Congratulations! You passed!

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1. Let (x_1, y_1) be the coordinates of a point in an image and (x_2, y_2) be its coordinates after the following transformation is applied to the image:

1 / 1 point

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & -4 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$

The transformed image is:

- ○ Stretched in the x direction
- ○ Rotated clockwise by 45°
- ○ Flipped about both the x and y axes
- ◉ Stretched in the y direction, and flipped about the x axis

✓ **Correct**

See transformations for stretching and mirroring. The –4 scales the image in the y direction and flips it about the x direction.

2. Let (x_1, y_1) be the coordinates of a point in an image and (x_2, y_2) be its coordinates after the following transformation is applied to the image:

1 / 1 point

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} 0 & 2 \\ 2 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}.$$

The transformed image is:

- ○ Scaled up by a factor of 2

- ○ Mirrored about y axis and rotated clockwise by 90°
- ○ Mirrored about x axis and scaled up by factor of 2
- ◉ Scaled up by a factor of 2 and mirrored about $y = x$

Correct
Since the diagonal elements are zero and the non-diagonal ones are not, the axes are being swapped. Since the non-diagonal elements are 2, the image is also being scaled in both directions.

3. Which of the following is NOT a possible result of applying a 2×2 matrix to the image of a rectangle? **1 / 1 point**

- ○ A square
- ○ A parallelogram that is not a square
- ○ A rectangle with a different area
- ◉ A trapezoid that is not a parallelogram

Correct
An application of a 2×2 matrix must leave parallel lines parallel. A rectangle has two sets of parallel sides, so the result must be a parallelogram.

4. Let $(x_1, y_1, 1)$ be the homogeneous coordinates of a point in an image and $(x_2, y_2, 1)$ be its coordinates after the following transformation is applied to the image: **1 / 1 point**

$$\begin{bmatrix} x_2 \\ y_2 \\ 1 \end{bmatrix} = \begin{bmatrix} 4 & 0 & 4 \\ 0 & 4 & 4 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix}.$$

The transformed image is:

- ○ Scaled by a factor of 4
- ○ Shifted by (4, 4)
- ◉ Scaled by a factor of 4 and shifted by (4, 4)

- ○ The same as the original image

Correct
The diagonal elements of the upper-left 2×2 matrix represent scaling. The first two elements of the third column represent the translation vector.

5. Any homography can be obtained applying a sequence of skew, rotation, translation, and/or scaling transformations.

1 / 1 point

- ○ True
- ◉ False

Correct
These transformations will form an affine transformation which keeps parallel lines parallel, however this is not necessarily true for homographies.

6. Consider two images taken by rotating a camera about its pinhole by an unknown amount. How many pairs of corresponding points in the two images are needed to align the two images by computing the homography matrix up to a scale factor?

1 / 1 point

- ◉ 4 pairs
- ○ 6 pairs
- ○ 8 pairs
- ○ 10 pairs

Correct
The homography matrix has $3 \times 3 = 9$ elements. However, there are only 8 degrees of freedom as the homography can only be computed up to an unknown scale factor. Each pair of corresponding points yields 2 equations. Therefore, 4 pairs are needed to solve for the matrix.

7. What is the point in pixel coordinates that corresponds to applying homography T to (5, 3)? **2 / 2 points**

$$T = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 4 & 1 \\ 0 & 0 & 2 \end{bmatrix}$$

- ○ (6, 13)
- ○ (5, 12)
- ◉ (3, 6.5)
- ○ (6, 4)

Correct

First convert the point to homogenous coordinates

$$\tilde{x} = (5, 3, 1).$$

After applying the matrix T, the result is

$$\tilde{y} = T\tilde{x} = (6, 13, 2).$$

To convert back into inhomogenous coordinates, we divide by the z coordinate, so

$$y = (3, 6.5).$$

8. Suppose we have triangle T_1 in image 1 and T_2 in image 2. How many possible homographies transform T_1 into T_2? **2 / 2 points**

- ○ 0
- ○ 1
- ○ 6
- ◉ ∞

Correct

Knowing a mapping between triangles will give information about 3 pairs of points or 6 degrees of freedom. However, a homography has 8 degrees of freedom, so this is an under-constrained problem. Note that points within the interior or edges of the triangle cannot be used for additional information since they can be written as a linear combination of the endpoints.

9. It is possible to compute a homography with only the minimum number of matching points, however it is usually computed with all matching points by solving the constrained least-squares problem. What is the advantage this approach gives?

1 / 1 point

- ○ The correct scale factor is calculated for the homography
- ◉ Robustness to small errors in localizing the matches
- ○ The stitching from the homography becomes more seamless
- ○ There is no advantage

Correct

The homography that is computed as the solution to the constrained least-squares problem is the one that minimizes the error of the predicted location given by the homography and the target location given by the target of the match. By minimizing this error, the model becomes robust to small errors in the location of the matching points.

10. Which of the following is not a step in the RANSAC algorithm?

1 / 1 point

- ○ Randomly sample sets of s data points to fit a model
- ○ Count the number of M data points which are inliers of a given model
- ○ Repeat the model selection process N times
- ◉ Select the model which minimizes the least-squares error

Correct

In RANSAC we select the model which produces the largest number of inliers.

11. Suppose an image f is being stitched onto image g, with homography T such that **3 / 3 points**

$$g(x, y) = f(T(x, y))$$

and

$$T = \begin{bmatrix} 1 & 5 & 2 \\ 0 & 2 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Which pixel in f should correspond to $(x, y) = (20, 6)$ in the merged image?

- ( ) (20, 16)
- ( ) (52, 12)
- ( ) (6, 6)
- (•) (3, 3)

Correct

Backward mapping can be used to compute the correct point to map to (20, 6). The inverse of T is

$$T^{-1} = \begin{bmatrix} 1 & -2.5 & -2 \\ 0 & 0.5 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

And applying it to (20, 6) will yield (3, 3).