The Australian National University
College of Engineering and Computer Science
Final Exam, First Semester 2021

ENGN6528 Computer Vision

Question Booklet

Reading time: 15 minutes
Writing time: 2 hours
Uploading time: 15 minutes

Instructions on next page

Allotted Time

You will have 2 hours to complete the exam plus 15 minutes of reading time (you are allowed to write during this time. An additional 15 minutes has also been allowed to accommodate the additional task of uploading your completed exam to the final exam Turnitin submission portal on the ENGN6528 Wattle site. Thus, you have 2 hours and 30 minutes to complete the exam. NO late exams and submissions will be accepted. You may begin the exam as soon as you download it.

Minimal requirements:

You may attempt all questions

You SHOULD NOT include an assignment cover sheet

You must type your ANU student identification number at the top of the first page of your submission

You must monitor your own time (i.e. there is no invigilator to tell you how many minutes are left).

Your answers must be clear enough that another person can read, understand and mark your answer. 11 or 12 point font with 1.5 spacing is preferred. Scanned images of handwritten equations or diagrams must be legible and of a suitable size. Please be aware that your submitted document should have at least 20 words based on the requirement of Turnitin. If it is not satisfied, it may lead to unsuccessful submission.

Numbering questions

- You must specify the question you are answering by typing the relevant question number at the top the page
- Each question should begin on a new page
- Multi-part questions (e.g. question 1 parts a and b) may be addressed on the same page but should be clearly labelled (e.g. 1a, 1b)
- Questions should be answered in order

You must upload your completed answers in a single document file within the allotted time using a compatible file type for Turnitin (Preference: MS Word's .doc or .docx or .pdf format) **It is the student's responsibility to check that the file has uploaded correctly within Turnitin. No late submission will be accepted.** Access to the Turnitin practise site can be found here: https://www.anu.edu.au/students/academic-skills/academic-integrity/turnitin

Academic integrity

Students are reminded of the declaration that they agree to when submitting this exam paper via Turnitin:
I declare that this work:

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- is original, except where collaboration (for example group work) has been authorised in writing by the course convener in the course outline and/or Wattle site;
- is produced for the purposes of this assessment task and has not been submitted for assessment in any other context, except where authorised in writing by the course convener;
- gives appropriate acknowledgement of the ideas, scholarship and intellectual property of others insofar as these have been used;
- in no part involves copying, cheating, collusion, fabrication, plagiarism or recycling.

Final Exam: How to

Do's and Don't's:

- You are recommended to record your exam process and keep the video to yourself (for at least 4 weeks).
- **Do not submit your video recording.** This file stays private to you, unless we have a specific reason to request this file from you.
- Feel free to **ask question directly posting to "Instructors"** on Piazza (public posting will be disabled for you during the exam) or send email to course convenors. Our class link on Piazza is: http://piazza.com/anu.edu.au/spring2021/engn6528
- **Do not use any communication system** (other than direct posts on Piazza to Instructors or sending emails to your course convenor) during your exam - if you do, it will be counted instantly as collusion and will have serious academic honesty consequences.
- **Do not upload any material** anywhere (other than to the Wattle upload link at the end of the exam). If you do so, you will also become part of an academic collusion case which will stay on your permanent record at the ANU.
- Be very careful **searching for any material on-line**. If you find yourself seeing references to material which might be the result of collusion (which hopefully will not exist), you are one click away from becoming part of a serious academic honesty case yourself. Remember that all of your activity must appear in your recording, and according to basic academic standards, we also expect you to reference in your pdf file anything which you might have included in your working. You will likely waste valuable time for your exam and expose yourself to serious risks, so we recommend deferring from doing so.

Step-by-step guide on how to sit your actual on-line Final Exam:

1. Find yourself a cozy spot and **power down all communication channels**, besides this forum here.
2. Start your full screen **recording now**.
3. **Download** the exam paper from wattle (link will become active at the time of the exam).
4. **Open** the exam in the pdf reader, which you tested before.
5. Take a moment to **read** the whole document. You don't need to spend exactly 15 minutes for reading and you can start working on the exam after you finish reading it at your pace.
6. Fill in **your answers**. You can initially write your answer using your favourite editor. You are strongly recommended to submit a word document or Pdf document. Whichever way you chose, all your activities **must appear on your recording**.
7. Don't forget to **save regularly or** use a system which does that for you.
8. When you are complete, upload a single file (word or PDF are OK), and upload via the Wattle Link. You can make multiple uploads; they will overwrite the last. Ensure you upload before the end of the time. We have allowed 15 minutes upload time so submit with some time to spare.
9. **Stop your screen recording** and make sure the video file is saved (keep this file for at least 4 weeks). **Do not submit** your video recording.

ENGN6528
Q1 – Q6

Please name your submission as
ENGN6528_u1234567.docx

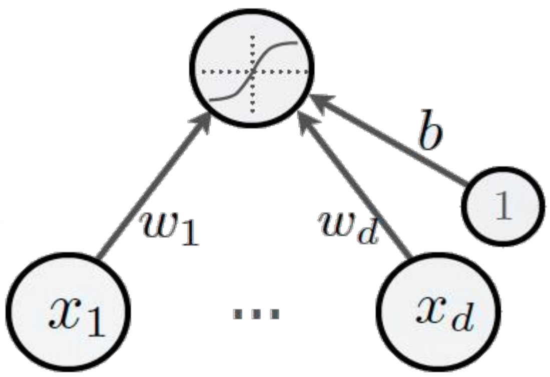
(or PDF as you prefer)

If you feel that some questions are ambiguous, please make reasonable assumptions and state them clearly.

Q1: (easy) (Basic Calculation)

a. Network Forward Propagation [3 marks].

Given below is a single node in a neural network. The forward propagation consists of a linear operation followed by a non-linear activation function. Suppose that d is 4, x={x_1, x_2, x_3, x_4}={3, 2, 1, 3}, and w={w_1,w_2,w_3,w_4} = {0.2,0.5,0.4,-0.4}, b=0.3, and that the activation function is a standard ReLU, that is f:=max(0,y), where y is the input to the activation function. What is the output of this node?



b. Stereo calculation [5 marks].

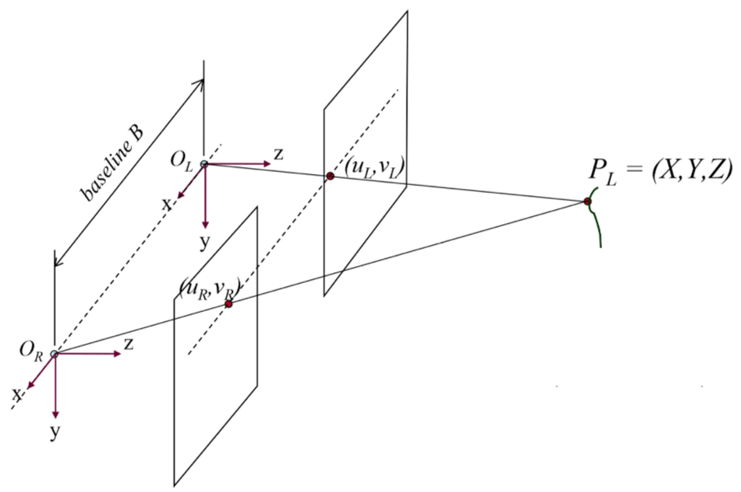


Fig. 1 Stereo Setup.

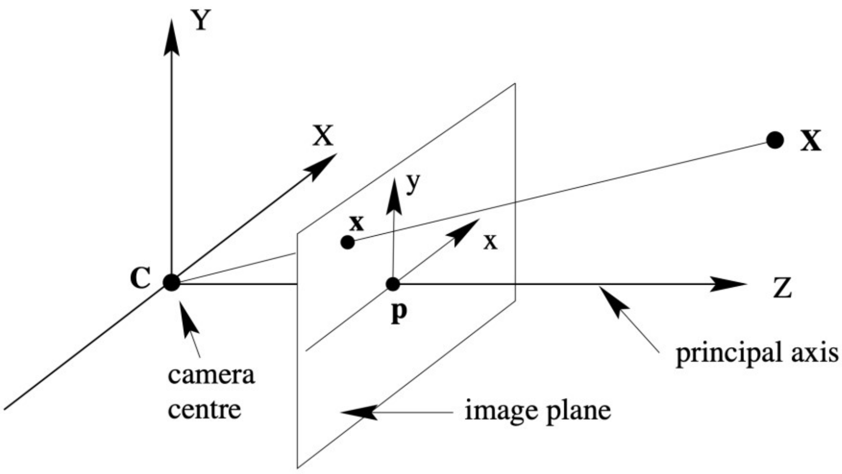
Given the stereo setup shown in Fig.1. Assume the baseline B = 1m, the focal length f_x= f_y =200 (measured in pixels) for both cameras. The measured pixel coordinates of the projected point P_L in the left and right views are $(u_l, v_l) = (100, 100), (u_r, v_r) = (50, 100)$, Please calculate the depth value of P_L relative to the camera, namely, the value of Z.

Q2. (easy) (Basic Calculation)

a. Perspective Projection [5 Marks].

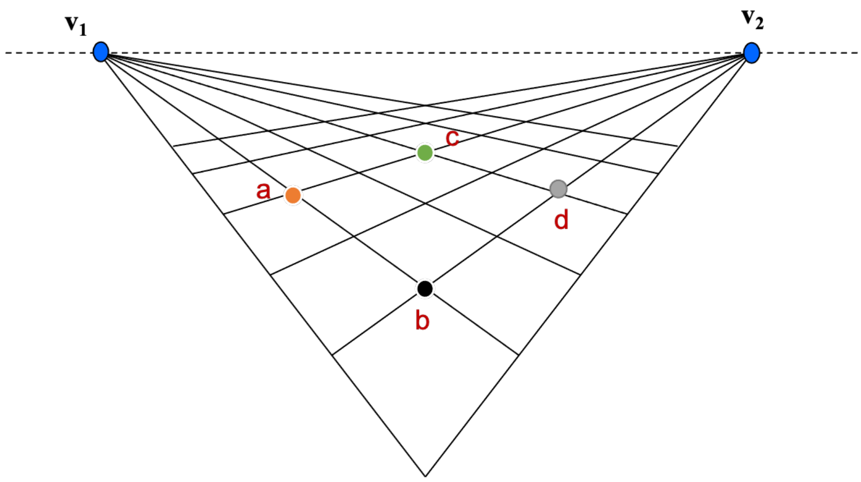
Given one calibrated camera, C1 has focal length of 530 in x and 540 in y, (measured in pixel unit) the camera has resolution 512x512, and the camera centre projected to the image is at (249, 245), with no skew.

Suppose that the scene has a point, P1, defined in the world coordinate system, which is aligned with C1, lying at (38, 40, 100). Note that the points in the world coordinate system are measured in cm. What location (to the nearest pixel) will that world point (P1) be mapped to in the image of C1?



b. Vanishing points [7 marks].

$$a = (79, 79), b = (100, 129), c = (102, 72), d = (120, 98)$$



Assume there are 4 points in the image denoted as a, b, c, and d. their pixel coordinates are listed above. Please calculate the vanishing points v_1 and v_2 in image coordinates.

Q3 (medium difficulty) (Basic Algorithm)

a. Optical Flow [5 Marks]
Optical flow defines the dense motion field of pixels across two image frames. Lucas & Kanade (1981) proposed a solution to solve the optical flow of all pixels by enforcing the local patch constant motion constraint, which is known as Lucas-Kanade algorithm. Please answer the following question based on your understanding of the algorithm.
What are the conditions that the optical flow for that patch can be calculated correctly and accurately?

b. Shape from Shading [5 Marks]
Shape from Shading methods aim to predict the geometric information such as the surface normal from an intensity image. Assume we can capture an image of a planar surface (Lambertian surface) illuminated by a point light source at infinity, that is, light rays are all parallel. It means that we have the image intensity information for this plane. Suppose that we have used other methods to know the brightness of the lighting, its direction and the reflectance properties of the surface in the above scenario.

Describe the distribution of the intensity values on this plane surface. Can the surface normals be obtained from this image given all this information? Please provide the analysis to your answers.

Q4 (medium difficulty) (Basic Concept).

a. Essential matrix VS Fundamental matrix [5 Marks]
What is the difference between essential matrix and fundamental matrix? Explain the answer in one sentence.

b. Stereo [5 Marks]
Assume we have a stereo setup where two cameras are set so that the images are coplanar, and the optical axes are parallel with the camera centres are lying at the same height. One pixel in one view (image) represents a ray that passing through this pixel and the camera centre. The projection of this ray in the other view defines an epipolar line. Describe the properties of epipolar lines for this stereo setup. Please provide a short answer to your analysis.

Q5: (challenging) (algorithm design) (10 marks)

Suppose that we have a grayscale video sequence taken by a moving vehicle in the front of the house (The video sequence shows multiple views of the house). The images were taken at 2pm. However, they were meant to be taken at 1pm. To correct this mistake, your task is to correct the lighting (namely, brightness of the lambertian surfaces) for post-production to make it appear as if the images were taken at 1pm. Both the original video sequence and the required correct one show a bright sunny day and should be taken on the same day of the year. There is no requirement to change the surroundings of the house, only the appearance of the house itself.

Please propose an algorithm and a set of steps to change the appearance of the images to match the requirement.

Hint: you may need to specify some information that you can reasonably assume to be provided, such as requiring some measurements to be taken of the house, and the sun has the same brightness, and the positions of the sun at these times of the day. Please note you do not need to be concerned about the shadow, just assume that all visible surfaces have direct illumination).

Fig. 1

Q6: (challenging) (algorithm design**) (10 marks)**

Suppose that you have been asked to write a software for a camera product: a stereo camera rig to obtain dense depth values for all the pixels. The stereo camera rig has been constructed so that two cameras are rigidly mounted, pointing with their optical axes in parallel, having their image planes coplanar. The cameras have lenses that can be accurately modelled as a pinhole. The rig comes with a large dice, for which we know the centre coordinates of each dot on each side, as a calibration device.

You are asked to write a software for the camera rig satisfying the following requirements.

First, design an algorithm for the configuration software, to calibrate the camera rig as required.

Second, design an algorithm that takes parameters which are the output of the above camera calibration process and returns dense depth values for all the pixels that are overlapping in the camera views. Please specify these parameters, (namely the output of the camera calibration algorithm). Your algorithm should be efficient and accurate.

Please clearly state any reasonable assumptions that you need to make to solve the problem.

-------------This is the end of the exam. ---------