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Artificial Intelligence Based Chatbot on Rasa NLU System Empowered with Deep Learning

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Abstract

This study explores the development of an interactive communication application designed to facilitate the exchange of information in a user-friendly manner. The application allows individuals to send queries in simple language and receive understandable, actionable responses. This feature is particularly beneficial for users who need specific, detailed information across a variety of topics. The application is designed with accessibility in mind, enabling users, including students, to easily obtain the knowledge they require. Additionally, the system incorporates a built-in guide to help users navigate and utilize the application effectively, ensuring they can operate it independently without requiring external assistance. This guide is instrumental in making the platform user-friendly, fostering self-sufficiency among individuals in diverse contexts. Not only does this application serve personal and educational purposes, but it also holds the potential to improve Information Retrieval (IR) relationships. By streamlining the process of retrieving and delivering information, it ensures that users receive relevant data in a timely and efficient manner. The application is also designed to support knowledge dissemination on a global scale, benefiting users in Pakistan as well as in other countries. Its ability to deliver precise information contributes to the expansion of educational opportunities, particularly in regions where access to resources may be limited. In this way, the application serves as a valuable tool for bridging knowledge gaps and enhancing the flow of information between different countries and cultures. Ultimately, this platform fosters educational development and helps users apply newly acquired knowledge to real-world situations, promoting both personal growth and

Spectrum of Engineering Sciences

SPECTRUM OF ENGINEERING SCIENCES

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broader socio-cultural advancements. The system's design ensures that it is accessible and beneficial to a wide range of audiences, improving learning experiences and IR capabilities across borders.

Keywords: Artificial Intelligence, Chatbot Development, RASA NLU framework, Deep Learning

Introduction

Artificial intelligence (AI) has become a pivotal component of technological advancement, transforming the way humans interact with machines (Narasimhamurthy 2024). One of the key applications of AI is the development of chatbots, which simulate human conversations to deliver information, respond to inquiries, and execute tasks. These systems have become indispensable across multiple industries, including customer service, healthcare, education, and e-commerce. As user expectations evolve, there is an increasing demand for chatbots that are more intelligent, context-aware, and efficient. This requirement has spurred the adoption of advanced platforms like Rasa, an open-source framework recognized for its flexibility and strong capabilities in building conversational AI systems (Gharbaoui and Castoldi 2024). By integrating Natural Language Understanding (NLU) and dialogue management, Rasa enables developers to design chatbots that effectively recognize intents, extract entities, and manage contextual interactions. Deep learning, a subset of machine learning, has significantly enhanced natural language processing (NLP), allowing chatbots to achieve higher levels of sophistication (Jayalakshmi et al. 2024). By employing neural network architectures such as recurrent neural networks (RNNs), transformers, and convolutional neural networks (CNNs), deep learning models excel in decoding complex language patterns,

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3007-312X

leading to more intuitive and contextually appropriate responses. These models enable chatbots to comprehend subtle linguistic nuances, adapt to diverse user inputs, and continuously improve through training on large datasets. When integrated with the Rasa framework, deep learning techniques greatly enhance the capabilities of conversational agents, promoting more meaningful and engaging interactions.

Furthermore, the incorporation of deep learning enables chatbots to evolve through user interactions over time. By employing reinforcement learning and continuous training, these systems can improve their functionality by adjusting to shifting user behaviors and preferences. This cyclic learning mechanism is particularly advantageous in domains where user demands are dynamic, such as e-commerce or technical support. Through the application of data-driven insights, chatbots can refine their reactions, foresee user requirements, and provide a tailored conversational experience. The implementation of an AI-driven chatbot utilizing the Rasa NLU framework, augmented by deep learning, also brings forth practical considerations (Jayalakshmi et al. 2024). A significant challenge is guaranteeing scalability and efficiency in handling large volumes of user interactions. As the complexity of the chatbot escalates, so does the computational need for processing and producing responses (Nivedhitha et al. 2024). Enhancing the system's architecture and utilizing cloud-based solutions can alleviate these issues, ensuring that the chatbot remains responsive and dependable under varied workloads. Moreover, data privacy and security are critical concerns, especially in industries such as healthcare and finance (Bagchi 2020). Adhering to data protection regulations and

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instituting robust security protocols are essential for preserving user confidence and safeguarding sensitive information.

Several widely used tools, including Slack, Twilio, Hassan Nawaz, Telegram, Mattermost, Nusrat Azeema and RocketChat, provide integration with Rasa NLU, facilitating smooth functionality across a range of applications. Although many messaging platforms enjoy extensive popularity, certain features continue to pose navigation challenges for users. The fundamental advantage of Rasa lies in its inherent natural language processing (NLP) abilities, which are underpinned by deep learning, allowing for improved chatbot performance through the comprehension of intents and extraction of entities. The Mul_Assistant_Bot serves as an illustration of this capability by delivering an intuitive user experience, enabling rapid responses to user inquiries, facilitating access to university-related information, and supporting concurrent interactions among multiple users without delays. This paper explores the design and implementation of an AI-based chatbot developed using the Rasa NLU system, augmented with deep learning methods. The primary objective is to demonstrate how this integration enhances the chatbot's natural language processing capabilities and overall performance in real-world applications. By addressing challenges such as intent recognition, entity extraction, and dialogue flow optimization, the study provides a comprehensive framework for creating advanced conversational agents. Additionally, the paper examines practical aspects of deploying such systems, offering insights into scalability, user adaptation, and the future prospects of conversational AI.

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Materials and Methods

Work Breakdown Structure

The architecture of the Rasa NLU framework illustrates in figure 1 a complex interaction of modular elements engineered to facilitate effective natural language understanding and dialogue management. This architecture is founded on two primary components: Rasa Open Source and Rasa X. Rasa Open Source includes the essential components, while Rasa X acts as an enhancement platform for the training, monitoring, and optimization of chatbots. At the heart of Rasa Open Source are the Rasa NLU and Rasa Core modules. Rasa NLU is tasked with processing and interpreting user inputs by utilizing deep learning-based NLP pipelines to identify user intents and entities. Rasa Core enhances this capability by employing dialogue policies to forecast the most appropriate subsequent action based on the dialogue history. Collectively, these components guarantee that the chatbot can accurately interpret natural language inputs and provide contextually relevant responses. The Agent functions as the central integration point within Rasa Open Source, facilitating the flow of data among Rasa NLU, Rasa Core, and other critical components like the Tracker Store and Lock Store.

The Tracker Store maintains the continuity of conversational context, whereas the Lock Store governs concurrency to enable seamless interactions among multiple users. Moreover, the Action Server permits the execution of custom actions and API integrations, empowering the chatbot to undertake elaborate tasks beyond mere responses. The framework's architecture also includes an Event Broker, which oversees event communication by directing tracker events to other elements such as Rasa X or

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external monitoring systems. This arrangement guarantees a real-time exchange of information across the various components of the system. Rasa X amplifies the functionalities of the open-source framework by offering tools for conversational analysis, model enhancement, and user-focused customization. It features a backend for data management, a user interface for developers to observe and refine interactions, and a file system for storing models and training data.

The incorporation of a Git Repository for version control supports collaborative development, while the SQL Database allows for persistent storage of metadata, training data, and conversations. The modular nature of the architecture is further enriched by external interfaces such as Input/Output Channels, which enable Rasa to connect with messaging services like Slack, Telegram, Twilio, Mattermost, and RocketChat. These integrations broaden the chatbot's accessibility and user engagement, making it applicable for various purposes ranging from customer support to educational settings. For deployment purposes, the architecture includes Nginx as a reverse proxy server, handling HTTP requests and ensuring secure communication between users and backend services. The system also addresses enterprise needs through an ID Provider for authentication and access control, thereby ensuring adherence to data security standards. The architecture's adaptability allows developers to enhance chatbot performance through iterative refinements. Features such as real-time event tracking, dialogue supervision, and ongoing learning from user interactions contribute to the development of chatbots that are exceptionally responsive, scalable, and adaptable.

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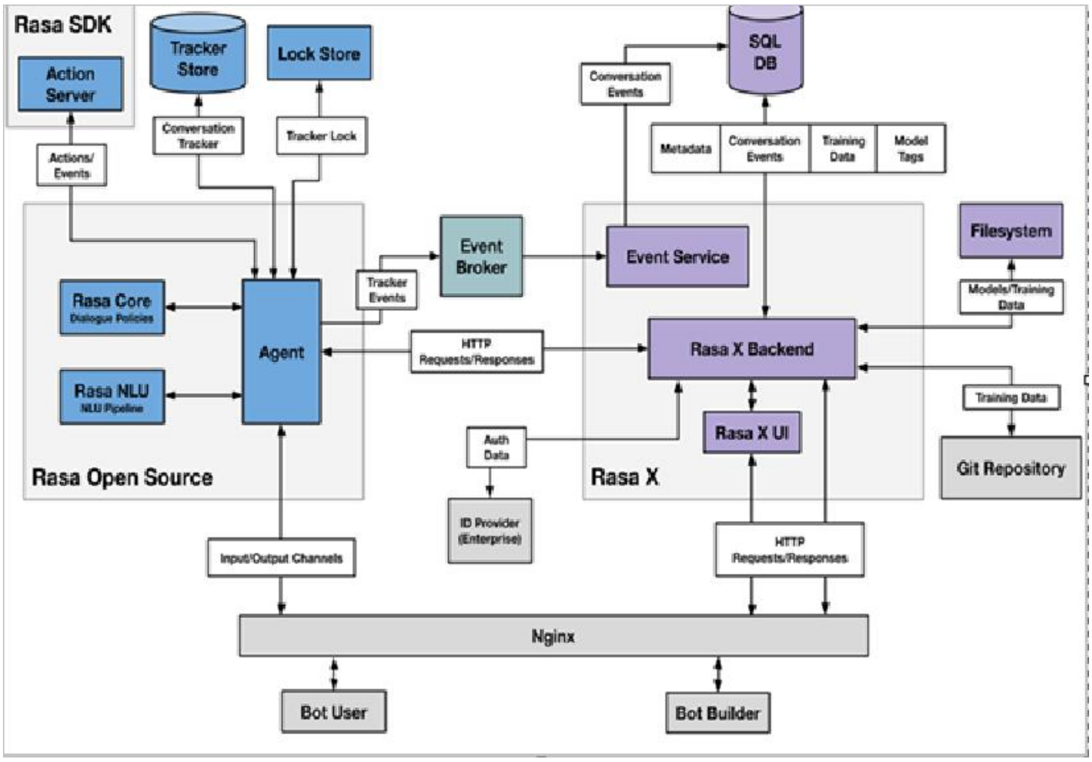

Figure 1 Work breakdown Structure

Service Perspective

Chat application is developed to help people communicate with minhaj university system. The application is developed using Python as programming language and natural language understanding (NLU). and design and coded in PyCharm IDE (Integrated Development Environment).

Service Function

The main function of this project is to get text and quires and audio messages (additional feature).

Product Functions

Features:

All Programs Details

Free for Public and Private Community

Chat (text)

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
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3007-3138
Print ISSN
3007-312X

Simple English language

Update Information

OCR

User Function:

Ask Questions

User Classes and Characteristics

Admin

The administrator can add, edit or delete queries and chats also change the expected queries for make the system more efficient. Admin manages all functionality of MUL_ASSISTANT_BOT.

Design and Implementation Constraints:

The device will have 8GB RAM.

Good quality Internet connection required.

Operating System Windows 10

Tools

PyCharm (Latest)

Python (3.8)

RASA CORE SDK

RASA NLU / ACTIONS

Spacy (python-library)

Ngrok (for deployment)

User Interfaces

The application provides a user-friendly and interactive user interface. In this application, the user will easily understand the use of every element and enjoy the user experience. User can interact with following things:

User can enjoy the application by gaining lots of educational career information and send and receive messages in user's own preference language.

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Print ISSN
3007-312X

Hardware Interface:

Processor: i3
Hard Disk: 500 GB
Memory: 8GB RAM
SSD (+point if available in your system)

Results & Discussion

RASA is an open-source machine learning framework for building conversational AI chatbots. Its architecture consists of several key components, which can be broadly divided into Rasa Open Source and Rasa X/Enterprise components.

Rasa NLU

At this place, rasa tries to understand User messages to detect Intent and Entity in your message. Rasa NLU has different components for recognizing intents and entities of user messages, most of which have some additional dependencies.

Rasa Core

This is the place where Rasa tries to help you with contextual message flow. It can predict dialogue as a reply based on User messages and can trigger Rasa Action Server.

Rasa X

It is a tool for Conversation-Driven Development (CDD), the method of listening to your user's requirements or queries and then further using those insights to reinforce your AI assistant. It's a browser-based GUI tool that will allow you to train a Machine Learning model by using GUI-based interactive mode. Rasa X is the latest release from Rasa that helps you build, improve, and deploy AI Assistants that are powered by the Rasa framework.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
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It layers on top of Rasa Open Source and helps you build a better chatbot assistant as per your specific requirements is a free, closed source tool available to all developers and can be deployed easily anywhere.

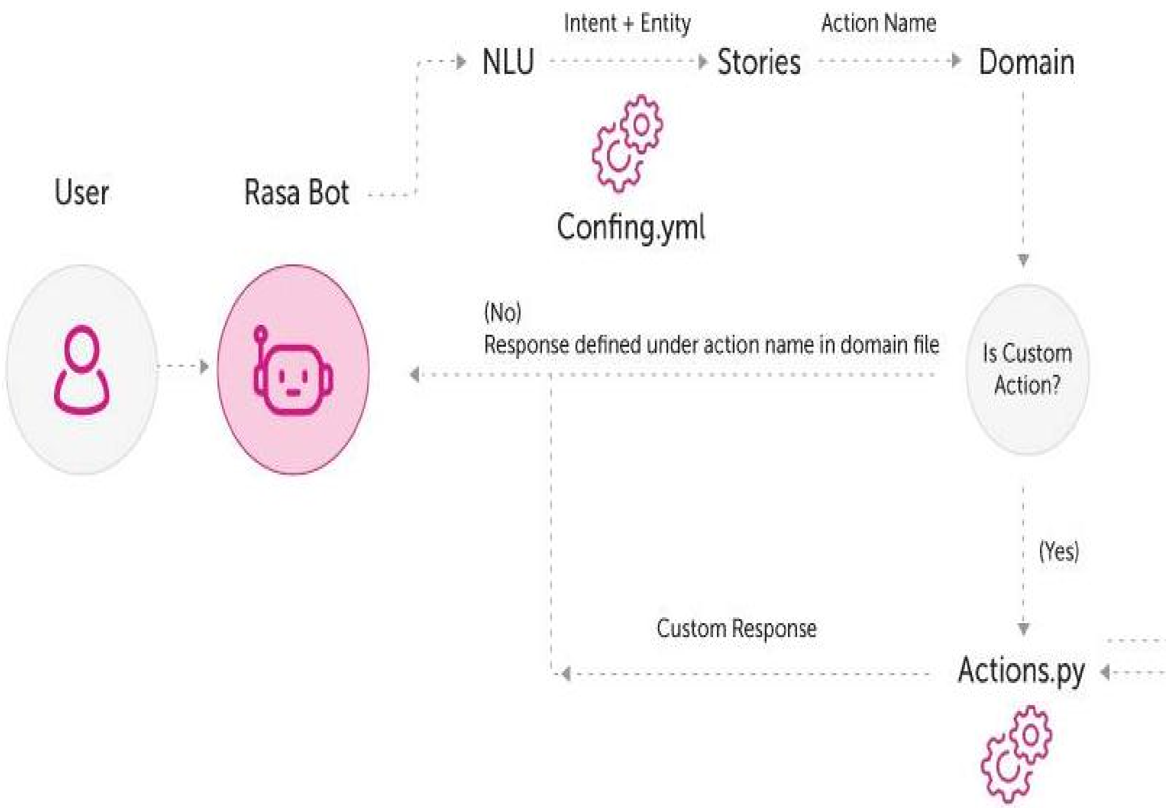

Figure 2: Case Model

Figure 3 represents the internal workings of the RASA conversational AI framework, delineating the interaction between its core components: Natural Language Understanding (NLU), Core (Dialogue Management), and Natural Language Generation (NLG). These components collaborate to process user input, determine the appropriate response, and deliver a coherent output, forming the backbone of an intelligent chatbot system. The process begins with the user query, which serves as the primary input to the system. For instance, in the provided example, the user asks,

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3007-312X

"What's the weather like tomorrow?" This query enters the NLU component, which is responsible for analyzing and interpreting the input. Within the NLU, two key tasks are performed. First, intent classification identifies the purpose or goal of the user's query—in this case, the intent might be categorized as "get_weather." Simultaneously, entity extraction identifies specific details within the query, such as the date "tomorrow," which provides contextual information for subsequent actions.

Once the input is processed, the extracted entities and intent are passed to the Core component. This part of the architecture manages the dialogue flow using a combination of machine learning and rule-based methods. A Recurrent Neural Network (RNN) is employed to evaluate the conversation's context and predict the next action. To ensure that only valid actions are considered, the system applies an action mask, which filters out irrelevant options. The resulting predictions undergo renormalization to determine the most appropriate action, which is then selected for execution. The chosen action might involve retrieving information from an external source, such as a weather API, or generating a predefined response. If the action involves dynamic data retrieval, the system makes an API call to the relevant service. For instance, it might fetch the weather forecast for the extracted date, "tomorrow." The response from the API is processed and reintegrated into the system for further action. If no external data is required, the process moves directly to the next stage.

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The final step in the workflow is handled by the NLG component, which converts the selected action into a human-readable response. This component ensures that the response is natural and

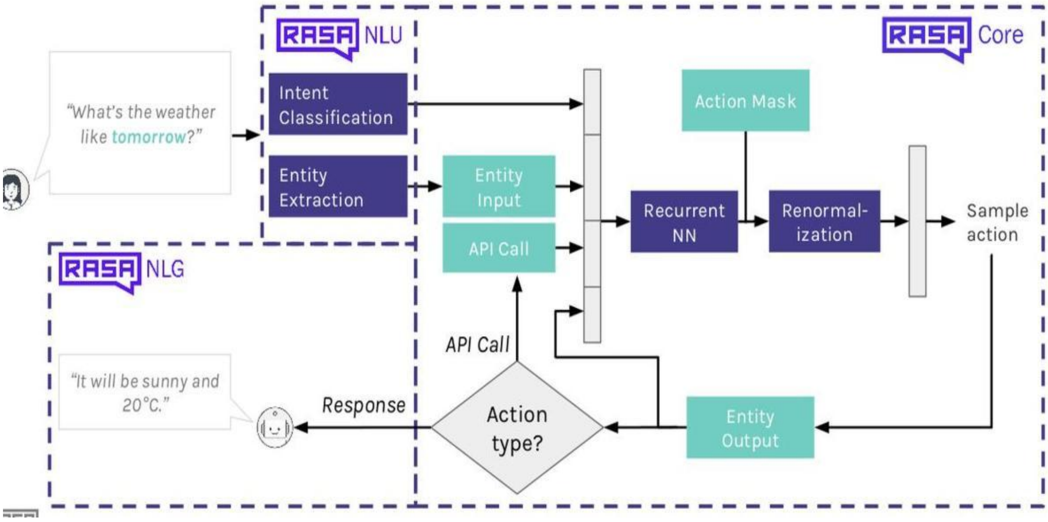

Figure 3: Architecture Diagram

contextually appropriate, incorporating extracted entities where necessary. For example, the output, "It will be sunny and 20°C," is tailored to include the requested weather details, aligning with the user's query.

Stress Testing: Ensuring System Stability and Resilience

Stress testing is a widely adopted methodology for evaluating a system's stability, reliability, and resilience under extreme operational conditions. It plays a pivotal role in determining the system's ability to handle faults, errors, and unexpected challenges effectively. By intentionally overloading the system beyond its designed operational capacity, stress testing provides critical insights into its behavior, identifying potential weaknesses and ensuring that the system can recover and function as expected. The primary aim of stress testing is to simulate harsh and adverse

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Print ISSN
3007-312X
SPECTRUM OF ENGINEERING SCIENCES

conditions to evaluate how the system responds under these scenarios. This process is crucial for validating the system's robustness and ensuring that all features and functionalities remain operational despite significant strain. Stress testing also examines the system's ability to manage errors gracefully, ensuring continuity and avoiding catastrophic failure during real-world scenarios.

In the context of the Translator Application Management System, stress testing confirms the system's reliability under unfavorable conditions. By subjecting the system to extreme workloads and analyzing its response, it is verified that all features, such as translation accuracy, processing speed, and user interface functionality, continue to perform as intended. This rigorous evaluation ensures that the system maintains its operational integrity, providing end-users with consistent and dependable performance. Incorporating stress testing as part of the system's development and quality assurance process ensures that the system is resilient to potential disruptions. Furthermore, it establishes confidence in the system's ability to handle extreme conditions while maintaining its core functionalities, a critical factor in its overall reliability and usability. This makes stress testing an indispensable component of ensuring the system's long-term stability and dependability in practical applications.

Conclusion and Recommendation

The development of an artificial intelligence-based chatbot using the RASA NLU system, empowered by deep learning, demonstrates significant advancements in conversational AI. By leveraging the capabilities of RASA’s modular architecture and the integration of deep learning techniques, the chatbot achieves enhanced

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
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3007-312X

performance in intent recognition, entity extraction, and context-aware dialogue management. This combination ensures a more intuitive and natural interaction between users and the chatbot. The integration of deep learning into the RASA NLU pipeline improves the system's ability to generalize across varied user inputs, effectively handling complex language patterns and delivering accurate responses. Additionally, the modularity of the RASA framework provides flexibility in adapting to diverse applications, including customer support, e-learning, and business automation, making it an ideal choice for modern AI-driven communication systems. The research underscores the importance of combining rule-based systems and deep learning models to create robust, scalable, and intelligent conversational agents. This study not only highlights the potential of RASA and deep learning but also opens avenues for further advancements in natural language processing, personalization, and adaptability in AI-driven chatbot solutions. Furthermore, it is recommended to make few changes like physical count, quality of Application, System level, add less language to see the impact.

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