CSE483-Mobile Robotics

Mid-semester exam

Monsoon 2019

September 21st

Maximum points: 30 Duration: 90 minutes

Instructions

- This is an **open-book** exam. You are allowed to use any paper notes or textbooks that you have brought with you.
- Laptops, tablets, or smartphones are NOT allowed. You also cannot collaborate with other students.
- Your answers must be concise and to-the-point. Verbosity will NOT fetch you additional marks.
- Sufficient space has been provided for each question. Using additional sheets are discouraged, if you need them you're probably doing something wrong.
- You do NOT get credit for replicating whatever is present in the textbook or your notes. Please do not fill your answer scripts with excerpts from such sources.
- Use the last page for rough work or for any of your answers, if necessary.
- State your assumptions clearly if there is any ambiguity with the question(s).

Roll number:

Seat:

Invigilator sign:

Q1	Q2	Q3	Q4	Q5	Q6	Total

Q1) *Warm-up:* Fill up the following table by indicating the quantities that are known, to be estimated, or unknown, and the type of measurements that are needed. **(5 points)**

Problem	Structure (Scene geometry)	Motion (Camera parameters)	Measurements
F-matrix estimation	Unknown	Estimate	2D - 2D features
Camera calibration	Known	Estimate	2D - 3D features
Triangulation	Estimate	Known	2D - 2D features
Stereo rectification	Unknown	Known	Unknown
PnP	Known	Estimate	2D - 3D features
Bundle adjustment	Estimate	Estimate	2D - 3D features

Q2) *Transformations:*

(i) Derive the expression for T_W^C if $\mathrm{T}_C^W = \begin{bmatrix} \mathrm{R}_C^W & \mathrm{P}_{CORG}^W \\ \mathbf{0}_{3\times1} & 1 \end{bmatrix}$. **(2 points)**

(ii) Consider the following figure and answer questions (a) to (c).

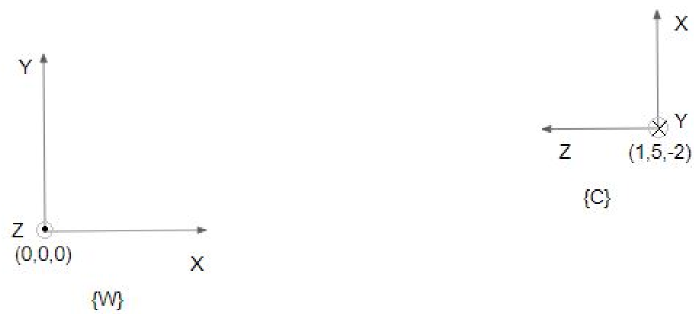

Figure 1: World Frame and Camera Frame

{W} represents the world frame and {C} represents the camera frame. The Z axis of {W} is coming out of the plane. Whereas the Y axis of {C} is going into the plane.

(a) Find R_C^W. **(1 points)**

(b) Find the YXZ-Euler angles representation for R_C^W. **(1 points)**

(c) Find P_{WORG}^C and T_W^C. **(1 points)**

Q3.1) *Single-view geometry:* Given a camera matrix P, detail how you can obtain the camera center and the rotation matrix R without knowing the intrinsic parameter matrix K. **(2 points)**.

Q3.2) *Reconstruction:* State and justify the cases when the 3D reconstruction obtained from two views is (a) Unambiguous (b) Up to an unknown scaling factor (c) Up to an unknown projective transformation. **(3 points)**

Q4) *Essential matrix:* Two cameras fixate on a point P in 3D space such that their *optical axes* intersect at this point. Show that the E_{33} element of their associated Essential matrix E is zero. **(5 points)**

Q5) *Homography*: Suppose a camera, with intrinsic matrix K, rotates about its optical centre by a rotation matrix R. (a) Show that its two views are related by a homography H such that $x_2 = Hx_1$ where x_1 is a point in the first image and x_2 is its corresponding point in the second image. **(2.5 points)** (b) Also show that if θ is the rotation between the two views, then the angle 2θ corresponds to the homography H^2. **(2.5 points)**

Q6) *Dense-VO*: Dense-VO is one other type of visual odometry where the camera motion is estimated by aligning consecutive image frames and then finding the transformation that best minimizes the *photometric error* between them. Suppose there is a camera C with known intrinsics K, and it captures two images $\mathrm{I}_1, \mathrm{I}_2$ from two views separated by a rotation R and translation t. The photometric error between these two views is given as $\sum_{\mathrm{x} \in \mathrm{I}_1} \|\mathrm{I}_1(\mathrm{x}) - \mathrm{I}_2(w(\mathrm{x}, (\mathrm{R}|\mathrm{t}))\|^2$ where $w(\mathrm{x}, (\mathrm{R}|\mathrm{t}))$ is a function that maps a point x in the first image to a point in the second image given the camera motion R, t. (a) Assuming d is the depth of the point x in I_1 relative to the first view, describe the steps involved to map this point to the second image, and hence provide a mathematical expression for $w(\mathrm{x}, (\mathrm{R}|\mathrm{t}))$. **(3 points)** (b) What is the nature of this photometric error? Very briefly in words mention how it can be solved for to find the best camera motion. **(2 points)**

Extra space

Extra space