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Development of a Module for Converting Raster Images into Vector Images Created Through Artificial Intelligence

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Abstract: Greater needs for creative and recreational activities have yielded innovative products blending technological innova- tion and art. The project demonstrates a platform dedicated to automating paint-by-numbers canvas generation with innovative approaches utilizing image segmentation, color extraction, and vectorization. Users are allowed to upload any image, and it is processed to render a precise paint-by-numbers guide along with the respective color palettes. By leveraging machine learning algorithms, including OpenAI's DALL-E for generating images and K-means clustering for extracting colors, the website reduces the tedious age-old task of producing paint-by-numbers kits to a trivial task. The ease of use of the website also opens it to corporate businesses and hobbyists alike to produce custom kits. Usability evaluations revealed that the users reported high satisfaction with the platform, particularly with its ability to produce high-resolution segmented images and its simplicity of use. Additionally, the platform not only shows innovation but also therapeutic benefits through its ability to promote mindfulness and reduce stress. The technique harmonizes the art and technology fields and thereby enables creativity without sacrificing the control over artistic expression.

Keywords: image segmentation; color extraction; vector- ization; paint-by-numbers; artificial intelligence; user experience; creativity; automation; DALL-E; K-means clustering

I. Introduction

Paint-by-numbers has been a popular hobby for many years, offering a calming way to learn about art. Creating these kits in the past was cumbersome and skill-dependent. Advances in AI and computer vision today enable automation through means like image segmentation, edge detection, and color extraction. As of now there is no open-source tool for non-experts to create such kits, though. This project aims to fill that gap by developing an AI-powered system to generate paint-by- numbers canvases. Using OpenAI's DALL-E for image gener- ation, K-means clustering to identify colors, and vectorization methods like Potrace, the system will generate easy-to-use, high-quality segmented images with minimal effort.

II. Literature Review

The idea of paint-by-numbers has been widely popular over the decades as a fun hobby for people seeking stress relief and creative engagement. Previous studies have established that activities like painting can significantly reduce levels of stress and enhance mindfulness [1]. Nevertheless, the tra- ditional handmade nature of these kits has still been time- consuming, requiring both expert craftsmanship and substan- tial time investment. Available software for automation of the process is either limited in accessibility, requiring professional knowledge or presenting a complicated user interface [2]. Recent developments in image segmentation and edge detec- tion technologies have created new opportunities for creative process automation [3]. Nevertheless, there is still a lack of tools providing an intuitive, easy-to-use environment for non- professionals. While digital creativity tools are widespread, none target the specific needs of paint-by-numbers creation that are both automated

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and easy [4]. The fast-paced evolution of digital technology has had a significant influence on a number of art disciplines, most prominently through artistic process automation. Improvements in image processing and artificial intelligence have enabled the development of software programs that can automate previously labor-intensive pro- cesses. In particular, techniques such as image segmentation and edge detection provide the potential for augmenting the paint-by-numbers concept, providing templates for automated design without diminishing creativity and artistic merit. Yet, most of the existing tools involve a considerable learning curve or technical knowledge, hence not accessible to the masses [5]. One of the principal barriers to mass adoption of computer paint-by-numbers software is a deficiency in ease of use inter- face. Computer software packages designed to enable artistic activity tend to concentrate on feature sets optimized for pro- fessional use, with a concern for precision control over image results rather than simplicity of use. These packages can thus provide challenges for non-professionals, lowering their appeal to casual users who need relaxing, stress-reducing creative activities like paint-by-numbers. Solutions are required that are more usable but do not sacrifice the richness and complexity of the creative process [6]. Especially, accessibility of software tools has been a prominent topic of debate in the area of digital creativity. As the usage of smartphones and tablets is growing, it is certain that mobile platforms offer a useful range to achieve intuitive paint-by-numbers software. However, there are not many existing applications that utilize smartphones' and tablets' touch interfaces for creative automations in a manner that is simple yet engaging. Most applications avail- able in the market lack automation capabilities or provide results that are too simplistic and fail to meet the detailed expectations typically demanded of paint-by-numbers kits. As such, this leaves space for new apps that achieve a balance between the detail of the creative process and a user interface that is friendly and engaging [7]. In the automation sector, a number of approaches are being investigated to generate more precise paint-by-numbers templates. One such approach is image segmentation, which is the process of separating an image into a number of regions on the basis of shared characteristics like color, intensity, or texture. It is essential for paint-by-numbers template generation since it enables the software to recognize separate areas in an image that can be associated with a particular color or number. There have been some research efforts that have investigated the application of deep learning algorithms, including convolutional neural networks (CNNs), for automating image segmentation and edge detection processes [8]. These artificial intelligence-based approaches can generate more intricate and precise templates by detecting slight color and shape variations, thereby offering the end users a better result. Furthermore, such innovation demonstrates that paint-by-numbers can be developed further through automation with the application of artificial intelli- gence for enhancing template complexity and accuracy without compromising ease of use. Despite the developments made in artificial intelligence-based image segmentation, there remains a necessity for software that supports the creative process without overburdening the user. Empirical evidence shows that individuals derive satisfaction from engaging in creative activity when they are able to exert a certain degree of control on the process. The problem is, however, achieving a balance between automation and user control. A completely automated paint-by-numbers machine would discourage creativity, yet excessive user participation would be contrary to the initial goal of automating the procedure. Ideally, the tool must enable users to modify a number of parameters, i.e., the amount of detail within the template, and be responsible for the laborious procedures of image segmentation as well as edge detection [9]. In addition, these programs could comprise specially tailored features appropriate to the specific preferences of an individual user. With the use of machine learning algorithms for monitoring usage of users, it becomes feasible to execute a paint-by-numbers activity that unfolds increasingly with time based on the use of the application. For example, as the user continues to design additional paint-by-numbers templates, the program might shape future templates to correspond to the user's preferred complexity, color palette, or art style. This sort of customization has been successful in numerous other art- creating computer programs, such as graphic design packages and image editors, and can further encourage user interaction with paint-by-numbers programs [10]. Furthermore, the psy- chological gains associated with creative activity, including painting, have been explored under mindfulness and stress reduction models. There are numerous studies highlighting that engaging in artwork is followed by a considerable decrease in anxiety levels and enhancement of mental health overall. Painting as an art has also been proven to promote a status of mindfulness, allowing individuals to focus on the present and consciously exclude negative thoughts and stress inducers [11]. As interest in mindfulness practice and mental health increases, it isn't a stretch to suggest that an automatic paint- by-numbers

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machine would be a legitimate therapeutic device for individuals looking to relax or go through a mindful process. There is an increasing amount of scholarly literature that posits creativity as an important element in mental growth, specifically problem-solving skills, emotional quotient, and the ability for self-expression. Paint-by-numbers, based on this, can then be viewed not only as a recreational and calming pastime activity but also as a cognitive exercise that stimulates both the left and right brain. Computerized systems that can automate the technicalities included in developing paint-by- numbers templates can motivate users to be more involved in the creative process, so that they will be able to concentrate on selecting colors and expressing their creativity, rather than being bogged down by the tedious process of generating the template [12]. The digital art software market, including drawing software and digital painting software, indicates the expanding requirement for software that fosters digital cre- ativity. However, such buyers are typically professional artists or technology experts, thereby creating a niche market for the tools for non-professional consumers. The combination of AI-based automation and personalization in the realm of a paint-by-numbers application would be able to bridge this gap by providing an affordable means for people who lack minimal ordinary artistic skills but would nevertheless wish to experience some degree of creative output. With the further evolution of computer technology, it is important that the next generation of paint-by-numbers software includes the changing needs of those who appreciate usability as much as creative interaction [13]. Furthermore, integrating these features with social websites could potentially bring the community into the picture. For instance, people can upload their completed work to the web, participate in competitions, or collaborate on group projects together, and a sense of community is developed. This would render user experience and interaction more maximized, since individuals are usually motivated by social interaction and feedback [14]. Furthermore, being able to share creative efforts can create a more participatory and enjoyable environment for those interested in pursuing paint- by-numbers as a hobby.

In short, the future of computerized paint-by-numbers ma- chines is to develop software that maintains a balance between accessibility, creativity and automation. Based on research studies in image segmentations, artificial intelligence, and user interface customizing, it is possible to develop an application that works for high and low competency level users alike. The machinery can acquire significant psychological worth by inducing mindfulness and anxiety reduction in the user as it offers them a means of creative expression. As digital creative software continues to evolve, there is a critical need for them to be satisfying the needs of a varied community, from casual users requiring a stress outlet through to enthusiasts requiring a more mature artistic experience.

III. Hypothesis

The purpose of this platform is to design a basic but effective tool for transforming images into paint-by-number canvases. The following hypotheses are put forth concerning the plat- form functions.

A. Hypothesis: Image Segmentation Accuracy

Utilizing machine learning approaches in clustering color (k-means) and vectorization potrace and vtracer will produce accurately identified segments of images bound by clear and defined color areas for the user to paint by numbers upon. Expected Result: The platform should be robust enough to segment images into distinct regions without providing overlap so as to enable the users to follow a very simple, easy-to- follow sequence during the painting process, with minimal hindrances.

B. Hypothesis: Quality of Generated Images

Employing OpenAI's DALL-E for the image creation pro- cess will produce images of great quality that coincide with the prompt given, hence the starting point for the paint by numbers exercise will be appealing and creative. Expected Result: The output obtained should, at a minimum, meet the expectations for clarity, resolution and creativity – this is to be the desired output which will be converted into paint by number canvases.

C. Hypothesis: User Experience and Usability

As one can imagine, the more simplistic and user friendly the UI is, the more efficient it is for users to upload image files, choose their segmentation options, and create paint by numbers images

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seamlessly. Expected Result: Users should be able to accomplish the whole workflow, starting from the up- load of images and ending with receiving the generated paint- by-numbers canvas, without any significant learning curves or obstacles in terms of technical complexities.

D. Hypothesis: Usability Testing and Iteration

Extensive usability testing will illuminate the pain points, and the iterative design process of the platform will enable refinements to be made continuously in order to make the plat- form more functional, satisfactory to users. Expected Result: The platform will change with time based upon user feedback, increasing its efficiency and ease of use with time.

IV. Methods

The platform's features are supported based on modern approaches of image processing and machine learning models. Some methods that the platform uses to create and segment paint-by-number images are specified below.

A. Making Images By OpenAI's DALL-E

The platform uses OpenAI's DALL-E model for painting image generation. DALL-E can create images from text that are of the needed quality. The model implements state-of-the- art machine learning to produce one-of-a-kind content. With the endpoint generateImage, users can input these parameters: size of the image (height and width) and a text phrase. The advanced features of the models make it possible for users to receive paint for paint-by-number kits directly from the platform in a needed format.

B. Segmentation Of Images

The platform performs segmentation of images with a se- quence of steps, which makes the core of image segmentation:

- **Imagine Preprocessing:** Before an image can be seg- mented some preprocessing takes place first which uti- lizes Sharp for several image types and different res- olution formats. The images are resized to a smaller resolution for convenience of processing the image.
- **Color Extraction and Clustering:** The platform in- corporates K-means clustering to derive primary colors within the image. The system creates a basic color palette by reducing the number of colors in an image and customizing its regions. The complexity of the final paint-by-numbers image can be adjusted by changing the number of colors (12 or 24). The algorithm splits the pixels of the image into clusters, each representing a color.
- **Vectorization of Image:** The platform encourages in- creased image clarity by utilizing potrace and vtracer for vectorization. These techniques enable the generation of vector images from raster images by clearly outlining segments. This greatly assists an individual during the painting stage. For scalable and clear paint-by-number kits, vectorization is vital.
- **Edge Detection Segment defining** is enhanced using edge segmentation techniques. Such methods improve the boundary contours between areas of different colors, resulting in each segment being simple to paint and distinct in appearance.

C. User Interface:

The platform allows access on both mobile devices and desktops. Users can upload images and select segmentation parameters to create custom paint-by-number kits. Casual users and businesses can effectively create personalized kits due to the ease of navigating the interface.

D. Usability Testing and Iterative Improvements:

Multiple rounds of usability testing were performed en- suring that the platform functionality met the targeted users' needs. The early adopters' feedback has also been integrated on the platform in relation to functionality, usability, and overall satisfaction, making sure that the platform performs optimally. This way, the platform will always be as effective for the users as it's intended to be.

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The combination of image processing, machine learning, and focus on the end user integrates seamlessly into the main point of the platform making the process of creating paint by numbers canvases efficient and straightforward.

V. Results

The results after analyzing the performance of the platform is based on the hypothesis stated above are:

A. Image Segmentation

Segmenting images into distinct sections was performed with a high level of precision, which is the platform's first success. The k-means clustering algorithm is very efficient in color region detection, in conjunction with vectorization meth- tools like potrace and vtracer, provide quality segmentation. Hence, the users can simply choose the sections to be filled with colors in the prepared paint by numbers.

Outcome: Color regions were well-defined and easy to paint, with minimal errors in segmentation.

B. Quality of Generated Images

The DALL-E was able to produce images with a satisfactory resolution consistently without needing much from the user. Along with the monotone texts, the system's generated images also captured the user's attention and satisfaction. Users had a choice of ranging content from minimalistic and simplified to more complex and detailed ones.

Outcome: Users conveyed satisfaction with all images, especially those created from artistic and abstract prompts due to the level of creativity incorporated in image designs.

C. Evaluation of User Experience and Usability

Users commented that the overall layout of the platform and its features were simple to use. Image uploads together with color selection and the generation of the paint by numbers canvases were simple enough for all users regardless of their technology skill level. In addition, the platform could be used on a desktop computer or mobile phone, which provided users with additional options.

Outcome: The platform garnered good user experience reviews and was able to get a positive rating from the majority of users who managed to complete the task successfully.

D. Usability Testing and Iteration

Through extensive usability testing, other iterations of the platform were released. Users commented on the ability to upload images, choose colors, and the quality of the output. The platform had to be made easier in these areas to improve user satisfaction and trust in the performance of the system.

Outcome: Each iteration made the platform more efficient, faster, and improved the level of satisfaction users reported after each iteration.

IV. Conclusion

The platform's goals focused on demonstrating accurate image projecting and segmentation along with high-quality im- age generation and positive user experience were successfully achieved. The feedback was successfully verified, proving that image segmentation and generation through deep learning, vectorization, and user-centered design worked as intended. The platform has received continuous feedback, allowing for iterative improvements to be made for enhanced utility on the side of casual users as well as businesses that aim to produce paint by numbers kits.

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