Radar-Based Soccer Ball Goal Line Detection System

William Ye (wby5033), Haoxuan Wei (hbw5303) and Md Sultan Mahmud (mqm7099)

Why is a goal at the goal line considered critical?

World Cup Qualifiers

Cristiano Ronaldo's ghost goal costs Portugal direct qualification to 2022 World Cup

Was overruled by referee in absence of goalline technology

Cristiano Ronaldo and his goal that was never in Portugal's 2-2 draw away at Serbia on March 27, 2021.

Hypothesis

Can a radar system, through the analysis of reflections, accurately track a soccer ball crossing the goal line, thus enabling reliable, real-time goal detection?

Challenges

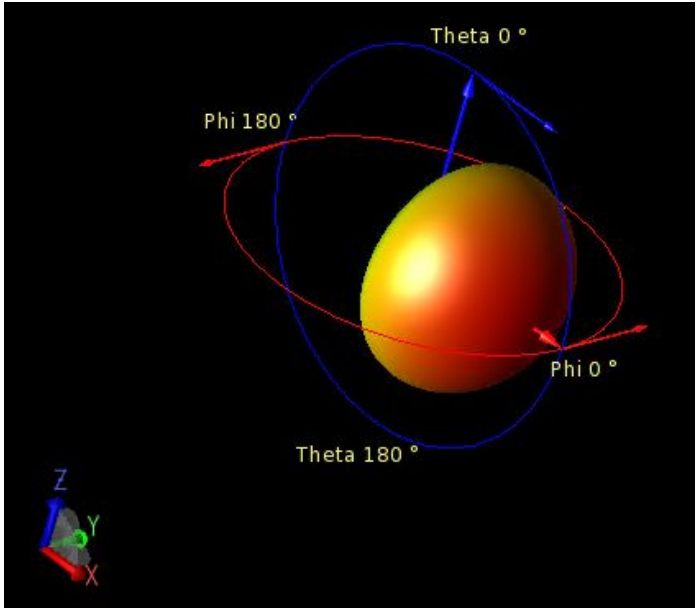
1. Differentiate a soccer ball from other objects such as players, by leveraging object-specific characteristics in radar reflection patterns.
2. Accurately track the soccer ball at the goal line cross section (critical area)
3. Make an automated goal detection system

Background

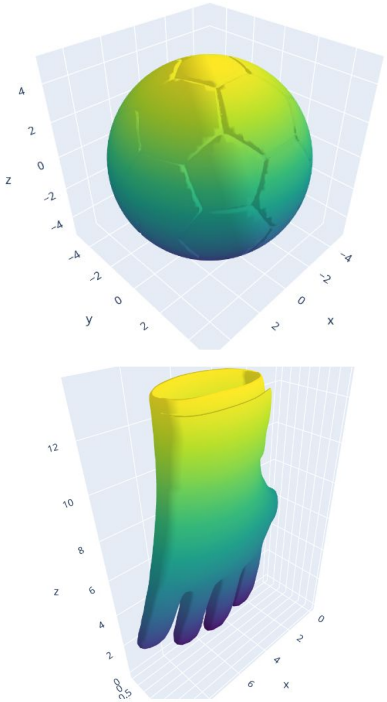
- Radar cross-section (RCS), also called radar signature, is a measure of how detectable an object is by radar. A larger RCS indicates that an object is more easily detected.
- An object reflects a limited amount of radar energy back to the source. The factors that influence this include:
  - the material with which the target is made
  - the size of the target relative to the wavelength of the illuminating radar signal
  - the absolute size of the target
  - the incident angle (angle at which the radar beam hits a particular portion of the target, which depends upon the shape of the target and its orientation to the radar source)
  - the reflected angle (angle at which the reflected beam leaves the part of the target hit; it depends upon incident angle)
  - the polarization of the radiation transmitted and received with respect to the orientation of the target.

Directional Radar

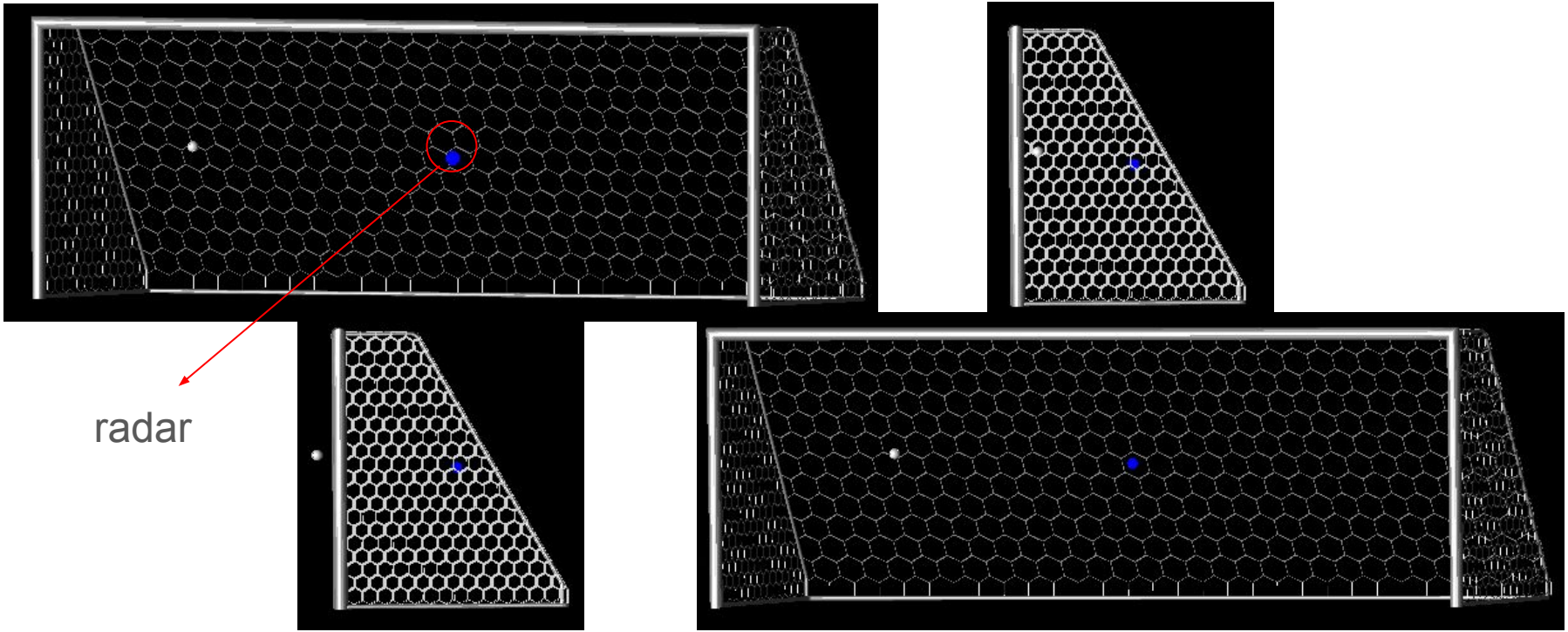
Directional RADAR provides the operator with the ability to select the direction of travel to be monitored.



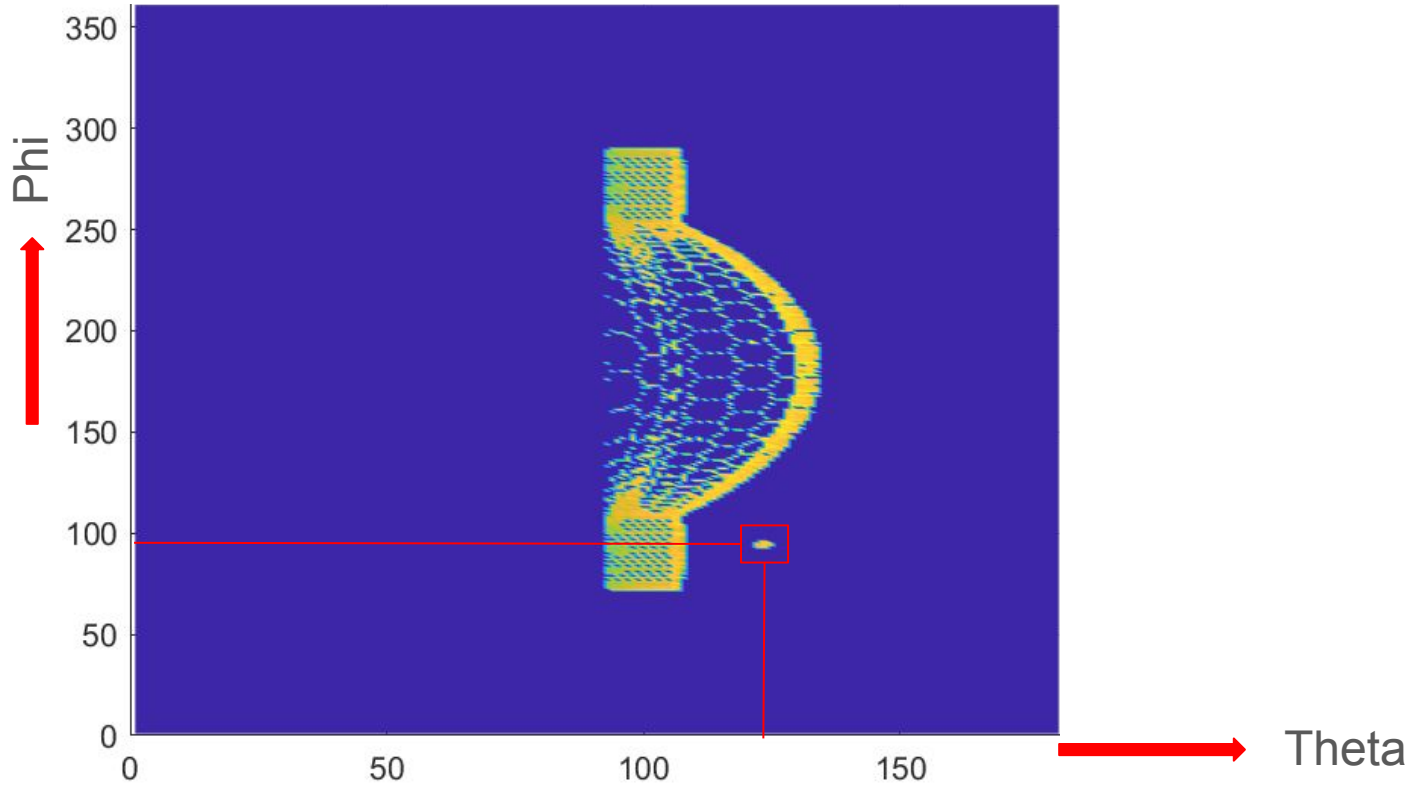
Challenge 1 (RCS vs Observation Angle)



Challenge 2

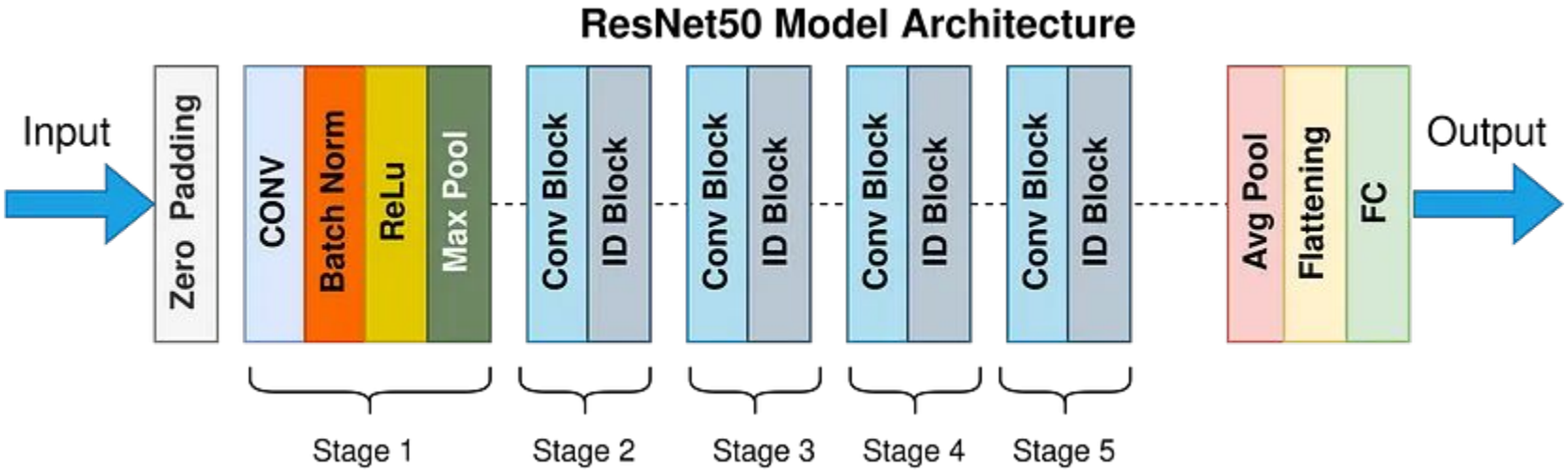


Radar Reflection

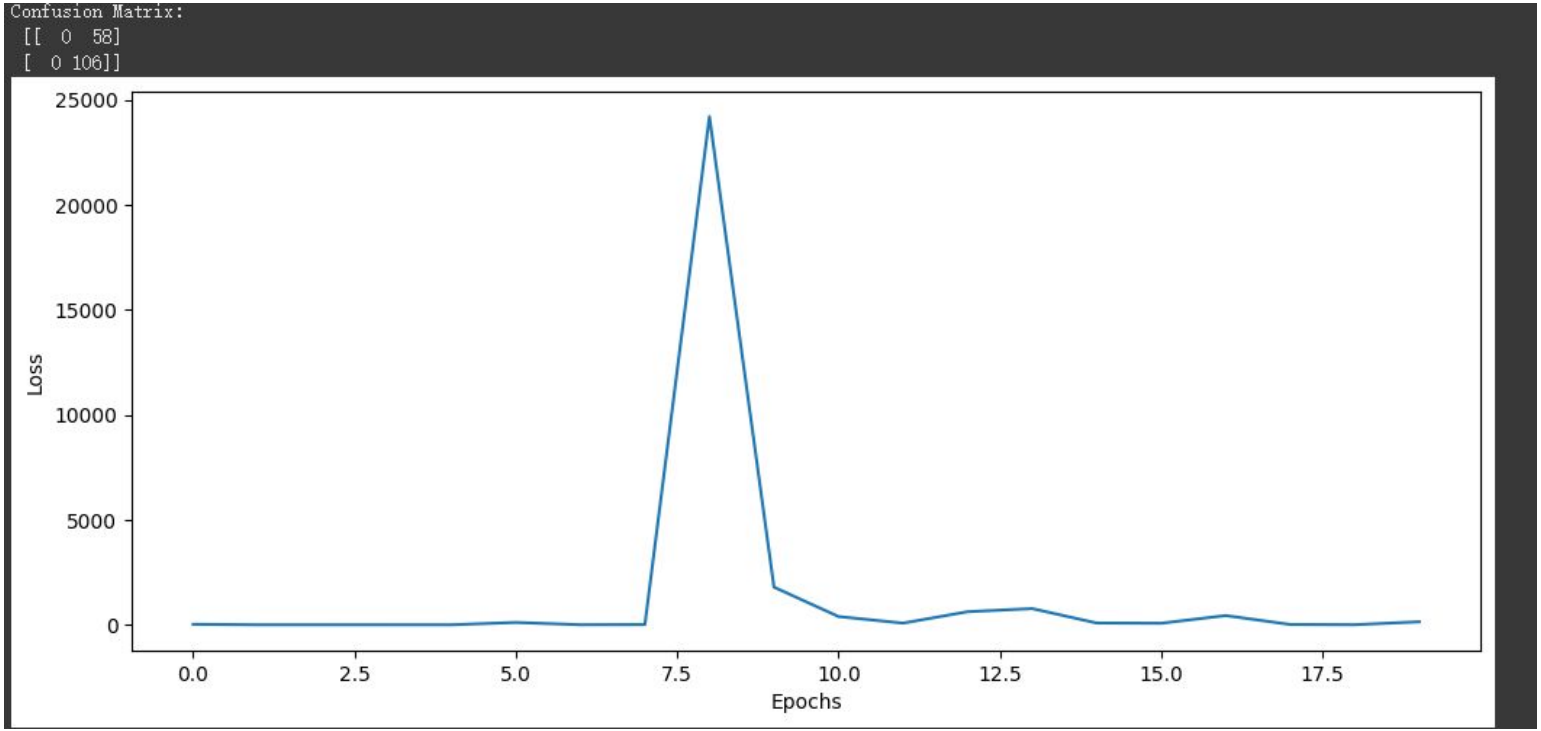


Challenge 3

- Used ResNet50 with ImageNet weights for binary classification (Goal/Not a Goal)
- Input to the model is a 2D matrix (dimension 360*180)



Results



Epoch:20
Batch Size:32

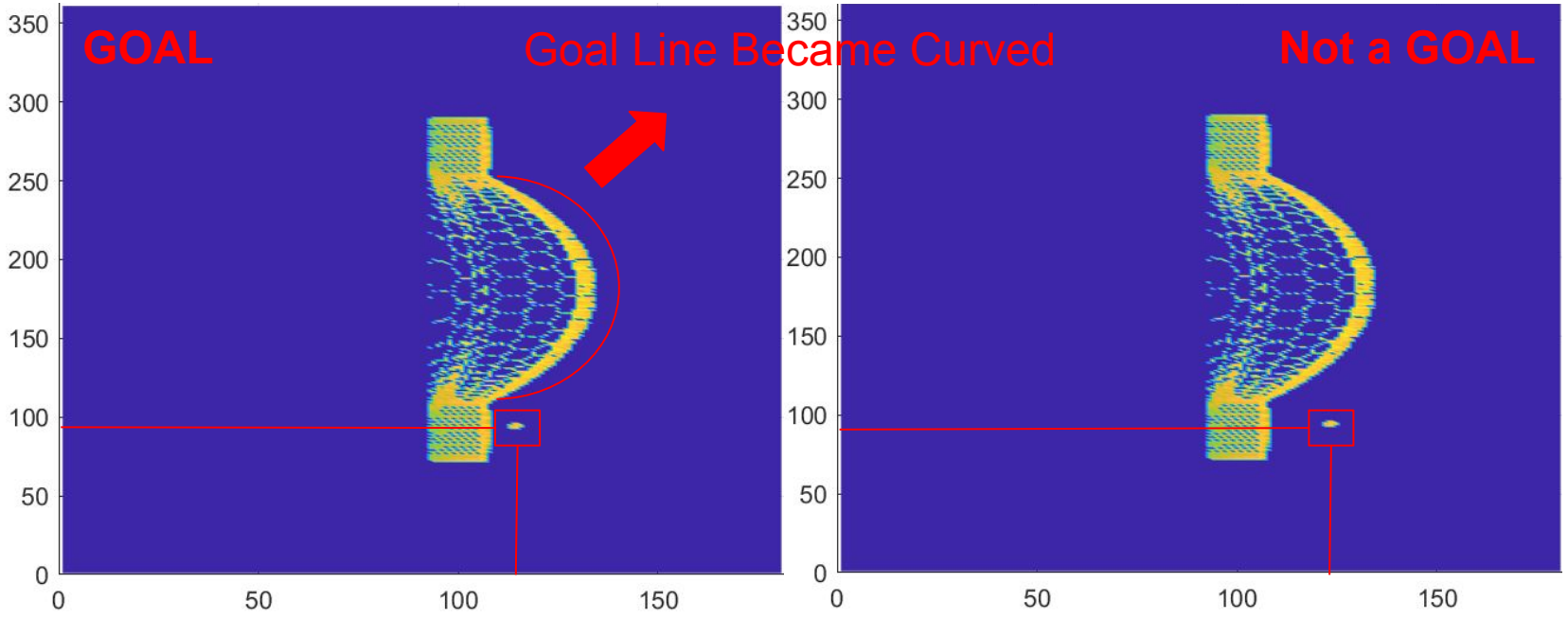
Results

# of Epochs	Batch Number	Best Loss	Which Epoch
100	32	0.6174	10
100	16	0.6292	40
100	8	0.4478	73
100	4	0.5623	33

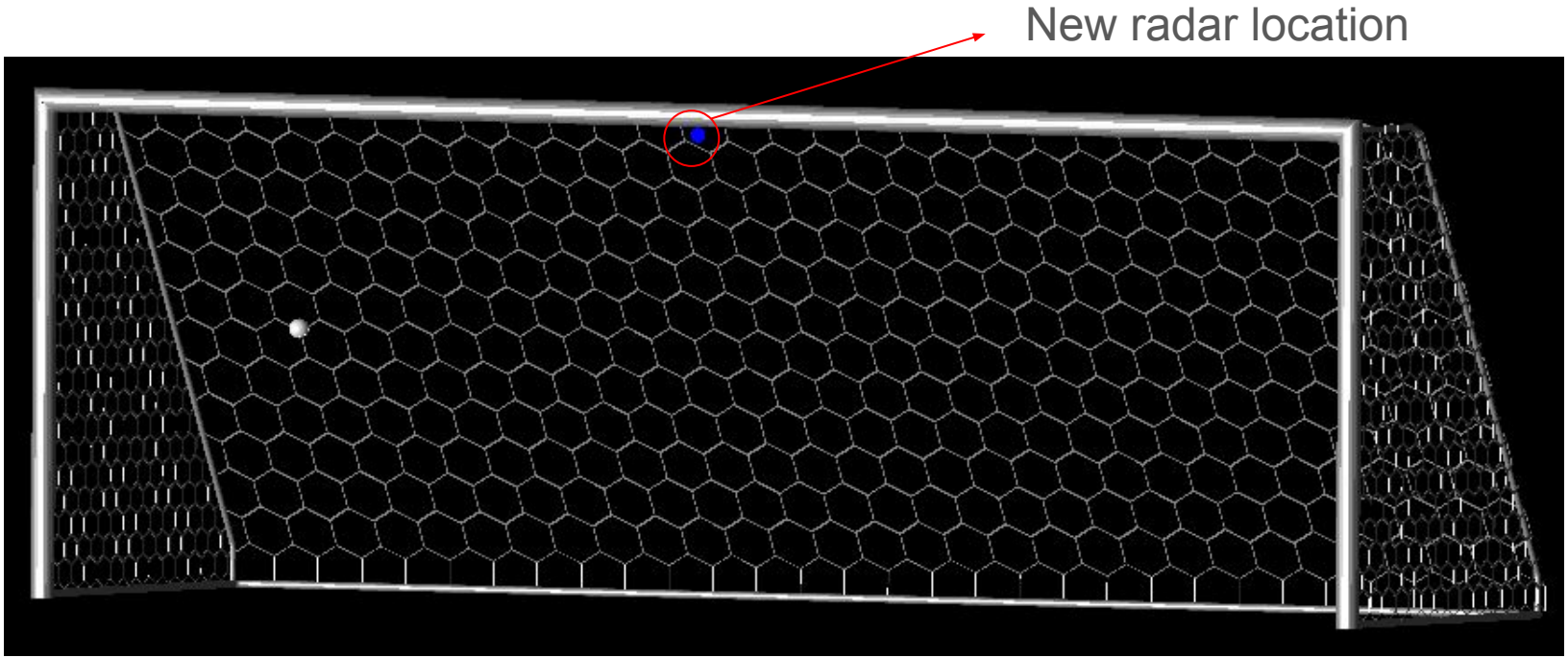
Trying to look for patterns in different batch numbers and different epoch numbers. Loss seems to decrease with lower batch number, but not necessarily directly

Why not a good result?

Radar location matters for a good result.



Why not a good result?



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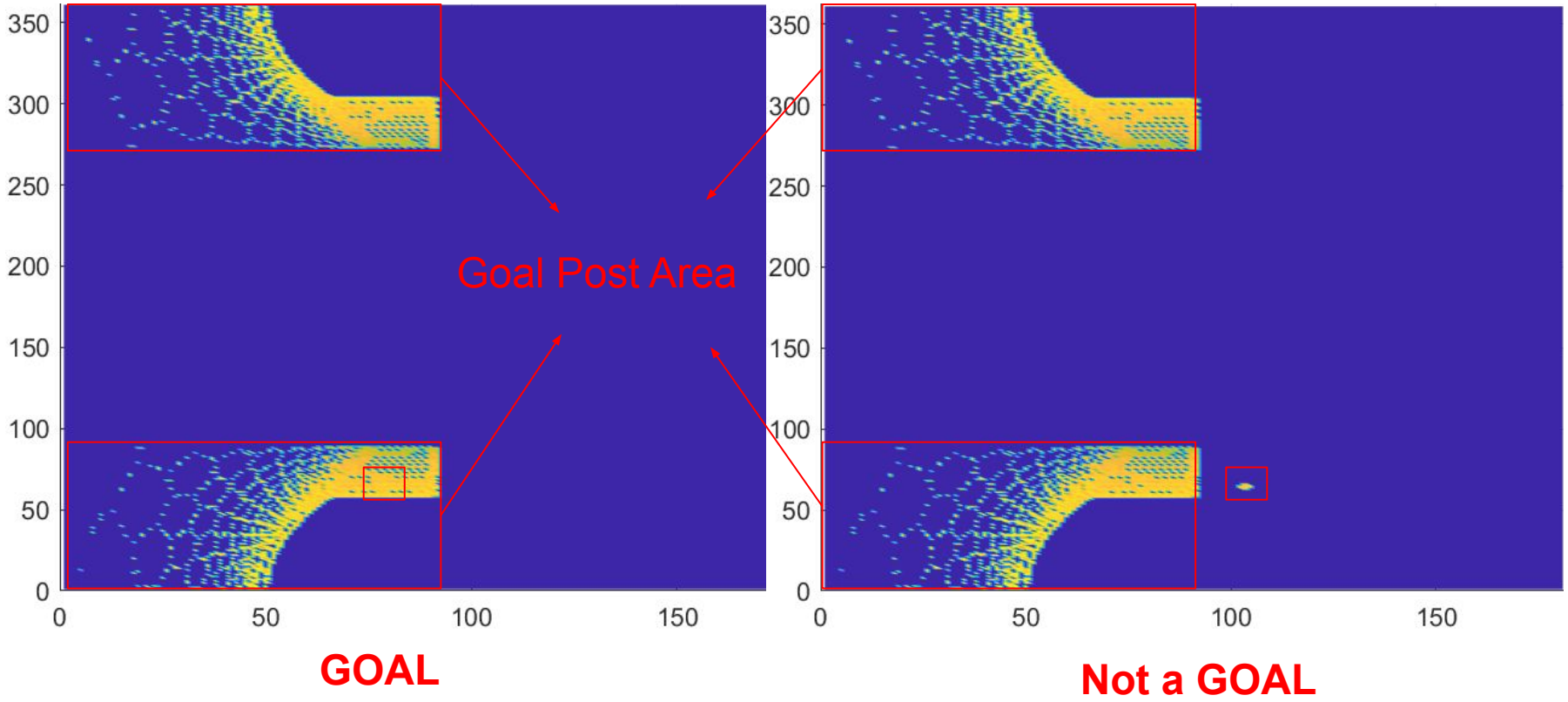

Evaluation Platform

Remcom WaveFarer simulation, Python, Matlab

Conclusion

- RCS characteristic can be easily distinguished for a soccer ball and any other objects in the radar observation area by utilizing techniques like correlation of two signals
- Tracking the soccer ball near goal line is critical but carefully locating the radar will be helpful for this task
- Dataset generation is another significant challenge for this task but domain adaptation will be useful to get a robust ML classifier
- Lastly, radar system will be a less expensive alternative for goal line technology and it is really a necessary thing for a professional soccer game

Thanks!

Any questions?

The link for all of our simulations in WaveFarer is given below.

Final_project.wf