Augmented Reality with ArUco Markers

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Disclaimer

The content of this document was created by the authors mentioned above. ChatGPT from OpenAI was used to improve readability. However, all content has been checked by the authors and adapted where necessary.

List of abbreviations

RWU Hochschule Ravensburg Weingarten

1 Introduction

1.1 Task definition

This work was created as part of the Computer Vision course at Hochschule Ravensburg Weingarten (RWU) as a project assignment. The aim of the project is to use the OpenCV library to modify the images that are provided in the dataset Room with ArUco Markers in such a way that a poster is integrated into the image in such a way that the viewer has the impression that the poster is actually in the room.
This image augmentation is applied to a given data set, whereby the results achieved are then to be transferred to self-created images.

1.2 Marker

A challenge in computer science disciplines, that work with image data, is the interpretation of spaces on the basis of individual perspectives. One promising approach to recognizing orientation and alignment is the use of markers.
The ArUco marker is used in this work. These are specially developed markers that consist of a square black and white pattern and enable clear identification and the calculation of position and orientation in space. [1]

2 Image Transformation Process

The image transformation process begins by loading the input image 1, which contains ArUco markers, as well as the poster (Figure 19) image.

Figure 1: Example Image from the Dataset with ArUco Marker

The script then scales and adjusts the poster dimensions to achieve the size the user wants it to be in the final image, ensuring the poster aligns properly with the marker's size and orientation. To achieve this, the script calculates the corners of the scaled poster and determines their correct positions relative to the marker's location. [3]
Next, the ArUco markers are detected within the image using OpenCV's ArUco.detectMarkers function, which identifies the marker's corners. A perspective transformation matrix is calculated based on the positions of the poster corners and the detected marker corners. This matrix is then used to warp the poster image so that it aligns precisely with the detected marker area.
To integrate the transformed poster into the original image, a mask is created, which isolates the transformed poster region. The mask is then inverted so that only the region outside the poster area is kept, ensuring that the poster seamlessly blends with the background. Finally, the mask is applied to the im-

Figure 2: Detected Marker Image.

age, and the transformed poster is combined with the original image using bitwise operations, resulting in the final image with the poster placed correctly within the marker-defined region.

3 Evaluation and Validation

Once the image transformation is complete, the script proceeds to evaluate the alignment of the poster placement.

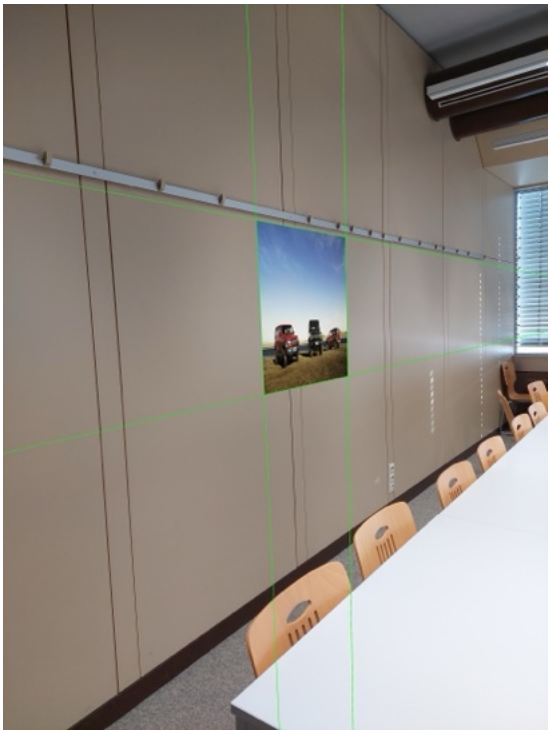

Figure 3: Final image with extended borders.

The first step in the evaluation is detecting the edges of the image using the Canny edge detection method. This process highlights the boundaries of the poster and the surrounding areas, providing a clear view of the poster's edges. Following edge detection, the script employs the Hough Line Transform to extract the prominent lines from the edge-detected image. This method identifies and highlights the linear features within the image, including the edges of the poster. By comparing the detected lines with the expected positions of the poster's edges, the script can assess whether the poster has been placed accurately. [2]

Finally, the evaluation results are visualized by overlaying the detected lines and edges on the original image. This allows for easy manual inspection of the poster's placement, providing immediate feedback on the transformation's accuracy. The combination of edge detection and line extraction ensures that any misalignment or distortion in the poster placement is clearly visible for quality assurance.

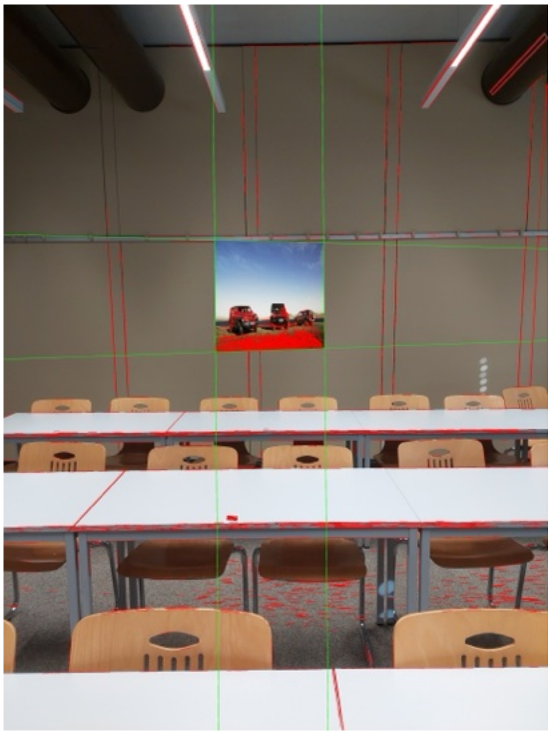

Figure 4: Bad Transformation but still good placement the poster is set stable on the marker but the edges dont line up with the background

However, when analyzing further images, it becomes apparent that the detection of the ArUco marker does not work reliably in every perspective. An example of this can be seen in Figure 14. When comparing the horizontal vanishing point lines of the poster (green) with the metal rod (red), it can be seen that the vanishing point lines deviate further and further from the rod as the distance increases and finally deviate. Apart from the vanishing point, the posters are consistent in terms of placement and aspect ratio and allow the posters to be inserted stably.

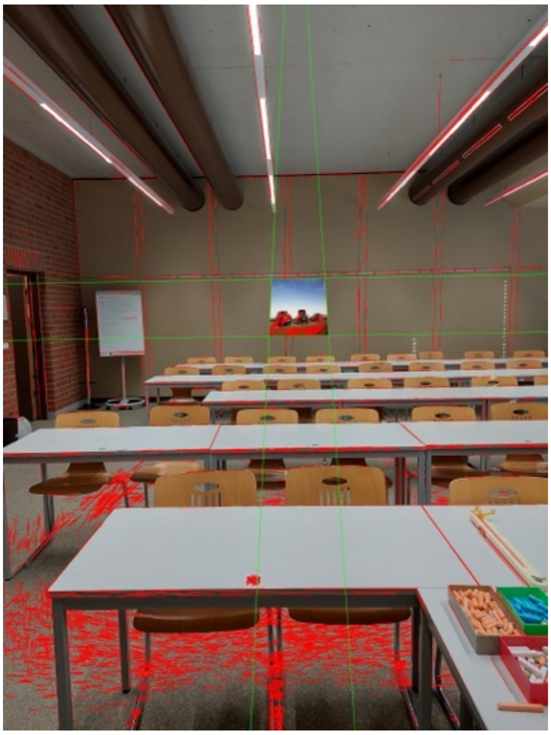

Figure 5: Decent Transformation but good placement the poster is set stable on the marker, but the edges dont line up with the background, especially in the horizontal

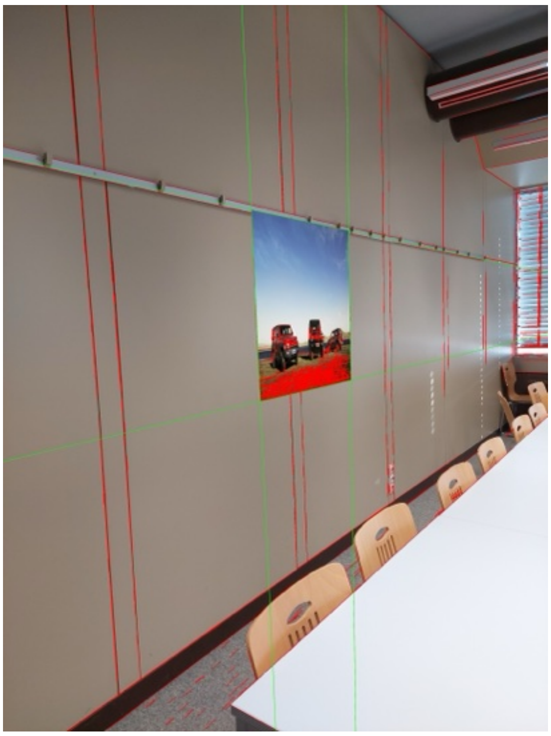

Figure 6: Good Transformation and good placement the poster is set stable on the marker

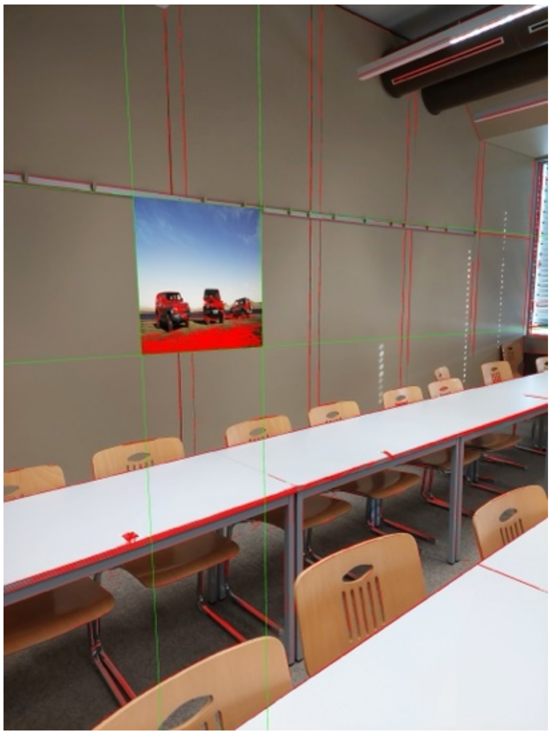

Figure 7: Detectedcent Transformation and good placement the poster is set stable on the marker, the edges also line up in the vertical but are slightly misaligned in the horizontal

Figure 8: Bad Transformation but decent placement the poster is set stable on the marker, but the edges dont line up with the background, especially in the horizontal

Figure 9: Good Transformation and decent placement the poster is set stable on the marker, but the edges dont line up with the background, especially in the vertical

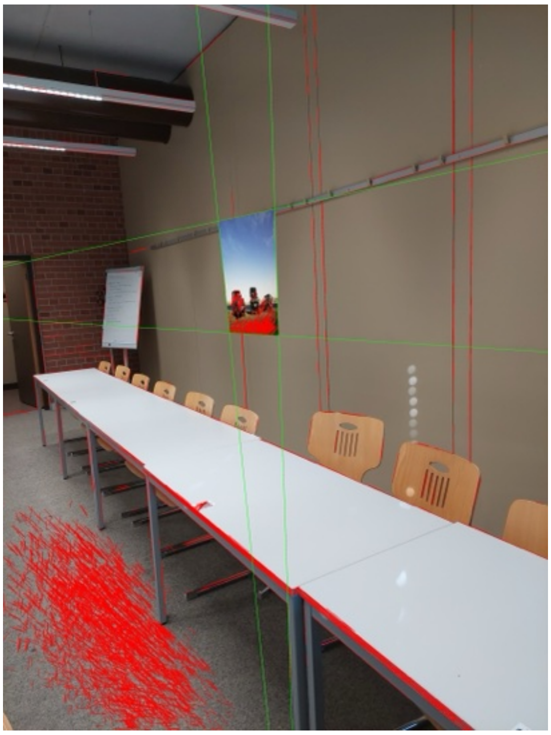

Figure 10: Decent Transformation and decent placement the poster is set stable on the marker, but the edges dont line up with the background, especially in the horizontal

Figure 11: Good Transformation and good placement the poster is set stable on the marker, the edges dont line up perfectly with the background

Figure 12: Decent Transformation and good placement the poster is set stable on the marker, the edges don't line up perfectly with the background and the part going out the frame doesn't look good

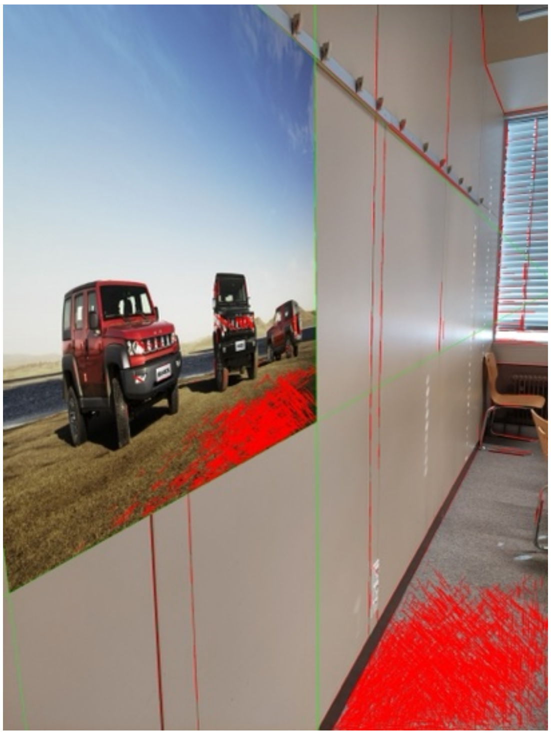

Figure 13: Good Transformation and good placement the poster is set stable on the marker, the edges line up with the background and the part going out the frame does look good

Figure 14: Example of a perspective in which the vanishing point was poorly recognized.

4 Conclusion

As part of this project, software for placing posters in an image was developed. The ArUco marker and the OpenCV library were mainly used for this.
The results of the poster placement are basically solid and position the poster in the correct size in the room. The deviation between the calculated and the actual distortion is so small in the analyzed images that the errors are not disturbing. Errors are much stronger if the Arcuo Marker has a lower resolution and therefore the corners are not recognized accurately.
An improvement of the marker detection was not possible within the scope of this work and could be further optimized in a more extensive scientific study.

References

[1] S. Garrido-Jurado, R. Muñoz-Salinas, F. J. Madrid-Cuevas, M. J. Marín-Jiménez. *Automatic generation and detection of highly reliable fiducial markers under occlusion.* Pattern Recognition, vol. 11, no. 6, 2021.

[2] *Extract vanishing point from lines with OpenCV*, StackOverflow user Ilke444. Available: `https://stackoverflow.com/questions/57535865/extract-vanishing-point-from-lines-with-open-cv`. Accessed: Nov. 28, 2024.

[3] OpenCV.org, *Tutorial: ArUco detection*, Available: `https://docs.opencv.org/4.x/d5/dae/tutorial_ArUco_detection.html`. Accessed: Nov. 28, 2024.

[4] Tim Schweitzer *Own example Images with ArUco Marker*, 2024.

[5] v_speed. *Poster used in Provided Images*, 2024. Available under Pixabay-Contentlicenz: `https://pixabay.com/de/photos/beijing-automotive-bj40-suv-bj80-2486704/`. Accessed: November 3, 2024, 18:01.

[6] NASA-Imagery. *Poster used in Own Images*, 2024. Available under Pixabay-Contentlicenz: `https://pixabay.com/de/photos/sonneneruption-sonnenlicht-eruption-978/`. Accessed: November 20, 2024, 16:55.

Appendix A: Additional Images

Figure 15: Own Image, Marker on Floor with a distortion in multiple directions[4]

Figure 16: Own Image, Marker on Floor with a distortion in multiple directions [4]

Figure 17: Own Image, Marker on a Wall with a steep angle from the top[4]

Figure 18: Own Image, Marker on a Wall with a steep angle from the top[4]

Figure 19: Poster used for Image Augmentation[5]

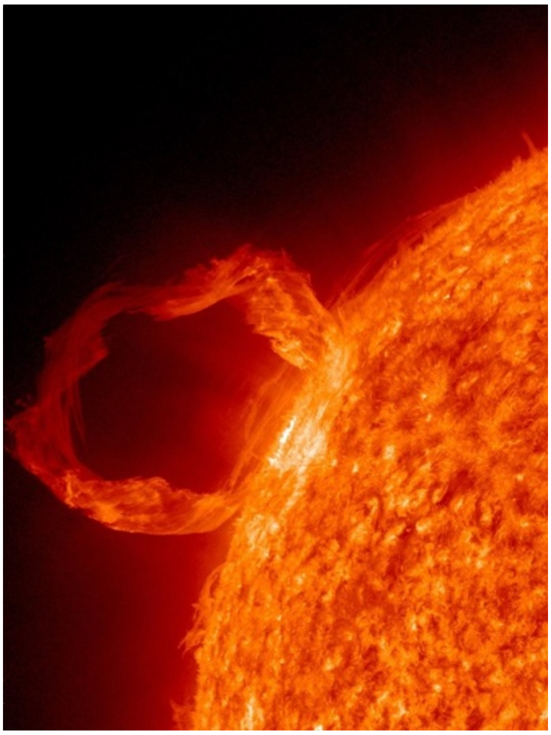

Figure 20: Poster used in Own Images[6]