

# Introduction to Vision and Robotics

## Assessed Practical 1: Robot Tracking

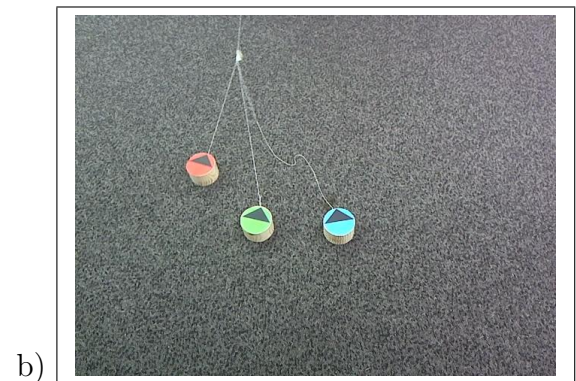
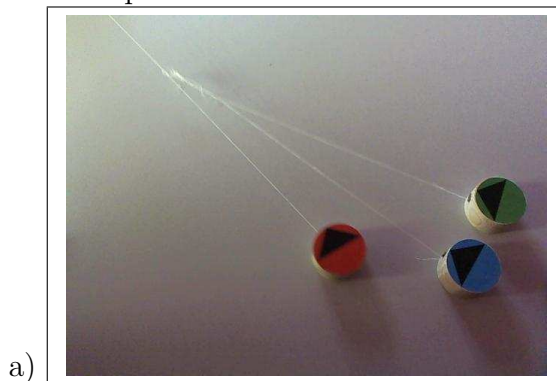
October 7, 2011

### 1 Introduction

This practical develops a Matlab program that detects and tracks three simulated robots in a set of video frames captured using one of the lab webcams. The program that you develop will:

1. Detect the three robots in each frame
2. Maintain correspondence between the detections between frames, using colour matching
3. Estimate the facing direction of each robot in each image
4. Draw the trajectory linking the centres-of-mass of each robot in each frame.

There are two different video sequences, with different backgrounds. A frame from each sequence is seen here:



You will work in pairs and must submit a joint report *but* this report must be accompanied by a short explanation of how the work was shared and how you think the (joint) mark should be distributed. 50:50 is OK if you shared the assignment fairly. **You can choose the partner yourself, but you will also have to choose a different partner for the second practical assignment.**

You should be able to normally access the IVR lab (AT 3.01) anytime with your swipe card. The webcams and ‘robots’ will generally be available in the lab - do not take them elsewhere!

You can use Matlab at any time on other DICE machines, but there are license number limits on availability so *never* stay connected to the programs when you are not using them.

## 2 Some Theory

In lecture, there was an example of background subtraction, **but how can one get a background image?** If one had the opportunity to **take a picture before any objects were in the scene**, then could be a solution. However, the data used here has foreground objects in all the images. **If the camera and illumination is largely stationary, as it is here, then you can synthesise a background image by median filtering the values observed over time at each pixel.** That is, if  $\{v_1, v_2, \dots, v_n\}$  are the values observed of the red colour channel at pixel  $(r, c)$  at different times, then the value  $\text{median}(\{v_1, v_2, \dots, v_n\})$  is an estimate of the background value of that colour channel at that pixel. Why? **Because we assume that a foreground object will be observed in a few frames at the given pixel, and most of the observations will be of the background.** **Repeat this at every pixel and colour channel** to build up a background image. This can be slow if you use all 100 time samples, so it is better to use a **subset, e.g. one out of every 5-10 images** because we assume that the foreground object is moving.

**How can you decide if the robot seen in one frame is the same as that seen in the next frame?** There are two useful sources of information: **1) Position** - assuming that the frame rate is high and the object velocity is low, then the target will not move much between images. **2) Colour** - the average RGB value of the pixels of a target will not change much between consecutive images.

How can you cope with the difference in **illumination** in different places in the image? **Use normalised RGB instead of raw RGB values.**

When you threshold the difference images, there might be many small regions detected due to image noise. How can they be removed? Look at the **`bwmorph(fore, 'erode', 1)` command.**

How might you determine the orientation of the robot? Look at properties of the detected and thresholded region. Investigate moments, centre-of-mass, template matching, etc.

How might you find the robot regions? Look at the `bwlabel(foremm,4)` and `regionprops(labeled,['basic'])` commands.

What to do if a robot is not detected in a given frame? Use an algorithm that allows the tracking to skip over up to  $N$  frames (e.g.  $N = 3$ ).

### 3 The Task

The overall goal is to develop an algorithm that takes the sequence of images and tracks each of the three robots.

Two sets of images are supplied. There are also sets of the robots and webcams available in the lab so you can capture additional image sets.

What you have to do is:

1. Develop an algorithm that detects the 'robot's in each image. In your report, present the criteria that defines a detection. Show examples of correct detections, missed detections and invalid detections (*i.e.* detections reported at locations where no robot is present). Report the number of correct, missed and incorrect detections. Explain the cause(s) of missed/invalid detections.
2. Develop an algorithm that correctly links together detections of the robot in consecutive frames. Show the path formed by linking together the centres of the detected robots drawn on top of the estimated background image. In your report, present the criteria that defines when two detections should be linked into a track. Show examples of correct tracks, broken tracks and incorrect tracks (*i.e.* tracks that join detections of different robots). Report the number of correct, broken and incorrect tracks. Explain the cause(s) of invalid/broken tracks.
3. Develop an algorithm that correctly identifies the direction that the robot is facing. There is an arrowhead on each robot that indicates the forward direction. Identify that direction and draw a line from the centre-of-mass of the robot in that direction. Do this for all 3 robots. Plot this line on top of each image frame, pausing using the `pause(1)` command to allow one second for the viewer to assess if the direction line is drawn correctly. Show examples of correct and incorrect directions in your report. Report the number of correct and

incorrect directions over each sequence (requires manual assessment). Explain the cause(s) of invalid tracks.

You should produce algorithms that are insensitive to changes in illumination and camera position (but assuming that both remain fixed during the capture of a sequence).

## 4 Files You Need

You will need these files (which can be downloaded from the IVR webpage):

Dataset 1: `ivr1112pract1data1.tar` first sequence of 100 images

Dataset 2: `ivr1112pract1data2.tar` second sequence of 100 images

Remember that the first image or 2 in a sequence might be bad.

## 5 Image Capture Details

Six robot ‘arenas’ are set up in the IVR lab containing high white walls, and there are 12 sets of ‘robots’. You can also capture images with the robots on the table tops or the floor.

Use `mplayer tv:// -tv driver=v4l2:width=640:height=480:device=/dev/... video0 -frames 100 -vo jpeg` to capture 100 frames of a new sequence. (Note: this is v4-ell-2, not v4-one-2, as in video-for-linux.)

**You should report average results on sequences that you have captured (*e.g.* 10+) using the lab materials, as well as the 2 supplied sequences.**

## 6 Writing the report

The report should be a concise description of what you did, why, and what happened. The entire report should be no more than 4000 words (excluding appendices). It should contain the following sections:

1. Introduction: an overview of the main ideas used in your approach.
2. Methods: Explain the vision techniques that you used. Then give a functional outline of how these ideas were implemented and the structure of your code. Explain how each part of it is meant to work. Where suitable, justify your decisions, *e.g.* why you used one method rather than another, what you tried that didn’t work as expected, etc.

3. Results: You should provide some actual data, from repeated trials (with the camera or robots in different positions) on how well your algorithm performs, as described previously. Show an example of your results for each stage of the detection. Well documented failure will get more marks than unsupported claims of success (well-documented success would be even better!).
4. Discussion: Assess the success of your program with regard to the reported results, and explain any limitations, problems or improvements you would make.
5. Code: the new Matlab code that you developed for this assignment. Do not include code that you downloaded from the course web pages. Any other code that you downloaded should be recorded in the report, but does not need to be included in the appendix.

Your final mark will be based on how well you explain your approach to the task and evaluate the capability of your Matlab program as well as the performance.

## 7 Live Demonstration

On Friday Nov 4, 10:00-17:00, you will have to demonstrate your program working on two new sequences that are similar to the sequences supplied here. You will be allocated to a demonstration time.

## Submission

Your submission should be a single PDF file and should be submitted electronically by *4pm Thursday Nov 3*. The command to use for on-line submission is:

```
submit ivr cw1 FILENAME
```

where FILENAME is the name of your PDF file.

This assignment is estimated to take 10-15 hours work. You must do this assignment in pairs and assign credit in your final report. The assignment will be marked as follows:

Issue	Percentage
Program Design, including comments	25%
Report Clarity	25%
Experimental Results (in Report)	25%
Live demonstration Results	25%

The live demonstration results will be marked based on a combination of target detection (5%), successful tracking (5%), target orientation (10%) and processing speed (5%).

## 8 Plagiarism

This assignment is expected to be in your own words and code. Short quotations (with proper, explicit attribution) are allowed, but the bulk of the submission should be your own work. Use proper citation style for all citations, whether traditional paper resources or web-based materials. Before submitting please acknowledge any additional sources of code that you use and ensure that your submission follows the university policy on plagiarism: [www.ed.ac.uk/schools-departments/academic-services/students/postgraduate-taught/discipline/academic-misconduct](http://www.ed.ac.uk/schools-departments/academic-services/students/postgraduate-taught/discipline/academic-misconduct)