Ethical challenges in the practice of remote sensing

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Introduction

Remote Sensing (RS) can be defined as the set of techniques used to obtain information about an object (target), area or phenomenon, through data acquired by a device (sensor) that is not in direct contact with the object, area or phenomenon under investigation (Campbell and Wynne, 2011). To acquire this data, sensors can be attached to aircraft or spacecraft, airplanes, balloons, buoys, etc. RS technologies have been widely applied in various areas of knowledge, such as:

- **Agriculture**: identification and mapping of different agricultural crops, monitoring of crop development stages, production estimates, etc.
- **Water Resources**: mapping water bodies, detecting oil stains and other contaminants, flood analysis, etc.
- **Environment**: mapping of forest remnants, wetlands, distribution of tree species, phenological changes in vegetation, differentiation of successional stages, estimation of forest biomass, detection of changes in land use and land cover, detection of deforestation, forest degradation, fires and their effects on biodiversity, etc.
- **Geology and Geomorphology**: digital models of the earth's surface, identification and mapping of surface soils, landslides, etc.
- **Urban Studies**: mapping types of urban land use, urban mobility, urban microclimate processes and population inferences, etc.

RS has several unique advantages as well as limitations. Among the advantages, it is considered to be non-invasive, because if the sensor is passively recording the electromagnetic energy reflected or emitted by the phenomenon of interest, it does not disturb the object, phenomenon or area of interest (Jensen, 2000). It also allows information to be obtained in a non-destructive way, as detection is carried out without physical contact with the object. RS data can be obtained systematically for very large geographical regions, including those that are difficult to access, or even areas where direct disturbance is prohibited. The greater frequency with which these data are obtained makes it possible to monitor/ surveillance the target of interest, as well as making the information generated from RS data available quickly.

According to Jensen (2000), perhaps the biggest limitation of RS is overestimation. Using a range of RS techniques provides only a few pieces of information in terms of spatial, spectral and temporal value. Errors produced by human methods can be introduced when the parameters of the RS mission and instruments are specified. RS data when obtained by active remote sensing systems, which emit their own electromagnetic radiation (such as LIDAR, RADAR and SONAR), are considered intrusive because they can affect the target being studied. In addition, remote sensing instruments can become uncalibrated, resulting in uncalibrated remote sensor data obtained by such remote sensors (Jensen, 2000).

The availability of satellite images, image processing software, geographic information systems (GIS), often available free of charge, as well as a wide range of tutorials, forums and information on websites, has allowed the use of these datasets to expand. This has enabled greater sharing of data and information, often on a global level. This data and information can be of a sensitive nature.

While on the one hand, RS makes it possible to obtain information using non-destructive and invasive methods, on the other hand, it can result in the disclosure and dissemination of sensitive data, and even the loss of control over natural and cultural resources. Consequently, it can, at different levels, compromise different territories, populations, landscapes and cultures (Davis and Sanger, 2021). The authors Sanger and Barnett (2021) and Bennett et al., (2024), state that RS data can also be potentially invasive.

Recently, discussions about ethical principles applied to RS have emerged, especially in environmental and archaeological research. In the field of environmental science, York et al., (2023) state that RS has played a key role in monitoring large areas for the purposes of biodiversity preservation and conservation, restoration of degraded areas and climate change. In archaeology, approaches based on RS and GIs have been used to carry out archaeological excavations and antiquarian collections (Davis and Sanger, 2021; Sanger and Barnett, 2021).

The discussion of the role of ethics and its implementation in RS applications needs to continue to be deepened and disseminated in a multidisciplinary way, permeating the natural, social and data sciences, in terms of the preservation and conservation of biodiversity, cultural heritage, legal property rights, exposure of spaces and items, especially those considered sensitive.

Negative impacts related to ethical negligence in RS research

Due to the nature of RS, which does not require physical contact with the targets of interest in order to detect them, datasets can be acquired without the need for fieldwork, collaboration or direct interaction with local communities. This lack of contact with the main actors involved is a way of dehumanizing past peoples and their descendants. (Davis and Sanger, 2021; Sanger and Barnett, 2021; York et al., 2023).

By neglecting ethical principles, applications of RS lead to a greater distance between the knowledge of the local community and scientific research. The way in which digital data is often processed, stored and accessed, as well as its interpretation, is not trivial, especially for local communities. Most of the time it requires highly specialized knowledge, and as a result, local communities become dependent on researchers to access their own heritage (Davis and Sanger, 2021; Sanger and Barnett, 2021; York et al., 2023).

Another negative impact is associated with the possibility of exposing confidential and/or sensitive information, which can consequently be easily disseminated, resulting, for example, in damage to local cultural heritage (Davis and Sanger, 2021). In Indigenous communities, sensitive features can be revealed in the landscape related to their important practices, social, cultural and spiritual values (Sanger and Barnett, 2021; Bennett et al., 2024).

In Indigenous communities with a history of resistance to scientific colonialism, the use of RS can be even more challenging. According to Sanger and Barnett (2021), the biggest beneficiaries of such research are usually the researchers themselves. Consequently, such research is seen as part of a longer tradition in which landscape, heritage and culture are threatened. Davis and Sanger (2021) state that neglecting ethical principles can foster and reinforce stereotypes that pit science against natives, devalue local traditional knowledge holders and desecrate sites that are home to ancestral peoples.

In addition, research involving RS requires some level of investment (e.g. purchase of satellite images, software, storage of large volumes of data, hiring experts, fieldwork, among others). The datasets generated from these investments are generally the legal property of the institutions that financially support such research, with few legal resources attributed to local communities, who consider this data to be their cultural heritage (York et al., 2023). In archaeological research, researchers are agreeing that local communities have the right to receive moral ownership over the data produced,

arguing that it is often the only way in which important aspects of cultural heritage can be accessed (Sanger and Barnett, 2021).

Negative impacts such as those mentioned above can also be reflected in the power dynamics that exist between researchers and the local communities involved. Such research is often designed and implemented by centralized power holders, be it government institutions, academia or private corporations that aim to study racial/ethnic minority groups (especially Indigenous peoples), economically disadvantaged groups or communities with less power. The exclusion of members and intellectuals from local communities in the production of knowledge by researchers, as well as the neglect of other ethical principles, can further reinforce this existing unequal power dynamic, especially among these minority groups, who often already live in a situation of marginalization, persecution, and/or domination (Sanger and Barnett, 2021; York et al., 2023).

Making ethics inclusive in RS research

Research involving RS is undergoing an ethical rethink, with researchers finding that the acquisition of data usually requires some level of consent. This is the case even when the data can be obtained without the prior knowledge of local communities, one of the main stakeholders. Consequently, ethical dilemmas related to consent arise when conducting research with RS, as the nature of these technologies is not common knowledge among all people (Sanger and Barnett, 2021).

In this context, Sanger and Barnett (2021), highlight the importance of consulting local communities before starting data collection, in order to consider how communities understand and/or view issues of personal and community privacy, and detection and surveillance/monitoring of their phenomena and/or territories, carried out remotely, in order to ensure that culturally sensitive sites and/or phenomena are not exposed and/or mapped without proper permission (Davis and Sanger, 2021; Bennett et al., 2024).

The stages of planning, data acquisition and generation, implementation, analysis of results, publication, and dissemination of the research project with RS data need to involve members of local communities from start to finish. Building spaces for dialog between researchers and communities ensures that opinions, ideas and decision-making are shared and incorporated into all phases of the project. It also ensures that the cultural values of the communities are not violated, reduces conflicts with the local communities and opens the way for additional projects to be carried out together with the local communities (Davis and Sanger, 2021; Sanger and Barnett, 2021; Bennet et al., 2024).

Another possibility is to offer training opportunities and transfer technological knowledge to communities, especially in regions where knowledge about RS is limited. This enables capacity building, empowerment, and autonomy of local communities, since they are primarily responsible for their territories, for the activities carried out there, and for protecting their cultural heritage and their spaces (Davis and Sanger, 2021; Sanger and Barnett, 2021; Bennett et al., 2024).

A study by Paneque-G'alvez et al. (2017) evaluated how innovative RS technologies can be useful to Indigenous communities in Central and South America. The authors found that the use of drones by communities has helped them map and monitor their territories as a means of defense against threats of invasion by external actors. Community drones are gaining popularity among Indigenous communities seeking to protect their lands and monitor environmental violations.

On the one hand, by neglecting ethical principles, research related to RS can compromise populations, territories and cultural heritage, especially the most sensitive ones. On the other hand, combining the scientific knowledge of remote sensing with the

knowledge of local communities in a complementary and non-exclusive way opens the door to creating a more holistic understanding of the historical context of local communities and to proposing innovative, collaborative and inclusive solutions to sensitive issues that are relevant to all stakeholders.

Conclusion

The applications of RS in different areas of knowledge have expanded rapidly in recent decades, mainly due to the large volume of digital data and the development of new technologies (e.g. satellite images with very high special resolution, drones, LIDAR, algorithms, among others). The different choices that remote sensing researchers make about the data (methodological approaches, types of satellite images, thematic classes to be mapped, etc.) and how this data will be used (who will use it, what is its purpose) can influence in different ways and cause potentially lasting impacts in different contexts. In view of these advances, it is necessary to investigate the ethical, social and cultural challenges associated with the use of these new technologies.

It is extremely important for researchers to reflect on how to use RS data ethically. Among the issues that need to be incorporated into this reflection are: inclusion of local stakeholders and informed consent; privacy of confidential and/or sensitive data; property rights; knowledge sharing; ethical practices that can make research in highly sensitive environments viable. Other issues that have not been mentioned in this document, but which are relevant within the particularity of each community and project, also need to emerge and be widely discussed in a multidisciplinary manner.

Furthermore, it is important to consider efforts on the part of researchers to establish a space for dialogue with the local community, in order to ensure that ideas, suggestions and local knowledge are built upon and implemented collectively by all parties directly involved, throughout all stages of research development. This enables the remote sensing community to be more inclusive and representative, and unites local and scientific knowledge, making science stronger and knowledge more reliable.

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