Mechanical Engineering

4TC00
Model-based System Engineering

Quartile 1: 2017-2018

Case 2: Testing and Buffering station

Final Report

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Introduction

The goal of this assignment is to develop and validate a real-time controller for the testing and buffering station. The controller should be:

- Time efficient, leading to a high throughput.
- Energy efficient, by switching off equipment that need not be active.
- Safe for equipment and operators.

The following assumptions have to be made:

- Products are only added in the testing station on the elevator when the testing station signals that it is ready.
- The entered products can be detected using the capacitive sensor.
- The rejected and accepted products can be distinguished using the optical sensor.
- The products vary in height, but are large enough to be detected by the sensors and small enough to fit on the elevator.
- It takes the product roughly 0.4 seconds to travel from the top to the bottom of the airslide, roughly 3 seconds until it reaches the sensor at the separator and one 0.5 seconds to leave the separator. The time difference between these modeled events and reality is maximally 5 seconds.
- The buffer for the rejected products can hold at least 5 products.
- There can be 5 products in the buffering station.
- The conveyor belt functions correctly.
- The system is not stopped when a product is entering the separator as this leads to undesirable results.
- When the system is in manual mode, the start button is pressed within 5 second

1 Control Strategy

This chapter describes the way the system is controlled. It describes the general control and the plant, and then the testing and buffering station.

1.1 General control & plant

The system is controlled from the perspective of the products. The product has different locations and different speeds are coupled to them. Because of physics, products cannot collide with each other, meaning they can crash into each other and stop. All of this is done in the automaton named "Box".

1.2 Testing station

In the testing station, the following operations will be controlled:

- The optical, capacitive and reflective sensors must determine when a product is accepted or not. Black products and products that are too thick have to be rejected.
- The lift has to transport products with the right color to the air slide. At the top of the lift, the height of the product is tested.
- The pusher pushes products off of the lift.
- The air slide gets activated after the the lift is at the top and the pusher is activated. The air slide transports the product to the buffering station.

The reflective sensor detects the arm that places the product on the lift. When the reflective sensor is on, it means either the arm, the lift, or something else, such as a finger, has passed the sensor. For safety measures, the system only starts detecting the color of the product when it is located on the lift, detected by the capacitive sensor. Then the optical sensor starts detecting the color of the product. When a product is black, the optical sensor will not turn on and the product is rejected. When a product red or metal is detected, the product is accepted. When 5 products have been rejected, the reject buffer is full. Q1 of the testing station lights up to tell the operator that he should remove the products. To maximize the throughput of the system, the system tries to continue operation as long as it does not to push a product on the reject buffer. When the system needs to reject a product, but the reject buffer is full, the system will wait until the products have been removed.

When a product is accepted, the lift must transport it from the bottom to the top of its range. This action starts on a timer, to make sure that there is time to detect the color of the product and time for the arm to retract. When the lift is at the top, the height sensor starts detecting whether the height of the product is right. A product can be too small or too big. Only products with a height of 23 mm are accepted. When a product is bigger than this height, it gets rejected and the elevator carries the product back down. When a product is accepted but the buffering station is full, the controller waits with pushing the product at the top of the lift until the buffering station is ready to accept a new product. This is also done to maximize the throughput of the system.

The air slide simply takes the products from the lift to the buffering station. It is activated when the pusher is activated and the lift is at the top.

1.3 Buffering station

In the buffering station the following operations will be controlled:

- The separator, which is triggered by the processing station.
- The conveyor belt, which has to move the products, but stop at the right times to optimize energy usage.
- The entry and exit sensors, which are used to stop the pusher when the buffering station is full where full means that 5 products are on the conveyor belt.

The separator starts empty, and gets filled when a product goes past the *s_atseparator* sensor. The separator reacts to the processing station when it gives the signal that it is not busy. It will then close and open again to remove its current product (open = product can enter the separator space; closed = product can exit the separator space). It is then ready to receive another product.

The conveyor belt turns on when it detects a product at the entry sensor. It then turns on for a limited time. This time is long enough to transport the product to the separator. The conveyor also turns on when the separator is closed to transport the product off the belt.

The controller keeps tracks of how many products are on the belt. It does this using the "CountFive" automaton. When a product goes past the entry sensor, the count goes up by one, and when a product goes past the exit sensor, the count lowers by one. When there are five boxes located on the belt, the conveyor belt is considered full. When the belt is full, the pusher cannot push more products on the belt.

The controller also has an internal model for each of the products that are in the buffering station. It uses this model to compare the box positions of the models with the output of the sensors to detect if a product has been removed. So if for example if according to the model, $s_atseparator$ should be on but is not, then a product must have been removed. If a mismatch between model and sensors is detected, then the conveyer belt is stopted for safety reasons and the operator is alerted by turning on Q1 of the buffering station.

1.4 Manual Mode

When the switch of the testing buffering station is vertical, the system operates in manual mode. When the system is in this mode, the system waits at three different places in the control loop for the operator to press the start button of the buffering station. The three places are:

- When the lift is at the bottom for at least 2 seconds
- When the lift is at the top for at least 2 seconds
- When a block is in the separator, and the processing station is not busy.

2 Functionality

In this chapter, the functionality of the system is described.

2.1 Physical buttons

The testing and buffering station both contain one of the following buttons and objects.

- A start button
- A stop button
- A reset button
- A switch between Auto and Manual
- Two LEDs named Q1 and Q2

Pressing the start button on the testing station starts the system. You can then decide between manual mode and automatic mode using the switch on the testing station. Automatic mode means that the system runs all by itself. It expects a product to come in from the arm, but it is also possible to place a product on the lift yourself, for testing purposes. The Stop button on the testing station makes the system finish its current action, and then stops the system. The stop button on the buffering station has no function. When the storage space for the rejected buffer is full, Q1 of the testing station will turn on. This communicates to the operator that he should remove the products. When the operator has done this, he can press the reset button on the testing station to resume normal operation. The reset button on the buffering station resets resumes normal operation after product removal has been detected.

When manual mode is enabled, pressing the start button makes the system go to the next step. This can be used to test parts of the controller separately.

The processing busy sensor is normally controlled by the processing station. However, it is also possible to control this manually by using the switch on buffering station (when manual mode is enabled, which is done by using the switch on the testing station). When the switch is vertical, the processing busy is turned on. When it is horizontal, the processing busy is turned off.

Testing station LED Q1 shows that the storage conveyor is full. Testing station LED Q2 shows that one of the sensors is malfunctioning. Buffering station LED Q1 shows that one of the sensors is malfunctioning. Buffering station LED Q2 shows that the processing station is busy.

2.2 Malfunction of actuators and sensors

The following malfunctioning sensors can be detected by the system:

- The *s_elevator_up* and *s_elevator_down* sensor, this is detected by measuring the time it takes for the lift to reach the top or bottom. If this takes more than 10 seconds, it is assumed the sensor is malfunctioning.
- The pusher sensor, this is detected by measuring the time it takes to extent the pusher. If this takes more than 5 seconds, the system assumes the sensor is malfunctioning.

When a malfunction is detected, the Q2 of the testing station is turned on. This is a way to warn the operator.

2.3 Removal of products

The system can deal with the removal of products on the air slide or on the conveyor belt. It does this by adding a blue opaque product that is basically the position where the controller expects the product to be. When a product is removed, a mismatch between the model of the controller and the sensors will occur and after 3 seconds the product is removed in the controller.

3 Use Cases

In this chapter, the use cases are brought up to test the functionality of the system. In all use cases, the buttons to continue operation of the system (such as pressing the reset buttons) is done automatically.

3.1 Use Case 1: Happy flow

In happy flow, the following is done: Only accepted products are generated, processing station is never busy. This Use case shows that when there are no odd occurrences, the system is fully functional.

3.2 Use Case 2: Black and thick

In case 2, 40% of the products are thick, and 40% of the products are black products. Processing station is busy for 3 seconds every 6 seconds. This use case shows that the testing station can handle thick and black products

3.3 Use Case 3: Removal of products

In removal of products, 5% of the products are thick, 5% of the products are black products. Processing station is busy for 3 seconds every 6 seconds. The product removal goes in different stages. In stage 1, a product has a 100 % chance of being removed on the air slide. In stage 2, a product has a 50% change of removed between the entry of the buffer and the separator. In stage 3, a product has a 50% of being removed in the separator.
In use case 3, the elevator up, elevator down and pusher sensor malfunctioning is simulated.
This use case shows that the buffering station can deal with the removal of products and malfunctioning of sensors.

4 Visualization

In this chapter, the functionality of the visualization will be described. The visualization is done with an SVG file which is interfaced through CIF. It uses the same controller that is being run on the real hardware, and the simulation has all functionality the hardware has. See figure 4.1 for an overview. It consists of 2 parts, the user interface and the visualization of the testing and buffering stations.

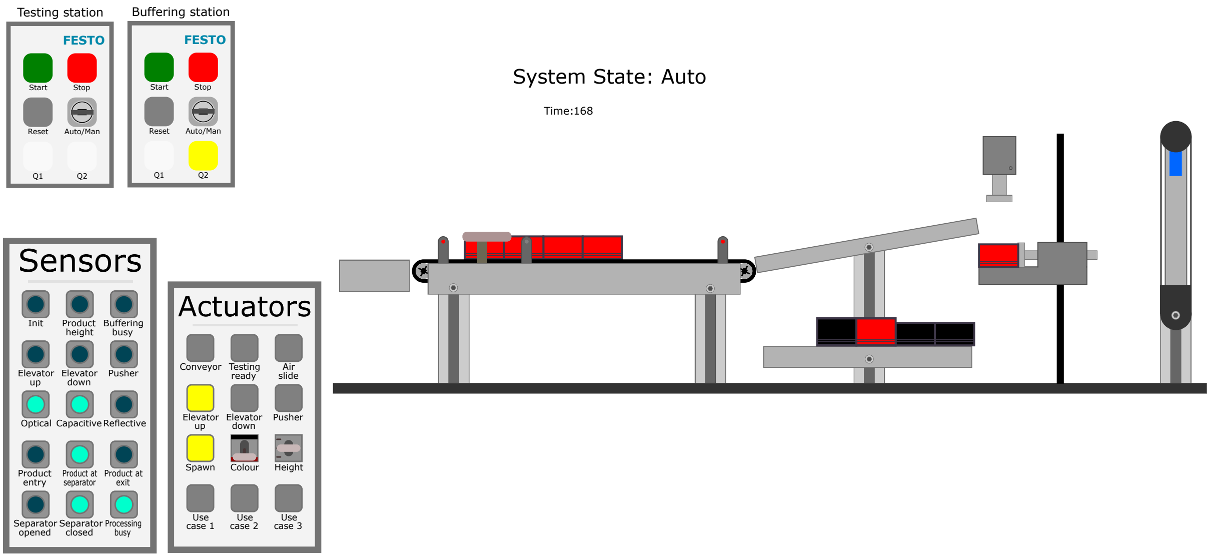

Figure 4.1: *Overview of the visualization*

4.1 The user interface

4.1.1 Overview

The user interface, that allows users to interact with the visualization is made up of 4 panels. 2 of those panels are direct copies of the panels found on the physical stations, with a start, stop and reset button, an automatic/manual mode key switch and two LED indicators. The function of these is identical to the physical panels explained in 2.1. However, since CIF only recognizes toggles, to simulate one button press on those panels the virtual button need to be pushed twice to work.

4.1.2 The sensor panel

The sensor panel has 15 indicators which show the current state of all sensors on the testing and buffering station. They light up blue when they are high/true. The elevator up, elevator down and pusher can be turned off by pressing them, which turns them orange. This simulates a sensor failure.

4.1.3 The actuator panel

The first 6 buttons of the actuator panel indicate the current state of actuators in the system. When an actuator is used the corresponding button lights up yellow. The next 6 buttons specify the input products. The next button is the spawn button, which initializes a product on the arm whose properties are defined by the Color and Height switches. When the Color switch is in the upper position, a black product is spawned. When it is in the lower position, a red product is spawned. When the Height switch is in the highest position, a thick product is spawned and when it is not a non-thick product is spawned. The last buttons can be used to run the use cases 1-3 which are specified in chapter 3. To successfully switch between use cases, turn your current use case off and select a different one.

4.1.4 Controller internals display

The system state, which can be manual or automatic, is displayed in text above the machine. This can be changed by toggling the auto/man key switch of the testing station. The purpose of this is mainly for quick reference and debugging purposes. Underneath the system state indicator the time indicator is counting seconds. This is done to quickly detect freezes and for debugging purposes.

4.2 Machine visualization

4.2.1 Testing station

When a product enters the testing station, it spawns on the arm of the handling station. We have modeled this to visualize that the elevator correctly waits for the arm to rotate away before the elevator goes up. The product goes onto the elevator platform, where it will be further sorted by the controller. If the item gets rejected, it will enter the discarded items buffer, at the lowest position of the elevator. The discarded items buffer will reset automatically when it gets full when a use case is active. If an item has been found to be correct, the height sensor will light up and the product will move down the slide into the buffering station.

4.2.2 Buffering station

The buffering station has 3 sensors, which signal gets blocked when the product passes. The product will stop at the separator, which will move to allow a product to pass when it is allowed to continue into the sorting station.

5 Operator Instructions

5.1 Starting up

1: Ensure the stations are empty and all switches are in their default position. Start the controller and wait for the Festo station to initialize. When all LEDs are turned off, the initialization has been executed correctly.
2: To start the controller, press the start button of the testing station.
3: You can now switch between manual mode and automatic mode using the switch of the testing station. Default (key in upward position) is manual mode.
4: Once the controller is on automatic, the station is ready to be used. You can now manually add products on the elevator, or let the handling controller do it for you.
5: To stop the controller, the stop button of the testing station can be pressed. The system will then stop after it finishes its current operation.

5.2 Error handling

Reset

If the rejection buffer is full (5 items), the controller cannot continue if it receives another faulty product. When this is the case, Q1 of the buffering station lights up indicating that the operator should remove all the products off the rejection buffer. After the operator has completed this task, he must press the reset button of the testing station to allow the system to continue.

Sensor malfunction

When a sensor malfunctions, i.e. does not turn on when it should, Q2 of the testing station lights up. After the operator has solved the problem, the start button of the testing station can be pressed to resume operation.

LED indicators

When a product is removed or a sensor fails, the operator is alerted by lighting up Q1 of the buffering station. When this is the case, the operator must identify what went wrong and press the reset button of the buffering station to resume normal operation.