Semester Long Internship Report

On

Scilab Case Study Project

Submitted by

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July 5, 2024

Acknowledgment

I would like to take this opportunity to express my deepest gratitude to all those who played a crucial role in the successful completion of my internship with the FOSSEE Team at IIT Bombay.

I am immensely thankful to my internship guide, Ms. Rashmi Patankar, for her unwavering guidance and motivation throughout the duration of this project. Her support has been invaluable.

I would also like to extend my heartfelt thanks to all the members of the FOSSEE Team at IIT Bombay for their continuous assistance and encouragement, which greatly contributed to my professional development. This internship would not have been possible without the generous support and help from numerous individuals and organizations, to whom I am sincerely grateful.

Furthermore, I am profoundly appreciative of my parents and the members of KJSCE for their unwavering cooperation and encouragement, which were instrumental in completing this internship successfully.

Contents

Chapter 1

Introduction

Scilab is widely utilized across critical sectors such as space exploration, aeronautics, automotive engineering, energy production, defense technologies, finance, and transportation, owing to its versatility and robustness in both industrial applications and scientific research.

Based at IIT Bombay, India, the Scilab team is dedicated to expanding the adoption of Scilab within educational institutions nationwide. Our primary mission under the FOSSEE (Free and Open source Software for Education) initiative is to empower students and educators by providing free, open-source tools for all their computational needs, thereby enhancing the quality of education and research without the financial burden of proprietary software licenses.

Xcos, Scilab's graphical modeling and simulation tool, plays a pivotal role in this initiative. Xcos enables effective modeling and simulation of complex systems, facilitating research and development across various domains. Additionally, Xcos Cloud by Scilab extends Xcos's functionality to a cloud-based platform. This innovation allows users to create, simulate, and share dynamic models and simulations through a web interface, fostering collaboration among researchers, engineers, and educators without the need for local installations. By leveraging Xcos Cloud, IIT Bombay facilitates efficient development and deployment of simulation solutions, contributing significantly to advancements in engineering, scientific research, and educational practices.

The Case Study Project at IIT Bombay serves as a platform to promote and document the practical application of Scilab and Xcos. It invites Scilab enthusiasts to tackle real-world challenges using Scilab's powerful computational capabilities, including those supported by Xcos and Xcos Cloud. Participation in these case studies not only enhances technical skills but also enhances employability in fields such as engineering and scientific research.

Moreover, the project focuses on addressing complex simulation challenges using Scilab and Xcos, demonstrating their effectiveness in solving high-level technical problems. By documenting successful case studies, IIT Bombay aims to cultivate a vibrant community of Scilab users who actively contribute to its development and application in diverse fields.

Chapter 2

Case Studies

Case studies utilizing Scilab and Xcos demonstrate their effectiveness in solving diverse technical challenges. Scilab serves as a powerful computational tool for numerical analysis, data visualization, and algorithm development, while Xcos provides a robust platform for graphical modeling and simulation of dynamic systems. These case studies highlight how Scilab and Xcos empower users to innovate and address complex engineering, scientific, and mathematical problems through practical application and simulation.

2.1 Finite Difference and Crank-Nicolson Methods for the Heat Equation

This case study explores the application of numerical methods, specifically the finite difference method and the Crank-Nicolson method, to solve parabolic partial differential equations (PDEs) in scenarios such as Heating, Ventilation, and Air Conditioning (HVAC) systems. The focus is on understanding these methods' principles and their practical use in modeling heat distribution and diffusion phenomena. The Crank-Nicolson method is highlighted for its stability and accuracy in discretizing time and space dimensions, crucial for simulating dynamic systems like those in HVAC engineering.

The study addresses the challenge of optimizing indoor conditions in an office building through effective temperature regulation while minimizing energy consumption. By employing the Crank-Nicolson method, the study accurately predicts temperature dynamics over time, essential for ensuring occupant comfort and enhancing energy efficiency in HVAC operations.

Key concepts:

- Equations Used: Applied the heat equation, a parabolic PDE, to model heat transfer in HVAC systems.
- Numerical Methods: Implemented Crank-Nicolson method to solve the heat equation numerically, ensuring stable and accurate results.

- Results: Analyzed temperature distribution across spatial domains using 2D and 3D visualizations.

- Application in HVAC: Studied temperature dynamics to optimize heating and cooling strategies for energy efficiency.

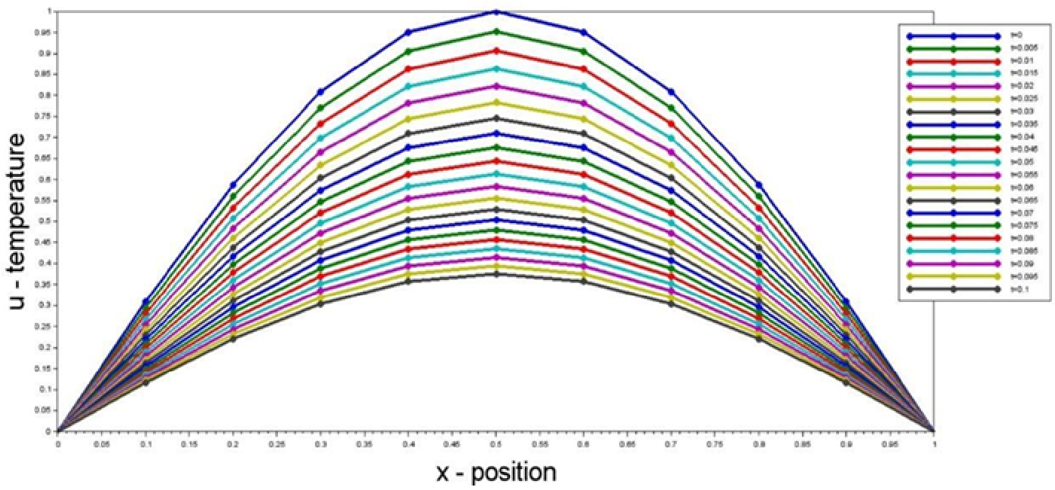
Through visualizations such as 2D and 3D temperature distribution plots, the study demonstrates temperature patterns across spatial and temporal domains within the building. Insights drawn from these analyses enable HVAC users to optimize heating and cooling strategies, improving system efficiency and reducing energy costs.

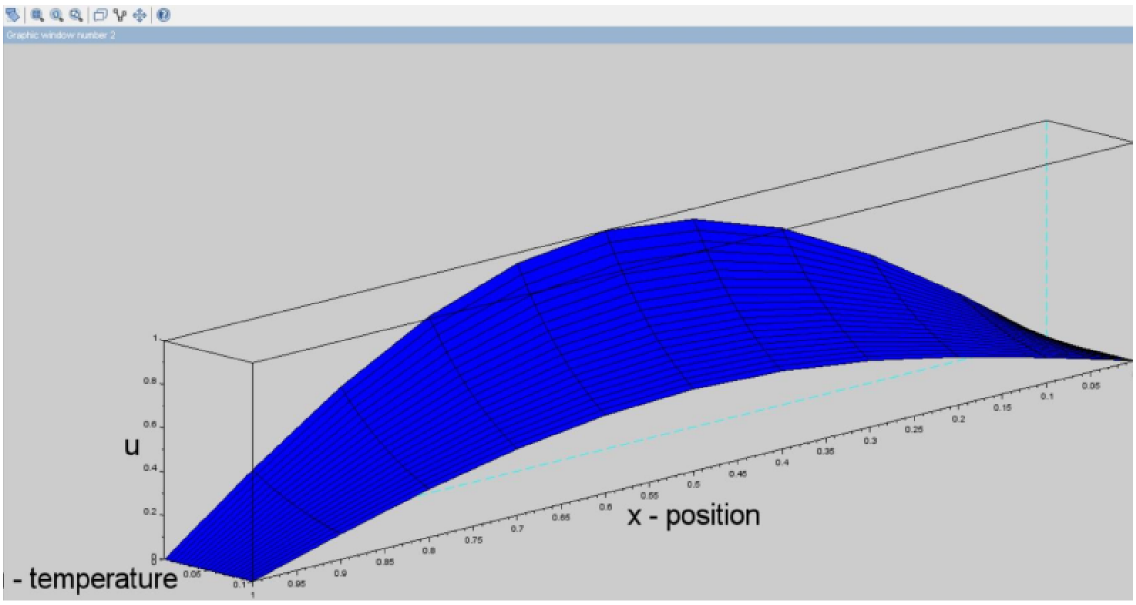
Values are entered as asked in the program.

```
Enter initial position along the x-axis (starting point of the length of the building) (in meters): 0
Enter final position along the x-axis (endpoint of the length of the building) (in meters): 1
Enter step size for x (distance between discrete measurement points along the x-axis) (in meters): 0.1
Enter initial time (starting point of the simulation) (in seconds): 0
Enter time step size (duration of each time step) (in seconds): 0.005
Enter number of time steps (total duration of the simulation) (dimensionless): 20
```

```
"Matrix a:"

 3.   -0.5   0.    0.    0.    0.    0.    0.    0.
-0.5   3.   -0.5   0.    0.    0.    0.    0.    0.
 0.   -0.5   3.   -0.5   0.    0.    0.    0.    0.
 0.    0.   -0.5   3.   -0.5   0.    0.    0.    0.
 0.    0.    0.   -0.5   3.   -0.5   0.    0.    0.
 0.    0.    0.    0.   -0.5   3.   -0.5   0.    0.
 0.    0.    0.    0.    0.   -0.5   3.   -0.5   0.
 0.    0.    0.    0.    0.    0.   -0.5   3.   -0.5
 0.    0.    0.    0.    0.    0.    0.   -0.5   3.

"Matrix b:"

 1.    0.5   0.    0.    0.    0.    0.    0.    0.
 0.5   1.    0.5   0.    0.    0.    0.    0.    0.
 0.    0.5   1.    0.5   0.    0.    0.    0.    0.
 0.    0.    0.5   1.    0.5   0.    0.    0.    0.
 0.    0.    0.    0.5   1.    0.5   0.    0.    0.
 0.    0.    0.    0.    0.5   1.    0.5   0.    0.
 0.    0.    0.    0.    0.    0.5   1.    0.5   0.
 0.    0.    0.    0.    0.    0.    0.5   1.    0.5
 0.    0.    0.    0.    0.    0.    0.    0.5   1.
```

Matrix A represents the coefficients used in the finite difference approximation for calculating the second derivative with respect to space, while Matrix B represents the coefficients used in the implicit time-stepping scheme.





This case study underscores the practical application of computational methods in HVAC engineering, offering valuable insights into temperature dynamics and system performance optimization.

2.2 Predictive Modelling of Housing Prices: A Linear Regression Approach in Scilab

This case study explores predictive modeling techniques applied to housing price analysis in Haryana, India, using Scilab. The dataset includes a comprehensive range of property attributes such as size, location, amenities, and condition ratings. To prepare the data for analysis, preprocessing steps are employed, including handling missing values, normalizing features, and transforming variables to ensure data integrity and suitability for modeling purposes.

The core methodology revolves around the application of linear regression models using the normal equation method. These models are trained to predict housing prices based on the dataset's features. Evaluation metrics such as Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), R-squared, and Adjusted R-squared are utilized to assess the accuracy and performance of the predictive models. These metrics provide valuable insights into how well the models capture and predict variations in housing prices, crucial for stakeholders in the real estate market.

The normal linear regression equation method was used to develop predictive models, trained on a dataset containing 19 features:

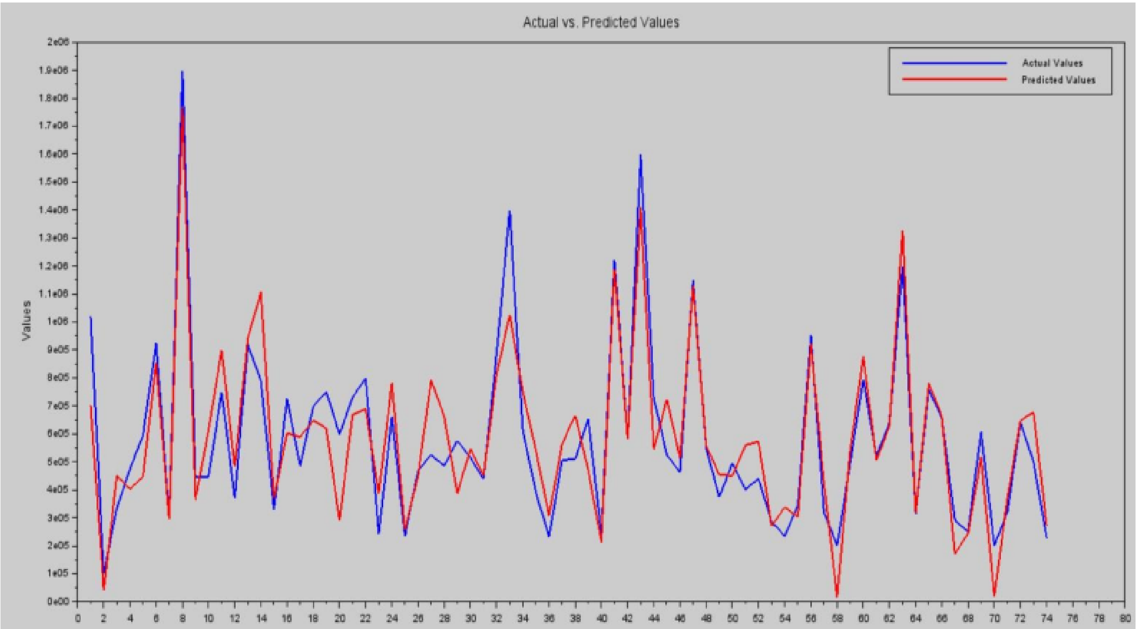
- Number of bedrooms
- Number of bathrooms
- Living area
- Lot area
- Number of floors
- Waterfront presence
- Views
- House condition
- Grade
- Areas of house and basement
- Year built
- Year of renovation
- Postal code
- Latitude
- Longitude
- Living area renovations
- Lot area renovations
- Nearby schools

- Distance from the airport

Key concepts:

- Dataset Preparation: Cleaned data by handling missing values and normalizing features.
- Linear Regression: Implemented the normal equation method for modeling housing prices.
- Evaluation Metrics: Used MSE, RMSE, MAE, R-squared, and Adjusted R-squared to measure model performance.
- Application: Developed a predictive tool for estimating housing prices based on property features.
- Visualization: Graphically compared predicted and actual prices to assess model accuracy.
- Stakeholder Impact: Enabled informed decision-making in Haryana's real estate market.

A significant aspect of this project is its practical application. Users can interact with the developed system to input new data, preprocess it using established techniques, and obtain predictions using the trained models. This functionality empowers stakeholders, including homeowners, real estate professionals, and policymakers, to make informed decisions based on data-driven insights into housing price trends and dynamics in Haryana.



```
Enter value for feature number_of_bedrooms: 3

Enter value for feature number_of_bathrooms: 2

Enter value for feature living_area (in sq.ft): 2010

Enter value for feature lot_area (in sq.ft): 6000

Enter value for feature number_of_floors: 1

Enter value for feature waterfront_present (Binary, 0 for no waterfront, 1 for waterfront): 0

Enter value for feature number_of_views: 0

Enter value for feature condition_of_the_house (Integer, Range: 0 to 5, where 5 represents the best condition): 3

Enter value for feature grade_of_the_house (Integer, Range: 0 to 5, where 5 represents the best grade): 4

Enter value for feature area_of_the_house_excluding_basement ()in sq.ft): 1330

Enter value for feature area_of_the_basement (in sq.ft): 680

Enter value for feature built_year (in years): 1975

Enter value for feature renovation_year (in years): 0

Enter value for feature postal_code (6 digit Integer): 122005

Enter value for feature latitude (Float): 52.92

Enter value for feature longitude (Float): -114.30

Enter value for feature living_area_renov (in sq.ft): 2080

Enter value for feature lot_area_renov (in sq.ft): 8260

Enter value for feature number_of_schools_nearby : 2

Enter value for feature distance_from_the_airport (in kilometers): 78

 "The predicted price of the house/property is 556368.08(INR), which translates to 5.5636808 lakhs OR 0.0556368 crores."
```

Through graphical outputs and numerical analyses, the project visualizes predicted housing prices against actual data, facilitating a clear understanding of the model's performance. Insights derived from these analyses not only validate the predictive capabilities of the models but also highlight areas where the models excel or require refinement. This iterative process of modeling and evaluation contributes to the ongoing improvement and applicability of predictive analytics in real-world scenarios.

In conclusion, this case study underscores the practical application of Scilab-based predictive modeling in understanding and forecasting housing prices. Despite inherent complexities in real estate markets, the developed models offer valuable tools for stakeholders seeking to navigate and capitalize on market trends effectively. By leveraging data-driven approaches, this study contributes to the broader discourse on predictive analytics in real estate, emphasizing its role in enhancing decision-making and strategic planning.

2.3 Optimizing Ride Quality through Damping Adjustment in Automotive Suspension Systems

This case study explores optimizing ride quality in automotive suspension systems through damping adjustments using Scilab and Xcos simulations. The study employs the Spring-Damper-Mass (SDM) model, which integrates mass, spring, and damper elements to simulate complex dynamics crucial for vehicle stability and passenger comfort. The SDM model is fundamental in understanding the interaction between these components and their collective impact on suspension performance.

The suspension system plays a critical role in vehicle safety and comfort by mitigating road shocks and vibrations, ensuring stability across diverse driving conditions. Analyzing and improving ride quality by adjusting damping coefficients within the SDM system under various scenarios is the core focus of this study. By employing both Scilab and Xcos, the study leverages advanced simulation capabilities to explore these dynamics comprehensively.
Key concepts include:

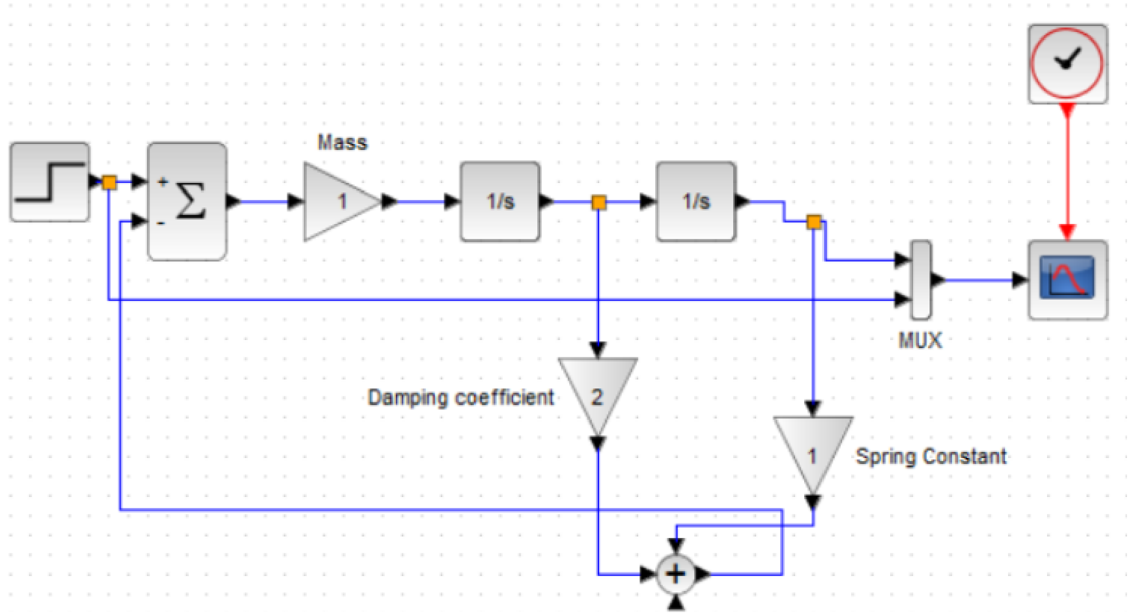
- **SDM Model**: Simulates dynamics in automotive suspensions with mass, spring, and damper elements.
- **Damping**: Controls oscillations and stabilizes the system by dissipating energy.
- **Differential Equations**: Govern motion within the SDM system, essential for understanding vibrations and stability.

Scilab (Version 6.1.1) and Xcos were utilized for the simulations on a Windows 11 platform with an Intel Core i7 processor and 8GB RAM. The procedure involved configuring damping coefficients in the Xcos model, running simulations, and observing system responses under different damping conditions. This approach allowed for a detailed examination of how variations in damping affect the suspension's performance.

Simulation outcomes were graphically visualized, demonstrating distinct behaviors under varying damping scenarios:

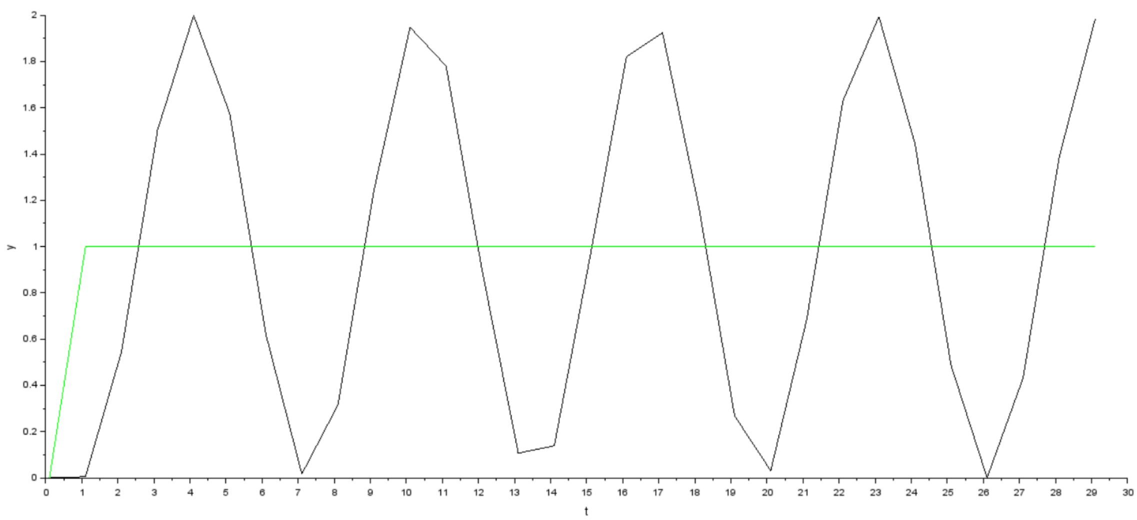
- **Undamped**: Persistent oscillations impair ride quality, compromising comfort and safety.
- **Critically Damped**: Rapid return to equilibrium enhances stability, minimizing bounce for smoother rides.
- **Overdamped**: Slower response with minimal oscillations sacrifices agility for enhanced comfort and stability.
- **Underdamped**: Reduced oscillations improve ride comfort but may require further damping adjustments for optimal performance.

Xcos Simulation Diagram:



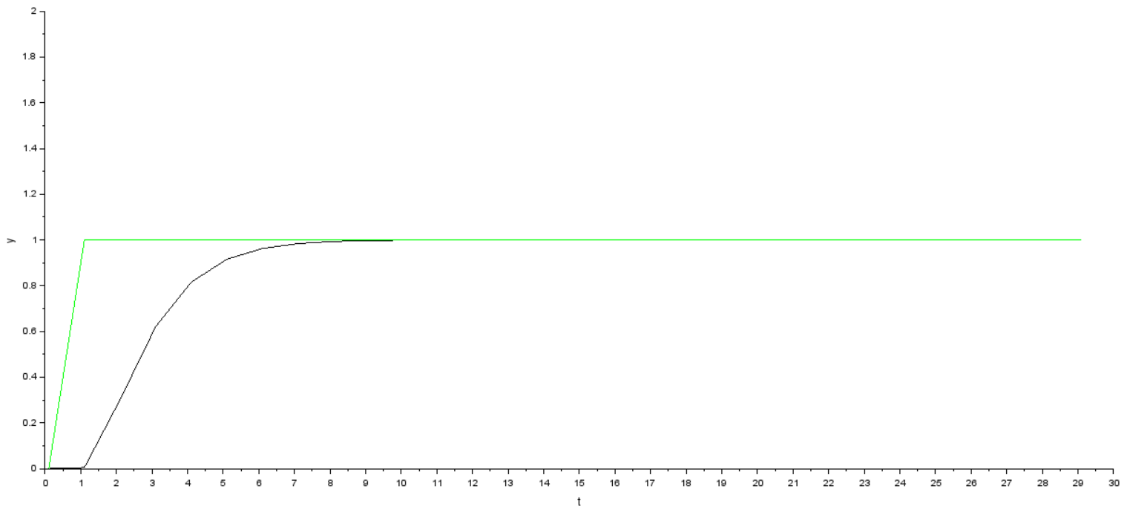
2.3.1 Undamped

When the damping factor is set to 0, the system behaves as purely elastic, with no energy dissipation due to damping, corresponding to an undamped system. The simulation showed pronounced oscillations following a step input, indicating that the system continues to oscillate around the equilibrium position without dissipating energy. Due to the lack of damping, the system never truly settles to equilibrium and continues to oscillate indefinitely.



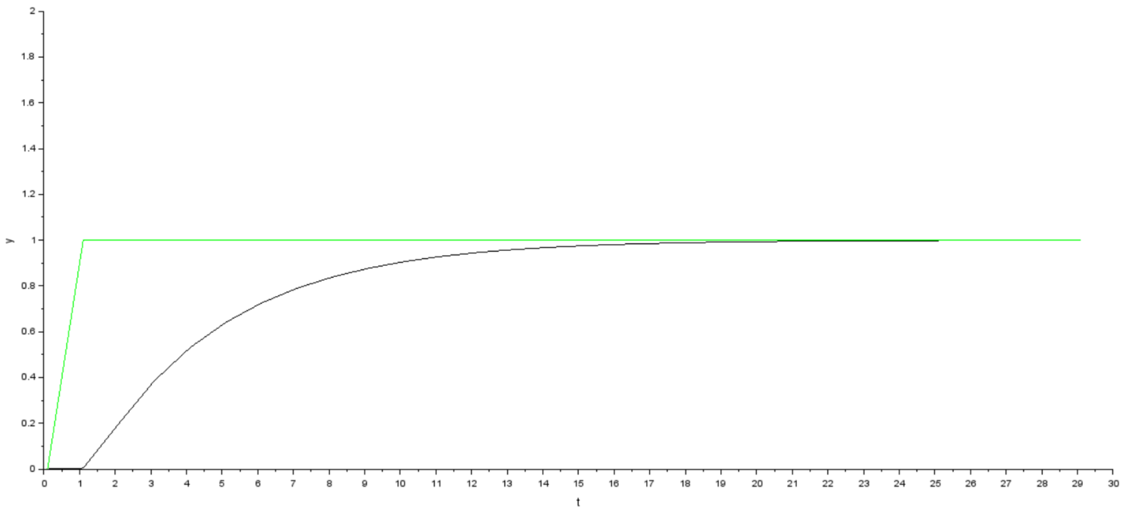
2.3.2 Critically Damped

Setting the damping factor to 2 resulted in a critically damped system, where the system returns to equilibrium as quickly as possible without oscillating. The system demonstrated a rapid return to equilibrium with no oscillations, indicating efficient shock absorption and minimal bounce. This is the fastest return to equilibrium among the scenarios, making it ideal for quick stabilization, such as sudden road changes or avoiding obstacles.



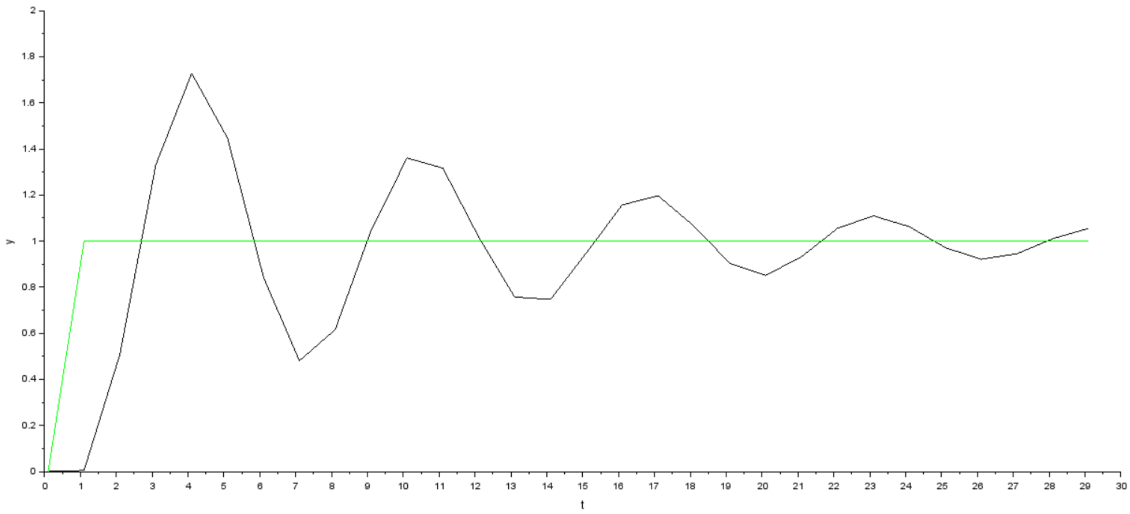
2.3.3 Overdamped

With a damping factor of 4, the system is overdamped, characterized by a slow return to equilibrium with negligible oscillations. The system took longer to return to equilibrium, with almost no observable oscillations, suggesting effective shock absorption but a sluggish response to sudden changes. Although the system eventually reaches equilibrium, it does so very slowly, sacrificing responsiveness for improved stability and comfort.



2.3.4 Underdamped

With a damping factor of 0.2, the system is underdamped, meaning there is some energy dissipation but not enough to prevent oscillations. The system exhibited damped oscillations, with the amplitude gradually decreasing over time. Despite the oscillations, the system eventually returns to equilibrium, though it takes longer than in overdamped or critically damped systems.



Chapter 3

Parameterization in Xcos

The parameterization task involved replacing fixed values with variables within Scilab scripts, enabling flexible simulations and allowing for varied outcomes. By adjusting these variables through the scripts and conducting simulations in the Xcos cloud platform, we observed different graph results that illustrated how changes in parameters affected the behavior of the system.

Specifically, our experimentation focused on adjusting constant block values in examples sourced from the book "Feedback Control of Dynamic Systems.", chapter "NonLinear Systems". The examples chosen were "Determination of Stability with a Hysteresis Nonlinearity" and "Stability of Conditionally Stable System Using Root Locus." During this process, we varied the constant block parameter ‘r‘, exploring values such as 1, 2, 3, 4, 5, and beyond.

This exploration allowed us to visually understand and quantify the impact of these parameter changes on system stability and behavior. Moreover, modifying the Scilab script files associated with these examples encouraged active engagement and experimentation, which deepened our comprehension of system dynamics and fostered creative approaches to problem-solving.

Chapter 4

Xcos Textbook Verification

For the task of verifying Xcos simulations against Scilab code examples from several textbooks, I undertook a systematic approach to ensure accuracy and consistency across different engineering disciplines. The objective was to validate that the outputs generated by Xcos accurately matched those obtained from Scilab simulations, as outlined in the textbooks.

Books Checked:

- Trigonometry: Verified 47 examples
- A Textbook of Fluid Mechanics and Hydraulic Machines: Verified 23 examples
- A Textbook of Engineering Mechanics: Verified 20 examples
- Principles of Electronics: Verified 20 examples
- Mechanical Vibration: Verified 20 examples
- Concepts of Physics-Volume 1: Verified 20 examples
- Heat Transfer: Verified 20 examples
- Engineering Thermodynamics: Verified 20 examples
- Fluid Mechanics: Verified 18 examples
- Vector Mechanics for Engineers: Statistics and Dynamics: Verified 20 examples

Chapter 5

Files and Links

This chapter includes case study files and Scilab scripts.

5.1 Section 1: Case Studies

- **Finite Difference and Crank-Nicolson Methods for the Heat Equation:** `https://scilab.in/case-study-project/case-study-run/3`
- **Predictive Modelling of Housing Prices: A Linear Regression Approach:** `https://scilab.in/case-study-project/case-study-run/6`
- **Optimizing Ride Quality through Damping Adjustment in Automotive Suspension Systems:** `https://scilab.in/case-study-project/case-study-run/16`

5.2 Section 2: Parameterization in Xcos

For parameterization and observing graphs in Xcos, refer to the following resources:

- **Parameterization in Xcos:** Google Docs Link
- **Modification of Scilab Scripts:** Google Docs Link

Chapter 6

Learnings

Learnings from this experience:

- Open-Source Software Training - Scilab
- Open-Source Software Training - Xcos
- Creation of real-life based case studies and usage of Scilab for programming purposes.
- Simulation of mathematical models and signal processing using Xcos.
- Understanding the importance of parameterization.
- Using LaTex to create presentations and documents.
- Official Etiquette and Professionalism.

Chapter 7

Challenges

Challenges that I faced during the internship were:

- Writing the first case study report in a proper format.
- Writing case studies from a real-life problem perspective.
- Understanding the proper method of parameterization tasks.
- Ensuring accuracy and precision in simulations.
- Managing time effectively to balance multiple tasks and deadlines.

Chapter 8

Conclusion

On the whole, this internship has been a useful experience. I have gained valuable knowledge and skills, and I was able to achieve my learning goals. I learned the different aspects of working to create comprehensive case studies. Furthermore, I experienced the importance of objectivity in education and the necessity of being aware of other people's perspectives. This helped me identify the skills and knowledge I need to improve in the future. The professional and technical skills I acquired

from this internship will certainly help me in my future endeavors. I feel much more confident in myself, and now I look forward to facing upcoming challenges. I hope this experience will be beneficial for my future career. Ultimately, this internship has provided me with new insights and motivation to pursue my career with renewed enthusiasm.

Chapter 9

Reference

- https://www.scilab.org/
- https://xcos.fossee.in/example
- https://scilab.in/case-study-portal/case-study-project