

IMAGE SIMULATION AND VISUALIZATION

INTERNSHIP PROJECT REPORT

Submitted by

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In partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY
in

Computer Science and Engineering

Parul Institute of Engineering and Technology, Limbda



VADODARA

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Parul Institute of Engineering & Technology

Internship Report



Parul University, Limbda

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Date: 12/11/2024

To,
Indian Space Research Organisation
Ahmedabad

Subject: NOC of the selected student for the internship

Dear Sir / Madam,

This is to inform that **Enrollment No 210303124014, Harshalkumar Sunilkumar Patel** from division **8B3** from our institute is allowed to join the internship from date **09-12-2024** up to **12-04-2025**. This student can join your organisation on full time basis but at the same time, he/she will be required to appear for all Weekly Tests, Mid-Sem Exams, External Semester Exams, vivas, submission and practical exams and must perform satisfactorily in order to become eligible to get degree certificate.

We would request you to kindly consider the same and approve leaves accordingly as per the exam schedule as & when gets finalised.

Yours Faithfully,

Dr.Sanjay Agal
Head-AI & AIDS Dept.,
Parul Institute of Engineering & Technology,
Parul University, Vadodara.



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Declaration

We here by declare that the Project report submitted along with the Project entitled **Image simulation Visualization** submitted in partial fulfillment for the degree of Bachelor of Engineering in **Computer Science Engineering** to Parul University, Vadodara, is a bonafide record of original project work carried out by me at **Indian Space Research Organisation** under the supervision of **Krishna Raulji** and that no part of this report has been directly copied from any students' reports or taken from any other source, without providing due reference.

Harshalkumar Sunilkumar Patel

Name of the Student

Sign of Student



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CERTIFICATE

This is to certify that the project report submitted along with the project entitled Point of Sale has been carried out by **Harshalkumar Sunilkumar Patel** under my guidance in partial fulfillment for the degree of Bachelor of Engineering in Computer Engineering, 8th Semester of Parul University, Vadodara during the AY 2024-25.

Krishna Raulji,

Project Guide

Dr. Amit Barve,

Head of Department,

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Abstract

The Moon Surface Image Simulation and Visualization project aims to assist in designing and evaluating satellite imaging systems by simulating how a camera would capture images in a lunar environment. By allowing users to define various camera parameters such as position, altitude, roll, yaw, pitch, and lens settings, this system generates simulated images that closely represent the expected results from actual lunar missions.

The project is developed using PyQt5 and Qt Designer for the graphical user interface, while NumPy, PyQtGraph, and GDAL handle image processing and spatial data operations. The iterative waterfall model is followed to ensure systematic development and refinement based on feedback at each stage.

This system plays a crucial role in optimizing camera settings before deployment on lunar satellites, reducing experimental costs and improving mission accuracy. The feasibility and effectiveness of the simulation ensure that future moon exploration missions can be planned with greater precision and confidence.

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1 OVERVIEW OF THE COMPANY

1.1 HISTORY OF SAC ISRO

The Space Applications Centre (SAC), located in Ahmedabad, is a premier unit of the Indian Space Research Organisation (ISRO), established in 1973. SAC plays a pivotal role in the development of space-based applications and technologies for communication, broadcasting, meteorology, Earth observation, and satellite payloads.

SAC is involved in designing and developing payloads and space systems for Indian satellites, contributing to various national and international missions.

SAC's primary focus has been on developing payloads that enable the delivery of services like telecommunication, television, remote sensing, meteorology, and satellite navigation.

SAC's efforts have been integral to the success of ISRO's commercial and scientific satellite programs.

1.2 DIFFERENT PRODUCTS / SCOPE OF WORK

SAC is responsible for the design and development of advanced payloads, satellite communication systems, and other critical components used in Earth observation and communication satellites. The major products and scope of work include:

- **Satellite Payloads** – Development of sensors, transponders, and communication equipment.
- **Spacecraft Bus Systems** – Design and development of the satellite structure, thermal management, and power systems.
- **Ground Systems** – Establishment of ground stations and communication infrastructure.
- **Earth Observation Systems** – Development of systems like remote sensing payloads for applications in agriculture, forestry, and disaster management.
- **Satellite Launch and Mission Support** – Assisting in mission planning and execution for satellite launches and operation of payloads.

1.3 ORGANIZATION CHART

The organization structure of SAC ISRO consists of multiple divisions and departments focusing on different aspects of space research, design, and development. The key departments include:

- Payload Design and Development
- Communication Payload Systems
- Spacecraft Integration and Testing
- Ground Segment Operations
- Satellite Data Processing
- Applications Development

A detailed organization chart will display the hierarchical structure from the Director down to the specialized teams responsible for various tasks in the development, integration, and testing of space systems.

1.4 CAPACITY OF PLANT

SAC is equipped with state-of-the-art facilities that cater to the design, integration, and testing of satellite payloads and communication systems. These facilities include:

- **Clean Room Facilities** – SAC's clean rooms ensure a contamination-free environment for sensitive satellite payload assembly.
- **Antenna Testing and Simulation Lab** – Used for the testing and simulation of communication systems and payloads.
- **Satellite Payload Integration Facility** – Where satellite payloads are integrated, tested, and validated.
- **Thermal and Vibration Testing** – Specialized testing facilities that simulate space conditions like temperature extremes and vibration during launch.
- **High-Performance Computing Systems** – Support the simulation, data analysis, and image processing for mission planning and satellite operation.

Capacity: SAC can handle the development and integration of multiple satellites simultaneously, supporting both Indian and international missions.

2 OPERATIONAL DETAILS

2.1 OVERVIEW OF DIFFERENT UNITS AND DEPARTMENTS

SAC ISRO is divided into various specialized departments that focus on the research, design, development, testing, and integration of space systems. The key departments involved in the development of satellite payloads and communication systems are:

2.1.1 Payload Design and Development

Scope: This department is responsible for designing the payloads used in communication satellites, remote sensing satellites, and other space applications.

Work Carried Out:

- Design and development of payload systems like communication transponders, sensor payloads, and optical instruments for Earth observation.
- Development of payload integration strategies and testing procedures.

2.1.2 Satellite Systems Integration and Testing

Scope: Focuses on integrating various subsystems of satellites (payloads, bus systems, etc.) and ensuring they function as a cohesive unit.

Work Carried Out:

- Integration of communication systems, electrical power systems, thermal management systems, and payload systems.
- Conducting rigorous testing (thermal, vibration, EMI, etc.) to ensure that the satellite meets the performance standards required for space missions.

2.1.3 Earth Observation and Remote Sensing

Scope: Development of remote sensing payloads for Earth observation and monitoring.

Work Carried Out:

- Design and testing of imaging sensors, radar systems, and hyperspectral sensors for applications like agriculture, disaster management, weather monitoring, and environmental monitoring.
- Development of data processing and analysis systems to handle large volumes of satellite imagery.

2.1.4 Communication Systems

Scope: Responsible for the development of space-based communication systems including telecommunication transponders, broadcasting systems, and satellite networks.

Work Carried Out:

- Designing transponders, antennas, and communication protocols to enable satellite communication services.
- Implementation of ground communication infrastructure to support satellite data transmission.

2.1.5 Ground Systems and Control

Scope: Design and implementation of ground stations to track, communicate with, and control satellites during their mission life cycle.

Work Carried Out:

- Setting up ground stations equipped with tracking and data receiving equipment.
- Managing satellite health and performing routine control functions for satellites.

2.1.6 Applications Development

Scope: Develop innovative space-based applications using the data provided by the satellites, such as satellite navigation, telemedicine, and e-learning.

Work Carried Out:

- Implementation of space technology for practical solutions in areas like disaster management, telemedicine, and education.
- Develop user interfaces and systems for end-users to access satellite-based services.

2.2 TECHNICAL SPECIFICATIONS OF MAJOR EQUIPMENT USED IN EACH DEPARTMENT

Each department at SAC ISRO employs specialized equipment and technology to carry out their tasks effectively. Below are the major technical specifications of some of the equipment used:

2.2.1 Payload Design and Development Department

Imaging Sensors:

- Resolution: Up to 1-meter resolution for Earth observation.
- Spectral Range: Multi-spectral (visible, infrared, thermal).

Communication Transponders:

- Frequency Range: C-band, Ku-band, S-band.
- Power Output: Up to 100 watts for high-efficiency communication.

2.2.2 Satellite Integration and Testing Department

Thermal Vacuum Chamber:

- Temperature Range: From -150°C to 150°C.
- Size: Can accommodate satellites of up to 6 meters in diameter.

Vibration Testing Equipment:

- Frequency Range: Can simulate vibration from 1 Hz to 10,000 Hz for satellite testing.

2.2.3 Ground Systems Department

Tracking and Data Reception Antennas:

- Size: 10m to 30m parabolic dish antennas.
- Frequency Range: Covers L-band, S-band, C-band, and Ku-band.

2.3 2.3 SCHEMATIC LAYOUT SHOWING SEQUENCE OF OPERATIONS FOR MANUFACTURING END PRODUCT

The manufacturing process at SAC ISRO follows a structured sequence for designing, developing, integrating, and testing space systems. The schematic layout of the workflow includes the following steps:

1. Design Phase:

- Conceptual design of payloads, subsystems, and satellite bus systems.
- Detailed system architecture design and simulations.

2. Development Phase:

- Procurement of components.
- Fabrication and assembly of satellite payloads and systems.

3. Integration Phase:

- Assembly of satellite components.
- Integration of payloads with satellite bus systems.

4. Testing Phase:

- Thermal, vibration, and electromagnetic interference (EMI) tests.
- Performance verification through ground-based simulations.

5. Launch and Deployment Phase:

- Satellite launch via ISRO's launch vehicles.
- Monitoring and control through ground stations post-launch.

2.4 2.4 EXPLANATION OF EACH STAGE OF PRODUCTION

- 1. Design:** In the design stage, concepts for payloads, spacecraft systems, and ground infrastructure are developed. The design is based on mission objectives and space conditions.
- 2. Development:** Components such as payloads, sensors, and communication equipment are designed, fabricated, and tested for functionality.
- 3. Integration:** In this phase, the various subsystems such as payloads, power systems, and thermal systems are integrated into the spacecraft.
- 4. Testing:** The integrated system undergoes rigorous performance testing, which includes thermal vacuum tests, vibration tests, and power system validation.
- 5. Launch and Deployment:** The final satellite is launched, and real-time data transmission and satellite health checks are conducted from the ground.

3 INTRODUCTION TO PROJECT

3.1 PROJECT SUMMARY

This project focuses on Moon Surface Image Simulation using satellite imaging technologies to simulate and visualize images of the moon's surface. The goal is to understand how a camera will capture an image in an unknown environment, such as the moon's surface, and help in designing and setting up camera parameters for such simulations. The project aims to provide an effective system for simulating images by adjusting parameters like camera position, altitude, roll, yaw, and pitch, which can be used in designing cameras for future lunar missions.

By simulating the moon's surface images based on user input, the system can assist in camera parameter optimization for space missions. It provides an interface where users can input pre-captured images and define specific parameters, and in return, they will get a simulated moon surface image. This helps in understanding how different camera parameters influence the final image, which is crucial for planning lunar exploration missions.

3.2 PURPOSE

The primary purpose of this project is to simulate and visualize how the moon's surface will appear based on different camera parameters such as position, altitude, and orientation. The system will serve as a tool for space scientists and engineers involved in the design and calibration of lunar imaging systems.

By offering an interactive platform, the project aims to:

- Provide a realistic simulation of moon surface images based on camera position and settings.
- Aid in the design of cameras used in lunar exploration missions by testing various parameters.
- Serve as a prototype system to assist future space missions, such as the Chandrayaan mission, in obtaining accurate images of the moon.

3.3 OBJECTIVE

The main objectives of this project are:

- To design a system that can take user input images (pre-captured) and simulate the appearance of the moon's surface under different camera parameters.
- To help in optimizing camera configurations for lunar missions by visualizing how the camera would capture images of the moon from different perspectives.
- To develop an intuitive user interface using PyQt5 that allows users to interact with the simulation and adjust parameters like latitude, longitude, altitude, and camera orientation.
- To provide insights into the impact of various camera settings (e.g., yaw, pitch, roll) on the quality and detail of the simulated lunar images.

3.4 SCOPE (WHAT IT CAN AND CAN'T DO)

Scope of the Project:

- The system can simulate images of the moon's surface, enabling users to visualize how different camera parameters impact the final image.
- The tool will allow users to input camera settings, such as camera position, altitude, and orientation parameters, and generate simulated images of the lunar surface.

What the Project Can't Do:

- It cannot provide real-time image capturing or real-world data from lunar surface cameras.
- It cannot generate new images of the moon based on raw data but will only work with pre-captured input images.
- The simulation is limited to a static model and does not include dynamic changes (e.g., changing lunar phases or real-time environmental variations on the moon's surface).

3.5 TECHNOLOGY AND LITERATURE REVIEW

The project uses the following technologies:

- **PyQt5:** For creating the graphical user interface (GUI) that allows users to input and manipulate parameters.

- **PyQtGraph:** Used for visualization, it provides a fast and efficient way to display simulated images and graphical representations of camera settings.
- **GDAL:** A library used to handle geographic data and transform spatial data for accurate simulation of images.
- **NumPy:** Essential for performing mathematical operations and data transformations involved in the image simulation.

Literature Review:

Image Simulation in Space Exploration: Previous research has shown the importance of image simulation for space missions, especially in visualizing how the environment will look from different angles. Studies have emphasized the need for tools that simulate environmental changes, camera settings, and perspectives.

3.6 PROJECT PLANNING

3.6.1 Project Development Approach and Justification

This project follows the Iterative Waterfall Model, allowing for incremental development and continuous feedback after each phase. The iterative model provides flexibility to refine the design after each cycle, ensuring that user needs are met and issues are addressed promptly.

Phase 1: Requirements Gathering and Initial Design: In this phase, project requirements were gathered from experts in space imaging and system designers, including input from space agencies involved in lunar exploration.

Phase 2: Prototype Development and User Interface Design: Based on the requirements, an initial prototype of the GUI was developed using PyQt5. Early simulations with predefined parameters were conducted to verify the system's functionality.

Phase 3: Iteration and Refinement: After initial feedback from users, the system was iteratively refined. New features like parameter adjustments and image enhancement tools were added based on user input.

3.6.2 Project Effort and Time, Cost Estimation

The project is expected to take 3-4 months for completion. This includes time for prototype development, testing, and refinement of the system.

Time Estimation:

- Prototype development: 1 month

- Testing and refinement: 2 months
- Final adjustments and presentation: 1 month

Cost Estimation: The project will primarily require investments in software tools, hardware for testing, and the time commitment of the development team.

4 SYSTEM ANALYSIS

4.1 STUDY OF CURRENT SYSTEM

Currently, there is no integrated system that allows users to simulate the appearance of the moon's surface based on varying camera parameters in a user-friendly way. Various image processing and satellite simulation tools exist but often focus on post-processing images or limited camera settings. Many of these systems are not adaptable to different space environments and fail to simulate the specific requirements of lunar missions. Therefore, a need exists for a customizable, efficient tool that can provide dynamic simulations of lunar surface images with the flexibility to adjust camera positions, orientations, and other parameters.

Existing systems for space imaging simulations may lack features like interactive user inputs or real-time adjustments for environmental factors such as altitude, yaw, and pitch. They also tend to be rigid in their design, focusing mainly on theoretical models rather than offering detailed user-driven simulations.

4.2 PROBLEM AND WEAKNESSES OF CURRENT SYSTEM

The current limitations and issues with existing systems can be summarized as follows:

- **Lack of User Interaction:** Existing systems often require specialized knowledge or manual calculations to adjust camera settings, creating a barrier for easy interaction.
- **No Integration with Space Mission Data:** Current systems don't easily integrate with space mission data like satellite position, latitude/longitude, or altitude, making them less effective for real-world use.
- **Static Simulation Models:** Existing models are often static and do not account for the variability in environmental factors on the lunar surface.

4.3 REQUIREMENTS OF NEW SYSTEM

To overcome the weaknesses of current systems, the new system must fulfill the following requirements:

1. **Customizable Parameters:** The system should allow users to input and modify camera parameters, such as altitude, latitude, longitude, pitch, yaw, and roll.
2. **User-Friendly Interface:** The system must have an intuitive graphical user interface (GUI) developed using PyQt5, enabling easy input of parameters and instant viewing of simulated results.
3. **Realistic Simulations:** It should simulate realistic moon surface images using pre-captured satellite images and account for camera distortion and light conditions on the moon.
4. **Support for Lunar Mission Data:** The system must allow integration with data from lunar missions such as Chandrayaan, enabling the simulation of different lunar regions and testing of different camera configurations.

4.4 SYSTEM FEASIBILITY

4.4.1 Does the system contribute to the overall objectives of the organization?

Yes, the system contributes to the overall objectives of ISRO, especially in the area of satellite imaging and space exploration. By helping engineers design and set up optimal camera parameters for lunar missions, the tool supports space mission readiness and camera configuration optimization. It aligns with the vision of advancing space technology and enhancing satellite-based remote sensing for lunar exploration.

4.4.2 Can the system be implemented using the current technology and within the given cost and schedule constraints?

Yes, the system can be implemented using current technologies such as PyQt5, NumPy, PyQtGraph, and GDAL. These tools are highly capable for developing the GUI, performing mathematical computations, and processing satellite image data. Additionally, the iterative waterfall model allows for efficient development within the cost and time constraints, as each phase will build upon feedback from the previous iteration. The estimated cost mainly involves software licenses (if necessary), hardware for testing, and labor for the development team.

4.4.3 Can the system be integrated with other systems already in place?

Yes, the system is designed to integrate with existing satellite imaging systems used by ISRO. By connecting to real-time satellite data, the system can utilize live position and camera data from spacecraft to simulate the lunar surface accurately. Additionally, it will support data from ISRO's lunar missions, providing continuity and improving integration with ongoing research.

4.5 ACTIVITY / PROCESS IN NEW SYSTEM / PROPOSED SYSTEM

The proposed system will include the following activities:

- **Input Data:** Users will provide pre-captured lunar images and set parameters such as latitude, longitude, altitude, camera orientation, etc.
- **Image Simulation:** Based on the input parameters, the system will simulate a new image of the moon's surface, reflecting how the camera would capture the scene in those specific conditions.
- **Visualization:** Simulated images will be visualized on a graphical interface, and users can interact with the interface to adjust parameters in real time.
- **Export:** After running the simulation, users can export the generated images or data for further analysis or mission planning.

4.6 FEATURES OF NEW SYSTEM / PROPOSED SYSTEM

- **Interactive User Interface:** Developed using PyQt5, allowing users to easily input and modify camera parameters and view simulated images.
- **Real-Time Simulation:** Based on pre-defined camera parameters and the moon's surface data.
- **Parameter Control:** Includes controls for various camera settings (e.g., latitude, longitude, altitude, pitch, yaw, roll).
- **Satellite Data Integration:** Allows integration with satellite data for precise simulations of the lunar surface.
- **Export and Report Generation:** Users can save simulated images and generate detailed reports for mission planning.

4.7 LIST OF MAIN MODULES / COMPONENTS / PROCESSES / TECHNIQUES OF NEW SYSTEM / PROPOSED SYSTEM

The main modules/components of the system will include:

- **User Interface Module:** Developed with PyQt5 for user input and interaction.
- **Simulation Engine:** Handles image processing and simulation based on camera parameters using NumPy and GDAL.
- **Visualization Module:** Uses PyQtGraph to display the simulated image and allow interactive viewing.
- **Data Integration Module:** Interfaces with satellite data for real-time simulation.
- **Export/Reporting Module:** Allows users to export simulated images and generate reports for analysis.

4.8 SELECTION OF HARDWARE / SOFTWARE / ALGORITHMS / METHODOLOGY / TECHNIQUES / APPROACHES AND JUSTIFICATION

4.8.1 Hardware:

The project will be developed on standard computers with sufficient computational power to handle image processing. No specialized hardware is required, but systems should have good graphic processing capabilities for efficient simulation and rendering.

4.8.2 Software:

- PyQt5 for GUI development
- NumPy for mathematical operations
- PyQtGraph for real-time image visualization
- GDAL for handling geospatial data

4.8.3 Algorithms:

Standard image processing algorithms for simulation, image distortion correction, and camera parameter adjustment will be used.

4.8.4 Methodology:

The project will follow the Iterative Waterfall Model, ensuring that each phase undergoes continuous refinement through feedback loops.

4.8.5 Techniques:

The system will employ camera parameter optimization and image simulation techniques to provide users with a realistic simulation of lunar surface imagery.