Demo Abstract: A Campus Prototype of Interactive Digital Twin in Cyber Manufacturing

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Abstract

Smart manufacturing and Industry 4.0 are bringing disruptive changes to the manufacturing sector. Smart manufacturing increases productivity, creates safer conditions for workers, and simplifies product customization, all while decreasing business expenses [2]. To this end, we have created a flexible three-component architecture for remote machine management, using it to build a digital twin prototype of a Creality Ender-3 Pro 3D printer located on the University at Buffalo campus. This twin provides users with the ability to monitor and control the machine from anywhere in the world through a web interface. Our system improves upon existing technologies, such as Octoprint [1], through the addition of twin views. It also relies upon cheaper components, using the Arduino and ESP32 rather than the Raspberry Pi. Finally, existing technologies tend to focus on one specific type of machine. In contrast, our framework is flexible, capable of supporting many different machines.

Keywords: Digital Manufacturing, IoT, Cloud Computing, Industry 4.0, Virtual Engineering

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1 Introduction

The Fourth Industrial Revolution (or Industry 4.0) is characterized by increasing automation. The rise of artificial intelligence, cloud computing, and the Internet of Things (IoT) has been instrumental in this revolution. By leveraging these technologies, smart manufacturing systems can increase product quality and create safer working conditions, all while decreasing costs [2]. As such, there is significant incentive to invest in Industry 4.0.

When discussing Industry 4.0, one may encounter the notion of a digital twin. A digital twin is a general term used to describe a virtual recreation of a physical object or process. In the context of smart manufacturing, such a twin would typically take the form of a piece of manufacturing equipment or a manufacturing process.

Motivated by the rise of Industry 4.0, we have created a framework for the remote management of manufacturing equipment. To demonstrate its effectiveness, we have used it to develop a digital twin prototype of a 3D printer located on the University at Buffalo campus.

2 System Description

The system architecture (Figure 1) is broken into three separate components: the mechanical component, the hardware component, and the software component. This design creates a high degree of modularity, where new implementations of individual components can be developed without disturbing the rest of the system.

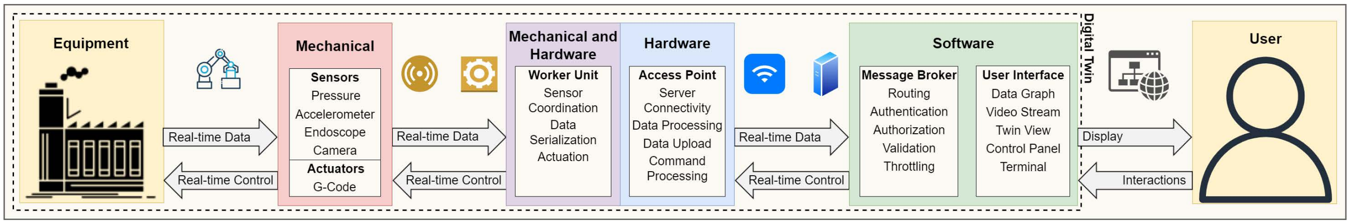

Figure 1. Architecture of the digital twin in Cyber manufacturing.

2.1 Mechanical Component

The mechanical component interfaces with the hardware component. It includes the configuration of sensors and actuators, as well as the development of the worker unit.

2.1.1 Sensors and Actuators. The MPU6050 is used as an inertial measurement unit to track the printer vibration. One MPU is attached to the linear stage, and another is attached to the printer bed. A pressure sensor is also attached between the linear stage and the syringe plunger. For the cameras, one ESP32 camera is attached to the printer bed to monitor the product being printed, and another is placed outside the printer to monitor the entire system. Additionally, an endoscope is focused on the printer nozzle to monitor the material flow rate. Finally, the system affects the machine by sending Marlin G-code to an SKR Mini E3 V2.0, which is used in place of the original printer board.

2.1.2 Worker Unit. The worker unit is an Arduino MEGA. This unit reads data from the sensors and performs local processing. When requested by the access point, the hardware interrupt of the Arduino is triggered, collecting available sensor data and sending it to the ESP32 over UART.

2.2 Hardware Component

The hardware component interfaces with both the mechanical and software components. It is concerned with the development of the access point and worker unit. The access point is implemented using an ESP32, which connects to the messaging server over WiFi and communicates using WebSocket. The access point is responsible for handling commands from the server and forwarding the sensor data that is pulled from the worker unit.

2.3 Software Component

The software component sits closest to the user. It is focused on high-level programming, being comprised of a messaging server and a web user interface.

2.3.1 Message Broker. The message broker is built using Python. It relays data and commands to the appropriate clients over WebSocket, decoupling web browsers from microcontrollers. It also performs validation, authorization, and throttling of client requests.

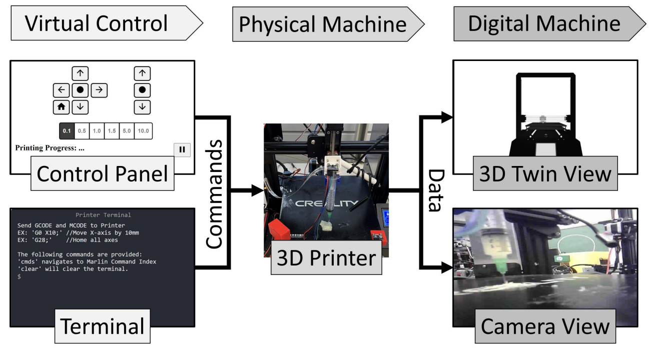

Figure 2. Dashboard relationship with physical world.

2.3.2 User Interface. The user interface is a web app built with React. It displays sensor and video data in real time. It also provides 2D and 3D twin views. These views contain animated models that synchronize with the physical state of the printer, inspired by the concept of a digital twin. Finally, the interface has a control panel and terminal which are used to send commands to the machine.

3 Future Works

In the future, we will create digital twins of other types of manufacturing equipment. We also plan on enhancing these digital twins by adding predictive capabilities, leveraging computer vision and machine learning to address manufacturing problems automatically. Once this is done, we will use the digital twin prototypes in a platform known as STREAM, which will serve as a centralized location for the coordination of distributed manufacturing processes. Finally, we hope to use this system to create an industrial metaverse, building a full 3D factory environment of digital twins.

Acknowledgments

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