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Recent Developments in Earth Observation | *Shankar Sivaprakasam*

A new form of gathering big data, known as earth observation (EO), has been gaining ground in recent years. It involves the use of hundreds of satellites with varied sensors in lower earth orbit, above 400 km from earth's surface. EO has the potential to proliferate and catalyse digital disruptions, further transforming industries, government business and the way people live, work, and learn.

Data and insights have transformed how we live, work, play and learn. Businesses have monetised data from our online and app activities, while governments have used such data to tailor services to their citizens. Amid this trend, a new form of gathering big data has emerged, with the potential to proliferate and catalyse digital disruptions and further transform industries and government business. Known as earth observation (EO), the new technology involves generating data in space through hundreds of satellites with varied sensors in lower earth orbit (LEO), above 400 km from earth's surface.

Earth Observation and Its Evolution

Three key trends merit highlighting.

First, frequency and detail of data. Earth Observation (EO) satellites and the use of data they generate have been around for several decades since the Landsat mission launched by NASA in the 1970s. These gigantic satellites take a picture of the earth in coarse resolutions once every few days. Similarly, the European Space Agency's Copernicus Sentinel satellites are also public good missions. The pictures these satellites take inform us of everything from forest cover degradation to issues with waterways. The science behind these analyses is called remote sensing.

However, several use cases, such as small object vessel detection during times of interest or extraction of a specific feature, such as a building footprint requiring higher temporal and spatial resolutions, limit their value. This is a gap that commercial providers began to fill. Often in the form of start-ups, these companies have played a significant role in introducing a new space era in the past decade and a half. They achieved this by miniaturising satellites through an agile aerospace approach, similar to software development and releases. These satellites were flown regularly with iterations, at a lower cost, and in a constellation design.

The new space design involved many satellites performing the same task, resulting in higher coverage and revisit. This unlocked the commercial value of EO beyond the academic and scientific use of Landsat and Sentinel data. The “NewSpace 1.0 companies”, as the pioneering commercial space players are referred to, enabled the wider usability of EO data. However, NewSpace 2.0 companies are solving the affordability issue by bringing down the unit costs significantly. They provide data under more liberal licensing regimes while being for-profit organisations.

Second, monitoring vs. tasking. Another trend that emerged with NewSpace companies is the distinction between monitoring and tasking missions. End-users cannot send task requests to public good satellites as they are monitoring missions. The operators of Landsat and Sentinel program their satellites to collect data routinely over the landmass and waters, making such data available to everyone as a public good.

Public goods satellites are like public transport on earth with fixed routes. Tasking satellites play a different role: targeted in collection over an area during a time of interest to an end user. They are also generally in higher resolutions and with fewer spectral bands. They are akin to private transport like taxis that serve the one-on-one requirements of customers. As with private taxis, tasking is not affordable and accessible to all.

Tasking satellites can serve specific uses of looking into particular details on earth. These satellites are used to understand internal displacements during conflicts, protect maritime and land borders, inspect and manage assets and infrastructure of importance, process claims and avoid fraud related to natural disasters, build digital twins of cities in 3D for planning and upkeep, etc.

Third, an explosion of sensors. Satellites carry sensors on board that generate data. Each of these sensors fits the use cases it addresses – everything from visually inspecting changes to identifying changes that the naked eye cannot easily decipher. Data from these sensors can inform if there has been a ground displacement because of a disaster, a disease affecting a certain crop, how much the city is heating, where illicit transhipments are taking place, etc., round the clock. The types and capabilities of such sensors have exploded in the recent past, with use-case-specific instruments, such as greenhouse gas or weather, to more general purposes, such as high-resolution night vision.

Current Advances in EO

There have been significant advances in EO in recent years, both in hardware and software. The satellites in the NewSpace paradigm are called smallsats as they are small, modular and easy to build and launch. Smallsats have replaced large EO satellites weighing hundreds of kilograms. They are built mostly using commodity hardware and do not weigh over tens of kilos. Furthermore, modular and services-based software stack speeds up satellite build, testing, and launching processes and facilitates efficient on-orbit satellite updates. The NewSpace approach has proven to be cost-effective, with design redundancy and resilient operations involving the launch of several tens of satellites at a fraction of the cost of a large satellite.

Digital twinning for the entire life-cycle management of satellites is becoming more common. Specifically, there are three advances to note.

First, multi-mission satellites**.** In hosting a sensor, satellite operators add multiple and complementary payloads in their constellations to offer multimodal data at marginal cost. Multi-mission constellations can help solve certain use cases since the same satellite captures various types of data simultaneously. Also, tip-and-cue workflow between satellites within the constellation is now possible. Tip-and-cue is a workflow in which one sensor detects an object or change of interest, and the subsequent sensor prosecutes that with a different sensor for further details.

Second, sensor fusion**.** We routinely perform data fusion with terrestrial data sources to extract information and generate insights from structured and unstructured data. Data collected by multiple and varied sensors from different satellites have inherent challenges when they are fused. While the fusion of more diverse sensors is an ongoing research interest, combining varied sensor data to compare and interpret an observation made from space has become more common. For example, multispectral bands can understand the object of interest, and synthetic aperture radar can provide information about the texture. This has applications both on land and in water.

Third, AI and cloud. The recent advances in computer vision and machine learning have been a boon for EO. The combination of more data, cloud infrastructure and AI has enabled the removal of clouds from images, identifying objects of interest, extracting features, and detecting changes, in short, allowing the meaningful use of EO data. Tasks ranging from detecting illicit transhipment, predicting rice yields and calculating commodity stockpiles to predicting inundation or fire trajectory for first responders and insurers are all made possible by combining multi-sensor data and machine learning/deep learning models.

Challenges

Despite the benefits of EO data, EO is not mainstream yet. EO was briefly appreciated during the COVID-19 pandemic, when businesses and governments needed to monitor or maintain their assets with limited staff and travel became either sparse or non-existent. People relied on satellites to provide situational awareness in far-flung and remote areas. However, the uptick did not continue in earnest past the pandemic, primarily because of affordability issues.

On-demand satellite access has been uncommon until recently, with start-ups beginning to solve the accessibility issue. The primary users of EO are still the defence and intelligence agencies monitoring borders while observing hostile forces or developments in enemy territory or countries of interest, all with commercial satellites. Governments are increasingly using EO during disaster response, and the criticism has been that the lack of real-time data during emergencies is costly to most.

Many factors, such as the number of satellites and their deployment orbits, location of ground stations or on-orbit relays with geostationary communication satellites, need to come together for low latency data and timely insights. Most decisions are trade-offs, as the satellites may serve a specific geography or select use cases. The recent advances in VLEO or very low orbit satellites, hovering about 200 km instead of above the usual 400 km where most EO satellites are today, are promising regarding very high resolution and low latency data.

Sovereign Satellites and Policy Impact

One of the emerging trends with space-faring sovereign states is the adoption of smallsat designs for their missions. With sovereign EO satellites, governments are now mandating the use of EO in governance besides enforcing the sale of products and services that heavily rely on EO data. For example, in some countries, the government uses EO data to support reporting progress in construction as a verification capability. In other instances, such as to protect farmers during poor harvests and insulate them from natural disasters, governments have made it mandatory for insurers to provide crop insurance and EO data to facilitate the management of crops in a vast country.

Countries also use EO data as soft power in diplomacy. Well-resourced neighbours with space assets help those that lack the means to invest in EO satellites. Among the most popular use cases is providing EO data as a form of aid in the national security or disaster and relief management arenas.

Conclusion

The accessibility, affordability and usability debate on using EO data for downstream applications has been ongoing. There are even more choices than before because of several commercial satellite constellations besides dual-use sovereign satellites. This has been possible because of the lower launch and hardware costs. However, with the choices comes fragmentation. There is no consistent way of accessing all the satellites with all the sensors in one place. There is significant friction in the source-fuse-use workflow today.

When EO becomes mainstream, as it is likely to, it would be a godsend if one can access satellites on-demand like using Uber, combine the various sensor data like ordering multi-cuisine picked up from several restaurants through Uber Eats, extract information from sensors automatically without needing to be a geospatial expert, and pay for such information as you use it.

About the Author

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