CS/RBE 549 Computer Vision
Fall 2020

Name:_______________________________
Thu 10 Dec 3:30 pm - Fri 11 Dec 11:59 pm

Exam #2

This examination is open book and open notes, including any materials on Canvas and Szeliski, “Computer Vision”.

You may consult resources on the World-Wide Web, but you must cite them.

You will be on your honor to take the exam with no human assistance other than the Instructor and TAs.

The Instructor and TAs are only able to provide clarification should any question be ambiguous.

The examination will end exactly 32.5 hours after it begins. Good luck!

Problem 1: /30
Problem 2: /25
Problem 3: /10
Problem 4: /15
Problem 5: /10
Problem 6: /10
Problem 7: /01
Total: /101

1. **Optical Flow (30 pts):** Suppose the image brightness is given by

$$I(x, y, t) = I_0 + \ln\big((x - c_1 t)(y - c_2 t)\big)$$

Ignore any singularity when $\ln(\dots) = 0$

a. (10 pts) What are I_x, I_y, and I_t?

b. (10 pts) Express the Optical Flow Constraint Equation $I_x u + I_y v + I_t = 0$ in the simplest terms possible for this image sequence, that is, with no fractions.

c. (10 pts) The equation from b. must hold for all *x*, *y*, and *t*. Find a constant solution for *u* and *v* that makes this true, that is, such that *u* and *v* do not depend on *x*, *y*, and *t*.

References cited, if any:

2. **Moving Camera (25 pts):** Suppose that the viewer (camera) is moving. We can model this in the imaging equations

$$\vec{X}^C = R\vec{X}^W + \vec{T} \text{ and } \vec{X}^I = \frac{\left|\vec{f}\right|^2 \vec{X}^C}{\vec{f} \cdot \vec{X}^C}$$

by letting R and $\vec{T}$ depend on time, $R = R(t), \vec{T} = \vec{T}(t)$. Assume that the camera is translating with velocity $\vec{V}^C \equiv \frac{d}{dt}\vec{T}(t)$ and that there is no rotation, $\frac{d}{dt}R(t) = 0$. As we know from experience, points in the image will seem to move.

a. (15 pts) Show that image point $\vec{X}^I$ will appear to move with velocity

$$\vec{V}^I \equiv \frac{d}{dt}\vec{X}^I(t) = \frac{1}{\vec{f} \cdot \vec{X}^C}((\vec{X}^I \times \vec{V}^C) \times \vec{f})$$

Hint: Use the vector triple product formula $(\vec{a} \times \vec{b}) \times \vec{c} = (\vec{c} \cdot \vec{a})\vec{b} - (\vec{b} \cdot \vec{c})\vec{a}$.

b. (10 pts) The Focus of Expansion is the point in the image toward which the camera appears to be moving, given by the projection of $\vec{V}^C$ into the image. That is,

$$\vec{X}^I{}_{\text{FOE}} = \frac{\left|\vec{f}\right|^2 \vec{V}^C}{\vec{f} \cdot \vec{V}^C}$$

Points in the image will seem to move away from the Focus of Expansion. Show that a point at the Focus of Expansion does not appear to move.

References cited, if any:

3. **Time to Impact – Volume (10 pts):**
   We saw in class that time-to-impact of a ball, with radius $R(t)$ in the image, heading towards a viewer (ignoring gravity, wind resistance, etc.) is given by

$$T_{\text{Impact}} = \frac{R(t)}{\frac{d}{dt}R(t)}$$

   Using his X-ray vision to see in 3 dimensions, Superman can use measure the volume $V(t)$ of a ball heading towards him. What is T_{impact} in terms of $V(t)$ and its derivative with respect to time $\frac{d}{dt}V(t)$?

References cited, if any:

4. **Stereo Velocity (15 pts):** We saw that one way to formulate the stereo problem yields

$$\vec{X}^W = \vec{X}_{AVG} \frac{\left|\vec{B}\right|^2}{\vec{B} \cdot \vec{\Delta}}$$

   as the solution to finding $\vec{X}^W$ from a stereo pair. If the world point is moving with velocity $\vec{V}^W$, then image points $\vec{X}_L$ and $\vec{X}_R$ will appear to move also. Express $\vec{V}^W$ in terms of $\vec{X}_L$ and $\vec{X}_R$ and their time derivatives $\vec{V}_L$ and $\vec{V}_R$

References cited, if any:

5. **Sonar Vision (10 pts):** In the movie *Batman Forever*, Batman (Bruce Wayne) wears a "Sonar Suit," which displays a sonar image of his environment. Although the physics of sound vision are never quite explained, presumably, the suit emits sound waves, which are then reflected back to him. Although sound waves can be focused, this is difficult to do. More commonly, sound waves are detected by a phased array of receivers. However they are detected, objects tend to lack distinct surface markings, because the reflected sound depends only on distance, surface orientation, and material reflectivity. *Briefly* discuss some of the challenges imaging the world using Sonar Vision.

6. **Object Detection (10 pts):** Based on your experience in Computer Vision, you are hired to design a pedestrian detection system for self-driving cars. List 4 types of knowledge / sources of information that you could use.

   a.

   b.

   c.

   d.

   e. How would you convince a governmental regulatory agency that the system is effective?

7. **Teamwork (1 pt):** On a scale of 1 to 5, with 1 being the lowest, 3 is neutral and 5 being the highest, rate how well your project team is working together.