Classifying Open-Air Radar Signals using a Simulation-Trained Machine Learning Network

THESIS

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Abstract

Abstract text here. Put in acronyms, like unmanned aerial vehicle (UAV). Or cite items like with [?] in a bibtex file auto-updated from Mendeley.

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List of Tables

Classifying Open-Air Radar Signals using a Simulation-Trained Machine Learning Network

I. Introduction

1.1 Problem Background

The Department of Defense recognizes the critical importance of the Electromagnetic spectrum – It is a battleground, inseperable from and with equivelent importance to the classical settings of war [1].

1.1.1 Subsection Title Here

Subsection text here

1.2 Research Objectives

Research objectives here.

1.3 Document Overview

Reference chapters and sections like Chapter I or Chapter II.

II. Background and Literature Review

Chapter starting text here.

2.1 First Section Title Here

Text description here, can reference other Chapters or Sections, like Chapter I or Figure 1.

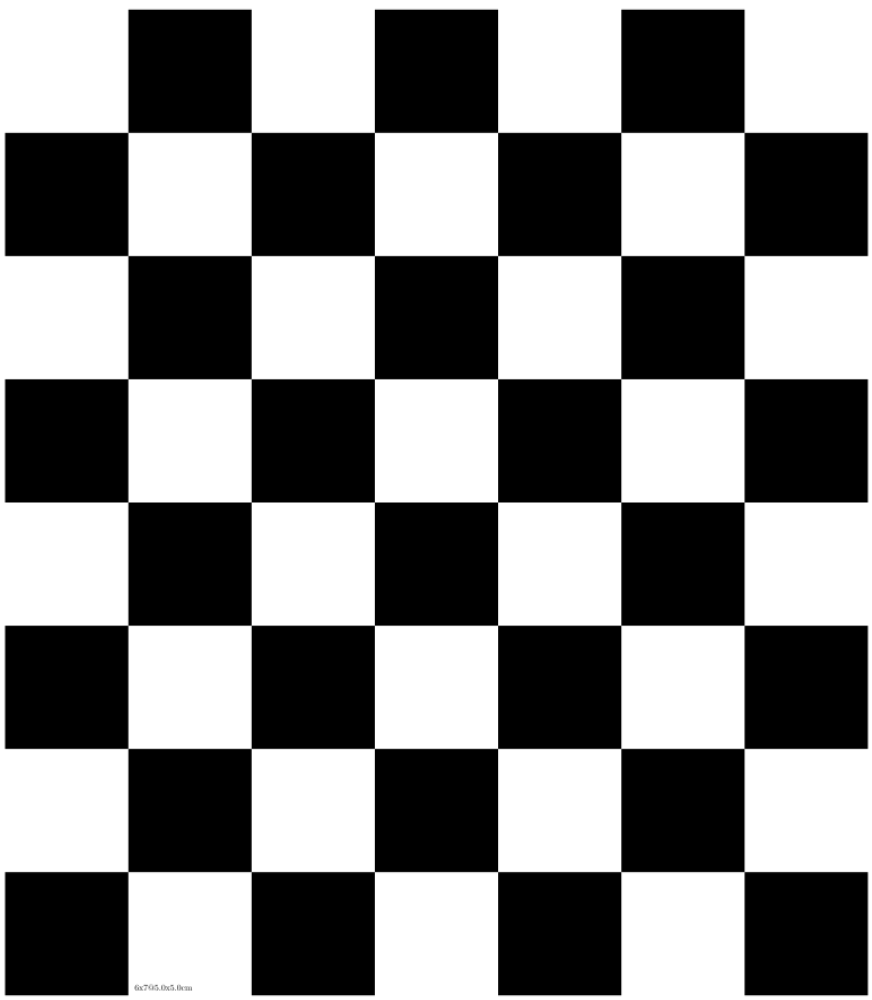


Figure 1: Title shown in text here: short paragraph description of picture here

2.1.1 Subsection Title Here

Take about an equation with text without space, like

$$\frac{1}{z}\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = K \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} \tag{1}$$

where λ can be referenced. Don't put lines before or after equations, unless the equation is the end of a paragraph's discussion.

You can also include an algorithm, like Algorithm 1.

Algorithm 1 Algorithm Title Here

function $\textsc{foo}(a, b, c)$
    $\mathbf{R}_W^{C_0}, \mathbf{p}_{C_0}^W \leftarrow \textsc{getPose}(e_0.t)$ ▷ Target pose
    for $k \leftarrow 1, N$ **do** ▷ Loop over events
        $\begin{bmatrix} x_H \\ y_H \end{bmatrix} \leftarrow \textsc{undistPos}(e_x, e_y)$ ▷ Pixel location to position
    end for
    return *image* ▷ Output
end function

III. Methodology

3.1 Preamble

Preamble text here.

3.2 Calibration

Target measurements are unknown to the observer until they have been calibration. Range calibration is done by first subtracting background measurements from the target data. The corrected target data is then normalized using a ratio of simulated and measured truth data from the calibration object. The calibration object is a 7.5 inch cylinder. Additionally, background measurements are taken for both the calibration cylinder and target mounts. The formula for target calibration is shown in equation 2 [CITE].

$$\sigma_{t,true} = \frac{\sigma_{t,raw} - \sigma_{t,bg}}{\sigma_{c,raw} - \sigma_{c,bg}} \sigma_{c,true} \tag{2}$$

The raw and true measurements for the target and calibration cylinders are $\sigma_{t,raw}$, $\sigma_{t,true}$, $\sigma_{c,raw}$, and $\sigma_{c,true}$ respectively. The background measurements are taken of the target and calibration cylinders mounts, shown in the equation as $\sigma_{t,bg}$, $\sigma_{t,bg}$ respectively.

3.3 Target Selection

This experiment is concerned with identifying the capability of a machine learning algorithm to correctly classify real radar measurements. To examine this interaction directly, targets have been chosen that produce readily measurable radar responses in a compact range. Three targets have been chosen: an oblate spheroid, a prolate spheroid, and a surrogate missile. The spheroid shapes were chosen due to their similarity, providing a classification stressor to the machine learning model. The surrogate missile has been chosen for three reasons: the nose, tail, and sides of the missile will produce 3 distinct RCS responses; the intensity of the responses for the nose, tail, and sides will be large; it is critically important for a modern military to correctly identify an ingressing missile [CITE SOMETHING FROM UKRAINE...LINK TO WHAT AIR DEFENSE DOING LOL].

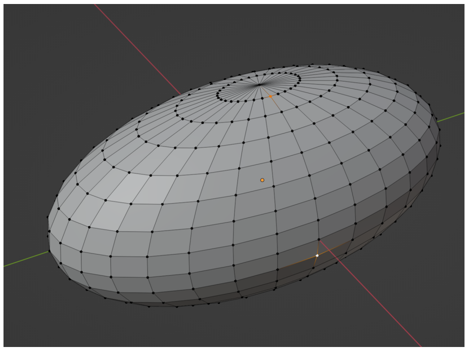
Each target is modeled in Blender 3D, and exported as a .stl file. The .stl file is then imported by FreeCAD, where it is convereted to a solid and exported as a .step file. Blender allows the easy development of complex mesh shapes that do not have "holes" or "seams". FreeCAD, while have more drafting tools, does not handle mesh creation well. Object files developed in FreeCAD and imported by CADFeko were rife with mesh errors, and Altair's CADFeko program does not handle mesh repair well. This development pipeline allowed for custom model development that could easily be imported to CADFeko.

CADFeko produces a final mesh overlay for the .step file. The size and dispersement of polygons in the final overlay are driven by the simulation frequency. "Discuss the sizing of polygons for electromagnetic simulations here, and cite something."

The physical dimensions, electrical length, and expected RCS response for each target will be detailed in the following sections.

3.3.1 Prolate Spheroid

The prolate sphere is oblong, measuring 6 inches along its longest axis, and 3 inches at its widest. The height and width of the prolate spheroid are equivalent.



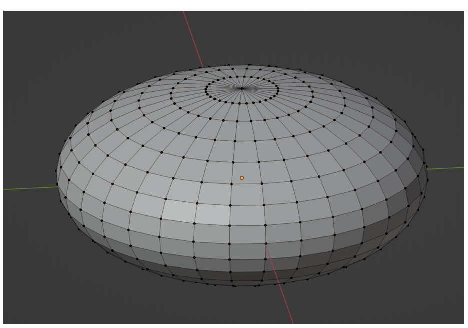
(a) Prolate sphere modeled in Blender 3D.

(b) Mounted prolate sphere.

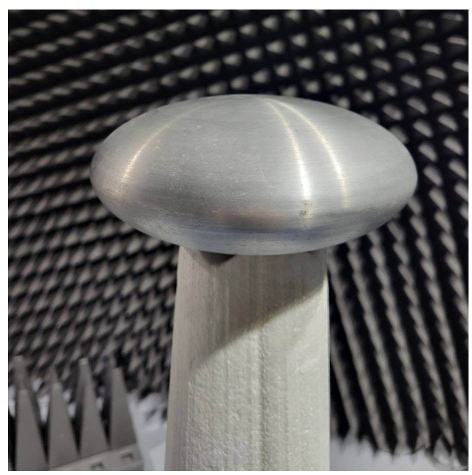
Figure 2: The simulated and physically mounted prolate sphere.

3.3.2 Oblate Spheroid

The oblate spheroid is rotationally symmteric, with a radius of 6 inches. The poles of the spheroid are 3 inches apart.



(a) Oblate sphere modeled in Blender 3D.



(b) Mounted oblate sphere.

Figure 3: The simulated and physically mounted oblate sphere.

3.3.3 Missile

IV. Results and Analysis

4.1 Preamble

Preamble text here.

4.2 Section Title

Reference equations a little differently like (1). Or reference a table like Table 1.

Table 1: Table Title Here

Description	**Variable**	**Value**
Focal lengths	f_x	198.444
	f_y	198.826
Image Center	c_x	104.829
	c_y	92.838
Radial Distortion	k_1	-0.394
	k_2	0.156
	k_3	0
Tangential Distortion	p_1	-0.125×10^{-3}
	p_2	-1.629×10^{-3}

V. Conclusions

Conclusion text here.

5.1 Future Work

Text here

- Item 1 text here.
- Item 2 text here.

Appendix A. Additional Results

Appendix B. Second Appendix Title

Bibliography

1. R. M. Hoffer. 2020 Department of Defense Electromagnetic Spectrum Superiority Strategy. US Department of Defense https://www.defense.gov/News/Releases/Release/Article/2397850/electromagnetic-spectrum-superiority-strategy-released/. (Accessed: 30 August 2022).

Acronyms

UAV unmanned aerial vehicle. iv

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