Imperial College London

GRASP: A Wearable Robotic Device Design for Human Augmentation

Haoyi Zheng, Zexing Zhao, Zeran Su, Efe Sen, and Rahim Mohammed

1. Introduction

Supernumerary fingers have potential applications in helping chronic stroke patients to carry out daily tasks [1] assisting healthy users holding large objects [2] or attaching tools to facilitate tasks [3].

In this study, we aim to propose a new wearable robot, called GRASP (General Robotic Augmentative Supernumerary-finger Project), with two dexterous robotic fingers, and has been tested to assist people in multiple grasping tasks.

2.System Design

Bio-inspired Finger Mechanism

Our robotic fingers feature one rotational joint perpendicular to three parallel rotational joints, forming a single open chain mechanism $SOC\{-R \perp R \parallel R \parallel R-\}$. Our work is inspired by the anatomical structure of the human hand as depicted in Figure 1.

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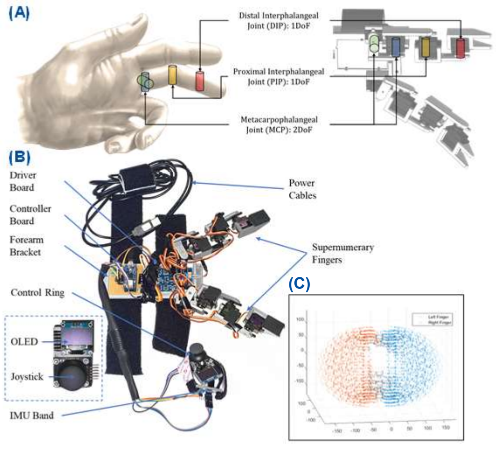

Figure 1: The 'GRASP' System. (A) Comparison of mechanisms between human and robotic fingers. (B) Main components of the wearable robotic system. (C) Workspace of two Fingers.

3. Control Methods

Among three categories of mapping strategies for synergetic robotic hand control: joint-to-joint, Cartesian and object-based [4], both joint-to-joint and object-based approaches are implemented in this study.

Joint-to-Joint Mapping Strategy

Robotic finger joints are coordinated to mimic the movement of intra-finger joints coupling behavior in the human hand. The joints' angles are mapped to inputs through a mapping matrix [c], allowing for low-dimensional input control of the 8-dimensional workspace movements.

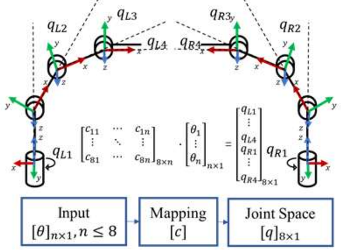

Figure 2: Joint-to-Joint Mapping Strategy.

Object-Based Human-Robot Synergy Control

An object-based mapping strategy is employed for human-robot synergy grasping to facilitate autonomous cooperation. The wrist movement is captured using two IMUs, and then mapped to robot joint space angles through a pre-encoded mapping strategy based on the object's shape, enabling human-robot synergy in grasping.

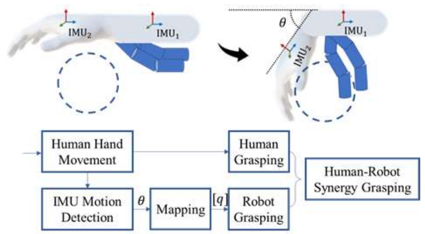

Figure 3: Human-Robot Synergy Control.

3. Experiment Results

Our prototype has been tested for several daily tasks and has demonstrated capability for multi-modal grasping. Especially for the synergy mode, which has indicated its ability to help people grasp large objects, as a type of human motor augmentation.

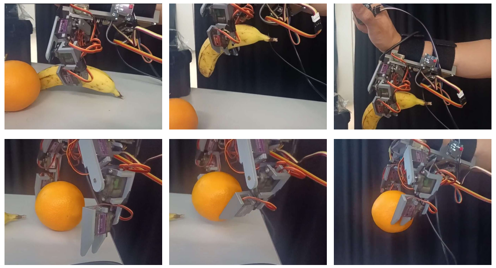

Figure 4: Experiments I: Grasping From Table Surface. *Experiments of using the robotic fingers to independently grasp objects with different shapes shows its multi-modal grasping capability.*

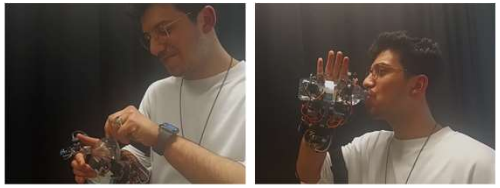

Figure 5: Experiments II: Daily Tasks. *The robot succeeded in helping people with daily tasks like drinking.*

Figure 6: Experiments III: Synergy Grasping. *Grasping a large object (such as a basketball) using synergy grasping, suggests its potentials in human motor augmentation, in which the robot autonomously moves to cooperate with the human user.*

4. Conclusions

In this study, we have realized prototyping a wearable robotic device that could be used for augmenting human grasping capabilities. Key features in our work includes:

Mechanism Aspect

- The 8 DoF robotic mechanism offers versatility in grasping and has been arranged in a bio-inspired scheme.
- The modular design two fingers allows for potential extensions.

Control Aspect

- The robotic system is controlled with both inter-joint and human-robot synergy, realized with a mapping technique and IMU motion detection.

Functionality Aspect

- Experimental results have demonstrated that such robot could offer daily tasks assistances.
- Synergy grasping offers a solution to expand human hand capabilities, such as grasping large objects.

5. Future Works

For future implementation and improvement, we plan to:

- Optimize the mechanical and electrical design, and add add more IMUs or flex sensors, for more complex human-robot synergy functionalities.
- Collect data from experiments and perform evaluation tests for more in-depth research on human cooperation with wearable robots.

References

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[3] F. Y. Wu and H. H. Asada, "Bio-artificial synergies for grasp posture control of supernumerary robotic fingers," in *Robotics: Science and Systems*, 2014.

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