

3D Unity Snake Game to Demonstrate Control System Transfer Function in Both Time and S-Domain

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Abstract. The transfer function, a key concept in control systems, is essential for undergraduate engineering students. This study aims to enhance the understanding and appreciation of control systems by visualizing transfer functions. The 3D Snake Game, developed using the Unity game engine, offers a real-time gaming experience that integrates both s and t domain transfer functions. It follows the function path using activated quantization, time, and input settings. The game features customizable settings, including game speed, pin tail, joystick, and collision toggle. It is deployable on Android, computers, and the WebGL online platform. The game was highly effective in the target population of 48 Electronics Engineering students enrolled in Control Systems. The majority of students reported that the game helped them visualize control systems (83.04%, $\bar{x}=4.15$, $p=0.004$), appreciate their applications (89.13%, $\bar{x}=4.46$, $p<0.001$), and apply various transfer functions (85.65%, $\bar{x}=4.28$, $p<0.001$). Additionally, the game was considered presentable (80.00%, $\bar{x}=4.00$, $p<0.001$), aided in obtaining correct settling times (83.91%, $\bar{x}=4.20$, $p<0.001$), and was user-friendly (82.50%, $\bar{x}=4.13$, $p<0.001$). Overall, the 3D Snake Game is a valuable educational tool, enhancing the learning experience by making complex control system concepts more accessible and engaging for students. The game's ability to provide a hands-on, interactive approach to learning allows students to grasp theoretical concepts better and see their practical applications in real-time. This innovative teaching method improves comprehension and increases student interest and motivation in the subject matter.

Keywords: Control system; Snake game; Transfer function; 3D unity; WebGL.

1.0 Introduction

Transfer functions are fundamental in control systems engineering, simplifying complex systems into manageable mathematical models. These models, often expressed through equations, can be analyzed using tools like Laplace transforms and frequency response analysis, aiding in designing controllers to meet specific performance criteria. In the context of visualization and human-robot collaboration, research by Brooks and Szafir (2020) emphasizes the role of visualization tools in enhancing shared control acceptance. Similarly, Vrba et al. (2011) highlight the growing use of technologies like Google Web Toolkit and HTML5 for dynamic user interfaces. As explored by Dichev and Dicheva (2017), gamification in education increases engagement by integrating game elements into learning environments. Studies, such as Boldadora's (2019) study of digital game-based learning in Davao, show that these strategies improve educational outcomes. Bangcaya et al. (2019) found that game-based learning significantly boosts science learning and motivation among senior high school students in the Philippines. Additionally, Sutiango's (2023) study in Pangasinan confirmed the effectiveness of using the Snake Game to visualize control systems, with 90% of participants finding it helpful and 92% appreciating the control systems.

Visualizing transfer functions of high-dimensional systems presents significant challenges due to the inherent difficulty in representing more than three dimensions in a two-dimensional space, as noted by Gribkova et al. (2019). The complexity of poles and zeros in transfer functions further complicates visualization, lacking

straightforward geometric interpretations. Stability analysis aids in identifying these poles and zeros, which are crucial for determining system stability, yet this process is particularly arduous for high-order systems (Jairath, 2020). While various visualizations, such as those by Brooks (2020) in human-robot interaction, Vrba (2011) in production control systems, and Danehy et al. (2009), demonstrate transfer functions' applications, they often require specific hardware. They are limited to niche research interests, making them unsuitable for classroom settings. Undergraduate engineering students encountering transfer functions in control systems courses must grasp their importance, as these functions encapsulate the transformation between the s and time domains, block diagram simplifications, signal flow charts, and applications to electronic and electrical components.

Snake games have proven effective in various educational contexts, such as teaching Pancasila (Setiawan et al.), encouraging walking (Chittaro and Sioni), and fostering children's social-emotional development (Wardhani et al.). However, a gap exists in applying snake games to teach technical knowledge, such as mathematics and transfer functions. International research by Vlachopoulos and Makri highlights the positive impact of games and simulations on learning goals in higher education, while studies by Ghavifekr and Rosdy and Schindler et al. demonstrate the significant effects of ICT integration and digital games on student engagement and learning quality. Local research in the Philippines, such as Boldaroda's work in Davao, Bangcaya's study on gamification in science education, and Bautista and Bautista's research at Bulacan State University High School, supports the effectiveness of digital game-based learning in various subjects. Despite these findings, there remains a gap in applying such methods to the specific technical topic of transfer functions, suggesting a need for innovative approaches like using snake games to enhance visualization and understanding in control systems education. Interviews with electronics engineering department heads revealed a lack of laboratory equipment and dedicated computer labs for control systems, highlighting the need for accessible online tools. A graduating student emphasized the challenges of complex mathematical concepts and programming in control systems, noting the potential of snake games to simplify these aspects by directly solving transfer function characteristics. Research by Sutiango in Pangasinan demonstrated a snake game for visualizing transfer functions using SciLab and WebGL, but this study was limited to three transfer functions. This research proposes using the Unity Game Engine for better optimization and deployment across various platforms, offering customizable transfer functions and parameters such as settling time and rise time.

The research aims to visualize and demonstrate control system transfer functions through gamification, specifically using a Snake game. The objectives include determining how the Snake game reflects control system transfer functions, its applicability and appreciation in a laboratory classroom setting, and how it facilitates deeper comprehension of concepts for students. The hypotheses propose that the responsiveness and accuracy of the Snake game's control system are directly proportional to the precision of the transfer function parameters and button interface and that using the Snake game as a teaching tool will significantly improve students' comprehension of control system dynamics and their ability to predict system behavior, and that employing the Snake game in control systems coursework will lead to a statistically significant increase in students' understanding and application of transfer function principles, as evidenced by positive feedback on learning experience surveys.

Also, the research aims to enhance the understanding of control system transfer functions by integrating video games, specifically the Snake Game, as an educational tool. This innovative approach contributes to motion theory by using transfer functions to manage real-time movements, making the concepts more accessible and engaging for users. Traditionally, transfer functions are explained through extensive book chapters and visual aids like pole-zero plots and block diagrams, but a direct relation to output is often missing. Applying transfer function characteristics to the Snake Game provides immediate feedback on input-output relationships without relying on complex methods like Laplace transforms. By integrating this interactive game into the curriculum, the research aims to demystify complex theoretical concepts, thereby facilitating a more engaging and effective learning experience. Using the Snake Game as a visual aid allows students to interact with and internalize the principles of control systems dynamically, fostering a deeper understanding and appreciation for the subject matter. Furthermore, the research posits that by augmenting traditional teaching methodologies with this interactive visualization tool, students' academic performance and interest in control systems will likely improve. This enhancement aligns with the broader objective of SDG 4, as it not only elevates the quality of education but also encourages students to pursue further studies and careers in this field, contributing to the advancement of global

education standards. In essence, the research can potentially transform educational practices in control systems by presenting a novel approach to learning that is both effective and enjoyable. By doing so, it supports the overarching aim of SDG 4, fostering an environment where quality education is accessible and appealing, thereby equipping students with the necessary skills and knowledge to thrive in an increasingly complex and technological world.

2.0 Methodology

2.1 Research Design

The research designs used are quantitative, descriptive, and experimental.

2.2 Research Participants

Forty-eight participants were selected by obtaining a list of ECE students studying the control system subject under a similar faculty handler. The general participants of the data source are as homogenous as possible and have similar course and subject approaches. Inclusion criteria for the participants must have taken or are currently taking control systems as their subject. This subject is usually given to undergraduate engineering students. The research excludes participants who are non-knowledgeable in control systems subjects. The research still includes whether they have excellent or poor knowledge as long as they have information regarding the control system transfer function.

2.3 Research Instrument

The snake game was done and entirely written by the author. The game would support the directional input from the user, the transfer function, and several behavioral settings for the input, output, and snake characteristics. The snake game was programmed using Unity and deployed through the WebGL engine. This would make the game available on the internet. Their devices can access the online resource face-to-face, as mentioned in the link. A backup device can be used, which the Android version of the snake game has installed on the device. Each user would play the snake game on the device one by one.

The pilot survey was administered in a private university in Pangasinan, Philippines. A registered professional psychometrician analyzed the results and found that the survey was reliable, with a Cronbach's alpha of 0.909.

2.4 Data Gathering Procedure

The researcher informed the participants about the research survey based on other published game-based learning questionnaires and game-based learning analysis research. This was done using Google Forms, an online lecture session through Google Meet, and a face-to-face meeting. The permission to obtain data was requested from their subject teacher in control systems, the department head of their course, and their dean. The survey and experimentation setup were performed individually, both online and face-to-face. The survey and experimentation setup would only be once and would take around one to three hours for the participant, either through online or face-to-face setup. The activity was conducted through their online platform, Google Classroom, and then in a face-to-face session. The activity will not be graded or required; thus, there is no coercion and voluntary participation. The participant can withdraw anytime and can contact the researcher. The data would be removed immediately and deleted.

2.5 Ethical Considerations

The research ensures informed consent from participants 18 years of age and above enrolled in control systems. Participation remains voluntary, with no consequences for opting out or withdrawing. The Data Privacy Act governs data privacy – RA 10173 – which maintains the confidentiality of collected information, including email addresses. The snake game used poses no harm, being virtual and visually designed. Risks are minimal, as the study is fully participant-controlled. Additionally, the research aims to develop a laboratory tool for control systems education.

3.0 Results and Discussion

3.1 3D Snake Game as Visualization Tool for Transfer Functions

Table 1 presents the t-test and descriptive statistics of responses to the snake game as a visualization tool for transfer functions.

Table 1. Analysis of the utilization of snake game as a visualization tool for transfer functions

	t	df	Sig. (2-tailed)	Mean	Percentage	Category
Question 1	3.01	43	.004	3.61	72.3%	Good
Question 2	9.41	47	.000	4.23	84.6%	Very Good
Question 3	1.29	47	.000	4.35	87.1%	Very Good
Question 4	4.42	47	.000	3.71	74.2%	Good
Question 5	6.37	47	.000	3.94	78.8%	Good

The columns of significant meaning are the Sig. (2-tailed), mean, percentage, and category are based on region. The Sig. (2-tailed) is considered significant on 0.05 or 5% significance level since all values are less than 0.05. The mean is calculated using the average and using the statistical tool SPSS. The percentage is obtained by dividing the mean by the total perfect score of the Likert Scale, which is 5. The category is discussed in the table below. The degree of freedom (df) and t-value are used to determine the p-value.

The table shows that the snake game indeed reflects the control system transfer function since the t-domain equation and s-domain equation provided are all correctly represented, as proven by the p-value of less than 0.05, meaning that all questions are statistically different from neutral and proves the hypothesis, the responsiveness and accuracy of the Snake game's control system are directly proportional to the precision of the transfer function parameters and button interface. Thus, accept the alternative hypothesis, the responsiveness and accuracy of the Snake game's control system are directly proportional to the precision of the transfer function parameters and button interface and reject the null hypothesis. The Snake Game's Graphical User Interface (GUI) is as interactive, more customizable, and responsive as the research by Sanchit Gupta and Ashutosh Kumar (2017)

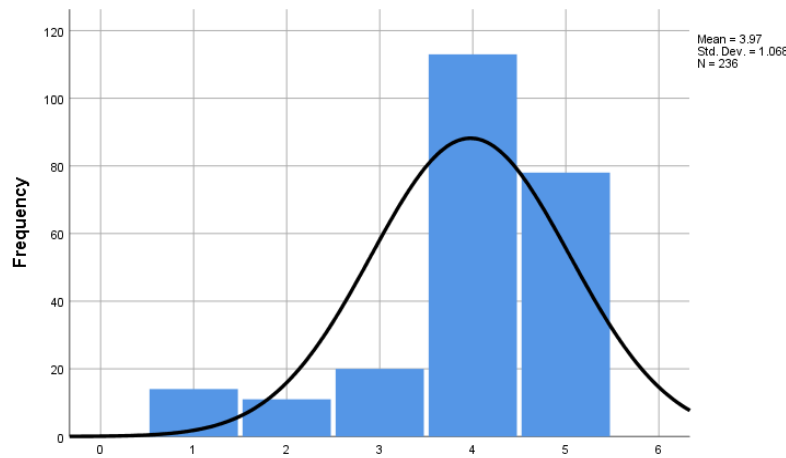


Figure 1. Frequency distribution histogram with normal curve on the responses of the questions on snake game as visualization tool for transfer functions

Forty-eight students answered the survey and found that question 3, the normal snake game, got the highest score. This is due to the assumed high level of knowledge of the participants of the classic Snake. This is also proven by Chittaro and Sioni (2012), who is "the classic Snake mobile game, in which users can control the snake." The lowest score is found in question 1, with a mean of 3.61, which is attributed to the technical nature of the transfer function, which now is $1-e^{-x}$. This can be related to feedback from a student who could not place the function. Two other questions also have a mean at line 3, implying that some, at around 20% of the students, cannot follow the provided equation. This can be attributed to how they encoded the functions with proper multiplication sign (*) and parenthesis, as mentioned in the question. Nevertheless, the statistics show that it is statistically significantly different from neutral and was interpreted qualitatively as Good. The last column of the table is categorized using

the Likert scale. [a] The categories are from the division of intervals where 1 to 5 comprises five categories: thus, $(5-1)/5=0.8$ interval. For each interval, it is classified as Very Good (4.2-5.0), Good (3.4-4.2), Neutral (2.6-3.4), Bad (1.8-2.6), Very Bad (1-1.8), which is similar to how Altanis et al. (2018) categories in excellent, ok, and weak in their research.

Figure 1 is obtained by creating a histogram for the frequency of the five questions mentioned. The normal curve shows that the mean is leaning to the right, implying a positive in an agreement as a response. There are still those who answered 1 and 2, which can belong to the 20% who did not agree. Nevertheless, a mean of 3.97, as implied in the skewed normal distribution table, shows an agreeing response.

3.2 Acceptance and Appreciation Towards 3D Snake Game in a Laboratory Classroom Setting

Table 2 presents the t-test and descriptive statistics of responses on the acceptance and appreciation of the snake game in a laboratory classroom setting.

Table 2. Analysis of the acceptance and appreciation towards 3D snake game in a laboratory classroom setting

	t	df	Sig. (2-tailed)	Mean	Percentage	Category
Question 6	11.19	45	.000	4.15	83.0%	Good
Question 7	13.15	45	.000	4.46	89.1%	Very Good
Question 8	10.43	45	.000	4.28	85.7%	Very Good
Question 9	6.160	45	.000	4.13	82.5%	Good

The table shows that the snake game is applicable and appreciated in a laboratory classroom setting since the survey is done in a laboratory setup, and students agree with the provided questions. The p-value is less than 0.000, meaning that all questions are statistically different from neutral. It proves the hypothesis that implementing the Snake game as a teaching tool in a laboratory classroom will significantly improve students' comprehension of control system dynamics and their ability to predict system behavior. Thus, accepting the alternative hypothesis and implementing the Snake game as a teaching tool in a laboratory classroom will significantly improve students' comprehension of control system dynamics and their ability to predict system behavior and reject the null hypothesis. Research by Sofyan et al. (2024) further proves that the snake game is indeed a learning tool and, in their case, can be used for speaking skills.

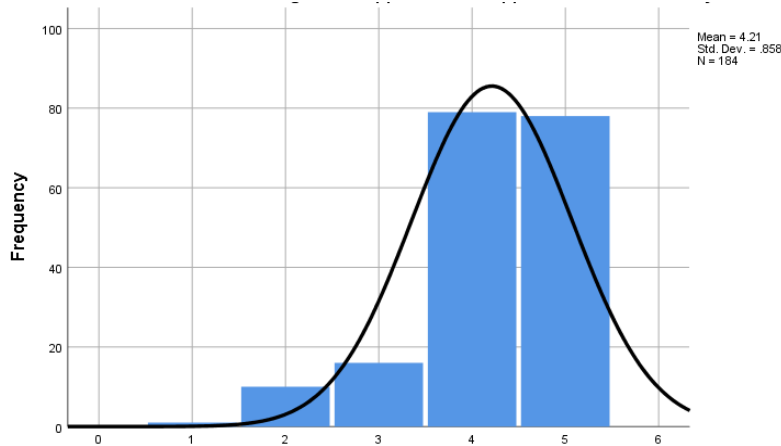


Figure 2. Frequency distribution histogram with a normal curve on the snake game as accepted and appreciated in a laboratory classroom setting

Figure 2 presents a frequency distribution histogram with a normal curve on the snake game as accepted and appreciated in a laboratory classroom setting. The normal curve is skewed to the right. This means that the answer is leaning to the right or in agreement. Some answered 2 and 3, which represent the students around 20% that somewhat disagree with the results. Nonetheless, the questions in problem two still garnered one of the highest mean, which is 4.21, categorizing it as the highest rating of Very Good. Thus, the Snake game is applicable and appreciated in a laboratory classroom setting.

3.3 Deeper Comprehension of the Concepts

Table 3 presents the t-test and descriptive statistics of responses to the snake game, facilitating a deeper comprehension of the concepts for the students. Item no. 10 in the table was item no. 8 in the survey, and item no. 11 in the table was item no. 9.

Table 3. Analysis for the impact of 3D snake game in deepening comprehension of the concepts

	t	df	Sig. (2-tailed)	Mean	Percentage	Category
Question 10	8.542	45	.000	3.91	78.3%	Good
Question 11	10.06	45	.000	4.20	83.9%	Very Good
Question 12	8.307	45	.000	4.00	80.0%	Good
Question 13	8.529	47	.000	4.13	82.5%	Good

The table shows that the snake game facilitates a deeper comprehension for the students. The p-value is less than 0.05 or exactly all at 0.000, meaning that all questions are statistically different to neutral and proves the hypothesis utilizing the Snake game as an educational tool in control systems coursework will lead to a statistically significant increase in students' ability to understand and apply transfer function principles, as evidenced by positive feedback on learning experience surveys. As gleaned from the table, the students could simulate settling time and steady state value accurately and visualize the transfer function with a presentable interface and a user-friendly system. These statements are similar and backed by Hsu and Liang (2021), who claim that games enhance inquiry-based learning in science and imply that games enhance learning in education.

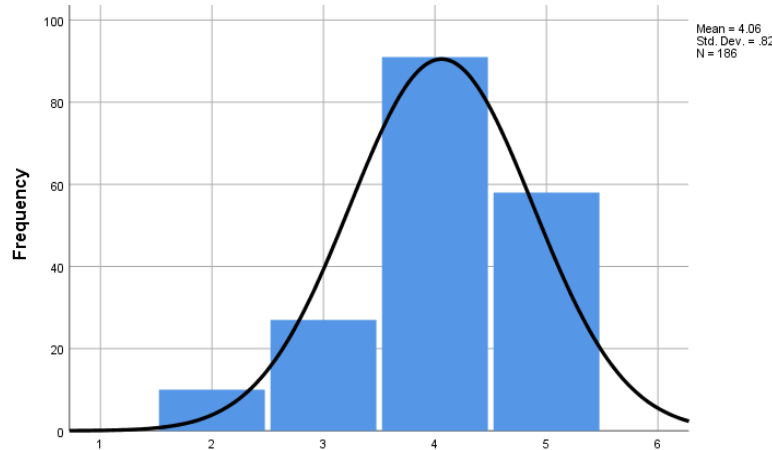


Figure 3. Frequency distribution histogram with normal curve on the responses of the questions on snake game facilitates a deeper comprehension of the concepts for the students

Figure 3 presents the frequency distribution histogram with a normal curve on the responses to the questions on the snake game, facilitating a deeper comprehension of the concepts for the students. The normal curve is skewed to the right. This means that the answer is leaning to the right or in agreement. Some answered 2 and 3, representing the students around 20% who somewhat disagree with the results. Nonetheless, the responses addressing the third problem statement still have a mean of 4.06, which is quantitatively categorized as the Snake game, accurately giving a deeper comprehension of the transfer function concepts. Other research, such as by Rahman and Prasetyo (2020), that correlated the Snake Ladder Game and student learning outcomes and motivation has proven deeper comprehension in learning.

3.4 Sentiment Analysis

Some students (n=9, 19%) gave the snake game negative feedback due to the interface and easiness, but 20 (42%) students gave positive feedback, 14 (29%) with no feedback, and 5 (10%) with mixed feedback using sentiment analysis. The snake game was applicable to college-level mathematics, which is the transfer function, as opposed to the game developed and researched by Bangcaya et al. (2019), which is for senior high school. Both are mathematical and prove that a higher level of math can be demonstrated and further visualized, helping students appreciate and learn better.

4.0 Conclusion

The study on the Snake game as a tool for visualizing control system transfer functions represents a significant advancement in control systems education. The Snake game successfully visualizes complex transfer functions in frequency (s) and time (t) domains, making abstract mathematical concepts more tangible and easier for students and practitioners. Empirical evidence supports the game's accuracy in representing various transfer functions, such as the equation $1 - e^{-x}$ (72.27%, $\bar{x} = 3.61$, $p = 0.004$), the equation 1 (87.08%, $\bar{x} = 4.35$, $p < 0.001$), the function $\{0.7\}/\{s+0.7\}$ (74.17%, $\bar{x} = 3.71$, $p < 0.001$), and the function $1 - e^{-7x}$ (78.75%, $\bar{x} = 3.94$, $p < 0.001$). This validation supports the reliability and accuracy of the game as a teaching tool. Additionally, the Snake game facilitated deeper comprehension of control systems, as evidenced by the population ($n=48$) being able to verify that the settling time of the Snake game matches the function's settling time (78.20%, $\bar{x} = 3.91$, $p < 0.001$), the steady-state value is correct with the time response (83.91%, $\bar{x} = 4.20$, $p < 0.001$), and they can place various transfer functions in the game (85.60%, $\bar{x} = 4.28$, $p < 0.001$). The ability of students to perform the technical side averages 79.37%, implying that they comprehended the control system and could apply it to the given activity questions. Thus, the alternative hypothesis that the Snake game facilitated a deeper comprehension of control system transfer function concepts is accepted.

The educational impact of the Snake game is significant, with students showing improved comprehension of control systems (83.04%, $\bar{x} = 4.15$, $p < 0.001$), appreciation for the subject (89.13%, $\bar{x} = 4.46$, $p < 0.001$), and ability to apply various transfer functions (85.65%, $\bar{x} = 4.28$, $p < 0.001$). The game is also rated as easy to use (82.5%, $\bar{x} = 4.28$, $p < 0.001$), making it accessible to many users. The researcher suggests that the Snake game be part of a laboratory activity in the control system curriculum, particularly during the topic of transfer functions, following the discussion on Laplace transforms. Future studies could explore the inclusion of a broader range of transfer functions, investigate the long-term impact on students' retention of concepts, integrate the game with other educational technologies, develop customizable features, and explore cross-disciplinary applications. By advancing the visualization and understanding of control systems through an interactive and engaging platform, this study paves the way for innovative educational tools to transform how complex mathematical concepts are taught and learned.

5.0 Contributions of Authors

The sole author indeed contributed to each section. The author reviewed and approved the final work.

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7.0 Conflict of Interests

The authors declare no conflicts of interest about the publication of this paper.

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