MLCV Coursework 1 Report

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1. Eigenfaces

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1.1. Eigenfaces

All manuscripts must be in English.

1.2. Application of Eigenfaces

Please refer to the author guidelines on the web page for a discussion of the policy on dual submissions.

2. Incremental PCA

Please follow the steps outlined below when submitting your manuscript to the IEEE Computer Society Press. This style guide now has several important modifications (for example, you are no longer warned against the use of sticky tape to attach your artwork to the paper), so all authors should read this new version.

2.1. Important parameter in implementation: d_3

To implement incremental PCA, we utilized the algorithm from the "Online Learning" slides presented in class. Here, a key parameter is d_2 and d_3). When new data arrives in incremental PCA, computing the eigenspace model for this subset requires $O(\min(D, N')^3)$ time, where N' is the number of data points in the subset. Additionally, merging this new eigenspace model with the existing data takes $O((d_1 + d_2 + 1)^3)$ time, where d_1 is equal to the previously computed eigenspace model's d_3 value. Therefore, to enhance time efficiency in incremental PCA, it is essential to keep d_3 small, although this results in a time-accuracy tradeoff by dropping less-significant eigenvector information, which is represented by our experiment result **??**

2.2. Comparison with other PCA

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3. LDA Ensemble for Face Recognition

PCA can effectively reduce the dimension of input data preserving important features. And LDA can maximize the variance of between-class while minimize between-class. Thus, using PCA-LDA is expected to increase computing efficiency and classification accuracy. In this section, we try to figure out the effect of PCA-LDA via some experiments.

3.1. Recognition accuracy of PCA-LDA

To implement PCA-LDA, we have to set M_{pca} and M_{lda} to determine projection dimensions of each of PCA and LDA. For best performance of the PCA-LDA model, we measure the accuracy of classification varying M_{pca} from 1 to 415 and M_{lda} from 1 to $min(M_{pca} - 1, 51)$. This is because, the maximum possible projection dimension for PCA is $(the\ total\ number\ of\ data) - 1$ since the total number of principal components can not be larger than overall data, and for LDA is $(the\ total\ number\ of\ classes) - 1$ since the number of direction for maximizing the distance of between-class anc minimizing within-class cannot be larger than the total number of classes. As we can see in Fig. 1, the accuracy was highest when $M_{pca} = 150$ and $M_{lda} = 50$ and decreases further away from this point. To be specific, the larger M_{lda}, the better performance. This is because, large M_{lda} helps to get more discriminative data. And for M_{pca}, the performance is highest when $M_{pca} = 100 - 200$. This is because, values smaller than this may ignore too much important information while values larger than this risk overfitting.

In addition, for LDA, the rank of within-class scatter matrix(S_w) is $min(364, M_{pca})$ where $N - n_{class} = 416 - 52 = 364$ and the rank of between-class scatter matrix(S_b) is $n_{class} - 1 = 51$. For the former, it is because, since $\sum_{x \in D_i}(x - m_i) = 0$, thus each class is linearly dependent, so $S_w = \sum_{i=1}^{c}\sum_{x \in D_i}(x - m_i)(x - m_i)^T$, can have at most $N - n_{class}$ linearly independent row vector. If we reduce the

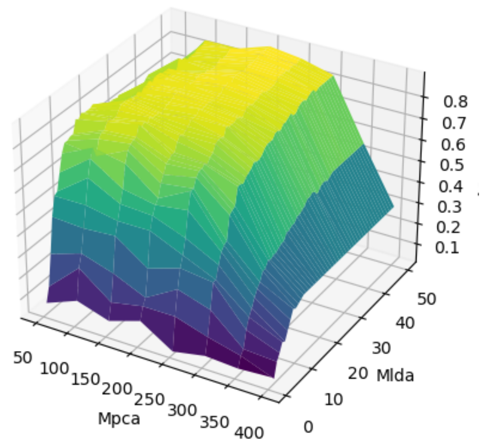


Figure 1. Classification accuracy varying Mpca and Mlda

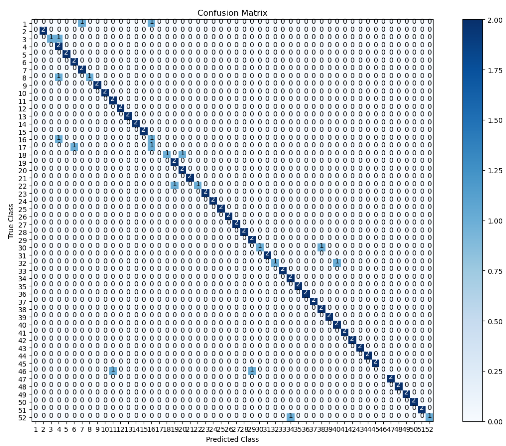


Figure 2. Classification accuracy varying Mpca and Mlda

dimension using PCA, the rank of S_w can not exceed M_{pca} since vectors are placed in PCA projection space. Next for the latter, since $S_b = \sum_{i=1}^{c}(m_i - m)(m_i - m)^T$, it only affected by class mean. Because the relationship of class mean does not change after PCA projection since it is linear transformation, and for the same linearly dependent relation as S_w, the maximum possible value for S_b is $N - n_{class}$

Based on this observation, we decided to fix $M_{pca} = 150$ and $M_{lda} = 50$ for further experiments.

3.2. Result of PCA-LDA

Fig. 2 is the confusion matrix of PCA-LDA classification result. As most of prediction result is on the diagonal entry, it indicates that most of prediction is successful. We take a closer look at success and failure cases. Fig. 3 shows successfully predicted cases. Despite the different angles of the faces, the model infer the class accurately. Fig. 4 is failure cases. It seems that the prediction failed because of the similar glasses and face expression.

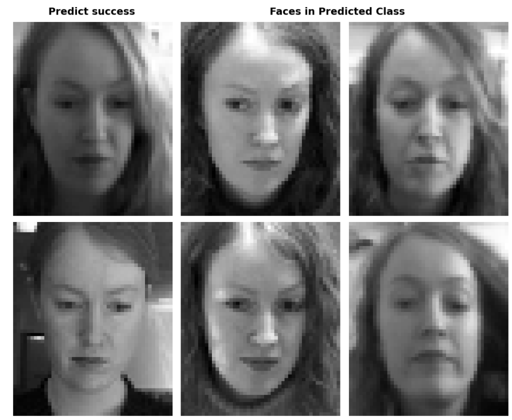


Figure 3. Classification accuracy varying Mpca and Mlda

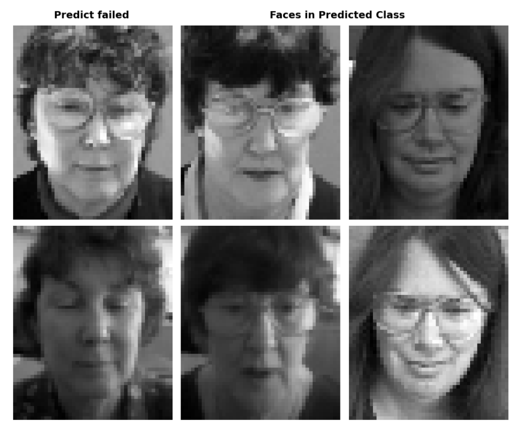


Figure 4. Classification accuracy varying Mpca and Mlda

3.3. Time and Memory

Comparison btw pca/pca-lda (accuracy), lda/pca-lda(time), pca/lda/pca-lda(memory)

3.4. PCA-LDA Ensemble

For PCA-LDA Ensemble model, we combined two different types of models. The first type is randomization in feature space, which select vectors for pca projection randomly by a certain percentage. The second type is randomization in data sampling, which randomly subsampling the train data by a certain percentage. Both models were used in equal numbers. For combining prediction results of each models, we used 'majority voting' among various fusion rules. This is because, since our task is predicting class for classification and each classes don't have special meaning in numeric value, majority voting looks the most reasonable compared to other methods like averaging and finding maximum.

3.5. Randomization

randomization in feature space (m0) randomization in data samples (subset_rate) randomization in model number (model_num) randomness parameter

3.6. Result of PCA-LDA Ensemble

error (committee machine, individual models) accuracy, confusion matrix

4. Introduction

Please follow the steps outlined below when submitting your manuscript to the IEEE Computer Society Press. This style guide now has several important modifications (for example, you are no longer warned against the use of sticky tape to attach your artwork to the paper), so all authors should read this new version.

4.1. Language

All manuscripts must be in English.

4.2. Dual submission

Please refer to the author guidelines on the web page for a discussion of the policy on dual submissions.

4.3. Paper length

Papers, excluding the references section, must be no longer than eight pages in length. The references section will not be included in the page count, and there is no limit on the length of the references section. For example, a paper of eight pages with two pages of references would have a total length of 10 pages. **There will be no extra page charges for .**

Overlength papers will simply not be reviewed. This includes papers where the margins and formatting are deemed to have been significantly altered from those laid down by this style guide. Note that this LaTeX guide already sets figure captions and references in a smaller font. The reason such papers will not be reviewed is that there is no provision for supervised revisions of manuscripts. The reviewing process cannot determine the suitability of the paper for presentation in eight pages if it is reviewed in eleven.

4.4. The ruler

The LaTeX style defines a printed ruler which should be present in the version submitted for review. The ruler is provided in order that reviewers may comment on particular lines in the paper without circumlocution. If you are preparing a document using a non-LaTeX document preparation system, please arrange for an equivalent ruler to appear on the final output pages. The presence or absence of the ruler should not change the appearance of any other content on the page. The camera-ready copy should not contain a ruler. (LaTeX users may use options of `cvpr.sty` to switch between different versions.)

Reviewers: note that the ruler measurements do not align well with lines in the paper — this turns out to be very difficult to do well when the paper contains many figures and equations, and, when done, looks ugly. Just use fractional references (*e.g.*, this line is 087.5), although in most cases one would expect that the approximate location will be adequate.

4.5. Paper ID

Make sure that the Paper ID from the submission system is visible in the version submitted for review (replacing the "*****" you see in this document). If you are using the LaTeX template, **make sure to update paper ID in the appropriate place in the tex file**.

4.6. Mathematics

Please number all of your sections and displayed equations as in these examples:

$$E = m \cdot c^2 \tag{1}$$

and

$$v = a \cdot t. \tag{2}$$

It is important for readers to be able to refer to any particular equation. Just because you did not refer to it in the text does not 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`.

4.7. 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 tech reports.)

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 supplemental material and cite it as

[1] Authors. "The frobnicatable foo filter", F&G 2014 Submission ID 324, Supplied as supplemental 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 tech report for further details. Thus, you may say in the body of the paper "further details may be found in [**?**]". Then submit the tech report as supplemental 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 that 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 1970 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. Do not 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] did not 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

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

Q: How do I cite my results reported in open challenges?
A: To conform with the double-blind review policy, you can report results of other challenge participants together with your results in your paper. For your results, however, you should not identify yourself and should not mention your participation in the challenge. Instead present your results referring to the method proposed in your paper and draw conclusions based on the experimental comparison to other results.

4.8. 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). 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*. 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

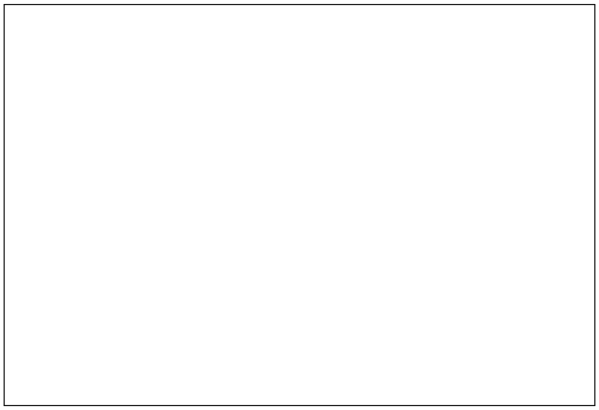


Figure 5. Example of caption. It is set in Roman so that mathematics (always set in Roman: $B \sin A = A \sin B$) may be included without an ugly clash.

by Alpher and Fotheringham-Smythe [**?**], and Alpher *et al*. [**?**]."

This is incorrect: "... subsequently developed by Alpher *et al*. [**?**] ..." because reference [**?**] has just two authors.

5. Formatting your paper

All text must be in a two-column format. The total allowable size of the text area is $6\frac{7}{8}$ inches (17.46 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 inch (2.54 cm) from the top edge of the page. The second and following pages should begin 1 inch (2.54 cm) from the top edge. On all pages, the bottom margin should be $1\frac{1}{8}$ inches (2.86 cm) from the bottom edge of the page for 8.5×11-inch paper; for A4 paper, approximately $1\frac{5}{8}$ inches (4.13 cm) from the bottom edge of the page.

5.1. Margins and page numbering

All printed material, including text, illustrations, and charts, must be kept within a print area $6\frac{7}{8}$ inches (17.46 cm) wide by $8\frac{7}{8}$ inches (22.54 cm) high. Page numbers should be in the footer, centered and $\frac{3}{4}$ inches from the bottom of the page. The review version should have page numbers, yet the final version submitted as camera ready should not show any page numbers. The LaTeX template takes care of this when used properly.

5.2. 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 $1\frac{3}{8}$ 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. $\frac{1}{6}$ 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 Figs. 5 and 6. 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.

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.

5.3. 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.

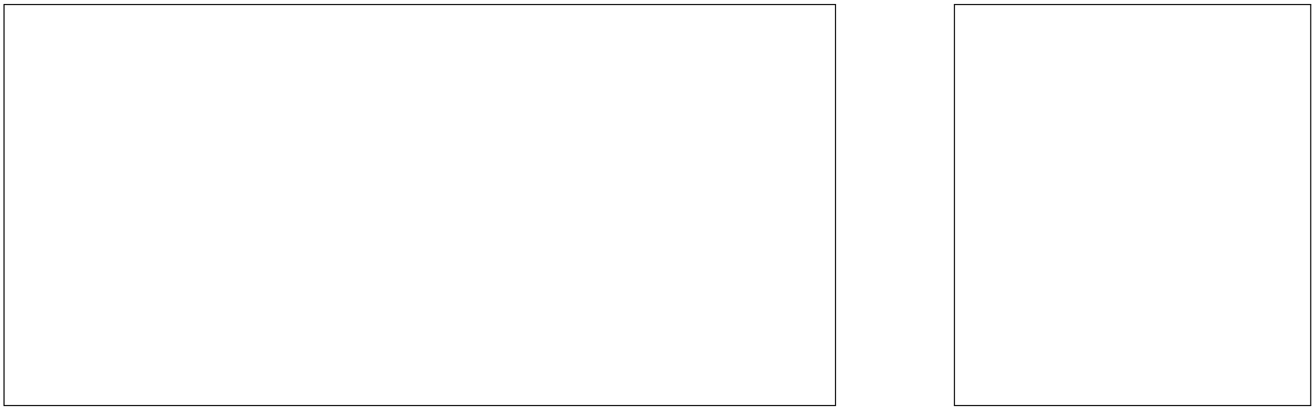
5.4. Cross-references

For the benefit of author(s) and readers, please use the

```
\cref{...}
```

command for cross-referencing to figures, tables, equations, or sections. This will automatically insert the appropriate label alongside the cross-reference as in this example:

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



(a) An example of a subfigure. (b) Another example of a subfigure.

Figure 6. Example of a short caption, which should be centered.

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

Table 1. Results. Ours is better.

> To see how our method outperforms previous work, please see Fig. 5 and Tab. 1. It is also possible to refer to multiple targets as once, *e.g*. to Figs. 5 and 6a. You may also return to Sec. 5 or look at Eq. (2).

If you do not wish to abbreviate the label, for example at the beginning of the sentence, you can use the

```
\Cref{...}
```

command. Here is an example:

> Figure 5 is also quite important.

5.5. 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 page numbers and the name(s) of editors of referenced books. When you cite multiple papers at once, please make sure that you cite them in numerical order like this [**? ? ? ? ?**]. If you use the template as advised, this will be taken care of automatically.

5.6. Illustrations, graphs, and photographs

All graphics should be centered. In LaTeX, avoid using the `center` environment for this purpose, as this adds potentially unwanted whitespace. Instead use

```
\centering
```

at the beginning of your figure. Please ensure that any point you wish to make is resolvable in a printed copy of the paper. Resize fonts in figures to match the font in the body text, and choose line widths that render effectively in print. Readers (and reviewers), even of an electronic copy, may 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{graphicx} ...
\includegraphics[width=0.8\linewidth]
                {myfile.pdf}
```

5.7. Color

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

If you use color in your plots, please keep in mind that a significant subset of reviewers and readers may have a color vision deficiency; red-green blindness is the most frequent kind. Hence avoid relying only on color as the discriminative feature in plots (such as red *vs*. green lines), but add a second discriminative feature to ease disambiguation.

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