Museum paintings retrieval and people detection

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Abstract

Image processing, retrieval and people detection are important computer vision applications. Here we present our work on the "Galleria Estense" dataset which contains videos and images from the "Galleria Estense" of Modena. We propose a method to detect and retrieve the paintings, the statues and the people in the museum based on different approaches: one with pure image processing and one with YOLOv3 network, trained with a custom annotated dataset of paintings and statues images.

1. Introduction

We have tackled the problem of detect paintings, statues and people in a museum (the Galleria Estense). Our objectives were: rectify the paintings correcting the perspective distortions, retrieve the correct paintings in the dataset, provide a precise segmentation of both detected paintings and statues, sum up all the information we had and link the paintings and the people to a precise room in the museum. In order to achive our results, as further discussed in section 3, many techniques are involved: image processing topics as edge detection, connected components analysis, relevant ROI detection, object segmentation; image retrieval; deep learning and neural networks.

1.1. The dataset

The dataset contains videos and images from the "Galleria Estense" of Modena.

We have 208 short videos taken using different cameras, aspect ratios and resolutions. Some video was taken with a GoPro camera which introduced some distortion and some video has frames particularly blurred due to the motion applied to the camera.

We have a database of 95 images that should represents all paintings of the "Galleria Estense", but during the development of the project we realized that many paintings were missing and so we had to expand the paintings db adding some paintings taken from the "Galleria Estense" website to improve the retrival and rectification tasks. We added 23 paintings that are named with a fixed suffix "A" followed by a zero-based sequential identifier, *e.g.* "A000.jpeg".

Finally the dataset contains also a CSV file with informations for every painting present in the db, including the position of the painting in the museum as a room number, and also an image representing the plant of the museum to do the people detection task. When we expanded the painting db we expanded the CSV file accordingly to maintain consistency.

2. Related works

To detect the paintings and statues in the museum we trained a YOLOv3 network with our custom annotated dataset. YOLO (acronym for "You Only Look Once") is an object detection network able to detect objects in images parsing the image only once, saving computation time w.r.t. other detection networks, however maintaining a good degree of precision. We choosed YOLOv3 because it can achieve good performaces both in terms of detection and speed as described in YOLOv3 paper:

[?]

After the detection with YOLOv3, we used GrabCut algorithm for segmentation. GrabCut is an algorithm used for foreground extraction with minimal user interaction. User should inputs the rectangle which border the object of interest: everything outside this rectangle is considered sure background, while everything inside the rectangle may be both foreground or background. This minimal user interaction required by GrabCut is reduced to zero in our case, because, in the case of statues, YOLOv3 network inputs the rectangle, while in the case of painting the input ROIs are the one detected in the Painting Detection.

> [2] C. Rother, V. Kolmogorov, A. Blake. GrabCut: Interactive Foreground Extraction using Iterated Graph Cuts. ACM Transactions on Graphics (SIGGRAPH'04), 2004.

3. Approach

The proposed approach involve several elements: Painting detection, Painting retrieval, Painting rectification, People detection and Statue detection.

3.1. Painting Detection

The first thing to do in order to detect relevant objects is to perform edge detection, but right before we have precessed the image with a gaussian filter in order to remove the gaussian noise and a bilateral filter. A good method to detect relevant edges is the Canny algorithm. It has been proposed with the following empirically determined thresholds

Thresholds	
Low	High
400	400

Table 1: Canny thresholds

with a Sobel operator with aperture of 5. With low threshold and high threshold set to an equal value, we don't accept weak edges, even if connected with strong edges.

The next step is to perform a Dilation 3x3 followed by an Erosion (Closing), in order to connect the edges of the same relevant object, and to detect the connected components in the output image thus obtaining a list of ROIs. In order to discard unrelevant ROIs, we have set some rules that have to be satisfied in order to be considered a relevant ROI:

$$ratio_{ROI} = \frac{max(width_{ROI}, height_{ROI})}{min(width_{ROI}, height_{ROI})} < 3 \quad (1)$$

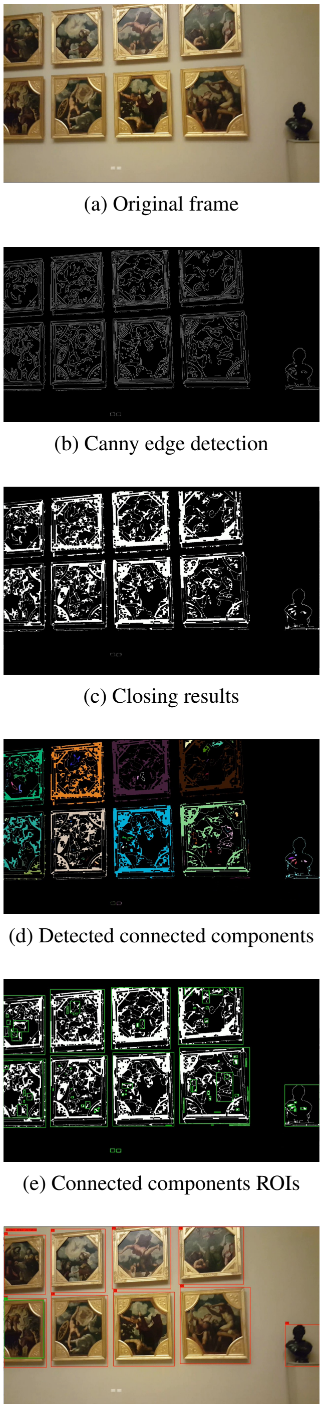
$$area_{ROI} > 0.015 \cdot area_{frame} \quad (2)$$

$$max\_overlap = 0.8 \quad (3)$$

If the overlap is greater than the threshold, the bigger ROI survives.

We then propose an optional optimization, named **otsu_optimization** and activated with the `otsu_opt_enabled` flag set to True,

$$otsu\_th(ROI) > 1.3 \cdot otsu\_th(frame) \quad (4)$$



(a) Original frame

(b) Canny edge detection

(c) Closing results

(d) Detected connected components

(e) Connected components ROIs

(f) Relevant ROIs; in green the discarded ROIs due to the overlap

Figure 1: Relevant ROIs results

where $otsu\_th(x)$ is the function that computes the Otsu threshold. This optimization helps when it comes to discard the ROIs containing *e.g.* wall sections, but sometimes affects the paintings that are overexposed to the light.

3.2. Painting Retrival

Painting retrival consists in the identification of ROIs passed from the Painting Detection. A ROI is extrapolated from the frame, and it is compared with all the painting in the database: - if the ROI is recognized as one of the painting in the database (with a certain level of security), it's labeled and information to decribe it are retrived from the database - if the ROI does not match any painting, they are classified as "unidentified object". The comparison is done with ORB, which is a keypoint detector, just like SIFT and SURF, but not patented. For every detected ROI, we use ORB to find the keypoint, and we compare them with every keypoints of evry paint in the database. The comparison of the keypoint returns an avarage distance: this distance represent how different are the keypoints found in the considered paint from the key of the ROI; the smaller the distance, the higher the probability that the considered paint from the database is the one that was filmed in the frame.

3.3. Painting Rectification

The paint with the smaller average distance from the database, that we will call the "Best Candidate", may not coincide with the object in the ROI; this may happend for many reasons: - the object is not a paint - the object is a paint, but the quality of that particular frame is very bad (the camera moving, the picture is overexposed to light) - the object is a paint, but is not in the databse Painting Rectification can be very helpful: with painting retrival, we select the paint that has the smallest avarage distace from the object in the roi, then, we try to rectificate the object in the frame based on the keypoints of the Best Candidate, and we obtain a rectified image, If the Best Candidate was actually the paint in the ROI, the rectification should be good, not distored: otherwise, the rectification will bring to a "Black Hole": a Black Hole happends when the wrong keypoints are used for the rectification. it can therefore be inferred that a Black Hole happend when our Best Candidate is wrong, it does not concide with the object in the paint. We can discard the first Best Candidate, and get the paint from the database which has the second smallest average distance. We repeat the process with the first 5 paint with smallest average distance, ot untill we obtain a good rectification.

immagini di black hole etc etc

Technically, we still use keypoint to detect if the rectified image is a Black Hole. After the rectification, we compute the keypoints on the rectified image: after that, we compute the avarage distance of the keypoints just calculated from the keypoints of the Best Candidate, that we already have. If the rectification was successful, the avarage distance shoul be low, otherwise it will be high, the rectification was a Black Hole and we have to try with another image. We set three threshold: - if the average distance is less than 35, it means that we are very confident that we have found the right paint in the database; for this reason, we identify the paint with the information retrieved from the databese and we set in qhich room we are in. - if the average distance is greater than 35, but less than 60, we are pretty sure that we get the right paint, but we are not sure enough to set the room - if the average distance is greater tha 60, we are in the situation of a Black Hole, the keypoints are too different, so we have to try with another paint

3.4. People Detection

We used YOLOv3 network pre-trained on COCO dataset to detect people on videos, getting the returned ROIs to draw them on output video.

3.5. Statue Detection

To detect the statues in the museum we fine-tuned the YOLOv3 network starting from weights trained on COCO dataset. At the beginning we thought to detect statues and paintings to improve the detection made with the Image Processing approach, so we trained the network on 2 classes: Paintings and Statues.

We made our custom annotated dataset ripping frames from all videos of the museum, storing them with a step of 250 frames for each video, obtaining 605 images mainly composed by paintings with only a 10% of images containing statues. We tried to train the network with this small and unbalanced dataset using different `Learning Rate` values but the result was unsufficient.

After those tries we thought to use the network only to detect the statues, because the Image Processing method was still better to detect paintings but often it wasn't able to detect statues. So we learned the lesson and we tried to balance the dataset selecting manually frames with statues from videos obtaining 282 images, each containg at least a statue with different point of views. We annotated those images with more focus on statues than paintings, then we made a simple data augmentation script to flip all statues frames, obtaining 564 images with statues. Finally our dataset contains 1169 images, slightly balanced in number of paintings and statues.

Using Adam optimizer with `Non Maxima Suppression` value of 0.4, `Confidence Threshold` of 0.8 and a `Learning Rate` of 0.004 we achieved an AP of **6.39%**, considering also the painting class that we discarded in detection phase.

To train the network we used an Nvidia GTX 1050 with 4Gb and it took us almost 4 days to reach the 242th epoch with a batch size of 2, then we just stopped the training due to overfitting on `confidence loss` [2]. We achieved the best results of AP with the 177th epoch and we used those weights to detect statues on videos trying different combinations of `Non Maxima Suppression` and `Confidence Threshold` values, defining them to

0.1 and 0.98 respectively.

3.6. Segmentation

The last section of the project deals with segmentation, both of paintings and Stautes. We used GrabcCut algorithm: exploiting the ROIs received both from Painting Detection and YOLOv3, we were able to use GrabCut algorithm without user interactions. In particular, we took evry ROI extrapolated in each frame, and enlarged it: in this manner, we had a section of the frame, in which we could draw the rectangle to define what was definitely background. At this point, we used GrabCut to extrapolate what in the ROI was our object of interest, was that a paint or a statue. We highlighted the objects of interest in green

***Foto con frame e rettangolo che identifa sfondo/unkown,Foto con statue e quadri in verde**

4. Results

In this section, some results frame and training graphs will be shown.

5. Discussion

- migliorare la rete con dataset pi ampio e bilanciato - potremmo eliminare alcune ROI inutili (e.g. le etichette) utilizzando alcune tecniche di Image Processing - Retrival, Rectification e Detection funzionerebbero meglio se avessimo un database di immagini completo anche con statue

5.1. Language

All manuscripts must be in English.

5.2. Dual submission

Please refer to the author guidelines on the CVPR 2019 web page for a discussion of the policy on dual submissions.

5.3. 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 CVPR 2019.**

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.

5.4. 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 uncomment the `\cvprfinalcopy` command in the document preamble.) 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 095.5), although in most cases one would expect that the approximate location will be adequate.

5.5. 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`.

5.6. Blind review

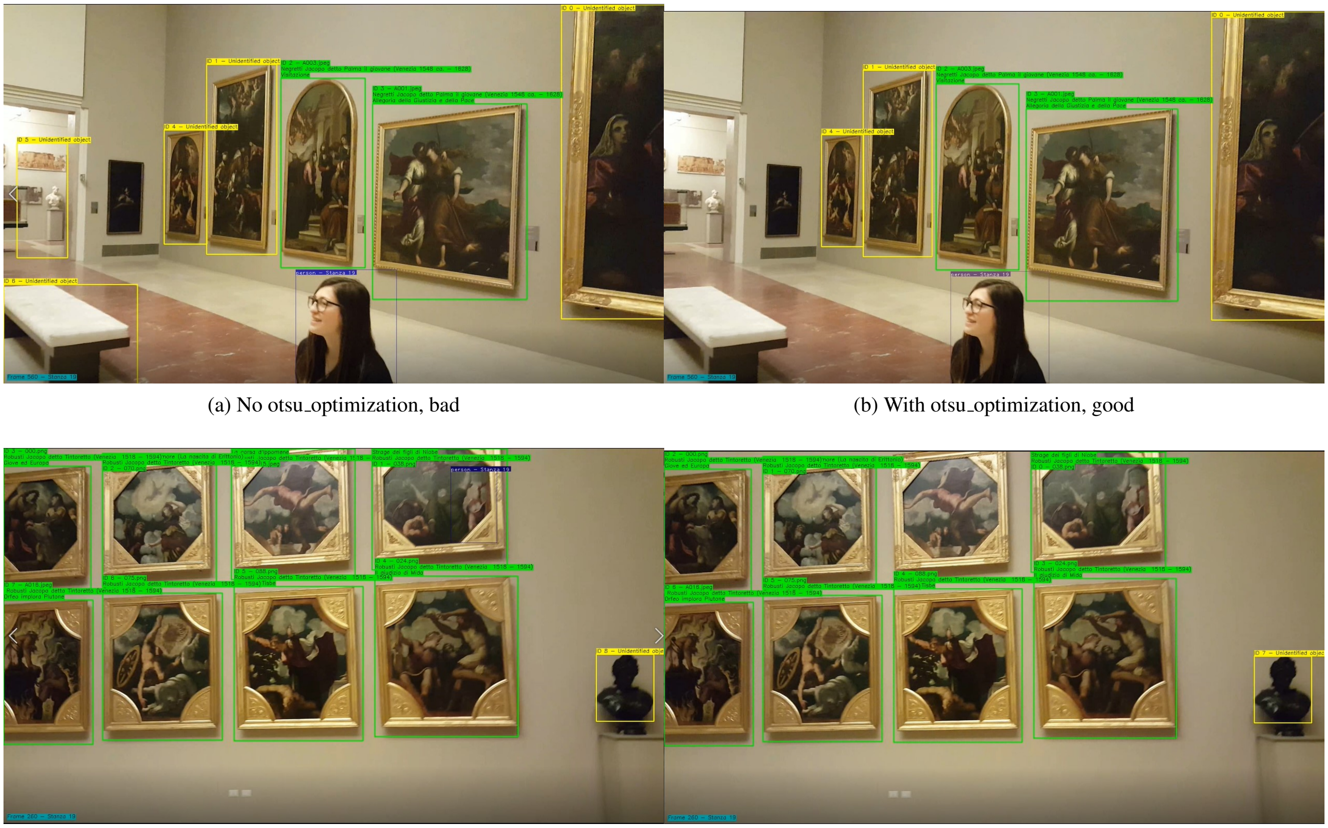
Many authors misunderstand the concept of anonymizing for blind review. Blind review does not mean that one must remove citations to one's own work—in fact it is often impossible to review a paper unless the previous citations are known and available.

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 in-



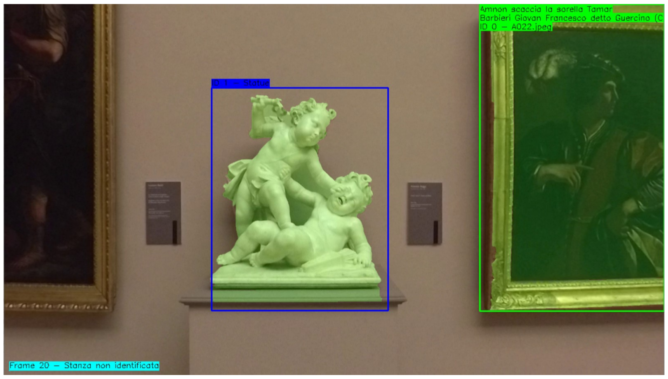
(a) No otsu_optimization, bad

(b) With otsu_optimization, good

(c) No otsu_optimization, good

(d) With otsu_optimization, bad

Figure 2: Example of otsu_optimization (no statue detection nor segmentation)


Amnon scaccia la sorella Tamar
Barbieri Giovan Francesco detto Guercino (C
ID 0 – A022.jpeg
Frame 20 – Stanza non identificata

(a)

Figure 3: Example of segmentation and statue detection

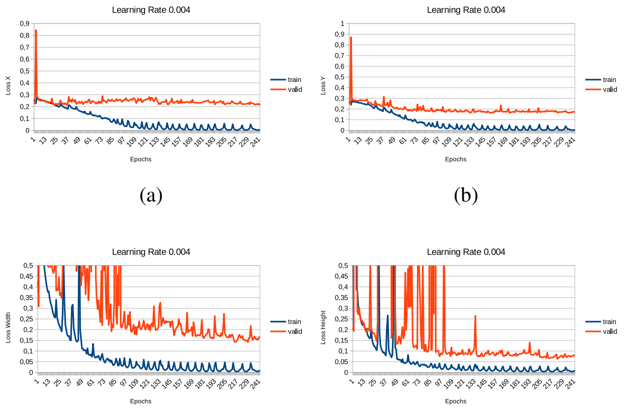
ferior to all previously known methods. Why the previous paper was accepted without this analysis is beyond me.

[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



(a) (b) (c) (d)

Figure 4: (a) Loss X, (b) Loss Y, (c) Loss Width and (d) Loss Height

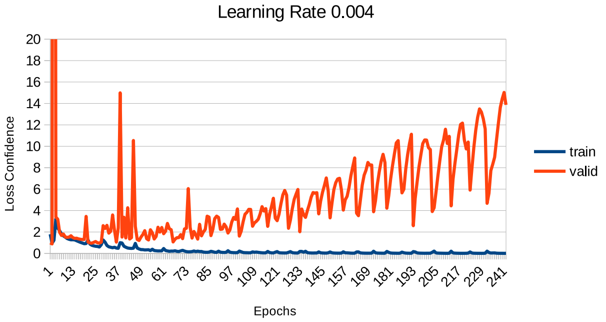


Figure 5: The Loss Confidence begins to overfit after few epochs, probably due to bad labeling of paintings when we expanded the dataset.

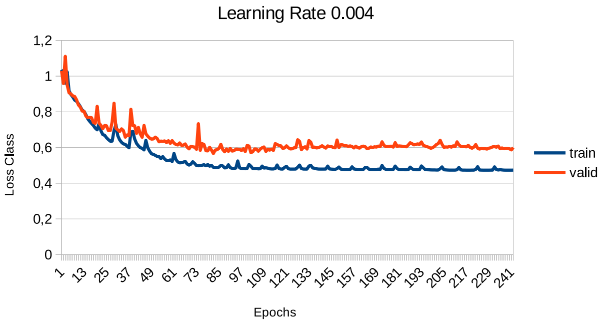


Figure 6: The Loss Class has a good trend.

is beyond me.

[1] Smith, L and Jones, C. "The frobnicatable foo filter, a fundamental contribution to human knowledge". Nature 381(12), 1-213.

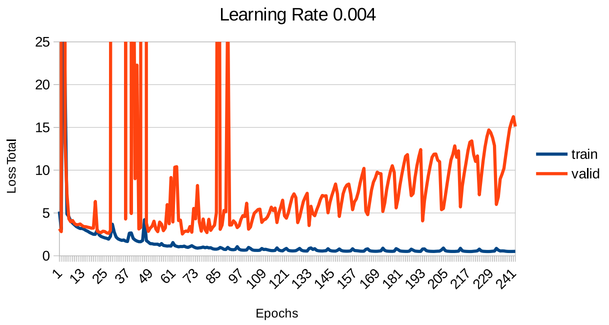
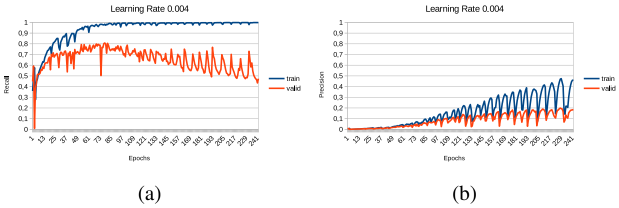


Figure 7: The Total Loss is affected mainly by the loss confidence curve [2], while the loss class [3] and localization losses [1] are good enough to improve the precision [5].



(a) (b)

Figure 8: (a) Recall and (b) Precision curves

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

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.

5.7. Miscellaneous

Compare the following:
`$conf_a$` $conf_a$
`$\mathit{conf}_a$` conf_a
See The TEXbook, p165.

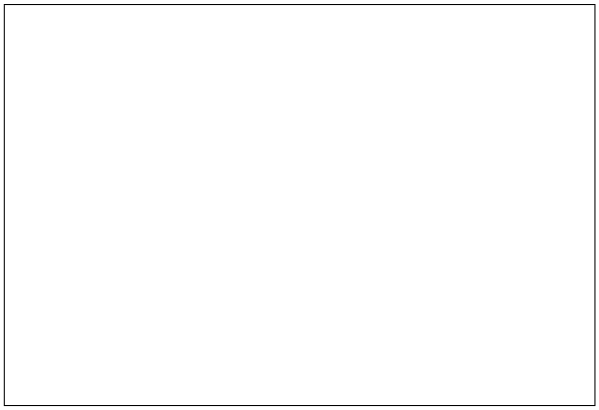


Figure 9: Example of caption. It is set in Roman so that mathematics (always set in Roman: $B \sin A = A \sin B$) may be included without an ugly clash.

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.* [**?**].”

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 [**?**, **?**, **?**].

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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.

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All printed material, including text, illustrations, and charts, must be kept within a print area 6-7/8 inches (17.5

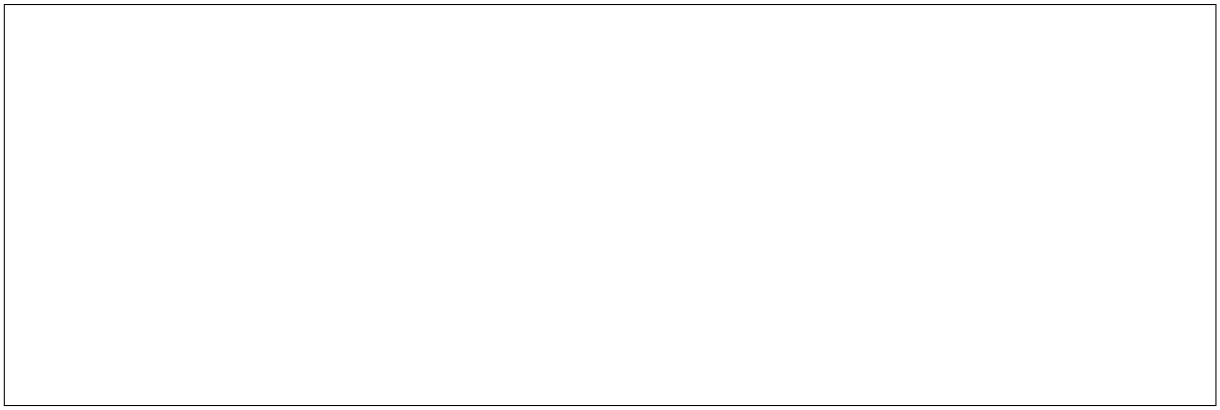

Figure 10: Example of a short caption, which should be centered.

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}
```

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}
```

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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.

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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.

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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.

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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.

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

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

Table 2: Results. Ours is better.

6.5. 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 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}
```

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