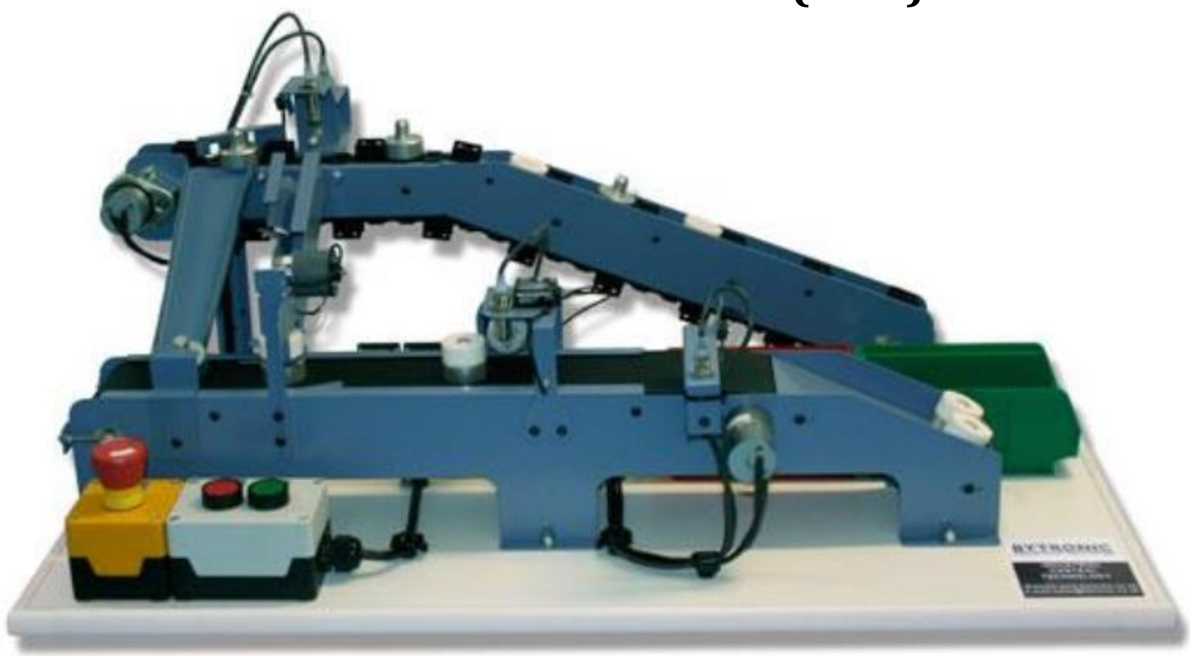
SCHOOL OF MECHATRONIC SYSTEMS ENGINEERING
SIMON FRASER UNIVERSITY

MSE 310

AUTOMATED WIDGET ASSEMBLY (AWA) SYSTEM



By: Dave Bhullar | Doordaneh Esfandiari | Eunice Kuatsjah

Student ID: 301217638| 301178989 | 301210734

Contents

Introduction

The objective of this project is to implement the Industrial Control Technology trainer unit (ICT3). The ICT3 (pictured below) is essentially an assembly line unit used to assemble two parts together to form an assembled part. This assembled part is referred to as a widget, thereby lending the name Automated Widget Assembly (AWA) System to the whole setup. Sensors and actuators on this unit are manipulated using control algorithms developed in LabView interfaced through the NI-Daq microcontroller.

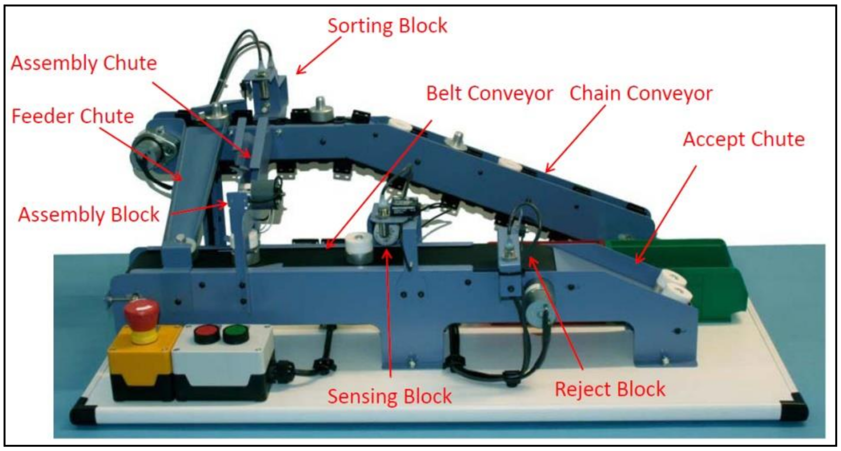


Figure 1: ICT3 unit made by Bytronic Ltd.

Statement of the problem

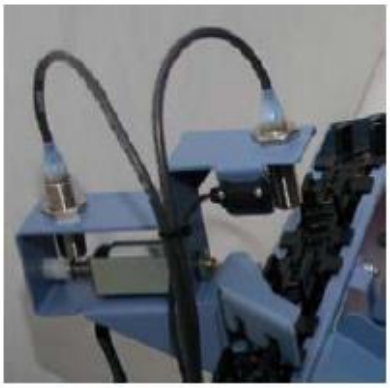
The widget assembly system is fed parts manually by placing them on the conveyor chain. The widget constitutes of two parts, metal peg and plastic ring, the former part fits perfectly into the latter part. The chain belt mechanism transfers the parts to a series of stations on ICT3 unit where the parts get identified, then separated and eventually assembled to form a widget, thereafter, the assembled part is inspected and rejected if it's incorrectly assembled. In addition to this, a GUI on the LabView front panel provides the following:

a. A real-time snapshot indicating what sensors and actuators are active
b. The number of sorted pins, sorted rings (in assembly chute), unsorted rings (when assembly chute is full), rejected pins and rings, and assembled widgets during system operation
c. The rate of assembled widgets processed per minute
d. The efficiency of the system
e. A pause button which will halt system operation, in the event of an error or dangerous act
f. A manual mode which enables the system operator to control the actuators with full control over the assembly line
g. A system recovery condition in the event of power-outage, such that variables are stored and no system data is lost

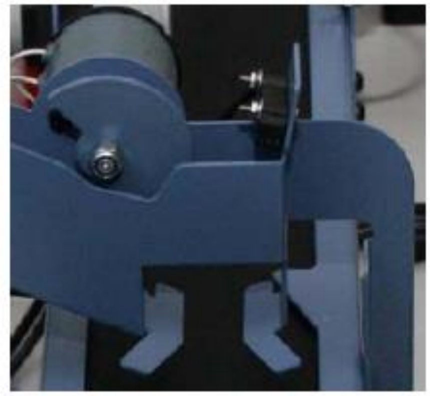
System Performance/Technical Description

The ICT3 unit consists of the following four stations/areas:

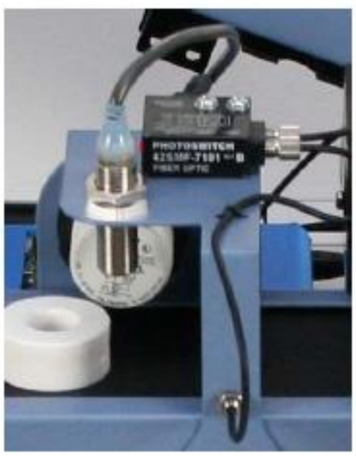
Sorting Station



Chute Area



Sensing Station



Rejecting Station

Figure2: Stations/Areas on ICT3

1. *Sorting Station*

The chain belt mechanism transfers the parts to this station. As the name implies, this station separates the plastic rings from the metal pegs. If the part is a plastic ring, the state of the inductive sensor remains unchanged, this sensor is followed by an infrared sensor which goes ‘HIGH’ in presence of any part. Conversely, if the part is a metal peg, the inductive sensor detects the metal part along with the infrared sensor. Thus, using the states of both sensors, parts can be identified and plastic rings can be separated using linear solenoid actuator. Another inductive sensor senses the return of the linear solenoid actuator.

2. *Chute Area*

This is where the plastic rings accumulate after they go through the sorting station, while the metal parts continue and slide down onto the belt conveyor heading under the chute area. Here a rotary solenoid actuator allows a plastic ring to be released from the feeder and be placed over the belt conveyor in such an orientation that when the metal peg goes under the chute area, the plastic ring fits on the metal peg. The infrared sensor in this area detects the presence of plastic ring above the belt conveyor. The chute itself is big enough to hold five plastic rings in addition to the one placed directly above the conveyor belt.

3. *Sensing block*

This is the only station that lacks actuators. It contains three sensors. The capacitive sensor detects assembled parts. The inductive sensor detects metal parts, therefore an assembled part will also trigger this sensor. The last sensor in this station is an infrared sensor that detects any parts. Using these combination of sensors, it can be determined if the parts were correctly assembled or not.

4. *Rejection block*

This station is equipped with an infrared sensor, a linear solenoid actuator and an inductive sensor for detecting return of the actuator. This station uses the sensing station’s output to determine if the part should be rejected using the linear solenoid actuator or not.

Algorithms and Flowcharts

Our automated widget assembler consists of six subsystems: start/stop, sorting area, chute area, sensing station, rejecting station & efficiency, and system recovery. The sensors and actuators work in digital binary value where 1 represents high and 0 represents low. A change in sensor value is monitored using a shift register that compares the previous and current states of the sensor. Each sensor and actuator value has its own local variable that is displayed in real time on the GUI by LED, push button, toggle, numeric indicator, and meter. Following is the details of their algorithms.

Start/Stop

Function: Control the starting and stopping of conveyor and chain belt.

Sensors: start button, stop button, start/pause button.

Start button and stop button are physical button on the ICT machine that user can press on to send input signal into the system while start/pause button is a button the user can click on to in the GUI. When start button is not pressed, its value is 0. When stop button is not pressed, its value is 1.

Actuators: chain conveyor, belt conveyor.

One variable (‘Conveyors’) controls both belt and chain conveyors as they are on and off at the same time. ‘Conveyors’ is controlled by ‘In Progress’ value. ‘In Progress value’ depends on ‘Start/Stop Button’ value which depends on ‘Start Button’ and ‘Stop Button’ user’s physical input or can be directly set by user on the GUI. Their dependencies are illustrated in Figure .

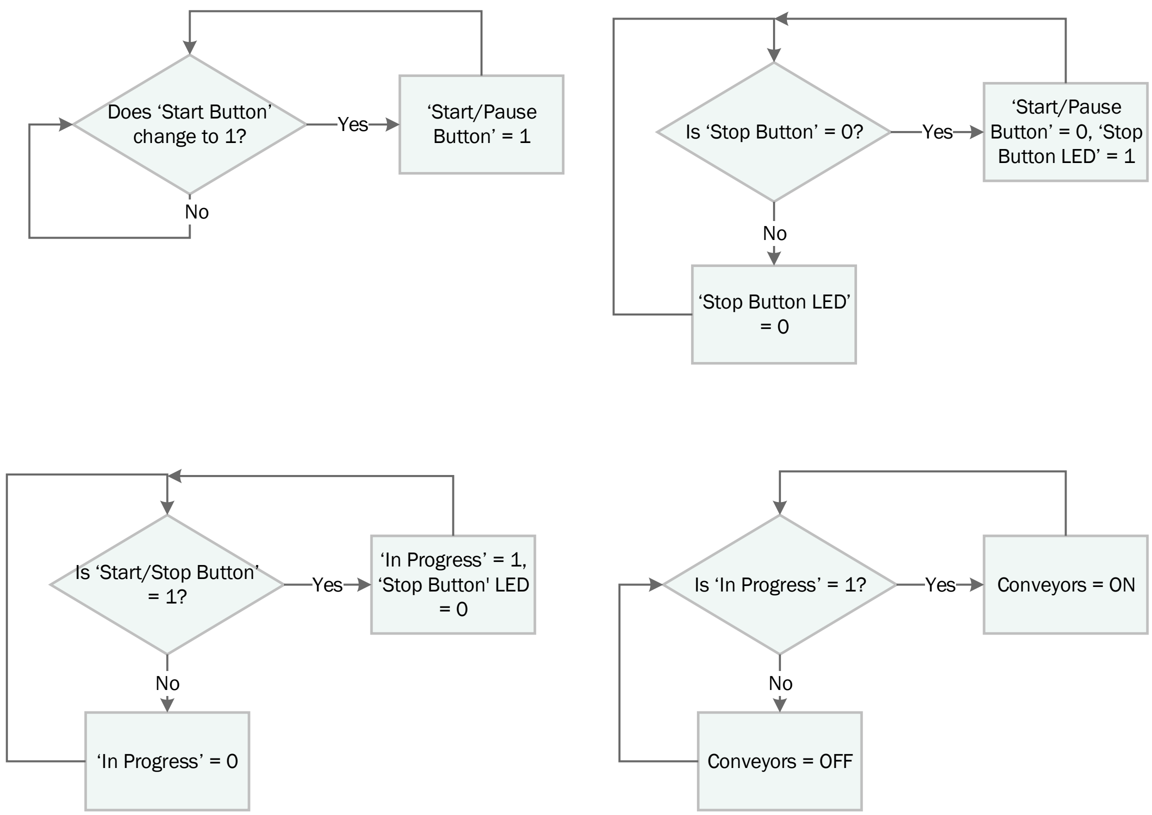


Figure 3: Conveyors Start/Stop Flowchart

Sorting Area

Function: Letting the metal peg to pass and putting plastic ring in queue to chute area.

Sensors: Inductive proximity switches ('Sort Metal Detect', 'Sort Solenoid Return'), infra-red ('Sort Area Detect').

Actuators: 24V DC linear solenoid ('Sort Actuator').

The sorting algorithm shown in Figure is described as follows. The metal sensor will detect the object first, if it is a metal the information is kept on 'Sort Metal Detect' LED by setting the value to 1. When the object passes the infra-red sensor, 'Sort Metal Detect' value is checked; if it is 1 then the object is metal and will let it pass through. If 'Sort Metal Detect' value is 0 that means the object is plastic and 'Sort Solenoid' actuator is activated to push the plastic into chute area, number of plastic in queue is increased by 1. After the actuator is activated the 'Sort Solenoid Return' sensor does not detect the shaft anymore (value = 0), it will then wait for delay and deactivate the 'Sort Actuator' to return to its back position.

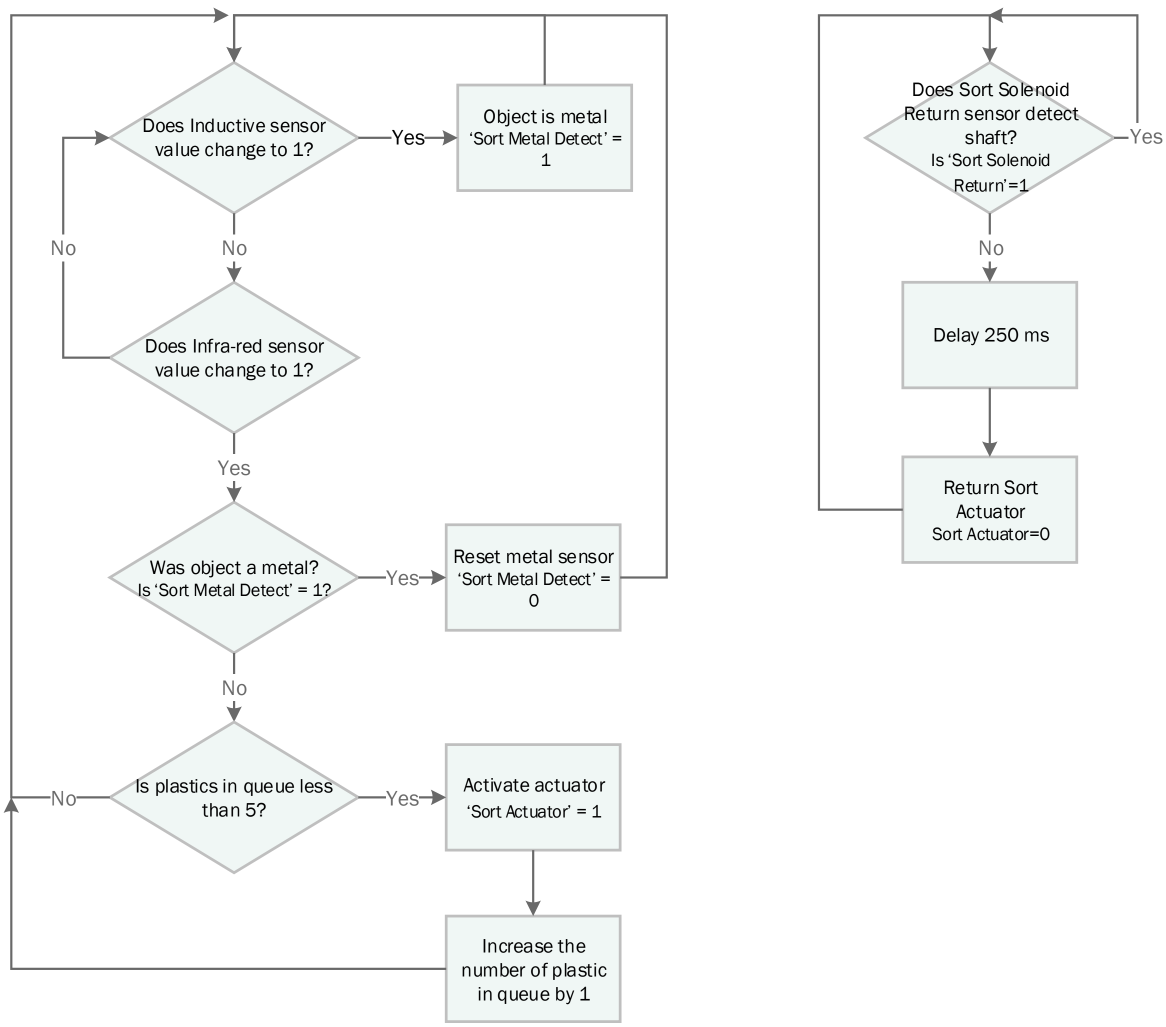


Figure 4: Sorting Area Flowchart

Chute Area

Function: Hold a maximum of 5 plastic rings in queue and dispense a plastic ring into hopper if it is empty.

Sensors: Infra-red ('Hopper Full').

Actuators: 24V DC rotary solenoid ('Rotary Actuator').

Rotary actuator is activated only when there is no plastic in the hopper and the number of plastic in queue is greater than 0. A time delay before activating rotary solenoid is needed to compensate the travelling time of plastic in the feeder. Every time a plastic is dispensed, the number of plastic in queue is decreased by 1. Plastic ring in the hopper waits until metal peg pass through it to be assembled together. Figure shows the plastic in queue checking and dispensing mechanisms.

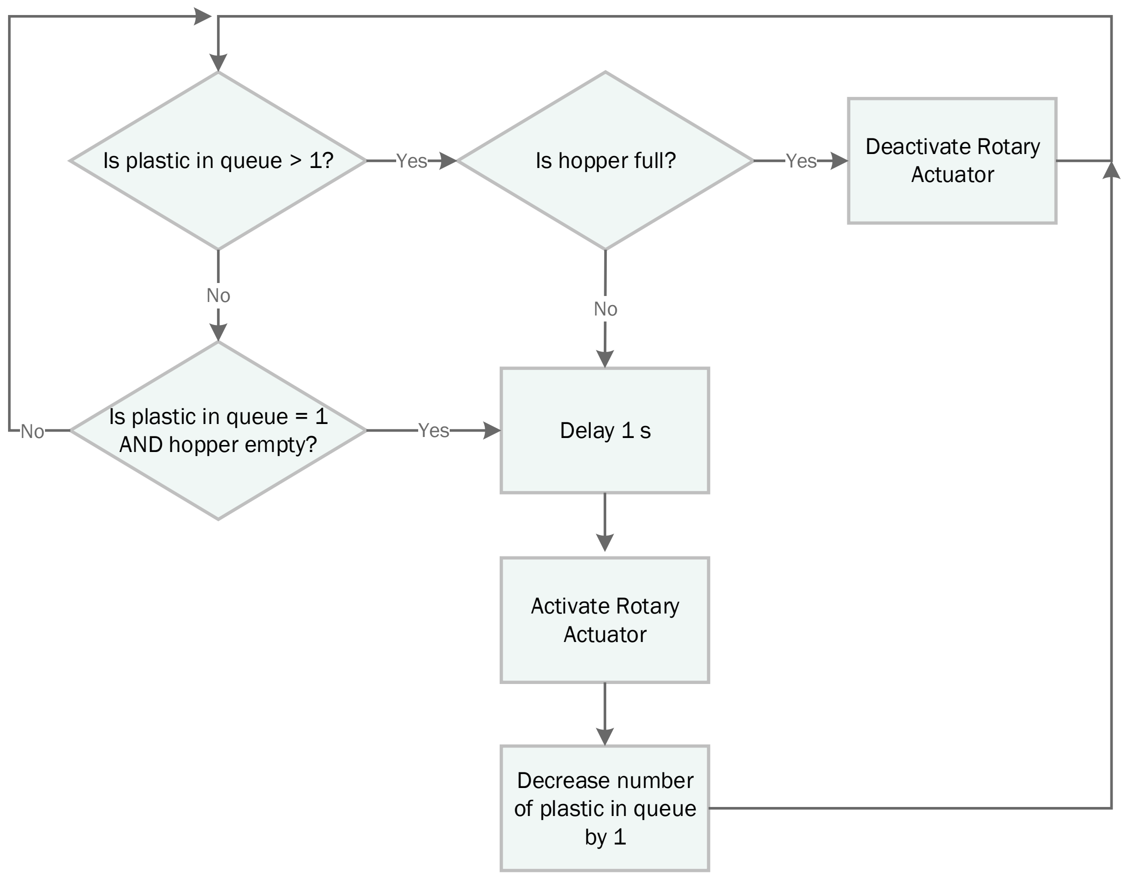


Figure 5: Chute Area Flowchart

Sensing Station

Function: identify whether the object is correctly assembled, a metal, or a plastic. The information is used in Reject Area & Efficiency station.

Sensors: Inductive proximity switch ('Proximity Sensor'), capacitive proximity switch ('Capacitive Sensor'), infra-red fibre-optic through beam ('Correct Assembly').

Actuators: none

Inductive proximity switch detects metal and store the information in 'Metal Sensor' LED, capacitive proximity switch detects a correct assembly and stores the information in 'Capacitive Sensor' LED. Infra-red sensor will detect a presence of an object and from the previous information of the other two sensors; the object is determined whether it is a correct assembly, a metal, or a plastic. Inductive, capacitive, and infra-red sensors default values when not detecting are: 0, 1, and 1 respectively. Each object type is counted for calculating system's efficiency. The last object detected is classified into correct or incorrect assembly in which the information is put into queue of size 5 which will be used in Rejecting Station. This last part status is also stored into 'Last Part Incorrect' variable to be used in System Recovery to resume the correct action to be done in Rejecting Station when emergency button is pushed. Figure 6*:* shows the details of these mechanisms.

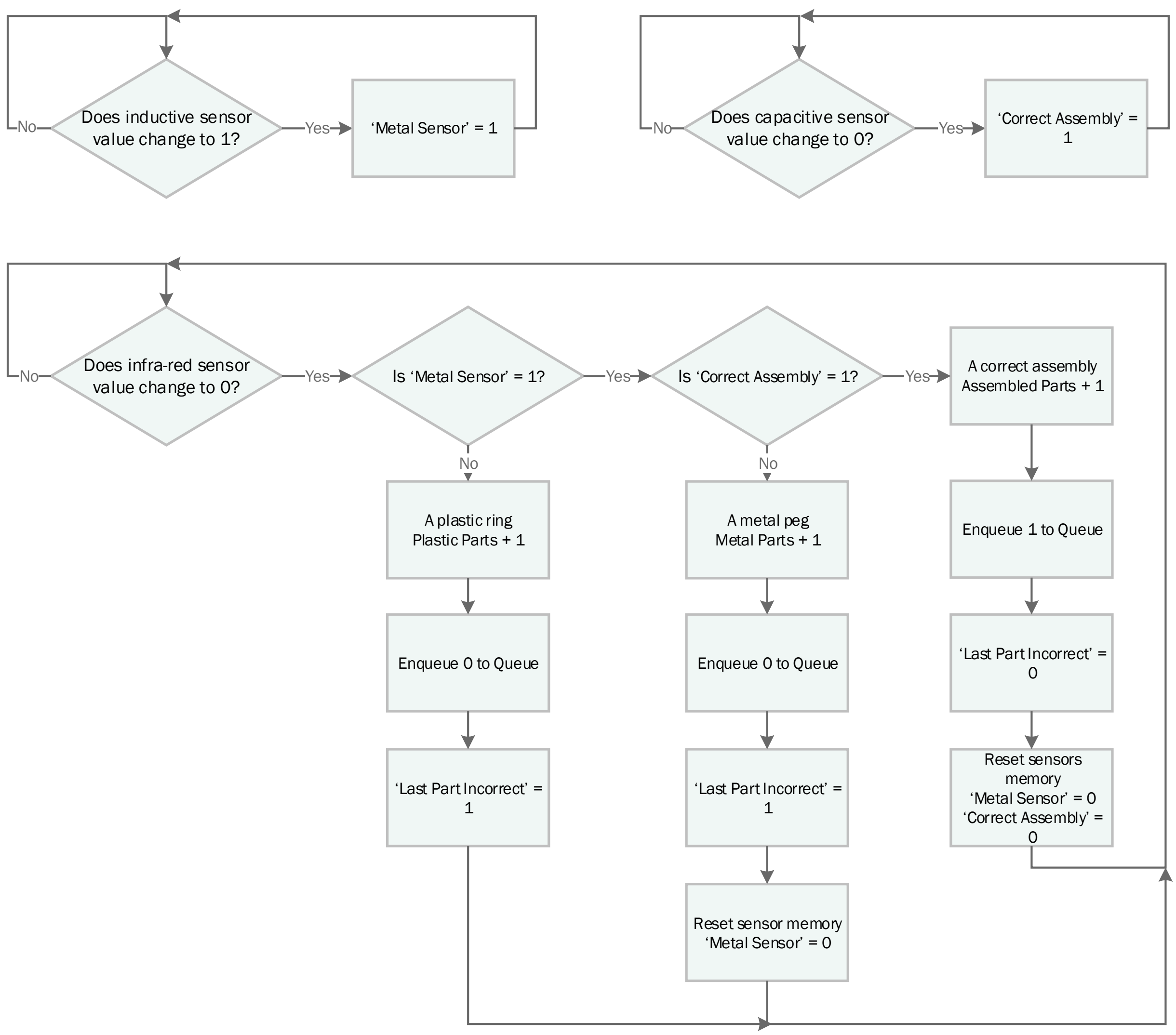


Figure 6: Sensing Station Flowchart

Rejecting Station & Efficiency

Function: Reject unassembled part, pass correct assembly, and calculate system's efficiency.

Sensors: Infra-red sensor ('Reject Area Detect'), inductive proximity switches ('Reject Solenoid Return').

Actuators: 24V DC linear solenoid ('Reject Actuator').

After infra-red sensor detects an object, the action whether to reject or let pass the object is determined from dequeued value of the queue filled from the Sensing station. Number of rejected parts is counted for statistic however our system's efficiency e is defined as follows:

$$Efficiency\ e = \frac{2\ \times\ Assembled\ Parts}{Total\ Parts} \times 100\%$$

$$Total\ Parts = Metal_{rejected} + Plastic_{rejected} + (2 \times Assembled\ Parts)$$

Number of assembled parts is multiplied by two since the correct assembly consists of two parts: metal and plastic. Number of total parts is defined as the total of each part that goes into the system. Therefore our system's efficiency is based on the number of single parts in correctly assembled part and the total number of parts into the system. For example, if there are 3 assembled parts with 2 metal parts and 1 plastic part rejected, the total parts is 9 and the efficiency is 66.67%. When there is no counted part yet, the efficiency is set to zero to avoid division by zero. The rejecting algorithm is illustrated in figure below.

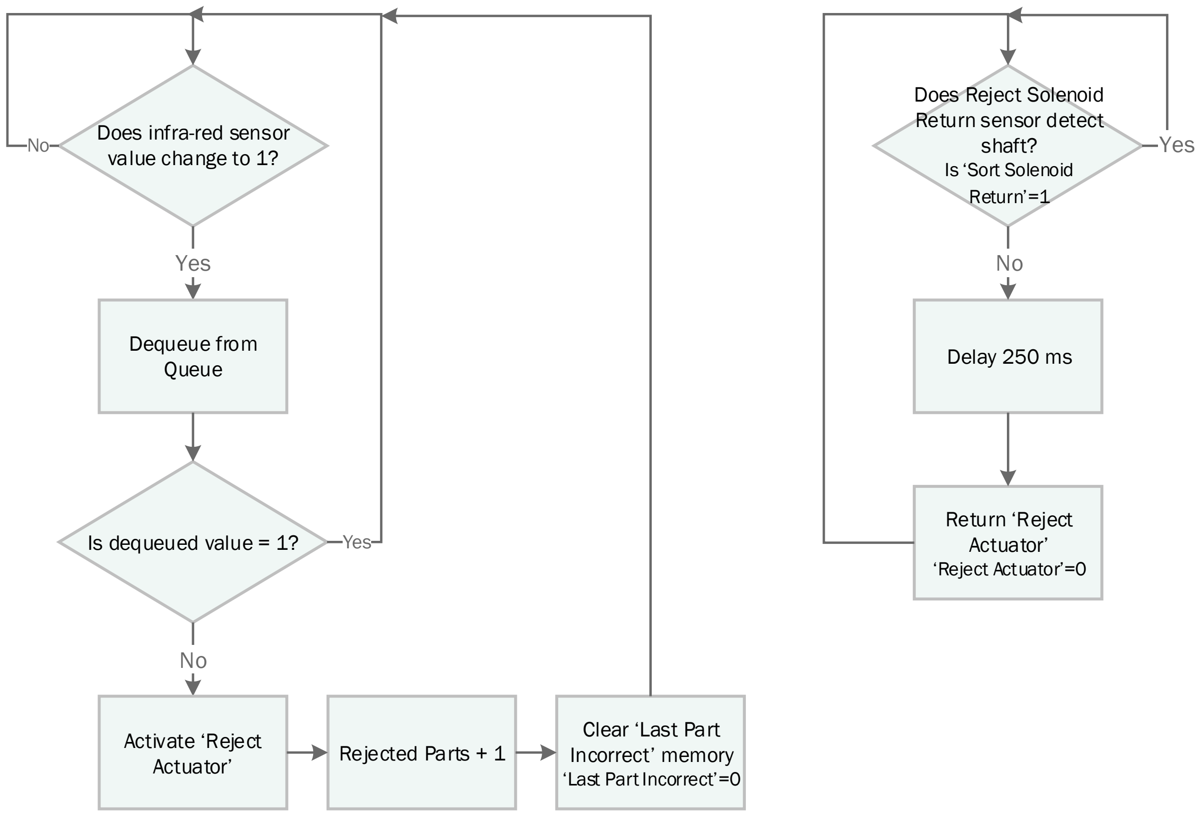


Figure 7: Rejecting Station Flowchart

System Recovery

The assembly system features an emergency stop switch which shuts off the power to all actuators and stops the ICT system completely until the switch is released. In any event of emergency, if this switch is pressed, our system is capable of recovery whenever the switch is released and the system is restarted. This capability is achieved by writing states of variables that are crucial to the controller to a file in real-time. Following are the variables that are written to the file: Assembled Parts, Metal Parts, Plastic Parts, Rejected Parts, Plastics in Queue, Stop Button, Hopper Full, Last Sensed Part Incorrect. Along with these variables, we also write the current time and data to the file, however this is never scanned during recovery as it is only for debugging purposes. This data is written to the file using the 'Format Into File' function which writes all the variables to the file separated by white space in the same order as they're wired to the function block (see picture below).

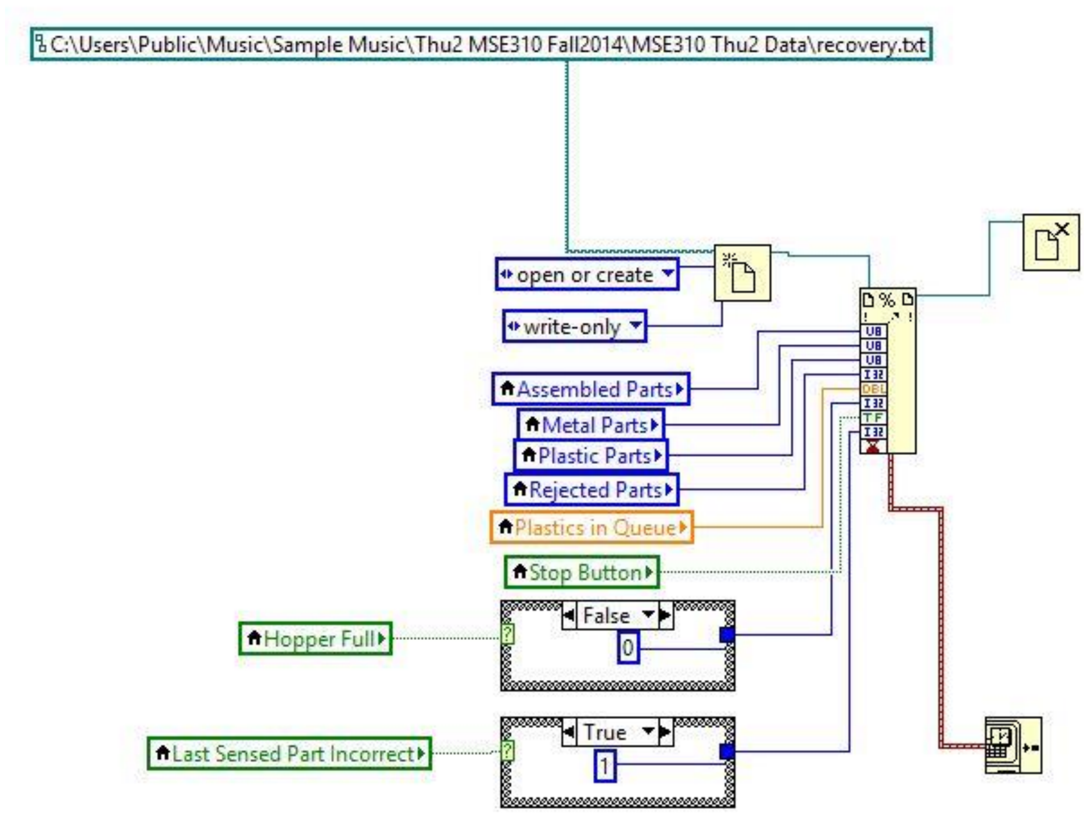


Figure 8. Variables Being Written To Recovery File In Real-Time

Upon recovery, first the recovery file is scanned to check the state of Stop Button. If the emergency stop switch was pressed during the previous run, this state should be FALSE, in this case a dialog box is displayed to the user giving them a choice of using the recovery file or not. If the user chooses to use the recovery file, then the states for the aforementioned crucial variables are restored from the recovery file, otherwise the system gets freshly restarted. Our system is capable of recovery from any point during the assembly process. The flowchart below demonstrates this algorithm.

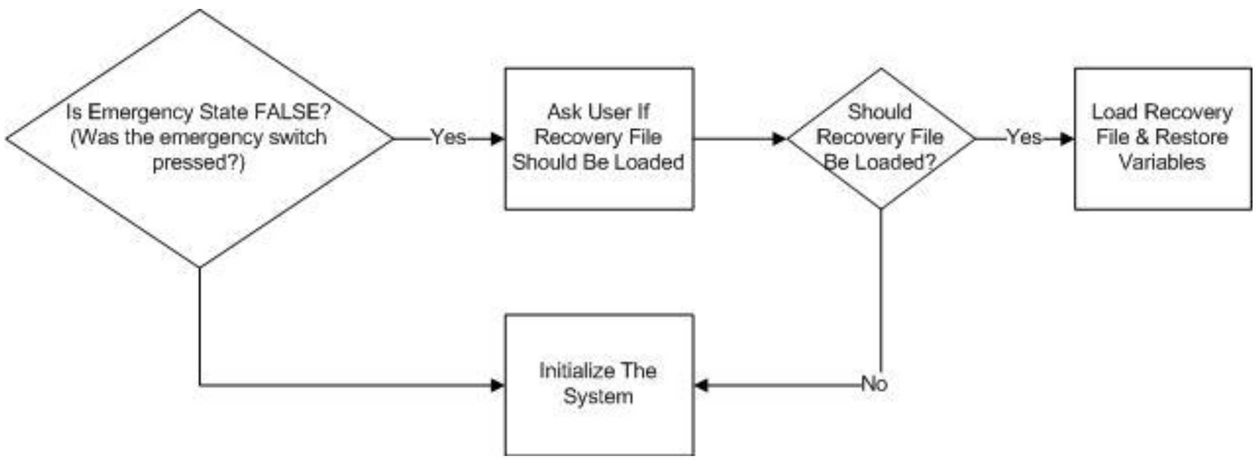


Figure 9. System Recovery Flowchart

GUI

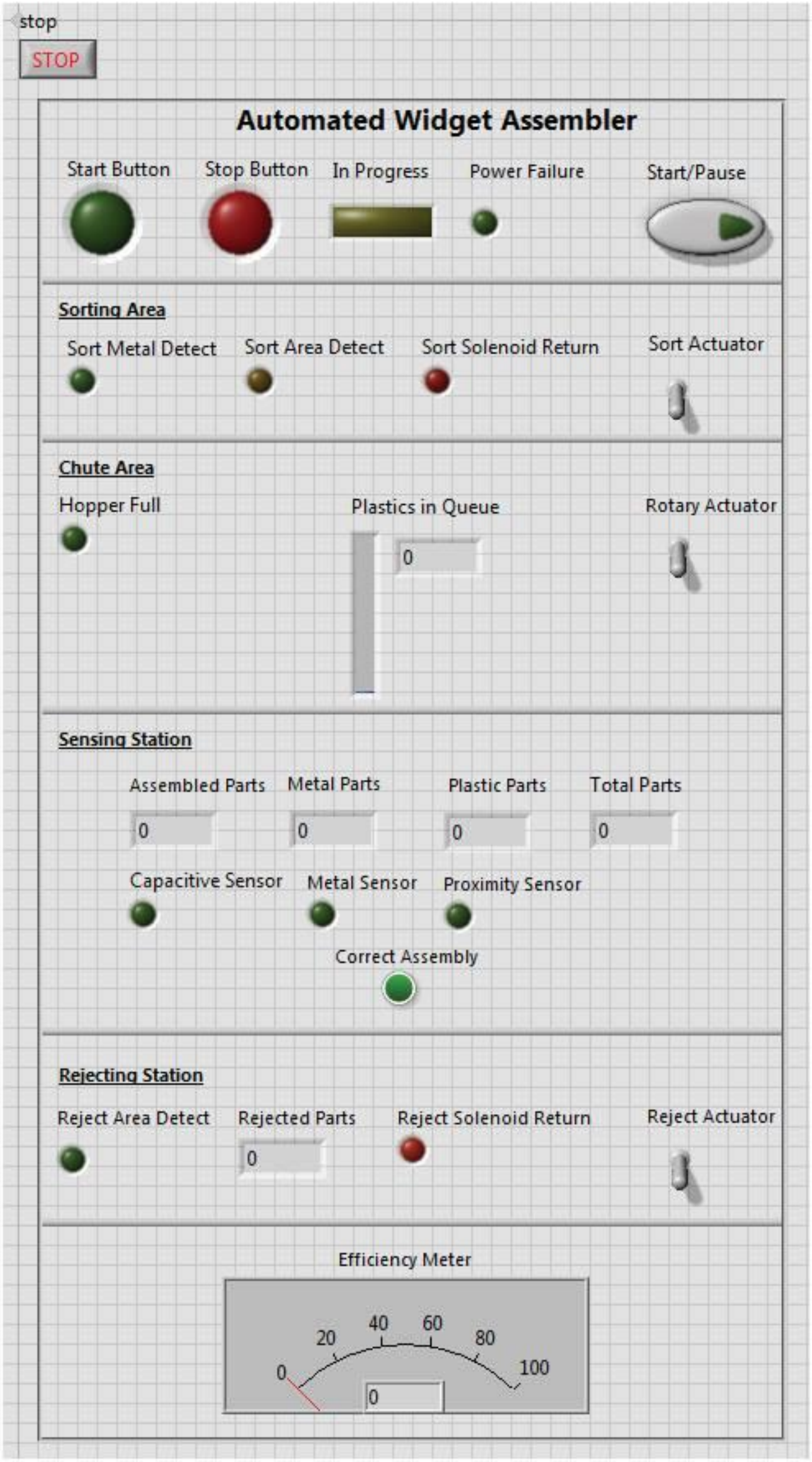


Figure 10: Automatic Widget Assembler GUI

The GUI displays the state of all sensors and actuators in real-time. As we can see in the above figure, the GUI of our VI is split into six sections. The order of these sections is consistent with the sequence of the stations a part goes through on the ICT3 system. This GUI was designed with the objective of displaying all relevant information in a functional and pleasing manner, all actuator controls are aligned to the far right for the convenience of the user. Details about each section are given below:

1. *AWA Status:* The topmost section lets the user monitor if the AWA is currently running or not using the 'In Progress' LED. The 'Start/Pause' push button can be used to start or pause the belt and chain conveyors. The 'Start Button' and 'Stop Button' LED's turn on/off according to the Start and Stop buttons on the ICT3 system. 'Power Failure' LED signifies that system was shut down abruptly due to power loss during the previous run.
2. *Sorting Area:* This section of the GUI corresponds to the sorting area on the ICT3 system. The user can observe the state of all sensors in this area in real-time using the three LED's. The 'Sort Actuator' toggle button displays the current state of the Sort Solenoid Actuator, the toggle button can also be used to control this actuator.
3. *Chute Area:* This section of the GUI corresponds to the chute area on the ICT3 system. 'Hopper Full' LED displays the current state of the infrared Assembly Hopper Full sensor. 'Plastics in Queue' progress bar displays the number of plastic parts in the chute area before the Rotary Solenoid actuator. 'Rotary Actuator' toggle button shows the state of Rotary Solenoid actuator in real-time and lets the user controls the actuator.
4. *Sensing Station:* This area corresponds to the sensing station on the ICT3 system. As each part goes through the sensing station, the respective numerical indicator gets incremented. Sum of all parts gone through the sensing station is displayed under 'Total Parts.' The state of all sensors on this station can be observed in real-time using the three LED's, each corresponding to the capacitive, metal and proximity sensor. 'Correct Assembly' LED turns on momentarily if an assembled part goes through the sensing station.
5. *Rejecting Station:* This area corresponds to the rejecting station on the ICT3 system. The two LED's represent the state of Reject Area Detect infrared sensor and Reject Solenoid

Return sensor respectively. ‘Rejected Parts’ numeric indicator displays the number of parts rejected by the station. ‘Reject Actuator’ toggle button shows the current state of the Reject Solenoid Actuator and it can also be used to control this actuator.

6. *Efficiency:* The last section of the GUI shows the efficiency of the widget assembler using the ‘Efficiency Meter’ which also contains an indicator to display the efficiency numerically.

Summary

The LabView control algorithms direct the ICT for widget assembly. Widget assembly is done by sorting, then assembling and rejecting the incorrectly assembled parts (rejecting the plastic ring and metal peg).

Some of the key logics used for the correct implementation of the algorithms are shift registers and queue. Shift registers are responsible for detecting the rising or falling edge of a sensor/button state which helps us make key decisions such as determining if the a part should be rejected or not. Queue is essential for storing a specific sequence in memory, for instance storing the sequence of parts going through the sensing station.

As discussed earlier, the NI-Daq provides an interface between the ICT unit and the computer (LabView control algorithm). Different I/O pins on the NI-Daq correspond to different sensors/actuators on the ICT unit. Therefore, we can read or manipulate sensors and actuators on the ICT unit by reading the corresponding pin on NI-Daq or making it 'HIGH'/'LOW' respectively. Sensors used on the ICT unit include inductive sensors, infrared sensors and capacitive sensors while the actuators used are 24DC linear and rotary solenoid where the former is used for sorting and rejecting and latter for releasing a plastic ring from the feeder. Other hardware components on the ICT unit include the chain belt, conveyor belt, stop, start and emergency switches.

Power failure is dealt by loading a recovery file which contains variables necessary for recovery. These variables are written to the recovery file in real-time so that no data is lost. Upon recovery, user can either choose to load the recovery file or start with clean memory.

Conclusion

During this project, different types of sensors and actuators were used in order to give a comprehensive understanding of the individual parts of the system. Consequently, functionality of each section of Automated ICT system has been studied which will prove to be vital when dealing with automated/robotic systems in future. Moreover, software development using LabView was learnt in this project. By the knowledge we gained from the outlines of this course and the previous backgrounds we had, we were able to program and produce a product well suited to be used in the manufacturing industry and gained helpful insight into the automation industry. Moreover, this project made us familiar with programming robust real time applications.

References

Bytronic Ltd. (2010). *ICT3 Data Sheet*. Retrieved 2010 14-11 from Bytronic Ltd: http://www.bytronic.net/datasheets/Automation/ICT3-DS091.pdf