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AI EFFECTIVENESS OF BACKGROUND REMOVAL FOR DIFFERENT DEPTHS OF FIELD IN PRODUCT IMAGES

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Abstract: *AI models are being used and further developed daily. In graphic design, one of the most common uses is background removal from product images. This paper analyzes the effectiveness of background removal for common products by varying the depth of field. Tests were conducted using two AI background removal models on products of different shapes and textures, with both uniform and structured backgrounds. The results indicate that a shallow depth of field can be beneficial for background removal when the background is not uniform. Conversely, for a uniform background, a larger depth of field can aid AI, especially when the product is larger in size.*

Key words: AI model, background removal, product images

1. INTRODUCTION

Artificial intelligence (AI) has emerged as a transformative force across numerous fields, with particular advancements in graphic design and image processing. AI models, particularly those utilizing machine learning and deep learning algorithms, now possess the ability to perform tasks that were once labor-intensive for humans. In the realm of graphic design, AI has become a vital tool for tasks such as image manipulation, enhancement, and background removal, significantly optimizing both the efficiency and quality of these processes. These advancements allow for increased productivity in design workflows while offering more consistent and refined outcomes (Bertão et al., 2023; Naima Obaid & Jarjis Namah, 2023). Background removal, the task of isolating a subject from its background, remains a fundamental step in many creative and technical processes, including photography, marketing, e-commerce, and virtual reality applications. Traditionally, this task required significant manual effort, whether through analogue techniques or early digital methods, making it both time-consuming and prone to human error. With the development of advanced digital tools, such as Adobe Photoshop, and the introduction of AI-powered features, background removal has seen substantial improvements in both accuracy and speed (Warnock & Geschke, 2019).

The integration of AI into modern image editing software, most notably through tools in Adobe Photoshop, has transformed the approach to background removal (Adobe, 2024). AI-driven models offer designers a faster and more efficient means of separating foreground elements from their backgrounds, significantly accelerating the overall workflow in graphic design. AI-based background removal leverages convolutional neural networks (CNNs) and other deep learning architectures to identify and isolate subjects within images, learning from large datasets of labeled images (Shah & Tembhurne, 2023). These models are trained to distinguish between foreground objects and background elements with high precision. However, despite their growing sophistication, the effectiveness of AI-based background removal is influenced by several factors. Complex image patterns, intricate textures, and varying depth of field can challenge the model's ability to perform accurate extractions (Hwang, 2023; Naima Obaid & Jarjis Namah, 2023; Rezk, 2023; Sindhura & Abdul, 2021). Moreover, AI models may struggle in cases where fine details, such as hair or transparent objects, are involved, often requiring manual post-processing (Wei et al., 2018).

This study aims to provide a comprehensive analysis of the performance of AI-based background removal techniques within Adobe Photoshop. Specifically, examines the impact of image complexity, background intricacy, and depth of field on the effectiveness of AI models in background extraction. By conducting a series of experiments, the research seeks to evaluate the success rates of AI-driven background removal methods and formulate recommendations for optimizing their application in professional design workflows.

2. METHODS

2.1 Samples

Twelve objects were selected as research samples for this study, with a focus on items commonly featured in everyday catalogue sales. The selected objects include a baseball, broccoli, a flower, an instant camera, a pack of coffee, a cabbage, a lantern, a moka pot, a Venus flytrap plant, tomatoes, a tennis ball, and a bottle of water. In addition to ensuring the suitability of the objects for catalogue sales, object size was carefully considered to minimize variation, thereby reducing potential discrepancies in the photographic process. The shape of the objects also played a critical role in the selection process, as the objects were categorized according to both shape and complexity. Objects with more irregular outlines were deemed as more complex as well as objects with holes and transparent surfaces. Objects were also divided in two main categories: organic (have more irregular curves and corners) and non-organic (more regular lines, corners and curves). The classification was: non-organic simple, non-organic medium complexity, non-organic complex, organic simple, and organic complex (Table 1). This classification framework allowed for a systematic analysis of background removal performance across a diverse range of object types. This was also a classification of the expected success rate.

Table 1: Research samples categorized

 ***pack of coffee*** *(non-organic simple)*	 ***bottle of water*** *(non-organic complex)*	 ***lantern*** *(non-organic complex)*	 ***broccoli*** *(organic complex)*
 ***baseball*** *(non-organic simple)*	 ***moka pot*** *non-organic medium complexity*	 ***tomatoes*** *organic simple*	 ***flower*** *organic complex*
 ***tennis ball*** *non-organic complex*	 ***instant camera*** *non-organic complex*	 ***cabbage*** *organic simple*	 ***Venus flytrap*** *organic complex*

2.2 Background

In addition to sample objects, three backdrops are chosen as additional variables. The backdrops simulate different complexity with a goal to function as noise for background removal. Matte grey backdrop with minimal texture as a neutral background (Figure 1a); backdrop with a lighter complex pattern and lower value contrast (Figure 1b); and backdrop with a darker complex pattern and higher value contrast (Figure 1c).

a) matte grey *b) light complex pattern* *c) dark complex pattern*

Figure 1: Background samples

2.3 Photographic setup

The camera used for this research was a Canon 60D equipped with a portrait Tokina 100 mm f/2.8 AT-X Pro Macro lens. For the samples used in this study, three aperture settings were defined to achieve three different depths of field. A shallow depth of field was achieved with aperture f/2.8, medium depth of field with f/8 and large depth of field with aperture f/32. Each depth of field was paired with an appropriate exposure setting 1/40s, 1/5s and 4s respectively. Additionally, the sensor sensitivity (ISO) was set to 100 for all images. This ensured optimal image quality, minimizing digital noise and resulting in sharper, clearer photographs. For the scene setup, specific parameters were established for photographing the objects Figure 2.

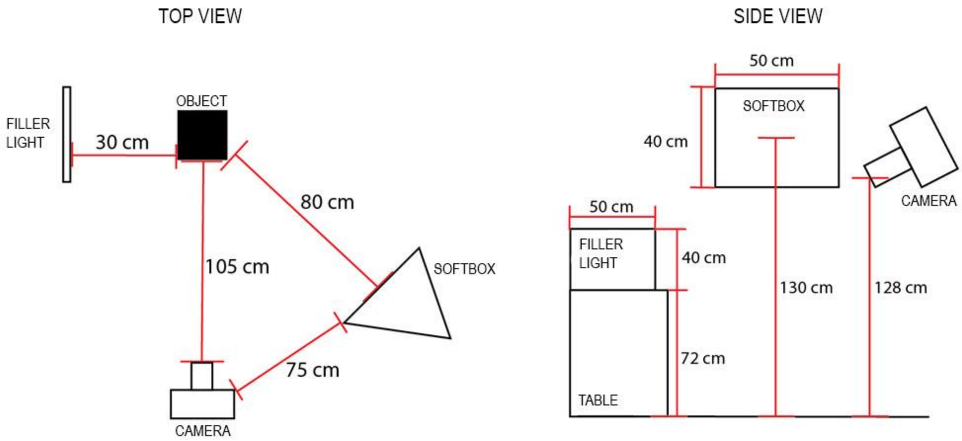

Figure 2: Photographic scene and light setup

The lighting setup utilized a Dedo Weigert Film Munich softbox, in combination with a Dedotec GmbH Munich lighting lamp, model DLH1000S with a 1-N-PE head (50/60 Hz).
ColorChecker Passport Photo 2 was used make a three camera profiles (one for each exposure setting). By utilizing the ColorChecker, consistent colour representation of the photographed objects was ensured.

2.4 AI background removal

After assigning the corresponding camera profile in Adobe Camera Raw 16.3 images were batched saved as JPG format. The images were additionally opened in Adobe Photoshop 2023, where the "Remove background" tool was used from the floating window option. Each image was subjected to three attempts of background removal to check the consistency of the results. The results obtained through AI were not altered or manually refined.
In addition, Removal.ai, was also employed as an open-source AI background removal tool. The photographs in JPG format were uploaded and the "remove background" option was selected. The tool autonomously removed the background from the image, and the resulting images were saved in JPG format same as the Adobe Photoshop workflow.

2.5 Grading

The results of the processed photographs were evaluated on a scale from one to five (Table 2). A rating of one was assigned to results that fully met the expected criteria. Two was given to results where small areas of the background remained, while a rating of three was assigned to results where larger areas of the background were still present.

Table 2: Grading description

Description	Grade
Successful – no visible flaws	1
Small areas of background remaining	2
Large areas of background remaining	3
Small segments of the object removed	4
Large segments of the object removed	5

Photographs in which small segments of the object were removed were given a rating of four, and those with larger portions of the object missing received a rating of five (Table 3). This grading method was adopted to facilitate comparison and better assess the success of background removal. The assumption was that is easier for the user to manually remove any remaining elements that the AI did not detect, rather than restoring portions of the object that were incorrectly removed. It is important to state that image results graded as 4 can be more acceptable if demonstrates no objection to losing smaller parts of the object that cannot be recognized as missing.

Table 3: Grading example

				
Successful – no visible flaws (1)	*Small areas of background remaining (2)*	*Large areas of background remaining (3)*	*Small segments of the object removed (4)*	*Large segments of the object removed (5)*

3. RESULTS AND DISCUSSION

The background removal process was conducted on June 24th, 2024, for Adobe Photoshop and on July 18th, 2024, for Removal.ai. Each result remained consistent when repeated three times. The results are presented in Tables 4, 5, and 6, based on the background used. The mean results provide as a general overview but examining individual cases is necessary for deeper insights and more conclusive findings.

Table 4: Grading results for matte grey (MG) background

		Adobe Photoshop			Removal.ai		
	aperture	f 2,8	f 8	f 32	f 2,8	f 8	f 32
matte grey (MG) background	Baseball	1	1	1	1	1	1
	Broccoli	4	1	1	4	1	1
	Flowers	3	4	3	2	2	2
	Instant camera	2	2	2	1	1	1
	Coffee pack	1	1	1	1	1	1
	Cabbage	1	1	1	1	1	1
	Lantern	3	3	3	2	2	2
	Moka pot	4	4	4	1	4	4
	Venus flytrap	4	4	4	1	1	1
	Tomatoes	4	4	4	1	1	4
	Tennis ball	4	4	4	4	4	4
	Bottle of water	4	4	4	1	1	1
	mean	2,92	2,75	2,67	1,67	1,42	1,67

Results from the MG background (Table 3) generally show superior background removal performance within the assigned grading system compared to other backgrounds, with a few exceptions. The LC background produced better results with tomatoes when using Adobe's AI and with the tennis ball when using both Removal.ai and Adobe across all aperture values (Tables 3 and 4). Additionally, the DC background showed improved results for the tennis ball when using Removal.ai at f/8 and f/32 aperture settings.

For the MG background, different aperture values mostly yielded consistent results, with two exceptions: parts of the broccoli were removed at f2.8 for both AI models, and a similar issue occurred with the tomatoes at f/32 using Removal.ai.

Table 5: Grading results for light complex (LC) background

		Adobe Photoshop			Removal.ai		
	aperture	**f 2,8**	**f 8**	**f 32**	**f 2,8**	**f 8**	**f 32**
light complex (LC) background	Baseball	2	4	4	1	3	3
	Broccoli	5	5	5	5	3	3
	Flowers	5	5	5	4	3	3
	Instant camera	5	5	5	5	5	5
	Coffee pack	4	3	4	4	2	2
	Cabbage	4	4	4	1	1	3
	Lantern	3	4	5	2	3	3
	Moka pot	5	5	5	4	4	4
	Venus flytrap	4	4	4	4	3	3
	Tomatoes	2	2	4	1	3	4
	Tennis ball	1	2	2	3	3	3
	Bottle of water	4	4	5	2	2	1
	mean	3,67	3,92	4,33	3,00	2,92	3,08

The LC background posed several challenges for the AI models, leading to inferior results compared to the MG background, but marginally better performance than the DC background (Tables 4 and 5). The LC background caused difficulties with the cabbage, while the DC background produced slightly better results for the moka pot and lantern when using Adobe AI. Removal.ai showed improved performance with broccoli, flowers, the coffee pack, and the Venus flytrap at f2.8 on the DC background, as well as with the Venus flytrap and cabbage at f/8 and f/32, respectively.

Table 6: Grading results for dark complex (DC) background

		Adobe Photoshop			Removal.ai		
	aperture	**f 2,8**	**f 8**	**f 32**	**f 2,8**	**f 8**	**f 32**
dark complex (DC) background	Baseball	4	4	5	4	5	5
	Broccoli	5	5	5	4	4	4
	Flowers	5	5	5	2	5	5
	Instant camera	5	5	5	5	5	5
	Coffee pack	4	4	4	3	2	2
	Cabbage	1	1	2	2	2	2
	Lantern	3	3	4	5	5	5
	Moka pot	4	4	4	4	4	5
	Venus flytrap	4	4	4	2	2	3
	Tomatoes	4	4	4	2	4	5
	Tennis ball	4	4	4	4	3	3
	Bottle of water	4	4	4	2	2	2
	mean	3,92	3,92	4,17	3,25	3,58	3,83

Overall, the results from Removal.ai were rated higher than those from Adobe, except for the tomatoes at f/8 and the tennis ball across all apertures with the LC background (Table 4). According to the grades 4 and 5 it is indicated that Adobe AI has a more aggressive process that results in smaller and larger parts of the objects removed. This can be observed as an advantage as Adobe AI removes more background than Removal.ai but Removal.ai process can be seen as a safer approach.

3.1 Different background discussions

LC and DC backgrounds introduced noise into the AI background removal process, as was expected based on the literature. It was observed that background texture and colour posed multiple types of issues. In the case of the baseball, the red stitching was recognized as part of the background, resulting in the removal of part of the ball (f/8 and f/32) in Adobe AI, and leaving the background in Remove.ai results (Table 4). The similarity between the pink background and the red coffee package also posed a challenge for AI models. In the MG background, Adobe AI removed parts of the tomato stem, while Remove.ai only related the stem to the background at f/32. This is likely due to the similarity in lightness, possibly caused by the lack of sharpness and chromatic aberration in the photograph.

3.2 Different object discussions

Broccoli was the largest object that had parts of the product out of focus at f/2,8 which is assumed to be the reason the AI mistakenly related it to the background. Similar issue was visible in the cabbage images but only for Adobe AI results. Conversely, the background reflection in the top of the moka pot also caused parts of the object removed. Larger portions were removed when complex background was used. Both AI tools remove background from holes in the objects (instant camera and lantern) but Adobe Ai struggles with smaller openings. It is also observed that both AI models cannot recognize transparent surfaces. The assigned complexity was mostly correct. Irregular curves in the organic object did not cause additional difficulties when compared to non-organic object but small details and thin elements, like fuzz on the tennis ball, are more prone to cause an issue (Microsoft, 2024; Wei et al., 2018). Improved results in Hair removal and similar issues can be expected in the future (Liang et al., 2023; Wei et al., 2018).

3.2 Different depth of field discussions

The results indicate that the depth of field does not pose a significant issue when dealing with uniform backgrounds. Therefore, using an aperture of f/8 is recommended to minimize the impact of camera lens imperfections, provided the size and distance of the object permit. For complex backgrounds, the findings suggest that a shallow depth of field can enhance the effectiveness of AI-based background removal. Moreover, complex backgrounds tend to interfere with background removal, particularly when a larger depth of field is used. The AI models appear to more accurately detect objects when the background is blurred, as they do not recognize perspective. In the case of reflective objects, a smaller depth of field has been observed to yield better results.

4. CONCLUSIONS

The primary goal was to assess how well the AI model distinguishes between the subject and various background types. As anticipated, the use of the matte grey background resulted in more accurate object extractions indicating that uniform background is better for obtaining successful outcomes. The analysis showed that, when using the Adobe Photoshop AI model, incomplete background removal or partial object removal frequently occurred. In contrast, the AI model used in Remove.ai produced superior results, successfully separating nine out of twelve objects from the background (Adobe achieved only four out of twelve).

When using uniform grey background, it can be concluded that depth of field is not a factor in AI object/background recognition. It is only observed as a factor when parts of an object fall out of focus meaning that for a successful background removal the whole object needs to be in focus. As expected, the light and dark complex background demonstrated that a shallow depth of field (while the full object is in focus) produces slightly better results, especially in Adobe AI model. This also produced better results in the product with the reflective surfaces. This suggests that out-of-focus areas help AI models distinguish background from object. However, this presents a challenge, as it is known that the middle value aperture of a lens produces the best picture quality but large object require higher aperture value to achieve larger depth of field (full focus). When object is not on a uniform background it can also be concluded that Adobe AI model has a more aggressive process that often results in partial object removal. This can be observed as a possible advantage if the main goal is speed over accuracy. It is also concluded that AI doesn’t offer solutions for objects with small holes and transparent and semitransparent surfaces. As AI is constantly improving it is expected that the same images will produce better results on the same platforms in the future. This research will be extended to investigate the influence and contrast as well as improvement in the AI models by repeating the process in a later time using the same samples.

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