Projec2_Proposal_Group_H

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Proposal

High Level View

We plan to create a data visualization that tells a story and convert it into an illustration, presenting both the computational and artistic aspects side by side. Our story is about visualizing and understanding different digital modulation schemes from their transmission data in Wireless Communication systems, and the role of modulation techniques in the evolution of wireless communication systems. Our artistic piece will be a 3D printed sculpture representing the insight into different digital communication schemes, along with building the Shiny App.

Motivation

Although Claude Shannon's landmark paper "A Mathematical Theory of Communication [1]" has been out there for more than 50 years, the insight into how digital communication systems work is not widespread due to their complicated and counterintuitive working principles [2]. This is because of their heavy reliance on complex mathematical concepts and the continuous emergence of new theories. Consequently, communication theory can be a challenging discipline to master. Furthermore, developing an intuitive grasp of these concepts often requires significant time and effort. Moreover, the role of digital modulation techniques in the wireless communication evolution is very hard to understand if people only read the mathematical formulations.

Therefore, we will design visualizations that maximize accessibility while acknowledging and preserving the inherent mathematical complexities of the subject matter. More precisely, the working mechanisms and insights of various digital communication schemes are chosen in this project. We are interested in visualizing the working mechanism and performance of widely adopted but lesser-known communication schemes such as:

1. Binary phase shift keying
2. Quadrature phase shift keying
3. Quadrature amplitude modulation with different modulation levels

It is our hope that this visualization project would enhance the interest and appreciation of our viewer for these concepts.

Research Questions

Research Question 1:

How does the choice of modulation scheme affect the performance of a wireless communication system?

Answer: To answer this question, you can compare the performance of different modulation schemes in terms of key metrics such as bit error rate (BER), coding gain, and transmission rate.

Methods of Answering:

- **BER Analysis:** Use R and Matlab to simulate communication systems employing different modulation schemes (e.g., Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM)) and calculate the BER for each scheme. Plot the BER versus signal-to-noise ratio (SNR) curves for comparison.
- **Bit Waveform Mapping Analysis:** The difficult relationship between transmitted bit and their corresponding waveform is visualized to illustrate the special property of abrupt phase change which is an interesting phenomenon.

Plot Charts:

- **BER vs. SNR Curve:** Line plot showing the BER performance of each modulation scheme against varying SNR.
- **Bit Waveform Mapping Analysis:** Overlay plot between data stream and transmitted waveform.
- **3D Surface Plot:** Three-dimensional surface plot showing the relationship between BER performance, energy efficiency, and SNR for different modulation schemes.

Research Question 2:

How do non-orthogonal multiple access schemes perform in terms of superposition coding, successive interference cancellation, and overall spectral efficiency ?

Answer: To answer this question, we first illustrate the superposition coding and successive interference cancellation procedure with some test data. Note that the data are presented as short bit stream to simplify the visualization. After that, we try to analyze the spectral efficiencies of non-orthogonal multiple access schemes compare to its orthogonal counterparts.

Methods of Answering:

- **Superposition coding and successive interference cancellation:** Create serveral data diagram to illustrate these procedures.
- **Spectral Efficiency Analysis:** Calculate the spectral efficiency of non-orthogonal multiple access scheme by measuring the data rate achieved per unit bandwidth. Particularly the unit is bit per second per Hertz. Plot the spectral efficiency versus SNR between non-orthogonal multiple access schemes and orthogonal multiple access schemes for comparison.

Plot Charts:

- **Spectral Efficiency vs. SNR:** Line plot showing the spectral efficiency of multiple access scheme against varying SNR.

Data Collection

We will collect the modulated data of these aforementioned schemes through the use of extensive Monte-Carlo simulations under different transmit power levels of transceivers, which is a practical consideration because most transceivers are battery-limited [3]. After data has been collected, we will visualize the corresponding insight regarding their effectiveness and start to make 3D printed sculptures.

Weekly Plan

Week 1 (12/04 - 14/04):

- Brainstorm ideas for the project (Võ Phi Sơn, Trương Tuấn Vũ, Nguyễn Minh Tường)
- Discuss the feasibility of visualizing digital modulation schemes (Võ Phi Sơn, Trương Tuấn Vũ, Nguyễn Minh Tường)

Week 2 (15/04 - 21/04):

- Develop the project proposal (Võ Phi Sơn, Nguyễn Minh Tường)
- Set up the structure for the repository (Trương Tuấn Vũ)
- Research and gather resources on digital modulation schemes (Nguyễn Minh Tường, Võ Phi Sơn)

Week 3 (22/04 - 28/04):

- Finalize and submit the project proposal (Võ Phi Sơn, Trương Tuấn Vũ)
- Begin designing the Monte-Carlo simulations for data collection (Trương Tuấn Vũ, Nguyễn Minh Tường, Võ Phi Sơn)

Week 4 (29/04 - 05/05):

- Conduct peer review on proposals (Võ Phi Sơn, Trương Tuấn Vũ, Nguyễn Minh Tường)
- Implement and run Monte-Carlo simulations for data collection (Trương Tuấn Vũ, Nguyễn Minh Tường)

Week 5 (06/05 - 12/05):

- Reply to reviews and update the proposal if needed (Võ Phi Sơn)
- Analyze collected data and begin designing visualizations (Trương Tuấn Vũ, Nguyễn Minh Tường)

Week 6 (13/05 - 19/05):

- Create visualizations for the selected digital modulation schemes (Trương Tuấn Vũ, Nguyễn Minh Tường)
- Design the 3D printed sculpture concept based on the insights from the visualizations (Trương Tuấn Vũ)
- Design the R Shiny app (Võ Phi Sơn)
- Set up a meeting with the teaching team if additional help is needed (Võ Phi Sơn)

Week 7 (20/05 - 26/05):

- Refine and finalize the visualizations (Trương Tuấn Vũ, Nguyễn Minh Tường, Võ Phi Sơn)
- Create the 3D model for the sculpture and prepare it for printing (Trương Tuấn Vũ)
- Design the R Shiny app (Võ Phi Sơn)
- Begin drafting the project report (Võ Phi Sơn, Nguyễn Minh Tường)
- Set up a meeting with the teaching team if additional help is needed (Võ Phi Sơn)

Week 8 (27/05 - 02/06):

- Print the 3D sculpture (Trương Tuấn Vũ)
- Finalize the project report (Võ Phi Sơn)
- Finalize the R Shiny App (Võ Phi Sơn)
- Prepare the presentation (Trương Tuấn Vũ)
- Submit the final report and presentation (Võ Phi Sơn)

Reference

[1] Shannon, Claude Elwood. "A mathematical theory of communication." The Bell system technical journal 27.3 (1948): 379-423.
[2] Tse, David, and Pramod Viswanath. Fundamentals of wireless communication. Cambridge university press, 2005.
[3] Tranter, William, et al. Principles of communication systems simulation with wireless applications. Prentice Hall Press, 2003.