Remote Sensing with Satellite Technology

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Abstract

This essay discusses the current capabilities in the field of remote sensing in multiple social and behavioral science fields (Anthropology, History, Government, Psychology, Sociology, and Social work), and shows how remote sensing is playing an increasingly important role in social and behavioral science research. Why social and behavioral scientists apply satellite data, or should apply remote sensing data, is reviewed and evaluated, especially in connection to nonsatellite datasets (including US census data). This study clarifies how high resolution satellite data will impact research in the social and behavioral sciences, especially considering the release of additional sensors in 2014 and later, including new potential application of data collected from drones. Social and behavioral scientists will also need to develop research methodologies appropriate to their subfields. Last, coverage is given to present capabilities and emerging trends for remote sensing research, with an emphasis on, future possibilities for applying satellite data in the social and behavioral sciences.

INTRODUCTION

The purpose of this essay is to explore fully the possibilities and potential of remote sensing for diverse applications in the social and behavioral sciences, as well as the state of the art and how scientists apply this technology today. This essay first asks how we should define the social and behavioral sciences. At this author's university, the fields of Anthropology, History, Government, Psychology, Sociology, and Social work all lay within what was formerly titled The School of Social and Behavioral Sciences (now named The College of Arts and Sciences). Most of these disciplines tend to be considered either social or behavioral sciences at other universities, with History being somewhat evenly split between the humanities and social sciences, although some fields in the social and behavioral sciences clearly use remote sensing data more than others, so it is crucial to include fields where satellite data applications may seem less clear. It is important to assess all the social and behavioral

Emerging Trends in the Social and Behavioral Sciences. Edited by Robert Scott and Stephen Kosslyn.
 ISBN 978-1-118-90077-2.

sciences fields regarding their individual potential for remote sensing applications. However, since countless applications of remote sensing exist in the social and behavioral sciences, the current constraints make it impossible to describe them all, so this study will only provide an overview. Regarding the fields where virtually no remote sensing work exists, remote sensing applications could open doors for further study and insights, connecting natural environments or built environments for health, census, and other datasets. The social and behavioral sciences are truly a blend of multiple approaches of data analysis, and so the use of satellite remote sensing is a natural fit, representing an outside the box approach for some disciplines. This essay will show that remote sensing is playing an ever increasing role in the social and behavioral sciences, and, as new sensors and ways of analyzing the data become available, that it can play an even larger role in moving beyond mere data analysis to encouraging policy changes.

HOW DOES REMOTE SENSING WORK?

It is necessary to understand the process of remote sensing and how it applies directly to the social and behavioral sciences. The term *remote sensing* refers to the very act of perceiving the world around us. Human beings not only sense their environments remotely via their eyes but through a whole range of cameras and sensors. In this particular paper, the term *remote sensing* refers to the general field of satellite imagery analysis, where scholars use satellite imagery and other sources to detect short and longer term landscape changes as well as investigating specific features (natural and human-made) on the ground. While the research goals of each social and behavioral science research project using satellite imagery analysis will differ, the process by which the research takes place is identical. Typically, a scholar will start by looking at previous peer reviewed literature for a given area, to determine if other scholars have conducted remote sensing research there previously. If not, they search for literature in related geographic areas or studies done with similar approaches in other parts of the world. They will also carry out a cursory examination on Google Earth if they are not familiar with the study area to ascertain land cover data. Once scholars have completed an initial research phase, they will design their research methodology and hypotheses, and determine the most appropriate satellite imagery based on availability (i.e., online search networks). Satellite imagery, and especially high resolution imagery, has dropped significantly in price over the past five years, with a standard 5 km × 5 km high resolution image costing between $250.00 and $600.00. Newly tasked data are significantly more expensive, but the majority of the data that scientists might need tend to occur in online archives. Also, a great deal of satellite data from NASA is free.

Once the data is obtained, scientists can use one of a number of standard satellite imagery processing programs (e.g., ER Mapper, ENVI, ERDAS Imagine) to analyze it. Hundreds of remote sensing processing techniques exist, while one or more approaches might be most appropriate for the project in question. Once analysis is complete, the scientists might import it into a geographic information system (GIS), which allows for visual data and information layering. They can then use census or other datasets for comparative purposes. Next, scientists typically evaluate their image results, create maps and tables, and write up their results for peer review or conference presentations. Each field will have final results presented differently: Some fields, such as archaeology, may feature journals that allow for more technical discussions, while history journal articles might focus more on the broader results and implications, with less technical approaches. If the research merits it, there could potentially be follow-up work with government officials, NGOs, or policy makers to implement new approaches or incorporate the data into their daily decision making processes.

ANTHROPOLOGY

Remote sensing is playing an ever increasing role in the field of Anthropology, with the majority of work occurring in archaeology. It has tremendous potential for aiding Cultural Anthropologists in their mapping research (especially with locating "lost" indigenous groups in rainforest areas), physical anthropologists in the discovery of potential fossil rich zones, and linguistic anthropologists in connecting specific environments with language development. Archaeological discoveries made with high resolution sensors and aerial approaches using 3D laser mapping have received a significant amount of global press coverage. These findings have shown the world the scale of archaeological sites in diverse locations, and how these sites are threatened by modern development and site looting. Satellite imagery analyses can also help us to understand past human-environment interactions, which have major implications today, especially in regards to how past cultures have adapted to major climate change events.

Archaeologists find new archaeological sites and features across the globe regularly with satellite images (Parcak 2009). They have helped to find lost settlements in the Middle East, pyramids in Egypt, sites in Central America and Cambodia, and many Roman features beneath fields in Europe. While lower resolution sensors from NASA can help archaeologists to map larger landscapes via the detection of entire sites, high resolution sensors can help in the mapping of specific features at individual sites. The high resolution sensors do not "see" beneath sands or soils, but buried features (whether made of stone, brick, or other materials) actually affect their overlaying soils, sands, and vegetation in subtle ways that can be revealed by processing satellite data using different technologies. For example, a thick buried stone wall would cause overlaying vegetation to be less healthy because of a lack of nutrients and root depth. While visible imagery might not show those changes in vegetation health, near infrared high resolution sensors data display this clearly, since chlorophyll in plants shows up as stronger in the near infrared part of the electromagnetic spectrum. Hence, a buried wall or structure would appear as a linear feature in processed satellite data, which archaeologists could then compare to known and excavated archaeological examples. Typically, straight lines and linear features do not occur in nature, so if archaeologists discover groupings of straight lines in recognizable shapes, it would appear to be a manmade structure or structures, while survey and excavation is always needed to confirm and date such findings. Also, LIDAR (which stands for light detection and ranging), an active sensor system flown on airplanes that allows for "seeing" beneath forest canopies, is being increasingly used by archaeologists to create 3D maps of many sites in Central America, South America, and Southeast Asia.

Future research directions in physical anthropology will likely involve using new satellite sensors to locate potential sites for fossils. At present, many anthropologists seem to find fossil sites the old fashioned way: namely intense foot surveys, accidental discovery, or annual exposure via climate and erosion. In contrast, detecting geological hotspots which may have higher yields of animal fossils or early hominid remains would be possible through using the mid infrared part of the electromagnetic spectrum. Studying known locations and chemical signatures of fossil locations would assist anthropologists in extending such data to find additional sites to test and explore. Also, studying ancient lake beds and dried up or buried rives has already revealed additional Paleolithic sites. The most famous case study comes from Egypt's Western Desert, where scientists used RADAR data to detect buried river courses buried 10 m beneath the desert surface. They then surveyed the relic courses and found multiple deflated Paleolithic sites that ancient peoples had left along the old river edges (Wendorf, Close, & Schild, 1987).

Ultimately, the tremendous scale of discovery in archaeology for monuments and sites is a key driver for using remote sensing, and protecting archaeological sites threatened by theft, or "cultural racketeering." Archaeologists now use satellite images increasingly in the mapping of looting at archaeological sites in Peru, Egypt, Syria and elsewhere, the looting of which is frequently exacerbated in times of war or political conflict. Accessing data rapidly to determine and quantify the extent of site looting has proven problematic. Regarding free resources such as Google Earth, without expertise in archaeology, it is difficult if not impossible to recognize both archaeological sites and the looting that has taken place on them versus excavated areas. Also, Google Earth may not have recently tasked satellite imagery. No open-source or well-published techniques currently exist to detect archaeological site looting, but this is changing. Following the Egyptian revolution of January 25, 2011, looters entered the Cairo Museum on January 28, 2011. News soon emerged about looting taking place on multiple archaeological sites throughout Egypt, including Saqqara, el Lisht, and at storehouses in the Delta. To date, a comprehensive report quantifying the total looting at well-known and less well-known sites, which would provide a much clearer picture of the pattern of site damage, has not appeared. This is changing with ongoing work by the author of this essay using satellite images, which has shown over a 1000% increase in site looting in Egypt since January 2011. This is important because looted archaeological materials are used by crime syndicates to raise funds for drugs, guns, and other crime related activities (related closely to Justice Sciences). This makes the stopping of archaeological site looting a critical matter for international security efforts, especially in Egypt where the type and quantity of the site looting suggests intensive crime cartel involvement.

JUSTICE SCIENCES

Crime mapping has seen a surge in the application of remote sensing data over the past 10 years, especially with the increasing availability and decreasing cost of high resolution datasets. GIS plays more of a role generally in the mapping of criminal patterns, since one can import statistics on these activities and overlay locations on top of maps to view potential relationships with census and other data (especially looking at population densities, income, and other important factors). However, there are criminal activities than can easily be seen from satellite data, and with the potential of using drones to monitor high risk areas, remotely sensed data will only play more of a role in this social science field.

One area where satellite and other datasets play a crucial role is in the mapping of field containing marijuana and poppies (used for heroin production). Every plant has a distinct chemical signature, and if one knows the typical signatures of the normal plants within a crop cycle, any anomalies that the remote sensing programs classify as vegetation merit further investigation. The correct times of year for growing illegal drugs must be known prior to purchasing satellite imagery. Also, there must be some known locations or regions of known illegal drug growing to test methods. High resolution sensors with a 0.5-m resolution would be ideal for this mapping. At present, good ground data for testing is either generally not known or classified by government operations because of the sensitivity of the drug trade. Of course, ground truthing would be out of the question for safety reasons.

What is well known is that crimes tend to occur in geographically specific areas. Slums (many of which are illegal) or inner city housing areas may have higher crime rates, which can be correlated with architectural changes seen with satellite imagery. In some cases, criminal activities can be easily mapped with high resolution data. Illegal tire dumps, a major problem in the South, can be mapped because of the color, shape, and density of tires. If one knows the chemical signature of rubber tires, then larger areas can be evaluated in the search for this zones, which are dangerous if set on fire. One case study showing controversial change over time took place with satellite images of Gauntanamo bay. The US government reported that the prison was much smaller than the satellite images suggested (Myers, 2010).

As sensors gain higher resolution, privacy is becoming an increasing concern. Now, satellites can take images at only a set time of day. If police are lucky, then perhaps that satellite image might show evidence for a vehicle being in a specific place at an unexpected time, thus suggesting criminal activity. The resolution is not so good at present to allow the identification of individual vehicles, but it might in 5–10 years. Also, we do not know at present the implications of using drones in crime mapping. What will we do when drones fly over our heads 24 h a day, monitoring everything we do? This could be our future, yet the ethics debate on this issue is lagging behind technological developments.

SOCIOLOGY/SOCIAL WORK

While no direct associations can be made from remotely sensed data and individual behavioral trends related to sociology, social and behavioral scientists can use the data gleaned from remote sensing studies to help them understand potential environmental and man-made impacts to people. The environment of where and how people live, whether it is their physical home or where they work (in and out of doors) all play enormous roles in short and long term economic and social trends. Satellites cannot see populations changing directly, but they can help scientists with mapping changes in built environments. This may be directly or indirectly related to socioeconomic statuses. The location of green spaces and their effects on income levels can also be compared. Social workers might benefit from having better maps of a given neighborhood, or understanding potential environmental hazards or challenges that the groups with whom they are working with face on a daily basis. Being able to correlate census data with good maps might help sociologists and social workers make stronger statistical analyses within a GIS.

PSYCHOLOGY

Psychology as a field deals with human behavior, which cannot be seen with satellite imagery. What is fascinating, however, is how psychologists have studied remote sensing data analysts, and how individual behavioral trends might affect the general interpretation of satellite data. Psychological effects of satellite imagery interpretation are becoming increasingly important, as well as decisions behind how to move that data forward (Hoffman & Conway, 1989). Human factors, such as age, experience, background, gender, nationality, and numerous others may give insights into key decisions made surrounding satellite imagery analysis (Gardin *et al.*, 2010). Psychological analysis can also give insights into human behavior that may aid analysts in predicting future patterns of growth/change/location of whatever is being studied, and a much better understand why short versus long term changes occur. This is an area that is ignored in remote sensing research, and holds much potential. Expert versus novice interpretation may also play an important role in remote sensing analysis. Senior scientists with more than 20 years of experience design their research based on years of experience, while more junior operators make not be as confident with their approaches. Senior scholars may also jump to conclusions too quickly, while more junior scholars might have their keen insights ignored because of a perceived lack of experience.

Remote sensing work is generally not questioned (seen as already checked during the peer review process), yet reviewers might now have the technical expertise to test processes (or the resources and imagery). The literature also shows that the same people interpret satellite data slightly differently with altered information on land classes. Bias is something that remote sensing specialists need to acknowledge more openly in their work, as it will only result in a better understanding of the satellite data.

GOVERNMENT/POLITICAL SCIENCE

Many applications exist for political scientists to use remote sensing, while the actual politics of remote sensing is an active field given the wide ranging implications satellite data has in the daily lives of US citizens and the US government. This is a social science field that has benefitted significantly from GIS research, with many government or political science departments now offering certificate programs or minors in GIS. Many social scientists have studied population changes related to census data and political party affiliation. These and demographic changes depend on housing, jobs, good schools, hospitals, and other factors than can be easily mapped. Redistricting, quite controversial for how it may benefit one political party or another, cannot be done unless one has an excellent study of voting patterns and geographic data.

Satellite data is crucial for the mapping of disasters and associated national and international fundraising efforts. It can pick up virtually instantaneous changes (high resolution satellites can visit a location within a day) to landscapes from tornadoes, hurricanes, mudslides, or sinkholes. The high resolution data can find the areas worst affected by the disaster for aid delivery, finding open roads for disaster relief delivery. One image, showing an individual trapped on top of a roof in New Orleans, with the words "help me," was shown numerous times by news outlets to show the extent of the flooding and the lack of response. This also data helped with major fundraising for the Southeast Asia tsunami, with before and after imagery helping to many millions of dollars by Presidents Bush and Clinton.

Satellite data also plays a crucial role in the daily operation of the US government and political decision making. Mapping troop movements or detecting of insurgent activities are both activities where satellite data or data from drones is essential. The US government has not yet found an effective method to detect ground explosives remotely, but it is an area of current work. Monitoring areas where nuclear testing or production takes place in locations such as North Korea or Iran is only possible with satellite data. Government officials use satellite data to study changing crop patterns for farm subsidies and water management, both major areas of political contention. Climate change is a major area of focus by the US government, specifically scientists at NASA and NOAA. With new sensors being launched, it seems that satellite data will play more and more of a role in daily government decision making.

HISTORY

Historians can benefit from remote sensing research via new mapmaking approaches as well as new insights gained from understanding key historic events in terms of the landscapes in which they occurred. The technical training needed to process satellite and GIS data is generally not provided in graduate school for historians, although this is a changing trend. As historians seen the potential of remote sensing data for their research, many individuals can form collaborative projects with remote sensing specialists at their universities or may encourage their graduate students to obtain this training. Having this expertise is a virtual job guarantee, mainly because archives and government agencies involved with mapmaking are moving to or already have large datasets contain within GIS databases. Old maps can be surprisingly accurate, while new mobile phone map applications can easily get people lost (seen in the Apple maps fiasco in 2013).

Historians can merge old and new technologies by testing historic maps against satellite data, and georeferencing, or correcting, the old maps to see if the data is still accurate. This author examined numerous plates from the *Description D'Egypte* expedition maps of Egypt from 1804 in her archaeological survey work in Egypt. She found a high degree of correlation between reported archaeological sites and features from the Napoleonic survey and modern observations: while many old sites had modern towns covering them, the old maps acted as a guide and check against processed satellite data. Many of the names remained the same or similar enough as to help with ground surveys, and more importantly, the engineers from 200 years ago had clearly mapped with a high degree of accuracy (georeferencing the data showed the early maps did not contain much distortion). Early British Ordnance survey maps of Egypt also contained significant information about archaeological sites. One example with a high degree of success georeferencing old maps with new satellite data is a project undertaken to map the specific route of Lewis and Clark's expedition across the US. Historians examined expedition maps and corrected them using Landsat satellite data (Lewis and Clark Bicentennial project, 2009). Based on their findings, and using eyewitness accounts from Lewis and Clark's description of landmarks, the historians projected a more accurate route of the expedition and its encampments which allowed them to gain additional insights about the historic journey.

Some historical maps are clearly more accurate than others, and can help historians to illustrate key points about changing landscapes. Georeferencing them will show historians better information about the location of specific cities or places where battles took place. Historians also find Google Earth useful in the classroom for illustrating journeys famous historic figures such as Alexander the Great took conquering the world, or using 3D landscape Google Earth views to understand key battles. One feature that helps in the classroom is Google's "add photo" option, which makes it possible to import maps or related data files to illustrate key points. If key places are "missing," or have undergone name changes over time, then historians can use a combination of old maps and satellite images in an attempt to locate those places or their modern counterparts. Borders, rivers, and roads all could have changed locations or paths over time, caused by either human or natural events (or a combination of both), and satellite images could help to identify now partially obscured older features that might help historians answer specific historic questions.

FUTURE APPLICATIONS OF REMOTE SENSING TO THE SOCIAL AND BEHAVIORAL SCIENCES

Thus, what does the future hold for remote sensing and potential future directions for applications within the social sciences? New technological developments, sensors, computer programs, open source approaches, and social media all will play important roles in how social scientists use and apply remote sensing data in their work. One of the largest areas of impact will be changing regulations existing that restrict the resolution sensors can have. At present, the US National Geospatial Intelligence Agency (NGIA) stipulates that the highest resolution data that can be made openly available is 0.5 m, or 1.5 feet. This data can be seen in Geoeye and WorldView-1 datasets. Sciences and others complain since aerial photographs generally have a much higher resolution, at 0.2 m, or 8 inches, and there are no restrictions on the resolution of aerial photographic data. In addition, much of this aerial data is made available on Google Earth for large parts of the United States and Europe, thus rendering the NGIA's arguments as backwards thinking. Protecting individual privacy is a paramount concern for all scientists using remotely-sensed data, and there is certainly a balance between getting good high resolution data and not being able to identify specific individuals. While this is now possible with drones (especially those used by the US government in conflict situations), there are not yet well defined privacy laws around the information that can and cannot be captured. For example, should a drone be allowed to fly above a town, viewing the activity in people's backyards, and spying into individual homes? What if criminal activities are taking place? Privacy issue debates around this issue will clearly continue, and will likely eventually make their way through the US court systems. Until that time, additional technological advances in remote sensing will only assist social and behavioral science research.

New satellite launches will play a large role in the advancement of social and behavioral science research, with the one of the most promising new sensors being WorldView-3 (WV-3), which will launch in early fall 2014. With a 0.31-m panchromatic resolution (if the NGIC lifts the restriction in place on data resolution), 1.24 m multispectral resolution, 3.6-m short wave infrared resolution, WV-3 will have 29 bands of data. One of these will be panchromatic, 8 in the multispectral range, 8 in the short wave infrared, and 12 bands in the CAVIS range (which will be used to examine aerosols, ice, snow, clouds, and aerosols). This sensor will have the ability to map features that previous could only be mapped using 15–30 m range data. Many archaeological features will appear that are invisible or only partially visible to current sensors, and many other subtle landscape changes will appear. WV-3 will have a major impact on many scientific fields as a result of the increased spatial and spectral ranges, and will certainly affect all the social and behavioral science fields described in this essay. LIDAR, which stands for Light Detection and Ranging is another sensor which many social and behavioral science fields utilize for mapping and landscape visualization. Flown on an airplane, this sensor system sends down thousands of laser pulse beams at different return rates (creating point cloud data), making it possible for scientists to remove any vegetation covering possible ground features. Archaeologists are only beginning to explore the full possibilities and potential of this sensor system in exploring hidden archaeological sites, while other social and behavioral science fields have not yet applied this technology in mapping.

Broader approaches and largescale data analyses via Big Data also hold much promise for social and behavioral science research with remote sensing. The greatest promise for this research is in the area of crowdsourcing. Current projects using crowdsourcing, such as Oxford University's Galazy Zoo project (where members of the public have helped to classify many thousands of galaxies), invite members of the public to help classify millions of datasets. Research has shown that the wisdom of the crowd can be more effective than "expert" analyses (cite social analytics study). One current project via DigitalGlobe's Tomnod crowdsourcing application includes large satellite datasets from Southeast Asia, which millions of people have used to attempt to find the Malaysian airlines flight 370 crash. While not successful, this case highlights how willing individuals can be to participate in group search activities with remote sensing. Another aspect of crowdsourcing includes using satellite data to show specific locations of potentially controversial activities. International technology advocates such as Ushuahidi support geotagging places where specific activities are occurring and being monitored (including elections, illegal activities, and disasters). This monitoring can help aid groups and democracy watchdogs with rapid information gathering for more effective ground based responses. As Big Data approaches become more user friendly, it will become possible to analyze satellite data from entire countries at once (at present this requires access to large computer processors), which has endless potential for social and behavioral science research in terms of seeing short and longer term landscape changes. At present, Google Earth and other open source satellite platforms are of great use to social and behavioral science researchers, yet do not have data than can be downloaded, processed, and evaluated within standard remote sensing programs. Also, Google Earth and other platforms do not have high resolution data coverage for 100% of the planet.

With all of the new satellite platforms, wither remote sensing research in the social and behavioral sciences? While social scientists have excellent satellite data, it is clear that remote sensing data analysis can no longer be knowledge for the sake of knowledge. The most advanced new technologies mean nothing if social scientists do not use the data they glean from their research to move towards action and policy changes, whether in protecting our shared global heritage, understanding social patterns via short and longer term changes, or understanding who we are as human beings. Fortunately, this is something we are seeing more and more, with social scientists who use remotely sensed data getting active on social media, participating in local, statewide, or national boards, and serving as strong voices to implement policy changes in Washington, DC and globally based on research results. This is the true emerging trend with remote sensing in the social and behavioral sciences; the power to move beyond data into real world action, which is a comforting direction, indeed.

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