RAC-Doon

Robot Aided Creation and Construction
National Cheng Kung University

BUILD THE FUTURE

構築未來：
成大數位智造工坊 2021 年鑑

2021
ANNUAL
REPORT

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01. ABOUT

RAC-Coon:
MAKE DIGITAL FABRICATION MORE ACCESSIBLE

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前言

成大建築身為國內首屈一指的建築名校之一，對未來的建築人才育成有何社會責任？對於國家整體的建築發展又應肩負何種使命？ 2020 年 9 月 12 日成大數位智造工坊 (RAC-Coon) 的開幕，以「智慧營建」的願景為建築的未來揭開嶄新的篇章。開幕式現場集結成大校內跨領域教師群、成大校友張清華、戴育澤等知名建築師、成大建築文教基金會董事長張國章，以及上銀科技經理廖文彬、東台精機董事長嚴瑞雄等產業合作夥伴也都到場與會，共同見證成大在推動建築產業數位轉型的宏願。開幕式由成功大學校長蘇慧貞親自操作機械手臂，為「數位雲牆」安上拱心石，宣告成大建築肩負社會創新使命，正式邁入建築界工業 4.0 的「智慧營建」殿堂。

機械手臂介入到建築所展現的是設計為製造的一體化思維 (Design for Build)，使設計端與製造端重新融合的新時代數位工藝精神。數位智造工坊開創了兩個全國唯一：第一個是機械手臂舉重最大的全國唯一，原因是建築的元件和其營建尺度都需要有高負載能力的機械手臂進行協助，才能跳脫實驗室走入到真實的場域。第二個是提供智慧營建全方位解決方案的全國唯一，從工作坊空間、大小不同尺度的機械手臂與實作空間、到與材料和結構測試設備的連結，使得這個場域成為全國唯一可以從設計到製造，更能延伸到建築結構真實性測試的全方位解決方案 (Total Solution) 獨創場域。

在智慧營建的前提下，跨域人才的育成以及人才與產業間的鏈結便成了關鍵的要素之一。RAC-Coon 不但要讓教學現場以專案導向學習 (PBL) 的精神成為工坊，更要讓工坊成為未來營建工法的孵化場域。因此為了能夠深耕國內智慧營建的扎根教育，RAC-Coon 對校內外教學的操作模式將以工作坊結合微課程這種彈性靈活的方式做為核心的教育模式之一，並在 2020/08/24 首次舉辦了為期六天的 “made_by” robots 機器製造工作營。

2021 年 RAC-Coon 更開始將機械手臂輔助的建築設計帶入到大學部建築設計 (八) 與研究所建築結構與造型整合設計等相關課程，成功發展出一套機械手臂輔助互承性木構築工法，並在工坊的入口實現出一座全尺度的涼亭：波簷 (Wave Eaves)。波簷 (Wave Eaves) 的實構帶動了許多智慧營建上的技術創新，除了在預製工法上的快速客製化 (Mass Customization) 創新、雙曲拋物面互承木製結構的造型與構造創新、更是國內首次實現了在建築構造物上的機械手臂輔助自動化組裝，使得建築產業的數位轉型在自動化上展開了新的一頁，具有其時代性的非凡意義。

數位轉型下的機器手臂智慧營建在建築產業將帶來一波革命性的創新，牽動從教育模式、人才輸出、產業升級、國際競爭等一整條產業鏈的進化。RAC-Coon 融入學校的研究與教育模式不但能孵育跨領域人機協作型 (Human-Robot Collaboration) 人才，更能誘發建築產業因新型人才的輸入而產生營建模式的數位轉型，提升產業競爭門檻，進而創造國際競爭優勢。最後引用馬丁路德金恩博士的名言：I Have a Dream! 我們希望，同時也是我們的責任，給下一代年輕人一個值得投注熱情的嶄新建築環境，攜手共建一個專屬於新世代的智慧營建舞台。

數位智造工坊　執行長　杜怡萱
數位智造工坊　副執行長　沈揚庭

Foreword

As one of the top architecture schools in Taiwan, what kind of social responsibility does NCKU Architecture have in cultivating talents in architecture? What kind of mission should it shoulder for the development of architecture in Taiwan?

On the 12th of September 2020, NCKU RAC-Coon made its debut with the vision of “Smart Construction,” opening a new chapter for the future of architecture. The opening ceremony gathered cross-domain teachers of NCKU, Chang, Ching-Hua and Tai, Yu-Tse and other famous architects and alumni of NCKU, Chang, Kuo-Chang, Chairman of the NCKU Architectural Cultural and Educational Foundation, and also representatives of the industry-academia cooperation partners such as Liao, Wen-Pin, Manager of HIWIN Technologies Corp. and Yen, Jui-Hsiung, Chairman of Tongtai Machine & Tool Co. to witness the great aspiration of NCKU of driving the digital transformation of the architectural industry. In the opening ceremony, Su, Huey-Jen, President of NCKU, operated the robot personally to place the keystone on “Digicloud” and announced that NCKU Architecture would carry out the mission of social innovation and officially enter the palace of “Smart Construction” in the era of the Architecture Industry 4.0.

The application of robots in architecture shows the concept of integrating design and manufacturing, and manifests digital craftsmanship in the new era. RAC-Coon initiated two unique breakthroughs in Taiwan: The first breakthrough is the deployment of industrial robots with the highest payload among architecture schools. This property enables researchers to manipulate massive architecture components with robots. Only in this way the projects could be transferred from the lab to the real field. The second breakthrough is that it provides the only total solution to smart construction in Taiwan. Various sizes of robots together with the material and structure test equipment make RAC-Coon the only field with total solutions in Taiwan that covering design, manufacture, and validation in one place.

One of the key factors to smart construction is the cultivation of cross-domain talents and the connection between talents and the industry. RAC-Coon not only aims to create a project-based learning place but also make school an incubator for future construction methods. Therefore, to provide a solid foundation for the education of smart construction in Taiwan, RAC-Coon will adopt flexible learning programs such as micro-course workshops. These workshops will combine lectures with practical application, and RAC-Coon has held its first 6-day workshop on the 24th of August 2020.

In 2021, RAC-Coon introduced robots to the undergraduate architecture design studio and graduate school structure design course. It has successfully developed a robotic assembly workflow for timber reciprocal frame structure. Moreover, it also constructed a full-scale pavilion at the entrance of RAC-Coon: Wave Eaves. Wave Eaves drove multiple technical innovations on smart construction, including rapid customization of the prefabricated construction, and the tectonic and structure innovation for hyperbolic paraboloid timber reciprocal frame. It is also the first in Taiwan to realize the automated robotic assembly of the building structure. It has set another milestone for the digital transformation of the architecture industry in the aspect of automation, carrying an epoch-making significance.

Smart construction with robots would bring revolutionary innovations, affecting the evolution of the whole industry from the education mode, talents output, industrial upgrading to international competition. By integrating itself with academic research and education, RAC-Coon will not only cultivate the interdisciplinary talents on human-machine collaboration but also boost the digital transformation in construction with the input of new talents. This will raise the bar for the industry competition and thus create an international competitive advantage. Finally, draw on a famous quote from Dr. Martin Luther King, "I have a dream!" It is both our expectation and responsibility to provide a brand-new architectural environment that is worth the enthusiasm of the next generation to join efforts in building an era of smart construction.

Professor. **Yi-Hsuan Tu**
CEO of RAC-Coon

Associate Professor. **Yang-Ting Shen**
Vice CEO of RAC-Coon

成大數位智造工坊 (RAC-Coon) 的成立宗旨為台灣營建產業的數位轉型，以「智慧營建」(Smart Construction) 做為發展的重點核心目標之一。機器輔助的創作與建造 (Robot-Aided Creation & Construction)，縮寫為 RAC-Coon。

工坊的建置由教育部高教深耕計畫支持，落腳於規劃設計學院的建築科技大樓，除了將該大樓內部結構實驗室的一部分空間改造成適合跨領域教學的工作坊環境外，並配置 2 支載重達到 300 公斤的大型 KUKA 機械手臂及 2 支兩隻中型的上銀機械手臂。數位智造工坊創造了兩個全國唯一：第一個是機械手臂舉重最大的全國唯一，原因是建築的元件和其營建尺度都需要有高負載能力的機械手臂進行協助，才能跳脫實驗室走入到真實的場域。第二個是提供智慧營建全方位解決方案的全國唯一，從工作坊空間、大小不同尺度的機械手臂與實作空間、到與材料和結構測試設備的連結，使得這個場域成為全國唯一可以從設計到製造，更能延伸到建築結構真實性測試的全方位解決方案 (Total Solution) 獨創場域。

The purpose of NCKU RAC-Coon is to foster the digital transformation of Taiwan's construction industry, with "Smart Construction" as one of its main targets.

RAC-Coon was established primarily with the support of the Higher Education Sprout Project of the Ministry of Education and also the generous donations by the alumni. It is located at the Architecture Research Building of College of Planning and Design, NCKU. The project refurbished the interior space of this building into a working space for interdisciplinary research, teaching, and construction experiment. It is equipped with two large KUKA robots with a payload of 300kgf and two medium HIWIN robots. RAC-Coon initiated two unique breakthroughs in Taiwan: The first breakthrough is the deployment of industrial robots with the highest payload among architecture schools. This property enables researchers to manipulate massive architecture components with robots. Only in this way the projects could be transferred from the lab to the real field. The second breakthrough is that it provides the only total solution to smart construction in Taiwan. Various sizes of robots together with the material and structure test equipment make RAC-Coon the only field with total solutions in Taiwan that covering design, manufacture, and validation in one place.

RAC-Coon

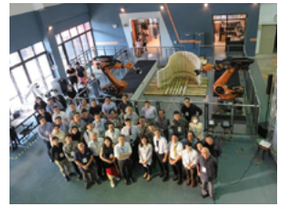
ROBOT AIDED CREATION AND CONSTRUCTION 2020 - 2021

The newly renovated Workspace RAC-Coon at NCKU leverages state-of-the-art industrial technology to perform architectural fabrication research.

/// RAC-Coon Timeline 2020 - 2021

[2020]

24 - 29 August
{"made_by" Robots} workshop
數位智造工坊第一個教學工作營



12 September
RAC-Coon Grand Opening
成大數位智造工坊 RAC-Coon 正式開幕

25 October
數位智造工坊與建築系大學部數位股軟體工作營
Software workshop with Dep. Architecture

29 October
First Industry-Academia Collaboration with Bio-Architecture Formosana
首次產學研究開發合作案 - 九典聯合建築師事務所

24 November
產學研究開發合作案 - 戴育澤建築師事務所
Industry-Academia Collaboration with TAI-Architects

09 December
First in-house End-Effector-Hot Wire Foam Cutting
開發工坊第一個專案研究用工具頭 - 保麗龍切割器

[2021]

05 March
工坊融入大學建築設計課程
Robotic Aided Tectonics Studio (RATs)

02 - 04 April
主動撓曲學生工作營
Bending_Active Workshop

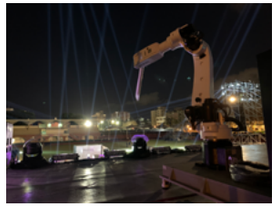
21 May
數位智造工坊與福德祠案正式簽約，首次參與實際建築工程案
First Construction project- Fu-De Temple

23 October
數位智造工坊 2021 周年慶
RAC-Coon 2021 Open House

08 January
Robotic Drawing Workshop
第一批訓練研究生開學生自主工作營

30 March
International Conference 2021 for CAADRIA
數位智造工坊首篇國際期刊發表在香港 2021CAADRIA

10 May
National Intercollegiate Athletic Games
首次對外跨領域合作案 - 全大運人機協同



23 July
"Wave Eaves" Pavilion
工坊首座由機械手臂輔助製造實構築作品

12 November
2021 Annual Report
數位智造工坊首本年鑑

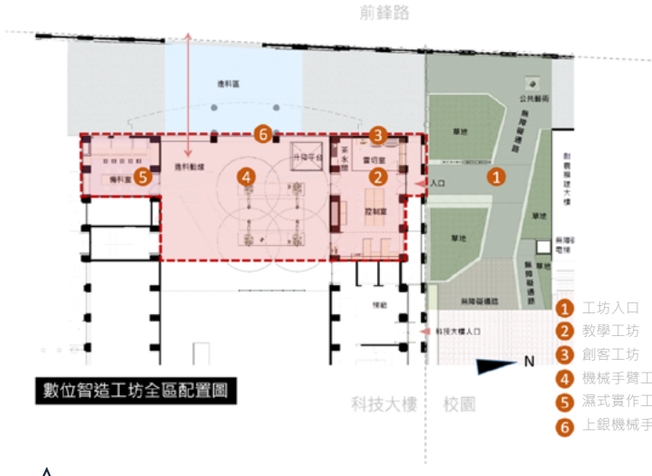
NCKU RAC-Coon 2021

Space of RAC-Coon

Robot Aided Creating and Construction
National Cheng Kung University
Headquarter: Tainan, Taiwan
23°00'00.1"N 120°12'53.0"E

數位智造工坊 (RAC-Coon) 的建置由教育部高教深耕計畫為主，再加上系友的熱情捐款支持，落腳於規劃設計學院的建築科技大樓。數位智造工坊在科技大樓內部空間改造成適合跨領域研究、教學、以及建造實驗的工坊型空間。主要的空間組成包括 1. 新設的工坊入口及其入口意象、2. 教學工坊、3. 創客工坊、4. 機械手臂工坊、5. 濕式實作工坊、6 上銀機械手臂區等六個空間。

RAC-Coon was established primarily with the support of the Higher Education Sprout Project of the Ministry of Education and also the generous donations by the alumni. It is located at the Architecture Research Building of College of Planning and Design, NCKU. The project refurbished the interior space of this building into a working space for interdisciplinary research, teaching, and construction experiment. The working space consists of : 1. New RAC-Coon entrance and its facade. 2. RAC-Coon Studio. 3. Workshop. 4. KUKA robot cells. 5. Casting lab. 6. HIWIN robot cells.



數位智造工坊全區配置圖

1 工坊入口 RAC-Coon Entrance
2 教學工坊 RAC-Coon Studio
3 創客工坊 Maker Lab
4 機械手臂工坊 Robot Cell
5 濕式實作工坊 Casting Lab
6 上銀機械手臂區 HIWIN Robot Cell

[教學工作室]

教學工作室具有多功能彈性的特性，分為經理及管理員辦公空間、學生多功能教學教室與會議場所。

/ RAC-Coon Studio /

RAC-Coon Studio is a multifunctional space, including the managers' and lab assistants' office, the multi-purpose classroom, and the conference room.

[機械手臂工坊]

機械手臂工坊具備實際製造的挑高實驗場域，其空間包含 2 支 KUKA KR 300 2500 Ultra 機械手臂和 2 台移動式上銀 RA620 機械手臂。

/ Robot Cell /

The robot cells sit in the room with elevated ceilings, where the actual fabrication and manufacturing happen. The robot cells are equipped with two KUKA robots with rails and two HIWIN robots mounted on mobile platforms.

Explore RAC-Coon

[濕式實作工坊]

濕式實作工坊提供學生測試製作濕式試體的清洗空間，備料的功能，另外也提供了基本的教學環境。

/ Casting Lab /

The casting lab provides a space for casting material research, where students conduct casting and curing test specimens. It can also be a teaching and learning space for a small group of students.

Robots

Robot Aided Creating and Construction
National Cheng Kung University
Robots: KUKA KR-300 R2500 ultra
HIWIN RA620-1739

[製造工業機器人]

工業機器人原為為製造業而設計，不限定於特定加工程序的定位設備，高度靈活的特性使其能夠將其精確度和與可重現性帶入各式各樣的加工程序。RAC-Coon 備有兩個機器人工作單元：位於實驗廠的工作單元有兩部安裝在線性軌道上的 KUKA KR-300，另一側為安裝於可移動式平台的兩部上銀機器人。

Industrial robots were originally designed for manufacturing and are not limited to positioning equipment for specific processing procedures. Their highly flexible characteristics enable them to bring their accuracy and reproducibility into a variety of processing procedures. RAC-Coon has two robotic workcells at its disposal: the first is located in the Robot Cell and contains two KUKA KR300 industrial robots mounted on linear axes; there are also two HIWIN robots mounted on mobile platforms beside the KUKA robot workcell.

[上銀關節式機械手臂 | HIWIN RA620-1739]

工坊內配有 2 台上銀關節式六軸機器人，其型號為 RA620-1739，搭載寬 80cm 移動式底座，可自由穿梭移不同空間及室內外，提高機械手臂的彈性使用及多功能支援性。

RAC-Coon has two HIWIN RA620 6-axis industrial robots mounted on 80cm-wide movable bases. They can be relocated both outdoors and indoors, providing robotic solutions for flexible usage scenarios.

[KUKA 六軸機器人 | KUKA KR300 R2500 ultra]

機械手臂工坊配置兩台 KUKA KR300 六軸工業機器人，並安裝於兩座線性軌道上。外圍設有感應式安全隔離護欄，可確保操作人員安全。第七軸線性軌道提供兩台機器人大範圍的施作空間及共同協作的可能性，同時工坊使用之機型載重達 300kgf，末端速度可達 2.5M/s，具有相當之危險性。校內課程、學程、工作營、研究計畫、論文如需使用工業機器人，請洽管理人員。管理人員將視當前工業機器人的使用情形，協助安排使用計畫及計價方式，並登記在案。

RAC-Coon has two KUKA 6-axis industrial robots installed on two linear rails, which are enclosed by safety fences to ensure the operators' safety. The linear rails enlarge the robots' work envelope. Also, these two robots are configured and calibrated to work both independently and collaboratively. The KUKA robots in RAC-Coon have a payload of 300kgf and a terminal velocity of 2.5M/s, which are with considerable potential hazards. If you need to use the industrial robots for a course, program, workshop, research, or essay, please consult the workspace managers. They would assist in evaluating your project and scheduling the robots depending on their availability.

數位智造工坊成員

數位智造工坊於鄭泰昇教授暨成大規劃設計學院院長任內成立，執行長為杜怡萱教授暨建築系主任，副執行長為沈揚庭副教授，邀請簡聖芬副教授和林軒丞助理教授擔任顧問，並編制有顏嘉慶經理與鄭方哲經理兩名，另有多位研究生參與專案的研究與發展。工坊成員除負責為系上乃至全校打造全新的跨領域課程外，更重要的是希冀由成大領軍帶動建築產業的數位轉型。

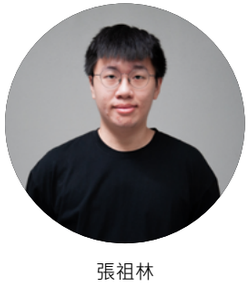
鄭泰昇 教授
Professor Tay-Sheng Jeng
[成大規劃設計學院院長
| Dean of NCKU CPD]

杜怡萱 教授
Professor Yi-Husan Tu
[數位智造工坊執行長 | CEO]

沈揚庭 副教授
Associate Professor Yang-Ting Shen
[數位智造工坊副執行長 | Vice CEO]

顏嘉慶
Chia-Ching Yen
[數位智造工坊經理 | Manager]

鄭方哲
Cheng Fang-Che
[數位智造工坊經理 | Manager]



張祖林
Zu-Lin Chang
[數位智造工坊管理員 | Administrator]

廖士豪
Shih-Hao Liao
[數位智造工坊博士研究生 | PhD Student]

TEAM RAC-Coon

RAC-Coon is established during the term of professor Jeng, Tay-Sheng, dean of CPD, NCKU. The CEO of RAC-Coon is professor Tu, Yi-Hsuan, chair of the department of architecture. Vice CEO is associate professor Shen, Yang-Ting. Associate professor Chien, Sheng-Fen, and assistant professor Lin, Hsuan-Cheng are invited as consultants. There are also two managers, Yen, Chia-Ching, and Cheng, Fang-Che, and many graduate students involved in the research and development projects. Besides organizing new interdisciplinary courses for the college, the members of RAC-Coon shoulder the most important role of driving the digital transformation of the architectural industry led by NCKU.

簡聖芬 副教授
Associate Professor Sheng-Fen Chien
[數位智造工坊顧問 | Consultant]

林軒丞 助理教授
Assistant Professor Hsuan-Cheng Lin
[數位智造工坊顧問 | Consultant]

蕭瑋廷
Wei-Ting Hsaio
[數位智造工坊管理員 | Administrator]

吳怡諄
Yi-Chun Wu
[數位智造工坊管理員 | Administrator]

吳杰叡
Jie-Rui Wu
[數位智造工坊研究生 | Graduate Student]

許家碩
Shiu-Jia Shuo
[數位智造工坊研究生 | Graduate Student]

02. PROJECTS

RAC-Coon: OUR PROJECTS AND RESEARCH THESE DAYS

波　簷

指導老師
沈揚庭

技術指導
蕭瑋廷｜顏嘉慶

參與學生
林彥甫｜王舜昱
涂孟綸｜龔柏宇｜蕭郁霖

NCKU RAC-Coon 2021

Wave Eaves

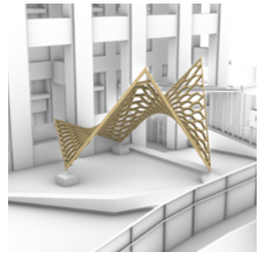
Advisor
Yang-Ting Shen

Technical Support
Wei-Ting Hsaio | Chia-Ching Yen

Participating Students
Yan-Fu Lin | Shun-Yu Wang
Meng-Lun Tu | Bo-Yu Gong | Yu-Lin Hsiao

概念

Wave Eaves 是藉由互承性構造組構而形成雙拋曲面構造物，並藉由機械手臂輔助整個數位智造的流程。
製造流程共分成 3 階段 : 第 1 階段成形查找、第 2 階段實虛整合、第 3 階段自動化組裝。藉由 Grasshopper 搭配 Kangaroo 物理引擎建構出符合現實層面帶有物理因素的構造雛型設計並透過參數化的方式整合進互承性結構佈署，並透過輸入實際木材模型進行實體的製造模型生成，在加工階段實現機械手臂的空間定位特性以及對組裝構件進行放樣與定位實現自動的組裝。



Concept

Wave Eaves is a hyperbolic-paraboloid-shaped reciprocal frame structure assembled with the assistance of robots.

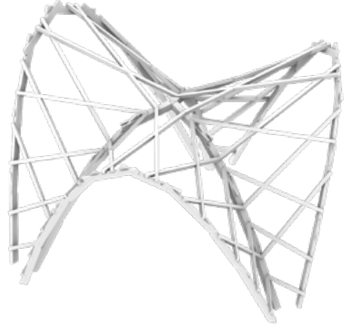
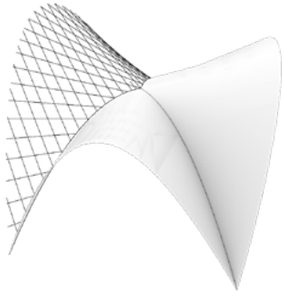
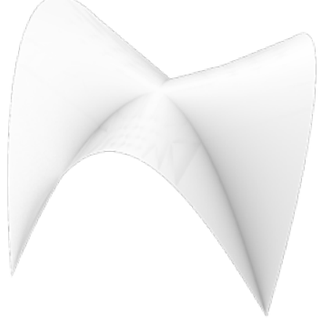
There are three steps for the process: forming finding, virtual-physical integration, and robotic assembly. The designers use the physic engine of GH, Kangaroo, to find the initial form, and the reciprocal frame is then defined accordingly. Finally, the geometrical model, which takes the dimensions of physical lumbers into consideration, is generated with the help of parametrical tools. While fabricating the pavilion, the team utilizes robots as a spatial positioning system to produce and assemble lumber components without fixtures.

NCKU RAC-Coon 2021

鞍　亭

指導老師
杜怡萱｜顏嘉慶

參與學生
林易騰｜潘守言｜張祖林｜陳俊利
方昱揚｜郭哲諺｜顏智弘｜卓英儒

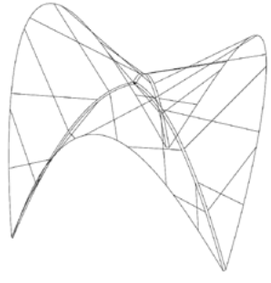
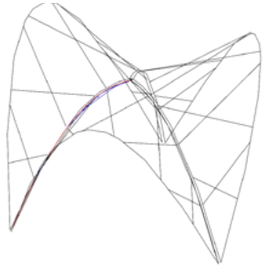
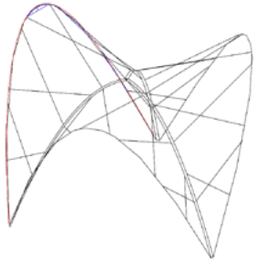
Saddle Pavillion

Advisor
Yi-Hsuan Tu、Chia-Ching Yen

Participating students
Yi-Teng Lin ｜ Shou-Yuan Pan ｜ Zu-Lin Chang ｜ Chun-Li Chen
Yu-Yang Fang ｜ Che-Yen Guo ｜ Chih-Hong Yen ｜ Ying-Ru Zhuo

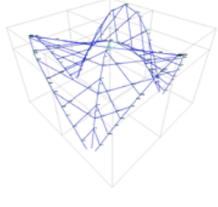
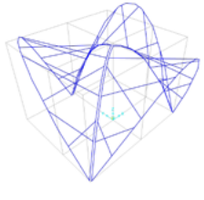
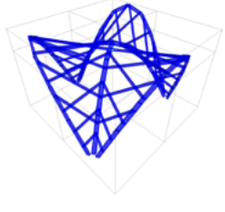
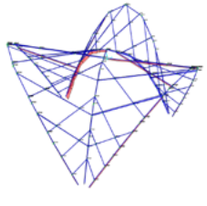
概念

本設計之主題為以木材構築曲面造型，因木材為直線型材料，故選擇可藉由漸變斜率之直線構成的雙曲拋物面作為發展原型。首先由雙曲拋物面中點以 120 度圓心角擷取局部，再將其沿截邊鏡射構成一 120 度轉動對稱之造型，曲面之交界為主要支撐傳力路徑至地面之三道主拱，另有三道副拱定義造型之外周邊界。曲面本身以兩向交錯之木桁條構成，主拱與副拱以不等長之折線段拼接。機器手臂用於精準切削木材各種角度不同之續接面。

Concept

This project focus on the timber construction of curved surfaces. As lumber is a straight-line material, the team choose hyperbolic paraboloid as the initial form, which can be defined by translating and rotating straight lines. The HP surface is first split with a 120-degree circular sector, then the part is mirrored along its edge to form a 120-degree rotational symmetry form. The intersections among the surfaces become the primary arcs that transmit the force down to the foundation. There are also three secondary arcs that define the boundary of the form. The surfaces are comprised of intersecting timber beams from two directions, and the primary and secondary arcs are composed of various length polylines. In this project, the team will use robots to precisely fabricate the various joinery on the beams.

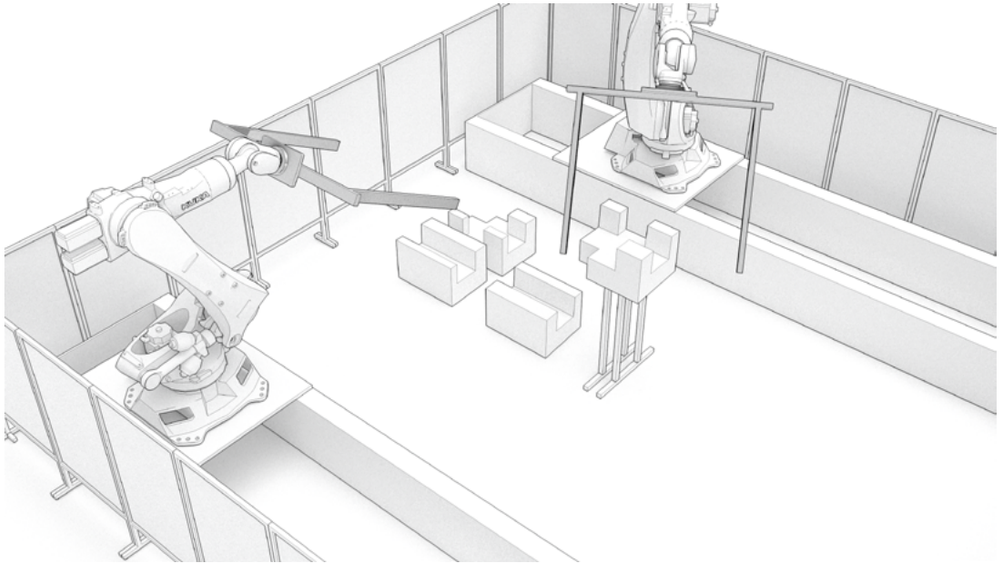





台中市大河里福德祠興建案

指導老師
沈揚庭｜顏嘉慶

設計
戴育澤建築事務所

參與人員
吳杰叡



Taichung Fude Temple Construction Project

Advisor
Yang-Ting She | Chia-Ching Yen

Design
Dai Yu Ze Architecture office

Participating students
Jie-Rui Wu

概念

台中大河里福德祠興建一案是將機械手臂帶入此案以進一步實現未來工業 4.0 與人機合作的實際工程案，利用機械手臂裝上保麗龍切割的工具頭，製作水泥造型模板，取代傳統的板模工程，彌補傳統工程在木板上拼接弧度的短處，而發揮到保麗龍在熱線切割上能自由製作出曲線弧度自由性的長處；此外提高模板生產的效率，解決工地現場板模工的缺工現象並能省去大量的釘板模與拆除的工程時數；而此案的曲牆造型與光明燈的孔位造型正是讓機械手臂首次進入工程讀實戰案例，利用熱切泡沫原理自由創造出適合此案的洞孔與正確的曲線弧度。

Concept

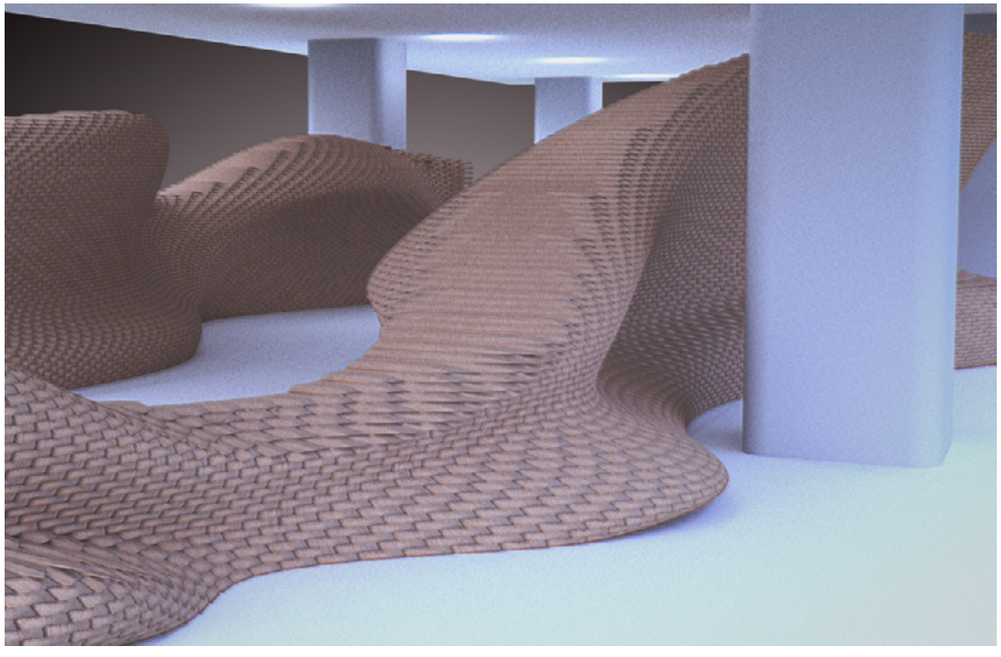
Taichung Fude Temple Construction is a project that brings robots to the construction site, pushing the progress in industry 4.0 and human-machine collaboration. The robot with a hot-wire cutter produces foam blocks that replace conventional wood formwork for concrete. The hot-wire foam cutting can fabricate curved geometry, and this overcomes the shortcoming of conventional formwork which approximate curved surfaces with flat boards. Also, this method will mitigate the labor shortage in construction sites by automating the fabrication of formwork, which was a tedious task. The curved wall and openings for votive lamps make this project a good entry point for the robot in construction, where it could precisely fabricate foam blocks of the desired form.

NCKU RAC-Coon 2021

設計
九典聯合建築師事務所

專案負責人員
顏嘉慶

九典木雲



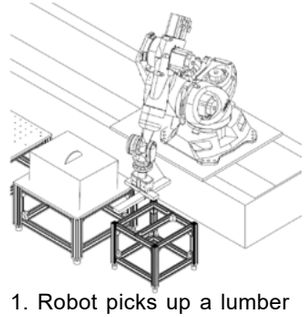
概念

Timber Flow 是一個與九典聯合建築師事務所合作的項目。這是位於台南沙倫智慧綠色能源科學城公共休息室的一系列家具。長凳和小馬牆遍布整個房間，將空間劃分為不同的地方。獨特的是，這些元素融合成一個整體，其中不規則的起伏設計用於坐姿和空間分隔。建築師沒有用實木塊銑削形式，而是製定了一項強調降低材料成本的策略。木板以磚塊圖案堆疊，水平間隙最大化，允許光線穿透。我們分析了表面曲率併計算了每塊木板的最佳長度。因此，該項目包含數千個具有不同切割的獨特塊。設計師提出了一個機器人組裝序列來製造這些塊，而無需打印成堆的圖紙。因此，它變成了一種中空結構，與 CNC 銑削方法相比，其材料成本僅為 25%。通過這種方式，Timber Flow 是計算設計和製造的產物，是智能建築的有力示範。

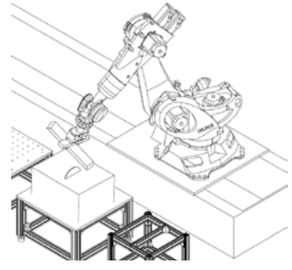
Design
Bio-Architecture Formosana

Project Designer
Chia-Ching Yen

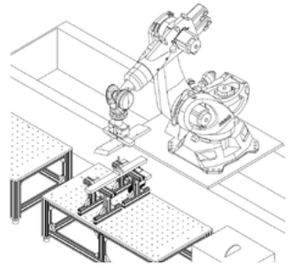
Timber Flow



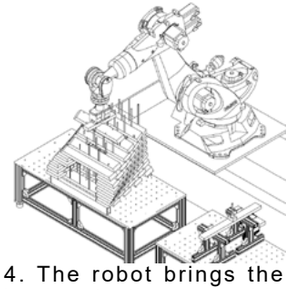
1. Robot picks up a lumber from the workpiece rack.



2. The lumber goes through table saw twice to get its bothends cut.



3. The fixed drilling station help robot to drill holes on the lumber.



4. The robot brings the lumber to the assembly position.

Concept

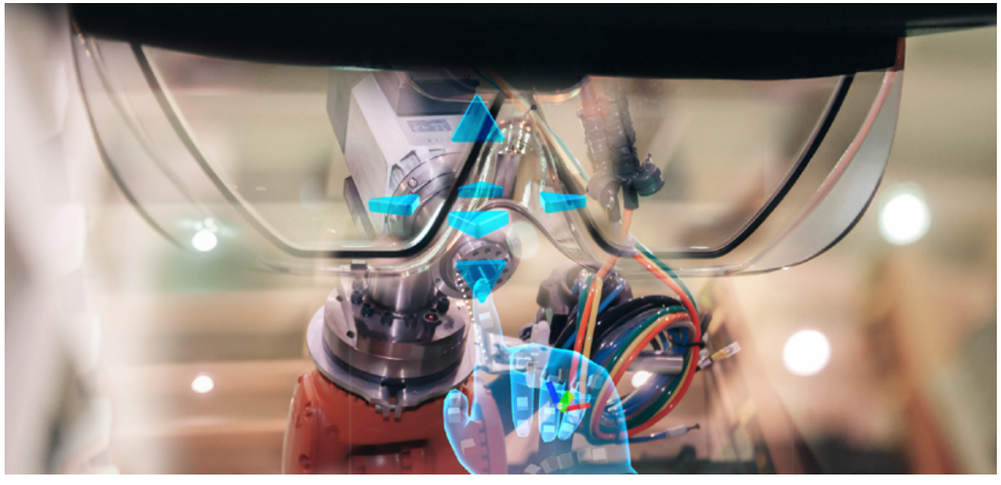
Following the coming industry 5.0, it is a nonreversible trend that workers will adapt to work with the intelligent machine. Therefore, the interaction of the robot with the worker could be the advanced demonstration of human-machine collaboration. Though the current operation and speed of the industrial robots are only suitable for industrial purposes, it is necessary to find the collaboration possibility from the perspective of a human. To achieve this target, we need to develop diverse ways of real-time robot control, and improve the offline programming of industrial robots. This research displayed a set of artistic performances of robot-human dancing based on the research of human-machine collaboration. It combines the real-time or non-real-time interaction between humans and robots. Such collaboration displayed a customizable, synchronized, intelligent, and innovative way of creating technological art, which can be further used in the application of human-machine collaboration in other industries.

全國大專運動會表演

技術總監
沈揚庭｜洪仲儀

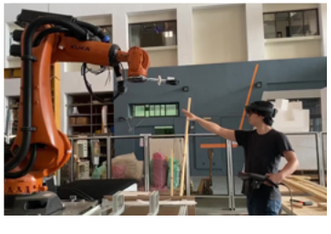
技術開發
廖士豪｜許家碩｜林應文｜李承儒

編舞師 / 舞者
巴魯·瑪迪霖｜陳瑋諭｜洪維婷



概念

轉型時代下機器人，隨著工業 4.0 的臨近，展示工人適應與智能機器一起工作的過程是未來不可逆的趨勢，因此應用機械手臂搭配表演者互動的方式可以作為人機協同前導示範。儘管目前機械手臂的運動和速度僅適用於工業用途，但需要找出協同合作的可能性，從人的需求出發找出協作的可能性，為了實現這一目標，需要發展更多樣化機械手臂的外部即時控制方式，打破傳統方式工業化控制手臂離線編程方法，本研究演示出一套以人機協同研究為基礎的人機共舞科技藝術創作模式，並串聯人與手臂間的即時或非即時的互動控制方式，人機協同研究演示一套具備客製化、同步化、智慧化的創新科藝創作模式，進而衍生運用到各產業的人機協同應用。

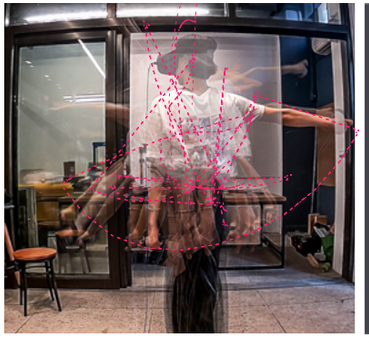


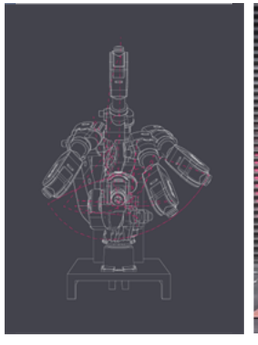
National intercollegiate athletic games

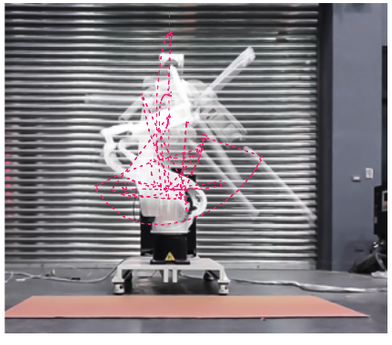
Chief Technology Officer
Yang-Ting Shen | Jung-Yi Hung

Technology Development
Shih-Hao Liao | Jia-Shuo Shiu
Ying-Wen Lin | Cheng-Ru Li

Choreographer / Dancer
Wei-Yu Chen | Wei-Ting Hung

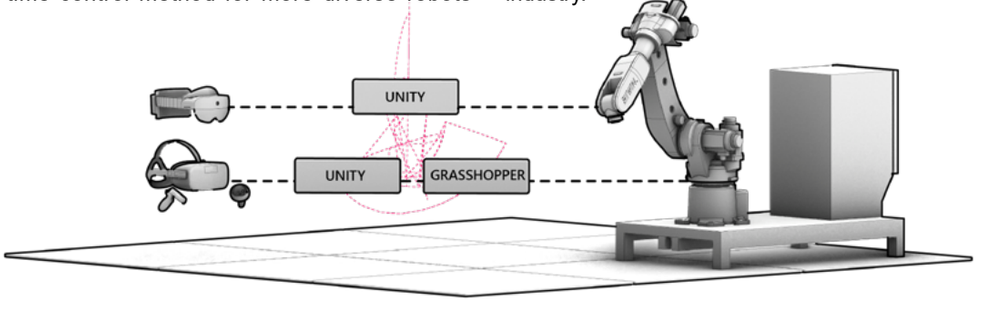






Concept

Following the coming industry 4.0, it is a nonreversible trend to show the process of workers adapting to work with the intelligent machine. Therefore, the interaction of the robot with the worker could be the advanced demonstration of human-machine collaboration. Even though the current operation and speed of the manipulator are only suitable for industrial purposes, it is necessary to find the collaboration possibility starting from the perspective of human demands. To achieve this target, we need to develop the external real-time control method for more diverse robots and break the offline programming method of the traditional industrial robots. This research displayed a set of artistic creations of human-machine dance based on the research of human-machine collaboration, and links the control method for the real-time or non-real-time interaction of humans and manipulators. The research on human-machine collaboration displayed a customized, synchronized, intelligent and innovative mode of technological art , which can be further used in the application of human-machine collaboration in each industry.



機器人映像繪圖

指導老師
沈揚庭

設計者
許家碩

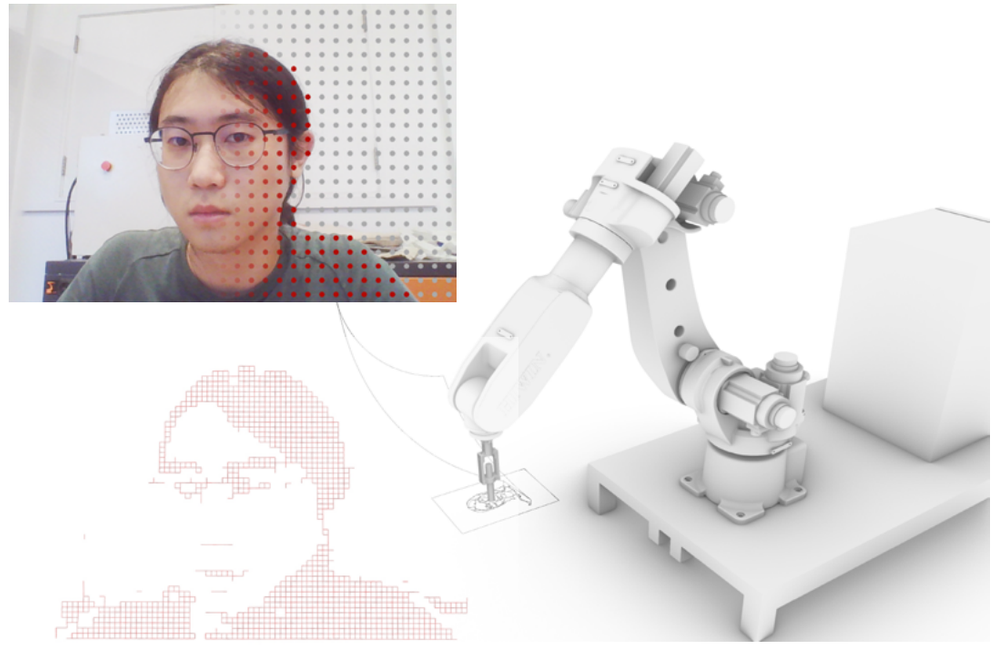
概念

當機器人與藝術相遇，藝術家與工程師的思維產生了前所未見的火花。機器人映像繪圖透過影像錄製記錄下畫面，再透過參數化設計的手法將影像轉化，最後針對影像的像素色彩，以黑色量為依據進行分析，分析完的結果就成了機械手臂繪圖的路徑。此專案以格狀線條作為作畫的形式，且將像素分析出的資訊轉化為現實中線條的粗細變化，以此類整合虛擬參數與現實物件的方式就與其他數位製造案例一樣，須先了解硬體的操作，才得以與軟體整合。

Robotic Reflection Drawing

Advisor
Yang-Ting Shen

Designer
Jia-Shuo Hsu

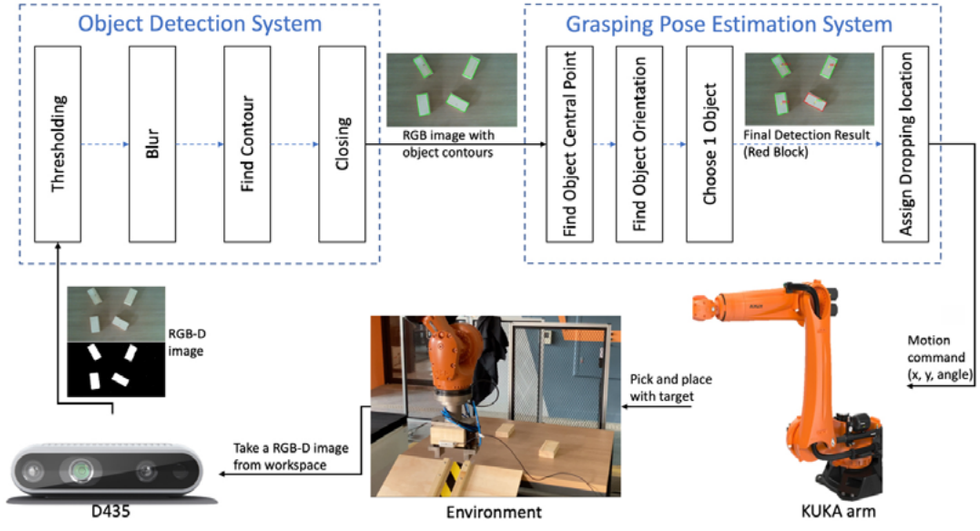


Concept

When robots meet art, it will trigger unprecedented sparks between artists and engineers. The robot drawing workshop introduced a process to convert camera images to robot-drawn graphics. The initial image was captured by a webcam, then processed by parametrical tools to generate the tool path for the robot. The robot draws grid lines on paper, and the stroke weight varies depending on the lightness value of the pixels. This process has thus created a physical presentation of virtual parameters. This method can also be found in other digital fabrication cases, indicating we should always understand the operation of hardware to be able to integrate it with the software.

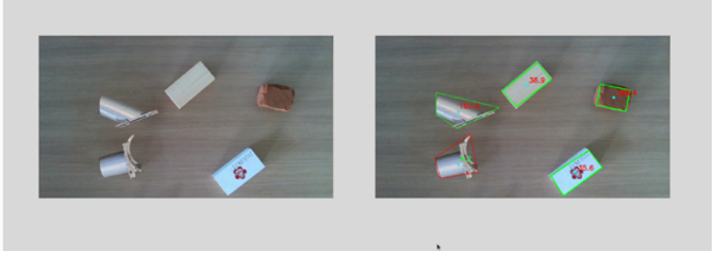
自主機器人識別系統：
基於電腦視覺的自主機器人物體識別與人機使用界面設計

研究作者
鄭方哲 | 顏嘉慶 | 鄭泰昇



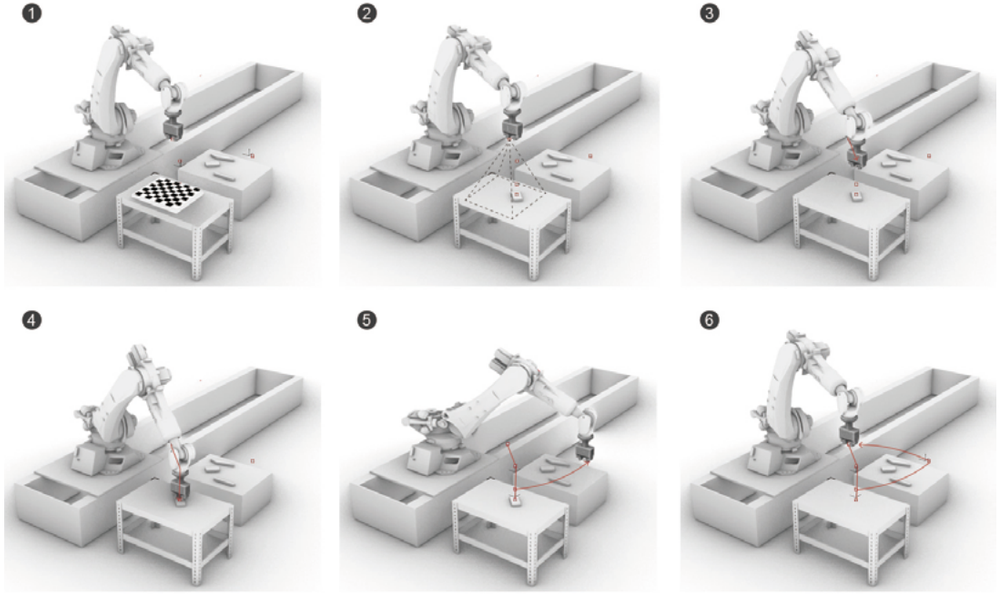
概念

機器人操作系統 (ROS) 與人機協作 (HMC) 的集成目前代表了建築工地自主機器人現場組裝的未來趨勢。與工業環境相比，由於建築構件和定制設計的不同，如今的建築工地極其複雜且不可預測。
本案提出了一種基於視覺的物體識別方法和其使用者界面，使現場機械臂能夠自主處理建築構件，在不受材料、形狀和環境影響的情況下構建特定設計。 該實現是一種對象識別方法，它與 KUKA 工業機器人機械手以及深度視覺立體相機一起使用，以手眼配置來抓取和操縱找到的單元以構建所需的結構。審查了在建築工地使用基於視覺的自主機器人原位組裝的機會。



Autonomous Robotic Recognition System
Object Recognition And User Interface Design For Vision-Based Autonomous Robotic Grasping Point Detwrmination

Researchers
Fang-Che Cheng
| Chia-Chin Yen
| Tay-Sheng Jeng



Concept

The integration of Robot Operating System (ROS) with Human-Machine Collaboration (HMC) currently represents the future tendency toward Autonomous Robotic In-Situ Assembly on Construction Sites. In comparison with the industrial environment, construction sites nowadays are extremely complex and unpredictable, due to the different building components and customized design.

This paper presents a visual-based object recognition method and user interface enabling on-site robot arms to autonomously handle building components, to build specific designs without the influence of material, shape, and environment. The implementation is an object recognition approach that serves with KUKA industrial robotic manipulator along with an RGB-depth stereo camera in an eye-in-hand configuration to grasp and manipulate found elements to build the desired structure. Opportunities for using vision-based autonomous robotic in-situ assembly on construction sites are reviewed.

International Conference on Computer-Aided Architectural Design Research in Asia, CAADRIA 2021 Hong Kong

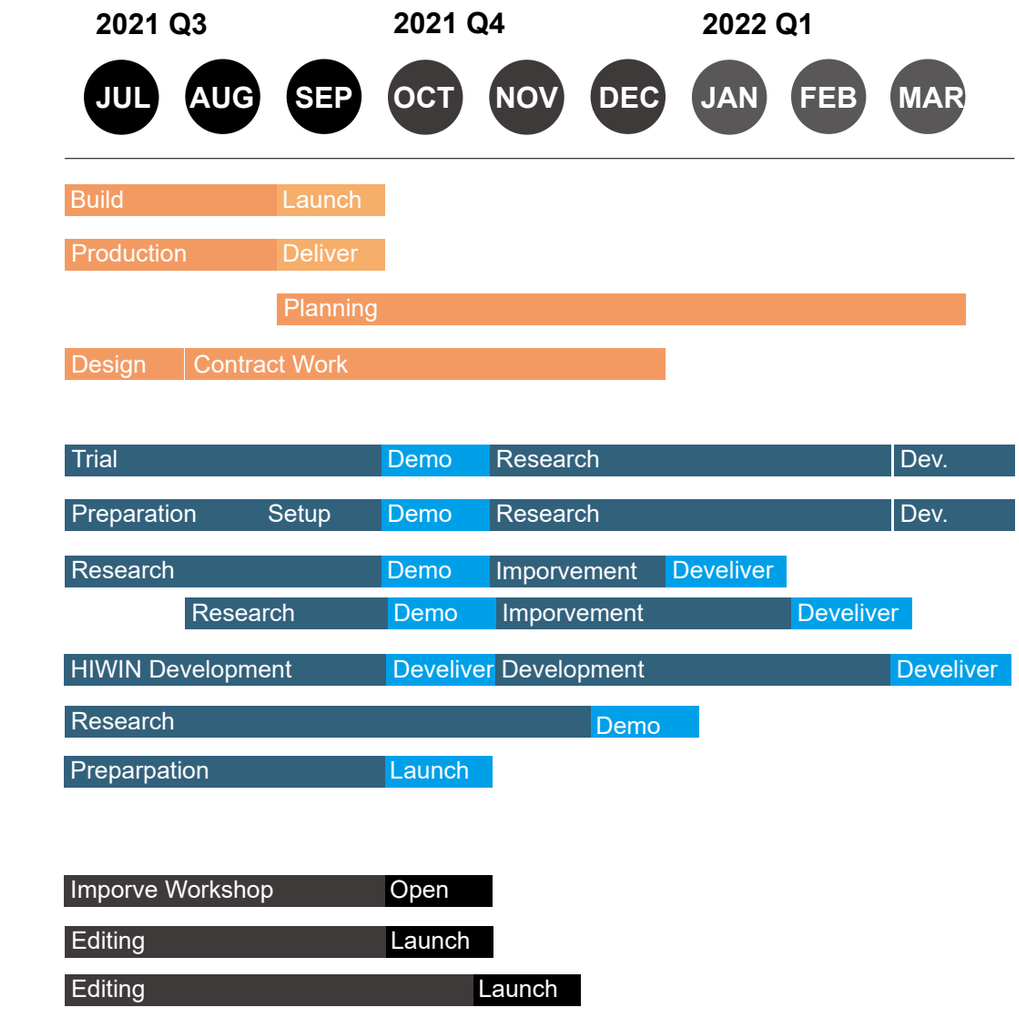
NCKU RAC-Coon 2021

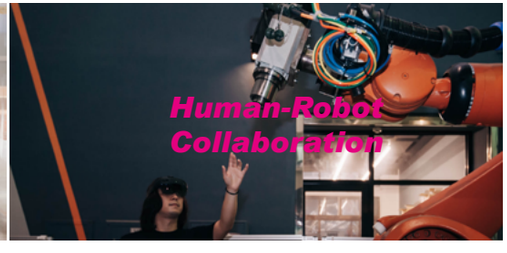
03. RESEARCH AND DEVELOPMENT

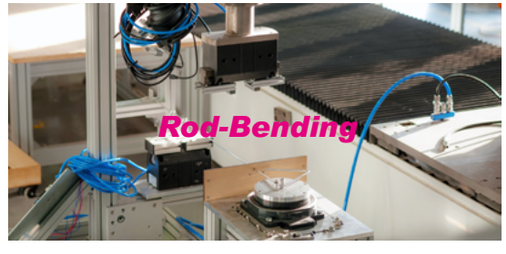
RAC-Coon: VISION FOR A SUSTAINABLE FUTURE

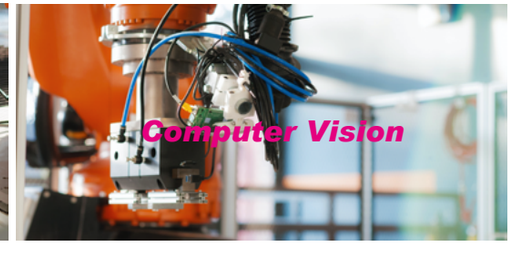
Roadmap

[Category]	[Projects]
Project	成大建築系大四實構築 **| Year Four Studio Pavilion**
	福德祠保麗龍切割案 **| Fude Temple Construction Project**
	人機協作 **| Human-Robot Collaboration**
	九典木雲案 **| Bio Architecture Formosana**
Research & Development	機器人大木作 **| Robotic Woodworking**
	東台主軸 **| Spindle**
	機器人金屬 / 鋼筋彎折 **| Robotic Rod / Rebar Bending**
	電腦視覺辨識 **| Raccoon-CV**
	Raccoon 插件 **| Raccoon-GH**
	Raccoon 機器人作業系統 **| Raccoon-ROS**
	程式學習 **| Programming Study**
Management	整建 maker space 和 CNC **| Refurbish Makerspace and CNC**
	數位智造工坊網站 **| Website**
	數位智造工坊年鑑 **| Annual Report**









Hardware Imporvement

數位智造工坊為了配合相對應的研究與合作開發案，除了和校外廠商合作外，學生也自主打造專屬於相關研究的工具頭，目前 RAC-COON 已有 7 款不同的工具頭正式加入研究和製造，也積極地開發不同的設備來達成新的挑戰。

RAC-Coon not only cooperates with the off-campus suppliers but also assists students to develop in-house end-effectors for the projects. Currently, RAC-Coon owns seven end-effectors for various research or fabrication purposes and would keep actively developing different equipment to tackle the new challenges.

氣動夾爪 | Gripper 2020.August

目前工坊設備內有 KUKA 和 HIWIN 的氣動夾爪，為數位智造工坊第一組工具頭，也是初階疊磚工作營的訓練工具頭。

Pneumatic grippers and HIWIN electric grippers are the earliest sets of end-effectors at RAC-Coon. They are mainly used as training end-effectors for the robotic brick assembly workshops.

上銀機器人繪圖筆 | HIWIN Drawing Pen 2020.September

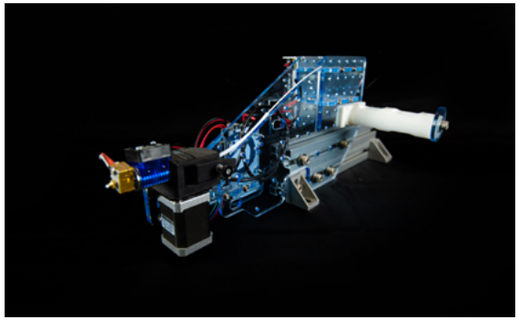
3D 列印的上銀機器人繪圖繪圖工具頭，由研究生許家碩所設計並製成，為數位智造工坊第一款開發的專屬工具頭。

The 3D-printed HIWIN robot drawing tool is the first in-house end-effector at RAC-Coon, which was designed and manufactured by the graduate student, Chia-Shuo Hsu.

3D 列印擠出器 | Filament 3D Printer Extruder 2020.October

由顏嘉慶經理所開發測試研究的 3D 列印擠出工具頭，主要運用在 KUKA 手臂上，未來也會開發相關的金屬列印研究。

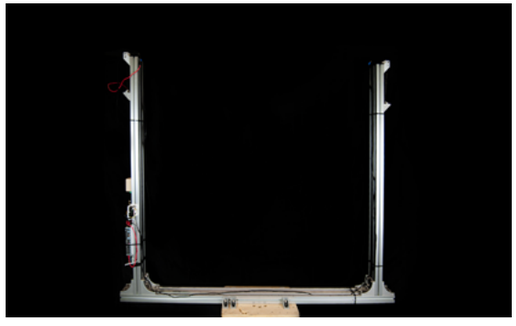
The 3d-printing extruder for KUKA robots is developed and tested by the RAC-Coon manager, Chia-Ching Yen. A metal 3d-printing extruder would also be developed in the future.



保麗龍切割器 | Hot Wire Foam Cutting 2020.November

福德祠保麗龍切割案所需工具頭，顏嘉慶所開發，並於 2020 年底完成第一期的研發測試，隔年正式簽約投入工程案。

The hot-wire cutter for foam cutting was developed by Chia-Ching Yen at the end of 2020 as the phase 1 R&D of the Fu-De Temple project. It is contracted to be used in the construction project next year.



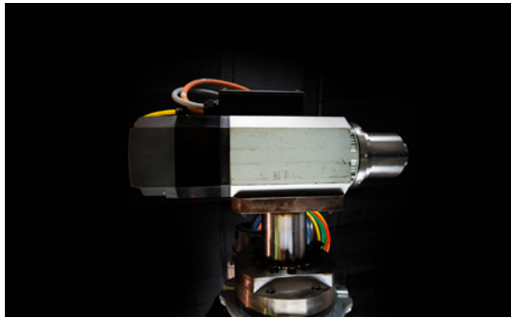
多功能替換組 | Exchangable Wood working Modules 2021.May

與成大工設系博士生陳俊利合作開發的機器人替換組件，右圖為雕刻機與組件之搭配。
The exchangeable robotic woodworking tools were developed by the Ph.D. student of NCKU Industrial Design Department, Chun-Li Chen. The wood router with mounting components is shown in the right pic.

東台主軸 | Tongtai Spindle 2021.August

於東台精機股份有限公司所購買的主軸，目前由研究生黃廉凱測試並投入相關大木作研究。

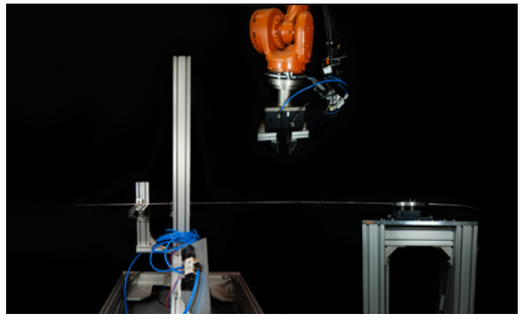
The spindle is a product from Tongtai Machine & Tool Co. and was used in the robotic wood milling research by the graduate student, Lien-Kai Huang .



金屬彎折器 | Rod-Bender 2021.September

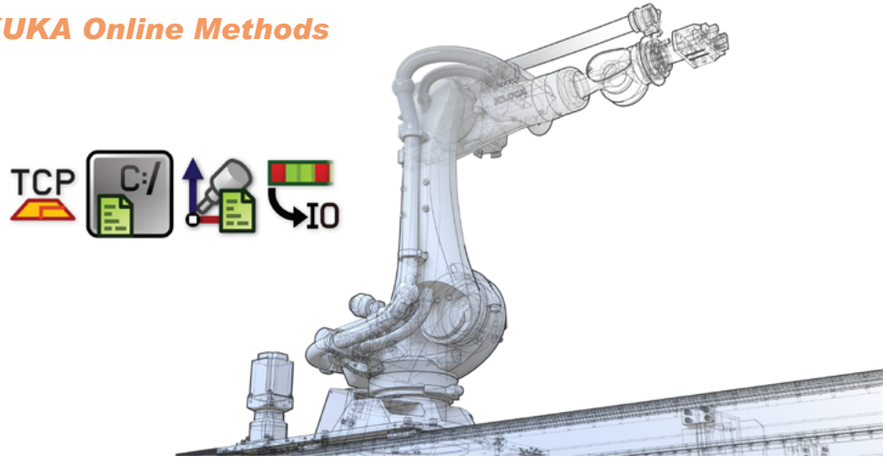
研究生蕭瑋廷致力於機器人金屬彎折的研究，並花費半年時間開發出金屬彎折組件。

The graduate student, Wei-Ting Hsiao is devoted to robotic rod bending research, and managed to develop the rod bending tools in half a year.

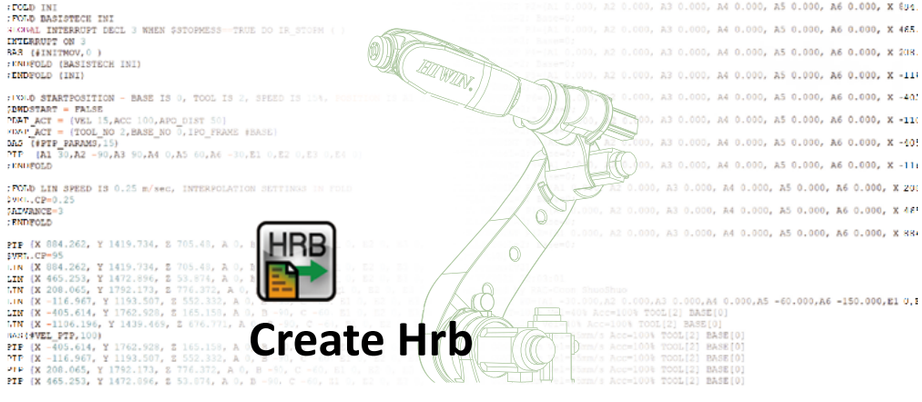


Software Imporvement

KUKA Online Methods

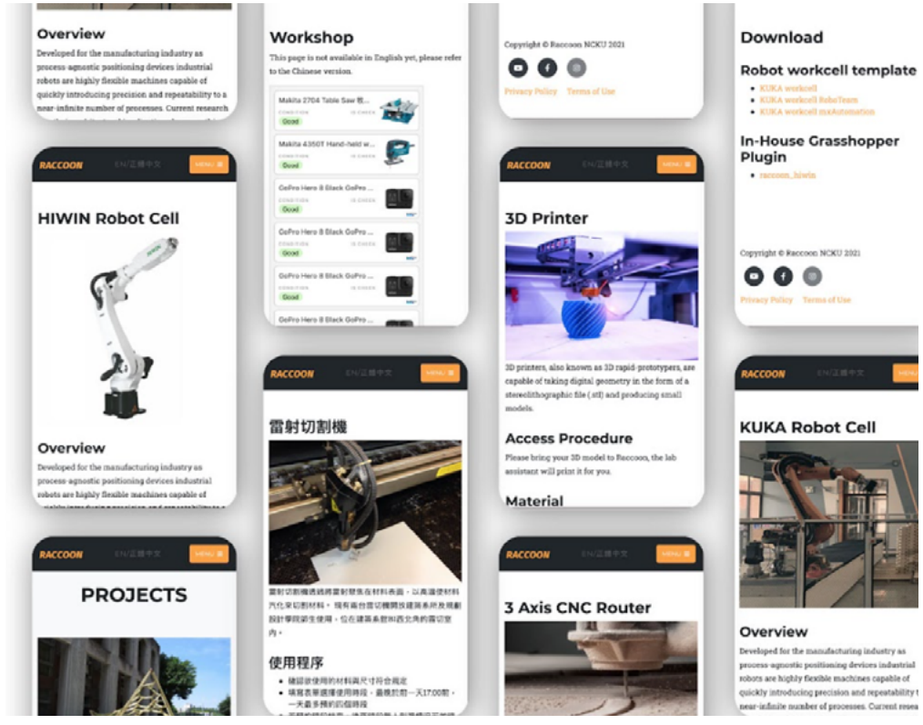


HIWIN Grasshopper Plugin



Create Hrb 可以將 KUKA|prc 導出的檔案轉換成上銀機械手臂專屬的檔案格式，使上銀機械手臂的設計流程能完全整合到 KUKA|prc 中。

Create Hrb is a Grasshopper plugin that translate the KUKA-robot-language files generated by KUKA|prc into the file format for HIWIN robots, allowing the workflow for HIWIN robots to be integrated into KUKA|prc.



使用與學習 | USE & LEARN

空間 | Space

安全 | Safety

專案登記 | Registered Project

審查程序 | Qualification Procedure

硬體設備 | HARDWARES

KUKA 7 軸機器人 | KUKA 7-AXIS ROBOT

HIWIN 6 軸機器人 | HIWIN 6-AXIS ROBOT

3 軸 CNC | 3-AXIS CNC ROUTER

製造 | Fabrication

全尺寸架構 | 產品製造

Full scale architecture / Product fabrication.

電腦運算設計 | Computational Design

開發基於製造的電腦運算設計方法

Developing fabrication-informed computational design methods.

研究與教學 | Research & Teach

數位製造的可及性

Make digital fabrication more accessible.

{made_by:Robots} Workshop

-
講師 : 顏嘉慶
參與學生數 : 40 人
參與系所 : 成大建築研究所、土木系研究所、資工系研究所、機械系研究所、戴育澤建築師事務所

透過工業機器人 KUKA KR300，數位資料與建築材料的能更密切結合，進而推動傳統建築知識與營建技術在數位時代的延續。

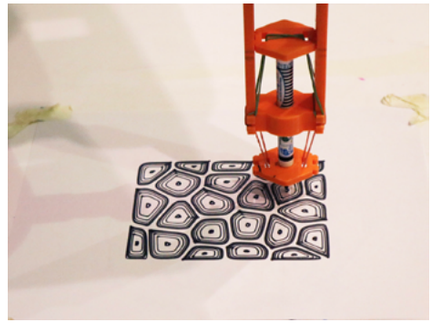
工作營將介紹工業機器人的工作原理，了解從設計到手臂製作的工作流程，最後實機操作手臂疊磚。藉此了解工業機器人的優勢、潛力與限制，以發掘未來應用於設計以及研究之中的可能性。

-
2020.08.24 - 29

-
Participants : 40
Departments: NCKU Architecture Research Institute, Civil Engineering Research Institute, Resource Engineering Research Institute, Mechanical Engineering Research Institute, Dai Yuze Architects

Through the application of industrial robot in architecture, digital data and physical materials could interact more closely. Conventional architectural knowledge and construction techniques could therefore continue evolving in the digital era.

The workshop introduces the fundamentals of robotics and the workflow from design to manufacturing. Participants operated the robot to build their robotic brickwork projects. In this way, the students could understand the advantages, potential, and limitations of industrial robots, exploring the opportunity to adopt robots in their future projects.



Robot Drawing Workshop

-
2021.01.10
講師 : 許家碩
參與學生數 : 20 人
Instructor : Hsu Jia-Shuo
Participants : 20

機器人映像繪圖透過影像錄製記錄下畫面，再透過參數化設計的手法將影像轉化，最後針對影像的像素色彩，以黑色量為依據進行分析，分析完的結果就成了機械手臂繪圖的路徑。此專案以格狀線條作為作畫的形式，且將像素分析出的資訊轉化為現實中線條的粗細變化，以此類整合虛擬參數與現實物件。

The robot drawing workshop introduced a process to convert camera images to robot-drawn graphics. The initial image was captured by a webcam, then processed by parametrical tools to generate the tool path for the robot. The robot draw grid lines on paper, and the stroke weight varies depending on the lightness value of the pixels. This process has thus created a physical presentation of virtual parameters.

Bending_Active Workshop

-
2021.04.02 - 05
講師 : 蕭瑋廷、趙家亘
參與學生數 : 20 人
Instructors : Hsiao Wei-Ting & Chap Jos-Hsuan
Participants : 20

以材料系統的思維來操作構造系統，為當代的建築領域的材料應用提供了強而有力的範式，這個過程促使材料設計重新成為數位建築設計中一個重要環節，透過在材料領域中數位化的理解及創造能力，使材料設計重新回到建築設計裡的可以被控制的設計因素。

This workshop introduces material-driven structure design, demonstrating a robust case of the contemporary material application in architecture. This process has made material back to be a significant part of computational design. By digitalizing the understanding and manipulation of material, material returns to be a controllable factor of architecture design.

04. INFORMATION

RAC-Coon: FOUNDATION FOR A RESILIENT MANAGEMENT

組織單位 | Organizers

協助數位智造工坊研究發展
國立成功大學 | National Cheng Kung University (NCKU)

成立數位智造工坊
國立成功大學規劃與設計學院 | College of planning and Design, NCKU

協助數位智造工坊經費發展
財團法人建築文教基金會 | NCKU Architecture Foundation

支援數位智造工坊活動及研究發展
國立成功大學建築學系 | Department of Architecture, NCKU

國立成功大學 National Cheng Kung University

國立成功大學 規劃與設計學院 College of Planning and Design National Cheng Kung University

財團法人成大建築文教基金會

國立成功大學建築學系 Department of Architecture National Cheng Kung University

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We are grateful to our generous sponsors

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贊助 2 台 RA620 機械手臂
上銀科技股份有限公司 | HIWIN Technologies Corp.

協助開發主軸工具頭
東台精機股份有限公司 | Tongtai machine & tool co., ltd.

贊助相關資訊 | Sponsorship Information

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張哲夫建築師事務所 CHE FU CHANG ARCHITECTS

九典 BaF

Tongtai

HIWIN 上銀科技

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NCKU RAC-Coon 2021

BUILD THE FUTURE

RAC-Coon

Robot Aided Creation and Construction

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2021 ANNUAL REPORT