2 Types of AI Applications Planned

- **Expert Systems** & **Machine Learning Applications**

  The difference is that expert systems (ES) are rule based systems while modern machine learning (ML) are based on statistical modeling of data.

  An **ES** uses *if-then* statements when doing inference while an **ML** is an application with the ability to automatically learn and improve given new **data** without being explicitly programmed.
Research Tools Depend on AI

**uqFEM**
- V1.0 (June 2018)
- V2.0 (2019)
- V3.0 (2020)
- V4.0 (2021)

**CWE-UQ**
- V1.0 (June 2018) Bluff Body
- V2.0 (Sept 2018) Building
- V3.0 (2019) UQ

**EE-UQ**
- V1.0 (June 2018) Uniform
- V2.0 (Sept 2018) Rock Outcrop
- V3.0 (2019) Soil Box

**PBE**
- V1.0 (Sept 2018) Earthquake
- V2.0 (2019) Wind
- V3.0 (2020) Water

**RDT**
- V1.0 (2019) Earthquake
- V2.0 (2020) Wind
- V3.0 (2021) Water
What Do We Need AI For

1. Generate SAM models (multi model) given BIM file (primary focus to date)
2. Generate BIM files given Misc. Info on Built Environment
3. Other Potential Uses: Damage & Loss estimation, Building Contents, ..

1. Generate SAM models given BIM

AI produces the SAM (structural analysis) models.

Initially the mapping between components and finite elements will be provided by a file, user will be able to modify, e.g. if a steel beam model it with N elements of type X else if concrete beam model with M elements of type Y

Ultimately will also provide some machine learning application that will use a knowledge base, KB-M, for the data.
Knowledge base contains information on observed data (experimental and actual buildings) and numerical simulations.

By comparing corresponding responses, use machine learning to provide SAM (multi model with RV for each model) given new BIM. We are collecting and populating the KB-M. Need Data to learn and test the algorithms.

We are Collecting experimental datasets:

<table>
<thead>
<tr>
<th>Dataset Name</th>
<th>Hazard</th>
<th>NDm</th>
<th>Material</th>
<th>Structural Type</th>
<th>Tool</th>
<th>Laboratory</th>
<th>FE Models</th>
<th># Models</th>
<th># Random Models</th>
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<tbody>
<tr>
<td>18-Story Steel Hi-Rise at E-Defense</td>
<td>Seismic</td>
<td>3D</td>
<td>Steel</td>
<td>Moment Frame</td>
<td>OpenSees</td>
<td>E-Defense</td>
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<td>3D</td>
<td>Steel</td>
<td>Moment Frame</td>
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<td>2D</td>
<td>RC</td>
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<td>Mac, OpenSees</td>
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<td>Large-Scale Bridge Column at OIEC</td>
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<td>3D</td>
<td>RC</td>
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<td>Large-Scale Steel Beam at USM</td>
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<td>Beam</td>
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</table>

and creating BIM, EVENT, EDP and SAM files for them
AI-M-1: Machine Learning application that will use related Experimental and Simulation Data to Generate SAM files

**Challenge:** To turn BIM and SAM files into a numerical representation on which machine learning algorithms can be turned loose.

**Current Working Approach:** Based on a component level approach to modeling:
1. From paired (BIM,SAM) files identify and model corresponding components.
2. Knowing how each component is modeled, create a model representation given BIM.
3. Generate possible SAM models for each component in the BIM.

We map each element of SAM to the corresponding component of BIM. By looking at the node coordinates of elements, we can figure out where the element is in the BIM file.
Data Representation of SAM Components

Bin location = element type or class.
Bin number = #elements in that class

0 0 0 0 2 2 2

Class 1 = ElasticBeam
Class 2 = CorotTruss
Class 3 = ForceBeamColumn
Class 4 = ZeroLength
Class 5 = DispBeamColumn
Class 6 = ForceBeamColumn

The left beam contains 4 elements.
2 DispBeamColumns and 2 ForceBeamColumns.

Stage 1: Predict element types & # elements.
Stage 2: Predict element locations.

Data Representation of BIM Components

We decompose each beam/column component into elementary shapes such as cuboids. Illustrated using rectangles in 2D, the left component is described by 12 rectangles, shown as 12 points in the 3D model space. The number of model points could vary with different BIM components, but the collection of model points can be turned into a fixed length vector representation using a set of fixed random projections.

Each cuboid in 3D is represented by its central location and its dimensions along X,Y,Z directions, in a 6D model space.
Real-world Representation and Structural Modeling

Current State

- For Moment Frame & Concrete Rectangular Shear Walls they can provide node & element discretizations for a SAM file (no section or material definition)
- Need to hook up their application with FE software so they can let their applications also gain information on how good the models they provide are.
2. Generate BIM From Misc. Data

Needed Information to Reduce the Uncertainties in RDT:
Building Heights, Structural Type, Building Contents

Needed Information for Validation of RDT:
Estimated Damage & Downtime from Events

Building Heights

177023 buildings
Height information
Learning height from satellite images?

Train application using SF data and apply that elsewhere?

QUESTIONS for Break Out

1. What building data sources should be explored?
   - Experimental Data with SAM Models?
     - Earthquake
     - Wind
     - Water
   - Misc. Data Sources
     - Building Heights
     - Structural Contents
     - Material & Lateral System

2. Other Approaches to Generating the SAM files

3. What common information gaps in modelling can be best addressed by Knowledge Bases/AI?
   - Lifelines (water, gas, elec.) & Transportation Networks
   - Other
QUESTIONS for Break Out

• User Preferences/Community Building and Information Sharing:
  • What would you hope the Knowledge Base of the SimCenter can enable that you cannot easily do yourself today?
  • Do you have data to contribute that can help grow the Knowledge base?
  • What other ways can you contribute to the AI effort?
  • What is the best way to share more information about our Knowledge Bases? (e.g. webinars, online office hours, in person workshops, video documentation, written documentation)