A Study on Intelligent Manufacturing Video and Control Data Transmission System Using 5G Communication

Lee Sung-Hun
dept. ICT Convergence Research
Gumi Electronics & Information
Technology Research Institute
Gumi, South Korea
leesh@geri.re.kr

Jung Yong-An
dept. ICT Convergence Research
Gumi Electronics & Information
Technology Research Institute
Gumi, South Korea
yajung@geri.re.kr

Han Dong-Cheul
dept. ICT Convergence Research
Gumi Electronics & Information
Technology Research Institute
Gumi, South Korea
cataegu07@geri.re.kr

Cho Soo-Hyun
dept. ICT Convergence Research
Gumi Electronics & Information
Technology Research Institute
Gumi, South Korea
leesh@geri.re.kr

Byun Sang-Bong
dept. ICT Convergence Research
Gumi Electronics & Information
Technology Research Institute
Gumi, South Korea
sbbyun@geri.re.kr

***Abstract*— In this study, we have studied a robot automation system that utilizes 5G communication in the sub-6GHz bands to transmit video data from cameras and performs object recognition and classification to transport a textile bobbin. The video images of the cameras attached to the autonomous mobile robot and the collaborative robot, i.e., the client, are transmitted via the transmission control protocol/internet protocol socket communication. On the server, an artificial intelligence (AI)-based recognition algorithm has been implemented to extract the size, color, and position information of the bobbin and deliver the control command for transporting it. By developing a system for controlling automated equipment and robots using 5G communication and AI, it is possible to reduce the defects and labor intensity caused by the mistakes committed by workers during manual transportation.**

Keywords*— *5G communication; Smart Factory; Real-time video transmission, Autonomous mobile robot

I. Introduction

The high throughput, improved spectral efficiency, low transmission latency, excellent mobility, and high connection density of 5G mobile networks imply that 5G mobile networks are optimized for streaming large 4K ultra-high-definition (UHD) signals. Relevant standards also stipulate support for streaming functions over 5G mobile networks.

When controlling robots based on videos acquired from cameras in a manufacturing facility, the challenge is to ensure stable transmission quality of the videos and low-latency transmission for command and control. In high-quality video transmission, the latency is bound to be relatively high as a large bandwidth is required.

The advent of 5G mobile networks has not only provided the foundation for UHD (4K) video transmission beyond the Full HD (1080p) resolution, by providing higher available bandwidth than previous generations, but has also enabled fast response speed in the wireless section by utilizing high-band radio frequencies. 5G-based communication may be sufficient for simply processing large amounts of serialized short data, but for real-time high-definition video transmission, it is necessary to design a system that considers data transmission reliability in the wireless and internet sections connected to the user terminals [1-2].

For 5G-based industrial internet of things (IoT) networks, ultra-reliable and low latency communication (URLLC) for real-time ultra-precise equipment control and process control in factories and massive machine-type communication (mMTC) for process monitoring using large-scale sensors are the most important factors. Furthermore, a certain level of enhanced mobile broadband (eMBB) transmission capability is required for augmented/virtual reality (AR/VR)-based human and machine Interface (HMI) and real-time video transmission. Based on this, the digital transformation of major industries is accelerating, such as research on technologies to improve industrial efficiency based on real-time control and image analysis for robots. The combination of 5G networks and the robotics industry is an area where synergistic effects can be achieved by applying ultra-high speed and ultra-low latency characteristics to robot control and large-scale information collection. Based on this, a few systems have been built to improve process efficiency and worker safety [3-5].

Numerous companies are using machine vision to distinguish between good and defective products to automate their manufacturing processes, and this aspect has recently become popular with the advancement of deep learning technology. Processes that require immediate judgment on whether the produced products are good or defective, rely on wired communication and internal servers capable of high-speed and large-capacity transmission. With the recent development of the artificial intelligence (AI) technology, the algorithms for analyzing good and defective products have become advanced, and cloud computing resources have become necessary for reducing the analysis time. Hence, taking advantage of the ultra-low latency characteristics of 5G communication, the utilization of cloud has been accelerating for machine vision technology in industrial sites [6-8].

In this study, we have proposed the implementation of a manufacturing process data transmission and control system to achieve ultra-low latency transmission between the cameras and the user terminal In addition, we have also facilitated 5G communication-based transmission of HD-quality videos in the wireless section by utilizing the cameras attached to the robots and a server equipped with AI algorithms. In Section 2, we present the method of implementing the manufacturing data and video transmission system based on 5G communication, and in Section 3, we describe the results of implementing and demonstrating the proposed system.

II. METHOD OF IMPLEMENTING A 5G-COMMUNICATION-BASED MANUFACTURING VIDEO AND CONTROL DATA TRANSMISSION SYSTEM

In this study, we have proposed a system that utilizes 5G communication to transmit a video from a camera attached to a robot arm to the server and recognizes and classifies textile bobbin objects using AI algorithms to transport the bobbins by a mobile manipulator in a textile plant.

The collaborative robot of the mobile manipulator and the autonomous mobile robot (AMR) transmit and receive data based on Ethernet, and the user, as a client, is connected to the server through 5G communication. The mobile manipulator recognizes the location information (coordinates), color, and size of the textile bobbin using the camera attached to the collaborative robot and transmits the vision data to the server via 5G communication. AI algorithms have been used to recognize and classify the bobbins, and transport and load them in the creel process.

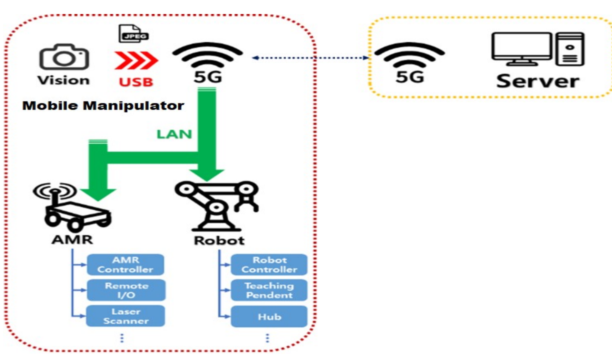

Fig. 1. Schematic showing the 5G-communication-based manufacturing video and control data transmission system.

A. *Hardware Design of the 5G-communication-based Manufacturing Video Data Transmission System*

The schematic of the 5G-communication-based manufacturing video data transmission system has been designed using OrCAD Capture v16-5. For the function and performance optimization of 5G communication, a 10-layer PCB has been considered and the artwork of the 5G communication system has been performed using the PADS Layout VX 1.2 development environment. The USB port used for debugging in the 5G communication-based video transmission system has been designed to let the processor communicate with the outside world through port forwarding.

Fig. 2. Hardware built for the 5G-communication-based data transmission system.

To cool the designed circuit board, the processor has been designed to control the fan according to the heat distribution of the board, and a heat sink has been installed. For data transmission through the 5G communication module (Telit, FN980), a USB3.0 interface has been used. The processor is ARM Cortex-A15 TI's Am5728, the RAM is DDR3 with a capacity of 1 GB, and the Ethernet supports 1 Gbps speed as a function for receiving data from an external board and a laptop computer (or personal computer (PC)).

B. *Software Implementation for 5G-communication-based Manufacturing Image and Control Data Transmission System*

The video data of the camera attached to the collaborative robot is transmitted via a transmission control protocol/internet protocol (TCP/IP) socket communication. The 5G-communication-based transmission system is operated using a Linux embedded operating system. Video data is acquired from the camera, and after calculating the size of the data, it is sent to the server. The client receives an ACK from the server and transmits data according to the size of the video image data (1,024 bytes).

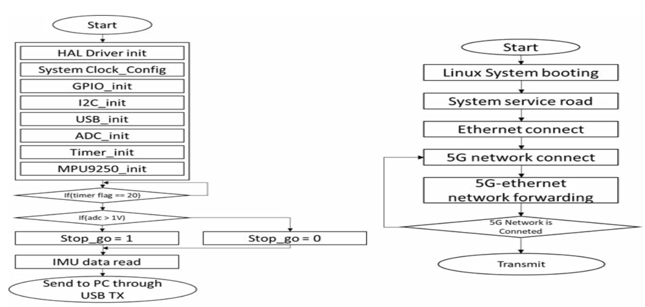

Fig. 3. Flowchart of the communication system for transmitting the manufacturing video data.

The client repeats the pattern of receiving ACK from the server and sends each image file compressed as a JPEG. If it receives NACK, it retransmits the image, and if it receives NACK three times, it terminates the TCP/IP socket communication and proceeds with the reconnection procedure.

III. EXPERIMENTAL RESULTS

By capturing the images of the textile bobbins in the creel process of the textile plant, attributes such as size, color, and abnormalities are extracted using the AI model, and the data are stored. The server is accessed by the client (Mobile Manipulator) using a fixed IP address and receives the correction value of the video image by building a database in the form of JSON (JavaScript Object Notation). When the client receives thea video capturing signal of the camera, it transmits the video data, and the server transports the bobbins to the coordinates for transporting and loading using the object recognition model based on the received data.

Fig. 4. Checking for receipt of video data based on 5G communication.

IV. CONCLUSION

In this study, we designed and implemented a system for transmitting and receiving the manufacturing video data and control signals using a 5G network. By applying a bobbin object recognition and classification technology based on AI image analysis to video image data received through 5G communication, we developed a mobile manipulator prototype to build an on-site automation system in a textile plant. To apply it to actual industrial sites, it is necessary to take the research results to the next level and review the quality and stability of communication. We plan to conduct various studies to see if the proposed system is effective in improving labor productivity and reducing industrial/safety accidents compared to the traditional way of utilizing workers.

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