2026/4/28 演講 @臺北市建築師公會

智慧建造

設計到建造一體化的數位轉型之路

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Professor in Program of Techno Art
Vice-CEO in RAC-Coon workshop
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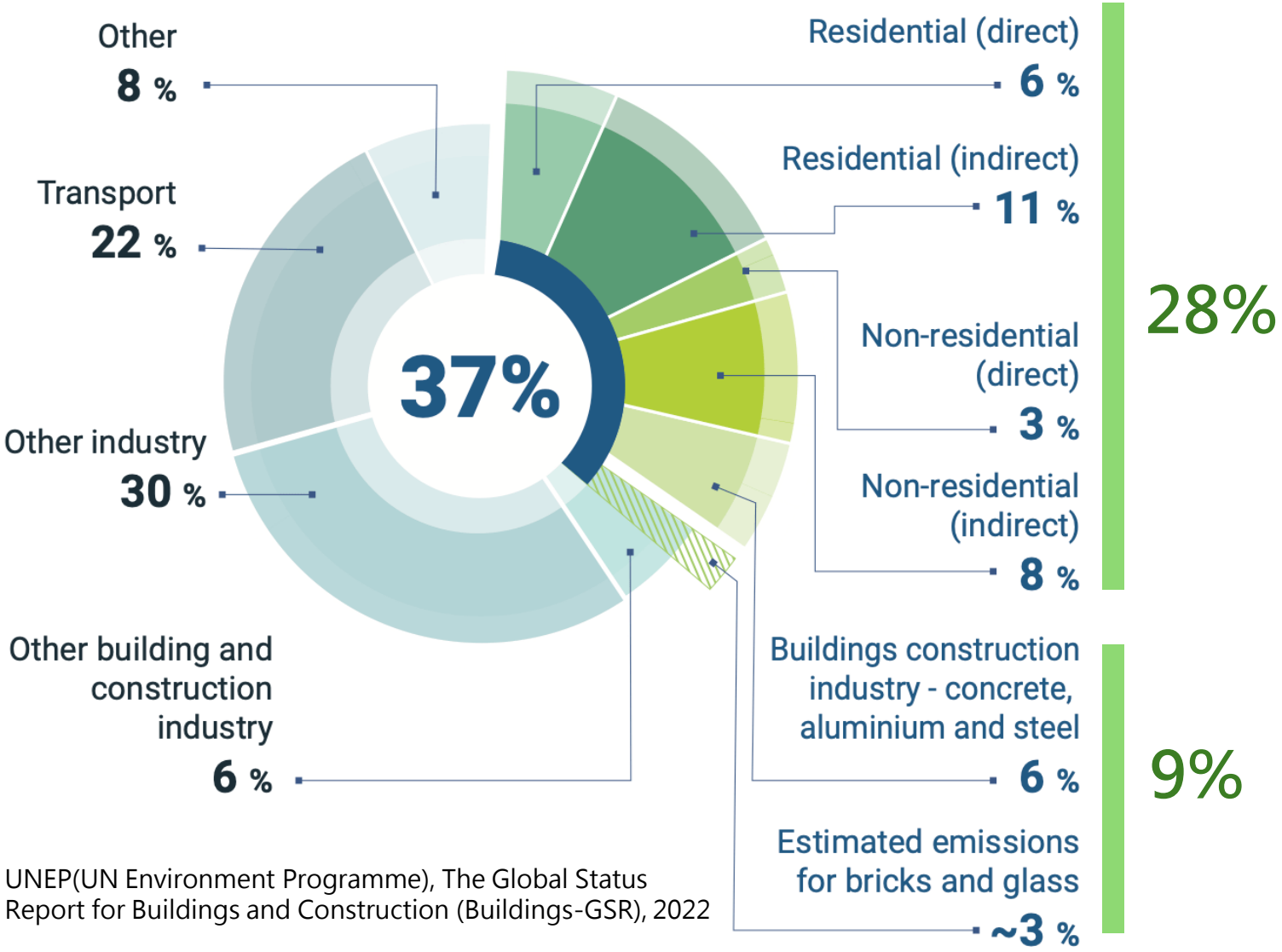
沈揚庭


AI
設計
淨零
轉型
建築工程營建產業的困境與轉型
缺工
少子
機器
取代

全球碳排類型占比 carbon emission 2022

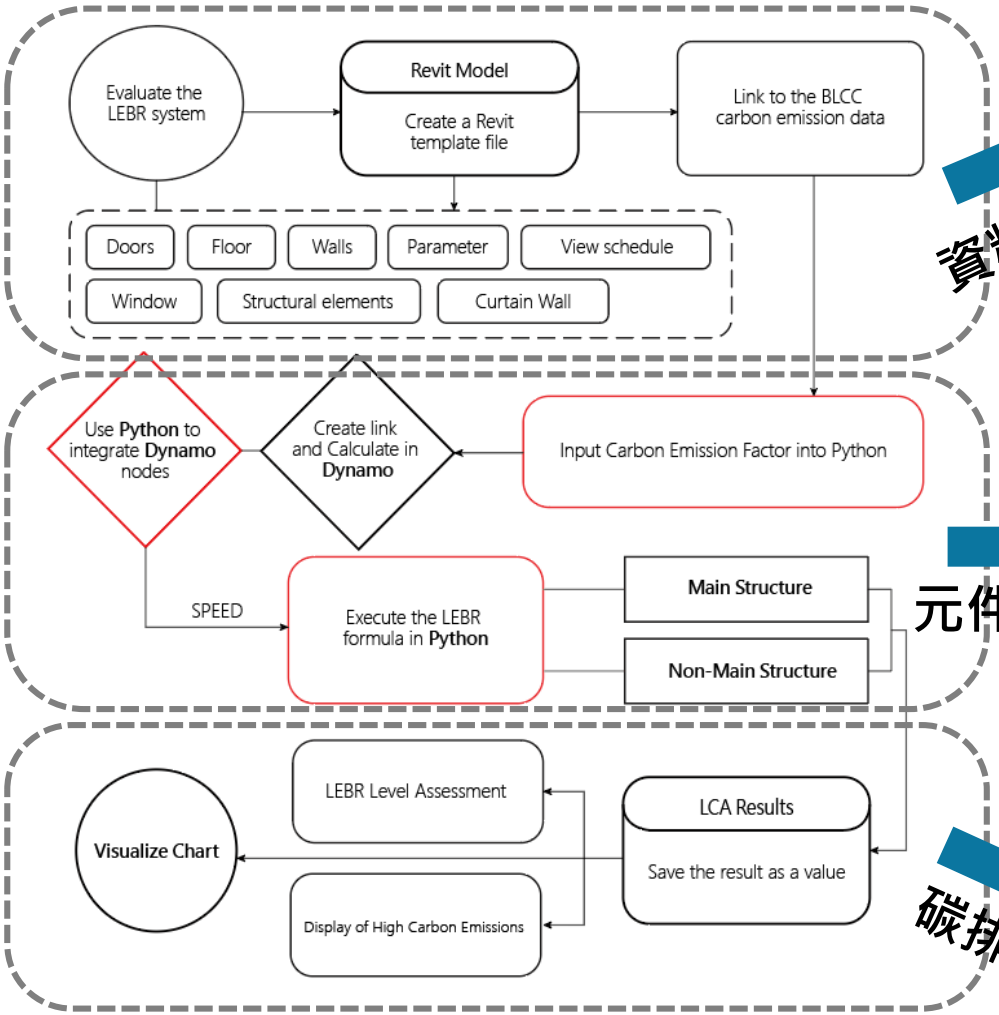


UNEP(UN Environment Programme), The Global Status Report for Buildings and Construction (Buildings-GSR), 2022

蘊含碳排揭露

- **三維化**
  運用3D模型正確帶入材質元件及其碳排資料庫，使操作流程與產出結果能以空間視覺化呈現
- **自動化**
  將計算流程與材料元件透過編程方法進行整合，內化繁瑣計算流程，自動化完成碳排計算
- **圖表化**
  碳排計算產出數據全面圖表化，降低認知負荷，並能實時連動3D模型變動即時更新

既有建築蘊含碳計算



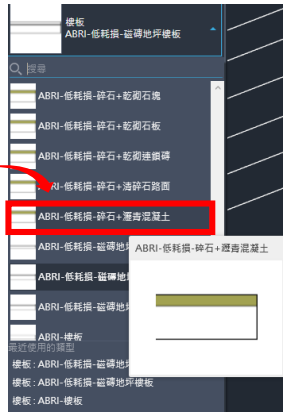
資料建材化

元件參數化

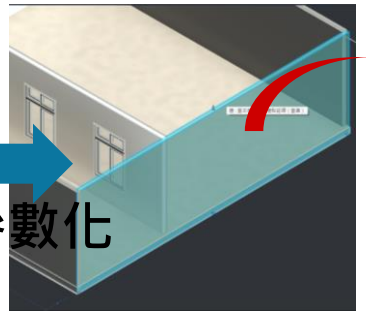
碳排視覺化

碳排資料庫

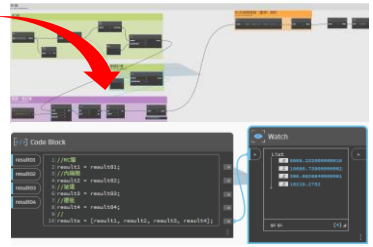
REVIT元件



Revit元建抽取

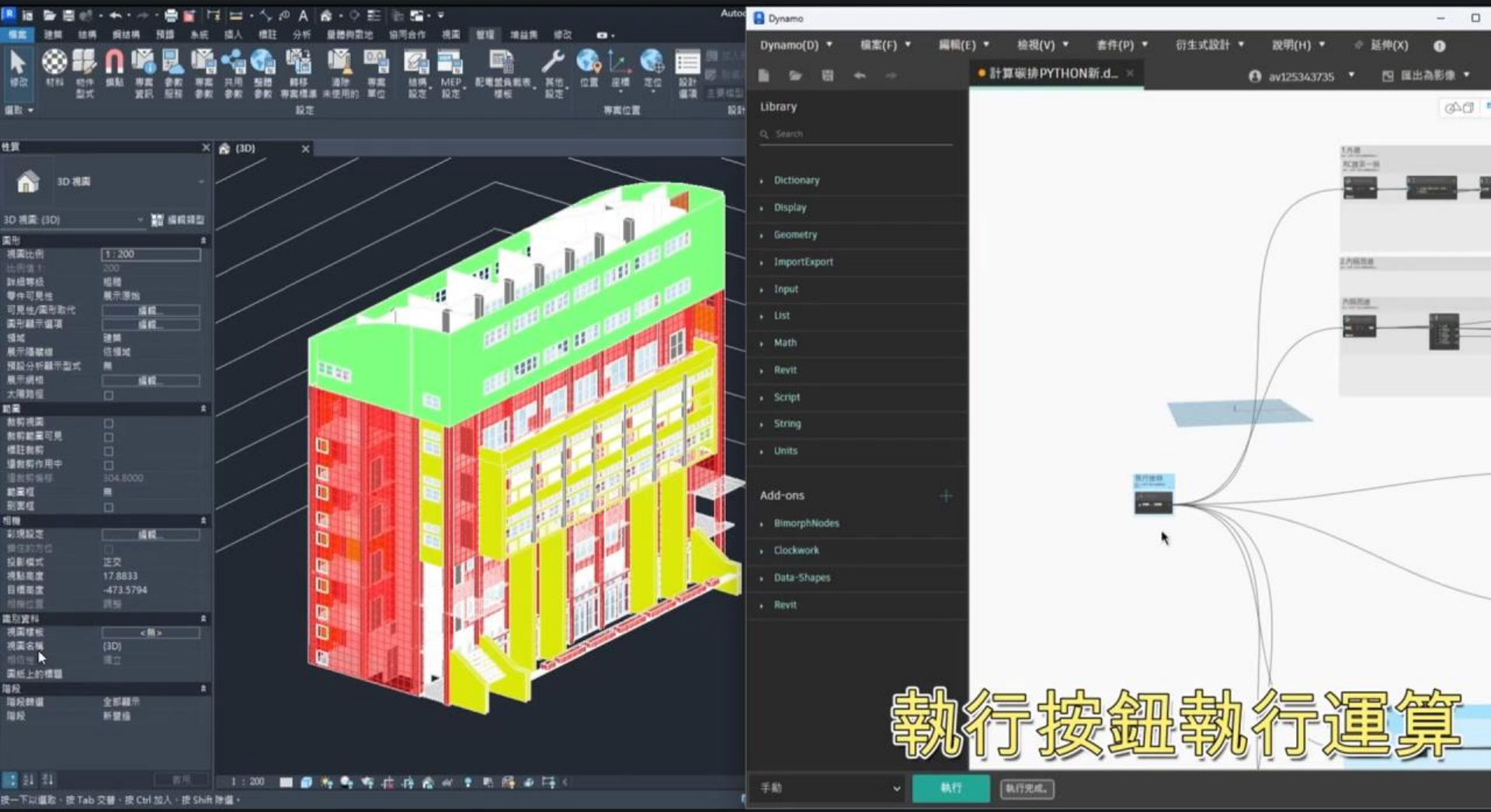


Dynamo匯流計算



Revit參數匯流

視覺化碳揭露-16%

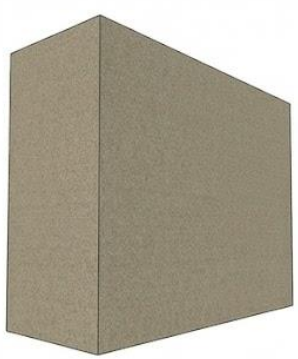

Dynamo
Library
Search
Dictionary
Display
Geometry
ImportExport
Input
List
Math
Revit
Script
String
Units
Add-ons
BimorphNodes
Clockwork
Data-Shapes
Revit
手動
執行
執行完成。
執行按鈕執行運算

設計即碳評
Design As Carbon

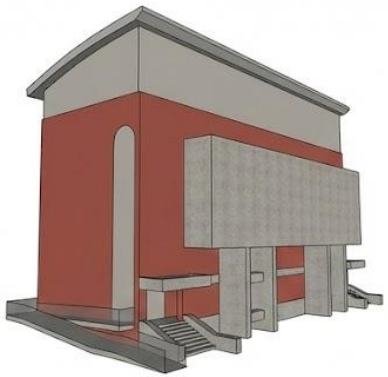
1.Pre Design
（量體雛型階段）
建築形狀
建築類型
建築功能

2.Concept Design
（概念設計階段）
建築的結構安排
結構類型
跨距變化

3.Schematic Design
（初設設計階段）
建築材料配置
建築構件
建築的開窗



LOD 0



LOD 100

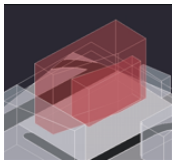
LOD 200

LOD 300

LOD 400

LOD 500

初設階段即時蘊含碳計算 BIMAC

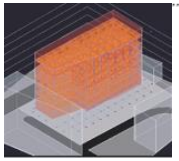


Stage：Pre Design

LOD0

Impact Factor：Mass

Result interval：Large



Stage：Concept Design

LOD100

Impact Factor：Strusture

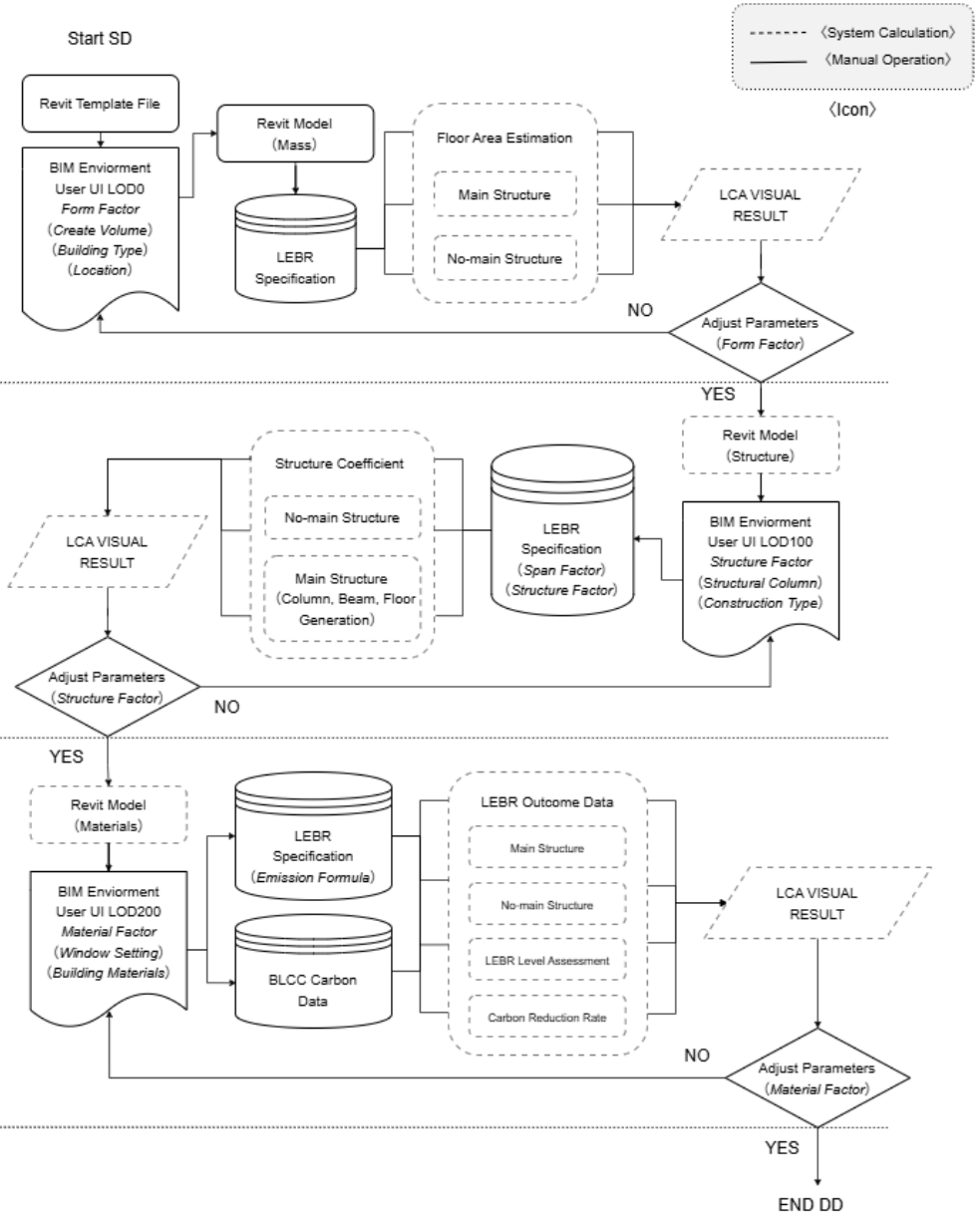
Result interval：Miduim

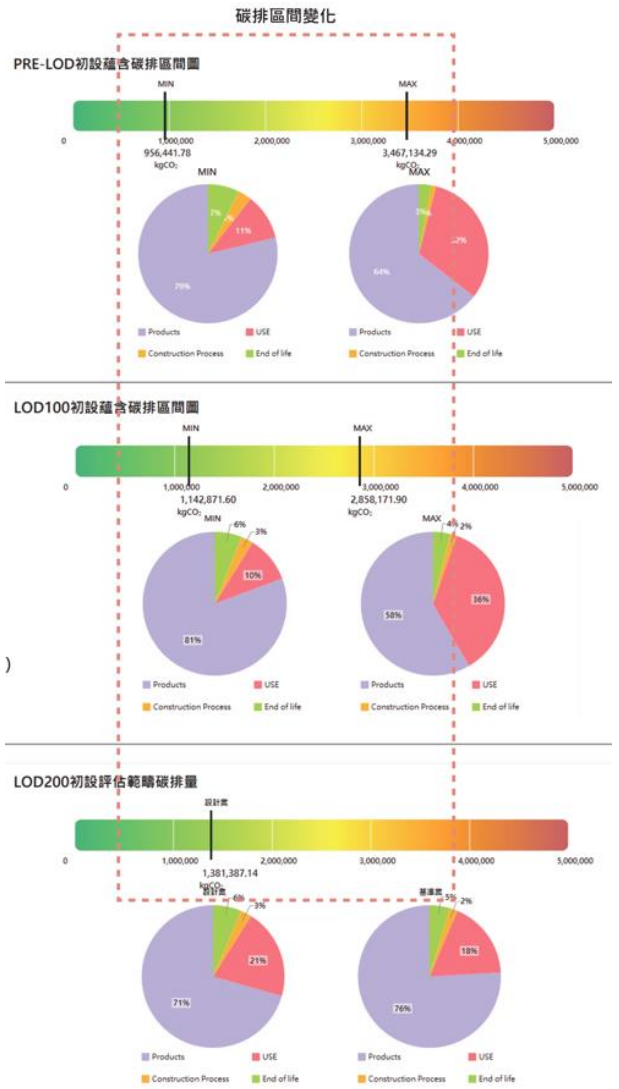
Stage：Schematic Design

LOD200

Impact Factor：Material

Result interval：Small





BIM-Integrated Auto-Carbon Decision-Support System

AI演算的核心價值

EMPOWER

AI演算的實體化

BIM

缺工
少子

機器
取代


三階段年齡人口變動趨勢
單位：萬人
800
700
600
500
400
300
200
100
0
707
728
726
683
709
656
584
471
265
213
203
176
2020
2025
2030
2040 年
45-64歲
25-44歲
15-24歲
資料來源：2020年國發會人口統計

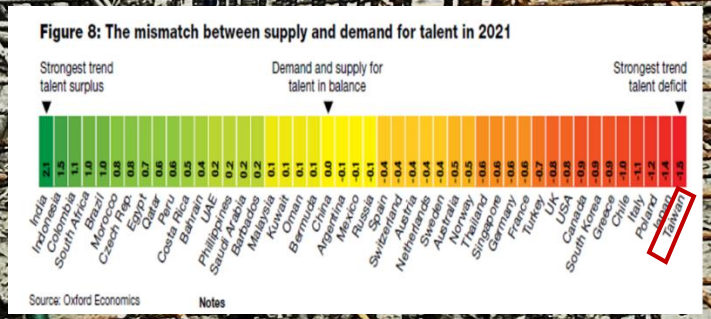
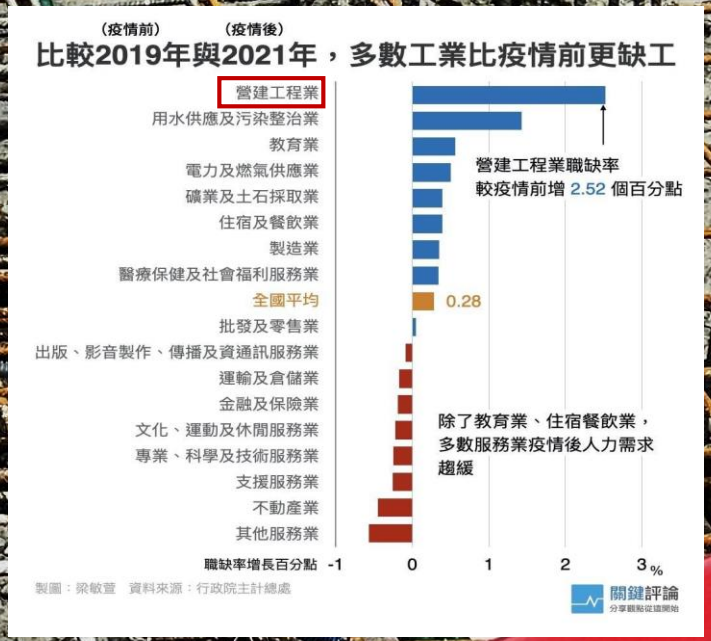
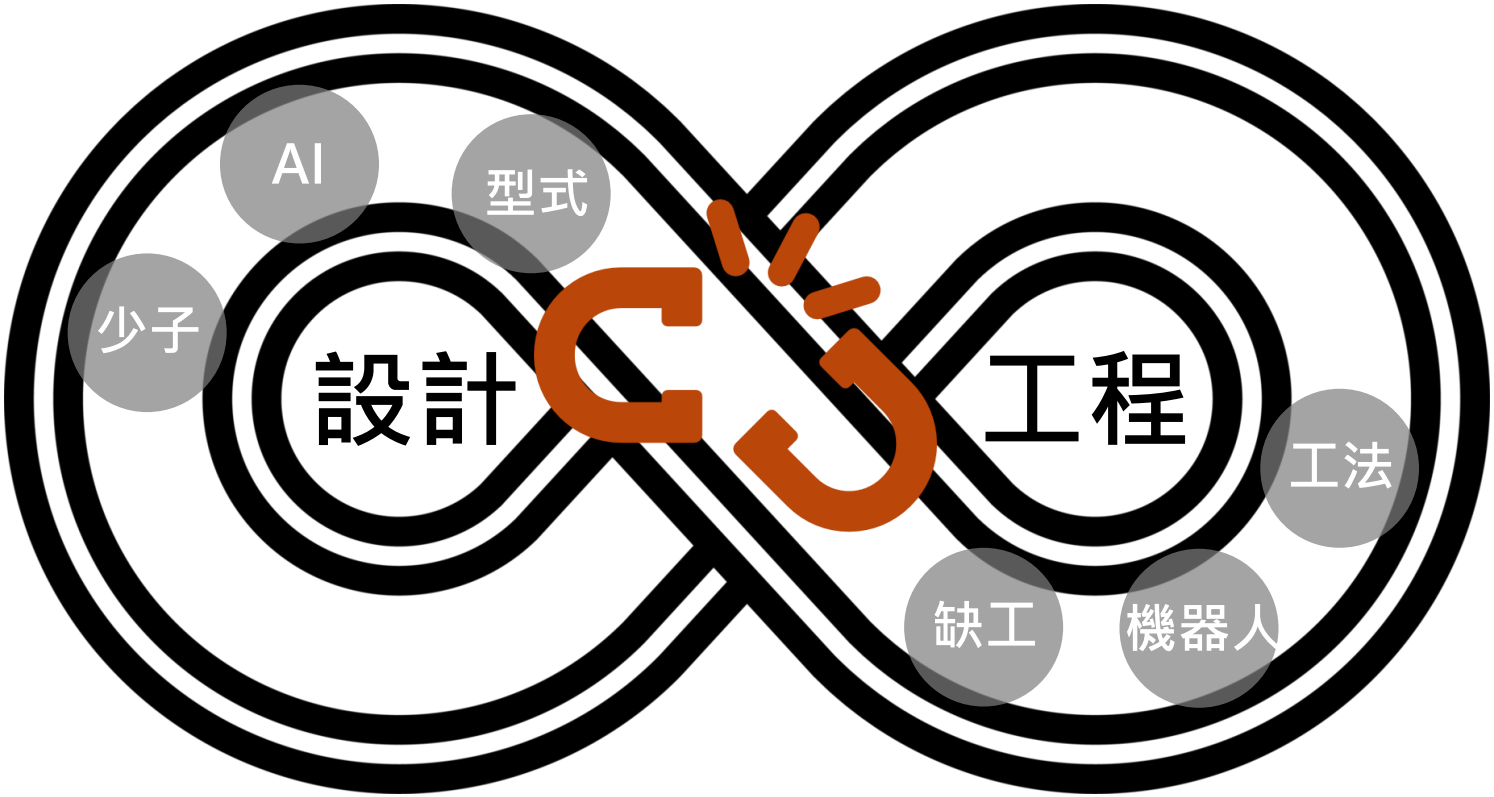
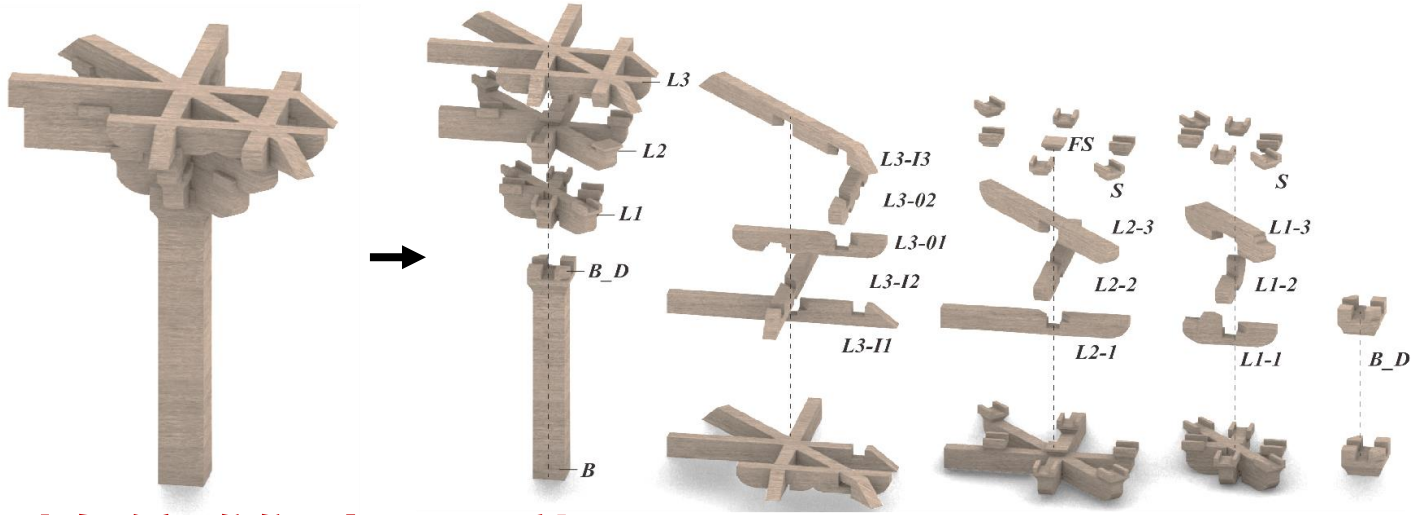


Figure 8: The mismatch between supply and demand for talent in 2021
Strongest trend talent surplus
Demand and supply for talent in balance
Strongest trend talent deficit
India
Indonesia
Colombia
South Africa
Brazil
Morocco
Czech Rep.
Egypt
Qatar
Peru
Costa Rica
Bahrain
UAE
Philippines
Saudi Arabia
Barbados
Malaysia
Kuwait
Oman
Bermuda
China
Argentina
Mexico
Russia
Spain
Switzerland
Austria
Netherlands
Sweden
Australia
Norway
Thailand
Singapore
Germany
France
Turkey
UK
USA
Canada
South Korea
Greece
Chile
Italy
Poland
Japan
Taiwan
Source: Oxford Economics
Notes


(疫情前)
(疫情後)
比較2019年與2021年，多數工業比疫情前更缺工
營建工程業
用水供應及污染整治業
教育業
電力及燃氣供應業
礦業及土石採取業
住宿及餐飲業
製造業
醫療保健及社會福利服務業
全國平均
批發及零售業
出版、影音製作、傳播及資通訊服務業
運輸及倉儲業
金融及保險業
文化、運動及休閒服務業
專業、科學及技術服務業
支援服務業
不動產業
其他服務業
營建工程業職缺率
較疫情前增 2.52 個百分點
0.28
除了教育業、住宿餐飲業，
多數服務業疫情後人力需求
趨緩
職缺率增長百分點
-1
0
1
2
3%
製圖：梁敏萱　資料來源：行政院主計總處
關鍵評論
分享觀點從這開始


AI
型式
少子
設計
CI
工程
工法
缺工
機器人

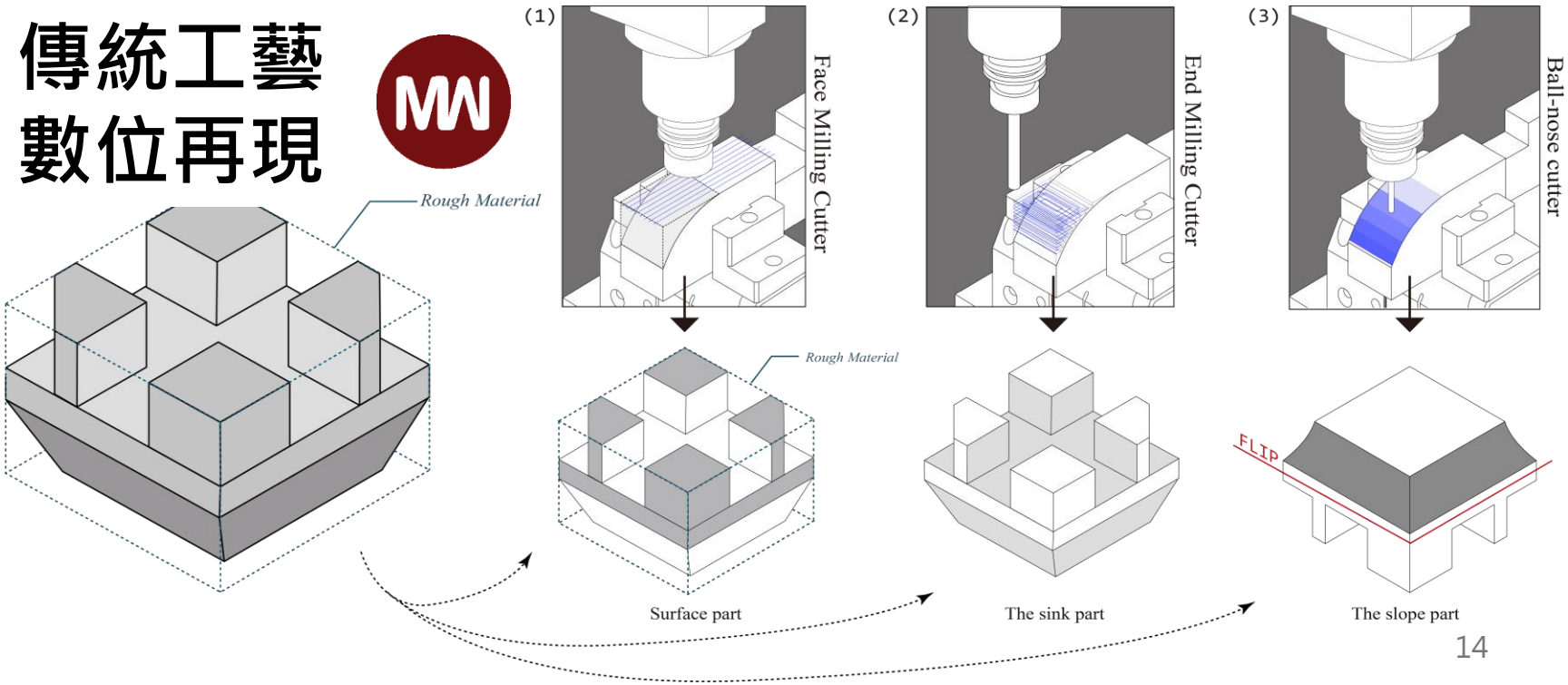

數位
雙生
設計為建造
Design for Build
設計到建造的一體化

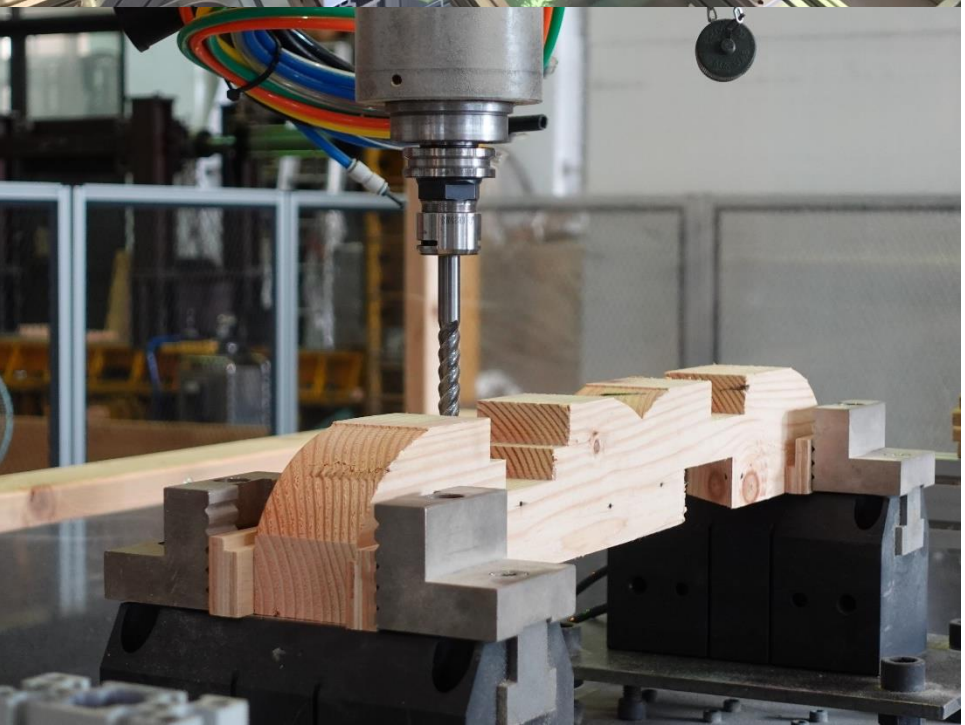


	Name	Assemble order
1	Zhu	B
2	Da-Dou	B_D
3	Ni-Dao	−L1-1
4	Hua-gong	−L1-2
5	Hua-gong	−L1-3
6	sheng	−S
7	Ni-Dao	—L2-1
8	Hua-gong	—L2-2
9	Hua-gong	—L2-3
10	sheng	—S
11	Pin-sheng	—FS
12	Ni-Dao	—— L3-I1
13	Hua-gong	—— L3-I2
14	Ni-Dao	—— L3-01
15	Hua-gong	—— L3-02
16	Hua-gong	—— L3-I3

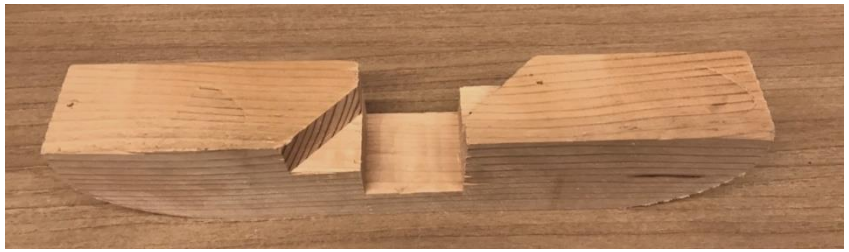
數位雙生驅動

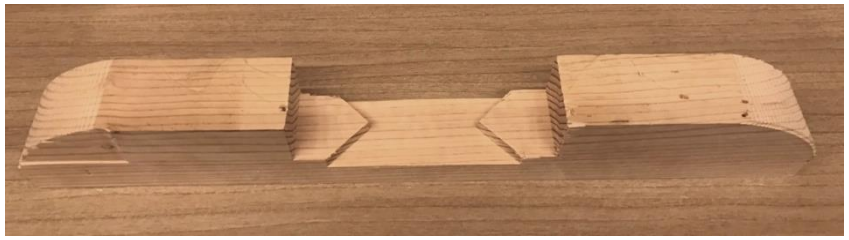
傳統工藝
數位再現

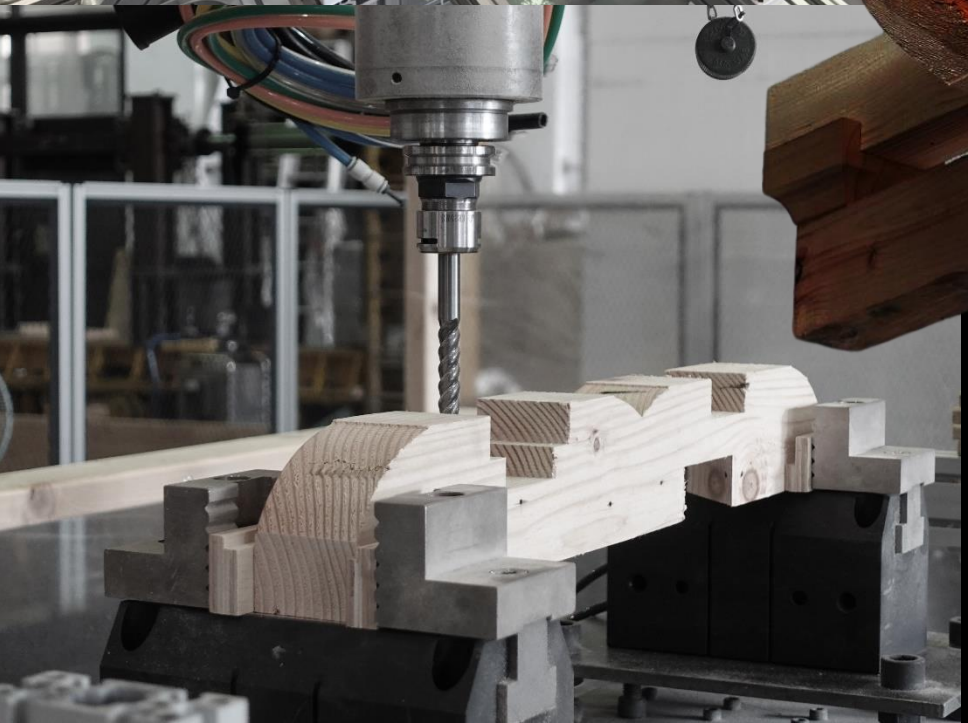


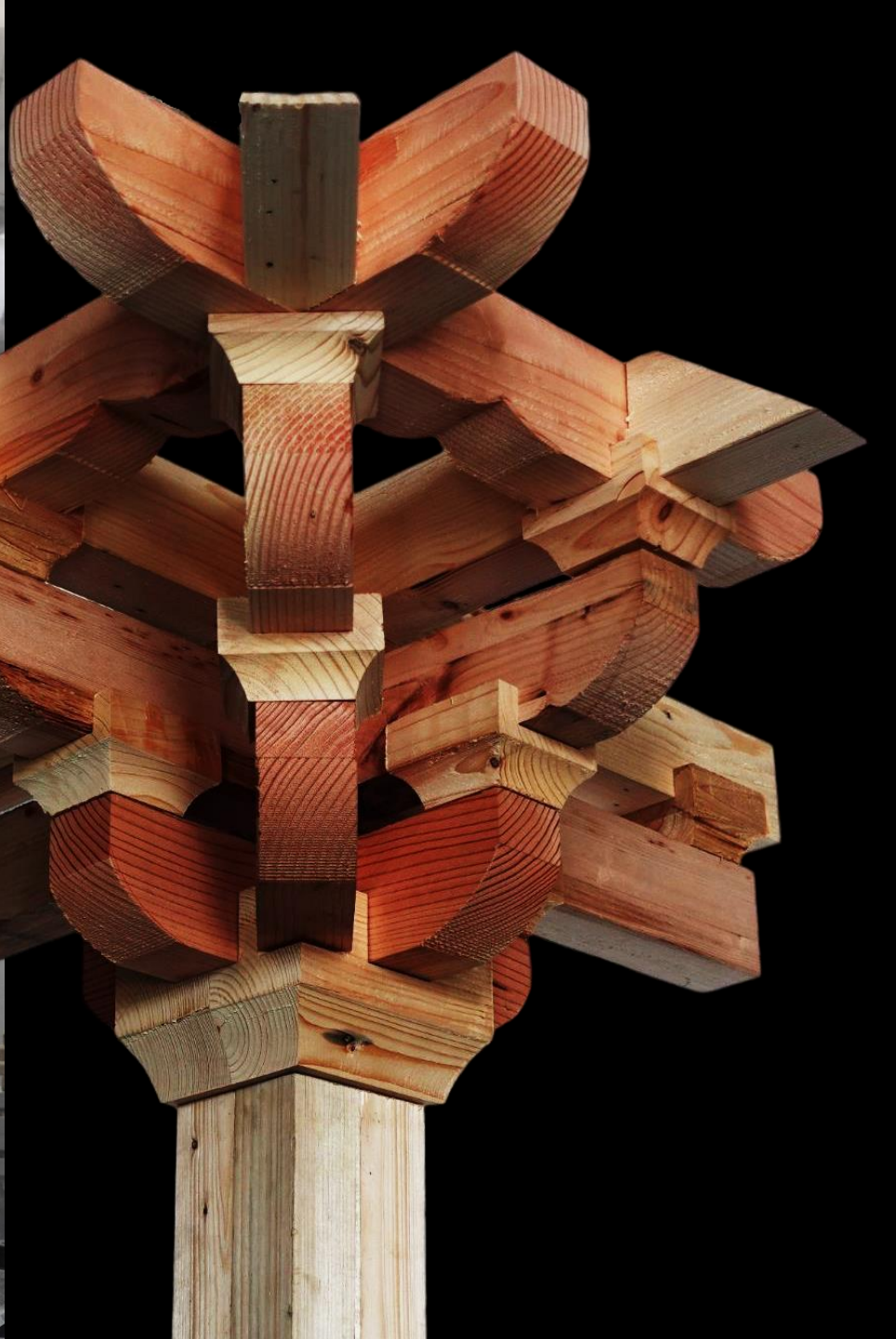


Digital Craft via Robot



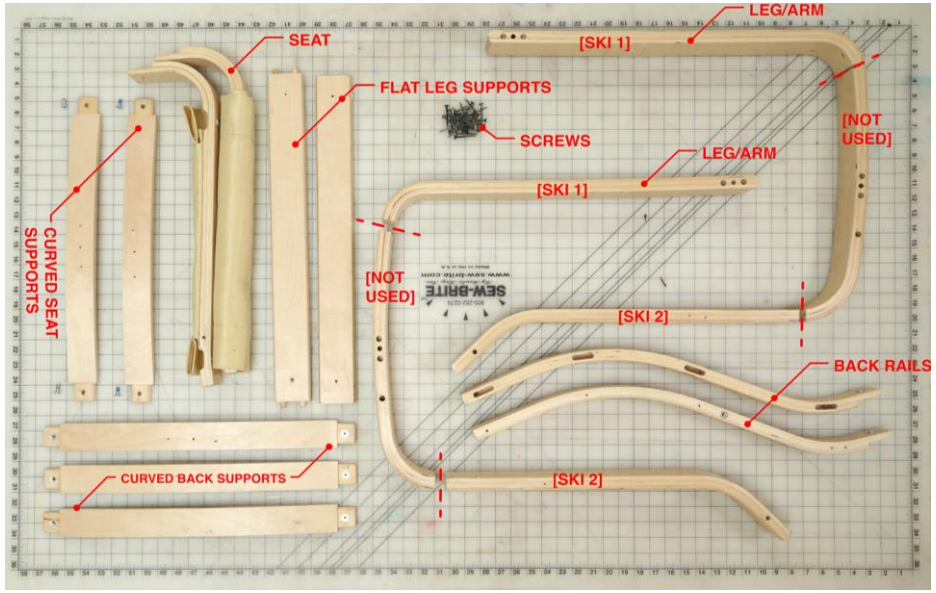


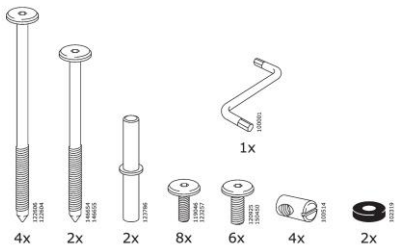


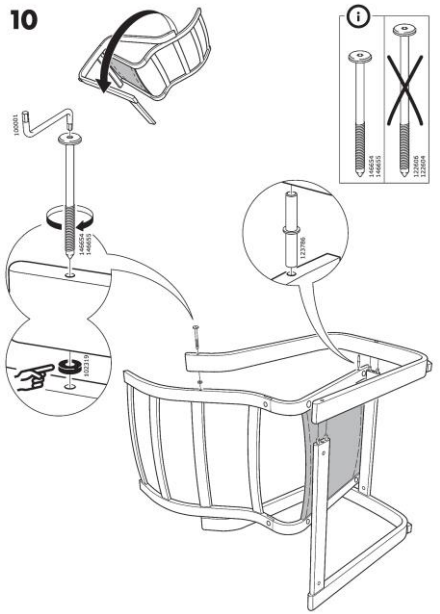


智慧建造
Smart Build
設計到製造的一體化流程

像組IKEA一樣簡單


SEAT
LEG/ARM
[SKI 1]
FLAT LEG SUPPORTS
SCREWS
[NOT USED]
LEG/ARM
[SKI 1]
CURVED SEAT SUPPORTS
[NOT USED]
[SKI 2]
BACK RAILS
CURVED BACK SUPPORTS
[SKI 2]


1x
4x
2x
2x
8x
6x
4x
2x

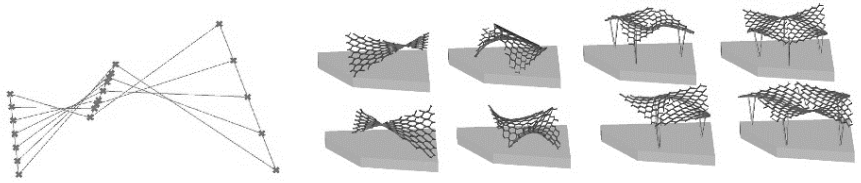

10


WAVE EAVES
波簷

Design for Build Process

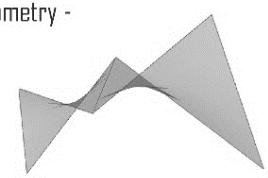
Form Finding

Hyperbolic Paraboloid Shape Finding - Curve

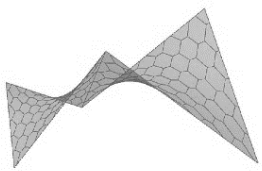


Pattern Deploy

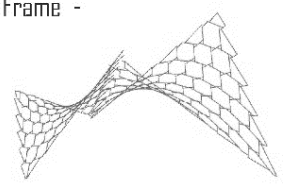
Create Geometry - Surface



Meshing - Mesh

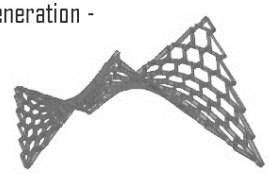


Reciprocal Frame - Curve



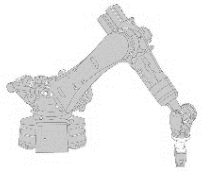
Element Generation

Member Generation - Mesh



Digital Fabrication

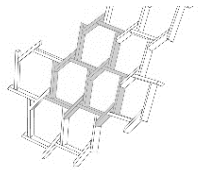
Fabrication



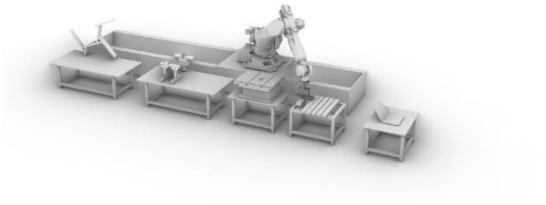
Auto Assembly

自動組裝

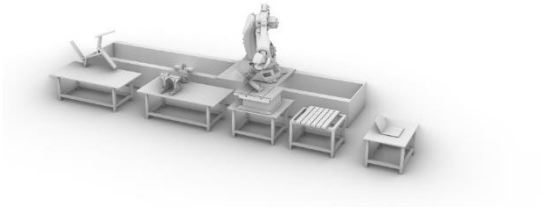
Assembly

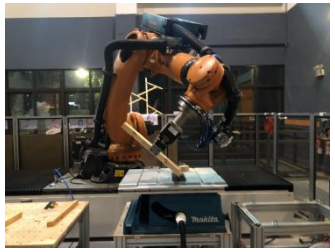


Digital Twin for
Robotic Arm Fabrication Workflow

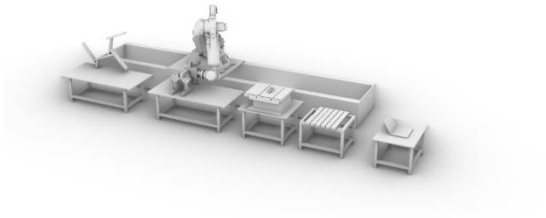


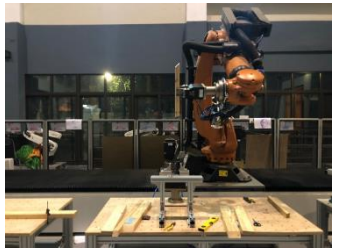
STEP 1　一次夾取



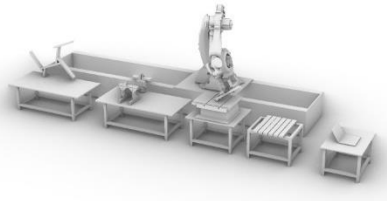


STEP 2　一次削切





STEP 3　二次夾取



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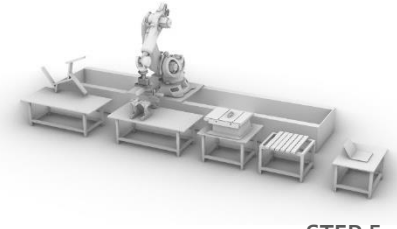
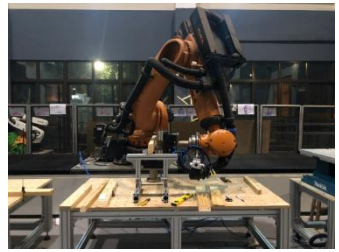
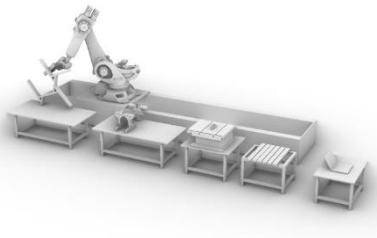
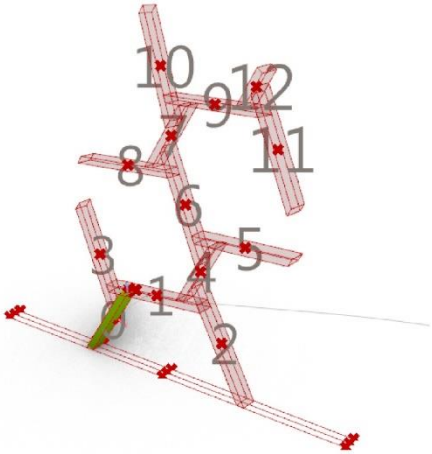




STEP 5　三次夾取



STEP 6　組裝



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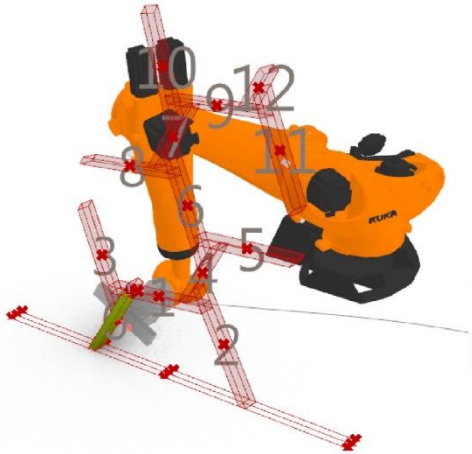
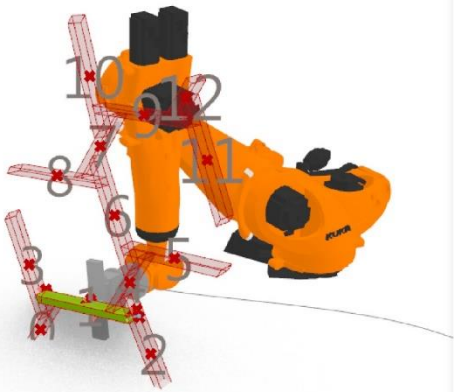


2



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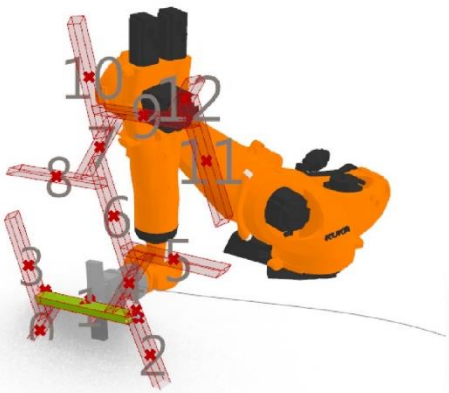
Digital Twin for Auto-Assembly



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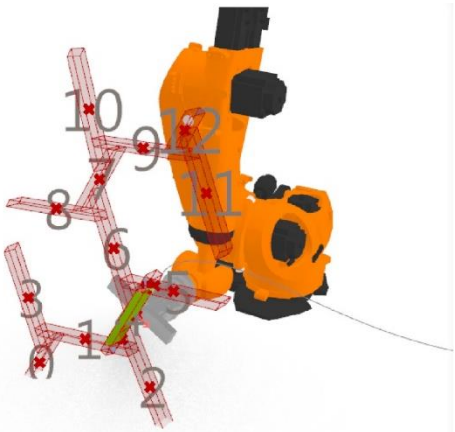

6


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Wave Eaves

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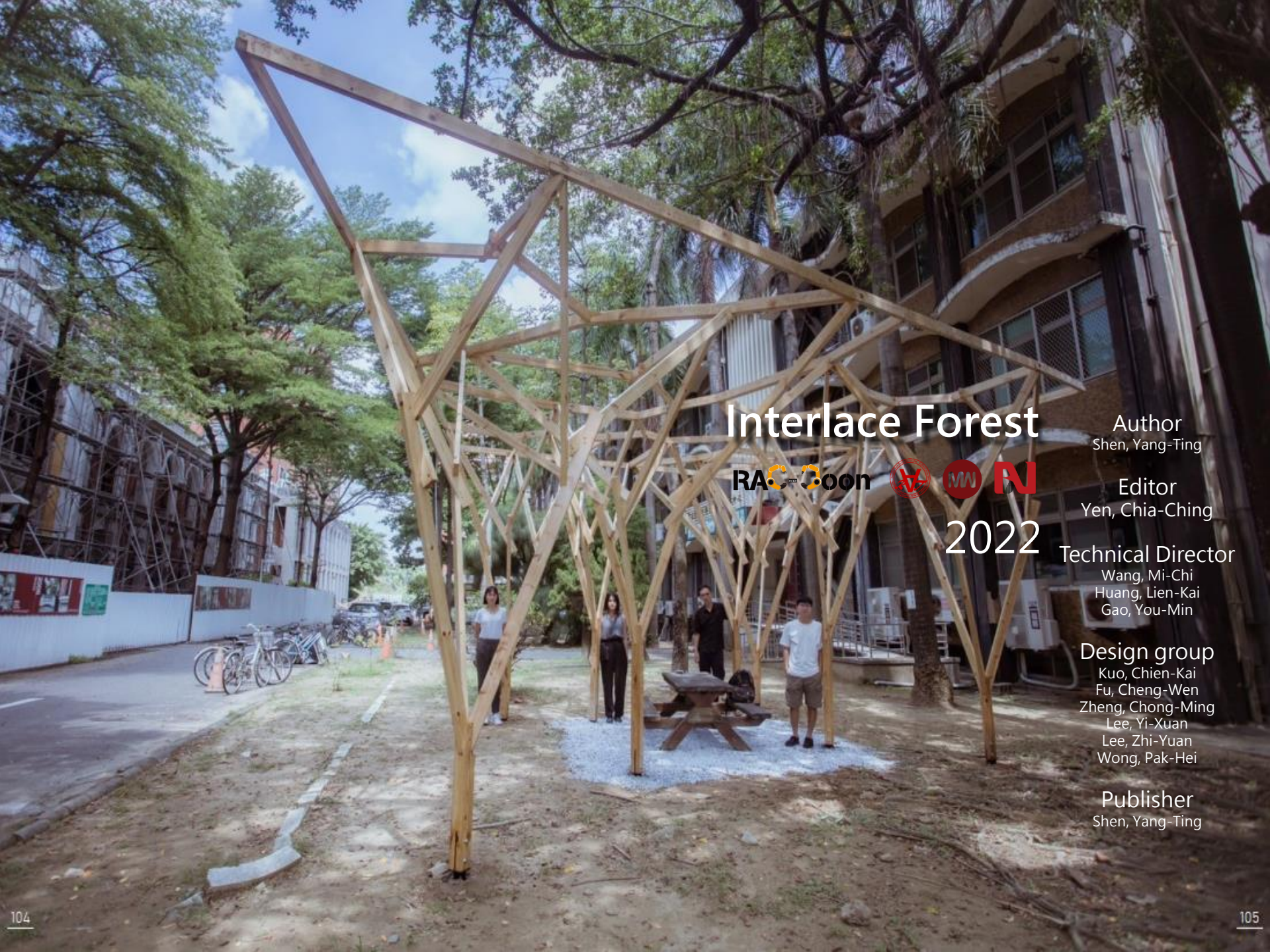

Interlace Forest

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THE VEIN OF FALLEN LEAVES

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RC>80%

免拆模RC

表 2: 無機聚合磚抗壓強度與齡期關係（河砂組）

齡期（天）	試體編號	飛灰：爐石粉比例			
		1:1	1:2	1:3	1:4
1	1	250	-	328	-
	2	~~310~~	-	341	-
	3	241	-	~~248~~	-
	平均值	246	-	335	-
3	試體編號	1:1	1:2	1:3	1:4
	1	486	-	617	-
	2	504	-	642	-
	3	~~428~~	-	594	-
	平均值	495	-	617	-
7	試體編號	1:1	1:2	1:3	1:4
	1	479	-	~~316~~	-
	2	~~296~~	-	~~185~~	-
	3	511	-	524	-
	平均值	495	-	524	-

表 1: 無機聚合磚抗壓強度與齡期關係（磚砂組）

齡期（天）	試體編號	飛灰：爐石粉比例			
		1:1	1:2	1:3	1:4
1	1	408	513	528	516
	2	358	~~405~~	~~449~~	515
	3	318	520	503	~~332~~
	平均值	361	517	516	516
3	試體編號	1:1	1:2	1:3	1:4
	1	523	566	672	606
	2	461	514	648	670
	3	383	596	618	-
	平均值	492	559	646	638
7	試體編號	1:1	1:2	1:3	1:4
	1	~~366~~	~~633~~	~~639~~	718
	2	556	719	745	798
	3	612	708	764	~~618~~
	平均值	584	714	755	758

表 3: 高早強無機聚合磚平均抗壓強度比較

齡期（天）	組別	飛灰：爐石粉比例			
		1:1	1:2	1:3	1:4
1	磚砂組	361	517	516	516
	河砂組	246	-	335	-
	磚砂組/河砂組	1.47	-	1.54	-
3	磚砂組	492	559	646	638
	河砂組	495	-	617	-
	磚砂組/河砂組	0.99	-	1.05	-
7	磚砂組	584	714	755	758
	河砂組	495	-	524	-
	磚砂組/河砂組	1.18	-	1.44	-

低碳建材

材料-無機聚合混凝土 Geopolymer Concrete

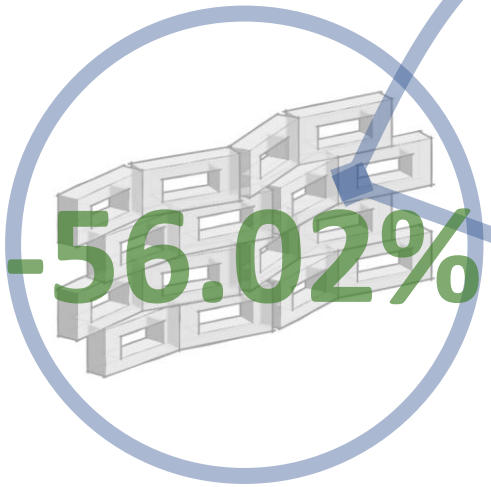
本主題主要目標是發展具備低碳高強度的磚體建材，用以取代傳統高耗能高環境衝擊的水泥磚體。具體作法以飛灰、爐石、鹼液等以及建築廢棄材料磚砂混和調製出具備無水泥且高強度的低碳漿體並進行磚體的灌模成形製造。

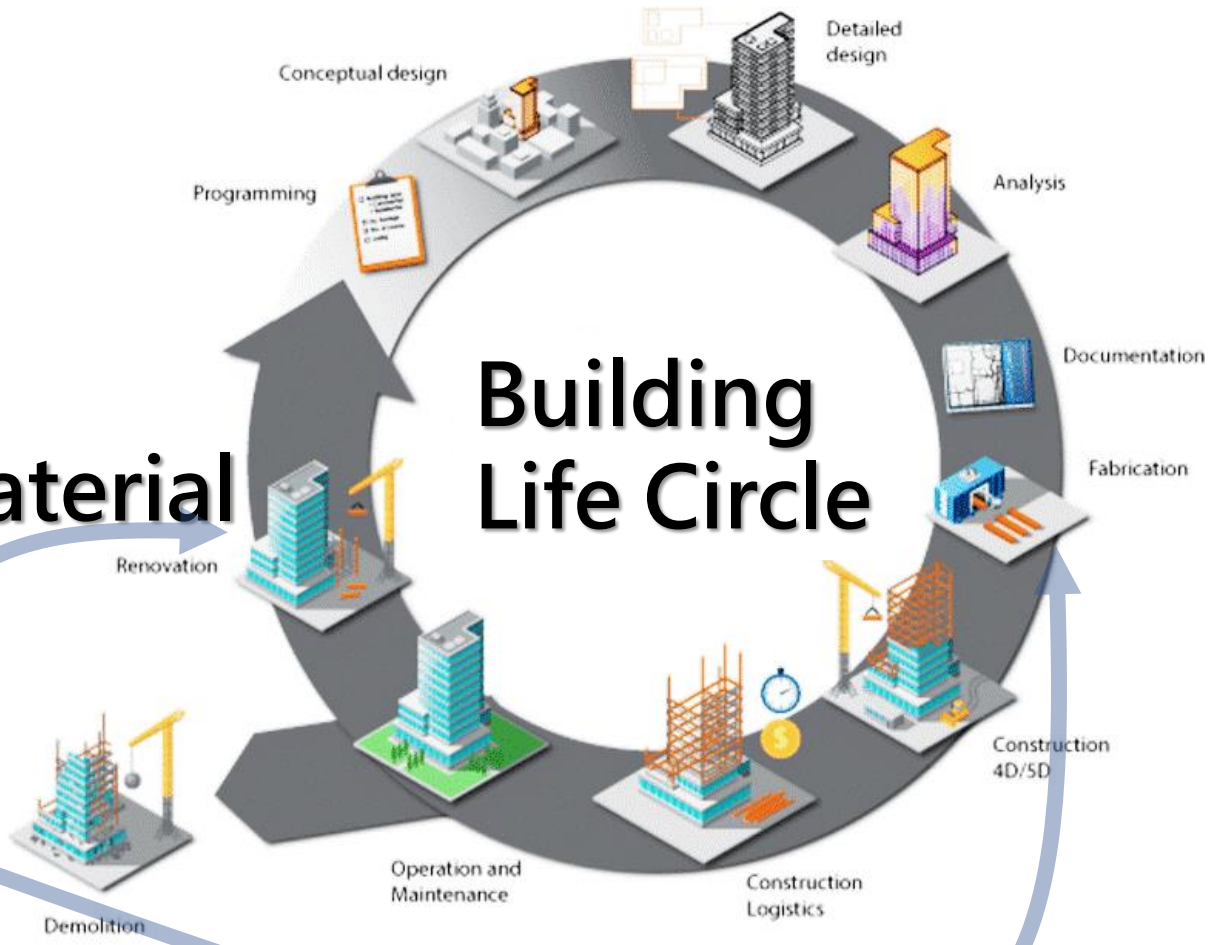
無機聚合混凝土是水泥含量為0%的混凝土材料。文獻指出1m³中所含的碳量，普通混凝土為552.22公斤，而無機聚合混凝土為242.87公斤，可**減少高達56.02%的碳排放**。

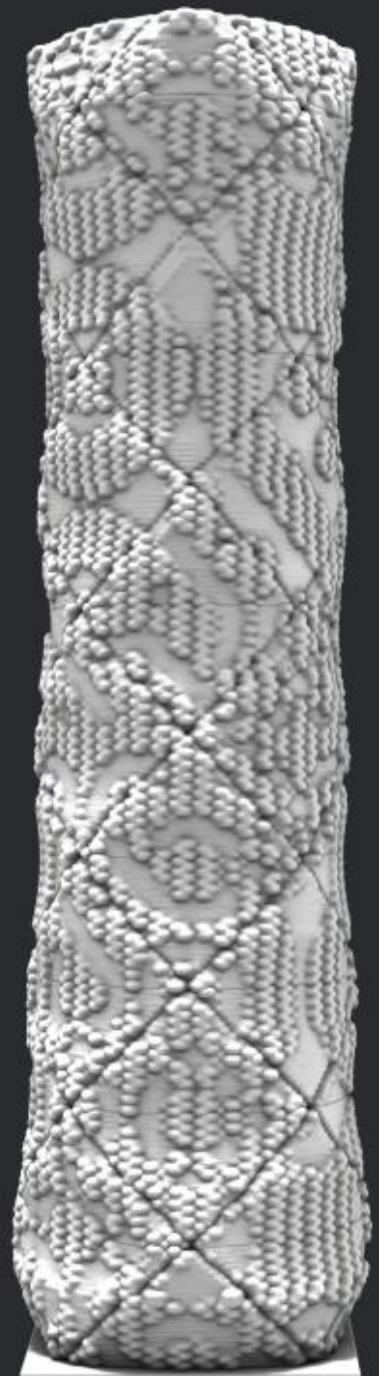
磚砂混合無機聚合混凝土

- 高早強 (一天可達>300 kgf/cm2)
- 免磚胚窯燒
- 可回收材循環
- 低碳排無水泥
- 縮短工期

低碳循環建材
Low Carbon Circulatable Material

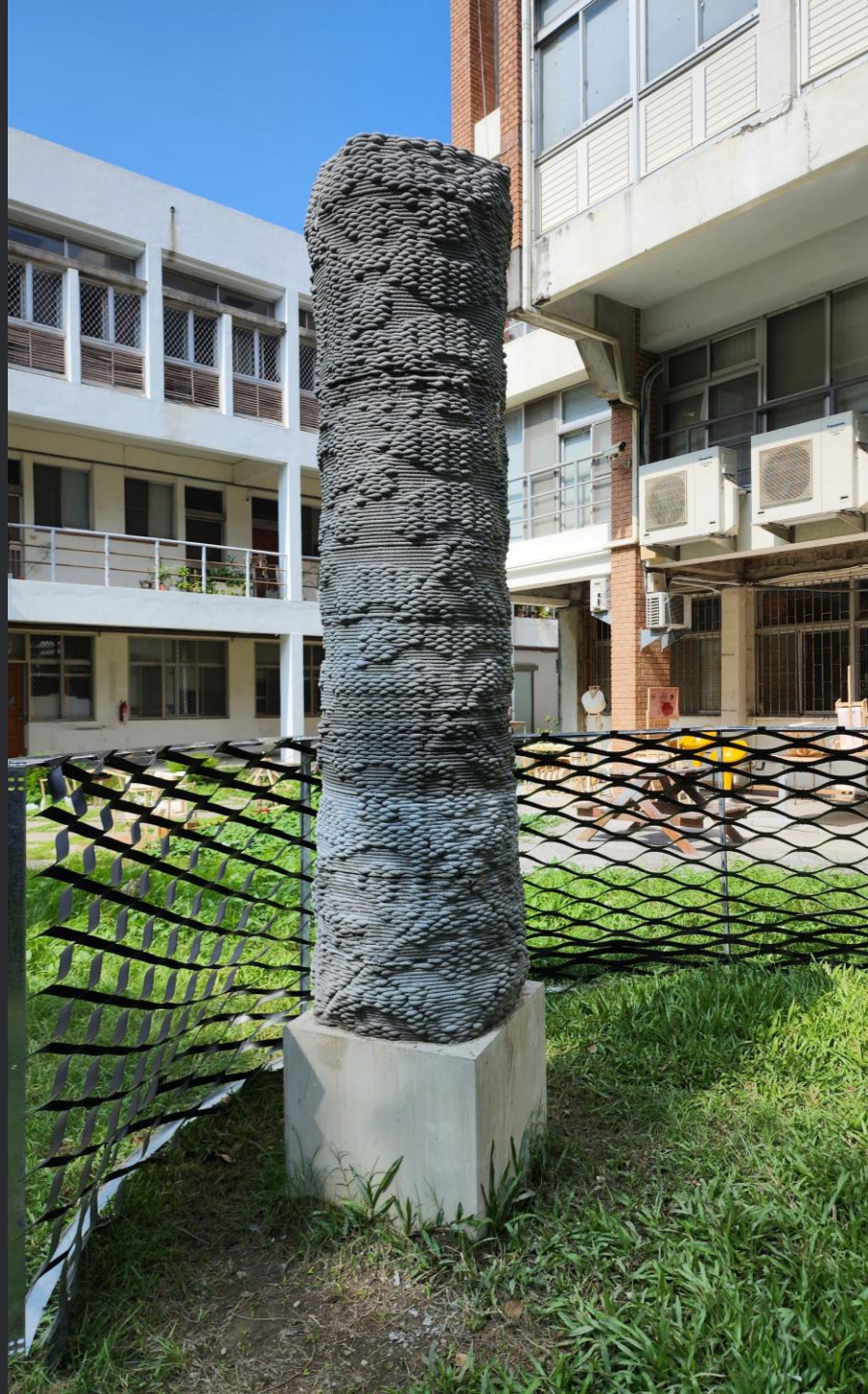


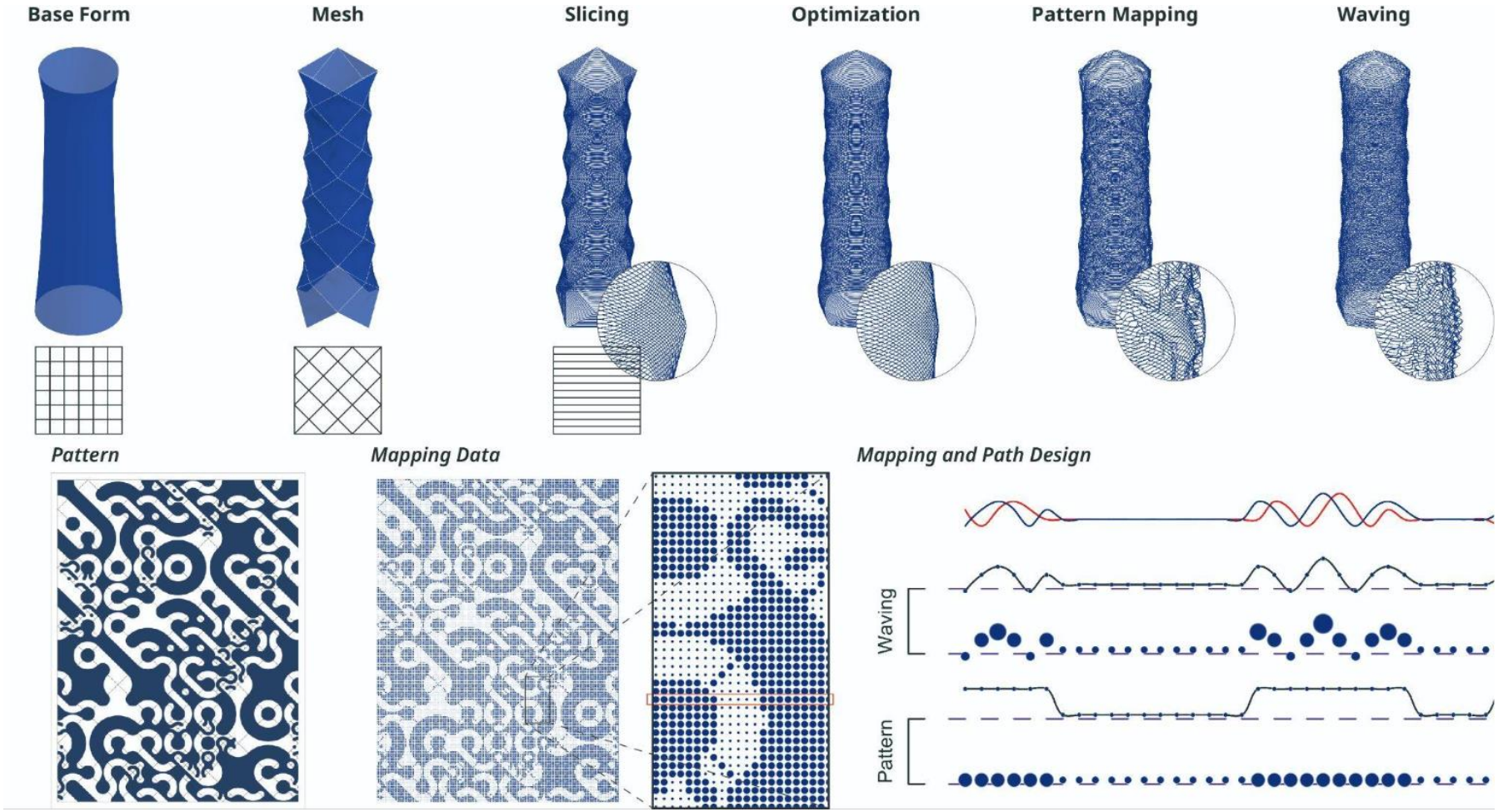


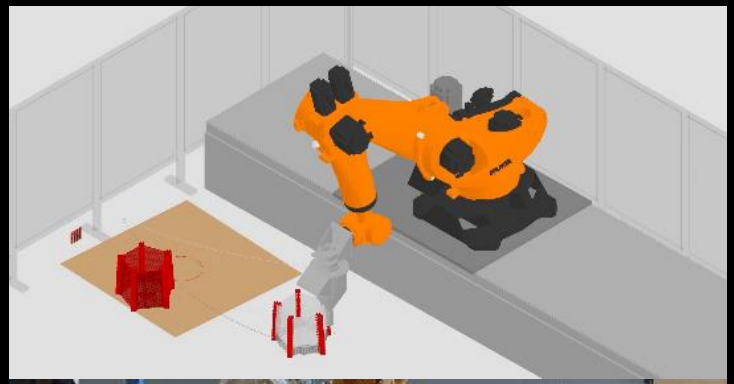


Graphcrete

: Robotic 3D Concrete Printing
for Mold Construction Methodology

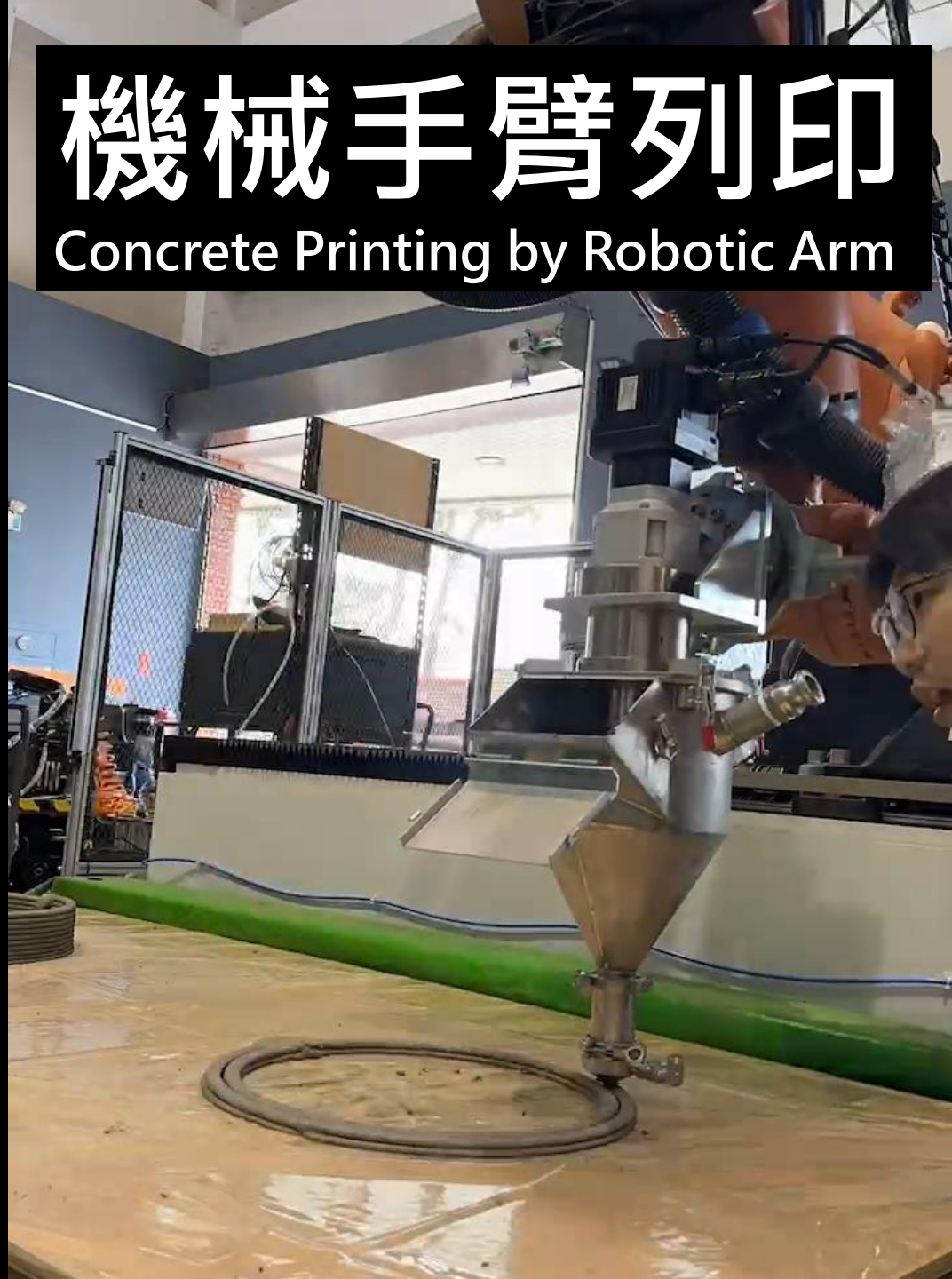



Base Form
Mesh
Slicing
Optimization
Pattern Mapping
Waving
Pattern
Mapping Data
Mapping and Path Design
Waving
Pattern



機械手臂列印

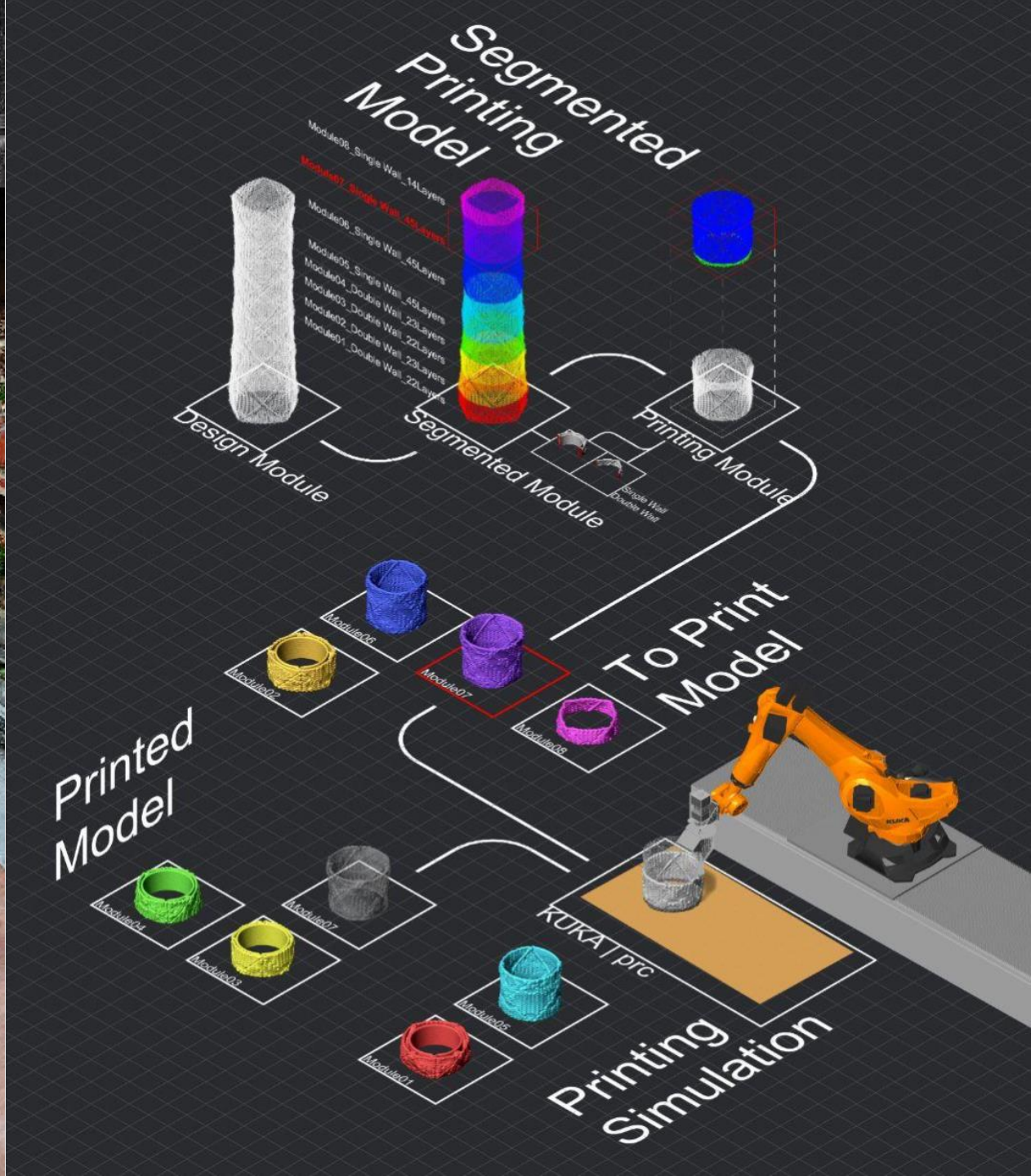
Concrete Printing by Robotic Arm



低碳循環無機聚合混凝土

Geopolymer Concrete

低碳指標	一般混凝土(水泥)	低碳混凝土(磚砂混合無機聚合混凝土)
高早強 (>300 kgf/cm2)	7天	1天
碳排	高	低
循環	無	有
可塑	高	高


Segmented Printing Model
Module06_Single Wall_14Layers
Module07_Single Wall_45Layers
Module06_Single Wall_45Layers
Module05_Single Wall_45Layers
Module04_Double Wall_23Layers
Module03_Double Wall_22Layers
Module02_Double Wall_23Layers
Module01_Double Wall_22Layers
Design Module
Segmented Module
Printing Module
Single Wall
Double Wall
To Print Model
Module06
Module02
Module07
Module08
Printed Model
Module04
Module03
Module07
Module05
Module01
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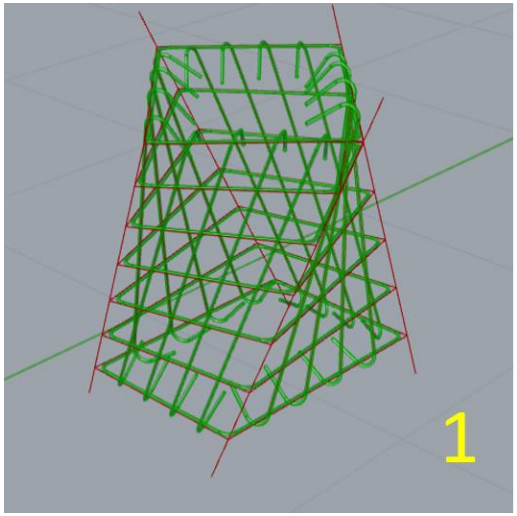
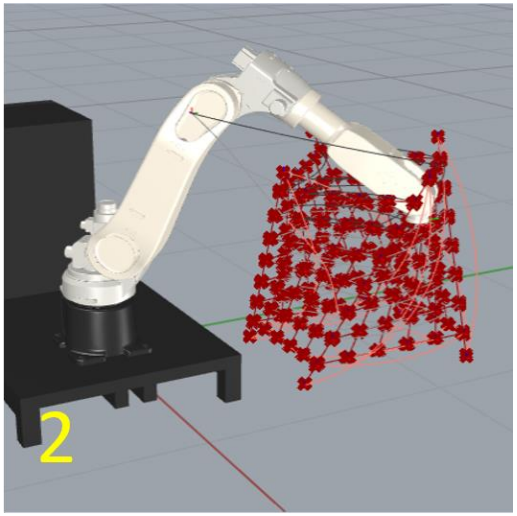
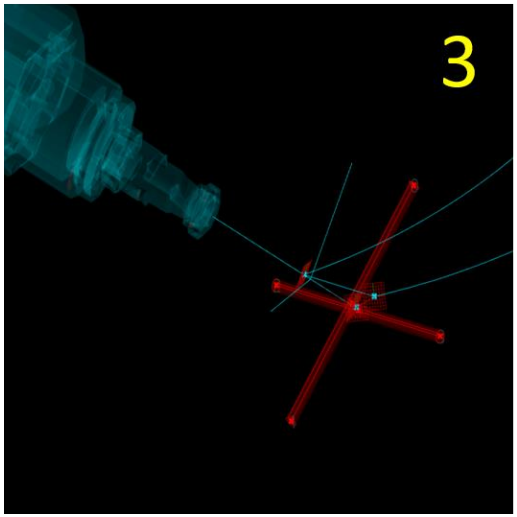
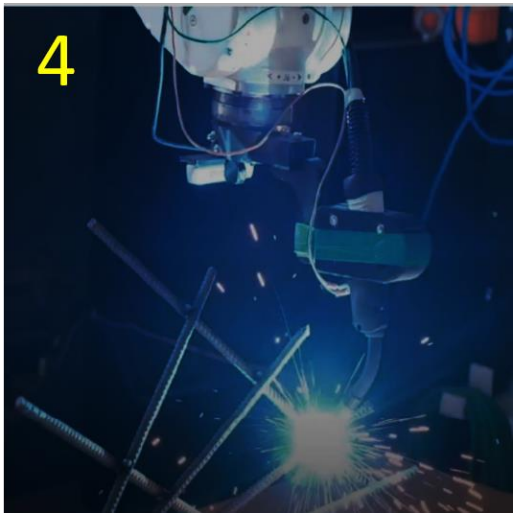
Printing Simulation

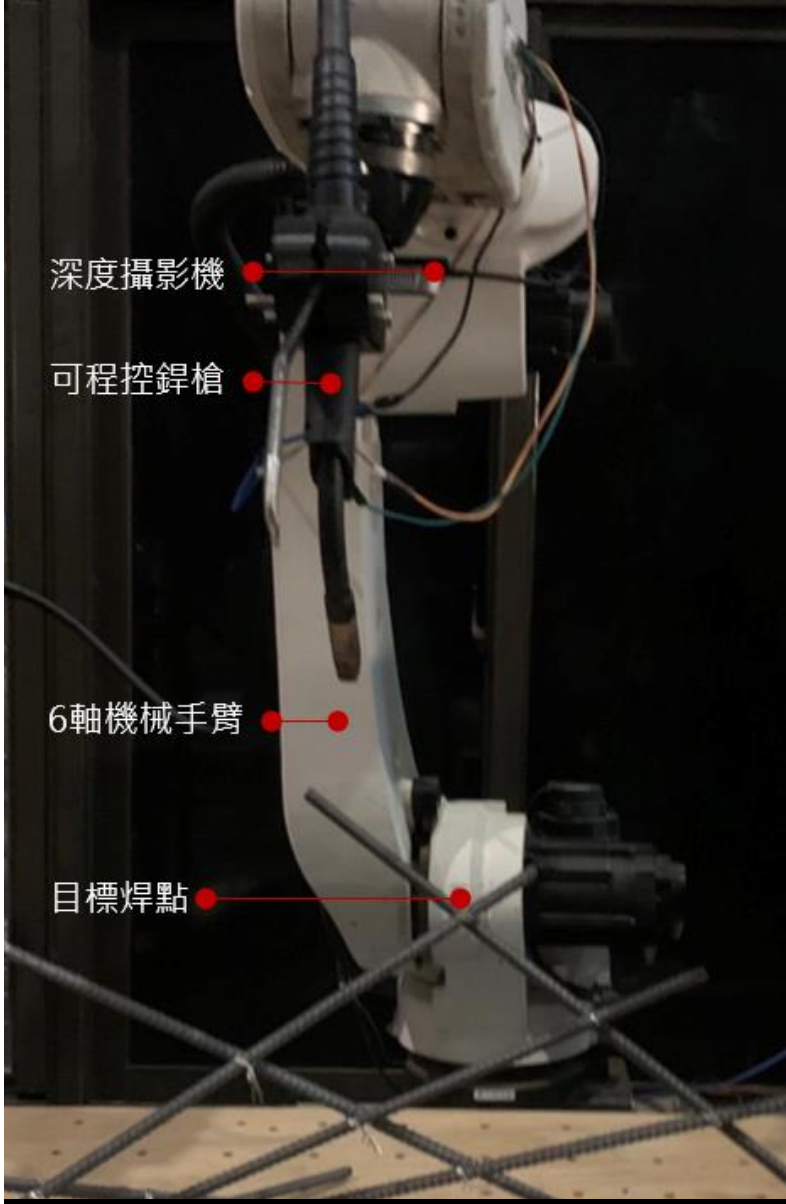
電腦視覺-焊點查找
智慧建造-自動焊接











智慧焊接

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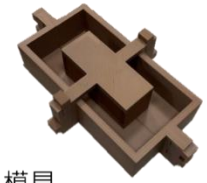
Robot。YOU
人機協作

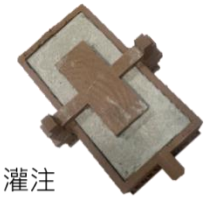
機器即工具

機器即助手

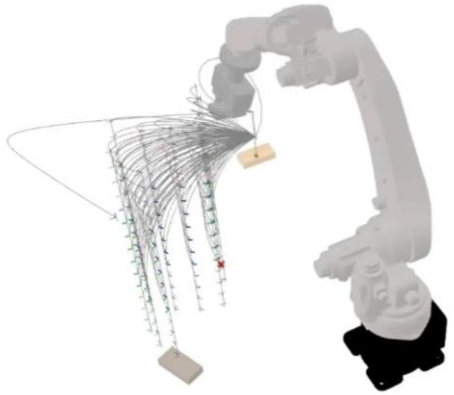
機器即夥伴



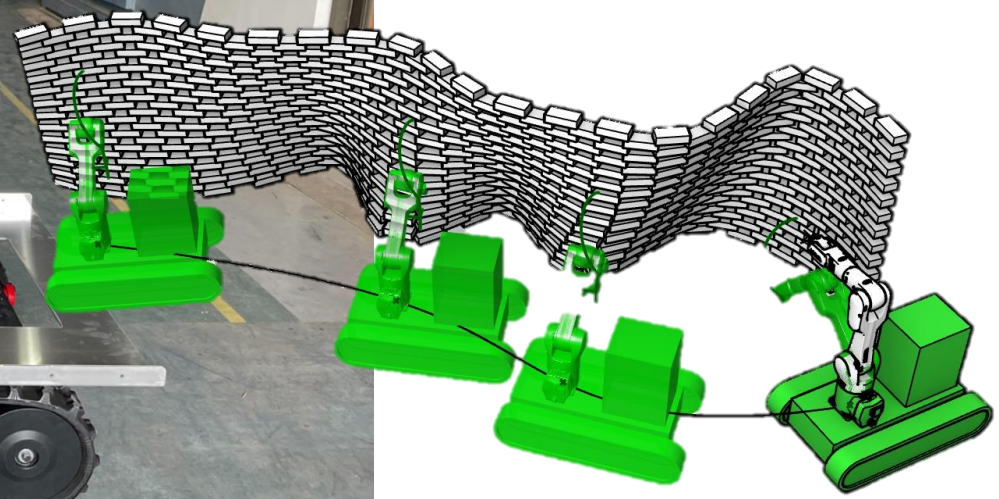
模具



灌注

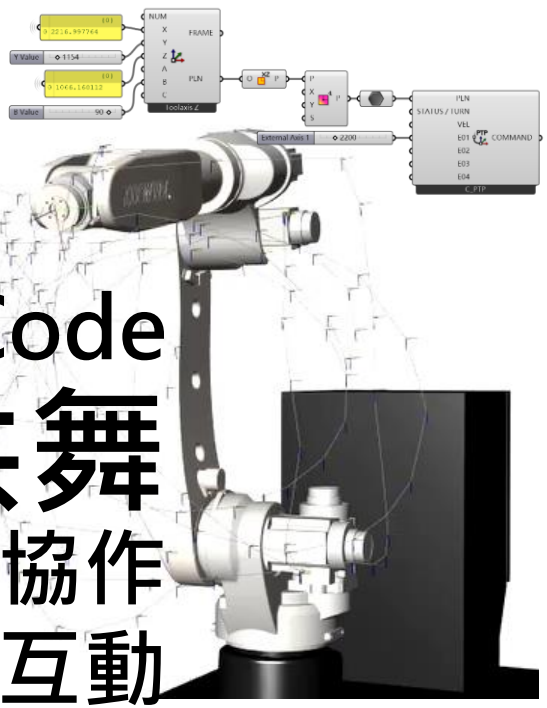


低碳循環建材暨建構系統

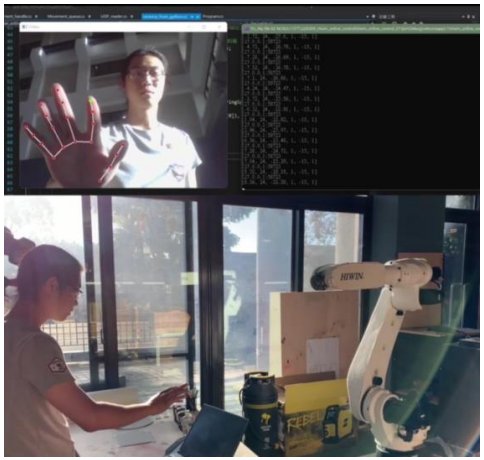


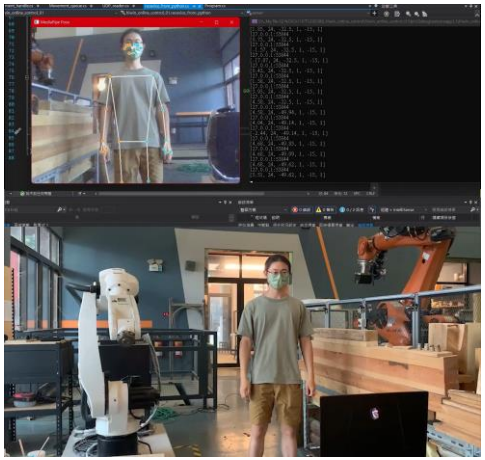
整合機械手臂與電腦視覺發展自組立低碳循環建材暨建構系統

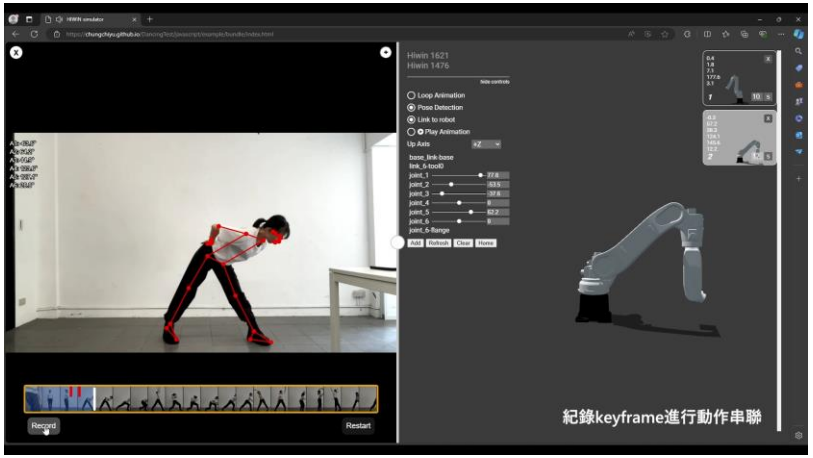
The Integration of Robotic Arm and Computer Vision Apply to the Development of Self-Construction Low Carbon Circular Materials and Tectonics System

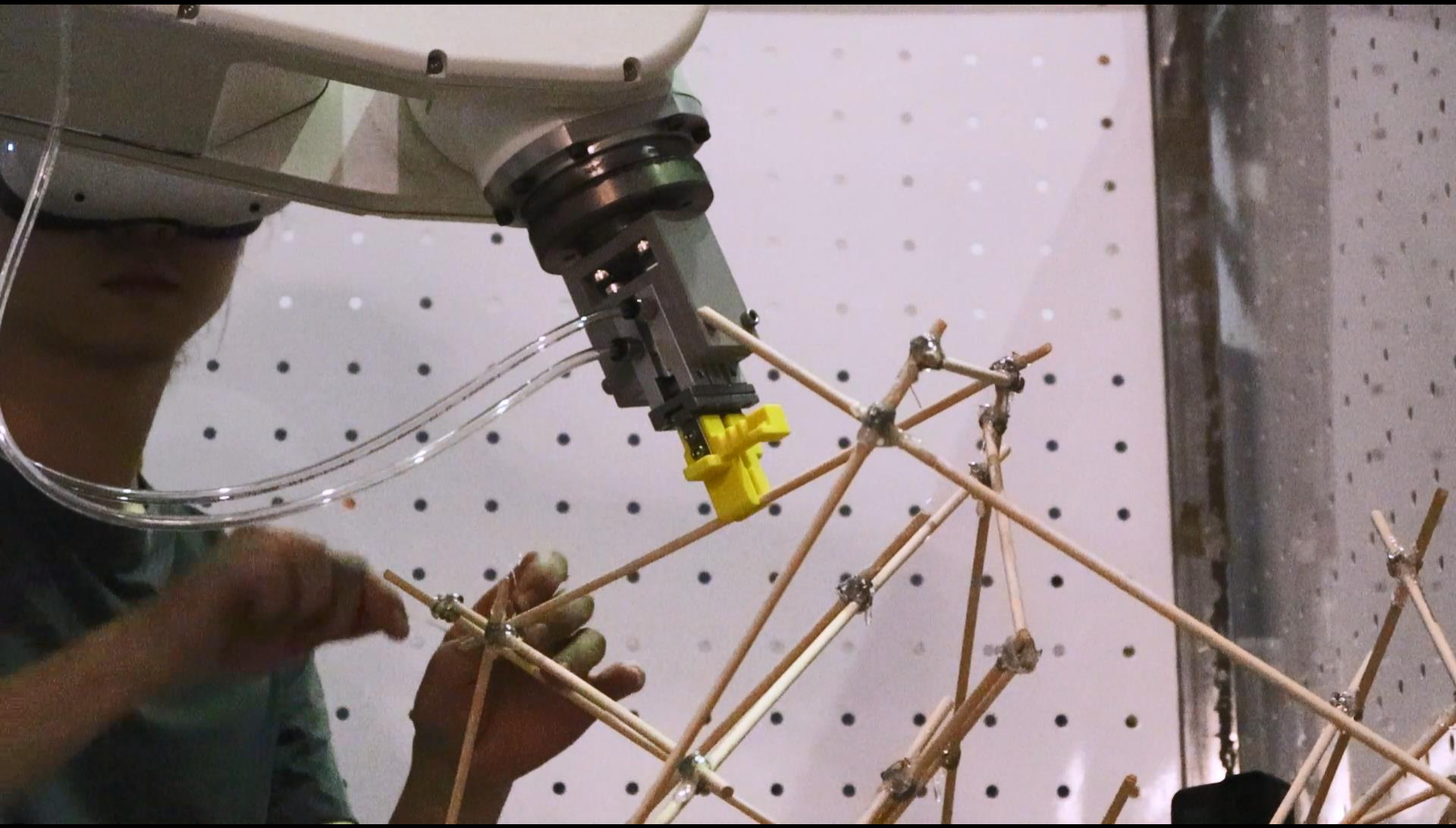


No Code
人機共舞
未來人機協作的直覺互動







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