Plans to Analyze the Performance of Various Chaotic Systems in a Monostatic Radar

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Table of Contents

Abstract	**p.2**
Overview	**p.2-3**
Problem	**p.3**
Project Goal	**p.3**
Design Specifications	**p.3-4**
Testing Plan	**p.5**
Ethical Considerations	**p.6**
Standards	**p.6-7**
Fall Schedule	**p.7**
References	**p.8**

Abstract

In this paper I discuss the overarching idea of my senior capstone project and I plan to achieve it in the following terms. I introduce the idea of implementing chaos based frequency modulated signals in a monostatic radar configuration and how only the Lorenz system was used in this research. I raise the idea of using other chaotic systems of equations on the same tests that were conducted on the Lorenz system and why it would be useful to compare the results from these tests to the work conducted on the Lorenz system. I then bring up the design specifications and testing plans for the project. Lastly, the materials I need to complete my goals are minimal, and there are a few ethical considerations and industrial standards that I should consider when working on the project.

Project Definition

Overview:

Radar is a fundamental, yet significant part of the defense industry. A prominent area of research in the development of radar is the use of Chaos Theory to generate radar signals. This is due to the inherent properties of chaotic signals in that they are well understood among modern researchers, and can be simulated and analyzed to see their efficiency in a radar system. Additionally, a chaotic signal is useful in radar as it is next to impossible for an outside source to decrypt the information brought by the radar signal. This is because a chaotic system relies on a few initial parameters, and if there is even a miniscule difference in an outside source's parameters and the correct ones, the outside source will be left with a completely noisy signal and have none of the actual information, or indication of how far off their parameters were. The

specific chaotic system of equations that have been used in observing chaos in radar is the Lorenz system.

Problem:

While the Lorenz system has produced satisfactory results, there has yet been sufficient research to compare these results to that of other chaotic systems. Because most of the research was conducted on only the Lorenz system, it is unknown whether other chaotic systems would produce equivalent, or even better results. Additionally, it is unknown if there are certain parameters that a chaotic system would need to have in order to be efficient in simulating and analyzing as a radar signal.

Project Goal:

The goal of my project will be to use different chaotic systems and replicate the research that has been conducted on the Lorenz system and compare my results to find the best chaotic system of equations to use in radar, or to confirm that the Lorenz is the best one. Also, in doing this I aim to find some correlation in the system's parameters, and how it performs under simulation.

Design Specifications

Materials:

- The main component that my project requires is a desktop computer capable of running mass computations (at least 200,000) to produce tests taking no longer than 10 minutes.
- The computer must be capable to run signal processing software such as MATLAB.

Performance:

- The testing framework should allow for tests to properly simulate a radar signal transmission and reception in a monostatic radar system.
- I should be able to confirm or deny whether there is a particular chaotic system that outperforms other chaotic systems.
- The signals simulated should be practical to use in a typical radar system. They should simulate transmission over at least 10 km at frequencies around 1MHz, produce high-resolution Doppler images, be incorporated with external noise, and be tested when in the presence of a radar jammer.
- The simulated waveforms must be able to be processed, analyzed, and evaluated.
- The tests I generate should be 100% repeatable, modular, and comprehensive.
- A successive researcher should be able to able to understand, replicate, and make adjustments to my work without difficulty.

Energy:

- The desktop computer will be powered by a wall outlet for a maximum running time of 10 minutes for a single test.

Safety:

- The project will be safe for everyone to use.

Engineering Standards:

- As the tests are for comparability with previous published research, I will need to abide by guidelines maintained by the IEEE standards of research, as well as the standards upheld by previous researchers.

Testing Plan

Baseline Framework: I will first need to design a baseline framework which embodies the fundamental tests that were used in previous research. The FM signal generation process, as well as the basic processes for signal transmission and reception will be included in this framework.

Chaotic Systems: With my baseline framework set up, I will modify the initial tests to be applicable to a variety of chaotic systems. This will provide some testing consistency in that I can compare the results of the baseline chaotic system with the new systems under the same testing conditions.

Noise Inclusion: With an understanding of the baseline for each chaotic system, I will then include noise to the tests. The results of this test will allow for a more practical analysis as in a real radar system, there is inevitably going to be some level of noise interference.

Jammer Resistance: The final testing configuration will be to implement a radar jammer in an attempt to interfere with the transmitted signals. With the inclusion of a jammer, there will be an additional level of complexity and practicality in my tests, and I will have a more confident conclusion to which system has the most optimal performance.

Ethical Considerations

There are a few potential ethical conflicts that my project could incite. The first ethical concern being that because my project involves simulation based on previous research, I would not be able to read every published work on what I am doing, and thus the project I work on could unintentionally interfere with results or techniques that have already been developed by another project or researcher. Another conflict I could foresee is more vague and indirect, and it involves who uses the system I plan on developing. If a smaller third party has access to my project, and they see the potential in developing a chaotic based radar system, this could lead to competition between a private company and the government. A third ethical issue that may arise from this project could result from possible system failures. Because chaotic based radar systems take on a new form of an older technology system, it is difficult to predict all possible outcomes that could result from using this new system. If the completed radar system were to malfunction while in use, the solution could be costly and detrimental to those who use the technology.

Standards

There are a few IEEE standards that I should keep in mind when designing my project. One of which includes how to determine a safe distance for a person to stay from a radar that is transmitting a signal with bandwidths from 0.5 MHz to 300 MHz [1]. I should be aware of this as if a person were to ever implement chaotic waveforms in a radar system, they would need to be at a safe distance from the actual radar to avoid potential injury. Additionally, I should conform to the IEEE standard definitions and terminology for a radar system [3]. This is the purpose that my research should be consistent with other research, and that I wish to avoid miscommunication

of ideas. Lastly, my project should be consistent with the standards for radar computer modeling and simulation techniques [2]. The methods I use should appropriately correspond to the standards determined by researchers and experts.

Fall Project Timeline

- Weeks 1-2: Layout exactly what specifications must be met
- Weeks 3-5: Begin planning all of the necessary tests, their significance and how they can be achieved
- Weeks 6-10: Learn basic simulation and analysis methods, begin implementing them on fundamental

References

1. “C95.4-2002 - IEEE Recommended Practice for Determining Safe Distances From Radio Frequency Transmitting Antennas When Using Electric Blasting Caps During Explosive Operations.” *IEEE*, standards.ieee.org/standard/C95_4-2002.html.
2. “1597.2-2010 - IEEE Recommended Practice for Validation of Computational Electromagnetics Computer Modeling and Simulations.” *IEEE*, standards.ieee.org/standard/1597_2-2010.html.
3. “686-2017 - IEEE Standard for Radar Definitions.” *IEEE*, standards.ieee.org/standard/686-2017.html.