1 Question 1

A single landmark $l^G = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$ is observed by two cameras with projection matrices M and M' at pixel coordinates $\begin{pmatrix} u \\ v \end{pmatrix}$ and $\begin{pmatrix} u' \\ v' \end{pmatrix}$ respectively.

1.1 a

Write a linear system of equations to estimate landmark from the two measurements, when:

1.1.1

M and M' are given in the world coordinate system

1.1.2

in the left camera coordinates when only calibration matrices K and K' are given, and cameras are b_s centimetres apart in the x axis, (camera x axes correspond).

1.2 b

Now we assume a camera observes n landmarks $\{l_i = \begin{pmatrix} x_i \\ y_i \\ z_i \end{pmatrix}\}_{i=1}^{n}$ at corresponding pixel coordinates $\{u_i, v_i\}_{i=1}^{n}$.

1.2.1

Write a homogeneous linear system to estimate camera matrix M. State a way to find a (non-trivial) solution to the system.

1.2.2

Suppose now that camera calibration matrix K is known. Calculate camera 6 DoF pose.

2 Question 2

A robot moves from (unknown) pose x_0 to x_1 and obtains observation z_1 of a landmark.

2.1 a

Assuming standard observation and motion models, write posterior over $x_{0:1}$, l in terms of the models.

2.2 b

Draw the corresponding factor graph. Explain in detail to what each node and edge in the graph corresponds.

2.3 c

Eliminating x_1 according to the procedure learned in class, write down the posterior, draw the new factor graph and Bayes net obtained as a result.

2.4 d

Assuming linear observation and motion models

$$x_{k+1} = x_k + F_k u_k + w \tag{2.1}$$

$$z_k(x_k, l_i) = H_k x_k + J_k l_i + v, \tag{2.2}$$

where w and v are Gaussian noise:

2.4.1

Solve the smoothing problem.

2.4.2

Show how to obtain estimates and uncertainties for each of $x_{0:1}$, l from above solution.