

發展高動態阻抗反應之協作型機器人及其應用

國立臺灣大學機械工程學系
藍兆杰 教授

人機協作



本技術提出具備高動態阻抗反應能力的新型協作型機器人，旨在解決現有協作型機器人與人類手臂間力覺反應性能上的顯著差距。透過研發高動態阻抗控制技術與扭矩控制關節模組，提升機器人的動態反應與柔順性，同時保持機械手臂的高剛性、高重複精度、優異的負載對總重量比及成本效益。本研究整合了變勁度機構設計與機器學習技術，建立精確的關節模組動態模型，以實現快速且柔性的運動控制，並能即時精準調節對環境的輸出力量。所開發之機器人已透過協作研磨、插件自動組裝及工具機上下料等實際應用場域進行測試與驗證，展現了本技術在高性能人機協作領域的廣泛應用潛力。

計畫亮點

- 扭矩控制關節模組技術開發與精確的數學動態模型建立，以提升機器人整體控制效能。
- 變勁度機構設計之動態阻抗反應系統，實現具高柔順性且可即時調節的阻抗控制性能。
- 協作型研磨機器人的系統整合與現場應用測試，驗證其高效率與實務操作性。
- 應用機器學習技術建構關節模組動態特性預測模型，提升控制精度與穩定性。
- 多自由度關節模組之自動化插件系統設計與示範，顯著提高生產效率及應用彈性。

產業應用

- 自動化機器人插件組裝，實現高效且靈活的零件裝配。
- 自動化機器人研磨與拋光，提高表面品質，有效降低人力成本與提升產品競爭力。
- 工具機自動上下料作業，優化生產流程與提高生產效率，降低作業人員的勞務負擔。
- 人機協作環境之高動態安全性與互動性應用，廣泛適用於智慧製造、精密裝配等多元產業領域。

AUG.21

Development of Collaborative Robots With High Dynamic Impedance Response for Industrial Applications

Department of Mechanical Engineering, National Taiwan University
Dr. Chao-Chieh Lan

Human-robot
Collaboration



This technology introduces a novel collaborative robot featuring high dynamic impedance response capabilities, addressing the significant gap in force-sensing performance between existing collaborative robots and human arms. By developing advanced high-dynamic impedance control techniques and torque-controlled joint modules, the robot achieves improved dynamic responsiveness and compliance without sacrificing arm rigidity, repeatability, payload-to-weight ratio, and cost efficiency. Integrating variable stiffness mechanism designs and machine learning models, the precise joint module dynamics facilitate rapid and compliant motion control, allowing for accurate real-time adjustment of interaction forces with the environment. The developed robot has been validated through practical applications, including collaborative grinding, automatic plug-in assembly, and machine tool loading and unloading tasks, demonstrating significant potential in various high-performance human-robot collaboration fields.

Project Highlights

- Development of torque-controlled joint modules and establishment of accurate mathematical dynamic models to enhance overall robot control performance.
- Dynamic impedance response systems based on variable stiffness mechanism designs, achieving highly compliant and real-time adjustable impedance control.
- System integration and practical field tests of collaborative grinding robots, demonstrating high efficiency and operational practicality.
- Application of machine learning techniques to construct predictive dynamic models for joint modules, improving control accuracy and stability.
- Design and demonstration of automated peg-in-hole systems for multi-degree-of-freedom joint modules, significantly enhancing production efficiency and application flexibility.

Industrial Applications

- Automated robotic peg-in-hole assembly for efficient and flexible component assembly, meeting diverse industrial requirements.
- Automated robotic grinding and polishing processes that enhance surface quality, effectively reducing labor costs and improving product competitiveness.
- Automated loading and unloading tasks in machine tools, optimizing production workflows, enhancing efficiency, and reducing operator workload.
- High-dynamic safety and interactive applications in human-robot collaboration environments, widely applicable in smart manufacturing, precision assembly, and other diverse industrial sectors.

Contact Person

National Taiwan University
Chao-Chieh Lan

TEL
Email

02-33662754
lancc@ntu.edu.tw

基於多模態感知及 AI路徑生成的多人多機協作避碰動作規劃

人機協作

國立臺灣科技大學機械工程系
林柏廷 教授團隊

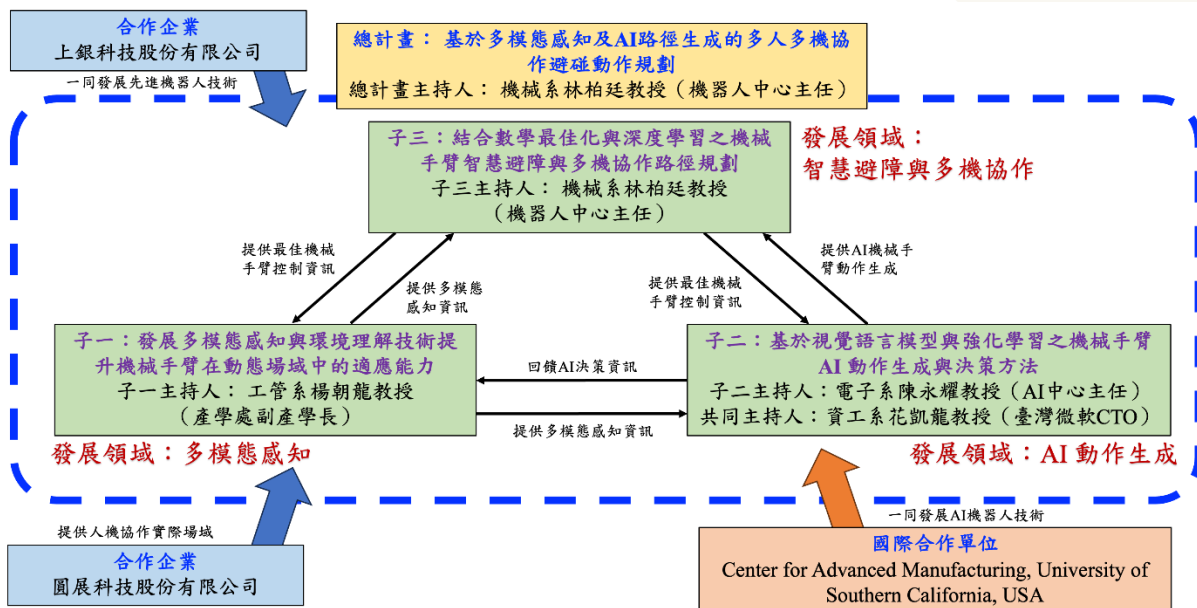


國立臺灣科技大學電子工程系
陳永耀 教授

當前製造業正朝向智慧化、自動化、人機協作的方向發展，然而傳統機械手臂仍存在感知能力有限、無法自主適應環境變化、避障策略不夠靈活等挑戰，使得人機協作的安全性與效率難以進一步提升。本計畫提出結合多模態感知、AI動作生成與智慧避障的研究架構，發展具備環境理解、決策適應與自主避障能力的智慧機械手臂。子一的多模態感知技術整合視覺、語音與人體動作資訊，提升機械手臂對環境與人類行為的即時理解能力；子二專注於AI動作生成技術，利用視覺語言模型與強化學習，使機械手臂能夠根據不同場景自主調整動作策略；子三負責發展智慧避障與多機協作技術，使機械手臂能夠在多人多機環境中即時避障並規劃最佳路徑，以確保人機協作的安全與效率。

計畫亮點

- 多模態感知資料同步與融合
- 即時AI語意驅動動作生成
- 多人多機智慧避碰動作規劃
- 視覺語言模型（VLM）與強化學習整合
- 邊緣運算平台與即時資料處理



產業應用

- 機械手臂人機協作組裝產線
- 多款機械手臂協作避碰系統
- 智慧製造現場作業效率優化
- 工業視覺及聲音異常事件偵測
- 智慧備料與加工任務執行系統

專利資訊：周邊物體快速探知方法及其系統

專利證書號 I811816

專利權期限 2021.10.21-2041.10.20

本發明提出一種以機器學習快速探測機械裝置周邊物體位置與距離之方法與系統，能即時判斷碰撞風險並自動修正路徑。

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Motion Planning with Collision Avoidance for Multi-Human-Multi-Robot Collaboration Based on Multi-Modal Sensing and AI Path Generation

Department of Mechanical Engineering, National Taiwan University of Science and Technology
Dr. Po-Ting Lin

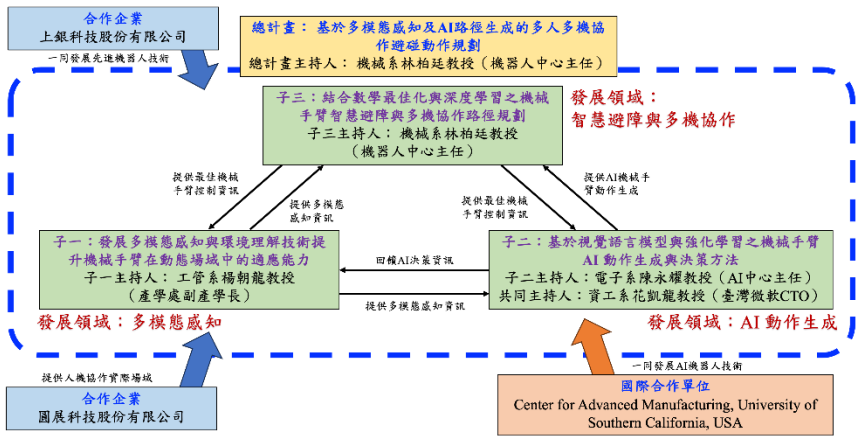


Department of Electronic and Computer Engineering, National Taiwan University of Science and Technology
Dr. Yung-Yao Chen

Modern manufacturing is shifting towards smart automation and human-robot collaboration, yet traditional robotic arms still face limitations in perception, adaptability, and obstacle avoidance. This project aims to address these challenges by integrating multi-modal perception, AI-driven motion generation, and intelligent obstacle avoidance. Multi-modal perception techniques allow robots to integrate visual, speech, and human motion data. AI-driven motion generation leverages Vision-Language Models and reinforcement learning to enable robotic arms to autonomously adjust their movements according to various scenarios. Intelligent obstacle avoidance and multi-robot collaboration strategies ensure real-time robot path planning and safe operation in dynamic environments.

Project Highlights

- Multi-modal perception data synchronization and fusion
- Real-time AI semantic-driven action generation
- Intelligent collision avoidance action planning for multi-person and multi-robot systems
- Integration of visual-language models (VLM) with reinforcement learning
- Edge computing platform and real-time data processing



Industrial applications

- Human-robot collaborative assembly lines
- Collaborative collision avoidance system for multiple robot arms
- Operational efficiency optimization for smart manufacturing sites
- Industrial visual and auditory anomaly detection
- Intelligent material preparation and machining task execution system

Patent: METHOD AND SYSTEM FOR QUICKLY DETECTING SURROUNDING OBJECTS

Patent Number I811816

Patent Term ~2041.10.20

This invention presents a method and system utilizing machine learning to rapidly detect positions and distances of surrounding objects relative to a mechanical apparatus, enabling instant collision risk assessment and automatic path correction.

Contact Person

National Taiwan University of Science and Technology
Dr. Po-Ting Lin

TEL

0983-033147

Email

potinglin@mail.ntust.edu.tw

結合AI之腫瘤消融機器人系統

國立臺灣大學生物機電工程學系
顏炳郎 教授

人機協作



本計畫開發之手術機器人系統為醫師在腫瘤消融手術中的機器人助手，在手術規劃階段，進針決策模型結合生成式AI與醫師的臨床經驗，透過AI與醫師的互動，更有效率地規劃安全且有效的下針路徑；在手術執行階段，本系統透過感測器與機器人系統提供精準定位控制，完成醫師所下達的操作指令，降低醫師手眼操作負擔；在安全監控方面，本系統結合CT影像與超音波影像融合技術，並搭配導航人機介面，提供術中即時的影像資訊，讓醫師不需要大量拍攝CT也能夠掌握進針過程的安全性與準確度。本計畫與醫師團隊緊密合作，已於台北榮總醫院進行多次手術機器人場域測試。

計畫亮點

- 結合生成式AI與醫師的臨床經驗，更有效率地規劃安全且有效的下針路徑。
- 機器人系統精準控制，降低醫師手眼操作負擔，減少病人CT掃描次數，提高手術安全性。
- CT與超音波影像融合技術，於術中提供即時資訊，避免軟組織變形造成穿刺誤差與手術風險。



產業應用

- 腫瘤消融治療：可應用於肝腫瘤、肺腫瘤等穿刺手術，提升精準度與安全性。
- 微創手術導引：結合即時影像與機器人控制，有助於各類微創手術的定位與導航。
- 術中決策輔助：為醫師提供個人化手術建議，提升決策效率。

專利資訊(1)：機器人導航系統以及機器人導航方法

專利證書號 I744037

專利權期限 ~2041/10/20

一種機器人導航系統包括手持式機器人、空間資訊量測裝置、計算模組以及顯示器介面。手持式機器人具有彼此連接的本體、工作具以及可動連接機構。可動連接機構連接於本體與工作具之間，藉以使工作具相對本體移動。空間資訊量測裝置設置以追蹤本體、工作具與目標。計算模組連接空間資訊量測裝置以獲得本體、工作具與可動連接機構相對目標之間的相對位置。計算模組根據相對位置與手持式機器人的機械參數計算導引區域。導引區域的坐標以目標為基準。顯示器的顯示介面至少包含了配置以目標的坐標為基準顯示導引區域以及手持式機器人的本體。

專利資訊(2)：協作式手術規劃系統及其操作方法

專利證書號

專利權期限

一種協作式手術規劃系統包括主機、分辨式人工智慧模組、使用者導航介面及生成式人工智慧模組。分辨式人工智慧模組電性連接主機，配置以根據複數個電腦斷層影像形成複數個器官分割影像。使用者導航介面電性連接主機，配置以顯示器官分割影像、初步下針路徑、複數個建議下針路徑與最終下針路徑。生成式人工智慧模組電性連接主機，使得主機將使用者導航介面與生成式人工智慧模組連接。生成式人工智慧模組配置以根據器官分割影像與初步下針路徑產生建議下針路徑並於使用者導航介面顯示。

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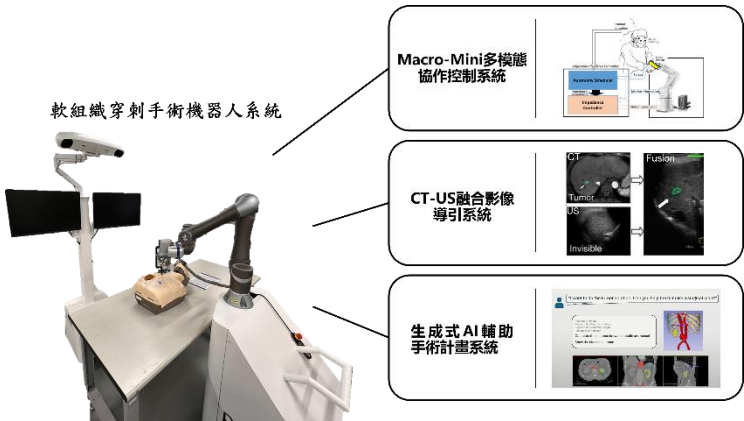
An AI-enhanced Robotic Platform for Tumor Ablation

Department of Biomechanics Engineering,
National Taiwan University
Dr. Ping-Lang Yen

Human-robot
Collaboration



This project develops a surgical robotic system that serves as an assistant to physicians during tumor ablation procedures. During the planning phase, the needle insertion decision model integrates generative AI with clinical expertise to collaboratively plan safe and effective insertion paths with greater efficiency. In the execution phase, the system leverages sensors and robotic control to provide precise positioning, executing physician commands while reducing manual coordination burdens. For intraoperative safety monitoring, the system fuses CT and ultrasound imaging, combined with a navigational human-machine interface, delivering real-time visualization that enables physicians to accurately monitor the insertion process without relying on frequent CT scans. The project is conducted in close collaboration with a medical team, and multiple field tests have been successfully carried out at Taipei Veterans General Hospital.



Project Highlights

- By combining generative AI with physicians' clinical expertise, the system efficiently plans safer and more effective needle insertion paths.
- Precision control of the robotic system alleviates manual coordination demands on physicians, reduces the frequency of patient CT scans, and enhances overall surgical safety.
- The fusion of CT and ultrasound imaging provides real-time intraoperative information, mitigating puncture errors and surgical risks caused by soft tissue deformation.

Industrial Applications

- Tumor ablation therapy: Applicable to needle-based procedures for liver and lung tumors, improving precision and safety.
- Guidance for minimally invasive surgery: Integrates real-time imaging and robotic control to assist in accurate tool positioning and navigation.
- Intraoperative decision support: Provides personalized surgical recommendations to enhance clinical decision-making efficiency

Patent (1) : ROBOT GUIDING SYSTEM AND ROBOT GUIDING METHOD

Patent Number I744037

Patent Term ~2041/10/20

A robot navigation system includes a handheld robot, a spatial information measuring device, a computing module and a display. The hand-held robot has a base, a tool and a movable connection mechanism. The movable connection mechanism is connected between the base and the tool, so that the tool can move relative to the base. The spatial information measuring device is configured to track the base, the tool and a target. The computing module is connected to the spatial information measuring device to obtain a plurality of relative positions between the base, the tool and the movable connection mechanism relative to the target. The computing module calculates a guiding region according to the relative positions and mechanical parameters of the handheld robot. The display is configured to display the guiding region and the handheld robot based on the coordinates of the target.

Patent (2) : ASSISTED SURGICAL PLANNING SYSTEM AND OPERATION METHOD THEREOF

Patent Number

Patent Term

An assisted surgical planning system includes a host computer, a discriminative artificial intelligence (AI) module, a user navigation interface, and a generative AI module. The discriminative AI module is electrically connected to the host computer, and is configured to form plural organ segmentation images based on plural computed tomography (CT) images. The user navigation interface is electrically connected to the host computer, and is configured to display the organ segmentation images, an initial needle insertion path, plural suggested needle insertion paths, and a final needle insertion path. The generative AI module is electrically connected to the host computer, such that the host computer connects the user navigation interface to the generative AI module. The generative AI module is configured to generate the suggested needle insertion paths based on the organ segmentation images and the initial needle insertion path, and display the suggested needle insertion paths in the user navigation interface.

Contact Person

Department of Biomechanics
Engineering, National Taiwan University
Ya-Shin Fong

TEL
Email

02-33665358
yashin@ntu.edu.tw

AI智慧機器人應用於工件去毛邊加工處理

國立清華大學 動力機械工程學系
張禎元 講座教授

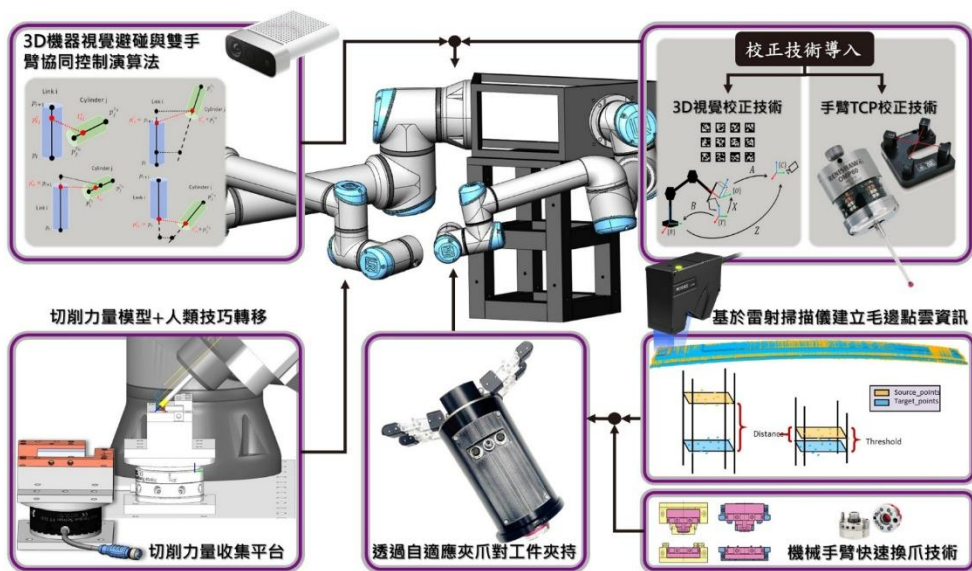
人機協作



本計畫聚焦於智慧型機器人在人機協作與智慧製造應用的技術整合。團隊開發結合語音理解、生成式AI、三維視覺與擬人機械手臂的系統，實現自主技能學習、物體夾取與力控制等功能，能執行如去毛邊加工、物品遞交與語音互動等任務。技術涵蓋雙手臂協同控制、感知融合、技能轉移與互動決策等面向，具模組化與彈性化優勢，展現於航太加工與智慧服務場域之落地潛力，符合人因導向的製造與服務新趨勢。

計畫亮點

- 結合語音辨識、生成式 AI 與智慧機械手臂控制技術，實現語意理解與動作生成的智慧互動系統。
- 發展具捏取功能之欠驅動機械夾爪，具備柔順控制與自適應包覆力，提升人機互動安全與抓握穩定性。
- 整合三維視覺、即時力感知與障礙物避讓控制，支援機器人於智慧製造與服務應用場域之落地部署。
- 開發創新力量控制演算法，結合主動式致動器，有效提升機器人於加工任務中的精度與強健性。



產業應用

- 結合語音 AI 與智慧機械手臂控制技術，推動人機協作應用場域之智慧化。
- 衍生應用包括智慧製造、教育陪伴、服務型機器人與高齡照護場域，如：自動物品夾取遞交、工廠人機協同作業與新進人員操作訓練輔助。

專利資訊：機器人與機器人手眼校正方法

專利證書號 US 12257726 B2

專利權期限 2043/06/01

本發明提供一種機器人手眼校正方法，結合機械手臂、攝影機與處理器，透過校正影像自動取得座標對應，建立相機與機器人間之對應關係，以提升感知與操控精度。

AUG.21

AI-Driven Intelligent Robots for De-Burring Manufacturing

National Tsing Hua University, Department of Power Mechanical Engineering
Dr. Jen-Yuan Chang

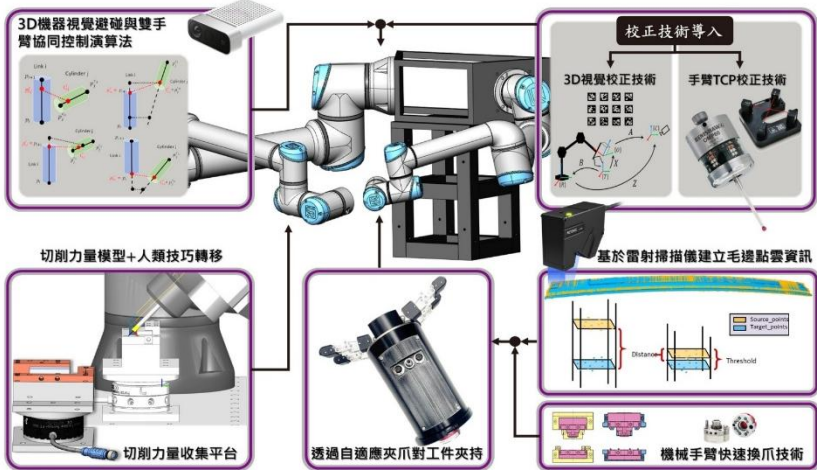
Human-robot Collaboration



This project focuses on human-robot collaboration for intelligent manufacturing and interactive service. Our team integrates generative AI, 3D vision, force sensing, and anthropomorphic robotic grippers to enable skill learning, force-aware manipulation, and voice interaction. Applications include de-burring, object delivery, and task planning via natural language. With modular and flexible design, the system features dual-arm coordination, perception-driven control, and human-in-the-loop adaptability, supporting future deployment in aerospace, smart factories, and assistive robotics.

Project Highlights:

- Developed an intelligent interactive system that integrates voice recognition, generative AI, and robotic arm control to achieve semantic understanding and action generation.
- Designed an underactuated robotic gripper capable of dexterous grasping, featuring compliant control and adaptive enveloping force for enhanced safety and stability in human-robot interaction.
- Integrated 3D vision, real-time force sensing, and obstacle avoidance to support on-site deployment in smart manufacturing and service-oriented applications.
- Proposed a novel force control algorithm combined with active actuators to improve precision and robustness in robotic machining tasks.



Industrial Applications:

- The technology integrates voice AI and intelligent robotic arms to enable smart human-robot collaboration.
- Applications include smart manufacturing, assistive education, service robotics, and elderly care, such as object handover, collaborative factory tasks, and training support for new operators.

Patent : ROBOT & ROBOT HAND-EYE CALIBRATING METHOD

Patent Number US 12257726 B2

Patent Term ~2043/06/01

The invention provides a hand-eye calibration method for robots that maps robot and camera coordinates via a calibration image, improving perception and manipulation accuracy.

Contact Person

National Tsing Hua University
Tsai, Han Hao

TEL

03-5715131 #33720

Email

pme0918087420@gapp.nthu.edu.tw

人機協同工業機器手臂 與無人車整合於鑄造件拋光研磨應用

國立臺北科技大學
蕭俊祥 教授團隊



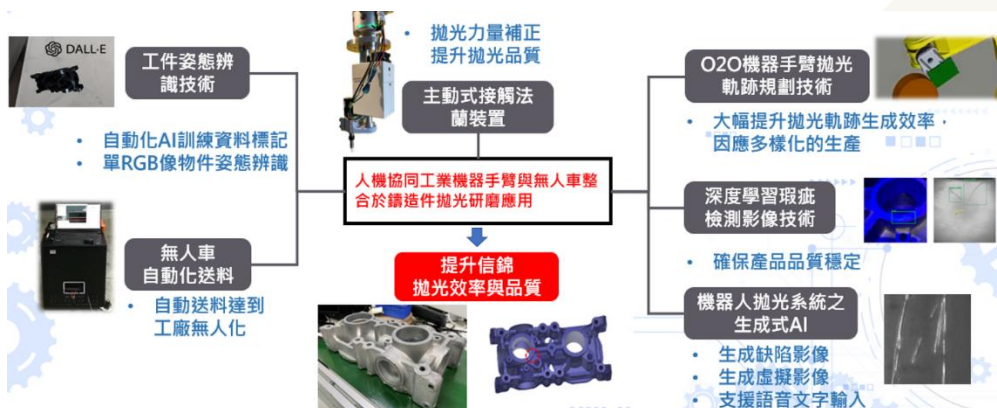
國立陽明交通大學
林顯易 教授

人機協作

本計畫針對鑄造件進行拋光自動化，開發整合人機協同工業機器手臂與AMR的應用系統，導入主動式接觸法蘭ACF、O2O軌跡教導系統、6D姿態估測、以及AOI瑕疵檢測流程。系統能精確自動完成物件定位、打磨、品檢與搬運任務，達成拋光製程之全流程自動化，預期可大幅降低人工負擔並提升拋光品質穩定性。

計畫亮點

- 開發主動式接觸法蘭 (ACF)，達成 $\pm 0.15\text{N}$ 高精度拋光力量控制
- 建立具備O2O功能之人機協同拋光軌跡教導系統，有效降低超過70%教導時間
- 整合6D姿態估測與三點校正，精確定位不規則鑄件並修正加工軌跡
- 導入AOI瑕疵檢測技術，30秒內完成表面檢測，準確率達97%，可檢出0.3mm沙孔
- AMR具備 $x, y < 2\text{cm}$ 與 $R_z < 3^\circ$ 定位精度，自主導航與遠端叫車成功率 $> 90\%$



產業應用

- 本技術可應用於鑄件、水五金與傢俱拋光產業，導入後可取代50%人工；物流倉儲使用AMR可減少30%人力；機器人塗裝透過O2O提升效率；導入AOI於鑄件與PCB檢測，準確率達90%以上。

專利資訊 (1)：基於機械手臂的三維物件輪廓數據建立系統及其方法

專利證書號 I845450

專利權期限 2024/06/11~2043/11/23

本發明提出一種基於機械手臂的三維物件輪廓數據建立系統與方法。透過物件輪廓計算裝置建立觀測物件與法蘭端部之間的物件法蘭運動矩陣，並自影像裝置取得影像參數，自控制裝置取得手臂空間座標及法蘭手臂運動矩陣。系統進一步依據上述資訊計算手臂影像運動矩陣，並將三組運動矩陣相乘以求得物件影像運動矩陣。接著，結合影像裝置內部參數，利用三角測量法計算觀測物件各三維座標點對應於二維平面的投影位置，進而生成物件的輪廓影像。此技術可有效建立高精度的三維物件輪廓數據，提升建模效率與應用便利性，適用於機器視覺、智慧製造等場域。

專利資訊 (2)：使用音圈馬達的法蘭裝置及其接觸控制方法

專利證書號 I802224

專利權期限 2024/05/11~2042/01/13

一種使用音圈馬達的法蘭裝置及其接觸控制方法，透過力量感測器、位移感測器以及慣性測量單元進行接觸數據的感測，將接觸數據透過慣姿態航向參考系統演算法進行濾波計算得到力量控制指令對法蘭裝置進行位移方向與位移距離控制，使法蘭裝置使用音圈馬達以調節拋光裝置與待拋光物件的接觸狀態，藉此可以達成提供安靜、控制精準以及響應快速的電磁式調節接觸狀態裝置的技術功效。

AUG.21

Human-Robot Collaboration and AMR
Integration for Polishing and Grinding of Casting Parts

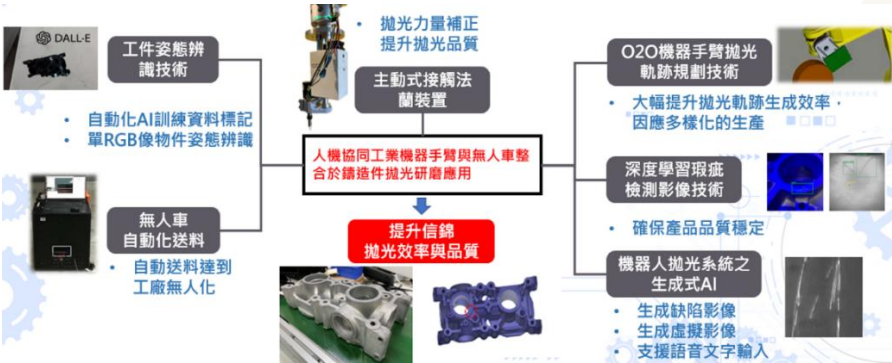
National Taipei University of Technology
Dr. Jin-Siang Shaw

Human-robot
Collaboration



National Yang Ming Chiao Tung University
Dr. Hsien-I Lin

This project develops an integrated system for automated polishing of casting parts by combining human-robot collaborative arms and Autonomous Mobile Robots (AMRs). The system features Active Contact Flange , O2O trajectory teaching, 6D pose estimation, and AOI-based defect inspection. It enables precise and automated polishing, inspection, and loading/unloading. In its fourth year, the system has been validated in real factory environments, demonstrating its capability to enhance quality, reduce labor, and support smart manufacturing applications.



Project Highlights

- Designed Active Contact Flange (ACF) with $\pm 0.15\text{N}$ precision for consistent polishing force
- Developed O2O human-robot trajectory teaching system, reducing path teaching time by over 70%
- Integrated 6D pose estimation with 3-point calibration for accurate casting part alignment
- Implemented AOI-based defect detection with 97% accuracy in 30 seconds, detecting defects $\geq 0.3\text{mm}$
- AMR achieved $< 2\text{cm}$ positional and $< 3^\circ$ angular precision, with $> 90\%$ remote call success rate

Industrial Applications

- The system applies to polishing of castings, metal hardware, and furniture, reducing 50% labor; AMR cuts logistics manpower by 30%; O2O improves robot painting; AOI enables 90%+ accuracy in casting and PCB inspection.

Patent (1) :

3D OBJECT OUTLINE DATA ESTABLISHMENT SYSTEM BASED ON ROBOTIC ARM AND METHOD THEREOF

Patent Number I845450

Patent Term 20240/6/11~2043/11/23

The present invention proposes a system and method for establishing three-dimensional object contour data based on a robotic arm. An object flange motion matrix is established between the observed object and the flange end through an object contour calculation device, and image parameters are obtained from an imaging device, and the arm space coordinates and flange arm motion matrix are obtained from a control device. The system further calculates the arm image motion matrix based on the above information, and multiplies the three sets of motion matrices to obtain the object image motion matrix. Then, combined with the internal parameters of the imaging device, the triangulation method is used to calculate the projection position of each three-dimensional coordinate point of the observed object corresponding to the two-dimensional plane, thereby generating a contour image of the object. This technology can effectively establish high-precision three-dimensional object contour data, improve modeling efficiency and application convenience, and is suitable for fields such as machine vision and smart manufacturing.

Patent (2) : FLANGE DEVICE USING VOICE COIL MOTOR AND CONTACT CONTROL METHOD THEREOF

Patent Number I802224

Patent Term 2024/05/11~ 2042/01/13

A flange device using a voice coil motor and a contact control method thereof senses contact data through a force sensor, a displacement sensor, and an inertial measurement unit. The contact data is filtered and calculated using an inertial attitude and heading reference system algorithm to generate force control instructions to control the displacement direction and distance of the flange device. The flange device uses the voice coil motor to adjust the contact state between the polishing device and the object to be polished, thereby achieving the technical effect of providing a quiet, precisely controlled, and fast-responding electromagnetic contact state adjustment device.

Contact Person

National Yang Ming Chiao Tung
University
Dr. Hsien-I Lin

TEL

03-5712121 #54411

Email

sofin@nycu.edu.tw