discussed in the previous section, such an option does exist since the IP scheme version 6 has been adopted.

Before we embark on further presentation of the proposed deployment of IoT for real-time mapping, we will illustrate the already outlined ideas by presenting a thematic map which resembles certain properties of a real-time mapping system built upon some elements of IoT technology. Figure 1 shows an online, real-time mapping system which enables the tracking of the flight progress of civilian aircraft: http://www.flightradar24.com/.

The Flightradar24 system relies on data which is broadcast by a 'transponder' on board an aircraft. Besides the aircraft ID, the transponder provides the geographical coordinates of the current position of the aircraft, speed, altitude, heading and the path which the aircraft has travelled since take-off. This data is supplied to the transponder by the on-board data acquisition system. Transponders broadcast the data as an unsecured stream using radio waves.

Trying to link the basics features of the Flightradar24 real-time mapping system to a set of features of IoT, one may notice that:

- An aircraft is a thing. In this case, the thing is a geographical object;
- The thing is equipped with a sensor which is able to communicate position, navigation and status data of the thing it represents. However, this is just one-way

communication: the sensor cannot receive any input from the outside world.
- There is a user interface allowing for discovery of a particular class of objects based on their IDs, geographical position and some of the properties of the object.

Figure 1: Example of a real-time map. Source: http://www.flightradar24.com/

The Flightradar24 real-time mapping system of aircraft indeed resembles some of the functionalities of IoT. Even without full accordance of the Flightradar24 system with the assumed features of IoT, one may already appreciate the benefits of the IoT approach for everyone requiring online, real-time maps. The question now is how to use the IoT approach in geomatics.

THE INTERNET OF THINGS FOR GEOGRAPHIC OBJECTS

One of the fundamental elements of Internet of Things technology is the requirement that each object be represented in the IoT network by sensors capable of two-way communication with other things in the system. The question is: how to fulfil this constraint if IoT technology were adopted in geomatics? To solve the problem, we propose equipping each geographical object with, at least, a 'virtual sensor'. A virtual sensor would be suitable for objects such as a river, road, house or land parcel, while a real sensor would be appropriate for things such as a total station, level instrument or GNSS receiver. A virtual sensor will be identified by an IPv6 address. As mentioned earlier, this is technically possible. It would also enable linking the IP to the Hypertext Transfer Protocol (HTTP) and implying that each geographical object would have its own web page. This suggestion is consistent with a proposal made several years ago already to represent people, places and things using web pages (Kindberg et al., 2002).

To facilitate the useful presence and functioning of a geographical object in the IoT network, a virtual sensor representing it would also be capable of updating the data on the object it represents. As one can imagine, in order to update the web page of an object that is a part of a network of interconnected things, web crawler software is an option to consider. A web crawler systematically scans the World Wide Web looking for changes in web pages. Once the relevant change is identified, the software is able to update the data stored for the object. The changes in an object of interest are always reflected somewhere in the IoT network because other objects are somehow involved in activities concerning the object of interest. For example, let us assume that a land parcel is an object of interest. Like all geographical objects, this parcel has a unique IPv6 address. All data concerning the parcel, including its location and attributes (the land title, land use, land cover, etc.), are stored on the server or ‘web page’ of the parcel. The parcel’s web page will also have an embedded service in the form of crawler software that will perform an IoT-wide search and keep the parcel’s web page current at all times. Let us consider how a particular change to the state of a land parcel will be reflected in the IoT network. The owner of the parcel has decided to subdivide the parcel of interest. The owner places an online request to a surveying company to perform the subdivision. As long as the IP address of the parcel is known, the virtual sensor of the parcel will be able to pick up the fact and record it on the parcel’s web page. This state change of the parcel from ‘idle’ to ‘subdivision in progress’ can also be discovered by a mapping system featuring real-time mapping. Figure 2 shows in a synthetic way how IoT may be used to make sure the databases of spatial objects can be updated automatically.

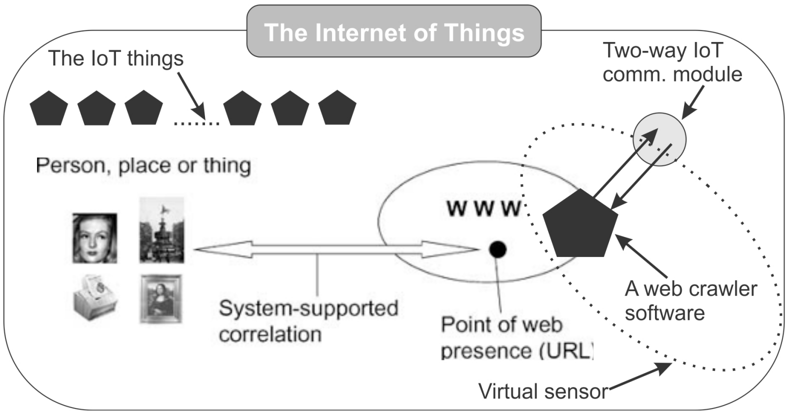

Figure 2. A concept of a Virtual Sensor.
Source: Modified Figure 1, (Kindberg et al., 2002)

A PARADIGM CHANGE IN GEOMATICS?

There is no doubt that the introduction of computer-based methods for spatial data acquisition has dramatically reshaped the field of geomatics. We believe that this trend will continue as a result of the technological progress that has occurred in the field of information technology. We also believe that the next stage of evolution of geomatics will originate from the advent of the Internet of Things technology. Reflecting on the above introduction of IoT, and the proposal of its deployment in geomatics, one may conclude that geomatics will be dramatically impacted. The major impact point would be the way in which the databases of spatial objects are updated. A full automatic process to update these databases is feasible, which implies that real-time mapping could become reality.

There is no doubt that a variety of societal, sociological, psychological, economic, legal and technical challenges must be faced before the fully operational real-time mapping based on IoT technology will become a reality. These various challenges are normal obstacles during a transition phase from the old paradigm to the new paradigm for all human activities, including geomatics. In geomatics, the dynamics of this paradigm change will be controlled by development of the Internet of Things. Moreover, rapid progress in the field of IoT is almost unavoidable, because 'A world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes' (Haller, 2009) is already here and expanding.

CONCLUSIONS

In this paper, we have outlined our vision of the unavoidable impact that the emerging Internet of Things technology will have on one of the fundamental processes in geomatics, which involves spatial data acquisition. Since their inception centuries ago, land surveying and cartography have operated within a framework or a paradigm in which a days-long, months-long or even a years-long time lapse exists between a field survey and the resulting map or an updated version of the map. This paradigm is based on the technologies of spatial data acquisition: a human being is the active agent who is the exclusive figure able to collect spatial data. For the first time in human history, the Internet of Things technology allows for the collection of spatial data so that physical objects become active participants in the process. Such a dramatic shift in the way that data and the attributes of spatially-related objects are going to be collected warrants the serious discussion within the geomatics community. For all the outlinedreasons propose that an FIG Commission 3 working group be formed to study the possible applications of IoT for spatial data and information management. We also encourage our younger colleagues to consider joining the efforts and addressing the challenges that we face in as we undergo the process of adopting IoT technology for the business processes related to geomatics.

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BIOGRAPHICAL NOTES

Dr. Habil. Eng. Kazimierz Becek obtained his PhD and DSc ('Habilitation') from the Technical University Dresden, Germany, in 1987 and 2010, respectively. He worked at the School of Surveying, UNSW, Sydney, Australia, from 1989 to 1994 before joining a publishing house on the Gold Coast, Australia in 1995 as head of the Cartography and Data Acquisition Department. He also worked for the Queensland state government and the Gold Coast City local government (both in Australia) from 1998. In 2003 he began working at the Geography Department, University of Brunei Darussalam, teaching Cartography, GIS, Photogrammetry, Remote Sensing and Surveying. His research interests include mathematical modeling of environmental systems, including landslide monitoring, natural hazard mapping, and applications of remote sensing methods for environmental studies. He is a former Vice-President of the Brunei Institution of Geomatics. He is currently holding the position of Senior Consultant at Soartech Systems, Brunei Darussalam, and Visiting Professor at the Wroclaw University of Environmental and Life Sciences, Poland.

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