RAPID Project

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A.1 The manufacturing process for the pharmaceutical factory robot can be broken down into two main processes: box decoration and picking and placing.

- Box Decoration: The robot receives incoming boxes containing medications from the production line. Using sensors or vision systems, the robot identifies the class of each incoming box and the type of medication it contains. Based on this, the robot selects appropriate drawing or painting tools and techniques to apply customized designs or labels on the boxes. For example, it may use inkjet printers or robotic arms with paint brushes to apply logos, barcodes, or other markings. Once decorated, the boxes are placed on a conveyor belt or designated area for further processing or packaging.
- picking and placing: The robot sorts the boxes based on their size and type of medication to facilitate efficient picking and placing. It may use vision systems or barcode scanners to identify and categorize the boxes. Based on predefined configurations and stacking patterns, the robot begins picking and placing the boxes onto containers. It carefully arranges the boxes to optimize space utilization and ensure stability during transport. The robot employs robotic arms or grippers to pick and place boxes onto the containers with precision and speed. Once picking and placing is complete, the robot conducts a final verification to ensure that all boxes are correctly positioned and securely stacked in the cases. The loaded and sealed pallets are ready for transportation to distribution centers or other facilities for delivery to pharmacies or healthcare providers.

A.2 The selected robot is IRB 1600-6/1.45:

- Workspace: robot's maximum range is 1.45 m. In the simulation the distance between the initial position of the end effector and the point where the boxes stop on the conveyor is approximately 0.580 m and between the end effector and the furthest point on the cardboard boxes is 1.30 m and 1.35 m respectively. Therefore, the specified workspace of the robot covers the entire production area where boxes are received, decorated, sorted, palletized, and prepared for delivery.
- Loads: The robot's datasheet indicates that it can hold loads of up to 6 kg when the arm is minimum extended and up to 1.5 kg when the arm is fully extended in both axes (see fig. 1).

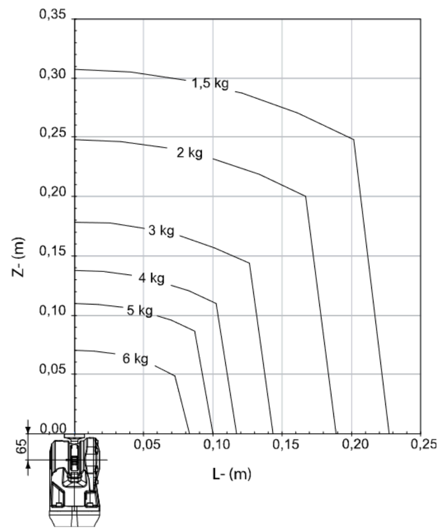

Fig. 1. *Load diagrams for IRB 1600-6/1.45*

- Degrees of Freedom (DOF): The Robot has six DOF (see fig. 2). In the context of the pharmaceutical factory scenario described above, where the robot needs to receive, decorate, sort, and palletize boxes of medications, having six DOF is not redundant. This is given by the variability of the box sizes, and the level of precision required for handling the medications. Having six DOF provides added flexibility and adaptability, allowing the robot to optimize its motions for efficiency and precision

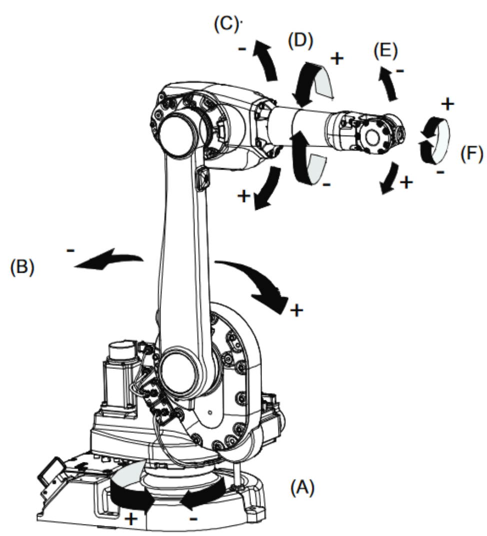

Fig. 2. *Manipulator axes*

A.3 For the two TCPs, it used the two-component tool of the computer room laboratories, the smart component named “VacuumPenToolSC”.

A.4 Two different work objects were declared: “wobj_conv” at one corner of the conveyor and “wobj_table” for the table.

A.5 Only one target was captured by guidance for each work object: “pwobj1_draw” for “wobj_conv” and “pwobj2_place” for “wobj_table”. All of the moving instructions were executed around transformations of these two points.

A.6 Each time the robot needs to interact with the objects, it utilizes approach points, gradually bringing the tool closer to them at decreased velocities. Constants like “off_flyby” and “off_approach” for position or “v_safe” and “v_approach” for speed were defined to facilitate this process.

A.7 Every time the tool needs to execute a rectilinear motion, the “MoveL” command is used, ensuring that the joints of the robot can achieve the required configuration. The “MoveC” instruction was used only for the drawing part. In any other case, “MoveJ” was used for moving the robot quickly from one point to another.

A.8 The conveyor underwent modification to specify the box type when generated. Therefore, every instruction executed by the robot is dependent on this variable. For example, the “Draw()” procedure performs distinct shapes corresponding to each box and for the picking and placing process, the “Pick_place” has a different effect depending on the size of the box, changing between the cardboard containers, and the number of boxes that were previously laid down.

A.9 The PROC “Pick_place” takes three parameters. The first one is the size of the box that is manipulated, “box_length”, ensuring it reaches its designated location within the cardboard containers. The second parameter is the robtarget “pwobj1_draw” that is modified, rotated so that the Z-axis points downwards, only inside the routine, not globally. This was done to position the “Vacuum” tool accurately for picking up the box. Finally, the last parameter represents the number of boxes previously transported to the cardboard containers, “number_boxes”, thus enabling the robot to determine the appropriate placement for the next box.

A.10 Firstly, given the process involves repetitive and monotonous tasks, automation through robotics can be highly beneficial. Robots are well-suited to perform repetitive tasks consistently and without fatigue, which can lead to increased efficiency and productivity compared to manual labor.

Secondly, robots offer a level of flexibility and adaptability that fixed automatisms may lack (see fig. 3). They can be programmed to perform a variety of tasks and accommodate changes in production requirements or product specifications with relative ease. This flexibility is particularly valuable in industries like pharmaceuticals, where product lines may change frequently or customization is required.

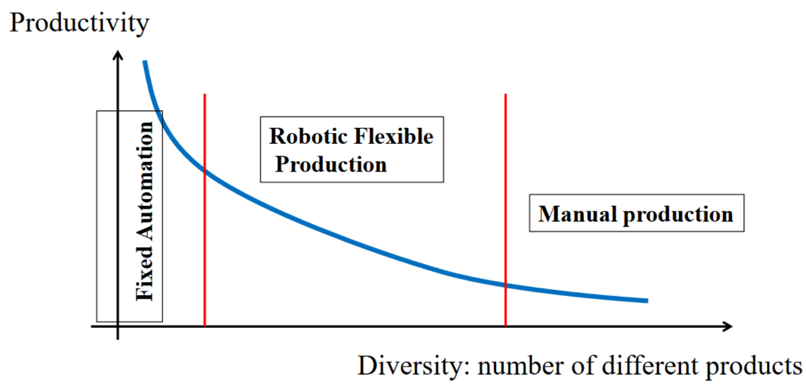

Fig. 3. *Impact of diversity on process productivity*

Last but not least, while the initial investment in robotics may be significant, automation can lead to long-term cost savings through increased efficiency, reduced labor costs, and minimized errors or rework. Over time, the benefits of automation can outweigh the initial investment, making it a cost-effective solution for the pharmaceutical factory.

B.2 Flowchart of the Module1 file is represented below (see fig. 4).

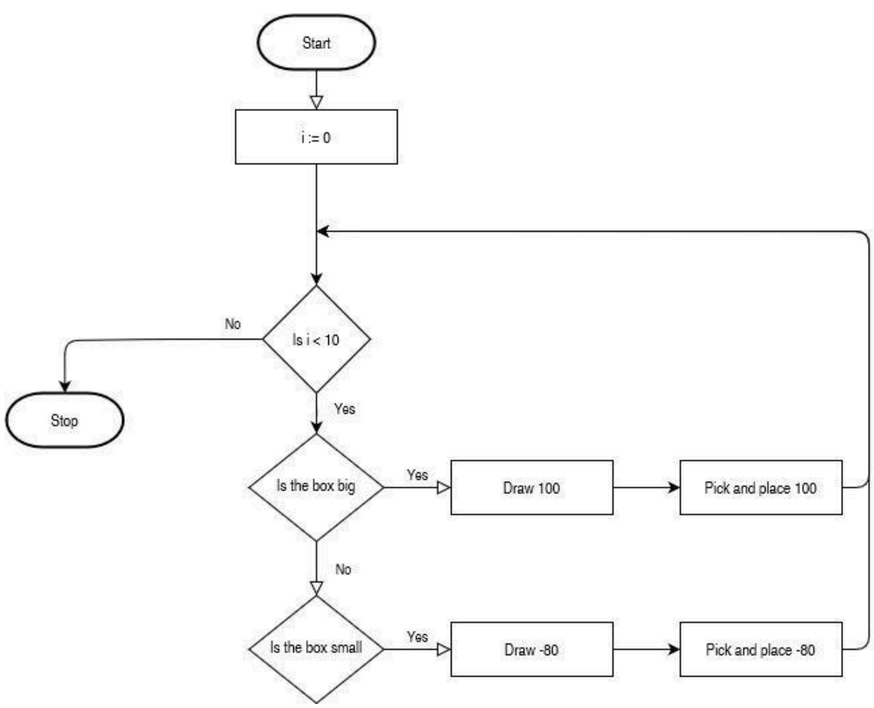

Fig. 4. *Flowchart Module 1*

B.4 RAPID functions used, that have not been studied in depth during the sessions:

- MoveC - Utilized in the “Draw()” procedure, it enables the robot to create various shapes using the pen tool (Line 95).
- CONNECT - Utilized at the start of the “main()” procedure in order to connect the interrupts to their corresponding TRAP routines (Line 27 and 28).
- ISignalDI - Used at the start of the “main()” procedure to order and enable interrupts from a digital input signal (Line 33 and 36).
- WaitUntil - Used to wait until the input signal “cube_ready” is high so that the robot can start its routine (Line 49).
- TestDI - Used to test whether the digital input “cube_ready” is set (Line 49).
- DInput - Used to return the value of digital input signals “big”and “small” to determine which procedure the robot should follow (Line 52 and 54).
- StopMove - Utilized in the TRAP routine “Emergency_Stop” to stop robot movements when an interrupt “emergency” occurs (Line 156).
- StartMove - Utilized in the TRAP routine “Emergency_Continue” to stop robot movements when an interrupt “em_continue” occurs (Line 162).
- PulseDO - used to generate a pulse on the digital output signal “resume” (Line 39 and120).

B.6 Two TRAP routines were defined:

- “Emergency_Stop” - Called when the digital input signal “em_stop” is set to high. Stops the movement of the robot (Line 154).
- “Emergency_Continue” - Called when the digital input signal “em_stop” is set to low. Resumes the movement of the robot (Line 160).

B.7 To streamline the procedures, variables and constants were defined to simplify the process of altering the program's flow:

- “number_of_boxes{2}” - Data to type VAR that was given an array to keep track of the number of pills boxes were previously transported to the cardboard containers. The first index determines the number from the big container whereas the second the number for the small one (Line 8).
- “off_flyby”, “off_approach” - Numeric constants defined to be used in determining the approaching points for the tools (Line 10 and 11).
- Speed data constants - Established to ascertain the speed of the tool as it approaches the objects (Line 13-16).

B.8 A number of different SmartComponents were used to improve the simulation’s appearance:

- Conveyor - The conveyor provided by the teacher was modified:
    - Previously generating three boxes, now generates only two, with any components related to the creation of the third box being removed. Two digital output signals were created, “small_out” and “big_out”, in order to be created with other two digital input signals, “big” and “small”, from the controller. This was done in order to identify the type of box that was generated. For example, when the conveyor will create a big box, the output signal “big_out” would be set to high, which in turn sets the input signal “big” from the station to high, the latter being used in the RAPID code to determine the direction of the program.
    - The digital input signal "start_or_resume" was linked to the output "big_out" and "small_out" for resetting after the pills box generation.
    - A digital output signal for the station was created, “resume”, that would be connected to the input signal “start_or_resume” from the conveyor. This way, the process of creating boxes and resetting the “big” and “small” signals can be controlled from the code.
    - The LinearMover’s speed was changed from 100 mm/s to 60 mm/s. This change was done to have enough time between the generation of the boxes. Furthermore, adjustments were made to the positions of the Source components, along with modifications to the values from the Comparers and Random items.
- Cardboard_container_*SC - Two smart components were created through the importation of custom CAD models. This simulates the picking and placing process and the movement of containers as the pill boxes are deposited.
    - Two line sensors were added to determine when and what objects were deposited in the cardboard containers.
    - When the pills boxes are added to the container, they will be introduced into a Queue that will keep track of them.
    - There is only space for two boxes in both containers, thus when the second one is added, the LogicGate will wait 4 seconds before sending a signal to the Queue so that it deletes the objects.
- EMERGENCY_STOP - This smart component was added to simulate the event of an emergency stop of the process.
    - It has a digital output signal “EMERGENCY_STOP” connected to an input signal at the station. When activated, this will trigger an interrupt and call a TRAP function.
    - When the output signal goes low, the movement resumes.

B.9 A video of the simulation was posted on YouTube and a link was provided in the course forum under the name: “Pharmaceutical_Manufacturing.mp4”.

Bibliography:

WiredWorkers Nederland B.V., “6 applications of robots in the pharmaceutical industry | WiredWorkers,” WiredWorkers, Apr. 23, 2024. https://www.wiredworkers.io/blog/6-applications-of-robots-in-the-pharmaceutical-industry/

M. Latzel and M. Latzel, “Robotics in the pharmaceutical industry - ESSERT Robotics,” ESSERT Robotics - The future of robot automation., Mar. 20, 2024. https://www.essert.com/blog/robotics/robotics-pharmaceutical-industry/

Wikipedia contributors, “Pharmaceutical manufacturing,” Wikipedia, Mar. 18, 2024. https://en.wikipedia.org/wiki/Pharmaceutical_manufacturing

CINEIST, “Medicine Manufacturing Process, How it’s made,” YouTube. Jul. 17, 2018. [Online]. Available: https://www.youtube.com/watch?v=KjpuOGDx_4E

US Pharmacopeia, “What is Pharmaceutical Continuous Manufacturing?,” YouTube. Dec. 06, 2022. [Online]. Available: https://www.youtube.com/watch?v=WnoQRr8IV1Y

“Technical reference manual - RAPID overview”, ABB Robotics, 2024. [Online]. Available: ABB Library - 3HAC050947-001. [Accessed: May 4, 2024].

Figure. 1. “IRB 1600/1660, Product specification”, ABB Robotics, 2024. [Online]. Available: ABB Library - 3HAC023604-001. [Accessed: May 4, 2024].

Figure. 2. “IRB 1600/1660, Product specification”, ABB Robotics, 2024. [Online]. Available: ABB Library - 3HAC023604-001. [Accessed: May 4, 2024].

“Operating manual - RobotStudio”, ABB Robotics, 2024. [Online]. Available: ABB Library - 3HAC032104-001. [Accessed: May 4, 2024].