

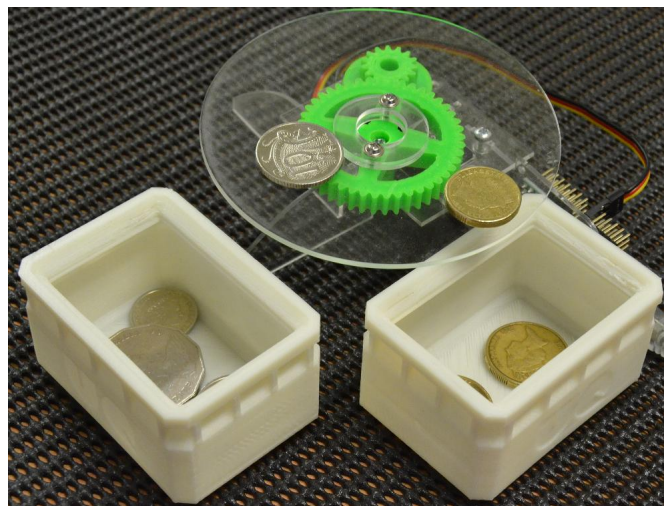
METR 4202 -- Advanced Controls & Robotics

Lab 3: Systems & Controls -- Robotic Systems: Change. the Future

Objective

As you maybe aware, a certain government is in near default over its obligations ([and politics](#)). This laboratory investigates the use of robotics technology to bring order to a small, but neglected, portion of the economy, [pocket change](#).

Economics engineers ethics. Thus, the focus of the laboratory is more than just the circulation of money, cash flows, or economies (of a certain scale). Extending from the [Laboratory 2](#), this laboratory will seek to not only identify coins on a (moving) plate, but also to sort the coins and determine their value as well as investigating the manipulation of small objects using a compliant robot arm. It features a custom [Brisbane Laser Turntable](#) and a [Pololu Mini Maestro 12-Channel USB Servo Controller](#).



Requirement

Design and build an automatic robotic system to sort pocket change into small coin containers (of your choosing or design, up to 100 mL in volume and with a maximum cross-sectional area of 50 cm²). Note, METR2800 containers [6 cm (length) × 4 cm (width) × 4 cm (height)] will be available during testing. Thus, the final system should:

- Start with coins (and potentially clutter) on turntable
- Finish with the coins correctly sorted (as explained in Sorting below)

Importantly, given that the laboratory is about economy, the system should do this completely and strictly within ten (10) minutes. Given that UQ shares the US's fiscal discipline, the system must operate with three (3) robot actuators or less (not including the turntable's servo).

Turntable and Compliant Arms

At the core of the laboratory is a moving (Brisbane Laser) turntable. [Assembly Instructions and Video for the Brisbane Laser Turntable](#) are on YouTube (thank you Mike Reed). It is driven by a [Mini Maestro](#) and requires [drivers](#) and external power (for the servo). Battery holders will be provided, but a 4-6V (500 mA) DC power supply should be sufficient.

The turntable kit comes with a [SpringRC SM-S4303R Continuous Rotation Servo](#) [datasheet]. Its speed can be controlled via the [Maestro Control Center](#) [cached download] or via serial commands (thus allowing for interfacing to [MATLAB](#) or [C++](#)).

As with [Lab 1](#), the robot arm structure may be built using provided Lego NXT kit (n.b., there is a provision to beta-test a Dynamixel-based, a candidate system for 2014). In addition to the compliance of the Lego structure, it is advised that teams consider using a compliant end effector. Some of the various mechanisms for this include: a small paint brush, an eraser, a pendulum mass (e.g., like a crane -- the string is a very compliant mechanism), plastic tuning, compressed air, vacuums, etc.). Teams are also allowed to place (print/write/tape) markings on the clear turntable so as to make it easier to see (this can include markings that fold down).

Workspace and Scene Structure

The scene is similar to [Laboratory 2](#), but with the extension of a turntable and a robot arm instead of a money plate. As with the previous laboratory, there is a basic level of operation and advanced level of the workspace. At more exceptional levels may include clutter in the form of foreign currency, keys, soda beverage cans, small chocolates, and other small random items (max height of 5 cm). The workspace will be defined with varying levels of structure and clutter, with lower performance standards having more structure. This is outlined as follows:

Item	Basic Level	Advanced Level
Background	Monocolor white paper (teams may remove it)	Anything (including clear) (Turntable paper disallowed) (encoder rings/paper okay)
Number of Coins	$1 \leq N \leq 4$	$0 \leq N \leq 32$
A\$ Notes	No	Maybe
Foreign Currency	No	Maybe
Clutter	No	Yes
Colour Calibration Target	Optional	No (except for task 1)
Calibration Pattern	Provided	Maybe
Mean turntable speed	$\omega \geq 0$ RPM	$\omega > 2$ RPM

System Candidate Tasks

The focus of the laboratory is advanced control and task planning along with integrated sensing and robot design. Much like a hard-drive, this involves coordinating the motion of the arm as well as the turntable. To demonstrate robotics and control operation, five **sorting** tasks (i.e., placing the coins/objects into the two containers) are proposed. These include:

1. **Golden Boy:** For Australian legal tender, sort the “Gold coins” (\$1 and \$2) from the “Silver Coins” (5¢, 10¢, 20¢, 50¢).
2. **No Big Deal:** Sort big diameter coins from small ones, such that coins with a $\phi \geq 25$ mm are in one container and those with $\phi < 25$ mm are in another.
3. **Australian Made:** Sort Australian legal tender from foreign coins.
4. **Sweet:** Sort small chocolate obstacles apart from the coins (n.b. for this challenge it is acceptable to move the coins or chocolates and leave the other item on the plate).
5. **Noteworthy:** For Australian legal tender, sort the notes (\$5, \$10, \$20) from coins (5¢, 10¢, 20¢, 50¢, \$1, and \$2).

As with [Laboratory 2](#), the tasks receive greater points (or in the colloquialism of this laboratory more “money”) for greater accuracy and for operation in more [advanced level scenes](#). For this laboratory, each task is equally weighted and nominally worth up to \$2 if done successfully in a basic scene. Operation in advanced level scenes results in up to double the value (i.e., up to \$4 if done successfully). Partial credit is determined via the following (general) scale:

- **Attempt:** The system operates, but with significant error (>90%): **10¢**
- **Some operation:** The system makes at least one successful classification into both bins: **50¢**
- **Partial operation:** The system operates, but has errors (>50%): **\$1.00**
- **Full operation:** The system operates fully (<20 % error): **\$2.00**
- **Super operation:** The system operates with no errors: **\$2.50**

Teams are allowed to set the speed of the turntable and vary the speed and direction during operation. Teams will receive up to **50¢** for accurately reporting the monetary value of the (Australian) coins in the scene (this may be done before or after sorting). Teams may combine tasks (e.g., have four bins - large gold, small gold, large silver, small silver). For higher values (e.g., super operation), the system should do these tasks robustly (i.e., without the need for controlled conditions, lighting, coin types, etc.) and with minimal intervention (remember that the robot has to be automatic) and in more advanced environments (i.e., with the plate moving faster than minimum speed with additional levels of clutter).

Other Robotic Systems, Languages and Cameras

Teams seeking to do advanced level operations may experiment with (at their own risk) next year’s proposed METR4202 robot hardware kit (based on three Dynamixel AX-12A actuators). Kits are available to teams on a limited, first in, best dressed basis (send emails to [metr4202 teaching team](#)).

Teams may elect to use programming languages and systems other than Matlab, such as Visual C++ or Python (i.e., the class is language / system neutral). In particular, teams may choose to use OpenCV. Teams may choose to operate the Kinect’s RGB camera in high resolution mode (i.e., they may use the 1280x1024 mode also provided by the MS Kinect SDK as compared to the 640x480 default mode provided by the OpenNI SDK). Similarly, teams may use another (web) camera on the proviso that the camera is autonomous (i.e., it operates **without manual intervention** including file copying) and that the maximum resolution is set to (or automatically down-sampled to) 1280x1024. (n.b., the allure of high-resolution can be a trap in vision and signal processing applications as this comes with higher data processing requirements and often comes with more noise).

Cachet: Assessment Criteria for Overall Lab Mark

While it is encouraged for teams to try all five tasks, teams do **not** have to try all areas. Grades will be determined by the teaching staff based on the performance and explanation of team members as they perform the aforementioned focus area tasks. A general, but not absolute, rule the mapping between points (or value) and the grades is:

Grade	Value Range	Description
2 (20-45)	20¢-\$1.00	At least one task performed. For example, you are able to get all the systems to turn on and for the robot to touch to turntable.
3 (45-50)	\$1.00-\$2.00	Very substandard performance, For example, you are able to detect the coins and move the arms.
4 (50-65)	\$2.00-\$3.50	Basic level operation. For example, you are able to detect and move at least two coins/object in some of the scenes.
5 (65-75)	\$3.50-\$6.00	Intermediate operation level. For example, you are able to sort at least one target object in each attempted task with good accuracy.
6 (75-85)	\$6.00-\$11.00	Very good intermediate to Advance Level performance. For example, you are able to sort target objects in each scene with great accuracy. At least one task is performed in an advanced level environment.
7 (85-100+)	\$11.00-\$30.00+	Excellent performance. Most of the tasks are attempted well. Teams are able to robustly move objects in complex scenes with superb accuracy. At least two tasks are performed in an advanced level environment.

Teams and Groups

The project will be conducted in **teams of up to five**. The is presumably, but not necessarily, your group from [Laboratory 1](#). That is, you are welcome to reform teams. If there are team dynamic issues, you are encouraged to do so and the teaching staff is happy to arbitrate (i.e., reassign team members). We ask that but you must notify the teaching staff of changes by October 18, 2013.

Due Date

The laboratory must be completed by Thursday, October 24, 2013. The code should be submitted online via UQ Blackboard by 11:59pm October 25, 2013. [A short individual report](#) (~1-2 pages) should be submitted by 11:59pm on October 25, 2013 via the Platypus submission system.

For teams seeking to attempt an advanced level task, submissions may be submitted up to one-week late with a no-penalty. That is, it may be completed by **Thursday, October 31, 2013**.

That being said, early submission is encouraged.

Demonstration

As with the previous laboratories, the system will need to be demonstrated. There will be signup times on October 24, October 30, and October 31. During the demonstration period, teams may choose to demonstrate the focus area tasks in **any order** they choose. For each of the tasks, teams may repeat a task once if they choose; however, the team receives the value from either not both (i.e., repeat task demonstrations do not add).

Given the number of teams, the demonstration times (of 10 minutes total including setup, leaving 5 minutes for discussion) will be strictly enforced. It is recommended that teams come 15-30 minutes in advance of their demonstration appointment. It is also recommended that teams practise their demonstrations as time limits will be enforced even if teams have not been able to demonstrate their solutions to the tasks (i.e., teams will receive grades on the solutions they demonstrate not the solutions they might have, but did not deliver).

Judges

The course coordinator, lecturers and tutors will act as judges. The course coordinator will act as chief judge. All decisions made by the judges will be final, and no correspondence will be entered into. Contestants may approach the organiser about possible designs that may be questionable under the rules listed above. Any queries will be treated confidentially and will not be divulged.

Extra Credit

As custom level and extra credit ideas are [sent in](#) and approved, they will be posted here for the benefit of other teams. Some approved custom advanced level and extra credit ideas are:

- Post the operation of the robot to YouTube -- Teams that post videos of the solutions on YouTube will get from 10¢ to \$2 depending on the quality and clarity (as determined by the teaching team and the award-winning, independent UQ Robotics film critic).
- Fastest Team -- The tutors will measure the time it takes the teams to complete the various tasks. The fastest team(s) for each task will get a reward (depending on its speed).
- Spinmeister -- The team with the fastest (mean) speed table that is able to partially sort.

Hints and Comments:

- It might help to have a compliant end effector (e.g., brush), but the arm can be rigid.
- You are allowed to put down a tablecloth / table paper (colored paper) of your own choosing and design (it can include a checkerboard pattern). You are allowed to insert your own targets (e.g., colour targets) and frames.
- If teams which to go **backwards**, please remember to **tape** (not screw) down the small servo drive gear or the turntable will come apart! (remember that speed does not include direction, it is the absolute value of the magnitude of the velocity vector)
- Teams are allowed to make an encoder ring (from paper) this does not count against the “transparent rule” as long as its area is less than 50% of the turntable’s area (not radius).
- Semi-transparent paper (e.g., wax paper) is considered transparent if one can “see” a coin inserted under the turntable.
- A pendulum mass (e.g., crane) is also an option (though this makes more sense in conjunction with input shaping (anti-sway control)).
- Unlike a hard drive the mechanism is not designed for stepper operation -- though if teams wish to operate the platter like a hard drive, they may “PWM the drive” as long as the mean speed is within the given speed threshold and that the duty cycle is >25%
- Yes it is still a controls problem, a hard drive would be impossible without control.
- Due Date: October 24, but a “free extension” to October 31 is allowed.

Caveats

Some general “reasonable person” rules apply to the code and its execution:

- Robot control should be inherently stable.
- Solutions should be designed so as not to purposely damage the turntable, etc.
- While teams may use compressed air, etc. all operations must be in compliance with the University’s OH&S rules and policies (in the spirit, intention and letter of the policy).
- Internet access may or may not be present -- the code should assume that it will not have Internet access during execution and thus operate in a self-contained manner. A “Mechanical Turk” or “phone home” solution is explicitly disallowed.
- Memory space may or may not be cleared between tasks. Thus, if your routines rely on parameters to be exchanged, it should do so by writing to a file. Similarly, if certain variables names (e.g, counters) are used between functions, then be sure to initialize them correctly.
- Each team’s submitted functions will be run in their own directory -- Reading other teams’ files or memory is disallowed.
- All source code(s) may be assessed -- Thus, it is requested that it is commented. If custom precompiled codes are used (e.g., mex files), the source code should also be submitted.
- Computational and memory resources -- the functions should be able to operate reasonably on a “standard” UQ EAIT Workstation. Judges may terminate execution after 5 minutes.

Advance METR 4202

Change the World!

Summary Links:

- [Assembly Instructions and Video for the Brisbane Laser Turntable](#)
- The Mini Maestro requires [drivers](#) and to power the servo it needs an external source (battery holders are in the mail)

Change Log:

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