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.

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*a**b* 

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## 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.)
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* Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
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* There is no period after the “et” in the Latin abbreviation “et al.”.
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1. Table Type Styles

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

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##### References

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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.