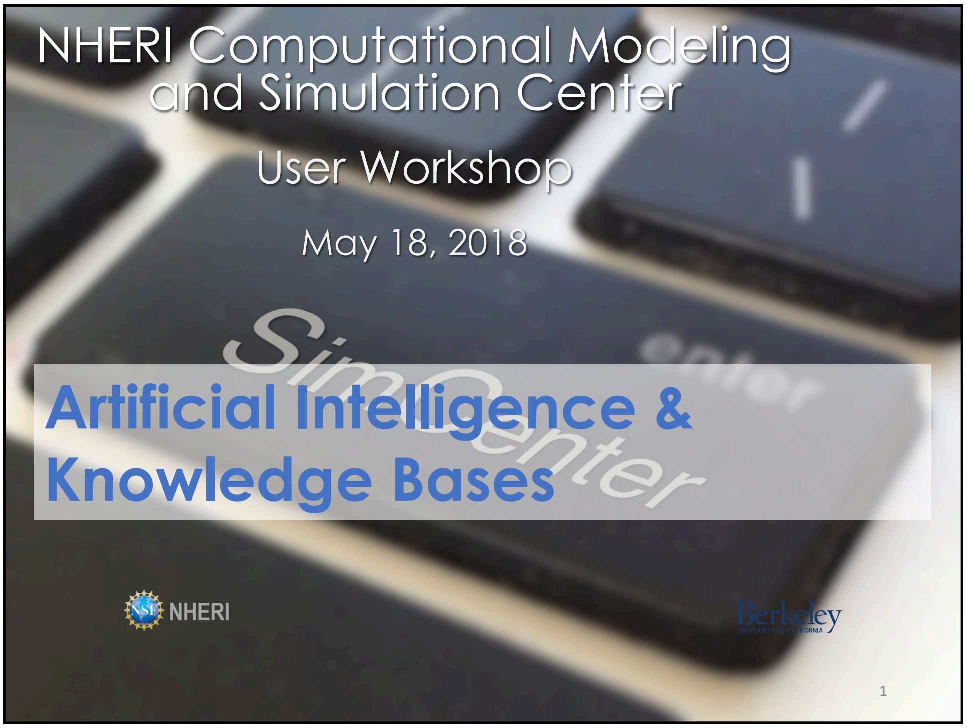


2 Types of AI Applications Planned

- **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.

WBS No.	Tool	Y1	Year 2												Y3	Y4	Y5
			Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept			
1.2.7	User Needs Workshop									+1							
1.3.2	Experimental Datasets	10			+1						+6			+2	+10	+10	+10
1.3.2	Simulation Models	802*									+25			+25	+50	+50	+50
1.3.3	Existing Building Data			+1.8M										+0.7M			
1.3.5	AI-M-1	IP													V1.0		
1.3.5	AI-M-2					V0.1		V1.0									
1.3.5	AI-M-3	V0.2			V1.0		V1.0							V1.1			
1.3.6	AI-DL-1	V0.1			V0.2		V1.0							V1.1			
1.3.6	AI-DL-2																
1.3.7	CWE-UQ		V0.1		V0.2		V1.0			V1.0				V2.0	V2.X	V3.X	
1.3.8	EE-UQ					V0.1		V0.2	V0.2		V1.0			V2.0	V2.X		
1.3.8	uqFEM				V0.1	V1.0				V1.0					V2.X		
1.3.9	PBE Tool			IP					V0.1			V0.2		V1.0	V1.X	V2.X	V3.X
1.3.10	RDT Tool														V1.X	V2.X	V3.X
1.3.11	Educational App (MDOF)	V1.0			V1.1												
1.3.11	Educational App (Pile Group)	V1.0					V2.0		V2.0								
1.3.11	Educational App (Base Isolation)				IP			V0.1			V0.2			V1.0			
1.3.11	Educational App (Wind vs. Earthquake)				IP				V0.1			V0.2		V1.0			
1.3.11	Additional Education App														+2	+2	+2
1.4.2	Large Testbed – Regional Earthquake Event			W1.0	W1.1						W1.2				W1.3	W1.4	W1.5
1.4.2	Large Testbed – Regional Wind, Storm surge, or Tsunami Event		IP											W2.1	W2.2	W2.3	W2.4
1.4.2	Large Testbed – TBD														W3.1	W3.2	W3.3

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

AI

EE-UQ

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

AI

PBE

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

AI

RDT

- V1.0 (2019) Earthquake
- V2.0 (2020) Wind
- V3.0 (2021) Water

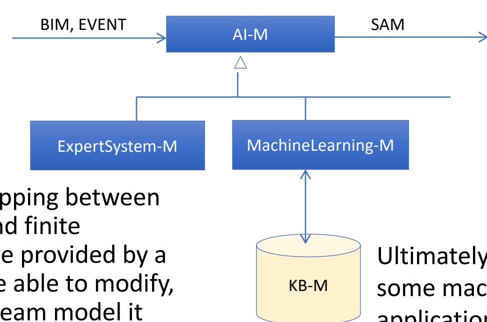
AI

What Do We Need AI For

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

1. Generate SAM models given BIM

AI produces the SAM (structural analysis) models.

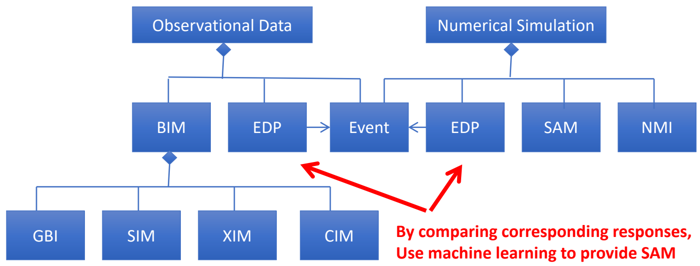


Initially the mapping between components and finite elements will be provided by a file, user will be able to modify, e.g. **if** a steel beam model it with N elements of type X **else if** concrete beam model with M elements of type Y

Ultimately will also provide some machine learning application that will use a knowledge base, KB-M, for the data.

KB-M 

Knowledge base contains information on observed data (experimental and actual buildings) and numerical simulations.

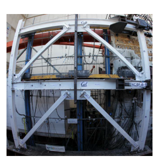


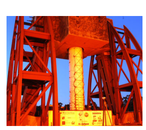
By comparing corresponding responses, Use machine learning to provide SAM (multi model with RV for each model) given new BIM. We are collecting and populating the KB-M. Need Data to learn and test the algorithms.

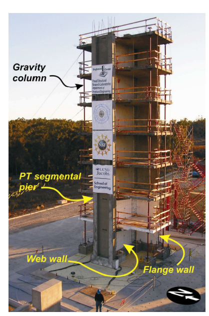
7

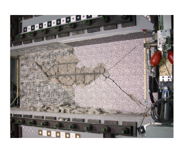
We are Collecting experimental datasets:

Dataset Name	Hazard	ndm	Material	Structural Type	Year	Laboratory	FE Models	# Models	# Random Models
18-Story Steel Hi-Rise at E-Defense	Seismic	3D	Steel	Moment Frame	2013	E-Defense	OpenSees	4	200
2-Story NCBF at UCB	Seismic	2D	Steel	Braced Frame	2012	UC Berkeley	OpenSees	3	0
7-Story RC Building at UCSD	Seismic	3D	RC	Shear Wall	2006	UC San Diego	Various	0	0
Collapse of 4-Story Steel Building at E-Defense	Seismic	3D	Steel	Moment Frame	2007	E-Defense	OpenSees	1	0
Collapse of RC Frame at Tsinghua University	Seismic	2D	RC	Moment Frame	2011	Tsinghua University	OpenSees, MSC Marc	4	200
RC Columns at Tsinghua University	Seismic	2D	RC	Moment Frame Comp.	2011	Tsinghua University	OpenSees, MSC Marc	6	200
RC Joint at Tsinghua University	Seismic	2D	RC	Moment Frame Comp.	2011	Tsinghua University	OpenSees, MSC Marc	4	0
Large-Scale Bridge Column at UCSD	Seismic	3D	RC	Inverted Pendulum	2010	UC San Diego	Various	3	200
Squat RC Shear Wall at ELSA	Seismic	2D	RC	Shear Wall Comp.	2012	ELSA, JRC Ispra	OpenSees	1	0









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

Stella Yu

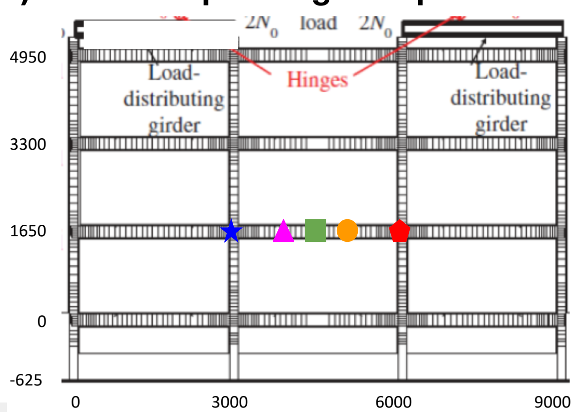
Challenge: Is to turn BIM and SAM files into a numerical representation on which machine learning algorithms can be turned loose.

Current Working Approach: based on 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

Parsing (BIM,SAM) for Corresponding Components

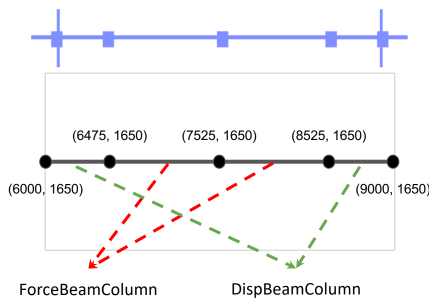
We map each element of SAM to the corresponding component of BIM. By looking at the node coordinates of elements, we can figure out **where** the element is in the BIM file.




```
"nodes": [
  {"name": "1025", "crd": [3000, 1650]},
  {"name": "1121", "crd": [4475, 1650]},
  {"name": "1122", "crd": [4525, 1650]},
  {"name": "1123", "crd": [5525, 1650]},
  {"name": "1035", "crd": [6000, 1650]},
  {"name": "2012", "crd": [0, 2350]},
  {"name": "2013", "crd": [0, 2650]},
  {"name": "2014", "crd": [0, 2950]},
  {"name": "2015", "crd": [0, 3300]},
  ......
]
```

```
"elements": [
  {"name": "1121", "type": "DispBeamColumn3d", "nodes": ["1025", "1121"]},
  {"name": "1122", "type": "DispBeamColumn3d", "nodes": ["1121", "1122"]},
  {"name": "1123", "type": "DispBeamColumn3d", "nodes": ["1122", "1123"]},
  {"name": "11230", "type": "DispBeamColumn3d", "nodes": ["1123", "1035"]},
  {"name": "2011", "type": "DispBeamColumn3d", "nodes": ["2011", "2012"]},
  {"name": "2012", "type": "DispBeamColumn3d", "nodes": ["2012", "2013"]},
  {"name": "2013", "type": "DispBeamColumn3d", "nodes": ["2013", "2014"]},
  {"name": "2014", "type": "DispBeamColumn3d", "nodes": ["2014", "2015"]},
  ......
]
```

Data Representation of SAM Components



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

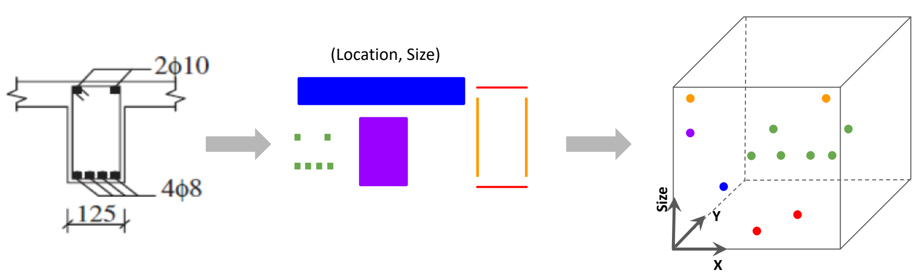
0	0	0	0	2	2	……

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.

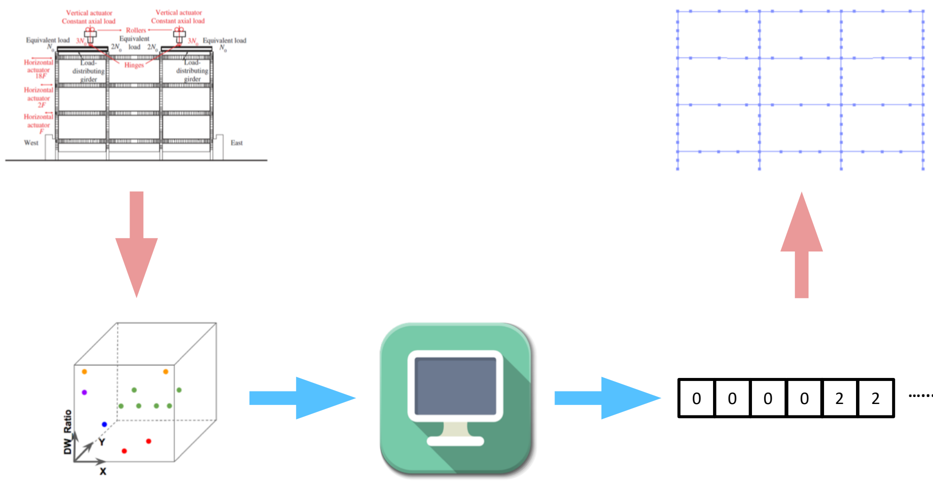
Data Representation of BIM Components



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)