Grenze International Journal of Engineering and Technology, January Issue

Design and Development of a Lunar Automatic Obstacle Avoidance Module for Space Applications

Dr. T.C. Manjunath[1], Dr. Pavithra G[2], Dr. Swapnil S. Ninawe[3], Dr. Arun Kumar G[4] and Dr. M.R. Prasad[5]
[1]Professor, Department of Computer Science & Engineering (IoT CS & BCT) Dean (Research – R & D), Rajarajeshwari College of Engineering, Bangalore, Karnataka
Email: tcmanju@iitbombay.org
[2-3]Associate Professor, Department of Electronics & Communication Engineering, Dayananda Sagar College of Engineering, Bangalore, Karnataka
[4]Professor & Head of the Department, Electronics & Communication Engineering JSS Academy of Technical Education Noida, Noida-201301, Uttar Pradesh
[5]Associate Professor, Department of Computer Science & Engineering Vidyavardhaka College of Engineering, Mysuru, Karnataka

***Abstract*—The Moon has always been the center of attention for mankind, more than any other heavenly body in More than any other heavenly body in the night sky, the Moon has long been the focus of human interest. The Moon has always presented mankind with a challenge to learn more about it and to marvel at its wonders because it bears the early history of the solar system. We can uncover the early evolution of the solar system and that of planet Earth by having a better understanding of the Moon. With the 2008 launch of the Chandrayaan-1 orbiter mission to the Moon, India's planetary exploration program was launched by the Indian Space Research Organization (ISRO). India launched Chandrayaan-2, its second lunar exploration mission, nearly twelve years after its first lunar exploration mission. Chandrayaan-2, India's most technologically advanced aircraft, is on an unprecedented mission. The South Polar Region of the Moon will be studied by India's second lunar trip, which will draw on nearly ten years of scientific and Engineering advancement. A major accomplishment for both India and humanity, Chandrayaan-2 was the first mission ever to be sent to the southern pole of the moon. Both the high cold and constant darkness in this area make it extremely unsafe and have a bad impact on missions. India faced a tremendously difficult assignment as a result, and the entire world was interested in its outcome.**

Chandrayaan-1's eleven remote-sensing scientific instruments from ISRO, NASA, and ESA have made important discoveries, such as the identification of a water signature, the discovery of spinel minerals, lunar lava tubes, signs of recent volcanism, impact-triggered boulder movements, and the detection of sputtered atomic oxygen and backscattered helium on the lunar surface. Three components made up Chadrayaan-2: an orbiter, a lander, and a rover. 2019 saw the launch of this mission. During this mission, the Orbiter was successful in reaching the moon's orbit, but communication with the Lander was lost, which caused Lander to perform poorly and crash with the Pragyan rover and other scientific equipment. The matter presented in this article is the work of the project (final year) done by the under-graduate students of the dept.

***Index Terms*— Planetary Exploration, Lunar Orbit Insertion, Orbiter Craft, Lander Craft, Lunar Rover, Soft Landing, Landing Sites, Craters.**

Grenze ID: 01.GIJET.11.1.557_1

I. Introduction

The Moon is the largest and brightest celestial object present in the night sky. As the only natural satellite of the Earth, it has been a subject of study to scientists and researchers all over the world. The exploration of the Moon began with Luna 1, a first flyby mission launched by the Soviet Union in January 1959. Although Luna 1 did not reach the Moon's surface and flew within about 5,995 km from it. On September 13, 1959, Luna 2 became the first spacecraft to land on the lunar surface making an impact. Whereas Luna 9 became the first spacecraft to achieve a controlled soft landing on the lunar surface and Luna 10 became the first spacecraft to orbit around the Moon. On October 22, 2008 India participated in the race of lunar exploration with the launch of Chandrayaan-1, ISRO began India's first planetary exploration mission of India.

After the success of Chandrayaan-1, The launch of Chandrayaan-2 took place atop a GSLV MK-III M1 on July 22, 2019 at 2:43 PM Indian Standard Time (IST) from the Second Launch Pad (SLP) at the Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota. The launch of GSLV MK-III M1 is captured. The Chandrayaan-2 spacecraft to the Moon is a composite module mission consisting of Orbiter, Lander and Rover. Chandrayaan-2 is planned to be launched onboard Geosynchronous Satellite Launch Vehicle (GSLV) in the summer of 2019. The Orbiter will carry the combined stack up to moon till the Lunar Orbit Insertion (LOI). The combined stack is then inserted into a lunar orbit of 100 km x 100 km. The Lander with the Rover is then planned to be separated from the Orbiter for soft-landing on a site near south polar lunar surface.

The overall objective of Chandrayaan-2 is to build on the successes of the Chandrayaan-1 mission, testing new technologies and conducting experiments on the moon. The rover will collect samples from the lunar surface and analyze them on site, relaying data to Earth via the orbiter. The orbiter will map the contents of the surface down to a depth of a few tens of meters and carry out a detailed study of the lunar exosphere. The Chandrayaan-2 mission will help us gain a better understanding of the origin and evolution of the Moon by conducting detail topographical studies, comprehensive mineralogical and morphological analyses and a host other experiment on the lunar surface. The primary objective of the mission was to demonstrate the ability to soft-land a lander and operate a rover at the South Polar Region of the Moon.

Whereas, the scientific goals of the mission include detailed study of topography, seismography, mineral identification and distribution, surface chemical composition, thermo-physical characteristics of top soil and composition of the tenuous lunar atmosphere. Unfortunately, during its attempt on September 7, 2019 lander (Vikram) gets deviated from its intended trajectory starting at an altitude of 2.1 km above the lunar surface and had lost communication with the ground station. Thus, Chandrayaan-2 will attempt more ambitious technical maneuvers that will put Indian space technology to the test. For the first time, ISRO will attempt to give a craft a controlled, or soft, landing. The agency has had to develop advanced systems that can guide the lander to a touchdown and successfully deploy the rover.

II. Literature Surveys / Reviews

- "Spacecraft command and data system simulator for the payload chaste in Chandrayaan-2 mission" by Aneesh, R. P, Dinakar Prasad Vajja, P. P. Pramod, PS Ajeesh Kumar, and Arun Peethambaran [2017]: This paper discusses the bus structure of the Orbiter Craft Module, which is a three-ton category structure created by HAL and delivered to ISAC for the Chandrayaan-2 mission. The paper also describes the modules of the Chandrayaan-2 mission, including the Orbiter, Lander, and Rover, and their propulsion and landing mechanisms.
- "Next generation rover for lunar exploration" by Harrison, Dan A., Robert Ambrose, Bill Bluethmann, and Lucien Junkin [2008]: This paper discusses the design and development of a lunar rover with six identical, independent wheel components. The paper explains the suspension, drive, and steering systems included in each wheel module and the advantages of the vehicle's ability to "level" and "belly" on the ground.
- "Analyzing and Designing of Lunar Rover Motion Controller" by Jiang Huiping [2016]: This paper addresses the problem of lunar rover motion control and presents a motion control strategy that simplifies the complicated kinematics and classifies the lunar rover's motion control problem into Path following and point Stabilization.
- "Retrieval of Lunar Surface Dielectric Constant Using Chandrayaan-2 Full-Polarimetric SAR Data" by Kochar Inderkumar, Himanshu Maurya, Ajeet Kumar [2022]: This paper focuses on the use of high-resolution full-polarimetric synthetic aperture radar datasets for the retrieval of the dielectric constant of the lunar surface from the Fresnel reflection coefficients. The paper also shows that it is possible to retrieve the lunar dielectric constant via the classical Freeman-Furden decomposition (FDD).

- "A Memorable Mission Conducted by ISRO" by Buddhadev Sarkar, Pabitra Kumar Mani [2020]: This paper discusses the significance of the Chandrayaan-2 mission, which aimed to wave the Indian flag on the dark side (South Pole) of the Moon, gather more scientific information about the Moon, and conduct a soft landing of the Lander and Rover modules.
- "Possible Landing site for Chandrayaan-2 Rover" [2016] by Calla, O. P. N., Shubhra Mathur, and Kishan Lal Gadri: This paper discusses the selection of landing sites for the Chandrayaan-2 mission's Rover module based on communication, the shape of the landing area, the topography, and lightning requirements. The paper describes the primary and backup landing sites chosen by ISRO at the Lunar South Pole, where it is hypothesized that ice may form in areas that are permanently in shadow.

III. Objectives

- To demonstrate the ability of soft land and operate a robotic rover on the lunar surface.
- To develop and demonstrate the key technologies for end-to-end lunar mission capability.
- The Orbiter will observe the lunar surface and relay communication between Earth Station and Lander.
- To map the lunar surface and help to prepare 3D maps of it.
- To study the topology, mineralogy, surface chemical composition, elemental abundance, lunar explore by employing Image Processing Technique.
- To build an application to analyses the data obtained from Rover.

IV. Hightlights of Chandrayan - 2

- Chandrayaan 2 fostered the findings of Chandrayaan 1 as reported by the ISRO.
- The mission targeted the "South Polar region" of the Moon which was completely unexplored.
- The mission focused on the extensive mapping of the lunar surface for studying variations in its composition and tracing the Moon's origin and evolution.
- Chandrayaan 2 was considered as a challenging mission as the South Polar Region of the Moon was totally unexplored by any space agency before.

V. Challenges of Moon Landing

There are various challenges in moon landing like; trajectory accuracy, communication with deep space network, extreme cold & hot temperature variation, lunar dust, lumpy gravity, soft landing etc. Some of the challenges involved in moon landing are mentioned here.

A. Communication with Deep Space Network

Communication to the satellite from the ground station is very important. It helps to control satellite during mission, send commands and new updates, give satellite location and its path, firing rocket engine and thruster. Indian deep space network is located at byalalu near the Bangalore (Karnataka). Usually most of the time lack of communication is responsible for the mission failure (ISRO, 2019a).

B. Soft landing

Soft landing was the main challenge in this mission and it was first time for India attempt a soft landing on lunar surface. The soft landing was executed by performing the rough braking and fine braking maneuvers by firing the onboard engines and it takes extreme precision. Lander was also capable to absorb shock impact without damaging onboard payload and systems (ISRO, 2019a).

C. Extreme Temperature

There is no atmosphere on moon which causes temperature variation is extreme. It takes 27.5 days to complete one rotation around its axis and also around the earth. Due to its rotation one side of moon remains 13.6 day in light which is called lunar day and another part remains in darkness for 13.6 days which is called lunar night. During the lunar day temperature can reach 260 F and in lunar night it can reach -280 F (ISRO, 2019a).

VI. Operations

According to the Daniel A. Harrison [7], in his paper "Next Generation Rover for Lunar Exploration", The Rover has six identical, independent wheel components. Systems for suspension, drive, and steering are included in each wheel module. Rover's suspension system enables a comfortable ride, as well as the capacity to "level" the vehicle, raise individual wheels, and place the bottom of the frame, commonly known as the "belly," on the ground. Chariot's capacity to put its "belly" on the ground is advantageous for a number of reasons, including making it easier for astronauts to board and exit the lunar truck, significantly lowering ground pressure when Rover is stationary, and requiring less maintenance work in many circumstances. The ability to "level" the vehicle has various advantages, including allowing the Rover to be levelled on uneven terrain, allowing the truck to "lean" into a slope, and enabling the positioning of tools at specific angles and heights.

The ability of Chariot to lift wheels independently has additional advantages, particularly with the six-wheel design: it enables Chariot to adjust the ground pressure at each wheel; increases the likelihood of escaping from "sticky" situations; offers a simple "work-around" of lifting a wheel off the ground if a wheel module fails; and, in many cases, lowers the maintenance effort.

The dual-arm suspension on the Chariot has inboard active and passive components and is load-sensing. Figure 6 illustrates how the specially created arms make the most of Chariot's capacity to alter the wheel height and locate the majority of the suspension components inside the car for safety. The upper arm is controlled by the sequence of the active and passive parts. The wheel module can be individually lifted or lowered with a range of more than 20 inches thanks to the active element. To do this, a linear actuator and guide rails are used to modify the passive suspension's lower pivot point. A low-frequency system called the active suspension may go through its whole range of motion in less than ten seconds.

Many off-road vehicles use a twin coil-over-shock layout for the passive element. With this more conventional design, Chariot has a wide range of choices to stiffen or soften the ride as well as change the mid-range of the suspension for different payloads [7].

VII. POWER DISTRIBUTION UNIT

By using CAN bus connectivity, the Power Distribution Unit (PDU), shown in Figure 1, allows for the control and distribution of battery power as well as regulated low-voltage DC power to Rover subsystems. Three layers of bus voltage monitoring will be used. The Battery Management System will keep an eye on the battery bank (BMS). The PDU Controllers will receive the individual cell health information from this system. The PDU system will take preventative action to guard against the batteries' voltages falling below their minimum levels. The response will involve alerting the driver to the issue and the requirement for a recharge within a predefined window of time, turning off some optional features, and finally shutting down the car. Recognizing that the batteries could be damaged beyond repair.

An electronic power supply sequencer will keep track of the output voltage of each converter. If the output of a converter veers outside of a predetermined window, this device will stop all converters. As a last resort, this will safeguard the electronics against disastrous occurrences. The PDU control software will keep track of the supply for each sub-assembly. As part of a health package, the voltage measurement will be transmitted to the chassis off chassis processor. The PDU control software will flag and alert the operator if the voltage is outside of a predefined window. Two layers of bus current monitoring will be used. The PDU control software will keep track of each converter's output current.

As part of a health package, the current readings will be transmitted to the vehicle's off-chassis processor. The off-chassis processor may be located at a teleoperator station or on the crew housing system. In the event that the converter's output exceeds a predetermined value, the PDU control software will shut down the converter. As a last resort, this will safeguard the electronics against disastrous occurrences. Since the batteries are connected in series, it is crucial that the "state of charge" of each battery always matches [7]. Also, from Lithium Technology, is utilized by the Rover to keep track of each battery pack's temperature and cell voltage. If any cell voltage drops too low or if the temperature limit is reached, the BMS will cut off vehicle power. The BMS additionally keeps an eye on the battery system when it's charging, which might be risky if done incorrectly. Overcharging has the potential to cause lithium metal to plate out, which is a very dangerous condition [7].

VIII. SYSTEM SOFTWARE

The software on the Rover system is extremely basic for its initial release. An embedded PowerPC running the vxWorksTM operating system in a small PCI chassis function as the brains of the system. Three CAN devices operating at 1 MBit/s are the Rovers's only sources of input and output (I/O). The power system, left and right side of the car, and CAN devices are all under its control. The network traffic was divided to increase the system's throughput. The power distribution system regulates the power distribution system and keeps an eye on the batteries.

A module that handles low-level control, sequencing, safety features, and I/O is at the center of the Rover program. The low-level safety and sequencing operations act as a simple system manager. The inverse kinematics solution of the vehicle points all wheels at the same location in space using the instantaneous centers method. The wheels are then turned at the correct speeds to propel the car at the desired linear and angular rates. The output of a visualization tool used to test the driving kinematics of the Chariot is shown in Figure 1. The six wheels of the car are represented by the arrows in the tool. The direction the wheel points in is indicated by the angle of the arrow. The size of the arrow indicates the wheel's drive velocity.

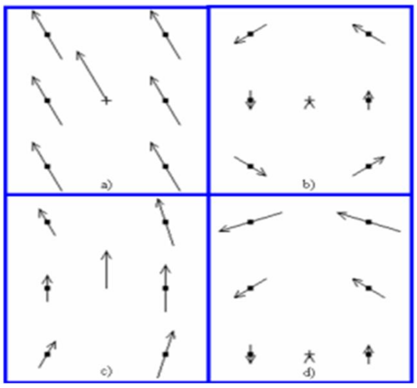

Fig. 1: a) driving in a general direction; b) zero turn radius; c) double Ackerman driving; d) turning about a general position.

An application programmer's interface allows an off-chassis processor to operate the system (API). This API is a clear interface for requesting data and status from the car as well as giving it driving and mode instructions. With the help of this API, the core motion system is able to handle commands consistently regardless of who is issuing them: an on-board driver, a teleoperator operating the vehicle across time delay from line-of-sight or inside a habitat, a semi-autonomous waypoint generator, or an Earth-based driver.

IX. Timing Analysis

The system was created using two micro controllers. The synchronization of the two microcontrollers was crucial to the system's overall success. This is an important step in putting these kinds of systems into place. These two micro controllers receive the tasks from the systems in a time multiplexed fashion [3]. Programs are created using timer control. A BDH controller timer is used to start the program for reading BDH data, and another timer is used to synchronously serially communicate with the spacecraft system. The data from the BDH is received using one of the timers in the spacecraft command and data system simulator, and UART communication is accomplished using the other timer.
To create a time strategy to efficiently operate the system, timing analysis is carried out. Different timer counts are used for the timing analysis at various clock frequencies. Visual Basic software was created to calculate the timer count for various clock frequencies. Two different types of errors are seen to occur at random in synchronous serial communication.

- Bit missing error: This error happens when bits are not received at a specific clock period.
- Bit duplication error: This error happens when the same bit is received more than once at various clock periods.

Both errors are detrimental to system operations and are the result of improper synchronization between these systems [3][6].

X. Lunar Rover Controls

According to the Jiang Huiping. We are addressing the problem of the lunar rover motion control and the. The problem can be overcome by presenting the motion control strategy go lunar rover, by simplifying the complicated kinematics and classifying the motion control problem of lunar rover into Path following and point Stabilization. The lunar rover from rover motion control the lunar rover motion control problem can be divided into Path following and point stabilization The path following is to generate control inputs to drive and steer the lunar rover to follow the reference path which was previously planned. The point stabilization is to Stabilize the lunar rover from any initial position to a given target position, the point Stabilization problem can be detected based on two conditional situations. That is according to the heading constraint condition of lunar rover at the target position. That is point stabilization with target heading position angle constraint & without target heading constraint.

XI. PROPOSED METHODOLOGY

The block diagram of the project, consists of 3 parts Lander/Orbiter, Rover, and Base Station as shown in Fig. 2.

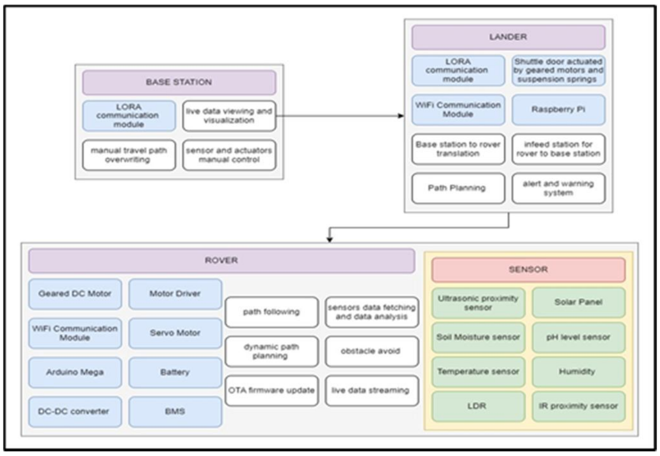

Fig. 2: Block Diagram

- Orbiter/Lander: The Orbiter revolves around the moon and collects samples from the rover and then then transmits it to the Earth Station. When the Lander lands, the sensors connected to the wheels of the lander sends the signal to the motor which in turn rotates and slowly the door opens. Once the door is opened, it'll send a signal to the rover that the door is opened.
- Rover: Once it receives the signal from the lander, it'll get ready to come out. When it moves to the surface of the moon, it will capture the images and sends to the Earth Station via orbiter.
- Base Station: Here, the received signals from the lander are analyzed for further applications like Image processing and etc. Which is linked to a Mobile application or Website and Base station has control over all the process of the system.

XII. CONCLUSIONS

It was a nation pride mission for India and it was the first time in the world when a nation launched mission to reach South Pole of the moon. Unfortunately landing on the moon of VIKRAM rover was not successful but this project achieved its 95 % success and objectives according to ISRO. Now ISRO has planned a new landing mission on the lunar surface with Chandrayaan-3.

REFERENCES

[1] Duda, Kevin R., Michael C. Johnson, and Thomas J. Fill. "Design and analysis of lunar lander manual control modes." In 2009 IEEE Aerospace conference, pp. 1-16. IEEE, 2009.
[2] Acharya, Hardik, T. P. Srinivasan, and B. GopalaKrishna. "A new approach for terrain analysis of lunar surface by Chandrayaan-1 data using open-source libraries." In 2013 Fourth National Conference on Computer Vision, Pattern Recognition, Image Processing and Graphics (NCVPRIPG), pp. 1-4. IEEE, 2013.
[3] Aneesh, R. P., Dinakar Prasad Vajja, P. P. Pramod, PS Ajeesh Kumar, and Arun Peethambaran. "Spacecraft command and data system simulator for the payload chaste in Chandrayaan-2 mission." In 2017 IEEE International Conference on Circuits and Systems (ICCS), pp. 97-102. IEEE, 2017.
[4] Calla, O. P. N., Shubhra Mathur, and Kishan Lal Gadri. "Possible Landing site for Chandrayaan-2 Rover." In 2016 International Conference on Recent Advances and Innovations in Engineering (ICRAIE), pp. 1-5. IEEE, 2016.
[5] Wan, Junlin, Hong Nie, Jinbao Chen, and Qing Lin. "Modeling and simulation of Lunar lander soft-landing using transient dynamics approach." In 2010 International Conference on Computational and Information Sciences, pp. 741-744. IEEE, 2010.
[6] Rui, Xu, Jiang Huiping, Tang Shengjing, Cui Pingyuan, and Yue Fuzhan. "Analyzing and designing of lunar rover motion controller." In 2007 IEEE International Conference on Robotics and Biomimetics (ROBIO), pp. 1574-1579. IEEE, 2007.

[7] Harrison, Dan A., Robert Ambrose, Bill Bluethmann, and Lucien Junkin. "Next generation rover for lunar exploration." In 2008 IEEE aerospace conference, pp. 1-14. IEEE, 2008.
[8] N. Lakshmi, G. Pavithra and T.C. Manjunath, “CMOS Implementation of Multipath Fully Differential OTA with Dual Flipped Voltage Follower in 50 nm and 75 nm CMOS Technologies using Cadence Tool,” IEEE International Conference on Distributed Computing and Optimization Techniques (ICDCOT), Bengaluru, India, 2024, pp. 1-8, doi: 10.1109/ICDCOT61034.2024.10515482.
[9] M. Suguna, M. Sangeetha, N. Shanmugapriya, G. Pavithra and V. Anandkumar, “AI Based Ontology-Driven Information Retrieval for Healthcare Information System,” IEEE International Conference on Computing, Power and Communication Technologies (IC2PCT), Greater Noida, India, 2024, pp. 1872-1875, doi: 10.1109/IC2PCT60090.2024.10486267
[10] V.K. Suhasini et.al., “Detection of Skin Cancer using Artificial Intelligence & Machine Learning Concepts,” IEEE 4th International Conference on Cybernetics, Cognition and Machine Learning Applications (ICCCMLA), Goa, India, 2022, pp. 343-347, doi: 10.1109/ICCCMLA56841.2022.9989146.
[11] G. Pavithra, K. Nikhil, M. Sreeraam, S. Pranjal, Sachin and T.C. Manjunath, “Design of a Smart Moving Road Divider for Effective Control of The Traffic Problems in Densely Populated Traffic Zones,” IEEE International Conference on Mobile Networks and Wireless Communications (ICMNWC), Tumkur, Karnataka, India, 2021, pp. 1-4, doi: 10.1109/ICMNWC52512.2021.9688392.
[12] T.C. Manjunath, G. Pavithra and B.G. Nagaraj, “Design & simulation of the workspace for a stationary robot system,” IEEE Region 10 Humanitarian Technology Conference (R10-HTC), Agra, India, 2016, pp. 1-5, doi: 10.1109/R10-HTC.2016.7906828.
[13] J. Rajesh, P. Prasanna, R. Akshith, T.C. Manjunath and G. Pavithra, “Conceptual view of a smart tonopen for biomedical engineering applications,” IEEE International Conference on Intelligent Computing and Control Systems (ICICCS), Madurai, India, 2017, pp. 636-639, doi: 10.1109/ICCONS.2017.8250540.
[14] G. Pavithra, T.C. Manjunath, D. Lamani and G. Anushree, “Hardware Implementation of Glaucoma using A PIC Micro-Controller – A Novel Concept for a Normal Case of the Eye Disease,” IEEE International Conference on Current Trends in Computer, Electrical, Electronics and Communication (CTCEEC), Mysore, India, 2017, pp. 1104-1109, doi: 10.1109/CTCEEC.2017.8455153.