Working With Unstructured Data: Using Machine Learning for Improved Efficiency Analysis

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Today’s Remote Analytics: Simulation-based

User Inputs
- Floors, footprint, orientation
- Envelope
- Windows
- Lighting
- Mechanical
- Utilities info
Today’s Remote Analytics: Continuous, Data-driven

Data Sources
- Utility Bills
- Interval Meters
- Weather Stations
- Building Automation System (BAS)
- IoT Devices
- Distributed Energy Resources

Data Warehouse

EMIS Capabilities
- Monthly Data Analytics
- Energy Information System
  - Interval Meter Data Analytics
  - Advanced M&V (Measurement and Verification)
- Fault Detection and Diagnostics
- Automated System Optimization
Remote ID of Capital and Operational Measures

Operational insights

• HVAC scheduling
• Space temperature setpoints
• Economizer use
• Reset strategies
• Under/over ventilation

‘New normal’ relevance

• Ventilation, outside air intake
• Pre/post occupancy flush
• Disabling demand controlled ventilation
• Low occupancy turn-down, setbacks
Continuous Analytics Enable Deep, Cost Effective Savings

Largest Dataset Documents the Costs and Benefits of EMIS

**104** ORGANIZATIONS

**6,500** BUILDINGS

**567** MILLION SQUARE FEET

EMIS SOFTWARE REPRESENTING **40** DIFFERENT EMIS VENDORS HAVE BEEN INSTALLED

ANNUAL ENERGY SAVINGS FOR ORGANIZATIONS WITH EMIS:

- **3%** EIS
- **9%** FDD

$3 million

$95 million

ANNUAL SAVINGS for the median portfolio (15 million sq ft)

PROJECTED ANNUAL SAVINGS for all organizations

FIRST-YEAR INSTALLATION AND SOFTWARE COSTS:

- **EIS** $0.02/sq ft
- **FDD** $0.08/sq ft

INVESTMENT PAYBACK:

**2 years**

1 2
Advancing the State of the Art
Partners

ADVISORY

PERFORMERS

nyserda

BERKELEY LAB

Signetron

TRC

Results you can rely on
Opportunity

- Recent advances in public data availability (disclosures and permit data), sensor technology, and falling costs

- Increasing number of data collectors for buildings

- These novel data + feature extraction hold promise to ID
  - Building characteristics and assets
  - Building-specific EE measures
Types of Data

Features Extraction Tools:
- Machine Learning
- Image processing
- Energy Analytics
- Natural Language Processing

Types of Data
- STREET VIEW
- RGB & THERMAL IMAGES
- AERIAL / SATELLITE IMAGES
- LIDAR

DATA FUSION

BUILDING CHARACTERISTICS
EFFICIENCY OPPORTUNITIES

PUBLIC DATA
METER DATA
WEATHER DATA
Drone-based Thermal and RBG Images

• Inexpensive camera and drone hardware

• Advances in photogrammetry software, machine learning, computer vision

• Adapted to
  - Auto-generate 3D geometry
  - Extract exterior features (e.g., windows, PV, packaged units)
  - Identify thermal anomalies
Drone-based Generation of 3D Geometry, RGB Images

Planned flights
Drone-based Generation of 3D Geometry, RGB Images

Planned flights

Position of the drone during the data capture

Collected imagery (2D)
Drone-based Generation of 3D Geometry, RGB Images

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3D Reconstruction (Photogrammetry)
Drone-based Generation of 3D Geometry, RGB Images

- Planned flights
- Position of the drone during the data capture
- Collected imagery (2D)
- Estimated building footprint
- Estimated building heights
- 3D Reconstruction (Photogrammetry)
Drone-based Generation of 3D Geometry, RGB Images

Planned flights

Position of the drone during the data capture

Collected imagery (2D)

Building 3-D model (GeoJSON format)

Estimated building footprint

3D Reconstruction (Photogrammetry)

Estimated building heights
Medium size building: ~2 hours to acquire images, ~1 day to process data (photogrammetry) and generate GeoJSON 3D model

Window-to-Wall Ratio Estimation

**Windows deep learning semantic segmentation**

Drone collected RGB images

**Neural Network Architecture:**
DeepLab V3+

Predict windows masks from RGB drone images using a trained DeeplabV3+* model

* Chen et al., 2018. Encoder-decoder with atrous separable convolution for semantic image segmentation. In *Proceedings of the European conference on computer vision (ECCV)* (pp. 801-818).
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**Façades detection in the drone RGB images**

3D building model

Projected façades (and roofs) onto the RGB images

Project the façades corners from the extracted 3D model onto the RGB images using photogrammetry metadata, matching each 2D pixel to 3D pixel
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Estimate windows-to-wall ratio

- Compute Window-to-Wall ratio
- Project Window into 3D
- Delaunay triangulation to position window points relative to façade corners
- Using windows mask and projected facades detect windows on each façade
Thermal Imaging and Anomaly Detection

Data capture → 2D imagery (RGB and Thermal) → 3D Reconstruction using Photogrammetry (Visual and Thermal) → 3D building model

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Thermal imaging and anomaly detection workflow

Superpose anomalous regions onto thermal image

Extract contours of detected anomalies - kmeans clustering, morphological ops

Extract building’s pixels from 2D thermal image

Project 3D model onto 2D thermal image
Additional Work

- Satellite/aerial images for building footprint extraction
  - Fusion w LIDAR for 3D geometries without drones
- Field testing with EE program implementer to assess value of new information obtained
- Open source release of code, training data sets to enable adoption, further extensions

https://github.com/LBNL-ETA/AutoBFE
Takeaways

• Remote analytics technologies are available and enabling cost effective savings today
  – Capital and operational, benefits under normal and ”new normal” conditions

• New data sources, extraction and fusion techniques hold promise to further advance technology capabilities

• Additional benefits beyond EEM ID
  – Outdoor asset identification, classification
  – Site and track distributed energy resources
  – Plan the hardscape: vegetation ratio, cool surfaces, water bodies
  – Inventory localized building typologies for program planning, targeting
Thank you

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