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1. [8] What are four (4) ways that you can control a camera’s exposure (i.e., intensity or brightness value) in a photograph?

2. [8] Fill in each of the following blanks with one of “smaller,” “larger,” or “same.”

   (a) [2] The smaller the f-number of a lens, the ______________ the depth of field.

   (b) [2] The shorter the focal length of a lens, the ______________ the depth of field.

   (c) [2] The closer the distance to the object in focus, the ______________ the depth of field.

   (d) [2] The faster the shutter speed, the ______________ the depth of field.

3. [9] Say I have a camera with lens focal length of 40mm, aperture f-number f/5.6, shutter speed 1/500 second, and ISO value 200.

   (a) [3] What is the diameter of the lens (in mm)?

   (b) [3] What shutter speed should I use to obtain the same exposure in a second photo using f/11 instead of f/5.6?

   (c) [3] What shutter speed should I use to obtain the same exposure in a second photo using ISO 400 instead of 200?
4. [4] Given a **pinhole camera** with focal length 60, what are the **image coordinates** of the 3D scene point at coordinates (100, 200, 400)?

5. [3] Does the **thin lens formula** apply to a pinhole camera for determining which scene points are in focus and which are not? Briefly explain why or why not.

6. [4] If I double the focal length of a camera lens and also move twice as far away from an object I focus on in a scene, what are **two** (2) things that will be different in the two images?

   
   (a) [3] regions of uniform intensity are unchanged by smoothing using this filter?

   (b) [3] the amount of smoothing does *not* depend on orientation of objects in the image?
8. [13] **Laplacian**

(a) [3] Define a 3 x 3 linear filter that can be used as an approximation of the Laplacian of an image f(x, y), i.e., \( \nabla^2 f = \left( \frac{\partial^2 f}{\partial x^2} \right) + \left( \frac{\partial^2 f}{\partial y^2} \right) \)

(b) [3] How can this filter be used to detect edges in an image? That is, specify how to create a binary edge image where a pixel's value is 1 if it is at an edge, and 0 otherwise.

(c) [3] How can this filter be used to “sharpen” an image by unsharp masking?

(d) [4] Describe the main steps to compute a 2-level Laplacian pyramid from an input image. Use a figure to aid your explanation, if desired.
9. [7] Say you want to **warp** an image, \( I \), into a new one, \( J \), by rotating \( I \) 45° about the origin of the image. This transformation can be described by the mapping from \( I \)'s \((u, v)\) coordinates to \( J \)'s \((x, y)\) coordinates as: 

\[
\begin{align*}
\text{x} &= u \cos \theta + v \sin \theta \\
\text{y} &= -u \sin \theta + v \cos \theta
\end{align*}
\]

(a) [4] If pixels in image \( I \) are all 0s except five 1s at coordinates \((0, 0)\), \((1, 1)\), \((2, 2)\), \((3, 3)\), and \((4, 4)\) (i.e., a diagonal line of five pixels), what is the resulting image \( J \) after 45° rotation of just the five “1” pixels in \( I \) using the above transformation and using 0-order (nearest neighbor) interpolation? Use \( \cos 45^\circ = \sin 45^\circ = 0.7 \).

(b) [3] What problem(s) does this example demonstrate?

10. [4] Use **bilinear interpolation** to compute the intensity value at point \((10.2, 4.5)\) assuming the four nearest neighbor pixels have the following intensity values: \((10, 4)\) has value 22, \((11, 4)\) has value 42, \((10, 5)\) has value 40, and \((11, 5)\) has value 25.
11. [7] Compute
   (a) [4] the gradient at the central pixel of the image:

   \[
   \begin{array}{ccc}
   1 & 3 & 10 \\
   2 & 4 & 11 \\
   3 & 5 & 12 \\
   \end{array}
   \]

   using the two first derivative (Sobel) filters in the x and y directions, respectively:

   \[
   \begin{array}{ccc}
   -1 & 0 & 1 \\
   -2 & 0 & 2 \\
   -1 & 0 & 1 \\
   \end{array} \quad \begin{array}{ccc}
   1 & 2 & 1 \\
   0 & 0 & 0 \\
   1 & 2 & 1 \\
   \end{array}
   \]

   (b) [3] the gradient magnitude at this same pixel.
12. [10] Say you’ve detected \( n \) point features in image 1 and \( m \) feature points in image 2 and you’d like to determine the 2D translation of image 1 so that it aligns best with image 2.

(a) [3] What is the form of the 3 x 3 homography matrix, \( H \), for this special case of 2D translation? Give your answer as a 3 x 3 matrix with letters in positions for unknowns and numbers where a known constant is used.

(b) [3] What is the minimum number of corresponding points between the two images that are needed to estimate \( H \) in this case of a 2D translation?

(c) [4] Give two (2) benefits from incorporating the RANSAC algorithm as part of the computation of \( H \).
   (a) [6] The **Image Quilting** algorithm for texture synthesis iteratively selects and adds texture blocks to a partially-defined output texture image.
   (i) [3] How is a new block selected to add at each iteration?

   (ii) [3] How are seams between adjacent blocks “hidden”?

(b) [3] What additional property/term does the **Criminisi best-first filling algorithm** include to improve on the Image Quilting algorithm? Describe qualitatively; no equation(s) required.
14. [8] **SIFT Descriptor**
   (a) [3] How is the SIFT descriptor made 2D orientation invariant?

(b) [3] Describe how the histogram(s) is (are) constructed for use in the descriptor.

(c) [2] What are the features contained in the descriptor’s feature vector?