二、 項目簡介

（*項目所屬科學技術領域、主要技術內容、授權專利情況、技術經濟指標及應用推廣情況*）

Robotic micromanipulation systems are demanding and peering devices for automated manipulation with high precision and high efficiency in fields such as micro/nano manufacturing, biomedical engineering, etc. Microinjectors and microgrippers are cutting-edge tools in the field of dexterous micromanipulation. In modern biotech industry, there are extensive needs for advanced micromanipulation robotic equipment with high-throughput and high-accuracy capabilities. The invention of automated bio-micromanipulation robotic systems enables extensive applications in the biological field with guaranteed safety and accuracy of advanced robotic manipulation.

Micromanipulation of biological samples such as zebrafish larvae is now conducted manually and no automated micromanipulation robot is available in the market. It is challenging to achieve automated high-throughput manipulation of live larvae with high success rate. The objective of this project is to lead innovative technologies in development of robotic bio-micromanipulation devices towards high-speed precision operation at the micro- and nanometer scales. The invented technologies and equipment made the following breakthroughs.

(1) Design and control technologies of compliant micromanipulators have been proposed to invent novel compact micropositioner and microgripper for high-speed manipulation of micro-objects with nanometer accuracy.

(2) Development technologies of micromanipulators with microforce sensing and haptics feedback have been presented to invent novel force-regulated microinjector for reliable and effective injection of biological cells with high safety and accuracy.

(3) Development technologies of constant-force micromanipulators have been introduced to eliminate the dependence on force feedback control, and novel constant-force robotic micromanipulators have been invented to enable efficient manipulation with reduced cost.

(4) For the first time, novel bio-micromanipulation robotic systems have been developed with force-sensing microinjector for both zebrafish larvae and cells with higher speed, higher survival rate, and higher consistency in comparison with existing approaches.

Technology transfer of the invented innovative technologies can lead to cost reduction of emerging product, and the project results exhibited significant impacts on academia and industry. The impacted outcomes have been well recognized and appraised by world renowned experts and robotics and biotech companies in the field.

Within 5 years, the project has trained/under training 3 PostDoc, 8 PhD, 9 MSc, and 26 BSc students, and led to 50 publications including 23 SCI journal papers and 27 EI conference papers. Among them, 12 papers have been published in some of the best and flagship journals in robotics and automation, including IEEE Trans. Industrial Electronics (No. 1/72 in Instruments & Instrumentation), IEEE/ASME Trans. Mechatronics (No. 13/133 in Engineering, Mechanical), IEEE Trans. Automation Science and Engineering (No. 16/63 in Automation & Control Systems), etc. The publications have been cited 300 times in Google Scholar, where

the PI has an H-index of 54. The involved students have been well trained and thus received the Best Paper Award in IEEE RCAR 2021. The project received 6 awards from both academia and industry, and 4 China and US patents have been authorized or filed. The results have been internationally recognized by the election of the 1st ASME Fellow in Macau for the exceptional achievements and contributions to precision robotics and mechatronics applications. The key technologies have extensive applications in multiple fields including biomedical engineering, gene engineering and drug development. They have attracted the investment of Huafa Group and commercialization cooperation with Suzhou robot and Guangzhou biotech companies. The outcomes speed up the advancement of S&T and moderate diversification of Macau's economy development.

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