Computer Integrated Manufacturing I

ME345: Automation and Manufacturing Methods

Boston University College of Engineering
Department of Mechanical Engineering

Fall 2021

Pre-lab assignments should be completed individually, online using Blackboard Learn.

Complete the pre-lab assignment before the start of your lab section.

Lab reports should be submitted in PDF format to Blackboard Learn. Lab reports are completed either as a whole lab section or with your lab partner, according to the course syllabus.

Submit the lab-report on Blackboard Learn before the start of your next lab section.

Contents

1 Learning Objectives

This lab introduces the ADML Flexible Manufacturing Cell (FMC) as a whole, including the software used to control and automate the system. The learning goals for this lab are:

- Consider the challenges of running the ADML FMC as a dynamic production system.
- Perform a time study on the "Cordganizer" demo including robot pick-and-place, machine tending, and CNC milling.

1.1 Lab Deliverables

- Pre-Lab Questions
- Lab Report, due before the start of your next lab.

1.2 Lab Groups

Complete this lab with your lab section as a whole. The laboratory instructor will setup the exercises, help troubleshoot, and check your programs.

2 Pre-Lab Reading

- Groover Fundamentals of Modern Manufacturing: Materials, Processes, and System
  `Blackboard >> Content >> Lab Material >> Lab 06 >> Groover, Sections 38.6 & 38.7`

3 Pre-Lab Questions

After completing the pre-lab readings and reading this lab manual, answer the following pre-lab questions. Use the contents of this lab manual, the pre-lab readings, ME345 lecture material, and intuition to answer the questions.

Each lab member must complete these questions individually on Blackboard Learn. Save a copy of your answers before submitting, in case there are any issues with Blackboard. If you have issues submitting answers, email the GST before your lab section.

1. What is the difference between a flexible manufacturing cell (FMC) and flexible manufacturing system (FMS)?
2. Why is the facility at BU considered an FMC and not an FMS?
3. Consider the five basic FMS (or FMC) layouts. Which layout, or combination of layouts, best describes the BU FMC?
4. Consider the role of humans in an FMC. Name four roles humans have in the BU FMC.

4 Lab Background and Description

In the previous labs, collaborative robots, PLCs, vision systems, and CNC milling machines were showcased and operated independently. Now, in this lab, the software used to operate the entire FMC autonomously will be showcased.

The software used to control the BU FMC is located on a centralized computer. Computer-integrated manufacturing (CIM) is the general term for a manufacturing system, like the BU FMC, that uses computers to control all manufacturing production. Although the BU FMC may not be a perfect representation of a true industrial autonomous system, the underlying principles of its operation (and the data it is able to generate) provides a valuable tool for data analysis and manufacturing planning.

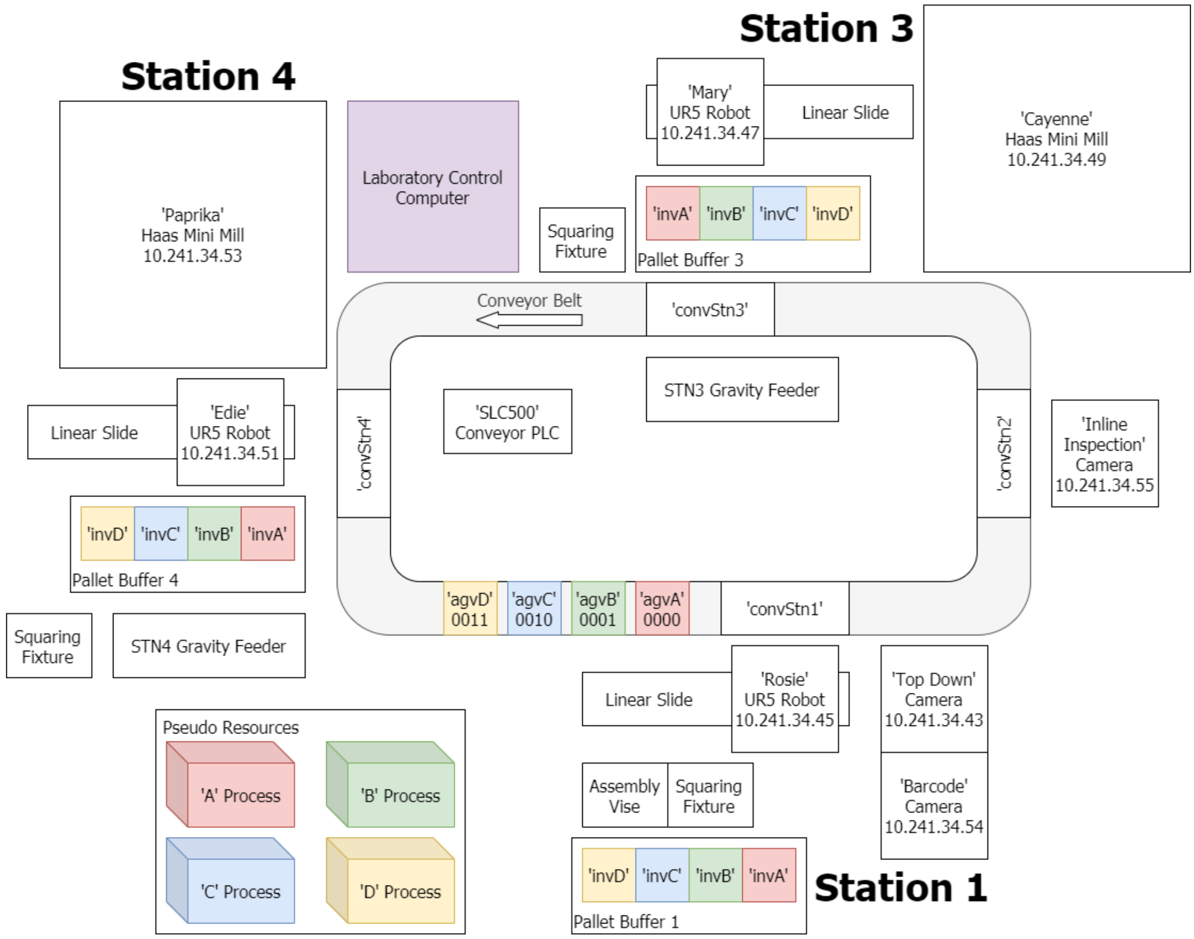

Figure 1: BU FMC Layout Overview

Figure 1 shows a top-down overview of the equipment in the FMC including the robots, CNC milling machines, conveyor belt, vision systems, and the laboratory control computer. The software used to control the FMC is called the Boston University Manufacturing Execution System (BUMES).

"Manufacturing execution systems (MES) are computerized systems used in manufacturing to track and document the transformation of raw materials to finished goods. MES provides information that helps manufacturing decision makers understand how current conditions on the plant floor can be optimized to improve production output."[1]

[1] McClellan, Michael (1997). Applying Manufacturing Execution Systems. Boca Raton, Fl: St. Lucie/APICS. ISBN 1574441353

The goal of this lab is to collect data from the Cordganizer demonstration which will then be analyzed in the lab report.

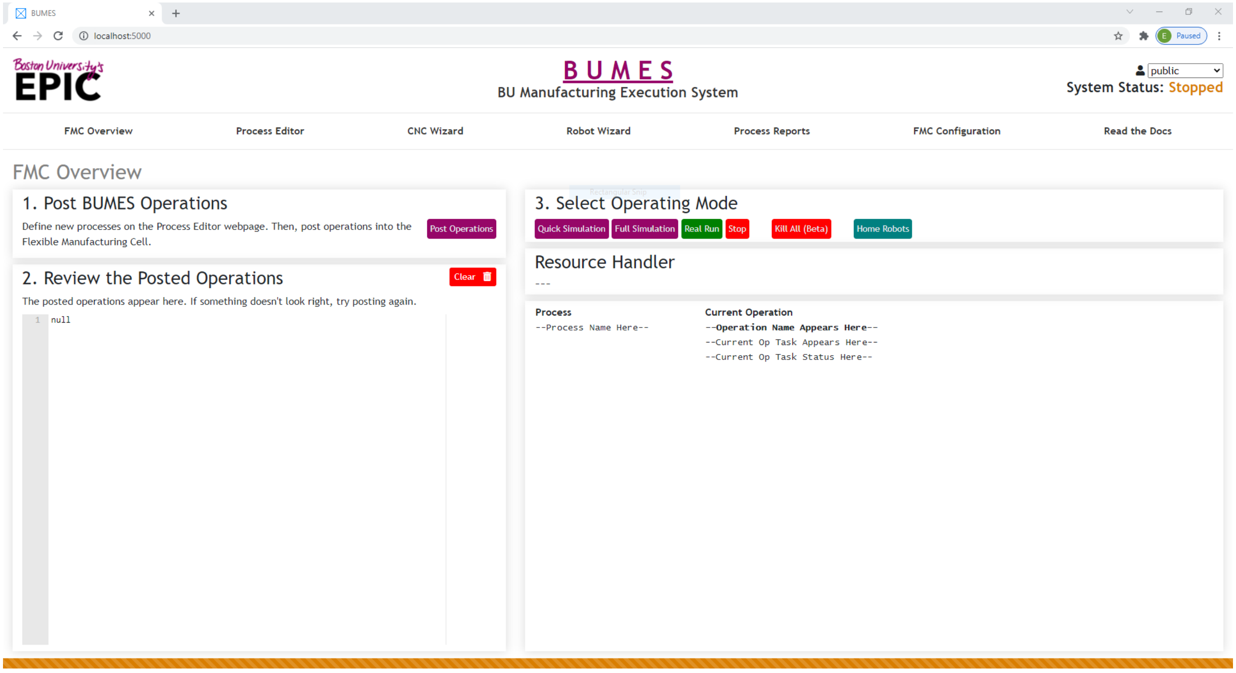

Figure 2: BUMES FMC Overview

The main interface for BUMES appears as it does in Figure 2. BUMES is, at its simplest, is a Python-based script executing on a Linux computer. The user-interface is a web server that allows the user to program, execute, or simulate the behavior of a fully autonomous manufacturing cell.

A ***Task*** is the base unit in BUMES. It is the simplest possible action that a user can complete in the system like the movement of a robot, a milling operation, vision inspection, or conveyor belt action. BUMES tasks are as follows:

- **resourceSeize**() - a semaphore command for controlling the conveyor or indicating that an operation would like exclusive access to a resource within the FMC
- **resourceRelease**() - a semaphore command for controlling the conveyor or indicating that an option no long needs access to a resource within the FMC
- **urDashboard**() - connect to a robot, load and play a URP file using the dashboard server
- **cncRun**() - connect to a cnc machine and execute GCode
- **visionInspection**() - connect to a camera, execute a solution file, return information about the outcome of the inspection
- **readyForAssembly**() - a macro semaphore command for indicating that an operation is ready or finished with an assembly to another component

A ***Process*** is a series of tasks strung together to achieve some greater goal, like the transformation of raw material into a finished good. An ***Operation*** is a process currently being executed in the flexible manufacturing cell. For a process to enter the FMC as an operation, it must first be ***Posted*** into the system, which simply involves selecting the quantity.

In summary, the BUMES workflow hierarchy is:
Task >> **Process** >> **Post** (Quantity Selection) >> **Operation**.

5 Lab Method

5.1 Starting up the BUMES and the FMC

5.1.1 Robot Startup

- ☐ Power on all robots.
- ☐ Initialize them with the correct installation file, `admin.installation`.
- ☐ Use the teach pendant to run the program `/programs/me345_admin/_adminRobotHome.urp`. This resets the robot and linear slide.

5.1.2 Milling Machine Startup

- ☐ Power on both milling machines.
- ☐ Press `Reset` to clear any errors and use the `Power Up|Restart` button to initialize the machines.
- ☐ Press `Setting/Graphic` and navigate to the `Network` page on the `I/O` tab. Press `F1` to refresh the network settings.
- ☐ Use `List Program Mode` and the `Select Program` button to load the correct startup file on each machine; `_mesCayenneStartup.txt` and `_mesPaprikaStartup.txt`.
- ☐ Reduce the machine rapids to `25%`.
- ☐ Close the door on the machine and press `Cycle Start`. The code on the machine should illuminate pink and enter an infinite while loop.

5.1.3 Conveyor

- ☐ Locate the conveyor belt power switch located at Station 1, near the additive assembly area.
- ☐ Press the black power button to start the conveyor.

5.1.4 BUMES Startup

- ☐ Click the BUMES shortcut on the desktop to open BUMES (web address: localhost:5000) in Google Chrome.

5.2 Simple Cordganizer Body Demo

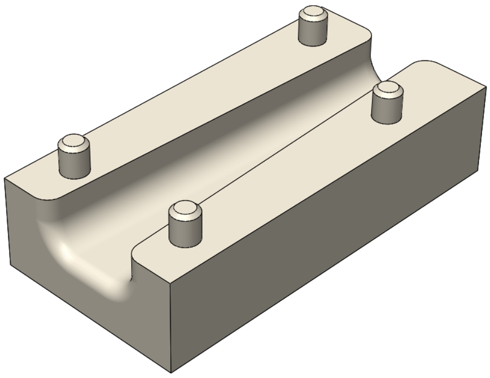

Figure 3: Cordganizer Body

This exercise demonstrates a simplified version of the Cordganizer body manufacturing process in the FMC. The goal is to build familiarity with the operation of BUMES. The Cordganizer body part is shown in detail in Figure 3. This part is manufactured from a 1.5" x 3" x 1" block of HDPE.

1. Navigate to the `FMC Overview` page of BUMES using the hyperlinks at the top of the interface.

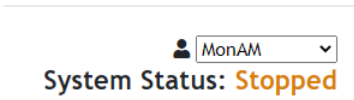

Figure 4: BUMES Change User

2. Locate the user drop down menu, shown in detail in Figure 4. Select the user corresponding to your lab section. The current user will appear at the top right of the interface.
3. Navigate to the `Process Editor` web page using the hyperlink at the top of the interface.

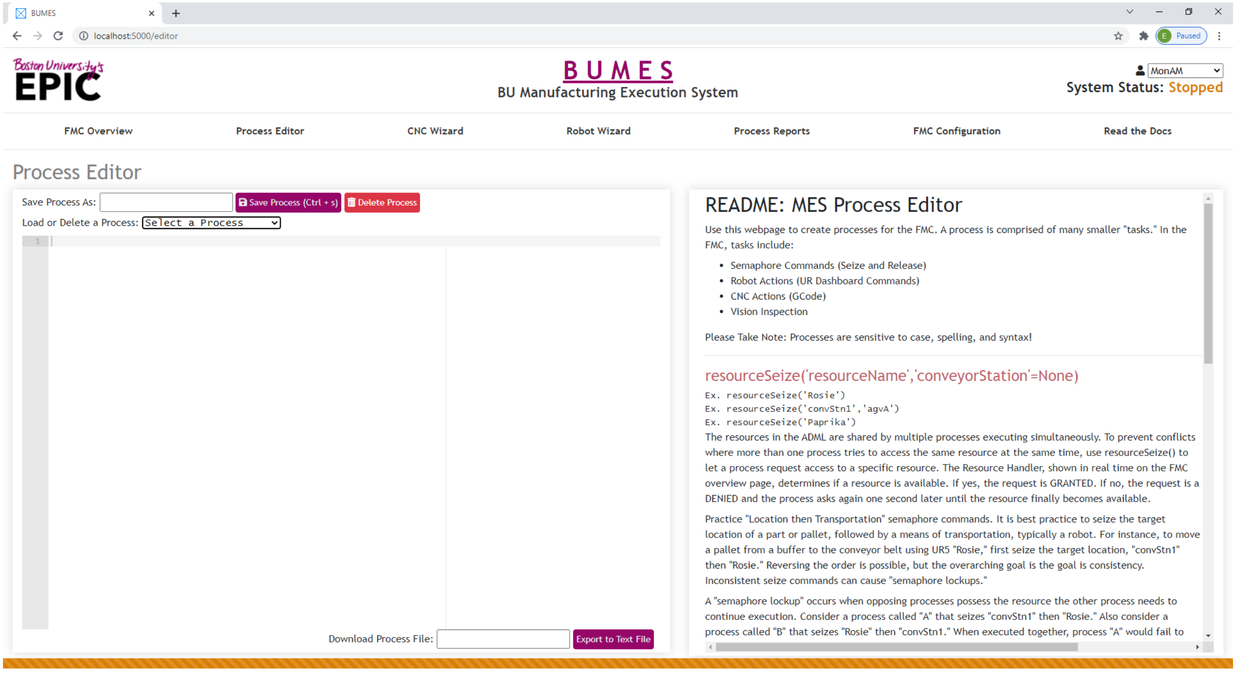

Figure 5: BUMES Process Editor

4. The laboratory supervisor has a prepared a process for Lab 06 called `Lab06CordganizerBody`. Find the drop down menu indicated by `Load or Delete a Process`.
5. Select the program from the drop down menu, also shown in Figure 5.

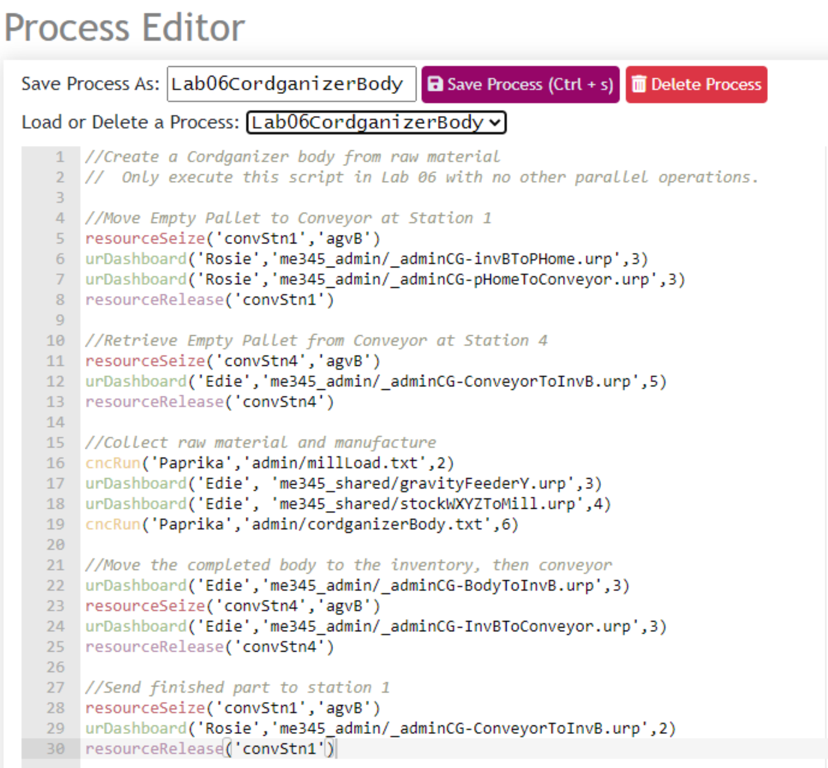

Figure 6: BUMES Process Editor, Loaded Process

6. If loaded correctly, the process should appear as it does in Figure 6. Each line of the process represents a task. This process is used to make a Cordganizer body from raw material.

7. The `Process Editor` web page provides a simple text editor with syntax highlighting (colored text) and some tools to make programming simpler and more reliable. However, in reality, the process files are just text documents. At the bottom of the page, find the field that reads, `Download Process File`.

8. Enter a name for the file, such as `MonAM_Lab6Process`, and click `Export to Text File`. The file will download automatically into the `Downloads` folder of the laboratory control computer.

9. Return to the `FMC Overview` webpage using the hyperlink at the top of the interface.

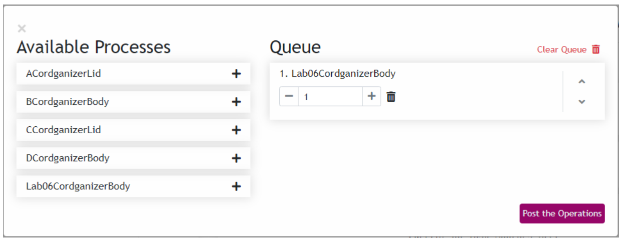

Figure 7: BUMES FMC Overview, Post Operations Menu

10. Once a process is defined, it is Posted into the FMC and executed in Quick Simulation Mode, Full Simulation Mode, or in Real Run Mode. Follow *Step One* by clicking `Post Operations`.

11. In the popup window, shown in Figure 7, click the plus sign and enter a quantity of 1 unit for the process `Lab06CordganizerBody`. Click `Post the Operations`.

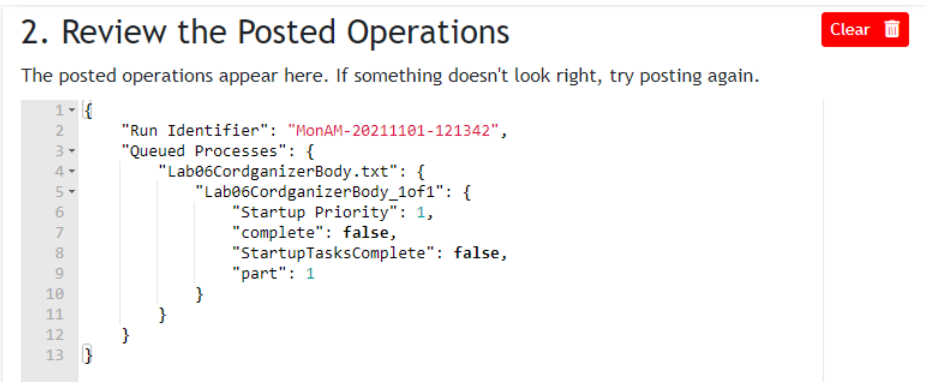

Figure 8: Posted Operations

12. *Step Two* on the `FMC Overview` asks the BUMES operator to check the posted operations. This is the final opportunity to review the operations before execution. This is shown in detail in Figure 8. The run-identifier contains the current user, and a timestamp. In a future step, this will also contain the execution mode.

13. Find the file downloaded in previously, in step 8 of the procedure. Open the file in notepad. In the next steps, you will follow along with the file as the program executes.

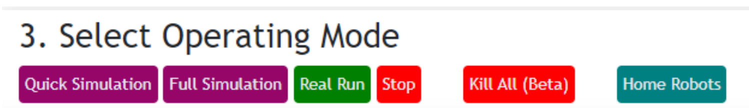

Figure 9: BUMES FMC Overview, Operating Mode

14. *Step Three* allows the operator to select an operating mode. For now, click `Quick Simulation`. The operation will start immediately.

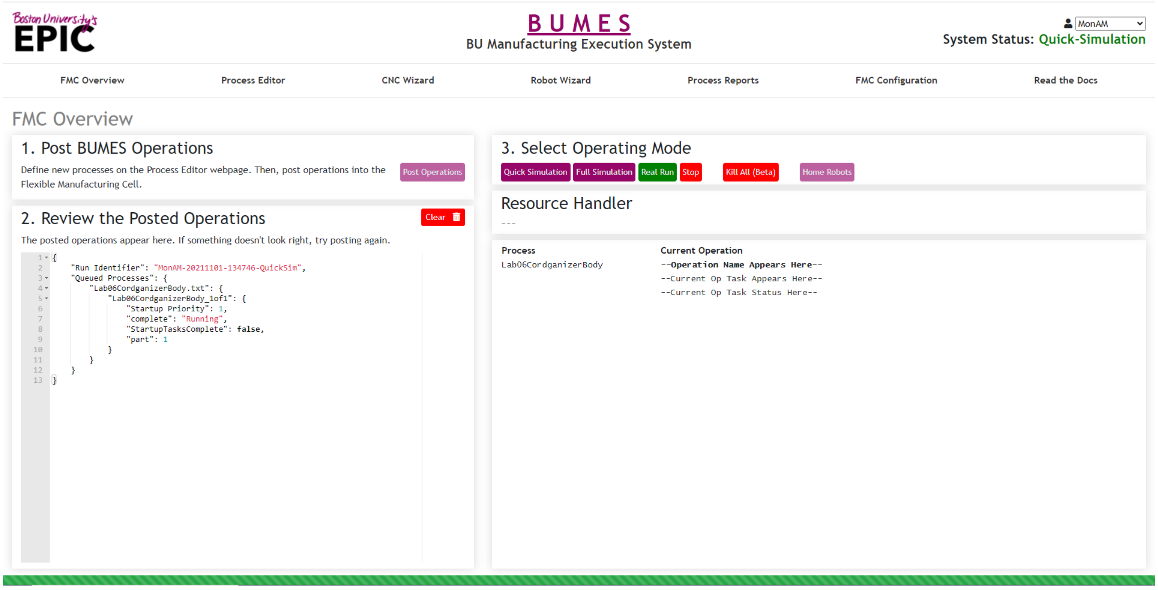

Figure 10: BUMES Quick Sim Interface Changes

15. As the quick simulation executes, take note of the following changes to the interface:
    (a) The *System Status* changes from *Stopped* to *Quick-Simulation*.
    (b) The operating mode is appended to the run-identifier within the posted operations. The completion status of the process changes to *"Running"*.
    (c) The *Resource Handler* is streaming the resource requests in real time.
    (d) The operation appears, in real-time, in the process table at the bottom of the interface. Each tasks appears until the process is complete.
16. Quick-Simulation executes a process as quickly as possible to verify the behavior of the program. While the simulation cannot capture every possible error in a program, it is a valuable starting point for verifying the behavior of a process. At the end of the simulation, the final task appears as `endProcess()` and the posted operations returns to `null`.
17. Repeat steps 11 through 16, creating a new operation, but choose the operating mode `Full Simulation` and observe the difference in behavior. Follow along with the process file downloaded earlier. Notice some tasks have a simulation time that correspond to the behavior in `Full Simulation` mode.
18. Finally, ask the laboratory instructor to ensure a piece of raw material is ready, then start a `Real Run` operation. The robots, CNC machine, and conveyor will actually move so proceed with caution. Watch the camera perspectives carefully and follow along with the process. See if you can follow each task as it executes and ask questions as necessary.

5.3 Manufacture a Full Cordganizer

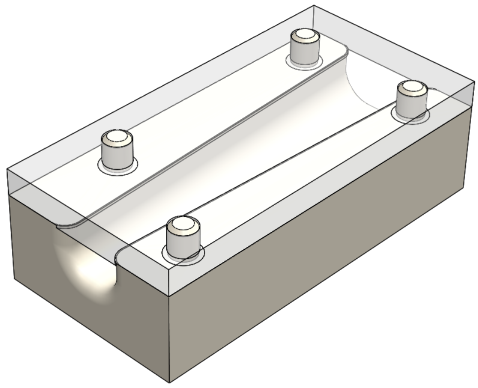

Figure 11: Cordganizer Assembly

Lab Method 5.2 deliberately simplified the manufacture of the Cordganizer body by removing all assembly steps and semaphore commands from the program. Semaphore commands are used let an operation gain exclusive access to a resource in the system like a robot or CNC machine. In this part of the lab method, two operations a Cordganizer Body and Cordganizer Lid will execute simultaneously. An assembled Cordganizer is shown in detail in Figure 11.

1. Return to the `Process Editor` web page.
2. Find and load the process called `ACordganizerLid`. Download it so it can be opened while the system runs.
3. Find and load the process called `BCordganizerBody`. Download it so it can be opened while the system runs.
4. Return to the `FMC Overview` web page. Open the Operations menu and Post `2` units of `ACordganizerLid` and `2` units of `BCordganizerBody`.
5. If the laboratory instructor approves, execute the operations in `Real Run` mode and watch the program execute. Try to follow each operation as it moves through the system.
6. After executing and before leaving your lab section, collect the following lab materials. Some, you will need in your lab report and others are for reference only.
   - Collect and save the three process files downloaded today.
   - Navigate to the `Process Reports` webpage in BUMES. Find and save your process reports from all of today's exercises. You will need some of this data for your report.
7. Review the contents of the lab report with the laboratory instructor to be sure you understand the deliverables.

In the CIM II Lab, other BUMES functions such as the Robot Wizard, CNC Wizard, and FMC Configuration will be explored in greater detail.

6 Lab Report

Complete the lab report with your lab section. Submit a PDF to Blackboard before the start of your next lab section.

6.1 Questions

1. Use the data generated in Lab Method 5.2, the simple Cordganizer body demo, to answer this question. Create a process chart for this process. An example process chart as well as a process chart template are included on Blackboard.

2. Using the process chart created in Lab Report Question 1, determine what percentage of the total processing time was non-value added.

3. Could the percentage of non-value added time in this operation be typical in industry?

4. Using the process chart created in Lab Report Question 1, determine which resource is a bottleneck in the Cordganizer body process. Could the bottleneck change when both the lid and body are running simultaneously?

5. Name at least two ways non-value added time could be reduced in the FMC for the Cordganizer body.

6.2 Topics for Discussion

6. How could the FMC be physically reorganized to make both Cordganizer operations (lid and body) more efficient? (Different gravity feeder locations, robot locations, pallet locations, machine locations, conveyor stops, etc). Explain why your changes would improve the efficiency of the system and create a sketch of your new layout, similar to Figure 1.

   The layout in Figure 1 was created using Draw.io (`https://app.diagrams.net/`). A copy of the file (ADML FMC) is included on Blackboard if you'd like to use that to create your new layout. A hand sketch is also fine.

7. Were there any issues with the Cordganizer demos? If yes, describe the problem and a possible solution for the future. Now that you have seen the full automated process in greater detail, do you think you would encounter any problems manufacturing your project?