BEYOND LLMS: A RAG CHATBOT FOR EFFICIENT LITERATURE SEARCH AND THESIS RETRIEVAL IN CSPC LIBRARY

A Thesis Project
presented to the Faculty of
College of Computer Studies

In Partial Fulfillment of the Requirements
for the degree Bachelor of Science in Computer Science

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APPROVAL PAGE

In partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science, this research entitled **BEYOND LLMS: A RAG CHATBOT FOR EFFICIENT LITERATURE SEARCH AND THESIS RETRIEVAL IN CSPC LIBRARY** prepared and submitted by **Divino Franco R. Aurellano**, **Herald Carl N. Avila**, **Almira L. Calingacion** has been examined and is recommended for approval and acceptance.

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This research project entitled, **BEYOND LLMS: A RAG CHATBOT FOR EFFICIENT LITERATURE SEARCH AND THESIS RETRIEVAL IN CSPC LIBRARY**, in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Sciencehas been examined and is recommended for acceptance and approval for ORAL EXAMINATION.

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DEDICATION

Ad Majorem Dei Gloriam

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ABSTRACT

Title: Beyond LLMs: A RAG Chatbot for Efficient Literature Search and Thesis Retrieval in CSPC Library

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CHAPTER 1

INTRODUCTION

This chapter provides an overview of the study, covering the challenges of the campus library, the study's objectives, and its significance. It defines the problem, outlines research goals, and highlights the proposed system's potential impact. The scope and limitations clarify its boundaries, while the project dictionary and notes offer essential terms and supporting details.

Background of the Problem

Large Language Models (LLMs) such as OpenAI's ChatGPT [2] and Deepseek [8] have made significant advancements in Natural Language Processing (NLP) by excelling in diverse applications such as conversational chatbots, text summarization [13], and code summarization and generation [17, 6] In addition, these advancements have benefited various fields, including academic research. However, LLM responses can depend heavily on the data on which the model was trained, and they cannot retrieve real-time or external information beyond their pre-trained knowledge. This makes them less effective for tasks that require up-to-date, specific institutional data, such as retrieving current academic resources in university libraries [15].

Writing an academic paper requires a deep understanding of the subject and a significant amount of related literature for credible evidence, which can be challenging and time-consuming [10]. It is essential to first visit the university library to search and gather existing related literature significant to the researcher's study. However, most libraries today still operate in traditional, non-digital formats where materials are only accessible on-site, making the process of finding and retrieving resources more difficult. Furthermore, some school libraries offer limited access and prohibit users from taking home thesis papers. These challenges significantly delay the progress of future academic research due to limited access to relevant literature in university libraries [18].

To address retrieval issues, several universities in the Philippines have recognized the importance of adopting digital archiving systems to improve academic access. This becomes more evident in the last previous year before covid-19 pandemic, when researchers were unable to access library resources, prompting libraries to adapt and make resources accessible even remotely. However, digitalization alone does not fully solve the problem [3, 12, 18]. Unfortunately, most digitalized libraries today still use outdated search systems that need an exact keyword search, which can result in irrelevant materials [21]. The current search mechanism of this digital archives including the Camarines Sur Polytechnic Colleges (CSPC) library still heavily depends on traditional keyword-matching algorithms. If users do not input the exact title or precise keywords, the system returns ”not found” even when relevant content exists. This limitation highlights a deeper issue in search functionality, where vague or topic-based queries cannot retrieve appropriate materials, thereby hindering access to valuable research. This inefficiency in retrieval presents a serious barrier for the academe community, particularly when conducting time-sensitive or exploratory academic work.

These challenges of university libraries in the Philippines, including the CSPC library, have shared difficulties in accessing academic resources, outdated search systems, and ineffective information retrieval that affect the efficiency of academic research. While numerous studies have also explored the integration of the emerging LLM-powered chatbots in academic research [1], their implementation and effect for thesis retrieval in specific university libraries, including CSPC, have not been established. This is primarily due to the limitations of LLMs, which rely solely on pre-trained knowledge and are unable to access or utilize the unique local archives maintained by individual libraries [4, 22].

To overcome these challenges, Retrieval-Augmented Generation (RAG) has emerged as a superior approach [14]. Unlike standalone LLMs, which require retraining and additional domain-specific data to adjust LLM weights, RAG presents an advanced approach by retrieving relevant external information to generate responses and holds significant practical implications for university libraries by improving search functionalities. Additionally, RAG ensures that the most relevant academic resources are retrieved quickly and straightforwardly, making it suitable for libraries with expansive collections of academic papers that are difficult for researchers and students to navigate [23, 9].

This thesis proposes an enhanced LLM-powered chatbot with the integration of the Retrieval-Augmented Generation (RAG) technique to improve information retrieval, especially in literature search and thesis retrieval of university-owned thesis PDFs at the Camarines Sur Polytechnic Colleges (CSPC) Library. This chatbot application will generate answers and retrieve relevant documents based on the user's prompt.

Statement of the Problem

Finding relevant thesis literature in a University's library, such as in CSPC, can be challenging. Many researchers in the academic community struggle to find the exact thesis paper they need, often requiring them to travel and physically visit the library just to retrieve specific documents.

Currently, CSPC's library website [25] only allows users to search by exact document title. Finding relevant research becomes difficult if users don't know the exact title. Furthermore, library policies restrict users from taking thesis books outside the premises, limiting accessibility to essential academic resources. In response to these challenges, this study aims to explore creating a chatbot that eliminates those limitations by enabling searches based on topics, keywords, or even vague descriptions. Additionally, we aim to make this available everywhere. This goal, with the use of the Retrieval Augmented Generation

(RAG) algorithm, will revolutionize how the academe community interacts with the CSPC library, making research faster, smarter, and more user-friendly.

Objectives of the Study

The objectives of this study are divided into two categories: general and specific. The general objective defines the overall goal of the study, while the specific objectives break down this goal into measurable and achievable steps. These objectives ensure a structured approach to developing an enhanced LLM chatbot for Camarines Sur Polytechnic Colleges.

General Objective

The general objective of this study is to develop a chatbot for Camarines Sur Polytechnic Colleges (CSPC) library, using Retrieval-Augmented Generation (RAG) to enhance thesis retrieval and literature search in CSPC Library, replacing the traditional keyword-based search with a more conversational and topic-oriented search and response approach.

Specific Objectives

To achieve the general objective, the study sets the following specific objectives:

1. To integrate a document ingestion and retrieval module for storing thesis documents.
2. To Implement a semantic search and thesis document retrieval system using RAG and Deepseek R1 LLM.
3. To Evaluate the performance of the RAG chatbot using RAGASS.
4. To Deploy the RAG chatbot on a local server

Significance of the Study

The result of this study will benefit the following:

Students. By integrating semantic search and retrieval capabilities, the chatbot will significantly improve search accuracy and efficiency, reducing the time spent on literature review. This will enable students and researchers to quickly find relevant studies without relying solely on exact keywords or titles.

Faculty Members. The chatbot will serve as a research aid for faculty members by providing easier access to relevant studies. This will enhance their ability to aid students in thesis writing, academic guidance, and collaborative research work, while at the same time reducing the extent of manual effort in literature searching.

CSPC Library Management. The implementation of a RAG-powered chatbot will modernize the library's digital infrastructure, making academic resources more accessible to users. By automating thesis retrieval and search functions, the system will improve library service and optimize resource utilization.

Researchers. The study will contribute to the field of AI-driven academic search and retrieval, providing insights into the practical applications of Retrieval-Augmented Generation (RAG). Future researchers can build on this work by exploring ways to further optimize search relevance, retrieval efficiency, and integration with other AI models.

Scope and Limitation

The scope of this study is to develop a chatbot for the Camarines Sur Polytechnic Colleges (CSPC) library, utilizing Retrieval-Augmented Generation (RAG) with the Deepseek R1 LLM. The goal is to address the challenges faced by the academic community in searching and retrieving thesis literature by replacing the current yet traditional keyword-based search with a more conversational and topic-oriented approach. This will be done through a website based with an access control where admin can upload new published pdf thesis and users can register through their cspc email. Additionally, we aim to deploy this on a local server. This project will be conducted over two whole semesters, allowing ample time for development and testing.

There are certain limitations to consider in this study. First, our team will focus only on utilizing the available PDF copies of undergraduate theses that have already been published. Second, the chatbot's accuracy will depend on the quality and structure of thesis records, and on the clarity and relevance of the user's prompts. Additionally, hardware limitations may constrain computational efficiency, which could affect the chatbot's real-time processing capabilities. Finally, while the RAG technique can reduce hallucination, users are advised to validate the outputs carefully as occasional inaccuracies or fabricated information may still occur.

Project Dictionary

The Project Dictionary contains the technical terms that defined the conceptual and operation of this study:

- **Academic Literature Retrieval.** The process of systematically searching for and obtaining scholarly documents, such as research papers and theses, to support academic work [20]. In this study, the implementation of LLMs is essential to improve the retrieval of academic literature.

- **Chatbot.** An AI-powered conversational agent designed to interact with users in natural language, providing assistance, answering queries, and facilitating access to information in a user-friendly manner [7]. In this study, chatbots will be implemented for answering questions with human-like responses.

- **CSPC Library.** The Camarines Sur Polytechnic Colleges (CSPC) Library serves as the primary academic resource center for students and faculty. It offers access to a diverse collection of books and theses inside the premises. The library has initiated steps toward digitalization, providing an online catalog for users to search materials. In this study, the CSPC Library is examined to assess its current digital infrastructure and explore enhancements to improve information retrieval and user experience.

- **Generative AI.** A kind of artificial intelligence that may produce original text, graphics, or code, frequently in response to a user-inputted prompt. More and more online applications and chatbots that let users enter instructions or inquiries into an input box are using its models. The AI model will produce a response in the output field that resembles a human response [5]. In this study, we will examine the implications of Generative AI in the education and academic integrity context.

- **Large Language Models (LLMs).** AI models trained on vast text datasets to understand and generate human-like responses. They excel in natural language tasks but struggle with retrieving real-time and domain-specific information [11]. In this study, the implementation of the Large Language Model (LLM) streamlines access to information, assists in literature searches, and facilitates query handling effectively.

- **Natural Language Processing (NLP).** A subfield of artificial intelligence (AI) called natural language processing (NLP) makes it possible for computers to comprehend and understand spoken, written, or even handwritten human language. NLP is essential to enabling seamless and organic human-computer interactions as AI-driven technologies grow more pervasive in daily life [19]. In this study, NLP significantly improves machine comprehension to understand human language and improves user interaction through chatbots.

- **Retrieval-Augmented Generation (RAG).** An AI framework that enhances LLMs by incorporating an external knowledge retrieval mechanism, improving the accuracy and contextual relevance of generated responses [14]. In this study, RAG will be developed for navigating and retrieving information from large amounts of academic papers.

- **Semantic Search.** A search approach that goes beyond keyword matching by understanding the intent and contextual meaning of queries to return more relevant results [16]. In this study, semantic search will significantly improve the performance of RAG in generating relevant and contextual responses due to the enhanced retrieval process by understanding user queries which is beneficial for the CSPC library that holds a large collection of academic papers.

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CHAPTER 2

RELATED LITERATURE AND STUDIES

This chapter provides a comprehensive overview of the literature and studies related to spatiotemporal landmark recognition and localization, focusing on Augmented Reality (AR)-based campus navigation. It also synthesizes critical similarities and differences among existing research on Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM). Lastly, the chapter identifies a gap in the current literature and discusses how the present study aims to address this gap.

Review of Related Literature and Studies

Spatiotemporal Landmark Recognition and Localization

Today, modern deep learning techniques are making rapid progress in the field of spatiotemporal landmark recognition and localization. Spatial feature recognition previously required manual labeling, which is quite labor intensive and very inefficient [**three**]; deep learning, according to recent work, particularly that of **three three**, has actually improved recognition performance by better elucidation of spatial relationships between objects.

In addition, **six six** showcased pre-trained CNN models that were effective in extracting spatial features from hyperspectral images for enhanced classification performance, thus establishing the value of transfer learning for improved performance in different image classification tasks bordering on complex geospatial data [**six**]. The adoption of Machine Learning (ML) in clustering and recognizing spatial data patterns has further widened the horizon of geospatial analysis. **seven seven** commented that this would help the automatic extraction of considerable patterns from complex datasets, which is very crucial for processing geographical data, such as satellite imagery, and unraveling hidden trends that would aid decision-making [**seven**].

In addition, **eight eight** examined a high-dimensional self-attention mechanism that combines spatial and temporal features to incrementally improve the predictive power behind systematic evaluations with varying neural network architectures. This work stands as an illustration of the growing finesse in the handling of spatiotemporal data [**eight**].

The excessive growth of images, especially in web and mobile applications, poses threats to efficient landmark recognition. Traditional methods, such as Support Vector Machines (SVM), revealed their limitations when handling variations in elevation and structure. Contemporary studies, including **nine nine**, show that CNN architectures such as ResNet-50 have proven successful in achieving high accuracy for the detection of landmarks in various view angles. These advancements justify the abilities of deep learning models, which are helpful in real-world applications, including navigation to identify unlabeled historical landmarks [**nine**].

This concludes that the changeover of the spatiotemporal landmark recognition and localization processes into deep learning is reshaping the domain, addressing issues of efficiency and accuracy. Continuous research will positively impact applications in the field with implications that center on advanced capabilities in understanding and articulating spatial environments.

AR-based Campus Navigation

Navigating large university campuses can be challenging, especially for new students and visitors unfamiliar with the environment. AR-based navigation systems provide an interactive solution, improving indoor and outdoor way-finding by overlaying digital content onto the real world, improving localization accuracy, and offering real-time guidance. Several studies highlight the practical benefits of AR in campus navigation. **one one** proposed an ARCore-based system that uses visual-inertial ranging and Unity3D to improve positioning in Global Positioning System (GPS)-limited areas [**one**]. Similarly, **ten ten** integrated IoT-based sensor fusion for adaptive route guidance, while **two two** combined GPS, Wi-Fi, BLE beacons and Artificial Intelligence (AI)-driven path optimization for voice-assisted, accessible navigation [**ten**, **two**]. **thirteens thirteens** explored AI integration through CNN and LSTM to improve the precision of localization [**thirteens**]. Hybrid systems were also developed, such as the AR-VR platform by **four four**, which allows real-time tracking, virtual campus tours and personalized routes, and the landmark-based system by **twelve twelve**, which improves spatial learning, especially for older adults [**four**, **twelve**].

In addition to supporting indoor-outdoor navigation, **five five** introduced an AR app utilizing computer vision and object detection, while **eleven eleven** and **fifteen fifteen** focused on indoor systems that integrate sensor data and AR overlays for improved accuracy and user experience [**ten**, **eleven**, **fifteen**]. **fourteen fourteen** also emphasized the broader developments in AR-assisted indoor positioning and mapping technologies [**fourteen**].

In conclusion, these studies collectively underscore the potential of AR-powered campus navigation systems in delivering accurate, accessible, and interactive guidance. With the integration of real-time tracking, AI, and immersive interfaces, AR systems continue to enhance the overall wayfinding experience in educational environments.

Convolutional Neural Networks

The integration of CNN into AR-based navigation systems has significantly enhanced localization accuracy, object recognition, and real-time spatial understanding, making navigation more intelligent and responsive.

Several studies have demonstrated the value of CNNs in improving AR navigation. **twentytwo twentytwo** emphasized how CNNs enhance scene recognition and real-time interaction in AR environments, while **twenty twenty** developed a CNN-augmented SLAM system using planar constraints for more stable positioning [**twentytwo**, **twenty**]. Similarly, **seventeen seventeen** applied CNNs to mobile robot localization in indoor spaces, and **twentyfivetwentyfive** extended this by applying deep CNNs to dynamic pathfinding in autonomous robot navigation [**seventeen**, **twentyfive**].

Other researchers have focused on CNNs to support accessibility. **sixteen sixteen** implemented CNNs in AR systems to assist visually impaired users by improving obstacle detection, while **eighteen eighteen** enhanced environmental perception through CNN-powered object recognition and tracking [**sixteen**, **eighteen**]. In terms of interaction, **twentyone twentyone** introduced a CNN-based multi-target classification model for AR-SSVEP to improve interaction precision [**twentyone**].

Broader reviews and advanced implementations further showcase CNN's potential. **nineteen nineteen** conducted a systematic review of CNN use across AR, VR, and MR, emphasizing their role in spatial computing and immersive navigation [**nineteen**]. **twentyfour twentyfour** combined CNNs with LSTM in Kalman filter fusion to refine path correction and trajectory prediction, while Shin-**twentythree twentythree** demonstrated CNNs' value in surgical AR navigation requiring high-precision localization [**twentyfour**, **twentythree**].

In conclusion, these studies collectively highlight the critical role of CNNs in advancing AR-based navigation. By enabling accurate object recognition, adaptive route planning, and robust spatial understanding, CNNs contribute significantly to making AR navigation systems more intelligent, accessible, and immersive.

Long Short-Term Memory

State-of-the-art positioning technology has traditionally produced large-scale trajectory data that plays a major role in location prediction for location-based services (LBS). Displacement forecast through long-term visitations following the traditional sense or real-time trajectory forecasting are the mainstream methods. An emerging approach has interest in integrating both the spatial and temporal dimensions together using LSTM Networks, where, even more specifically, the Spatial-Temporal Long Short-Term Memory (ST-LSTM) model tackles data sparsity and caters to better urban mobility and personalized LBS applications [**twentysix**]. The SPATIAL architecture provides yet another example of such integration with improved prediction accuracy [**twentyseven**].

It is noteworthy that Wi-Fi-based positioning has gained some traction, especially in the indoor setting, but with its challenges in accuracy due to varying signal conditions. A recent spatial-temporal positioning algorithm adopts a residual network for the extraction of spatial features and LSTM, greatly increasing the precision of localization [**twentyeight**].

LSTMs may also find utilization in environmental monitoring, thus performing weather prediction and applicable scenarios better than traditional CNN and LSTM methods with a hybrid model among variates [**twentynine**].

Another area is traffic management. According to **thirty thirty**, LSTM models outperformed classical methods in estimating traffic speed [**thirty**]. **thirtyone thirtyone** demonstrated the successful application of the improved Bi-LSTM model to real-time traffic flow forecasting, further stating that spatial-temporal modeling is crucial in urban traffic systems [**thirtyone**]. **thirtytwo thirtytwo** improved trajectory prediction of vehicles by using spatial and temporal attention mechanisms in the STAM-LSTM, capable of capturing the relationships between vehicle and associated motion features [**thirtytwo**].

Apart from transportation, LSTM networks have made strides in facial expression recognition; the Enhanced ConvLSTM model leverages the spatial and temporal connections and is efficient in complex environments [**thirtythree**]. In a parallel manner, the STGA-LSTM framework by **thirtyfour** predicts short-term demand for bike-sharing using Graph Convolutional Networks, witnessing an unprecedented advancement in demand forecasting [**thirtyfour**]. Then, in predicting outlet temperature for energy systems, a hybrid model CNN-LSTM was established on modeling spatial-temporal features for better thermal energy management [**thirtyfive**], proposed by **thirtyfive thirtyfive**.

This coupling of spatial and temporal factors in LSTMs has led to the elimination of boundaries in predictive analytics across various fields. This development indicates that the model may be the answer to stochastic problems posed in real-life scenarios, such as intelligent transportation systems, environmental monitoring, urban mobility, and energy management. LSTM has also begun to set the way for future breakthroughs in predictive modeling and analytics as research continues.

Evaluation Metrics and Performance Analysis

Evaluating the effectiveness of AR-based campus navigation systems requires a comprehensive assessment of their positional accuracy. Different metrics serve to illuminate various aspects of system performance. For large deployable mesh reflectors, **thirtyseven thirtyseven** highlights the usefulness of the root-mean-square (RMS) error as an effective surface accuracy measure. RMS calculates the average deviation between the actual surface and the intended shape, providing a single value that summarizes overall surface fidelity. Yuan's study compares several RMS measurement approaches: nodal deviation offers highly localized details but demands extensive computational effort; the best-fit surface method provides a balanced, global view of shape accuracy; and direct RMS error yields a simple overall deviation metric, though it may miss localized imperfections. Incorporating assessments focused on critical surface regions enhances the evaluation by highlighting areas most vital to system performance [**thirtysix**].

In the context of indoor positioning, **thirtyseven thirtyseven** demonstrate the importance of path-based error metrics like the Mean Euclidean Error (MEE). Their research compares different methods and finds that the Visibility Graph (VG) approach achieves the lowest average error of about 2.2 meters, closely reflecting the actual routes pedestrians walk in complex indoor spaces. The Navigation Mesh (NM) method follows with an error near 2.4 meters, while the Fast Marching (FM) method results in a higher average error of approximately 3.7 meters. These findings emphasize that MEE, which measures the length of paths pedestrians would realistically follow, provides a more practical, real-world assessment of localization accuracy than simple straight-line distances. Since MEE closely relates to how users navigate environments, it offers valuable insights into system usability and reliability. [**thirtyseven**].

The evaluation results for navigation time in the study of **one one**, indicates that during the experiments, the AR navigation system achieved approximately a 20% reduction in navigation times compared to traditional maps at Shanghai University, which is a notable improvement in efficiency. The mention of ”p ¡ 0.05” refers to the p-value obtained from statistical testing, likely a t-test or similar, which measures the probability that the observed difference occurred by chance. A p-value less than 0.05 is commonly considered statistically significant, meaning there is less than a 5% probability that the observed reduction in navigation time was due to random variation alone. This significance level provides confidence that the AR system genuinely enhances navigation speed, validating its effectiveness. The combination of practical results (20% reduction) and statistical validation (p ¡ 0.05) supports the conclusion that the AR-based system offers a meaningful and reliable improvement for campus navigation [**one**].

Synthesis of the State of the Art

The evolution of spatiotemporal landmark recognition and localization has been significantly shaped by deep learning techniques, particularly with the integration of CNN and LSTM networks. Traditional spatial recognition methods, which relied heavily on manual landmark identification, have proven inefficient and time-consuming [**three**]. The work of **three three** emphasized the use of deep learning in enhancing recognition accuracy and spatial relationship modeling [**three**]. **six six** highlighted the benefit of transfer learning with pre-trained CNNs in improving classification accuracy, especially in hyperspectral imagery [**six**]. Similarly, **seven seven** noted that ML improved spatial clustering and pattern recognition, which are vital in geospatial analysis [**seven**].

To further boost prediction accuracy, **eight eight** proposed a high-dimensional self-attention mechanism for fusing spatial and temporal features [**eight**]. In contrast, **ninenine** pointed out the limitations of traditional algorithms like Support Vector Machines (SVMs), especially when dealing with orientation variations, where CNN models such as ResNet-50 performed better in landmark detection [**nine**]. These advancements have practical applications in navigation, automated mapping, and landmark identification across diverse environments.

AR-based campus navigation systems have emerged as practical applications of these models, offering interactive and real-time wayfinding solutions. **one one** designed an ARCore-based system utilizing visual-inertial ranging algorithms for enhanced positioning, while **ten ten** incorporated IoT-based sensor fusion to enable adaptive route guidance [**one**, **ten**]. Similarly, **two two** integrated GPS, Wi-Fi triangulation, BLE beacons, and AI-driven path optimization to support voice-assisted and event-based routing [**two**]. **thirteens thirteens** focused on AI-enhanced AR systems using CNN and LSTM models to improve navigation accuracy. **four four** developed a hybrid AR-VR system that supports virtual campus exploration and personalized routing [**thirteens**, **four**].

twelve twelve developed a landmark-based navigation system targeting older adults, while **fourteen fourteen** provided a broad overview of AR-assisted localization techniques [**twelve**, **fourteen**]. **five five** emphasized the use of computer vision and object detection, and **eleven eleven**focused on enhancing indoor navigation through sensor integration [**five**, **eleven**]. Lastly, **fifteen fifteen** streamlined campus wayfinding by overlaying directional markers in AR environments. Together, these works highlight the growing impact of AR in educational settings for real-time and user-friendly navigation [**fifteen**].

CNN integration continues to be a major force behind advancements in AR. **twentytwo twentytwo** and **twenty twenty** showed how CNNs enhance real-time scene recognition and positioning [**twentytwo**, **twenty**]. **sixteen sixteen** and **seventeen seventeen** applied CNNs to assist visually impaired users and optimize indoor navigation [**sixteen**, **seventeen**]. **twentyfive twentyfive**, **eighteen eighteen**, and **twentyone twentyone** further validated CNNs' capacity for object recognition and interaction in AR contexts [**twentyfive**, **eighteen**, **twentyone**].

nineteen nineteen reviewed CNN applications in AR, VR, and MR, while **twentyfour twentyfour** and **twentythree twentythree** demonstrated CNNs' effectiveness in surgical and predictive navigation systems [**nineteen**, **twentyfour**, **twentythree**].

LSTM networks also play an important role by capturing spatial-temporal dependencies in path prediction and localization. **twentysix twentysix**, **twentyseven twentyseven**, **twentyeight twentyeight**, all demonstrated the application of LSTM networks to improve accuracy in various domains, from location tracking to environmental forecasting [**twentysix**, **twentyseven**, **twentyeight**]. **twentynine twentynine** and **thirty thirty** showed LSTM networks' predictive accuracy in temperature modeling and traffic speed forecasting [**twentynine**, **thirty**]. **thirtyone thirtyone** and **thirtytwo thirtytwo** focused on LSTM variants such as Bi-LSTM and STAM-LSTM for vehicle trajectory predictions, while **thirtythree thirtythree**, **thirtyfour thirtyfour**, and **thirtyfive thirtyfive** explored their integration with CNN and GCN for specific applications such as emotion recognition and energy modeling [**thirtyone**, **thirtytwo**, **thirtythree**, **thirtyfour**, **thirtyfive**].

In evaluating AR-based campus navigation systems, several key metrics are utilized to assess efficiency, accuracy, and reliability. Root Mean Squared Error (RMSE) helps capture significant localization discrepancies by emphasizing larger errors, as supported by **thirtysix thirtysix**, who demonstrated that RMSE effectively assesses surface accuracy, with methods such as the best-fit surface that offers balanced global evaluations [**thirtysix**]. Mean Euclidean Error (MEE), according to **thirtyseven thirtyseven**, provides realistic information on positioning performance by measuring the average distance between predicted and actual paths, and their study shows that VG achieved lower MEE values around 2.2 meters, highlighting its importance in dynamic real-world environments [**thirtyseven**]. Navigation time, evaluated in the study by **one one**, showed that AR-based systems reduced navigation time by approximately 20% compared to traditional map applications, significantly improving user navigation speed and efficiency in campus environments [**one**]. Together, these metrics; RMSE, MEE, and navigation time offer a comprehensive evaluation of AR navigation systems, guiding future improvements to improve precision, operational speed, and overall user experience.

In summary, deep learning and AR technologies have converged to significantly improve spatial navigation. CNNs and LSTM networks excel in localization, prediction, and interaction modeling, while the integration of RMSE, MEE, and Navigation Time ensures the continuous advancement of more accurate and user-centric navigation systems.

Gap Bridged by the Study

Existing studies have shown the success and potential of spatial models for AR navigation and positioning. However, there is still room for improvement, especially since many current AR navigation systems rely on GPS which uses internet connectivity and focuses mainly on indoor navigation. This creates a gap in the provision of effective outdoor navigation solutions, particularly in large campus areas where reliable guidance is crucial.

This study aims to address this gap by developing an offline spatiotemporal localization model that uses CNN and LSTM networks. The main goal is to create an interactive wayfinding solution for Camarines Sur Polytechnic Colleges (CSPC).

CHAPTER 3

METHODOLOGY

CHAPTER 4

RESULTS AND DISCUSSION

CHAPTER 5

CONCLUSION

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APPENDICES

APPENDIX A

LANGUAGE EDITING CERTIFICATION

This is to certify that the undersigned has reviewed and went through all the pages of the Bachelor of Science in Computer Science thesis manuscript titled

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of **AuthorName1**, **AuthorName2**, **AuthorName3**, as against the set of structural rules that govern research writing in accord with the composition of sentences, phrases, and words in the English language.

JUAN DE LA CRUZ

Language Editor

Date:______________________

APPENDIX B

SECRETARY'S CERTIFICATION

This is to certify that the undersigned has provided accurate recommendations, suggestions, and comments unanimously agreed and approved by the panel of examiners during the oral examination of the thesis titled

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prepared and submitted by **AuthorName1**, **AuthorName2**, **AuthorName3**, and that the same have not been amended, modified or obliterated.

MS. MARIA DAISY R. BELARDO

Secretary

Date:______________________

APPENDIX C

JOINT AFFIDAVIT OF UNDERTAKING (PLAGIARISM)

JOINT AFFIDAVIT OF UNDERTAKING

VITA

- **Joseph Jessie S. Oñate** is a faculty member of the College of Computer Studies. He finished his Master of Science in Computer Science degree at Ateneo de Naga University. His research interests focused on Intelligent Systems, Algorithm and Complexity, Web Technologies, Computer Vision, and Graphics.

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