Earth Observation – Between Public Interest and Privacy

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During the last decades we have seen an exponential increase of Earth observation systems generation huge amounts of data. Many nations and organizations own their own satellites and many – developed and developing – are joining them. Similar as with the digital revolution, tremendous success of space technology and remote sensing is outpacing its public understanding and acceptance, inluding regulatory aspects.

In the paper we focus on the current capabilities of the remote sensing imagery and image (information) processing. With todays systems we can get high spatial resolution (below one meter) data, that is capable to detect small objects and its changes due to spectral differences (high spectral resolution) every couple of days (good temporal resolution). The data is being processed automatically, almost in real time, without human interaction in the stationary or mobile ground stations or close to them. The images and products are immediately served to the public via simple web based applications on desktop or mobile devices.

How much care is or should be given to the security of these systems? Should they be tightly controlled (and who should control it) or completely open? How should we balance between public interest and privacy? We are sure on one side that everyone should be notified about the extent of a natural disaster (fire of flood for example) but no one is willing to be tracked by the "big brother". In the paper several technical and scientific aspects of use and abuse of space data are discussed to stimulate thinking and discussion of those important topics.

I. Introduction

During the last decades we have seen an exponential growth of the number of Earth observation systems that are generating huge amounts of spatial data. Many nations and organizations own their own satellites and many – developed and developing – are joining them. According to the UCS Satellite Database [1], there were almost 1200 operational satellites in orbit in the

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beginning of 2014. 237 of them – i.e. about a quarter – are Earth observation satellites, from 46 countries (see Fig. 1). The large majority of satellites are coming from USA and China, followed by India, Russia, Germany and Japan; there are less than dozen countries with more than five satellites in orbit. Most of the satellites are governmental or civil and military; 11% of the Earth observation satellites are partially commercial, and only 6% are purely commercial (Fig. 2). Governments of different countries have therefore a significant role in global Earth observation. They are both the owner of the systems and the regulator who controls their use.

In the last years we have seen a significant shift from large satellites – weighting several tons – to smaller ones (in the range bellow 100 kg or even less). Small satellites using off-the-shelf technologies or missions focused on specific physical phenomena have been perceived to offer an opportunity for countries with a modest research and development budget and little or no experience in space technology, to enter space-borne Earth observation and its applications. Small satellite technology has democratized the space and brought within the reach of every country the opportunity to operate small satellite Earth observation missions and utilize the data effectively at low costs, as well as to develop and build application-driven missions [2].

What is seen for the digital revolution is true also in space sector: tremendous success of space technology and remote sensing is outpacing our understanding of its social aspects. In the paper the technological advances, its potential and its social implication are discussed.

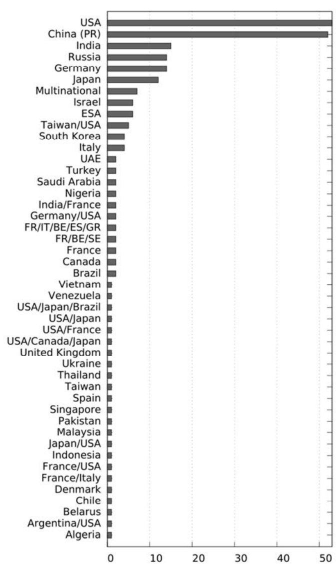

Fig. 1: Number of Earth observation satellites by country [1]. The large majority of satellites are coming from USA and China, followed by India, Russia, Germany and Japan.

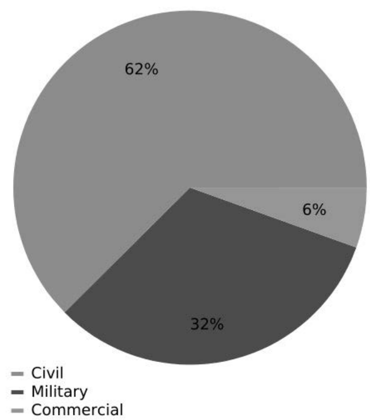

Fig. 2: Percentage of Earth observation satellites by usage [1]. Only 6% of the satellites are commercial, almost one third is military and the majority is civil.

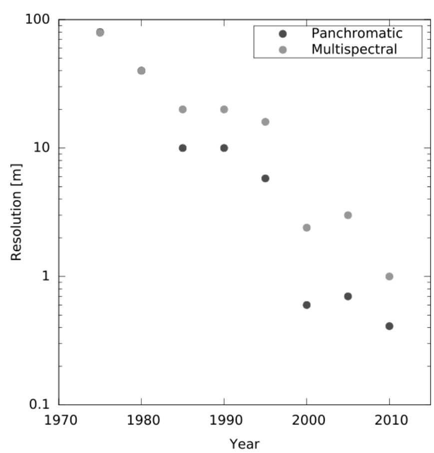

Fig. 3: Spatial resolution achieved from panchromatic and multispectral sensors in time [3]. In forty years since the first Earth observation satellites appeared the resolution has decreased from several hundred meters to well bellow one meter.

II. Where is Earth Observation Technology Today

Since the introduction of remote sensing we have seen a constant enhancement of its capabilities. The main technological advances are a steady increase of resolution (spatial, spectral and temporal), development of simpler and cheaper small satellite systems, and huge popularization of web data delivery services.

The spatial resolution of space-borne Earth observation systems has increased drastically since the launch of first satellites [3]. As seen in, staring with several hundred meters we have reached well bellow one meter in forty years. Currently the best civilian satellites are reaching 0.46 m (WorldView-2), 0.41 m (GeoEye-1) and 0.31 m (WorldView-3). The level of detail seen at different resolution is given in Fig 4. In addition to increasing spatial resolution we have seen also an increase in spectral resolution. Panchromatic and simple RGB sensors have been complemented with NIR and IR sensors in several multispectral systems (four or more bands), with hyperspectral sensors (having several hundred bands), radar and lidar (laser) [3], [4]. Sophisticated imaging mechanisms and satellites flying in constellations have increased temporal resolution to several days (e.g. RapidEye constellation is capable of imaging daily) [4].

For almost two decades, small satellites offered an opportunity for educational institutions, smaller governmentally and privately funded organizations to establish its capabilities in space-based Earth observation [5]. The opportunity to use small, economical satellites (and associated launchers, ground stations, and data distributions structures) has enabled the establishment of several new players in the global market. The capabilities of small satellites in terms of spatial and spectral resolution are close to what larger satellites can provide. Small satellites offer also the unique possibility to install affordable constellations to provide good daily coverage of the globe and/or allow us to observe various dynamic phenomena through their potential of increasing the temporal resolution [5].

Development of services like Google Earth, i.e. web base visualization and delivery of satellite imagery in the beginning of 2000s has completely changed the perception and availability of satellite data [3], [6]. The users are now aware that (high-resolution) satellite imagery is available to anyone, preferably free of charge. But they are not aware and mostly don't even care, that this imagery can have several drawbacks (e.g. geometric or radiometric errors, no validation performed). While such services have created huge potential for individuals and businesses, they have also raised privacy issues.

III. What are Social Implications of Earth Observation

Technical capabilities described in previous section are raising several social implications that can be narrowed into relation between public interest and privacy. It is without doubt that Earth observation provides huge benefits to the humanity. Satellite and airborne images can be used to monitor natural disasters (e.g. floods, forest fires, landslides), to observe crop state and damage and to predict crop yield, to monitor the changes in forests, to map land use and land cover changes, to detect loss of coastal areas, to monitor maritime traffic and oil spills, to detect change in urban areas etc. [7]–[9].

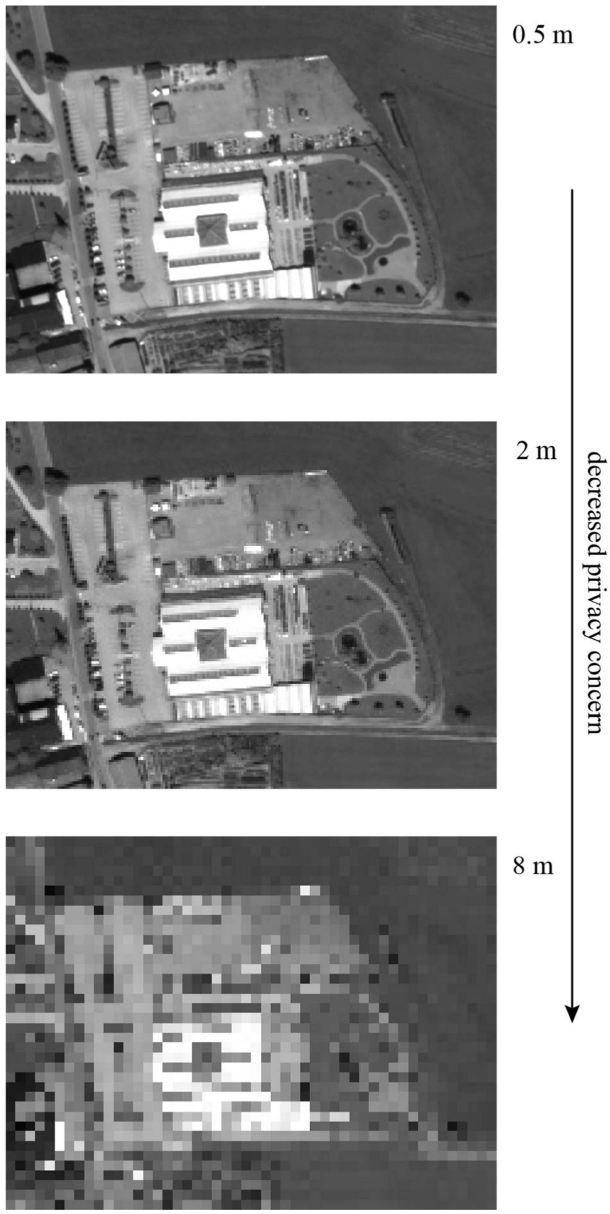

Fig. 4: Level of detail seen at different spatial resolution. At 0.5 m one can see individual cars, parking lots, roof detail, trees, and even traces of grass cutting. With 2 m things are starting to be generalized and at 8 m we can

only see general information about individual objects. By lowering resolution our concern about privacy decreases.

There is a huge public interest in having systems providing up-to-date, accurate and reliable remote sensing data and information to the right end users, being either governmental institutions, professionals or general public. By offering abundance of such information, without mattering who needs or is allowed to get such information, we are being in constant danger of privacy violation.

What is privacy in the context of Earth observation? Privacy is a complex notion. It has different meanings in different cultures and enjoys different levels of protection through the world [10]. Privacy is the ability of an individual or group to seclude themselves, or information about themselves, and thereby express them selectively. The boundaries and content of what is considered private differ among cultures and individuals. The right not to be subjected to unsanctioned invasion of privacy by the government, corporations or individuals is part of many countries' privacy laws, and in some cases, constitutions. Almost all countries have laws, which in some way limit privacy. Privacy may be voluntarily sacrificed, normally in exchange for perceived benefits and very often with specific dangers and losses [10].

Fig 5. shows how our perception of privacy invasion changes with the changing imaging mean or platform. We all agree that photographing over a fence is a huge invasion in one's privacy. Our concern is lower, but still present when we are dealing with Google's Street View cars. We are partially concerned with imaging from low elevation balloons and drones, but far less when higher altitude aerial systems are used. When observing from space, the distress almost disappears.

This perception changes drastically if we take into consideration the amount and level of detail satellite based Earth observation systems can provide. When images are acquired systematically, with high spatial (see Fig. 5), spectral and temporal resolution far more information can be obtained from satellite than from a ground-based photo (Fig. 6).

With todays systems we can get high spatial resolution (well below one meter) data that enables detection of small objects and their changes every couple of days. The data is being processed automatically, almost in real time, and without human interaction in the stationary or mobile ground stations or close to them. The images and products are immediately served to the public via web-based applications on desktop or mobile devices.

Our awareness of privacy must follow the fast technological trends and cannot be left in the hands of individuals and organizations dealing with the development or operation of Earth observation systems. It is also critical not to rely on governments or private operators. Governments are regulating, controlling and often even themselves undertaking space activities, while private operators undertake them, either for the governments or for their own private gain.

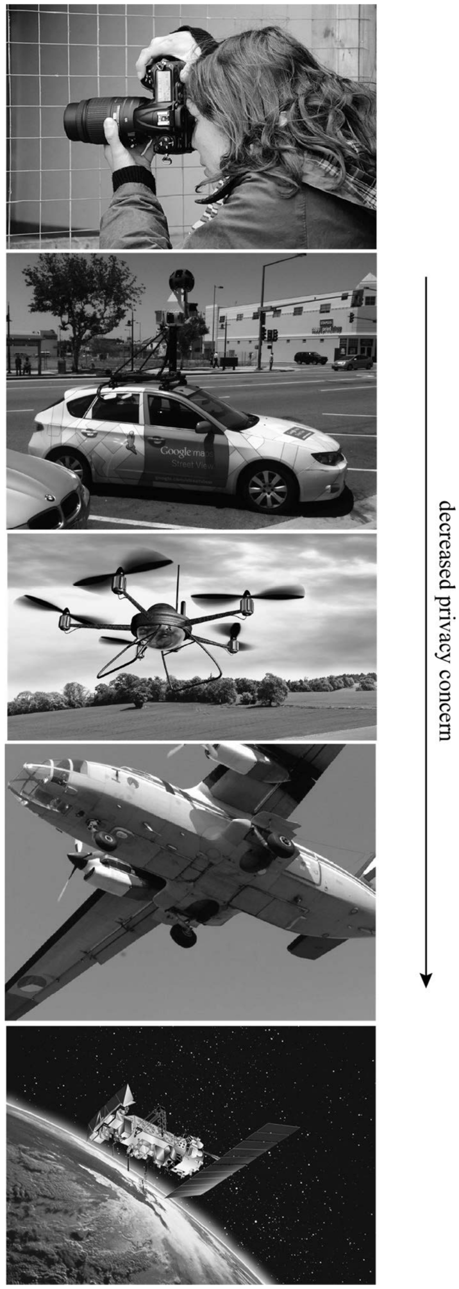

Fig. 5: The perceived level of invasion of privacy depends on the way of observation (platform). From top to bottom the level of privacy concern decreases – ground-based photographing, Google's Street View cameras, drones, aerial imaging and satellite observation.

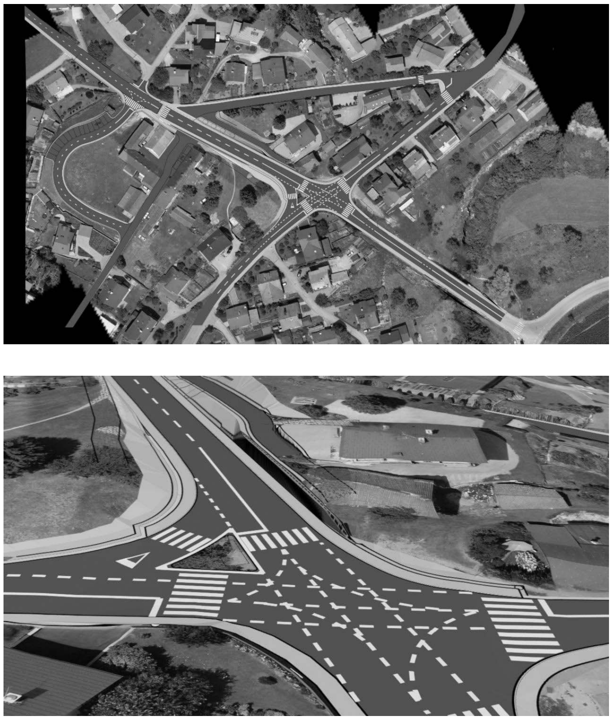

Fig 6: Example of image interpretation of road structure mapping.

IV. What are the Challenges

With the increasing capabilities of space Earth observation data, new questions arise regarding the risks and threats of use and abuse of such data at three levels: abuse of space infrastructure, abuse of ground segment, and abuse of data.

Several levels of software and hardware security protect space infrastructure owned by governments, military and international organizations. Although a popular cliché in Hollywood production it is very unlikely that the sophisticated security systems would be broken, and definitely not without the awareness of the owner of infrastructure. In the case of small satellite systems, not so much effort is paid to security. On every satellite system there exist several on-board computers performing tasks such as attitude control, payload support, communication and housekeeping. Such systems are vulnerable to attack (usually some kind of custom based Linux is used) as long as communication protocols are known. Although software and hardware documentation for small satellite projects is less extensive, it is usually more easily available or even completely public.

The next level of possible abuse is at the ground segment. Running an efficient dedicated ground segment is a considerable cost that only commercial and governmental institutions can cover in full. The communication is encrypted, data store and access is secure. The image formats are sometimes propriety, but due to user request we are seeing at least some standardization. Less demanding missions are relaying on shared ground segment with much more open and vulnerable access.

Abuse of space data is the last, but most probable and thus most problematic. Nowadays, Earth observation images are available to a broader public by services like Google Maps and Bing Maps. The awareness of the Earth observation data has grown and to some extent also image interpretation skills have increased. If the imagery is available, we can say that almost anyone can perform recognisance. This represents a huge potential for citizen (or community) remote sensing in solving several important problems (e.g. for humanitarian response after a natural disaster, for a scientific study of an ecosystem) [3], [10]. But it also poses a huge threat to abuse of the data, especially regarding security, privacy, intellectual property rights, and liability.

V. Conclusions

It is beyond doubt that Earth observation provides huge benefit to the society. On the other side the community is only slowly following the rapid development of technology. In a similar way as with digital revolution, we are seeing the introduction of new capabilities that are changing our basic behaviour and perception of our rights. Public understanding and legal regulations are several steps behind the development.

However, we – public, governments, satellite developers, and satellite operators – must be involved in establishing common standards and technical measures regulating Earth observation from all aspects.

Acknowledgement

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