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# Use of Remote Sensing Applications and Its Implications to the Society

Stefan Robila
*Montclair State University*, robilas@mail.montclair.edu

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Stefan A. Robila
*Center for Imaging and Optics*
*Department of Computer Science*
*Montclair State University*
*Montclair, NJ, USA*
*robilas@mail.montclair.edu*

## Abstract

*Remote sensing, i.e. the technology that allows measuring object's properties from a distance, is currently undergoing tremendous advances in both precision and areas of applicability. Our study provides an overview of the recent developments in RS applications and their implications to the society. This was approached from three distinct directions, all with significant influence on the human's perception of the technology. First, we discuss how disaster prevention, reaction, and recovery can be supported by remote sensing. Next, we look at the popular view of remote sensing, as illustrated by media and commercial applications. Finally, we discuss legal implication of sensing technologies especially in the context of law enforcement, surveillance and security.*

## 1. Introduction

Remote sensing (RS) was originally described as the measurement, from a distance, of spectral features of the Earth's surface and atmosphere [1]. These features are recorded by satellite and aircraft-carried instruments and are usually stored as digital or film data. RS applications refer to methods that use electromagnetic energy (light, heat, and radio waves) to detect and extract the target and ground characteristics [1, 2]. More recently the RS term has been expanded to cover any type of sensing technology that does not require direct contact with an object, irrespective of the location of the sensor (on the ground or in the air).

At the basis of RS lays the concept that when an energy beam (such as light, heat, etc.) is projected onto an object, the reflected energy's intensity depends on the object's properties [3]. Having a readily available energy source (such as the sun) it is normal to expect that in most of the cases, RS methods employ data produced by a sensor recording solar energy that reflects from the observed scene or object or energy that is emitted by the object itself (such as heat). In both cases, the sensing is called passive since the instruments measure only information already released by the object. When the sensor also emits energy waves or signals (such as microwaves) aimed at the object (such as radar or sonar), the methods are called active RS [4]. Fig.1 shows the differences between the passive and active RS.

From this description, one can easily understand that RS technology has a large area of applicability. Whether used for military purposes, for agricultural or urban planning, for medical investigation or surveillance, remote sensing will certainly affect human life. The ability to sense from a distance, without direct interaction with the objects brings powerful new knowledge to the human understanding of the surrounding world. This study investigates how the society is impacted by the ongoing development within RS whether be it through popular channels such as the internet and the media or formal ones such as laws and state or local governments.

The rest of the paper is organized as follows. In the next section we provide a brief overview of the RS data types and technologies. In Section 3 we look at the use of RS in disaster and emergency prevention and management. Section 4 presents a brief overview of how informational channels such as media and the internet employ remote sensing in their communication.

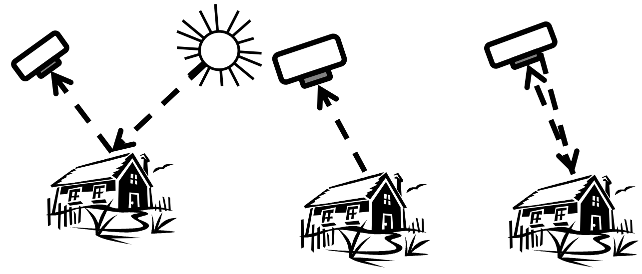


Figure 1. Remote Sensing approaches a) passive - using reflected solar energy, b) passive - using emitted energy (such as heat), c) active – measuring the reflected energy from a signal emitted by a sensor

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Section 5 discusses the use of RS in law enforcement and homeland security. The paper ends with conclusions and bibliography.

## 2. Remote Sensing Data and Applications

In most cases, the sensed data are formed as reflectance images [2]. Early on, research has revealed that different materials expose different properties when analyzed under various light wavelength intervals [3]. This allows easier discriminations of vegetation (higher reflectance values for near infrared wavelengths compared with certain visible wavelengths) from bare soil or man made materials (with relatively the same reflectance for both of the wavelength ranges) [3, 4, 5]. Fig. 2 shows such differences for an image taken with a sensor able to distinguish between near-infrared and visible wavelengths. The scene includes a plant arrangement that combines natural and artificial leaves. Although the differences are unnoticeable in a regular color or grayscale image, the natural leaves display significantly brighter intensity when compared with artificial ones in the near-infrared wavelength image.

We also note that while the energy frequency varies widely, the visible light (i.e. the one customarily perceived by humans) covers only a relatively narrow interval within the overall spectrum (see Fig. 3). RS currently provides sensors and application methods that cover much larger frequency intervals both below and above the visible range.

Popular types of RS data are the multispectral and hyperspectral images, collected as tens or hundreds of images (also called spectral bands), with each image corresponding to narrow wavelength intervals (see Fig. 4a). In such data, it is a common practice to define *spectra* as the vectors formed of pixel intensities from the same location, across the bands (Fig. 4b) [3]. Each pixel corresponds to a certain region of the scene surveyed and will represent the spectral information for that region.

a) b) c)

Figure 2. Differences in material reflectance a) regular color image, b) regular grayscale image, c) image recording near-infrared reflectance.

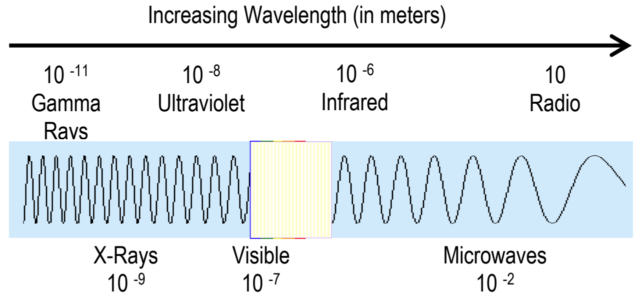
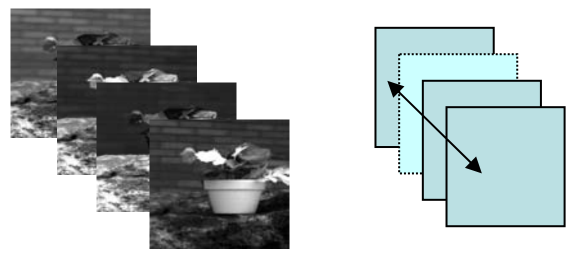



Figure 3. Electromagnetic Spectrum. The center area corresponds to the visible and infrared spectrums usually covered by multispectral and hyperspectral sensing platforms



a) b)

Figure 4. - a) Examples of spectral bands for visible (green, blue and red) and near infrared wavelength intervals b) Formation of pixel vectors or spectra

The main difference between hyperspectral and multispectral data resides in the number of spectral bands collected as well as the width of the frequency intervals associated to each of the bands. While hyperspectral data are usually understood to correspond to hundreds of narrow adjacent wavelength intervals, multispectral images have only few spectral bands with large wavelength intervals (see the shaded area in Fig. 3 for wavelength coverage of .multispectral and hyperspectral images).

Due to the narrow bandwidth of the spectral bands and the abundance of observations, in hyperspectral data the spectra for each pixel location resembles a continuous function of wavelengths. This function describes the reflectance of the material for wavelengths within the frequency interval covered by the sensor. This richness of information allows for detection of targets covering areas smaller than a pixel or separation of objects and shapes otherwise undistinguishable in regular images or by the human eye.

Single band (grayscale) or color imaging sensors as well as multispectral and hyperspectral platforms have been deployed on aircraft and satellite installations immediately following their development. In addition, multi-angle sensors, as well as high resolution imagers have been deployed. In the recent decade, an increased interest in the technology has resulted in the use of similar platforms on the ground. Such applications include medical imaging, surveillance and security, industry quality control, etc [2].

Multispectral and hyperspectral imagery also pose significant drawbacks. Current they are mainly considered to be passive sensing [3] and are limited in their capability by the solar energy and atmospheric conditions. A flight mission in a rainy day will likely reveal little useful information due to the cloud's reflecting properties. This explains the ongoing development of active sensing platforms. A technology with a long history is the radar sensing, deployed starting with WWII and used ever since. Radar waves (part of the microwaves) have the advantage of penetrating cloud formations and can be used in any illumination conditions [4]. Other novel technologies include Terahertz (THz) imagers (with wavelengths located between the infrared and microwave). The advantage of such approach is that while the terahertz waves have penetrating capabilities similar to x-ray or microwaves, they lack the malign effect on organisms [6].

## 3. Emergency Prevention and Management using Remote Sensing

UN's principles mandate that "Remote sensing activities shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic, social or scientific and technological development, and taking into particular consideration the needs of the developing countries" (Principle II, [7]). Moreover, "Remote sensing shall promote the protection of mankind from natural disasters." (Principle XI, [7]).

According to the US Veteran Administration's National Center for Post Traumatic Stress Disorder (PTSD), "disasters and terrorist attacks are often widespread with many people who directly experience the event and many more who may witness or be indirectly impacted"[8]. Significant segments of the population expose symptoms associated to PTSD and have behavioral and readjustment problems. Media coverage and lack of accurate information influences the public perception on the events as well as the ability to cope.

Recent decades have seen a significant number of disasters and attacks both within and outside North America. In many instances, the affected areas were unreachable by regular means of transportation for extended periods of time. Assessing the situation on ground was possible mainly through the use of RS [9]. In recent publications on the use of geospatial information and RS in the reaction and recovery phases of the World Trade Center attack in 2001, it was revealed that accurate satellite RS data were produced approximately three hours after the incident by a French SPOT satellite [10]. Within the next few days, commercial (IKONOS) and government (Landsat 7, Modis, Hyperion) satellite and airborne data were provided for both emergency response agencies as well as posted online for public information. Sensors such as LIDAR (Light Detection and Ranging) and thermal cameras were immediately used to detect 'hot spots', i.e. parts of the area with potential to ignite. GIS devices were used to accurately map locations in areas no longer recognized by streets [11]. We note that many of the techniques were previously used with success in fire and disaster prevention in various parts of the world [12, 13]. In the following months, RS data was used to quantify the amount of material remaining at the disaster site and allowed for planning of cleanup and transportation [10]. Overall, the experience strongly supported the integration of RS data in emergency response. At the same time, it suggested the immediate need for improved processing and data integration among agencies. Drawbacks observed were the lack of experience and software in analyzing the data as well as the absence of a centralized repository of knowledge on the best sensing tools and platforms available [10].

In September 2005, immediately following the hurricane Katrina's landing on the Gulf coast, various agencies extensively used RS for assessment of the damage and management of the emergency situation. Subjectively, we note an increased openness in providing the data and information to the general public and the research world compared with previous events. United States Geological Survey (USGS) currently maintains and extensive repository of RS data collected in September 2005. Based on this we estimate that at least a dozen satellite and six airborne platforms were used to obtain and process data [14].

An example of such use is presented in Fig. 5. A satellite multispectral image was collected on September 6, 2005 over the greater New Orleans area. The data were recorded using the Advanced Land Imager Scene, installed onboard of the EO-1 (Earth Observing 1) satellite and are formed of ten distinct bands covering the visible to mid-infrared ranges [15]. The bands were then processed using Principal Component Analysis (PCA) to render a color composite image formed of the three highest variance PCA bands. A popular technique in multispectral imagery, PCA transforms multidimensional correlated data into multidimensional uncorrelated ones also maximizing the individual component's variance [16]. Fig. 5a clearly show in darker tones the areas covered by water at that date. The close-up in Fig. 5b shows details of the central New Orleans area as well as possible smoke from a large fire (diagonal in the image).

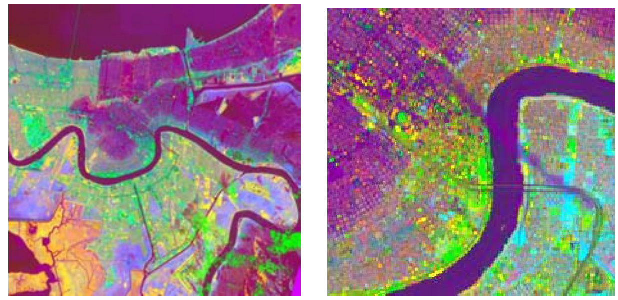
An emergency situation also occurs in the case of disease outbreaks. Here, again, RS and GIS tools have been used successfully in prevention and containment. Examples of such applications are described in [17] where GIS is used to map patient's original location in order to detect points of origin for the outbreak, in [18] where a thermal tool for SARS detection is presented and studied, as well as in [19] where the use of remote sensing for avian influenza is investigated.

RS use in disaster environment has broad implications to the society. Apart from the direct impact to the improving prevention and management efficiency, RS has provided informational tools of great value to the general population. Images and data are used as information tools by government agencies to support public policies and by news organizations to provide detailed information on the events.

## 4. Internet and Media use of Remote Sensing

At its origins, remote sensing was primarily supported by defense and other governmental organizations. This meant that access to RS data and applications was heavily restricted based on individual government's interests and regulations [20]. While international conventions such as the United Nations Resolutions in 1961 and 1963 (discussed in [20]), and the Resolution on Principles Relating to Remote Sensing in 1986 [7] promoted international collaboration and distribution of data, little was done to enact these principles. Only advances in technology that reduced the sensor and computing costs, coupled with decentralization of government activities allowed private entities to increase their role in the field.

Significant progress in RS coincided with the tremendous expansion and diversification of the internet. As such most of the societal understanding of RS comes through internet channels. Computer and internet based mapping tools have already become an integral part of human life. Websites such as Mapquest.com as well as mapping sections on Yahoo and MSN receive over 40 million unique visits each month. While the accuracy of the available mapping data is constantly improving, a recent application released by Google Inc. – Google Earth (GE) has the merit of introducing RS to the masses. According to the company's description as well as to published studies [21], GE provides a mechanism for combining satellite and airborne imagery with other geodata and map layers, as well as user's own data (see [21] for a discussion on the application and [22] for examples of popular user data). While the current version mainly allows for single band integration, it is only a matter of time until when multispectral/hyperspectral data or actively sensed data will be added to the application.



a) b)

Figure 5. - Use of RS data in emergency situations. a) Processed multispectral image of New Orleans, LA, USA b) Close-up of the downtown and historical district areas. Data collected on Sept. 06, 2005

GE's impact on the society is still at its incipient stage. At the very least, the application constitutes a formidable pedagogical tool for geography learning. The ability for the general population to see land areas from space will change people's perception on the world and its size.

The tool is also not without controversy. The inability to know the exact collection date of the imaged data could provide inaccurate information to the general public contradicting general ethics codes for RS and GIS professionals [23]. In addition, a number of governments have expressed concerns related to national security due to images of sensible or military sites being made freely available [24]. These fears seem to e mostly unfounded since the information currently available on Google Earth is mostly outdated or available elsewhere also for free [21].

Media in all its forms has used maps and images to enrich the public's experience in acquiring information. It was a natural step that RS technologies be embraced by these outlets. Popular news channels license currently license satellite and airborne imagery to deliver up to date information on current events. Microwave sensing has become the most accurate means of data collection for weather forecast

## 5. Security and Remote Sensing

Homeland security and law enforcement constitute some of the most active research and development areas of application in RS. This is explained both by the governmental agencies willingness to support such initiatives and the efficiency of the RS techniques that are developed.

The legal and social implications of the use of RS in law enforcement are not yet clearly understood [25]. Research reveals that RS data, while used in legal cases are often thrown out due to the large number of manipulations and alterations that occur between the collection moment and the result analysis moment [25]. In addition, the processing methods and results must be closely peer-reviewed and accepted by the larger academic community prior to being presented in the court [25]. Studies show a mixed experience with remote sensing [26] with cases where the data were allowed and cases were the data were not. In many of these instances, the relevance of the data to the case and the qualifications of the expert witness played significant roles [26].

A secondary concern arises from the individual's rights for privacy as illustrated by the fourth amendment of the US Constitution [25]. Court cases have concluded that individual's privacy is not protected when the subject or the property is in plain or public view. Given that most sensors record solar reflected light, it is generally understood that RS techniques do not violate privacy rights. A more delicate balance is maintained in case of thermal or active sensors where normal human sensing is not just enhanced but augmented by new capability. Previous cases that used thermal imagery for detection of drug production or activity were accepted in court [26].

Techniques for mapping crime areas using GIS and RS tools have been devised and are in use by various law enforcement agencies [27] showing that imagery can play an important role in enhancing general safety. In addition, shape and face recognition applications are used for surveillance and security at various events and border entry points. Together with biometrics [28] they constitute popular tools in the field [29].

## 6. Conclusions

Most of the human senses allow for perception without direct contact to objects. As such, it is natural to see remote sensing as an answer to human society's search to enhance and improve the individual's senses. In today's society, it has become impossible for most of the activities to take place without a remote sensing component. Whether RS is used for informing and entertaining the public, for planning for and managing disasters, or for enhancing individual and group security, the basic ability to sense from the distance has proven its value in enhancing the society.

Our overview of RS implications on various human activities is not exhaustive. However, in today's context, the areas covered have an immediate impact on society's perception on technology and on large segments of population. While effective, RS can also lead to significant implications related to personal privacy and wellbeing. As with any other technology, one must balance the technological advances with ethical and moral components. Industry forecasts suggest that RS will continue to increase in accuracy, diversity and availability, in turn increasing its impact on the human society.

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