Experiments Steps

1 Automated Solubility

1. The N9 robot picks up a vial from the deck and places it on the on-deck gripper.
2. The N9 robot picks up the vial.
3. The Quantos door opens.
4. The N9 robot places the vial inside the quantos.
5. The Quantos measures the weight.
6. The N9 robot removes vial from the Quantos and places it on the on-deck gripper.
7. The Quantos door closes.
8. The N9 robot uncaps the vials and places the cap on the on-deck caper.
9. The N9 robot picks up the vial.
10. The Quantos door opens.
11. The N9 robot places the vial inside the quantos.
12. The Arduino Stepper Motor moves down towards the vial.
13. The Quantos door closes.
14. The Quantos starts the dosing of the solid.
15. Once dosing is done, the Arduino Stepper Motor moves the dosing head up.
16. The Quantos door opens.
17. The N9 robot picks up the vial.
18. The Quantos door closes.
19. The N9 robot places the vial on the on-deck gripper.
20. The N9 robot moves the slider where the vial is going to be placed.
21. The N9 robot picks up the vial and places on the magnetic stirrer.
22. The N9 robot closes the slider.
23. The N9 robot goes to the needle station, picks up the needle and removes the lid.
24. N9 robot moves to the liquid dosing station.
25. The Tecan Cavro pumps the liquid.
26. The N9 robot moves to the vial.
27. The Tecan Cavro dispenses liquid inside the vial.
28. The Magnetic Stirrer starts.
29. The Magnetic Stirrer stirs the mixture of the vial.
30. The camera on the deck takes a picture of the vial to check the turbidity of the solution.
31. The steps from 24 to 30 are repeated until the mixture is dissolved.
32. Once this is done, the cleanup vial is called.
33. The N9 robot arm discards the needle.
34. The N9 robot arm picks the vial.
35. The Quantos door opens.
36. The N9 robot places the vial inside.
37. The Quantos measures the weight.
38. The N9 robot picks the vial from Quantos.
39. The N9 robot places the vial solution on the vial tray.

2 Automated Solubility with UR3 Arm

1. The N9 robot picks up a vial from the deck and places it on the on-deck gripper.
2. The N9 robot picks up the vial.
3. The Quantos door opens.
4. The N9 robot places the vial inside the quantos.
5. The Quantos measures the weight.
6. The Quantos Balance checks the solid inside the quantos
7. If it is different from the one that is required for the experiment, the solid is replaced.
8. To replace the solid, the UR3 robot moves to the Quantos.
9. UR3 robot removes the solid tube and places it to the on-wall RFID positions of the tubes.
10. UR3 robot picks up the correct one and moves towards the Quantos.
11. UR3 robot fixes the correct solid tube inside the Quantos.
12. The vial is removed from the Quantos and placed on the on-deck gripper.
13. The Quantos door closes.
14. The N9 robot uncaps the vials and places the cap on the on-deck caper.
15. The N9 robot picks up the vial.
16. The Quantos door opens.
17. The N9 robot places the vial inside the quantos.
18. The Arduino Stepper Motor moves down the dosing head.
19. The Quantos door closes.
20. The Quantos starts the dosing of the solid.
21. Once dosing is done, the Arduino Stepper Motor moves the dosing head up.
22. The Quantos door opens.
23. The N9 robot picks up the vial.
24. The Quantos door closes.
25. The N9 robot places the vial on the on-deck gripper.
26. The N9 robot moves the slider where the vial is going to be placed.
27. N9 robot picks up the vial and places on the magnetic stirrer.
28. The N9 robot closes the slider.
29. The N9 robot goes to the needle station, picks up the needle and removes the lid.
30. The N9 robot moves to the liquid dosing station.
31. The Tecan Cavro pumps the liquid.
32. The N9 robot moves to the vial.
33. The Tecan Cavro dispenses liquid inside the vial.
34. The Magnetic Stirrer starts.
35. The Magnetic Stirrer stirs the mixture of the vial.
36. The camera on the deck takes a picture of the vial to check the turbidity of the solution.
37. The steps from 31 to 36 are repeated until the mixture is dissolved.
38. Once this is done, the cleanup vial is called.
39. The N9 robot arm discards the needle.
40. The N9 robot arm picks the vial.
41. The Quantos door opens.
42. The N9 robot places the vial inside.
43. The Quantos measures the weight.
44. The N9 robot picks the vial from Quantos.
45. The N9 robot places the vial solution on the vial tray.

3 Crystal Solubility Profiling

1. The N9 Arm picks up a tube with a filter from the deck and opens its cap.
2. The N9 Arm removes the filter from the tube and puts the filter in the filter holder.
3. The N9 robot picks up the tube.
4. The Quantos door opens.
5. The N9 robot places it inside the quantos.
6. The Arduino Stepper Motor moves the dosing head down.
7. The Quantos door closes.
8. The Quantos starts dosing of the solid.
9. Once dosing is done, Arduino Stepper Motor moves the dosing head up.
10. The Quantos door opens.
11. The N9 Arm picks up the tube and moves out of Quantos.
12. The Quantos door closes.
13. The N9 Arm places the tube in vial tray, removes filter from holder and places the filter in tube
14. The N9 Arm goes to the needle station, picks up the needle and removes the lid.
15. The N9 Arm moves to the liquid dosing station.
16. The Tecan Cavro pumps the liquid.
17. The N9 Arm moves to the tube.
18. The Tecan Cavro dispenses liquid inside the tube.
19. The N9 Arm closes the tube cap and transfers it to the Magnetic Stirrer.
20. The Magnetic Stirrer stirs the solution.
21. The N9 Arm picks up the tube and puts it on the mini tube tray.
22. The N9 Arm moves away.
23. The UR3 Arm picks up the cap of the centrifuge and places the cap on the deck.
24. The camera checks the centrifuge position.
25. The UR3 Arm picks up a rod, adjusts centrifuge position and places the rod back.
26. The UR3 Arm then picks up the vial and puts it inside the centrifuge.
27. The Centrifuge then puts the cap back.
28. The Centrifuge is started to filter the solid from liquid.
29. Once this is done, the UR3 Arm picks up the cap and places it on the deck.
30. The Camera checks the centrifuge position, picks up the rod, adjusts centrifuge position and places the rod back.
31. The UR3 Arm picks up the tube from the Centrifuge and places it on the station.
32. The UR3 Arm places the cap back.
33. The N9 Arm picks up the tube, opens the tube cap and sends the tube to the vial tray.
34. The N9 Arm picks up the new tube from the tube tray and uncaps the new tube.
35. The N9 removes the filter from the old tube, sends the filter to the new tube.

4 Joystick

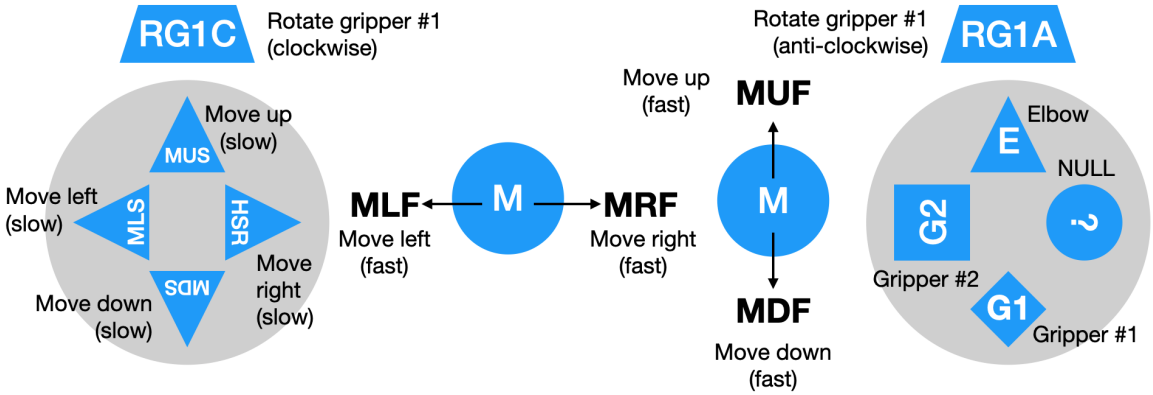

Figure 1: Mapping between joystick buttons and N9 actions

Fig. 1 illustrates the different actions for which the joystick buttons are programmed. Table 1 shows six experiments that were performed using Joystick in two modes on the middlebox: DIRECT or REMOTE. The DIRECT mode is used to collect the tracing data whereas the REMOTE mode is used to collect the tracing data along with sending the commands to the robots.

Name	Experiment Steps
EXP1	Start by moving the arm up and down using MDF and MUF. Repeatedly move the arm left and right by pressing MLF and MRF.
EXP2	Bring the arm to a valid position. Repeatedly move the arm up and down using MDF and MUF. Repeatedly open and close both grippers using G2 and G1.
EXP3	Move arm very slowly to the left using MLS. Move arm very slowly to the right using MRS.
EXP4	Move arm very slowly upward using MUS. Move arm very slowly downward using MDS. Repeatedly toggle the elbow position using E. Adjust the arm slightly using MLF and MRF. Repeatedly toggle the elbow position using E.
EXP5	Move arm near the vial. Pick the vial using gripper and take it to the on-deck gripper. Open the arm gripper, let the vial fall, close the on-deck gripper. Few more things.
EXP6	Rotate arm gripper clockwise for some time using RG1C. Rotate arm gripper anti-clockwise for some time using RG1A. Close the arm gripper using G1. Rotate arm gripper clockwise for some time using RG1C. Rotate arm gripper anti-clockwise for some time using RG1A.

Table 1: Joystick Experiments