

3BYX0P CBL Systems and Control Project – Group 3

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“Design and program a model which can control a robot arm to detect, track and place the objects into two different places with enough accuracy, robustness and reliability”

CUSTOMER

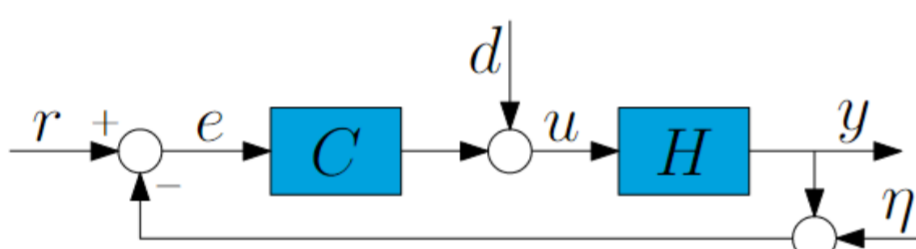
Customer: Bell pepper distributor that separates rotten, diseased or misfit bell peppers from red bell peppers.



EXPERIMENTS

1. FRF measurements:

- Sine wave as input (r) and known controller ($C(s)$)
- White noise as disturbance (d) for closed loop
- Open loop Bode plot ($H(s) = C^{-1}(s) * S^{-1}(s)$)



2. Control design and motion smoothing:

- Manipulate gain to increase the bandwidth
- Add lead/lag filter to increase phase margin
- Try to compensate friction with feedforward proportional controller

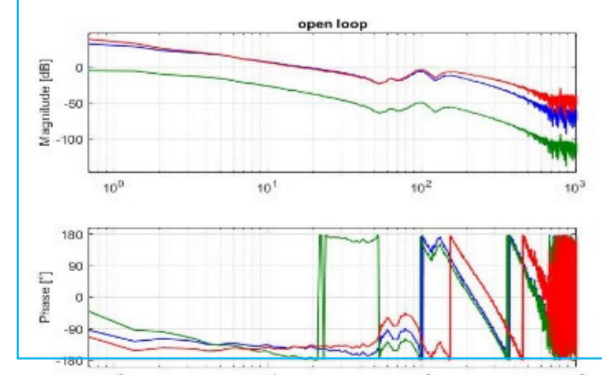
3. Stateflow and camera:

- Inverse kinematics using analytical method with intersecting circles

CONTROLLER DESIGN

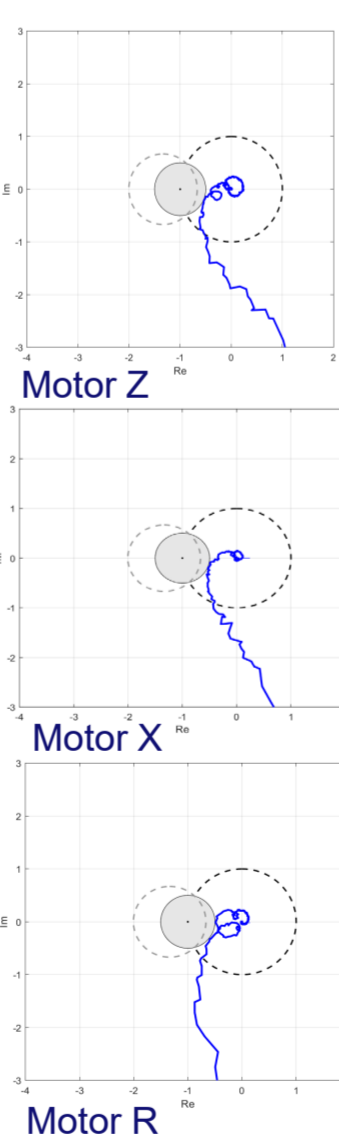
Feedback:

- Use of a lead lag filter to remove undesirable frequency response
- Have a good bandwidth for the robot to work at higher frequencies
- Respect the Nyquist Plots to have stability of the system and a good robustness



Legend:
█ Transfer function
█ PID controller
█ Lead/lag filter

	R	X	Z
Gain	16	25	40
Lead zero	3	10	10
Lead pole	27	90	90
Bandwidth	22.2	28.3	31.7
GM	6.3	9.3	8.1
PM	42.6	64.9	58.1
MM	5.83	5.86	5.86



CONCLUSION & EVALUATION

The results obtained are hand in hand with the goal proposed. The separation of orange and dotted peppers while collecting red healthy bell peppers can be done with the robot arm.

BUT:

- 3D printed peppers do not resemble real life peppers
- Different robots used → each has different characteristics, meaning different FRFs
- Bell peppers too tall → when positioned too far, the robot-arm is unable to reach for them

RPCs:

1. Bandwidth → >25Hz
2. Combination of feedback and feedforward controllers → error ≤ 1%
3. Have a reliability of 90% and precision of 85%
4. Design robust controllers to test on different robots

Assumptions:

1. Constant height of bell peppers
2. Constant conveyor velocity
3. Constant position of bell peppers
4. 50% red peppers, 25% diseased and 25% orange

STATEFLOW

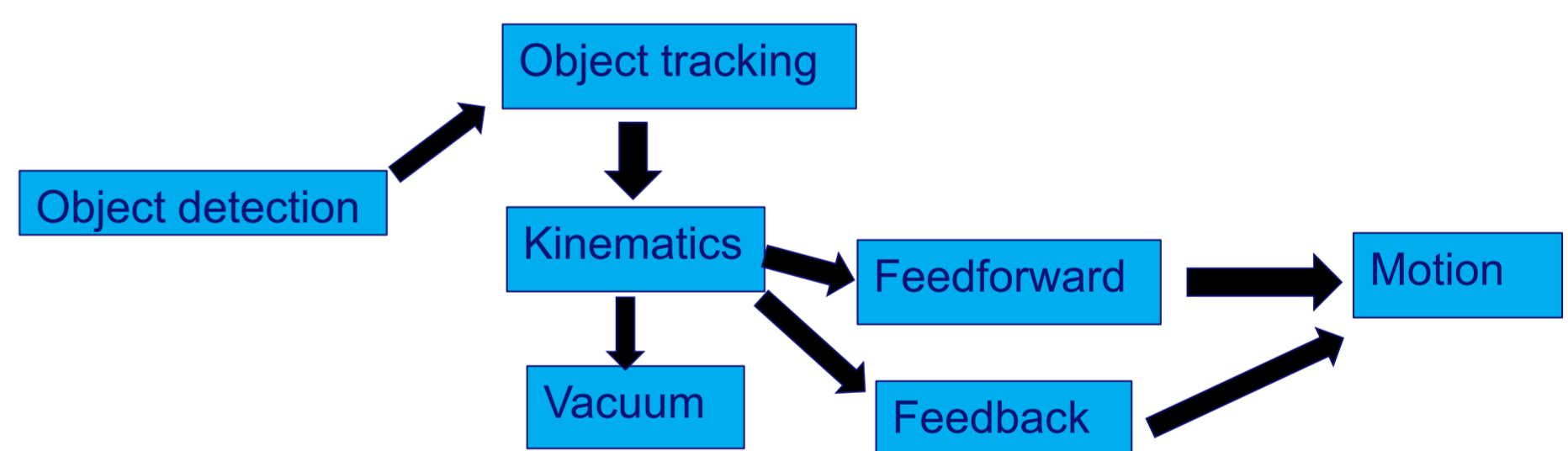
Object detection:

1. Change h-values for color detection
2. Vary blob size/pixels to detect dots
3. Change brightness of camera so it is consistent



Robot arm motion:

1. Track object and vacuum after 2 seconds
2. Pick up and move to predetermined position
3. Lower and place pepper in the box
4. Wait at final position until next pepper is detected



RESULTS

Metrics:

- Pick-up velocity: $3 \frac{\text{peppers}}{\text{min}}$
- Time for a complete motion: 10s (from detection), 6s (from first movement)
- Minimal distance between peppers: 180mm
- Approximate error during tests: 4 flawed peppers out of 5 are correctly identified and eliminated

The robot arm set-up can reliably differentiate, track and pick up hexagonal-shaped bell peppers and place them in a predetermined position in a uniform, smooth, accurate and robust manner.

Recommendations:

- Perform all tests on same robot arm
- Second camera in the XZ plane for more advanced camera vision
- Test with real bell peppers
- Make the camera differentiate between colors to have two different motions (one crate for rotten ones, one for orange ones)
- Add trajectory planning in order to have a constant smooth motion of the robot
- Improve the feedforward to minimize disturbances, improve the feedback controllers and meet the requirements even better