SYNCHROTRON THAILAND CENTRAL LAB

MOTION CONTROL DEVELOPMENT OF THE MATERIAL HANDLING SYSTEM FOR INDUSTRIAL LINAC PROJECT AT SLRI

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INTRODUCTION

Synchrotron Light Research Institute (SLRI) has been developing a prototype of linear accelerator for industrial applications. One of the main purposes of this new project is for food irradiation application. There are three key elements in this system, an accelerator system that delivers the energetic beam, a scanning system that provides uniform beam coverage of the product, and a material handling system that moves the product through the beam in a precisely controlled manner [1]. The primary goal of the irradiation facility is to deliver the specified amount of required radiation to the products without unnecessary, wasteful, and excessive dose. Thus, monitoring and control of the process parameters and the information of objects to be scanned are important in order to effectively spread the beam with appropriate field strength. Once the parameters and object information are known, the motion of the conveyor belts in the material handling system must be precisely controlled.

Figure 1: A prototype of accelerator-based irradiation facility.

SYSTEM DESIGN

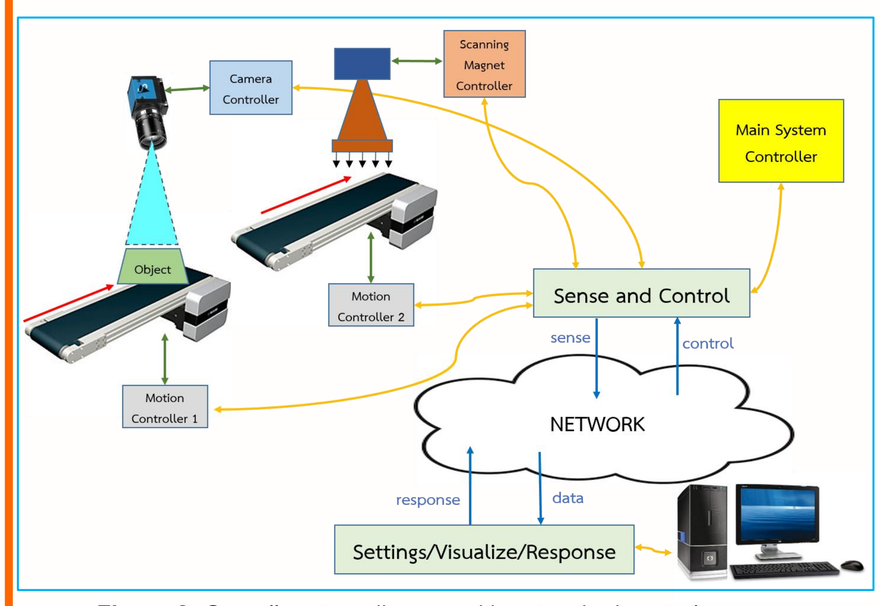


Figure 2: Overall system diagram with networked control system.

Machine subsystems

- **Accelerator system** delivery energetic beam.
- **Scanning system** provide uniform beam coverage of the product.
- **Material handling system** moves the product through the beam in a precisely controlled manner.

All subsystem controllers are connected in a private network to form a networked control system. These controllers are responsible for motion control of the conveyor belt, camera control for object detection [2], and scanning magnet control for the generation of time-dependent magnetic field deflection of the beam. The main system controller is designed to implement control algorithms in order to oversee the operation and stability of the whole system. Personal computer is connected to the network to receive and display all process parameters and send settings and responses to the main system controller's various requests.

Hardware

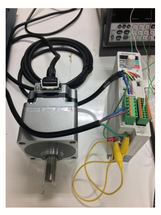
Conveyor Belts

- 2 sets of a two-meter long convey belt with desired specifications (loads and speed range) are selected because of a limited experimental space.
- Commercially available.
- Custom motor fixtures are fabricated for motor installation.

Figure 3: Conveyor belt and motor fixtures.

BLDC Motor and Electronic Driver

- Commercially available.
- Electronic driver with easy settings through the front panel.
- Motor speed can be arbitrarily controlled by applying external DC voltage.
- Motor speed can be measured from the driver's pulse output (30 pulses per one motor shaft rotation.



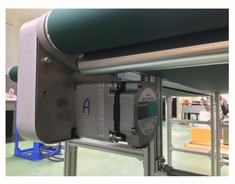


Figure 4: Motor, driver, and installation.

Controller Boards

- 1 motion controller consists of 2 microcontroller boards, STM32 and ESP32.
- STM32 performs general low-level measurement and control tasks
  - motor speed detection, and pulse frequency and duty cycle measurements using timers,
  - DAC control
  - General time-based interrupt service routines
  - UART communication
  - Digital PID controller implementation for motor speed control
- ESP32 reports parameters while receiving motor speed setpoint from the main system controller.

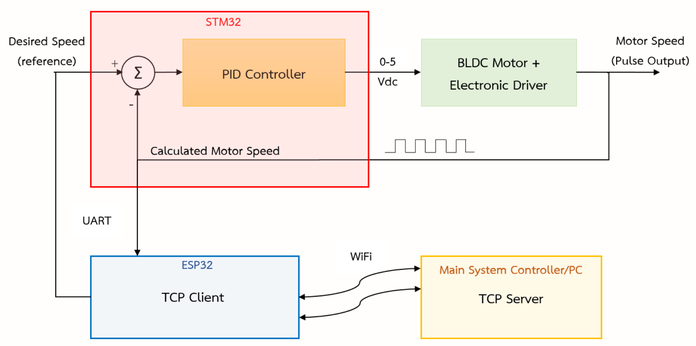


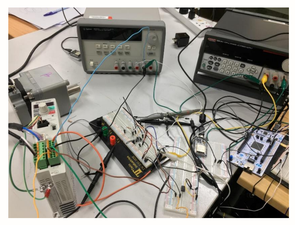
Figure 5: Feedback control loop and communication between controllers.

Software

- The software running on STM32 is coded in C. Standard HAL drivers are used in most of the code. For ESP32, the code is designed in C++ for Arduino IDE.
- Communication between one TCP server and multiple TCP clients (multiple motion controllers) is managed using standard JSON data format.

RESULT AND DISCUSSION

- BLDC motor and driver are tested. System identification is performed to obtain transfer function of the black-box model.
- Motion of the combined motor and conveyor belt system is tested after installation of the motor with the custom fixtures.
- The primary tests for controller boards are motor speed detection using STM32's timer, DAC output test, and interrupt tests. Tests for ESP32 are accomplished by carefully testing its IoT-ready capability. UART communication between STM32 and ESP32 is tested to ensure the correction of information exchange.
- TCP communication between PC and multiple ESP32 clients is fully tested with satisfactory result. Small transmission delay occurs during the entire test for the wireless network.



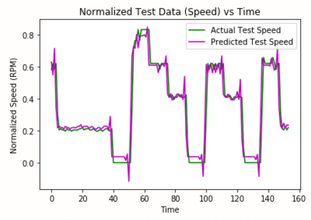


Figure 6: Lab test and system identification.

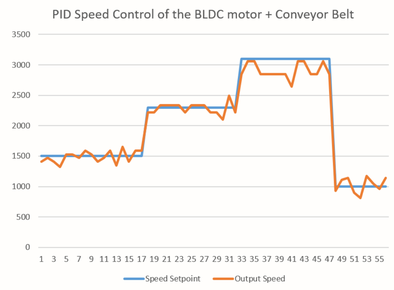


Figure 7: PID speed control test over network.

- Controller performance for low speed is acceptable, which covers the desired conveyor speed of the machine and the beam output from the linac. Better control performance, however, is still needed for our motion control system.
- More improvement in controller tests will be performed to achieve better speed control, for example, resolution of the controller output signal, motor speed detection (use external encoder), transmission delay of the network, and communication between different microcontroller boards.

CONCLUSION

The proposed motion control for the material handling system is developed for the prototype of linear accelerator for industrial applications, specifically for food irradiation application using x-ray. The primary purpose of the system is to provide automatic control strategies for the motion of the conveyor belts, including motors and electronic drive systems, in order for the product to be scanned to move through irradiation zone in a proper manner with respect to the generated time-dependent magnetic field shape. From the series of tests performed, overall performance of the motion control system is satisfactory. Discussion on control system performance improvement is provided with respect to operational condition of other subsystems of the machine prototype. This motion control system is currently ready for overall real-time system tests and further development of the machine.

REFERENCES

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