

Design of a real-time prayer clock using geographic coordinates

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ABSTRACT

Prayer times and calendar clock are a valuable system that relies on programs that we developed in Mikroc that allow to mathematically calculate these prayer times, which differ from one place (city) to another and from one day to another using geographical coordinates. The more precise these coordinates (latitude and longitude), the more precise the prayer times are. The research that we conducted was carried out using a 16F876A microcontroller that uses the 74HC595 circuit, an 8-bit serial input and parallel output shift register for storage. Outputs can be added to the microcontroller thanks to this. It is possible to manage this integrated circuit from three pins of our microcontroller.

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1. INTRODUCTION

Time plays a central role in structuring both human activities and religious practices. In Islam, prayer (Ṣalāt) represents one of the fundamental pillars of faith and must be performed five times daily at specific intervals: Fajr, Dhuhr, Asr, Maghrib, and Isha. The correct timing of these acts of worship is not arbitrary but closely linked to the apparent movement of the sun. For this reason, the accurate determination of prayer times has always been of critical importance for Muslim communities [1].

Historically, the calculation of these times relied on direct observation of astronomical phenomena. Early scholars developed sophisticated methods based on the sun's altitude, twilight angles, and shadow lengths, which later evolved into tabular calendars and astronomical handbooks. With the expansion of cities and the advancement of science, printed prayer timetables became widespread and provided standardized references for mosques and households [2].

However, these traditional methods present significant limitations in modern contexts. Printed schedules are static and location-dependent, and they cannot adapt to the mobility of individuals who frequently travel or relocate. Mobile applications, while popular and highly practical, usually require access to the internet, GPS permissions, and regular software updates [3]. In addition, their accuracy can vary depending on the adopted convention for twilight angles (12°, 15°, or 18°), which sometimes leads to confusion among users. Pre-programmed electronic clocks offer another alternative but often rely on fixed lookup tables or limited sets of predefined cities, making them unsuitable for dynamic environments.

These shortcomings highlight the need for more autonomous and intelligent systems. Advances in microcontrollers, GPS modules, and real-time embedded processing now enable the design of devices that can calculate prayer times directly from geographic coordinates without external dependencies. Such systems

can operate independently of the internet, provide real-time updates, and automatically adjust to any location on Earth [4].

The work presented in this paper focuses on the development of a real-time prayer clock that integrates GPS-based geographic data with astronomical models for precise calculation. The proposed design leverages a PIC16F876A microcontroller to implement the computation of solar positions and prayer times, while multiplexed displays and shift registers ensure efficient visualization of results. Compared to existing solutions, this system provides a portable, self-sufficient, and highly accurate alternative, particularly valuable for travelers and communities in remote areas with limited access to technology.

2. RESEARCH METHOD

2.1. Prayer calendar, calculation details

The determination of prayer times depends on both the geographic position of a location (latitude and longitude) and the date. Several astronomical conventions are used to define the exact start of each prayer [5]. Figure 1 illustrates the sun's apparent path used to determine the timing of daily prayers.

- Fajr (dawn prayer): begins at the appearance of true dawn (Fajr Šādiq). Under the nautical twilight convention, this is when the sun is about 12° below the horizon before sunrise. Other organizations adopt the astronomical twilight value of 18° . To avoid uncertainty, some authorities apply a precautionary offset of a few minutes [6].
- Chourouk (sunrise): occurs when the upper edge of the solar disc becomes visible at the horizon. To account for atmospheric refraction, an adjustment of approximately 0.6° is applied.
- Dhuhr (noon prayer): starts shortly after the sun passes the local meridian. A small delay—often around five minutes—is conventionally added after solar noon before the beginning of this prayer.
- ASR (afternoon prayer): according to the Shafi'i school, this time is determined when the length of an object's shadow equals its height plus the shadow length at noon [7].
- Maghrib (sunset prayer): begins immediately after sunset, which is defined as the sun being about 0.6° below the horizon. As a safeguard, some timetables add a short margin before the transition to Isha.
- Isha (night prayer): begins after the disappearance of twilight. The nautical twilight convention sets this at 12° , while the astronomical standard places it at 18° . In Algeria, for instance, an alternative practical rule sets Isha at 90 minutes after Maghrib [8].

These definitions make it possible to adapt prayer times to seasonal changes, latitude variations, and local traditions, thereby ensuring precise and reliable scheduling.

2.2. Structure and algorithm of prayer time

The proposed system is composed of two primary units: a GPS receiver and a microcontroller-based processing unit (Figure 2). The GPS module supplies the geographic coordinates, while the microcontroller executes the necessary computations to determine the prayer times [9].

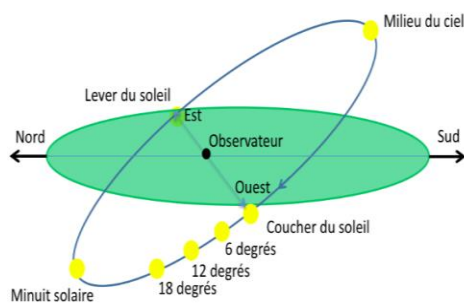


Figure 1. Apparent trajectory of the sun over a day and night on March 21 in Paris (angles and distances are not to scale) [10]

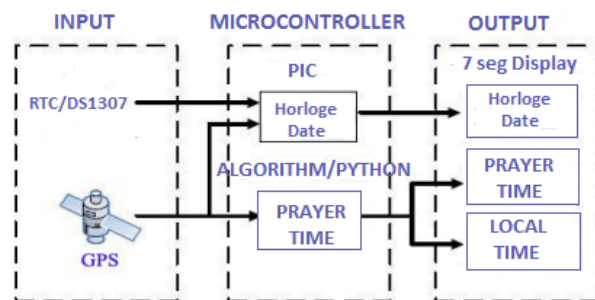


Figure 2. Apparent trajectory of the sun over a day and night on March 21 in Paris (angles and distances are not to scale [11])

The proposed device integrates two main components: a GPS receiver and a microcontroller-based processing unit. The GPS module continuously provides geographic coordinates, while the microcontroller executes astronomical equations to determine prayer times.

To compute these times, three key parameters must be known: the latitude (B), longitude (L), and reference longitude (R) of the location. Latitude and longitude are directly obtained from the GPS, whereas

the reference longitude is calculated by multiplying 15° by the time-zone offset between local time and GMT (since the Earth rotates 15° per hour) [12].

In addition, two astronomical quantities are required: the solar declination angle (δ) and the equation of time (T). The declination angle accounts for the seasonal tilt of the Earth (approximately 23.45°), while the equation of time corrects for the irregularities in the apparent solar time caused by the Earth's elliptical orbit and axial tilt.

The solar declination can be approximated as (1) [13]:

$$\delta = 23.45^\circ * \sin\left[\frac{360}{365}(d - 81)\right] \quad (1)$$

Where d is the day of the year (with $d=1$ on January 1st).

The equation of time (EoT) is estimated by:

$$T = 229.18 * \{0.000075 + [0.001868 * \cos[\beta]] - [0.032077 * \sin[\beta]] - [0.014615 * \cos[2 * \beta]] - [0.040849 * \sin[2 * \beta]]\} \quad [14] \quad (2)$$

Where β is the day angle, defined as (3):

$$\beta = \frac{360}{365}(d - 1) \quad [15] \quad (3)$$

The five daily prayer times can then be derived from a combination of these parameters:

– Solar noon (Zuhr):

$$Z = 12 + \frac{(R-L)}{15} - \frac{T}{60} \quad [16] \quad (4)$$

– Sunrise and sunset (Chourouk and Maghrib):

$$U = \frac{1}{15} * \text{ArcCos} \left[\frac{-\sin(h_0) - \sin(\delta) * \sin(B)}{\cos(\delta) * \cos(B)} \right] \quad [17] \quad (5)$$

– Fajr and Isha (based on twilight angle G):

$$V = \frac{1}{15} * \text{ArcCos} \left[\frac{-\sin(G) - \sin(\delta) * \sin(B)}{\cos(\delta) * \cos(B)} \right] \quad [18] \quad (6)$$

– Asr (shadow length method):

$$W = \frac{1}{15} * \text{ArcCos} \left[\frac{\sin\left(\arctan\left(\frac{1}{n} + \tan(|B - \delta|)\right)\right) - \sin(B) \sin(\delta)}{\cos(\delta) * \cos(B)} \right] \quad (7)$$

Where: h_0 is the solar altitude at sunrise/sunset ($\approx -0.83^\circ$ including refraction), G is the twilight angle (commonly 12° or 18° depending on the adopted convention), and n is the ratio used for ASR ($n=1$ for Shafi'i, $n=2$ for Hanafi) [19].

Finally, the prayer times are determined as: Fajr= $Z-V$, Zuhr= Z , Asr= $Z+W$, Maghrib= $Z+U$, and Isha= $Z+V$.

This algorithm ensures that all six daily timings (five obligatory prayers and sunrise) are computed dynamically and adjusted to the exact geographical location, without reliance on preloaded tables or internet-based services [20].

2.3. Comparative overview of existing prayer time tools

To emphasize the novelty and autonomous nature of the proposed system, it is useful to compare it with existing solutions currently used to provide prayer schedules. Common alternatives include mobile applications, pre-programmed static clocks, and online calculators. These tools differ in terms of adaptability, dependency on external resources, and level of autonomy [21].

- Mobile applications generally offer accurate results but depend heavily on internet connectivity and frequent software updates. They also require user interaction, such as manual entry of location or GPS permission, which may not always be convenient.
- Static prayer clocks provide local schedules but are typically based on preloaded lookup tables. As such, they cannot adapt to changing locations and are unsuitable for travelers or remote areas.
- Web-based calculators offer flexibility, since users can enter geographic data manually. However, they are not portable and require continuous access to a computer or mobile browser.

In contrast, the proposed embedded system operates independently of internet access and does not rely on preconfigured databases. It dynamically computes prayer times using GPS coordinates and astronomical algorithms, ensuring both portability and real-time adaptability [22]. Table 1 summarizes and compares the main features of the proposed system with existing solutions, emphasizing its superior autonomy and adaptability. This comparison illustrates that the proposed design combines the advantages of portability, autonomy, and accuracy while avoiding the main limitations of existing alternatives.

Table 1. Feature-based comparison of the proposed prayer time system with existing solutions [23]

Feature	Proposed system	Mobile app	Static clock	Web calculator
Internet required	No	Yes	No	Yes
Location adaptability	Yes (GPS-based)	Yes (manual)	No	Yes (manual entry)
Real-time computation	Yes	Sometimes	No	Yes
Embedded/standalone operation	Yes	No	Yes	No
Portability	High	High	Low	N/A
Power source	Electric/solar	Battery	Plug-in	N/A

3. RESULTS AND DISCUSSION

3.1. System architecture and operational flow

The overall structure and workflow of the proposed system are shown in Figure 3. This diagram provides a high-level representation of the hardware components and the data flow required to compute prayer times. Once the GPS module delivers the geographic coordinates (latitude and longitude), the microcontroller executes the set of astronomical equations (subsection 2.2) and displays the computed values on multiplexed 7-segment displays [24].

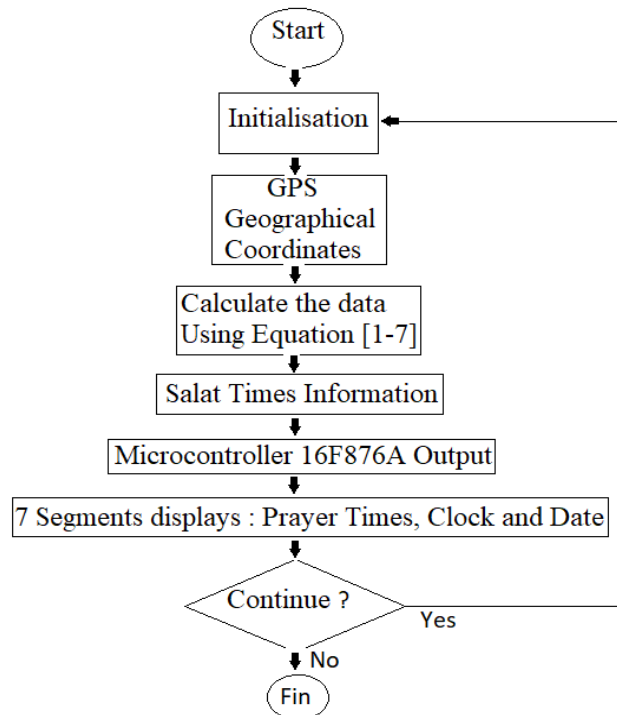


Figure 3. General system scheme [25]

The program developed in MikroC was specifically optimized to handle the calculations efficiently and to control the display with minimal hardware resources. This allows the system to provide continuous real-time updates of both the date and the six daily prayer times.

3.2. Display of prayer times

Figure 4 illustrates an example of the displayed prayer times for the city of Tlemcen, Algeria. The output includes the five daily obligatory prayers—Fajr, Dhuhr, ASR, Maghrib, and Isha—along with sunrise and the current clock time. As expected, the exact timing varies depending on the geographic coordinates of the location.

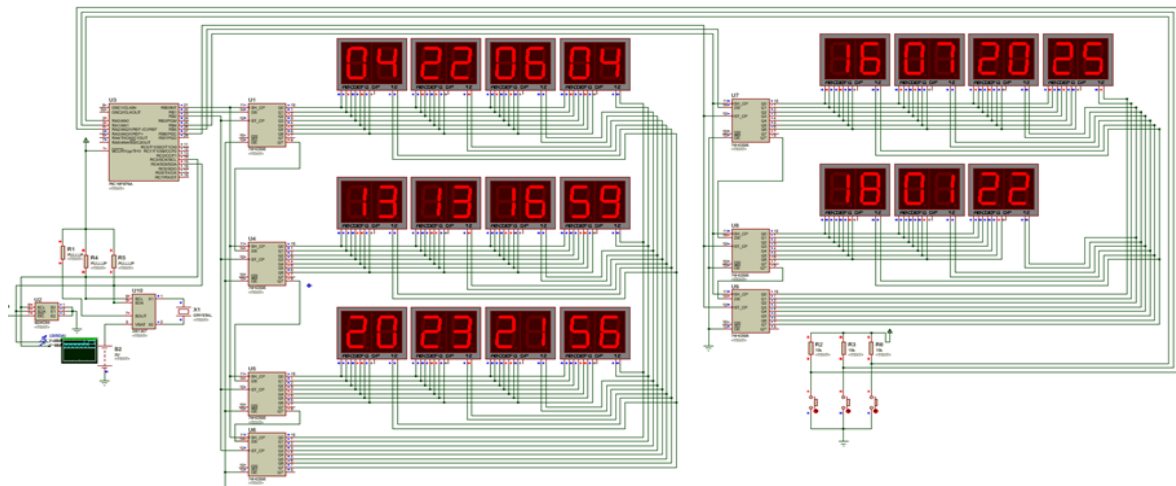


Figure 4. Display of the five prayer times as well as clock and the Gregorian date

Fajr: 04:22, Chourouk: 06:04, Zuhr: 13:13, ASR: 16:59, Maghrib: 20:23, Icha: 21:56, Date: 16/07/2025, and Clock: 18:01:22

Figure 5 shows the digital clock functionality in the hh:mm:ss format, where hours, minutes, and seconds are represented using multiplexed 7-segment displays. This configuration is widely adopted in embedded systems, as it enables real-time visualization of time with efficient use of microcontroller input/output pins.

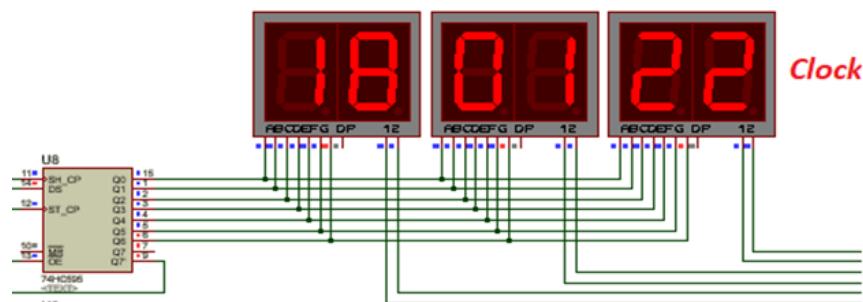


Figure 5. Display of hours, minutes, and seconds

Figure 6 presents another view where selected prayer times (Fajr, Chourouk, Dhuhr, and ASR) are displayed simultaneously. The use of shift registers (74HC595) reduces the required hardware resources while ensuring accurate updates of each display unit.

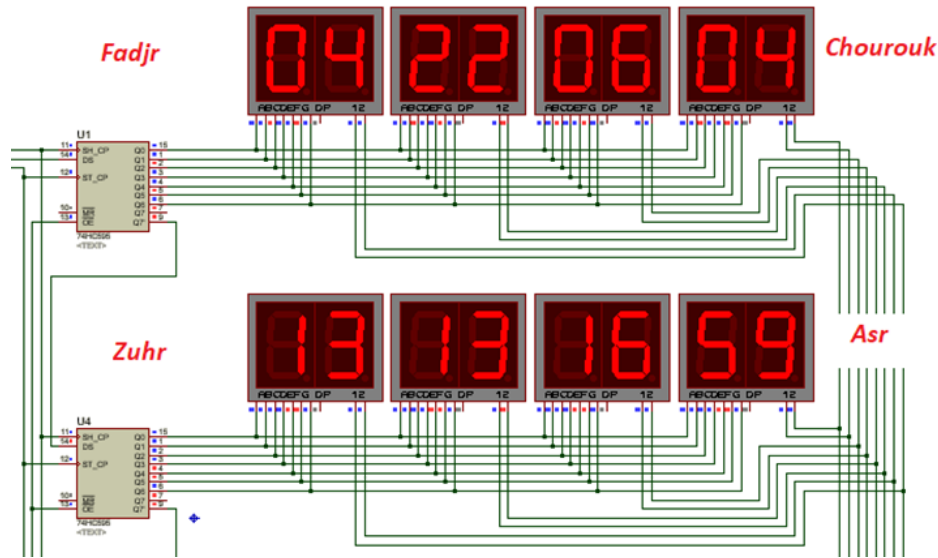


Figure 6. Exhibition of prayer times, Fajr and Dohr as well as 16F876A microcontroller

3.3. Geographic data integration

Figure 7 demonstrates the integration of geographic data. The GPS module retrieves the latitude and longitude of the city of Maghnia (approximately 34.85° N, -1.78° E). These values, combined with the current date from the RTC module, are transmitted to the microcontroller, which computes the six prayer times using the implemented astronomical algorithm [26]. This mechanism ensures that the system automatically adapts to the user's exact location.

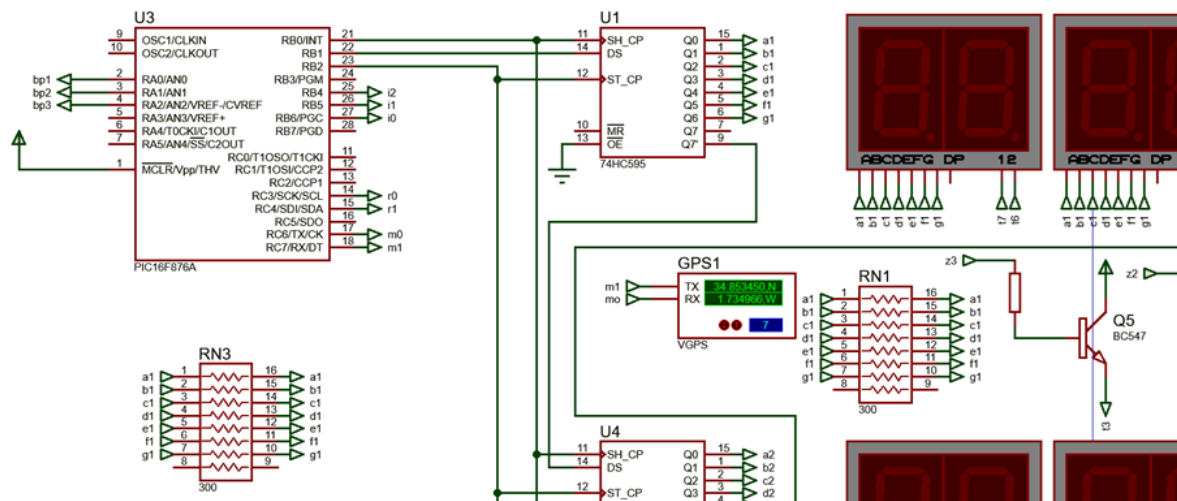


Figure 7. Geographic data (latitude and longitude) of the city of Maghnia sent to the microcontroller for calculating prayer times

Figure 8 shows the push-button interface designed for user configuration. Three buttons allow navigation between system parameters, including time, date (Gregorian or Hijri), and prayer settings. A debouncing technique was implemented in software to avoid multiple triggers and enhance reliability.

The “Select” button enables the user to cycle through the editable fields (such as hour, minute, day, month, year, or prayer time entries). Once a field is selected, the “Up” and “Down” buttons allow the user to increment or decrement the value, respectively [27]. This intuitive navigation method offers an efficient way to adjust settings without the need for an external interface. The buttons are debounced in software to avoid multiple false triggers.

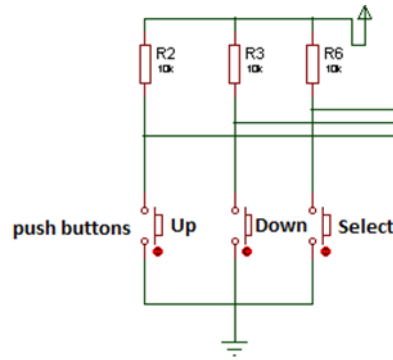


Figure 8. Push button circuit

3.4. Accuracy evaluation

To evaluate accuracy, the calculated prayer times were compared with reference data obtained from IslamicFinder for the same date and location. Table 2 summarizes the results. The differences between the proposed system and the reference values range from 0 to 2 minutes, which is acceptable given the variations in twilight conventions and rounding of astronomical constants. The results confirm that the proposed system maintains a high level of precision, with only minimal deviations from the official data.

Table 2. Comparison of calculated prayer times with IslamicFinder reference data [28]

Prayer	IslamicFinder time	System	Difference (min)
Fajr	04:20	04:22	+2
Chourouk	06:05	06:04	-1
Dhuhr	13:14	13:13	-1
Asr	16:58	16:59	+1
Maghrib	20:23	20:23	0
Isha	21:55	21:56	+1

4. CONCLUSION

This work presented the design and implementation of a real-time clock-calendar system capable of automatically calculating and displaying the daily Islamic prayer times. The solution is built around a PIC16F876A microcontroller, supported by a GPS module for geographic positioning and an RTC for date and time management. A set of astronomical equations was implemented to compute prayer times with high accuracy, and the results were displayed using resource-efficient 7-segment interfaces.

The main contributions of the system can be summarized as follows: i) autonomous determination of prayer times (Fajr, Chourouk, Dhuhr, ASR, Maghrib, and Isha) without the need for internet access or preloaded tables; ii) real-time visualization of both Gregorian and Hijri calendar dates, in addition to the clock time in hh:mm:ss format; iii) efficient hardware design using shift registers (74HC595) and multiplexed displays, which reduces complexity while ensuring accuracy; and iv) integration of GPS-based location data to dynamically adapt the prayer schedule to any geographic position.

Validation against reference data from IslamicFinder demonstrated a maximum deviation of ± 2 minutes, confirming the reliability and precision of the proposed design. This level of accuracy is sufficient to satisfy religious requirements while ensuring portability and ease of use. From a broader perspective, this project contributes to the emerging field of embedded religious technology, where modern microcontrollers and astronomical modeling are applied to address traditional spiritual needs. The proposed solution offers a practical, portable, and autonomous alternative to static prayer clocks and internet-based applications, making it particularly valuable in remote areas or regions with limited connectivity.

Future work could focus on extending the system with additional features, such as: i) supporting multiple international conventions for prayer time calculation, ii) automatic adjustment for daylight saving time and regional time zones, iii) integration of Qibla direction detection using digital compasses, iv) enhanced accessibility features such as audio or vibration alerts, and v) a multilingual, menu-driven user interface. In summary, the developed system demonstrates how embedded technologies can be effectively combined with astronomical models to create a smart and autonomous Islamic assistant. Its adaptability, portability, and precision position it as a valuable tool for both individual users and communities.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Moulai Khatir Ahmed Nassim	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓		✓

C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nvestigation

R : **R**esources

D : **D**ata Curation

O : Writing - **O**riginal Draft

E : Writing - Review & **E**diting

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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