National Institute of Building Sciences

Provider Number: G168

Leveraging Artificial Intelligence for Structural Design

Course Number

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Date

January 8, 2019

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Course Description

Thornton Tomasetti has been researching artificial intelligence (AI) and machine learning (ML) since 2015 and believe that the use of AI/ML will radically disrupt the consulting engineering practice.

This course will provide a brief history of Artificial Intelligence and how AI/ML can be leveraged in structural engineering design and beyond.

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Learning Objectives

At the end of the this course, participants will be able to:

1. Understand the history of Artificial intelligence and its uses
2. Understand the typical algorithms used in Artificial Intelligence
3. Learn about an automated building design software and how it can be used in practice
4. Learn about automated inspection using artificial intelligence

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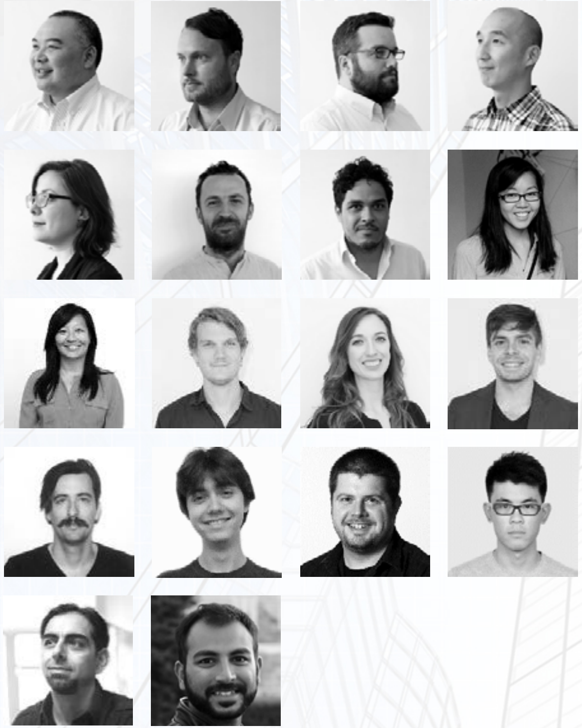
CORE studio | Thornton Tomasetti



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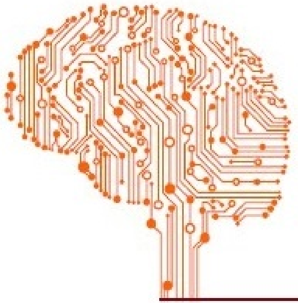
What is AI?

1.1 What is AI?

Artificial intelligence refers to the ability of a computer or a computer-enabled robotic system to process information and produce outcomes in a manner similar to the thought process of humans in learning, decision making and solving problems. By extension, the goal of AI systems is to develop systems capable of tacking complex problems in ways similar to human logic and reasoning.

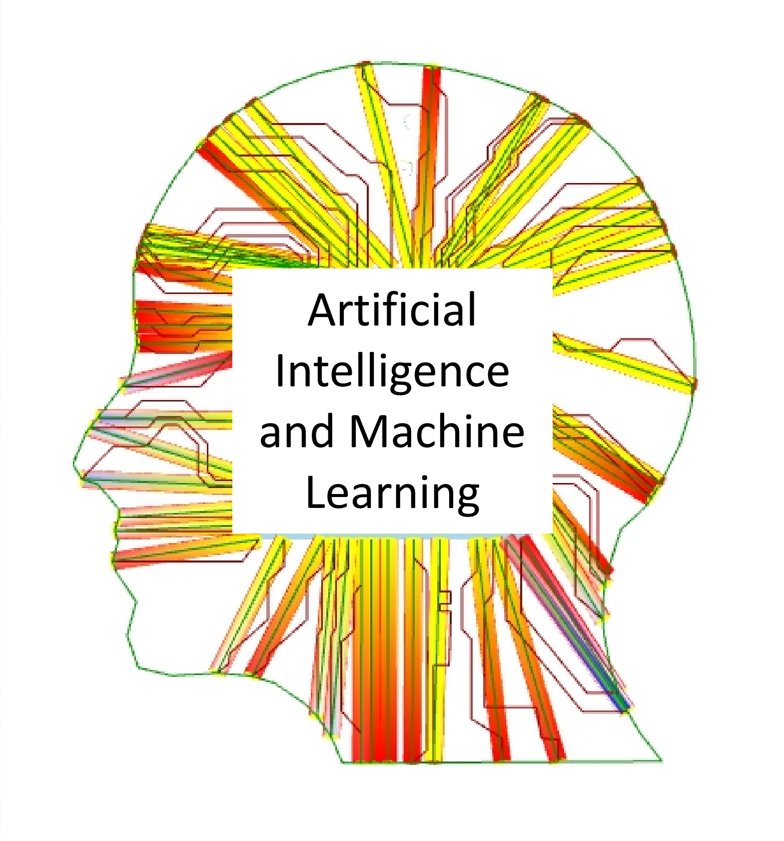


Artificial Intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs.

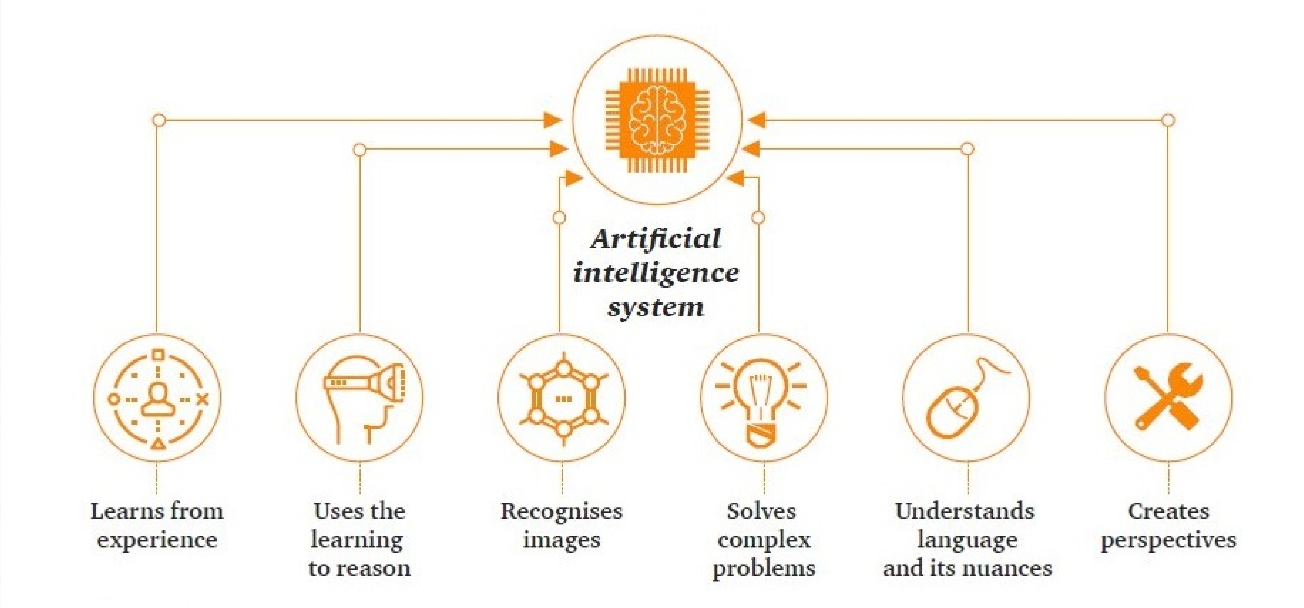
- John McCarthy, father of AI

Geospacial World: "What is Artificial Intelligence, Machine Learning and Deep Learning" By Meenal Dhande

What is AI?



What is AI?



Geospacial World: "What is Artificial Intelligence, Machine Learning and Deep Learning" By Meenal Dhande

Why use AI?

- In designing structures, there are many mundane and repetitive tasks that engineers are “overqualified” for. AI can automate those tasks. This allows engineers to spend their time being creative and solving problems.

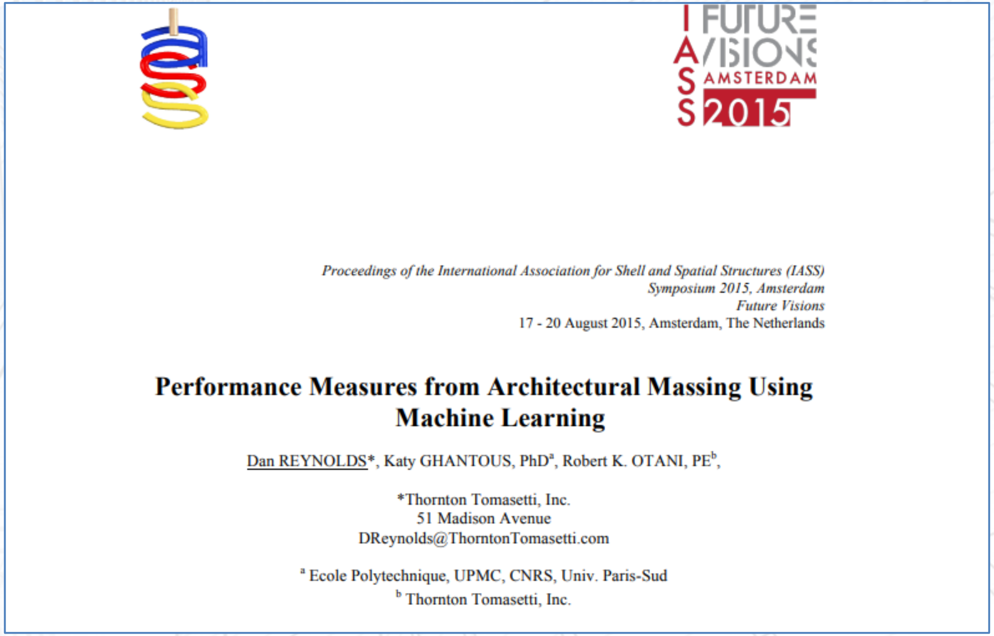
- AI can also automate QA/QC since it can find “outlier” patterns

Why use AI?

- AI can process millions of data points and therefore can understand patterns in engineering decision
- AI can be learning tool. AI can assist large firms by capturing institutional knowledge from the “experts” in firm and allow that knowledge to be at the fingertips of the younger engineers.

AI at Thornton Tomasetti

2015 Thornton Tomasetti published this research paper outlining the use of Machine Learning for the design of buildings at the 2015 Internation Shell and Spatial Structures symposium



IASS FUTURE VISIONS AMSTERDAM 2015

Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium 2015, Amsterdam Future Visions
17 - 20 August 2015, Amsterdam, The Netherlands

Performance Measures from Architectural Massing Using Machine Learning

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AI at Thornton Tomasetti

Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium 2015, Amsterdam
Future Visions

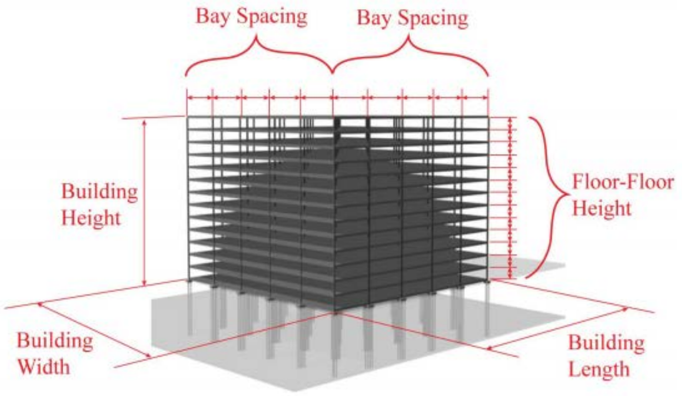


Figure 1: Geometric input parameters for embodied energy calculation.

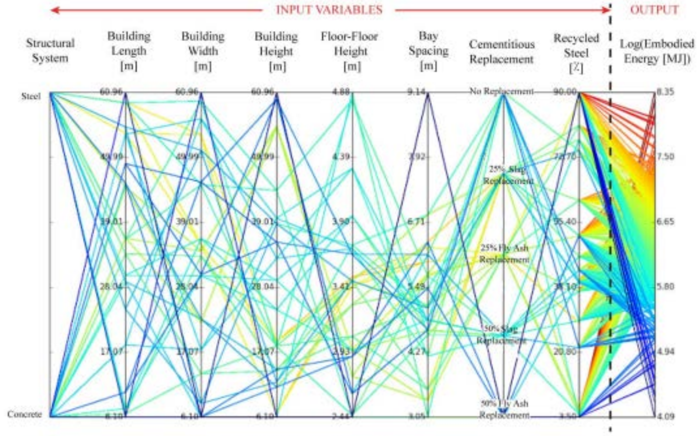


Figure 3: Parallel Coordinate Graph of Building Input Parameters and Total Embodied Energy.

AI and Automation

ASTERISK

"Asterisk" is a software application developed in CORE studio | Thornton Tomasetti as an ongoing research initiative to leverage AI/Machine Learning.

Asterisk

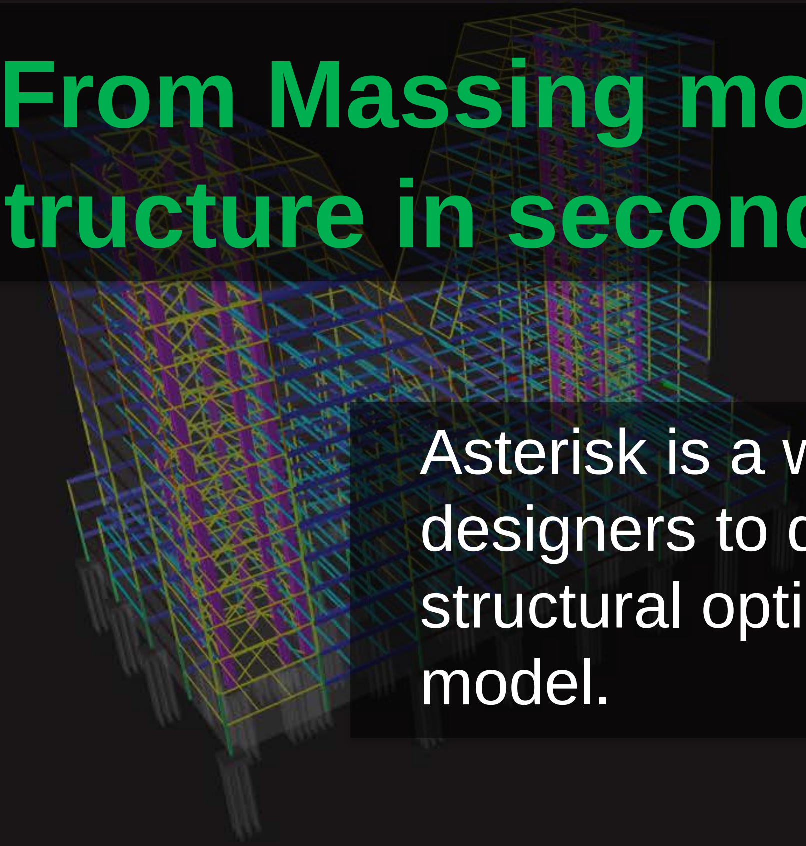
"Asterisk" is an application developed at Thornton Tomasetti that performs a structural design of a building in seconds.

The application uses Thornton Tomasetti past building design data and machine learning algorithms to "predict" structural member sizing for floor framing, columns, slabs, foundations, and core walls for both steel and concrete buildings as well as embodied energy metrics. Only a building massing is necessary.

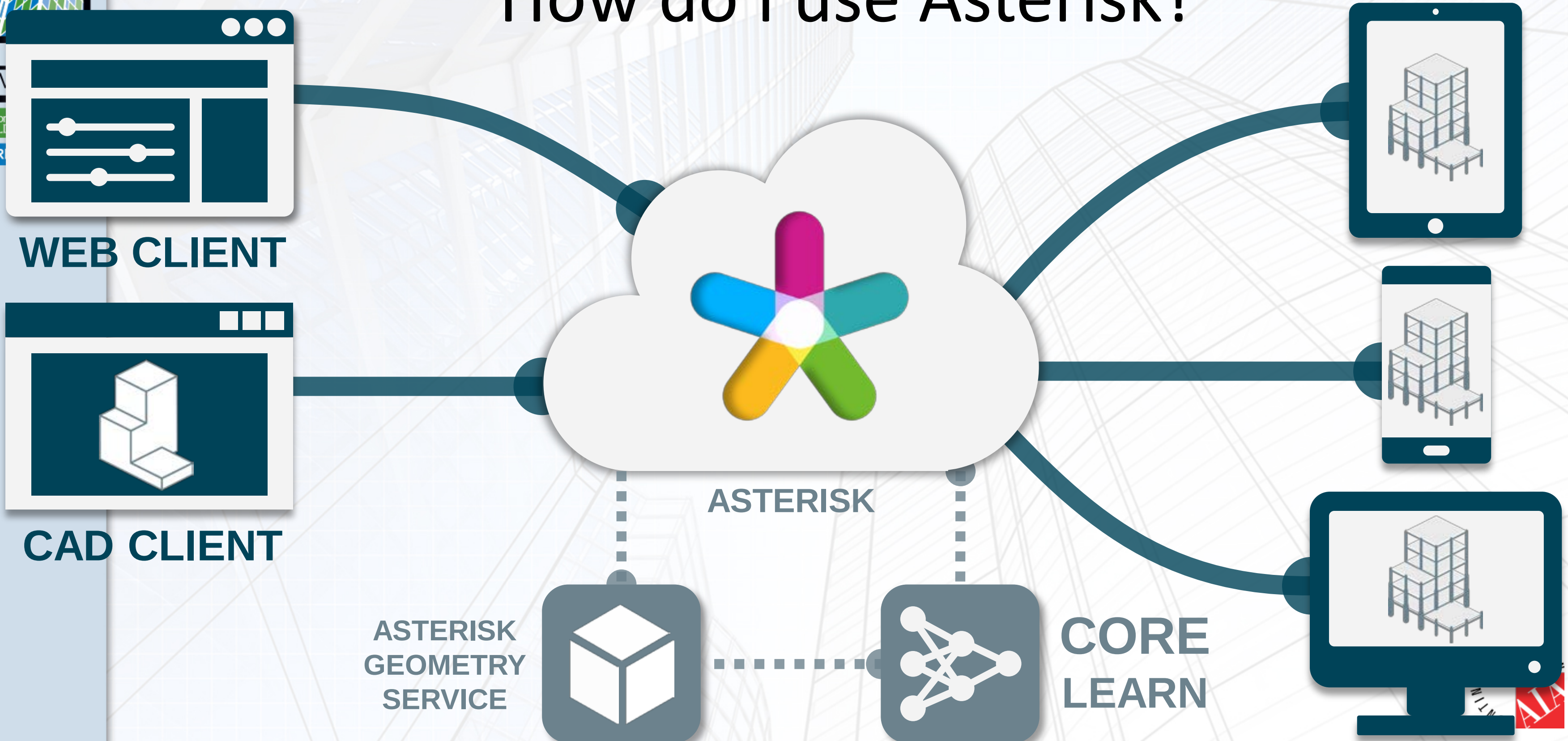
This speed of design and modeling is not possible otherwise. A single iteration would take a team of engineers a minimum of a week to provide the same level of design.

“From Massing model to Structure in seconds*

Asterisk is a web application that enables designers to develop, filter, and compare structural options from an uploaded massing model.

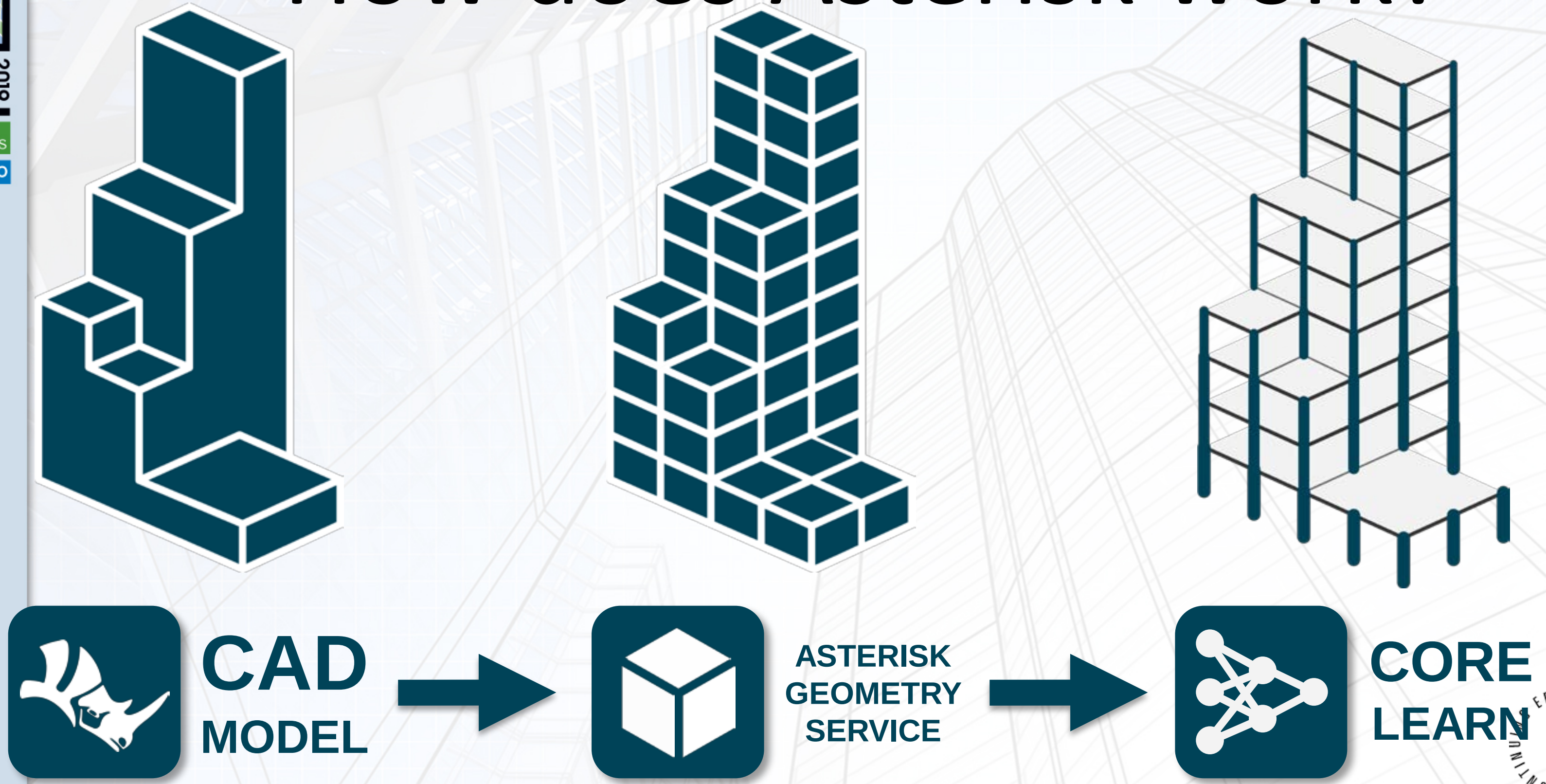


How do I use Asterisk?



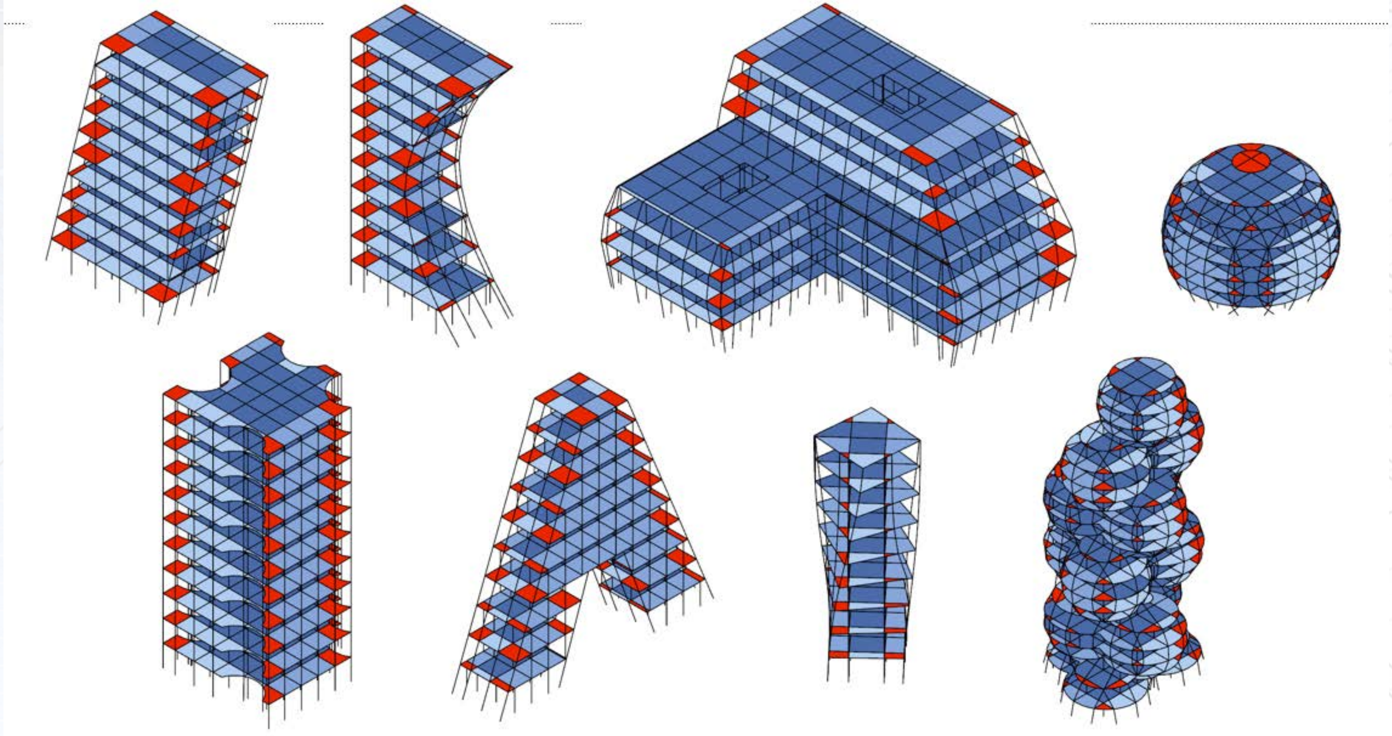
How does Asterisk work?

Asterisk Alpha



- Asterisk Alpha

How does Asterisk work?



ASTERISK GEOMETRY SERVICE

Why should I use Asterisk?

- Asterisk Alpha

FAST

Leveraging machine learning for rapid assessment and delivery of solutions.

ACCURATE

Built on Thornton Tomasetti's decades of applied industry knowledge

ROBUST

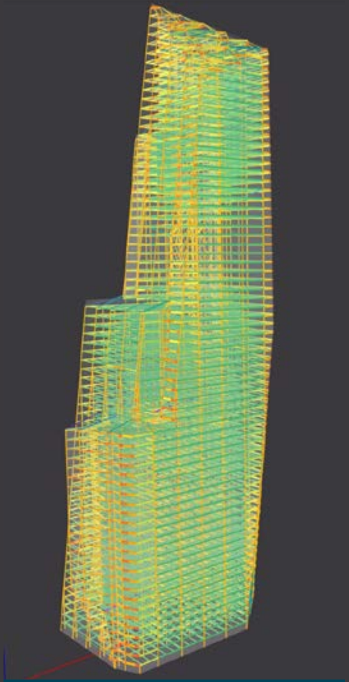
Asterisk provides comprehensive metrics for architects, developers, & engineers.

OPTIONEERING

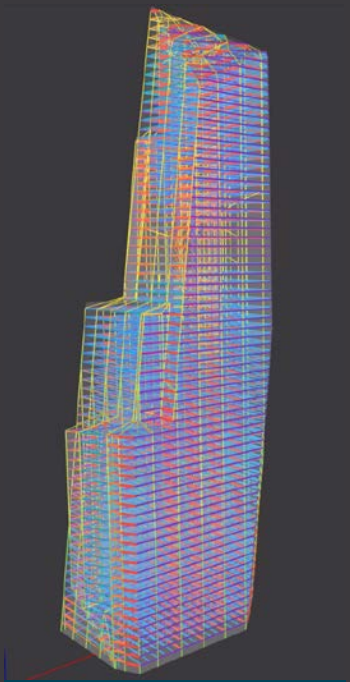
Asterisk is the designers app for structural optioneering

Analysis

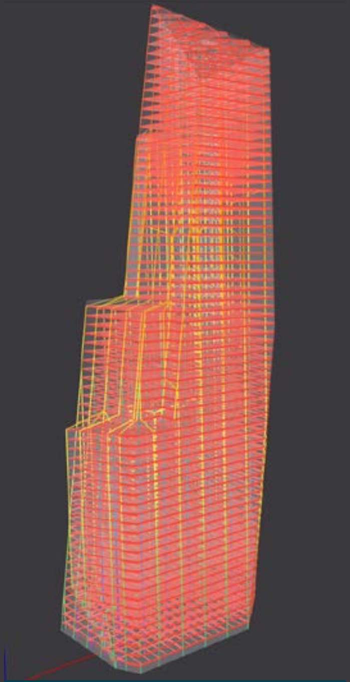
- Select Analysis Types



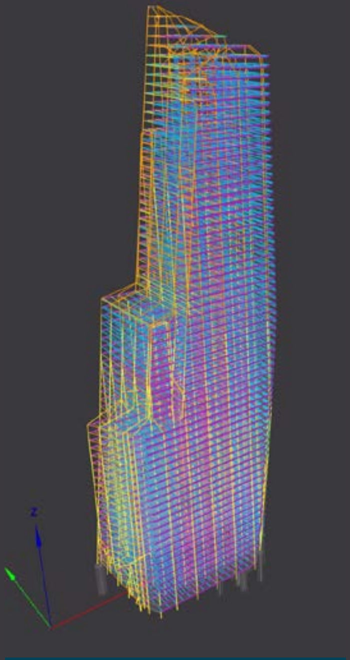
Length



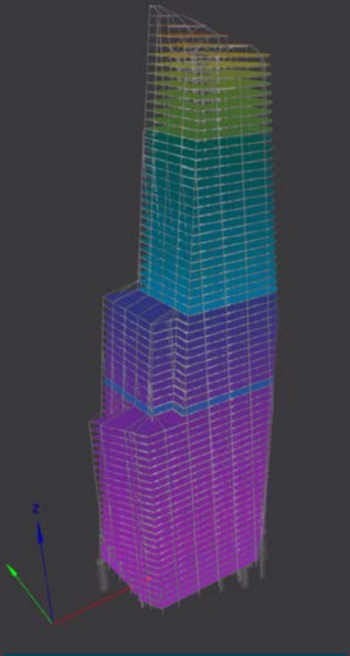
Profile



Trib Area



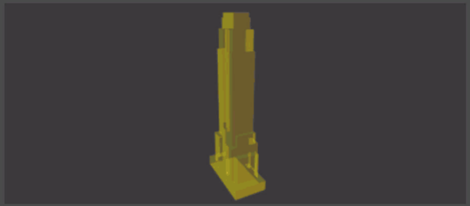
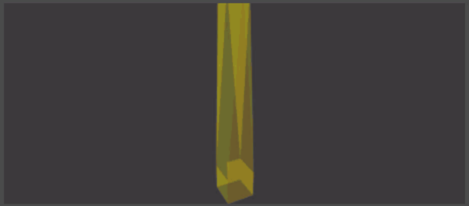
Depth



Floor Area

Asterisk *alpha* TOWERS Compare Modified: 02/22/2018

Compare Iterations

Iteration	2/22/18 9:25 PM - Sergey Pigach		2/22/18 9:20 PM - Sergey Pigach		2/22/18 9:16 PM - Sergey Pigach
					
Results					
Total Area (ft²)	2,738,191 ft²		3,615,440 ft²		4,749,613 ft²
Cost ($/ft²)	52 $/ft²		41 $/ft²		43 $/ft²
Embodied Energy (MJ/ft²)	318 MJ/ft²		243 MJ/ft²		254 MJ/ft²
Weight (lbs/ft²)	16 lbs/ft²		11 lbs/ft²		12 lbs/ft²
Rating					
Inputs	1 Massing		2 Massings		2 Massings
Facade Material	Metal Panel	Metal Panel	Metal Panel	Metal Panel	Metal Panel
Program	Office	Office	Office	Office	Office
Floor-to-floor height	12.5 ft	12.5 ft	12.5 ft	12.5 ft	12.5 ft
Grid: X dimension	35.1 ft	35.1 ft	35.1 ft	35.1 ft	35.1 ft
Grid: Y dimension	29.9 ft	29.9 ft	29.9 ft	29.9 ft	29.9 ft

Thu 09:16 PM - Thu 09:32 PM

Compare Iterations

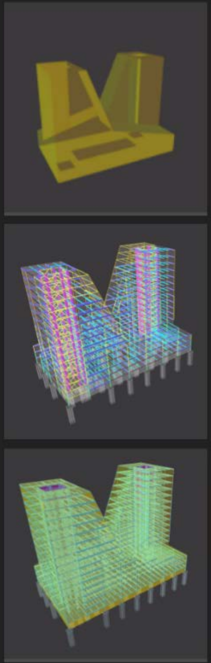
Reports

Asterisk *alpha* — Iteration Cut Sheet

Project: Handan Mountains

Document Created on: 01.10.18 | 5:55 p.m. (-5 gmt)

Option 1: Dual Mountain Scheme



Project	
Program	Office
Total Height	180 ft
Total Floors	15
Flr-Flr	12 ft
Gross Area	392,862 ft2
Facade Area	100,256 ft2

Engineering	
System	Steel
Slabs	Composite Deck
Foundation	Pilings
Core	Steel Braced
Grid: X dimension	30.0 ft
Grid: Y dimension	30.0 ft

Performance	
Cost	42 $/ft2
Steel Cost	10% (Typical)
Concrete Cost	30
Weight	12 lbs/ft2
Embodied Energy	222 MJ/ft2
Complexity	10% (Typical)

Asterisk *alpha* — Iteration Comparison Report

Project: Handan Mountains

Document Created on: 01.10.18 | 5:55 p.m. (-5 gmt)

Dual Mountain Scheme

Option 1

Program	Office	392,862	46	299	14
Flr-Flr	12.5 ft				
No Floors	15				
Grid: X dimension	30.0 ft				
Grid: Y dimension	30.0 ft				
Facade Material	Metal Panel				

Option 2

Program	Office	421,375	46	310	15
Flr-Flr	11 ft				
No Floors	17				
Grid: X dimension	30.0 ft				
Grid: Y dimension	30.0 ft				
Facade Material	Metal Panel				

Option 3

Program	Office	353,584	46	270	13
Flr-Flr	13.0 ft				
No Floors	14				
Grid: X dimension	30.0 ft				
Grid: Y dimension	30.0 ft				
Facade Material	Metal Panel				

Total Area	Cost	Energy	Weight
ft2	$/ft2	MJ/ft2	lbs/ft2

Asterisk *alpha* — Project Comparison Report

Project: Handan Mountains

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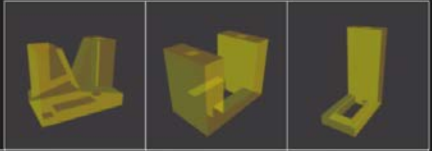
Handan Mountain Schemes



Results	Mountains	Book Ends	Iconic Tower
Total Area (ft2)	328,375	392,862	320,873
Cost ($/ft2)	46	34	46
Embodied Energy (MJ/ft2)	299	222	301
Weight (lbs/ft2)	14	9	14
Rating			

Inputs	1 Massing	3 Massing	1 Massing
Facade Material	Metal Panel	Metal Panel	Metal Panel
Program	Office	Office	Office
Floor-to-floor height	12.5	12.5	12.5
Grid: X dimension	35.1	35.1	35.1
Grid: Y dimension	29.2	29.2	29.2

Iteration Cut Sheet

Massing Comparisons

Project Comparisons

AI and Automation

DAMAGE DETECTOR

"Damage Detector" is an application that process building structural damage to be found and documented by using image recognition AI

Damage Detector

What damage can AI detect?

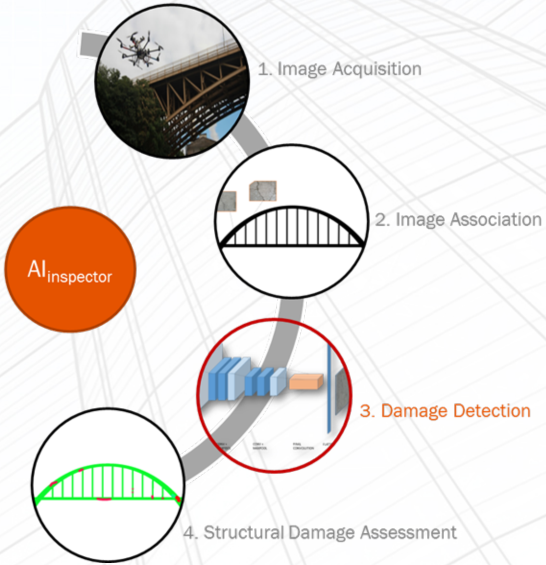
Anything a human inspector can find by visual inspection!

- Cracks, spalls, exposed rebar, (concrete/masonry)
- Moisture ingression, mold, (stucco)
- Corrosion, cracking, buckling (steel)
- Rot (wood) etc. etc.

Damage Detector

How does it work?

- Supervised learning of deep convolutional neural nets on lots of labeled images
- Leverages pre-trained models for faster training



Damage Detector

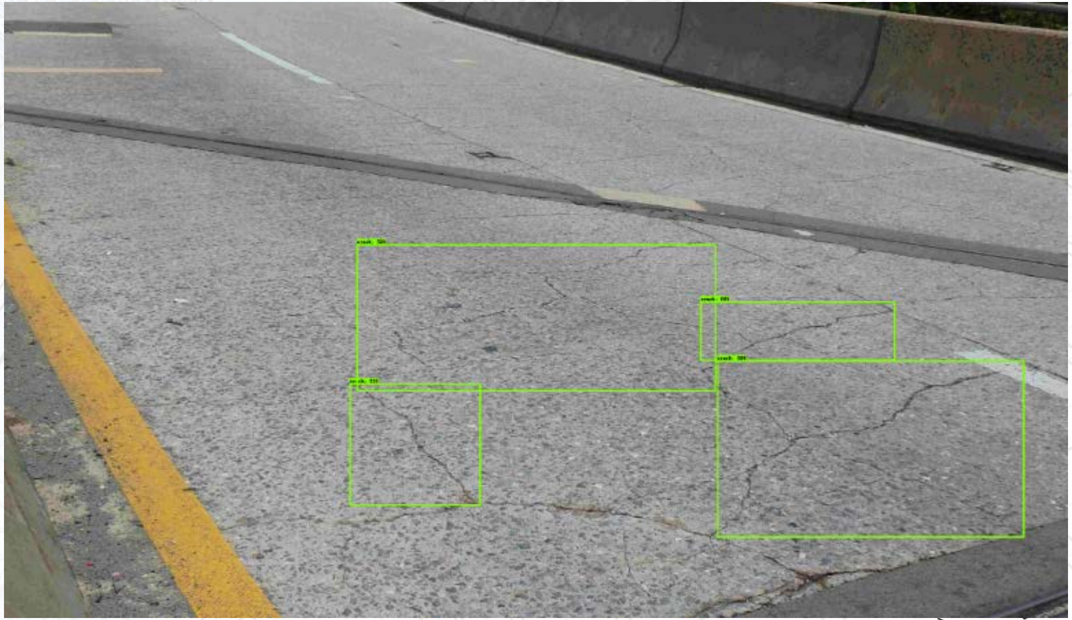
How does it work?

- Using just images, types of damage can be found using AI

Damage Detector

How does it work?

- We will be able to inspect structures faster, more frequently, and in areas where people may be otherwise at risk.



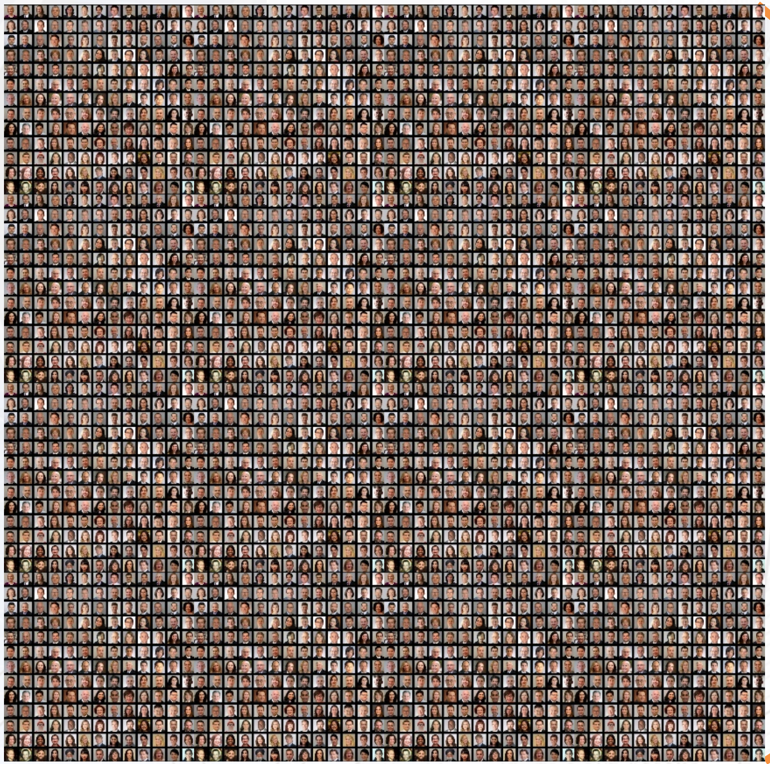
Damage Detector

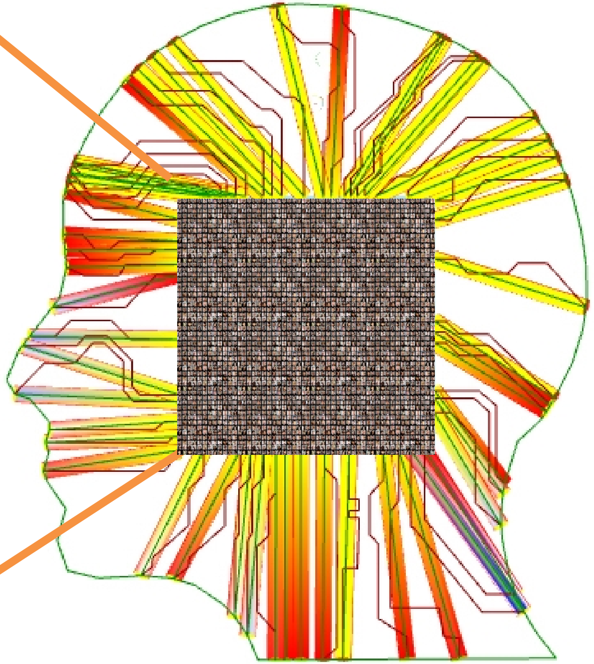
Future Plans

- Integrate with 3D photogrammetry (via drone-captured imagery) to build a *3D digital twin* of inspected structure including damage zones

Image courtesy: geocue.com

What if the entirety of your firms' knowledge was accessible in an app?





In Summary

- 20-30% of current engineering workflows can be automated using AI
- AI can increase productivity by automating engineering tasks
- AI can learn to assist checking our work to find errors
- AI can find trends and learn from large data (engineering/financial) sets quickly that can assist engineers to manage projects more efficiently and make key decisions faster
- AI can process domain knowledge of engineering firms and enable knowledge capture from generations of engineers

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This concludes The American Institute of Architects Continuing Education Systems Course

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