Feature Extraction and Matching

Sharif Anani
South Dakota School of Mines & Technology
Rapid City, South Dakota, SD
sharif.anani@mines.sdsmt.edu

Abstract

In this project paper, an attempt is made at extracting corner features from an image and matching them with others in an image showing a similar scene. The project relies on Harris corners for the features and operates on the feature patches to make them invariant to rotation and increase their invariance to illumination. Section 1 introduces the general project, section 2 shows the steps taken to execute the algorithm, section 3 shows results and discusses their success, sections 4, 5, and 6 analyse, conclude, and discuss future improvement.

1. Introduction

Finding good features in an image is an ongoing problem in the field of Computer Vision. It is very important to find the good features that are repeatable in multiple types of scenes, and at the same easy enough to distinguish from other features in an image. The features chosen for this project are Harris corners, found using the Harris response (discussed later in the paper).

1.1. Background

Before discussing how the corners are found, need to know how corners are respresented in a digital image in order to be able to identify them. In a gray scale image, edges are transitions from light values to dark values (i.e. 255 to 0 for a uint8 image). We can think about corners the same way; corners are generally a transition from dark to light(or vice versa). Knowing this, we know that edges will show on the gradient of the image (the vector containing its directional derivatives).
The problem with stopping at the gradient is that edges also show up as high values in the gradient image, so we need a method to differentiate between edges and corners in a gradient image, and this is where the Harris response comes into play.

1.2. Edges Vs. Corners

The harris corner detector can be considered as a "combined corner and edge detector". The basic idea of operation is simple: taking a small window over the image, we can distinguish corners and edges from flat surfaces by looking at the changes in intensity as we move the window in all the directions. If the intensity changes significantly when moving in one direction, but not the other, then we have an edge. If intensity changes significantly in all directions, then we have a corner.

1.3. The mathematics

As mentioned before, the Harris detector works with directions and changes in intensity. To quantify these changes, Harris and Stephens looked at this change using the response operator:

$$R = det(M) - k * trace(M) \tag{1}$$

Where

$$M = \sum_{x,y} w(x,y) \begin{bmatrix} I_{xx} & I_{xy} \\ I_{xy} & I_{yy} \end{bmatrix}$$

and $w(x,y)$ is a window function - in our case, Gaussian - and k is empirically measured to be between 0.04 and 0.06.

2. Algorithm Development

The solution developed for this project is a simple algorithmic program running through simple stages.
The first step is preconditioning the image: the image is read into MATLAB, converted to grayscale, and then run through histogram equalization; histogram equalization will create better repeatable illumination conditions across different shots of the same scene, and this helps the detector be invariant to more factors. The image is then normalized by subtracting the mean and dividing by the standard deviation.
The second step is detecting the features: the result of the first few operations is passed into

cornerDetection.m, a function created to calculate and threshold the harris response. The function is available on https://github.com/sharifanani/ComputerVisionF15.
in cornerDetection.m, the gradients are calculated along with the Harris response. The Harris response is then subjected to a threshold and finally non-maximum suppression. Non-maximum suppression is applied in one of two ways:
The first method of non-maximum suppression goes through every pixel that is seen as a corner and then loops through the whole image checking for pixels that are corners and are within a 10 pixel radius. If the pixel response value is higher than that of the pivot pixel, it is left alone, otherwise, it is set as zero.
The other method is faster and uses MATLAB's blockproc function, and finds the maximum in every block. The second method does not work as good because the blocks do not overlap, so pixels at the boundaries can be local maxima in other blocks, but they are being brought down to zero earlier. However, it is much faster than the first method.

The following block of code shows non-maximum suppression for the blockproc approach:

```
supp =@(block_struct) suppressNonMax(
    double(block_struct.data));

J2 = blockproc(R,[45 45],supp);

[rows,cols]=find(J2 == 1);%return
    locations of corners
```

Where suppressNonMax.m is a simple function that returns a matrix where the maximum element of a black is set to 1 and the rest are set to 0:

```
function [B] = suppressNonMax( I )
Z = zeros(size(I));
[row,col] = find(I == max(I(:)));
Z(row,col) = 1/max(I(:));
B = I.*Z;
end
```

2.1. Mathematics

Please number all of your sections and displayed equations. It is important for readers to be able to refer to any particular equation. Just because you didn't refer to it in the text doesn't mean some future reader might not need to refer to it. It is cumbersome to have to use circumlocutions like "the equation second from the top of page 3 column 1". (Note that the ruler will not be present in the final copy, so is not an alternative to equation numbers). All authors will benefit from reading Mermin's description of how to write mathematics: http://www.pamitc.org/documents/mermin.pdf.

2.2. Blind review

Many authors misunderstand the concept of anonymizing for blind review. Blind review does not mean that one must remove citations to one's own work—in fact it is often impossible to review a paper unless the previous citations are known and available.

Blind review means that you do not use the words "my" or "our" when citing previous work. That is all. (But see below for techreports.)

Saying "this builds on the work of Lucy Smith [1]" does not say that you are Lucy Smith; it says that you are building on her work. If you are Smith and Jones, do not say "as we show in [7]", say "as Smith and Jones show in [7]" and at the end of the paper, include reference 7 as you would any other cited work.

An example of a bad paper just asking to be rejected:

> An analysis of the frobnicatable foo filter.
>
> In this paper we present a performance analysis of our previous paper [1], and show it to be inferior to all previously known methods. Why the previous paper was accepted without this analysis is beyond me.
>
> [1] Removed for blind review

An example of an acceptable paper:

> An analysis of the frobnicatable foo filter.
>
> In this paper we present a performance analysis of the paper of Smith *et al*. [1], and show it to be inferior to all previously known methods. Why the previous paper was accepted without this analysis is beyond me.
>
> [1] Smith, L and Jones, C. "The frobnicatable foo filter, a fundamental contribution to human knowledge". Nature 381(12), 1-213.

If you are making a submission to another conference at the same time, which covers similar or overlapping material, you may need to refer to that submission in order to explain the differences, just as you would if you had previously published related work. In such cases, include the anonymized parallel submission [**?**] as additional material and cite it as

> [1] Authors. "The frobnicatable foo filter", F&G 2014 Submission ID 324, Supplied as additional material fg324.pdf.

Finally, you may feel you need to tell the reader that more details can be found elsewhere, and refer them to a technical report. For conference submissions, the paper must stand on its own, and not *require* the reviewer to go

to a techreport for further details. Thus, you may say in the body of the paper "further details may be found in [**?**]". Then submit the techreport as additional material. Again, you may not assume the reviewers will read this material.

Sometimes your paper is about a problem which you tested using a tool which is widely known to be restricted to a single institution. For example, let's say it's 1969, you have solved a key problem on the Apollo lander, and you believe that the CVPR70 audience would like to hear about your solution. The work is a development of your celebrated 1968 paper entitled "Zero-g frobnication: How being the only people in the world with access to the Apollo lander source code makes us a wow at parties", by Zeus *et al*.

You can handle this paper like any other. Don't write "We show how to improve our previous work [Anonymous, 1968]. This time we tested the algorithm on a lunar lander [name of lander removed for blind review]". That would be silly, and would immediately identify the authors. Instead write the following:

> We describe a system for zero-g frobnication. This system is new because it handles the following cases: A, B. Previous systems [Zeus et al. 1968] didn't handle case B properly. Ours handles it by including a foo term in the bar integral.
>
> ...
>
> The proposed system was integrated with the Apollo lunar lander, and went all the way to the moon, don't you know. It displayed the following behaviours which show how well we solved cases A and B: ...

As you can see, the above text follows standard scientific convention, reads better than the first version, and does not explicitly name you as the authors. A reviewer might think it likely that the new paper was written by Zeus *et al*., but cannot make any decision based on that guess. He or she would have to be sure that no other authors could have been contracted to solve problem B.

FAQ: Are acknowledgements OK? No. Leave them for the final copy.

2.3. Miscellaneous

Compare the following:

`$conf_a$`	$conf_a$
`$\mathit{conf}_a$`	conf_a

See The TEXbook, p165.

The space after *e.g*., meaning "for example", should not be a sentence-ending space. So *e.g*. is correct, *e.g.* is not. The provided `\eg` macro takes care of this.

When citing a multi-author paper, you may save space by using "et alia", shortened to "*et al*." (not "*et. al.*" as "*et*" is a complete word.) However, use it only when there are three or more authors. Thus, the following is correct: " Frobnication has been trendy lately. It was introduced by Alpher [**?**], and subsequently developed by Alpher and Fotheringham-Smythe [**?**], and Alpher *et al*. [**?**]."

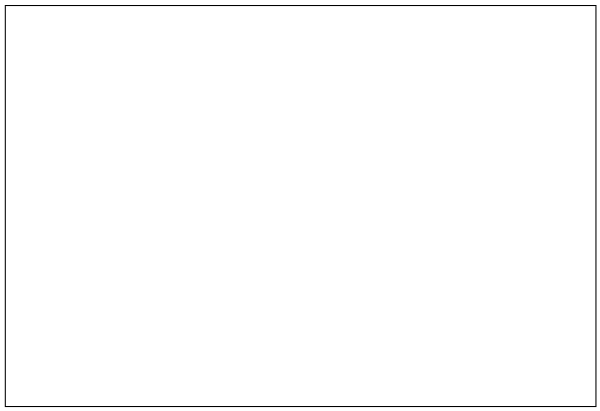

Figure 1. Example of caption. It is set in Roman so that mathematics (always set in Roman: $B \sin A = A \sin B$) may be included without an ugly clash.

This is incorrect: "... subsequently developed by Alpher *et al*. [**?**] ..." because reference [**?**] has just two authors. If you use the `\etal` macro provided, then you need not worry about double periods when used at the end of a sentence as in Alpher *et al*.

For this citation style, keep multiple citations in numerical (not chronological) order, so prefer [**?**, **?**, **?**] to [**?**, **?**, **?**].

3. Formatting your paper

All text must be in a two-column format. The total allowable width of the text area is $6\frac{7}{8}$ inches (17.5 cm) wide by $8\frac{7}{8}$ inches (22.54 cm) high. Columns are to be $3\frac{1}{4}$ inches (8.25 cm) wide, with a $\frac{5}{16}$ inch (0.8 cm) space between them. The main title (on the first page) should begin 1.0 inch (2.54 cm) from the top edge of the page. The second and following pages should begin 1.0 inch (2.54 cm) from the top edge. On all pages, the bottom margin should be 1-1/8 inches (2.86 cm) from the bottom edge of the page for 8.5×11-inch paper; for A4 paper, approximately 1-5/8 inches (4.13 cm) from the bottom edge of the page.

3.1. Margins and page numbering

All printed material, including text, illustrations, and charts, must be kept within a print area 6-7/8 inches (17.5 cm) wide by 8-7/8 inches (22.54 cm) high. Page numbers should be in footer with page numbers, centered and .75 inches from the bottom of the page and make it start at the correct page number rather than the 4321 in the example. To do this fine the line (around line 23)

```
%\ifcvprfinal\pagestyle{empty}\fi
\setcounter{page}{4321}
```

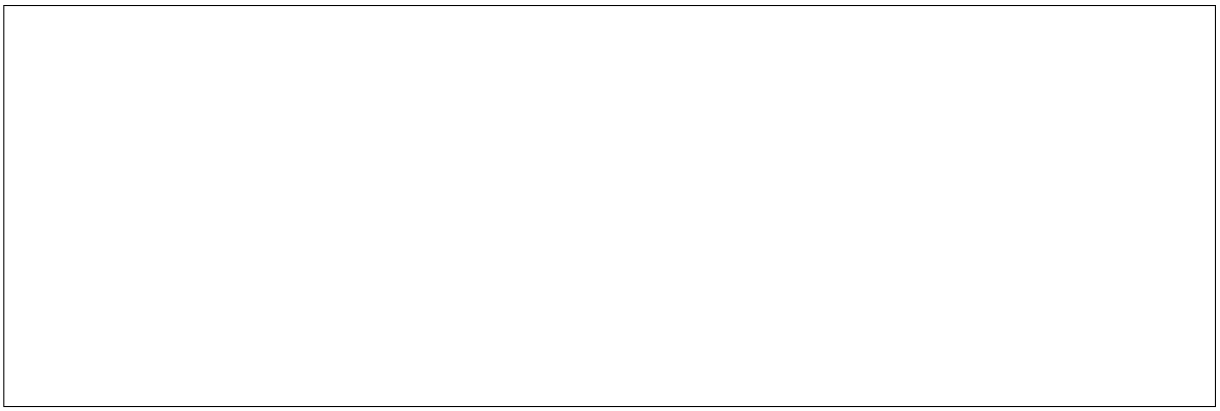

Figure 2. Example of a short caption, which should be centered.

where the number 4321 is your assigned starting page.

Make sure the first page is numbered by commenting out the first page being empty on line 46

```
%\thispagestyle{empty}
```

3.2. Type-style and fonts

Wherever Times is specified, Times Roman may also be used. If neither is available on your word processor, please use the font closest in appearance to Times to which you have access.

MAIN TITLE. Center the title 1-3/8 inches (3.49 cm) from the top edge of the first page. The title should be in Times 14-point, boldface type. Capitalize the first letter of nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, or prepositions (unless the title begins with such a word). Leave two blank lines after the title.

AUTHOR NAME(s) and AFFILIATION(s) are to be centered beneath the title and printed in Times 12-point, non-boldface type. This information is to be followed by two blank lines.

The ABSTRACT and MAIN TEXT are to be in a two-column format.

MAIN TEXT. Type main text in 10-point Times, single-spaced. Do NOT use double-spacing. All paragraphs should be indented 1 pica (approx. 1/6 inch or 0.422 cm). Make sure your text is fully justified—that is, flush left and flush right. Please do not place any additional blank lines between paragraphs.

Figure and table captions should be 9-point Roman type as in Figures **??** and **??**. Short captions should be centred.

Callouts should be 9-point Helvetica, non-boldface type. Initially capitalize only the first word of section titles and first-, second-, and third-order headings.

FIRST-ORDER HEADINGS. (For example, **1. Introduction**) should be Times 12-point boldface, initially capitalized, flush left, with one blank line before, and one blank line after.

Method	Frobnability
Theirs	Frumpy
Yours	Frobbly
Ours	Makes one's heart Frob

Table 1. Results. Ours is better.

SECOND-ORDER HEADINGS. (For example, **1.1. Database elements**) should be Times 11-point boldface, initially capitalized, flush left, with one blank line before, and one after. If you require a third-order heading (we discourage it), use 10-point Times, boldface, initially capitalized, flush left, preceded by one blank line, followed by a period and your text on the same line.

3.3. Footnotes

Please use footnotes[1] sparingly. Indeed, try to avoid footnotes altogether and include necessary peripheral observations in the text (within parentheses, if you prefer, as in this sentence). If you wish to use a footnote, place it at the bottom of the column on the page on which it is referenced. Use Times 8-point type, single-spaced.

3.4. References

List and number all bibliographical references in 9-point Times, single-spaced, at the end of your paper. When referenced in the text, enclose the citation number in square brackets, for example [**?**]. Where appropriate, include the name(s) of editors of referenced books.

3.5. Illustrations, graphs, and photographs

All graphics should be centered. Please ensure that any point you wish to make is resolvable in a printed copy of

[1] This is what a footnote looks like. It often distracts the reader from the main flow of the argument.

the paper. Resize fonts in figures to match the font in the body text, and choose line widths which render effectively in print. Many readers (and reviewers), even of an electronic copy, will choose to print your paper in order to read it. You cannot insist that they do otherwise, and therefore must not assume that they can zoom in to see tiny details on a graphic.

When placing figures in LaTeX, it's almost always best to use `\includegraphics`, and to specify the figure width as a multiple of the line width as in the example below

```
\usepackage[dvips]{graphicx} ...
\includegraphics[width=0.8\linewidth]
                {myfile.eps}
```

3.6. Color

Please refer to the author guidelines on the CVPR 2015 web page for a discussion of the use of color in your document.

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