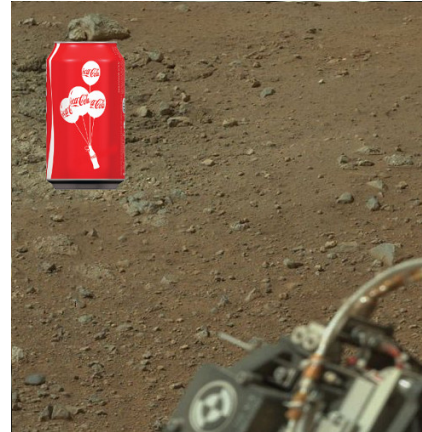


# Lab/Prac 3: Systems & Controls: Sweet Explorations

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## Objective

Good news everyone! Given the precarious nature of NASA's funding, aerospace engineers and scientists have had to turn to corporate sponsors to make the next giant leap for mankind. Fortunately, advertising money is a never-failing source of quick cash. This next Mars mission will be sponsored by a popular candy bar maker, an edgy manufacturer of extreme snacks, and a certain ubiquitous cola brand that happens to share the red planet's colours. In a live pay-per-view broadcast, the exploration rover will touch down in nail-biting fashion using a daring and complicated technique incorporating a hovering platform and the first bungee jump to another planet.



At the same time as the landing takes place, a variety of sponsor branded chocolate bars, Xtreme Snacks and cola containers will be jettisoned from the spacecraft to land via parachute on the ground below. As part of the promotional activities following the successful touchdown, the rover will be required to locate a can or bottle and televise the opening of the first cola beverage on another planet - in THREE DEE!

## Requirement

As the engineering team designing the robot manipulator, it is up to you to put a straw into the can and thus 'serve' the drink to whatever thirsty martians may happen to appear. The mission budget helpfully covered the cost of the suitably pressurised self-deploying, self-opening promotional Space Cans™ for the rover (now available in stores!), so you won't have to use the robot's manipulator to lift the can's stay-tab. Unfortunately, the cost of the patented Space Cans™ and attendant advertising campaign has left the engineering teams somewhat underfunded. Consequently, there is only enough budget to cover three actuators.

You must do the following:

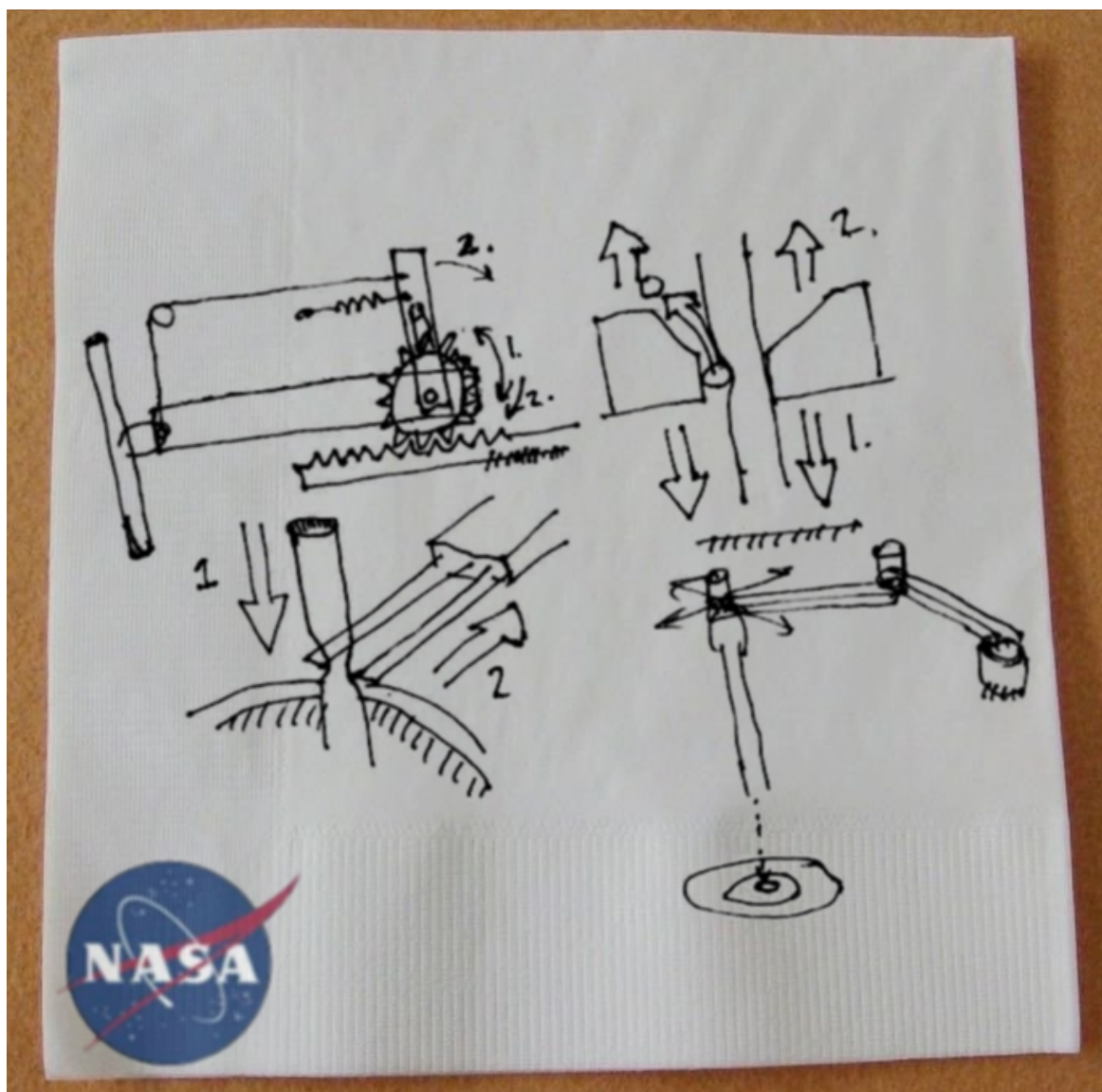
- Locate the can in front of the rover
- Place a straw into the opening of the can
- Retract the end-effector, leaving the straw behind.

## Underactuation (& Hints)

Bob, the grizzled NASA veteran by the watercooler, has heard about the budget overrun:

“It’s not so bad. The trick is to use everything you’ve got to the fullest extent. Why don’t you use some kind of doohickey to let go of the straw, like a sprung release mechanism or something, or maybe you could make a gripper open if you drive a motor backwards with a ratchet? Or, you could put the straw between some fixed tines and scrape it off on the side of the can? Or, if you’re accurate enough, you could just drop the straw without any Z control at all. I’m sure you clever young folk can come up with something even better. Why, back in my day, we sent people to the moon with nothing but hard work, a bit of duct tape and an IOU from Nixon!”

Bob has helpfully provided you with a napkin on which he has hastily sketched some mechanism concepts that he thinks might do the job:



## Lab Structure

This laboratory will integrate kinematics, sensing and control to **accurately and smoothly control a robot to autonomously position** a straw inside a target beverage can or bottle in a cluttered environment. This involves several more advanced robotics and mechatronics concepts including system integration, manipulation and grasping (or in this case ungrasping), super-precision (using feedback/feed-forward control to position more accurately and have less vibration), and handling sensor noise plus uncertainty. It brings together:

- [Arm Kinematics \(Lab 1\)](#)
- [Perception \(Lab 2\)](#)
- Dynamics and Control -- Lecture 10
- Sensor Uncertainty -- Lecture 11

As such, it uses the resources of both Lab 1 and Lab 2: including a Lego Mindstorms kit, a Kinect RGB+D camera, the [RWTH Mindstorms NXT Toolbox for Matlab](#), and the [Kinect/Vision Toolboxes \(as per Lab 2\)](#). Other MATLAB toolboxes are allowed, but will have to be included in the team's code submission.

It expands on the previous labs by *allowing for a consideration* of:

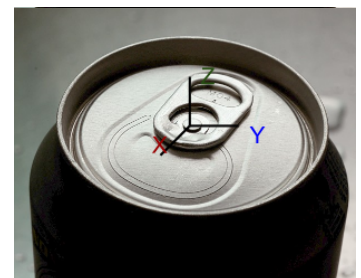
- the arm's dynamics (particularly to compensate for arm compliance),
- manipulation/gripper release (i.e., underactuated operations),
- Kinect sensor placement,
- interactive Kinect repositioning/reorienting depending on current measurements (i.e., active sensing), and
- design (e.g., straw selection & placement, motor placement)

The additional sensors in the Lego kit may also be used, but should not be necessary.

When performing the tasks, teams are allowed to have one small planar object fiducial in the scene of dimension less than or equal to a sheet of A6 paper (e.g., a calibration pattern). For the purposes of demonstration, the cans will have a quantity of sand that approximates the weight (**not** volume) of soda (i.e, 375 *grams* for a standard Australian soda can and 330 *grams* for the bottle).

## Coordinate Frames

The base locations will be defined in *mm* (not HLU) from the Lego mat origin, which is located at bottom left (or cell {1,1} in Lab 1) and oriented *z*-axis up, *x*-axis horizontal (as in Lab 1). The default frame of interest for the can is assumed to be the top center at the center of the stay-tab rivet (as in Lab 2). The workspace is 320 *mm* x 192 *mm* (as in Lab 1) and 256 *mm* in height (96 *mm* more than in Lab 1).



Please note that aside from the size of the workspace, the dimensions used and orientation should not matter. This is because you will not receive any information about the can locations from the judges - and so it is an arbitrary space.

When opened by stay-tab, the cover will be fully pushed in and the stay-tab lever removed. The orientation of the can (particularly of the yaw or spin around the rivet) will nominally be at 90° CW yaw relative to the base (i.e., cover oriented front), but this is **not** guaranteed and thus it is highly encouraged to directly sense this opening.

## The Exploration Tasks

This laboratory consists of increasingly difficult tasks. All tasks are to be performed with the same kinect and robot arm configuration. The glorious world that your robot is about to explore is filled with many delightfully quaint objects. Namely Coke cans, certain chocolate bars and *extreme* snacks (not other cans like Sprite, etc). Coke cans are key to proving life in this Martian landscape and so your robot must place testing straws into these cans to gather further data...

Description	Max Value
<b>1. Task 0: Basic functionality</b> Not really a challenge at all! Your arm moves, your vision system finds objects, and arm motion somehow depends on the images. Marks awarded depend on demonstrated level of functionality.	1 point
<b>2. Task 1: Put a straw in a can with the top removed</b> The robot deposits a straw in a standard can which has had its top lid removed with a can opener (>50mm opening). The arm returns to the starting position, sans straw. Of 5 attempts, one must be successful. ( <i>Bonus A. available</i> )	3 points
<b>3. Task 10: Put a straw in an opened can</b> The robot deposits a straw in a standard can which has been opened by its stay-tab. The arm returns to the starting position, sans straw. Of 5 attempts, one must be successful. ( <i>Bonus A. available</i> )	5 points
<b>4. Task 100: The Graceful Challenge Task</b> The robot deposits a straw in a narrow-necked clear standard bottle (330 ml) with its cap removed. The arm returns to its starting position, sans straw. ( <i>Bonus C. available</i> )	7 points
<b>5. Task 1000: The Big Challenge Task</b> The robot deposits straw(s) in a standard can which has been opened by its stay-tab amongst many cans and other clutter. Of the multiple cans, the robot must successfully deposit straws in at least 2 cans.	7 points
<b>6. Task 2042: The Ultimate Robot Challenge!</b> The robot deposits straw(s) in can(s) which have been opened by its stay-tab and narrow-necked bottle(s) with cap(s) removed in a cluttered environment. The cans and bottle do not necessarily have to be sitting at the height of the lego mat. The robot must successfully deposit straws in at least 1 can and 1 bottle. ( <i>Bonus C. available</i> )	10 points

<b>Bonus Points</b>	
<b>A. Consistency</b> For some tasks you may be awarded for showing you can consistently get the straw in the can (5/5 attempts)	2 points
<b>B. Staw Automatic Loading</b> If the system can autonomously load straw(s) itself	3 points
<b>C. Bottle has all labels removed</b> The glass coke bottle no longer has any distinctive colours	3 points

A deposit attempt is considered “successful” if any part of the straw remains inside the can or bottle after the robot has returned to its start position, and the robot is not touching the straw. The robot may touch or manipulate the can or bottle, but the can or bottle must remain upright at all times. If the robot drops the straw before reaching the can or bottle, it will be scored as a failure. Based on the performance of the robot, the judges may elect to score a ‘near miss’ straw that bounces off the lip of a can or bottle as successful. During the tests the cans and bottles will be empty.

For the purpose of this lab, straw reinsertion into the mechanism may be done manually only at the pre-defined base locations. Please note that there should only one straw per can/bottle and that the straw must extend past the opening.

Obstructions can be as tall as the workspace. You may remove obstructions that are too high for your robot, but you will lose points for that task.

## Operation & Timing

The end-effector must return to its start position once the straw has been placed. The robot may begin with the straw already positioned in the end-effector. You may insert one fiducial, mirrors or other objects into the scene *before the demo begins*.

Scoring begins when your robot begins its first task; and scoring ends after your robot finishes its last task. While scoring is in progress you may not manually move or modify your robot. You may, however, modify the software between tasks. Note that the judges will not stop the clock at any stage.

During testing, the students will have 5 minutes to set up the system, and 10 minutes to perform tasks. At the end of 10 minutes, no further points may be scored except at judges discretion. The testing area is the same size and shape as that used in Laboratory 1, within which the can may be located anywhere. The robot and vision system need not be co-located, but the robot and camera, or any supporting structure on which they are mounted, must rest on the level test-bench.

## Deliverables

Students must bring their robot and vision system for testing at the announced time and date. Any computer provided by students must be disconnected from the Internet, and have any radio telecommunications devices disabled. If a computer cannot be provided by the students, a standard laboratory computer (with the same capabilities and limits imposed in Lab 2) may be requested ahead of time.

## 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.

## Caveats

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

- Internet access 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.
- Reading other teams’ files or memory during execution 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.

## Assessment Criteria for the Lab

The mark awarded will be the number of points earned from completing tasks.

### Excellent (7):

You are able to detect the locations of all target objects in each scene and deposit a straw with superb accuracy and fully complete at least one challenge task. (>20 Points)

### Very Good (6):

You are able to detect the location of some target objects in each scene with great accuracy, or place the straw with good precision and handle at least one challenge task. (>15 Points)

### Good (5):

You are able to complete the assigned task of putting a straw in the opening of a standard can.

Well done! (≥8 Points)

### Satisfactory (4):

You are able to find the can and place a straw in a larger opening than specified. (≥4 Points)

**Conceded Pass (3):**

Your robot shows basic functionality - the arm moves, the vision system demonstrably analyses images; the motion of the arm in some way depends on the image received.

**Poor (2):**

The robot has limited functionality - the arm or vision system operates. The arm moves, or the vision system can be shown to analyse images in some fashion.

**Very Poor (1):**

Nothing submitted or no functionality demonstrated. Robot is partially complete or vision system unable to analyse images.

**Due Date**

The demo will happen on October 26, 2012. **There will be no extensions to this.** A short individual report (~1-2 pages, details in class) will be due October 27, 2012 via the EAIT submission system. Code to be submitted via UQ e-Learning system. Early submission is encouraged.

**Crescendo**

If all teams score  $\geq 5$ , the sponsors will reward everyone with 5 points of extra credit on the exam. If all teams score  $\geq 6$ , the sponsors will reward everyone with 10 points of extra credit on the exam.

Pepsico Australia has agreed to reward the best team with a tour of their Queensland operations.

*If you want to build a ship, don't drum up the men to gather wood, divide the work and give orders.  
Instead, teach them to yearn for the vast and endless sea.  
-- Antoine de Saint-Exupery*

**To METR 4202 and Beyond!!!**

#### Change Log / Minor Clarifications:

1. Oct/7: Clarified orientation of can, formatting changes to work around Google Docs pagination bug
2. Oct/8: Clarified that it is one single fiducial. It is preferred if it is placed by the robot. If it is placed manually, then this manual placement must be done in advance of the system's motion (i.e., once the system starts, the operation should be autonomous). If it is being placed by the robot, on the other hand, it can be placed at any time of the operation (with special dispensation granted for insertion into the gripper as per the multiple straw insertion rules).
3. Oct/9: Small note: Note that the units are in *mm* and not HLU (or Lego) units.
4. Oct/12: Emphasised lack of importance of the absolute workspace orientation. Added "feedback" into Lab Structure intro. Clarified that things can't be added to the scene once the demo begins.
5. Oct/12: Clarified the height of obstructions. Mentioned that during the demo, robots cannot be moved in between tasks. Described the world in Exploration Tasks.
6. Oct/12: Clarified Bonus Points based on team enquiries.
7. Oct/16: "Standard" coke bottle will have a small label still on it (available from St. Lucia). No foreign cans will be used as clutter. For Task 6, cans and bottles don't necessarily have to be sitting at the height of the mat.
8. Oct/16: As mentioned last week's prac session, teams **are allowed** to use / build a Kinect camera support frame (e.g. tripod) to place the camera in a location and orientation of their own design. The only constraint is that once the operation begins, no direct human intervention of the support is allowed (i.e., you can not move the support manually, but you could move it with the robot if you choose to do so. Of course this is optional, you do need to do so).
9. Oct/16: An interesting paper on sensing glass objects using the Kinect is [here](#): "[Recognition and Pose Estimation of Rigid Transparent Objects with a Kinect Sensor](#)", *Proceedings of Robotics: Science and Systems, 2012*. **The core idea is to "look for the void" of the glass object.**
10. Oct/25: New addendum for the soda bottle: for the bottle tests teams the choice of: (1) an empty bottle filled with an equivalent weight in sand (as per the lab guidelines) (2) an empty bottle (3) a (new) bottle full with soda. In this last case, however, IF the teams spill the soda, THEN \_ALL\_ marks for the challenge will be relinquished (as one can not soil Mars!)