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Generic Virtual Control and Monitoring Framework for Improved Safety and Ergonomics: Case Study on Robotic Hand

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1 Introduction

Current industrial trend are towards reduced human presence on shop floors as well as encouraging remote working for reduced overhead and worker safety [1]. This was also clearly seen with the recent COVID 19 epidemic that forced the closure of various production facilities.This has led to increased demand for technology based frameworks that facilitate such remote working operation [1, 2]. Robots have also been an integral part of manufacturing production lines and will continue to do so, especially within current industrial revolution [3, 4]. This leads to the increased sharing of workspace between humans and robots as well as robots augmenting the human workforce on production lines. Human-robot collaboration is thus essential in increasing flexibility and reactivity to product and situational change within manufacturing systems. Current research is focused on providing physical mechanism and control algorithms that improve user safety and boosts human-robot interaction [5]. A key technology that is under exploration in solving this issue are cyber-physical systems (CPS).

A variant of CPS prominently utilised in industrial systems are Digital twins (DT). Literature contains various definitions of DTs and comparing the differences between digital twins, digital models and digital shadows [6]. In this research the definition of digital twin will be a digital representation of a physical system that facilities control through sensor data communication and computing [7]. With the ability to transmit control commands, system operation can be carried out by a human regardless of the distance between them i.e. tele-operation using DTs. Various research teams have endeavoured to build such systems with applications in industry . Real-time sensor data on the physical system provides an understanding of the system state and thus informs operator actions and decisions. By updating the DT state based such sensor data, the model increasingly becomes a true representation of the system state. By enabling simulation through system static and dynamic computation, the DT offers a valuable test-bed to observe system behaviour given a desired user input. This further improves the operator's control and decision making in system operation. With these characteristics, DTs have shown their usability in tele-operation.

Despite their merits, DTs implementation still face a few challenges as highlighted by [7]. These include:

1. The creation of Cyber-physical involves the fusion of various technologies; collaborative control, data capture and transmission which require a robust and fault tolerant structure still yet to be achieved.
2. The novelty of cyber-physical systems means that a universal framework for their implementation is still lacking.
3. Due to the capture and transmission of data between cyber and physical, this leads to security gaps that can be exploited. needs to be addressed
4. A standardized framework for the connection and communication protocols

This research aims at tackling some of these underlying issues. The main research objective was to generate a generic framework for implementing digital twins for the remote control and real-time monitoring of collaborative robotic systems. The case application is human-human collaboration via an allegro robotic hand system[8]. A human will control the robotic hand remotely and participate in collaborative tasks with a fellow human in close proximity to the robotic hand. The specific research objectives of this work:

1. The development of a virtual model of the robot hand in Unity 3D software.
2. The development of a control algorithm capable of moving the hand and achieve the desired end-effector position using and industry standard robot control middle-ware; Robot Operating System (ROS).
3. The development of a data communication pathway between the virtual model and the physical hand using industry standard communication protocol; MQTT.

2 Materials and Methods

In this research, the overall system control architecture involves the physical system under control (allegro robotic hand) and its interactive digital twin. The robotic hand is a 16 DOF robotic hand produced by Wonik robotics co ltd. The hand joints are actuated by torque-controlled servo motors capable of a 1.5kg payload. A digital model of the hand was constructed and imported into the virtual environment. Data and commands between the physical hand and its digital model are communicated using ROS messages and publishes-subscriber model. The following sections discuss in detail the implementation of the digital twin.

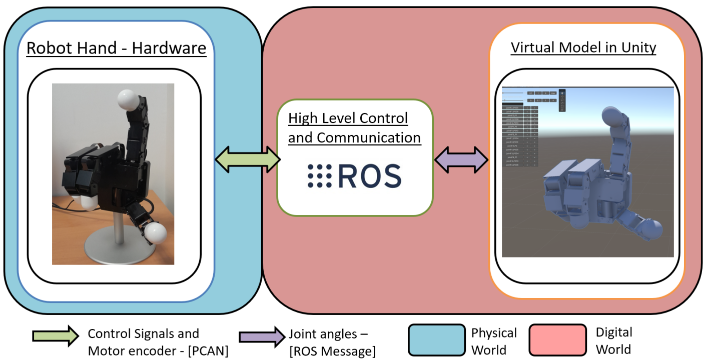

FIG. 1: Allegro-Hand Digital Twin Block Diagram

Figure 1 shows an overview of the allegro hand digital twin. With the completion of the of virtual model representing the digital space and the ROS network controlling the robot hand in the physical space. To form the digital twin, data and commands are exchanged via MQTT protocol. The ROS network has a node that transmits servo motor positions to an mqtt server. The server holds this information and provides it to any subscriber in need of the same. The virtual model contains a script that makes the virtual model an mqtt client. The client is subscribed to the joint position topic receives real-time data on joint positions.

3 Results and Discussion

The work presented in the paper covers the framework design and initial system implementation. An interactive digital twin was constructed by modeling the robotic hand in Unity 3D software. The model consisted of links and joints arranged to form the kinematic structure of the hand as well as a model of the servo motors that control the joints. The physical robotic hand was controlled using a ROS network. Both the physical system and virtual model contain mqtt scripts which enable connection to an online mqtt server. Through this pathway, both systems can exchange data and commands forming the digital twin.

Current typical system operation consists of a user interfacing with the hand via keyboard commands, the position of the hand is captured through the motor encoders. This is then transmitted to the Unity through MQTT ROS node. The transmitted information consists of the joint ID, position, velocity and acceleration and based on this, the virtual model is moved to reflect the actual physical system state. A second user can observer the position of the virtual hand and observe the current physical hand state.

4 Conclusion and Perspective

This research aims to improve human-robot collaboration through the implementation of digital twin technology in collaborative robotic systems. This is achieved through the development of a user controllable robotic hand virtual model. This model is given position commands which are then relayed to the physical robot system. The communication between the virtual and the physical is mediated through MQTT protocol. Once received the robot control system based on ROS actuates the robot motors to achieve the desired position. The current motor positions are also sent back to the user through the same pathway.

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