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Streamlining Electricity Billing: A Smart, QR-Driven Approach with Deep Learning Integration

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***Abstract*—Traditional electricity billing processes suffer from manual errors and inefficiencies. The Smart Electricity Billing System (SEBS) aims to address these challenges by utilizing QR code technology for data input and implementing an LSTM deep learning algorithm for accurate consumption prediction. SEBS integrates QR code technology for data input simplification and utilizes a secure payment gateway for transactions. An LSTM deep learning algorithm predicts electricity consumption based on historical data patterns. Developed on the MERN stack, SEBS ensures scalability, flexibility, and security. SEBS reduces manual data entry errors, enhances transaction security, and improves billing accuracy through its innovative features. The system demonstrates its capability to streamline the electricity billing process and offer a user-centric solution.SEBS offers a revolutionary approach to electricity billing, providing a seamless, technologically advanced solution. With its potential to redefine the landscape, SEBS promises to enhance efficiency and user experience in electricity billing processes.**

***Index Terms*— Smart Billing Automation, QR Code Integration, Deep Learning Prediction, Error minimization in billing, Digital billing systems, Cost effective solution.**

I. INTRODUCTION

Ref. [1] Electricity billing processes have long been mired in manual data entry procedures, presenting significant challenges in terms of accuracy, efficiency, and user satisfaction. The reliance on outdated methods has resulted in errors, delays, and administrative burdens for both consumers and utility providers. In response to these limitations, there is a growing imperative to embrace innovative solutions that can revolutionize the billing landscape.

This paper introduces the Smart Electricity Billing System (SEBS), a forward-thinking platform that seeks to redefine the way electricity consumption is monitored, billed, and managed. SEBS represents a paradigm shift from traditional billing practices, harnessing the power of modern technologies to automate and optimize every facet of the billing process.

Ref. [2] At its core, SEBS leverages QR code technology to streamline data input, eliminating the need for manual entry and minimizing the potential for errors. By providing users with unique QR codes that encode their consumption data, SEBS simplifies the billing process, making it more efficient and user-friendly. Additionally, the system integrates advanced deep learning algorithms to analyze historical consumption patterns and generate accurate predictions for future usage. This predictive capability not only enhances billing accuracy but also

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enables proactive resource planning and optimization.

Moreover, SEBS prioritizes user experience by offering a seamless and intuitive interface for managing billing-related tasks. From viewing consumption history to making payments securely, users have access to a comprehensive suite of features that empower them to take control of their electricity usage. Furthermore, SEBS provides utility providers with valuable insights and analytics, enabling them to optimize resource allocation, detect anomalies, and improve overall operational efficiency.

Ref. [1] SEBS builds upon existing technologies to offer advancements in various aspects of electricity billing. While previous systems have relied solely on SMS notifications , SEBS implements a digital payment system, enhancing convenience and efficiency for users. Additionally, unlike systems that incur high costs due to camera installation for data capture.

Ref. [5] SEBS utilizes QR code technology for a more cost-effective solution. Furthermore, while some systems have enabled digital billing using GSM 900 technology, SEBS ensures reliability and security through the implementation of an advanced payment gateway.

II. Literature Survey

1. Tae-Young Kim., Sung-Bae., “Predicting residential energy consumption using CNN-LSTM neural networks”(2019).This report will explain about CNN-LSTM neural network for forecasting housing energy consumption, showcasing its superior accuracy over conventional methods. It highlights the fusion of spatial and temporal feature extraction, illustrating how advanced neural network architectures can tackle energy consumption prediction challenges amidst rapid population growth and technological advancement.
2. "LSTM Forecasts for Smart Home Electricity Usage" by Rosemary E. Alden., Huangjie Gong.,Cristinel Ababei.,Dan M. Ionel(2020) [3]. This investigation explores the effectiveness of LSTM models for predicting individual house power, considering hourly and daily prediction horizons across various datasets. While LSTM models demonstrate potential accuracy for longer prediction horizons, they fall short in providing satisfactory accuracies for shorter prediction horizons due to increased variability and uncertainty in user consumption behavior.
3. “Design and Development of E-Meter Reading Web Services for Android Application”. This conference discusses the inefficiencies of traditional electricity billing systems and proposes E-Meter billing systems to address these challenges. By leveraging open-source cloud technologies and Android platforms, E-Meter aims to streamline the billing process, reducing it to just three steps and seconds for meter reading, thus offering a faster and more efficient solution.
4. “Convenient Electricity Billing System through QR Code Android Application”. This conference presents a solution to improve the complex and manual process of electrical meter reading and bill generation through QR code technology. By introducing a modernized system with QR code scanning and an Android-based application, the project aims to enhance efficiency, accuracy, and customer convenience while reducing human error and the potential for fraud.

III. Proposed Methodology

The proposed system depicted in Figure 1 is an efficient system compared to existing systems as it ensures the accurate prediction of bills. The whole process of prediction is divided as follows: Dataset collection, Preprocessing, Prediction Using LSTM(Long Short-Term Memory).

A. Dataset

To collect data for electricity billing from the provided features, we would need to gather information on various aspects related to household electricity consumption and demographic characteristics.

<u>Number of Rooms:</u> Record the total number of rooms in each household, including bedrooms, living rooms, kitchen, etc.

<u>Number of People:</u> Document the total number of individuals residing in each household.

<u>House Area:</u> Measure the total area of the house in square meters.

<u>AC Usage (is_ac):</u> Determine whether the household has an air conditioning system installed or not. This would be a binary variable (1 for yes, 0 for no).

<u>TV Usage (is_tv):</u> Determine whether the household has a television set or not. Again, this would be a binary variable (1 for yes, 0 for no).

<u>Type of Residence (is_flat):</u> Identify whether the household resides in a flat/apartment or a standalone house. This would also be a binary variable (1 for flat, 0 for standalone house).

Average Monthly Income: Gather information on the average monthly income of the household.
Number of Children: Record the total number of children in the household.
Urban or Rural Location (is_urban): Determine whether the household is located in an urban or rural area. This would be a binary variable (1 for urban, 0 for rural).
Amount Paid: Finally, record the amount paid by each household for electricity consumption during a specific billing period.

TABLE I. DATASET

num_room	Int
num_people	Int
housearea	Float
is_ac	Boolean
is_tv	boolean
is_flat	Boolean
ave_monthly_income	Float
is_urban	Boolean
amount_paid	Float

B. Preprocessing

Preparing data for an LSTM model involves a series of preprocessing steps to ensure optimal model performance and accurate predictions. Initially, the raw data undergoes cleaning to address inconsistencies, missing values, and outliers, employing techniques like imputation, interpolation, or outlier removal. Subsequently, the data is normalized or standardized to maintain a consistent range, facilitating stable training and preventing certain features from dominating others.

As LSTM models are designed for sequential data, the input is structured into fixed-length sequences through sequence generation. This step partitions the data into overlapping or non-overlapping sequences, aligning with the problem domain's requirements. Feature engineering follows, where relevant features are extracted to enhance the model's ability to capture meaningful patterns. Techniques such as Fourier transforms, wavelet analysis, or time-series decomposition may be applied based on domain-specific knowledge.

Moreover, categorical variables within the data are encoded into numerical representations using methods like one-hot encoding, label encoding, or embedding layers. Optionally, sequences may be padded to ensure uniform length, appending zeros or placeholders to shorter sequences. Finally, the preprocessed data is split into training and testing sets, preserving temporal order to prevent data leakage and allowing for evaluation of model performance on unseen data.

These preprocessing steps collectively prepare the data for effective training and deployment of LSTM models, enabling them to learn and predict from sequential data with enhanced accuracy and reliability.

C. Algorithms

Long Short-Term Memory (Lstm)

Long Short-Term Memory (LSTM) represents a type of recurrent neural network (RNN) adept at handling sequential data. It addresses the vanishing gradient problem prevalent in traditional RNNs and conventional machine learning algorithms. LSTMs find utility across various domains such as natural language processing, speech recognition, time series forecasting, sentiment analysis, language modeling, and video analysis. They operate akin to conveyor belts, facilitating the flow of information through different layers for addition, modification, or removal. Each memory cell within an LSTM possesses an internal state alongside multiple multiplicative gates. These gates serve to determine whether incoming input should influence the internal state, whether the internal state should reset, and whether the internal state of a particular neuron should influence the cell's output. Compared to RNNs, which excel in short-term dependencies but struggle with grasping context,

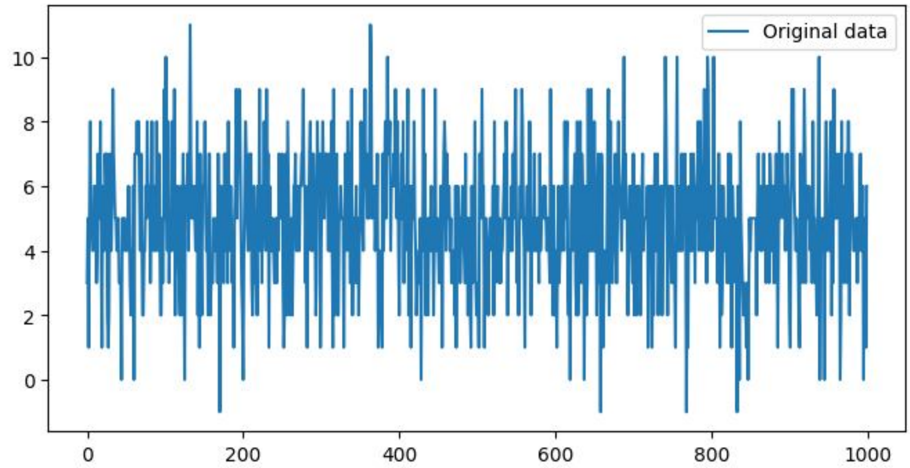

Fig. 1 Data before preprocessing

LSTMs offer a significant advancement. They exhibit the ability to selectively retain and discard information based on relevance and context.

Working of Lstm

Figure 2 shows the working of LSTM. In the operation of an LSTM unit, a single time step encompasses three distinct parts or gates: the Forget gate, the Input gate, and the Output gate. These gates regulate the flow of information within the memory cell, determining what to remember, what to learn anew, and what to pass to the next timestamp. Visual representations of LSTM functionality often illustrate these processes. Additionally, an LSTM unit comprises a hidden state, denoted as H(t-1) for the previous timestamp and H(t) for the current timestamp, along with a cell state denoted as C(t-1) and C(t) for the previous and current timestamps, respectively. The hidden state serves as short-term memory, while the cell state functions as long-term memory.

D. Integration of MERN Stack and Digital Payment for Smart Electricity Billing:

In the realm of modern technology, the integration of innovative software solutions is pivotal in transforming traditional systems. The combination of the MERN (MongoDB, Express.js, React.js, Node.js) stack and digital payment methods represents a powerful fusion that revolutionizes the landscape of electricity billing systems. This section elucidates the seamless integration of the MERN stack and digital payment functionalities within the context of the Smart Electricity Billing System (SEBS).

MERN Stack

The MERN stack encompasses a comprehensive suite of technologies, each playing a crucial role in the development of web applications. MongoDB, a NoSQL database, provides a flexible and scalable platform for storing data related to electricity consumption, user profiles, and billing information. Express.js, a robust web application framework for Node.js, facilitates the creation of RESTful APIs, enabling seamless communication between the server and client-side components. React.js, a JavaScript library for building user interfaces, offers a dynamic and responsive front-end interface for users to interact with the billing system. Node.js, a server-side JavaScript runtime environment, powers the backend of the application, handling data processing, authentication, and other server-side functionalities.

Digital Payment Integration

The incorporation of digital payment methods within the SEBS adds a layer of convenience and security for users. By leveraging digital payment gateways, such as Stripe or PayPal, users can seamlessly initiate transactions for their electricity bills through secure online platforms. This eliminates the need for manual payment processing, reducing administrative overhead and enhancing user satisfaction. Moreover, digital payment integration allows for real-time processing of payments, ensuring prompt settlement of bills and facilitating efficient revenue management for utility providers.

Implementation Details

In the development of SEBS, the MERN stack serves as the foundation for building a robust and scalable web application. MongoDB is utilized to store user data, electricity consumption records, and billing information in a structured and efficient manner. Express.js facilitates the creation of RESTful APIs, enabling seamless

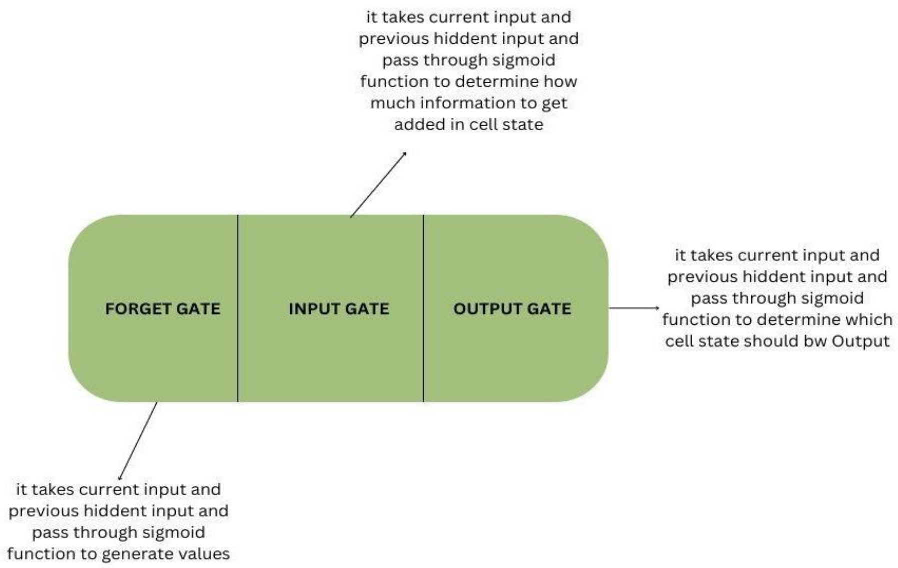

Fig. 2 Working of LSTM

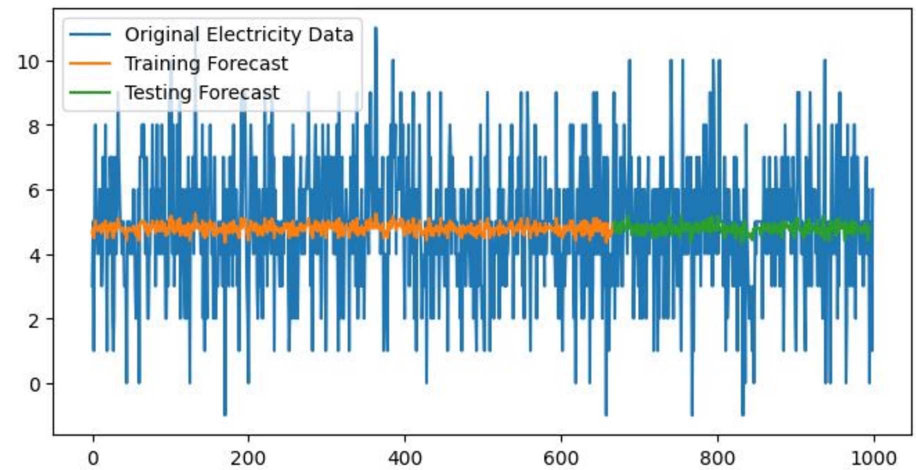

Fig. 3 Forecasted data

communication between the front-end React.js components and the backend Node.js server. React.js, with its component-based architecture, provides an intuitive user interface for users to view their consumption history, make payments, and manage billing preferences. Node.js powers the server-side logic, handling authentication, data validation, and payment processing functionalities. For digital payment integration, SEBS leverages industry-standard payment gateways such as Razorpay or PayPal. These gateways offer secure and PCI-compliant platforms for processing online transactions, ensuring the confidentiality and integrity of users' financial information. Through seamless API integration, users can securely initiate payments using various payment methods, including credit/debit cards, digital wallets, and bank transfers.

IV. System Architecture

The system architecture gives an overview of the organizational system that shows the system boundaries, external entities that interact with the system, and the major information that flows between the entities and the system. Figure **[4]** shows the system architecture of the system.

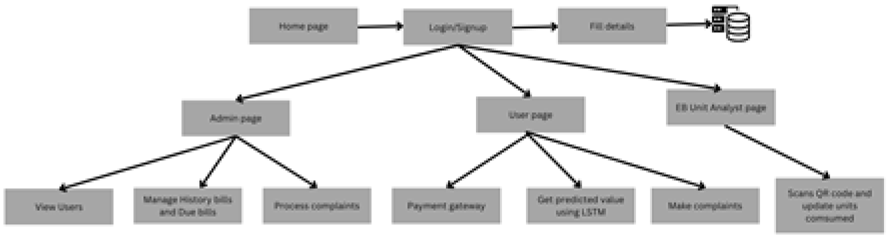

Fig. 4 Overall System Architecture

V. CONCLUSION

In conclusion, the Smart Electricity Billing System (SEBS) represents a significant advancement in the domain of electricity billing processes. By integrating QR code technology for simplified data input and implementing an LSTM deep learning algorithm for consumption prediction, SEBS addresses the longstanding challenges of manual errors and inefficiencies in traditional billing systems. The system's use of a secure payment gateway ensures transactional integrity, while its development on the MERN stack underscores its scalability, flexibility, and robust security measures.

The results of our study demonstrate the tangible benefits of SEBS, including a reduction in manual data entry errors, enhanced transaction security, and improved billing accuracy. Moreover, SEBS offers a user-centric solution that streamlines the billing process and enhances the overall user experience. These findings underscore the potential of SEBS to revolutionize the electricity billing landscape, offering a technologically advanced and efficient alternative to traditional systems.

As future work, further enhancements and optimizations can be explored to continuously improve SEBS's performance and expand its capabilities. Specifically, the integration of IoT technology to automatically capture images of the electricity unit box and apply image processing techniques to update the amount of units consumed and the total amount automatically will be pursued. Additionally, real-world deployment and user feedback will be invaluable in refining the system and ensuring its seamless integration into existing electricity infrastructure.

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