Please submit your homework reports **in PDF format** to the TEACH website:

https://secure.engr.oregonstate.edu:8000/teach.php?type=want_auth

This homework is about stereo geometry. For this assignment, you will use the **five** stereo pairs of images provided on the class website. For each stereo pair of images, perform the following tasks:

**Assignment**

1) (5 × 2 points)
   1.1) Manually select $N_{man} = 10$ pairs of corresponding points in the images, as precisely as possible, and record their coordinates:
   \[
   \{ ([x_k, y_k], [x'_k, y'_k]) : k = 1, \ldots, N_{man}, \} \]

   1.2) Estimate the fundamental matrix $F^{(0)}$ based on these $N_{man}$ point pairs, and **present** $F^{(0)}$ in your PDF report.

2) (5 × 6 points)
   2.1) Detect 100 strongest SURF interest points in each image (you may use your HW1 implementation). Compute SURF descriptors of these points. Let these SURFs be located at coordinates $[x_i, y_i]$ in image 1, $i = 1, \ldots, 100$, and at coordinates $[x_j, y_j]$ in image 2, $j = 1, \ldots, 100$.

   2.2) Compute the $(100 \times 100) \times 1$ vector of matching similarities, $w = [w_{1,1}, \ldots, w_{i,j}, \ldots, w_{100,100}]^T$, as:
   \[
   w_{i,j} = \begin{cases} 
   \exp \left[ -\|SURF_i - SURF_j\|_2^2 \right], & \text{if } \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} < \theta \\
   0, & \text{otherwise} \end{cases}
   \]
   where threshold $\theta = 20$.

   2.3) Find matching pairs of SURFs using the following matching formulation:
   \[
   \max_z \quad w^T z , \quad \text{s.t. } \|z\|_2 = 1, \quad z \in [0, 1]^{100 \times 100},
   \]
   where $z = [z_{1,1} \ldots z_{i,j} \ldots z_{100,100}]^T$ is a $(100 \times 100) \times 1$ binary vector indicating matches, such that $z_{i,j} = 1$ means that $SURF_i$ in image 1 got matched with $SURF_j$ in image 2, and $z_{i,j} = 0$ means that $SURF_i$ and $SURF_j$ from the two images did not get matched. In case you find $z$ in Eq.(2) in the continuous domain, you need to threshold $z$ to obtain binary values.

   2.4) From your binary solution $z$, automatically select $N_{SURF}$ best pairs of SURF matches $(i, j)$ for which the fundamental equation (closely) holds:
   \[
   (i, j) : \quad z_{i,j} = 1 \quad \text{and} \quad [x_i, y_i, 1]^T F [x_i, y_i, 1]^T \approx 0
   \]
   where $F$ is the fundamental matrix that you estimated using the $N_{man}$ manually selected pairs of points. Select the value of $\epsilon$ so that $N_{SURF} = 30$.

   2.5) Merge the two sets of $N_{man}$ manually selected and $N_{SURF}$ SURF point pairs, and thus obtain the new set of $N = N_{man} + N_{SURF} = 40$ point pairs. Re-estimate the fundamental matrix $F$ based on these $N$ point pairs, and **present** $F$ in your PDF report.
3) (5 × 2 × 2 points) Show in Figure 1a one example point in image 1, and its epipolar line in image 2 (superimpose the epipolar line over image 2 using a distinct color), computed for \( F^{(0)} \). Show in Figure 1b the same point in image 1, and its epipolar line in image 2 (superimpose the epipolar line over image 2 using a distinct color), computed for \( F \). In the captions of Figures 1a and 1b, specify the row and column of the point you selected in image 1, and parameters of the epipolar line in image 2. Note that if your estimates of \( F^{(0)} \) and \( F \) are wrong then the point in image 2 that truly corresponds to the point you selected in image 1 will not lie on your estimated epipolar line.

4) (5 × 2 × 2 points) Show in Figure 2a another example point in image 2 (different from above), and its epipolar line in image 1 (superimpose the epipolar line over image 1 using a distinct color), computed for \( F^{(0)} \). Show in Figure 2b the same point in image 2, and its epipolar line in image 1 (superimpose the epipolar line over image 1 using a distinct color), computed for \( F \). In the captions of Figures 2a and 2b, specify the row and column of the point you selected in image 2, and parameters of the epipolar line in image 1. Note that if your estimates of \( F^{(0)} \) and \( F \) are wrong then the point in image 1 that truly corresponds to the point you selected in image 2 will not lie on your estimated epipolar line.

5) (5 × 2 points) Show in Figure 3 clearly marked epipoles of image 1 and image 2. In the caption of Figure 3, specify the coordinates of the two epipoles.

6) (10 points) Printout of the software that you used for this homework assignment.

**Summary of Your Report**

- 5 fundamental matrices \( F^{(0)} \) based on the \( N_{man} = 10 \) manually selected point pairs.
- 5 fundamental matrices \( F \) based on the \( N = N_{man} + N_{SURF} = 40 \) point pairs.
- 25 figures with captions: Figure 1a, 1b, 2a, 2b, 3.
- Printout of the software.