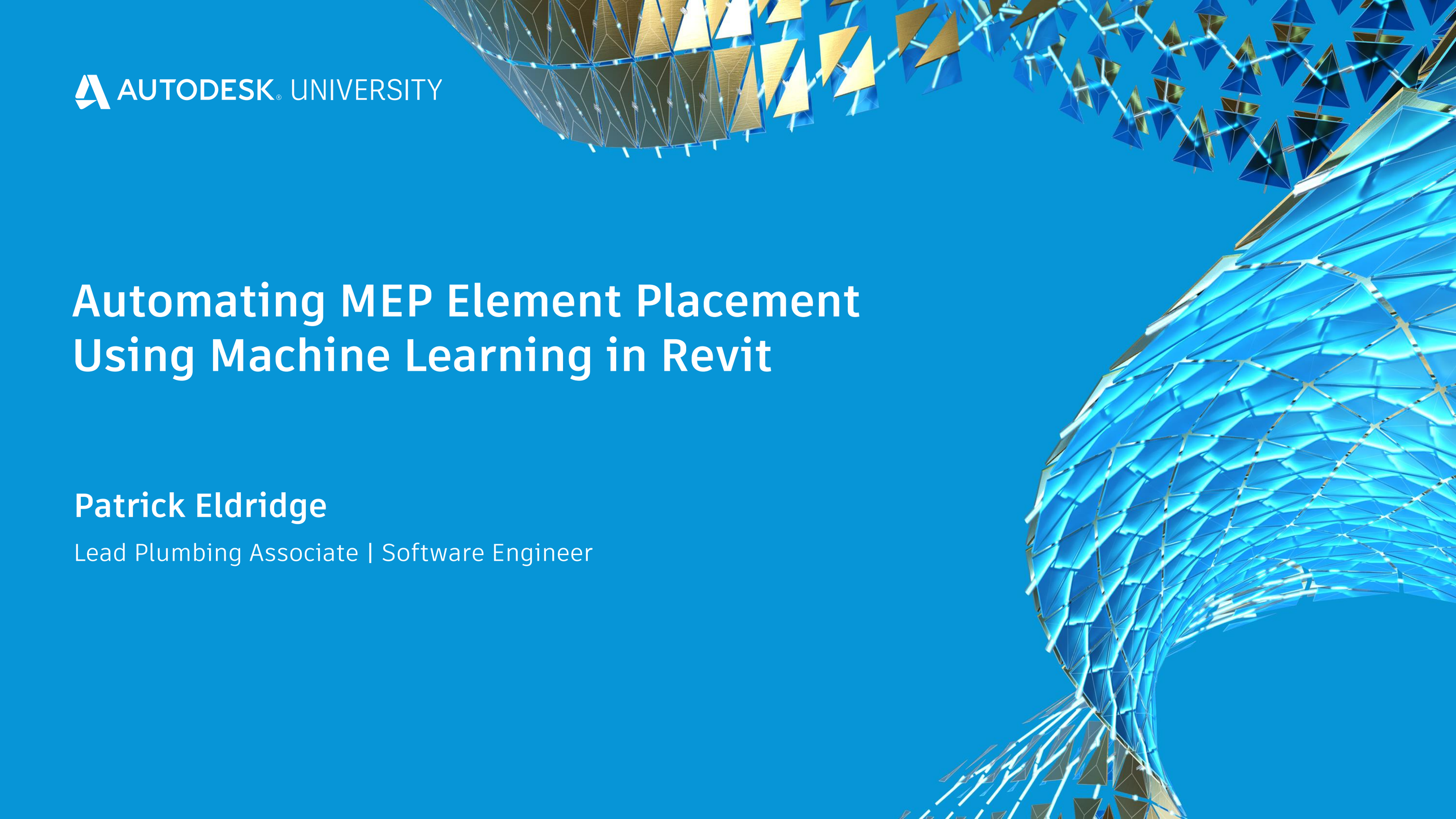
AUTODESK. UNIVERSITY

Automating MEP Element Placement Using Machine Learning in Revit

Patrick Eldridge

Lead Plumbing Associate | Software Engineer



Patrick Eldridge

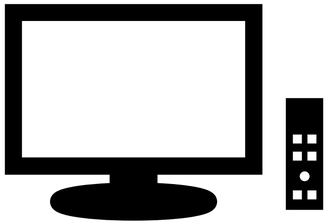
Lead Plumbing Associate | Software Engineer
KLH Engineers

Patrick Eldridge started in the AEC industry working as a co-op for a plumbing contractor during the great recession. After starting at KLH, Patrick was drawn to creating and programming tools for engineers and other members of the AEC value stream. After five years at the company, Patrick has released several tools that drive the company and our clients forward in the industry. Patrick holds a Bachelor of Science in Mechanical Engineering Technology from the University of Cincinnati. Since 2016 KLH has been on a journey to move the industry forward, including being a 100% Revit company, and having a software department to bring innovative ideas to life.

Learning Objectives

- Discover how machine learning can be used as a tool in the AEC industry.
- Learn how KLH trained a model on a small dataset of objects.
- Learn how to integrate a concrete use of machine learning into a company’s workflow.
- Learn that you don’t need super computers and a PHD to develop and deploy this technology.

Who is already using machine learning?



STREAMING SERVICES

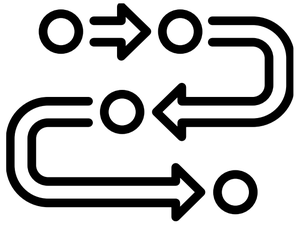
Recommendations for what to watch next, predicting how much you'll like something before you've seen it.

SOCIAL MEDIA

Automatic tagging of people in photos, which ads to show you, language translation.

HEALTHCARE

MRI analysis, drug discovery and development, treatment and prediction of disease.



LOGISTICS

Optimizing supply chains

In the AEC Industry . . .

Not as many uses . . . Yet.

- A Practical Use of Machine Learning in the AEC Industry.

Traditional Design Workflow

STEP 1

START WITH INPUT DATA

Revit files, .dwg files, survey point clouds, codes, owner req’s, etc.

STEP 2

POPULATE MODEL

Place elements in 3D, coordinate with other trades, size rooms for equipment, etc.

STEP 3

VERIFY INTENT MEETS NEEDS

Finalize service sizes and Equipment weights, final adjustments to room sizing, etc.

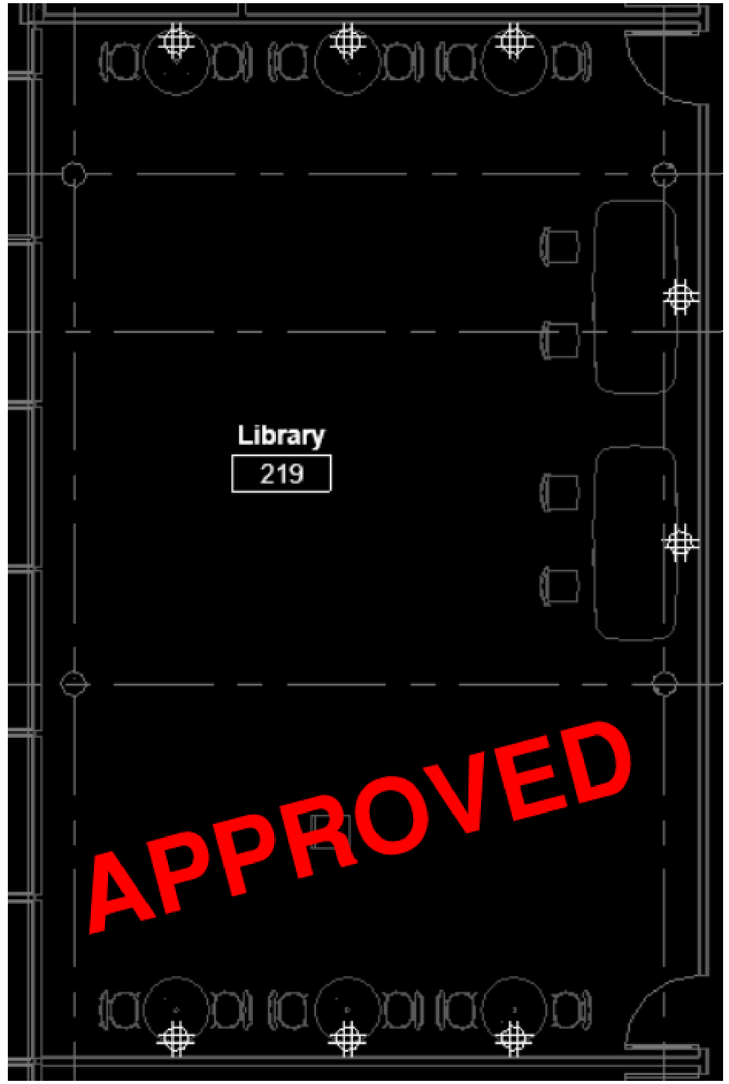
STEP 4

DELIVER DRAWINGS AND SPECIFICATIONS

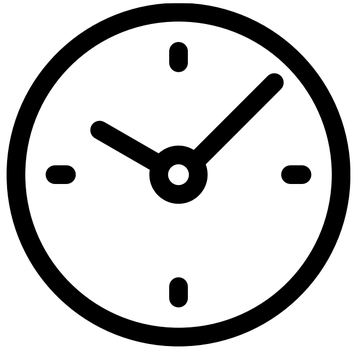
Send packages to owner/architect for use by GC’s and subcontractors.

Current Process

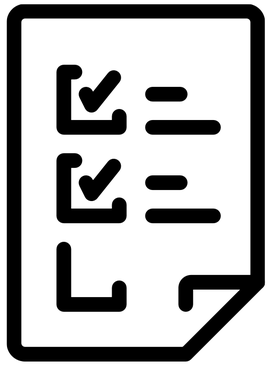
- Scan floor plans room by room.
- Place elements based on knowledge.
- Review with design team, signing engineer, etc.



Background – Why try to automate placement?



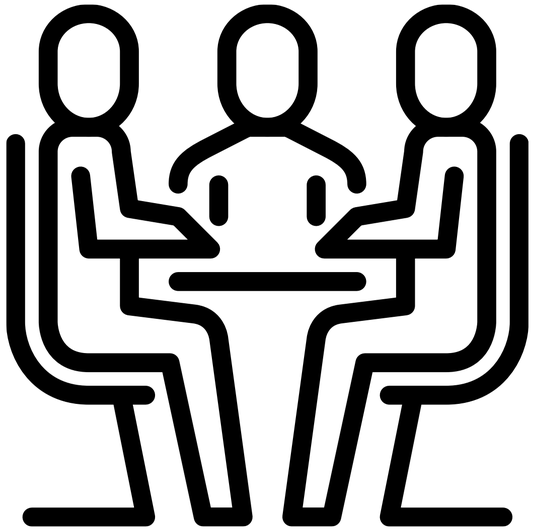
PRESERVE TIME FOR HIGHER LEVEL TASKS



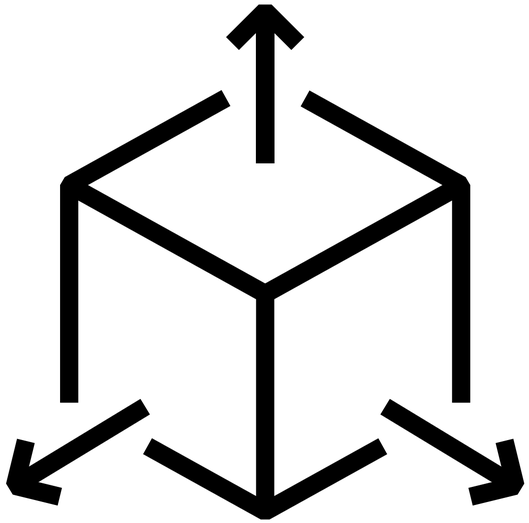
MEET CLIENT STANDARDS AND REQUIREMENTS

INCREASE CONSISTENCY

Background – Challenges to Automated Placement

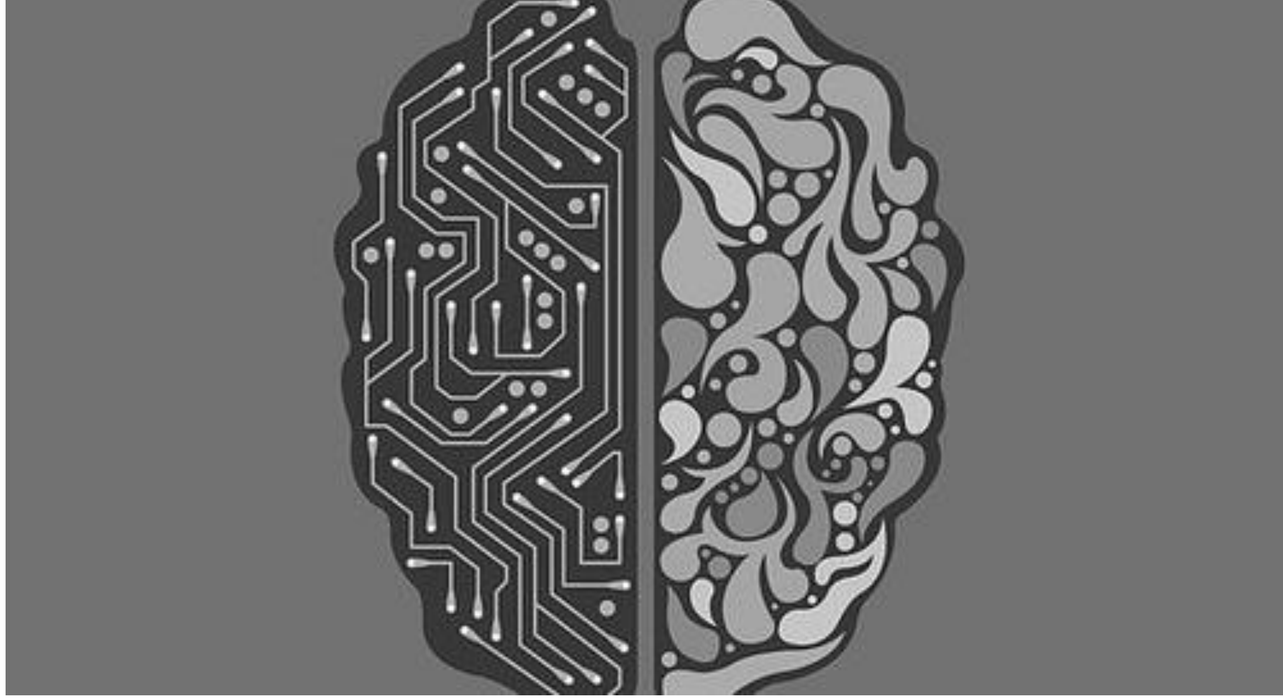


GETTING CONSISTENT BIM DATA ACROSS CLIENTS



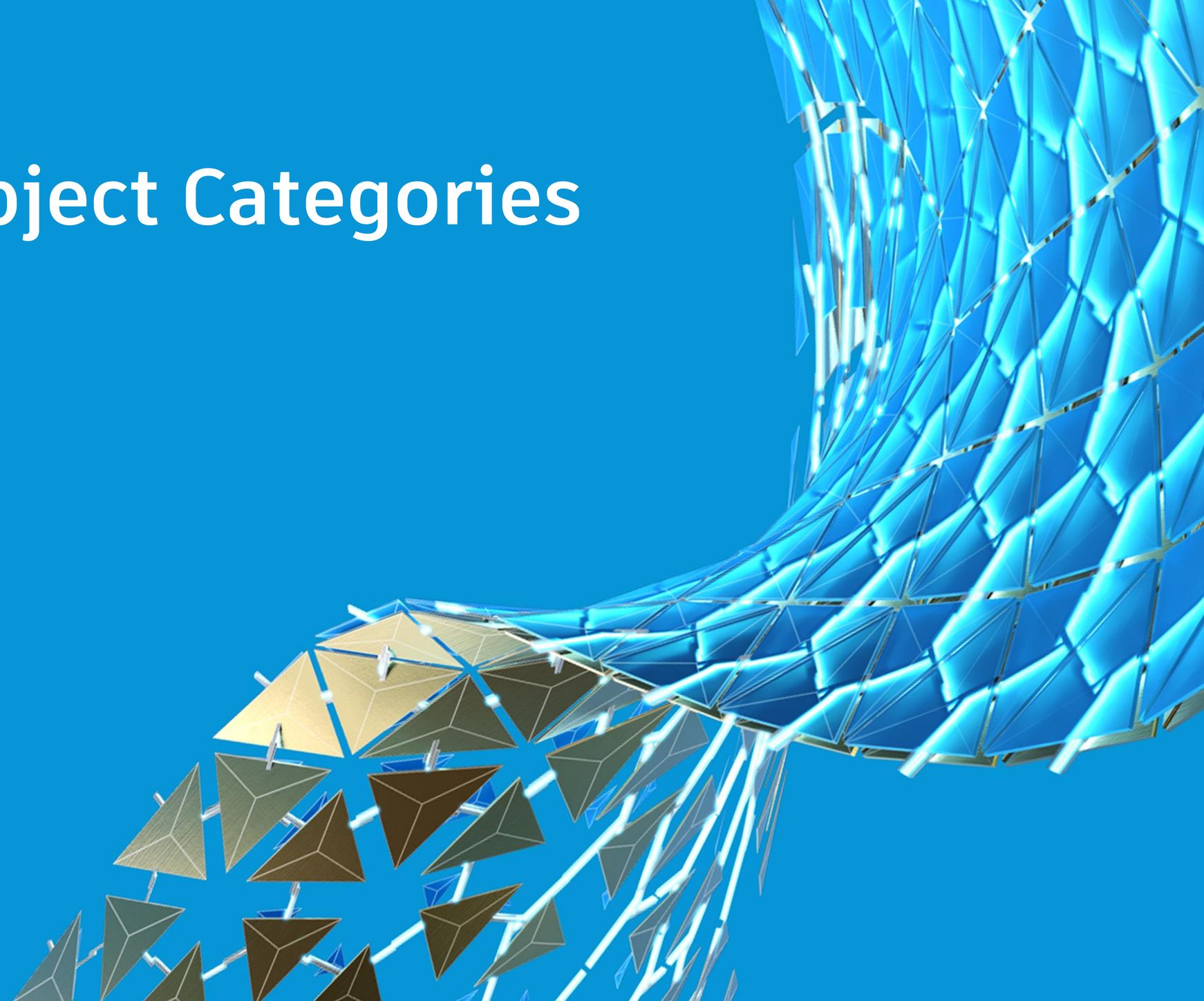
GETTING CONSISTENT BIM DATA ACROSS REVIT FAMILIES

Rules based Placement for Object Categories

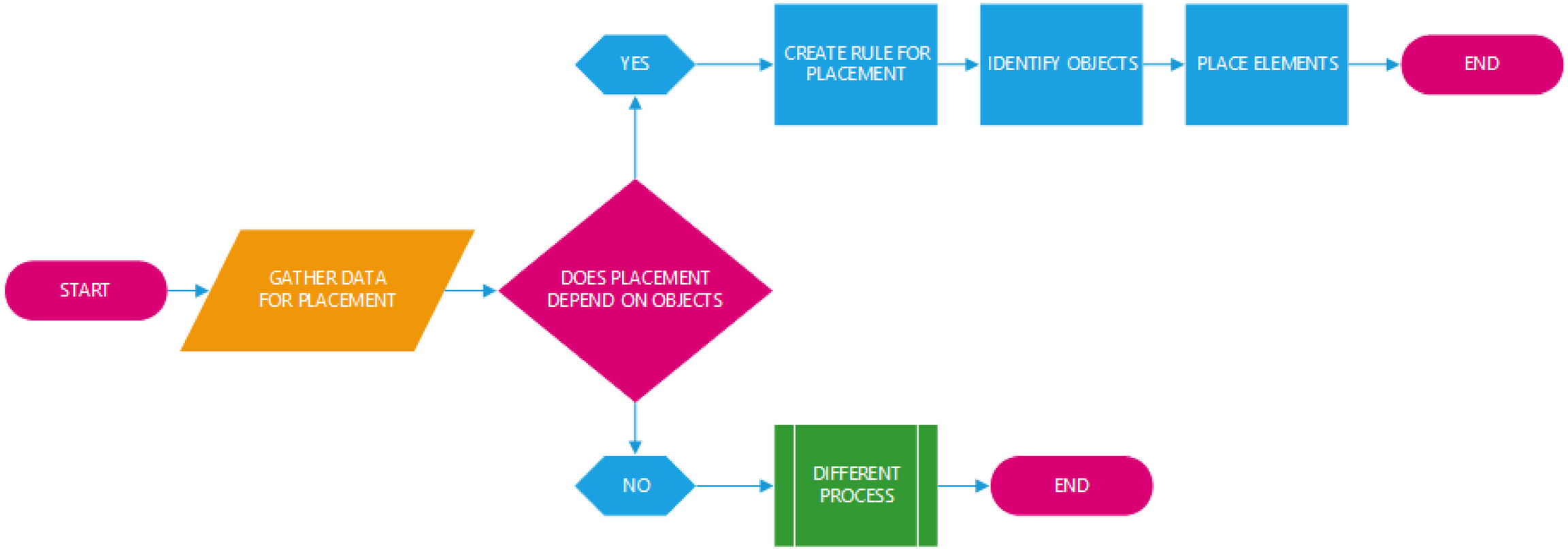


Automatic Categorization of Objects

Rules for Object Categories



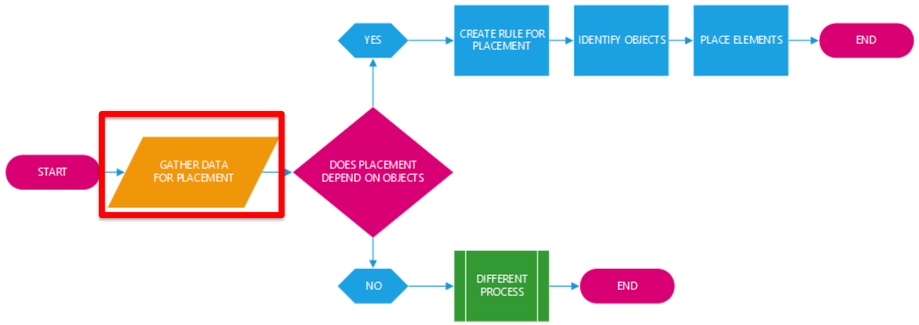
Overview


START
GATHER DATA FOR PLACEMENT
DOES PLACEMENT DEPEND ON OBJECTS
YES
CREATE RULE FOR PLACEMENT
IDENTIFY OBJECTS
PLACE ELEMENTS
END
NO
DIFFERENT PROCESS
END

Gathering Data for Element Placement

Population of MEP elements can be heavily effected by objects the architect or others have placed in the room along with building codes, and owner/tenant requirements.

- **Electrical**
  - Data drops for desks, GFCI outlets near water hazards, dedicated circuits for printers, microwaves, etc.
- **Plumbing**
  - Water connections for fixtures placed by architect
- **Mechanical**
  - Diffuser layout based on windows



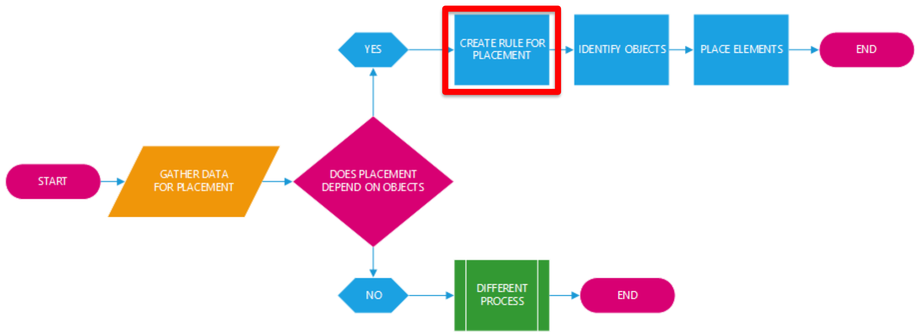
-Project Needs:

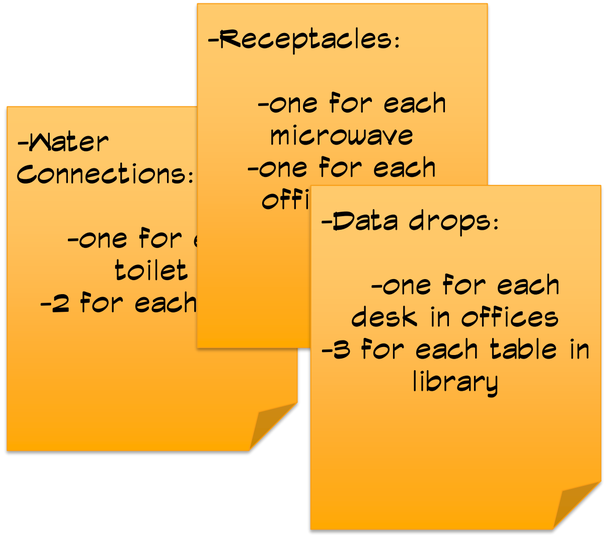
-Receptacles
-Water Connections
-Data drops
-etc.

Create Rules for Placement

For each device or fixture that needs to be placed, identify what the rules are.

- **Electrical**
  - Data drop on nearest wall center of desks. Duplex 44” AFF centered on wall behind microwave, etc.
- **Plumbing**
  - Cold water connection 8” AFF with a 4” offset from center of lavatory.
- **Mechanical**
  - Linear slot diffuser above all windows greater than 24” in width.

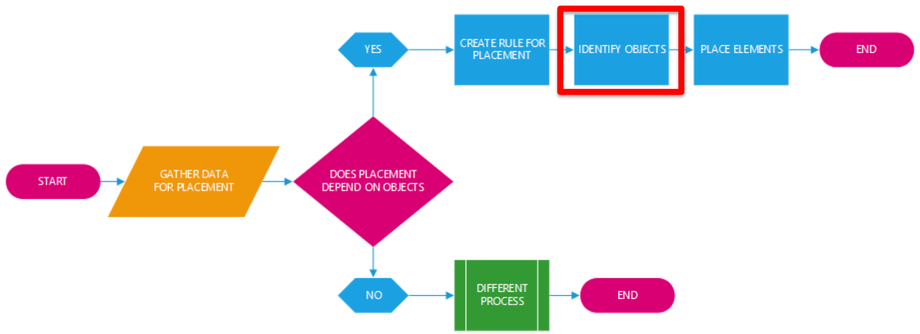


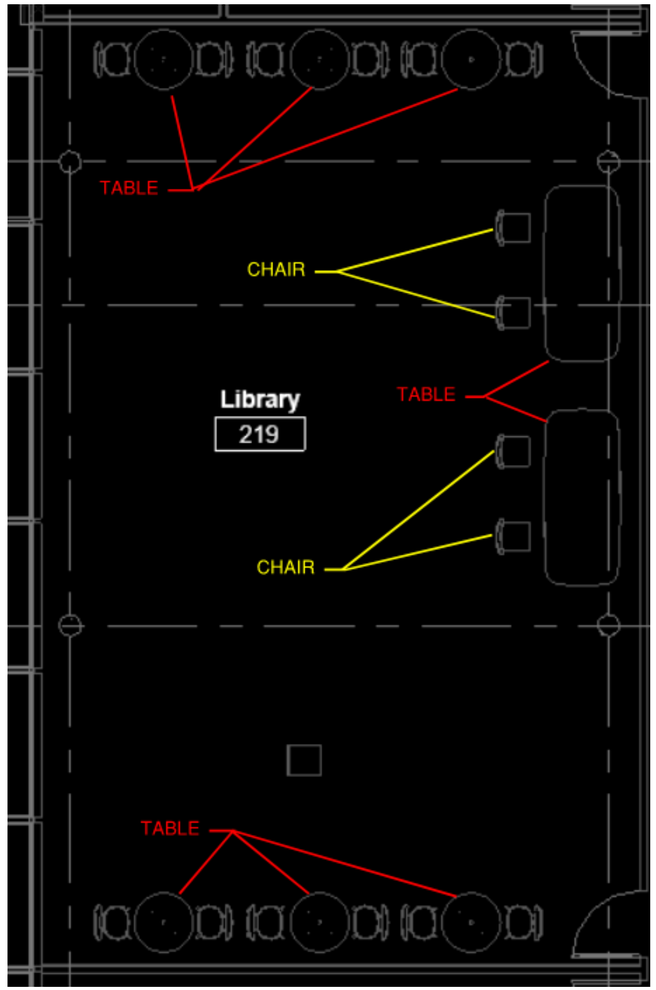


Identify Objects in Space

After you have rules for MEP elements involving baseplan objects, categorize each baseplan object.

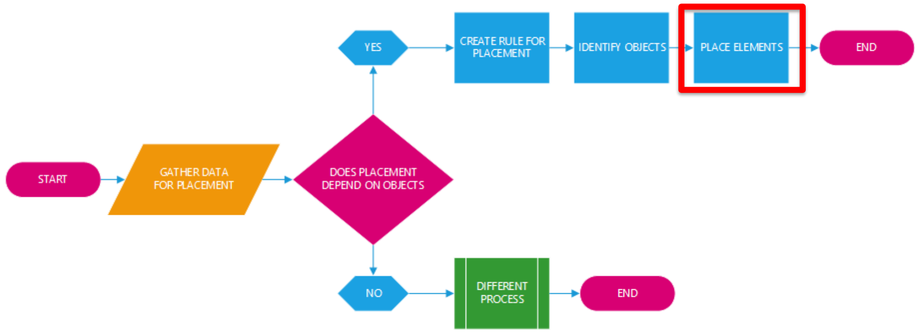
- **Electrical**
  - Tables, Chairs, Desks, Windows, Countertops, etc.
- **Plumbing**
  - Toilets, Sinks, Urinals, Countertops, Dishwashers, etc.

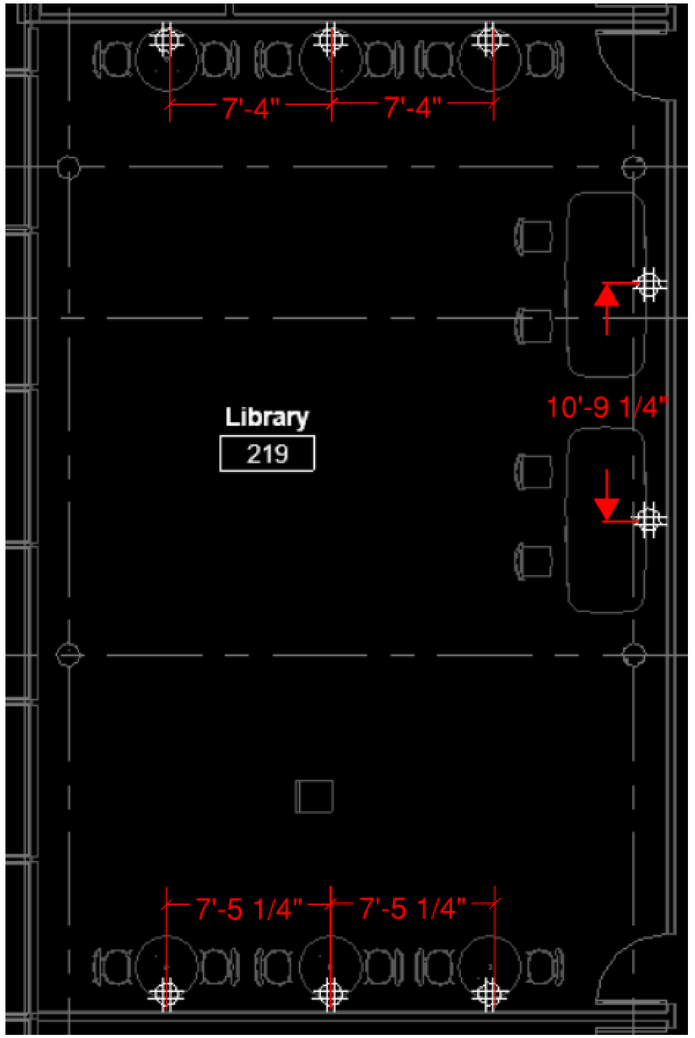




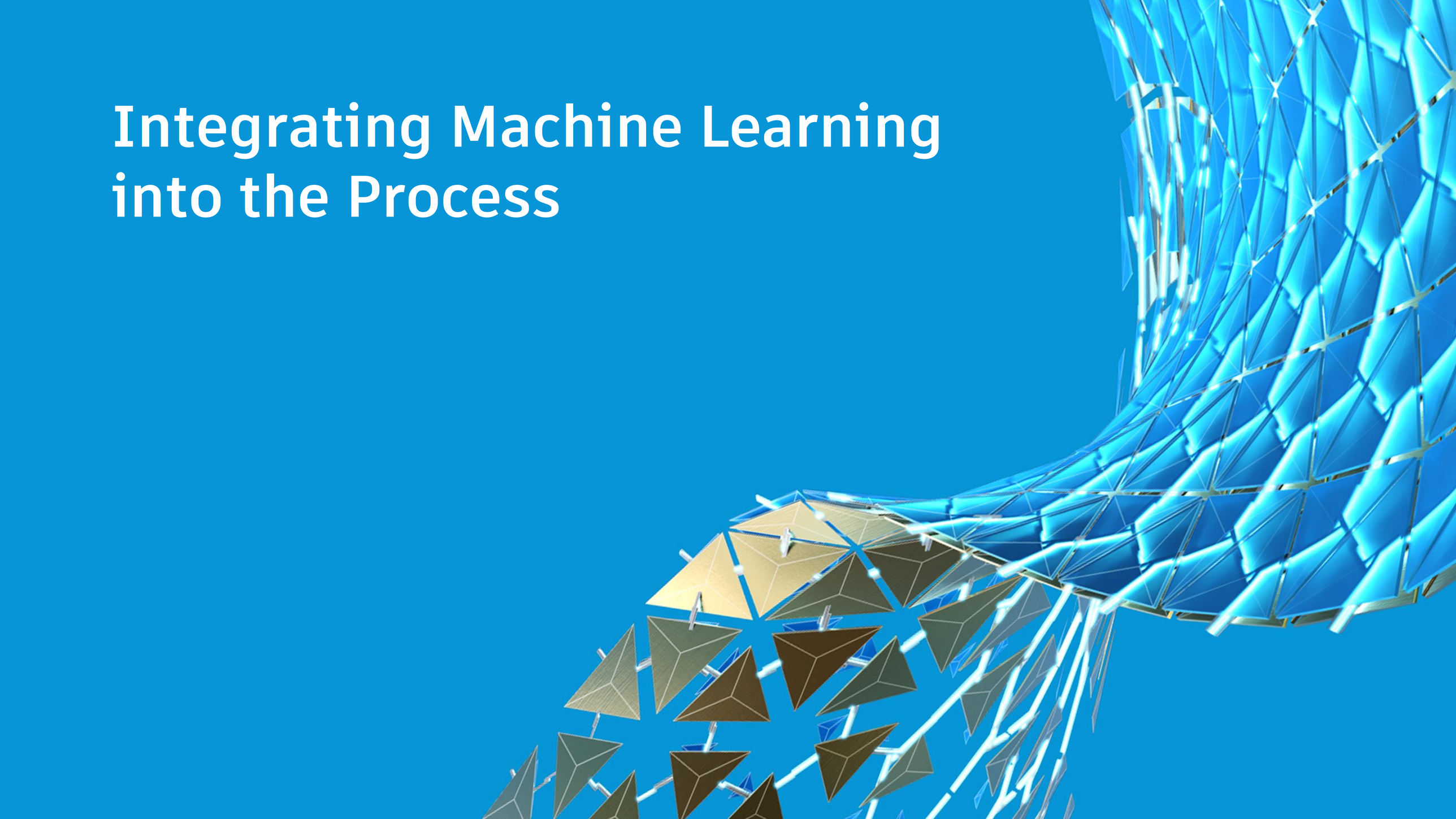
PLACE ELEMENTS

After you have rules for MEP elements involving baseplan objects, and the baseplan objects identified, you can place MEP elements according to the rules.





Integrating Machine Learning into the Process

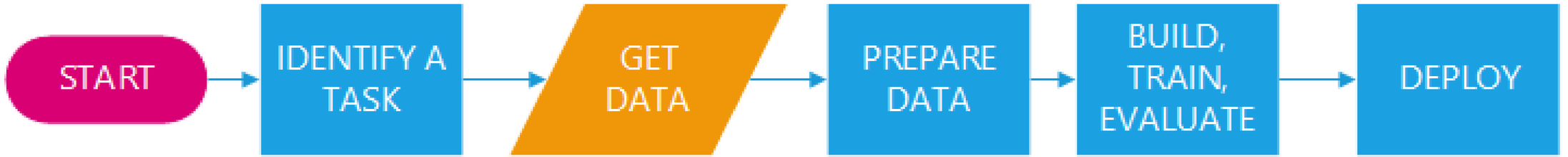


Enter Machine Learning

What does machine learning do well?

- **Examines data and finds ingrained patterns.**
  - This happens during training.
- **Makes predictions on new data, based on previously seen data.**
  - This happens after deploying trained model.

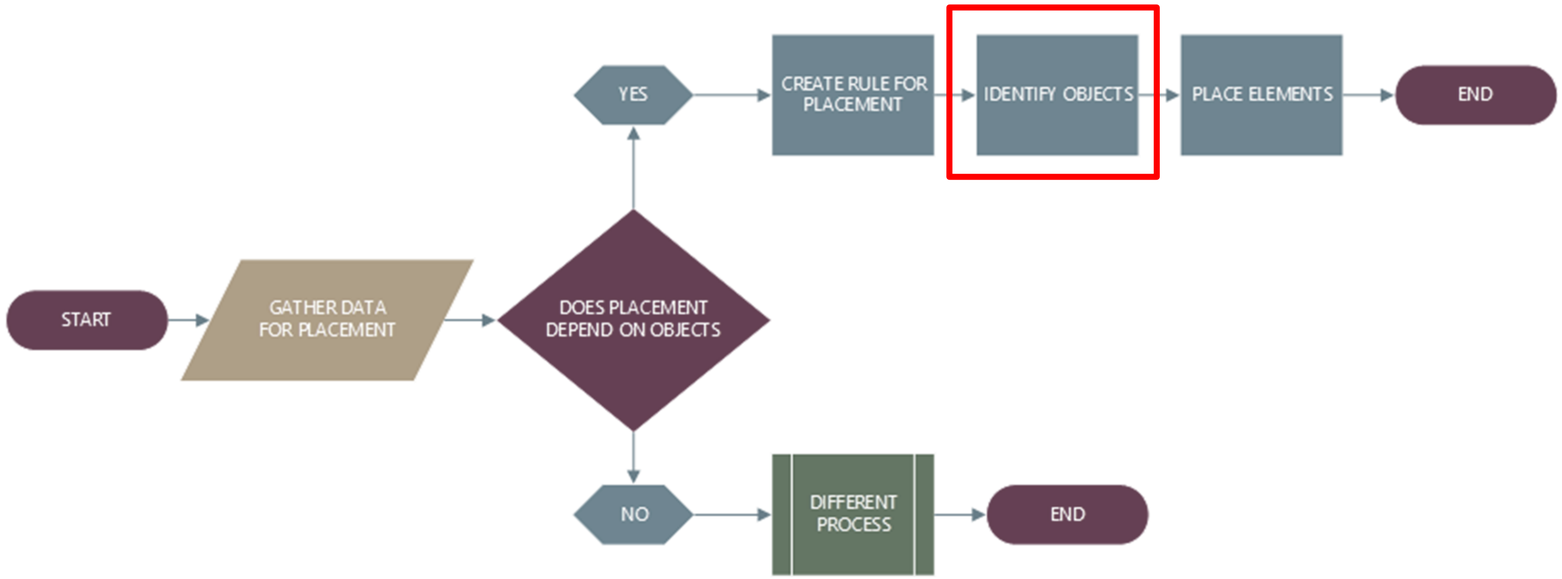
Overview

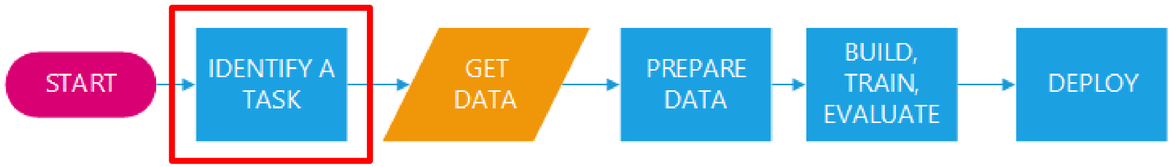

START
IDENTIFY A TASK
GET DATA
PREPARE DATA
BUILD, TRAIN, EVALUATE
DEPLOY

Identify a Task

Task: Categorize an object

- Small task that is part of a larger process
- Patterns exist based on what information can be gathered.

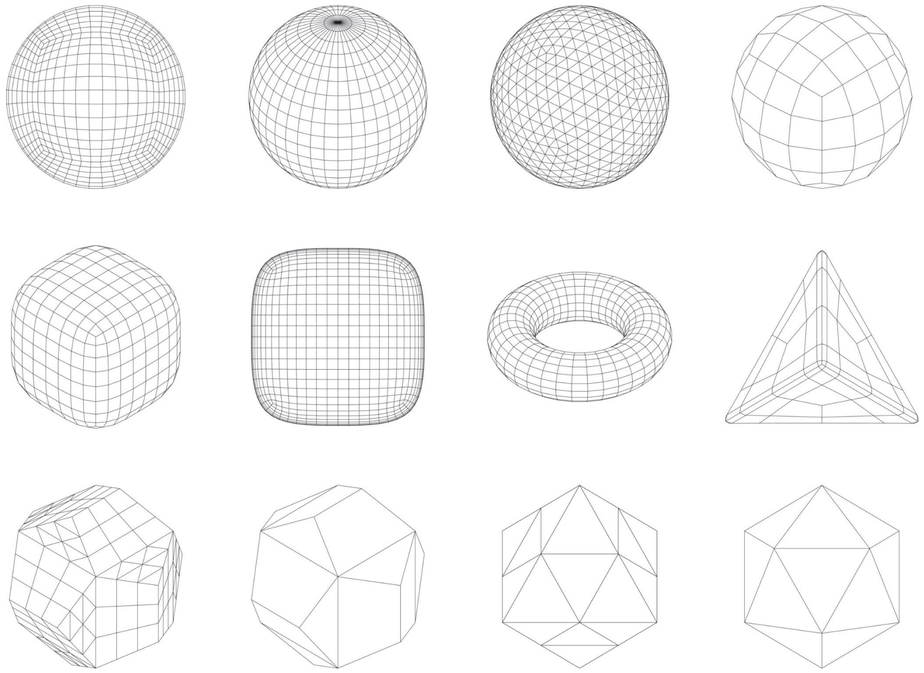


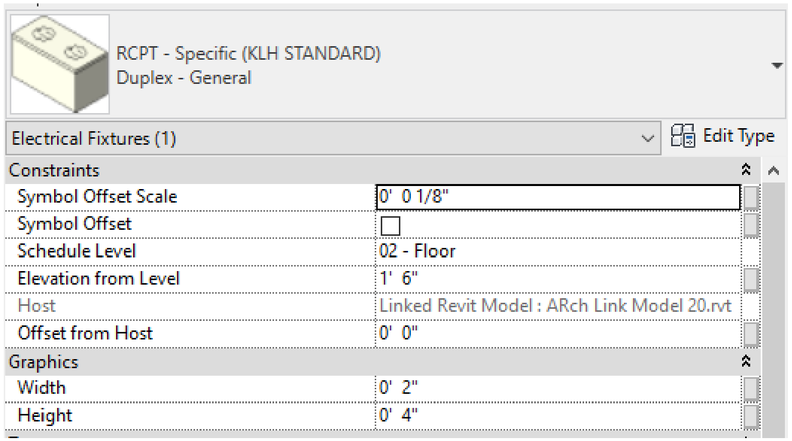


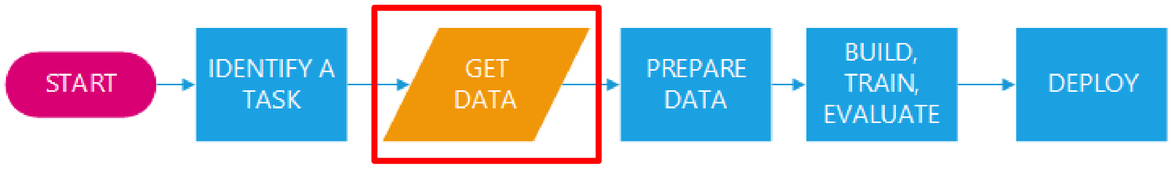
What information do we need?

What is available from the Revit Model?

- Geometry (meshes, solids, faces, etc)
- Name of family



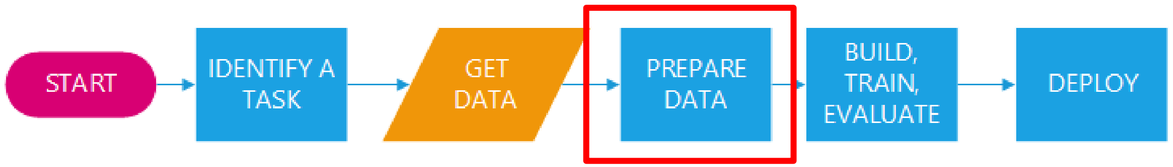




What kinds of information does a ML model understand?

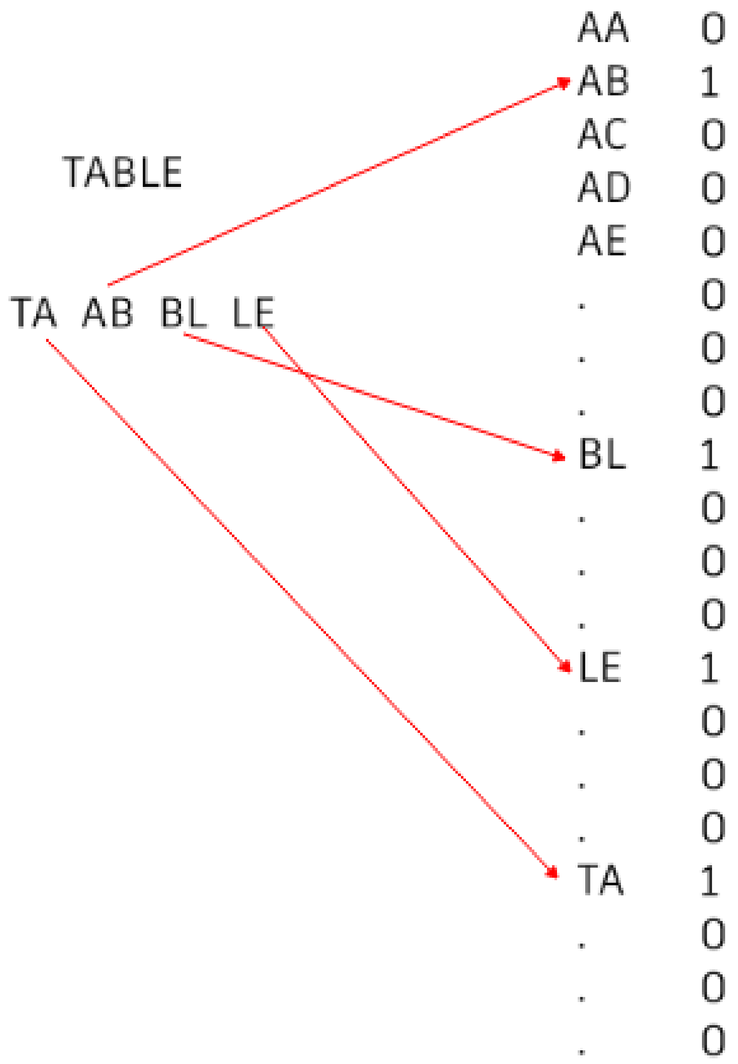
Machine Learning models can understand a lot of different types of data.

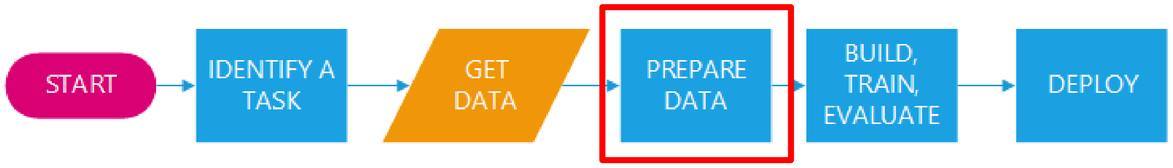
- **Numbers in a 2d or 3d array.**
- **Categories of things (room hazards for fire code, building occupancy types)**
  - These categories can't be added together like numbers, they represent logical distinctions
  - Others include RGB values for pixels, time series data.



How do we capture what an object is then?

- **The geometry of the family was turned into a voxel representation.**
- **Name data was turned into bi-grams, then the bigrams were tallied for each name.**
  - Create an Array with every possible combination of any 2 letters of the alphabet.
  - Break the name into bigrams, add 1 to the array for each occurrence of the letter pairing in the Family Name.

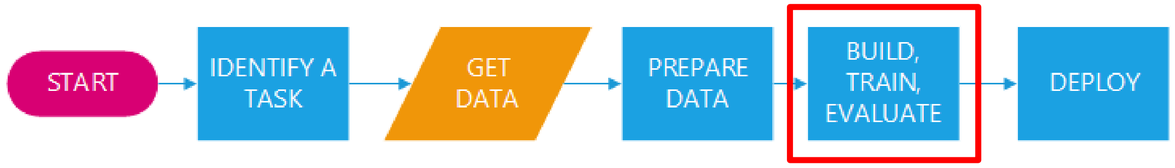




Build and Train Model

Lots of different tools available to developers, PyTorch, TensorFlow, ML.NET, etc.

- KLH uses Keras + TensorFlow because documentation and tutorials were easy to find when we started on our ML Journey.

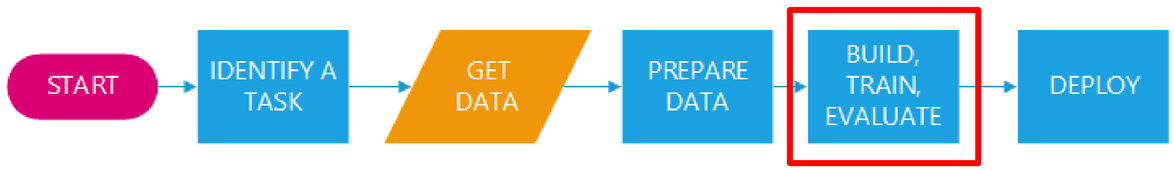


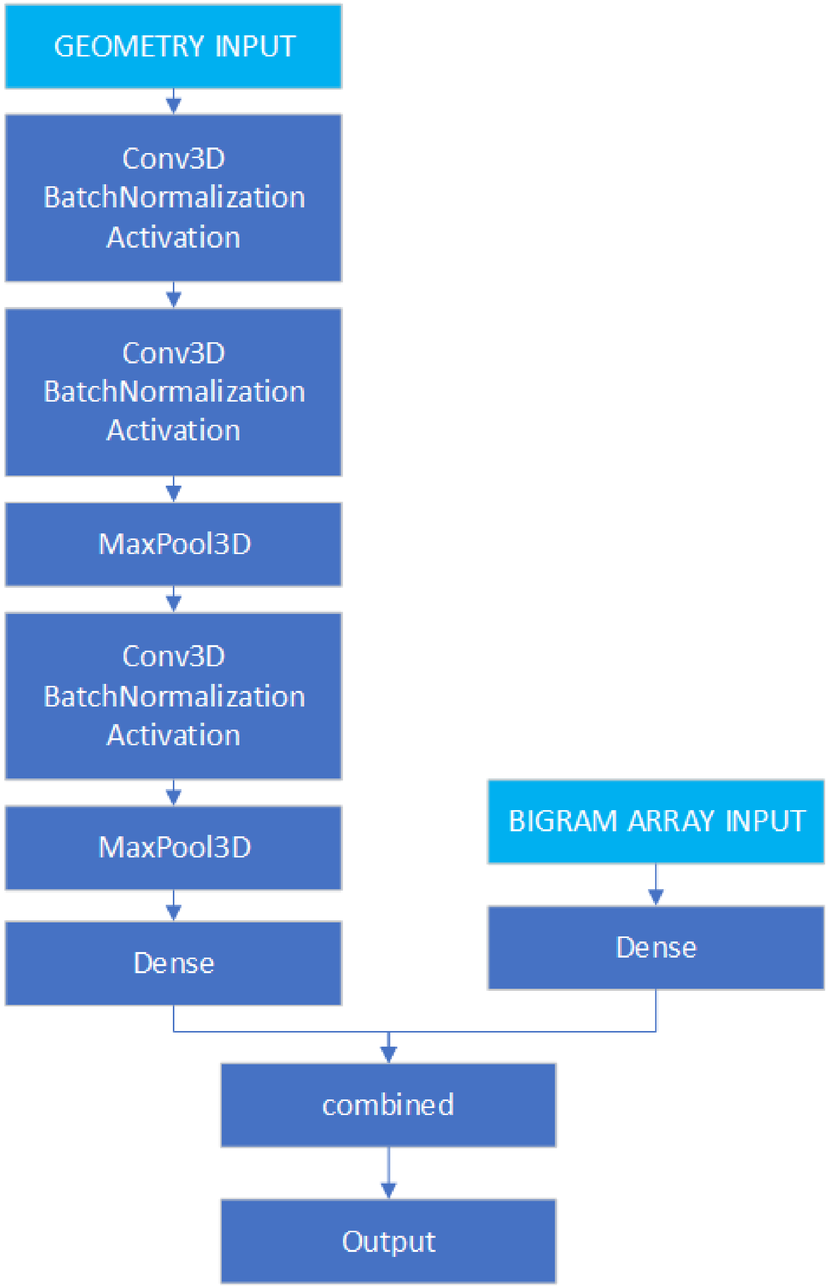
Build the Model

Used the TensorFlow 2.0 functional API with Keras

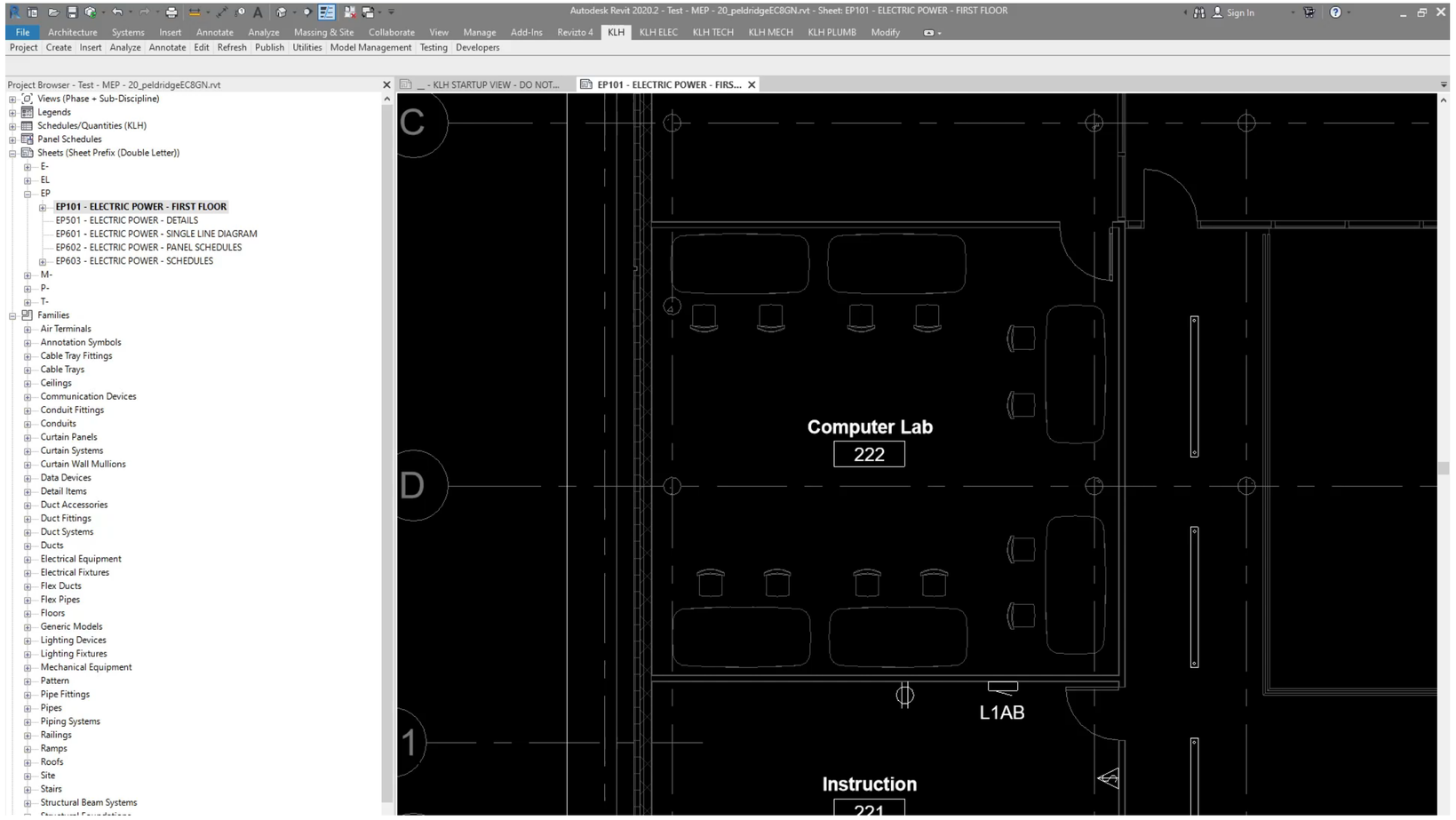
- **2 Inputs**
  - Geometric data
  - Family and type name
- **1 Output**
  - Object category

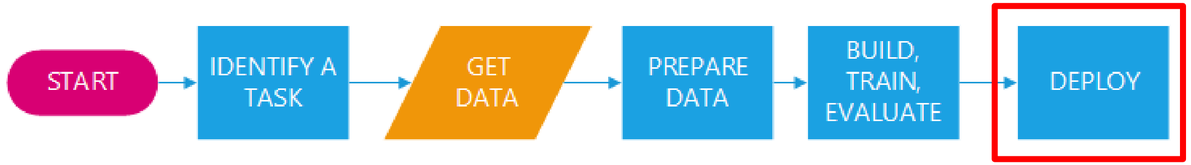
```
history = model.fit(x=[x_train_vox,x_train_names],
                    y=y_train,
                    batch_size=batch_size,
                    epochs=epochs,
                    validation_data=([x_valid_vox,x_valid_names],y_valid),
                    verbose=1,
                    callbacks=[earlystop, learning_rate_reduction, mcp]
                    )
```



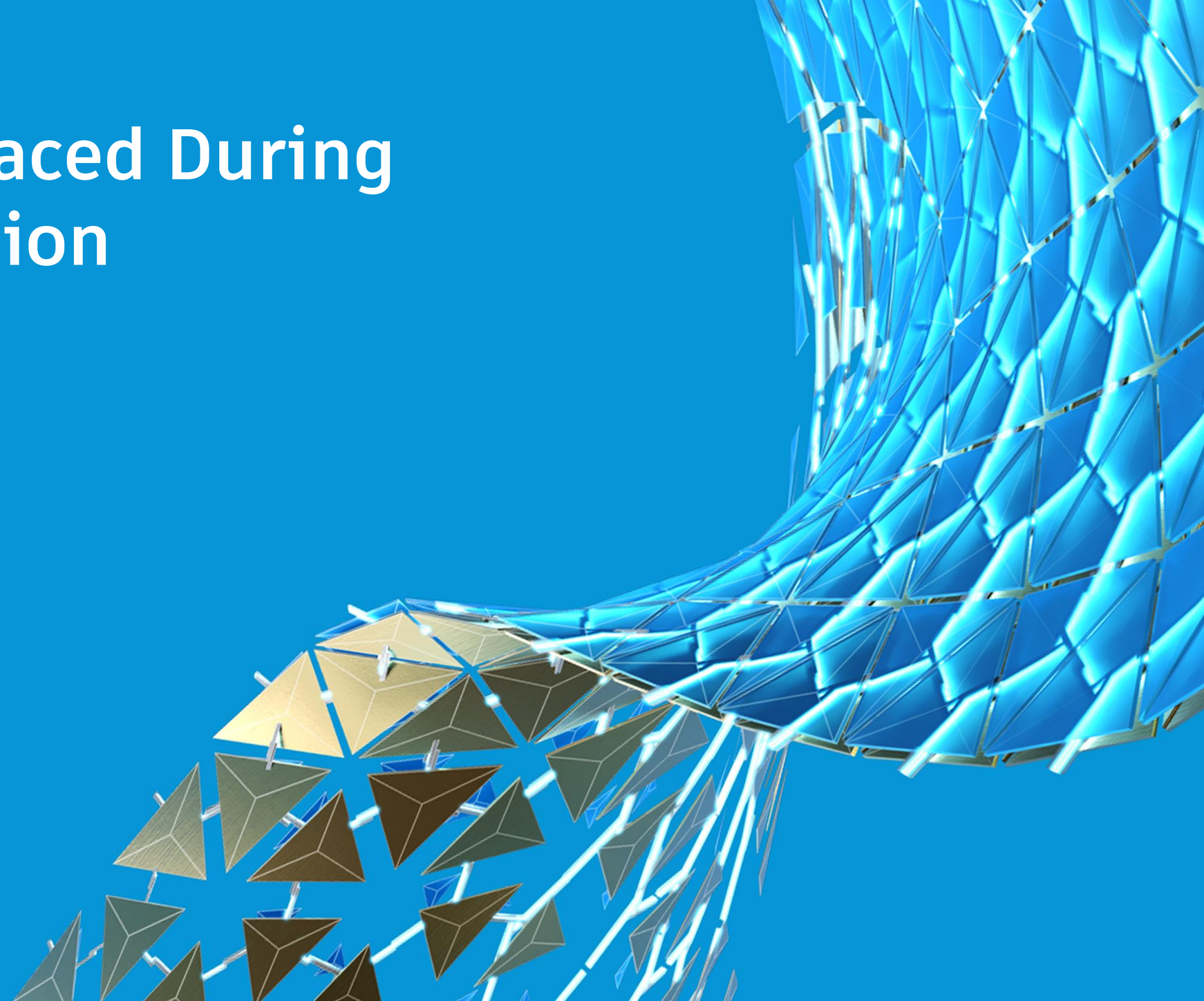


Seeing the Process in Action





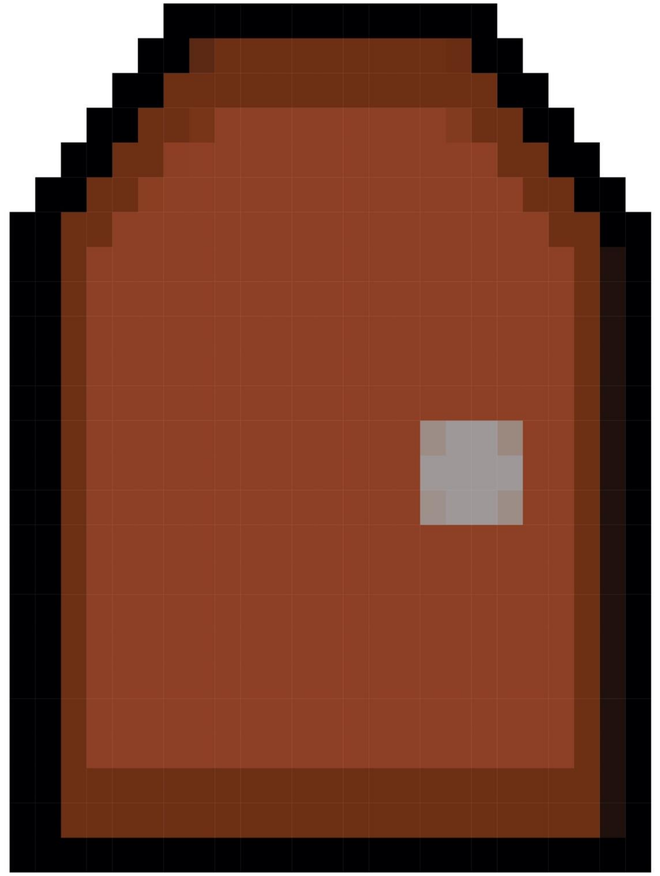
Challenges Faced During Implementation



Model Architecture

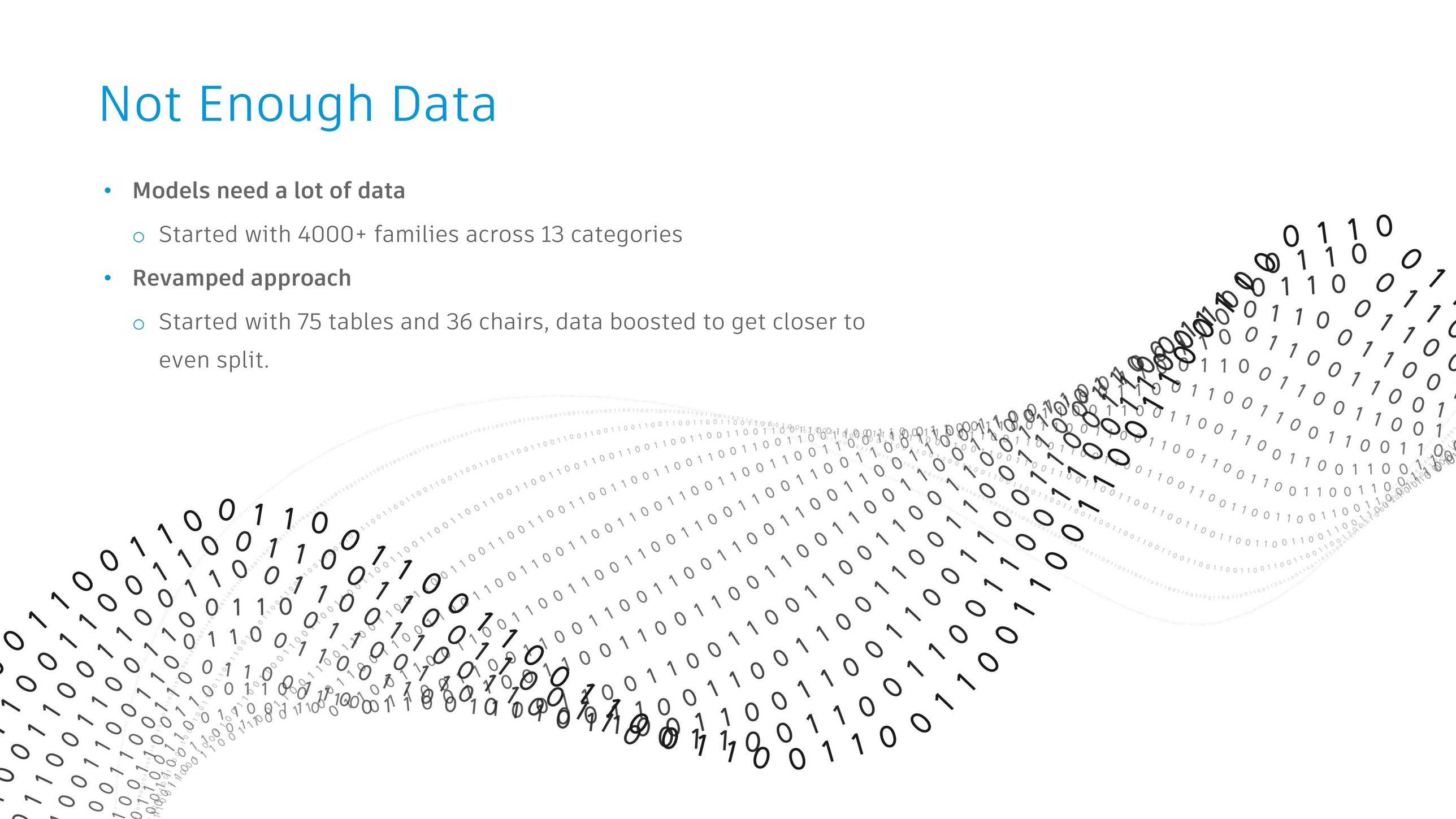
Less performant with only voxel data

- First few model architectures had only voxelized data as input
- Transitioned to including family name

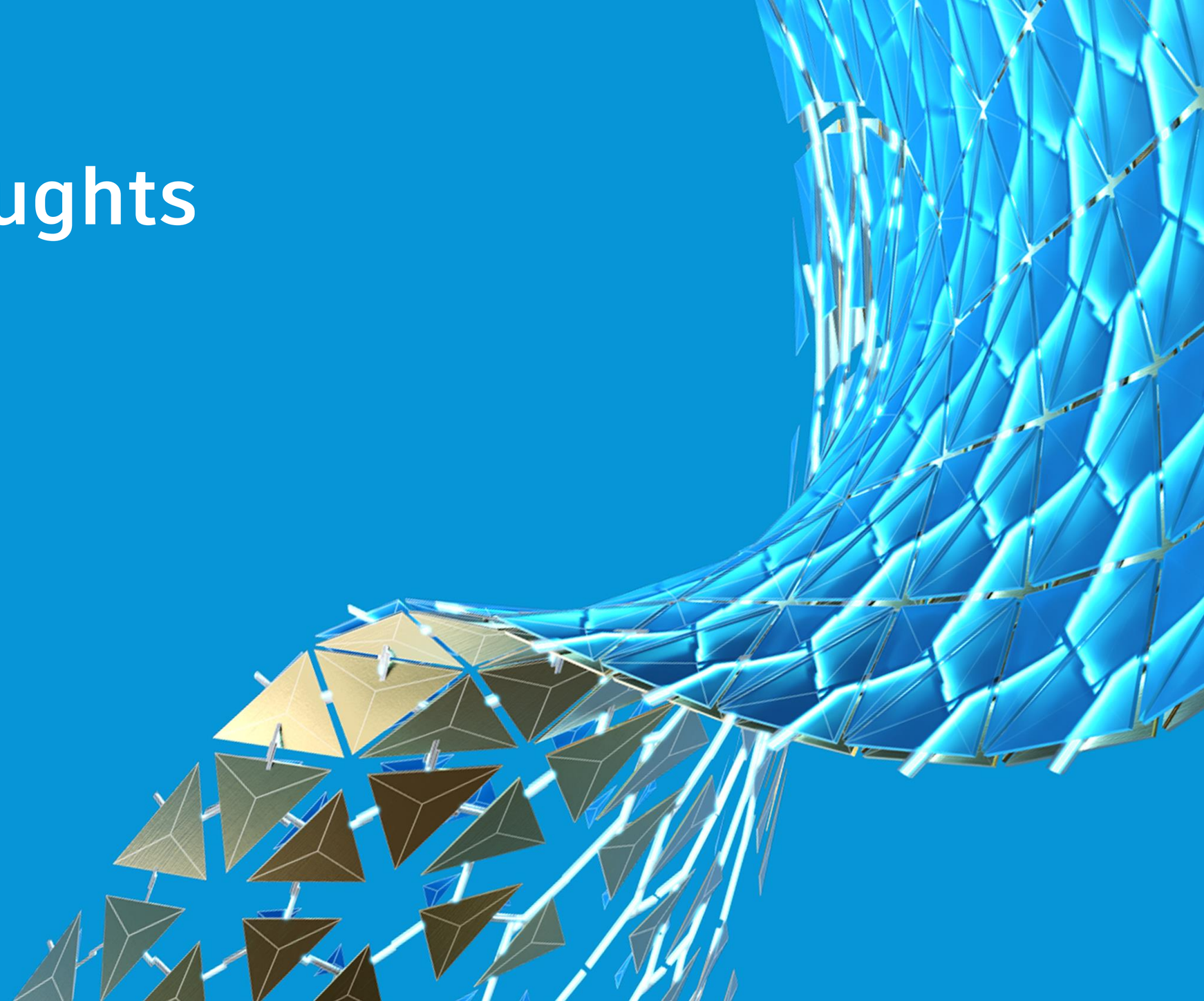


Not Enough Data

- **Models need a lot of data**
  - Started with 4000+ families across 13 categories
- **Revamped approach**
  - Started with 75 tables and 36 chairs, data boosted to get closer to even split.



Closing thoughts



How much does machine learning cost?

- How much does training a model cost?
- How much did KLH spend training the model for object categorization?

Learning Objectives

- Discover how machine learning can be used as a tool in the AEC industry.
- Learn how KLH trained a model on a small dataset of objects.
- See how to integrate a concrete use of machine learning into a company's workflow.
- Understand that you don't need super computers and a PHD to develop and deploy this technology.