

RetroGAN: Translating Unpaired Video Game Images Using CycleGANs

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Abstract

Video games from the retro era have a signature style due to the limitations of technology at the time. Limitations on resolution, color, bandwidth, and power all created constraints that led video game creators to make certain patterns. Using a CycleGAN architecture to allow unpaired translation, we can learn from data of two separate video game generations and translate images from one generation to the other. Our results show that we can take images from the Nintendo Entertainment System(NES) and Super Nintendo(SNES) and translate screenshots from both consoles into the style of the other. Experiments demonstrate that the CycleGAN architecture can learn many constraints of each system in order to translate realistic images.

1. Introduction/Background/Motivation

(5 points) What did you try to do? What problem did you try to solve? Articulate your objectives using absolutely no jargon. We tried to create a network for converting screenshots from the NES console to the SNES console and vice-versa. The main problems is that the various consoles have various limitations that define how they look, things like limited color palettes, sprite pixel limit, ability to have transparency or gradients or not.

(5 points) How is it done today, and what are the limits of current practice? There is limited current research on this particular domain, as it is limited by lack of proper datasets and the lack of paired data between console generations.

(5 points) Who cares? If you are successful, what difference will it make? If success, this can allow the content of a game of a particular video game console to be translated into the style of another's. Pixel artists are a very high demand job and creating high quality pixel art is one of the largest financial strains that can be put on games. Pixel artists are often so hard to find that games will save money by switching to 3D modelling as there are many more artists with more tools to assist with them. This could allow for pixel artists to become more more efficient and could allow taking images from a previous game or gen-

eration, and translating it to the current project's generation. For instance, if you had worked previously on a NES game and were making its sequel for the SNES, this could allow someone to take the images of their original game and create new baseline screenshots to allow the pixel artist to only have to tweak the translation instead of starting from scratch. This is also not constrained to translation between NES and SNES, and could be done on other consoles and generations given the proper datasets.

(5 points) What data did you use? Provide details about your data, specifically choose the most important aspects of your data mentioned [here](#). You don't have to choose all of them, just the most relevant. A dataset for NES/SNES images doesn't exist in a proper form, so we created our own from various screenshot databases. We implemented our own pre-processing, which included unsupervised color clustering to remove PNG artifacts, and clamping colors to more closely adhere to the console's original color palette from other image color manipulation. (Andrew can easily improve this, we should probably also talk about the motivation, and recommended use from that link maybe)

2. Approach

(10 points) What did you do exactly? How did you solve the problem? Why did you think it would be successful? Is anything new in your approach? We wanted to try translation between video game consoles images of different generations, the issue is that it isn't realistic to have paired data of this since each generation of console will consist almost solely of different games(with a small exception of remakes). We thought CycleGAN would be a good option for success as it doesn't require paired data and is also able to take flexible image sizes, which is a great quality as we added our own custom datasets. We initially started by taking the driver code for the original CycleGAN paper [6]. We then removed all of the code related to pix2pix and added our own datasets, pre-processing, augmentation, hyper-parameter tuning code, and metrics. Our approach is using the existing CycleGAN architecture, however our dataset is unique and to our knowledge, no one has properly explored this type of translation in this architecture.

(5 points) What problems did you anticipate? What problems did you encounter? Did the very first thing you tried work? We anticipated plenty of issues. While the main difference between the NES and SNES is their available color palettes, the NES also has several other restrictions such as pixel limits and more limited color palettes per sprite. This was anticipated to be very difficult to generalize without magnitudes more data. We didn't see great results in our first attempt, however after doing some fairly basic pre-processing to remove artifacts from our images, we started seeing interesting results with convincing translations very early on.

Important: Mention any code repositories (with citations) or other sources that you used, and specifically what changes you made to them for your project.

3. Experiments and Results

(10 points) How did you measure success? What experiments were used? What were the results, both quantitative and qualitative? Did you succeed? Did you fail? Why? Justify your reasons with arguments supported by evidence and data. Should probably save this entire section for after we've established our final metrics and have screenshots to show.

Important: This section should be rigorous and thorough. Present detailed information about decision you made, why you made them, and any evidence/experimentation to back them up. This is especially true if you leveraged existing architectures, pre-trained models, and code (i.e. do not just show results of fine-tuning a pre-trained model without any analysis, claims/evidence, and conclusions, as that tends to not make a strong project).

4. Other Sections

You are welcome to introduce additional sections or subsections, if required, to address the following questions in detail.

(5 points) Appropriate use of figures / tables / visualizations. Are the ideas presented with appropriate illustration? Are the results presented clearly; are the important differences illustrated? This seems like free points, just properly caption tables and figures. We just need to make sure when we're showing before-after images to make sure we show the metric improving and talk about it in analysis.

(5 points) Overall clarity. Is the manuscript self-contained? Can a peer who has also taken Deep Learning understand all of the points addressed above? Is sufficient detail provided? This seems like free points. We probably just need to briefly touch on GANs and give a proper section on how CycleGANs work, as well as some

detail between NES and SNES color palettes.

(5 points) Finally, points will be distributed based on your understanding of how your project relates to Deep Learning. Here are some questions to think about: This also seems free. We should probably go into the architecture of each GAN just so we can estimate how many parameters we have. (should probably wait until final HPs are done)

What was the structure of your problem? How did the structure of your model reflect the structure of your problem?

What parts of your model had learned parameters (e.g., convolution layers) and what parts did not (e.g., post-processing classifier probabilities into decisions)? Should definitely cover this, at least briefly.

What representations of input and output did the neural network expect? How was the data pre/post-processed? What was the loss function? This is Andrew's section. Should talk about the pre-processing we did.

Did the model overfit? How well did the approach generalize? This is probably a good way to talk about our augmentation and how it helps with over-fitting.

What hyperparameters did the model have? How were they chosen? How did they affect performance? What optimizer was used? Probably should only talk about the major ones we used (dataset size, LR, the GAN types, whatever)

What Deep Learning framework did you use? GANs? I guess we should probably just talk about GANs+CycleGAN and it'll cover us on this.

What existing code or models did you start with and what did those starting points provide? This is already kind of mentioned in the intro where I cite it, but we can add more if we want.

Briefly discuss potential future work that the research community could focus on to make improvements in the direction of your project's topic. This is an interesting one, we could talk about using sprites, more data, other consoles, using the metrics we made with loss, all sorts of stuff.

5. Work Division

Please add a section on the delegation of work among team members at the end of the report, in the form of a table and paragraph description. This and references do **NOT** count towards your page limit. An example has been provided in Table 2.

6. Miscellaneous Information

The rest of the information in this format template has been adapted from CVPR 2020 and provides guidelines on the lower-level specifications regarding the paper's format.

6.1. Language

All manuscripts must be in English.

6.2. Paper length

Papers, excluding the references section, must be no longer than six 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 six pages with two pages of references would have a total length of 8 pages.

6.3. 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 0.95.5), although in most cases one would expect that the approximate location will be adequate.

6.4. 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>.

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 [5]". 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.

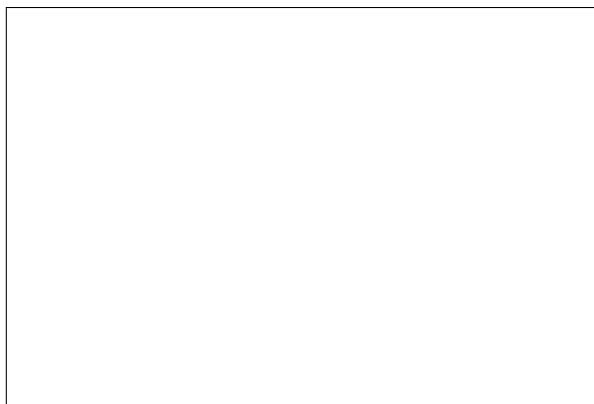


Figure 1. Example of caption. It is set in Roman so that mathematics (always set in Roman: $B \sin A = A \sin B$) may be included without an ugly clash.

6.5. Miscellaneous

Compare the following:

`$conf_a$` $conf_a$
`conf_a` conf_a

See The T_EXbook, 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: “Frobination has been trendy lately. It was introduced by Alpher [1], and subsequently developed by Alpher and Fotheringham-Smythe [2], and Alpher *et al.* [3].”

This is incorrect: “... subsequently developed by Alpher *et al.* [2] ...” because reference [2] 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 [2, 1, 4] to [1, 2, 4].

6.6. 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.

6.7. 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.

6.8. 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 1 and 2. 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.

6.9. Footnotes

Please use footnotes¹ sparingly. Indeed, try to avoid footnotes altogether and include necessary peripheral observations in the text (within parentheses, if you prefer, as

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

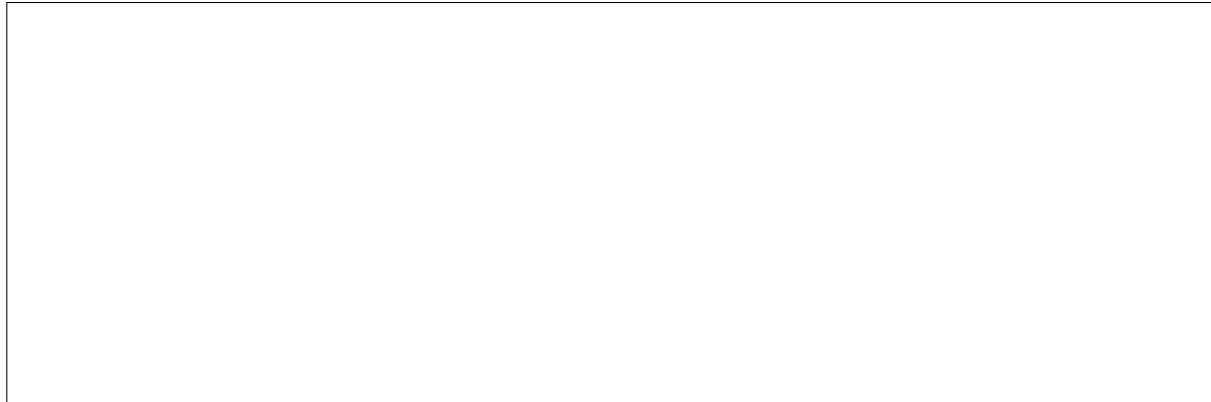


Figure 2. Example of a short caption, which should be centered.

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

Table 1. Results. Ours is better.

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.

6.10. 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 [4]. Where appropriate, include the name(s) of editors of referenced books.

6.11. 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}
```

6.12. Color

Please refer to the author guidelines on the CVPR 2020 web page for a discussion of the use of color in your document.

References

- [1] FirstName Alpher. Frobnication. *Journal of Foo*, 12(1):234–778, 2002. 4
- [2] FirstName Alpher and FirstName Fotheringham-Smythe. Frobnication revisited. *Journal of Foo*, 13(1):234–778, 2003. 4
- [3] FirstName Alpher, FirstName Fotheringham-Smythe, and FirstName Gamow. Can a machine frobnicate? *Journal of Foo*, 14(1):234–778, 2004. 4
- [4] Authors. The frobnicatable foo filter, 2014. Face and Gesture submission ID 324. Supplied as additional material `fg324.pdf`. 4, 5
- [5] Authors. Frobnication tutorial, 2014. Supplied as additional material `tr.pdf`. 3
- [6] Jun-Yan Zhu, Taesung Park, Phillip Isola, and Alexei A. Efros. Unpaired image-to-image translation using cycle-consistent adversarial networks. *CoRR*, abs/1703.10593, 2017. 1

Student Name	Contributed Aspects	Details
Andrew Rollings	Dataset Pre-processing, Architecture Design, Implementation, HP tuning, Report	Came up with initial idea of using Video Game images, created dataset, pre-processing. Tuned GAN hyper-parameters, wrote report.
Michael Townsend	Implementation, HP tuning, Metrics, Report	Implemented metrics, Tuned GAN hyper-parameters, Helped with report
Tyler Thurston	Implementation, Metrics, HP tuning, Version Control, Report	Setup team in version control, Created color palette metric, Tuned GAN hyper-parameters, wrote report.

Table 2. Contributions of team members.