BIG DATA
CASE Study

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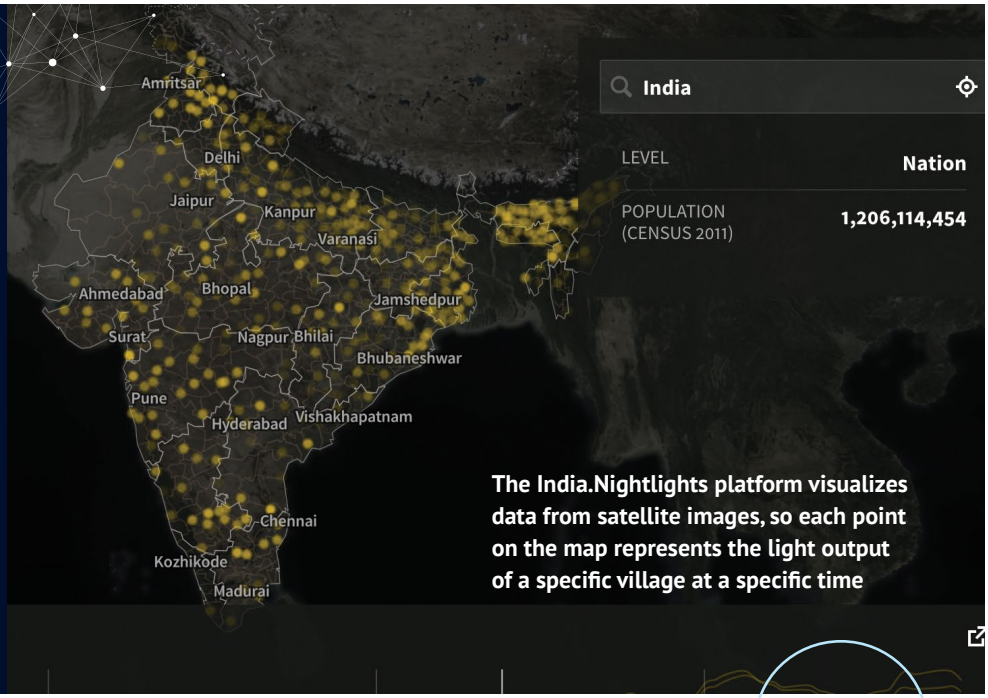

Monitoring Rural Electrification from Space

Kwawu Mensan Gaba

SUMMARY

Electricity is essential to human wellbeing worldwide, yet 1.2 billion people still live without it. Key to improving service provision is accurate tracking of the availability and supply of electricity at local level. By collecting and analyzing a unique historical archive of nighttime satellite imagery, this project developed a novel data-intensive strategy to improve the monitoring of electricity provision to rural areas across the developing world. Drawing on a multi-terabyte image archive spanning over 8,000 nights since 1993, the team used computationally intensive methods to extract and analyze patterns of light output observed nightly over all 600,000 villages in India. This pioneering dataset paints a dynamic portrait of rural energy access over two decades, enabling observation of how access to electricity has expanded, and identification of villages that remain dark. It also enables the detection of power supply irregularities. These insights are particularly useful

in rural and remote regions where traditional monitoring is difficult. To make the data accessible to governments, power companies, regulatory agencies and other users, the team developed an online visualization platform, India.Nightlights. The site allows users to see how light output has evolved over two decades, from state level right down to individual villages. Ultimately, the approach could help optimize electrification planning according to an accurate understanding of electrical supplies on the ground.

CHALLENGE

In much of the world, access to electricity is uneven and irregular, undermining development and welfare. Rural electrification and lighting improvement projects are high on the development agenda. These are regularly monitored and evaluated, but there have been no mechanisms to track the sustainability of electrification schemes after projects end, or to identify easily and precisely who has electricity and who does not.

Data processing technologies are now enabling new ways to monitor access to electricity. Night lights data measured by satellite has been a useful resource for the development community for several years. However, the complexity of accessing, processing and manipulating this data has been a barrier to widespread use. While analysts have previously examined summaries or subsets of historical nighttime lights data, there has been no systematic effort to study the entire raw nightly data stream. This stream reveals the distribution of electricity at high resolution over the last two decades.

In 2011, a team from the University of Michigan, the US National Oceanic and Atmospheric Administration and the World Bank Group's Energy and Extractives Global Practice began to explore how to use night lights data in a scalable, systematic way. Their early work focused on validating ('ground-truthing') the relationship between satellite-detected light output and the use and the availability of electricity in several hundred villages across Senegal, Mali and Vietnam. The next step was to develop a strategy to exploit the detailed information from the full archive of nighttime satellite imagery to improve the monitoring of electricity supply around the world.

The resulting dataset represents the most comprehensive database known describing electricity access and variability

INNOVATION

The team's pilot studies explored the use of night light data to monitor rural electrification in countries with low electrification rates, such as Mali and Senegal. This was expanded to Vietnam, which has near-universal electrification. Following the Big Data Innovation Challenge, the team refined its approach and scaled it up to look at all of India, a country with a high density of villages and a major rural electrification program. This project took two parallel tracks, in close collaboration:

- ***Mapping India's power supply***
  With its high density of villages and a flagship national electrification strategy, India was an ideal country to assess the validity and reliability of a satellite-based approach for monitoring rural electrification over time. The first step was to evaluate the large-scale electrification program, launched in 2005 to bring power to over 100,000 villages.

The team acquired the complete historical archive of nighttime satellite imagery from the Defense Meteorological Satellite Program, run by the National Oceanic and Atmospheric Administration. This has taken pictures of the Earth every night for over 20 years, creating an archive of multiple terabytes of high-resolution image data. Using geographic information systems (GIS) and data processing tools, the team analyzed the nightly light signatures of India's 600,000 villages (identified by geographical coordinates). The resulting dataset of almost 5 billion observations represents the most comprehensive database known describing electricity access and variability. It enables new analysis, exploration of signal- processing techniques and generation of data visualizations that better capture space and time patterns in electricity distribution.

Drawing on official electrification program records, the project linked newly electrified villages to their nighttime light signatures, covering around 8,000 nights during a 21-year period (1993-2013). This enabled verification of improvements to electrical supply, and identification of potential implementation problems.

The approach is a departure from prior research on nighttime lights. Most analysis uses annual composite images, which describe the average brightness of a locality over a calendar year. Yet in India and elsewhere, day-to-day variability in access to electricity is a far larger concern. By applying statistical and machine learning techniques, the team developed new methods to visualize patterns of supply disruptions. One objective is to use variability in light output data to identify regional instability in power supply, increased incidences of power cuts, and indications of electrical supply problems as they occur.

- ***Creating visual tools***
  Building on the insights gained from the satellite data study of India, the team developed an online toolkit to provide power companies, regulatory agencies and relevant partners with geo-referenced maps and satellite imagery depicting current patterns and recent trends in electricity supply. It visualized electrification trends on a web platform, India.Nightlights.io.

  The open-source platform comprises a pipeline to process massive amounts of data, an application programming interface that enables technical partners to query light output at village, district, region or state levels across India, and a dashboard map to allow users to explore light output trends. The platform offers high-level overviews or enables users to compare villages, plot trends and share data. Freely explored from any part of the world, it has the potential be a powerful tool in driving rapid electrification.

  Each point on the map of India represents the light output of a specific village at a specific time. At district level, users can filter to view villages that have participated in India's electrification program and see changes in light output, which can be used to complement research about electrification in the country

  The platform was tested by various users involved in expanding electricity supply, including private firms, universities, regional governments, non-governmental organizations and development partners. It was then refined ahead of a public launch at the World Economic Forum in Davos, Switzerland, in January 2016.

RESULTS

The project demonstrated that nighttime satellite imagery can be reliably used to detect the use of electricity in the developing world, even in rural contexts where electricity use is characterized by low power loads, small numbers of dispersed users, limited infrastructure and erratic service provision.

India.Nightlights presents an online platform that enables visualizations and interactive exploration of the night lights data over India. The team now wants to refine the platform, build new capabilities and generate nuanced reports to meet the myriad needs of potential country-level beneficiaries. It also wants to see how this approach could be replicated across the developing world.

The platform shows the great potential of satellite-based monitoring to radically transform rural electrification planning and assessment. Drawing on satellite-based data will sharpen program targeting in the village selection process, improve implementation assessment and allow ongoing monitoring by interested parties after projects have officially closed.

Next steps include promoting adoption of the tool and exploring where to focus future electrification efforts. The team is looking at where electrification has been successful, what other variables are related to faster electrification, and whether other development indicators can be added to the platform's dashboard. The tool could be used in poverty analysis, as the geo-referenced data can be combined with other databases, drawing more correlations between electricity access and development outcomes.

LESSONS LEARNED

The project's success rests on the importance of validation when pioneering big data approaches, and of persevering when faced with hurdles.

- ***Validate novel data approaches thoroughly***
  Rigorous validation or 'ground-truthing' is imperative to establish confidence in novel data sources and new methods. Because the team was able to demonstrate in its earlier work in Senegal, Mali and Vietnam the strong correlation between light outputs captured in satellite imagery and electricity supply on the ground, the project generated confidence in its approach.
- ***Take the long view***
  Perseverance is essential. The overall process took five years to reach the stage of publicly launching the web platform. The team had to overcome several hurdles in the process, in particular, data availability and processing requirements to ensure quality data.
- ***Partnerships are crucial for success***
  Working with other organizations brings valuable insight from new perspectives, and can generate solutions from unexpected quarters. In Vietnam, for example, the agency that ran the survey also provided access to electricity consumption data not publicly available. For the visualization platform, the team ran a competition to select the website developer, having benefited from free technical assistance from the GIS mapping software company and contributions from other World Bank global practices to formulate the terms of reference.

www.india.nightlights.io