

# Semantic Enrichment of Building Models for Checking Code Compliance

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## Outline



The need to supplement BIM models with explicit information according to the concepts defined in building codes is a significant barrier to broad adoption of automated code-checking for BIM models.

Semantic enrichment using various AI methods presents a possible path to comprehensive automation.



## A prediction of BIM code-checking

Eastman, C. M. (1975). "The Use of Computers Instead of Drawings in Building Design." *Journal of the American Institute of Architects*, March: 46–50. (See chapter 9, *BIM Handbook*, 3<sup>rd</sup> edition)

*"Designing would consist of interactively defining elements... It should be possible, then, to derive sections, plans, isometrics or perspectives from the same description of elements... Any change of arrangement would have to be made only once for all future drawings to be updated. All drawings derived from the same arrangement of elements would automatically be consistent... any type of quantitative analysis could be coupled directly to the description. All data preparation for analyses could be automated. Reports for cost estimating or material quantities could be easily generated... Thus BDS will act as design coordinator and analyzer, providing a single integrated database for visual and quantitative analyses, for testing spatial conflicts and for drafting. ... Later, one can conceive of a BDS supporting automated building code checking in city hall or the architect's office. Contractors of large projects may find this representation advantageous for scheduling and materials ordering."*



## A Brief History

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- Research in 1980s and 1990s was restricted to **symbolic AI**, primarily rule-inferencing Expert Systems

HI-RISE for preliminary structural design of tall buildings (Maher and Fenves 1985)

EIDOCC for design of reinforced concrete columns (Sacks and Buyukozturk 1987)

- The necessary **symbolic representations of building designs** were unavailable until the advent of BIM, circa 2000

- However, even BIM representations are not perfect:

- broad **variations in modeling practice**
- **redundancy in model exchange schema (IFC)**

- Commercial software products:

Solibri Model Checker, BIM Assure, SMARTreview, DAICA, Upcodes



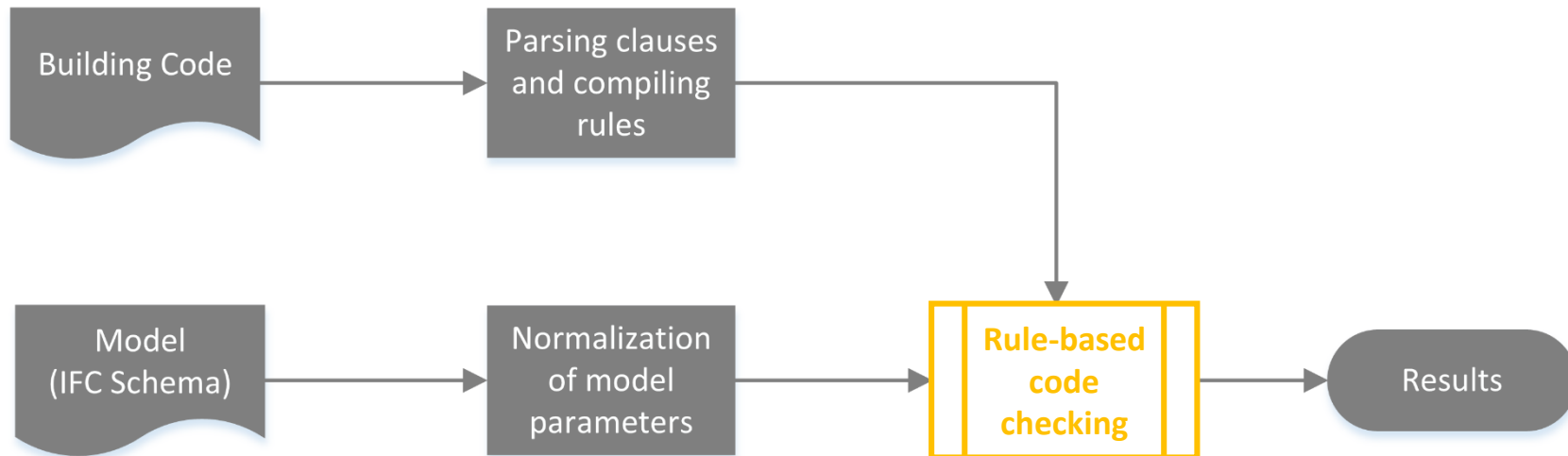
# Automated code compliance checking



Existing software tools that check BIM models are mostly limited to simple dimensional or text checks

# Automated code compliance checking

Old way, using symbolic AI (rule inferencing) only



*EIDOCC - Expert Interactive Design of Concrete Columns*

Master's Thesis, MIT – Massachusetts Institute of Technology, 1985.

Sacks, R., and Buyukozturk, O., (1987), 'Expert Interactive Design of Concrete Columns under Bi-axial Bending', Journal of Computing in Civil Engineering, Vol. 1 No. 2 pp. 69-81.



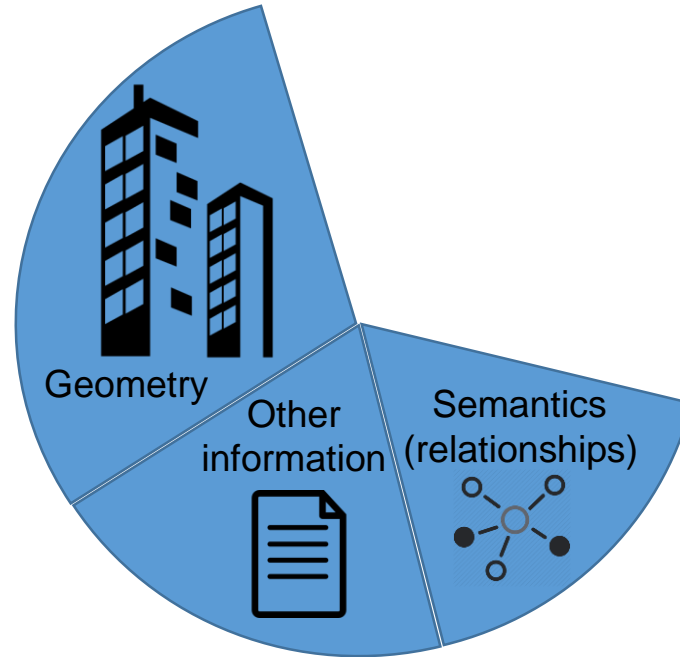
# Automated code compliance checking

The screenshot displays a software application window titled 'Checking'. The menu bar includes 'File', 'Model', 'Checking', 'Communication', 'Information Takeoff', and '+'. The 'Checking' window has a toolbar with icons for 'Check', 'Report', and '3D'. On the left, a 'Ruleset' tree shows a hierarchy: 'Advanced Space' (expanded) containing 'Space Program' (expanded) with sub-items like 'Total Space', 'Space Count', 'Space Name', 'Space Area', 'Number of S', 'Space Group', and 'Distances Between Spaces'. A yellow 'To-Do' pop-up window is overlaid on the interface, listing tasks: 'Classification Tasks' (Do 'Space Usage' classification), 'Parameter Values Tasks' (Fill in parameter values for various rules), and 'Other Tasks' (Specify allowed space identification pattern). Below the 'To-Do' list is a 'Result Summary' section and a 'Results' section with the text 'Please select a checked rule with results.' and the SMC logo. To the right of the software window is a 3D perspective view of a multi-story building with a grid of windows.

Existing software tools that check BIM models require a process called **'normalization'**

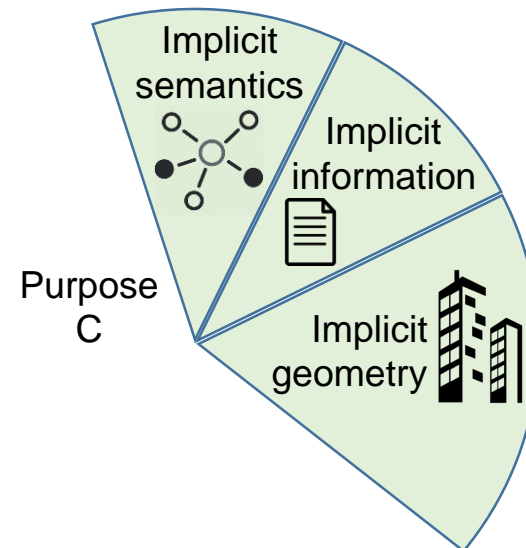
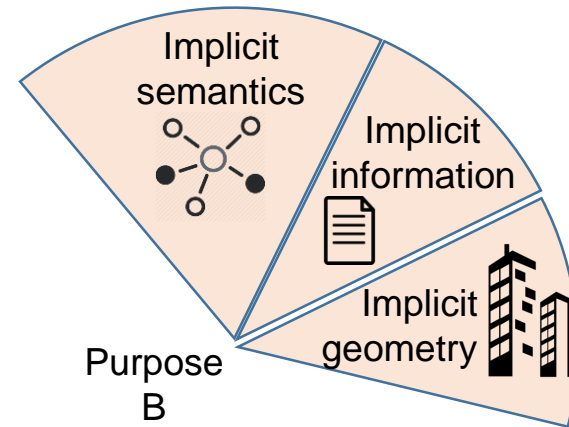
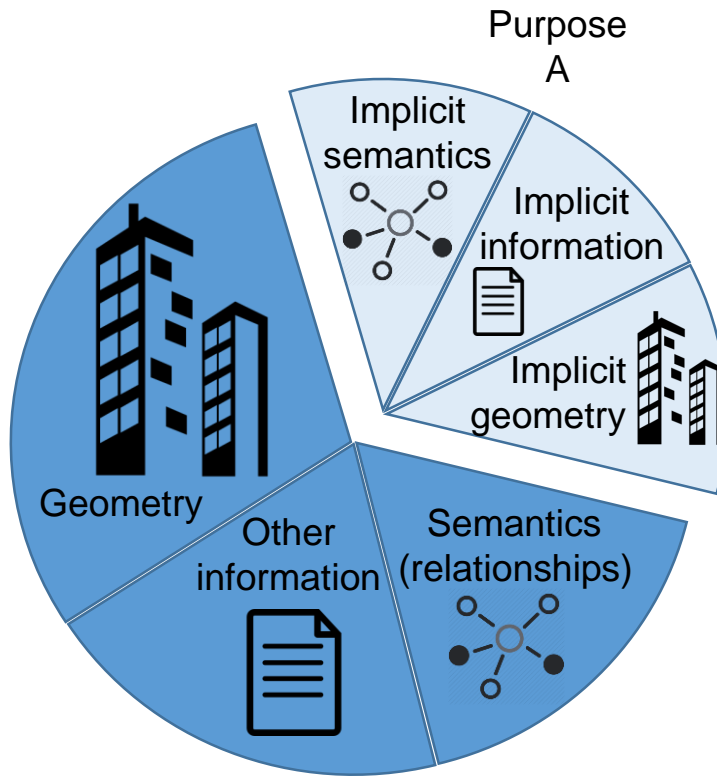


# What's in a BIM model?





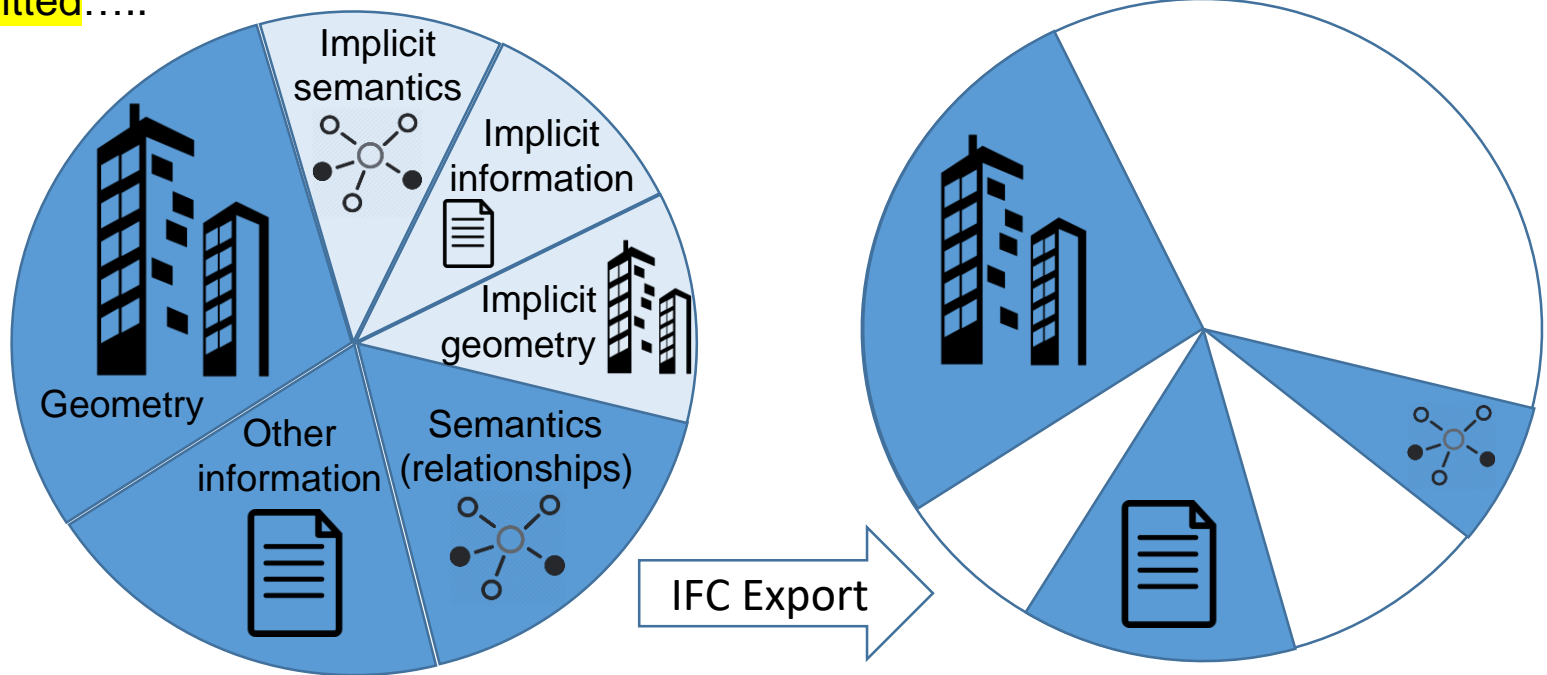
# What's in a BIM model?



1. **Explicit information**
2. **Implicit domain specific information**

# What's in an exported BIM model?

When models are exported to the Industry Foundation Class (IFC) open file format, **some of the information and most of the semantic relationships are omitted.....**



....and thus **inaccessible to generic model review systems** which require explicitly defined parameters, aggregations, connections and other topological structures.



## Solution direction

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- A manual pre-processing stage, '**normalization**', is required for most rule-based code checking routines (Eastman et al., 2009).
  - Labour intensive
  - Prone to errors
- A **semantic enrichment** process is an alternative approach that offers to automate the interface (Belsky et al., 2016).
- Previous research demonstrated successful application of rule-inferencing to enrichment tasks (Sacks et al., 2017).
- More recent work (Bloch & Sacks, 2018) has shown that some semantic enrichment tasks can be performed more efficiently using supervised machine learning techniques.

# BIM Design review and code checking

Today's model checking applications are capable of checking building models for conformance to code clauses which restrict explicit dimension values, but very little more than that.

Complex, implicit code clauses are still beyond the scope of such applications.

Much R&D is needed for semantic enrichment (to pre-process models for checking) and for automating checking of complex conditions.

- **How can we automate semantic enrichment?**
- **How can we automate design review?**





# Semantic enrichment

*What is Semantic Enrichment for BIM?*

Semantic enrichment applies AI tools to interpret and enrich the semantic content of models so that they can be re-used for multiple purposes with minimum rework.

Belsky, M., Sacks, R., and Brilakis, I., (2016). '[Semantic Enrichment for Building Information Modeling](#),' Computer-Aided Civil and Infrastructure Engineering, Vol. 31, No. 4, pp. 261-274.

# ○ Semantic enrichment

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To date, none of the available BIM tools can generate information beyond that explicitly provided in the exchange file.

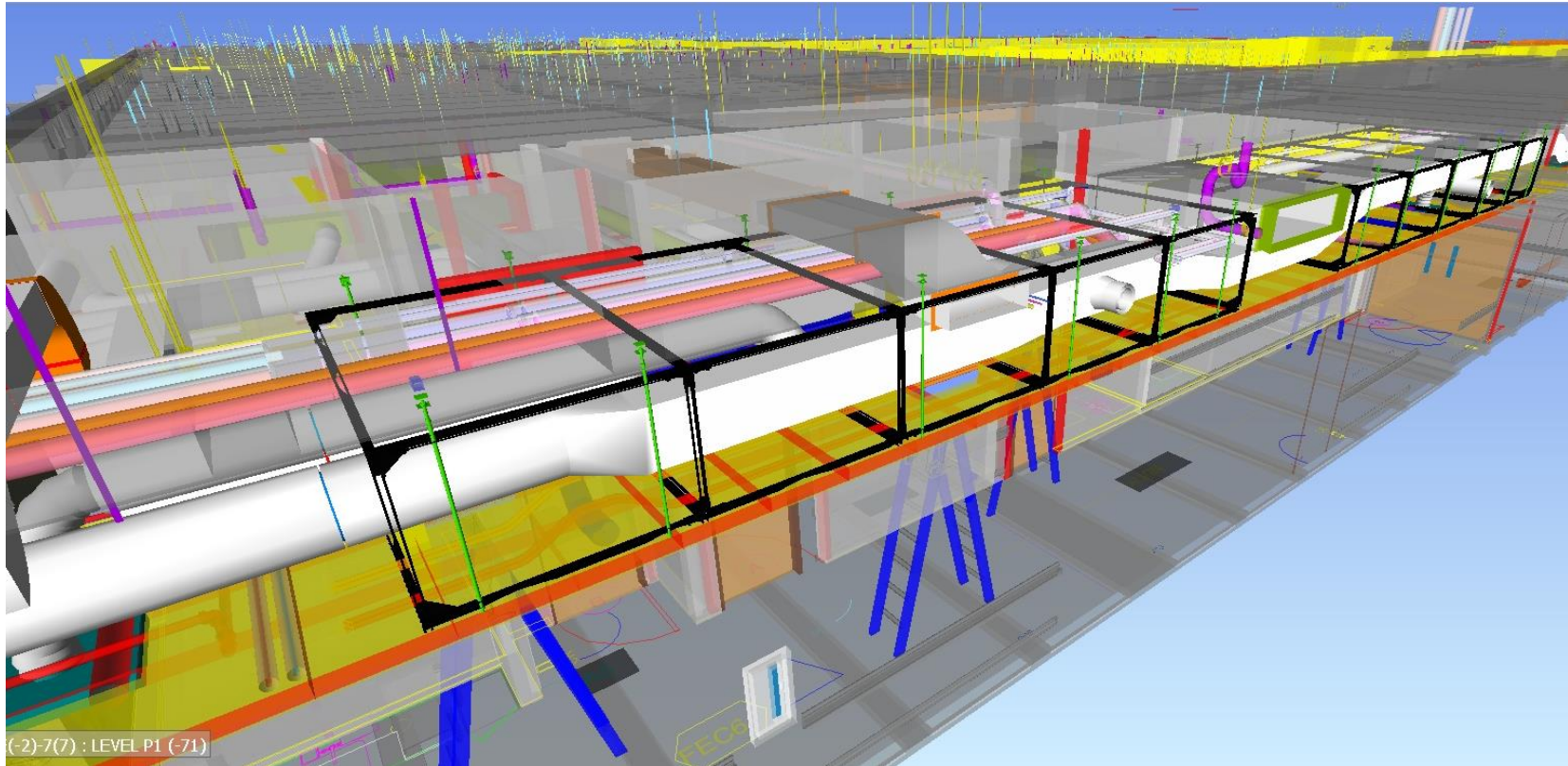
Yet a human professional engineer can **See** and infer far more information from a **BIM** model, which suggests that, using AI, we can post-process exported models, enriching and standardizing their content as needed.



<http://vclab.technion.ac.il>

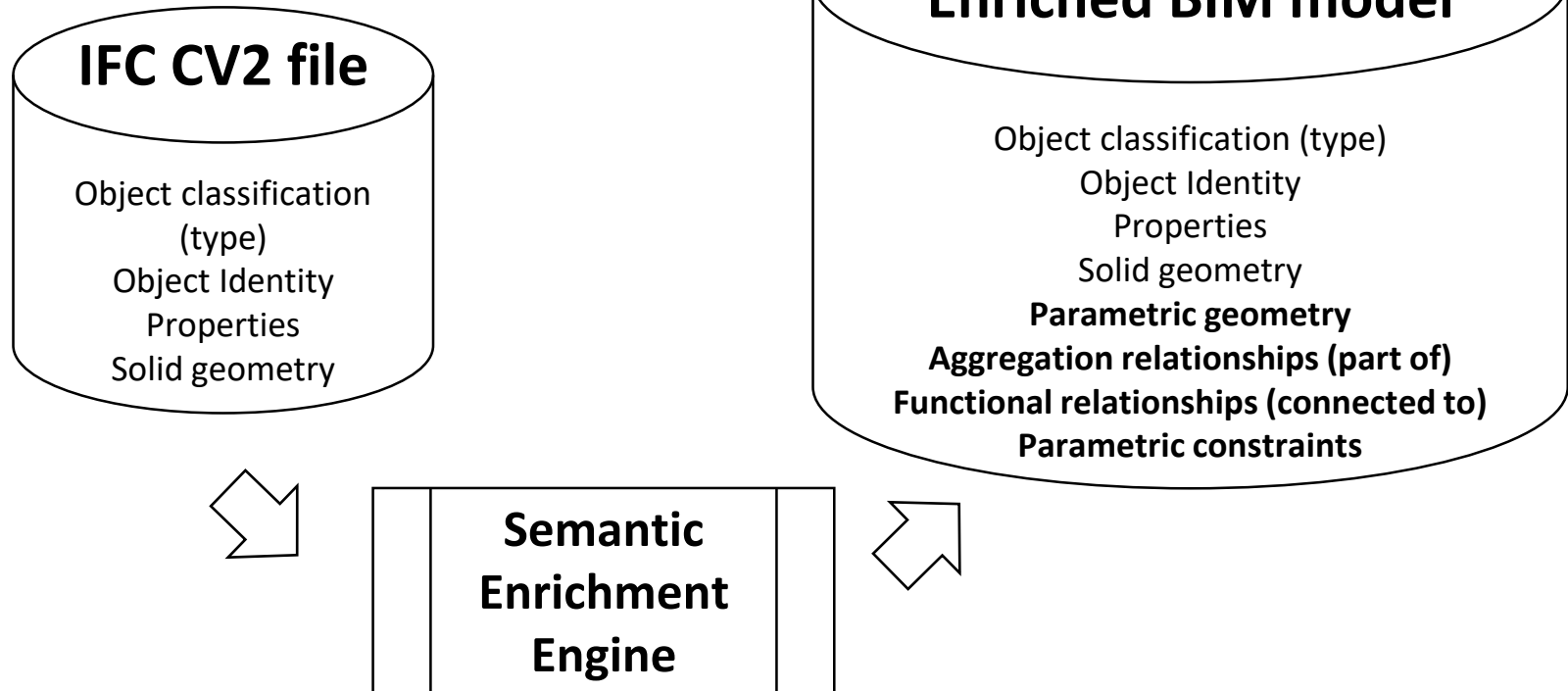
# ○ Semantic enrichment

What do you see....?



# Semantic enrichment

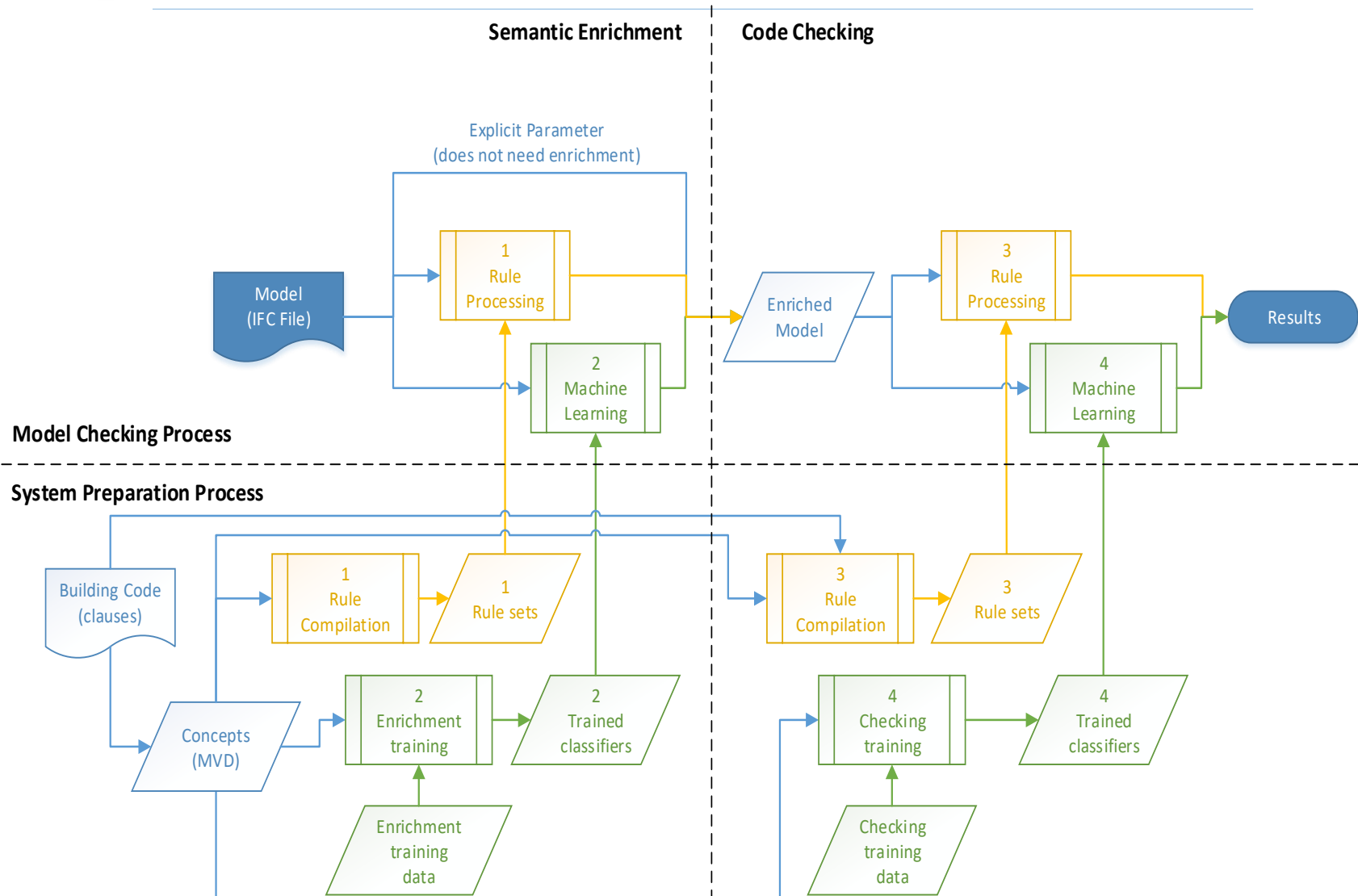
What do you see....?





# Automated code compliance checking

New way, using rule inferencing and machine learning

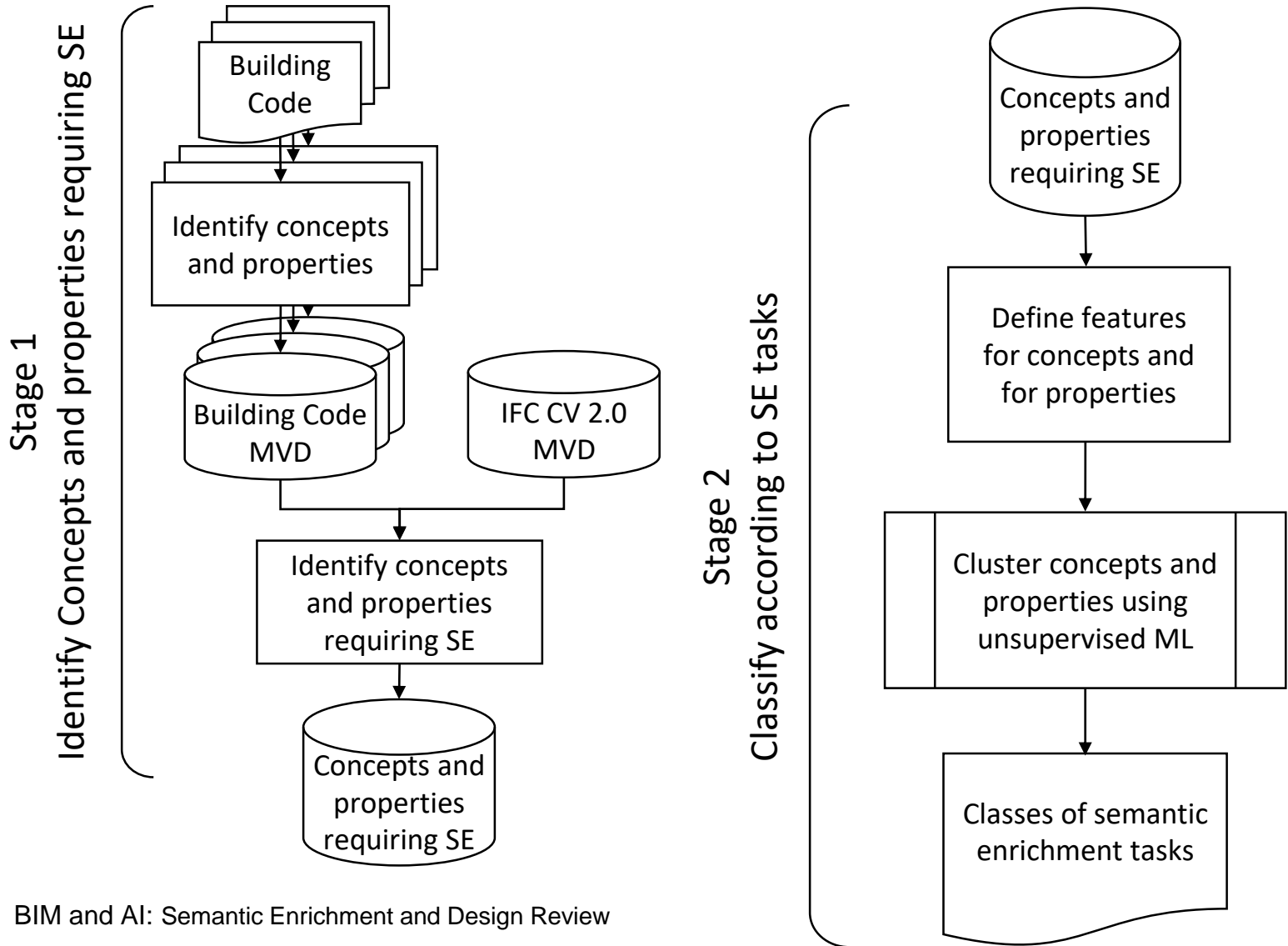


BIM and AI: Semantic Enrichment and Design Review

# Research Agenda

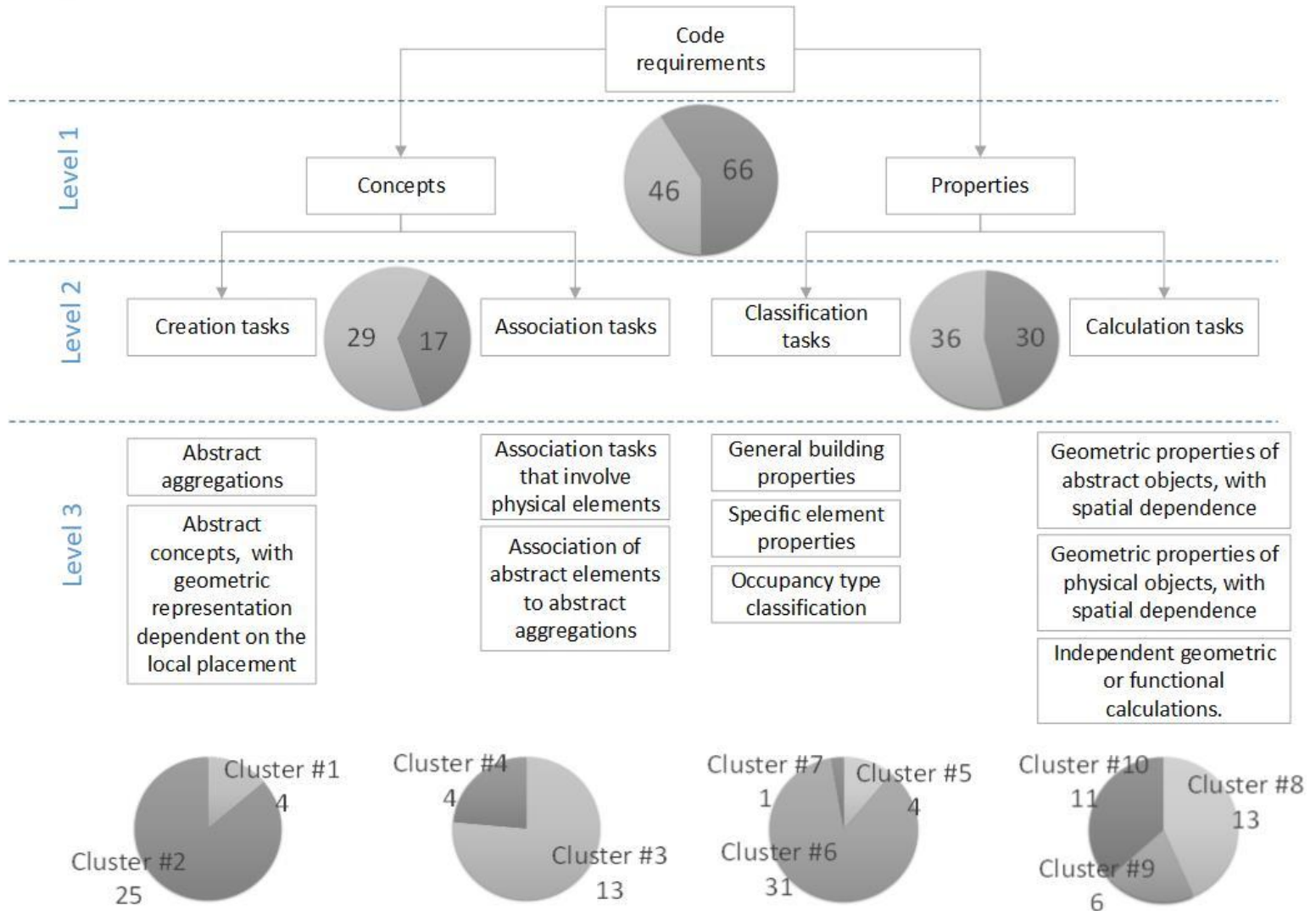
1. Classify concepts according to Semantic Enrichment types
  - Review multiple codes to prepare Model View Definitions – identify the information concepts
  - Cluster concepts according to enrichment type
2. Identify appropriate AI strategies for each type
  - Experiment with different strategies for each type

# Cluster Concepts for SE





# Cluster Concepts for SE



# Identify AI Approaches for Clusters

**Which AI methods, or combinations of methods, should be used?  
Symbolic or sub-symbolic?**

- *A mix of methods, suited to purpose*

**What are appropriate representations of BIM models for application of AI methods?**

- *Graph representations are very promising...*

Bloch, T., and Sacks, R. (2018). [‘Comparing Machine Learning and Rule-based Inferencing for Semantic Enrichment of BIM Models’](#), [Automation in Construction](#), Vol. 91, pp. 256–272.

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**Thanks for your attention,**

***Any questions?***

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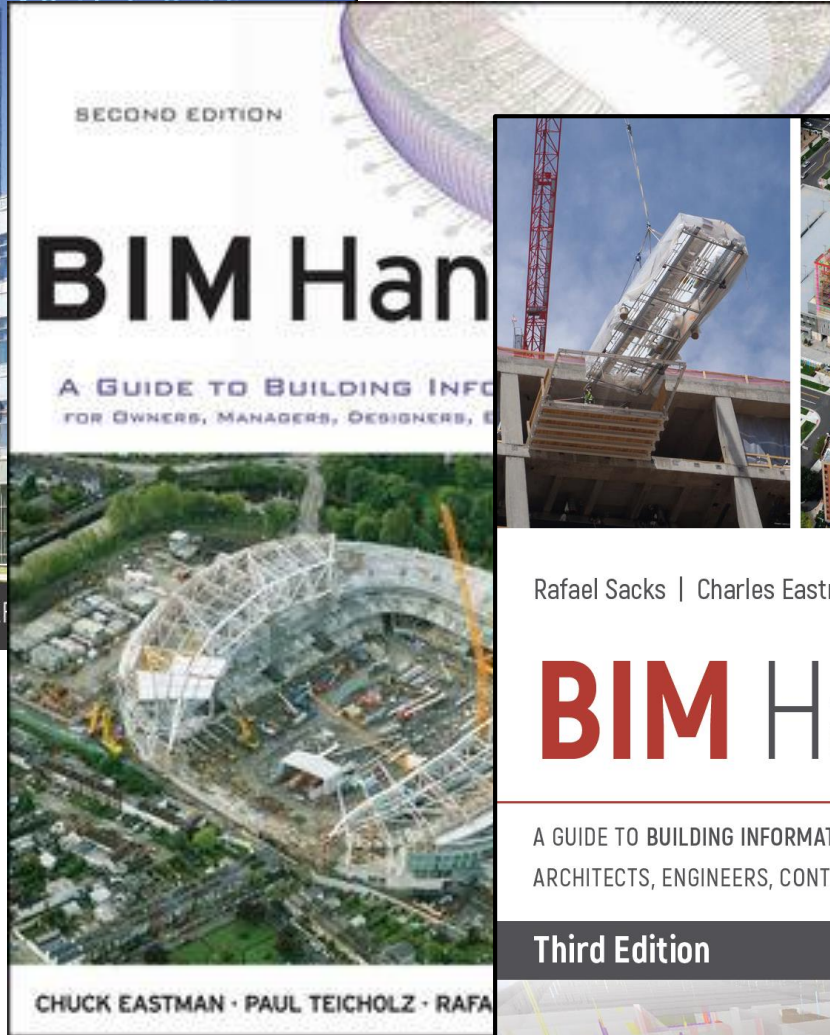
CHUCK EASTMAN · PAUL TEICHOLZ · RAFAEL SACKS

# BIM HANDBOOK

2008  
1<sup>st</sup> Edition

2011  
2<sup>nd</sup> Edition

2018  
3<sup>rd</sup> Edition

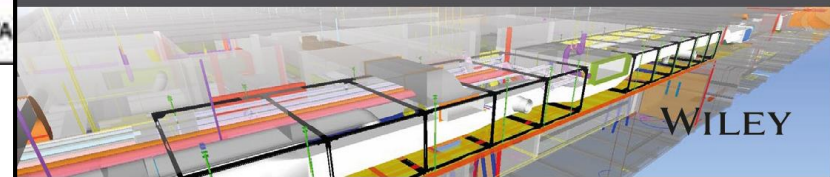


Rafael Sacks | Charles Eastman | Ghang Lee | Paul Teicholz

# BIM Handbook

A GUIDE TO BUILDING INFORMATION MODELING FOR OWNERS, MANAGERS,  
ARCHITECTS, ENGINEERS, CONTRACTORS, AND FABRICATORS

Third Edition



WILEY

BIM and AI: Semantic Enrichment and Design Review

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BIM and AI: Semantic Enrichment and Design Review