A Smart Menstrual Health Monitoring System with Predictive Analytics Using Machine Learning and Lifestyle Data

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Abstract
Menstrual health is a vital aspect of a woman's overall well-being. It has been observed that menstrual cycles are often influenced by various lifestyle factors such as stress, sleep patterns, physical activities, and body mass index (BMI). Many women experience menstrual irregularities, including frequent or delayed cycles, which may impact overall health. Many menstrual tracking systems have been proposed, but they primarily focus on recording cycle dates and lack predictive analysis and personalized health recommendations. This work proposes a web based menstrual health prediction and alert system using machine learning to support effective management of mensural related issues. Furthermore, this system enables users to input historical menstrual cycle data along with lifestyle related information. This data is analyzed using a Linear Regression model to predict the next expected menstrual cycle date. Data preprocessing techniques are also employed to improve the reliability and accuracy of predictions. The predicted results are presented through a user friendly web interface developed using Flask, ensuring ease of interaction. Additionally, an alert mechanism is incorporated to notify users when the predicted menstrual date approaches or occurs. This enables users to prepare in advance and better understand their cycle patterns. The proposed system also focuses on identifying irregular patterns to enhance user awareness, while explicitly avoiding any form of medical diagnosis. Our results demonstrate that the proposed system effectively promotes menstrual health awareness through a user friendly, smart and predictive platform.

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Keywords: mensural health, machine learning, linear regression, lifestyle data, alert system

1. Introduction

Menstrual health is a crucial aspect of women's physical and emotional well-being [1]. However, it is often overlooked or inadequately addressed due to a lack of awareness, social stigma, and limited access to personalized healthcare tools [2]. A regular menstrual cycle serves as an important indicator of overall health. Irregularities such as frequent, delayed, or missed cycles may be influenced by factors including stress, sleep patterns, lifestyle habits, hormonal changes, and body mass index (BMI) [3, 5]. Many women track their menstrual cycles manually or rely on basic calendar-based applications. These systems primarily record dates but do not provide meaningful predictions or personalized health insights. Machine learning has emerged as a powerful tool for analyzing health-related data and identifying patterns that are not easily noticeable through manual tracking. Machine learning models can analyze historical menstrual cycle data along with lifestyle inputs to predict future cycles more accurately. However, most existing menstrual tracking systems do not utilize machine learning effectively and fail to provide predictive analysis or alert mechanisms that help users prepare in advance. Although several machine learning based

approaches have been proposed for menstrual health prediction, most of them primarily focus on data tracking and lack integrated alert mechanisms and user-friendly implementations. In this work, we designed a user friendly web-based menstrual health prediction and alert system using machine learning algorithm to effectively manage mensural related issues with health recommendations. The proposed system collects historical menstrual cycle data along with lifestyle inputs such as stress, sleep, and BMI to predict the next cycle date using a Linear Regression model. Furthermore, the proposed system focuses on identifying irregular patterns to enhance user awareness and support effective management of menstrual health. By detecting deviations such as frequent or delayed cycles, the system enables users to take timely precautions and make informed decisions. It serves as a supportive tool for better understanding and managing menstrual irregularities. Overall, it demonstrates the practical effectiveness of machine learning in addressing real-world challenges in women's health.

2. Problem Statement and Objectives

Although many ML based systems have been proposed, many still lack lifestyle data collection, integrated alert mechanisms and userfriendly implementations that support effective menstrual health management. As a result, many women experience difficulties in understanding irregular menstrual patterns influenced by factors such as stress, sleep patterns, and BMI. The absence of predictive analysis and timely alerts makes it challenging for them to anticipate cycle changes and manage their health effectively. Therefore, there is a strong demand for a smart system that can analyze historical menstrual data along with lifestyle factors to predict future cycles, identify irregularities, and provide timely alerts. The following objective are considered in this work:

- To develop a userfriendly web based menstrual health prediction system that allows users to track cycles and receive predictions.
- To collect and analyze lifestyle factors that influence menstrual cycles.
- To predict the next menstrual cycle date using historical data.
- To implement a Linear Regression model for accurate prediction of mensural cycle patterns.
- To identify irregular mensural patterns.
- To provide an alert mechanism that notifies users.

3. Related Work

This section emphasizes on the existing work, highlighting their strengths and limitations. Research gaps are also highlighted in this section.

Yu *et al.* [5] developed ML based prediction model to predict the fertile window and menses. This system requires continuous monitoring of BBT and HR through wearable devices. The major limitations of this model are that it does not fully consider lifestyle factors and is complex to implement.

M.Sneha *et al.* [6] demonstrated ML based model for prediction of PCOS at early stage. They focused more on analysis rather than individualized prediction. This system does not adapt to user specific cycle variations.

S. Ruengdat *et al.* [7] explained a menstrual date prediction model that uses social media emotional post as input. This study explains how sentimental analysis can be integrated with prediction models to estimate mensural cycle timing. However, this system has limitations, as social media posts may not be complete and irregular. This model relies on noisy and inconsistent social media data, which may reduce prediction accuracy. Additionally, it lacks consideration of biological and medical factors influencing menstrual cycles.

The following research gaps are identified:

- Limited prediction accuracy
- No lifestyle factors analysis
- Lack of personalization
- No proactive alert mechanism
- Inability to identify causes of irregularities

3. Proposed Methodology

3.1. Proposed Model

This section describes the proposed model with its underlying methodology. To overcome the limitations of existing mensural tracking systems, the proposed system uses a linear regression model that incorporates lifestyle factors for improved accuracy. The proposed framework is explained in the three steps.

3.1.1. Data Pre-processing

In proposed framework a pre-processing pipeline is implemented to ensure data quality and consistency. This process involves handling missing values using suitable imputation methods, removing noisy and inconsistent data, and normalizing numerical features. Different lifestyle attributes such as stress level, sleep duration, and BMI, along with menstrual cycle data, are standardized to ensure equal contribution during model training. Effective preprocessing enhances the model's ability to learn meaningful patterns and improves overall prediction accuracy.

3.1.2. Linear Regression Model

The proposed linear regression based model predicts the next menstrual cycle date using historical menstrual records and lifestyle-related features such as stress level, sleep duration, and bmi. Since the target variables (e.g., cycle length and next cycle date) are continuous, Linear Regression is an appropriate choice for this prediction task. This model establishes a linear relationship between independent variables (input features) and the dependent variable (cycle prediction) by minimizing the error between actual and predicted values. Its low computational complexity and interpretability make it ideal for healthcare related applications.

3.1.3. Prediction and Alert Logic

After training, proposed model predicts the next expected menstrual cycle date using user input and historical data. The predicted date is stored in the system and continuously compared with the current date during user interaction. If the predicted date matches the current date, an alert is generated to notify the user. This proactive alert mechanism helps users prepare in advance and enhances menstrual health awareness. The flow diagram of the proposed system is depicted in Fig.1.

The proposed mensural health prediction system is designed by using a layered approach to ensure efficient data processing, accurate prediction, and timely alert generation.
The proposed system is implemented as web based application in four layers: User Layer, Processing Layer, Machine Learning Engine, and Data & Alert Layer as shown in fig.1.

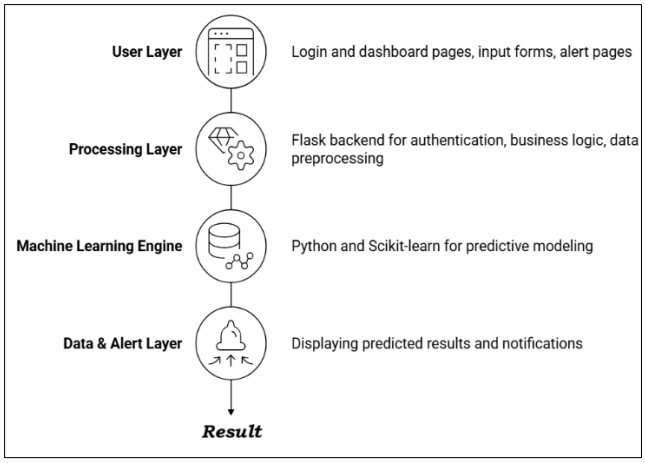

Fig 1: Flow diagram of Proposed System

1. **User Layer:** The workflow begins with this layer. It serves as the interface between the user and the system. This layer provides functionalities such as user login, dashboard access, and input forms for entering menstrual cycle data and lifestyle parameters (e.g., stress level, sleep duration, and BMI). It also displays predicted results and alert notifications to the user.
2. **Processing Layer:** This layer receives input data from the user layer. This layer is implemented by using Flask. This layer is responsible for user authentication, manages application logic, and executes data preprocessing operations. This layer also incorporated preprocessing module. The preprocessing module handles missing values, removes inconsistencies, and formats the data into a structured form suitable for model input. Additionally, this layer controls the data flow between the frontend, machine learning engine, and storage components. After preprocessing, the cleaned data is passed to ML Engine.
3. **ML Engine:** This layer is implemented by using Python and Scikit-learn. This receives pre-processed data and utilizes historical training data to build a predictive model that captures patterns in menstrual cycles along with lifestyle factors. The trained model processes the input features and predicts the next expected menstrual cycle date. Furthermore, the system generates personalized recommendations based on the prediction results.
4. **Data and Alert Layer:** The predicted output is stored and managed by this layer. This layer is responsible for data storage and notification services. User data and historical records are maintained in a CSV file, which acts as a lightweight storage solution suitable for this application. The alert mechanism continuously compares the predicted date with the current date and triggers notifications, such as email alerts, to inform users about upcoming menstrual cycles or potential delays.

Finally, the prediction results and alert notifications are communicated to the user through the user layer.
This layered architecture ensures a systematic and efficient flow of data from user input to prediction and alert generation. It enhances system performance, scalability, and user experience.

3.2. Implementation of Proposed Framework

The proposed system is implemented as a web based application that uses linear regression to generate accurate predictions based on given input data. The proposed system is implemented by using the following technologies, tools and packages listed in Table 1.

Table 1: Tools and Technologies Used

Category	Specification
Operating System	Windows 10 or higher
Programming Language	Python 3.x
Web Framework	Flask
IDE Tool	Visual Studio Code
Frontend Technologies	HTML, CSS
Template Engine / UI	Jinja2 (Flask Templates)
Libraries Used	NumPy, Pandas, Scikit-learn, Joblib
Database / Storage	CSV File (Prototype Level)
Web Browser	Google Chrome / Microsoft Edge
Model Deployment	Joblib (Model Serialization)

The following sequence of activities are performed to access our proposed web based prediction and alert system.

1. The user accesses the system through a web browser.
2. The user registers to create a new account.
3. The user logs in securely to access the application.
4. After successful authentication, the user is redirected to the dashboard.
5. The user navigates to the data entry form provided in the interface.
6. The user enters details such as previous menstrual cycle dates, cycle length, and health-related inputs including age, Body Mass Index (BMI), stress level, sleep duration, diet, and physical activity.
7. Input validation is performed to ensure that all required fields are correctly filled and formatted.
8. Upon submission, the entered data is transmitted to the backend server.
9. The backend performs data preprocessing, including handling missing values, cleaning inconsistent data, and normalizing features.
10. The preprocessed data is fed into the trained machine learning model for prediction.
11. The model analyzes the input features and predicts the next menstrual cycle date and expected duration.
12. The predicted results are stored in the system and displayed on the user dashboard.
13. The system continuously compares the predicted date with the current date.
14. When the predicted date matches or approaches, an alert is triggered to notify the user through reminders or email notifications.
15. In case of delays or irregularities, the system analyzes lifestyle factors and provides possible reasons along with health-related suggestions.

Our dataset consists of historical menstrual cycle data and lifestyle factors such as BMI, stress level, and sleep duration, stored in CSV format. This sample dataset is used for training and prediction.

4. Results

Our proposed system is successfully implemented using tools and technologies mentioned in Table 1 and also evaluated using user provided inputs. This system was trained and tested on collected and preprocessed data. The output of proposed mensural health prediction system with inputs are shown in figure 2,3,4,5,6 and 7.

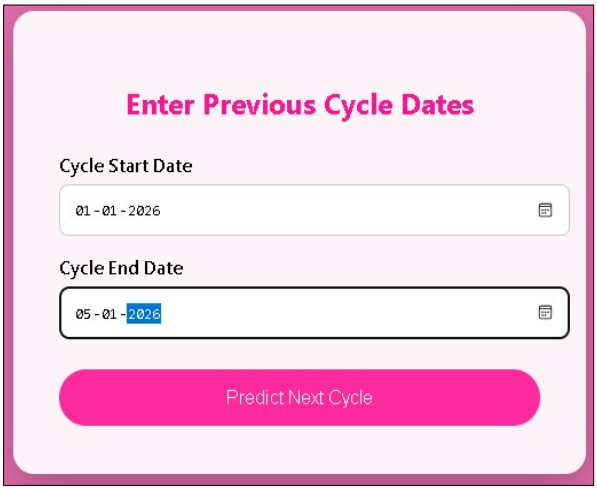

Fig 2: User Input- Cycle Dates

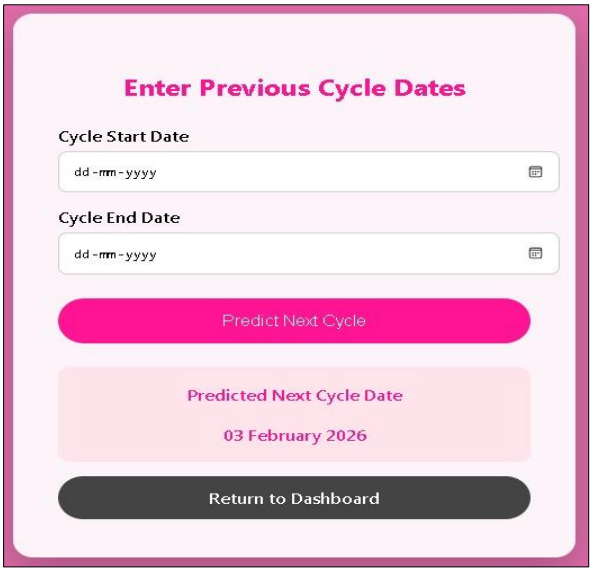

Fig 3: Predicted Date

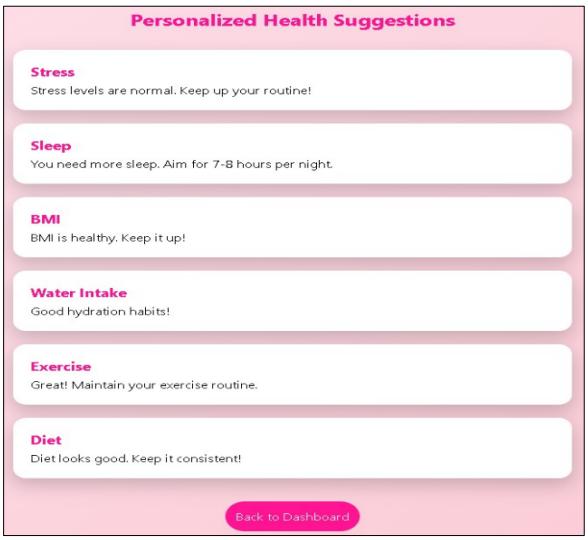

Fig 4: Personalized Health Suggestion

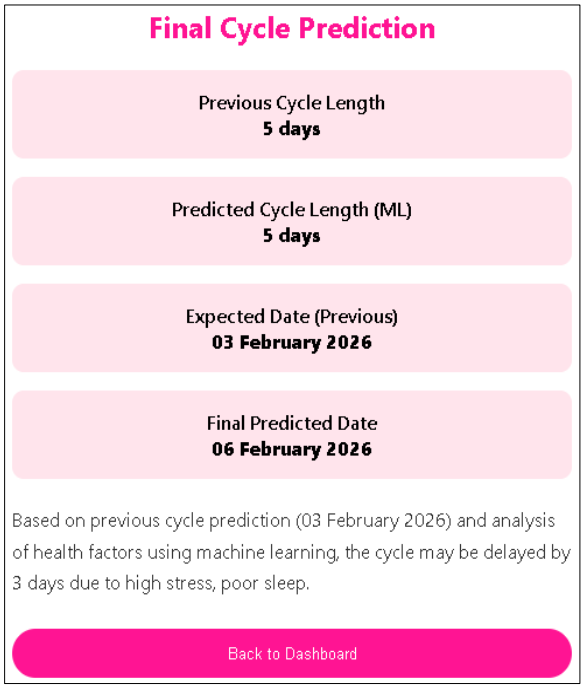

Fig 5: Mensural Cycle Prediction

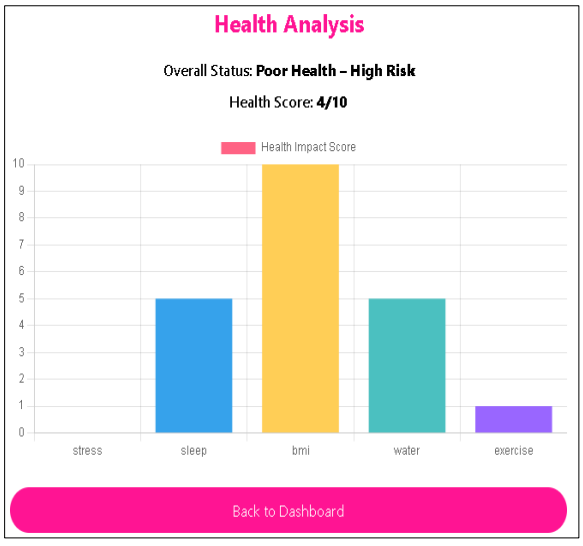

Fig 6: Health Analysis

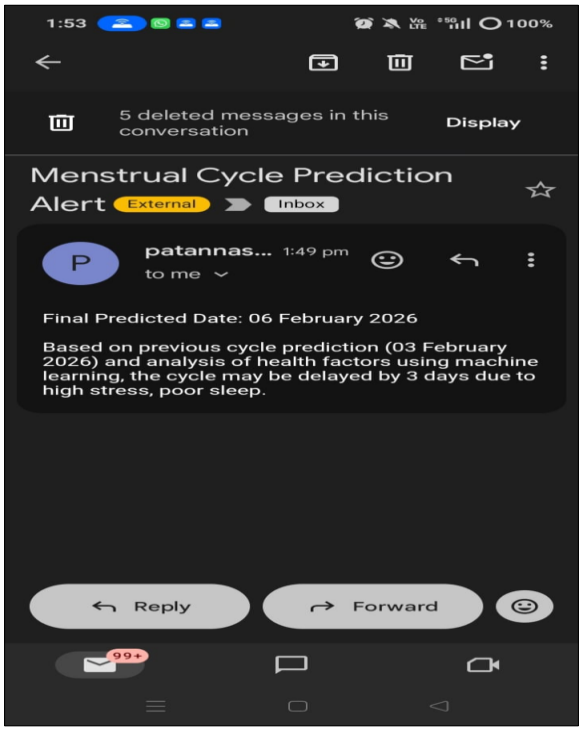

Fig 7: Email Alert

The proposed web-based menstrual health prediction system was tested using user inputs such as previous cycle dates and lifestyle factors including stress, sleep, BMI, water intake, and exercise. The system successfully generated the predicted next menstrual cycle date. It also provided a comparative analysis between the expected date based on historical data and the final predicted date after considering lifestyle influences. The output screens demonstrate that the system can identify slight variations in cycle timing (e.g., delay due to poor sleep) and present them clearly to the user as shown in fig.5. Additionally, the health analysis module assigns a health score and highlights contributing factors through graphical representation, enabling users to understand the impact of their lifestyle on menstrual health as shown in fig.6. Overall, these results justify that the proposed system functions effectively by delivering consistent predictions and meaningful health insights through an interactive and user-friendly web interface.

5. Conclusion

The proposed web based menstrual health prediction system was successfully implemented by integrating user-provided cycle history and lifestyle factors into a single platform. It also generates meaningful predictions and health insights based on user provided inputs and historical data. The proposed system provides an intuitive interface for data entry. It predicts upcoming cycle dates. It also highlights the influence of factors such as stress, sleep, and physical activity through a clear health analysis. This improves user awareness and engagement. Although the system focuses on functional implementation, it does not include quantitative evaluation. However, it establishes a strong foundation for personalized menstrual health tracking.

In future, the system can be improved by using large real time datasets. Advanced machine learning and deep learning models can be added to improve prediction accuracy and reliability.

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