# Advanced Vision Practical 2

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**Abstract**

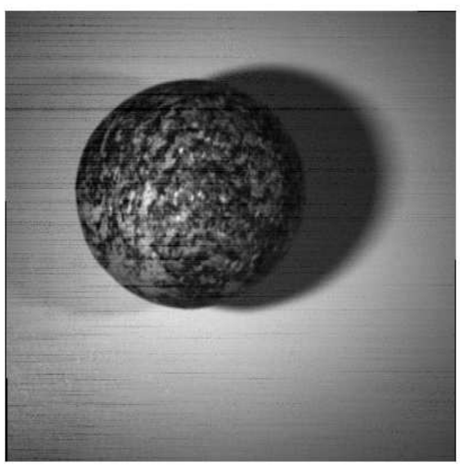
This describes the second assignment for assessment on Advanced Vision. The main goal is to detect and track a falling sphere in noisy 3D data. The assignment is due: **4pm Thursday 19 March**. You must do this practical in teams of 2, and submit 1 PDF report only. There will also be an assessed live demonstration of your practical.

## Task Background

At the URL:

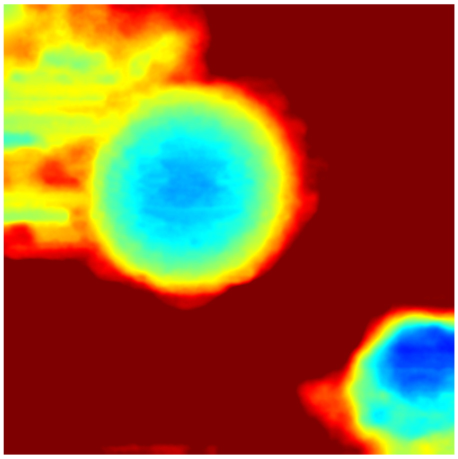
`http://homepages.inf.ed.ac.uk/rbf/AVDATA/AV215`

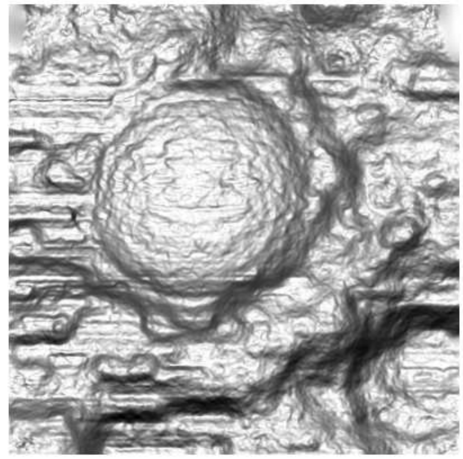
you will find a tar file `dataset2_1415.tar` of the data from 46 consecutive 3D data captures of a falling sphere. The images show a single sphere falling. A 1000 frame per second stereo vision observed the falling sphere. The camera is stationary and viewing the sphere against a stationary background. Note: the tar file is big (c. 1.2 Gb). You can see one frame of the intensity image data here:



The tar file contains 46 files named `falling_ball_XX.mat`, where XX = 01...46. Each file contains an array `XYZ(M,N,3)`, where $x = XYZ(col, row, 1), y = XYZ(col, row, 2), z = XYZ(col, row, 3)$, where $(col, row)$ is the pixel position. The file `falling_ball_XX.mat` also contains an intensity image `Img(M,N)` captured from the upper stereo camera. The values in $Img(col, row)$ are in the range [0,1].

Below, on the left is a false colour coded depth image computed from the stereo pair, where blue is closer. The right image shows a flat shaded rendering of the depth image.





Because the wall behind the sphere is an untextured and white, the stereo system does not have much data for proper stereo matching. This explains the unusual depth data observed for the wall. On the other hand, the data from the sphere is clearly better, although still noisy.

Your high level task is to estimate the gravitational acceleration acting on the sphere, by tracking the 3D centre of the sphere.

The acceleration $\vec{a}$ is estimated by a least square fit of the second order movement model $\vec{x}(t) = \vec{a}t^2 + \vec{b}t + \vec{c}$ to the sphere position at time $t$.

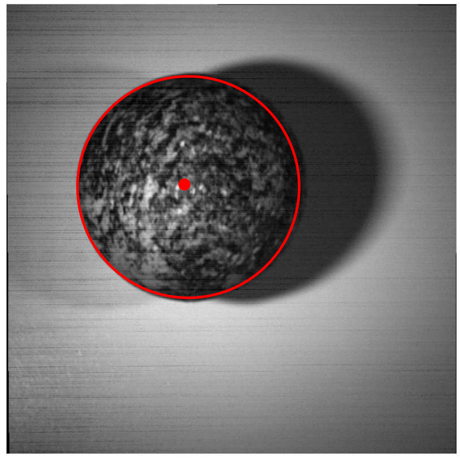
The sphere centres are found by doing a least squares fit to the 3D points from the surface of the sphere.

The surface of the sphere is found by using RANSAC on a subset of the noisy 3D points, where the subset is found by creating a mask from the light background wall seen in the intensity image. This masking will remove much of the noisy 3D data, except for the data from the sphere and the shadow. RANSAC will need 4 (or 5) points to initialise each hypothesis. Note that the many of the points on the wall are quite far from the ball, either closer or further. You can pick some distance thresholds (by hand) to eliminate these points from RANSAC's consideration.

## Evaluation

For each image, you want to show:

- the mask that was created
- the estimated centre of the sphere projected back into the intensity image: if $(x, y, z)$ is the sphere centre, then draw the centre at the pixel whose corresponding $(x, y)$ value is closest to the centre. This is not perfect, because the cameras use perspective projection, but the ball and wall are at a similar depth and are far from the camera, so the projection is almost orthographic.
- the estimated radius of the sphere: Use the radius from the least squares calculation plus the sphere centre. Compute a circle lying in a plane at the same distance from the camera as the sphere centre. Project the circle points onto the left intensity image. Use the same image as used when drawing the sphere centre. An example result is here:



Plot the vertical component of the fitted sphere centre acceleration model (ie. vertical component of $\vec{x(t)}$ as a function of $t$) along with the measured vertical positions. What is the mean and the standard deviation of the difference between the predicted and observed vertical positions? Here we approximate the falling motion as being completely vertical. What are the acceleration and velocity vectors $\vec{a}$, $\vec{b}$? How does $\vec{a}$ compare to the gravitational acceleration value?

### Your Report

Each team writes a single report that describes:

- The algorithms that you used for each stage of the process.
- How well the algorithms performed on the supplied test data. Show the statistical results and images requested above.
- Show all of the mask and centre/circle images, eg. 9 images to a page as an appendix.
- Show examples of successful and unsuccessful sphere shape and position estimates.
- Discussion on performance: successes and failures, causes of failures and potential remedies.
- Your code. Do not include code that was downloaded from the AV or IVR web sites, or the web.

## Other Comments

1. You can use the lecture example code from:
   `http://www.inf.ed.ac.uk/teaching/courses/av/MATLAB/`
2. Because there are a limited number of MATLAB Image Processing library licenses available, use alternative MATLAB functions from
   `http://www.inf.ed.ac.uk/teaching/courses/av/MATLAB/UTILITIES/`

## Assignment Submission

Submit your report in PDF online by 4pm Thursday March 19. The online submission line is:

```
submit av 2 FILE
```

where `FILE` is the name of your PDF file.

## Live Demonstration

There will be a live demonstration session assigned between 9:00-13:00 on Friday March 20, where you will have to demonstrate your sphere detection and fitting code on a single frame (taken also at the same time as the other images, including the same background). We'll email you about the location and schedule.

You will need your matlab program to show:

1. The original intensity and range images
2. The binary mask image
3. The estimated sphere centre and radius drawn on the original intensity image.

The assignment is estimated to take 10 hours coding/test and 5 hours report writing per person, resulting in a 5 page report plus the image appendix and the code appendix. You must do this assignment in teams of 2. You must find your partner and email Bob Fisher (rbf@inf.ed.ac.uk) the name of your partner. A single, joint, report is to be submitted. Split the work so that each partner does some independently (i.e. share the work rather than duplicate it).

The assignment will be marked as follows:

| Issue | Percentage |
|---|---|
| 1. Clear description of sensible algorithms used | 40% |
| 2. Performance on supplied data set | 20% |
| 3. Clear Matlab code | 20% |
| 4. Discussion of result quality and causes of any failures | 10% |
| 5. Live demonstration performance on new video data set | 10% |

## Publication of Solutions

We will not publish a solution set of code. You may make public your solution **but only 2 weeks after the submission date**. Making the solutions public before then will create suspicions about why you made them public.

## Plagiarism Avoidance Advice

You are expected to write the document in your own words. 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.

If you use small amounts of code from another student or the web, you must acknowledge the original source and make clear what portions of the code were yours and what were obtained elsewhere. You can ignore this condition for the AV lecture examples, which can be used freely.

The school has a robust policy on plagiarism that can be viewed here:

`http://www.inf.ed.ac.uk/teaching/plagiarism.html`

The school uses various techniques to detect plagiarism, included automated tools and comparison against on-line repositories. *Remember: a weak assignment is not a ruined career (and may not reduce your final average more than 1%), but getting caught at plagiarism could ruin it.*

Good Scholarly Practice. Please remember the University requirement as regards all assessed work. Details about this can be found at:

`http://www.ed.ac.uk/schools-departments/academic-services/students/`
`.../undergraduate/discipline/academic-misconduct`

and at:

`http://www.inf.ed.ac.uk/admin/ITO/DivisionalGuidelinesPlagiarism.html`

The School's Late Policy:

`http://www.inf.ed.ac.uk/student-services/teaching-organisation`
`.../for-taught-students/coursework-and-projects/late-coursework-submission`

The School's Conduct Policy:
`http://www.inf.ed.ac.uk/admin/ITO/DivisionalGuidelinesPlagiarism.html`