Immersive Reality Technology and Robotic Arm Applications in Plastic Microsurgery

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Summary

This study introduces an AR-based surgical robotic platform that integrates AR glasses, robotic arm assistance, and surgical instrument delivery. The system allows intuitive, hands-free camera control and provides real-time video streaming. Key features include head-rotation-based control of camera view and instrument grasping using a 2.5D camera. The detection accuracy reached **91.67%**, with a minimum instrument spacing of **1.4 cm**. The system demonstrated an average latency within **0.2 s**. This system can reduce the interruption and non-ergonomic postures compared to the traditional method.

Introduction

Microsurgery, particularly in plastic surgery for microvascular or nerve suturing, requires visual magnification to observe fine tissue structures. Traditional control methods, such as hand-held controls or mouth-operated devices, often disrupt procedures and force surgeons into non-ergonomic postures, leading to fatigue and musculoskeletal strain [1]. Augmented Reality (AR), through holography, integrates virtual interfaces with the real world, offering immersive solutions and is widely applied in medical procedures [2,3].

This study proposed an AR-based surgical robotic platform that integrated AR glass, robotic arm assistance, and surgical instrument delivery. The system tried to enable intuitive control of the hands-free camera and provides real-time video streaming, improving efficiency, reducing fatigue, and improving surgeon satisfaction.

Methods

The system interface was designed using Unity developed to integrate data transmission between a computer, a smartphone, and a Universal Robot robotic arm using the User Datagram Protocol (UDP). The system connected AR glasses with an Inertial Measurement Unit (IMU) to send data from the smartphone to the computer for filtering. The filtered data was then transmitted to the Universal Robot system to control the robotic arm, which was equipped with a microscope camera for display. An Arduino microcontroller was used to adjust camera parameters, including focus, exposure, and zoom. This system interface allowed head rotations to control the spatial movements of the robotic arm and adjust the camera display.

For instrument grasping, the system utilizes the OnRobot Eyes system. Using the 2.5D camera to identify surgical instruments by the contours of the object (Fig. 1). To evaluate the accuracy of detection, we created a database with six different types of surgical instruments. Each instrument was placed in six regions and at different rotation angles.

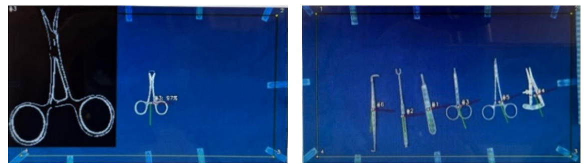

Figure 1: Contours of different surgical instruments

Results and Discussion

The AR glass interface provided a live camera display, with modes that can be switched using head rotation and crosshair aiming (Fig. 2), including: 1. IMU mode: Synchronizing rotation of the head and robotic arm. 2. Linear speed mode: Useing head movement to control the robotic arm linearly. 3. Free-drive mode: Allowing manual manipulation of the robotic arm. The latency assessment showed **within 0.2 s** between user input and system response.

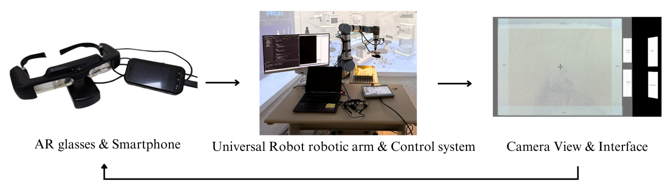

Figure 2: AR Glasses Interface and Robotic Arm System

The detection accuracy of measured surgical instruments was **91.67%** in a 40 x 26 cm space, with a minimum distance of **1.4 cm** maintained between each instrument.

Conclusions

This research builds an AR glasses interface for the control of surgical camera display and surgical instrument grasping. With this effective assistance, it can reduce interruption and non-ergonomic postures compared to the traditional method.

Acknowledgments

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