KickFlow Tracker

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Problem, Motivation & Objective

Problem

- Traditional techniques for statistical tracking in soccer often employs the use of paper and pencil, especially on the non-professional level.
  - Limited
  - Lack precision and accuracy
  - Slow
  - Manual
- There is a wealth of information available in videos and images that should be extracted to provide…

Benefits of Computer Vision

Enhance Perception

1

Computer vision improves the ability to interpret and analyze visual information

Insight from Data

2

Extract useful information from visual data

Real-Time Analysis

3

Computer Vision systems can provide instant analysis for decision making

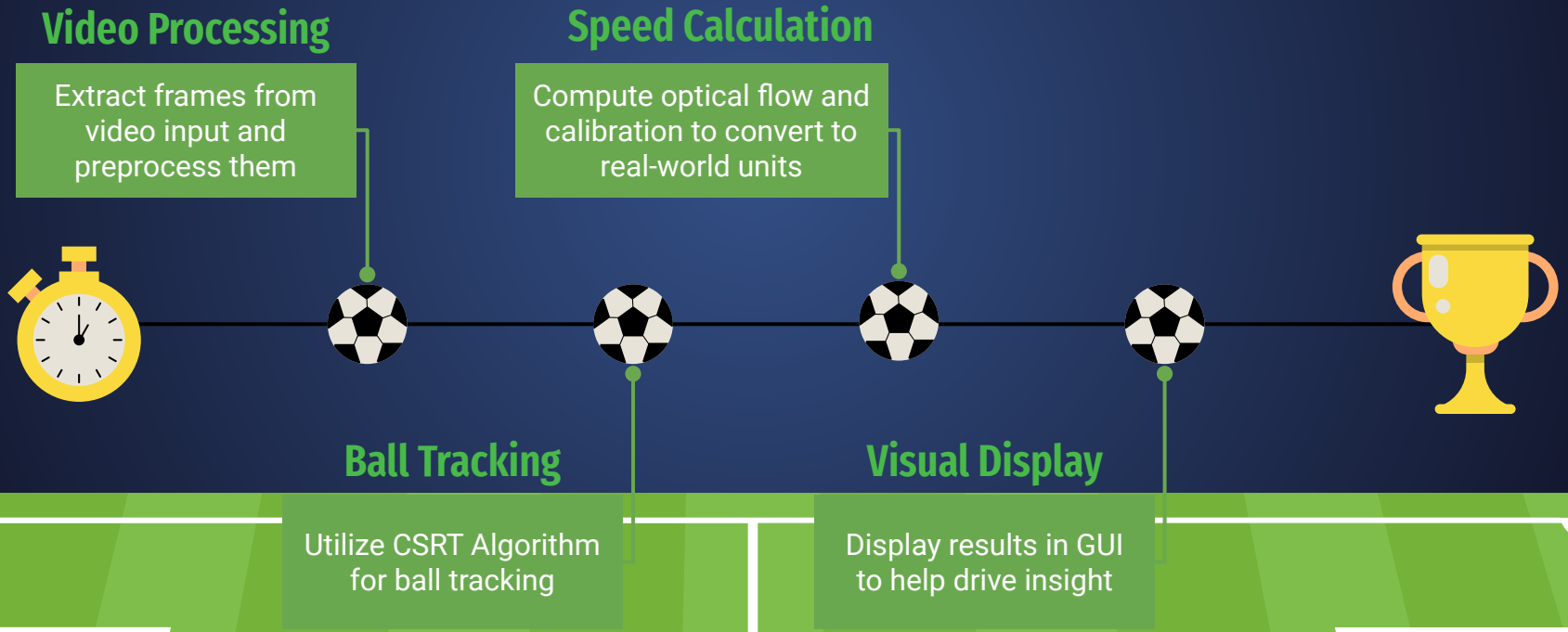
Immersive Experiences

4

Allows for overlays of statistics and visualizations during broadcasts

Objective & Proposed Approach

- Utilize Computer Vision to track a soccer ball and compute its instantaneous speed



Related Work

Related Work

- Multiple studies for player/ball detection and tracking utilize deep learning techniques (Naik et al. 2022):
  - You Only Look Once (YOLO), Single Shot MultiBox Detector (SSD), Variational Autoencoder (VAE)
  - Common tracking difficulties include
    - Complex occlusions
    - Similar appearance of objects
    - Unpredictable movements
    - Unstable camera motion
    - Motion blur
- Orwell et al. 2009 used the Kalman filter to obtain ball paths using features like ground plane velocity, longevity, normalized size, and color
  - Assigns a likelihood measure to estimate the relative likelihood that the obtain paths represent the motion of the ball

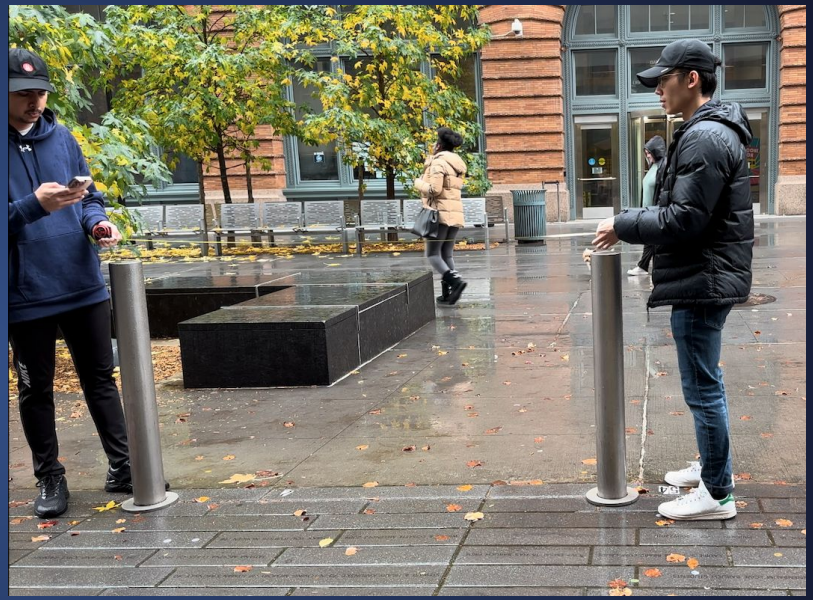
Methodology

Ground Truth

- Measured scene with tape measure
- Ensured fixed camera relative to scene
- Computed the average speed of the ball
  - Number of frames to travel from Point A to B
  - Convert to m/s

$$\Delta Time = \frac{EndFrame\ \# - StartFrame\ \#}{Frames\ Per\ Second}$$

$$Speed = \frac{\Delta Distance}{\Delta Time}$$



Camera Calibration

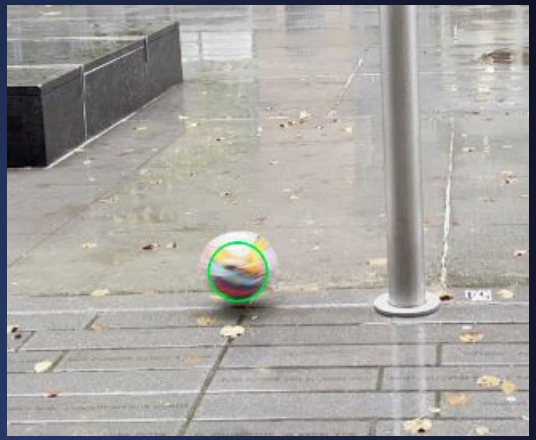
- Created calibration pattern
- Found and defined object and image points
- Computed Camera Calibration
  - Direct Linear Transform (DLT) Algorithm

$$M_{int} = \begin{bmatrix} 3796.232 & 0.000 & 544.075 \\ 0.000 & 2877.279 & 959.079 \\ 0.000 & 0.000 & 1.000 \end{bmatrix}$$

$$f_{phone} = 24mm$$

Soccer Ball Detection & Tracking

- Preprocessing
  - Grayscale
  - Gaussian Blur w/ 9x9 Kernel
- Object Detection Initialization
  - Hough Transform (CHT) for detecting circles
- Object Tracking
  - Channel and Spatial Reliability of Discriminative Correlation Filter (CSRT)
    - Non-deep learning approach
    - Correlation filter based on the appearance of the target object in the initial frame
    - Correlation to estimate object's position in subsequent frames



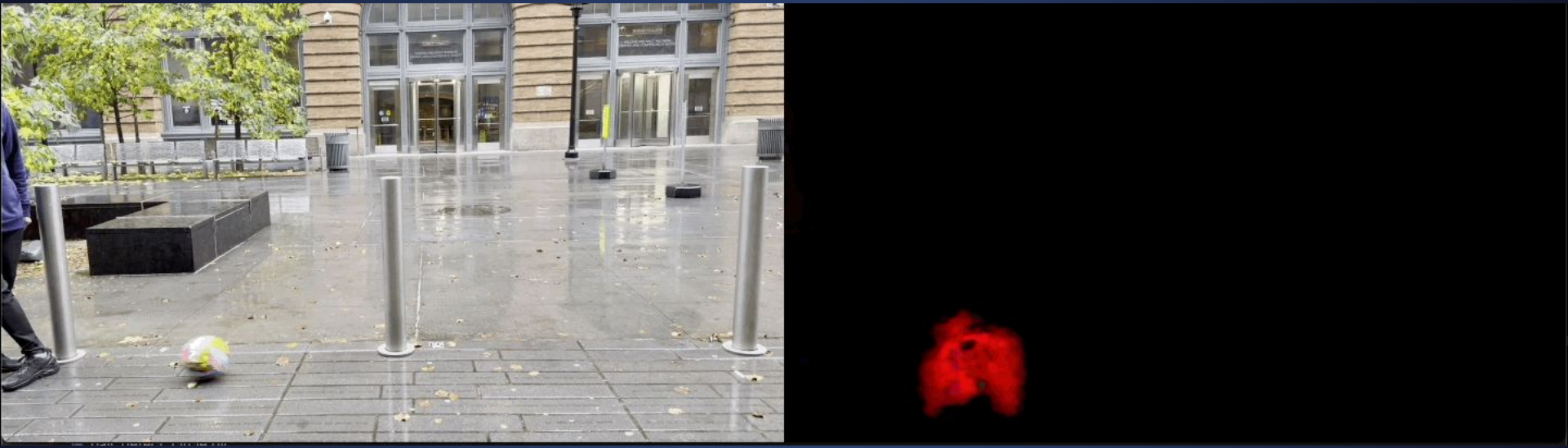
Optical Flow Based Speed Computation

- Optical Flow
  - Apparent motion of pixels between consecutive frames
  - Solve for the Optical Flow Equation ⟶ (u,v) = Displacement of Pixels over Time
- Farneback Optical Flow Implementation
  - Estimate Dense Optical Flow
  - Convert from Pixels/Time to m/s using camera parameters

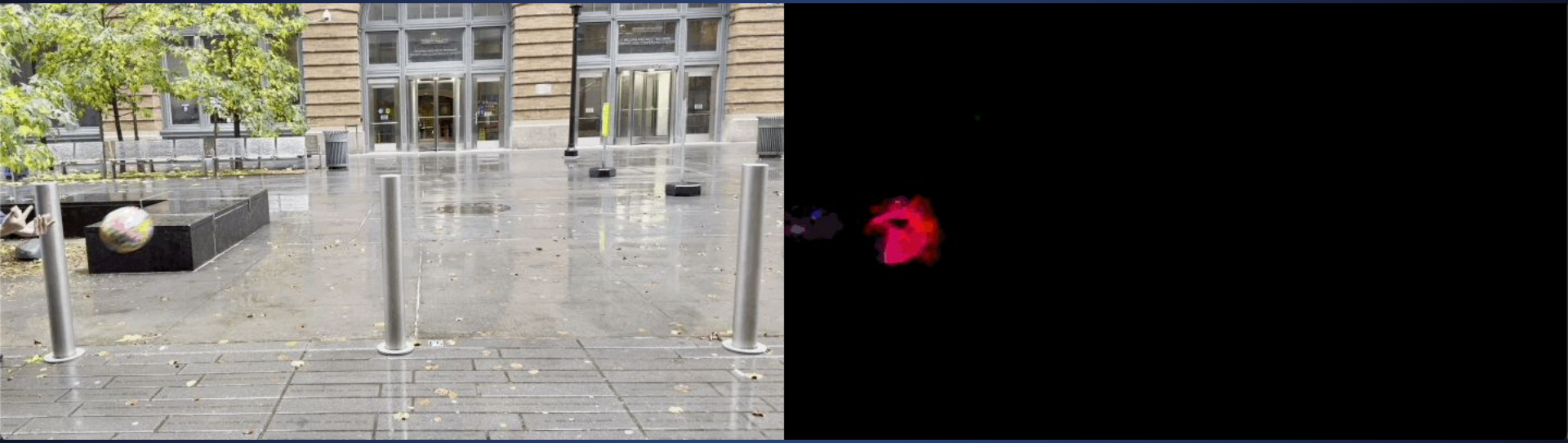
$$\frac{dI}{dx}u + \frac{dI}{dy}v + \frac{dI}{dt} = 0$$

Results & Analysis

Kickflow Tracker



Kickflow Tracker



Evaluation

$$\Delta Time = \frac{EndFrame\ \# - StartFrame\ \#}{Frames\ Per\ Second}$$

$$Speed = \frac{\Delta Distance}{\Delta Time}$$

Ground Truth (distance traveled = 1.8288 meters)		
Trial Number	Number of Frames from Point A to B	Average Speed Calculation (m/s)
1	24	4.57
2	23	4.77
3	20	5.48
4	25	4.39

Evaluation

Ground Truth vs. Estimated Speed			
Trial Number	Ground Truth Average Speed (m/s)	Optical Flow Derived Average Speed (m/s)	Error (m/s)
1	4.57	3.86	0.71
2	4.77	3.36	1.41
3	5.48	4.02	1.46
4	4.39	4.29	0.10

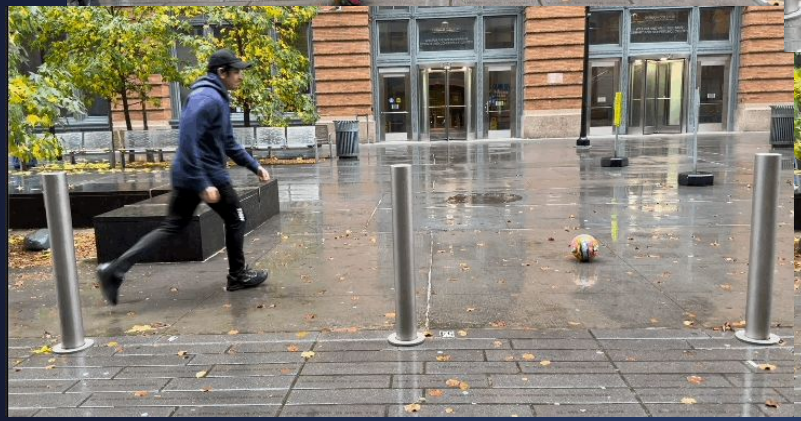
RMSE Error = 1.08 m/s
RMSE Std = 0.65 m/s

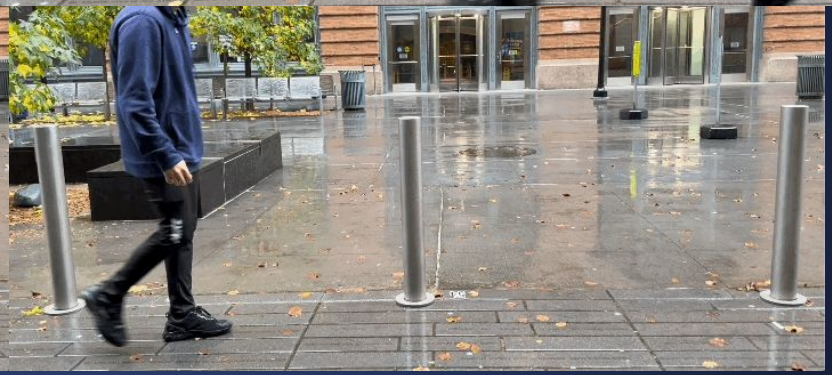
Discussion & Conclusion

Conclusion & Discussion

- Modern object detection and tracking algorithms rely on deep learning algorithms
  - However, this presents barriers to entry…
    - Cost, Technology, Technical, Interpretability
- KickFlow Tracker utilizes non-deep learning techniques to decrease the impact of these barriers so that organizations with less resources can leverage computer vision with their videos
  - Instantaneous Speed
  - Automated ball tracking
- KickFlow Tracker improvements
  - Improved Camera Calibration
  - More robust logic for object detection initialization
  - Additional objects and motions tracked
    - Velocity (speed & orientation)
    - Biomechanics of players kicking

Bloopers





Thank You!

Questions

References

[1] Naik BT, Hashmi MF, Bokde ND. A Comprehensive Review of Computer Vision in Sports: Open Issues, Future Trends and Research Directions. *Applied Sciences*. 2022; 12(9):4429. https://doi.org/10.3390/app12094429

[2] Ren J, Orwell J, Jones GA, Xu M. Tracking the soccer ball using multiple fixed cameras. *ScienceDirect*. 2009. https://www.sciencedirect.com/science/article/abs/pii/S107731420800043X?casa_token=jjFki9U-7jAAAAAA:gaupldu4Zry5lXTewevTU7mYEnr1WbXxX_a53yMcwU1KGWg7UEspGx6w7Panj9wObvKsHTTgddo

[3] OpenCV Documentation. (2023)