CARTE-Enbridge Bootcamp

AI and Renewable Energy

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
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Predicting Capacity Levels

- With a growing proportion of energy coming from renewable sources, base generation from sources like coal has declined
- This leads to a loss of grid inertia, increasing risk of blackouts and instability
- Using AI to predict capacity levels ensures grid stability even with reduced inertia

Predicting Capacity Levels: SunShot

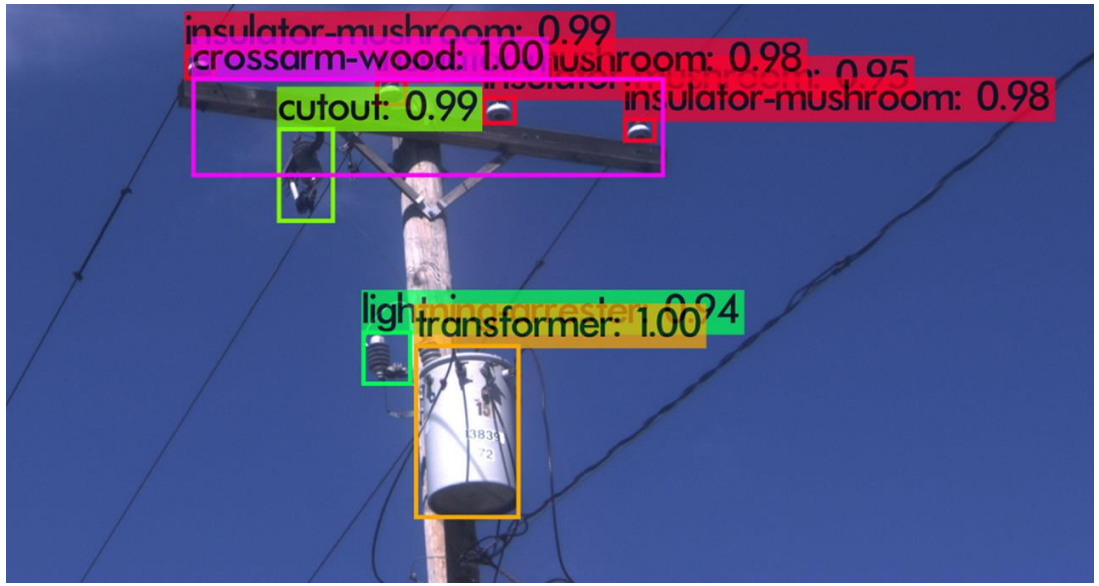
- Major initiative from the US Department of Energy, aiming to reduce the total costs of solar energy
- IBM developed a sophisticated model for predicting capacity
- Previously, sources like solar and wind have depended on individual weather models, that offer a narrow understanding of variables affecting energy availability
- IBM's approach combines self-learning weather models, historical data, real-time measurements and cloud information
- Result: 30% improvement in forecasting accuracy

Predicting Demand

- Not only is it essential to predict energy availability, but also demand
- Increasing installation of smart meters has enabled access to a wealth of demand data
- AI systems can predict a building's thermal energy demand to produce heating and cooling at the correct times
- Home battery storage can intelligently draw energy at optimal times, balancing load from the main grid

Grid Infrastructure Maintenance

- FirstEnergy Corp serves 6 million customers in the US
- Responsible for maintenance of 269,000 miles of distribution lines
- Standard approach: send out workers to manually inspect a fraction of the infrastructure
- Entire network is surveyed over 10 years!



Grid Infrastructure Maintenance

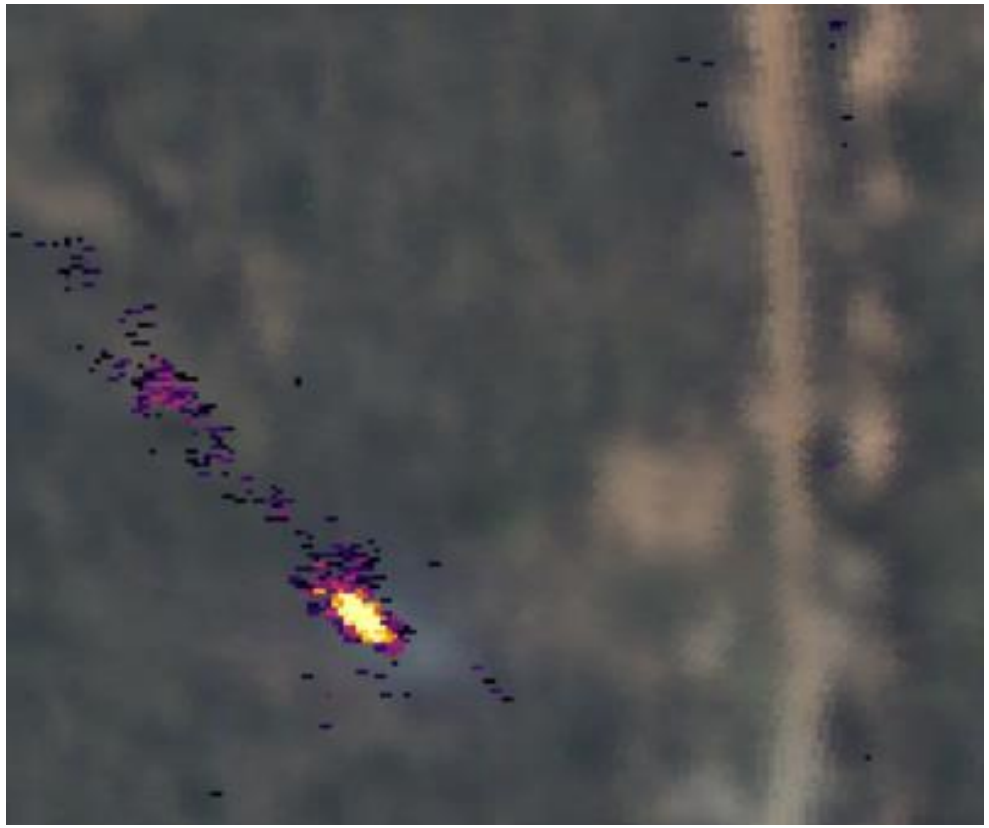
- Solution: Fit existing trucks with smart cameras
- In 30 days, two trucks collected over 5,000 images
- By capturing data on infrastructure automatically, time to survey the entire network drops drastically

Pipeline Leaks

- Hydrocarbon and gas leaks represent a major challenge for the energy sector
- Leaks are costly, challenging to detect, and harmful to the environment
- 6,000 US pipeline incidents from 2002-2021 resulted in over $11bn in damages!
- Often, pilots fly small aircrafts and try to spot leaks by eye

Pipeline Leaks

- Orbital Sidekick is a startup developing technology to spot leaks from space
- The company operates a constellation of satellites that collect hyperspectral imagery
- Using AI, chemical leaks can be detected quickly, with global coverage
- So far, the platform has detected nearly 100 methane leaks and 200 liquid hydrocarbon leaks



Google Maps: Eco-Friendly Routing

- Google Maps is responsible for one billion active monthly users
- They realized that even a minor reduction in emissions per-car would result in a massive reduction at the scale of their customer base
- Google collaborated with the US government's National Energy Renewable Laboratory

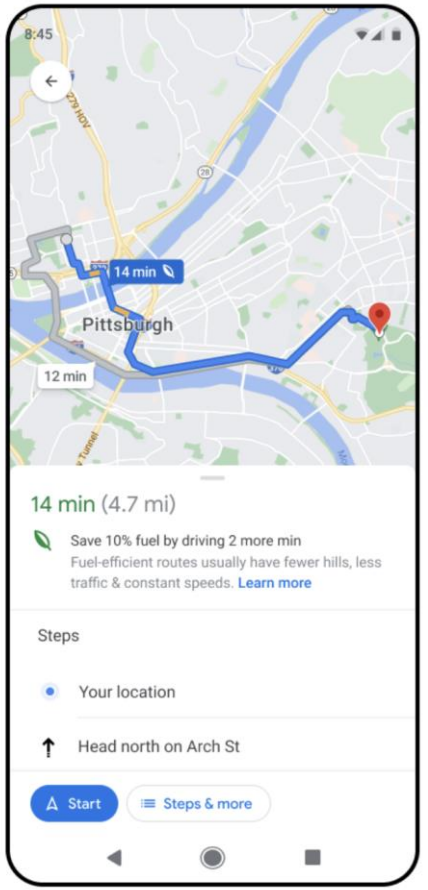
Google Maps: Eco-Friendly Routing

Step 1

Simulate vehicle fuel efficiency across vehicle powertrains

Google Maps: Eco-Friendly Routing

- Eco-friendly routing is widely available in Google Maps today
- Typically reduces fuel usage without dramatically changing travel times
- Google estimates that this technology has the equivalent effect of removing 200,000 cars from the road



Apple Clean Energy Charging

- iPhones make up 55% of the smartphone market share in the US
- Equivalent to ~125 million users
- Most people charge their phones overnight, and don’t need full charge until the morning
- Apple realized: why not wait to charge when renewable energy is at its peak?

Apple Clean Energy Charging

- In the US, iPhones now receive a forecast of carbon emissions in the local area
- This is used to charge during times of cleaner energy production
- Incremental effect per phone, but real impact at the country scale

Climate Impact of Large Language Models

- With the rapid growth in scale of deep learning models, researchers are increasingly concerned about the climate impact of training LLMs
- Estimating the climate costs of training a deep learning model is a difficult task
- Energy demands are only one factor – ChatGPT consumes 500ml of water for every 5 to 50 prompts

Case Study: HuggingFace BLOOM

Embodied Emissions

- Emissions linked to the production of computing equipment for ML models.
- Comparable equipment has a footprint of ~2500 kg CO2eq, excluding GPU emissions estimated at 150 kg CO2eq.
- With a 6-year replacement rate and 85% usage, the embodied carbon footprint is 0.056 kg CO2eq/hour for server time and 0.003 kg CO2eq/hour for GPU time.
- Training totaled 1.08 million hours using 384 GPUs across 48 nodes,
- Result: 7.57 tonnes for servers, 3.64 tonnes for GPUs, and a combined 11.2 tonnes CO2eq

Dynamic Power Consumption

- Refers to CO2 emissions from electricity used in model training.
- Calculated by multiplying GPU hours, GPU thermal design power, and the carbon intensity of the energy grid.
- Utilized 1.08 million GPU hours on Nvidia A100 GPUs, equates to 433,195 kWh of electricity during training.
- Using a carbon intensity of 57 gCO2eq/kWh for the energy grid, the total emissions from dynamic energy consumption amounted to 24.69 tonnes of CO2eq.

Idle Power Consumption

- Beyond the energy used to power GPUs, the broader also consumes significant energy, termed as idle consumption
- Experiments showed power consumption of 27 kWh in Infrastructure mode, 64 kWh in Idle mode, and over 109 kWh during BLOOM training.
- Only 54% of this consumption is due to running the code, with the remaining 46% for maintaining computing nodes.
- This results in an additional 14.6 tonnes of CO2eq to BLOOM's carbon footprint.

Case Study: HuggingFace BLOOM

50.5 Tonnes

Mitigations

- Train less often
  - Since training represents a major component of lifetime emissions, training less often is an easy way to reduce total impact
- Train for shorter times
  - Ending training as soon as possible (e.g. using early stopping) reduces the risk of wasted energy consumption
- Choose regions carefully
  - Training a model here in Ontario represents a lower impact than Iowa, for example

Challenges of applying AI to energy

- **AI in Renewable Energy**: Offers transformative potential but comes with challenges.
- **Cybersecurity Concerns**: Over-reliance on AI may expose energy networks to cyber threats.
- **Ukraine 2015 Incident**: Hackers disabled 30 substations, impacting 230,000 people for six hours due to a successful phishing campaign.
- **Firewall Vulnerabilities**: Recent attacks exploit firewall firmware weaknesses. In 2019, a US grid faced communication outages due to external party rebooting firewalls, lasting 10 hours in total.

Challenges of applying AI to energy

- Operational technology systems are isolated from IT systems, making large-scale attacks less probable.
- These systems are customized and less familiar, posing challenges for potential hackers.
- Hackers would need to understand unique equipment and setups; manipulating physical processes demands expertise and extended effort.
- Most grid-penetration incidents likely to be limited to spear phishing.