ORNL projects related to the Urban Dynamics Institute (UDI) and Automatic Building Energy Model creation (AutoBEM)

Smart Cities Week
Workshop in collaboration with:
Argonne National Laboratory
Lawrence Berkeley National Laboratory
National Renewable Energy Laboratory
Oak Ridge National Laboratory

Presented by:
Joshua New, Ph.D., C.E.M.
BTRIC, Software Tools & Models
Oak Ridge National Laboratory

October 3-5, 2017
Energy-Water Nexus

Maximize the efficiency, sustainability and resiliency of interconnected energy and water systems in the planning, development, and operation of urban infrastructures.

Changes 2012 to 2050

CFSR–WRF Flood Simulation
CCSM4–WRF Flood Simulation
Population and Land Use

Provide insights into the evolving **sociodemographic patterns** of human activity that respond to and transform **urban landscapes** and systems at **varying spatial and temporal scales**.

**Morphology 1: Proposed (mixed use)**

**Morphology 2: High Building Density**
Sustainable Mobility

Improve transportation **sustainability, safety, and accessibility** through enhanced understanding of the **energy and environmental implications** of emerging transportation systems and their interdependencies with other critical infrastructures.

DOE SMART Mobility Consortium

Multi-modal
Connectivity & Automation
Vehicles & Infrastructure
Urban Science
Mobility Decision Science
Enhance cities understanding of the **risks, challenges, and opportunities** of the integrated framework of population, energy, water, transportation, and policy **under changing environmental conditions**.

**Urban Resiliency**

Downscaled and analyzed 10 CMIPS global climate models with RCP8.5 scenario at 4km and 1km resolution for 1965-2005 and 2010-2050.

+2.14°F in daily Tmax
+2.51°F in daily Tmin
+0.88 in. in precipitation
UrbanSense
Real-time Urban Activity Monitoring Using Pervasive Sensor Networks

PlanetSense – web-based, API-accessible, subscription service for real and virtual sensors

Population Distribution  Water Quality  Air Quality  Temp., Humidity  Pollutants
Vibration  POI Popularity  Bi-directional Traffic Flow  Simulation and Modeling  Social Media
From Visual Analytics and Simulations To Actualized Energy Savings in the Marketplace

**DOE: Office of Science**

Engine (AtticSim/DOE-2) debugged using HPC Science assets enabling visual analytics on $3 \times 10^6$ simulations

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**CEC & DOE EERE: BTO**

Roof Savings Calculator (RSC) web site/service developed (estimates energy and cost savings from roof and attic technologies)

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**Industry & Building Owners**

CentiMark, the largest nation-wide roofing contractor (installs 2500 roofs/mo), and Carlisle integrating RSC into their proposal generating system

20+ companies interested

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Leveraging HPC & Vis resources to facilitate deployment of building energy efficiency technologies
Automatic Building Energy Model Creation (AutoBEM) Acknowledgements

• U.S. Department of Energy
• National Nuclear Security Administration
• Oak Ridge National Laboratory
• Building Technologies Office
• Office of Electricity
Model America 2020 – calibrated BEM for every U.S. building
Database and image sources for urban model generation

- Satellite and airborne imagery
- Cartographic data
- Ground level images
- Elevation data
- Building information databases
- 3D building model databases

<table>
<thead>
<tr>
<th><strong>Summary</strong></th>
<th>Satellite imagery, including panchromatic and multispectral images</th>
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</thead>
<tbody>
<tr>
<td><strong>Data type</strong></td>
<td>Image</td>
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<tr>
<td><strong>Company</strong></td>
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<tr>
<td><strong>Website</strong></td>
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<tr>
<td><strong>Temporal resolution</strong></td>
<td>Cities - 3-11 times per week</td>
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<td><strong>Spatial resolution</strong></td>
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<td><strong>Measure accuracy</strong></td>
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<td><strong>Cost</strong></td>
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<td><strong>Format</strong></td>
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<tr>
<td><strong>Mapping to building input variables</strong></td>
<td>Building footprints</td>
</tr>
<tr>
<td><strong>Mapping to area properties</strong></td>
<td>Vegetated areas, road surface, buildings, parking lots</td>
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<tr>
<td><strong>Mapping to material properties</strong></td>
<td>Road pavement materials (e.g., concrete, asphalt), parking lots (e.g., gravel, soil)</td>
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<tr>
<td><strong>Coverage of US</strong></td>
<td>Over 10 million km² of coverage of the contiguous US</td>
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<tr>
<td><strong>Orientation</strong></td>
<td>Aerial</td>
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<td><strong>Existing internal software</strong></td>
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<td><strong>Existing expertise</strong></td>
<td>Remote sensing data analysis tool</td>
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<td><strong>Comments</strong></td>
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</table>
Manual Segmentation of DC
Automatic Road Extraction
Automatic Building Footprint Extraction

Algorithm: Deep Learning extended and using GPUs for fast building footprint and area extraction over large geographical areas.

Multi-company Competition Precision/Recall – 30/35; Current Precision/Recall – 60+/60+
Automatic Building Footprint Extraction

Portland, OR (25,393 m²)
Imagery: June – July 2012
Lidar: September 2010

Frankfort, KY (14,801 m²)
Imagery: June 2012
Lidar: June 2011

Part of Knox County, TN (18,527 m²)
Imagery: June 2012
Lidar: October 2014

- 220,005 NAIP images
- 1 meter multispectral
- 2012-2014
- 5.8 TB compressed
- 9.8 trillion pixels
Processing Street-Level Imagery

3D Building Model Generation
Titan is the world’s fastest buildings energy model (BEM) simulator

>500k building simulations in <1 hour

130M US buildings could be simulated in 2 weeks

8M simulations of DOE prototypes (270 TB)

<table>
<thead>
<tr>
<th>CPU Cores</th>
<th>Wall-clock Time (mm:ss)</th>
<th>Data Size</th>
<th>EnergyPlus Simulations</th>
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Oak Ridge National Laboratory (interactive)
The University of Tennessee (2 days)
Utility Use Cases for Virtual EPB

• Peak Rate Structure - model peak segment customers in aggregate as disproportionate contributors to electric utilities’ wholesale demand charges for more equitable rate structures.

• Demand Side Management – identify DSM products and grid services for better distribution grid management that allow both utilities and rate-payers to share in peak reduction

• Grid stability services – quantify improved load models

• Emissions – accurately account for emissions contributed by each building, providing enhanced abilities for utilities to best comply with national emission policies.

• Energy Efficiency – accurate modeling/forecasting of every building energy profile virtually in a scalable fashion allows better follow-up and more targeted energy audits/retrofits.

• Customer Education - better understand building’s energy usage as a function of weather to provide better information during customer billing enquiries.
Chattanooga, TN (135,000+ buildings)

Next Step:
Compare to electrical data

Extract Geometry
Create Building Models
Simulate Buildings
Analyze Building Data
Interactive Visualization
Resources

• Toolbox for Urban Mobility Simulations (TUMS) - tums.ornl.gov
• City-scale sensing and visual analytics (PlanetSENSE) - planetsense.ornl.gov
• Adaptation Tool, stormwater management (UrbanCAT) - urbancat.extranet.ornl.gov/
• Roof Savings Calculator (RSC) - roofcalc.com
• World’s fastest buildings simulator, Titan supercomputer (AutoSIM):
  • https://www.olcf.ornl.gov/support/getting-started/olcf-director-discretion-project-application/
• Automatic Building Energy Models (AutoBEM)
  • The University of Tennessee: bit.ly/ut_buildings
  • Chattanooga, TN: bit.ly/epb_buildings
• Contact: Dr. Joshua New (newjr@ornl.gov)
Discussion

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HPC Tools for Modeling and Simulation
Capturing building energy consumption