Identifying the Optimal Edge Enhancement Technique for Application with Stylized Media

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1. Introduction

Edge enhancement is an image processing filter that enhances the edge contrast of an image, with the ultimate goal of improving the image's overall acutance, apparent sharpness. This filter achieves perceived contrast by creating bright and dark highlights, called overshoot and undershoot, respectively, around the edges of an image to create the illusion that the edge is more defined than it actually is. This is distinct from generalized sharpening, which is applied to an entire image and tends to not be as discerning about which edges should have their contrast increased. As a result, general sharpening can result in sharpening the edges of noise rather than important edges in the image, which edge enhancement aims to avoid.

Edge enhancement has been implemented in commercial televisions to create sharper-looking, more attractive images. For the most part, however, commercial televisions show images of the real world taken with a camera of some kind, and as a result their edge enhancement techniques tend to be specific to these subjects. Yet, due to the nature of the medium, the same edge enhancement algorithm may interact well with a photograph but more poorly with a similar scene rendered using more stylized methods (Figure 1).

Our goal is to identify what edge enhancement technique is most effective when dealing with more stylized forms of media, such as traditional art, animation, and video games. We aim to identify whether there is a blanket approach that would work for as many different art styles as

Figure 1. A side-by-side comparison of a real-world location on the right and its post-apocalyptic recreation in the game *Fallout 76* shown on the left. The top is the original image, while the bottom is the image with the same edge enhancement filter, an exaggerated unsharp mask, applied to both. Despite both being depictions of the same location and undergoing the same process, afterwards, the photograph on the right appears sharper but relatively unchanged and could be considered an improvement. Meanwhile, the digital recreation on the left seems significantly more artificial after processing, appearing flatter and less believable and having lost some realism in the process that the photograph did not.

possible, and to determine what might make certain styles exceptions.

2. Compelling Images

We first began with the more subjective goal of identifying what makes an image look visually appealing in order to identify how to improve the image. To this end, we reviewed various types of art that we found visually appealing, covering examples of paintings of varying eras and art styles, photography, and architecture. We focused largely on traditional art, as we wanted to study the techniques used by artists in order to later apply them in a digital context.

The primary conclusions we drew were related to contrast. In particular, we divided contrast into two different types - color contrast and brightness contrast - and found that both types had unique situations in which they thrived. For example, one of the paintings that we studied was Giorgio de Chirico's *The Nostalgia of the Infinite* (Figure 2). This painting is characterized primarily by two colors: the orange ground and the blue sky. We found this painting appealing in large part because of the color contrast between these two areas, as orange and blue are complementary colors. This color contrast, however, is not the focus of the image - rather, the brightness contrast is. In the center of this painting are two very small individuals standing at the base of a massive tower, with their black shadows stretching away from them on the ground. The contrast between their very dark shadows and bright orange surroundings draws attention to their figures, despite being dwarfed by the tower behind them.

In addition, the brightness contrast of the tower against the sky is not nearly as sharp as the

Figure 2. *The Nostalgia of the Infinite*, by Giorgio de Chirico.

contrast between the ground and the shadows. Although the bright white face of the tower contrasts with the darker blue sky and therefore draws attention initially, the abruptness of a pitch-black shadow on an otherwise plain bright orange surface is much more noticeable. Thus, we found that brightness contrast is more attention-catching than color contrast and is more

Figure 3. *The Magpie* by Claude Monet (above), and a close-up of a section of snow in the image (below).

effective at redirecting the viewer's attention to the important parts of an image, although both contribute to aesthetic appeal.

We, therefore, established that the main factor we wanted to manipulate was contrast. Since our goal was to enhance the images of others, however, not create them ourselves, we knew that large-scale contrast manipulations would be too noticeable and deviate too strongly from the artist's original intent. As a result, we took a lesson from the painting *The Magpie* by Claude Monet (Figure 3). In *The Magpie*, Monet created the illusion of twinkling snow by actually painting with a whole series of colors other than white: visible in the bottom half of Figure 3, for example, are red, blue, and yellow. These additional colors, along with the darker shadows cast by the textured paints, create a variegated surface with many high-contrast edges between darker colors and brighter ones. This contrast makes white speckles appear even brighter by setting them next to darker colors, thereby creating the illusion of twinkling. From this we drew the conclusion that images do not need large sections to contrast one another in order for contrast to have an effect; instead, a small area of contrast can still create an effect that noticeably improves the experience of viewing the image.

We initially considered an approach like tone mapping, which would increase relative contrast scaled to the dynamic range of the image. We ultimately decided that this would be too extreme an edit to make as someone who did not create the piece. Tone mapping is better suited to photos and art pieces which were created with the intent to use tone mapping. As a result, we decided that the best way to enhance an image without substantially changing it would be to increase contrast at the edges of an image. This was also optimal because it was a technique that could theoretically be broadly applied to most images and have the same beneficial effect, as opposed to other techniques with more narrow applications that would primarily be applied by the artist. After further research, we established that this technique was already established and was known as edge enhancement.

3. Edge Enhancement Parameters

We found that "edge enhancement" was a relatively broad term that simply encompassed increasing contrast at edges of an image. How exactly that would be accomplished was up to us. We started by testing different approaches on the same image to identify a technique that seemed most effective. We would then later apply this technique to a series of images with more diverse artistic styles. Since we wanted to start with something simple, we chose the painting *Composition II with Red Blue and Yellow* by Piet Mondrian (Figure 4).

Through a series of analytical studies in Photoshop, we identified a combination of effects, called adjustment layers, (increased contrast, slightly decreased vibrance, and increased saturation) that created the edge enhancing effect we wanted. Next, we tested the effectiveness of existing methods of edge enhancement, specifically Adobe Photoshop's **unsharp mask**, which increases sharpness in an image by enhancing contrast. We used the results from the unsharp mask as a baseline for how we wanted our images to look and what we wanted to improve. Our next step was to create a combination of adjustment layers that had an edge-enhancing effect similar to the unsharp

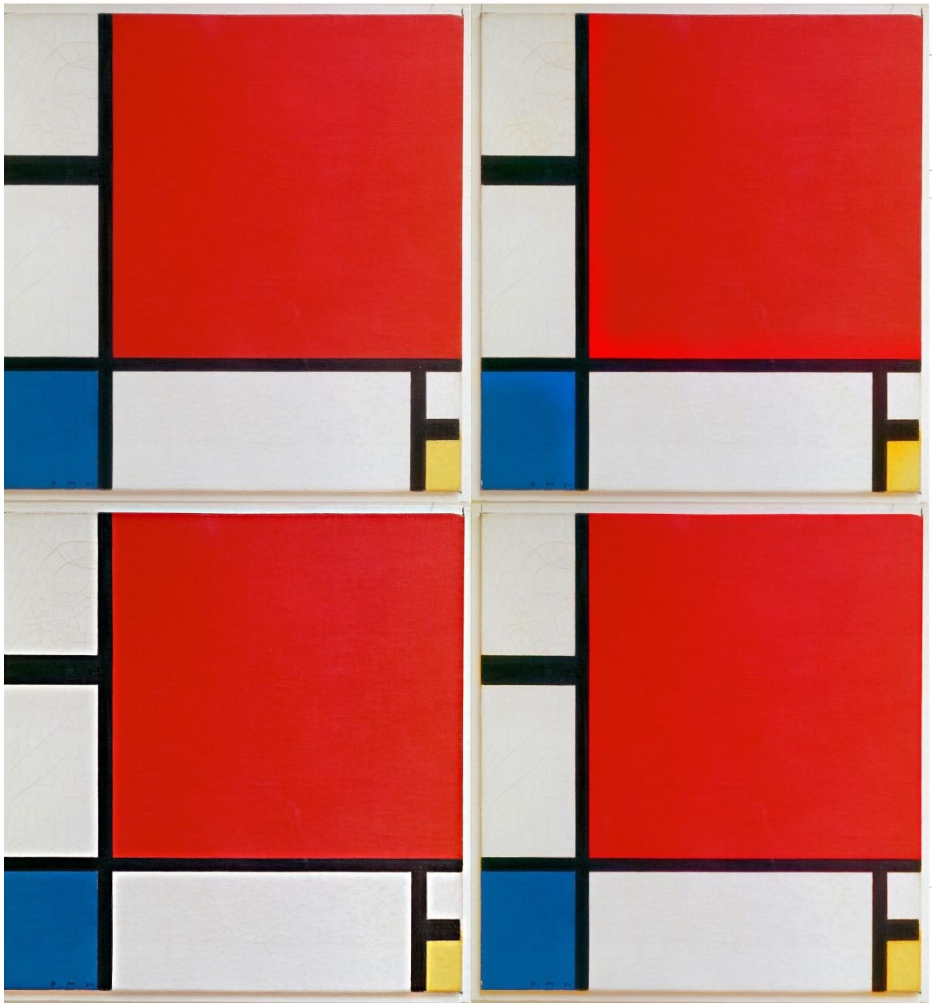

Figure 4.
Top Left: *Composition II with Red, Blue, and Yellow* by Piet Mondrian
Top Right: our first photoshop edit, increasing saturation and vibrance on a hand selected part
Bottom Left: a photoshop edit with unsharp mask at a high radius
Bottom Right: our later version of photoshop editing process.

mask. We were able to define the variables that we wanted to change and create a system to refine the image.

We concluded that the parameters we wanted to test were vibrance, saturation, contrast, and edge radius. **Saturation** modifies color intensity of all pixels. **Vibrance** modifies the color intensity of pixels with muted colors (low saturation values). **Contrast** regulates the range of shades in the image by modifying variation of brightness between light and dark areas of an image. Edge enhancement radius refers to the number of pixels from the edge that would be modified through this process. Our goal was to find the optimal combination of modifying these parameters to create an improved image, regardless of what that image is. We approached this by taking a series of image samples and experimenting with those to try and come up with a blanket edge enhancement approach.

The image samples we tested were from a variety of media, though we primarily focused on computer-generated images from video games and virtual reality (VR) as we intended to potentially create an algorithm based on the results of our studies. Since our ultimate goal was to identify an approach that would work for all different art styles, we picked representatives from a multitude of styles. The video games we selected images from were: *Half-Life: Alyx*, for a realistic urban scene; *Superhot*, for a highly abstract art style; *No Man's Sky*, for a slightly less abstract but still very stylized representation of outdoor landscapes; and *Cuphead*, for hand-drawn cartoons reminiscent of the rubber hose animation era. The art pieces we focused on were: *Composition II with Red Blue and Yellow* by Piet Mondrian (1929), to clearly identify our research goals; *A Sunday on La Grande Jatte* by Georges Seurat (1886), to test our process on an impressionistic piece which does not have clear edges; and *Orange And Red On Red* by Mark Rothko (1957), a painting which does not have clear edges. While our video game selections were to test our editing process on a variety of edges, our art selections allowed us to find the boundaries of our edge enhancements. Photoshop was used to apply our edge enhancements techniques to these images.

Since a majority of these images are more crowded and complex than the Mondrian, we needed an automated approach to edge enhancement. We found that the best way to accomplish this was to create a black-and-white mask of an image's edges, then use that mask as a matched filter and apply enhancement techniques to only the edges of the image.

Photoshop has an edge detection tool that we used for our enhancements. In our editing process, we controlled three things: the sensitivity of Photoshop's edge detector, the radius of the edge, and the filters applied to the edge. The Photoshop edge detection tool works by selecting pixels that have large differences between value, saturation, and vibrance. Since this is a Photoshop-specific tool, we are unclear on precisely what algorithm they use to identify edges, but we will assume for the sake of this paper that it is a generic edge detection algorithm that can be replicated by anyone else. We wanted our edge enhancement process to edit the edges of only high-value contrast since values are the defining aspect of an image.

We used two different approaches for each image: first, we applied a simple unsharp mask, which is the most common method of edge enhancement, to serve as a control to compare our edge enhancement algorithm against. Next, we created our own edge enhancement process using the following steps: we first created an edge mask by using an edge detection function, which in our case was provided by Photoshop, the software we used. A Gaussian blur was applied onto the original image to control the sensitivity of the edge mask, where a stronger blur resulted in a less detailed mask. These edge masks were then used as matched filters to apply enhancements in contrast, saturation, and vibrance to just the edges of the images. In some cases, a Gaussian blur was also applied to the edge mask in order to increase the radius of our enhancements and ensure that they blended more naturally into the image, rather than having a sharp cutoff at the end of the edge.

4. Results and Discussion

The Unsharp Mask Conclusions: The unsharp mask is an insufficient method of edge enhancement. Firstly, the limited settings on the unsharp mask resulted in too many edges being modified. Secondly, it does not alter the adjustments enough in relation to the original image. Therefore, it makes inappropriate edits that make the image have overly adjusted regions and outlines and eliminates the depth already prevalent in the original image. For the following discu, we will define edge density such that a greater edge density indicates a greater concentration of edges in the same area.

***Half-Life Alyx*:** medium density edges, high contrast image

Results: Edge density is too strong, resulting in entire regions of the image being edited. Adjustments are too strong, resulting in overly contrasted and garrish looking images.

***Superhot*:** low density, low contrast image

Results: Overly detects the low-contrast background, altering the perspective blurring, then overly modifies the figures, resulting in glowing people. Therefore, our combination of edits should distinguish between the foreground and background.

Seurat: High density, medium contrast image

Results: Over detects edges and their radii, thus over modifying the image and making the pointillism look noisy. The adjustments are too strong, overly sharpening the image.

***Cuphead*:** low-medium density, high contrast image

Results: Edge density and adjustments too strong, overly modifying the trees and increasing the brightness of the image, while darkening the outlines of the figures

***No Man's Sky*:** wide range of density, medium contrast image

Results: Over detects edges, especially in the foreground, where the ground becomes overly intense.

Rothko: low density, low contrast

Results: Little to no change, which is good for by the soft edges of the painting.

Edge Detection Process Conclusions: We were able to find a baseline edit (Refer to the Edge Enhancement Parameters section to review our process), yet some images required a variation of

this approach. These variations primarily altered the Gaussian blur at the beginning of the process and at the end of the process when it is applied to the adjustment.

Increasing the Gaussian blur tool (step 2) allows one to edit the foreground of an image and not the background. This isolation of the foreground is essential for increasing focus on the subjects of an image while ensuring the background stays subtle. Increasing the blur's strength causes the edge selection tool to detect only higher contrast edges, which typically are located in the foreground. In *Superho*t, increasing the Gaussian blur kept the focus on the figures in the foreground by lessening the impact of the adjustments on the low-contrast background. Also, in Seurat's painting, a higher Gaussian blur made the edge density of the tiny brushstrokes more acceptable by decreasing their edge radius.

The Gaussian blur applied to the edge mask (step 7) ensures that the edits transition seamlessly to the original image. In *Superhot*, the second Gaussian blur made the edge mask, which previously outlined the edges, appear natural and subtle. In Seurat's painting, this Gaussian blur was ensured that the edits incorporated smoothly into the original painting, making the increased-contrast edges seem like an artistic choice rather than a post-processing adjustment.

5. Conclusion

Our edge enhancement process effectively reacts to a variety of media styles. While this process does have a baseline approach that works for a variety of images, this approach is modified according to an image's composition and colors.

The most significant conclusion we drew through our comparison of basic unsharp mask sharpening and our more specialized edge enhancement techniques was that there are significantly more situations where an unsharp mask does more harm than good than there are for our color-based edge enhancement techniques. For all our images, we used an unsharp mask with the same parameters, but some images did noticeably poorer than others after processing - for example, as an example of pointillism, the Seurat had far too much detail enhanced by the unsharp mask when compared to one of our screenshots from a video game. As a result, we concluded that although unsharp masks may be the most popular method of edge enhancement currently, it has significant room for improvement because of its limited success with more stylized images such as the Seurat. This illustrates that our edge enhancement technique would be widely applicable in displaying stylized images. Having confirmed that, we then moved on to determine what parameters our specialized technique should have to be most applicable, as well as what factors would interfere most with its generalized applicability.

We found that the first Gaussian blur and the selection tool in Photoshop were the most significant elements in filtering the edges. This step allowed us to filter out the noisiness of the image, leaving the high contrast edges, which we wanted to edit. This Gaussian blur was also the main interference in our edge enhancement techniques' generalized applicability since it needed to be adjusted depending on the density of the edges in the image to prevent overlapping the effect of our enhancement.

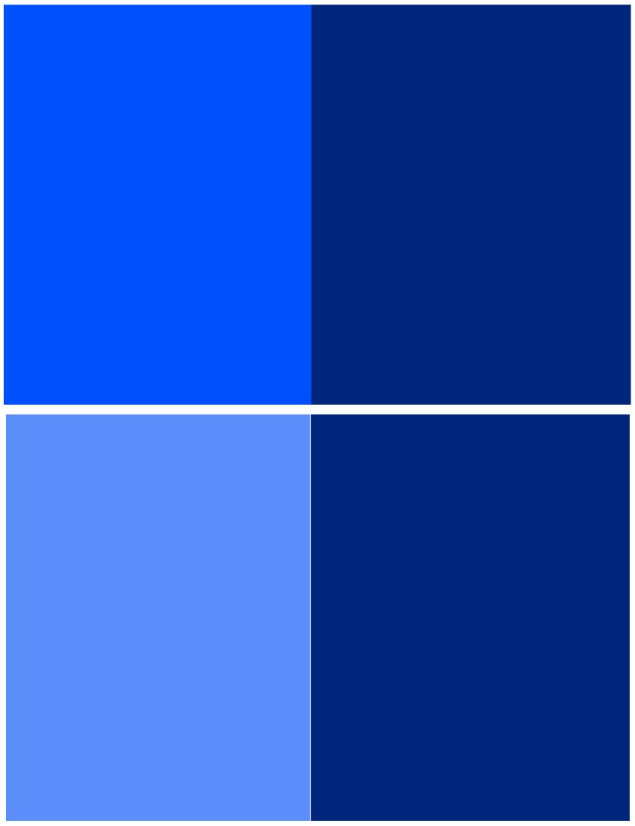

Figure 5. Saturation Study
Top: The left color, which is lighter, looks more saturated than the right color, despite having equal saturation levels.
Bottom: The left color looks equally as saturated as the right color, despite statistically having a lower saturation value.

Using a Gaussian blur on the final edge mask allows the increased-contrast edges to flow naturally into the original image. This second Gaussian blur allows the edge enhancement to appear as an artistic choice rather than a post-processing adjustment.

Also, areas of low contrast should be modified minimally since they usually are not supposed to attract attention. Areas of high contrast should be edited with higher contrast adjustments. There must be a negative vibrance adjustment when the contrast is increased to maintain the perceived saturation of the colors. Colors with lighter values are perceived as more saturated than darker colors with the same saturation levels (Figure 5).

We also noted that the level of detail in the edge mask of the original image versus various

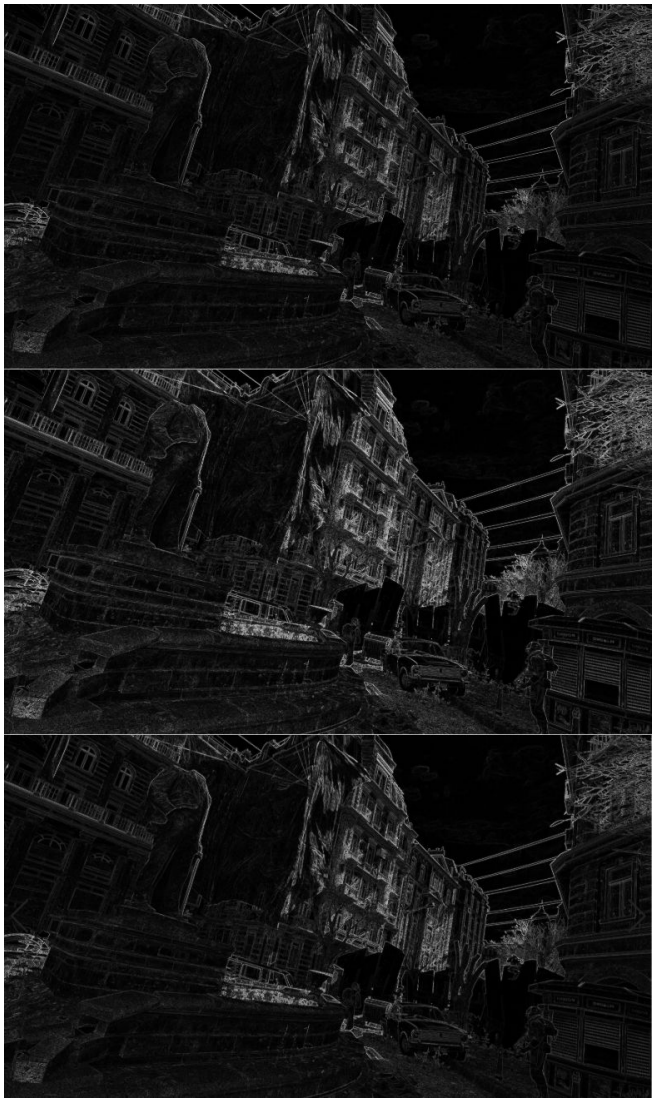

Figure 6. Edge masks obtained with a Sobel operator of the original image from *Half-Life: Alyx* (top), the version with an unsharp mask applied (middle), and the version with a color enhancement applied (bottom). There is no discernable difference when a color enhancement is applied, but the edge mask after applying an unsharp mask shows a distinctly higher level of detail than the original.

processed versions changed. As seen in Figure 6, the image with an unsharp mask applied resulted in a higher level of detail being detected by a simple Sobel operator, a specific algorithm for edge detection, than both the original and our color-based edge enhancement techniques. This knowledge has potential application in foveated rendering, as the eye could be tricked into not noticing that the periphery is a lower resolution if the right major markers, like the edges, are still present. Our method does not change the edges significantly from the original, meaning it could be applied to the fully-rendered part of the image that the fovea views without making the lower-resolution periphery more obvious. In addition, the periphery could be sharpened using a method like an unsharp mask to make the edges more significant, which could help in disguising that it is lower resolution than the part of the image that the fovea is viewing.

6. Future Goals

Our hope is that in the future, an edge enhancement algorithm similar to the one we settled on can be applied to, for example, VR headsets, much like this enhancement would be used for televisions. However, as it currently is, our algorithm is not nearly complex enough, nor does it improve the original image enough to find commercial use, so finding a variation that works more effectively would be a goal for the future. Our method was also done manually in Photoshop, but from what we have learned from this process, we could develop an automated way of applying our edge enhancement algorithm to an image, which would give it an application for something like VR. In addition, trying more complex additions like saliency mapping - which is a technique used in Blu-ray players to enhance the quality of the image - would be something to consider.

7. References

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8. Appendix

8.1 Process

Each image used the same process of value-contrast edge detection (image desaturation, Gaussian blur, find edges, color selection, layer mask) and optical adjustments (contrast, vibrance, and saturation). However, each image needed a specific amount of edges detected, edge radius size, and optical adjustments according to the image's existing subjects.

Our specific steps are as follows:

1. Desaturate Image: We began our edge-enhancement process by making a black and white copy of the image that could be used to select only the value-contrast edges.
2. Gaussian Blur: Secondly, we used a Gaussian blur filter on the black and white images to control the sensitivity of the edge detector. Increasing the strength of the blur tool decreases the value contrast between pixels, thereby decreasing the sensitivity of the edge detector.
3. Find Edges: Next, we used Photoshop's find edges tool on the edited grayscale image. This tool reduces the grayscale image to its edges, which are shown in black on a white screen.
4. Select Colors: After, we used the Select Colors tool to select the black color of the edges. The Select Colors works by selecting similar colors, whose range is determined by a fuzziness value. The goal of this selection is to only select the edges, so we adjusted the fuzziness value qualitatively according to the density of the edges to have additional control over the amount of edge enhanced. Denser images require a lower fuzziness value — thereby decreasing the range colors selected by the edge detector — than less dense images.
5. Edge Selection and Layer mask: Subsequently, we used this edge selection to create a layer mask, a function that allowed us to edit only the edges while not touching the rest of the image — on the original colored image.
6. Adjustment Layers: Next, we used this layer mask to enhance the edges of the photo by using combinations of higher saturation, vibrance, and contrast. We tried to create a single adjustment process that could be used on different images. A baseline edit consisting of limited contrast and saturation might be effective, especially on images with lower edge density. However, we confirmed that needed adjustments highly depend on images' existing levels of saturation, vibrance, and contrast.
7. Gaussian Blur on the Adjustment Layer: We learned in some of our later studies, particularly with *Cuphead* and our impressionistic paintings, that we could use the Gaussian blur filter on just the adjustment layer. This blurred the edges of the adjustment, allowing for a greater edge enhancement with a less obvious change from the surroundings of the edit.

Half-Life Alyx: Understanding Edge Enhancement

1. *Reference Unsharpening Mask*: we began by making a reference edit with Photoshop's unsharpening filter because it had a similar effect to what we wanted with our custom adjustment combination.

The unsharpening mask works by detecting edges then increasing their contrast. In the *Half-Life Alyx* image, the unsharp mask greatly increased the sharpness and contrast of the entire image. However, we believed the unsharp filter's effect was too strong: the radius of the adjustment was too large, resulting in adjusting the values of entire regions rather than just the edges. Therefore, in our edits we wanted to refine the radius adjusted.

2. *Edit 1:* Contrast. For our first edit, we used a smaller Gaussian blur, with a radius of 2.5 pixels; a fuzziness value of 30 for our selection of the edges, then applied a contrast filter with a value of 70, increasing the contrast at the selected edges. We found that the adjustments edited the majority of the image, therefore the edge radius was too large and needed a stronger Gaussian blur value. Regarding the optical adjustments, we thought the increase in value-contrast was an improvement, but the increase in color contrast made the muted colors appear too saturated. Therefore, going forward we wanted to use the vibrance tool to ensure the muted colors are not greatly affected by the contrast filter.
3. *Edit 2:* Identical Edges and Contrast, Adding Vibrance and Saturation Filters. In this edit, we added two additional filters: Vibrance with a negative 100 value, significantly decreasing the vibrance at the selected edges; and Saturation with a value of 50, increasing the saturation to balance out the vibrance change. We believe this edit was a huge step forward, modifying the values at edges while maintaining relatively similar hues of the original. The edit was effective for most of the image, in places of high contrast, but ineffective in the minority regions that had lighter values (such as the first floor of the building, where the shadows became too strong). Therefore, images could benefit from the strength of adjustment layers changing in different parts of the image depending on pre-existing value and contrast levels in certain areas.
4. *Edit 3:* Identical Edges and Contrast, Lesser Vibrance and Saturation Filters. We decreased the strength of the vibrance and saturation filters to more accurately match the original image. This change is most apparent in places with muted colors, such as the central building. Areas with higher saturation and lower saturation, such as the clouds, sidewalk, and taxi, were not greatly affected. We found this edit to be most similar to the original image while still having a clear change in terms of clarity of the edges.
5. *Find Edges:* We then took the original photo, the unsharp mask version, and the final version of our edit (Edit 3), and applied the find edges tool to each of them. This allowed us to compare the effects of our edits by looking at how the edges vary between each version. The unsharp mask edit intensifies edges throughout the entire image, while our edit intensifies the main edges of the image without enhancing the insignificant details.

Superhot: Selected for its low-contrast and vector-art style. This image differs from our *Half-Life Alyx* image because it has a very strong foreground with figures right in the front of the composition.

1. *Reference Unsharpening Mask:* This mask from the same process used with *Half-Life Alyx* creates an almost negligible effect because the low-contrast art style does not create many edges, which are detected from places of high contrast. The only areas affected by the unsharp mask are the hatch lines on the figures (which become more distinguished), and the seams on the floor. This mask has no significant effects on the background.
2. *Edit 1:* We used the best adjustment combination from *Half-Life Alyx* as our first test for *Superhot*. The *Half-Life Alyx* edit, which focused on increasing contrast, was unsuccessful on *Superhot*, which has a low-contrast art style. The increased contrast edit gave the low-contrast figures a glowing hue and more significantly, made the background contents, such as the pool table and the arches, too sharp. It interfered with the image's perspective blurring of the objects further away from the viewer, a common optic technique used to enhance depth in an image.
3. *Edit 2:* Regarding adjustment layers, we removed the increased contrast adjustment, only editing the colors through the Saturation and Vibrance adjustments to avoid interfering with the low-contrast art style. *This part was successful*. Since the previous edit operated on too much of the image, we tried to increase the strength of the Gaussian blur filter, creating a larger radius of effect, to decrease the edge severity. This change ultimately was ineffective in combination with the vibrance and saturation adjustments, resulting in outlines and the overemphasis of certain highlights.

   To elaborate, this scene is lit from the left-hand side. Therefore, the brightest highlights from the direct light should be on the figures' left. However, the edit modifies the highlights on the left figure's arms until they were perceived equally, thereby lighting the scene incorrectly.

   The Gaussian blur decreases edge severity by widening the radius. Therefore, we first increased the edge radiuses with Gaussian blur to make them less noticeable, but next increased their vibrance and saturation levels, causing them to be more distinguished.
4. *Edit 3:* With this version, we resolved the outlines created from the previous edit by adding a Gaussian blur directly to the adjustment mask, thereby smoothing the transition between the edit and the original image.
5. *Find Edges:* Again, we applied the find edges filter to the original, the unsharp Mask version, and Edit 3 for *Superhot*. By comparing these, we noticed that the unsharp Mask version intensifies all of the edges, including the hatches, while Edit 3 intensifies just the outlines. Since the original image already has very distinct edges due to the nature of its artistic style, our final edited version, Edit 3, is not as differentiated in its edges from the original as *Half-Life Alyx*'s variance after applying the find edges filter.

A Sunday on La Grande Jatte by Georges Seurat (1886): Selected as a pointillism painting without distinct edges:

1. *Reference Unsharp Mask:* The same unsharp mask was highly ineffective because Photoshop detects the edges of each of the points within the image, thus over modifying the image and making the dots look noisy. The adjustments are too strong, overly sharpening the image.
2. *Unsharp Mask with higher Tolerance:* By increasing the tolerance of the unsharp mask, our issue with photoshop's detection of each point was lessened, yet not fully improved as the final image still appeared noisier. The adjustments were still applied too strongly despite this change.
3. *Edit 1:* The best *Half-Life Alyx* edit increased the image's contrast, making the foreground and midground pop out to the viewer. This change was effective for the foreground, which became more distinguished, but ineffective for the midground, which was brought to a similar perceived depth as the foreground. The high-contrast adjustment also was ineffective by over darkening in some areas and creating outlines.
4. *Edit 2: Half-Life Alyx* Post-Gaussian Blur: We made the adjustment layers more seamless by adding a Gaussian blur to the adjustment layers. This edit increased the edge contrast while making the transition between the adjustment and the original painting much smoother and more natural. Since Seurat's painting is made up of points rather than clear edges, the post-Gaussian-blur edit is most effective as it emphasizes the subjects of the image rather than the edge of the points, like the unsharp mask filter does.
5. *Find Edges:* We applied the find edges filter to the original, both of the unsharp mask versions, and Edit 2 for Seurat's pointillism painting. As we described earlier, the unsharp mask filter intensifies all of the points in the image. The unsharp mask version with a higher tolerance amount does this to less of a degree where there would not be an edge if this were a photo for example. Edit 2 is a good example of achieving our goal as it only affects the points outlining the subjects of the painting.

Cuphead: Selected for the cartoon-style outline on all of the figures where the edge enhancement would be most prevalent:

1. *Reference Unsharp Mask:* We noticed that applying the unsharp mask was ineffective as the mask simply brightened the overall image and darkened the outlines further.
2. *Edit 1:* The best *Half-Life Alyx* edit seemed to create a halo effect on all of the outlines. We realized that *Cuphead*'s high-contrast line-art style needed a specialized adjustment process to avoid overly adjusting the edges and creating outlines.
3. *Edit 2*: We added a Gaussian blur to the adjustment itself, modifying *Cuphead*'s edges more naturally. This edit resulted in the subtlest edit. Through a series of trial and error of simply decreasing the amount of vibrance, saturation, and contrast of the edit; decreasing the original Gaussian blur;

and removing contrast, we were able to conclude that this approach works best on images with very bold edges. We were able to use this approach in our last edit, Edit 3, of *Superhot*, to further prove this idea.

4. *Find Edge:* We applied the find edges filter to the original, the unsharp mask version, Edit 1, and Edit 2. The desired enhancement of the main edges is noticeable in both Edit 1 and Edit 2, while the unsharp mask increases the intensity of the entire image. The images illustrate our desired effect in both Edit 1 and Edit 2. Comparing Edit 1 and Edit 2 with the find edges filter demonstrates that we can add this Gaussian blur to the adjustment layer to create the visual effect we want without significant change to the actual edges of the image.

No Man's Sky: Selected for its variety in edge density, with the intense edge density of the grass and the leaves of the tree but the little edge density of the sky:

1. *Reference Unsharp Mask:* The unsharp mask over intensifies the image. This mask edits all of the edges in the image, including the dirt and other details. For example, the pebbles in the foreground seem to glow in the dirt, which now seems to have too heightened of a texture for dirt.
2. *Edit 1:* This image allowed us to test our same process from the final *Half-Life Alyx* edit on an image with a variety of edge densities. We were able to study the relationship between edge density and the radius of the Gaussian blur. In areas with intense edge density, a lower radius is better since a high radius might start to overlap with other edits or change a whole section of the image. In areas with fewer edges, and therefore a lower edge density, a greater radius is preferred, but a smaller radius still works. Therefore, if an image has both areas of high-density edges and low-density edges, a lower radius is better.
3. *Find Edges:* Applying the find edges filter on these edits is another example of our enhancement working as seen in the previous examples.

Orange And Red On Red by Mark Rothko (1957): Selected as a painting which does not have clear edges:

1. *Reference Unsharp Mask:* Unlike previous examples, applying an unsharp mask to this painting does not appear to affect the painting at all. Rothko's painting has soft edges that dissolve the end of the orange rectangle into the surrounding red space. The unsharp mask does not detect these soft edges and consequently has little to no impact on the piece.
2. *Edit 1:* Using our best edit from *Half-Life Alyx*, we were able to use a small radius for the Gaussian blur and still detect some edges. Despite detecting edges, our editing process yielded negligible changes from the original painting. At any other Gaussian blur radius, there were not enough pixels of edges to be detected in the find edges step of our process. This example challenged our editing method as it helped define the boundaries of our edge enhancement technique.
3. *Find Edges:* We applied the find edges filter to the original, the unsharp mask

version, and Edit 1. Since the image does not have clear edges, the enhancement does not make any noticeable change, and photoshop has trouble detecting any edges. This emphasizes that not all images may be edited through this method. However, as an image with soft edges, which are not meant to be enhanced or more noticeable in any way, our editing process was successful.

8.2 Images

Note: Images for all edits for *Composition II with Red Blue and Yellow* by Piet Mondrian (1929), *Half-Life Alyx*, *Superhot*, *A Sunday on La Grande Jatte* by Georges Seurat (1886), *No Man's Sky*, *Cuphead*, and *Orange And Red On Red* by Mark Rothko (1957) are located at the following link: (https://docs.google.com/presentation/d/1zUllpzenAG5c8CdRVV1JTNduAVUd7IGilyjY9Ul-tAw/edit?usp=sharing)

Figure 8.2. Larger version of Figure 1

Figure 8.2. Larger version of Figure 2

Figure 8.3. Larger version of Figure 3

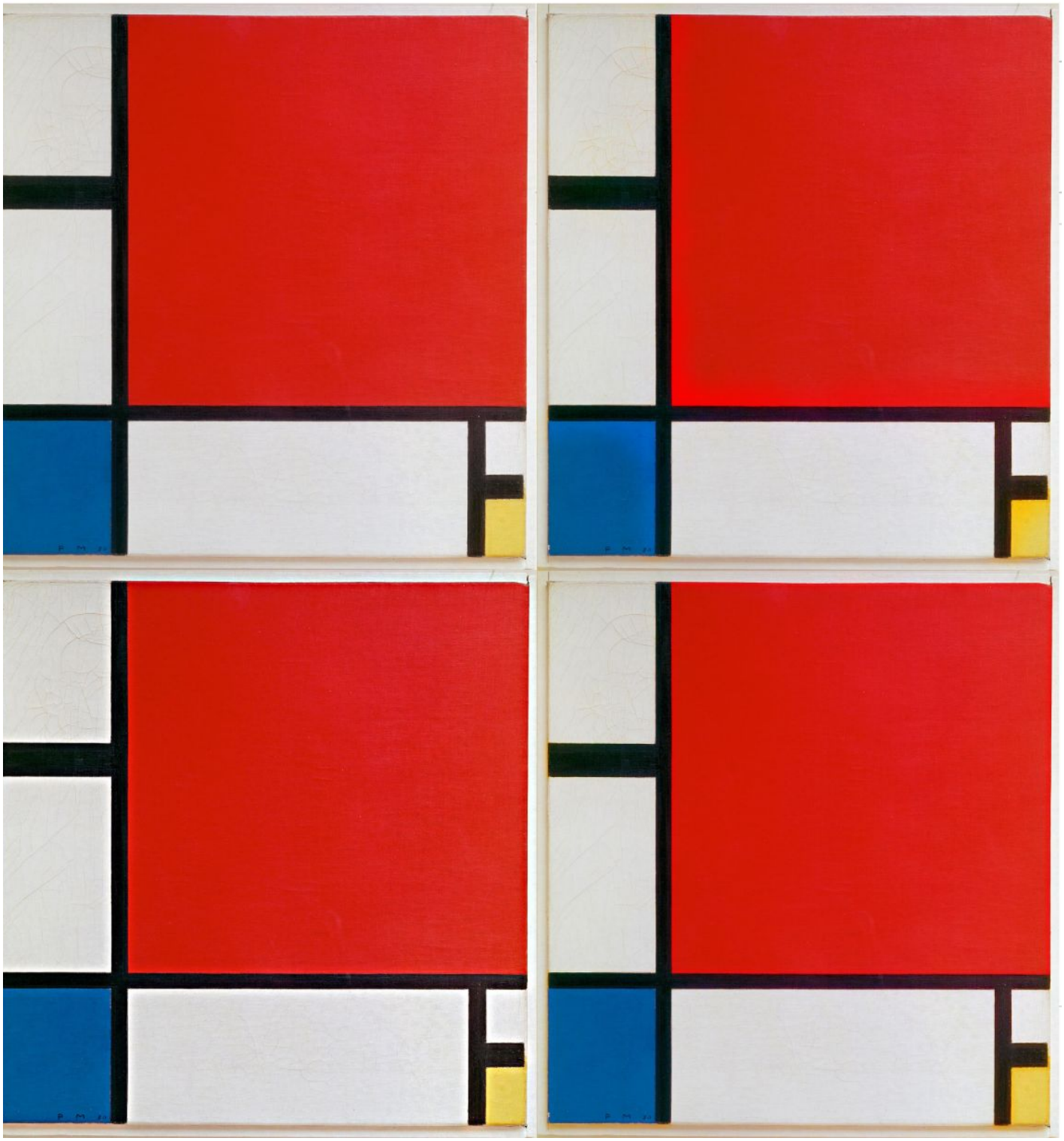

Figure 8.4. Larger version of Figure 4

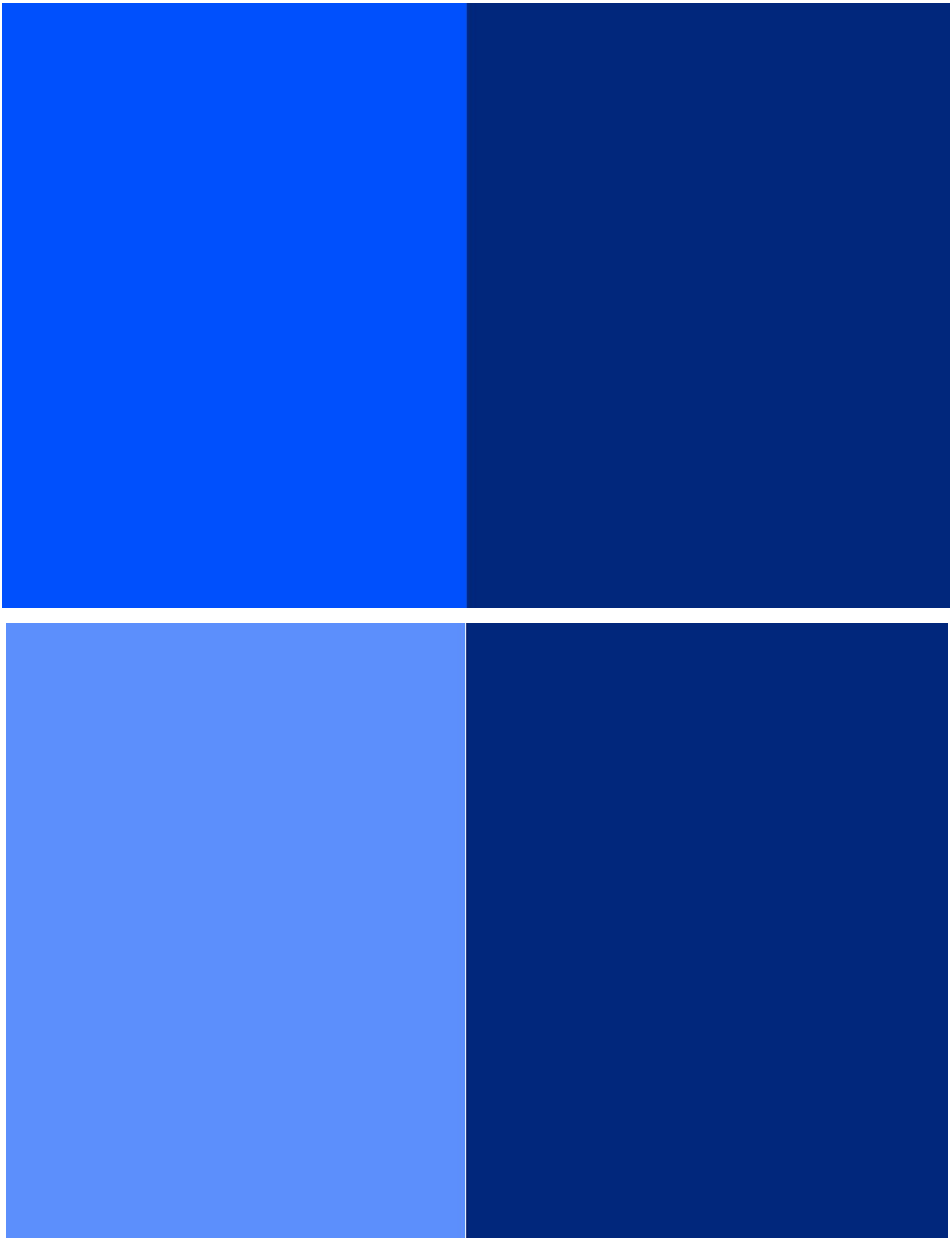

Figure 8.5. Larger version of Figure 5

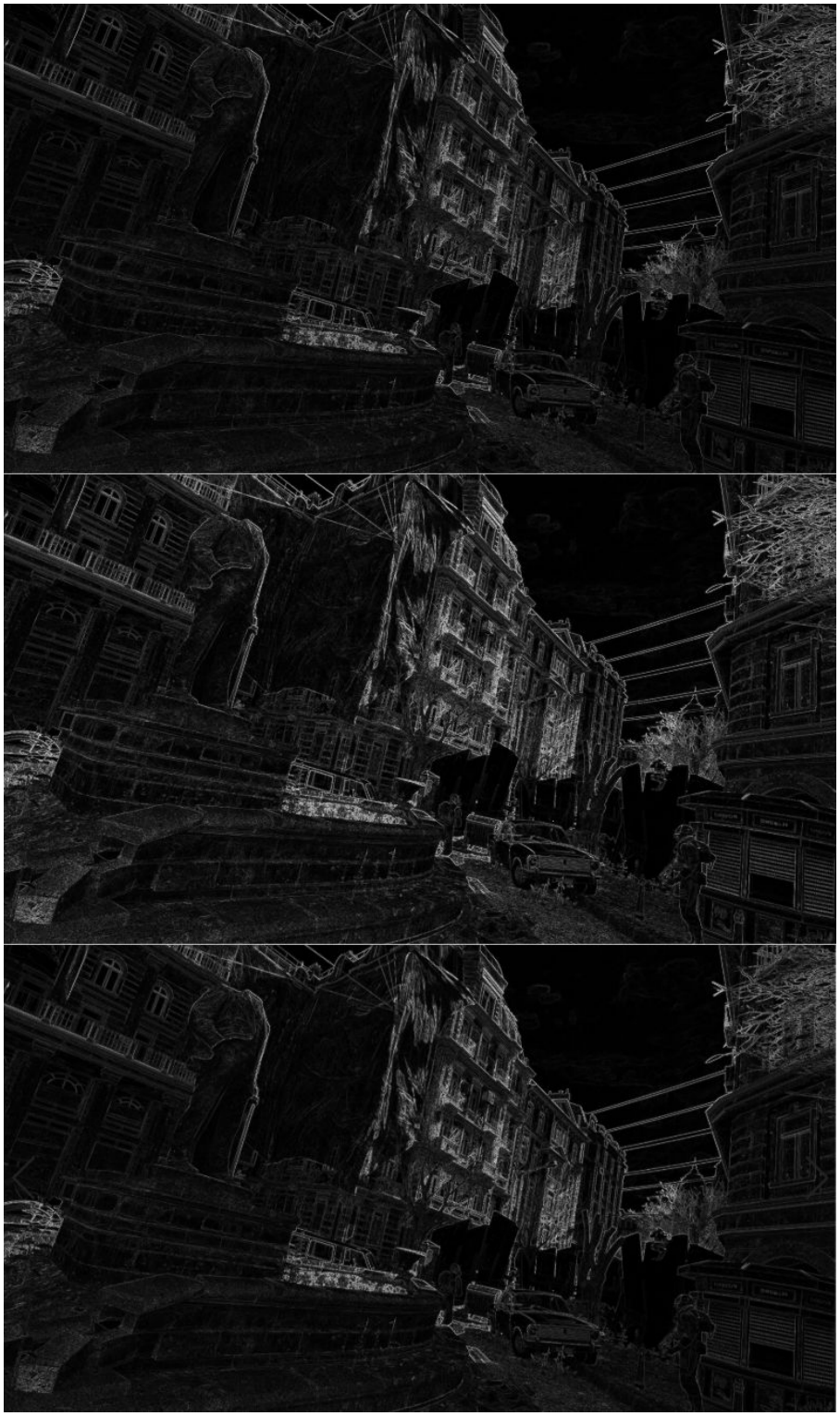

Figure 8.6. Larger version of Figure 6