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Teleoperation of a Hand-Arm-Glove

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Abstract: This paper presents a controlled teleoperation system to deal with some of the key issues that arise in the teleoperation of robotic hand-arm systems.The system consists of two magnetic trackers and two sensitized gloves that guide two industrial robots and the mechanical hands they are fitted with respectively.The risk of collisions and achieving singular configurations, either internally or due to the limitations of the workspace is controlled by monitoring and stopping the state of the hand-arm system when necessary.The automated re-synchronization procedure allows the teleoperation to restart as soon as the danger is gone, and also allows the user to adjust the mapping when his / her posture is uncomfortable.The resulting system allows for intuitive, simple and secure teleoperation of a dual robotic hand-arm system.A glove system used to accurately and reliably capture hand kinematics.It can provide doctors with angular velocities, accelerations, and joint angles to adjust medical procedures.Three validations – raw data verification, static angle verification, and dynamic angle verification – are performed to verify the data glove's reliability and accuracy.

Keywords: Data Glove,Flexible Finger Units (FFU),Inertial Measuring Unit (IMU),Magnetic Tracker, Teleoperation.

INTRODUCTION

Robot teleoperation plays an important role in applications where the operator still makes the decisions and the robots carry out the actions following the operator's movements.Advances in robots teleoperation are based on advances in robot control systems, improvements in communications velocity and quality, and device development to capture the operator's gestures or intentions in a reasonable time and with reasonable precision[1].One of the problems associated with anthropomorphic interface teleoperation is the complexity created by the large number of degrees of freedom that are involved.The most intuitive way to control these systems is to capture human operator movements and map them to a robotic system.Three main approaches related to mapping issues in anthropomorphic devices teleoperation are presented, especially when anthropomorphic hands are involved.Joint-to-joint mapping, in which each operator movement’s sensor is directly linked to a robot joint.Pose mapping, in which each operator's pose is linked to a predefined robot pose.It is important to capture hand kinematics for several medical purposes, such as rehabilitation and manual dexterity assessment[2].By capturing the movement of the hands, the doctors can record and accurately evaluate the condition of the hands of patients after neurological diseases or manual surgery.

Non-contact systems use camera-based devices and image processing techniques to record movements by hand.Users are not required to wear any devices but environmental conditions such as lighting and occlusion can easily affect these systems.Various sensors, such as optical fibre sensors, resistance sensors, and inertial measuring units (IMUs), can be used to record hand motions in data gloves.A data glove based on IMU can reliably measure hand kinematics and provide useful parameters, such as acceleration or angular velocity. Furthermore, most gloves based on IMU are lightweight and can be comfortably worn.This new data glove involves a modular system that adapts to different sizes of the hand and enhances the maintenance. In addition, the sensors are stably attached to the finger surfaces using a novel method; thus the sensors accurately measure finger attitudes[3].

System Architecture and Design

1. *Data Glove System:*

A data glove machine is built during physical therapy as a method for recording the hand motion. This comprises a Motion Capture Board (MCB), five Flexible Finger Units (FFUs), an Arm Chair, and a Host. The system architecture is shown at Figure 1.

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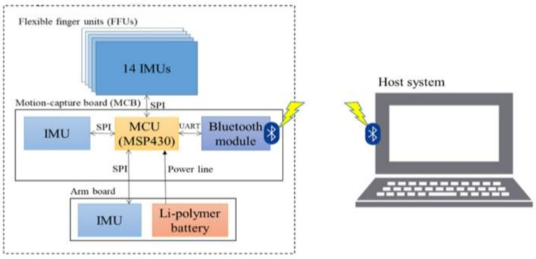

Figure 1: Data Glove System

The data glove consists of 16 IMU sensors. IMU sensor includes an accelerometer with 3 axes and a gyroscope with 3 axes and measures parameters such as acceleration,angular velocity, and motion range (ROM).The parameters accurately represent the movement of the fingers while the patients are doing rehabilitation exercises[4]. The finger sensors can measure the distal interphalangeal and proximal interphalangeal joints on the ROM.The sensor on the back of the hand is called a guide and used to test the metacarpophalangeal (MCP) joints with the finger sensors on the ROM.The sensor collocated to the forearm on the back of the hand is used to calculate the wrist's ROM.MCB contains a microcontroller unit (MCU), a Bluetooth module,an IMU and a battery with Li-polymer.The MCB's size is 42mm x 50 mm x 8mm. The MCU uses a serial peripheral interface to request the data from all sensors.

The data glove system has a sampling rate of 50 Hz.The data collected from the IMUs is encapsulated and transmitted to the host system at 115.200 bps via Bluetooth. A 1000-mAh Li-polymer battery is inserted in the data glove to provide power for at least 5 hours which is sufficient to perform different recovery tasks.The C software on the host device measures the finger rom and records the parameters collected, allowing the physicians to perform comprehensive patient assessments[5].

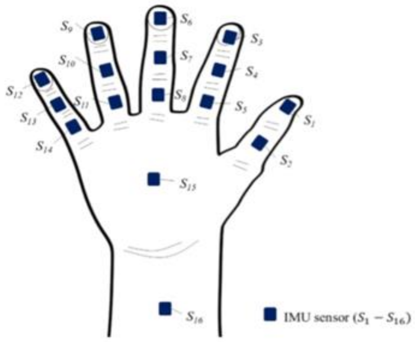

Figure 2: Positions of Sensors on the Data Glove

2. *Mechanical Design of the Data Glove:*

The data glove consists of five FFUs, one MCB and one arm-board. Each FFU's width is 0.8 cm, which is constrained by the IMU sensor and layout, and using four different lengths 6.5, 9.5, 10.5, and 11.5.Each FFU is independent and has two or three IMU sensors. The weight can be reduced by embedding the sensors directly on the FFU to improve finger mobility.When an IMU sensor is disabled on any FFU, FFU can be quickly and easily replaced due to the modular design, which improves the maintenance.In addition, flame retardant masses 4 (FR4) are applied to the bottoms of the FFUs, where the sensors are mounted, to avoid solder cracking while the fingers are working actively[6].

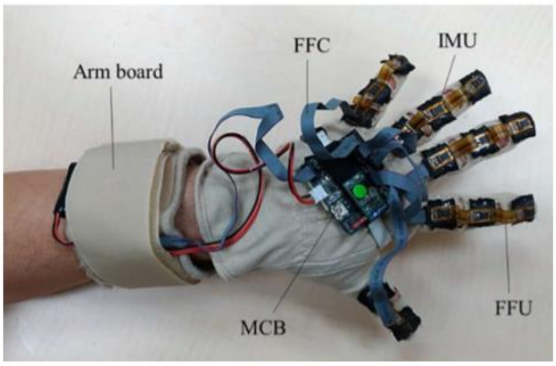

Figure 3: Modular Design of the Data Glove

The data glove contains three main mechanisms: MCB-glove mechanism,FFU-glove mechanism, and arm board module.The padding over the locations of the

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interphalangeal joints has been withdrawn to increase the stability of the finger joints.The IMU sensors are connected by a strong double-sided tape on the transparent soft plastic to an elastic fabric, which can be quickly mounted and removed.The two edges of the elastic fabric are connected by an elastic tape as a circular ring which fixed the location of the sensors.This design prevented the IMUs from slipping in the data glove, allowing accurate measurement of finger attitude[7].A patient's hand may constantly drag the MCB and glove wires in this data glove a flexible flat cable has been used to connect the FFU and the MCB.This method prevents the transmission instability caused by dragging the wires.In order to prevent the FFU wires from breaking when the FFU is folded, the contact point between the FFU and the connector has been covered with special glue to form a soft substance which prevents the base edge from folding on the sensor pad.Arm board module is made of a Li-polymer battery and an IMU sensor. The IMU can evaluate the forearm's attitude, and the MCB's attitude and that of the arm board module can calculate the wrist ROM.The arm board module is integrated into a tennis elbow support that can easily be worn. Its purpose is to measure the wrist ROM and move the bulky components to the forearm to improve the mobility of the hands[8].

Figure 4: Mechanical Design between the FFU and the Glove

The proposed teleoperation system consists of two industrial robots equipped with mechanical hands to be teleoperated by an operator equipped with wrist trackers and sensitized gloves.Allows intuitive teleoperation, both at the level of the hand in terms of mapping between the glove joints and those of the mechanical hand, and also at the level of the robot assuming the possibility of using different cameras to feed back the image from the remote location.Safe teleoperation used to stop the robot if necessary to avoid collisions and unique configurations, and resume teleoperation to recover from these situations automatically and smoothly[9].

Synchronization: Provided to synchronize the data that the wrist trackers and sensitized gloves provide separately.

Mapping: Required for the robots and mechanical hands to convert the data provided by the trackers and gloves into joint values. This module must verify whether the configuration obtained is kinematically right, i.e. not singular, and within limits.

Collision Validation: Required to verify commanded configuration is collision-free.

*Magnetic Trackers:*Two different trackers of different brands are used to capture the operator wrist's position and orientation with respect to a global reference frame, allowing for a mapping of the user arm displacements to the robot arm.One tracker is a flock of birds developed by Ascension Technology and the other a fast-track created by Polhemus, both of which are shown in Figure above the boxes with the respective names. All trackers are designed for use in combination with sensitised gloves.These devices are magnetic in type, measuring a small sensor's position and orientation with regard to a fixed base in the workspace.The flock of birds has a static accuracy of 1.8 mm for position and 0.5 for orientation and allows for 144 samples per second, and the fast-track has a static accuracy of 0.8 mm for position and 0.15 for orientation and allows 120 samples per second[10].

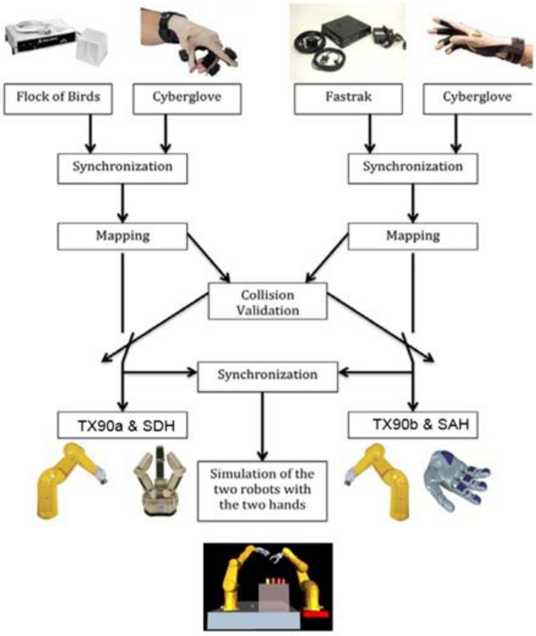

Figure 5: Magnetic Trackers

CONCLUSION

Implementation of a dual-arm robotic teleoperation system comprising two industrial robots and two mechanical hands, one with anthropomorphic characteristics, controlled with two sensitised gloves and two trackers attached to the operator's wrists.The mappings are used to transform the information captured from the operator's movements into the robotic system's movements, the functional scheme of the entire teleoperation system, and the specific modules developed for communication and monitoring issues.A data glove with 6-axis sensors is designed to capture hand kinematics. The modular style can be adapted for users who have different hand sizes and features to use.Advances in robots teleoperation are based on advances in robot control systems, improvements in communications velocity and quality, and device development to capture the operator's gestures or intentions in a reasonable time and with reasonable precision.Teleoperation system consists of two industrial robots equipped with mechanical hands to be teleoperated by an operator equipped with wrist trackers and sensitised gloves.A data glove based on IMU can reliably measure hand kinematics and provide useful parameters, such as acceleration or angular velocity. Furthermore, most gloves based on IMU are lightweight and can be comfortably worn.

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