FINAL YEAR PROJECT (FYP) DOCUMENTATION

Visualizing Car Wraps with Artificial Intelligence In-Painting Methods

By

Arthur Kynan Wong Jun Siang

TP058030

APD3F2305CS(IS)

A report submitted in partial fulfillment of the requirements for the degree of

Bachelor of Computer Science (Hons) (Intelligent Systems)

at Asia Pacific University of Technology and Innovation.

Supervised by Dr. Vazeerudeen Abdul Hamed

2nd Marker: Assoc. Prof. Dr. Nirase Fathima Abubacker

10-January-2024

DECLARATION OF THESIS CONFIDENTIALITY PAGE

DECLARATION OF THESIS CONFIDENTIALITY

Author's full name: **ARTHUR KYNAN WONG JUN SIANG**

IC No./Passport No.: **TP058030**

Thesis/Project title: **VISUALIZING CAR WRAPS WITH ARTIFICIAL INTELLIGENCE IN-PAINTING METHODS**

I declare that this thesis is classified as:

- ☐ CONFIDENTIAL
- ☐ RESTRICTED
- ☑ OPEN ACCESS

I acknowledged that Asia Pacific University of Technology & Innovation (APU) reserves the right as follows:

1. The thesis is the property of Asia Pacific University of Technology & Innovation (APU).
2. The Library of Asia Pacific University of Technology & Innovation (APU) has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Author's Signature: ……*RTR*……

Date: 10 January 2024

Supervisor's Name: Dr. Vazeerudeen Abdul Hamed

Date: 27 September 2015

Signature: ……**VAZ**……

LIBRARY FORM

Please fill in **all** the following details for library cataloguing purposes.

First Name: Arthur
Middle Name (only if applicable) : Kynan Jun Siang
Last Name: Wong
Title of the Final Year Project / Dissertation / Thesis : Visualizing Car Wraps with Artificial Intelligence In-Painting Methods
Abstract : Visualizing car wraps can be a challenging task, especially for individuals unfamiliar with the final objective. The rarity of car wraps on public roads is caused by societal stigma, which limits exposure to enthusiasts. However, advancements in technology now enable the generation of realistic images from text prompts. This document explores the development of a system leveraging these technological innovations to facilitate the visualization of car wraps, thereby bridging the gap for a broader audience and revolutionizing the way car enthusiasts engage with this form of automotive expression.
A few keywords associated with the work : Computer Vision, Stable Diffusion, ControlNet, Masking, Inpainting
General Subject: Computer Vision, Machine Learning, Image Processing, Web Development
Date of Submission : 10th January 2024

ACKNOWLEDGEMENT PAGE

I would like to provide my most appreciation to my lecturers, my classmates, my family and the Stable Diffusion community. While my classmates were going through their own assignments as well, they had motivated me in a way that pushed me to achieve more than I can. Secondly I'd like to send applications to my supervisors, that really gave me another perspective through confusing times. I really thank my Project Management lecturer, "Ts. Jerry Chong Chean Fuh", while he had zero power or interest in this research, his teachings of being "unique" had stuck with me. Next would be my family as they had little to no knowledge of the subject of this project, they kept me going to push to my best. Someone to note is Chan Yee Qi who would be the one closest to me, as we would be encouraging each other to complete our projects. Lastly the Stable Diffusion community who recommended me with parts of the process of the image to image processing in the project.

ABSTRACT PAGE

Abstract

Visualizing car wraps can be a challenging task, especially for individuals unfamiliar with the final objective. The rarity of car wraps on public roads is caused by societal stigma, which limits exposure to enthusiasts. However, advancements in technology now enable the generation of realistic images from text prompts. This document explores the development of a system leveraging these technological innovations to facilitate the visualization of car wraps, thereby bridging the gap for a broader audience and revolutionizing the way car enthusiasts engage with this form of automotive expression.

Keywords — Computer Vision, Stable Diffusion, ControlNet, Masking, Inpainting

TABLE OF CONTENTS

LIST OF FIGURES

List Of Images

LIST OF TABLES

List Of Tables

CHAPTER 1: INTRODUCTION

1.1 Introduction

A car wrap visualizer stems from the evolving landscape of vehicle customization and the integration of cutting-edge technologies, particularly Artificial Intelligence (AI) image generation. As this system plans to blend the technological ability, visual expression, and a commitment to providing users with an enriched and immersive experience in the pursuit of creating truly personalized and visually stunning vehicles.

Car wrapping has gained appeal not only among individual car enthusiasts but also among businesses recognizing its marketing potential. Personal vehicles have become canvases for self-expression, with a plethora of colors, textures, patterns, and finishes available for customization. Meanwhile, businesses leverage vehicle wraps as dynamic advertising tools, enhancing brand visibility as wrapped vehicles traverse public spaces.

Despite the disfavored popularity of car wraps, there are challenges associated with the visualization of customized wraps, especially for personal vehicles. Unlike traditional services where customers can preview outcomes, car wrapping often relies on customers' imagination and trust in the installer's expertise. This lack of visualization options can be a deterrent for those seeking a more concrete preview of the final look.

The influence of AI technology on various industries in recent years, has started to affect many industries. AI has demonstrated significant capabilities in image processing and generation. This includes AI In-Painting and Image to image methods, which can analyze images, patterns, and color schemes to create realistic visualizations.

1.2 Problem Background

It's common that people tend to be very overwhelmed with choices, especially when there are too many of them. (Cuncic A., 2022) Car wrapping offers an abundance of choices, from colors to styles, materials and even cars. However, the lack of proper visualization options poses a challenge for customers. Without a clear visual representation, customers may hesitate or make the wrong decision when selecting a wrap. To address this, developing advanced visualization tools would greatly improve the customer experience, enabling informed decisions and minimizing regrets. Along with preventing the customer to be disappointed as they compare their vision with their imagination

Having a system to allow customers to have an easier time to visualize their personal car through a visualizer. Will bring the customers an easier time to visualize instead of relying on their imagination. As this system will be able to create hyper-realistic images generated from a generative artificial model that combines the customer's car image input provided by them and applying a new wrap through in-painting techniques.

1.3 Project Aim

The aim of the development of this system is to be able to utilize the uprising technology of image generation to provide a way of visualizing car exteriors. Allowing enthusiastic and newcomers to use this system to gain an idea of the final outcome of their vehicle customizations.

1.4 Objectives

- To utilize Artificial Intelligence image generation in the system to create image visualizers for the users.
- To reimagine the user's image input to what they requested in the system inputs.
- To recreate the vehicle in the image with different colors, patterns, materials and styles.
- To develop a system that is simple to use for users while retaining the option to be highly detailed.

1.5 Scope

The scope of the car wrap visualizer project requires a comprehensive exploration and development effort to improve the field of vehicle customization visualization through the integration of cutting-edge technologies. The project aims to develop a system that utilizes Artificial Intelligence (AI) image generation to generate realistic visualizations of car wraps, allowing users to experiment with a wide range of different customization options. The primary focus lies in addressing the challenges associated with limited visualization options for personal cars, catering to both individual car owners and businesses. As the visualizer is to help bridge the gap between imagination and reality, offering users a preview of their chosen car wraps. Furthermore, the project extends its scope to provide businesses with a dynamic tool for visualizing brand elements on their fleet of vehicles, enhancing marketing strategies. Enforcing a user-centric approach, which inspires consumer confidence, satisfaction, and empowerment in the decision-making process.

1.6 Potential Benefit

1.6.1 Tangible benefits

More Customers - With new technology bounds in an industry to have new customers coming to the industry. (Ghosh A., 2021) As the system is new and will be widely usable, it would be the same situation as when better cameras came to iPhones, it brought new customers to Apple the company. As this would be the same concept marketing and exposure.

Increase revenue - Coffed mentions that customers will be more likely to purchase products when its customizations are provided. (Coffed K., 2020) With this system allowing customers to explore many areas of exterior customization it will provide the automobile companies explore more areas of customization, bringing in more revenue.

Labor and Expense - Labour would be increased and decreased in both good ways. As the new system will provide customers with less doubt, during the process of wrapping the customer will not request to stop and change the wrap mid process. (Salimova et al., 2022) This would reduce the expenses as well too. Along with where there are more customers, it's bound to have more work.

1.6.2 Intangible benefits

Personalization - Car wrapping is all about getting the exterior visuals of the vehicle to look good, the visual can be fit to what the customer can customize for.

Customer Satisfaction - The customer will be greatly satisfied to find a car wrap that would best fit their car.

Demand Forecasting - With the system allowing customers to find their car wrap, the system would be able to track customer's preferences and be able to forecast the demand of certain wraps.

1.7 Overview of the IR

Chapter 1:

The first chapter of the IR delves into the pressing issue at hand within the specific domain area of the problem context. Here, we shed light on the intricacies and challenges that have prompted this investigation project. Within this section, we outline the aim and objectives that serve as the guiding principles of our research. They provide a clear direction for our endeavors and establish the framework for addressing the identified problem. Additionally, we explore the potential benefits that can be derived from the findings of this investigation. By understanding the positive outcomes that may arise, we can emphasize the significance and relevance of our work. Moreover, we specify the target users who stand to gain from the results of this report. By identifying and addressing their needs, we ensure that our research has a tangible impact on the intended audience and contributes to their specific requirements.

Chapter 2:

The second chapter contains a literature review that diligent research has been conducted within the domain area and the thorough literature review on the subject of Visualizing Car Wraps with Artificial Intelligence In-Painting Methods. Gathering relevant and valuable data, as the report aims to present a detailed and insightful summary, divided into two essential sections: domain research and research on similar works. Compiling this information, the research strives to provide a comprehensive understanding of the topic and its relevant aspects, ensuring that the report serves as a valuable resource in this chapter.

Chapter 3:

This chapter contains technical research that goes in depth of Artificial Intelligence In-Painting techniques, and how it can be applied to a virtual wrap on cars. Exploring models such as Midjourny, OpenAI - DALL-E, or Stability-AI - Stable Diffusion. Image processing techniques will be analyzed within this section.

Chapter 4:

The fourth chapter consists of the System Development Methodology discussion (SDM) on which SDM will be used during the system's development. Exploring different SDMs and analyzing which SDM will be best fit for this development.

Chapter 5:

This chapter explores the research method that will be used to gather requirements through data collection and analysis. Where the survey questions created will be analyzed and explained on why the question would be relevant and required within the survey.

Chapter 6:

With the research method chapter completed, the answers analyzed, here will show validation for the requirements collected from the respondents. The answers given from the survey will be compiled, visualized, and evaluated. Exploring the reasons for the answers provided and validating requirements for the system.

Chapter 7:

In this concluding chapter, the researcher will compile a comprehensive summary and engage in a brief discussion regarding the key points addressed throughout this Investigation Report. Furthermore, this section will encompass the drawing of conclusions and reflections on the entire project, highlighting the significant insights gained. By encapsulating the essence of the research journey, this final chapter aims to provide a cohesive and insightful overview, showcasing the culmination of efforts and the meaningful outcomes derived from this investigation.

1.8 Project Plan

TASK NAME	DURATION	START DATE	END DATE	STATUS
(IR) Chapter 1: INTRODUCTION TO THE STUDY	4 Days	26 June 2023	29 June 2023	Completed
1.8 Project Plan	<1 Day	26 June 2023	26 June 2023	Completed
1.1 Background to the project	<1 Day	26 June 2023	26 June 2023	Completed
1.2 Problem context	<1 Day	26 June 2023	26 June 2023	Completed
1.3 Rationale	<1 Day	26 June 2023	26 June 2023	Completed
1.4 Potential benefits	<1 Day	26 June 2023	26 June 2023	Completed
1.4. 1 Tangible benefits	<1 Day	27 June 2023	27 June 2023	Completed
1.4. 2 Intangible benefits	<1 Day	27 June 2023	27 June 2023	Completed
1.5 Target users	<1 Day	27 June 2023	27 June 2023	Completed
1.6 Scope and objectives	<1 Day	27 June 2023	27 June 2023	Completed
1.6.1 Aims	<1 Day	28 June 2023	28 June 2023	Completed
1.6.2 Objectives	<1 Day	28 June 2023	28 June 2023	Completed
1.6.3 Deliverables - Functionality of the proposed system	<1 Day	28 June 2023	28 June 2023	Completed
1.6.4 Nature of Challenges	<1 Day	29 June 2023	28 June 2023	Completed
1.7 Overview of this Investigation report	<1 Day	29 June 2023	29 June 2023	Completed
(IR) Chapter 2: LITERATURE REVIEW	7 Days	8 July 2023	15 July 2023	Completed
2.1: Introduction	1 Day	8 July 2023	8 July 2023	Completed
2.2: Domain research	4 Days	9 July 2023	12 July 2023	Completed
2.3: Similar Systems	2 Days	13 July 2023	15 July 2023	Completed
(IR) Chapter 3: TECHNICAL RESEARCH	4 Days	15 July 2023	18 July 2023	Completed
3.1: Programming languages	1 Day	15 July 2023	15 July 2023	Completed
3.2: IDE (Interactive Development	1 Day	16 July 2023	16 July 2023	Completed

Environment)				
3.3: libraries chosen / Tools chosen	1 Day	17 July 2023	17 July 2023	Completed
3.5: Operating System chosen	1 Day	18 July 2023	18 July 2023	Completed
3.8: Summary	< 1 Day	18 July 2023	18 July 2023	Completed
(IR) Chapter 4: SYSTEM DEVELOPMENT METHODOLOGY	3 Days	20 July 2023	22 July 2023	Completed
4.1 Introduction	1 Day	20 July 2023	20 July 2023	Completed
4.2 Kanban	1 Day	21 July 2023	21 July 2023	Completed
4.3 Lean Development	1 Day	22 July 2023	22 July 2023	Completed
4.4 Comparison Table	< 1 Day	22 July 2023	22 July 2023	Completed
(IR) Chapter 5: RESEARCH METHODS	4 Days	25 July 2023	28 July 2023	Completed
5.1: Introduction	1 Day	25 July 2023	25 July 2023	Completed
5.2 Research Method Types	1 Day	26 July 2023	26 July 2023	Completed
5.3 Survey Method Selection Justification	1 Day	27 July 2023	27 July 2023	Completed
5.3 Survey Design	1 Day	28 July 2023	28 July 2023	Completed
(IR) Chapter 6: REQUIREMENTS VALIDATION	1 Day	2 August 2023	2 August 2023	Completed
6.1 Analysis of Data	< 1 Day	2 August 2023	2 August 2023	Completed
6.1.1 Analysis of data collected through Questionnaire	< 1 Day	2 August 2023	2 August 2023	Completed
6.2 Summary	< 1 Day	2 August 2023	2 August 2023	Completed
(IR) Chapter 7: CONCLUSION AND REFLECTIONS	1 Day	7 August 2023	7 August 2023	Completed
7.1 Conclusion	< 1 Day	7 August 2023	7 August 2023	Completed
7.2 Reflection	< 1 Day	7 August 2023	7 August 2023	Completed
7.3 References	< 1 Day	7 August 2023	7 August 2023	Completed

7.4 Appendices	< 1 Day	7 August 2023	7 August 2023	Completed
(Project) Project Plan	5 Days	9 August 2023	13 August 2023	Completed
Plan for features to include	< 1 Day	9 August 2023	9 August 203	Completed
Draft versions of each plan	2 Days	10 August 2023	11 August 2023	Completed
Create Test Plan	2 Days	12 August 2023	13 August 2023	Completed
(Project) Implementation		15 August 2023	15 December 2023	Completed
Coding, Debugging & Testing	122 Days	15 August 2023	15 December2023	Completed
(Project) Documentation	30 Days	18 December 2023	5 January 2023	Completed
Write documentation of the system	30 Days	18 December 2023	5 January 2024	Completed
(Project) Conclude	3 Days	6 January 2024	9 January 2024	Completed
Record and edit video	2 Days	6 January 2024	8 January 2024	Completed
Compile system and files	1 < Day	9 January 2024	9 January 2024	Completed

Table 1.

CHAPTER 2: LITERATURE REVIEW

2.1 Domain Research

2.1.1 Visualizing Cars

Selling a product is hard, while selling a product without knowing how it looks is even harder. The automotive industry and its sub industries have been slowly approaching this issue with the current trend of online purchasing. Having images from different angles or a 3D model of a car will help give the customer an idea of how it looks, these methods are the most common way to visualize a car. While the researcher's project is targeted toward visualizing exterior customization, that also has a big issue that is related to what was mentioned of not knowing the final look of the product. Commonly also known in the business industry as "Planned buying". As the customers will make sure they fully understand and know what they are purchasing before actually paying. (Khan, Y., et al, 2023)

As to address the customer habit of "Planned buying", Planned buying is explained as "A planned purchase is characterized by deliberate, thoughtful search and evaluation that normally results in rational, accurate and better decisions" by researcher Paul (2004). Planned buying is a positive and advantageous behavior for both customers and businesses. With the customers ensuring their purchase from the company will not disappoint them. (Paul B., 2004) To help with customers' decisions with their habit of planned buying, a lot of information needs to be provided to them. In an automotive exterior customization sub-industry, the most important of knowledge is knowing how the final product looks like.

In the automotive customization sub-industry, providing knowledge and information about a visual change can happen in a few ways. The best option would be giving the customer a full size comparison with the actual product. (Paul B., 2004) As this is simple as it is just showing a sample of an already completed wrap. While this would be the best option, it is just not viable to have a car wrapped ready, as the customer can have a wide range of car models.

To combat the issue of not being able to have a ready car to be sampled, the second best options would be pictures or videos that can display the wrapped car accurately. This method can be implemented through 3D models of the cars or regular pictures.

Commonly in cheaper locations wrapping companies utilize regular pictures to showcase their works to provide an example. Where this method's limitation is how the company would only have done a limited range of car models. Whereas on the internet it can be different, such as the majority of car visualizers online use a type of 3D models made in 3D modeling software, such as Blender. Using 3D models does not require the actual car and can implement the wrap onto the car without actually doing it. While it "can" create very realistic 3D models it often has issues. As Silvestre and team had mentioned that 3D models can only get so realistic, with its provided limitations. (Silvestre, I., et al., 2015)

Figure 1. Image of 2014 FORD FIESTA ST HATCHBACK Visualized by "In Motion Brands."

Two major issues that can be identified for using 3D models are a lack of realism and unavailable preset models. As the realism of the image can be easily identifiable through the system commonly using 3D modeling software. On the other issue of unavailable presets, it's caused by the system's dataset as you can only keep up to date and store so much variation of different cars and models. (Silvestre, I., et al., 2015)

To justify the researcher's methodology of using AI In-painting, comparisons between 3D car models and images from image generative AI will be compared.

2.2.1.1 3D Models vs Image Generative AI

Before continuing this section, first note that the images chosen are what is available online, not within a 3D model application. While 3D models have proven its potential for its realism in movies such as Avatar. (David P., 2022)

Although the differences here are the manpower and budget, due to how much time and effort it takes to create one 3D model, there can be many small details to create during the creation of the 3D model. (Li, C., et al., 2023)

To move on to the next topic of determining the "best" image result from 3D Models vs Image Generative AI is very subjective. While here in this paper the objectives mentioned were to provide realistic visualization. Which means that the following images should be rated based on realism, but based on what was mentioned above, 3D models can be as realistic as real life as long as manpower and hours are put in. (Liu, V., et al., 2023) These other factors need to be included as well. For how much effort it takes to make the quality. As mentioned by Smaczyński, the more detailed a 3D model is, the more hours it takes to create one. (Smaczyński, M., 2021) The following images below are a set of 3D model images created by people and images generated by AI with human promptings.

	
3D Model (sketchfab - Martin Trafas - 360 View)	Image Generative AI (Reddit - Superb-Ad-4661)

Table 2.

	3D Model (McLaren 720s) (Artstation - Loïc Deux - 360 View)
	Image Generative AI (McLaren 720s) (Reddit - Ill_Ad107)

Table 3.

	3D model (Rolls-Royce Phantom) (sketchfab - kurojishi - 360 View)
	Image Generative AI (Rolls-Royce Phantom) (Reddit - Superb-Ad-4661)

Table 4.

	3D Model (BMW E46) (HUM3D - BMW 3 Series sedan (E46) 2006 3D model - 360 View)
	Image Generative AI (BMW E46) (Lexica - with prompt “forest green e46 bmw, stock sedan, driving through Connecticut, realistic”)

Table 5.

2.2 Computer Vision

2.2.1 Image Segmentation

The vision of the system process flow from the researcher has in mind includes image segmentation. Image segmentation in this system will be used to extract the location and the pixels of the vehicle's body. This happens through splitting the image into regions, parts "segments". Those regions that are segmented can be based on many factors set by the researcher. (Minaee, S. et al. 2021)

To provide a basic explanation of image segmentation, it involves giving each pixel or region in an image a label or identifier. This is done by analyzing certain characteristics or factors, like color, intensity, texture, or other visual features. By grouping similar pixels or regions together and separating them from the rest of the image, we can distinguish different parts effectively. (Zhang, Q., et al., 2020) This process is vital in extracting valuable information and identifying various objects or elements within the image. While it can find many applications in computer vision and image processing, it can be utilized to detect the vehicle's body. (Minaee, S. et al. 2021)

From that vehicle body can be detected and segmented to apply a car wrap onto the segmented location. Image segmentation would help achieve the final output of this system. This section explores and discusses the two types of image segmentation, traditional and deep learning techniques, and how each of their benefits and functionalities can be used with Visualizing Car wrap.

2.2.2 Traditional Segmentation

With all possible segmentation techniques, the traditional method is and was the first of techniques that start it all. Through the handcrafted rules and parameters. These rules make effective use of low-level image features like color, intensity, texture, and edges, skillfully applying clustering algorithms to group pixels into coherent regions. This meticulous process allows for the identification of distinct elements within the image, enabling a meaningful partitioning of the visual data. One of the significant advantages of these methods is their ability to deliver satisfactory results without the burden of extensive labeled data for training. By relying on carefully crafted rules, they can achieve segmentation with reasonable accuracy, even in situations where labeled datasets are limited or unavailable.

Moreover, the computational efficiency of traditional segmentation methods sets them apart from the resource-intensive nature of deep learning approaches. Unlike deep learning, which often requires large-scale datasets and extensive computations, these handcrafted methods prove to be more lightweight and faster to execute. The reduced computational load makes them an attractive choice for real-time or resource-constrained applications. As a result, traditional segmentation methods continue to find relevance and practicality in various fields, from computer vision tasks to image processing applications. (Romera, E., et al., 2019) Their blend of ingenuity and practicality has stood the test of time, making them a valuable tool for researchers and practitioners seeking effective segmentation solutions without compromising on accuracy and speed.

As mentioned above, usually each method used within the traditional way had a human hand written the algorithm. Such methods are: Thresholding, Region-Based Segmentation, Edge-Based Segmentation, and many more. The discussion for either traditional or deep learning methods will be used by the researcher for the upcoming project will be discussed below.

To list the key strengths and weaknesses it has on its own:

Strengths

- Simplicity: Traditional methods are easier to understand and implement due to their straightforward techniques.
- Speed: They exhibit computational efficiency, making them suitable for real-time applications or resource-constrained environments.
- No Data Dependency: Traditional segmentation can work well even with limited labeled data.

Weaknesses

- Limited Complexity: Traditional methods may face challenges when dealing with complex scenes or images containing overlapping objects, as the handcrafted features might not be sufficient to capture intricate details.
- Sensitivity to Parameters: The effectiveness of traditional segmentation methods often relies heavily on fine-tuning parameters tailored to specific applications, which can be a laborious process.
- Generalization: They might not generalize well to unseen data or different types of objects, limiting their adaptability and robustness in diverse scenarios.

Note that the strengths and weaknesses identity above is not for the system but rather for itself. (Ghosh, S., et al. 2019) While if it were for the system, the benefits from the above mentioned would be the benefit of “No Data Dependency”. While it is possible to find data of cars and wrapped cars, it would be largely time consuming to classify it all. Although there are a lot of down sides to the traditional method within the car visualizer system. As the plan of the system is to allow the user to take an image of a car from a reasonably good looking angle and apply in-painting, this means that it would bring a lot of “Generalization” and effect the image segmentation greatly since it’s “Sensitivity to Parameters”. This is due to how the image provided by the user can vary a lot from different lighting of sunlight, or different angles and many other factors. (Ikeuchi K., 2021)

2.2.2.1 Threshold image segmentation

Threshold image segmentation is a technique to complete the task of image segmentation. It is able to distinguish objects from the background in grayscale images by converting the image into a binary format. (Chakkaravarthy, A., et al., 2019) As an example provided below, to explain it, white pixels represent the foreground, and black pixels indicate the background, making it easier to analyze and identify objects in the image.

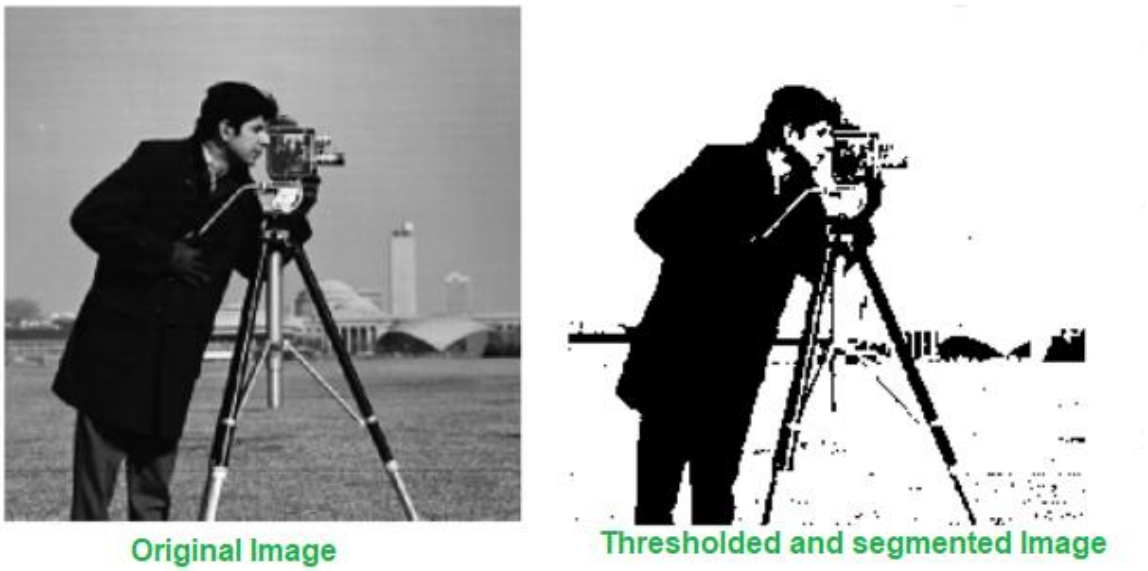


Figure 11. Thresholded and segmented image comparison (Geeksforgeeks, 2018)

Sensitivity to Lighting Conditions presents a notable challenge in thresholding, as it heavily relies on intensity values. Variations in lighting, such as uneven illumination or pronounced shadows in the image, can adversely impact segmentation accuracy, yielding inaccurate results. (Ikeuchi K., 2021)

Noise Interference is another concern when using thresholding. The presence of noise, with its random fluctuations in pixel values, can disrupt the process, leading to misclassification and the formation of noisy or fragmented segmented regions. (Ikeuchi K., 2021)

Dealing with complex backgrounds proves to be a daunting task for thresholding. In scenarios where the background exhibits intensity values similar to the objects of interest, distinguishing between foreground and background becomes problematic, potentially resulting in erroneous segmentations. (Ikeuchi K., 2021)

Variations in Object Intensity add another layer of difficulty. When the objects of interest share intensity values similar to either the background or each other, finding an appropriate threshold that effectively separates them becomes an intricate challenge. (Ikeuchi K., 2021)

Uneven Object Lighting introduces additional complexities. If the objects themselves exhibit non-uniform illumination or shading, thresholding may struggle to establish accurate boundaries, leading to incomplete or imprecise segmentation outcomes. (Ikeuchi K., 2021)

2.2.2.1 Region-based image segmentation

Region-based image segmentation technique is able to split an image into purposeful regions, united by their resemblance in the visual attributes. To initiate the process, seed points or initial regions are selected, serving as the foundation algorithm takes place. The regions are nurtured and expanded, taking the neighboring pixels that share similar features. The algorithm keeps going on until certain criterias are met. Commonly but optional, post-processing steps can be included, like merging or splitting regions, as it can improve the segmentation's quality. The final output provides regions with each unique representative characteristic. (Gould, S., et al., 2009) While also there are other ways to do this other than split and merge, there is region growing, and graph cut, which both will also provide a similar result.

Although this technique of segmentation can lead to two contrasting outcomes. In some cases, it may result in over-segmentation, where the image gets excessively divided into small and fragmented regions. On the other hand, it also can suffer from under-segmentation, where some regions remain merged, and distinct objects lose their separation. Both effects can be caused by bad parameters or very difficult images, which affects the accuracy in the segmentation.

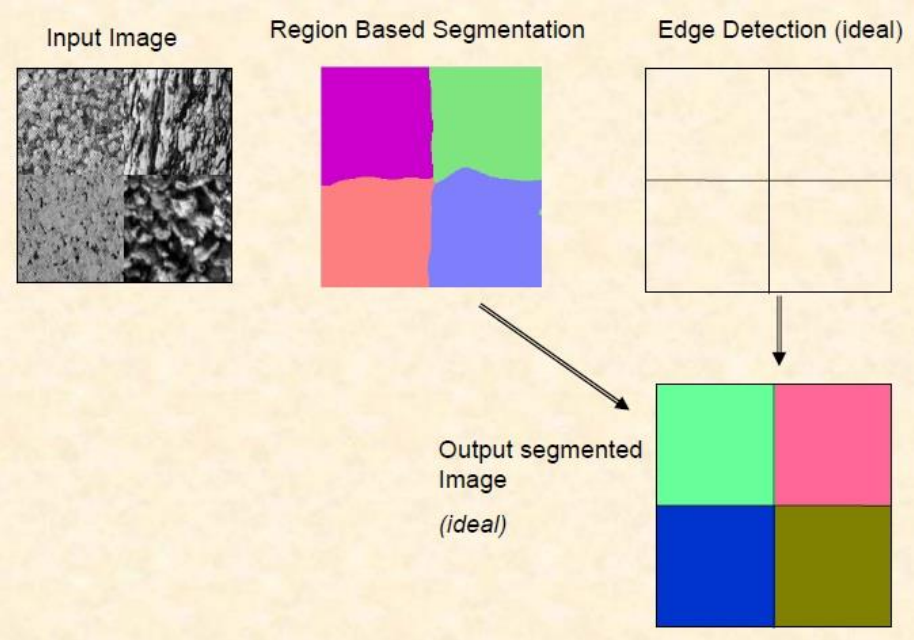


Figure 12. Result of Region Based with edge detection post-processing step (IPPR Practical, 2012)

Provided there are many more different and unique traditional image segmentation methods which are very commonly combined together to create a better segmented output. (IPPR Practical, 2012)

With the research content shown above in traditional image segmentation, it has shown that such it is able to provide good segmentation results but it is limited to certain situations. With the researcher's objective it would be an issue, as the researcher aims to allow the user to input any image without constrictions, thus making deep learning segmentation the next best option.

2.2.3 Deep Learning Segmentation

While on the other hand, Deep Learning Segmentation presents a new method of computer vision segmentation. It uses the power of deep learning techniques, particularly convolutional neural networks (CNNs), to handle the challenging task of image segmentation. While it has the same objective with traditional methods of breaking down an image into meaningful regions or segments, with each pixel receiving a specific label that signifies the object or category it pertains to. It does it in a way of using capabilities of CNNs to learn certain patterns and features, deep learning-based image segmentation achieves remarkable precision, opening up a world of possibilities in various applications across the field of computer vision. (Pasupa, K., et al., 2022) Through its ability to provide a more fine-grained understanding of visual data, Deep Learning Segmentation proves to be a valuable asset in advancing the frontiers of computer vision research and development. As to list the strengths and weaknesses of the Deep Learning Segmentation which are:

Strengths

- High Accuracy: Deep learning segmentation models excel in achieving exceptional accuracy, particularly in challenging and complex segmentation tasks. They can discern intricate patterns and semantic information, leading to precise and reliable segmentations. (Pasupa, K., et al., 2022)
- Generalization: Deep learning segmentation models have the ability to generalize effectively to unseen data and different data distributions. When trained on diverse and labeled datasets, these models can adapt to variations in appearance, lighting conditions, and viewpoints, ensuring robust performance in various scenarios. (Pasupa, K., et al., 2022)
- Flexibility and Adaptability: Deep learning segmentation models offer flexibility and adaptability, making them well-suited for diverse tasks and datasets. Leveraging transfer learning, they can be fine-tuned using pre-trained models on large datasets, saving valuable training time and resources.
- Availability of Pre-trained Models: The availability of numerous pre-trained deep learning segmentation models serves as a valuable resource for different applications. Utilizing these models as a starting point allows for faster development, and they can be further fine-tuned on specific datasets to meet specific requirements.

Weaknesses

- Data Requirements: Deep learning segmentation models often demand a substantial amount of labeled training data for optimal performance. Obtaining such high-quality labeled data can be costly and time-consuming, especially in specialized domains.

- Computationally Intensive: Training deep learning segmentation models can impose significant computational demands, especially for large networks or high-resolution images. The process of inference, i.e., segmentation on new data, can also consume considerable resources. (Lin, Y., et al., 2021)

- Overfitting: To avoid overfitting issues, deep learning models require adequate data augmentation and regularization during training. Otherwise, they may become too tailored to the training data, leading to poor generalization and performance on new and unseen data. Which also leads back to the data requirements issue. (Lin, Y., et al., 2021)

While the strengths and weaknesses discussed above are key points of the deep learning method in general. As both will be analyzed to find which will be used by the researcher.

2.2.3.1 Deep Learning Image Segmentation Justification

When it comes to extracting pixels off an image of a specific region of a vehicle's body. The researcher will be choosing Deep learning segmentation. The main benefits are “Availability of Pre-trained Models”. Deep Learning segmentation will take more computational power and can affect the performance of the system, the benefits outweighs it. Pre-trained Models will be able to provide higher accuracy detection of the vehicle's body and greatly reduce development time of the system. (Lin, Y., et al., 2021) Such deep learning models can be used to segment and classify car parts to properly identify the region to in-paint.

2.2.3.2 Pre-trained Models

Such “Pre-trained models” can be used for this research, while not entirely already trained, as it would require classification of either the car body part or the car itself. The short list below shows the commonly used segmentation models, but not specified to the vehicle's body. (Pasupa, K., et al., 2022)

- Segmentation Models PyTorch: A library for deep learning with pre-trained models like Unet, Linknet, FPN, PSPNet, PAN, DeepLabV3 (resnet101), etc. Offers a pre-trained car segmentation model on CamVid dataset.
- YOLO (You Only Look Once): Object detection system for real-time processing. First 20 conv layers pre-trained with ImageNet, then converted for detection to improve performance.
- TensorFlow: Provides multiple pre-trained image segmentation models for applications like medical imaging, self-driving cars, and satellite imaging.

2.2.3.3 Car Segmentation and classification through Mask R-CNN, GCNet and more.

As mentioned above the task of segmenting car body parts is not a new task, and some research has already been done for it. As Kitsuchart and team has completed research, they have used a semantic segmentation technique to detect and segment and classify car body parts out, as shown in the image below. (Pasupa, K., et al, 2022)

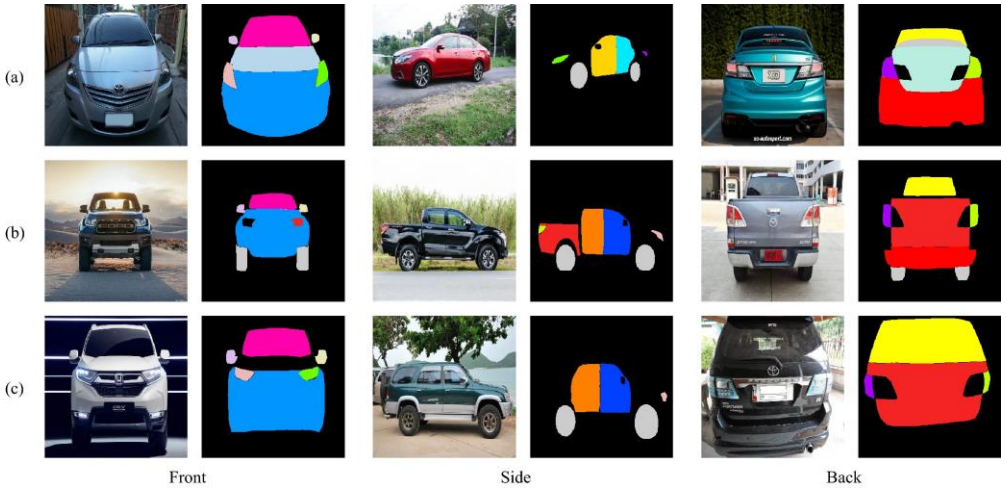


Figure 13. Samples of pair images and instance mask from the DSMLR Car Part data set: a sedan, b pickup and c sports utility vehicle (SUV) (Pasupa, K., et al., 2022)

As their work was to identify car damage and evaluate it for car insurance, Kitsuchart and team had experimented with many different models for semantic segmentation tasks in different weather conditions. Through their meticulous experiments, the team made remarkable discoveries regarding the performance of various models in object detection and semantic segmentation tasks under normal weather conditions. Topping the charts was the HTC model, exhibiting the best results, followed closely by Mask R-CNN and GCNet. (Pasupa, K., et al, 2022)

Taking the evaluation a step further, the team sought to assess the algorithms' robustness in real-world environmental and lighting conditions, akin to the scenarios encountered while capturing photos using smartphones in the field. The results unveiled an impressive feat by GCNet, which showcased unparalleled robustness in most real conditions, solidifying its position as the top-performing model overall, except in scenarios with varying brightness levels. (Pasupa, K., et al, 2022)

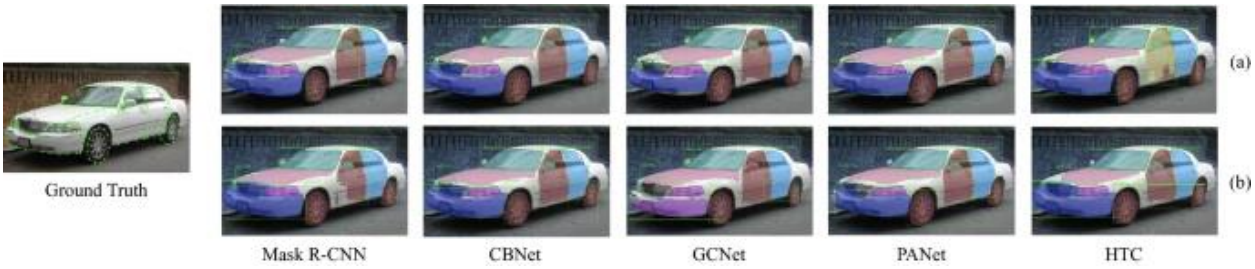


Figure 14. Sample of object detection and semantic segmentation results: a ResNet-50 Encoder and b ResNet-101 Encoder (Pasupa, K., et al., 2022)

2.2.3.4 Car Segmentation through UNet Implementation using PyTorch

Yakhyokhuja Valikhujaev a Machine Learning Engineer who published a work of Car Segmentation through UNet Implementation. As the title of the section mentions, it uses a UNet Implementation. As it is a very attractive model to be applied to various segmentation tasks commonly in medical images, road segmentation, and many others. Its technical details will be explained in a different section. While Yakhyokhuja's implementation had used a dataset from Carvana to train and test the model, and using dice loss implementation for its evaluation. The image below was provided by the Yakhyokhuja result sample. As it would be perfect for the researcher's goal to also integrate this implementation with the project. (Yakhyokhuja V,, 2022)

Figure 15. Example of image segmentation in the car masking challenge. The left image is the image to be segmented and the right one is the segmentation. (Xu, J., et al., 2018)

2.2.2 In-Painting

This project's main goal is to be replacing pixels on a vehicle's body, to achieve that, the research will be using a computer vision technique of In-Painting, more specifically Image generative AI technology that replaces pixels in an image seamlessly with new pixels that will show the same image but with a different vehicle body. As to use deep learning models to generate new pixels that fit with an image. (Guillemot, C., et al., 2013)

In-painting the technique itself is not new as it was done as a way of art restoration, whereas restoring images was a practice of having missing or damaged components of an image find their way back to completion. This could be done through skillfully reconstructing the absent parts of a visual composition, ensuring a seamless integration that leaves the final result looking as though the damage or missing elements were never present. (Elharrouss, O., et al, 2020) While the

research plans on implementing AI to Inpaint on to the images of cars, which then Image Generative AI needs to be explored.

With new technologies released by Stability A.I. They have released an Open Source project that allows developers and users to create images from text. (Lee, S., et al., 2023) Along with recently releasing an image to image and inpainting plus masking features. These features are not catered to replace paint on vehicle body to car wrap. The researcher plans to use this technique and merge the two domains together. (Zhang, C., et al., 2023)

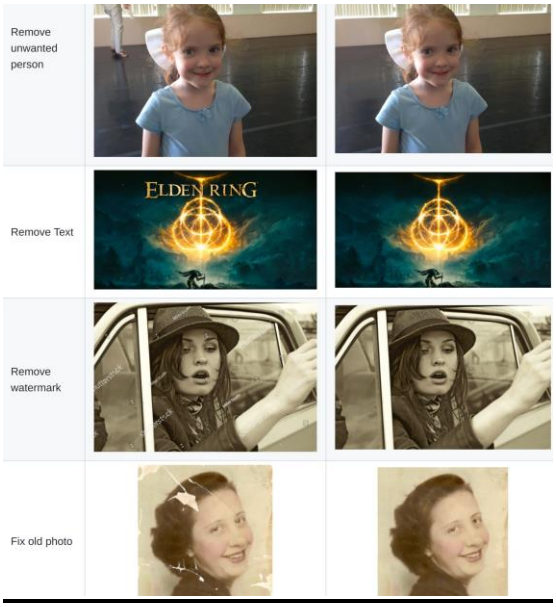


Figure 16. Sample comparison of Lama Cleaner, integrating multiple inpainting Models including LDM (Sanster, 2022)

2.2.2.1 Image Generative AI

A research done by Zhang and team had explored the domain of Image Generative AI. As in the paper, they explore the past and present of text-to-image generation, a crucial aspect of Image Generative AI. As it focuses on the approaches and models used to create visually realistic images from textual descriptions. Notably, it covers the application of GAN-based methods, autoregressive methods, and diffusion-based models in this context. While with the current time of growing interest within diffusion models that has emerged as a new state-of-the-art technique in text-to-image generation. The paper's primary goal was to explore the recent advancements in text-to-image generation, with a specific emphasis on the impressive progress made through

diffusion models. (Zhang C., et al., 2023) As the image provided below shows the recent years of massive improvement of image generative AI through diffusion based models.

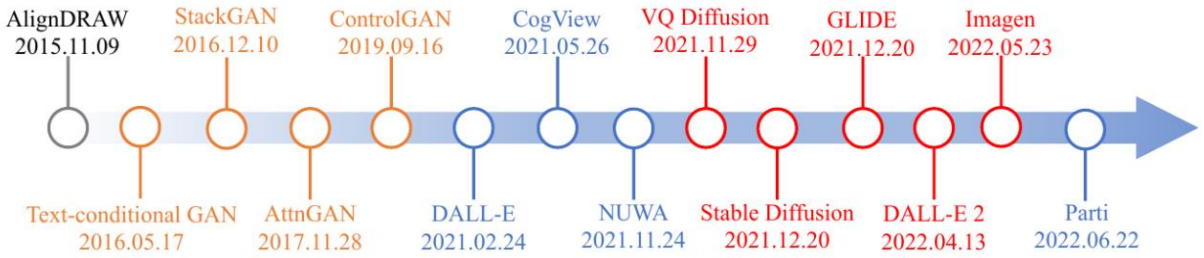


Figure: Over time, various approaches to the text-to-image task have emerged as represented by works using GAN-based methods (marked in yellow), autoregressive methods (marked in blue), and diffusion-based methods (marked in red). (Zhang C., et al., 2023)

Figure 17.

Generative Adversarial Network

To explore the different techniques of image generation for in-painting, the first technique that can be explored would be Generative Adversarial Network and its variants. Generative Adversarial Networks' (GAN) process includes a generator and a discriminator. These generators and discriminators are responsible for training and model output.

The inputs for the generator and discriminator are used in different ways, where in the generator it takes in input of latent variables (representation of compressed data (Tiu E., 2020)) which turns it into fake data. This fake data is later used within the discriminator, discriminator takes in 2 inputs, which includes fake data and real data. Its process is to determine which data is real. Then this process is repeated until the fake data is indistinguishable to the real data.

Variations of Generative Adversarial Network

The variations of GAN contain many different variations, with each slightly different from each other but contains the main concept of GAN. To list a few would be the following

- Conditional GAN (cGAN)
- Information Maximizing GAN (InfoGAN)
- Least Squares GAN (LSGAN)
- Deep Convolutional GAN (DCGAN)
- Boundary Equilibrium GAN (BEGAN)
- Progressive-Growing GAN (ProGAN)
- Any many more

One which can be explored to analyze the differences from the original GAN would be cGan. Conditional Generative Adversarial Network, one of many variations of GAN, now includes more data during its training. These data are noise, class labels and extra conditioning information. These additional data will guide and control the output of the model. In ways such as providing a class label of "blue" it will push the model to generate images that include the color blue. This happens because extra conditioning information is included into the training process, where on top of the regular GAN process, it includes the conditions.

Diffusion Model

The main concept of a diffusion model requires two main steps. One is after taking an image input, it slowly adds Gaussian noise to it gradually in a series of T steps, this is considered the forward process. On a side note, to create a neural network that is able to reverse the process, it is required to generate the targets for the neural network (the image after applying t<T noise step). (Luo, C. 2022) (Sergios K., 2022) (Ho, J., 2020)

Followed by that, to reverse the noise process, the neural network created from the targets will be able to recover the original data through reversing the noise process. Through the model's reverse process, new data can be generated. This can be called the reverse process. Although doing this process multiple times will not generate the exact same image every time, as it can diverge slightly. (Cao H., et al., 2022)

The process can be seen in the image below.

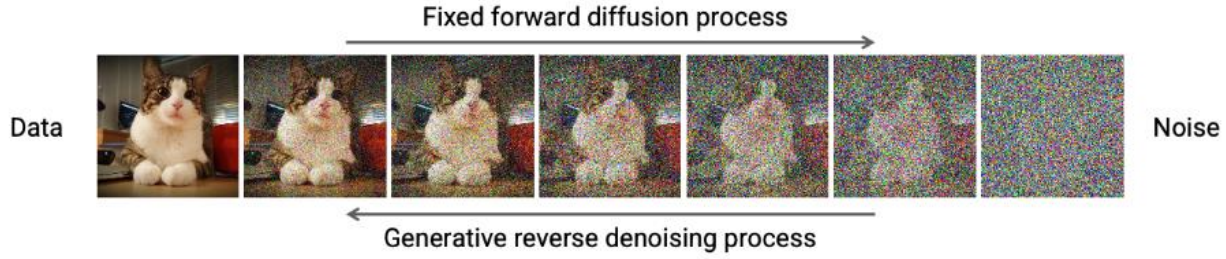


Figure 18. Diffusion models processes: forward and reverse. (Zhang L., et al., 2023)

Diffusion Autoencoder

A diffusion autoencoder has an encoder, decoder, and a noise map with semantics. The semantic and noise map allows for nearly perfect reconstruction almost every time. Although if we change the noise map with a random sample noise map, the output will be changed slightly, as shown in the sample below where the features on the face changed slightly.

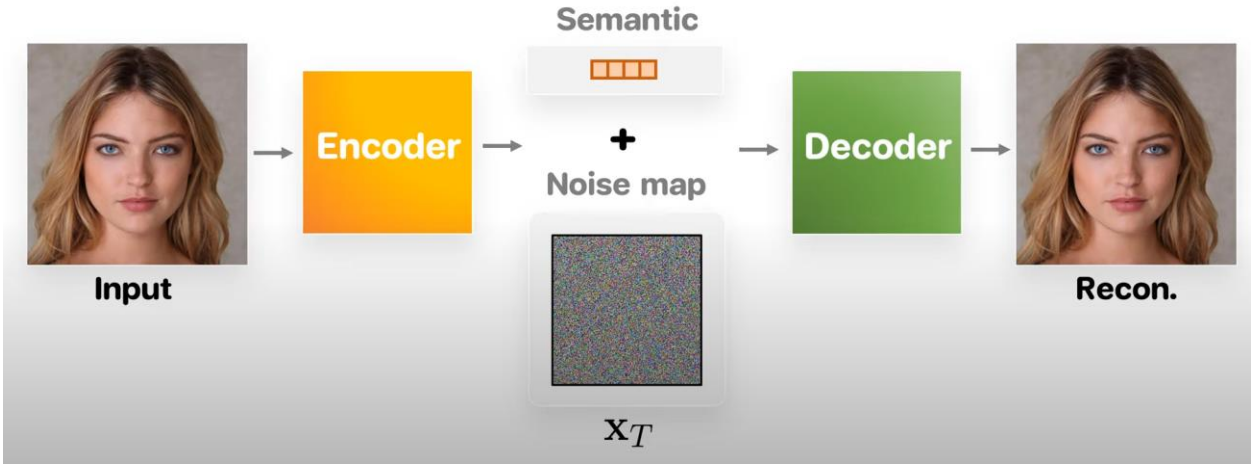
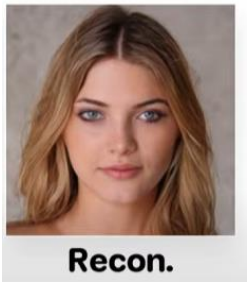


Figure 19. Diffusion model with Semantics (Sergios K., 2022)



Attributes	Ours	StyleGAN-W
5_o_Clock_Shadow	**0.96**	0.94
Arched_Eyebrows	**0.88**	0.86
Attractive	**0.90**	0.86
Bags_Under_Eyes	**0.89**	0.85
Bald	0.99	0.99
Bangs	**0.98**	0.95
Big_Lips	**0.73**	0.68
Big_Nose	**0.88**	0.85
Black_Hair	**0.96**	0.93
⋮	⋮	⋮
Weighted average	**0.92**	0.89

Figure 21. Semantics Attribute changes with result. (Sergios K., 2022)

While semantic code inside can be adjusted slightly to add some weights to areas of the image, in the table above shows the semantic code being adjusted to change the face features slightly by increasing or decreasing the weights. Such as encouraging the Autoencoder to add or remove features that were not there before. (Preechakul K., et al., 2022)

Stable Diffusion

The Stable Diffusion model, developed by Stability AI as mentioned earlier, serves as a remarkable latent text-to-image diffusion model, creating photo-realistic images from textual inputs. However, its capabilities extend beyond text-to-image generation, as it can skillfully in-paint images using masks. The Stable-Diffusion-Inpainting model originates from stable-diffusion-2-base, fine-tuned with an additional 200k steps, while ingeniously incorporating the mask-generation strategy proposed in LAMA and latent VAE representations of the masked image as additional conditioning. (Vartiainen, H., et al., 2023) (Gozalo-Brizuela, R., et al., 2023)

Text-Guided Image Editing

Zhang and team explored diffusion models (DM) for controlled and stable image manipulation, distinguishing them from traditional methods like GANs. DM's strength lies in precise image editing without unintended alterations. The process starts with a pretrained DM, encoding the input image into a noise vector in the latent space, allowing manipulation guided by text prompts or other inputs. (Zhang C., et al., 2023)

To ensure stability and fidelity, a reverse process reconstructs the edited image from the modified noise vector. Techniques like Exact Diffusion Inversion via Coupled Transformations (EDICT) enhance reconstruction quality. Textual prompts and cross-attention maps guide the image editing process for precise results. (Zhang C., et al., 2023)

Stable diffusion-based image editing offers a reliable approach, minimizing unintended changes while producing high-quality edited images. Its versatility makes it a promising technique for various image editing tasks, including mask-based editing. (Zhang C., et al., 2023)

Text-guided Image Editing with Mask

The challenge of editing on a region masked out is making sure of the coherency. Text-guided image models are required to know the image context to only be able to provide a proper edit of the image. (Xu X., 2022) Through car visualization we need to understand the background, the shape of the car, and other factors. As there are two major concerns stated by the paper, Alignment Loss and Content Preservation Loss. (Zhang C., et al., 2023)

- Alignment Loss encourages alignment between the masked image and the corresponding text caption, ensuring consistency between the image modification and the textual description. (Zhang C., et al., 2023)
- Content Preservation Loss ensures that the unmasked region of the image remains unchanged and preserves its original content to maintain image integrity. (Zhang C., et al., 2023)

To achieve seamless coherence between edited and unedited areas, the Blended diffusion approach spatially blends a noisy image with a local text-guided diffusion latent, progressively ensuring smooth transitions. (Zhang C., et al., 2023)

Additionally, the Blended diffusion approach can be combined with LDM (Latent Diffusion Model) to improve the local text-driven image editing process. (Xu X., 2022) A multi-stage variant of Blended diffusion was also explored to improve the resolution of the edited images. (Xu X., 2022)

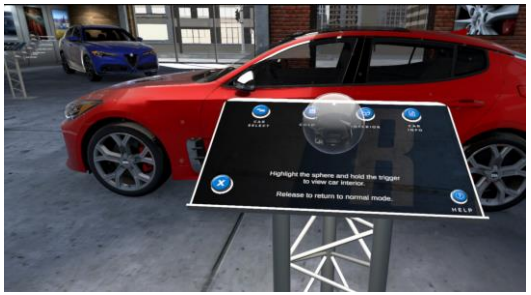
DALL-E

DALL-E is another image generative AI that also uses a Diffusion Model. While also using the same model it is trained on different datasets and the developers have different philosophical approaches of how it would be developed and produced. As they are both currently the most popular Image generative AI, and yet slightly similar in design, they will both provide very different images from the same prompt. (Harry G., 2023)

Mentioned by Witteveen and team, they note that Stable Diffusion effectively addresses the shortcomings of traditional generative models by combating mode collapse and promoting stable training. This unique method adopts a step-by-step diffusion process, encouraging the gradual generation of data, resulting in more realistic and diverse samples. On the other hand, we have DALL-E, a specific generative model developed by OpenAI, known for its ability to create highly creative and diverse images based on textual descriptions. However, it's worth noting that DALL-E's realism might sometimes be limited by the dataset on which it was trained. (Marcus G., et al., 2022) Despite this constraint, DALL-E remains an impressive model for generating images from text prompts. On the other hand, Stable Diffusion offers a versatile approach that can be applied to various generative models, ensuring stable and diverse sample generation across different domains. (Witteveen, S., et al., 2023) While the researcher’s project aims to bring realism to car visualizers, currently DALL-E would be a second pick to Stable Diffusion.

2.2 Similar Systems/ Works

2.2.1 Similar Systems of Vehicle Visualizer

System Name	Methodology	Feature	Advantage	Disadvantage	Process
Plus360degrees - Plus360Degrees (2023) 	Javascript and WebGL 3D rendering	Color Picker 8 available vehicles	Wide Range of colors to pick from 360 View of the vehicle	Only 8 available vehicles Unrealistic (Subjective) Long loading time	Upon start up, a car is loaded, the user can pick between 8 vehicles, and a wide range of colors, and can view around the car.
RelayCars - RelayCars.com. (2023) 	Unreal Engine Virtual Reality 3D Models	Interactive Interior	Interactive Interior 360 View of the vehicle	Small selection of cars to choose, in 3 categories. (Running-Target, 2021) Unrealistic (Subjective) Only in VR	Upon start up, user can select a car they want to interact with, its loaded with limited number of colors
Porsche AR mobile visualizer - Porsche (2023)	Augmented Reality	Only Porsche vehicles	Portability, can view it in any	Unrealistic (Subjective)	Upon start up, the user can select a car from Porsche's selection

	3D models	On mobile	location 360 View of the vehicle	Hardware intensive	and place it within the camera frame, selection of color is also possible, but limited
VR Automotive Visualizer Customizer and Simulator | A2 VR - a2vr (2020) 	Unreal Engine 3D models	Interactive Multiplatform (Mobile, PC, VR)	Very detailed in every aspect of the vehicle from engine, interior, and etc. 360 View of the vehicle	Hardware intensive Unavailable to public currently	N/A
Aura Vinyl Color - Aura Vinyl (2023)	WebGL and Javascript 3D Rendering	22 Vehicles 100+ Available	A Lot of available wraps 360 View of the vehicle Free	Unrealistic (Subjective) Long loading time	Upon start up, a car is loaded, the user can pick between 22 vehicles, and a wide range of wraps, and can view around the car, with the option of multiple different

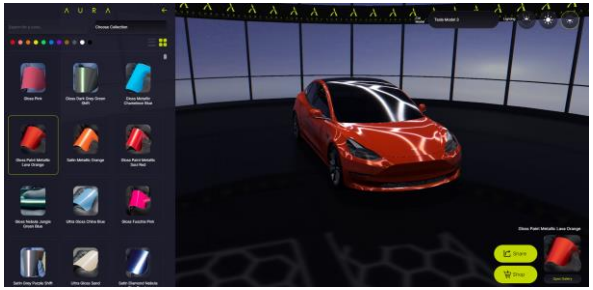
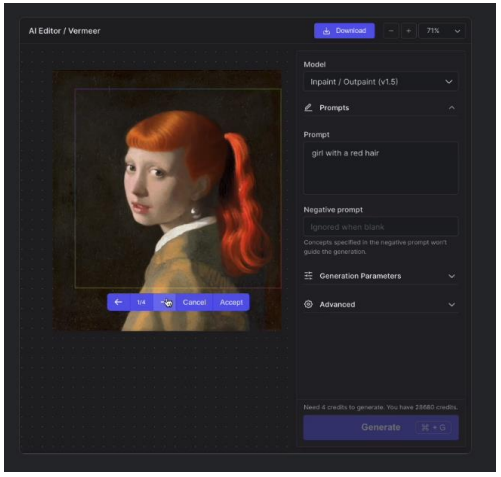
		colors and material			lighting
3D Changer - Exists, U. (2023) 	Unreal Engine 3D Rendering	230+ Vehicles 2,300+ wraps Photo Rendering Can import personal wraps and car models	Wide range of available vehicles (including trucks), wraps Allows usage of personal vehicles	Hardware intensive Expensive	N/A

Table 6.

2.2.2 Similar Systems of Image In-painting System

System Name	Methodology	Feature	Advantage	Disadvantage	Process
Fotor - Fotor. (2023) 	Stable Diffusion	User Input Text as Prompt User Draw Masking Has 15 styles to pick from	Uses text prompt 15 different AI generative styles to pick from	Limited Aspect Ratio (1:1, 4:3 & 3:4)	Users can upload an image, then can draw a mask around the location and input text prompt for the in-painting to begin.
Getimg.ai - getimg.ai. (2023) 	Stable Diffusion	User Input Text as Prompt User Draw Masking	Uses text prompt 15 different AI generative styles to pick from Very advanced settings users can pick	Complicated and technical	Users can upload an image, then can draw a mask around the location and input text prompt for the in-painting to begin.

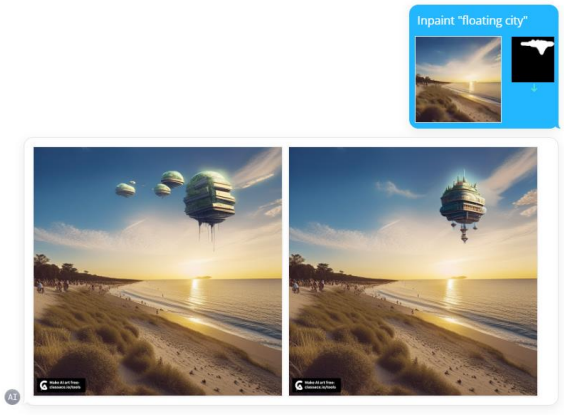
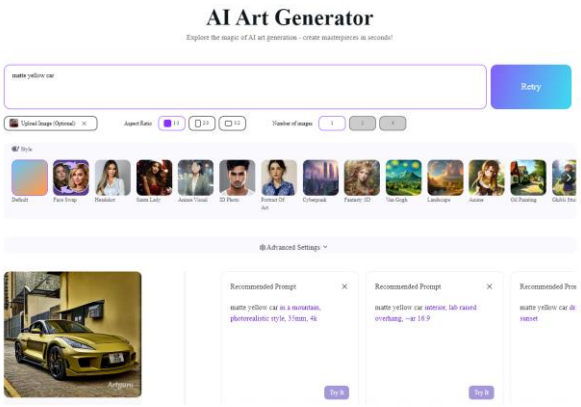
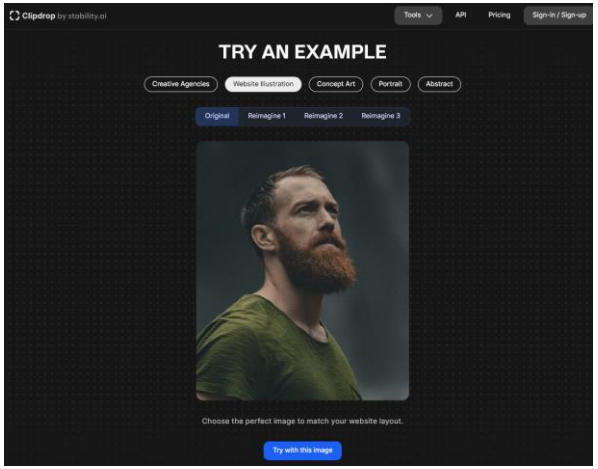
Classace.io - classace.io (2023) 	Stable Diffusion	User Input Text as Prompt User Draw Masking	User Friendly	Limited number of settings Subscription Based	Users can upload an image, then can draw a mask around the location and input text prompt for the in-painting to begin.

Table 7.

2.2.3 Additional Similar Systems

System Name	Methodology	Feature	Advantage	Disadvantage	Process
Artguru 	Stable Diffusion	Input image and text prompt to transform the image	Very fast processing and generation of new images, Allows for a range of aspect ratios, Can create up to a batch of images	Not very realistic	User uploads an image, enters a text prompt, selects an aspect ratio and uploads. Which then can be upscaled when the user wishes to download it.
Clipdrop (REIMAGINE XL) 	Stable Diffusion	Receives an image input and reimagines it	Very fast processing and generation of new images	No control over any input	User uploads an image and waits for 4 different images to be processed, which then can be upscaled when the user wishes to download it.

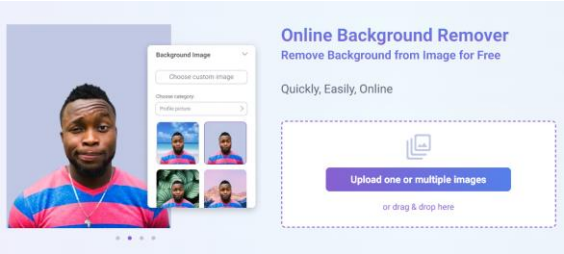
Retouched 	Stable Diffusion	Input image and extracts the object and obtains a PNG	Very fast processing, allows for a range of image editting	Limited to 3 images, paywall	User uploads an image and waits for the extracted object of the image. Users can apply image editing based on its features.
3dTuning 	3D Models	Car panel editing	Wide range of cars and colors	Many of the cars assets are missing from the website	Select a vehicle from a list, select a panel of the vehicle and select a color for that panel
STuner 	3D Models	Car Part editting	Able to edit each detail of the vehicle	Many assets are missing from the website	Pick a vehicle from a list, and edit it by choice of body part, from tires to hood to windscreen and more.

Table 8.

2.2.4 Discussion & Conclusion

Discussion Similar Systems of Vehicle Visualizer

These are the few best vehicle visualizers found by the researcher after an intensive search, the listed inside the table has been found. Plus360degrees, RelayCars, Porsche AR mobile visualizer, VR Automotive Visualizer Customizer and Simulator | A2 VR, Aura Vinyl Color, 3D Changer. These listed Vehicle Visualizers are similar to the researcher's project objective. While each of them use very similar methodology to each other, 3D models. Note that "3D Changer" contains the most realistic looking 3D model from the researcher's perspective, 3D Changer is able to achieve this due to having created highly detailed 3D models. As already noted above, 3D models are able to achieve very highly detailed and realistic replicates, but this is very time consuming.

Also to note that all vehicle visualizers found had yet to use in-painting technique. A reason for this could be that 3D models provide the user a 360 view of the vehicle, which can be a very big benefit for the users. Or another reason could be that 3D models would be easier to implement compared to In-painting systems.

Discussion Similar Systems of Image In-painting System

The mentioned similar systems of image in-painting found after some time spent searching, the following were found Fotor, Getimg.ai, Classace.io. While there were more, the majority were the same with those listed. While the majority when using tends to change the model and shape of the vehicle, this is due to the mask being hand drawn. The mask is very important to determine the area where the In-painting system will work on. Along with the text-prompts are required as there are no color selector. This is due to the system required to be very generalized, the researcher's project goal is very specific on vehicles.

Side note: Midjourny was not explored due to it requiring a certain payment for usage. Although to mention that Midjourny is very similar through its training process, but is unable to generate realistic images compared to Stable Diffusion, this is due to the difference between dataset amounts used to train. (Calvin W., 2023)

The inpainting systems had required the users to input the locations of its intended area of inpainting. This added a step to the user having to draw out the location. While to addon these systems also rarely maintained the tested vehicles' shapes and would rather change the shape and orientation of the vehicle

2.3 Technical Research

Programming Language Chosen

Python

Python provides a platform for developers to create code with readability, simplicity, and clean syntaxes. It is a high-level programming language that gained popularity most recently .(Python W., (2021) As it provided junior and young developers a programming language to code on as it was a favored option for junior and young developers to learn and create a wide range of applications. (Python W., (2021) While Python seems to be very beneficial for developers, before settling on Python, there are limitations and shortcomings that will be explored within this section along with its benefits. (Python W., (2021)

To talk about the limitations of Python, its performance limitations, coming from its high-level nature, commonly results in slower execution for compute-intensive tasks such as big systems, while compared to lower-level languages like C and C++ it is vastly gapped in performance. (Sovietov, P., et al., 2022) Along with, when it comes to mobile app development, Python would not be the optimal choice as it is not as widely used compared to Java or Swift in this domain, as the researcher's project could potentially be made as a mobile application, this disadvantage is one to take into consideration. Additionally, Python's recent upgrade to version 3, as transition from version 2 to version 3 brought compatibility issues with some legacy codebases and many libraries. (Sovietov, P., et al., 2022)

As mentioned above Python's simple and readable syntax makes it easy for developers to learn quickly and allows them to focus on problem-solving. It allows it to be used for various applications like web development, data analysis, AI, and automation which most importantly majority of AI libraries implementations has been done in Python. (Sovietov, P., et al., 2022) The extensive standard library and active community contribute to faster development and continuous improvements. Python would be an excellent selection for the researcher's project.

3.1.2 Java

The saying of "Write Once, Run Anywhere" has been ingrained into developers who code on Java. Java is an object-oriented programming language that has been one of the most popular programming languages of the past decades. As it allows developers to build enterprise-level

applications, web services and many different applications. (Farrell, J. 2022) While Java has been a very independent, robust, and versatile language, before the researcher selects one, a discussion on its advantages and disadvantages will need to be understood before selection.

The benefits of Java really comes from its platform independence, object-oriented programming (OOP) principles, and a big ecosystem of existing developers. As a "Write Once, Run Anywhere" language, Java allows developers to craft applications that seamlessly operate across different operating systems without the need for many modifications. (Farrell, J. 2022) While its dedication to OOP brings modular and maintainable code, allowing the foundation for scalable projects with reusable components. Along with some Java libraries and frameworks, such as Deeplearning4j, Weka, and Java-ML, that can provide AI capabilities and machine learning algorithms. (Farrell, J. 2022)

While Java, known for its robust and versatile features as mentioned above, is not without its drawbacks. For one, its object-oriented nature might prove challenging for beginners unacquainted with OOP concepts, leading to a steep learning curve. Additionally, Java's verbosity may demand more lines of code to accomplish tasks, potentially affecting development speed. (Brown, N. C. et al., 2022) Lastly, the language's high-level nature might not be the best fit for low-level programming tasks that demand direct memory manipulation or hardware-specific operations. When opting for Java for particular projects, these factors should be carefully considered, as they can influence the development process and overall performance in specific scenarios. Additionally Java is not well known to be developing AI code, compared to Python which has a vast community of developers in the AI community. (Brown, N. C. et al., 2022)

Programming Language Selection Justification

Python will be chosen for the researcher’s project, for many different reasons. One of them is that the readability of the language provides faster development, as the time limit for the project is only a few months long. (Whelan, A. M., et al., 2022) Along with the community of developers that comes with AI development with Python, the large community has resulted in a creation of a big ecosystem of libraries, frameworks, and resources tailored to AI development. (Whelan, A. M., et al., 2022) Allowing merging of resources that can be used to create a vehicle visualizer. The library

created by Stable Diffusion and their community has mainly developed within the Python language. To also add on, the researcher has more experience on Python that he gained during internship, this would greatly benefit the researcher during the project's development.

IDE (Interactive Development Environment) Chosen

Visual Studio

Visual Studio is a highly rated integrated development environment (IDE) that can handle large-scale projects easily through Git control or others. As for its support of programming languages, it has support throughout all programming languages, with a strong focus on Python for AI development, this allows the researcher to easily develop on Visual Studio easily. Along with the fact that it is integrated with AI libraries like TensorFlow and PyTorch, which provided a big benefit.

Jupyter Notebook

Jupyter Notebook is an interactive web-based environment that is currently very popular with data analysis and AI prototyping. Its Python-centric nature, coupled with a rich ecosystem of readily available AI libraries, can be a very positive benefit for the researcher during development. However, when it comes to debugging capabilities, it may not match the depth and comprehensive tools provided by Visual Studio. This difference might be crucial for developers seeking advanced debugging features. Additionally, while Jupyter Notebook is undeniably powerful for small to medium-scale projects, it may not be as scalable as Visual Studio when it comes to large-scale production systems. In such cases, Visual Studio's capabilities might better accommodate the requirements of scaling up AI applications for real-world deployment. While that statement is not really required by the researcher, as the objective does not include deployment of the system to the real world, it does require functionality as a system. Jupyter Notebook is more catered towards data analysis and AI prototyping as mentioned, which will not benefit the researcher much.

Libraries chosen / Tools chosen

This section discusses the libraries chosen to be used with the researcher's project. These libraries will be used for tasks for creating image masks and inpainting.

Creating Masks

As to achieve the objective to in-paint on the selected area of the image, a mask is required to be created. Such libraries that can be used to create a masks are the following:

NumPy

OpenCV

PIL (Python Imaging Library)

scikit-image

PyTorch

Mask-RCNN

These 6 libraries are the common libraries to be used to create an image mask, while number 5 and 6 are using machine learning compared to the others using just algorithms. As the object is to create a mask for the vehicle within the image, a combination of libraries will be used to achieve it. Nonetheless all will be explored by the researcher during development to understand which will be best fit for the project.

Inpainting

The final objective is to recolor the vehicle within the image, with accurate lighting reflections and color. The researcher aims to do this with Inpainting, which the library that will be used for it will be Stable Diffusion. While it is not only Stable Diffusion that has image-to-image models, there can be merging of models as well. The researcher aims to explore models created within the community of Stable Diffusion and find which is best fit for the project. It is also possible for the researcher to create a new model based on a dataset of wrapped cars.

Operating System chosen

This section discusses the Operating System that the project will be done on. The Operating Systems that the researcher aims to discuss are Windows, Android.

Windows

Windows, a very common operating system made by Microsoft, has become a default among many developers and users. As for the researcher's project's system, as if it were to be developed on Windows, it would allow for more potential users compared to other operating systems such as MacOS. As for the development phase, Windows is an operating system that the researcher has been using for a long time and has a lot of experience developing projects on this operating system.

Android

Android has had an exploding growth during the past two decades, Android developed by Google for mobile phones, which now at the present time of 2023, that is 70% of all phones are powered by Android OS. (Forbes, 2023) As for the system to be able to run on Android will be able to access a bigger number of users compared to any other operating system available. While developing for AndroidOS requires experience in Kotlin and Java. The researcher has little experience on developing on Kotlin, compared to Python, which could be an issue for the researcher.

Software Chosen

The chosen software for the project is Stable Diffusion, specifically opting for the open-source version. Stable Diffusion offers both proprietary and open-source models, providing a range of options for image generation. This selection implies a deliberate choice by the researcher to leverage the capabilities of Stable Diffusion for the intended objectives of the project. Stable Diffusion (SD) is noted for releasing multiple models with different versions. This indicates a dynamic and evolving nature of the software, potentially offering various features and improvements across its iterations. The inclusion of different versions implies adaptability and the possibility of selecting the most suitable model for the project's requirements. These models are SD 1.0, SD1.4, SD 1.5, SD 2.0, SD 2.1, SD XL 1.0, and SD XL Turbo.

Other developers have contributed to the usability of Stable Diffusion by creating a Web User Interface (UI) with an Application Programming Interface (API). The specific software mentioned is automatic1111. This development extends the accessibility of Stable Diffusion, allowing users and developers to interact with the software more conveniently. The existence of a Web UI and API suggests a user-friendly approach and emphasizes the collaborative nature of the software ecosystem.

The researcher has specifically chosen automatic1111 over other image generation software for several reasons. These include the software's ease of use, its development environment, and a notable factor being that it is available for free. The emphasis on ease of use and development implies a focus on user experience and efficient integration into the research project. The mention of free availability indicates a consideration of budget constraints or a preference for open-source solutions. Additionally the community of developers of SD users are helpful to newer developers. As they use Discord as a communication platform to share their ideas, projects and many other things.

Overall, the researcher's choice of Stable Diffusion and the specific utilization of automatic1111 underscores a strategic decision-making process, considering factors such as functionality, accessibility, and cost-effectiveness.

Hardware Required

Given the computational demands of image generation tasks, particularly when working with advanced models like those found in Stable Diffusion, here's an opinion on the hardware specifications that might be beneficial for optimal performance:

Graphics Processing Unit (GPU):

The recommended GPU from experienced SD developers was commonly a high-performing GPU. As that is essential for accelerating the training and inference processes. Consider using a modern GPU with a high CUDA core count, such as an NVIDIA RTX or A-series GPU. Multiple GPUs can be employed for parallel processing, enhancing performance for large-scale image generation tasks. Although image generation (not training) from SD models will also require a high-performing GPU.

The GPU hardware that the researcher had during the development of this was a **NVIDIA RTX 3060**.

Random Access Memory (RAM):

The nature of image generation requires a substantial amount of RAM. With SD Depending on the size of datasets and models, a system with at least 32GB to 64GB of RAM, or more if budget allows, can provide the necessary headroom for efficient processing.

The amount of RAM hardware that the researcher had during the development was **32GB**.

Storage Required:

Commonly with any system that requires fast response to the user, fast storage is crucial. A high-speed SSD with ample capacity, considering the large datasets involved in image generation tasks. A fast and big NVMe SSD can provide enough speed and capacity. Additionally, SD Models, Controlnets, Loras and other parameters files add up to a lot of used storage. The researcher had his development process add up to **100gb+** of files and models.

Central Processing Unit (CPU):

Commonly the GPU primarily handles the heavy lifting, a multicore CPU with good parallel processing capabilities is beneficial for overall system coordination. A modern CPU, such as a high-core-count AMD Ryzen or Intel Core processor, can complement GPU performance.

As the CPU hardware that the researcher had during the development was a **i7 6th Gen** at 3.4Ghz.

Web Framework Chosen

A web framework is a software framework designed to aid and streamline the development of web applications, including websites, web services, and web APIs. Where it is a structured way to build and organize code. The chosen framework is **FastAPI**. It is a modern web framework for building APIs with Python 3.7+ based on standard Python type hints. FastAPI has existing tutorials and plenty of documentation on how to develop with FastAPI. As that makes the development process much more smoother, the other reason this framework was chosen is the API based off automatic1111 is built upon FastAPI as well. Maintaining consistency should be important in system developments.

CHAPTER 3: METHODOLOGY

3.1 System Development Methodology

3.1.1 Introduction

System Development Methodology will provide the researcher a reliable roadmap, which will help guide the entire process. From enhancing project management to mitigating risks, optimizing resources, and achieving success in delivering systems. (Geambaşu, C. et al., 2011) As having a methodology ensures a smooth and quality development journey. The chosen methodologies to be analyzed for the project will be Kanban and Lean Development. The chosen methodologies here have gained some reputation of being beneficial for solo development. (Moyo, S., et al., 2019) As the researcher will be developing the project entirely alone, thus finding a methodology that fits for a solo development is best.

3.2 Kanban

Kanban utilized a board that allows to visualize the workload and workflow. As there are columns that display the workflow until completion, which can be “To Do”, “In Progress”, “Complete” or more complex and in depth. As more in depth can be by adding more columns and specific tasks such as validate, testing, and many others. (Junior, M. L., et al., 2010).

3.2.1 Process of Kanban

Kanban can be simple or complex as the manager likes it to be as stated by Max (2023). Each column can represent different stages of the development. Each card would represent the task. Here will discuss the process of Kanban in its simplest form. (Ahmad, M. O., et al., 2013)

3.2.3 “To Do” - Highest Priority

Within this column contains tasks that need to be completed as soon as possible. Which means that all tasks no matter what within this column gains high priority throughout the project.

3.2.4 “In Progress”

Within this column contains tasks that are currently in progress. As all tasks in this column will have either 2 outcomes, either moved to another column that states the task is completed or needs validation, or moved to the “To Do” column, which then it is set to high priority.

3.2.5 “Complete”

Within this column contains tasks that have been completed. As the final output of the entire project is to have all tasks inside this column.

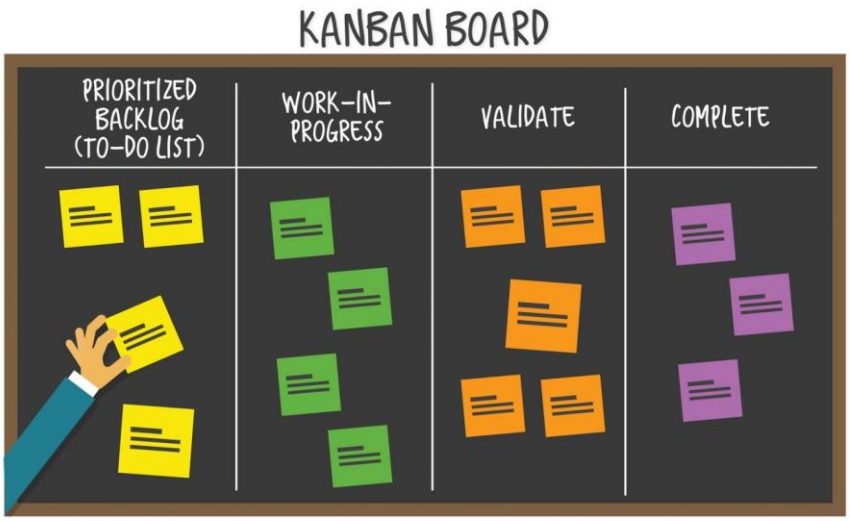


Figure 36. Kanban Board Visualized (Umair A., 2020)

4.2.6 Additional Columns

These columns are optional to Kanban, but are possible columns that can be added to the Researcher’s Kanban if and when the researcher chooses this methodology.

- Testing (or Verification)

As testing is the act of checking the work completed is up to functionality. This can be done through automated testing, user acceptance testing, or other kinds of verifications tests.

- Blocked (Impediments)

Blocked would mean that the work task cannot progress due to an issue external or internal. As the task will stay here until it has been resolved

- In Review (Feedback)

In review would mean that the task is awaiting feedback from stakeholders, where the stakeholder can provide an input before the work can be finalized.

- On Hold (Waiting)

Having a task on hold would mean that work should stop on this specific task. The reason could be that there are other priorities, resource constraints or other reasons.

While there are more possible columns these are the common ones used widely in development teams. (Ahmad, M. O., et al., 2013)

4.2.2 Benefits of Kanban as a solo developer

While Kanban is commonly used for team-based projects, it does provide many benefits for a solo developer. As being a solo developer provides a lot of flexibility, Kanban can be used to maximize the development. (Gravel, M., et al., 1991)

The benefits are allowing easier work prioritization, increased monotasking (opposite of multitasking), visualization of bottlenecks, increased motivation. The tasks being cards and stages being columns turns the work more into a game, which would provide motivation to the researcher, although this is very subjective. Along with that, is the visualization of bottlenecks and better work prioritization, the cards and columns will provide an idea of where the research would get stuck on and can have an easier idea of which work needs to be completed first. Lastly, increased monotasking (opposite of multitasking), this benefits comes from how Kanban encourages the task to be completed before moving onto another task. (Gravel, M., et al., 1991)

3.2 Data Gathering Design

3.2.1 Introduction

A research method's objective is to determine how data is collected and analyzed. With the data collected, requirements, justifications, and validations of findings can be made from it, through analyzing the data. (Browne, J. et al., 2019) This chapter will analyze the types of research methods there are, and which method was used for this investigation report.

3.2.2 Research Methods Types

To briefly describe the research methods types, there are two types of research methods, qualitative and quantitative. Quantitative is the collection of data that is numerical data, commonly data that is numerically represented, measurable, or continuous. (Wagner, S., et al., 2020) Examples would be like a person's age, or "How often they see a wrapped car" which both questions are included in this project's survey. While on the other hand, qualitative data, as it is data that cannot be expressed in number but more in open ended questions. (Wagner, S., et al., 2020) An example would be "What are your perceptions and preferences regarding car wraps? Please provide your reasons for liking or disliking car wraps."

While merging and creating a mixed methods approach, it allows a survey to have overall comprehensive questions, collecting numerical and non-numerical data at the same time. (Wagner, S., et al., 2020) This method was used for the research method type.

3.2.3 Survey Method Selection Justification

As there are many methods that can be used, each has their benefits and shortcomings. Thus selecting the best research methodology depends on the situation of the research. (Wagner, S., et al., 2020) Especially the deadline and available work hours. As the research only has a limited time duration of less than a few months, a selection of research method that is not time-consuming yet provides standardized results (would allow quicker data analyzation) needs to be selected. (Wagner, S., et al., 2020) The researcher selected Survey, as it provided an efficient way to collect data, not time consuming and allows for quicker spread of survey.

3.2.4 Survey Design

The purpose of the research was to understand different participants' views on car wraps, along with finding out if an individual would have trouble visualizing car wraps. With this in mind the survey's design had to have questions that were able to tackle the questions.

The survey was created by the research on Google Forms, and was distributed to the researcher's applicable friends, family, and classmates, to do the survey. The survey consisted of 23 questions, many of them were Quantitative, and had qualitative answer options as well. The participants were informed of the objective and a disclaimer of the survey while receiving the Google Forms link and on the cover page of the form. The following images are the cover page and the questions the survey contained.

Visualizing Car Wraps - Survey

Dear Participants,

Thank you for participating in the survey for my final year project titled " Visualizing Car Wraps with Artificial Intelligence In-Painting Methods." My name is Arthur, and I am a final-year degree student at Asia Pacific University. As part of my academic journey, I am conducting this survey to gather valuable insights and feedback for my project.

The objective of this research is to explore the potential of virtual car wrapping and its impact on the automotive industry. Your participation and input are essential in shaping the success of this project. By sharing your experiences, opinions, and suggestions, you will contribute to the development of a comprehensive understanding of virtual car wraps and its applications.

Rest assured that all responses will be kept confidential and used strictly for academic purposes. Your participation in this survey is entirely voluntary, and you may withdraw at any time without any consequences.

Once again, I express my sincere gratitude for your willingness to take part in this survey. Your valuable input will greatly contribute to the success of my final year project. Should you have any questions or concerns, please do not hesitate to contact me.

The following consent form is designed to confirm that the participant has given all relevant information about the research and how both the researcher and participant are protected. please read the following statement fully and carefully.

1. By completing this questionnaire, you consent that the following data will be used in a research project taken at Asia Pacific University.
2. By participating in this Questionnaire, you are agreeing to provide the most honest answers. Any response you provide will be anonymized, all data collected will be treated in strict confidence and that your name and any sort of identity will be anonymized.
3. By participating in this questionnaire, you understand that this participation is voluntary, participants are free to withdraw from the project at any time without reason.

Thank you for your time and participation.

Best regards,

Arthur Kynan Wong Jun Siang
TP058030@mail.apu.edu.my
Bachelor of Computer Science (Hons) Intelligent Systems
Asia Pacific University of Technology and Innovation, Malaysia

Table 9.

Your Gender ○ Male ○ Female ○ Other: _____
Description: Simple question to help ease the participants into the survey

Table 10.

Your Age Group ○ 16-20 ○ 21-26 ○ 27-29 ○ 30+
Description: Helps identify the qualification of the participants by age

Table 11.

Do you drive / own a car * ○ Yes ○ No
Description: Helps identify the qualification of the participants by if they drive

Table 12.

Have you seen car wrapped? *						
	1	2	3	4	5	
Not Often	○	○	○	○	○	Very Often

Description: Helps identify the participants' qualification of cars by how often they see one

Table 13.

Whats do you think are benefits of car wraps *

- ☐ Customisation & Personalization
- ☐ Protection for the Original Paint
- ☐ Cost-effective alternative to paint job
- ☐ Quick Installation
- ☐ Advertising and Promotion
- ☐ Other: _____

Description: Helps identify possible benefits a car wrap can provide

Table 14.

What factors would affect your consideration on getting a car wrap? *

- [ ] Cost of the car wrap
- [ ] Type of installation services
- [ ] Possible dissatisfaction from final product
- [ ] Durability and longevity of the wrap
- [ ] Color and material of the wrap
- [ ] Other:

Description: Helps identify factors that prevents participants to get a car wrap

Table 15.

Would you wrap your car in the future? *

- ◯ Yes, definitely
- ◯ Maybe, I'm not sure
- ◯ No, never

Description: Helps identify the interest level of participants that are into car wraps

Table 16.

Selecting a **color** for your car wrap is difficult. *

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

Description: Helps identify the importances of car visualization

Table 17.

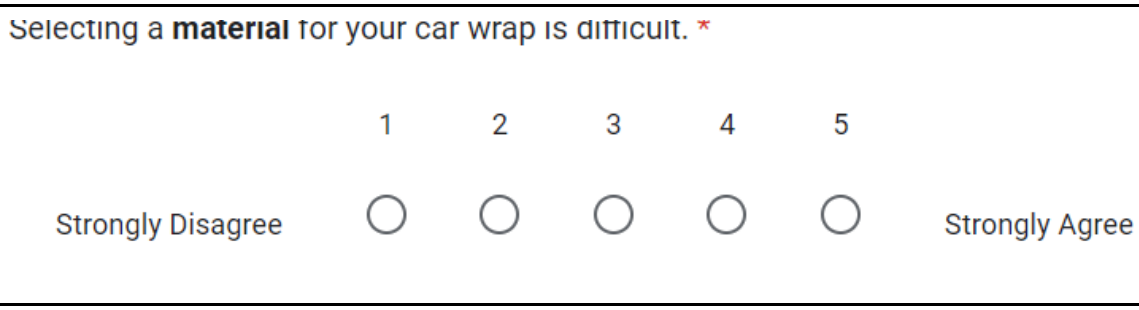

Description: Helps identify the importances of car visualization

Table 18.

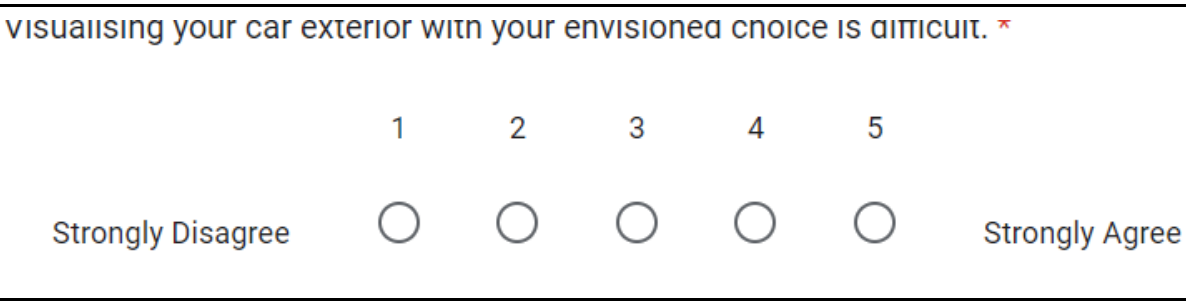

Description: Helps identify the importances of car visualization

Table 19.

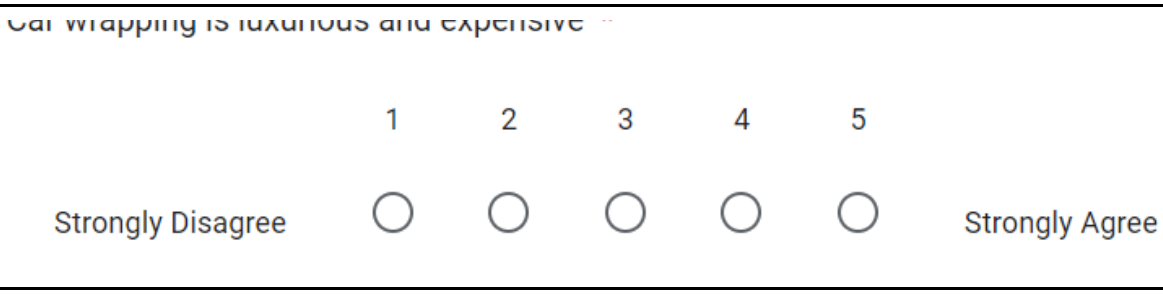
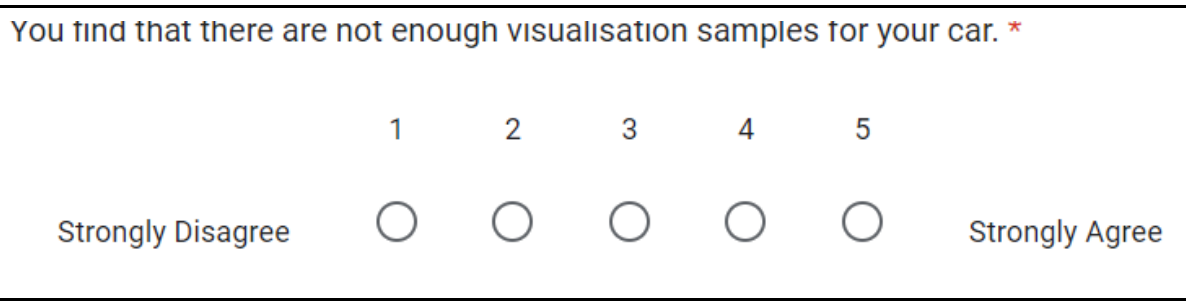

Description: Helps identify participants view on car wraps

Table 20.



Description: Helps identify the importances of car visualization

Table 21.

Your opinions on car wraps are normally negative * 1 2 3 4 5 Strongly Disgree ○ ○ ○ ○ ○ Strongly Agree
Description: Helps identify participants view on car wraps

Table 22.

How important is it for you to visualize the final look of a car wrap before making a decision? * 1 2 3 4 5 Not Important ○ ○ ○ ○ ○ Very Important
Description: Helps identify the importances of a car visualizer

Table 23.

Would you be interested in using a digital tool or software that allows you to visualize different car wrap designs on your vehicle before making a decision? * ○ Yes ○ No ○ Maybe
Description: Helps identify importance of a car visualizer

Table 24.

Have you used any Car Visualizers *   ◯ Yes   ◯ No
Description: Helps identify participants experience on car visualizers

Table 25.

You more confident to rely on your imagination or a Car Visualizers for an wrapped car *   1 2 3 4 5   Strong Disagree ◯ ◯ ◯ ◯ ◯ Strongly Agree
Description: Helps identify the importances of a car visualizer

Table 26.

How likely are you to use a car wrap visualization tool to assist you in selecting a design for your personal vehicle? *   1 2 3 4 5   Very Unlikely ◯ ◯ ◯ ◯ ◯ Very Likely
Description: Helps identify the importances of a car visualizer

Table 27.

You are confident that a visualizer tool will accurately provide a realistic image *   1 2 3 4 5   Strongly Disagree ◯ ◯ ◯ ◯ ◯ Strongly Agree

Description: Helps identify the requirements of this project's requirements

Table 28.

What features or capabilities would you expect from a car wrap visualization tool? * (Select all that apply) ☐ Ability to upload a photo of your own vehicle ☐ Wide range of pre-designed wrap templates to choose from ☐ Customization options for colors, patterns, and graphics ☐ Realistic rendering of the chosen wrap on the vehicle ☐ Other:
Description: Helps identify the requirements of this project's requirements

Table 29.

How would a car visualizer tool influence your decision on purchasing a wrap * ◯ Yes, it would influence my decision ◯ No, it would not influence my decision ◯ Not sure
Description: Helps identify the importances of a car visualizer

Table 30.

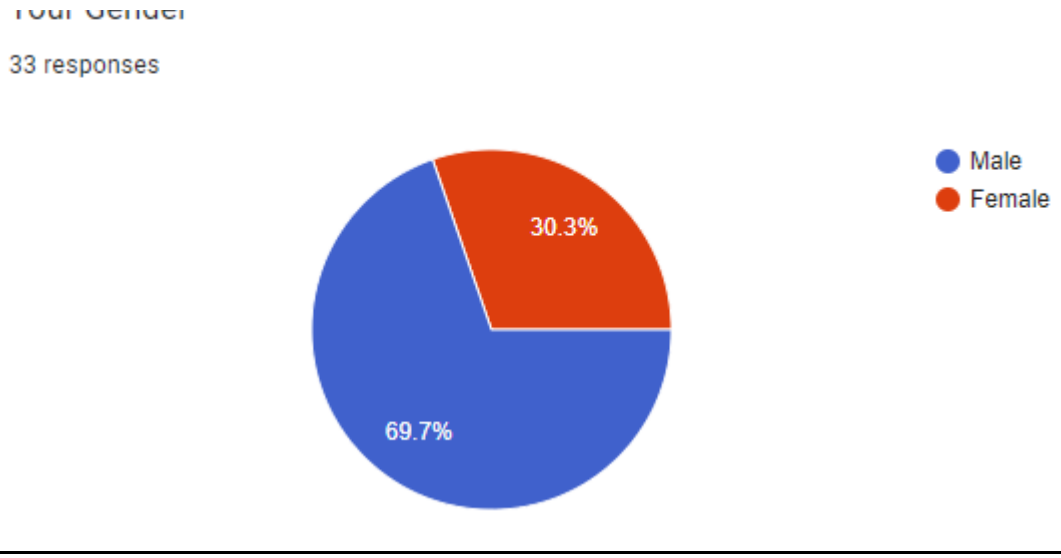
	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree
Description: Helps identify the potential usage of a car visualizer						

Table 31.

How likely would you be to share a car visualizer tool to your friends or family?						
	1	2	3	4	5	
Very Unlikely	○	○	○	○	○	Very Likely
Description: Helps identify the potential popularity of a car visualizer						

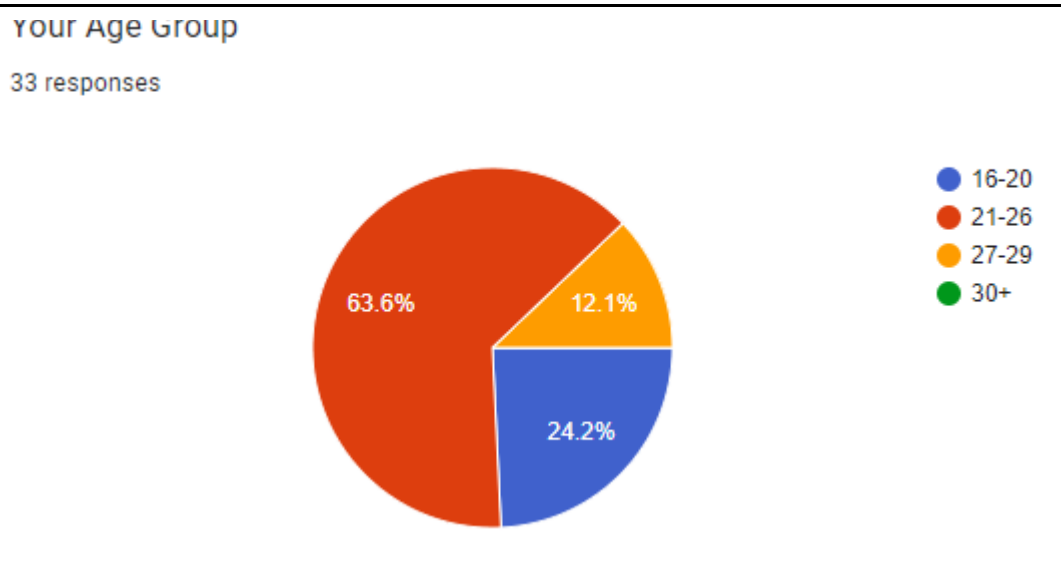
Table 32.

3.2.5 Analysis



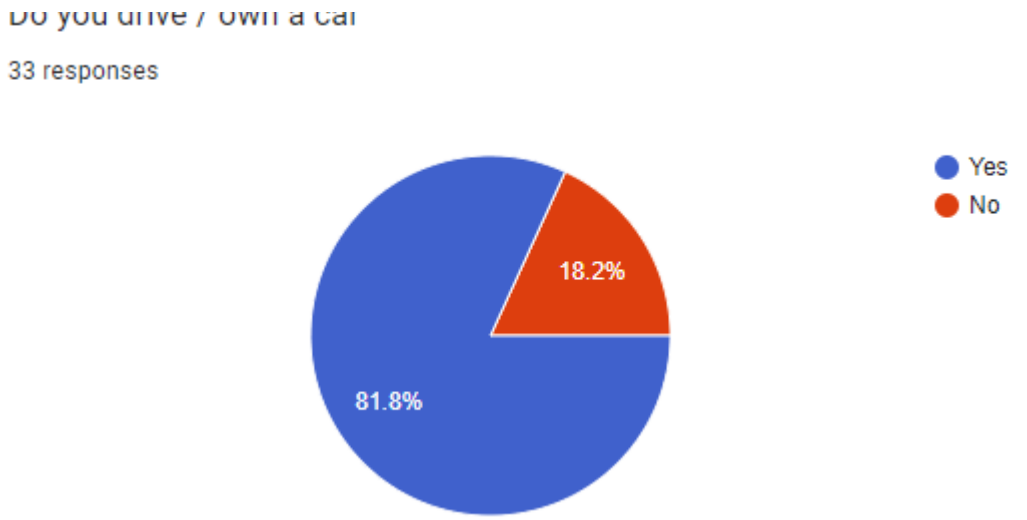
Description: The above pie chart displays that 69.7% of participants are of the male gender, with 30.3% female.

Table 33.



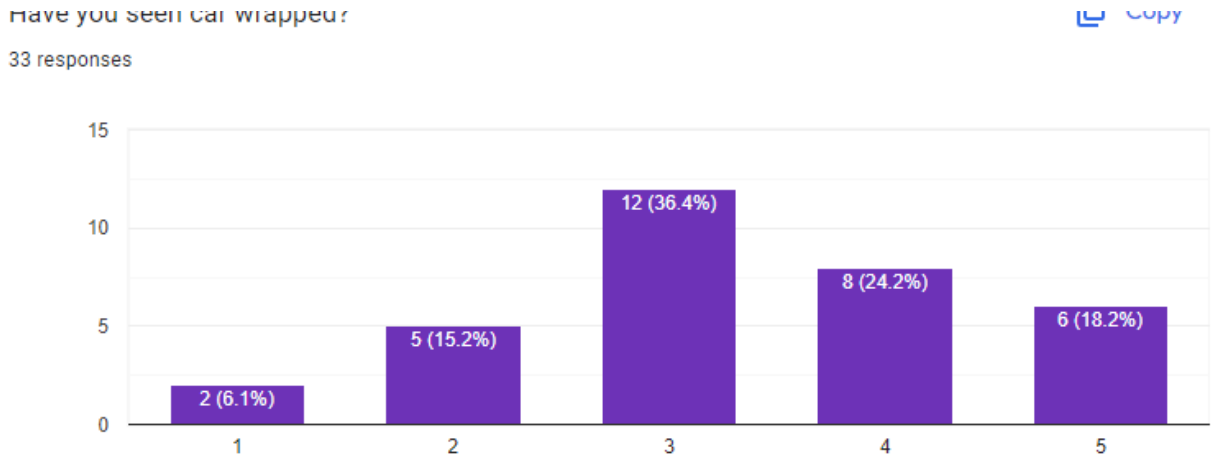
Description: The above pie chart displays that 63.6% of participants are in the age group between 21 to 26, with 24.2% between 16 to 20, and 12.1% in between 27 to 29, with none in the above 30+ age group.

Table 34.



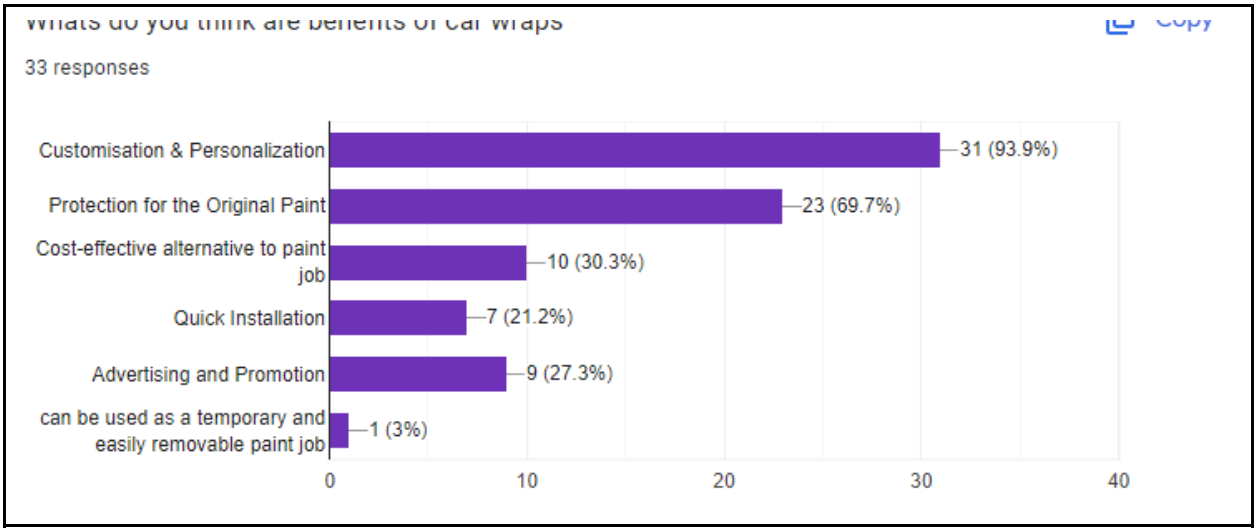
Description: The above pie chart displays that 81.8% of participants own or drive a car, while 18.2% do not.

Table 35.



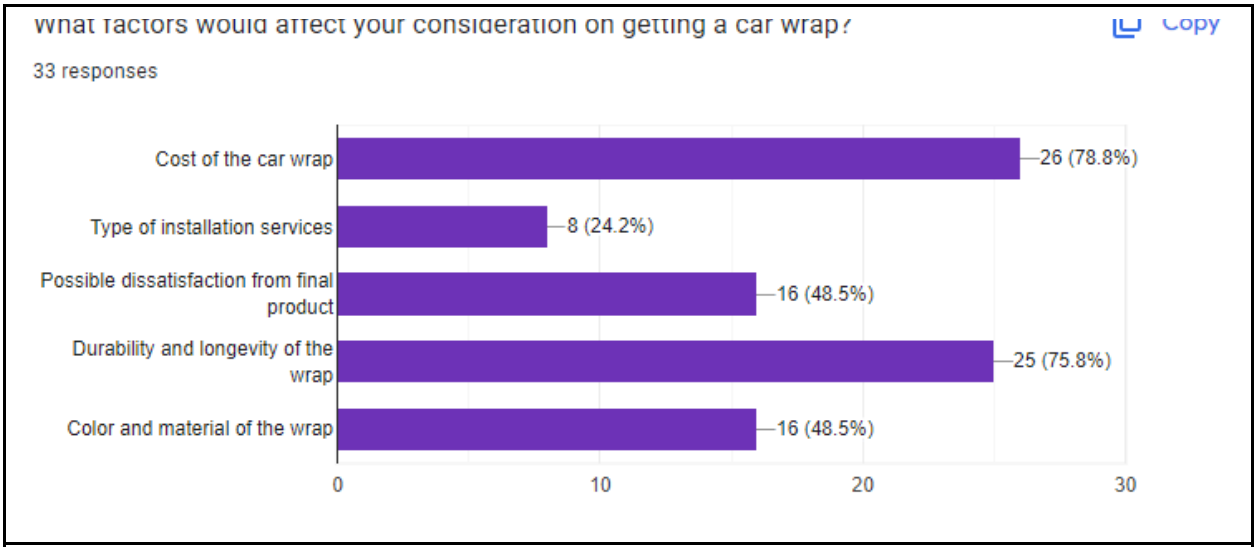
Description: The above bar chart displays a positive bell curve to participants has “Very Often” a car wrapped.

Table 36.



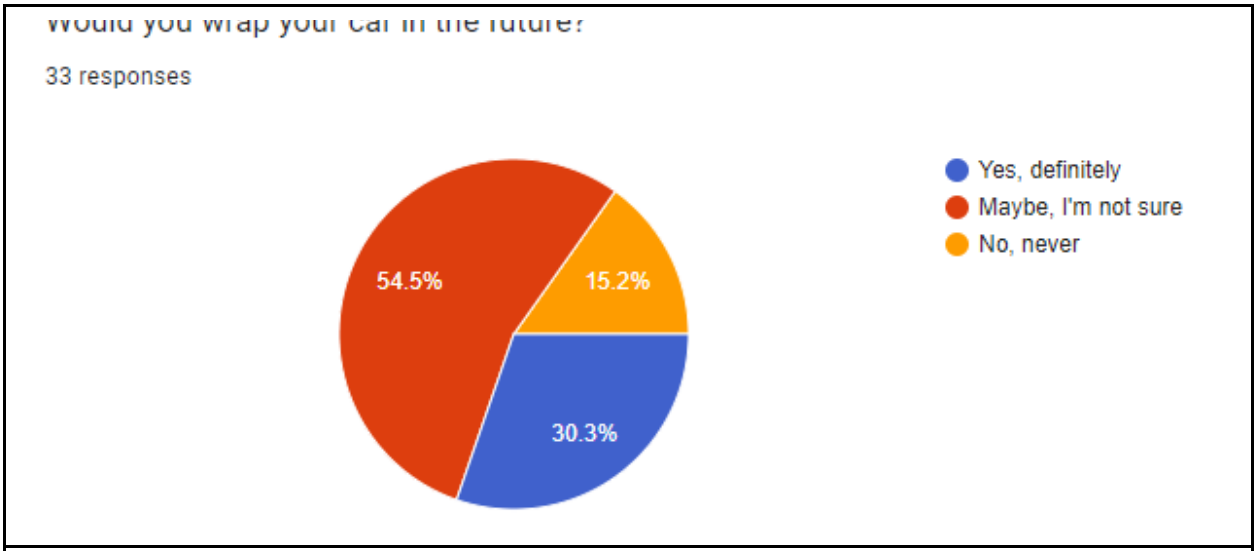
Description: The above bar chart displays that 94% of participants value “Customisation & Personalization” with 69.7% values“Protection for the Original Paint” moreover than the other benefits.

Table 37.



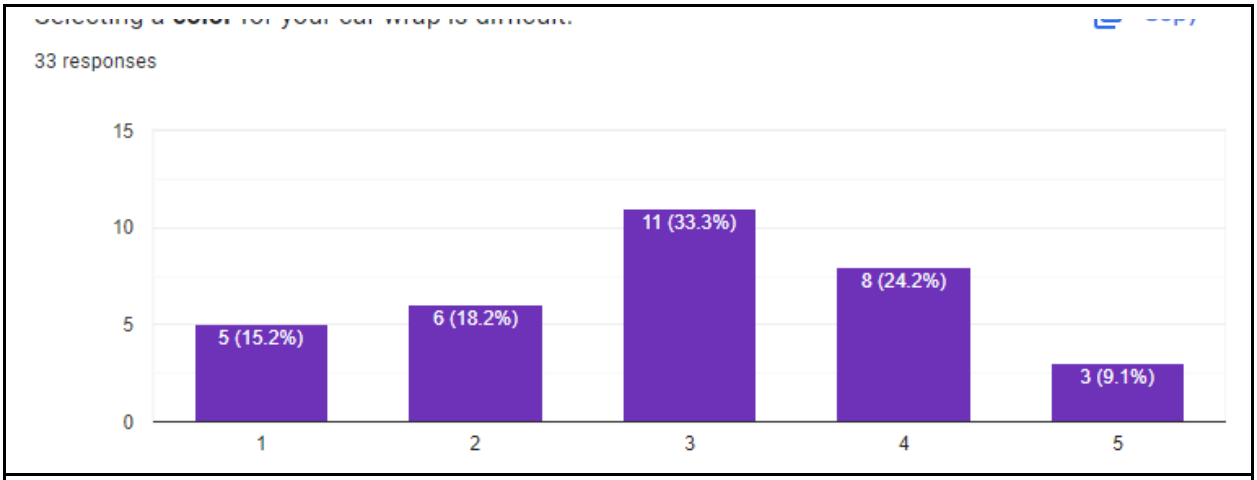
Description: The above bar chart displays that 75% of participants value “The price” and “quality”, as almost half of the participants values “Possible dissatisfaction from final product” and “Color and material of the wrap”.

Table 38.



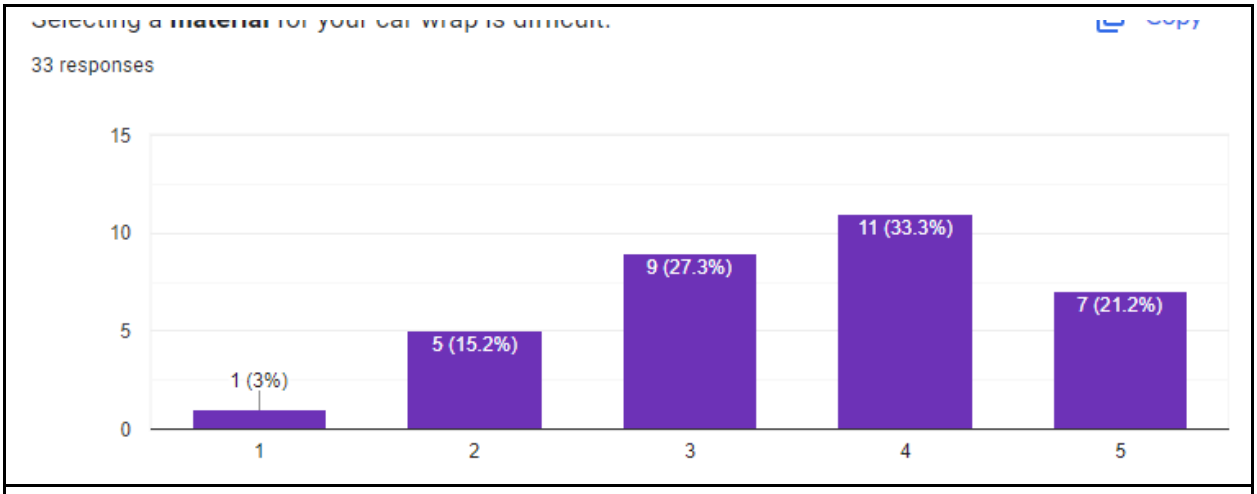
Description: The above pie chart displays that 54.5% of participants are unsure of getting a car wrap, while 30.3% will get a car wrap, with 15.2% will never

Table 39.



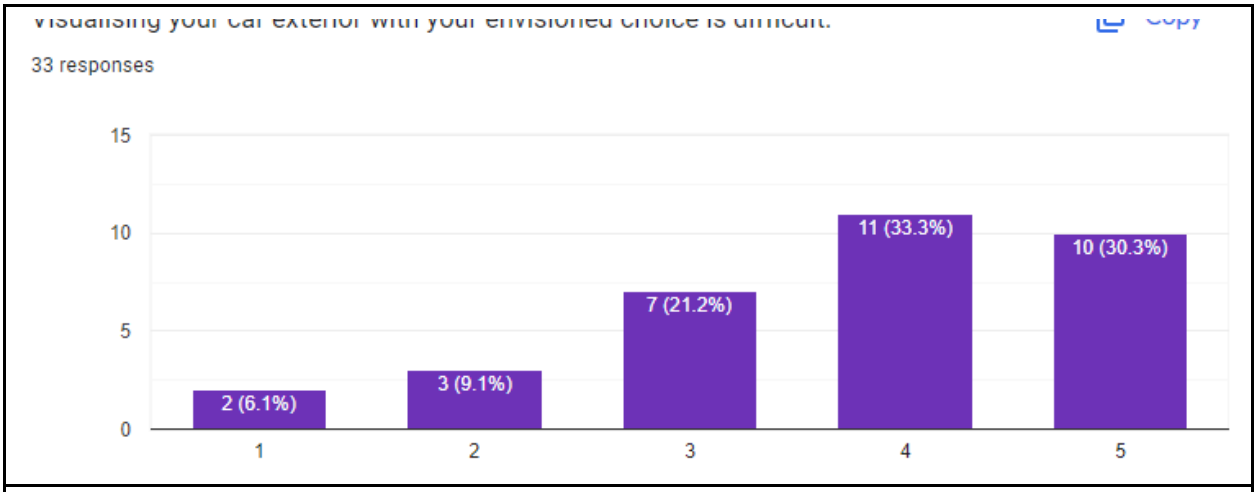
Description: The above bar chart displays that 11 participants (33.3%) were neutral to the statement, while another 11 participants (33.3%) "Agrees" or "Strongly Agrees" to the statement, with another 11 participants (33.3%) "Disagree" or "Strongly Disagree" to the statement.

Table 40.



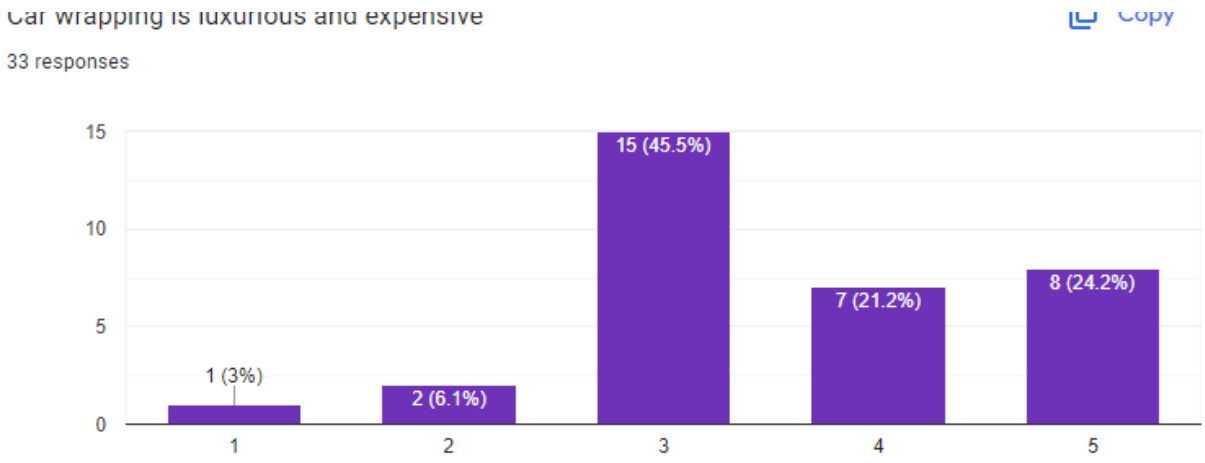
Description: The above bar chart displays that 9 participants (27.3%) were neutral to the statement, while another 18 participants (54.5%) "Agrees" or "Strongly Agrees" to the statement, with another 6 participants (18.2%) "Disagree" or "Strongly Disagree" to the statement.

Table 41.



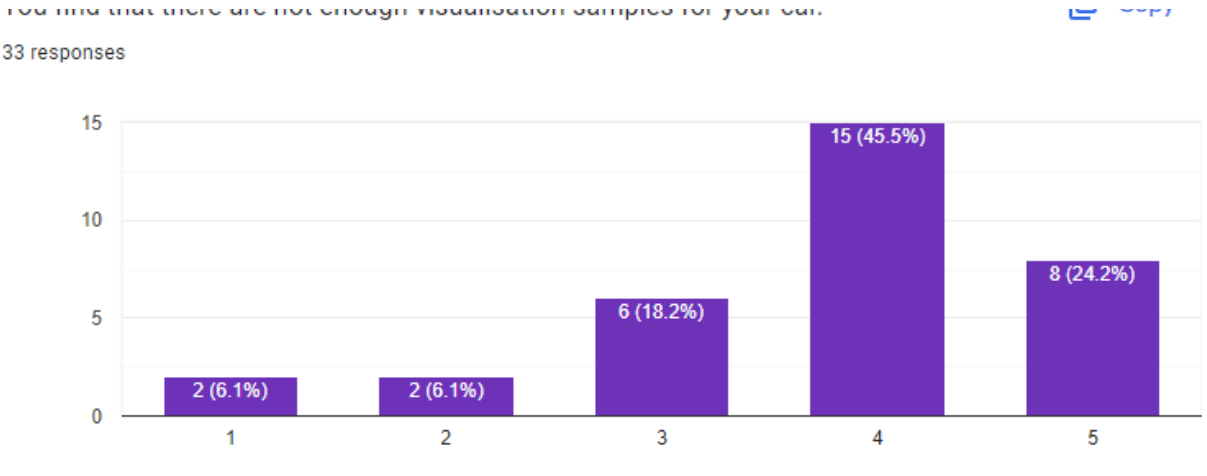
Description: The above bar chart displays that 7 participants (21.2%) were neutral to the statement, while another 21 participants (63.6%) "Agrees" or "Strongly Agrees" to the statement, with another 5 participants (15.2%) "Disagree" or "Strongly Disagree" to the statement.

Table 42.



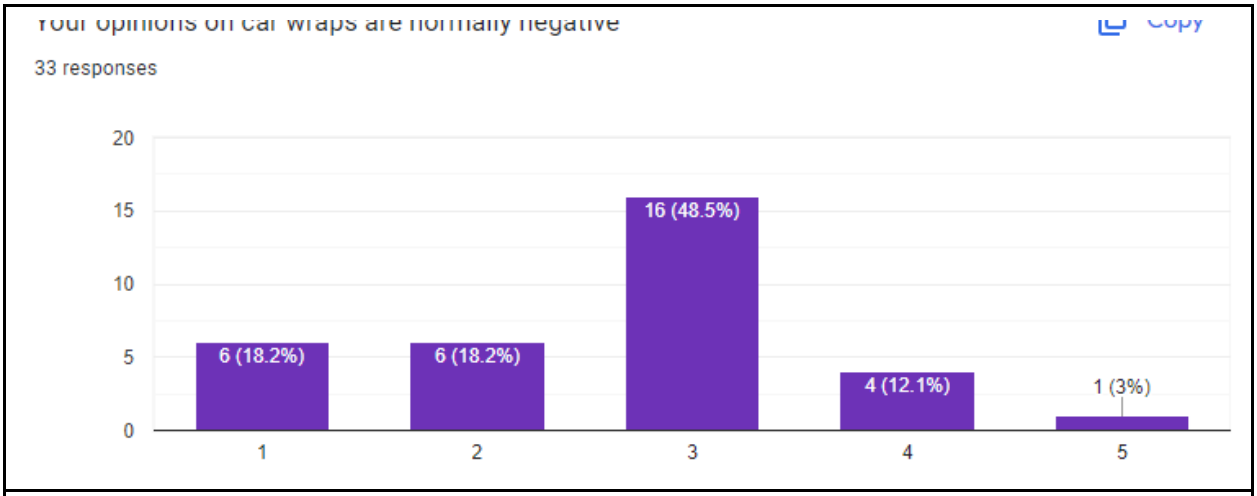
Description: The above bar chart displays that 15 participants (45.5%) were neutral to the statement, while another 15 participants (45.4%) “Agrees” or “Strongly Agrees” to the statement, with another 3 participants (9.1%) “Disagree” or “Strongly Disagree” to the statement.

Table 43.



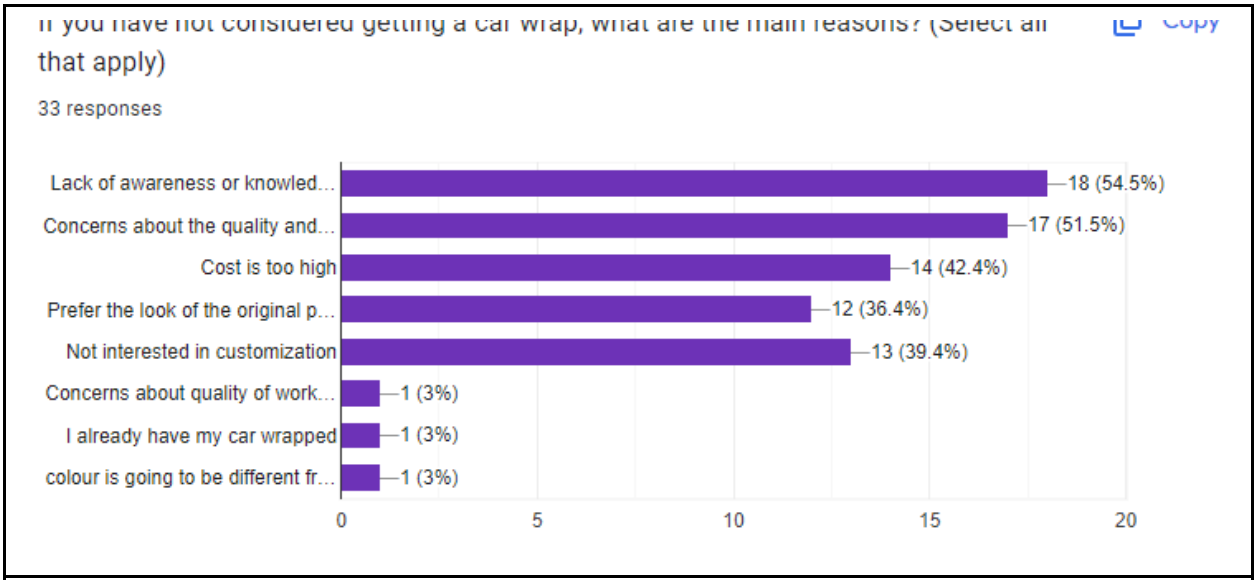
Description: The above bar chart displays that 6 participants (18.2%) were neutral to the statement, while another 23 participants (69.7%) “Agrees” or “Strongly Agrees” to the statement, with another 4 participants (12.2%) “Disagree” or “Strongly Disagree” to the statement.

Table 44.



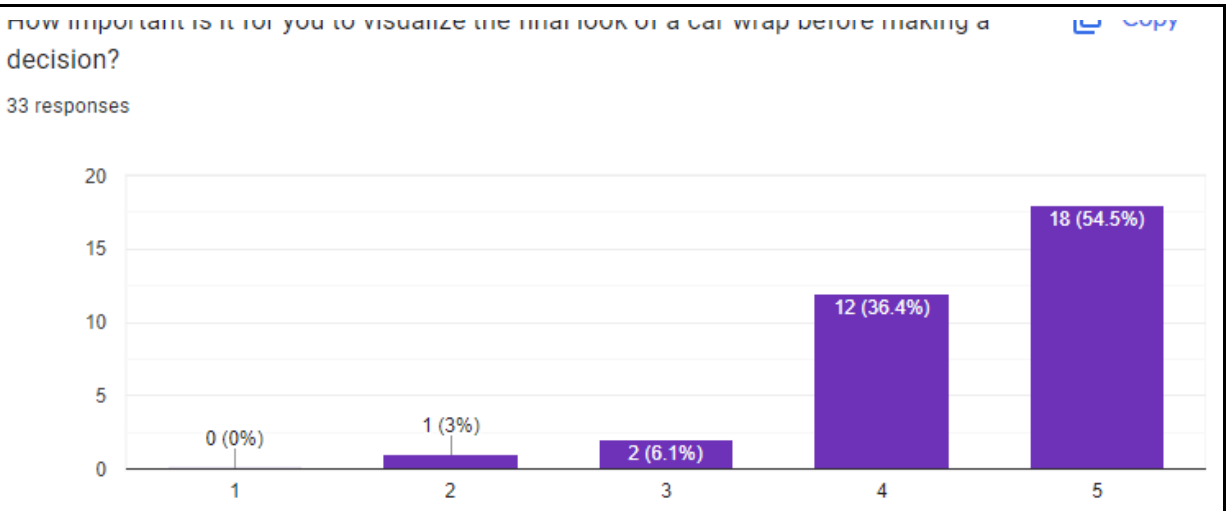
Description: The above bar chart displays that 16 participants (48.5%) were neutral to the statement, while another 5 participants (15.1%) "Agrees" or "Strongly Agrees" to the statement, with another 12 participants (36.4%) "Disagree" or "Strongly Disagree" to the statement.

Table 45.



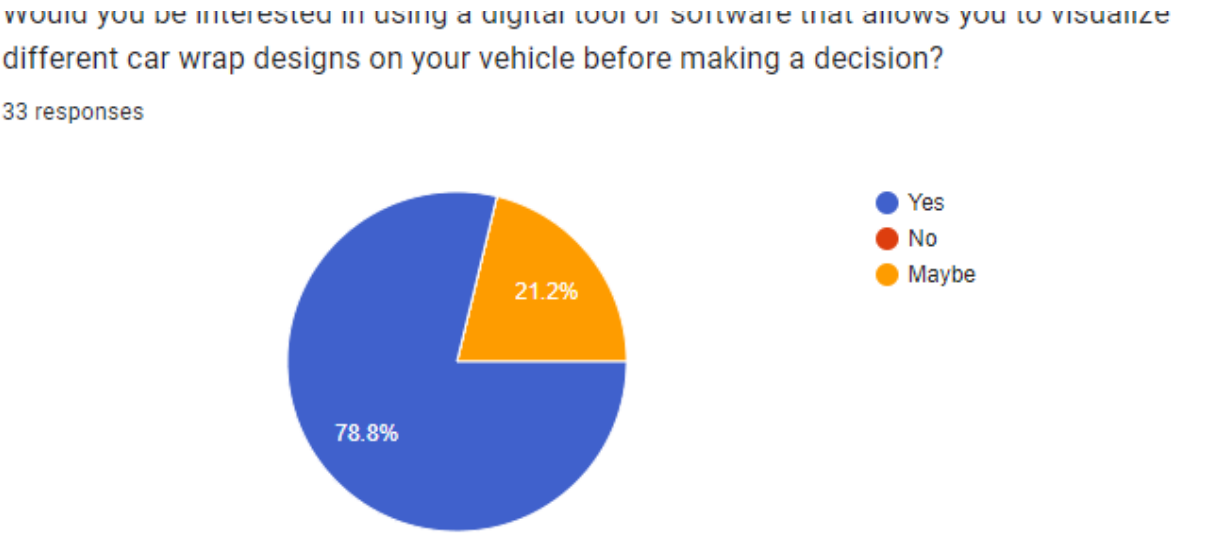
Description: The above bar chart displays that almost half of all participants (17 & 18) have "Lack of awareness or knowledge about car wraps" & have "Concerns about the quality and durability of the wrap", while below half find "Cost is too high" or "Prefer the look of the original paint" or is "Not interested in customization" in general.

Table 46.



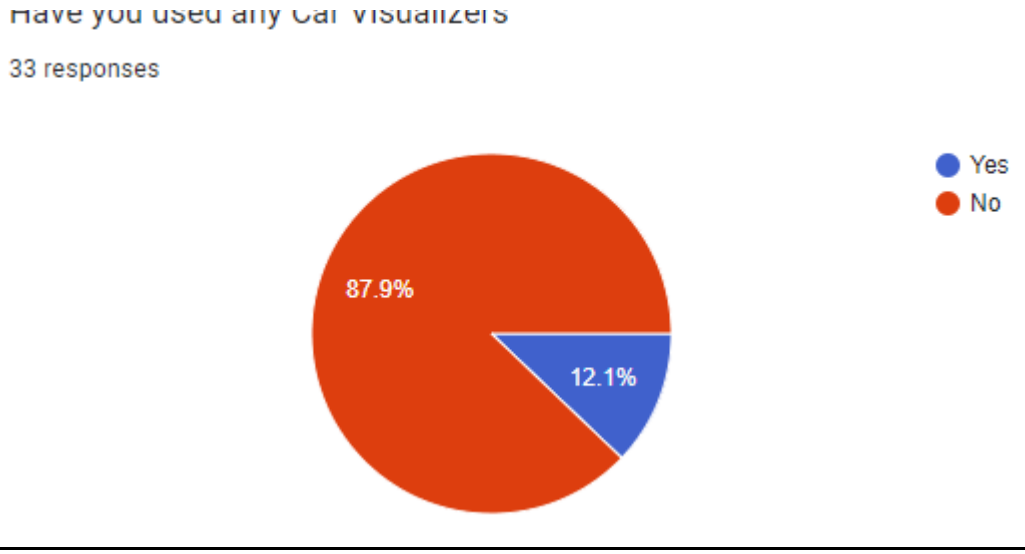
Description: The above bar chart displays that only 2 participants (6.1%) were neutral to the statement, while another 30 participants (90.9%) “Agrees” or “Strongly Agrees” to the statement, with another 1 participant (3%) “Disagree” to the statement.

Table 47.



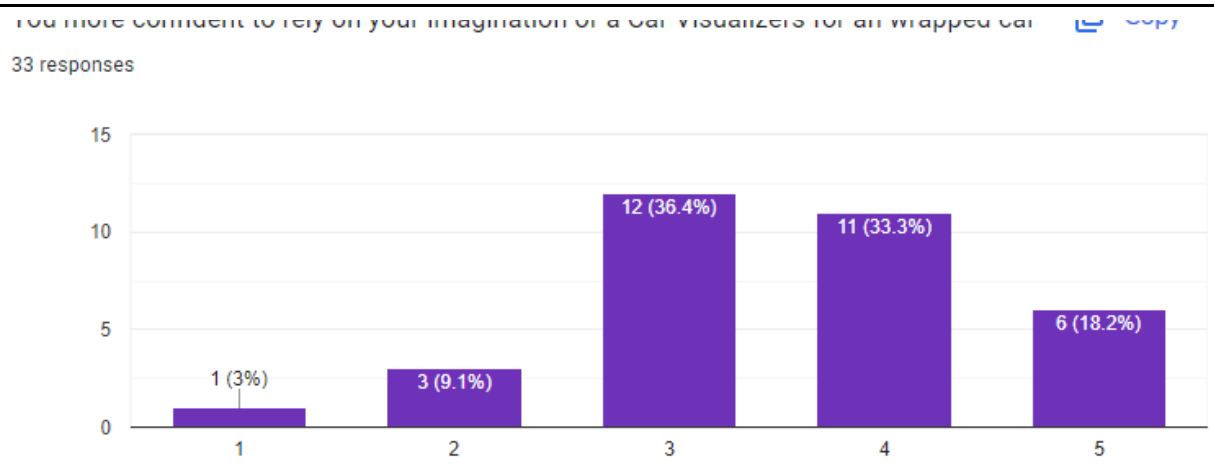
Description: The above pie chart displays that 78.8% of participants would use a tool to visualize a car wrap, while 21.2% are unsure.

Table 48.



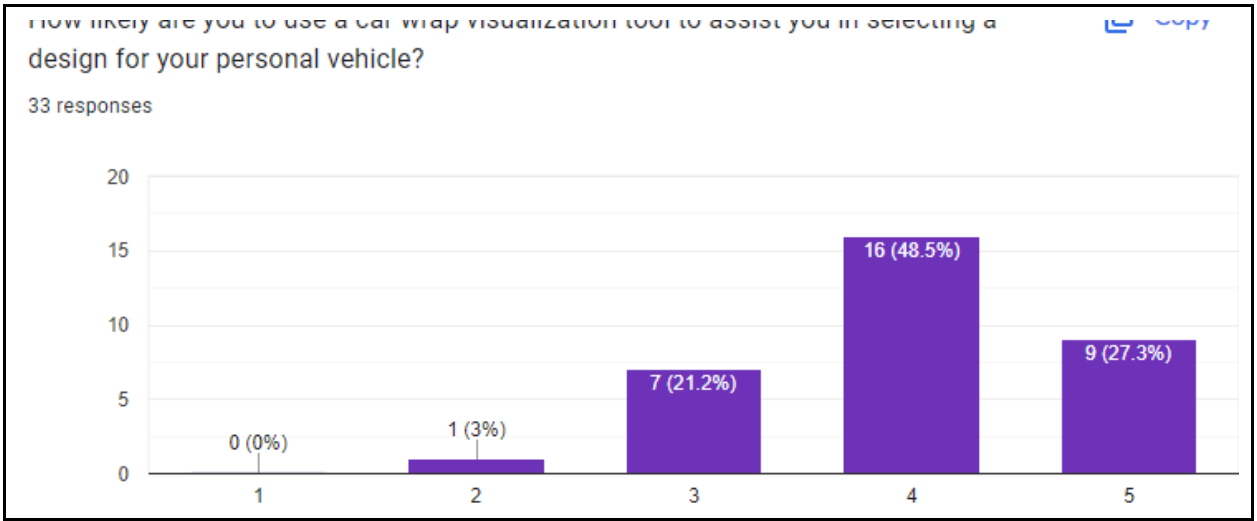
Description: The above pie chart displays that 87.9% of participants have not used a tool to visualize a car, while 12.1% has.

Table 49.



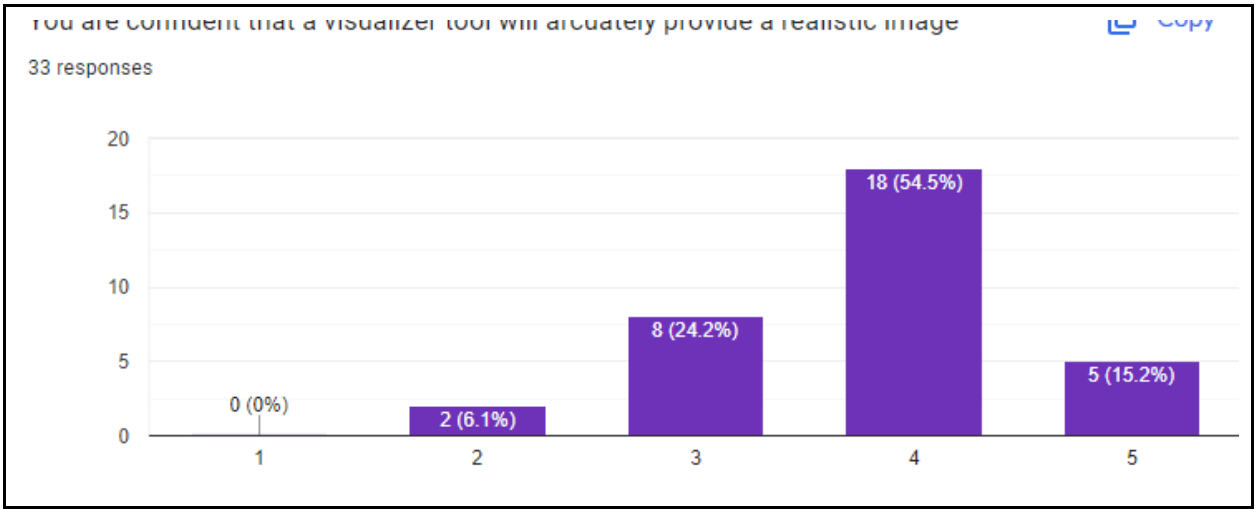
Description: The above bar chart displays that only 12 participants (36.4%) were neutral to the statement, while another 17 participants (51.5%) “Agrees” or “Strongly Agrees” to the statement, with another 4 participant (9.1%) “Disagree” or “Strongly Disagrees” to the statement.

Table 50.



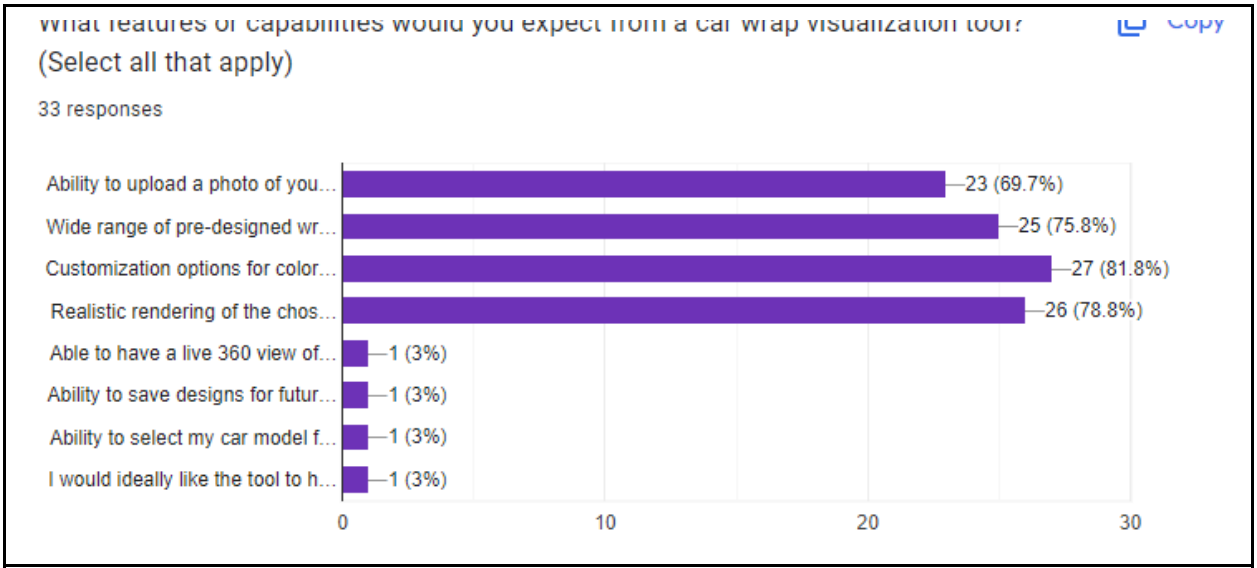
Description: The above bar chart displays that only 7 participants (21.4%) were neutral to the statement, while another 25 participants (51.5%) “Agrees” or “Strongly Agrees” to the statement, with another 1 participant (3%) “Disagrees” to the statement.

Table 51.



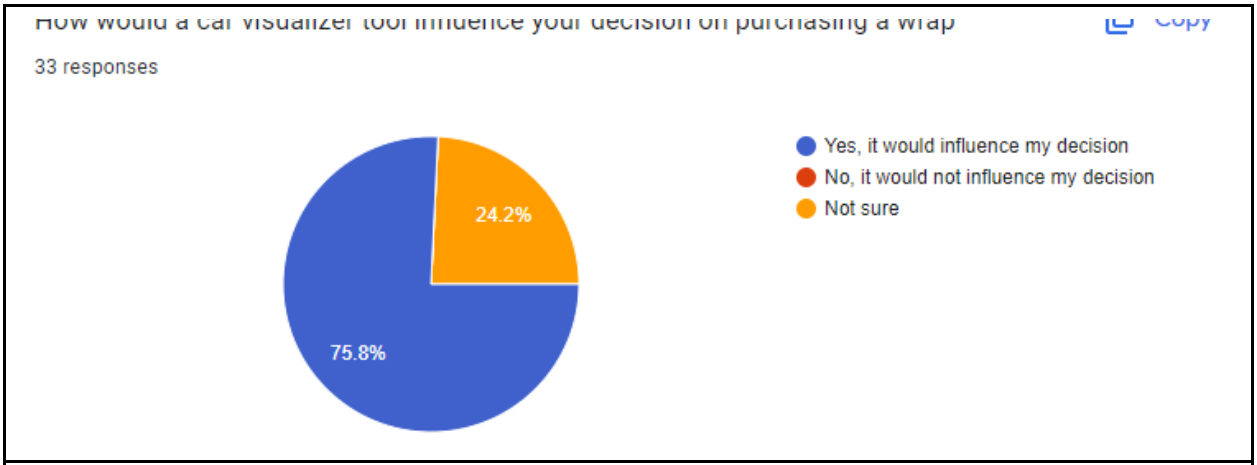
Description: The above bar chart displays that only 3 participants (24.2%) were neutral to the statement, while another 23 participants (69.6%) “Agrees” or “Strongly Agrees” to the statement, with another 2 participant (6.1%) “Disagrees” to the statement.

Table 52.



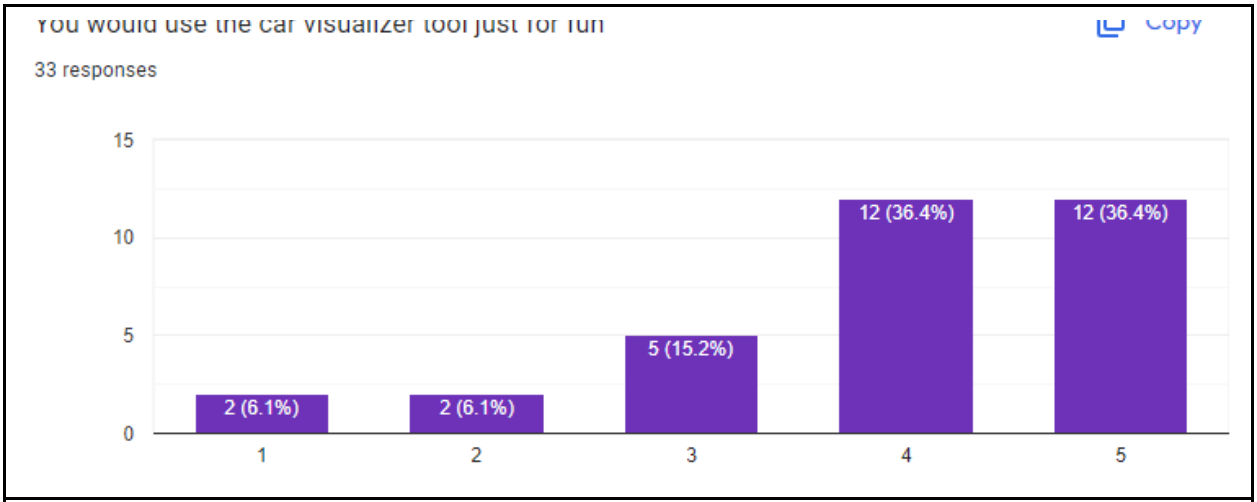
Description: The above bar chart displays that majority of favored features within a car visualizer are: “Ability to upload a photo of your own vehicle”, “Wide range of pre-designed wrap templates to choose from”, “Customization options for colors, patterns, and graphics” and “Realistic rendering of the chosen wrap on the vehicle”.

Table 53.



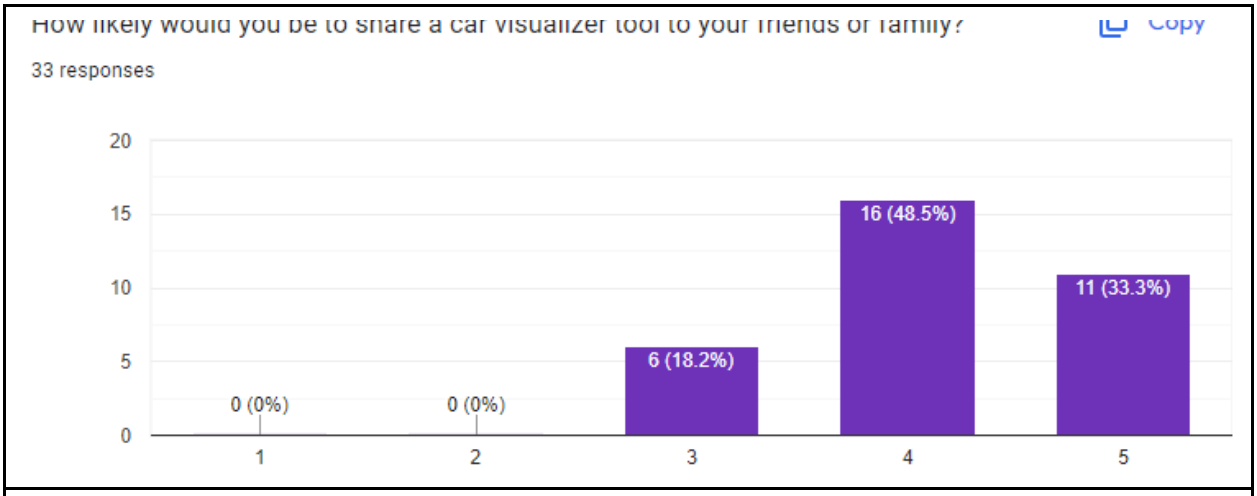
Description: The above pie chart displays that 75.8% of participants agree that a visualizer tool would influence their decision, while the rest 24.2% are not sure.

Table 54.



Description: The above bar chart displays that only 5 participants (15.2%) were neutral to the statement, while another 24 participants (72.8%) “Agrees” or “Strongly Agrees” to the statement, with another 4 participant (12.2%) “Disagrees” or “Strongly Disagrees” to the statement.

Table 55.



Description: The above bar chart displays that only 6 participants (18.2%) were neutral to the statement, while another 27 participants (81.8%) “Agrees” or “Strongly Agrees” to the statement, with no participants disagreeing

Table 56.

3.2.6 Summary

After compiling the results, there were a few notable items of discussion to be had, which was on the question “Would you wrap your car in the future”, which had a result of 69.7% were either unsure or will never wrap their car. While in the question of “How would a car visualizer tool influence your decision on purchasing a wrap”, it had changed to 100% of participants saying it would influence them positively or might influence them, with none settling with no. Which shows that with a good enough car visualizer, it could influence people one way or another, which justifies the reason for creation for this system.

As with the question “What features or capabilities would you expect from a car wrap visualization tool?”, majority of all participants had agreed on the set answers, which were the proposed requirements that were planned in the beginning. Adding onto that there were some participants that had included their input of additional features of “Ability to save designs for future reference or to make comparisons to”, “I would ideally like the tool to have a function for bodykits as well, or custom bodykits too” and “Able to have a live 360 view of the car (able to see it from all angles and different lighting conditions)”. These additional inputs could be considered to add into the system.

CHAPTER 4 DESIGN AND IMPLEMENTATION

4.1 Introduction

This chapter of the documentation will discuss the design of the system. It will contain a Data Flow Diagram of context level, level 0, use case diagram, and an interface diagram. Along with the execution of merging all research together and the ideas into a project.

4.2 Design

Context Level

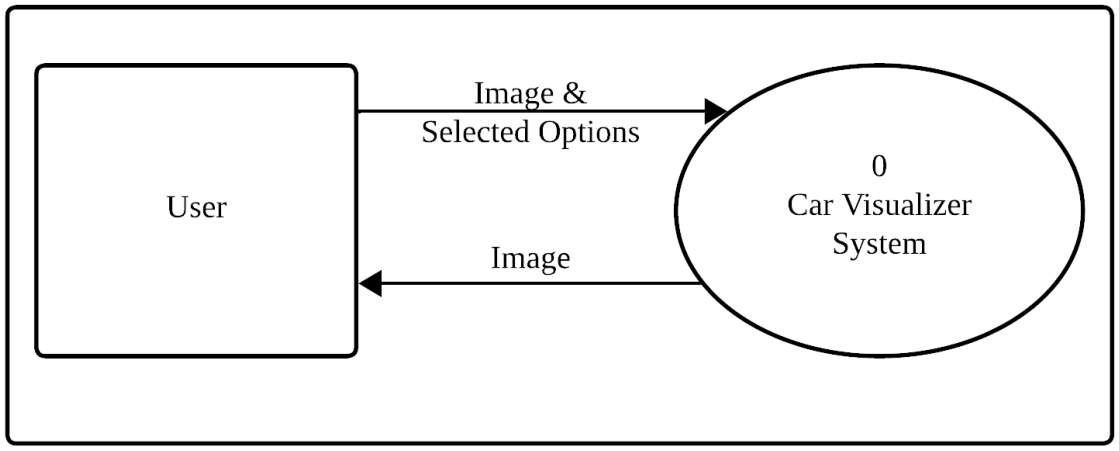



Diagram: DFD Context Level

Table 57.

Level 0

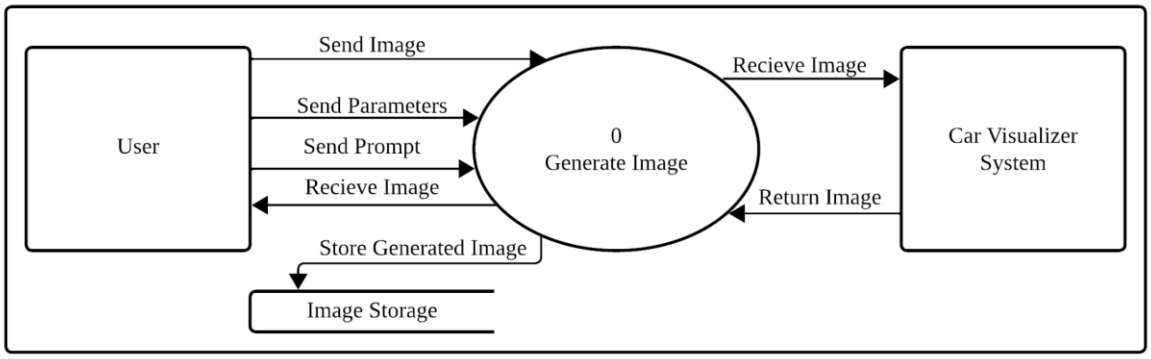



Diagram: DFD Level 0

Table 58.

Use case

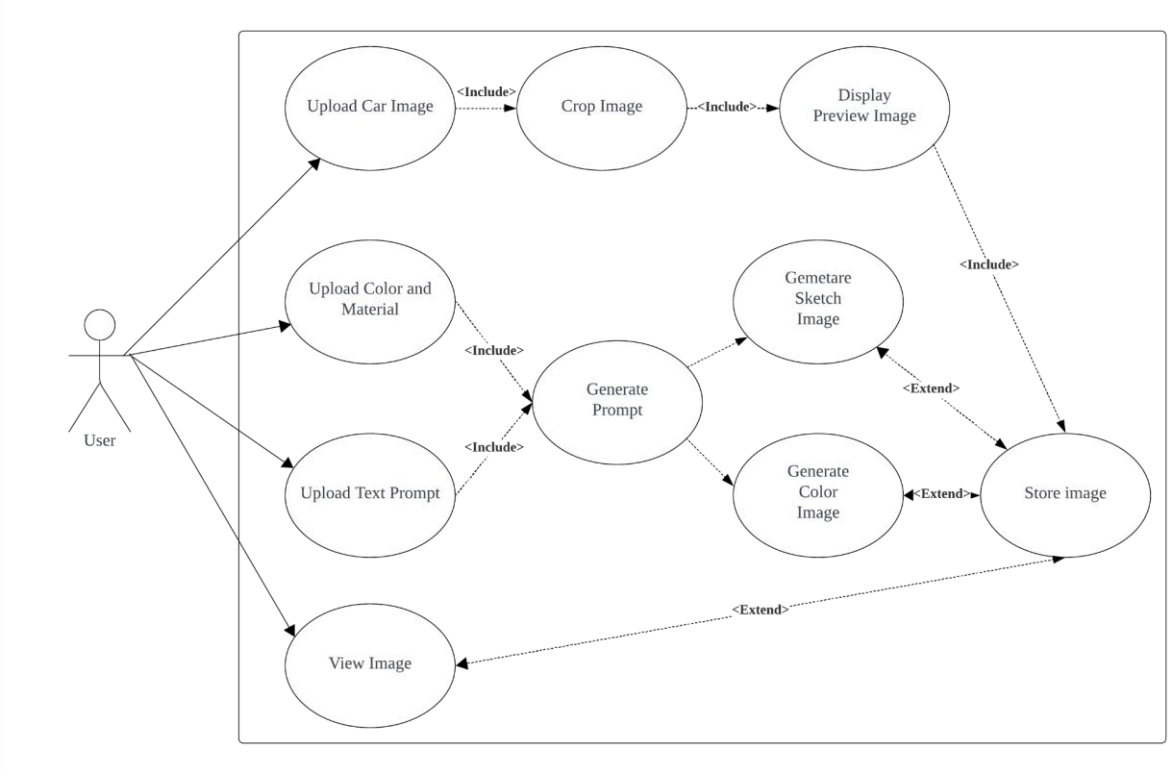



Diagram: Use Case

Table 59.

Use Case 1: Upload Car Image

Use Case Name	Upload Car Image
Use Case Descriptions	This use case is to ensure the user will be able to upload their own image to the system
Include Use Case	Store Image
Preconditions	User must prepare an image to upload a car image

Postconditions	1. User must crop the area of interest 2. User must upload color & material or text prompt 3. System will save the cropped image 4. System will begin generation of sketch from the cropped image 5. System will begin generation of colored sketch from the sketch result 6. System will save and return the image
Primary Actor	User
Secondary Actor	None
Main Flow:	1. User uploads image of a car 2. User crops the image 3. User selects color & material or writes a text prompt 4. User click Create! button 5. System generates a sketch and colored image from the user inputs 6. System saves the image and displays the resulting image
Alternative Flows	4a. User's clicked on Create! Without uploading an image

4.4 Interface Design

Interface Design (Front Page)

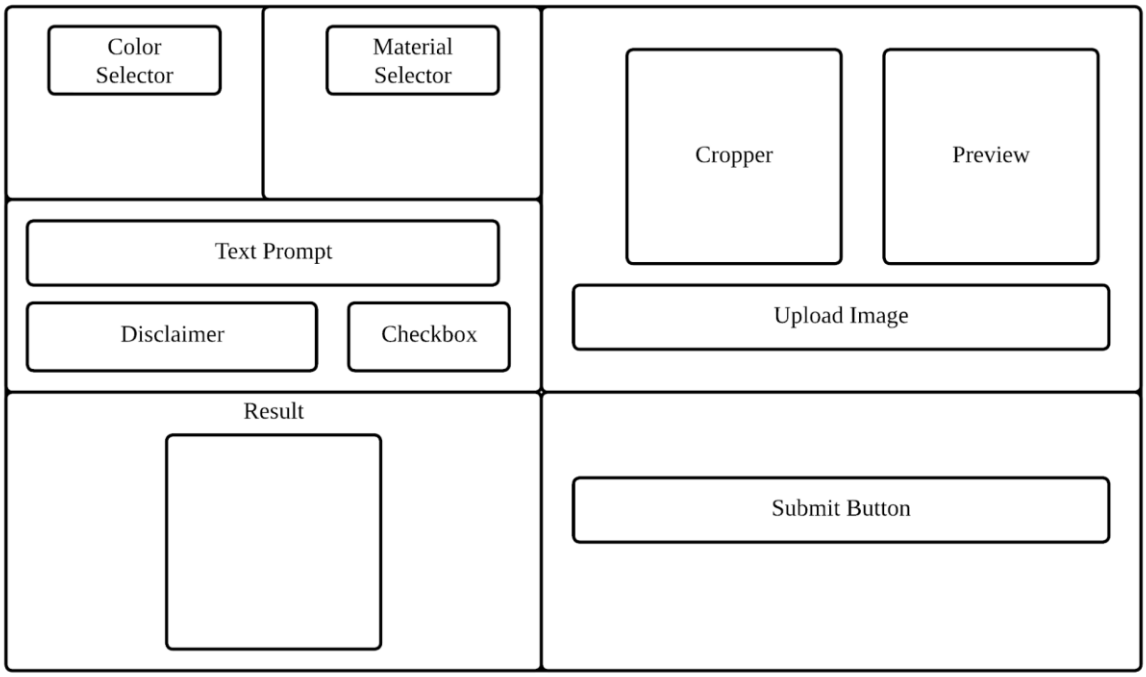



Diagram: Front Page Storyboard

Table 60.

4.5 Execution

4.5.1 FastAPI

The web framework chosen is FastAPI, as it is used as the backend of this system. FastAPI is a Python based web framework. As when the URL and path is requested it returns a page, error or image.

```python
@app.get("/", response_class=HTMLResponse)
def main(request: Request):

    files = [f for f in Path("static/final_results/img2img").iterdir() if f.is_file()]

    # Sort files based on creation time in ascending order (oldest first)
    files.sort(key=lambda f: os.path.getctime(f), reverse=True)

    oldest_files = [str(file) for file in files[:5]]

    return templates.TemplateResponse("demo.html", {"request": request,
                                                    "first_img": oldest_files[0],
                                                    "second_img": oldest_files[1],
                                                    "third_img": oldest_files[2],
                                                    "fourth_img": oldest_files[3],
                                                    "fifth_img": oldest_files[4]
                                                })
```

Code Snippet: Front page call

Table 61.

The code snippet above function is to call the front page of the project. Note that it responds to a HTML file with a group of images. These groups of images are the most recent generated images.

4.5.2 HTML, Javascript, Bootstrap

The system is website based, requiring HTML and styling. The styling utilized by the researcher is Bootstrap, as Bootstrap allows for an easier process of development of a responsive website. It is a popular framework that is focused on styling of the website.

On the other hand, Javascript allows for the function of the website's cropper and also handles sections of the page's styling and handling the request calls of the API. The below snippet of Javascript code handles the request sent to the backend. It catches any submit request and formats the data form to add in the image cropped preview.

```
document.getElementById('myForm').addEventListener('submit', function(event) {
event.preventDefault();
    var formData = new FormData(event.target);

    formData.forEach(function(value, key) {
        console.log(key, value);
    });

    // Step 1: Load the Imageconst previewImage = ;
    var img = new Image();
    img.src = document.getElementById("preview-image").src;

    // Step 2: Canvas Conversion
    var canvas = document.createElement('canvas');
    var context = canvas.getContext('2d');
    canvas.width = img.width;
    canvas.height = img.height;
    context.drawImage(img, 0, 0, img.width, img.height);

    // Step 3: Data URL to File
    var dataURL = canvas.toDataURL('image/jpeg'); // Adjust format if needed
    var blob = dataURItoBlob(dataURL);
    var file = new File([blob], 'converted_image.jpg', { type: blob.type });

    formData.append('image', file)
    document.getElementById('submit-button').className = "btn btn-primary btn-lg btn-light invisible";
    document.getElementById('loading').className = "btn btn-primary btn-lg btn-light";
    document.getElementById("change-me").innerHTML = ""

    // Now, send the data to your backend using fetch or another method
    fetch('submit', {
        method: 'POST',
        body: formData
    }).then(response => {
        document.getElementById('submit-button').className = "btn btn-primary btn-lg btn-light";
        document.getElementById('loading').className = "btn btn-primary btn-lg btn-light invisible";
    if (!response.ok) {
        throw new Error('Network response was not ok');
```

Code Snippet: Javascript handling submit form data

Table 62.

4.5.3 Automatic1111

The main API used is Automatic1111, as discussed in the above document, Automatic1111 was built by open source developers. It streamlines the process of image generation to a function call. Additionally it allows for extensions to be added, these extensions can also help with image generation through different ways such as skewing the weights to a certain way, an example used would be Controlnet. To summarize Automatic1111 it is used for image generation, where it receives an input image and many different parameters. The below code snippet has two calls to Automatic1111. One to change the checkpoint and and the other to call the img2img API with the parameters all contained within the payload. The payload is formatted to a Json file, as it contains the required images and the parameters such as the Controlnet choices and other minor parameters.

```
#create the sketch - uses img2img with controlnet
async def create_Sketch_API(originalImage): #takes original image as path | image has to be size of 512
    print("start creating Sketch")
    option_payload = {
        "sd_model_checkpoint": "dreamshaper_8.safetensors [879db523c3]",
    }

    response = requests.post(url=f'{url}/sdapi/v1/options', json=option_payload)
    originalImg = encode_file_to_base64(originalImage)

    payload = {···

    response = await call_api('sdapi/v1/img2img', payload)

    for index, image in enumerate(response.get('images')):
        save_path = os.path.join(out_dir_sketch, f'img2img-{timestamp()}-{index}.png')
        decode_and_save_base64(image, save_path)
        return save_path
```

Code Snippet: Automatic1111 img2img API call

Table 63.

These parameters are selected thoroughly after many different tests with each parameter. These parameters are selected to achieve a good img2img result with generalized image inputs. As there are a lot of parameters, some important ones are as in the below table:

init_images	An array of base64-encoded images that are used as the starting point for image generation.
sampler_name	The name of the sampler used to generate the images.
steps	The number of steps taken during the diffusion process.
prompt	A text prompt that is used to condition the generation of new images.
negative_prompt	A text prompt that is used to condition the generation of new images in a negative way.
cfg_scale	A scale that controls how strictly it follows the prompt input when generating images
ControlNet	A set of parameters that determines ControlNet used
Table: Autoamtic1111 important parameters	

Table 64.

4.5.4 Hardware

The hardware used during the development was sufficient but could be further improved to achieve a better result. While the NVIDIA RTX 3060 used by the researcher takes an estimated 5 minutes to fully run 1 generated item. Having an improved hardware could definitely improve the development process and could generate a better result.

4.5.5 Development process

This section will discuss the process of development from the initial research to the final ready system. Each step will be discussed and explained. First step that the researcher had developed would be the process of masking the image. While it would make it into the final project. Understanding it is important

4.5.5.1 Masking

First process of inpainting is obtaining the area of image that you intend to modify. With object detection, vehicles are a very popular object to work with. Thus there are already a lot of existing projects that contain or are about detecting the vehicle. Following that idea, the research has landed on a few existing projects of car detection and the Segment Anything Model and GroundingDINO. The projects of car detection's results were mainly obtaining the bounding box of the vehicle and had no results in obtaining the vehicle's shape. While there were other car segmentation works that specifically focused on obtaining the area and segmenting the area of the car. Although there were some limitations to it as their model's training was on a dataset of vehicles side profile. As shown in the figure below.

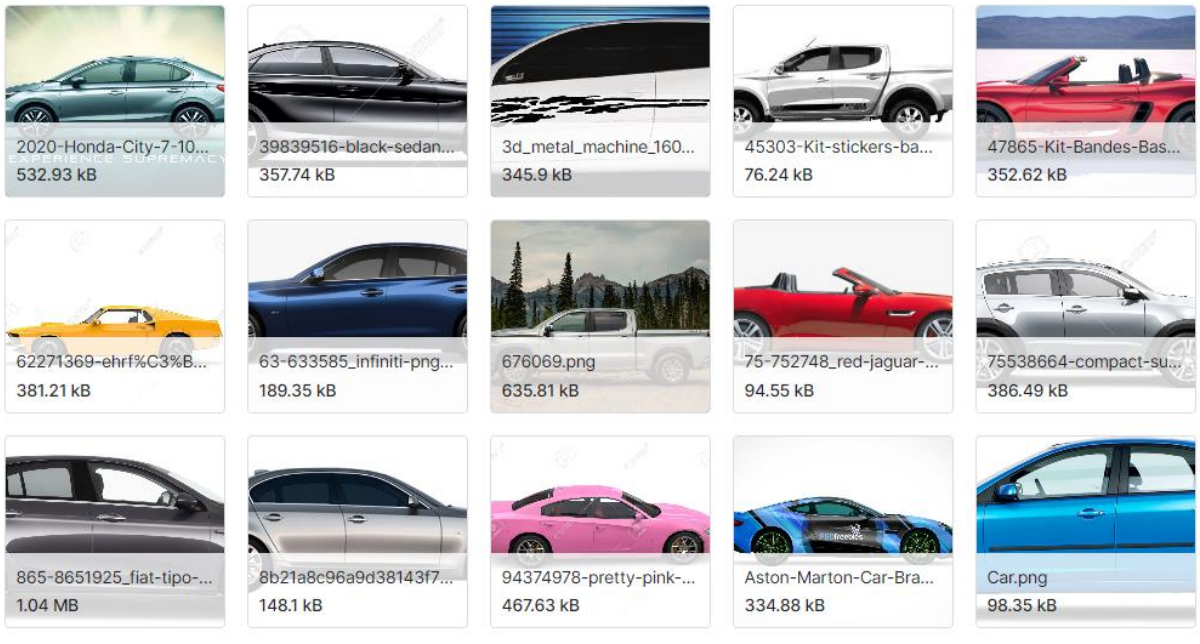


Figure: Car segmentation project's training dataset

Table 65.

With the remaining project mentioned would be the merged projects of Segment Anything Model (SAM), a AI computer vision research done by Research Meta (Facebook), and groundingDINO, made by Shilong Liu and her group of researchers. groundingDINO is a “state-of-the-art zero-shot object detection model” (Roboflow, 2023) [ref] This detector can detect arbitrary objects with human inputs such as category names or referring expressions. The key solution of open-set object detection is introducing language to a closed-set detector for open-set concept generalization. (Liu S., et al., 2023) With the merge with SAM was able to achieve object detection through text prompts while being able to create masks for them as well. SAM was trained on a dataset of 11 million images and 1.1 billion masks 1. The authors of the paper used a single machine with 8 NVIDIA V100 GPUs to train the model. (Liu S., et al., 2023)

The researcher had managed to use the merged project to obtain masks for the vehicles he had tested with. Some samples are shown below.

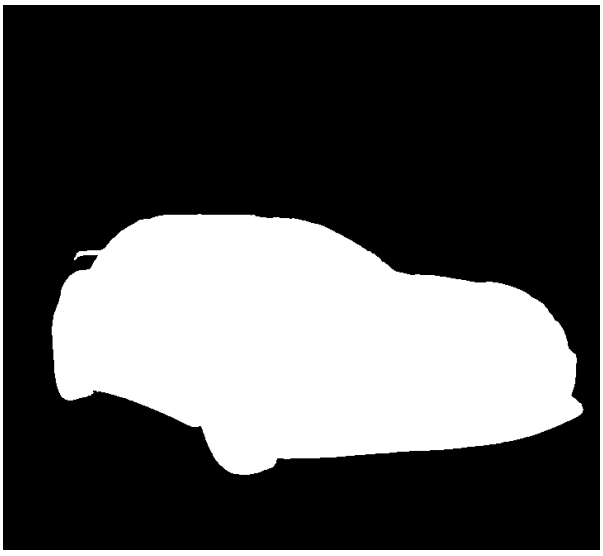
Original Image	Mask Created
	
Table: Obtain masks	

Table 66.

4.5.5.2 Basic Image Processing

With the obtained mask, some basic image process can be applied to obtain other sessions or outright change the pixel's RGB and hue values with the masked area. This technique was able to obtain the mask of the background and even change the vehicle color, as shown below.

	
Background Mask Obtained	Pixel Hue changed

Table 67.

4.5.5.3 Image Generation

Basic image processing can achieve so much, which then began the experiments with image generation models from Stable Diffusion (SD). As mentioned above, SD has released many different models, in versions of SD 1.0, SD1.4, SD 1.5, SD 2.0, SD 2.1, SD XL 1.0, and SD XL Turbo. While SD XL and SD XL Turbo had shown many realistic results found online, the research was not confident with running SD XL verison with the current hardware. Thus leads to the research using only SD 1.5.

Some background on the SD 1.5 model and its checkpoints. In technical terms, Stable Diffusion models are a latent text-to-image diffusion model that can generate images from a given text input. Being able to modify and generate images from a text prompt is what the research requires for this project. Stable Diffusion SD 1.5 is more of a checkpoint. A checkpoint refers to a saved version of the model's weights that can be used for inference or fine-tuning. OpenAI had released 6 checkpoints from the original model, as the checkpoint mainly used is SD 1.5.

This checkpoint was initialized with the weights of the Stable-Diffusion-v1-2 checkpoint and subsequently fine-tuned on 595k steps at resolution 512x512 on “laion-aesthetics v2 5+” and 10% dropping of the text-conditioning to improve classifier-free guidance sampling. (Saharia, C., et al., 2022)

Additionally this checkpoint would be further fine tuned by the community to further achieve an image generated result they would prefer. The research would look for checkpoints that were fine tuned to achieve realistic images. Note that these models had to specialize towards inpainting otherwise it would generate inaccuracies some examples would be below.

Figure: Generated by a checkpoint that was not specialized in inpainting

Table 68.

There were parameters that determined the inpainting technique. Such as a parameter amount of noise applied (denoise strength), and a parameter to instruct to inpaint with what kind of noise should apply to the masked area (masked content). With the options top following closely to the original image (retains shape, orientation, and color), latent noise (retains a portion of shape, orientation, and color) or latent nothing (does not retain any shape, orientation, and color). Furthermore through the research and development, overtime research gathered had influenced the research to use technologies such as a Lora and Controlnet.

A Lora stands for Low-Rank Adaptation, where it is a fine-tuning method that can influence the image generated to be skewed towards a certain style or concept. A Lora can also improve the resolution of the image generated. While the topic of cars and vehicles in the SD community is very small with little growth to it, the Lora found was on Widebody Cars. The image generated using the Lora had very good quality, but no examples of inpainting.

		
Figure: Image generated using the Widebody Lora [https://civitai.com/models/89032/widebody-cars]		

Table 69.

The researcher had applied the Lora to process and had created the following images. It can be noted that the images generated while had mainly followed the original shape and orientation of the car and had greatly improved the quality and resolution of the generated images. Although it had added a “wide body kit” to the car.

	
Figure: Generated with a text prompt of (Yellow car) with Lora	

Table 70.

ControlNets were next worked on in the project. ControlNet is a neural network model that also steers the SD model's image generation to certain conditions. Commonly used to specify human pose or copy a composition from another image. The researcher would experiment with ControlNet models using different variations of it, mixing multiple models at the same time and each with different parameters. Which then the resulting image generated from an img2img without inpainting and various ControlNets. There were a few ControlNet modes that were able to retain the shape of the vehicle. Notably Canny, depth, and lineart.


Figure: Image generated with ControlNet Canny

Table 71.

A major pivoting point of the project would be when the research had used certain ControlNets and prompts to generate a sketch of the image. This sketch would serve as a starting point for img2img where you can use it to apply colors to it. The sketch would greatly improve the consistency of the final output image's car's shape and orientation. The following table will show different models tested. To Note that majority of the generated images were surveyed with the researcher's friends and mostly had preferred the images generated from img2img instead of inpainting.

Figure: Images generated with a set of ControlNets with different checkpoints (Y Axis) and Classifier Free Guidance scale (X axis)

Table 72.

The chosen checkpoint for creating a sketch would be dreamshape_8 with a Classifier Free Guidance scale of 4. With the sketch image, it would be used as an input to color the sketch. Many different checkpoints were tested and surveyed to find which was most appealing. The following models were as below, with the text prompt of matte black.

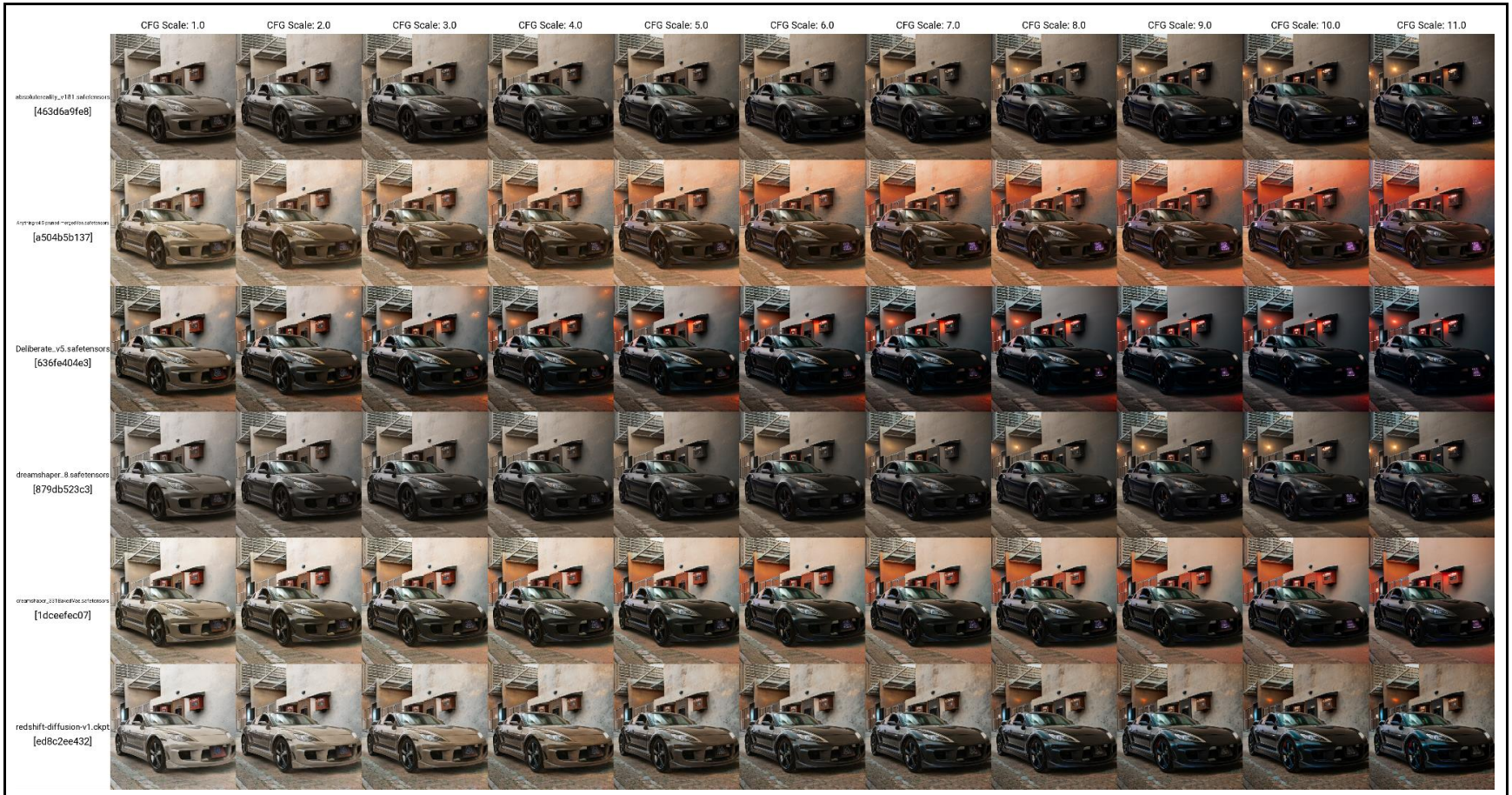
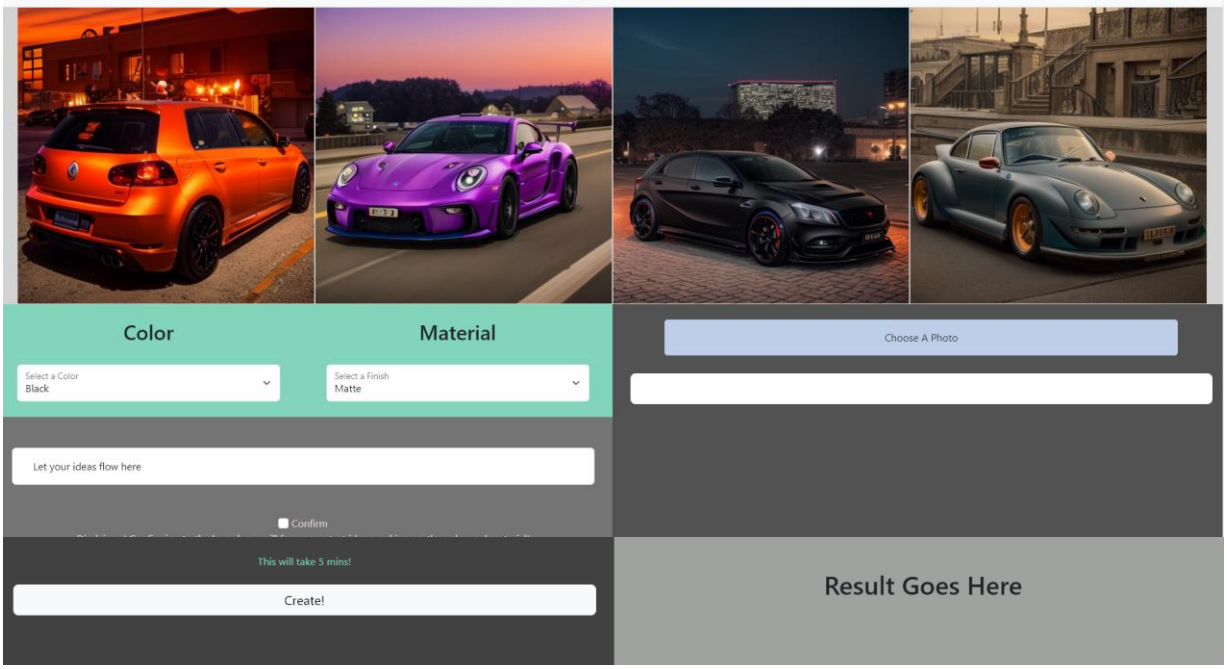


Figure: Images generated with a set of ControlNets with different checkpoints (Y Axis) and Classifier Free Guidance scale (X axis)

Table 73.

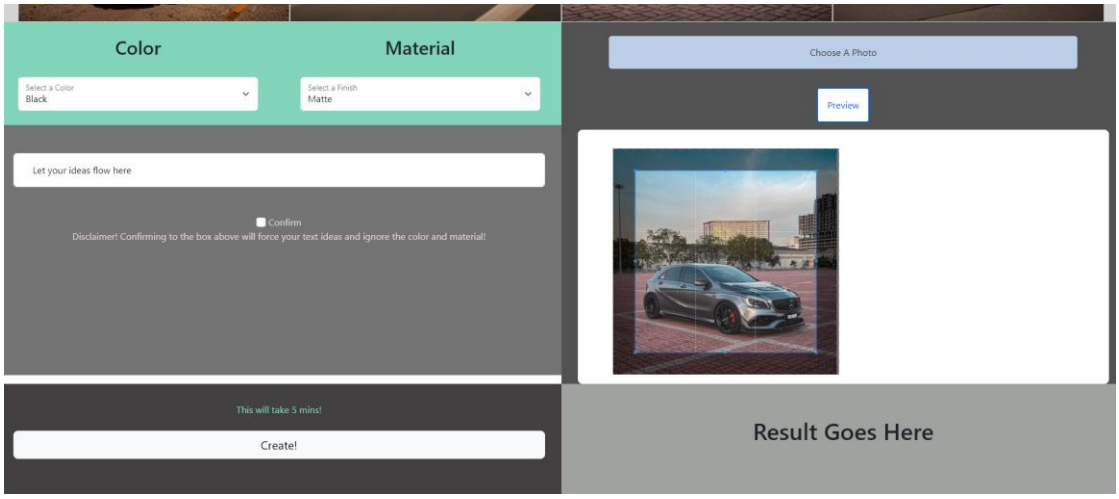
4.6 Screenshot



This landing page contains all the required inputs for the system. While each section contains different background colors to separate each input

Landing Page

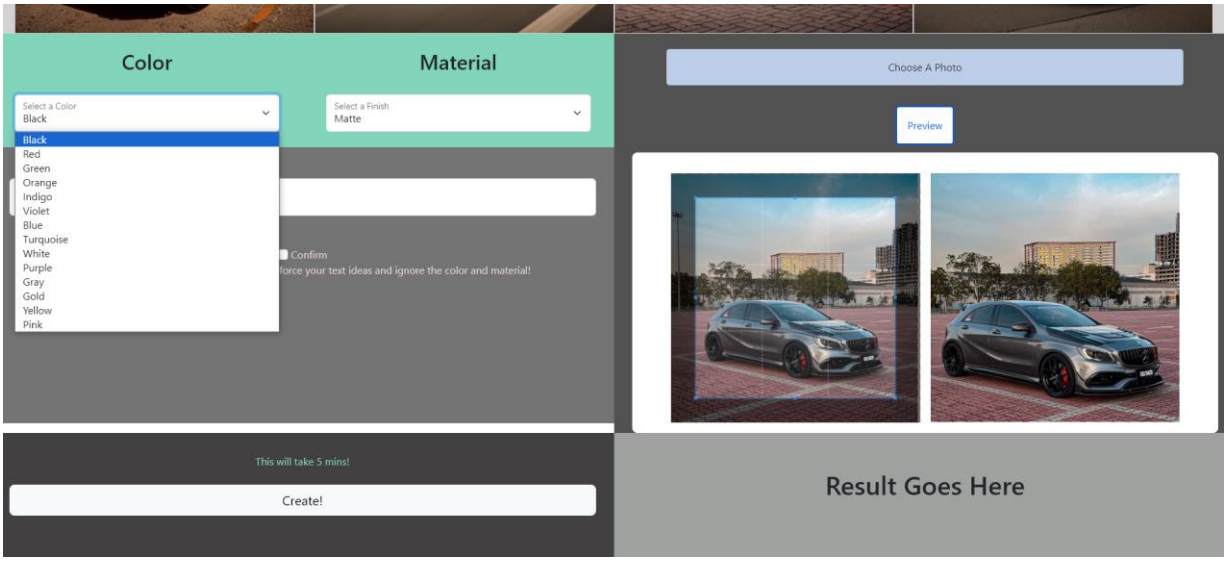
Table 74.



This shows when the user selected an image to upload

Uploading an Image

Table 75.



Clicking Preview and selecting color

Table 76.

4.7 Summary

To quickly summarize the research and development process, the project had undergone several phases, initially starting with mask generation utilizing Meta's Segment Anything Model (SAM) with groundingDINO, yielding promising results. However, the researcher opted for a pure image-to-image process, excluding inpainting and masking. Subsequent phases involved experimenting with various iterations of realistic Checkpoints, ControlNet, Loras, and parameters. The project concluded with two distinct sections: one focused on generating sketches and the other on coloring these sketches. The researcher conducted surveys among friends through word of mouth, ultimately gathering votes to determine the most preferred model for the desired results.

CHAPTER 5: RESULT AND DISCUSSION

5.1 Introduction

This section will discuss on the project's test plan, the research had used User Acceptance Test and System Usability Scale. This test plan would be sent to 3 testers who consider themselves as car enthusiasts. They had spent approximately 30 minutes on the website, with each of them generating 3 images of their choice.

5.2 Testing Design / Plan

User Acceptance Test Design (1 - Strongly Disagree | 2 - Disagree | 3 - Neutral | 4 - Agree | 5 - Strongly Agree)

	User Interface Criteria	1	2	3	4	5
1)	The overall design of the interface is visually appealing and well-crafted.					
2)	The aesthetics of the interface are pleasing and make for an enjoyable user experience.					
3)	The combination of colors used in the website is eye-catching and pleasing.					
4)	The layout of the website is well-organized and follows a logical structure.					
5)	Elements such as buttons, fonts, and navigation menus are consistent across different pages of the website.					
6)	Interactive elements, such as buttons and forms, respond promptly to user actions.					

Table 77.

	General Functionality Criteria	1	2	3	4	5
1)	The process of uploading your car image is straightforward and user-friendly.					
2)	Entering prompts for image generation is intuitive and easy to understand.					
3)	The website generates new images promptly after submitting prompts and car images.					
4)	The quality of the images generated meets or exceeds your expectations.					
5)	The website provides sufficient options to customize the generated images according to your preferences.					
6)	The website provides clear feedback or progress indicators during the image generation process.					

Table 78.

System Usability Scale Design

1	I found the website unnecessarily complex.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
2	I think that I would like to use this website frequently.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3	I think that I would need the support of a technical person to be able to use this website.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4	I thought there was too much inconsistency in this website.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5	I would imagine that most people would learn to use this website very quickly.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
6	I would like to use a website with similar functionality as this one.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
7	I needed to learn a lot of things before I could get going with this website.				

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
8	I would imagine that most people would learn to use this website very quickly.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Table 79.

5.3 System Testing and Discussion

Result (Tester 1)

Tester Demographic Profile	
Name	Chan Yee Qi
Age	24
Type of Car Enthusiast [(1- Not Interested | 5 Very Interested)]	5

Table 80.

User Acceptance Test Design (Tester 1)

(1 - Strongly Disagree | 2 - Disagree | 3 - Neutral | 4 - Agree | 5 - Strongly Agree)

	User Interface Criteria	1	2	3	4	5
1)	The overall design of the interface is visually appealing and well-crafted.				/	
2)	The aesthetics of the interface are pleasing and make for an enjoyable user experience.				/	
3)	The combination of colors used in the website is eye-catching and pleasing.					/
4)	The layout of the website is well-organized and follows a logical structure.				/	
5)	Elements such as buttons, fonts, and navigation menus are consistent across different pages of the website.				/	
6)	Interactive elements, such as buttons and forms, respond promptly to user actions.				/	

Table 81.

	General Functionality Criteria	1	2	3	4	5
1)	The process of uploading your car image is straightforward and user-friendly.					/
2)	Entering prompts for image generation is intuitive and easy to understand.					/
3)	The website generates new images promptly after submitting prompts and car images.					/
4)	The quality of the images generated meets or exceeds your expectations.					/
5)	The website provides sufficient options to customize the generated images according to your preferences.				/	
6)	The website provides clear feedback or progress indicators during the image generation process.	/				

Table 82.

System Usability Scale Design (Tester 1)

1	I found the website unnecessarily complex.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
2	I think that I would like to use this website frequently.				
	Strongly Disagree	Disagree	Neutral	Agree	**Strongly Agree**
3	I think that I would need the support of a technical person to be able to use this website.				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4	I thought there was too much inconsistency in this website.				
	Strongly Disagree	**Disagree**	Neutral	Agree	Strongly Agree
5	I would imagine that most people would learn to use this website very quickly.				
	Strongly Disagree	Disagree	Neutral	Agree	**Strongly Agree**
6	I would like to use a website with similar functionality as this one.				
	Strongly Disagree	Disagree	Neutral	**Agree**	Strongly Agree
7	I needed to learn a lot of things before I could get going with this website.				

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Table 83.

Result (Tester 2)

Tester Demographic Profile	
Name	Avvinesh Murugappan
Age	21
Type of Car Enthusiast [(1- Not Interested | 5 Very Interested)]	5

Table 84.

User Acceptance Test Design (Tester 2)

(1 - Strongly Disagree | 2 - Disagree | 3 - Neutral | 4 - Agree | 5 - Strongly Agree)

	User Interface Criteria	1	2	3	4	5
1)	The overall design of the interface is visually appealing and well-crafted.				/	
2)	The aesthetics of the interface are pleasing and make for an enjoyable user experience.					/
3)	The combination of colors used in the website is eye-catching and pleasing.				/	
4)	The layout of the website is well-organized and follows a logical structure.			/		
5)	Elements such as buttons, fonts, and navigation menus are consistent across the website.					/
6)	Interactive elements, such as buttons and forms, respond promptly to user actions.					/

Table 85.

	General Functionality Criteria	1	2	3	4	5
1)	The process of uploading your car image is straightforward and user-friendly.				/	
2)	Entering prompts for image generation is intuitive and easy to understand.					/
3)	The website generates new images promptly after submitting prompts and car images.					/
4)	The quality of the images generated meets or exceeds your expectations.					/
5)	The website provides sufficient options to customize the generated images according to your preferences.					/
6)	The website provides clear feedback or progress indicators during the image generation process.		/			

Table 86.

System Usability Scale Design (Tester 2)

1	I found the website unnecessarily complex.				
	Strongly Disagree	**Disagree**	Neutral	Agree	Strongly Agree
2	I think that I would like to use this website frequently.				
	Strongly Disagree	Disagree	Neutral	**Agree**	Strongly Agree
3	I think that I would need the support of a technical person to be able to use this website.				
	Strongly Disagree	Disagree	**Neutral**	Agree	Strongly Agree
4	I thought there was too much inconsistency in this website.				
	Strongly Disagree	**Disagree**	Neutral	Agree	Strongly Agree
5	I would imagine that most people would learn to use this website very quickly.				
	Strongly Disagree	Disagree	Neutral	Agree	**Strongly Agree**
6	I would like to use a website with similar functionality as this one.				
	Strongly Disagree	Disagree	Neutral	**Agree**	Strongly Agree
7	I needed to learn a lot of things before I could get going with this website.				

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Table 87.

Result (Tester 3)

Tester Demographic Profile	
Name	Haresh Suri
Age	21
Type of Car Enthusiast [(1- Not Interested | 5 Very Interested)]	5

Table 88.

User Acceptance Test Design (Tester 3)

(1 - Strongly Disagree | 2 - Disagree | 3 - Neutral | 4 - Agree | 5 - Strongly Agree)

	User Interface Criteria	1	2	3	4	5
1)	The overall design of the interface is visually appealing and well-crafted.					/
2)	The aesthetics of the interface are pleasing and make for an enjoyable user experience.				/	
3)	The combination of colors used in the website is eye-catching and pleasing.			/		
4)	The layout of the website is well-organized and follows a logical structure.				/	
5)	Elements such as buttons, fonts, and navigation menus are consistent across different pages of the website.					/
6)	Interactive elements, such as buttons and forms, respond promptly to user actions.					/

Table 89.

	General Functionality Criteria	1	2	3	4	5
1)	The process of uploading your car image is straightforward and user-friendly.					/
2)	Entering prompts for image generation is intuitive and easy to understand.				/	
3)	The website generates new images promptly after submitting prompts and car images.					/
4)	The quality of the images generated meets or exceeds your expectations.				/	
5)	The website provides sufficient options to customize the generated images according to your preferences.			/		
6)	The website provides clear feedback or progress indicators during the image generation process.			/		

Table 90.

System Usability Scale Design (Tester 3)

1	I found the website unnecessarily complex.				
	Strongly Disagree	Disagree	**Neutral**	Agree	Strongly Agree
2	I think that I would like to use this website frequently.				
	Strongly Disagree	Disagree	Neutral	**Agree**	Strongly Agree
3	I think that I would need the support of a technical person to be able to use this website.				
	Strongly Disagree	Disagree	**Neutral**	Agree	Strongly Agree
4	I thought there was too much inconsistency in this website.				
	Strongly Disagree	**Disagree**	Neutral	Agree	Strongly Agree
5	I would imagine that most people would learn to use this website very quickly.				
	Strongly Disagree	Disagree	Neutral	**Agree**	Strongly Agree
6	I would like to use a website with similar functionality as this one.				
	Strongly Disagree	Disagree	Neutral	**Agree**	Strongly Agree
7	I needed to learn a lot of things before I could get going with this website.				

	Strongly Disagree	**Disagree**	Neutral	Agree	Strongly Agree

Table 91.

5.3.2 Discussion

	User Interface Criteria	1	2	3	4	5
1)	The overall design of the interface is visually appealing and well-crafted.				2	1
2)	The aesthetics of the interface are pleasing and make for an enjoyable user experience.				2	1
3)	The combination of colors used in the website is eye-catching and pleasing.			1	1	1
4)	The layout of the website is well-organized and follows a logical structure.			1	2	
5)	Elements such as buttons, fonts, and navigation menus are consistent across different pages of the website.				1	2
6)	Interactive elements, such as buttons and forms, respond promptly to user actions.				1	2

Table 92.

	General Functionality Criteria	1	2	3	4	5
1)	The process of uploading your car image is straightforward and user-friendly.				1	2
2)	Entering prompts for image generation is intuitive and easy to understand.				1	2
3)	The website generates new images promptly after submitting prompts and car images.					3
4)	The quality of the images generated meets or exceeds your expectations.				1	2
5)	The website provides sufficient options to customize the generated images according to your preferences.			1	1	1
6)	The website provides clear feedback or progress indicators during the image generation process.	1	1	1		

Table 93.

System Usability Scale Design

1	I found the website unnecessarily complex.		
	1 Strongly Disagree	1 Disagree	1 Neutral
2	I think that I would like to use this website frequently.		
	2 Agree	1 Strongly Agree	
3	I think that I would need the support of a technical person to be able to use this website.		
	1 Strongly Disagree	2 Neutral	
4	I thought there was too much inconsistency in this website.		
	3 Disagree		
5	I would imagine that most people would learn to use this website very quickly.		
	1 Agree	2 Strongly Agree	
6	I would like to use a website with similar functionality as this one.		
	1 Disagree	3 Agree	
7	I needed to learn a lot of things before I could get going with this website.		
	2 Strongly Disagree	1 Disagree	

Table 94.

5.4 Summary

From the compiled results from the testing discussion, it shows that the website's overall design is subpar, and has room to improve. On the other hand, the website's function has managed to be user friendly and easy to learn. Additionally, the images generated had matched or even exceeded expectations. Although the loading button process was found not to be enough for a progress indicator.

CHAPTER 6: CONCLUSION

6.1 Critical Evaluation

As the project comes to its conclusion, the project has created a website that is able to receive a wide range of car images and with text prompts or certain inputs can generate the same car in different lighting, color and material. This project is one of its kind in the car visualization industry. As AI image generation had mainly focused on generation on humans and different art styles. This system of AI image generation was able to achieve a new system for the car customization industry if and when it is fully deployed.

Additionally to speak outside of the project. Throughout the project timeline, AI image generation development progressed very quickly. Being able to visually see other developers in the community sharing their works and research had made the researcher shocked to see such quick development to new technology first hand.

6.2 Limitation

The biggest limitation of this project is the image generation speed and the hardware requirement. Its speed is its downside as it would take more than 5 minutes for each generation. With a direct correlation of the hardware requirement and image generation speed, having better hardware will definitely improve the generation speed. This would mean that a higher initial investment into the hardware is required to fully deploy the system for future users.

Another limitation is that the system is unable to queue up image generation jobs. As now it only processes one user request and once completed will be able to accept another user request.

6.3 Recommendation

The project can be greatly enhanced by utilizing better hardware during its research and development. Due to the hardware limitation of the researcher, testing models and parameters took a long time. To add on is that while the research had chosen to opt for a pure image to image process, future works can include the inpainting process by utilizing ControlNets.

References

1. Giovanni Sisinna on LinkedIn: How Generative AI Is Changing Industries. (2023). Retrieved 5 August 2023, from https://www.linkedin.com/feed/update/urn:li:activity:7036289932973252609/
2. Wooten, J., & Wooten, J. (2020). Under Wraps: The Latest Wrapabull Projects. Retrieved 5 August 2023, from https://www.signshop.com/news/under-wraps-wrapabull/
3. Behzadinasab, S., Williams, M. D., Falkinham III, J. O., & Ducker, W. A. (2023). Facile Implementation of Antimicrobial Coatings through Adhesive Films (Wraps) Demonstrated with Cuprous Oxide Coatings. *Antibiotics*, *12*(5), 920.
4. Hagerty, M. (2022, March 22). Used & New Cars for sale, dealerships, reviews, and more. Capital One Auto Navigator. https://www.capitalone.com/cars/learn/managing-your-money-wisely/car-wrap-vs-paint-which-is-better/1377
5. Inkarbekov, M., Monahan, R., & Pearlmutter, B. A. (2023). Visualization of AI Systems in Virtual Reality: A Comprehensive Review. *arXiv preprint arXiv:2306.15545*.
6. Bertoni, A., Bertoni, M., & Isaksson, O. (2013). Value visualization in Product Service Systems preliminary design. *Journal of cleaner production*, *53*, 103-117.
7. Deng, D., Wu, Y., Shu, X., Wu, J., Fu, S., Cui, W., & Wu, Y. (2022). VisImages: A fine-grained expert-annotated visualization dataset. *IEEE Transactions on Visualization and Computer Graphics*.
8. Salimova, G., Ableeva, A., Galimova, A., Bakirova, R., Lubova, T., Sharafutdinov, A., & Araslanbaev, I. (2022). Recent trends in labor productivity. *Employee Relations: The International Journal*, *44*(4), 785-802.
9. Minaee, S., Boykov, Y., Porikli, F., Plaza, A., Kehtarnavaz, N., & Terzopoulos, D. (2021). Image segmentation using deep learning: A survey. *IEEE transactions on pattern analysis and machine intelligence*, *44*(7), 3523-3542.
10. Ghosh, S., Das, N., Das, I., & Maulik, U. (2019). Understanding deep learning techniques for image segmentation. *ACM computing surveys (CSUR)*, *52*(4), 1-35.
11. Pasupa, K., Kittiworapanya, P., Hongngern, N. *et al.* Evaluation of deep learning algorithms for semantic segmentation of car parts. *Complex Intell. Syst.* 8, 3613–3625 (2022). https://doi.org/10.1007/s40747-021-00397-8
12. Lin, Y. Y., Yu, C. C., & Lin, C. H. (2021). Automatically Segmentation the Car Parts and Generate a Large Car Texture Images. In *DeLTA* (pp. 185-190).
13. Elharrouss, O., Almaadeed, N., Al-Maadeed, S., & Akbari, Y. (2020). Image inpainting: A review. *Neural Processing Letters*, *51*, 2007-2028.
14. Guillemot, C., & Le Meur, O. (2013). Image inpainting: Overview and recent advances. *IEEE signal processing magazine*, *31*(1), 127-144.
15. Zhang, C., Zhang, C., Zhang, M., & Kweon, I. S. (2023). Text-to-image diffusion model in generative ai: A survey. *arXiv preprint arXiv:2303.07909*.
16. Lee, S., Hoover, B., Strobelt, H., Wang, Z. J., Peng, S., Wright, A., ... & Chau, D. H. (2023). Diffusion Explainer: Visual Explanation for Text-to-image Stable Diffusion. *arXiv preprint arXiv:2305.03509*.

17. Vartiainen, H., & Tedre, M. (2023). Using artificial intelligence in craft education: crafting with text-to-image generative models. *Digital Creativity*, *34*(1), 1-21.
18. Gozalo-Brizuela, R., & Garrido-Merchan, E. C. (2023). ChatGPT is not all you need. A State of the Art Review of large Generative AI models. *arXiv preprint arXiv:2301.04655*.
19. Pasupa, K., Kittiworapanya, P., Hongngern, N., & Woraratpanya, K. (2022). Evaluation of deep learning algorithms for semantic segmentation of car parts. Complex & Intelligent Systems, 8(5), 3613-3625.
20. Xu, X., Wang, Z., Zhang, E., Wang, K., & Shi, H. (2022). Versatile diffusion: Text, images and variations all in one diffusion model. *arXiv preprint arXiv:2211.08332*.
21. Guinness, H. (2023, May 5). *Stable diffusion vs. dall·e 2: Which is better? [2023]*. Zapier. https://zapier.com/blog/stable-diffusion-vs-dalle/
22. Witteveen, S., & Andrews, M. (2022). Investigating prompt engineering in diffusion models. *arXiv preprint arXiv:2211.15462*.
23. Marcus, G., Davis, E., & Aaronson, S. (2022). A very preliminary analysis of DALL-E 2. *arXiv preprint arXiv:2204.13807*.
24. Khan, Y., Hameed, I., & Akram, U. (2023). What drives attitude, purchase intention and consumer buying behavior toward organic food? A self-determination theory and theory of planned behavior perspective. *British Food Journal*, *125*(7), 2572-2587.
25. Silvestre, I., Rodrigues, J. I., Figueiredo, M., & Veiga-Pires, C. (2015). High-resolution digital 3D models of Algar do Penico Chamber: limitations, challenges, and potential. *International Journal of Speleology*, *44*(1), 25-35.
26. Smaczyński, M., & Horbiński, T. (2021). Creating a 3D model of the existing historical topographic object based on low-level aerial imagery. *KN-Journal of Cartography and Geographic Information*, *71*(1), 33-43.
27. Prabhu Chakkaravarthy, A., & Chandrasekar, A. (2019). An automatic threshold segmentation and mining optimum credential features by using HSV model. *3D Research*, *10*, 1-17.
28. Ikeuchi, K. (Ed.). (2021). *Computer vision: A reference guide*. Cham: Springer International Publishing.
29. Gould, S., Gao, T., & Koller, D. (2009). Region-based segmentation and object detection. *Advances in neural information processing systems*, *22*
30. Preechakul, K., Chatthee, N., Wizadwongsa, S., & Suwajanakorn, S. (2022). Diffusion autoencoders: Toward a meaningful and decodable representation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 10619-10629)..
31. Cao, H., Tan, C., Gao, Z., Chen, G., Heng, P. A., & Li, S. Z. (2022). A survey on generative diffusion model. *arXiv preprint arXiv:2209.02646*.
32. Luo, C. (2022). Understanding diffusion models: A unified perspective. *arXiv preprint arXiv:2208.11970*.
33. Ho, J., Jain, A., & Abbeel, P. (2020). Denoising diffusion probabilistic models. *Advances in neural information processing systems*, *33*, 6840-6851.
34. Cai, Z., Xiong, Z., Xu, H., Wang, P., Li, W., & Pan, Y. (2021). Generative adversarial networks: A survey toward private and secure applications. *ACM Computing Surveys (CSUR)*, *54*(6), 1-38.

35. AI Image Inpainting: AI Access to Image Creation and Recreation | Fotor. (2023). Retrieved 2 August 2023, from https://www.fotor.com/features/image-inpainting/
36. A Suite of Powerful AI Tools | getimg.ai. (2023). Retrieved 2 August 2023, from https://getimg.ai/
37. Redraw Image Free AI Tool. | classace.io (2023). Retrieved 2 August 2023, from https://www.classace.io/tools/redraw-image
38. Aura Vinyl - Premium Quality Conformability & Adhesive Car Vinyls. (2023). Retrieved 2 August 2023, from https://www.auravinyl.com/
39. Exists, U. (2023). 3D changer - 3D car wrap configurator. Wrapstock. https://www.3dchanger.com/
40. VR Automotive Visualizer Customizer and Simulator. | a2vr(2020). Retrieved 2 August 2023, from https://www.a2vr.co/post/vr-automotive-visualizer-customizer-and-simulator
41. Porsche AR Visualizer | Porsche (2023). Retrieved 2 August 2023, from https://play.google.com/store/apps/details?id=com.porsche.parv&hl=en&gl=US
42. Research & Compare Cars by Year, Make and Model | RelayCars.com. (2023). Retrieved 2 August 2023, from https://www.relaycars.com/
43. Plus 360 Degrees - High End Realtime 3D. | Plus360Degrees (2023). Retrieved 2 August 2023, from https://plus360degrees.com/
44. Learn once and for all how to prompt VERY COOL CARS!!! and tailored for this negative prompt! (17 nice cars and 1 hunk of junk) come on in road lovers... | Superb-Ad-4661 (2023). Retrieved 2 August 2023, from https://www.reddit.com/r/StableDiffusion/comments/10xaduu/learn_once_an_for_all_how_to_prompt_very_cool/
45. Li, C., Zhang, C., Waghwase, A., Lee, L. H., Rameau, F., Yang, Y., ... & Hong, C. S. (2023). Generative AI meets 3D: A Survey on Text-to-3D in AIGC Era. *arXiv preprint arXiv:2305.06131*.
46. Liu, V., Vermeulen, J., Fitzmaurice, G., & Matejka, J. (2023, July). 3DALL-E: Integrating text-to-image AI in 3D design workflows. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference* (pp. 1955-1977).
47. Zhang, Q., Chang, X., & Bian, S. B. (2020). Vehicle-damage-detection segmentation algorithm based on improved mask RCNN. *IEEE Access*, *8*, 6997-7004.
48. Romera, E., Bergasa, L. M., Yang, K., Alvarez, J. M., & Barea, R. (2019, June). Bridging the day and night domain gap for semantic segmentation. In *2019 IEEE Intelligent Vehicles Symposium (IV)* (pp. 1312-1318). IEEE.
49. Python, W. (2021). Python. *Python Releases for Windows*, *24*.
50. Sovietov, P. N., & Gorchakov, A. V. (2022, May). Digital Teaching Assistant for the Python Programming Course. In *2022 2nd International Conference on Technology Enhanced Learning in Higher Education (TELE)* (pp. 272-276). IEEE.
51. Farrell, J. (2022). *Java programming*. Cengage Learning.
52. Brown, N. C., Weill-Tessier, P., Sekula, M., Costache, A. L., & Kölling, M. (2022). Novice use of the Java programming language. *ACM Transactions on Computing Education*, *23*(1), 1-24.

53. Price-Whelan, A. M., Lim, P. L., Earl, N., Starkman, N., Bradley, L., Shupe, D. L., ... & Astropy Collaboration. (2022). The Astropy Project: sustaining and growing a community-oriented open-source project and the latest major release (v5. 0) of the core package. *The Astrophysical Journal*, *935*(2), 167.
54. Geambaşu, C. V., Jianu, I., Jianu, I., & Gavrilă, A. (2011). Influence factors for the choice of a software development methodology. *Accounting and Management Information Systems*, *10*(4), 479-494.
55. Moyo, S., & Mnkandla, E. (2019). A metasynthesis of solo software development methodologies. In *2019 International Multidisciplinary Information Technology and Engineering Conference (IMITEC)* (pp. 1-8). IEEE.
56. Junior, M. L., & Godinho Filho, M. (2010). Variations of the kanban system: Literature review and classification. *International Journal of Production Economics*, *125*(1), 13-21.
57. Ahmad, M. O., Markkula, J., & Oivo, M. (2013, September). Kanban in software development: A systematic literature review. In *2013 39th Euromicro conference on software engineering and advanced applications* (pp. 9-16). IEEE.
58. Gravel, M., & Price, W. L. (1991). Visual interactive simulation shows how to use the Kanban method in small business. *Interfaces*, *21*(5), 22-33.
59. Poppendieck, M., & Cusumano, M. A. (2012). Lean software development: A tutorial. IEEE software, 29(5), 26-32.
60. Moyo, S., & Mnkandla, E. (2020). A novel lightweight solo software development methodology with optimum security practices. *IEEE Access*, *8*, 33735-33747.
61. Nyström, A. (2011). Agile solo-defining and evaluating an agile software development process for a single software developer.
62. Browne, J., Coffey, B., Cook, K., Meiklejohn, S., & Palermo, C. (2019). A guide to policy analysis as a research method. *Health promotion international*, *34*(5), 1032-1044.
63. Wagner, S., Mendez, D., Felderer, M., Graziotin, D., & Kalinowski, M. (2020). Challenges in survey research. *Contemporary Empirical Methods in Software Engineering*, 93-125.
64. Liu, S., Zeng, Z., Ren, T., Li, F., Zhang, H., Yang, J., ... & Zhang, L. (2023). Grounding dino: Marrying dino with grounded pre-training for open-set object detection. *arXiv preprint arXiv:2303.05499*.
65. Saharia, C., Chan, W., Saxena, S., Li, L., Whang, J., Denton, E. L., ... & Norouzi, M. (2022). Photorealistic text-to-image diffusion models with deep language understanding. *Advances in Neural Information Processing Systems*, *35*, 36479-36494.

Appendices

Appendix A: PPF - Visualizing Car Wraps with Artificial Intelligence In-Painting Methods

Office Record	Receipt
Date Received:	Student name:
Received by whom:	Student number:
	Received by:
	Date:

DRAFT PROJECT PROPOSAL FORM

Proposal ID :

Supervisor :

1) Dr. Vazeerudeen Hameed

2) Dr. Juan Yik June

3) Assoc. Prof. Dr. Imran Medi

4) Mr. Zailan Arabee Abdul Salam

5) Assoc. Prof. Dr. Sivakumar Vengusamy

Student Name : **ARTHUR KYNAN WONG JUN SIANG**

Student No : **TP058030**

Email Address : **tp058030@mail.apu.edu.my & kynan2000@gmail.com**

Programme Name : Bachelor in Computer Science (Hons) (Intelligent System)

Title of project : **Visualizing Car Wraps with Artificial Intelligence In-Painting Methods**

Please record which module(s) your topic is related to:

AI Methods (CT002-3-2-AIM)

Imaging and Special Effects (CT029-3-2-ISE)

Introduction

As the world gradually turns towards AI automation, there's a few jobs that require the human touch, which is the Automobile Car Wrap industry. As having robotic machinery to apply car wraps is yet to come, and to really envision your own car in a wrap you'd have to see it in person or in a picture.

Car wrapping is the act of wrapping your personal vehicle with a certain type of material, color or design, which changes the vehicle's exterior appearance slightly or greatly. This is common within the car enthusiast community to wrap their personal vehicles. As this act is to greatly improve the appearance of the vehicle, as this would be their intention. These car wraps have different materials, some common examples are: Glossy Wrap, Matte Wrap, Satin Wrap and Brushed Car Wrap, to add on top of that, these wraps can come in different colors. IMAGES, T. (2020) There are more exotic and less common wraps, which all can cost a lot to purchase and to install.

To have the ability to see your car in a wrap before actually applying it is a huge lifesaver on our wallets. Especially if the car wrap you have purchased and wrapped and turns out it did not fit your preferences, this would turn out to be bad news. As it would be a costly action to change it to another wrap. The Automobile Car Wrap industry currently only really has pictures of wraps on cars that have been wrapped before. As to showcase how a certain wrap looks like, the industry takes a picture of how it looks when a car is newly wrapped.

The following proposal is to show areas of improvement and implementation of A.I. In-Painting methods that can assist with the process of visualizing car wraps. Analyzing literature reviews to explore problem statements where this project can potentially solve. The following research will analyze how "Visualising Car Wrap with AI In-Painting Methods" can enhance user's experience in the industry.

Problem Statement

1. **The Factors that Influences on Customer's Decision on Buying Car Wraps**

There are some factors regarding the influences that affect the customer's decision on buying car wraps. To list a few good ones are:

- Cheaper than a new paint job - More design options - Faster Installation - Paint protection

The one states above the few benefits from a list mentioned by a successful wrapping studio. (SpeedPro, 2021) While those factors could sound so beneficial to the customer, why do we not see more cars wrapped? This question can be answered when we explore the other factors why customers avoid buying it, such as:

- Expensive - Too much attention - It's only for luxury - Best fit for factory-finished paint

The statements are contradicting and conflicting with the good statements. To explain how it is expensive yet cheaper than a new paint job, a few other key points need to be said. "Since a good paint job can cost more than double the cost of a professional vehicle wrap" mentioned by "SpeedPro" in their blog. While on the other hand, "Accutint Bellevue" does not mention that it's more expensive, but says that key points such as: "age and wear over time", "wraps don't last as long", and "limited short term potential". These can eventually lead to more maintenance for a vinyl wrap and could drive the prices up much more. (bellevueaccutint, 2020)

Along with exploring the statements of "Luxury and attention", the majority of adults have seen car wraps as childish and pointless, this is due to how the car wrap industry gained its bad reputation by "outlandish" car wraps. As shown by Deadmau5 on his Ferrari.

([Deadmau5 Receives Cease-and-Desist From Ferrari, To Unwrap his 'Purrari'], 2014)

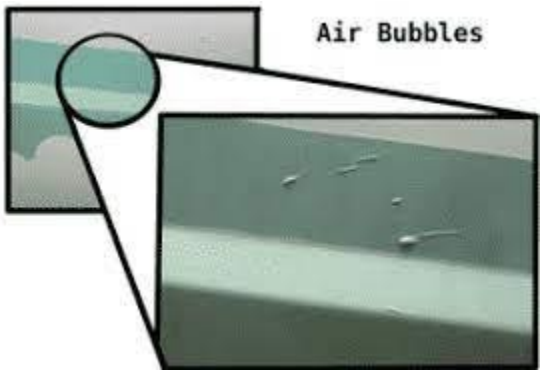
2. **The gap between customer's expectations and actual experience**

After purchasing a brand new vehicle, which takes a large life and money commitment, applying a wrap to it will be a consideration, with that, customers would try to save money where they can. This would eventually lead them to not getting what they expected. As stated by 4 different companies, which all standby the saying of "You Get What You Pay For!". Meaning that if you are cheap on the car wrap, then you will also receive a poor wrap. (Guys, 2020) (Perkins, 2018) (Frog, 2022) (graphicsolutions, 2020)

The wrap quality can go bad by a few ways:

- Bubbling - Peeling Edges - Bad Trimming - Creased Edges

These are the few areas where the quality will truly show in a cheap car wrap. As most common are bubbling. As shown below



([Car Wrapping Bad Examples], N.A.)

3. **Lack of Visualising Samples**

As customers go through the creative process, going through and selecting a certain wrap, these "visualizers" are through physical books or in pictures examples that were previously made. With that customers have "to have faith and visualize what their new wrap will look like". (Kearns, 2020)

This can lead to a bad reputation due to how it could possibly disappoint the customer. While the customer spent 1,000$ or more, which would eventually lead to giving the car wrap studio a bad name. Requiring the improvement of the visualization process is much needed.

3. Project Aim and Objectives

The aim of the project is to improve the process of users selecting a car wrap by allowing them to visualize their car with an A.I. software In-Painting wraps. To save user's time and money by allowing the customer to use a software to visualize their car in a wrap that fits their preferences, which then they can show to a car wrap outlet to reference it.

The objectives of this project are:

1. To allow users to easily visualize a car wrap of their preferences onto a picture of their own car through Artificial Intelligent In-Painting.
2. To explore computer vision and Artificial Intelligent In-Painting techniques for car wraps
3. To identify and analyze methodologies for Artificial Intelligent In-Painting for car wraps
4. To investigate factors impacting customer's experience when choosing a car wrap

4. Literature Review

Within this section the research will explore related discussions and reports covering the car wrap industry and Artificial Intelligence In-Painting methods. To provide an overview by investigating to find supporting statements on the project idea. The following literature on car wraps and In-painting are to explore the improvements to the customer's experience during the choosing process, along with the information of limitations and improvements to those reports collected. With that it can gather ideas to provide solutions to the limitations so as to improve the system.

To first explore ways of wrapping, starting with the 3D wrapping research by Lee and team. They explored a way of computation origami, through obtaining the 3D shape of the object, they then tested different materials through and wrapping it onto the object. Lee et al., (2020) While this could be used on car wraps, their methodology was mainly used on small objects, due to the requirement of using a 3D scanner, which is an issue due to how the project's target audience would be towards users with phones.

The following research by Nanayakkara, used augmented reality through smart phones to apply the car wraps visually. They showed that this was feasible, but it had a few limitations and complications. One was that this implementation had good performance on phones that had high processing power, while powerful phones are still common, this can limit the users slightly. Additionally another limitation was that the AR provided a not completely realistic result. With that a common issue was the AR had either overlapped the masked image or even did not cover enough of the mask. (Nanayakkara, 2019). Although they had the feature of being able to use it on a live camera on their phones.

As in this research by Kuys, Ranscombe, & Zhang, in a different industry but still the idea of trying to convey an idea without visualizations appears here. The research had shown the researchers attempting to create a type of visualization for their collaborator. Even so the result of the research had shown that even after visualizing, their collaborator could not fully visualize the final product until it was a development process. This can prove that the car wrap industry is in this sort of conundrum for the customers will be a similar situation.

With this research below they explored Realistic Visualization of Car Configurator Based on Unreal Engine 4. Zhong, Yun, & Lee, the researchers had studied different platforms of car configurators, such as Porsche's online car configurator or even Assetto Corsa's configurator. Within their future research section, they explained that they could improve the realism of the graphics. Along with trying to address an FPS issue, expanding to other platforms and having more preset cars inside the system was a requirement. (Zhong et al., 2022) Using this information learnt, Unreal Engine 4 could be a possible platform to explore during the development.

For computer vision, this research uses in-painting to repair damaged images or even compressed images. Sharieff and team used an intelligent framework to be applied on the image, repairing badly compressed images. They further proposed "curvelet instead of SMVQ compression" to improve it even more. (Sharieff. et al, 2020)

Within the research done by Alyasiri and Obaid in 2018, they experimented with a

way of object detection and recognition. Their work was focused on old art works, which also had an accuracy of 60%. As they mentioned that their works can be expanded out into new areas. in different images and objects. (Alyasiri et al., 2018) This can be applied to car detection on images to detect if the user uploaded the image that contains a car.

This research from Stability AI, they focus on improving their existing works of the sampling speed of diffusion models. While also demonstrating more practical applications to a distillation approach of “text-guided image-to-image translation and inpainting tasks”. In here they improved the “inference cost of classifier-free guided diffusion models”. (Meng et al, 2023) This could be applied within the project to provide the project a good benefit from this research.

The following research by Yu, Feng, Ruoyu, Liu, Jin, Zeng, & Chen had done research and created “Inpaint Anything” in April 2023. They had created a software system that had used powerful vision models of SAM, LaMa and Stable Diffusion (SD), to allow the possibility of an image inpainting system. Inpaint Anything also known as IA, has the ability of many features such as removing objects in images, replacing objects, refilling objects, replacing backgrounds and many more. (Yu et al., 2023) Their methods could be explored with the visualizing car wraps implementations.

All the research above had shown very little similar works, this is due to how sparse this project topic is. Although finding research that touched closed domains such as computer vision and the car industry. As to conclude, a method that could be investigated more would be Stable Diffusion methods and car segmentation.

5. Deliverables

A.I. In-Painting will allow the car wrap industry and their potential customers smoothen the process of choosing a wrap that fits their preferences. These new or existing customers can use the web-browsers such as Google Chrome, Firefox, etc. to access this application to create visualized wrap they want to envision. The functionalities of this application should allow users to do the following:

1. Allows users to upload an image of a car to apply the A.I. In-Painting Techniques on
2. Allows users to create any wrap style they want through color and wrap type
3. Allow users to save the car wraps they created to the system
4. Allow the user to download the car wrap they created as an image

6. References

- IMAGES, T. (2020). *What is car wrapping-and do you need it?*. Turbo Images. https://www.turbo-images.com/en/blog/what-is-car-wrapping
- Mark P. (2014). [Ferrari Sends Deadmau5 Cease-and-Desist Over His 'Purrari']. Retrieved June 02, 2023, from https://www.huffpost.com/archive/ca/entry/deadmau5-receives-cease-and-desist-from-ferrari-sadly-unwraps-n_n_5732422
- Pro, S. (2021). *Car wrap vs paint: 11 reasons to wrap your car*. SpeedPro. https://www.speedpro.com/blog/wrap-car-instead-of-painting/
- 3domwraps (N.A.). [Car Wrapping Bad Examples]. Retrieved June 02, 2023, from https://www.3domwraps.com/car-wrapping/bad-vinyl-wrap-examples/
- Bellevue, accutint. (2020, August 7). *Potential problems with vinyl wraps*. Accutint Bellevue. https://www.accutintbellevue.com/services/vinyl-wraps/problems-vinyl-wraps/
- Sharieff, A. H., Sabena, S., Sathiyavathi, V., & SaiRamesh, L. (2020). Intelligent framework for joint data hiding and compression using SMVQ and fast local image in-painting. *Int. J. Sci Technol. Res*, *9*(2), 2267-2271.
- Alyasiri, S., & Obaid, A. J. (2018). A new approach for object detection, recognition and retrieving in painting images. *Journal of Advanced Research in Dynamical and Control Systems*, *10*(2), 2345-2359.
- Meng, C., Rombach, R., Gao, R., Kingma, D., Ermon, S., Ho, J., & Salimans, T. (2023). On distillation of guided diffusion models. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 14297-14306).
- Yu, T., Feng, R., Feng, R., Liu, J., Jin, X., Zeng, W., & Chen, Z. (2023). Inpaint anything: Segment anything meets image inpainting. *arXiv preprint arXiv:2304.06790*.
- Zhong, Y., Yun, T. S., & Lee, B. C. (2022). Realistic Visualization of Car Configurator Based On Unreal Engine 4 (UE4). International Journal of Internet, Broadcasting and Communication, 14(1), 105-115.
- Kuys, B., Ranscombe, C., & Zhang, W. (2023). Visualising product concepts to engage manufacturers with little or no industrial design capability. *Design Studies*, *87*, 101188.
- Nanayakkara, D. I. (2019). *Dynamic Application of Vinyl Wraps on Vehicles using Augmented Reality* (Doctoral dissertation).
- Lee, Y. K., Xi, Z., Lee, Y. J., Kim, Y. H., Hao, Y., Choi, H., ... & Choi, I. S. (2020). Computational wrapping: A universal method to wrap 3D-curved surfaces with nonstretchable materials for conformal devices. *Science advances*, *6*(15), eaax6212.
- Guys, W. (2020, January 9). *Pros and cons of wrapping a car: Wrap guys*. WrapGuys. https://wrapguys.com/wraps/pros-and-cons-of-wrapping-a-car/
- Perkins, S. (2018, June 18). *Car styles: The Pros and cons of car wrapping*. ChipsAway. https://www.chipsaway.co.uk/blog/pros-and-cons-of-car-wrapping/
- Frog, V. (2022). *How much does it cost to wrap a car? - an honest wrap-up*. vinylfrog. https://www.vinylfrog.com/blogs/car-wrap-tips/how-much-does-it-cost-to-wrap-a-car
- graphicsolutions, I. (2020, October 22). *Bad car wraps, you get what you pay for*. Lucent Graphic Solutions. https://www.lucentgraphicsolutions.com/2014/02/bad-car-wraps-you-get-what-you-pay-for/
- Kearns, I. (2020). *Unlimited potential. less work.* LinkedIn. https://www.linkedin.com/pulse/unlimited-potential-less-work-ilana-kearns/

Appendix B: Ethics Form

Office Record	Receipt – Fast-Track Ethical Approval
Date Received:	Student name: Student number: Received by:
Received by whom:	Date:

APU / APIIT FAST-TRACK ETHICAL APPROVAL FORM (STUDENTS)

Tick one box (level of study):
- ☐ POSTGRADUATE (PhD / MPhil / Masters)
- ☑ UNDERGRADUATE (Bachelors degree)
- ☐ FOUNDATION / DIPLOMA / Other categories

Tick one box (purpose of approval):
- ☑ Thesis / Dissertation / FYP project
- ☐ Module assignment
- ☐ Other: _____

Title of Programme on which enrolled: Bachelor of Computer Science (Hons) (Intelligent Systems)

Tick one box: ☑ Full-Time Study or ☐ Part-Time Study

Title of project / assignment: Visualizing Car Wraps with Artificial Intelligence In-Painting Methods

Name of student researcher: Arthur Kynan Wong Jun Siang

Name of supervisor / lecturer: Dr. Vazeerudeen Hameed

Student Researchers- please note that certain professional organisations have ethical guidelines that you may need to consult when completing this form.
Supervisors/Module Lecturers - please seek guidance from the Chair of the APU Research Ethics Committee if you are uncertain about any ethical issue arising from this application.

		YES	NO	N/A
1	Will you describe the main procedures to participants in advance, so that they are informed about what to expect?			√
2	Will you tell participants that their participation is voluntary?	√		
3	Will you obtain written consent for participation?			√
4	If the research is observational, will you ask participants for their consent to being observed?			√
5	Will you tell participants that they may withdraw from the research at any time and for any reason?	√		
6	With questionnaires and interviews will you give participants the option of omitting questions they do not want to answer?	√		
7	Will you tell participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	√		
8	Will you give participants the opportunity to be debriefed i.e. to find out more about the study and its results?	√		

If you have ticked **No** to any of Q1-8 you should complete the full Ethics Approval Form.

		YES	NO	N/A
9	Will your project/assignment deliberately mislead participants in any way?		√	
10	Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort?		√	
11	Is the nature of the research such that contentious or sensitive issues might be involved?		√	

If you have ticked **Yes** to 9, 10 or 11 you should complete the full Ethics Approval Form. In relation to question 10 this should include details of what you will tell participants to do if they should experience any problems (e.g. who they can contact for help). You may also need to consider risk assessment issues.

			YES	NO	N/A
12	Does your project/assignment involve work with animals?			√	
13	Do participants fall into any of the following special groups? **Note that you may also need to obtain satisfactory clearance from the relevant authorities**	Children (under 18 years of age)		√	
		People with communication or learning difficulties			
		Patients			
		People in custody			
		People who could be regarded as vulnerable			
		People engaged in illegal activities (eg drug taking)			
14	Does the project/assignment involve external funding or external collaboration where the funding body or external collaborative partner requires the University to provide evidence that the project/assignment had been subject to ethical scrutiny?			√	

If you have ticked **Yes** to 12, 13 or 14 you should complete the full Ethics Approval Form. There is an obligation on student and supervisor to bring to the attention of the APU Research Ethics Committee any issues with ethical implications not clearly covered by the above checklist.

STUDENT RESEARCHER
Provide in the boxes below (plus any other appended details) information required in support of your application, THEN SIGN THE FORM.

	Please Tick Boxes
I consider that this project/assignment has no significant ethical implications requiring a full ethics submission to the APU Research Ethics Committee.	√
Give a brief description of participants and procedure (methods, tests used etc) in up to 150 words. Participants for this survey can include car enthusiasts, automobile customization professionals, graphic designers, marketing and advertising professionals, vehicle wrap installers, individuals with car wrap experience, and car owners. Gathering input from these diverse backgrounds ensures that the Visualise Car Wraps system meets the needs and expectations of its users. To gather quantitative data, a structured questionnaire consisting of multiple-choice questions and rating scales will be utilised. In addition, the survey will include open-ended questions to gather qualitative insights from participants. The survey will be distributed through various online platforms and industry forums, encouraging widespread participation.	
I also confirm that: i) All key documents e.g. consent form, information sheet, questionnaire/interview are appended to this application.	√
Or ii) Any key documents e.g. consent form, information sheet, questionnaire/interview schedules which need to be finalised following initial investigations will be submitted for approval by the project/assignment supervisor/module lecturer before they are used in primary data collection.	N/A

E-signature… AKW … … … … Print Name…Arthur Kynan Wong Jun Siang Date… 14 July 2023
(Student Researcher)

Please note that any variation to that contained within this document that in any way affects ethical issues of the stated research requires the appending of new ethical details. New ethical consent may need to be sought.

The completed form (and any attachments) should be submitted for consideration by your Supervisor/Module Lecturer

SUPERVISOR/MODULE LECTURER
PLEASE CONFIRM THE FOLLOWING:

	Please Tick Box
I consider that this project/assignment has no significant ethical implications requiring a full ethics submission to the APU Research Ethics Committee	√
i) I have checked and approved the key documents required for this proposal (e.g. consent form, information sheet, questionnaire, interview schedule) Or	√
ii) I have checked and approved draft documents required for this proposal which provide a basis for the preliminary investigations which will inform the main research study. I have informed the student researcher that finalised and additional documents (e.g. consent form, information sheet, questionnaire, interview schedule) must be submitted for approval by me before they are used for primary data collection.	

SUPERVISOR AND SECOND ACADEMIC SIGNATORY

STATEMENT OF ETHICAL APPROVAL (please delete as appropriate)

1) **THIS PROJECT/ASSIGNMENT HAS BEEN CONSIDERED USING AGREED APU/SU PROCEDURES AND IS NOW APPROVED**

2) **THIS PROJECT/ASSIGNMENT HAS BEEN APPROVED IN PRINCIPLE AS INVOLVING NO SIGNIFICANT ETHICAL IMPLICATIONS, BUT FINAL APPROVAL FOR DATA COLLECTION IS SUBJECT TO THE SUBMISSION OF KEY DOCUMENTS FOR APPROVAL BY SUPERVISOR (see Appendix A)**

E-signature… …V. A. Z. … … Print Name… … Dr. Vazeerudeen Abdul Hameed … Date… 18 July 2023… … …
(Supervisor/Lecturer)

E-signature… … … … … … … … … … … … Print Name… … … … … … … … … … … … Date… … … …
(Second Academic Signatory)

Office Record	Receipt – Appendix A (Fast-Track Ethics Form)
Date Received:	Student name:
	Student number:
	Received by:
Received by whom:	Date:

APPENDIX A
AUTHORISATION FOR USE OF KEY DOCUMENTS

Completion of Appendix A is required when for good reasons key documents are not available when a fast track application is approved by the supervisor/module lecturer and second academic signatory.

I have now checked and approved all the key documents associated with this proposal e.g. consent form, information sheet, questionnaire, interview schedule

Title of project/assignment: … … …… … … … … … … … … … … … … … … …

… ……………………..

Name of student researcher: ….

Student ID: … … … … … … … ……………   Intake: … … … … … … … … … … … … … … …

E-signature… … … … … … … … … … … … … Print Name… … … … … … … … … … … … … Date… … …….. …
(Supervisor/Lecturer)

Appendix C Log Sheets

(APU: Serial Number)

PLS V1.0

Project Log Sheet – Supervisory Session

Notes on use of the project log sheet:

1. This log sheet is designed for meetings of more than 15 minutes duration, of which there must be at minimum SIX (6) during the course of the project (SIX mandatory supervisory sessions).
2. The student should prepare for the supervisory sessions by deciding which question(s) he or she needs to ask the supervisor and what progress has been made (if any) since the last session, and noting these in the relevant sections of the form, effectively forming an agenda for the session.
3. A log sheet is to be brought by the STUDENT to each supervisory session.
4. The actions by the student (and, perhaps the supervisor), which should be carried out before the next session should be noted briefly in the relevant section of the form.
5. The student should leave a copy (after the session) of the Project Log Sheet with the supervisor and to the administrator at the academic counter. A copy is retained by the student to be filed in the project file.
6. It is recommended that students bring along log sheets of previous meetings together with the project file during each supervisory session.
7. The log sheet is an important deliverable for the project and an important record of a student's organisation and learning experience. The student **must** hand in the log sheets as an appendix of the final year documentation, with sheets dated and numbered consecutively.

Student's name: Arthur Kynan Wong Jun Siang.. Date: 26 June 2023… Meeting No: 01…...

Project title: Visualizing Car Wraps with Artificial Intelligence In-Painting Methods…
Intake: APD3F2305CS(IS)…

Supervisor's name: Dr. Vazeerudeen Abdul Hamed… Supervisor's signature: VAZ……..…

Items for discussion (noted by student before mandatory supervisory meeting):

1. Explanation of topic
2. Discussion of topic acceptability
3. Discussion on survey

Record of discussion (noted by student during mandatory supervisory meeting):

1. Greenlight on topic
2. Use survey to gather system requirements
3. Able to use survey data to justify my research

Action List (to be attempted or completed by student by the next mandatory supervisory meeting):

1. Complete survey question

Note: A student should make an appointment to meet his or her supervisor (via the consultation system) at least ONE (1) week prior to a mandatory supervisor session – please see document on project timelines. In the event a supervisor could not be booked for consultation, the project manager should be informed ONE (1) week prior to the session so that a meeting can be subsequently arranged.

(APU: Serial Number)

PLS V1.0

Project Log Sheet – Supervisory Session

Notes on use of the project log sheet:

8. This log sheet is designed for meetings of more than 15 minutes duration, of which there must be at minimum SIX (6) during the course of the project (SIX mandatory supervisory sessions).
9. The student should prepare for the supervisory sessions by deciding which question(s) he or she needs to ask the supervisor and what progress has been made (if any) since the last session, and noting these in the relevant sections of the form, effectively forming an agenda for the session.
10. A log sheet is to be brought by the STUDENT to each supervisory session.
11. The actions by the student (and, perhaps the supervisor), which should be carried out before the next session should be noted briefly in the relevant section of the form.
12. The student should leave a copy (after the session) of the Project Log Sheet with the supervisor and to the administrator at the academic counter. A copy is retained by the student to be filed in the project file.
13. It is recommended that students bring along log sheets of previous meetings together with the project file during each supervisory session.
14. The log sheet is an important deliverable for the project and an important record of a student's organisation and learning experience. The student **must** hand in the log sheets as an appendix of the final year documentation, with sheets dated and numbered consecutively.

Student's name: Arthur Kynan Wong Jun Siang.. Date: 18 July 2023… Meeting No: 02…...

Project title: Visualizing Car Wraps with Artificial Intelligence In-Painting Methods…
Intake: APD3F2305CS(IS)…

Supervisor's name: Dr. Vazeerudeen Abdul Hamed… Supervisor's signature: VAZ……..…

Items for discussion (noted by student before mandatory supervisory meeting):

1. Greenlight on survey (Provided full control of survey questions)
2. Minimum participants required 30
3. Obtained signature on Fast Ethic form

Record of discussion (noted by student during mandatory supervisory meeting):

1. Checking on survey questionnaire
2. Checking on survey data requirements
3. Obtain signature on Fast Ethic form
4. Do not disturb 2nd Marker (Do not require their signature on Fast Ethic Form)

Action List (to be attempted or completed by student by the next mandatory supervisory meeting):

1. —

Note: A student should make an appointment to meet his or her supervisor (via the consultation system) at least ONE (1) week prior to a mandatory supervisor session – please see document on project timelines. In the event a supervisor could not be booked for consultation, the project manager should be informed ONE (1) week prior to the session so that a meeting can be subsequently arranged.

(APU: Serial Number)

PLS V1.0

Project Log Sheet – Supervisory Session

Notes on use of the project log sheet:

15. This log sheet is designed for meetings of more than 15 minutes duration, of which there must be at minimum SIX (6) during the course of the project (SIX mandatory supervisory sessions).
16. The student should prepare for the supervisory sessions by deciding which question(s) he or she needs to ask the supervisor and what progress has been made (if any) since the last session, and noting these in the relevant sections of the form, effectively forming an agenda for the session.
17. A log sheet is to be brought by the STUDENT to each supervisory session.
18. The actions by the student (and, perhaps the supervisor), which should be carried out before the next session should be noted briefly in the relevant section of the form.
19. The student should leave a copy (after the session) of the Project Log Sheet with the supervisor and to the administrator at the academic counter. A copy is retained by the student to be filed in the project file.
20. It is recommended that students bring along log sheets of previous meetings together with the project file during each supervisory session.
21. The log sheet is an important deliverable for the project and an important record of a student's organisation and learning experience. The student **must** hand in the log sheets as an appendix of the final year documentation, with sheets dated and numbered consecutively.

Student's name: Arthur Kynan Wong Jun Siang.. Date: 25 July 2023… Meeting No: 03…...

Project title: Visualizing Car Wraps with Artificial Intelligence In-Painting Methods…
Intake: APD3F2305CS(IS)…

Supervisor's name: Dr. Vazeerudeen Abdul Hamed… Supervisor's signature: VAZ……...…

Items for discussion (noted by student before mandatory supervisory meeting):

1. Discussion and verification of Chapter 2

Record of discussion (noted by student during mandatory supervisory meeting):

1. Provided full freedom of quality and information of the research paper
2. Only request for assistance for technical difficulties (Such as signatures)

Action List (to be attempted or completed by student by the next mandatory supervisory meeting):

1. —

Note: A student should make an appointment to meet his or her supervisor (via the consultation system) at least ONE (1) week prior to a mandatory supervisor session – please see document on project timelines. In the event a supervisor could not be booked for consultation, the project manager should be informed ONE (1) week prior to the session so that a meeting can be subsequently arranged.

(APU: Serial Number)

PLS V1.0

Project Log Sheet – Supervisory Session

Notes on use of the project log sheet:

1. This log sheet is designed for meetings of more than 15 minutes duration, of which there must be at minimum SIX (6) during the course of the project (SIX mandatory supervisory sessions).
2. The student should prepare for the supervisory sessions by deciding which question(s) he or she needs to ask the supervisor and what progress has been made (if any) since the last session, and noting these in the relevant sections of the form, effectively forming an agenda for the session.
3. A log sheet is to be brought by the STUDENT to each supervisory session.
4. The actions by the student (and, perhaps the supervisor), which should be carried out before the next session should be noted briefly in the relevant section of the form.
5. The student should leave a copy (after the session) of the Project Log Sheet with the supervisor and to the administrator at the academic counter. A copy is retained by the student to be filed in the project file.
6. It is recommended that students bring along log sheets of previous meetings together with the project file during each supervisory session.
7. The log sheet is an important deliverable for the project and an important record of a student's organisation and learning experience. The student **must** hand in the log sheets as an appendix of the final year documentation, with sheets dated and numbered consecutively.

Student's name: ARTHUR KYNAN WONG JUN SIANG **Date: 26 September 2023…**
Meeting No: 1 / Semester 2……...

Project title: Visualizing Car Wraps with Artificial Intelligence In-Painting Methods
Intake:APD3F2305CS(IS)

Supervisor's name: Dr. Vazeerudeen Abdul Hamed….. **Supervisor's signature: …VAZ……..…**

Items for discussion (noted by student before mandatory supervisory meeting):

1. Asked about result of the IR
2. What is required to do now
3.

Record of discussion (noted by student during mandatory supervisory meeting):

1. Wait for the IR results are released
2. Proceed with system design
3. Any progress update inform Dr Vazeerudeen

Action List (to be attempted or completed by student by the next mandatory supervisory meeting):

1. System Design

Note: A student should make an appointment to meet his or her supervisor (via the consultation system) at least ONE (1) week prior to a mandatory supervisor session – please see document on project timelines. In the event a supervisor could not be booked for consultation, the project manager should be informed ONE (1) week prior to the session so that a meeting can be subsequently arranged.

(APU: Serial Number)

PLS V1.0

Project Log Sheet – Supervisory Session

Notes on use of the project log sheet:

1. This log sheet is designed for meetings of more than 15 minutes duration, of which there must be at minimum SIX (6) during the course of the project (SIX mandatory supervisory sessions).
2. The student should prepare for the supervisory sessions by deciding which question(s) he or she needs to ask the supervisor and what progress has been made (if any) since the last session, and noting these in the relevant sections of the form, effectively forming an agenda for the session.
3. A log sheet is to be brought by the STUDENT to each supervisory session.
4. The actions by the student (and, perhaps the supervisor), which should be carried out before the next session should be noted briefly in the relevant section of the form.
5. The student should leave a copy (after the session) of the Project Log Sheet with the supervisor and to the administrator at the academic counter. A copy is retained by the student to be filed in the project file.
6. It is recommended that students bring along log sheets of previous meetings together with the project file during each supervisory session.
7. The log sheet is an important deliverable for the project and an important record of a student's organisation and learning experience. The student **must** hand in the log sheets as an appendix of the final year documentation, with sheets dated and numbered consecutively.

Student's name: ARTHUR KYNAN WONG JUN SIANG **Date: 31 October 2023…**
Meeting No: 2 / Semester 2……...

Project title: Visualizing Car Wraps with Artificial Intelligence In-Painting Methods
Intake:APD3F2305CS(IS)

Supervisor's name: Dr. Vazeerudeen Abdul Hamed….. **Supervisor's signature: …VAZ……..…**

Items for discussion (noted by student before mandatory supervisory meeting):

1. Asked about the usage of Stability AI's open source model usage
2. Ask on any possible improvements that can be made from the IR report

Record of discussion (noted by student during mandatory supervisory meeting):

1. Permitted to use the open source models but fine tune it through parameters or other techniques
2. No improvements required focus on the system development

Action List (to be attempted or completed by student by the next mandatory supervisory meeting):

1. Develop System

Note: A student should make an appointment to meet his or her supervisor (via the consultation system) at least ONE (1) week prior to a mandatory supervisor session – please see document on project timelines. In the event a supervisor could not be booked for consultation, the project manager should be informed ONE (1) week prior to the session so that a meeting can be subsequently arranged.

(APU: Serial Number)

PLS V1.0

Project Log Sheet – Supervisory Session

Notes on use of the project log sheet:

1. This log sheet is designed for meetings of more than 15 minutes duration, of which there must be at minimum SIX (6) during the course of the project (SIX mandatory supervisory sessions).
2. The student should prepare for the supervisory sessions by deciding which question(s) he or she needs to ask the supervisor and what progress has been made (if any) since the last session, and noting these in the relevant sections of the form, effectively forming an agenda for the session.
3. A log sheet is to be brought by the STUDENT to each supervisory session.
4. The actions by the student (and, perhaps the supervisor), which should be carried out before the next session should be noted briefly in the relevant section of the form.
5. The student should leave a copy (after the session) of the Project Log Sheet with the supervisor and to the administrator at the academic counter. A copy is retained by the student to be filed in the project file.
6. It is recommended that students bring along log sheets of previous meetings together with the project file during each supervisory session.
7. The log sheet is an important deliverable for the project and an important record of a student's organisation and learning experience. The student **must** hand in the log sheets as an appendix of the final year documentation, with sheets dated and numbered consecutively.

Student's name: ARTHUR KYNAN WONG JUN SIANG **Date: 22 December 2023…**
Meeting No: 3 / Semester 2……...

Project title: Visualizing Car Wraps with Artificial Intelligence In-Painting Methods
Intake:APD3F2305CS(IS)

Supervisor's name: Dr. Vazeerudeen Abdul Hamed….. **Supervisor's signature: …VAZ……...…**

Items for discussion (noted by student before mandatory supervisory meeting):

1. Discussed on the additional features and minimum required features
2. Discussed on how many models should be tested and compared
3. Inform about joining the FYP showcase

Record of discussion (noted by student during mandatory supervisory meeting):

1. Informed to complete the features required to achieve the project's objectives
2. Minium 2 models are required to test and compared
3. Relax and take it easy during the FYP showcase

Action List (to be attempted or completed by student by the next mandatory supervisory meeting):

1. Test and compare different models

Note: A student should make an appointment to meet his or her supervisor (via the consultation system) at least ONE (1) week prior to a mandatory supervisor session – please see document on project timelines. In the event a supervisor could not be booked for consultation, the project manager should be informed ONE (1) week prior to the session so that a meeting can be subsequently arranged.

(APU: Serial Number)

PLS V1.0

Project Log Sheet – Supervisory Session

Notes on use of the project log sheet:

1. This log sheet is designed for meetings of more than 15 minutes duration, of which there must be at minimum SIX (6) during the course of the project (SIX mandatory supervisory sessions).
2. The student should prepare for the supervisory sessions by deciding which question(s) he or she needs to ask the supervisor and what progress has been made (if any) since the last session, and noting these in the relevant sections of the form, effectively forming an agenda for the session.
3. A log sheet is to be brought by the STUDENT to each supervisory session.
4. The actions by the student (and, perhaps the supervisor), which should be carried out before the next session should be noted briefly in the relevant section of the form.
5. The student should leave a copy (after the session) of the Project Log Sheet with the supervisor and to the administrator at the academic counter. A copy is retained by the student to be filed in the project file.
6. It is recommended that students bring along log sheets of previous meetings together with the project file during each supervisory session.
7. The log sheet is an important deliverable for the project and an important record of a student's organisation and learning experience. The student **must** hand in the log sheets as an appendix of the final year documentation, with sheets dated and numbered consecutively.

Student's name: ARTHUR KYNAN WONG JUN SIANG **Date: 08 January 2024…**
Meeting No: 3 / Semester 2……...

Project title: Visualizing Car Wraps with Artificial Intelligence In-Painting Methods
Intake:APD3F2305CS(IS)

Supervisor's name: Dr. Vazeerudeen Abdul Hamed….. **Supervisor's signature: …VAZ……...…**

Items for discussion (noted by student before mandatory supervisory meeting):

1. Asked on the requirement of database features
2. Asked on the submission file size

Record of discussion (noted by student during mandatory supervisory meeting):

1. Not require as long as the features completed achieves the project's objective
2. Submit only the important files, or submit into a online drive and submit the link

Action List (to be attempted or completed by student by the next mandatory supervisory meeting):

1.

Note: A student should make an appointment to meet his or her supervisor (via the consultation system) at least ONE (1) week prior to a mandatory supervisor session – please see document on project timelines. In the event a supervisor could not be booked for consultation, the project manager should be informed ONE (1) week prior to the session so that a meeting can be subsequently arranged.

Appendix D Poster

A P U
ASIA PACIFIC UNIVERSITY
OF TECHNOLOGY & INNOVATION

Visualizing Car Wraps with Artificial Intelligence In-Painting Methods

Arthur Kynan Wong Jun Siang (TP058030)
Bachelor of Computer Science (Hons)
(Artificial Intelligence) - APD3F2305CS(IS)

Introducing Car Vision

Visualize your car in a different color! With AI technology you can reimagine your car in any color or material

Problem Statement

The car customization industry does not have a satisfying visualization methods

Objectives

- To utilize Artificial Intelligence image generation in the system to create image visualizers for the users.
- To reimagine the user's image input to what they requested in the system inputs.
- To recreate the vehicle in the image with different colors, patterns, materials and styles.
- To develop a system that is simple to use for users while retaining the option to be highly detailed.

Conclusion

The developed system employs multiple Stable Diffusion 1.5 Checkpoints and ControlNets to visualize the vechcle in a different way while maintaining the original shape and orientation

Methodology

Utilizing AI Image Generation from Stable Diffusion to generate custom images to visualize the customized car

Supervisor

Dr. Vazeerudeen Abdul Hamed

2nd Marker

Assoc. Prof. Dr. Nirase Fathima Abubacker

Appendix E Gantt Chart

Gantt Chart For Semester 1				June				July																August		
Tasks	Start Date	End Date	Duration	26	27	28	29	8	9	10	11	12	13	14	15	16	17	18	20	21	22	25	26	27	28	2	7	
Chapter 1: INTRODUCTION TO THE STUDY	26 June 2023	29 June 2023	4 Days																									Completed
1.8 Project Plan	26 June 2023	26 June 2023	<1 Day																									Completed
1.1 Background to the project	26 June 2023	26 June 2023	<1 Day																									Completed
1.2 Problem context	26 June 2023	26 June 2023	<1 Day																									Completed
1.3 Rationale	26 June 2023	26 June 2023	<1 Day																									Completed
1.4 Potential benefits	26 June 2023	26 June 2023	<1 Day																									Completed
1.4. 1 Tangible benefits	27 June 2023	27 June 2023	<1 Day																									Completed
1.4. 2 Intangible benefits	27 June 2023	27 June 2023	<1 Day																									Completed
1.5 Target users	27 June 2023	27 June 2023	<1 Day																									Completed
1.6 Scope and objectives	27 June 2023	27 June 2023	<1 Day																									Completed
1.6.1 Aims	28 June 2023	28 June 2023	<1 Day																									Completed
1.6.2 Objectives	28 June 2023	28 June 2023	<1 Day																									Completed
1.6.3 Deliverables - Functionality of the proposed system	28 June 2023	28 June 2023	<1 Day																									Completed
1.6.4 Nature of Challenges	29 June 2023	29 June 2023	<1 Day																									Completed
1.7 Overview of this Investigation report	29 June 2023	29 June 2023	<1 Day																									Completed
Chapter 2: LITERATURE REVIEW	8 July 2023	15 July 2023	7 Days																									Completed
2.1: Introduction	8 July 2023	8 July 2023	1 Day																									Completed
2.2: Domain research	9 July 2023	12 July 2023	4 Days																									Completed
2.3: Similar Systems	13 July 2023	15 July 2023	2 Days																									Completed
Chapter 3: TECHNICAL RESEARCH	15 July 2023	18 July 2023	4 Days																									Completed
3.1: Programming languages	15 July 2023	15 July 2023	1 Day																									Completed
3.2: IDE (Interactive Development Environment)	16 July 2023	16 July 2023	1 Day																									Completed
3.3: libraries chosen / Tools chosen	17 July 2023	17 July 2023	1 Day																									Completed
3.5: Operating System chosen	18 July 2023	18 July 2023	1 Day																									Completed
3.8: Summary	18 July 2023	18 July 2023	< 1 Day																									Completed
Chapter 4: SYSTEM DEVELOPMENT METHODOLOGY	20 July 2023	22 July 2023	3 Days																									Completed
4.1 Introduction	20 July 2023	20 July 2023	1 Day																									Completed
4.2 Kanban	21 July 2023	21 July 2023	1 Day																									Completed
4.3 Lean Development	22 July 2023	22 July 2023	1 Day																									Completed
4.4 Comparision Table	22 July 2023	22 July 2023	< 1 Day																									Completed
Chapter 5: RESEARCH METHODS	25 July 2023	28 July 2023	4 Days																									Completed
5.1: Introduction	25 July 2023	25 July 2023	1 Day																									Completed
5.2 Research Method Types	26 July 2023	26 July 2023	1 Day																									Completed
5.3 Survey Method Selection Justification	27 July 2023	27 July 2023	1 Day																									Completed
5.3 Survey Design	28 July 2023	28 July 2023	1 Day																									Completed
Chapter 6: REQUIREMENTS VALIDATION	2 August 2023	2 August 2023	1 Day																									Completed
6.1 Analysis of Data	2 August 2023	2 August 2023	< 1 Day																									Completed
6.1.1 Analysis of data collected through Questionnaire	2 August 2023	2 August 2023	< 1 Day																									Completed
6.2 Summary	2 August 2023	2 August 2023	< 1 Day																									Completed
Chapter 7: CONCLUSION AND REFLECTIONS	7 August 2023	7 August 2023	1 Day																									Completed
7.1 Conclusion	7 August 2023	7 August 2023	< 1 Day																									Completed
7.2 Reflection	7 August 2023	7 August 2023	< 1 Day																									Completed
7.3 References	7 August 2023	7 August 2023	< 1 Day																									Completed
7.4 Appendices	7 August 2023	7 August 2023	< 1 Day																									Completed

Gantt Chart For Semester 2				August													Sept		Oct		Nov		December																			January										
Task	Start Date	End Date	Duration	9	10	11	12	13	14	15	16	17	18	19	20	...	...	...	...	...	...	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	39	31	1	2	3	4	5	6	7	8	9	10	
Project Plan	9 August 2023	13 August 2023	5 Days																																																Completed
Plan for features to include	9 August 2023	9 August 2023	< 1 Day																																																Completed
Draft version of each plan	10 August 2023	11 August 2023	2 Days																																																Completed
Create Test Plan	12 August 2023	13 August 2023	2 Days																																																Completed
Implementation	15 August 2023	15 December 20	122 Days																																																Completed
Coding, Debugging & Testing	15 August 2023	15 December 20	122 Days																																																	Completed
Documentation	18 December 20	5 January 2023	30 Days																																																	Completed
Write documentation of system	18 December 20	5 January 2023	30 Days																																																	Completed
Conclude	6 January 2024	9 January 2024	4 Days																																																	Completed
Record sample video and edit it	6 January 2024	8 January 2024	3 Days																																																	Completed
Complie system and files required	9 January 2024	9 January 2024	< 1 Day																																																	Completed

Appendix F Sample Code Implementation

```python
@app.post("/submit")
async def submit(
    request: Request,
    color: str = Form(...),
    material: str = Form(...),
    prompt: str = Form(""),
    chcked: bool = Form(False),
    image: UploadFile = File(...)
):
    data = await image.read()
    saveto = Upload_DIR /"upload1.jpg"
    if len(data)==0: #error handling ···
    try: #saving the file···
    except Exception as e:···

    inputPrompt=""
    if not chcked:
        #create prompt here
        inputPrompt = material + " " + color

        # #create sketch
        output = await api_util.create_Sketch_API(saveto)
                                                  #originalImage, sketchImage, prompt
        final = await api_util.color_Sketch_API(saveto, output, inputPrompt)
    else:
        inputPrompt = prompt

        output = await api_util.create_Sketch_API(saveto)
                                                  #originalImage, sketchImage, prompt
        final = await api_util.color_Sketch_API(saveto, output, inputPrompt)

    print(inputPrompt)
    #"api_out\img2img\img2img-20240106-043133-0.png"
    image_path = Path(final)
    return FileResponse(image_path)
```

Code that handles the “Create!” button

```python
#create the sketch - uses img2img with controlnet
async def create_Sketch_API(originalImage): #takes original image as path | image has to be size of 512
    print("start creating Sketch")
    option_payload = {
        "sd_model_checkpoint": "dreamshaper_8.safetensors [879db523c3]",
    }

    response = requests.post(url=f'{url}/sdapi/v1/options', json=option_payload)
    originalImg = encode_file_to_base64(originalImage)

    payload = { #parameters···

    response = await call_api('sdapi/v1/img2img', payload)

    for index, image in enumerate(response.get('images')):
        save_path = os.path.join(out_dir_sketch, f'img2img-{timestamp()}-{index}.png')
        decode_and_save_base64(image, save_path)
        return save_path
```

Figure: Code that generates the sketch image from the original image (Also sets the model to use)

Image Generation Parameters

<table>
<tr>
<td>

```
"ControlNet": {"args": [
  {
      "batch_images": "",
      "control_mode": "ControlNet is more important",
      "enabled": "true",
      "guidance_end": 1,
      "guidance_start": 0,
      "input_image": originalImg,
      "input_mode": "simple",
      "is_ui": "true",
      "loopback": "false",
      "low_vram": "false",
      "model": "control_v11p_sd15_canny [d14c016b]",
      "module": "canny",
      "output_dir": "",
      "pixel_perfect": "true",
      "processor_res": 512,
      "resize_mode": "Crop and Resize",
      "save_detected_map": "true",
      "threshold_a": 100,
      "threshold_b": 200,
      "weight": 1.8
      },
      {"batch_images": "",
      "control_mode": "Balanced",
      "enabled": "true",
      "guidance_end": 1,
      "guidance_start": 0.15,
      "input_image": originalImg,
      "input_mode": "simple",
      "is_ui": "true",
      "loopback": "false",
      "low_vram": "false",
      "model": "control_v11p_sd15_normalbae [316696f1]",
      "module": "normal_bae",
      "output_dir": "", "pixel_perfect": "false",
      "processor_res": 512,
      "resize_mode": "Crop and Resize",
      "save_detected_map": "true",
      "threshold_a": -1,
      "threshold_b": -1,
      "weight": 0.25
      },
      {"batch_images": "",
       "control_mode": "Balanced",
       "enabled": "true",
       "guidance_end": 1,
       "guidance_start": 0.1,
       "input_image": originalImg,
       "input_mode": "simple",
       "is_ui": "true",
       "loopback": "false",
       "low_vram": "false",
       "model": "control_v11p_sd15_lineart [43d4be0d]",
       "module": "lineart",
       "output_dir": "",
       "pixel_perfect": "true",
       "processor_res": 512,
       "resize_mode": "Crop and Resize",
```

</td>
<td>

```
#here is automatic1111 options
"Extra options": {"args": []},
"Refiner": {"args": [*false*, "", 0.8]},
"Seed": {"args": [-1, "false", -1, 0, 0, 0]}},
"batch_size": 1, "cfg_scale": 4, "comments": {},
"denoising_strength": 0.99,
"disable_extra_networks": "false",
"do_not_save_grid": "false",
"do_not_save_samples": "false",
"height": 512,  #change according to original image size
"image_cfg_scale": 1.5,
"init_images": [encode_file_to_base64("whiteImage.jpg")], #WHITE IMAGE ------
"initial_noise_multiplier": 1.0,
"inpaint_full_res": 0,
"inpaint_full_res_padding": 32,
"inpainting_fill": 1,
"inpainting_mask_invert": 0,
"mask_blur": 4,
"mask_blur_x": 4,
"mask_blur_y": 4,
"n_iter": 1,
"negative_prompt": "colors, colorful, blurry, <EasyNegative: 0.8>",
"override_settings": {},
"override_settings_restore_afterwards": "true",
"prompt": "masterpiece, best quality, realistic, high detailed car, lineart, monochrome, <lora:animeoutlineV4_16:1>",
"resize_mode": 0,
"restore_faces": false,
"sampler_name": "DPM++ 2M Karras",
"script_args": [],
"seed": -1,
"seed_enable_extras": "true", "seed_resize_from_h": -1, "seed_resize_from_w": -1,
"steps": 40, "styles": [],
"subseed": -1, "subseed_strength": 0,
"tiling": "false",
"width": 512  #change according to original image size
```

</td>
</tr>
<tr>
<td>ControlNet</td>
<td>Automatic1111 Parameters</td>
</tr>
</table>

Appendix G: Respondents Demographic Profile

Name	Gender	Age Group	Drives a car
Justin	Male	16-20	Yes
Cordelia	Male	16-20	Yes
Samson	Male	21-26	Yes
Mohamed	Male	21-26	Yes
Trey	Male	21-26	Yes
Sally	Female	21-26	No
Anais	Female	16-20	No
Alia	Female	21-26	No
Maxim	Male	21-26	Yes
Dawud	Male	16-20	Yes
Holly	Female	21-26	Yes
Robert	Male	21-26	Yes
Erin	Male	21-26	Yes
Sherman	Female	16-20	Yes
Arron	Male	21-26	Yes
Heath	Female	16-20	No
Madison	Male	27-29	Yes
Macauley	Male	27-29	Yes
Olive	Female	21-26	Yes
Allison	Female	21-26	Yes
Steve	Male	16-20	Yes
Nicolas	Male	21-26	Yes
Olivier	Male	21-26	Yes

Virginia	Male	16-20	Yes
Sophia	Female	21-26	Yes
Timothy	Male	21-26	Yes
Chad	Male	21-26	Yes
Raja	Male	21-26	Yes
Charlie	Male	27-29	Yes
Eden	Female	27-29	Yes
Safa	Male	21-26	Yes
Drew	Male	21-26	No
Rhonda	Male	21-26	No

Note the names of the participants are pseudonyms to keep the participants’;s confidentiality

Appendix H: First 2 pages of Turnitin Report

Turnitin Originality Report

Processed on: 09-Jan-2024 22:33 +08
ID: 2268386746
Word Count: 24009
Submitted: 1

Arthur Kynan Wong Jun Siang - FYP Document - TP058030.pdf By ARTHUR KYNAN WONG JUN SIANG .

Similarity Index	Similarity by Source
11%	Internet Sources: 8% Publications: 5% Student Papers: 8%

2% match (Internet from 21-Dec-2023)
https://docs.google.com/forms/d/e/1FAIpQLSfZg2EJ1DIVNSM0XIYqO_I4m7lA3vxCD38prh7ZglphFzUJhA/viewform?usp=send_form

1% match (student papers from 19-Aug-2020)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2020-08-19

1% match (Internet from 08-Dec-2019)
https://docs.google.com/forms/d/e/1FAIpQLSctesGNqZtcdqDVGMKXngVtTIfaAeSIy29MXM7SkfGiRUjZxQ/viewform?usp=send_form

1% match (Internet from 26-Nov-2022)
https://www.hepdata.net/search/?author=Augsten%2C+Kamil&observables=MULT

< 1% match (student papers from 09-Aug-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-08-09

< 1% match (student papers from 10-May-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-05-10

< 1% match (student papers from 02-Feb-2018)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2018-02-02

< 1% match (student papers from 09-May-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-05-09

< 1% match (student papers from 08-May-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-05-08

< 1% match (student papers from 10-Aug-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-08-10

< 1% match (student papers from 31-May-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-05-31

< 1% match (student papers from 12-Aug-2020)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2020-08-12

< 1% match (student papers from 23-Sep-2017)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2017-09-23

< 1% match (student papers from 20-Sep-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-09-20

< 1% match (student papers from 23-Dec-2020)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2020-12-23

< 1% match (student papers from 10-May-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-05-10

< 1% match (student papers from 17-Jan-2019)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2019-01-17

< 1% match (student papers from 04-Apr-2016)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2016-04-04

< 1% match (student papers from 09-May-2023)
Submitted to Asia Pacific University College of Technology and Innovation (UCTI) on 2023-05-09

< 1% match (student papers from 22-Jul-2023)
Class: FYP (052023-DWO) (Moodle PP)
Assignment: Ethics Form (Full and Fast Track) (Moodle PP)
Paper ID: 2134940827

< 1% match (Internet from 06-Nov-2022)
https://link.springer.com/article/10.1007/s40747-021-00397-8?code=d4330bc5-2f9b-41a0-b1dd-2fe468db52ac&error=cookies_not_supported

< 1% match (Internet from 30-May-2023)

http://www.arxiv-vanity.com/papers/2303.07909/

< 1% match (Internet from 22-Oct-2023)
https://www.arxiv-vanity.com/papers/2308.16316/

< 1% match (student papers from 30-May-2021)
Submitted to University of Denver on 2021-05-30

< 1% match (student papers from 05-Jan-2024)
Submitted to Bridgepoint Education on 2024-01-05

< 1% match (Internet from 07-Dec-2022)
https://replicate.com/stability-ai/stable-diffusion/versions

< 1% match ("Pattern Recognition and Computer Vision", Springer Science and Business Media LLC, 2024)
"Pattern Recognition and Computer Vision", Springer Science and Business Media LLC, 2024

< 1% match (Internet from 30-May-2023)
https://scholar.archive.org/work/zgqsq62vobafbmeo2tnihtnvhy

< 1% match (Internet from 07-Feb-2017)
https://www.ukessays.com/essays/information-technology/what-is-occupational-safety-and-health-information-technology-essay.php

< 1% match (Internet from 08-May-2016)
https://www.ukessays.com/essays/computer-science/benefits-of-an-online-boat-rental-system-computer-science-essay.php

< 1% match (Internet from 15-Jan-2023)
https://myfik.unisza.edu.my/www/fyp/fyp20sem1/report/051607.pdf

< 1% match (student papers from 04-May-2023)
Submitted to Florida State University on 2023-05-04

< 1% match (Internet from 28-Oct-2022)
https://eudl.eu/pdf/10.4108/eai.21-6-2018.2276586

< 1% match (Internet from 20-Oct-2022)
https://academic.oup.com/ajcn/article/112/3/669/5869814

< 1% match (Internet from 28-Sep-2023)
https://webthesis.biblio.polito.it/27647/1/tesi.pdf

< 1% match (student papers from 27-Jul-2021)
Submitted to National Open University of Nigeria on 2021-07-27

< 1% match ("Computer Vision – ECCV 2020", Springer Science and Business Media LLC, 2020)
"Computer Vision – ECCV 2020", Springer Science and Business Media LLC, 2020

< 1% match (Internet from 04-Jan-2024)
https://apidog.com/articles/how-to-use-fastapi-apirouter/

< 1% match (Internet from 27-Nov-2023)
http://export.arxiv.org/pdf/2308.06721

< 1% match (Internet from 25-Nov-2023)
http://export.arxiv.org/pdf/2305.06131

< 1% match (Frida Nordeström, Marianne Granbom, Susanne Iwarsson, Magnus Zingmark. "Ageing in the right place—usability of a web-based housing counselling service", Scandinavian Journal of Occupational Therapy, 2023)
Frida Nordeström, Marianne Granbom, Susanne Iwarsson, Magnus Zingmark. "Ageing in the right place—usability of a web-based housing counselling service", Scandinavian Journal of Occupational Therapy, 2023

< 1% match (student papers from 04-Sep-2014)
Submitted to The University of Manchester on 2014-09-04

< 1% match (student papers from 03-May-2007)
Submitted to University of Hong Kong on 2007-05-03

< 1% match (Internet from 29-Oct-2022)
https://alto-palo.com/blogs/singleton-design-pattern-in-java

< 1% match ()
UI Hasan, Muneeb. "A conceptual framework of information security database audit and assessment in university based organization", 2018

< 1% match (Bastien François, Soulivanh Thao, Mathieu Vrac. "Adjusting spatial dependence of climate model outputs with cycle-consistent adversarial networks", Climate Dynamics, 2021)
Bastien François, Soulivanh Thao, Mathieu Vrac. "Adjusting spatial dependence of climate model outputs with cycle-consistent adversarial networks", Climate Dynamics, 2021

< 1% match (Internet from 20-May-2023)
https://ir.uitm.edu.my/id/eprint/58834/1/58834.pdf

< 1% match (Internet from 27-May-2023)