CODEX (Color-Object Detection and Extraction)

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Abstract

Interior design, based on roots and principals in color theory, is an art of creating aesthetically pleasing and visually harmonious spaces. Color identification, selection, matching with respect to a palette ca be a time-consuming and difficult task–hardly an art as much as it is a precise science of balancing, weighting, statistical significance, and relationship vectors to other items and colors in a space. This research project explores the development and implementation of an automated system for color analysis and palette generation, aimed at assisting interior designers and hobbyists alike in creating effective and visually appealing color schemes. as it significantly impacts the overall aesthetic and ambiance of a space.

Contents

1 Introduction

1.1 Problem Statement

The current manual process of selecting color palettes for interior design is often subjective, time-consuming, and requires significant expertise. This can lead to inconsistent results and challenges for both designers and clients seeking specific visual effects or moods.

Consider an interior designer who is trying to keep track of a defined color palette as they design a space. Besides paint colors that can be physically stored for reference, it can be challenging for a designer to color match décor items based on memory alone and could be cumbersome to carry a physical color palette reference at all times when sourcing new items. It is often difficult to identify the precise shade of a color that is already incorporated into a space or finding colors that complement each other well in this manner.

1.2 Human Perception vs Computer Perception

Computers only have the ability to extract quantitative metrics about color. Humans, on the other hand, can qualitative judgments based on a lifetime of learning and emotional associations to color. This relationship with color allows us to perceive depth, texture, and even the "feel" of a space, influencing our emotions and behavior in ways that are difficult to quantify.

1.3 Bridging the divide with CODEX

This project offers to bridge the gap between human expertise and computers in color analysis and object segmentation. CODEX utilizes common digital image processing techniques to extract the dominant colors from an interior image and create a color palette to represent the interior at large. This capability was fine tuned using a human-in-the-loop approach to ensure that the generated palettes are not only statistically valid but also aesthetically pleasing.

2 Major Components

There are several major components to this project related to digital image processing.

2.1 Generating a Custom Segmentation Model

Object segmentation and detection, the crucial first step in many visual analysis tasks, can be a time-consuming process. Traditionally, it involves manually defining masks for individual objects and specific backgrounds to achieve optimal results.

Generalized object segmentation models, trained to automatically detect and mask a wide range of objects with minimal human intervention offer a unique solution. These models offer several advantages over traditional methods. They can efficiently process large datasets and handle diverse lighting conditions and backgrounds. They are well-equipped to handle objects in cluttered environments, such as photographs from magazines, showrooms, or hardware stores, eliminating the need for controlled settings.

2.2 Color Statistics

Color plays a powerful role in design, influencing emotions, establishing moods, and defining the overall atmosphere of a space. Creating a visually pleasing color palette requires an understanding of balance.

A large component of this project aims to use subjective opinions paired with concrete statistics so that we can analyze their distribution, identify dominant and complementary hues, and quantify the overall balance of the palette. This statistical approach allows us to move beyond guesswork and create palettes that basic principles of color harmony.

3 Approach and Implementation

The following section describes the detailed approach to solve this problem and create CODEX from the ground up.

3.1 Creating a Color Palette

The very first thing that this project does, is create a color palette from a given interior reference image. The process includes:

- **Color Decimation**: Eliminates redundant colors that are too similar to others, ensuring a diverse palette.
- **Standard Deviation Calculation**: To differentiate between bright and muted colors in an interior and weighting them accordingly so that the palette does not over-represent common neutral tones.

- **Random Sampling**: To selects a final set of colors from the refined palette to a reasonable size for viewing
- **Euclidean Distance Comparison**: This operation assesses the color differences between individual colors and that result can be used to ultimately decide how similar two colors are.

3.1.1 Custom Segmentation Model

Applying object segmentation is necessary for this project so that input images require little to no preprocessing. A user should be able to snap a picture of an object of interest without worrying about separating it from other potential objects nearby, or about the consistency of the background with the ultimate goal of finding if that object's color is a match to a palette. A popular method for object segmentation is utilizing the YOLO (You Only Look Once)[5] segmentation model. This is a popular model that has been trained on the MS COCO (Common object in context)[7] data set to recognize a range of common items that are not uniquely placed for easy extraction.

While existing models YOLO segmentation models offer a good starting point, they usually lack training on interior design applications. MS COCO, while a large training set, does not encompass the full range of furniture, decor elements, and materials commonly encountered in interior design.

In order to use segmentation for decor object specifically, it was necessary to generate a custom segmentation model to attempt to match the object of interest to a common object category. If the object has a high enough confidence score, the model will apply isolating segmentation to the object of interest and use a finer-scale color matching scheme focused solely on the object of interest.

The intent behind this approach is to stretch the capabilities of this program so that input images require little to no pre-processing. A user should be able to snap a picture of an object of interest without worrying about separating it from other potential objects nearby, or about the consistency of the background.

Additionally, by matching the object of interest to a common object category, the segmentation and labeling can be used to extract multiple objects of interest from the same image, and compare all potential common objects to the interior color palette. An example of this use case might be the user snapping a photo of a catalog page, or taking a photo in a show room with multiple objects, and then be able to decide which object(s) would be

the best fit for their interior space.

The model was developed using a custom dataset that I created using Roboflow.[1] This allowed me to select a large amount of data from images that are open source around the web and on RoboFlow, and add hand-drawn segmentations to the dataset. Then, using the Ultralytics YOLOv8 model, I was able to train the model extensively on the dataset to acheive a high level of accuracy.

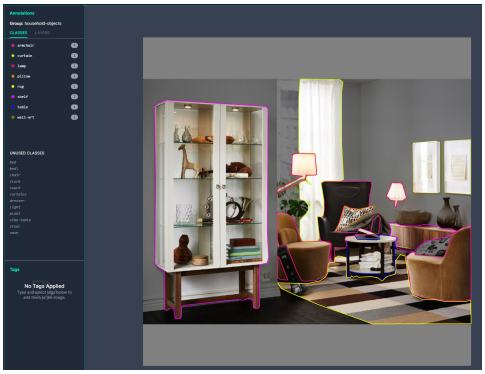

Figure 1: Applying Hand-drawn Segmentation Masks to Interior Objects

The YOLOv8 model was chosen because it is a fast, lightweight model, that is trained on the MS COCO (Common Objects in Context) dataset, which contains 80 common object categories and over 300,000 images. Since many items in an interior space are a part of the COCO dataset, it was a good starting point for the CODEX model. Additional categories not in the MS COCO dataset were added the CODEX model and trained.

There are 16 supported object categories in the CODEX model:

1. bed
2. chair
3. clock
4. couch
5. curtain
6. dresser
7. lamp

8. light
9. pillow
10. plant
11. rug
12. rug
13. shelf
14. stool
15. table
16. vase
17. wall-art

3.2 Color Matching

There determination for color matching results is based on a weighted score of the relatedness of the objects most common HSV colors to the interior palette. A score greater than 500 is considered a match, and therefore a good fit for the interior space.

```
# Function to compare two color palettes
# and return a score of how similar they are
def color_score(ref_colors, obj_colors):
    relative_score = 0
    neutral_score = 0
    # HSV values are in range 0-180 for H,
    #0-255 for S and V, so normalize them to 0-1
    for i in range(len(ref_colors)):
        ref_colors[i] = ref_colors[i] / [180, 255, 255]
    for i in range(len(obj_colors)):
        obj_colors[i] = obj_colors[i] / [180, 255, 255]

    # compare to neutral tones
    #white, black, gray, brown, beige, and cream
    for neutral_color in neutral_colors_hsv:
        for color in obj_colors:
            dist = np.linalg.norm(neutral_color - color)
            if dist < 0.15:
                neutral_score += 1

    # compare relative to each other
```

```
    for r_color in ref_colors:
        # compare to ref_hsv_color by euclidean distance
        for o_color in obj_colors:
            # calculate the euclidean distance between
            # current and next color (normalized)
            dist = np.linalg.norm(r_color - o_color)
            # shot distance indicates a good match,
            # so add to score
            if dist < 0.15:
                relative_score += 1

    if relative_score + neutral_score > 500:
        match_str = "Good"
    else:
        match_str = "Poor"

    return match_str
```

4 Results

4.1 Color Palette Validation

Figure 2 and Figure 3 Show a few examples of the Color Palette Extraction function and by showing the reference interior with it's corresponding color palette stitched to the bottom.

4.2 Custom Segmentation Model Validation

Figure 4 Displays the output of the validation training of the CODEX segmentation model. Note how it can now identify new decor objects that were not a part of an existing model before.

Figure 5 Displays the Precision/Confidence (normalized) of the object mask and the CODEX object class. The x-value shows the epoch training iteration and notably, you can see that the model gets better at a certain point. The custom CODEX model used was extracted to use the "best weights", meaning when the model performed best against the validation image set.

4.3 CODEX Results

Figure 6 used the "examples/interiors/interior1.jpg" and "examples/objects/plant.jpg" as input arguments to codex.py. The segmentation model did well at extracting the object, applying a mask, and the color palette of the

Figure 2: Color Palette Validation - Interior Palette

Figure 3: Color Palette Validation - Interior Palette

Figure 4: Model Training Validation - Predicted Decor Objects

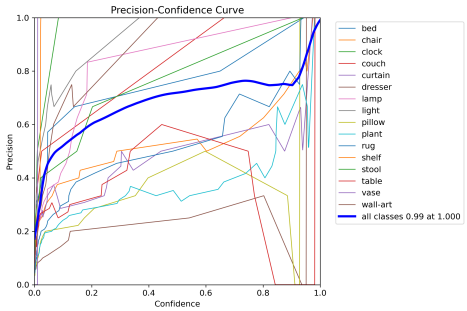

Figure 5: Model Training Validation - Segmentation Mask Precision Curve

Figure 6: Simple Match

extracted object is only local colors to the actual plant (i.e. not the white space) which means this set worked as intended. Additionally, the color matching function was able to find two colors close enough, or enough similarities to neutrals that this object is designated as a color match. This is expected given that the interior also has a plant, and the color shows up in that palette.

Figure 7 showcases how CODEX handles multiple object detections, color palettes, and matches all at once using "examples/interiors/interior5.jpg" and "examples/objects/couch.jpg". This model did fairly well, although it did show a failed color match for one of the pillows that seems erroneous. Looking at the palette it does make sense that they weren't matched, however it should also be noted that the palette of that pillow is not a great match like others. For very small items, the color palette creator isn't as robust as it is for larger interiors. Since small segmented objects have less pixels to work with, compare, and iterate over it can potentially degrade the fidelity of those palettes.

Figure 8 highlights how the custom trained CODEX data set can detect objects that are unique - curtains are not part of the MS COCO data set which means that our custom model with high confidence was able to detect

Figure 7: Multiple Objects

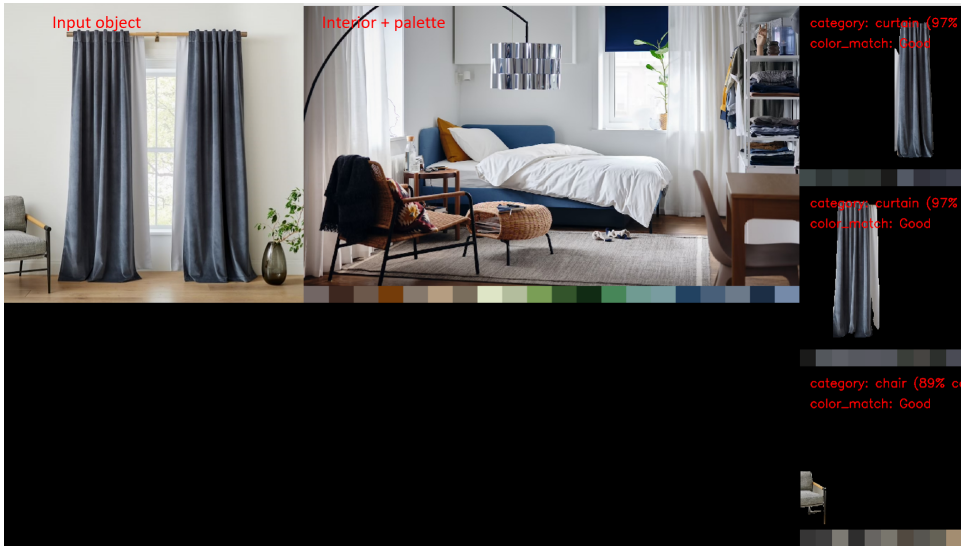

Figure 8: CODEX Custom Categories Detected Succesfully

new objects.

5 Conclusion

Overall, the model performed well for the sample datasets provided. Like all models, there is room for improvement, specifically with how handling colors when you have a smaller sample size affect something like this. While a larger and more comprehensive validation would further vet the model, it is clear that it has met the established goal of segmenting decor objects from busy backgrounds, masking them, finding their color palette, and comparing it to a greater interior. With more human intervention to expand the model, I might guess that this could get better with time.

6 References

This annotated bibliography provides a collection of relevant academic papers and publications that explore the underlying principles of object detection, color matching, and interior design color palettes. The references provide insight into both theoretical and practical applications of these techniques. These sources provide a framework that ultimately aids in the development of the project for accuracy, effectiveness, and addressing the needs of interior designers.

The scope of this bibliography covers a range of topics related to the project, including:

- Object detection algorithms for identifying common décor items in images.
- Color matching techniques for accurately identifying and comparing object colors.
- Interior design color palettes and the principles of color harmony.
- User interface design considerations for creating an intuitive and user-friendly interface.
- Testing and evaluation methodologies for assessing the performance and accuracy of the software program.
- Using large object databases for object detection models

References

[1] codex, "codex$_s egmentation_v 5 dataset,''$ $https$: $//universe.roboflow.com/codex-oqz5i/codex_segmentation_v 5, dec 2023, visitedon 2023-12-11.[Online].Available : https : //universe.roboflow.com/codex-oqz5i/codex_segmentation_v 5$

[2] W. e. a. Feng, "A survey of color palettes in interior design," *ACM Transactions on Graphics (TOG)*, vol. 40, no. 4, pp. 1–14, 2021.

> This paper provides a survey of color palettes used in interior design. It discusses the different types of color palettes, their characteristics, and their applications. This reference is relevant for understanding the role of color palettes in interior design and for selecting appropriate color palettes for the project.

[3] R. e. a. Girshick, "Object detection and instance segmentation with deep learning: Challenges and opportunities," *IEEE Transactions on Pattern Analysis and Machine Intelligence (TPAMI)*, vol. 40, no. 1, pp. 7–27, 2018.

> This paper provides a comprehensive overview of object detection and instance segmentation techniques using deep learning. It discusses the challenges and opportunities in this area, as well as the latest state-of-the-art methods. This reference is particularly relevant for the object detection component of the project, as it provides a foundation for understanding and selecting an appropriate object detection algorithm.

[4] Y. e. a. Huang, "Interactive color matching for interior design applications," *ACM International Conference on Interactive Surfaces and Spaces (ISS)*, pp. 1–6, 2019.

> This paper presents an interactive color matching system for interior design applications. The system allows users to select a color and then finds all matching objects in a scene. This reference is relevant for the user interface design of the project, as it provides an example of how to integrate color matching functionality into a user-friendly interface.

[5] G. Jocher, A. Chaurasia, and J. Qiu, "Ultralytics yolov8," 2023. [Online]. Available: https://github.com/ultralytics/ultralytics

[6] T.-Y. e. a. Lin, "Detecting objects as paired keypoints," *Proceedings of the European Conference on Computer Vision (ECCV)*, pp. 729–744, 2018.

This paper presents a novel object detection algorithm called CornerNet that detects objects as paired keypoints. CornerNet is based on the concept of corner detection, which is a more robust and efficient method for detecting objects than traditional bounding box-based methods. The proposed method achieves state-of-the-art results on the MS COCO (Microsoft Common Objects in Context) large-scale image object detection benchmark. This reference is particularly relevant for the object detection component of the project, as it provides a highly accurate and efficient object detection algorithm that is well-suited for the task of identifying common décor items by utilizing MS COCO dataset images from the furniture, appliances, kitchen/dining, bedroom, living room, and bathroom categories for a potential object detection benchmark model.

[7] T. Lin, M. Maire, S. J. Belongie, L. D. Bourdev, R. B. Girshick, J. Hays, P. Perona, D. Ramanan, P. Doll'a r, and C. L. Zitnick, "Microsoft COCO: common objects in context," *CoRR*, vol. abs/1405.0312, 2014. [Online]. Available: http://arxiv.org/abs/1405.0312

[8] M. e. a. Luo, "Color harmony rules and their applications in interior design," *Color Research and Application*, vol. 45, no. 5, pp. 715–733, 2020.

This paper discusses the principles of color harmony and their application in interior design. It provides a comprehensive overview of various color harmony rules and their impact on visual perception. This reference is relevant for understanding the factors that influence human color perception and color matching in interior design.

[9] Y. e. a. Zhang, "Color matching using cnn-based color distance metrics," *Journal of Electronic Imaging*, vol. 27, no. 4, pp. 1–10, 2018.

This paper presents a method for color matching using convolutional neural networks (CNNs). The proposed method uses a pre-trained CNN to extract color features from images and then compares these features to identify color matches. This

reference is particularly relevant for the color matching component of the project, as it provides a framework for implementing an accurate and efficient color matching algorithm.