Homework 3: Camera Geometry

Kaveh Fathian, Email: fathian@ariarobotics.com

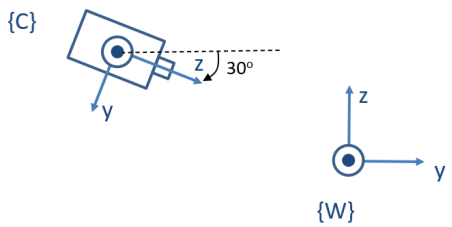
Handout: 2024-10-11
Due: 2024-10-25, at 3:00 PM on Canvas

Instructions:

- Homework is on a "**rolling"** basis and more **questions will be added until 1 week** before the due date. There will be an announcement (on Discord or in class) when new questions are added.
- For all problems in this homework, you can convert your images to **grayscale** for simplicity. So, no need to work with RGB images (unless you want to).
- You can get help from your teammates (or others) for all problems and/or code. However, you will need to code the problems and submit your report **individually** on Canvas. Reports/code that are **identical** will receive a grade of **zero**.
- The **quiz** will strongly resemble homework questions, and if you understood/coded the homework yourself, you will be able to answer the quiz questions immediately. Because the quiz will be closed-notes & no internet access, understanding the homework is crucial!
- **Deliverables**: You will submit a **single PDF** file to Canvas. The PDF must contain your **answers**, your **code** (copy-paste in the document), and any requested **outputs** (like images). For convenience, you may use Jupyter notebook and convert it to a PDF.
- Only use **images provided** in the homework material, as requested by each problem. Using any other image, will result in a **grade of zero**.
- **Grading:** This homework will be scaled to **10pts** of your final grade. Grading **rubric** will be posted on **Canvas** after the assignment due date.

Problem 1: Coordinate transformation:

- 2D transformation: Compute the coordinate of a 2D point p = $(10, 20)^T$ using a transformation of 45 degrees about the x-axis, and a translation of t = $(40, -30)^T$. Answer/explain the following:
  - What is the point representation in homogeneous coordinates?
  - What is the rotation matrix R?
  - What is the translation vector t?
  - What is the full transformation matrix (consisting of R, t) that can be used to transform the homogeneous point coordinate?
  - How do we apply this transformation to the point (in homogeneous coordinate form)?
  - What is the coordinate of the transformed point, in homogeneous coordinates, and in the cartesian coordinates?
- 3D transformation: A camera is located at point (0,-5,3) in the world frame. The camera is tilted down by 30 degrees from the horizontal. We want to find the 4x4 homogeneous transformation ${}^{C}H_{W}$ from the world frame {W} to camera frame {C}. Note that in "the world" Z is up (X-Y ground plane) but in "the camera", Z is out (X-Y image plane).



Answer/explain the following:

- What is ${}^{C}H_{W}$? Explain how you computed it.

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- Using transformation ${}^{C}H_{W}$, transform the point ${}^{W}p = (0,0,1)$ in the world frame to the camera frame. Hint: use the homogeneous coordinates of the point for this transformation.

Notes:

- If you are not familiar with coordinate transformations, please take a look at the notes "Coordinate_Transforms.pdf" in the HW3 folder of course materials.

Problem 2: Camera calibration:

- Find the calibration/ intrinsic matrix of a camera (e.g., your cellphone camera). Use the camera calibration board (print PDF file) provided in the HW3 folder.
  - Provide a copy of your code in the report
  - Display the images you took from the calibration board (at different angles/locations)
  - After calibration, print out the camera intrinsic matrix
  - Print out five distortion parameters, and explain what they are for.
  - Print out camera extrinsic matrices for all of your images

Notes:

- For this problem, you can follow the camera calibration instructions at
  - https://docs.opencv.org/4.x/dc/dbb/tutorial_py_calibration.html
  - https://www.geeksforgeeks.org/camera-calibration-with-python-opencv/

Problem 3: Least-squares estimation:

Problem 4: Panorama:

Problem 5: 3D reconstruction: