Machine Perception Assignment 1

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# Task 1

## Harris Corner Detector

The Harris corner detector [1] is variant under scaling and invariant under rotation. Scale invariance is not achieved since the size or standard deviation of the window function is a fixed parameter of the algorithm; with images of different scale, the window will cover a different size image patch. I expect that the higher the ratio of window size to feature size, the lower the corner response, since the window will include a higher proportion of non-corner pixels. The experimental results are shown in Fig. 1. Interestingly, as the image size increases, the number of corners detected decreases, contrary to my hypothesis. I believe that in the process of upsampling the images, the increase in the size of the edges has reduced the gradient, reducing the corner response. This effect is likely dependent on the resampling method used (preliminary testing with nearest-neighbour resampling indicates different results).

Rotational invariance is achieved because the corner response is calculated based on the eigenvalues of the autocorrelation matrix at a point [2]. These eigenvalues give the magnitudes of curvature of the image surface in the directions of most and least curvature [1]. That is, any rotation present has no effect on the eigenvalues, and therefore no effect on the corner response. The experimental results are shown in Fig. 2; as expected, the same corners are detected regardless of rotation.

The experimental results for the dugong image are similar and may be reproduced using the code in Appendix 1.

## Intensity Histograms

Image histograms are variant under scaling and may be variant under rotation (depending on the rotation). Scaling an image changes its resolution, and since histograms are based on pixel counts, the histogram will be affected. However, for small or moderate changes in scale, the relative ratios of intensities will be retained, i.e. the histogram will have approximately the same “shape” (if normalised histograms are used, then scale invariance is achieved). This is demonstrated in Fig. 3. Notice that the histogram peaks are vastly different, but the overall shape is almost identical.

Histograms may be invariant under rotation, depending on whether the rotation affects the image bounds. Typically, histograms are calculated across an image or bounding box, the content of which will change under most rotations (consider the 45-degree rotation of an entire image – some regions are cut off, and empty regions are introduced). If we apply a rotation but adjust the bounds within which we calculate the histogram accordingly, then the histogram will be approximately unchanged. The experimental results are shown in Fig. 4. A fixed bounding box was selected, with the image rotates with respect to it. The image content inside the box did change, but since the background (ocean) is mostly homogeneous, the histograms are similar.

The experimental results for the playing card image are similar and may be reproduced using the code in Appendix 1.

|  |  |  |
| --- | --- | --- |
| **Rotation** | **Keypoints** | **Keypoints common with 0°** |
| 0° | 16 | 16 |
| 15° | 16 | 12 |
| 45° | 16 | 11 |
| 75° | 15 | 10 |

|  |  |  |
| --- | --- | --- |
| **Scale** | **Keypoints** | **Keypoints common with 1x** |
| 1x | 16 | 16 |
| 1.25x | 25 | 13 |
| 1.5x | 32 | 16 |
| 2x | 45 | 16 |

## Scale-invariant Feature Transform (SIFT) keypoints

SIFT [3, 4] keypoints are moderately invariant under small to moderate scaling and rotation. Scale invariance is achieved by examining the image at many scales (via Gaussian filtering and image downsampling), transforming the image into “scale space” [3, 4]. Keypoints are detected within this scale space, yielding not only the keypoint’s location in the image, but also the scale at which the keypoint exists [3, 4]. Further processing of the keypoint is adjusted for this scale, producing keypoints which are largely invariant to scale [3, 4]. The experimental results are summarised in Fig. 5. As the image size increases, the number of keypoints detected increases (presumably since there are simply more pixels in the image), but a significant proportion of them match the keypoints in the original image region. The match proportions upwards of 80% for small scaling factors coincides with the results presented in [3].

Rotational invariance is (theoretically) achieved since keypoint detection only considers the magnitude of the difference of Gaussians (which is isotropic) [3, 4]. The experimental results are summarised in Fig. 6. Surprisingly, only about 65-75% of keypoints from the original image region are present in the rotated versions. My only explanation as to why such a large proportion of keypoints did not match is that it is as a result of the image resampling during rotation, especially given that the image region is small, however, I am unsure. It seems plausible that a more complex explanation exists, due to the many steps in the SIFT algorithm.

The keypoint-annotated images are omitted for brevity but may be reproduced using the code in Appendix 1. The experimental results for the playing card image are similar and may be reproduced using the same code.

# Task 2

## Local Binary Patterns (LBP)

TODO

## Scale-invariant Feature Transform (SIFT)

TODO

## Histogram of Oriented Gradients (HOG)

TODO

## Comparison of SIFT and HOG Descriptors

TODO

# Prepare Your Paper Before Styling

Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sections A-D below for more information on proofreading, spelling and grammar.

Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

## Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

## Units

* Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
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* Do not mix complete spellings and abbreviations of units: “Wb/m2” or “webers per square meter”, not “webers/m2”. Spell out units when they appear in text: “. . . a few henries”, not “. . . a few H”.
* Use a zero before decimal points: “0.25”, not “.25”. Use “cm3”, not “cc”. (*bullet list*)

## Equations

The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please no other font). To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

Number equations consecutively. Equation numbers, within parentheses, are to position flush right, as in (1), using a right tab stop. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

*a**b* 

Note that the equation is centered using a center tab stop. Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(1)”, not “Eq. (1)” or “equation (1)”, except at the beginning of a sentence: “Equation (1) is . . .”

## Some Common Mistakes

* The word “data” is plural, not singular.
* The subscript for the permeability of vacuum **0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
* In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
* A graph within a graph is an “inset”, not an “insert”. The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).
* Do not use the word “essentially” to mean “approximately” or “effectively”.
* In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.
* Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
* Do not confuse “imply” and “infer”.
* The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
* There is no period after the “et” in the Latin abbreviation “et al.”.
* The abbreviation “i.e.” means “that is”, and the abbreviation “e.g.” means “for example”.

An excellent style manual for science writers is [7].

# Using the Template

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**The template is designed for, but not limited to, six authors.** A minimum of one author is required for all conference articles. Author names should be listed starting from left to right and then moving down to the next line. This is the author sequence that will be used in future citations and by indexing services. Names should not be listed in columns nor group by affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization).

### For papers with more than six authors: Add author names horizontally, moving to a third row if needed for more than 8 authors.

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Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is “Heading 5”. Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract”, will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced. Styles named “Heading 1”, “Heading 2”, “Heading 3”, and “Heading 4” are prescribed.

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#### Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation “Fig. 1”, even at the beginning of a sentence.

1. Table Type Styles

| Table Head | Table Column Head | | |
| --- | --- | --- | --- |
| Table column subhead | Subhead | Subhead |
| copy | More table copya |  |  |

1. Sample of a Table footnote. (*Table footnote*)
2. Example of a figure caption. (*figure caption*)

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity “Magnetization”, or “Magnetization, M”, not just “M”. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write “Magnetization (A/m)” or “Magnetization {A[m(1)]}”, not just “A/m”. Do not label axes with a ratio of quantities and units. For example, write “Temperature (K)”, not “Temperature/K”.

##### Acknowledgment *(Heading 5)*

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

##### References

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Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the abstract or reference list. Use letters for table footnotes.

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For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

1. G. Eason, B. Noble, and I. N. Sneddon, “On certain integrals of Lipschitz-Hankel type involving products of Bessel functions,” Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. *(references)*
2. J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
3. I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
4. K. Elissa, “Title of paper if known,” unpublished.
5. R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.
6. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
7. M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.

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##### References

[1] C. Harris and M. Stephens, “A combined corner and edge detector,” *Alvey Vision Conference*, vol. 15, no. 50, pp. 147-151, 1988.

[2] R. Szeliski, *Computer Vision: Algorithms and Applications*, 2nd ed. Accessed Sep. 14, 2020. [Online]. Available: http://szeliski.org/Book.

[3] D. G. Lowe, “Object recognition from local scale-invariant features,” in *Proceedings of the Seventh IEEE International Conference on Computer Vision*, 1999, pp. 1150-1157 vol.2, doi: 10.1109/ICCV.1999.790410.

[4] D. G. Lowe, “Distinctive image features from scale-invariant keypoints,” *International Journal of Computer Vision*, vol. 60, no. 2, pp. 91-110. Nov. 2004, doi: 10.1023/B:VISI.0000029664.99615.94.