Semi-Supervised learning for Cat mood/illness emotion recognition

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Introduction

Cats are generally quiet and subtle in their facial expressions. Their behaviors are also difficult to interpret, so this makes it challenging for humans to accurately understand their moods and interact with them. Unlike other humans, we cannot communicate with them using verbal means, so there is no way to ascertain cat emotions using words. Humans who want to deeply and accurately understand how cats feel, such as caring cat owners or veterinarians, would benefit from an easier or more accurate method to understand cat emotions. That is, to understand how cats feel is important, particularly in environments where many cats are gathered together with humans. One good example is cat cafe, where so-called cat lovers may be less aware of cats’ behaviors. Another, more serious, environment is in Veterinary hospitals where detecting cats’ mood or pain is vital. Additionally, adoption centers or shelters, where cats along with other animals are rescued and taken care of, can also benefit from facial expression recognition to better manage cats’ stress and possibly improve the chance of the cats being adopted [1].

Understanding cats’ facial expressions can possibly change our ways of interaction with cats. With accurate interpretation of the cats’ subtle facial expressions, we can enhance our ability to handle tasks such as pain management in Veterinary hospitals to reduce acute possible cases due to cats’ unstable conditions or behavioral control in both cat cafe and adoption centers to avoid possible negative cats’ reaction.

Humans may believe that they can understand cats well due to the time they spend with them, whether due to years of living with their pet cats for cat owners, having daily interactions with numerous cats for shelter workers, or professional training of veterinarians to handle cats’ health issues, but according to a study [2], when cats exhibit more subtle emotions, humans cannot reliably detect such emotions. This calls for a more systematic and objective approach to identifying cat emotions.

Related Work

The first work that needs to be mentioned in cat emotion recognition is CatFACS [1, 3], an objective cat facial action description system inspired by the well-known Facial Action Coding System (FACS) [4] used in humans. As the basis of CatFACS is facial action, in terms of media requirements, the user would need videos that show cat movement to use CatFACS if they are not observing a live cat. Another method researchers have used for recognition of cat emotions, such as being angry, happy or neutral, is through cat sound [5]. Although these approaches provide good results, facial expression recognition through static images is still of interest as finding and evaluating cat images are much simpler than processing of videos or sounds.

Surprisingly, cat facial emotion recognition based on static images is not as well-studied. One notable approach we will explore in our study is based on geometric morphometric of cat facial landmarks [6, 7] specifying 4 regions of interest (eyes, ears, nostrils and mouth) to analyze cats’ facial structure and expressions in pain recognition. In direct relation to our work, there have also been other studies that use deep learning image classification for cat facial emotion recognition with promising results, but with limited depth [8, 7, 9]. Feighhelstein et al. used pre-trained Resnet50 network to distinguish cat in pain and not in pain [7], while Jain et al. [9] and Vishwakarma et al. [8] used custom convolutional neural networks to identify 2 cat emotions (happy and sad) based on images. Since there are very few studies on cat facial expressions recognition, we look further for related work in other animals. One study uses CNN-based deep learning models with improved whale optimization algorithm (IWOA) achieving 89.91% accuracy on 5 dog emotions [10]. Another study uses SVM classifiers based on encoded facial data of non-human primates achieving 82% accuracy on 4 classes of emotions [11].

Drawing comparison from human facial expression recognition is a natural next step as there is much more research on humans compared to animals with regards to facial expression recognition. Common experiments on facial expression recognition in humans involve obtaining humans’ straight facial images [12] [13] as an established dataset and are less likely to use images of human faces that are tilted. According to Li and Deng [12], the state-of-the-art static-based human facial expression recognition is still largely based on convolutional neural network (CNN), albeit with more advanced techniques such as auxiliary blocks (layers to enhance the expression-related representation capability of learned features), network ensemble and cascaded networks (sequentially combining modules for different tasks). Some of the well-known benchmark datasets for human facial expression recognition include

*CK+* [14]: a laboratory-controlled images of a change in expression from neutral to peak expression

*FER2013* [15]: an image database of human facial expressions in the wild collected from Google image search

*AffectNet* [16]: large-scale database of over 1 million images queried from the internet using emotions-related tags

*RAF-DB* [17]: a crowd-sourced collection of 29,672 annotated human facial emotion images where each image is annotated about 40 times

On the contrary, as noted earlier, there is no established state-of-the-art for cat facial emotion recognition machine learning algorithms. There is also no benchmark dataset for cat facial expression recognition. From these facts, it becomes clear that cat facial expression recognition based on machine learning algorithms remains very much underexplored.

In addition to the scarcity of research in cat facial expression recognition, there are other challenges when trying to identify cat facial expressions. Most importantly, animals cannot tell us what they feel, causing ground truth verification to be more complicated than in humans. Solving this issue by using experts to rate animals’ affective states could also introduce bias due to difference in perception from humans to animals [7]. Animals may also display different facial expressions to human under similar emotional state [18]. Capturing facial expressions using action units is also subject to errors caused by complexity of facial musculature and may not cover facial emotions in specific species, not to mention the action units’ inherent unsuitability to use on static images [6]. Difference in individuals is another factor that complicates facial emotion recognition. In human facial expression recognition, difficulties include not only visible muscle on human faces, but also flexibility in appearance or shape of the facial expression and probably inter-person differences in facial expression [13]. Likewise, in animals such as cats, their variations of facial expression are not in control due to greater variation in their facial morphology and certain absent facial features like pain feelings in some breeds. This variability can make population-level evaluations challenging for cats. In addition, hair covering may also obstruct certain facial features such as wrinkles [6].

To address these difficulties, we propose combining deep learning computer vision techniques with geometric morphometric from facial landmarks to predict cat emotion from cat facial images. This approach leverages both the strength of deep learning to learn subtle features and the explainability of geometric morphometric, which consist of vectors obtained from different landmarks of cat faces. There are studies showing that the use of geometric morphometric can help in identifying facial expressions in cats [6] and in humans [19].

Another challenge we face with cat facial expression recognition (FER) is the lack of directly comparable labeled datasets for cat expressions, unlike those available for humans. To this end, in addition to running supervised classification model, we will also take one of the more academically established cat facial datasets, the Cat Facial Landmarks in the Wild dataset or CatFLW [20] and try to label the images. We follow the state-of-the-art in human facial expression recognition semi-supervised learning according to Roy and Etemad [21], using FixMatch and Mean Techer as the 2 best-performing semi-supervised methods out of 8 methods they examined. The study also shows that performances of the aforementioned methods are not far below that of the fully-supervised methods on *FER13*, *RAF-DB* and *AffectNet* [21]. Finally we will run the classification again on the combined dataset.

Summary of Related Work

Facial Expression Recognition in Humans

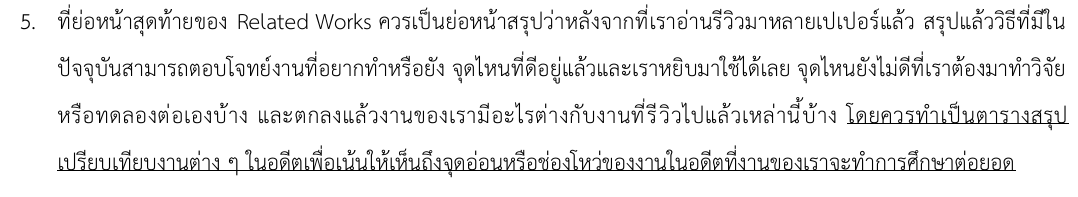
* Human FACS as qualitative approach to capture human emotions
* State-of-the-art machine learning approach established for human static-based facial expressions recognition
* Countless benchmark datasets including CK+, FER2013, AffectNet and RAF-DB

Facial Expression Recognition in Cats

* CatFACS for capturing cat facial emotions qualitatively, inspired by human FACS
* Cat sound also used in cat emotion classification
* Cat facial landmarks – geometric morphometric used to recognize cat pain
* No state-of-the-art machine learning approach for cats
* No benchmark datasets

Our contributions

* Introduce a multimodal deep learning classification approach combining image input and facial landmark vector input
* Use the resulting model to label the CatFLW and re-train the classification model on the labeled CatFLW dataset

Note: 

Below are the steps for our approaches.

Initial Dataset Preparation

Firstly, we obtain an open image dataset having 3 specific classes of cat facial emotions including Anger, Happiness and Sadness.

Due to weak label and low volume of images from the above dataset, we secondly search for more cat facial pictures using 3 keywords (Anger, Happiness and Sadness) and apply such keywords as our cat emotion classes.

All cat face images acquired are in straight direction.

We then combine images from the 2 approaches above into a single image dataset for further usage.

Facial Landmark Extraction

We use an animal facial landmark detector belonging to an experiment which devoted to Cat facial landmark automated detection using Ensemble Landmark Detector (ELD) [20]. By using this detector, it returns 48 landmarks on cat face.

Feature Engineering

Identify 5 regions on cat face using 48 landmarks: Left ear, Right ear, Left eye, Right eye and Nose-Mouth-Whiskers.

Determine the mean point (center point) of each region.

Calculate the distance and angle between each specific region below.

* The Euclidean distance between both ears and both eyes
* The angle between the mean point of left eye and the mean point of nose-mouth-whiskers, and the angle between the mean point of right eye and mean point of nose-mouth-whiskers
* The angle between the left ear and nose, and the right ear and nose
* Normalize the distance since we expect the picture is zoom in or out, sizing)
* Input vectors by indicating from the mean point or center point of each region to other points/landmarks in their regions. For example, the center point of left eye is direct to each one of the points/landmarks in eyebrow area or lower eyelid.

Model Implementation

Supervised Learning

Utilize the features of distance and angle obtained from Facial Landmark Extraction state for self-supervised learning using Auto ML (PyCaret) to see the most suitable model for further classification.

Self-Supervised Learning

xxxxx

By following these steps, we will be able to compare the effectiveness of different classification techniques and benchmark our results against prior studies.

Draft: เริ่มจากเรามีรูปภาพ (datasets)

2 approaches to get datasets

2.1 เอารูปภาพมาจาก kaggle, ที่่ถูก label แล้ว 🡪 ปัญหาคือ

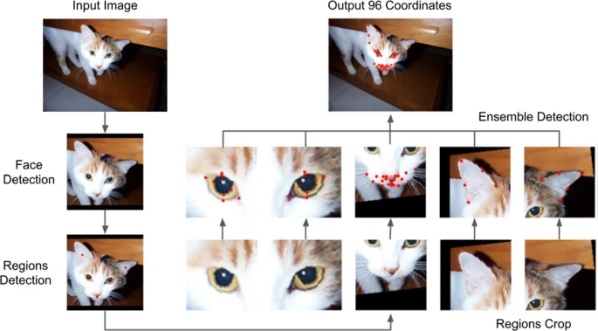
* + รูปน้อยเกิน 🡪 หารูปเพิ่ม 50 each/class
  + องค์ประกอบรูปไม่ครบ เช่น หูขาด หูพับ, โครงหน้าแมว zoom เกินไปจนเห็น element ของหน้าแมวไม่ชัดเจน
  + Landmark (median)

2.2 (ยังไม่ได้ทำ) either search by keyword as a label and เอารูปภาพจาก keyword นั้นๆ มาเลย or manual label รูปภาพจาก dataset ที่ไม่มี label

Then cat datasets + Model (Landmark)

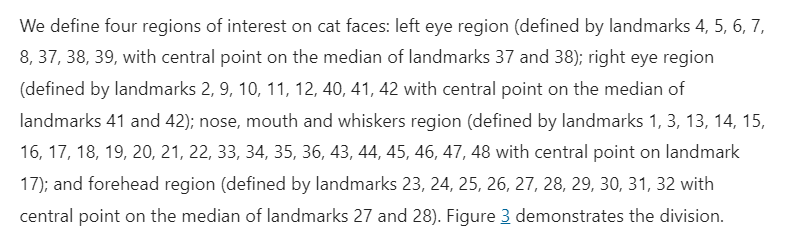
Model

* โมเดลที่นำมาทำ landmark มีโอกาส predict class แมวเป็นหมา 🡪 แก้ยังไง?



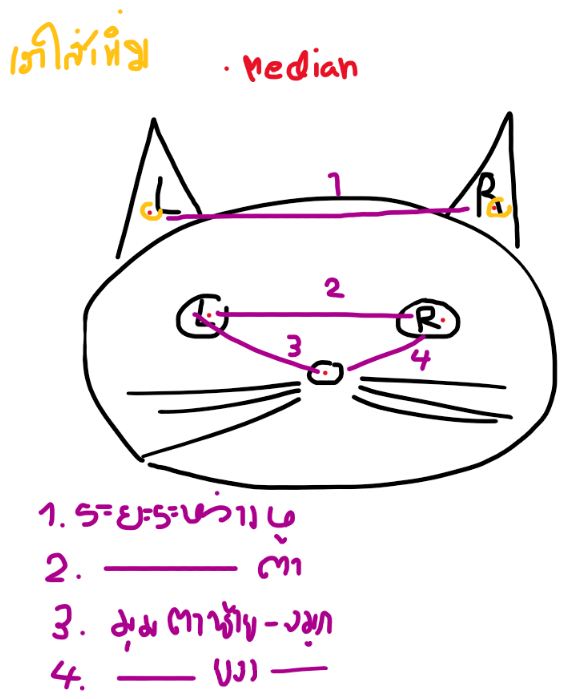
The Model (ถ้าโอเค) เราจะได้ 4 regions จากภาพแมว คือ 1. Forehead (หน้าผาก), 2. Left eyes (ตาซ้าย), 3. Right eyes (ตาขวา), 4. Nose-Mouth-Whisker (จมูก-ปาก-หนวด) โดยอ้างอิงจาก paper below [Automated recognition of pain in cats](https://www.nature.com/articles/s41598-022-13348-1#citeas)

และได้ค่า median



พอได้ median point ของแต่ละ region มาแล้ว เราหาระยะระหว่างตา 2 ข้าง, หู 2 ข้าง, มุมระหว่างตากับจมูก เช่น ตาขวากับจมูก หรือ ตาซ้ายกับจมูก

* หาจุดกึ่งกลางระหว่าง region โดยใช้ mean or median
* คนมีจุด 2 step Origin 1. จมูก 96 landmark 2.ตาซ้าย-ขวา 3. ปาก และมี 3 rigion
* แมวจะมี 4 rigion 48 landmark



ระยะแต่ละส่วน คือ float ที่จะใช้ train auto ML (Supervised Learning – PyCaret)

* เลือก model ที่ดีที่สุดจาก PyCaret มา
* Evaluation metric = Accuracy?

Self-sup

เอาค่า landmark มาเข้า auto coder

เอาค่า sup และ self มา compare และ จากงาน

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|  |  |
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The next subsections provide instructions on how to insert figures, tables, and equations in your document.

Tables

Tables are “float elements” which should be inserted after their first text reference and have specific styles for identification. Do not use images to present tables, or they will be inaccessible to readers using assistive technologies.

Authors can insert tables by using the MS Word option (INSERT ->Table) and providing the required row and column size. Every table must have a caption (title) above it, which must have the **“TableCaption**” style applied. Please note that tables **should not** be supplied as image files, but if they are images they must have the “Image” style applied. As an example, Table 1 shows all the styles available in this template, to be applied to the respective element of your text.

Table 1: Styles available in the Word template

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| Subtitle | subtitle of article | Statements | math statements |
| Authors | author name | Extract | block quotations |
| Affiliation | author affiliation information | Algorithm Caption | caption for algorithm |
| AuthNotes | footnote to author(s) | AckHead | heading for acknowledgements |
| Abstract | abstract text | AckPara | acknowledgements text |
| CCSHead | heading for CSS Concepts | GrantSponsor | sponsor of grant |
| CCSDescription | CSS terms | GrantNumber | number for the grant |
| KeyWordHead | heading for keywords | ReferenceHead | heading for references |
| Keywords | keywords text | Bib\_entry | references |
| ORCID | author's ORCHID # | AppendixH1 | appendix heading level 1 |
| Head1 | heading level 1 | AppendixH2 | appendix heading level 2 |
| Head2 | heading level 2 | AppendixH3 | appendix heading level 3 |
| Head3 | heading level 3 | TableCaption | title of table |
| PostHeadPara | first paragraph after a heading | TableHead  TableFootnote | column head of table  footnote to table |
| Para | Subsequent paragraphs of general text | Image | figures |
| ParaContinue  DisplayFormula | flush left text after display items like math equations, lists etc.  numbered math equation | DOI | Digital object identifier |
| DisplayFormulaUnnum | unnumbered equations | Label | labela |
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| Short Title | Short title of article | History | Dates of article |

a This is example of table footnote.

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1. Select that table’s row, then right-click the row and select “Table Properties”;
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Or

Apply the “table head” style by highlighting the respective row and applying the “**TableHead**” style found in the “Body Element” section of the ACM Master Article Template.

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To accommodate readers with color vision differences, figures should still be usable when printed in grayscale. Refer to elements of the figure with non-color terms, for example “indicated as squares” instead of “indicated in blue”. Use different patterns in bar charts, different line patterns in graphs, and different shapes in plots to distinguish groups of elements and reinforce color differences.

Half Width Figures.

Figure 1 is an example of a figure and caption spanning the half-page width (one column in a two column format) with the styles applied. If your figure contains third-party material, you must clearly identify it as such, as shown in the example below.



Figure 1: 1907 Franklin Model D roadster. Photograph by Harris & Ewing, Inc. [Public domain], via Wikimedia Commons. (https://goo.gl/VLCRBB)

Full Width Figures.

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Figure 2: Mockup of a bombe machine at Bletchley Part. Photograph by Sarah Hartwell. [Public domain], via Wikimedia Commons. (<https://commons.wikimedia.org/wiki/File:TuringBombeBletchleyPark.jpg>)

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| --- | --- |
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Figure Descriptions.

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A figure description must be unformatted plain text less than xxx characters long. Figure descriptions should not repeat the figure caption – their purpose is to capture important information that is not already provided in the caption or the main text of the paper. For figures that convey important and complex new information, a short plain text description may not be adequate. More complex alternative descriptions can be placed in an appendix and referenced in a short figure description. For example, provide a data table capturing the information in a bar chart, or a structured list representing a graph. For additional information regarding how best to write figure descriptions and why doing this is so important, please see [https://www.acm.org/accessibility.](https://www.acm.org/accessibility)

The instructions below describe the required steps authors need to follow in order to insert descriptive text for figures (alt-txt value) in **MS Word 2019 on Windows or Word 2016 and later on Mac**:

1. Insert a picture in the document.
2. Right-click the image and select “Edit Alt Text”.
3. In the “alt text” section, provide your text description of the image.

Below are the steps to insert figure descriptions in **MS Word 2013 and 2016**:

1. Insert a picture in the document.
2. Right click on the inserted picture and select the **Format Picture** option.
3. In the settings at the right side of the window, click on the “Layout & Properties” icon (3rd option).
4. Expand **Alt Txt** option.
5. In the “Title” and “Description” text boxes, type the text you want to represent the figure, and then click “Close.”

Below are steps to insert the alt-txt value in **MS Word 2010/2011 for Windows\***:

1. Insert a picture in the document.
2. Right click on the inserted picture and select the **Format Picture** option.
3. Select the **Alt Txt** option from the left-side panel options.
4. In the “Title” and “Description” text boxes, type the text you want to represent the picture, and then click “Close.”  
   \* The Mac 2011 version 14.0.0 and later allows the option for inserting “alt-text.” In the MAC version of Word 2016, right-click on the image and select “Edit Alt Text” from the pop-up menu and then enter the description for the alt text.

Quotations and Extracts

There are styles for block quotations, which should be used for quotes that are separated from in-line text. Below is an example.

“Microsoft tried to revive the idea of an assistant with Clippy, who began popping up in Microsoft Office in 1997. Its creator, Kevan Atteberry, was actually contracted by Microsoft to design Clippy, which, funnily enough, he did on a Mac … Sure, people could disable Clippy, but the fact he was on by default angered people.” [10]

Equations

There are two types of math equations: the *numbered display math equation* and the *un-numbered display math equation*. Below are examples of both.

DisplayFormula.

The **DisplayFormula** style is applied in the numbered math equation. A numbered display equation always has an equation number (label) on the right.

(1)

DisplayFormula.Unnum.

The **DisplayFormulaUnnum** style is applied only in unnumbered equations. An unnumbered display equation never contains an equation number Bertot and Grimes (2012) on the right—this element distinguishes it from the numbered equation.

Please note: the subsequent text after the **DisplayFormula** (numbered equation) or **DisplayFormulaUnnum** (unnumbered equation) must have the paragraph style **ParaContinue** applied.

Math statements

Math statements should have the “Statement” style applied.

**Theorem/Proof/Lemma.** Math statements should have the “**Statement**” style applied. This paragraph is an example of the “**Statement**” style.

Algorithms

Algorithms use the styles “AlgorithmCaption” and “Algorithm”.

ALGORITHM 1: Iterative Algorithm

current\_position center

current\_direction up

current\_position is inside circle

while current\_position is inside circle, do

neighborhood all grid hexes within two hexes from current\_position

for each hex in neighborhood, do

for each neuron in hex do

convert neuron\_orientation to vector

scale vector by neuron\_excitation

vector\_sum vector\_sum + vector

end

end

normalize vector\_sum

end

COMPUTER CODE

Display Computer codes can be inserted using “ComputerCode” style.

CHAT Start

SAY Welcome to my world

WAIT 1.2

SAY Thanks for Visiting

ASK Do you want to play a game?

OPT Sure

OPT No Thanks

Similary, this is an example of intext code text.

Similary, this is an example of intext code text.

Citing Related Work

This section cites a variety of journal [5, 15], conference [1, 6, 8, 12, 13], and magazine [3] articles to illustrate how they appear in the references section. It also cites books [9, 10], a technical report [7], a PhD dissertation [4], an online reference [14], a software artifact [11], and a dataset [2].

As you build your article, you should note where you will be placing citations. If you are using numbered citations and references, the reference number - "...as shown in [5]..." is sufficient. If you are using the "author year" style, a reasonable placeholder is the primary author's last name and the year of publication - "...as shown in [Harel 1978]..." - we will be updating this placeholder later in the process with the citation label as generated by the Word macros in the "master template.

ACKNOWLEDGMENTS

Acknowledgments are placed before the references. Add information about grants, awards, or other types of funding that you have received to support your research. Author can capture the **grant sponsor information**, by selecting the grant sponsor text and apply style ‘GrantSponsor’. After this, select grant no and apply ‘GrantNumber’ from style panel. Example of Grant sponsor: Competitive Research Programme and example of Grant no: CRP 10-2012-03.

HISTORY DATES

In case of submissions being prepared for Journals or PACMs, please add history dates after References as (*please note revised date is optional*):

Received November 2019; revised August 2020; accepted December 2020

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A  APPENDICES

In the appendix section, three levels of Appendix headings are available.

A.1 General Guidelines (AppendixH2)

1. Save as you go and backup your file regularly.
2. Do not work on files that are saved in a cloud directory. To avoid problems such as MS Word crashing, please only work on files that are saved locally on your machine.
3. Equations should be created with the built-in Microsoft® Equation Editor included with your version of Word. (Please check the compatibility at <http://tinyurl.com/lzny753> for using MathType.)
4. Please save all files in DOCX format, as the DOC format is only supported for the Mac 2011 version.
5. Tables should be created with Word’s “Insert Table” tool and placed within your document. (Tables created with spaces or tabs will have problems being properly typeset. To ensure your table is published correctly, Word’s table tool must be used.)
6. Do not copy-and-paste elements into the submission document from Excel such as charts and tables.
7. Footnotes should be inserted using Word’s “Insert Footnote” feature.
8. Do not use Word’s “Insert Shape” function to create diagrams, etc.
9. Do not have references appear in a table/cells format as it will produce an error during the layout generation process.
10. MS Word does not consistently allow the original formatting to be modified in the text. In these cases, it is best to copy all the document’s text from the specific file and paste into a new MS Word document and then save it.
11. At times there are font problems such as “odd” stuff/junk characters that appear in the text, usually in the references. This can be caused by a variety of reasons such as copying-and-pasting from another file, file transfers, etc. Please review your text prior to submission to make sure it reads correctly.

A.1.1 Preparing Graphics (AppendixH3)

1. Accepted image file formats: TIFF (.tif), JPEG (.jpg).
2. Scalable vector formats (i.e., SVG, EPS and PS) are greatly preferred.
3. Application files (e.g., Corel Draw, MS Word, MS Excel, PPT, etc.) are NOT recommended.
4. Images created in Microsoft Word using text-box, shapes, clip-art are NOT recommended.
5. IMPORTANT: All fonts must be embedded in your figure files.
6. Set the correct orientation for each graphics file.

A.2 Placeholder Text

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