Design and Development of an Expenses Tracker App using the Flutter Framework

Clinton Laishram
UG Student, Department of Computer Science,
Amity University, Greater Noida,
Uttar Pradesh, India
Email: clintonlai.cl@gmail.com

Abstract – **This research paper provides the design and development of an "Expenses Tracker Application" with the Flutter framework. As modern life becomes more and more busier, effective financial management solutions are more important, and mobile applications are becoming an essential tool for such purposes. This research focuses on creating a user-friendly, cross-platform application that helps users manage and track their spending efficiently. The research outlines the architectural choices, development methodology, key features, and design considerations of the Expenses Tracker App. The application uses Flutter's capabilities to offer an easy and intuitive experience to the user. It comprises categorization, expense entry, monthly budget setting, user-centric design principles, and data visualization. The significance of this research lies in creating a practical and user-oriented tool for financial management, utilizing the capabilities of Flutter's cross-platform nature. The concluding observations reflect on the contribution, achievements, and future advancements of the Expenses Tracker App to ease expense management. The research upholds Flutter as a practical solution for developing applications that cater to real-world requirements in a user-centric and modern method.**

Keywords – Dart, Flutter, Realm, Expenses, User, SDK, Package, Application

I. INTRODUCTION

Proper monitoring of spending is becoming ever more important for households and individuals in today's financial landscape. A proper understanding of financial outflows or inflows enables better decision-making, attaining savings goals, and optimizing resource allocation. The constant advancement of mobile technologies has boosted the progression of applications streamlining expenditure tracking. The objective of this project is to design a user-friendly expense tracker app by utilizing the versatile Flutter framework. The capabilities of Flutter's cross-platform guarantee a uniform experience on iOS or Android. The app will allow budgeting, categorizing, and insights into expense patterns. The research focuses on making a simplified expense tracker app that offers a seamless experience to the user. The research delves into user interface, essential features, and design data management. The result is an application that also enables proper financial decisions to improve financial health. As personal finance continues to play an important role in modern lives, this Flutter-based application can significantly transform financial behaviour. Offering an intuitive tool for expense management, it assists the users in attaining financial prosperity and literacy.

II. LITERATURE REVIEW

Expense tracking has evolved from manual methods to digital solutions, playing a crucial role in personal financial management. A myriad of existing expense-tracking solutions and mobile apps cater to users seeking to manage their finances more effectively. These solutions range from standalone expense trackers to integrated personal finance management tools, offering various features such as categorization, budgeting, and reporting.

A. Existing Expense Tracking Solutions And Mobile Apps

Numerous expense-tracking applications are available in today's app market. Prominent examples include Monetal, Money Manager Expenses & Budget, Spendee Money & Budget Planner, Fleur, and Monefy. These apps often offer advanced features, such as linking bank accounts for automatic transaction syncing, generating detailed spending reports, and providing insights into spending habits. However, some users may find these feature-rich applications overwhelming, leading to a demand for more straightforward alternatives.

B. Advantages of Using Flutter for Cross-Platform App Development

Flutter, a popular open-source framework, has gained traction due to its ability to create natively compiled applications for mobile, web, and desktop platforms from a single codebase. This cross-platform capability reduces development time and resources, ensuring consistent user experiences across multiple platforms. By utilizing Flutter, developers can efficiently address the challenge of developing and maintaining separate applications for Android and iOS.

C. Importance of a Simple and User-Friendly App

While feature-rich apps offer comprehensive tools for financial management, a simpler approach can be equally effective. Many users, especially those new to expense tracking, may feel overwhelmed by complex interfaces and

excessive features. A simple and user-friendly app caters to this audience, ensuring easy adoption and sustained usage. Clarity in design and functionality reduces cognitive load, enabling users to focus on the primary task—tracking expenses—without unnecessary distractions.

In light of the diversity of existing expense-tracking solutions, the advantages of Flutter's cross-platform development capabilities, and the significance of simplicity in user experience, this research seeks to develop a minimalistic yet effective expense-tracking app. The aim is to strike a balance between offering essential features and fostering user engagement, catering to individuals seeking an uncomplicated approach to managing their finances.

III. METHODOLOGY

This section outlines the step-by-step methodology employed in designing and developing a user-friendly expense-tracking app using the Flutter framework. The app features four distinct tabs – Expenses, Reports, Add, and Settings – along with a category creation feature to enhance the user experience.

A. Requirement Analysis

The initial phase involves defining the purpose and scope of the expenses tracking app. The emphasis is on creating a simple and intuitive app targeting individuals who seek a straightforward solution for managing their expenses. The four tabs – Expenses, Reports, Add, and Settings – are designed to provide the user's needs. By identifying these key functionalities, the app's foundation is established.

B. Design and User Experience

Creating a seamless user experience is crucial. To achieve this, wireframes are developed for each of the four tabs. The goal is to ensure that the user interface is minimalistic, with intuitive navigation between tabs. A cohesive colour palette and typography are chosen to maintain a consistent visual theme throughout the app. The decision to use a bottom navigation bar is driven by its ease of use and familiarity with users.

C. Development Using Flutter

The implementation phase involves using the Flutter framework with Dart programming language for cross-platform development. This enables the app to function seamlessly on both iOS and Android platforms. The bottom navigation bar is realized by designing separate screens for each of the four tabs. The utilization of Flutter's built-in widgets and third-party packages aids in efficient and feature-rich app development.

IV. DESIGN AND USER INTERFACE

In the development of our expense-tracking app, meticulous attention has been paid to crafting an intuitive and user-friendly interface. This section delves into the core design principles that underpin our design choices and offers insights into the visual aspects of the app through wireframes and mock-ups.

A. Design Principles

The primary focus during the design phase has been on adhering to fundamental design principles that enhance the overall user experience. These principles encompass:

1) ***Simplicity:*** We believe in keeping things simple. The user interface is designed to be clean and uncluttered, ensuring that users can easily comprehend and navigate the app's functionalities.
2) ***Consistency:*** Consistency in design elements, such as colour schemes, typography, and iconography, has been maintained throughout the app. This consistency fosters a sense of familiarity and helps users feel at ease.
3) ***Readability:*** The choice of typography and text formatting prioritizes readability. Information is presented clearly and legibly, allowing users to absorb content effortlessly.
4) ***User-Centric Approach:*** Every design decision has been made with the user in mind. User feedback and usability testing have been integral in shaping the interface to align with users' expectations and preferences.
5) ***Wireframes and Mockups:*** To provide a visual representation of our design choices, we present wireframes and mockups of the app's screens. These visuals offer a glimpse into the app's layout, colour scheme, and typography:
6) ***Layout:*** The wireframes showcase the layout of each screen, including the arrangement of elements such as buttons, input fields, and navigation bars. Our goal is to optimize the user flow and prioritize essential actions.
7) ***Colour Scheme:*** The mockups reveal the chosen colour scheme, emphasizing a harmonious and visually pleasing palette. Colours have been selected not only for aesthetics but also to convey information effectively.
8) ***Typography:*** Typography plays a crucial role in our design. The mockups illustrate the selected fonts and text styles, emphasizing legibility and consistency across the app.

To summarise, our expenses tracking app places a strong emphasis on design principles that prioritize simplicity, consistency, readability, and user-centricity. The wireframes and mockups presented here offer a glimpse into the visual aspects of our app, showcasing the thought and care put into creating an interface that is both intuitive and visually appealing. We believe that this user-focused design approach will enhance the overall user experience and make expense tracking a seamless and enjoyable task.

V. OVERVIEW OF THE APPLICATION

A. System Architecture

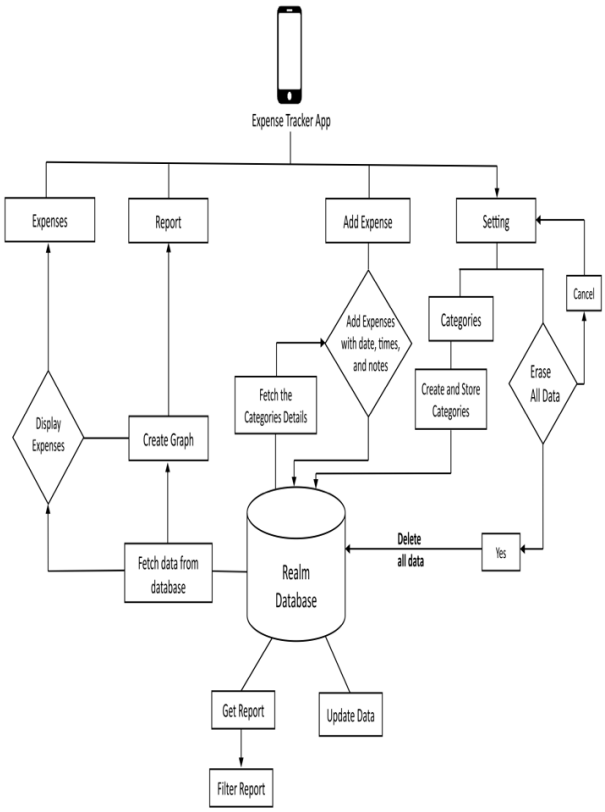


Fig. 1: System Architecture of the proposed system

Fig 1 unveils our system architecture, seamlessly blending the Flutter framework's prowess in routing and frontend development with the Realm database's robust storage capabilities for user expense data. Realm, a dynamic mobile database, operates directly within smartphones, tablets, and wearables, ensuring data accessibility without the necessity of an internet connection. This repository hosts the essential source code for the Realm SDK tailored for Flutter™ and Dart™. This unique setup eliminates the need for constant internet connectivity.

To add a touch of visual elegance, we've harnessed the FL chart package, enhancing user engagement by creating interactive bar graphs that dynamically reflect user expenses based on selected filter options, enriching the user experience within the Expenses and Reports tabs.

B. Application Workflow

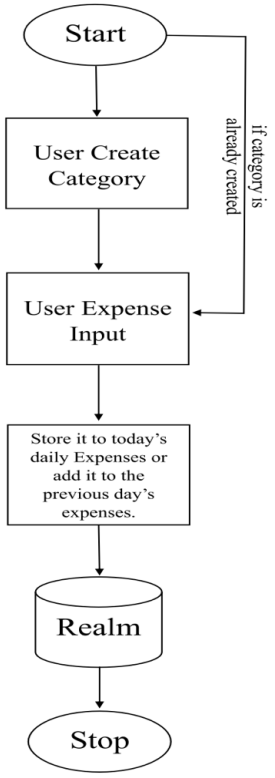


Fig. 1.1: Input Workflow of the proposed system

Fig. 1.1 shows the application workflow of inputs and storing user expenses in the database

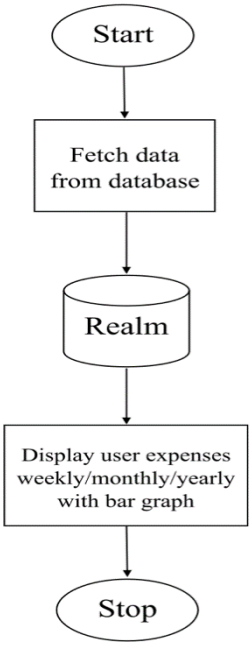


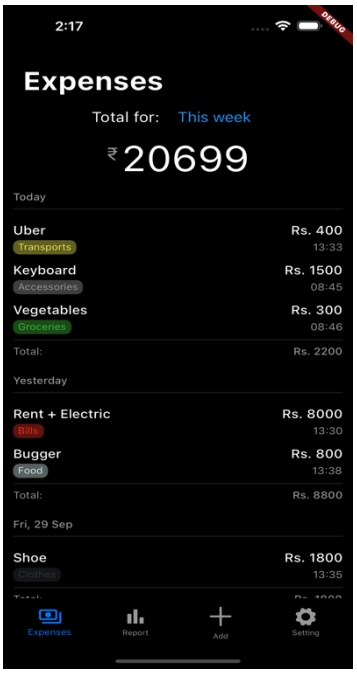
Fig. 1.2: Data retrieval of the user from the database

Fig. 1.2 shows the workflow of user data getting retrieved from the database & displaying user weekly/monthly/ yearly expenses with a bar graph.

C. Application Modules

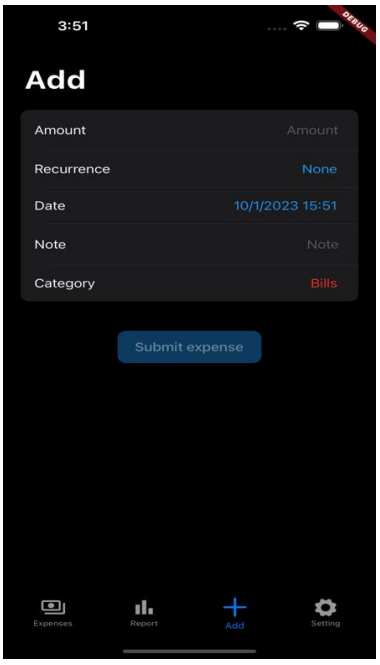
1) Expenses Module:

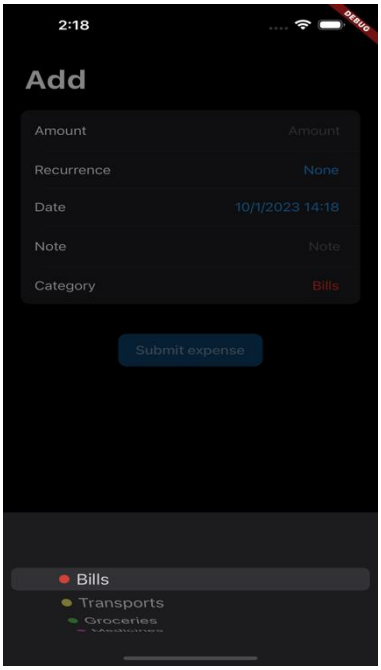
Within this module, users can effortlessly view their expenses, complete with a comprehensive overview of the total expenditure. Additionally, users have the flexibility to select their preferred display interval, choosing between weekly, monthly, or yearly views.



2) Add module:

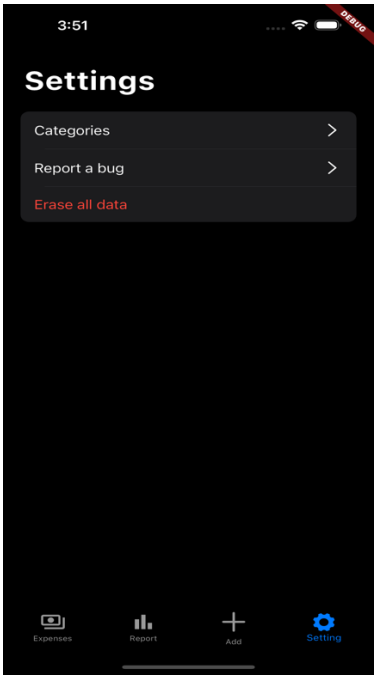
Within this module, users have the option to manually input their expenses by selecting from available categories. If a category is not yet created, users are prompted to create one beforehand. Moreover, users can specify the date and time of the expenditure and even include additional notes about the transaction.





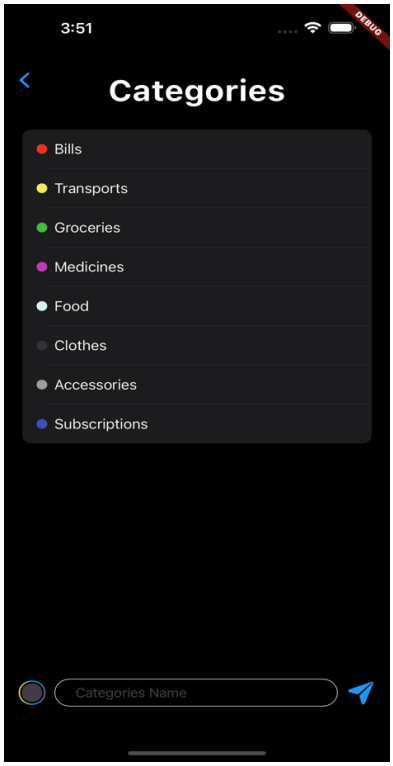
3) Setting module:

Within this interface, you'll find three distinct tabs. The first is the Category tab, enabling users to generate new categories as needed. The second is the Report a Bug tab, allowing users to promptly report any encountered issues. Lastly, the third tab, Erase All Data, permits users to reset the entire application to its initial state.



4) Create categories module:

Within this module, users can generate categories. Furthermore, users can personalize these categories by selecting specific colour codes, facilitating easy identification of categories within the Expenses and Reports tabs.



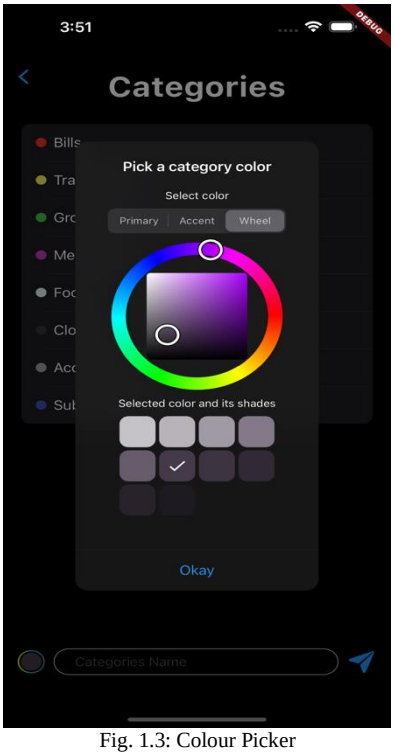
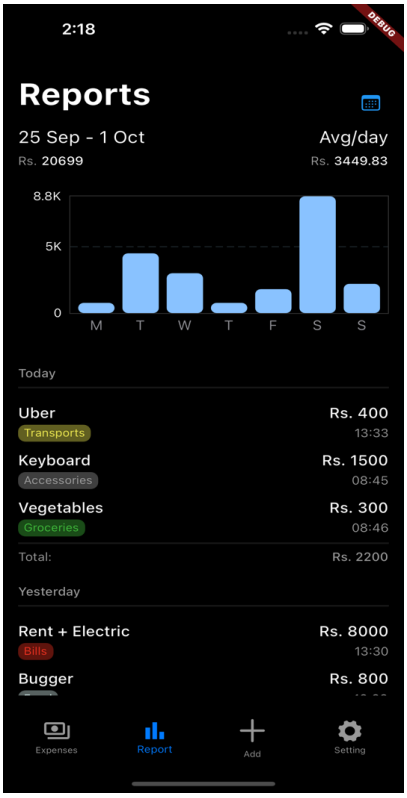


Fig. 1.3: Colour Picker

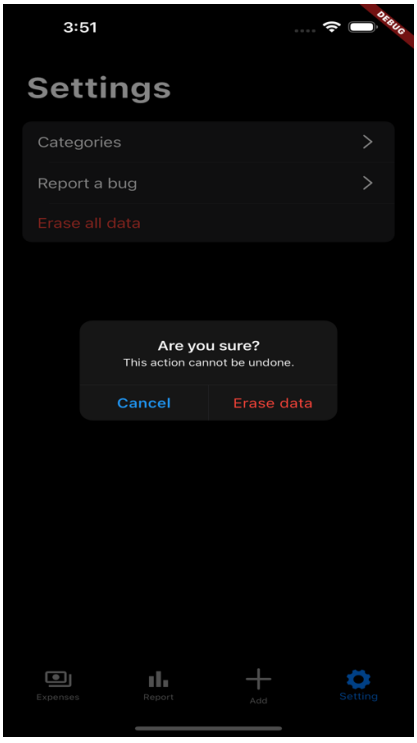
5) Report module:

Within this module, users can conveniently visualize their weekly expenses through a bar graph presentation, fostering a deeper comprehension of their daily spending patterns. The filtering feature also empowers users to switch between weekly and monthly graph views, offering flexibility in their data analysis.



6) Erase all data modules:

Within this module, users can perform a complete application reset, effectively erasing all user-entered data. This feature serves as a valuable tool for users who wish to eliminate all their previously entered data when they decide to discontinue using the application.



VI. CONCLUSION AND FUTURE SCOPE

In conclusion, this research paper has detailed the development of an Expenses Tracker App utilizing the Flutter framework, addressing the critical need for efficient financial management in today's fast-paced world. By creating a user-friendly, cross-platform application, we have aimed to empower users to effectively track and manage their expenses. The paper has provided insights into our development methodology, architectural choices, and design considerations, with a strong emphasis on user-centric principles. The Expenses Tracker App, driven by Flutter's capabilities, offers a seamless and intuitive experience encompassing essential features such as expense entry, categorization, budgeting, and data visualization.

The significance of this research lies in the creation of a practical and user-oriented financial management tool that simplifies expense tracking while promoting informed financial decision-making. It highlights the potential of Flutter as a powerful solution for developing modern applications that cater to real-world needs. Our design principles, focusing on simplicity, consistency, readability, and user-centricity, ensure that users can easily navigate and utilize the app to manage their finances effectively.

Looking to the future, the Expenses Tracker App holds substantial scope for further enhancements and refinements. We envision the integration of advanced features, potentially including expense synchronization with bank accounts, additional customization options, and expanded reporting capabilities. User feedback will continue to guide our efforts, ensuring that the app remains responsive to the evolving needs of users. In summary, this research underscores the significance of creating accessible and user-centric financial management tools, making a valuable contribution to simplified expense management in the modern world.

A. Future Scope

Here are some potential future enhancements that could be integrated into the suggested solution:

- Enhancing security and reliability by implementing the option to create or log in to an account using email or phone number.
- Introducing data backup functionality to the cloud for added data protection.
- Improving data visualization by incorporating features such as colour-coding the bar graph based on category colour codes.
- Enabling synchronization with bank accounts and third-party wallet applications to facilitate automatic input of expense data.

REFERENCE

[1] https://docs.flutter.dev

[2] https://www.mongodb.com/docs/realm/sdk/flutter/

[3] Prithvish Rahul P, Mohd Tajammul, “Expense Manager Flutter,” Application School of CS & IT, Jain University, Bangalore, Karnataka, India, (IJTSRD) Volume 6 Issue 3, March-April 2022

[4] Adepegba O.A., Fayemiwo M.A., Oduwole O.A. and Onamade A.A., “An Android Based Mobile Application for Tracking Daily Expenses,” Adeleke University, Conference January 2019, doi:10.22624/AIMS/iSTEAMS-2019/V21N1P9

[5] Velmurugan. R, Mrs. P Usha, “Expense Tracker Application,” March 2021, IJIRT, Volume 7 Issue 10, ISSN: 2349-6002

[6] Andtek.T (2012)., “Just Expenses: Expense Tracker”, Retrieved October 20, 2012, from Google Play: https://play.google.com/store/apps/details?id=com.andtek.just.expense

[7] L Carvalho, C Basso, Carvalho L. A and Basso C.(2014).Telecom Expense Management for Large Organizations; A Practical Guide. iUniverse LLC Bloomington, IN 47403.

[8] Peijiang, H. (2012), “Daily Expense Tracker (income and cash-flow Lite)”, Retrieved August 20, 2012, from http://tiny4.org/app/App_by_tinyfool/Tiny4Money

[9] WildJ. (2010). Fundamental Accounting Principles (18th edition.). New York: McGraw-Hill Companies. pp. 630-633. ISBN 0-07-299653-6.Vol 18

[10] Ghusoon Idan, Kadhum Al-Majid, “A Freights Status Management System Based on Dart and Flutter Programming Language”, May 2020, Journal of Physics Conference Series1530(1):012020, DOI:10.1088/1742-6596/1530/1/012020

[11] Anjali Chauhan, “A Review on Various Aspects of MongoDb Databases”, IJERT, Vol. 8 Issue 5, May 2019, ISSN: 2278-0181

[12] Benymol Jose, Sajimon Abraham,” Exploring the Merits of NoSQL: A Study Based on MongoDB”, 978-1-5090-6590-5/17/$31.00 ©2017 IEEE

[13] YunhuaGu, ShuShen, Jin Wang, Jeong-UkKim, “Application of NoSQL Database MongoDB”, 978-1-4799-87450/15/$31.00 ©2015 IEEE

[14] https://docs.sentry.io/platforms/flutter/?original_referrer=https%3A%2F%2Fsentry.io%2F.

[15] P. K. Kushwaha and M. Kumaresan, "Machine learning algorithm in healthcare system: A Review," 2021 International Conference on Technological Advancements and Innovations (ICTAI), Tashkent, Uzbekistan, 2021, pp. 478-481, doi: 10.1109/ICTAI53825.2021.9673220.

[16] P. K. Kushwaha, V. Bibhu, B. P. Lohani and D. Singh, "Review on information security, laws and ethical issues with online financial system," 2016 International Conference on Innovation and Challenges in Cyber Security (ICICCS-INBUSH), Greater Noida, India, 2016, pp. 49-53, doi: 10.1109/ICICCS.2016.7542350.

[17] G. Gulati, B. P. Lohani and P. K. Kushwaha, “A Novel Application Of IoT In Empowering Women Safety Using GPS Tracking Module,” 2020 Research, Innovation, Knowledge Management and Technology Application for Business Sustainability (INBUSH), Greater Noida, India, 2020, pp. 131-137, doi: 10.1109/INBUSH46973.2020.9392193.

[18] D. Pareta, I. N. Verma, B. P. Lohani, P. K. Kushwaha and V. Bibhu, "IoT Enabled Smart and Efficient Musical Water Fountain," 2022 2nd International Conference on Innovative Practices in Technology and Management

(ICIPTM), Gautam Buddha Nagar, India, 2022, pp. 369-373, doi: 10.1109/ICIPTM54933.2022.9754129.

[19] B. P. Lohani, M. Trivedi, R. J. Singh, V. Bibhu, S. Ranjan and P. K. Kushwaha, "Machine Learning Based Model for Prediction of Loan Approval," 2022 3rd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2022, pp. 465-470, doi: 10.1109/ICIEM54221.2022.9853160.

[20] V. Bibhu, A. Kumar, B. P. Lohani and P. K. Kushwaha, "Robust Secured Framework for Online Business Transactions over Public Network," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2021, pp. 555-560, doi: 10.1109/ICIEM51511.2021.9445380.

[21] V. Bibhu, P. K. Kushwaha and B. P. Lohani, "A review of security of the cloud computing over business with implementation," 2016 International Conference on Innovation and Challenges in Cyber Security (ICICCS-INBUSH), Greater Noida, India, 2016, pp. 192-198, doi: 10.1109/ICICCS.2016.7542342.

[22] M. Chandra, P. K. Kushwaha and S. Saxena, "Modified Fractal Carpets," 2011 International Conference on Computational Intelligence and Communication Networks, Gwalior, India, 2011, pp. 537-540, doi: 10.1109/CICN.2011.115.

[23] V. Bibhu, P. K. Kushwaha, R. Kohli and D. Singh, "Secret key watermarking in WAV audio file in perceptual domain," 2015 International Conference on Futuristic Trends on Computational Analysis and Knowledge Management (ABLAZE), Greater Noida, India, 2015, pp. 629-634, doi: 10.1109/ABLAZE.2015.7154940.

[24] Ranjan, Ankur A. et al. “An Approach for Netflix Recommendation System using Singular Value Decomposition.” Journal of Computer and Mathematical Sciences (2019)

[25] Makkar, Bhavya et al. “Map Reduce concept-based Sentiment Analysis Approach.” International Journal of Computer Sciences and Engineering (2019)

[26] Bhatia, Ayush & Bibhu, Vimal & Lohani, Bhanu & Kushwaha, Pradeep. (2020). An Application Framework for Quantum Computing using Artificial intelligence Techniques. 264-269. 10.1109/INBUSH46973.2020.9392164.

[27] V. Bibhu, A. Kumar, B. P. Lohani and P. K. Kushwaha, "Black Hole Attack in Mobile Ad Hoc Network and its Avoidance," 2021 International Conference on Innovative Practices in Technology and Management (ICIPTM), Noida, India, 2021, pp. 103-107, doi: 10.1109/ICIPTM52218.2021.9388366.

[28] Srivastava, A.V., Lohani, B.P., Kushwaha, P.K., Tyagi, S. (2021). Dual-Layer Security and Access System to Prevent the Spread of COVID-19. In: Prateek, M., Singh, T.P., Choudhury, T., Pandey, H.M., Gia Nhu, N. (eds) Proceedings of International Conference on Machine Intelligence and Data Science Applications. Algorithms for Intelligent Systems. Springer, Singapore. https://doi.org/10.1007/978-981-33-4087-9_28

[29] A. Khuran, B. P. Lohani, V. Bibhu and P. K. Kushwaha, "An AI Integrated Face Detection System for Biometric Attendance Management," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2021, pp. 29-33, doi: 10.1109/ICIEM51511.2021.9445295.

[30] V. Bibhu, S. Salagrama, B. P. Lohani and P. K. Kushwaha, "An Analytical Survey of User Privacy on Social Media Platform," 2021 International Conference on Technological Advancements and Innovations (ICTAI), Tashkent, Uzbekistan, 2021, pp. 173-176, doi: 10.1109/ICTAI53825.2021.9673402.

[31] S. Singh, D. Chaudhary, A. D. Gupta, B. Prakash Lohani, P. K. Kushwaha and V. Bibhu, "Artificial Intelligence, Cognitive Robotics and Nature of Consciousness," 2022 3rd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2022, pp. 447-454, doi: 10.1109/ICIEM54221.2022.9853081.

[32] S. Suman, P. Kaushik, S. S. N. Challapalli, B. P. Lohani, P. Kushwaha and A. D. Gupta, "Commodity Price Prediction for making informed Decisions while trading using Long Short-Term Memory (LSTM) Algorithm," 2022 5th International Conference on Contemporary Computing and Informatics (IC3I), Uttar Pradesh, India, 2022, pp. 406-411, doi: 10.1109/IC3I56241.2022.10072626.

[33] P. K. Kushwaha and M. Kumaresan, "Machine learning algorithm in healthcare system: A Review," 2021 International Conference on Technological Advancements and Innovations (ICTAI), Tashkent, Uzbekistan, 2021, pp. 478-481, doi: 10.1109/ICTAI53825.2021.9673220.

[34] P. K. Kushwaha, B. P. Lohani and D. Singh, "Review on information security, laws and ethical issues with online financial system," 2016 International Conference on Innovation and Challenges in Cyber Security (ICICCS-INBUSH), Greater Noida, India, 2016, pp. 49-53, doi: 10.1109/ICICCS.2016.7542350.

[35] G. Gulati, B. P. Lohani and P. K. Kushwaha, “A Novel Application Of IoT In Empowering Women Safety Using GPS Tracking Module,” 2020 Research, Innovation, Knowledge Management and Technology Application for Business Sustainability (INBUSH), Greater Noida, India, 2020, pp. 131-137, doi: 10.1109/INBUSH46973.2020.9392193.

[36] D. Pareta, I. N. Verma, B. P. Lohani, P. K. Kushwaha and V. Bibhu, "IoT Enabled Smart and Efficient Musical Water Fountain," 2022 2nd International Conference on Innovative Practices in Technology and Management (ICIPTM), Gautam Buddha Nagar, India, 2022, pp. 369-373, doi: 10.1109/ICIPTM54933.2022.9754129.

[37] B. P. Lohani, M. Trivedi, R. J. Singh, V. Bibhu, S. Ranjan and P. K. Kushwaha, "Machine Learning Based Model for Prediction of Loan Approval," 2022 3rd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2022, pp. 465-470, doi: 10.1109/ICIEM54221.2022.9853160.

[38] A. Kumar, B. P. Lohani and P. K. Kushwaha, "Robust Secured Framework for Online Business Transactions over Public Network," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2021, pp. 555-560, doi: 10.1109/ICIEM51511.2021.9445380.

[39] P. K. Kushwaha and B. P. Lohani, "A review of security of the cloud computing over business with implementation," 2016 International Conference on Innovation and Challenges in Cyber Security (ICICCS-INBUSH), Greater Noida, India, 2016, pp. 192-198, doi: 10.1109/ICICCS.2016.7542342.

[40] M. Chandra, P. K. Kushwaha and S. Saxena, "Modified Fractal Carpets," 2011 International Conference on Computational Intelligence and Communication Networks, Gwalior, India, 2011, pp. 537-540, doi: 10.1109/CICN.2011.115.

[41] P. K. Kushwaha, R. Kohli and D. Singh, "Secret key watermarking in WAV audio file in perceptual domain," 2015 International Conference on Futuristic Trends on Computational Analysis and Knowledge Management (ABLAZE), Greater Noida, India, 2015, pp. 629-634, doi: 10.1109/ABLAZE.2015.7154940.

[42] Ranjan, Ankur A. et al. “An Approach for Netflix Recommendation System using Singular Value Decomposition.” Journal of Computer and Mathematical Sciences (2019)

[43] Makkar, Bhavya et al. “Map Reduce concept-based Sentiment Analysis Approach.” International Journal of Computer Sciences and Engineering (2019)

[44] Bhatia, Ayush & Bibhu, Vimal & Lohani, Bhanu & Kushwaha, Pradeep. (2020). An Application Framework for Quantum Computing using Artificial intelligence Techniques. 264-269. 10.1109/INBUSH46973.2020.9392164.

[45] A. Kumar, B. P. Lohani and P. K. Kushwaha, "Black Hole Attack in Mobile Ad Hoc Network and its Avoidance," 2021 International Conference on Innovative Practices in Technology and Management (ICIPTM), Noida, India, 2021, pp. 103-107, doi: 10.1109/ICIPTM52218.2021.9388366.

[46] Srivastav, A.V., Lohani, B.P., Kushwaha, P.K., Tyagi, S. (2021). Dual-Layer Security and Access System to Prevent the Spread of COVID-19. In: Prateek, M., Singh, T.P., Choudhury, T., Pandey, H.M., Gia Nhu, N. (eds) Proceedings of International Conference on Machine Intelligence and Data Science Applications. Algorithms for Intelligent Systems. Springer, Singapore. https://doi.org/10.1007/978-981-33-4087-9_28

[47] A. Khuran, B. P. Lohani, V. Bibhu and P. K. Kushwaha, "An AI Integrated Face Detection System for Biometric Attendance Management," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2021, pp. 29-33, doi: 10.1109/ICIEM51511.2021.9445295.

[48] S. Salagrama, B. P. Lohani and P. K. Kushwaha, "An Analytical Survey of User Privacy on Social Media Platform," 2021 International Conference on Technological Advancements and Innovations (ICTAI), Tashkent, Uzbekistan, 2021, pp. 173-176, doi: 10.1109/ICTAI53825.2021.9673402.

[49] S. Singh, D. Chaudhary, A. D. Gupta, B. Prakash Lohani, P. K. Kushwaha and V. Bibhu, "Artificial Intelligence, Cognitive Robotics and Nature of Consciousness," 2022 3rd International Conference on Intelligent Engineering and Management (ICIEM), London, United Kingdom, 2022, pp. 447-454, doi: 10.1109/ICIEM54221.2022.9853081.

[50] S. Suman, P. Kaushik, S. S. N. Challapalli, B. P. Lohani, P. Kushwaha and A. D. Gupta, "Commodity Price Prediction for making informed Decisions while trading using Long Short-Term Memory (LSTM) Algorithm," 2022 5th International Conference on Contemporary Computing and Informatics (IC3I), Uttar Pradesh, India, 2022, pp. 406-411, doi: 10.1109/IC3I56241.2022.10072626.

[51] P. William, Y. V. U. Kiran, A. Rana, D. Gangodkar, I. Khan and K. Ashutosh, "Design and Implementation of IoT based Framework for Air Quality Sensing and Monitoring," 2022 2nd International Conference on Technological Advancements in Computational Sciences (ICTACS), Tashkent, Uzbekistan, 2022, pp. 197-200, doi: 10.1109/ICTACS56270.2022.9988646.

[52] Mridul Bhardwaj and Ajay Rana. 2015. Impact of Size and Productivity on Testing and Rework Efforts for Web-based Development Projects. SIGSOFT Softw. Eng. Notes 40, 2 (March 2015), 1–4. https://doi.org/10.1145/2735399.2735404

[53] Bhardwaj, Mridul, and Rana Ajay. "Estimation of testing and rework efforts for software development projects." Asian Journal of Computer Science and Information Technology 5.5 (2015): 33-37.

[54] Dubey, Gaurav, Ajay Rana, and Jayanthi Ranjan. "A research study of sentiment analysis and various techniques of sentiment classification." International Journal of Data Analysis Techniques and Strategies 8.2 (2016): 122-142.

[55] R. Sharma, M. Mogha, S. Tanwar and A. Rana, "Emerging Part of Industry 4.0: The Digital and Physical Technology," 2020 9th International Conference System Modeling and Advancement in Research Trends (SMART), Moradabad, India, 2020, pp. 149-154, doi: 10.1109/SMART50582.2020.9337064.

[56] Dubey, Sanjay Kumar, and Ajay Rana. "Assessment of usability metrics for object-oriented software system." ACM SIGSOFT Software Engineering Notes 35.6 (2010): 1-4.

[57] Singh, Archana, Jyoti Agarwal, and Ajay Rana. "Performance Measure of Similis and FPGrowth Algo rithm." International Journal of Computer Applications 62.6 (2013): 25-31.

[58] Tyagi, Neha, Ajay Rana, and Vineet Kansal. "Load distribution challenges with virtual computing." Intelligent Computing in Engineering: Select Proceedings of RICE 2019. Springer Singapore, 2020.

[59] Singh, Jaya, and Ajay Rana. "Exploring the big data spectrum." International Journal of Emerging Technology and Advanced Engineering 73 (2013).

[60] N. M., P. Chawla and A. Rana, "A Practitioner’s Approach to Assess the WCAG 2.0 Website Accessibility Challenges," 2019 Amity International Conference on Artificial Intelligence (AICAI), Dubai, United Arab Emirates, 2019, pp. 958-966, doi: 10.1109/AICAI.2019.8701320.

[61] Tyagi, N., Rana, A., Awasthi, S., & Tyagi, L. K. (2022). Data Science: Concern for Credit Card Scam with Artificial Intelligence. In Cyber Security in Intelligent Computing and Communications (pp. 115-128). Singapore: Springer Singapore.

[62] Jain, Piyush, Sanjay Kumar Dubey, and Ajay Rana. "Software usability evaluation method." International Journal of Advanced Research in Computer Engineering & Technology 1.2 (2012): 28-33.

[63] Pal, S. K., et al. "Hanging suicides in himachal pradesh: an analysis of forensic cases." Int J Forensic Sci Pathol 4.11 (2016): 297-304.

[64] Rana, A., and S. Manhas. "Significance of diatoms in diagnosis of drowning deaths: a review." Journal of Forensic & Genetic Sciences 5 (2018): 77-81.

[65] Bansal, Sangeeta, and Dr Ajay Rana. "Transitioning from relational databases to big data." International Journal of Advanced Research in Computer Science and Software Engineering 4.1 (2014): 394-400.