

# Augmented Reality First Down Line Drawing for American Football Broadcasts

Computer Science MS Capstone Project  
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## Introduction

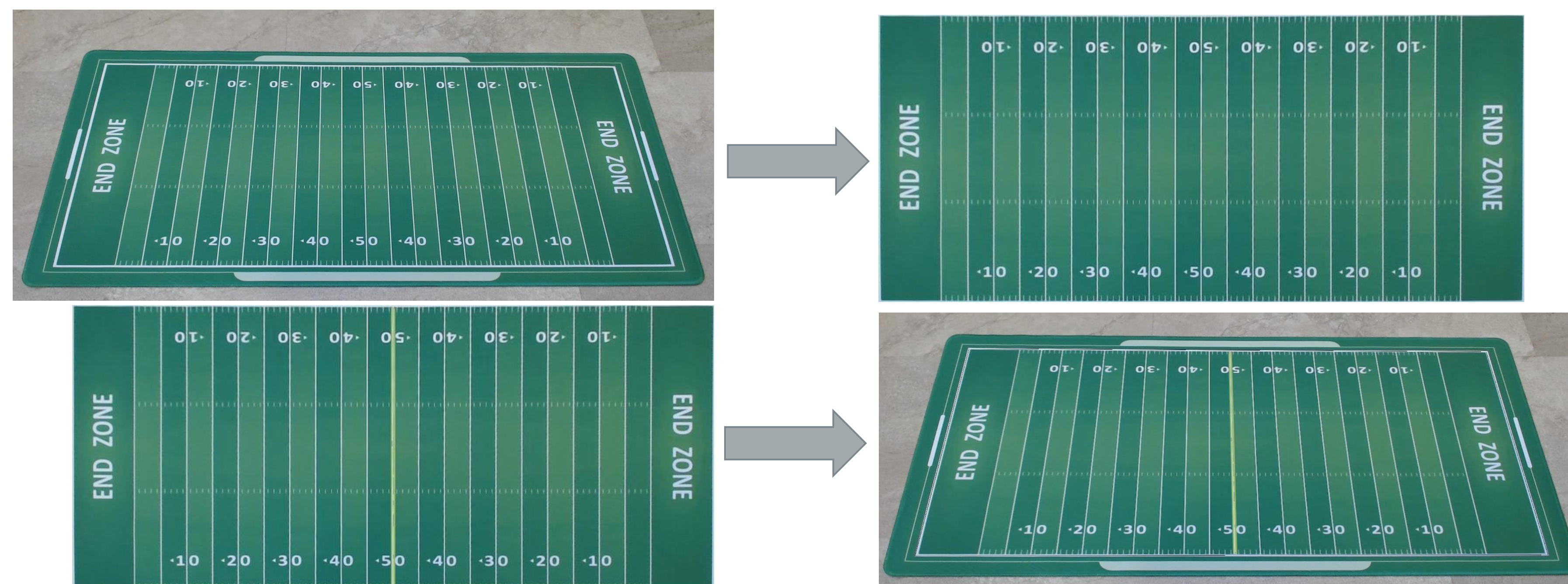
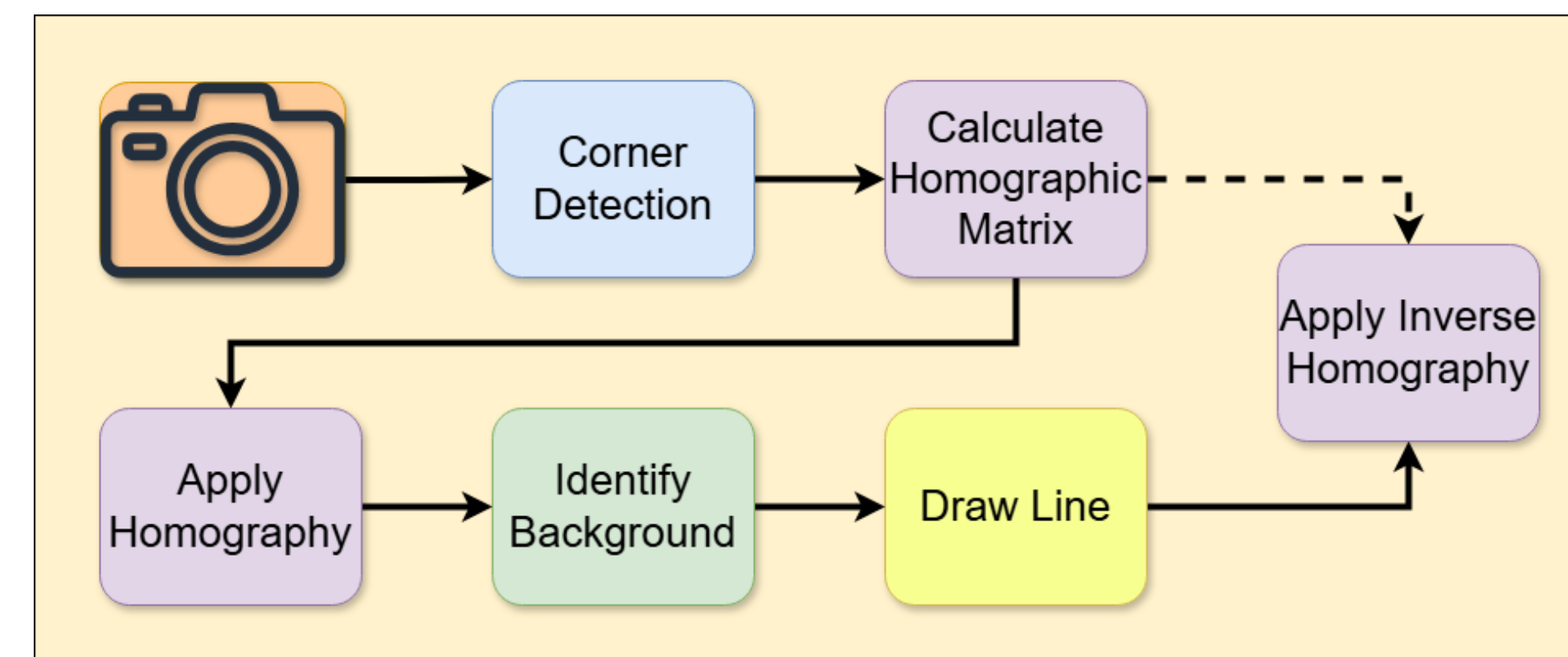
- American football is the **most popular sport** in the United States, with hundreds of millions viewers tuning in every week of the NFL season.
- One of the first things a viewer will notice during the game is the **yellow line** is drawn across the field every play denoting where the first down is. This line helps viewers understand what is going on in the game and makes the **viewing experience better**.
- The goal of this project is to attempt to **replicate the first down line** at a fraction of the price, such that any **lower budget** broadcast of a game will be able to include the line for viewers.

## Background

- The company **Sportvision** created the technology that professional leagues use to add the first down line to their broadcasts. The way it is done is using **specialized mounts** that record the pan, tilt, and zoom of the camera. Additionally, measurements of the field and the **positioning of the cameras** are recorded before the game. Using this data of where the camera is located and pointed, software calculates exactly where the line should be in frame [1].
- This project **removes the expensive mounts and measurements**. The way this is done is by using **corner detection** to identify where the field is relative to the camera.

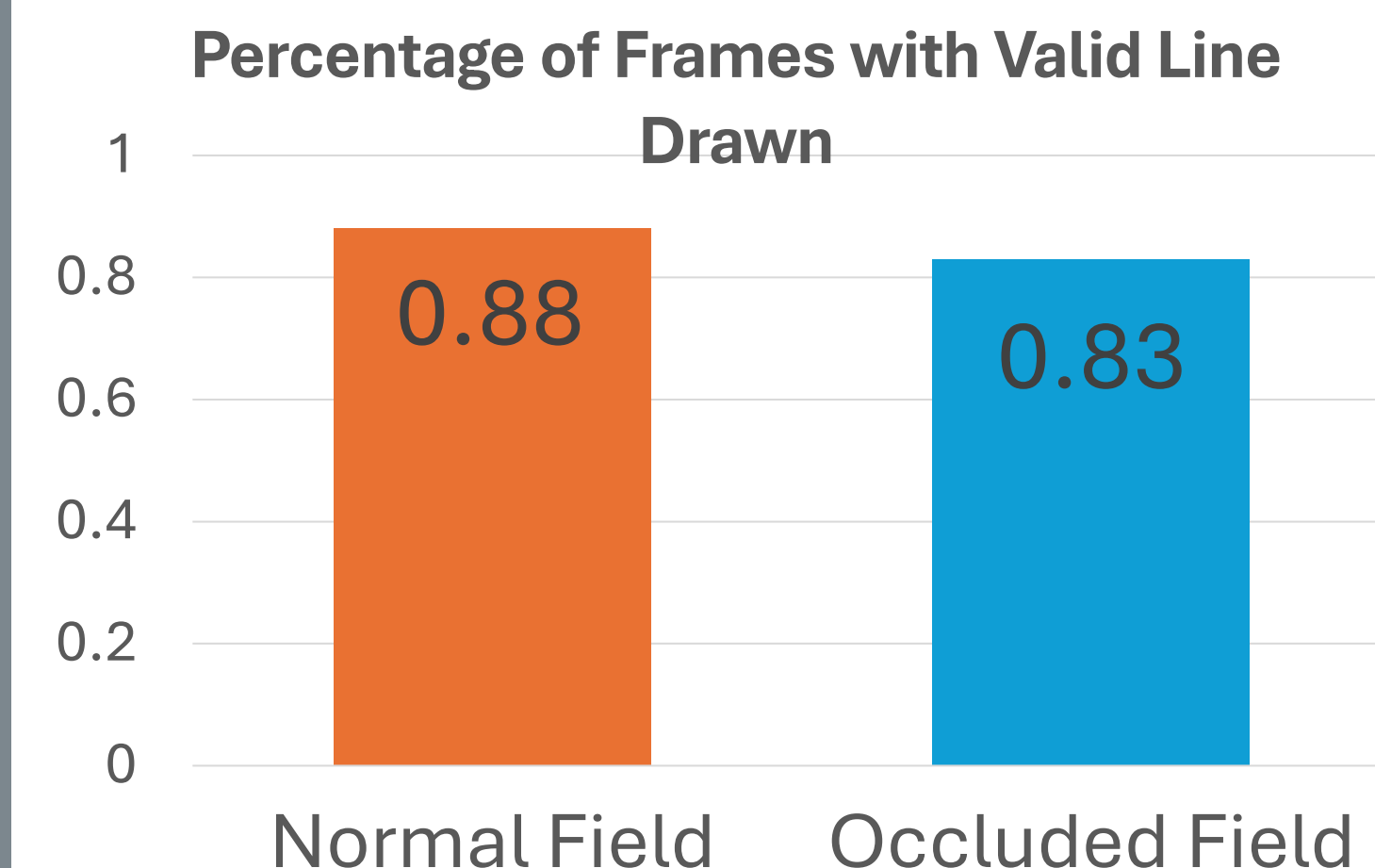
## Project Design

- The first step in the project flow is **receiving the video** of the field from the camera. Once we have the video, we can take the individual frames from it and send it to different threads to be processed.
- The first step in processing is **to find the corners of the field**. This includes some preprocessing and using the **Harris Corner Detector** to find the corners of the field. The Harris Corner Detector works by finding locations in the image with high gradients in the horizontal and vertical directions.
- Once we have the corners we know where the field is relative to the camera. We then take each corner of the field and define arbitrary vertices of a rectangle, being the top-down rectangular view of the field. We are then able to **calculate a homographic matrix** that can transform each pixel in the image to match the ideal shape we defined. Additionally in this process we can calculate the **inverse homography** to transform the warped image back to the original shape.
- After calculating the homographic matrix, we then need to apply it to our base image by **multiplying each pixel's location** by the homography matrix resulting in the new position and our new shape.
- At this point in the process, we are ready to start drawing our line. To do this we first have to **identify the background**. We do this by analyzing the **color of the pixels** to check if they **fall in the range of green values** found in the field.
- We then **draw a straight vertical line** from the top of the field to the bottom with the horizontal position being calculated based on what yard line is input by the user, insuring to only **draw on the field in the background**.
- The last thing to do is to take the **inverse homography** calculated earlier and apply it to the field with the line and replace the old field with our new field line and all.



## Results

- This project was tested on a data set **created for this project**. The data set consists **100 images** of the field, and an additional **100 images** of the field with **occlusions** in the way. Each image has **different angles and lighting** to account for many different scenarios.
- Each image was processed and then **human evaluated** to either have a valid line or not. A valid line is one where the line is drawn in the **correct position** on the field while not drawing **on top** of any objects.
- The results below show that the model is quite accurate at drawing a valid line. Most cases where a valid line is not drawn are images with **very sharp camera angles** or with **dark and bright lighting** in the image.



## Conclusion

This project provides an effective way to recreate the yellow first down line seen in the NFL broadcasts at a fraction of the cost. This is a potential product that can be used for any football broadcast that does not have the means to setup an NFL level production but still wants to maintain the quality that viewers come to expect when watching a broadcast of a football game.

## References

J. Vardalas, "Your engineering heritage: The making of football's yellow first-and-ten line," Dec 2021.[Online]. Available: <https://insight.ieeeusa.org/articles/your-engineering-heritage-the-making-of-footballs-yellow-first-and-ten-line/>