Get More From Your Data with Data Analytics
What do we have to work with?
Buildings have thermodynamic properties

\[
\frac{\partial u}{\partial t} - \alpha \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right) = 0
\]
Temperatures change

![Graph showing temperature changes from January 2013 to January 2014.](image-url)
Electricity demand varies
Humans have comfort bounds
\[ \frac{\partial u}{\partial t} - \alpha \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right) = 0 \]
BuildingIQ Develops Proactive Algorithms for HVAC Energy Optimization in Large-Scale Buildings

Office buildings, hospitals, and other large-scale commercial buildings account for about 30% of the energy consumed worldwide. The heating, ventilation, and air-conditioning (HVAC) systems in these buildings are often inefficient because they do not take into account changing weather patterns, variable energy costs, or the building's thermal properties.

BuildingIQ has developed Predictive Energy Optimization™ (PEO), a cloud-based software platform that reduces HVAC energy consumption by 10–25% during normal operation. PEO was developed in cooperation with the Commonwealth Scientific and Industrial Research Organisation (CSIRO), HVAC pressure sensors, as well as weather and energy cost data. A single building often produces billions of data points, and the scientists and engineers needed tools for efficiently filtering, processing, and visualizing this data.

To run their optimization algorithms, the scientists and engineers had to create an accurate mathematical model of a building's thermal and power dynamics. The algorithms would use this calculated model to run constrained optimizations that maintained occupant comfort while minimizing energy costs.

BuildingIQ needed a way to rapidly develop mathematical models, test optimization algorithms, and fine-tune the PEO platform.
Traits of Data Analytics applications

- Diverse and/or Big Data
- Advanced Algorithms
- Deployment
Why MATLAB?

1. Analytics that increasingly require both business and engineering data

2. Enable Domain Experts to be Data Scientists

3. Develop embedded systems with analytics powered functionality

4. Develop analytics to run on both enterprise and embedded platforms

DATA
• Engineering, Scientific, and Field
• Business and Transactional

Embedded Systems

Business Systems
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1. Smarter Embedded Systems
   - Develop embedded systems with analytics powered functionality

2. Enable Domain Experts to be Data Scientists

3. Business Systems
   - Develop analytics to run on both enterprise and embedded platforms

4. DATA
   - Engineering, Scientific, and Field
   - Business and Transactional
“No matter what industry our client is in, and no matter what data they ask us to analyze—text, audio, images, or video—MATLAB enables us to provide clear results faster.”

Dr. G Subrahmanya VRK Rao, Cognizant
Accessing Data
Preprocessing Data

Read in engine data
The data used is the sensor readings taken off of the equipment. Maintenance was done after 125 cycles of use, regardless of whether the equipment seemed to need it or not, so we only have the first 125 cycles of each engine. Our maintenance staff tells us that while some of them were in need of maintenance, many were fine and could have run longer before being serviced. So far no failures have occurred prior to maintenance.

```matlab
sensorData = readtable('train_FD001_Unit_1.csv','ReadVariableNames',true);
```

Select relevant variable names
```matlab
variableNames = {'Unit' 'Time' 'LPCOutletTemp' 'MPCOutletTemp' ...}
```
Preprocessing for Signal and Image Processing Applications

- cheby2
- filter
- rms
- pwelch
- periodogram
- xcov
- findpeaks
- movmean
- movstd
-...

- Image display and exploration
- Image enhancement
- Image analysis
- Morphological operations
- Image registration
- Geometric transformation
- ROI-based processing
# Feature Engineering – Extracting Information from Data

<table>
<thead>
<tr>
<th>Data type</th>
<th>Common Techniques for Deriving Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor data</td>
<td>• Peak analysis</td>
</tr>
<tr>
<td></td>
<td>• Pulse and transition metrics</td>
</tr>
<tr>
<td></td>
<td>• Spectral measurements (power, bandwidth, mean frequency, median frequency)</td>
</tr>
<tr>
<td>Image and video data</td>
<td>• Bag of visual words</td>
</tr>
<tr>
<td></td>
<td>• HOG (Histogram of Oriented Gradients)</td>
</tr>
<tr>
<td></td>
<td>• Minimum Eigenvalue algorithm</td>
</tr>
<tr>
<td></td>
<td>• Local feature descriptors</td>
</tr>
<tr>
<td></td>
<td>• Edge detection</td>
</tr>
<tr>
<td>Transactional data</td>
<td>• Decomposing timestamps into components (day, month, day of week, etc.)</td>
</tr>
<tr>
<td></td>
<td>• Calculation of aggregate values</td>
</tr>
</tbody>
</table>
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Smarter Embedded Systems

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Business Systems
MATLAB has helped accelerate our R&D and deployment with its robust numerical algorithms, extensive visualization and analytics tools, reliable optimization routines, support for object-oriented programming, and ability to run in the cloud with our production Java applications.”

Borislav Savkovic, BuildingIQ
Apps - Classification Learner app
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Smarter Embedded Systems

Data Scientist

Business Systems
Smarter Embedded Systems

**RESEARCH**

**REQUIREMENTS**

**DESIGN**
- Environment Models
- Physical Components
- Algorithms

**IMPLEMENTATION**
- C, C++
- VHDL, Verilog
- Structured Text
- MCU
- DSP
- FPGA
- ASIC
- PLC

**TEST AND VERIFICATION**

**INTEGRATION**

- Airbus
  - Battery management
- GM
  - Climate control
- Festo
  - Industrial robots
- Sonova
  - Hearing implants
- Weinmann
  - Transport ventilator
- ABB
  - Smart Grid controller
- manroland
  - Printing presses
- FLIR
  - Thermal imaging
- Daimler
  - Cruise controller
MATLAB Code Generation
C Code Generation
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Business Systems
How is the processing split?

Why don’t we transfer all the data?

- Can see self (and neighbors)
- Limited battery life
- Limited processing power
- Limited storage
- Difficult to update

- Has global view of data
- Unlimited power
- Unlimited processing resources
- Unlimited storage
- Easy to update
We don’t transfer all the data because of ...

- Data privacy concerns
- Cost of network/transfer
- Power required to transmit data from device (for wireless)
- Response time
Splitting computation
Deploying Algorithms to Enterprise Systems

**MATLAB Compiler** enables sharing MATLAB programs without integration programming

**MATLAB Compiler SDK** provides implementation and platform flexibility for software developers

**MATLAB Production Server** provides the most efficient development path for secure and scalable web and enterprise applications
Enterprise Integration – Forecasting Model
MATLAB Differentiators

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Smarter Embedded Systems
thank you!