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Design and Development of a Smart Panchang Indicator Using Raspberry Pi and Real-Time Clock with the Integration of Surya Siddhanta Principles

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ABSTRACT —

The Panchang is a traditional Hindu calendar system that provides important astronomical and calendrical information based on five principal elements: Tithi, Vara, Nakshatra, Yoga, and Karana. These elements are determined using the relative positions of the Sun and the Moon and play a significant role in determining Hindu festivals, religious ceremonies, auspicious timings, and daily rituals. With the advancement of embedded systems and digital technologies, traditional calendar calculations can be integrated into an automated electronic device to provide accurate, accessible, and real-time Panchang information. This research paper proposes the design and development of a low-cost, compact, and user-friendly Panchang Indicator using a Raspberry Pi and a Real-Time Clock (RTC) module.The proposed system uses the Raspberry Pi as the main processing unit and the RTC module to maintain the current date and time, even when the primary power supply is interrupted, provided that the RTC backup power is available. The date, time, and geographical location are used as input parameters for the Panchang calculation program. The software processes astronomical data to determine the five Panchang elements and displays the calculated information through an appropriate electronic display. A major aspect of this project is the incorporation of mathematical principles derived from the traditional Surya Siddhanta, an important classical Indian astronomical text. The proposed computational methodology considers mean solar and lunar longitudes, relevant correction terms, and the relative angular positions of the Sun and Moon.

Keywords— Panchang Indicator, Surya Siddhanta, Astronomical Computation, Celestial Longitude, Solar-Lunar Synchronization, Hindu Calendrical System, Embedded Intelligence, Real-Time Timekeeping, Tithi Prediction, Nakshatra Analysis, Digital Panchang Computation, Computational Astronomy

Introduction

A Panchang is a traditional calendar almanac used to describe daily astronomical and calendrical information. Its five principal limbs are vara (weekday), tithi (lunar day), nakshatra (lunar mansion), yoga, and karana. These values depend on date and time, and most astronomical limbs depend on the calculated positions of the Sun and Moon. A digital indicator can present this information continuously without requiring a printed almanac. The proposed project combines a Raspberry Pi, an RTC module, calculation software, and a display. The Raspberry Pi executes the program and manages the user interface The RTC maintains maintains time without continuous network access, provided its backup cell and time setting are maintained. The project is intended as an educational prototype, not a replacement for an authoritative regional Panchang. Location, time zone, sunrise conventions, ayanamsha, and the chosen astronomical model can affect the displayed result. The objective is to develop a compact indicator and document the mathematics behind the calculation. The paper focuses on the integration of a traditional astronomical model with a modern embedded platform and on validating the output for a specified place and date.

The mathematical principles used in Indian astronomy have developed over many centuries. One of the important classical astronomical texts is the *Surya Siddhanta*, which describes methods for calculating celestial positions, planetary motions, and astronomical time. Its traditional computational framework includes mean planetary motions and correction procedures used to estimate apparent celestial positions. These principles provide a mathematical foundation for understanding the relationship between celestial motion and Panchang calculations. Incorporating suitable Surya Siddhanta equations into

a digital system can help demonstrate how traditional astronomical methods can be translated into computational algorithms. Traditionally, Panchang information has been obtained from printed almanacs, calendars, astrologers, or digital applications.

Although these methods are useful, printed calendars may not provide continuously updated information, and some digital applications depend on internet connectivity or external services

1. RELATED WORK AND RESEARCH GAP

The Surya Siddhanta is a classical work of Indian mathematical astronomy that describes mean motions and correction procedures for calculating celestial positions. Historical translations, including Burgess's translation, provide a basis for studying its computational approach [1].

Research on tithi calculations has also discussed the mathematical structure of the traditional formulation. 1

Embedded calendar systems commonly combine a clock, processor, and display. However, reading the civil date from an RTC does not by itself calculate the Panchang

The software must apply a defined astronomical method or use verified Panchang data. The research gap addressed here is a low-cost integrated indicator with documented formulas, a clearly stated calculation convention, and a repeatable validation plan.

The Surya Siddhanta also discusses the relationship between astronomical time, planetary positions, and the observation of celestial phenomena. Its computational procedures use prescribed astronomical constants and elapsed time to estimate the mean positions of celestial bodies. Further calculations apply correction methods to obtain more representative positions according to the traditional model. This approach demonstrates the systematic use of mathematical relationships in classical Indian astronomy and provides a foundation for studying traditional astronomical computation in digital applications

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The conversion of traditional astronomical procedures into software requires a clear understanding of the units, constants, reference points, and sequence of calculations. Angular quantities must be represented consistently, and values exceeding 360 degrees must be normalized to the range from 0 degrees to less than 360 degrees. The program must also handle transitions between successive angular intervals without producing incorrect results at their boundaries. These requirements make mathematical verification an important part of the software development process.

The traditional astronomical framework can be integrated with the Raspberry Pi by dividing the calculation process into individual software modules. One module can process the date and time obtained from the RTC, another can calculate the required solar and lunar longitudes, and subsequent modules can determine Tithi, Nakshatra, Yoga, and Karana. Vara can be determined from the relevant calendar date. The calculated results can then be formatted and presented on an electronic display. This modular approach improves the readability of the program and makes individual calculations easier to test.

The implementation must also distinguish the traditional astronomical model from the hardware used to execute it. The Raspberry Pi provides the computational capability, while the RTC maintains the time reference. Neither component independently guarantees the correctness of the astronomical results. The reliability of the displayed Panchang depends on the correctness of the mathematical model, the implementation of its equations, the handling of time and location parameters, and the validation of the output.

2. MATHEMATICALFORMULATION

Let λS be the Sun's geocentric ecliptic longitude and λM the Moon's geocentric ecliptic longitude, each in degrees in the range $[0°, 360°)$. The operation $\mathrm{mod}(x, 360°)$ returns the equivalent angle in this range. The following formulas define the angular sectors of the Panchang limbs; the accuracy depends on how the solar and lunar longitudes are calculated.

A. *Tithi*

Tithi represents a lunar day and is determined by the angular separation between the Moon and the Sun. The Moon–Sun angular elongation is calculated as:

$$D = \mathrm{mod}(\lambda M - \lambda S, 360°) \quad (1)$$

where λM represents the lunar longitude and λS represents the solar longitude.

One Tithi corresponds to an angular interval of 12°. Therefore, the Tithi number is calculated as:

$$\text{Tithi Number} = \mathrm{floor}(D / 12°) + 1 \quad (2)$$

Values 1–15 represent Shukla Paksha (waxing phase), while values 16–30 represent Krishna Paksha (waning phase), according to the selected naming convention. A Tithi may begin or end at any time of the day and is not necessarily identical to a civil calendar date.

B. *Nakshatra*

Nakshatra represents the lunar mansion occupied by the Moon along the sidereal zodiac. The complete zodiac of 360° is divided into 27 equal Nakshatras. Each Nakshatra covers an angular interval of:

$$\text{Nakshatra Span} = 360° / 27 = 13°20' \quad (3)$$

The Nakshatra number is calculated using the Moon's sidereal longitude:

Nakshatra Number = floor(λM,sidereal / (360° / 27))

+ 1 (4)

where λM,sidereal represents the Moon's sidereal longitude normalized to the range from 0° to less than 360°.

The resulting value ranges from 1 to 27. The corresponding Nakshatra name is obtained from a predefined sequence. The calculation requires a consistent sidereal reference and, where applicable, an appropriate ayanamsha.

C. *Yoga*

Yoga is determined from the sum of the solar and lunar sidereal longitudes. The combined angular value is first normalized to a complete circle:

Y = mod(λS,sidereal + λM,sidereal, 360°) (5)

The zodiac is divided into 27 equal Yoga intervals. Therefore, the Yoga number is calculated as:

Yoga Number = floor(Y / (360° / 27)) + 1 (6)

Each Yoga spans approximately 13°20′. The calculated number ranges from 1 to 27 and is used to identify the corresponding Yoga name from a predefined list.

D. *Karana*

Karana represents half of a Tithi. Since one Tithi spans 12° of Moon–Sun angular elongation, one Karana corresponds to an angular interval of 6°.
The Karana number within the 60 half-Tithi intervals of a lunar month is calculated as:
Karana Index = floor(D / 6°) + 1 (7)
The resulting index ranges from 1 to 60. The Karana name is determined using the traditional sequence, which includes repeating Karana names and fixed Karana names. Therefore, a lookup table implementing the selected traditional convention is required to convert the calculated index into the correct Karana name.

E. *Vara*

Vara represents the weekday and is determined from the local calendar date. Unlike Tithi, Nakshatra, Yoga, and Karana, Vara does not require the angular difference between the Sun and Moon for its basic calculation.
The weekday can be obtained using the system date or a calendar function in Python. For example:
Vara = Weekday(Local Date) (8)
The calculated weekday is mapped to the traditional names Ravivara, Somavara, Mangalavara, Budhavara, Guruvara, Shukravara, and Shanivara.
For a traditional sunrise-based Panchang, the assignment of Vara may require additional logic based on the local sunrise time rather than the midnight boundary of the civil calendar.

F. *Implementation in the Proposed System*

In the proposed Panchang Indicator, the Raspberry Pi processes the date and time supplied by the RTC module and executes the mathematical calculations using Python. The solar and lunar longitudes are obtained according to the selected astronomical model. These values are then used to calculate Tithi, Nakshatra, Yoga, and Karana, while Vara is determined from the applicable calendar convention.
The calculated values are converted into their corresponding traditional names and displayed on the connected display unit. To ensure reliable operation, the software must handle angular normalization, interval boundaries, date transitions, and time-zone settings. The results should be compared with a trusted Panchang for the same location, date, and calculation convention.

3. PROPOSED SYSTEM ARCHITECTURE

The proposed Panchang Indicator is designed as an embedded system that integrates timekeeping hardware, a processing unit, astronomical calculation software, a display interface, and a power supply. The primary objective of the architecture is to automatically determine and display the five Panchang elements: Vara, Tithi, Nakshatra, Yoga, and Karana. The system combines traditional Indian astronomical calculations with modern embedded computing technology to provide a compact, economical, and user-friendly solution.
The architecture consists of five major functional blocks: the Real-Time Clock (RTC) module, Raspberry Pi, Panchang calculation software, display interface, and power supply. Each block performs a specific function and communicates with the other components to complete the calculation and display process.

A. *Real-Time Clock (RTC) Module*

The RTC module provides the current date and time required for Panchang calculations. In the proposed system, a DS3231 or another compatible RTC module can be used to maintain time when the Raspberry Pi is disconnected from the internet. The RTC communicates with the Raspberry Pi through the Inter-Integrated Circuit (I^2C) interface, which allows the processor to read the stored time and date.
The RTC module generally includes a backup battery that maintains its timekeeping function during interruptions in the main power supply. Before operation, the module must
be configured with the correct date and time. The Raspberry Pi uses this information as the initial input for the Panchang calculation program. Accurate timekeeping is important because the angular positions of the Sun and Moon change continuously, resulting in changes to the Panchang elements.

B. *Raspberry Pi Processing Unit*

The Raspberry Pi serves as the main processing unit of the proposed system. It receives date and time information from the RTC, executes the Panchang calculation software, and manages the output display. Its processing capabilities and support for Python programming make it suitable for performing mathematical calculations and controlling connected electronic devices.

The Raspberry Pi also manages configuration parameters such as the geographical coordinates, local time zone, and selected astronomical calculation method. These parameters are required to ensure that the calculated results follow a clearly defined convention. The processor can be programmed to update the displayed Panchang information periodically and refresh the output whenever a relevant value changes.

C. *Panchang Calculation Software*

The Panchang calculation software is the central computational component of the proposed system. It processes the date, time, and configured parameters to determine the five Panchang elements. The software is intended to use mathematical relationships based on solar and lunar longitudes, with the possibility of incorporating the relevant equations and correction procedures of the traditional Surya Siddhanta framework.

The calculation process begins by obtaining or calculating the solar and lunar longitudes for the selected instant. The angular difference between the Moon and Sun is used to determine Tithi. The Moon's sidereal longitude is used to determine Nakshatra, while the sum of the solar and lunar sidereal longitudes is used to calculate Yoga. Karana is determined from the half-Tithi intervals, and Vara is obtained from the applicable calendar convention.

TABLE I. MAIN BLOCKS OF THE PROPOSED PANCHANG INDICATOR

Block	Function	Example / Implementation
RTC Module	Maintains the date and time when network access is unavailable.	DS3231 RTC
Processing Unit	Executes the program and manages hardware communication.	Raspberry Pi
Calculation Software	Calculates the five Panchang elements using the selected astronomical model.	Python program
Display Interface	Presents the date, time, and Panchang information.	LCD, OLED, or monitor
Power Supply	Provides stable power to the processing unit and peripherals.	Regulated supply compatible with the selected Pi

G. *Advantages of the Proposed Architecture*

The proposed architecture offers several advantages. First, it combines the required hardware and software components into a single compact system. Second, the use of an RTC reduces dependence on continuous internet connectivity for timekeeping. Third, Python programming allows the mathematical calculations to be organized into reusable functions and tested independently. Fourth, the modular design makes it possible to replace the display, modify the calculation method, or introduce additional features without redesigning the complete system.

The architecture also supports educational applications by demonstrating how traditional Indian astronomical principles can be implemented using a modern embedded platform. Its practical usefulness will depend on the correctness of the astronomical model, the reliability of the hardware, and the results of validation against a trusted Panchang.

4. INCORPORATING SURYA SIDDHANTA

The *Surya Siddhanta* is an ancient Indian astronomical text that explains the motion of celestial bodies, including the Sun and Moon. It describes methods for calculating their mean positions and applying astronomical corrections to estimate their true positions.

In the proposed Panchang Indicator project, the principles of the *Surya Siddhanta* can be used to calculate important Panchang elements such as Tithi, Nakshatra, Yoga, and Karana. The Raspberry Pi acts as the main processing unit, while the Real-Time Clock (RTC) module provides the current date and time.

The following equations explain the basic mathematical calculations used in the system. These equations are simplified representations of the calculation process and do not represent a complete numerical implementation of the original *Surya Siddhanta*.

A. MEAN LONGITUDE CALCULATION

Mean longitude represents the average angular position of a celestial body, such as the Sun or Moon, measured from a reference direction. It is calculated using the starting longitude, the mean angular motion, and the elapsed time.

Equation (7): Mean Longitude $\lambda_mean = \mod(\lambda_0 + n \times \Delta t, 360°)$ Where:

- λ_mean = Mean longitude of the celestial body
- λ_0 = Mean longitude at the selected starting epoch
- n = Mean angular motion per day

- Δt = Time elapsed from the epoch in days
- mod = Operation that keeps the result within 0° to 360°

This equation estimates the mean position of the Sun or Moon at a given time. To implement the traditional method, the epoch and angular-motion constants must be taken from the selected *Surya Siddhanta* reference.

B. MANDA CORRECTION

The *manda* correction is a traditional astronomical correction used to adjust the mean position of a celestial body. It accounts for variations in apparent motion according to the selected classical calculation procedure.

Equation (8): Corrected Longitude $\lambda_true = mod(\lambda_mean \pm C_manda, 360°)$ Where:

- λ_true = Corrected longitude
- λ_mean = Mean longitude
- C_manda = Calculated manda correction

The correction depends on the body's position and the parameters used in the selected traditional method. The correct sign and calculation procedure must be established from the chosen reference. This equation illustrates the general structure of the correction but is not sufficient by itself to reproduce classical results.

C. CALCULATION OF PANCHANG ELEMENTS

After obtaining the solar and lunar longitudes, the system uses their angular relationship to calculate the Panchang elements.

1. *Tithi Calculation*

Tithi is determined by the angular difference between the Moon and the Sun. One Tithi corresponds to a 12-degree increase in their angular separation.
Equation (9): Angular Difference $D = mod(\lambda_M - \lambda_S, 360°)$ **Equation (10): Tithi Number** $Tithi = floor(D / 12°) + 1$
Where:

- D = Angular difference between the Moon and Sun
- λ_M = Moon's longitude
- λ_S = Sun's longitude
- floor = Function that takes the greatest integer less than or equal to the value

The resulting number identifies one of the 30 Tithis in a lunar month. Tithi names are assigned according to the applicable lunar-calendar convention.

2. *Nakshatra Calculation*

Nakshatra is determined using the Moon's sidereal longitude. The full 360-degree zodiac is divided into 27 equal sections, each measuring 13 degrees and 20 minutes.

Equation (11): Nakshatra Number

$Nakshatra = floor(\lambda_M,sidereal / 13°20′) + 1$
Where $\lambda_M,sidereal$ represents the Moon's sidereal longitude. The calculated number identifies one of the 27 Nakshatras. The system converts this number into the corresponding traditional Nakshatra name.

3. *Yoga Calculation*

Yoga is calculated by adding the sidereal longitudes of the Sun and Moon. The result is normalized to a range of 0° to 360° and divided into 27 equal sections.

Equation (12): Combined Longitude

$Y = mod(\lambda_S,sidereal + \lambda_M,sidereal, 360°)$

Equation (13): Yoga Number

$Yoga = floor(Y / 13°20′) + 1$
Where Y represents the combined angular value of the Sun and Moon.
The resulting number identifies one of the 27 traditional Yogas. The corresponding Yoga name is obtained using a predefined mapping table.

4. *Karana Calculation*

Karana represents half of a Tithi. Each Karana interval corresponds to a 6-degree increase in the angular separation between the Sun and Moon.

Equation (14): Karana Index

$Karana\ Index = floor(D / 6°) + 1$
The index ranges from 1 to 60 across a complete lunar month. The corresponding Karana name must be determined using the traditional Karana sequence and mapping rules.

RESEARCH METHODOLOGY

The research methodology of the proposed Panchang Indicator describes the steps followed in designing, developing, and testing the system. The main aim of this project is to display important Panchang details such as Tithi, Nakshatra, Yoga, and Karana using a Raspberry Pi and RTC module. The system combines traditional Indian calendar concepts with modern electronic technology to provide Panchang information in a simple and convenient way.

The first step of the methodology is the selection and arrangement of the required hardware components. The main components used in this project are Raspberry Pi, RTC module, display unit, connecting wires, and power supply. The Raspberry Pi acts as the main processing unit, while the RTC module provides the date and time. The display unit is used to show the calculated Panchang information to the user. All hardware components are connected properly and checked before starting the software development process.

After completing the hardware connections, the RTC module is tested to verify the accuracy of the date and time. Correct time information is important because Panchang elements change according to the positions of the Sun and Moon. The time shown by the RTC is compared with a trusted clock. The correct time zone is selected to ensure that the displayed information matches the local time. The RTC is also checked after switching the power supply off and on to verify whether it retains the time correctly.

The next step is software development. Python programming is used to control the Raspberry Pi and perform the required operations. The software reads the current date and time, processes the information, performs the necessary calculations, and displays the final output. The program is divided into simple sections so that the date and time can be handled separately from the Panchang calculations and display functions. This approach makes the program easier to understand, test, and modify.

The astronomical concepts of Surya Siddhanta are considered while studying the calculation of Panchang elements. Surya Siddhanta is an ancient Indian astronomical text that explains the movement of celestial bodies. The positions of the Sun and Moon play an important role in determining Panchang values. The angular difference between the Sun and Moon is used to determine Tithi and Karana. The Moon's position is used to determine Nakshatra, while the combined positions of the Sun and Moon are used to determine Yoga. The calculation formulas are implemented according to the selected astronomical method.

After the calculation process, the numerical results are converted into traditional Panchang names. For this purpose, predefined lists are used in the program. These lists help display the correct names of Tithi, Nakshatra, Yoga, and Karana instead of only showing numerical values. The information is then arranged in a suitable format and sent to the display unit.

The developed software is tested using different dates, times, and input values. The purpose of testing is to check whether the calculations and displayed results are correct. Special attention is given to values near the boundaries where one Panchang element changes into another. The program is also checked to ensure that it does not display incorrect names or invalid values. If any error is found, the program is modified and tested again.

The calculated results are compared with a trusted Panchang for the same date, time, and geographical location. This comparison helps evaluate the correctness of the system. Different dates are selected for testing, including dates when Tithi or Nakshatra changes. The time zone and astronomical calculation method are kept consistent as far as possible because different calculation methods may produce slightly different results. The observations and differences are recorded for further analysis.

The display unit is tested to ensure that the information is clear and easy to read. The date, time, and Panchang details should be displayed in a proper arrangement. The system is checked to confirm that all required information appears correctly and updates according to the program's operation. A simple display layout helps users understand the information without difficulty.

Finally, the complete Panchang Indicator is tested to evaluate its overall performance. The Raspberry Pi is restarted several times to check whether the software starts correctly. The RTC is tested after a power interruption, and the system is operated continuously for some time to observe its stability. The same input values are tested repeatedly to confirm that the program produces consistent results.

The observations collected during testing are recorded and analyzed. The accuracy of the date and time, correctness of the Panchang calculations, readability of the display, and reliability of the hardware are considered during evaluation. Any differences between the calculated values and the reference Panchang are examined to identify possible causes, such as time-setting errors or differences in the astronomical calculation method.

Thus, the research methodology provides a systematic approach to developing and evaluating the Panchang Indicator. By following these steps, the project aims to provide a simple and reliable digital system for displaying important Panchang information. It also demonstrates the practical application of Raspberry Pi, RTC technology, Python programming, mathematical calculations, and traditional Indian astronomical concepts in an engineering project.

CONCLUSION

The Panchang Indicator project successfully demonstrates the integration of traditional Indian calendar concepts with modern embedded system technology. By using a Raspberry Pi, RTC module, and software-based processing, the system provides a convenient platform for displaying date, time, and Panchang-related information. The incorporation of selected Surya Siddhanta principles helps connect traditional astronomical knowledge with modern computational

methods. The project reduces the need for manual calendar checking and offers a user-friendly approach to accessing important Panchang details.

The system can be further improved by implementing more accurate astronomical calculations, automatic sunrise and sunset timings, location-based Panchang information, multilingual support, and historical data storage. In conclusion, the Panchang Indicator represents a useful combination of Indian astronomical traditions and modern engineering technology, with potential applications in homes, educational institutions, temples, and research activities.

LIMITATIONS AND FUTURE SCOPE

The accuracy of the Panchang Indicator depends on the selected astronomical model, mathematical formulas, reference epoch, constants, geographical location, time zone, and calculation methods. Incorrect input data or software errors may produce inaccurate Panchang values. The RTC module maintains the system time but cannot independently calculate planetary positions, Tithi, Nakshatra, Yoga, Karana, or sunrise timings. Therefore, the system requires proper astronomical algorithms and validation against reliable Panchang references.

The system may also face limitations related to power supply, hardware performance, display readability, and regional calculation conventions. Future improvements may include automatic location selection, advanced Surya Siddhanta calculations, automatic sunrise and sunset calculation, multilingual display, lunar phase monitoring, historical data storage, and voice announcements. The system can also be connected to a web dashboard or mobile application for remote access and improved user interaction.

Further development may include comparing traditional Surya Siddhanta calculations with modern astronomical data to identify differences and improve accuracy. Additional features such as automatic date updates, backup power, error detection, and customizable display settings can improve reliability. The project may also be expanded into an educational tool to explain traditional Indian astronomy and Panchang calculations. These improvements can make the Panchang Indicator more accurate, user-friendly, reliable, and useful for educational and daily applications.

REFERENCES

[1] E. Burgess, *Translation of the Sûrya-Siddhânta: A Text-Book of Hindu Astronomy, with Notes and an Appendix*. American Oriental Society, 1860.
[2] J. Meeus, *Astronomical Algorithms*, 2nd ed. Willmann-Bell, 1998.
[3] Raspberry Pi Ltd., *Raspberry Pi Documentation*.
[4] Analog Devices, *DS3231: Extremely Accurate I²C-Integrated RTC/TCXO/Crystal*.
[5] Python Software Foundation, *Python 3 Documentation*.
[6] Python Software Foundation, *The Python Tutorial*.
[7] International Astronomical Union, *The International Astronomical Union*.
[8] NASA, *Solar System Exploration*.
[9] NASA Jet Propulsion Laboratory, *Horizons System*.
[10] Linux Kernel Organization, *The Linux Kernel Documentation*.
[11] Git, *Git Documentation*.
[12] E. Burgess, *The Sūrya-Siddhānta: A Text-Book of Hindu Astronomy*. American Oriental Society, 1860.
[13] J. Meeus, *Astronomical Algorithms*, 2nd ed. Willmann-Bell, 1998.
[14] Analog Devices, *Real-Time Clock (RTC) Technical Documentation*.
[15] Raspberry Pi Ltd., *Getting Started with Raspberry Pi*.
[16] Python Software Foundation, *Python Programming Language Documentation*.
[17] NASA, *Astronomical Data and Planetary Science Resources*.
[18] International Astronomical Union, *Fundamental Astronomy and Celestial Coordinate Systems*.
[19] D. M. Etter, J. C. Kuncicky, and H. Moore, *Introduction to MATLAB*. Pearson.
[20] R. A. Seber and C. J. Wild, *Nonlinear Regression*. John Wiley & Sons, 1989.
[21] J. L. Heilbron, *The Sun in the Church: Cathedrals as Solar Observatories*. Harvard University Press, 1999.