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PROJECT PHASE - II REPORT

on

'VOICE-BASED BANKING FOR RURAL AREAS'

Submitted by

Sushrutha Shanbhogue	4SF22CS225
Raghavendra S S	4SF22CS158
Sowndarya S	4SF22CS218
Iram A.K Shaikh	4SF23CS404

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Under the Guidance of

Mr. Raghavendra Sooda

Assistant Professor, Department of CSE at

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College of Engineering & Management

An Autonomous Institution

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SAHYADRI

College of Engineering & Management

An Autonomous Institution

Department of Computer Science & Engineering

CERTIFICATE

This is to certify that the phase - II work of project entitled **"Voice-Based Banking for Rural Areas"** has been carried out by **Sushrutha Shanbhogue (4SF22CS225), Raghavendra S S (4SF22CS158), Sowndarya S (4SF22CS218) and Iram A.K Shaikh (4SF23CS404)**, the bonafide students of Sahyadri College of Engineering and Management in partial fulfillment of the requirements for the VII semester of Bachelor of Engineering in Computer Science and Engineering of Visvesvaraya Technological University, Belagavi during the year 2025 - 26. It is certified that all suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said degree.

Mr. Raghavendra Sooda	**Dr. Mustafa Basthikodi**	**Dr. S S Injaganeri**
Assistant Professor	Professor & Head	Principal
Dept. of CSE	Dept. of CSE	SCEM

Examiners' Name	**Signature**
1.	.....
2.	.....

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Department of Computer Science & Engineering

DECLARATION

We hereby declare that the entire work embodied in this Project work Phase - II report titled **"Voice-Based Banking for Rural Areas"** has been carried out by us at **Sahyadri College of Engineering & Management, Mangaluru** under the supervision of **Mr. Raghavendra Sooda**, in partial fulfillment of the requirements for the VII semester of **Bachelor of Engineering** in **Computer Science and Engineering**. This report has not been submitted to this or any other University for the award of any other degree.

Sushrutha Shanbhogue (4SF22CS225)

Raghavendra S S (4SF22CS158)

Sowndarya S (4SF22CS218)

Iram A.K Shaikh (4SF23CS404)

Dept. of CSE, SCEM, Mangaluru

Abstract

Language remains a significant barrier in accessing digital and financial services for many regional language speakers in India. This project presents the development of an intelligent, voice-driven system designed to assist Kannada-speaking users in filling out English bank forms efficiently. The proposed solution integrates Microsoft Azure services such as the Speech Service, Speech Studio, Translator, and Azure Functions—to automate the end-to-end process of voice-based data collection, translation, and document generation.

The system enables users to communicate naturally in Kannada with an AI Avatar that captures and transcribes their speech into text. The Azure Translator Service subsequently converts the transcribed Kannada text into English, which is then used by an Azure Function to populate a predefined bank form. The function, developed in Python, ensures accurate text placement and professional formatting of the final output. Through comprehensive local and cloud testing, the system demonstrates reliable performance and accuracy in translation, transcription, and form generation. This work contributes toward enhancing linguistic inclusivity and accessibility in digital banking systems, particularly for users with limited proficiency in English.

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Sushrutha Shanbhogue (4SF22CS225)
Raghavendra S S (4SF22CS158)
Sowndarya S (4SF22CS218)
Iram A.K Shaikh (4SF23CS404)

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Chapter 1

Introduction

1.1 Overview

In recent years, India has witnessed an extraordinary growth in the financial services sector, marked by the emergence of digital banking infrastructure and widespread usage of mobile and internet-based financial tools. Initiatives such as Digital India, Jan Dhan Yojana, and the Unified Payments Interface (UPI) have played a pivotal role in enabling access to formal banking services for millions of citizens. These initiatives have significantly contributed to the country's vision of financial inclusion, fostering economic development and reducing disparities between urban and rural populations.

1.2 Scope and Motivation

However, despite these commendable efforts, a significant portion of India's population—particularly those residing in rural and semi-rural areas—continues to face substantial challenges in accessing and effectively utilizing digital banking services. These challenges are often rooted in fundamental socio-economic and infrastructural issues. Among the most pressing barriers are low literacy rates, limited digital literacy, poor internet connectivity, and a strong reliance on regional languages and oral communication. While urban users may navigate complex banking applications with ease, rural users frequently find these systems unintuitive, inaccessible, and alienating.

Most traditional banking interfaces are designed with literate, tech-savvy users in mind, often using English or Hindi as the default language. This leaves speakers of regional languages like Kannada, especially when those languages have limited digital representation or lack standard written forms. As a result, many individuals are excluded

from even the most basic banking functions, such as checking account balances, initiating transfers, or applying for loans, simply because they are unable to interact with the system in a language or format they understand.

Chapter 2

Literature Survey

2.0.1 Overview

The development of a voice-based banking assistant for regional languages sits at the intersection of several key domains of research: financial inclusion, conversational AI, speech technology, and multimodal systems. This survey synthesizes relevant work in these fields to contextualize our project's contributions.

A. Financial Inclusion and the Language Barrier

A significant body of research establishes the critical link between financial inclusion and economic development. The Global Findex Database consistently highlights that access to formal financial services is a key driver for poverty reduction and economic growth [18]. However, studies specific to the Indian context reveal that linguistic exclusion acts as a formidable barrier.

As noted by Mathew [19], digital financial services often fail to penetrate rural markets due to a reliance on English or Hindi interfaces, creating a "digital language divide." This forces populations to rely on informal credit systems, perpetuating a cycle of debt and hindering investment in education and agriculture [20]. Our project directly addresses this gap by designing a system that operates entirely in the user's native language, thereby aligning with the goal of true financial democratization.

B. The Evolution of Conversational AI and LLMs

The core intelligence of our avatar agent is built upon the advancements in Large Language Models (LLMs). The transformer architecture, introduced by Vaswani et al. [1], revolutionized natural language processing (NLP) by enabling more effective modeling of long-range dependencies in text. This was followed by the development of powerful pre-trained models like BERT [4] and the GPT series [7, 8], which demonstrated remarkable

language understanding and generation capabilities. A critical innovation for creating useful AI assistants was Reinforcement Learning from Human Feedback (RLHF), as detailed by Ouyang et al. [2], which allows models to be aligned with human intent and follow instructions more reliably. Furthermore, techniques like Chain-of-Thought (CoT) prompting [5] have been shown to enhance the reasoning abilities of LLMs, which is crucial for guiding users through complex procedures like loan applications.

C. Speech Recognition and Synthesis for Low-Resource Languages

For a voice-based system, accurate speech processing is paramount. While early speech recognition systems required extensive labeled data [17], recent self-supervised learning methods have dramatically improved performance, especially for low-resource languages. Models like wav2vec 2.0 [10] and HuBERT [11] learn powerful speech representations from unlabeled audio, which can then be fine-tuned with minimal supervised data. On the synthesis side, end-to-end models like Tacotron 2 [24] have enabled the generation of highly natural and intelligible speech. For our project, the ability to create a custom, relatable voice is essential; research into neural voice cloning [12] demonstrates that generating synthetic speech from just a few samples is now feasible, allowing for the creation of region-specific avatar voices.

D. Digital Avatars and Multimodal Interaction

The final layer of our system involves presenting the AI through an engaging visual interface. Research in real-time neural rendering and audio-driven animation provides the foundation for creating realistic digital humans. Studies like MeshTalk [14] show how 3D facial animation can be driven directly from speech audio while disentangling identity from expression for robustness.

Similarly, work on neural voice puppetry [13] enables the synchronization of a digital avatar's lip movements and expressions with generated speech in real-time.

In conclusion, our project integrates these distinct threads of research—financial inclusion studies, LLMs, speech technology, and avatar animation—into a cohesive, practical application. By leveraging the scalability of cloud AI services [25], we implement a system that is not only technologically advanced but also socially impactful, directly addressing the critical challenge of linguistic exclusion in financial services.

A critical consideration in deploying such AI systems in rural contexts is the robustness of the underlying models when faced with linguistic diversity and noisy environments. Research by Joshi et al. [26] on "How Can We Accelerate Progress Towards Human-Like Linguistic Generalization?" highlights that even state-of-the-art NLP models can strug-

gle with code-switching, dialectal variations, and non-standard grammatical structures common in day-to-day speech. This is particularly relevant for a system targeting Kannada speakers, who may use a mix of Dravidian syntax with loanwords from English, Hindi, or Urdu. Furthermore, speech recognition in real-world settings must contend with background noise, overlapping speech, and low-quality microphones on affordable devices. Studies on noise-robust speech processing, such as those employing data augmentation and deep learning denoising techniques [27], provide essential methodologies for ensuring the system's reliability and accessibility for its intended users.

Finally, the deployment of AI-driven financial assistants necessitates a rigorous examination of ethical and trust-related dimensions. The work of Shneiderman [28] on "Human-Centered AI" emphasizes that for technology to be widely adopted, especially among vulnerable populations, it must be perceived as trustworthy, reliable, and accountable. In the context of financial services, this translates to the system's ability to provide transparent explanations for its queries, handle user data with the highest security standards, and fail gracefully when encountering uncertainty. Research into explainable AI (XAI) for conversational systems [29] is crucial for ensuring that users are not simply following instructions but understand the "why" behind a question, such as why a specific document is required for a loan application. Building this layer of transparency and trust is not an ancillary feature but a foundational requirement for the long-term success and ethical integrity of the project.

2.0.2 Limitations

While existing research in conversational AI, speech recognition, and digital inclusion has advanced significantly, several limitations persist that constrain the deployment of effective voice-based banking systems for regional contexts.

First, **linguistic diversity and data scarcity** remain major challenges. Most state-of-the-art speech and language models, including wav2vec 2.0 and GPT-based systems, are trained predominantly on high-resource languages such as English, Mandarin, and Spanish. Consequently, these models exhibit degraded performance for low-resource languages like Kannada, where annotated datasets and domain-specific corpora are limited. Even with transfer learning and self-supervised approaches, fine-tuning accuracy is often compromised by phonetic and syntactic variations unique to Dravidian languages.

Second, **infrastructure and connectivity constraints** in rural areas limit the

feasibility of deploying cloud-heavy AI systems. Continuous reliance on internet connectivity for inference, especially in regions with intermittent networks, leads to latency and accessibility issues. Although hybrid models combining on-device inference and cloud processing are emerging, their implementation for complex multimodal systems (voice, text, and avatar) is still underexplored.

Third, the **human–AI interaction design** in low-literacy populations introduces unique usability challenges. Most existing interfaces assume a basic level of digital literacy, which may not hold true for rural or first-time users. The lack of culturally contextualized avatars, appropriate voice tone, and localized expressions can negatively affect user trust and engagement.

Fourth, there are **ethical and privacy concerns** related to deploying AI systems in financial contexts. Sensitive user data, including biometric voice signatures and transaction histories, demand robust encryption, secure storage, and transparent governance. However, many prior studies prioritize model accuracy over responsible AI design, resulting in systems that are technically efficient but socially fragile.

Finally, the **evaluation benchmarks** for multimodal voice-based systems are still evolving. Most models are tested under controlled conditions, which fail to reflect real-world acoustic noise, dialectal variation, and unpredictable user behavior. Hence, performance metrics often overstate system reliability when deployed at scale in rural environments.

2.0.3 Research Gaps Identified

From the synthesis of existing literature, several key research gaps can be identified that motivate the present work:

1. **Lack of Region-Specific Voice Banking Systems:** While numerous studies focus on digital inclusion and mobile banking, few systems are designed to handle end-to-end banking interactions through native-language voice input, especially in rural Indian contexts.

2. **Insufficient Support for Low-Resource Languages:** There is limited work on fine-tuning large-scale speech and NLP models for languages like Kannada. Existing multilingual models (e.g., XLSR, Whisper) lack domain adaptation for financial vocabulary and rural speech patterns.

3. **Inadequate Integration of Multimodal Interaction:** Although advances in avatar-based interfaces exist, most implementations are confined to entertainment or customer service. Integrating real-time speech recognition, intent understanding, and avatar feedback in a single cloud-deployed framework remains an open challenge.

4. **Limited Focus on Explainable and Trustworthy AI:** Very few conversational systems in the financial sector incorporate explainable AI (XAI) mechanisms that clarify why specific questions or actions are taken, a crucial factor for trust and adoption among first-time users.

5. **Absence of Context-Aware Error Handling:** Most speech-driven systems fail to manage incomplete, noisy, or ambiguous inputs effectively. Research into adaptive error recovery mechanisms for rural dialects is notably lacking.

6. **Neglect of User-Centric Design for Low-Literacy Populations:** The intersection of AI usability and sociolinguistic factors in rural settings remains underexplored. A user-centered design approach that accounts for cultural and behavioral patterns is missing in most current systems.

These gaps collectively highlight the need for a comprehensive, multilingual, and multimodal framework that not only performs accurate speech and intent processing but also ensures usability, transparency, and trustworthiness for rural financial users.

2.1 Contribution of the Present Work

The present work aims to bridge the aforementioned research gaps by designing and implementing a **Voice-Based Banking System** tailored specifically for rural users in Karnataka. The proposed system contributes to both technological innovation and social empowerment through the following key aspects:

1. **End-to-End Native Language Banking:** The system enables rural users to fill a bank application form in their native language. This removes the linguistic and literacy barriers that hinder adoption of digital financial services.

2. **Integration of Cloud-Based Speech and Language Services:** Leveraging Microsoft Azure Cognitive Services, the system integrates Speech-to-Text, Natural

Language Understanding (NLU), and Translation APIs to process multilingual voice input. The use of a cloud-based infrastructure ensures scalability and efficient handling of real-time interactions.

3. **Modular Multimodal Architecture:** The proposed architecture consists of clearly defined layers—Input, Processing, Data, and Output—interconnected through RESTful APIs. This modularity supports rapid scalability, component-wise testing, and easy integration of additional features like emotion-aware avatars or multilingual expansion.

4. **Humanized Avatar Interface:** A 3D digital avatar, powered by real-time neural rendering and audio-driven animation, provides visual feedback and natural engagement. This human-centric design enhances accessibility and builds user trust, especially among low-literacy populations.

5. **Enhanced Noise Robustness and Context Handling:** The system employs advanced denoising and intent correction mechanisms inspired by recent research in robust speech processing. This ensures reliable performance even in noisy environments and across dialectal variations.

6. **Social and Economic Impact:** Beyond technical innovation, the system contributes to digital financial inclusion by empowering rural communities to access formal banking services autonomously, reducing dependency on intermediaries and promoting economic participation.

In summary, this work presents a unified, cloud-enabled, and socially responsible architecture that operationalizes cutting-edge AI technologies for tangible societal benefit. The system demonstrates that advances in speech recognition, LLMs, and multimodal design can converge to create inclusive, trustworthy, and contextually aware AI assistants capable of transforming rural financial accessibility in India.

Chapter 3

Problem Formulation

3.1 Problem Description

Despite India's remarkable progress in digital banking and financial technologies over the past decade, a significant portion of the rural population continues to face challenges in accessing and utilizing formal banking services. One of the primary causes of this disparity is the language barrier that persists between urban and rural communities. Most banking procedures, forms, and interfaces are designed predominantly for English or Hindi speaking users, leaving many regional language speakers at a considerable disadvantage. This linguistic divide often results in rural users not being aware of essential banking rules, services, and application procedures, ultimately affecting financial inclusion.

3.2 Problem Statement

In states like Karnataka, where Kannada is the primary language of communication, most rural inhabitants are unable to read, write, or comprehend English effectively. Mainstream banking systems, which typically operate in English, do not accommodate this demographic, thus excluding a large segment of potential users from digital financial participation. In addition, many rural individuals lack familiarity with standard banking operations, such as filling out application forms, opening bank accounts, or applying for loans. These challenges create a significant dependency on intermediaries, often leading to delays, miscommunication, and reduced trust in digital systems.

Although voice-based technologies have been introduced in recent years to facilitate easier customer interaction, most existing solutions are limited in functionality and linguistic coverage. Conventional voice assistants typically rely on predefined command

structures and do not provide adequate support for regional languages like Kannada or other lesser documented languages. Consequently, they fail to provide a seamless and intuitive experience for rural users who require end-to-end support in their native language.

3.3 Objectives

- **Design a voice-based user-friendly system** that enables individuals with low or no digital literacy to fill bank application forms and avail banking services in their regional language.
- **To develop an interactive Avatar which assists in filling bank application forms** allowing rural users create bank accounts and avail loans in their regional language itself.
- **To integrate advanced speech recognition and translation technologies**, including **Microsoft Azure services**, for accurate transcription and real-time translation of spoken Kannada into English for automated form generation and processing.

3.4 Functional Requirements

3.4.1 FR 1: Voice Input Handling

The system shall accept real-time voice input in Kannada through the Azure AI Avatar interface. The Avatar shall capture audio using Azure Speech Service and convert it into text for backend processing. This capability enables users to interact with the banking system using their native language without requiring keyboard input or English proficiency. The voice input mechanism shall be optimized for noisy environments and shall provide visual feedback to indicate when the system is actively listening.

3.4.2 FR 2: Speech Recognition

The system shall use Azure Speech-to-Text (within Speech Studio) to accurately transcribe spoken Kannada into machine-readable text. The recognizer shall be configured to handle regional accents and variations typical of Karnataka. The speech recognition

engine shall support continuous speech recognition with real-time processing capabilities. It shall maintain a minimum accuracy rate of 85% for standard Kannada speech and shall automatically adapt to individual user speech patterns over time to improve recognition accuracy.

3.4.3 FR 3: Language Translation

The system shall employ the Azure Translator Service to convert transcribed Kannada text into English. This translation shall be invoked by the Azure Function using REST API calls and used to populate English-based bank forms. The translation component shall preserve the semantic meaning and context of banking-specific terminology. It shall handle common banking terms, numerical values, dates, and addresses with specialized translation rules to ensure accuracy in the generated documents.

3.4.4 FR 4: AI Avatar Interaction

The Azure AI Avatar shall guide the user through form-filling by prompting for required banking fields such as full name, date of birth, address, mobile number, and branch name. The Avatar shall collect each response, validate it, and send the final structured JSON to the backend. The Avatar shall provide a conversational and friendly interface that explains each field requirement in simple terms. It shall offer examples when needed and shall confirm collected information with the user before proceeding to the next field, ensuring data accuracy through interactive validation.

3.4.5 FR 5: User Data Management

The system shall maintain structured user data temporarily during a session in the form of key–value pairs (e.g., `name`, `address`, `dob`). This data shall be forwarded to the Azure Function as a JSON object under the `"fields"` attribute. The data management component shall implement session-based storage that automatically expires after form completion or timeout. It shall support data modification capabilities, allowing users to correct previously entered information before final submission. All temporary data shall be encrypted during transmission and storage.

3.4.6 FR 6: Word Document Generation

The backend Azure Function written in Python shall generate a filled Word document (`.docx`) using the `docxtpl` templating engine. The function shall extract template placeholders, map translated values to placeholders, and generate the filled bank form dynamically. The document generation process shall maintain proper formatting, fonts, and layout as specified in the template. It shall support multiple template types for different banking forms and shall include validation to ensure all mandatory fields are populated before document generation.

3.4.7 FR 7: Secure API Communication

The Azure Function App shall expose a secure HTTP endpoint that accepts POST requests from the Avatar Agent. The endpoint shall receive JSON data, process translation, fill the Word template, and return a binary `.docx` file as an HTTP attachment. The API communication shall implement HTTPS protocol with TLS 1.2 or higher for data encryption in transit. It shall include request validation, authentication tokens, and rate limiting to prevent unauthorized access and abuse. Response times shall be optimized through asynchronous processing where applicable.

3.4.8 FR 8: Error Reporting and Logging

If translation or template rendering fails, the system shall log the error using Azure Function logging and return a meaningful error message to the Avatar, without stopping execution. The error handling mechanism shall categorize errors by severity (critical, warning, informational) and shall provide actionable feedback to users. Detailed error logs shall include timestamps, user session identifiers, input data snapshots, and stack traces for debugging purposes. The system shall implement graceful degradation, attempting alternative processing paths when primary methods fail.

3.4.9 FR 9: Text-to-Speech Output

The Avatar shall convert backend responses into natural-sounding voice output using Azure Text-to-Speech, informing the user about form submission status or errors. The text-to-speech component shall use neural voice models for natural intonation and pronunciation in Kannada. It shall adjust speaking rate and volume based on message

importance and shall support phonetic corrections for banking-specific terms and proper nouns. The system shall provide audio feedback for all user interactions to maintain engagement and accessibility.

3.4.10 FR 10: Web-Based Interaction Interface

Users shall interact with the system entirely through Azure Speech Studio's Speech Playground or integrated Avatar Agent interface, with no need for manual text input or English language proficiency. The web interface shall be responsive and accessible across different screen sizes and devices. It shall provide visual indicators for system status, microphone activity, and processing stages. The interface shall include minimal UI elements to reduce cognitive load and shall support touch-based interactions for mobile devices.

3.5 Non-Functional Requirements

3.5.1 NFR 1: Usability

The system shall be usable by individuals with low digital literacy by relying exclusively on speech-based interaction instead of typing or menu navigation. The user interface shall follow universal design principles with intuitive visual cues and minimal text. It shall provide audio instructions at each step and shall not require users to remember complex commands or navigate through multiple menus. The system shall accommodate users with varying levels of familiarity with technology through progressive disclosure of features and consistent interaction patterns.

3.5.2 NFR 2: Reliability

The Azure Function shall handle network failures, translation errors, and template issues gracefully by returning fallback values or error prompts without system crashes. The system shall maintain a minimum uptime of 99.5% during business hours and shall implement automatic retry mechanisms for transient failures. It shall include circuit breaker patterns to prevent cascade failures and shall provide meaningful fallback responses when external services are unavailable. All critical operations shall be logged for post-incident analysis and continuous improvement.

3.5.3 NFR 3: Scalability

The architecture shall support adding new languages, templates, or additional banking forms with minimal changes, owing to modular placeholder extraction and document templating. The system shall be designed with extensibility in mind, using configuration files and template repositories that can be updated without code modifications. It shall support horizontal scaling to handle increased user load during peak hours. The document generation pipeline shall be capable of processing multiple concurrent requests without performance degradation.

3.5.4 NFR 4: Performance

The full process (speech input → translation → Word file generation → avatar response) shall complete in under 5 seconds for typical inputs, leveraging Azure's serverless execution. The system shall optimize API calls through batching where possible and shall implement caching for frequently accessed data such as translation mappings and template structures. Speech recognition shall provide real-time feedback with latency under 300 milliseconds. Document generation shall be completed within 2 seconds for standard forms containing up to 20 fields.

3.5.5 NFR 5: Security

API keys, translator credentials, and environment variables shall be securely stored in Azure Function App settings and shall not be hardcoded. The function endpoint shall be protected via Function Keys. The system shall implement role-based access control (RBAC) for administrative functions and shall encrypt all sensitive data both at rest and in transit. It shall comply with banking industry security standards and shall undergo regular security audits. User data shall be anonymized in logs and shall not be retained beyond the session duration. The system shall implement input validation to prevent injection attacks and shall sanitize all user inputs before processing.

3.5.6 NFR 6: Maintainability

The codebase shall follow modular design principles, including separate modules for translation, placeholder extraction, context building, and document rendering. Each module shall have well-defined interfaces and single responsibility to facilitate independent test-

ing and updates. The code shall adhere to PEP 8 style guidelines for Python and shall include comprehensive inline documentation. Unit tests shall cover at least 80% of the codebase, and integration tests shall validate end-to-end workflows. Version control and continuous integration pipelines shall be established to streamline deployment and rollback procedures.

3.5.7 NFR 7: Compatibility

The system shall be compatible with major desktop browsers used for Speech Playground (Chrome, Edge, Firefox) and support microphone-based audio capture. It shall gracefully degrade functionality on older browser versions while maintaining core features. The system shall support both Windows and macOS operating systems and shall be tested across different browser versions to ensure consistent behavior. Mobile browser compatibility shall be verified for iOS Safari and Android Chrome, with responsive design adapting to various screen orientations and sizes.

3.5.8 NFR 8: Resilience

When Azure Translator or Speech Services experience downtime or SSL certificate errors, the backend shall return original Kannada text as fallback and log the incident. The system shall implement health check endpoints for monitoring service availability and shall automatically switch to backup services or degraded modes when primary services fail. It shall queue failed translation requests for retry when services are restored and shall notify administrators of prolonged service disruptions. The resilience mechanisms shall be tested through chaos engineering practices to validate failure recovery procedures.

3.5.9 NFR 9: Availability

The system shall be deployed on Azure's serverless environment ensuring high availability and automatic scaling under variable workloads. The deployment shall span multiple availability zones to protect against data center failures and shall implement automated failover mechanisms. Scheduled maintenance windows shall be communicated in advance and shall occur during low-usage periods. The system shall support zero-downtime deployments through blue-green deployment strategies. Monitoring and alerting shall be configured to detect availability issues within 1 minute and trigger automated remediation workflows.

Chapter 4

System Design

4.1 Proposed Project Architecture

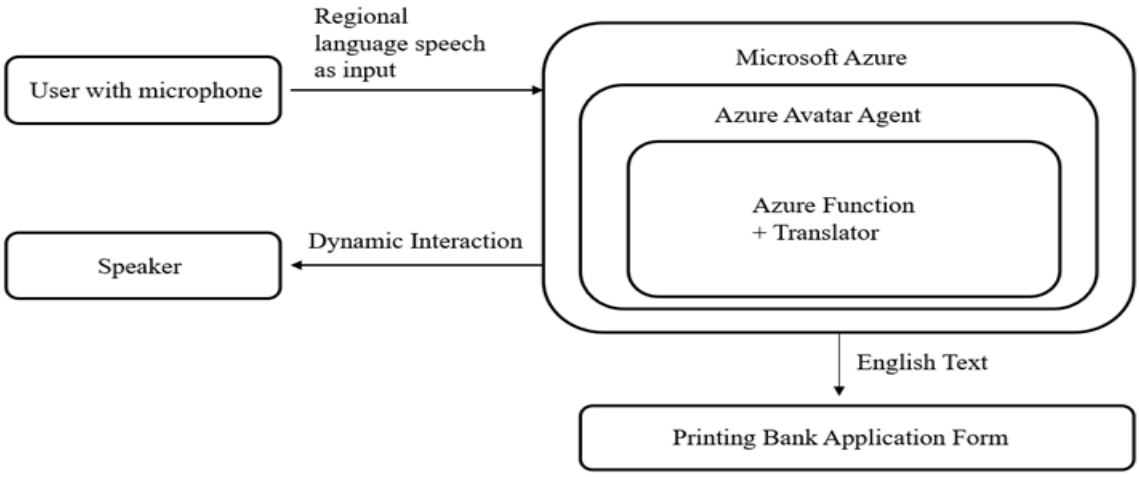


Figure 4.1: High-level system architecture showing components and data flow

This Project Design illustrates a cloud-based conversational AI solution focused on bridging the language barrier for administrative tasks, specifically for a Printing Bank Application Form. The workflow is initiated by the User with microphone, providing regional language speech as input. This input immediately enters the main processing environment, Microsoft Azure, which serves as the robust, scalable cloud platform hosting the entire application. Within Azure resides the Azure Avatar Agent, which acts as the application layer, managing the dialogue state and interaction context. The intelligence of the system is encapsulated within a nested component: an Azure Function + Translator. The Azure Function is a serverless computing unit that orchestrates the workflow, first utilizing Azure's Speech-to-Text capabilities to transcribe the regional language speech, and then feeding that transcription into the Translator service.

This is the critical step where the user's input is reliably and instantly converted into its corresponding English meaning. Throughout this data collection phase, the system ensures a human-like flow via Dynamic Interaction, sending synthesized speech in the regional language back to the Speaker, allowing the system to ask clarifying questions or provide prompts. Once all necessary data has been successfully collected and translated, the final output is the gathered English Text. This text, representing the complete, translated data points (e.g., name, address, required details), is then passed to the final output stage: the automation system responsible for populating and enabling the Printing Bank Application Form, effectively allowing a user to complete an English-only document purely through a regional language conversation.

4.2 High Level Design

4.2.1 Data Flow Diagram

A Data Flow Diagram (DFD) represents how data moves through the system - from data generation to storage.

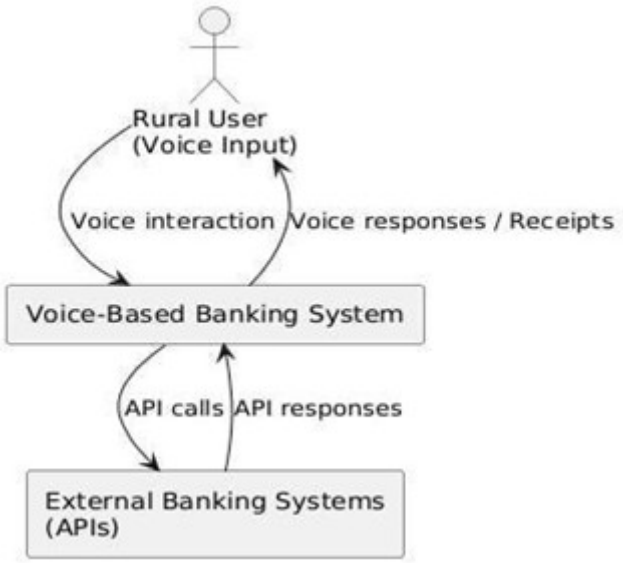


Figure 4.2: Level 0 Data Flow Diagram

1. **Level 0 DFD:** The main external user is the Rural User, who initiates the interaction using Voice Input. The flow of data between the user and the system is bi-directional: the user provides Voice Input and receives Voice interaction (prompts, confirmations) and possibly Voice responses / Receipts from the system, confirming the conversational, language-inclusive nature of the assistant. Below the core

system is the External Banking Systems (APIs), representing the actual back-end infrastructure of the bank that holds user accounts and executes transactions. The interaction between the Voice-Based Banking System and these external systems is entirely technical, consisting of API calls (the system requests data or actions) and API responses (the external systems send back the results of those requests). Essentially, the central system acts as the intelligent, voice-driven middleman, translating the user's spoken intent into digital instructions for the bank's core systems and translating the bank's digital responses back into understandable voice feedback for the user.

1. **Level 1 DFD:** The voice-based banking process begins with the Rural User providing Voice Input, which is immediately transmitted as a Voice call to 1.0 Voice Input Processing. This initial step handles the raw audio transmission before forwarding the resulting Audio stream to 2.0 Speech Recognition (Azure Speech Services). This second critical process, leveraging cloud services, converts the spoken audio into Transcribed text. The transcribed text then flows into the "brain" of the system: 3.0 Banking Logic (Azure Functions). This stage, hosted as serverless functions, interprets the user's intent from the text and orchestrates the necessary actions. The Banking Logic interacts with two main external components: it sends Query / Update requests to 4.0 Data Storage (Azure SQL DB) to manage user data, and it executes API calls to 5.0 External Banking APIs to perform actual transactions like transfers or account inquiries. Finally, if the user requested a record or a transaction was completed, the Banking Logic sends a command to 6.0 Printing Output (Receipt / Statement) to Print receipts/statements. This printed output is then delivered back to the Rural User, completing the cycle with a tangible Printed receipt/statement.

3. **Level 2 DFD:** The 3.0 Banking Logic (Azure Functions) acts as the central router and control mechanism, directing the user's request to one of four specialized subprocesses. All critical operations, regardless of type, first rely on 3.1 Validate User Identity, which sends a "Fetch user info" query to the Banking Data (Azure SQL DB) to ensure the user is who they claim to be. If the request is a money movement or inquiry, it goes to 3.2 Process Transaction Request, which executes the necessary action by making "Call transaction APIs" to the External Banking APIs (the bank's core system). If the user is simply changing their phone number or address, the

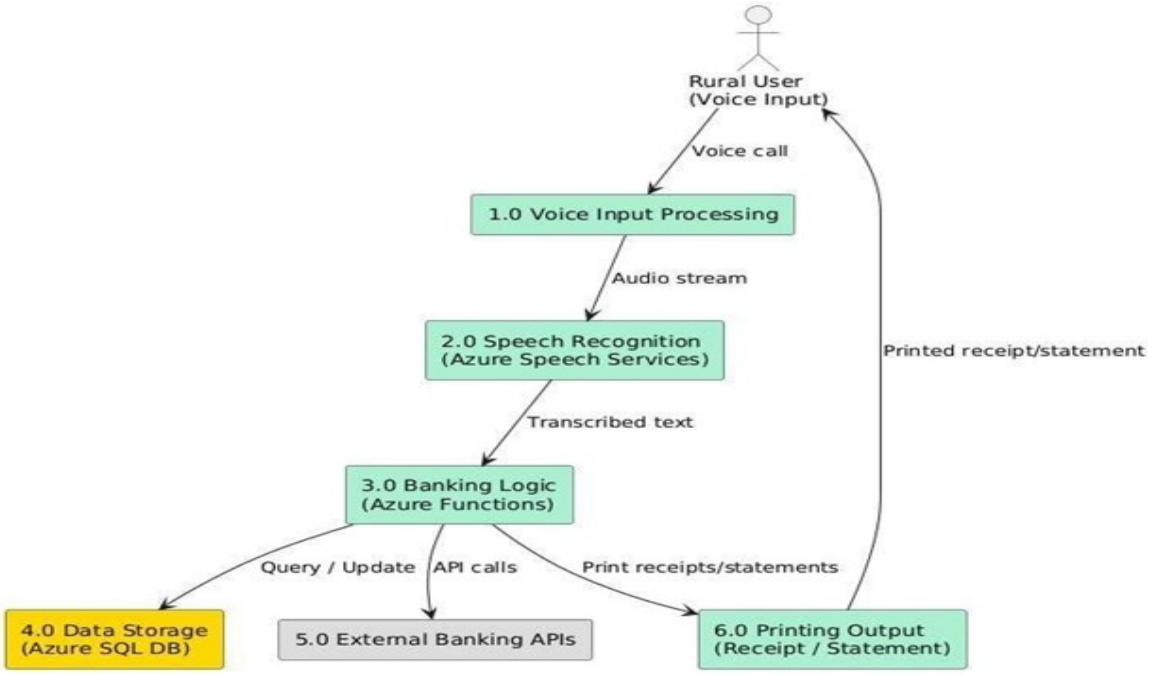


Figure 4.3: Level 1 Data Flow Diagram

request is handled by 3.3 Update Account Information, which executes an "Update account data" command directly to the Banking Data (Azure SQL DB). Finally, after any of these processes are complete, the system proceeds to 3.4 Generate Response, which takes the resulting data or confirmation and either prepares the required statement or receipt for the Printing Output (Receipt / Statement) or sends a voice response back to the user, effectively closing the loop on the user's spoken request.

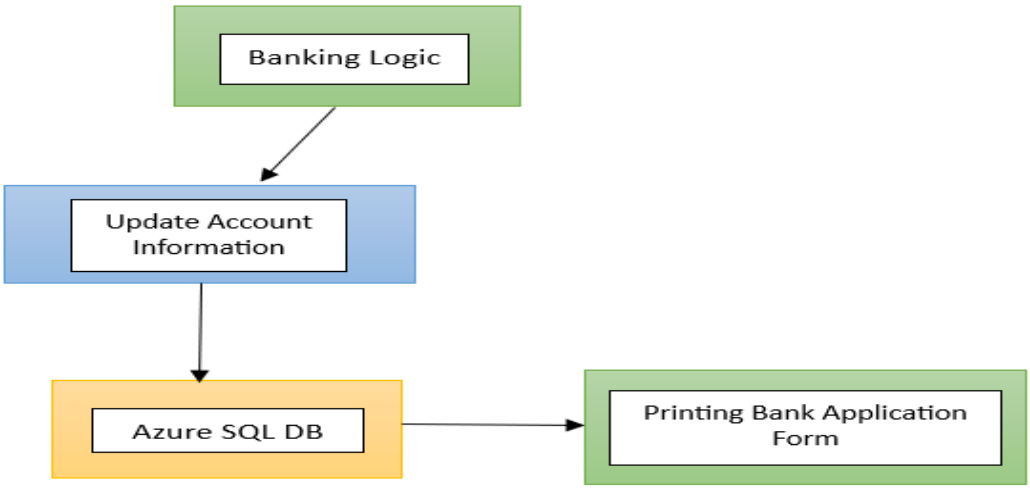


Figure 4.4: Level 2 Data Flow Diagram

4.3 Detailed Design

4.3.1 Use-Case Diagram

1. **Overview of the Use Case Diagram:** The use-case diagram provides a high-level functional view of the Voice-Based Banking System, representing the interaction between users and the system. It identifies the main actors, their goals, and the associated use cases that describe how the system responds to user actions. In this context, the primary actor is the **Rural User**, who interacts with the system using voice commands in their local language (e.g., Kannada). The system processes these voice inputs through a series of use cases such as speech recognition, translation, intent identification, transaction processing, and document generation. The diagram serves as an abstraction of the system's functionality, illustrating how external entities trigger system operations through voice-based communication. It emphasizes inclusivity and accessibility, enabling banking operations through speech for users with limited literacy or digital experience.

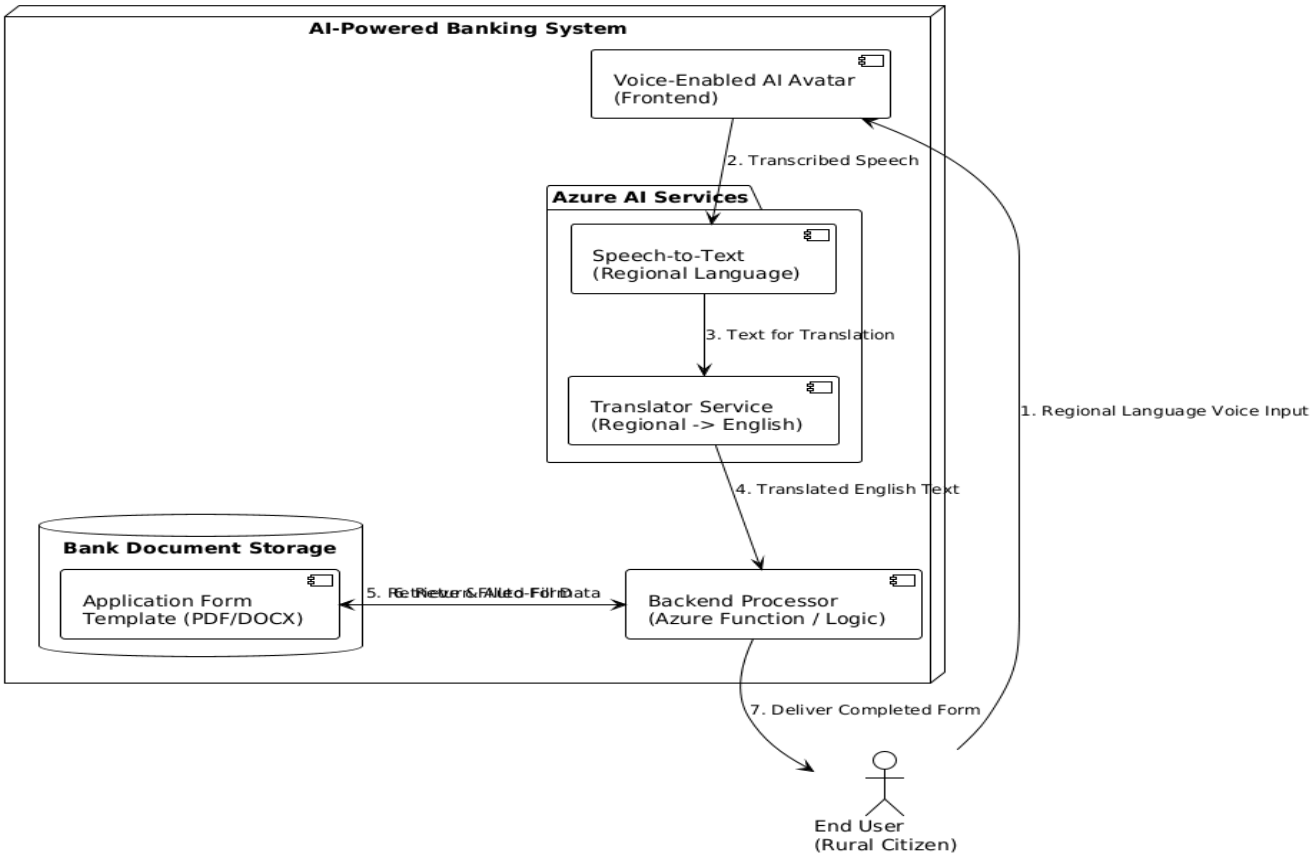


Figure 4.5: Use Case Diagram

2. **Use Case Diagram for the Project:** The use-case diagram for the Voice-Based

Banking System demonstrates how various functional modules collaborate to deliver voice-driven banking services. The system comprises four major layers: Input, Processing, Data, and Output, all working cohesively to ensure a seamless user experience. The **Input Layer** enables the user to provide voice input through mobile devices or IVR systems. The **Processing Layer**, hosted on Azure Cloud, employs services like Speech-to-Text conversion, Natural Language Processing (NLP), and Translation to interpret and process the user's spoken requests. The **Banking Logic Module** then manages key operations, such as user authentication, transaction initiation, and form generation, through internal functions or API calls to existing banking systems. The **Data Layer** manages the storage of user information, transaction logs, and system-generated files using Azure SQL Database and Blob Storage. Finally, the **Output Layer** handles the response delivery, which may include a voice confirmation, printed document, SMS alert, or callback. The Rural User interacts with the system throughout this process, providing voice inputs and receiving corresponding audio or printed outputs in their local language. This design ensures that every stage—from input to output—is optimized for simplicity, automation, and accessibility.

3. **Workflow of the System:** The workflow of the proposed system, as illustrated in the use-case diagram, follows a structured and modular flow between its core functional layers. The process can be described as follows:

   (a) **Voice Input:** The user initiates interaction by providing a voice command (e.g., "Check my balance" or "Open an account") in their regional language via mobile or IVR.

   (b) **Speech Processing:** The captured audio stream is transmitted to the Azure Speech Service, which converts the speech into text.

   (c) **Language Translation and NLP:** The transcribed text is processed by Azure Cognitive Services for translation into English and intent recognition, identifying the specific banking operation requested.

   (d) **Request Handling:** The interpreted intent is passed to the Banking Logic module, which determines the appropriate backend action, such as fetching user data or generating a transaction form.

   (e) **Data Access and Processing:** The system retrieves or updates the necessary information from the Data Layer (Azure SQL Database or Blob Storage).

(f) **Response Generation:** Based on the operation performed, the Output Layer generates the required feedback, which can be in the form of an audio response, printed receipt, or digital document.

(g) **Voice Response Delivery:** The final output is converted to the user's preferred language and played back as a voice message, completing the interaction loop.

This workflow ensures a fully automated and language-inclusive banking process, minimizing the need for manual intervention while enhancing usability for rural and non-digital users.

4. **Advantages of the Use Case Diagram:** The use-case diagram provides several critical advantages in the design and development of the Voice-Based Banking System:

   (a) **Simplified Functional Representation:** It offers a clear and concise visualization of the system's key functionalities and user interactions.

   (b) **Improved Stakeholder Communication:** The diagram bridges the gap between technical designers and non-technical stakeholders, enabling shared understanding of system requirements.

   (c) **Identification of Core System Requirements:** It helps in capturing essential use cases early in the design process, ensuring that all functional needs are addressed.

   (d) **Support for Modular Development:** The decomposition of system functionalities into discrete use cases facilitates parallel development and easier debugging.

   (e) **Enhanced User-Centric Design:** By focusing on user interaction, the diagram ensures that the system is intuitive and aligned with user expectations, especially for rural and semi-literate users.

   (f) **Ease of Maintenance and Scalability:** Each use case represents an independent functionality that can be modified or extended without disrupting other components.

   (g) **Effective Documentation:** The diagram serves as a visual documentation tool for system functionality, aiding future developers and testers.

Overall, the use-case diagram establishes a solid foundation for understanding, designing, and implementing the voice-based banking system by effectively representing both the functional scope and the interaction flow of the application.

4.3.2 Class Diagram

1. **Overview of Class Diagram:** The class diagram provides a structural representation of the Voice-Based Banking System, detailing the system's components, their attributes, and the relationships between them. It focuses on how different classes collaborate to enable voice-based banking operations, from speech processing to document generation. This diagram serves as a blueprint for the system's object-oriented design, ensuring that each class has a clear and defined responsibility. The overall structure is hierarchical, with the **MainController** managing communication among subordinate classes such as **VoiceBankingSystem**, **VoiceInterface**, **AzureSpeechRecognition**, **RequestProcessor**, **BankAPI**, **DocumentGenerator**, **BankingForm**, and **UserProfile**. The **VoiceInterface** class manages user interaction by capturing voice input and delivering audio responses. The **AzureSpeechRecognition** class handles speech-to-text conversion and translation using Azure Cognitive Services. The **RequestProcessor** interprets the transcribed data, detects user intent, and coordinates appropriate backend operations. The **DocumentGenerator** and **BankAPI** work together to process banking forms, execute transactions, and generate outputs. Finally, the **UserProfile** and **BankingForm** classes manage user-specific and form-related data respectively. This design promotes modularity, scalability, and clear data flow across system components, making it easier to integrate, maintain, and extend functionalities in the future.

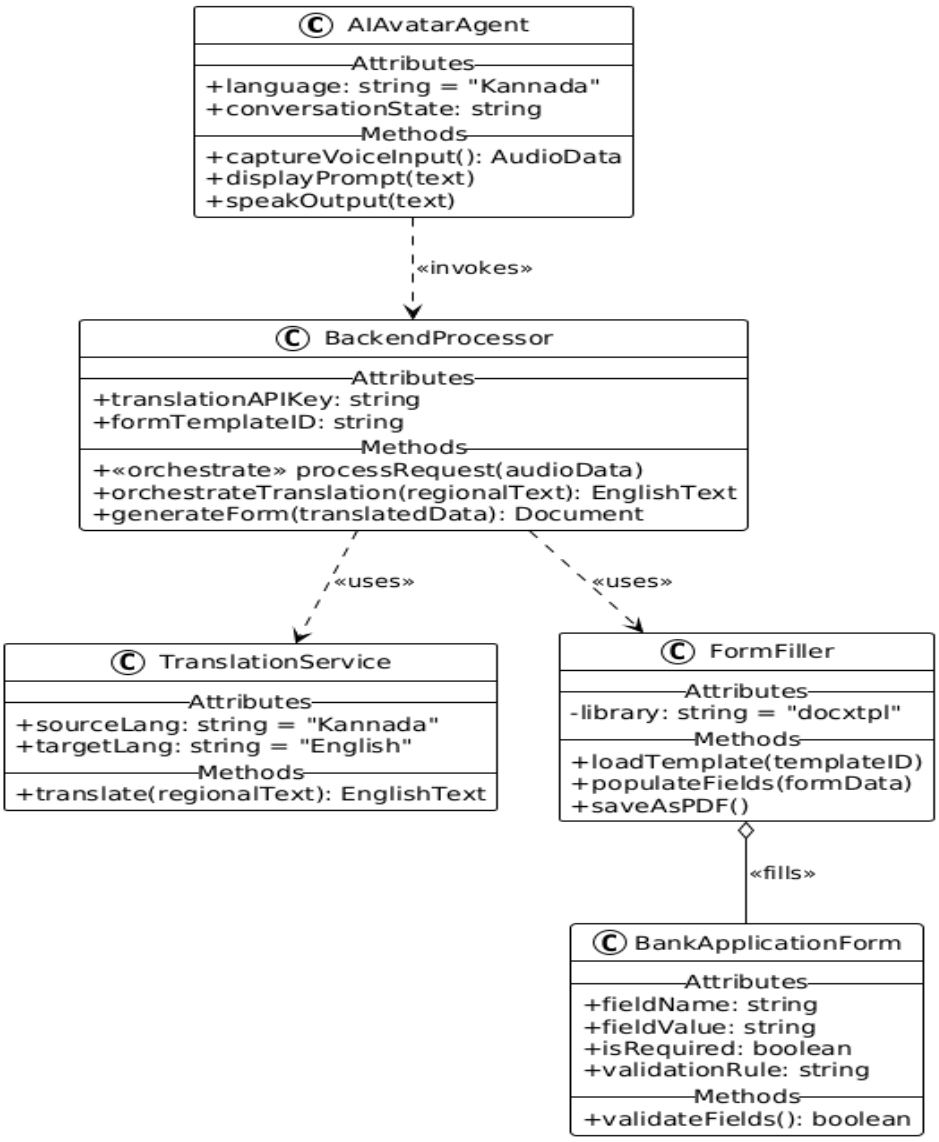


Figure 4.6: Class diagram of system components and relationships

2. **Class Diagram for the Project:** The class diagram for the proposed Voice-Based Banking System illustrates the interconnection between functional modules responsible for enabling a natural, voice-driven banking experience. At the top of the hierarchy, the **MainController** orchestrates all modules, handling the workflow and maintaining session states. It coordinates the **VoiceBankingSystem** class, which encapsulates the overall application configuration such as system name, supported languages, and initialization routines. The **VoiceInterface** class interacts directly with the user, capturing their audio input through the `captureVoice()` method and returning the spoken response using `playResponse()`. The **AzureSpeechRecognition** class, dependent on Azure Cognitive Services, implements methods like `speechToText()` and `translate()` to convert Kannada input into

English text, bridging linguistic differences seamlessly. The **RequestProcessor** acts as the system's decision engine, performing intent detection (`detectIntent()`) and entity extraction (`extractEntities()`) to interpret the user's goal. It connects with the **BankAPI** class to execute backend operations such as form submission, account verification, and data retrieval. The **UserProfile** class maintains essential user information—such as user ID, preferred language, and transaction history—ensuring a personalized and secure experience. The **BankingForm** class stores the structure and metadata of bank documents, including template paths and field mappings. The **DocumentGenerator** then leverages this information through `generateFormTemplate()` and `exportPDF()` methods to create and store completed banking forms. Together, these classes form an integrated system where the control, data, and response flow are logically defined, facilitating efficient processing and modular software design.

3. **Workflow of the System:** The system workflow, as depicted in the class diagram, outlines the logical flow of control among various modules from user interaction to document generation. The steps are as follows:

   (a) The **MainController** initiates the session and manages communication between all system modules.

   (b) The **VoiceInterface** captures the user's voice input and sends the recorded audio stream to the **AzureSpeechRecognition** module.

   (c) The **AzureSpeechRecognition** class performs speech-to-text conversion and language translation, producing structured textual input in English.

   (d) The translated text is then sent to the **RequestProcessor**, which identifies the user's intent and extracts required entities (e.g., name, account type, date of birth).

   (e) Based on the detected intent, the **RequestProcessor** either fetches user information from the **UserProfile** or interacts with the **BankAPI** to process backend banking operations.

   (f) Once the required details are gathered, the **DocumentGenerator** uses the **BankingForm** template to generate a filled PDF form or transaction record.

   (g) The final document or response is transmitted back to the user via the **VoiceInterface**, completing the interaction cycle.

This workflow ensures that each module operates independently but contributes to a cohesive and automated process flow. The design enhances modularity, fault isolation, and scalability of the entire system.

4. **Advantages of the Class Diagram:** The class diagram offers several significant advantages in understanding, designing, and implementing the Voice-Based Banking System:

   (a) **Clear Structural Representation:** It provides a detailed visualization of classes, their properties, and relationships, offering a comprehensive view of the system's architecture.

   (b) **Encapsulation and Modularity:** By defining separate classes for each functional component, the design promotes encapsulation and modularity, simplifying code maintenance and scalability.

   (c) **Improved Reusability:** Common functionalities, such as speech processing or document generation, are encapsulated within reusable classes, enabling integration into other systems or future upgrades.

   (d) **Ease of Debugging and Testing:** The explicit separation of concerns between modules allows for independent testing and easier identification of faults or bottlenecks.

   (e) **Enhanced Extensibility:** The structure supports the addition of new features—such as multilingual support or additional banking services—without affecting existing components.

   (f) **Efficient Data Flow Management:** The relationships between control, data, and interface classes ensure seamless information flow from voice input to output generation.

   (g) **Alignment with Object-Oriented Principles:** The design adheres to object-oriented concepts such as abstraction, inheritance, and composition, providing a strong foundation for scalable software engineering.

   Overall, the class diagram plays a crucial role in defining the logical and structural organization of the system. It guides both development and future enhancements, ensuring that the system remains robust, maintainable, and adaptable to evolving technological and user needs.

4.3.3 Sequence Diagram

1. **Overview:** The sequence diagram represents the dynamic behavior of the Voice-Based Banking System by illustrating how different system components interact over time to complete a specific task. It focuses on the message flow between objects and modules in a time-ordered sequence. Each lifeline corresponds to a core module of the system, such as the Voice Interface, Azure AI, Request Processor, Document Generator, Bank API, and User Database. The diagram effectively models the communication sequence during the account opening process initiated by a rural user. It captures how the system processes voice inputs, performs natural language translation, validates user information, generates bank documents, and provides feedback to the user. This visualization allows designers and developers to understand the exact control and data flow across various system components, supporting modular implementation and testing of the interaction logic.

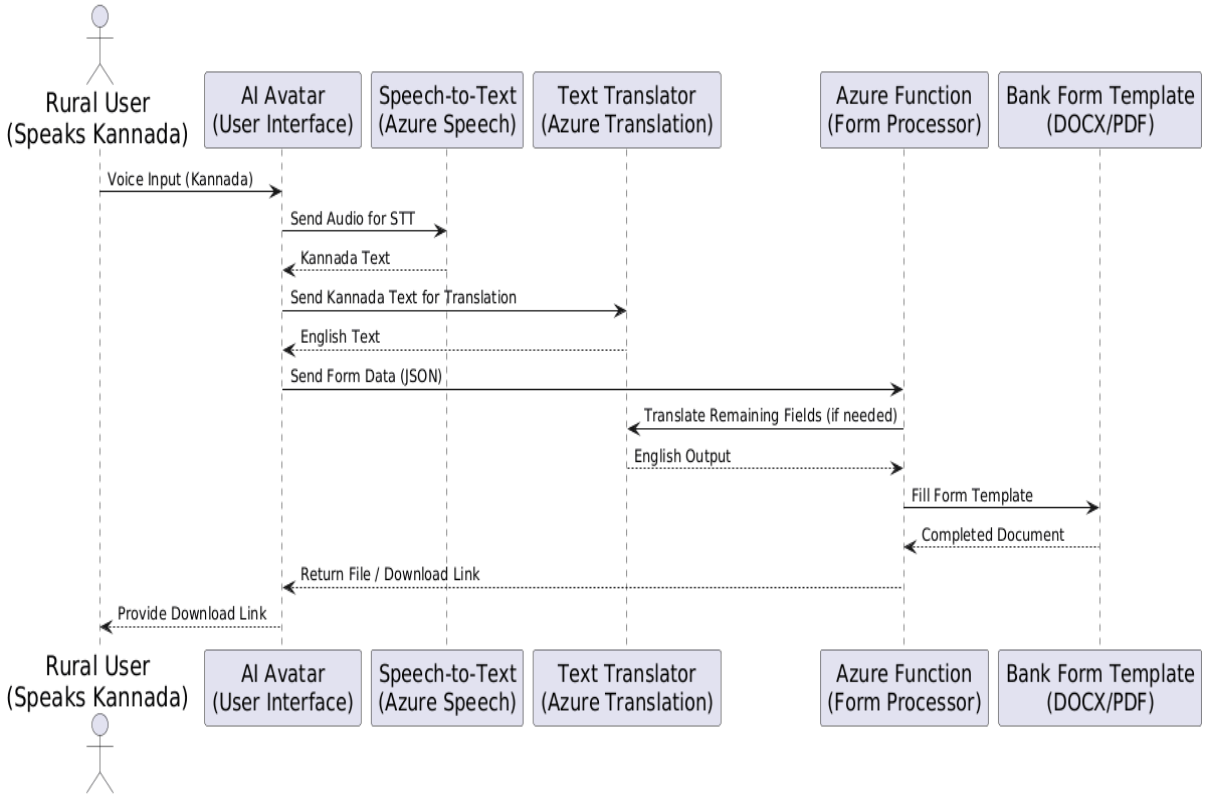


Figure 4.7: Sequence diagram of key system interactions

2. **Sequence Diagram for the Project:** The sequence diagram illustrates the real-time interaction among the major modules of the proposed Voice-Based Banking System during an account opening operation. The process begins when the Rural

User initiates a request in Kannada, such as *"I want to open an account"*, which is captured by the **Voice Interface**. The interface records the spoken input as an audio stream and forwards it to **Azure AI** for further processing. **Azure AI** performs the *Speech-to-Text* conversion on the input audio to obtain the transcribed Kannada text. It then performs a *machine translation* operation to convert the transcribed text into English. The translated text, which represents the user's intent, is sent to the **Request Processor**. The **Request Processor** attempts to retrieve the corresponding user profile from the **User Database**. If no existing record is found, an alternate path is followed where the system identifies the user as new and triggers a new interaction flow. The processor commands the **Voice Interface** to play a voice prompt in Kannada, asking the user to provide their details. The user responds with the required details through speech, which are again captured by the Voice Interface and processed by Azure AI for transcription and translation. The Request Processor then utilizes this translated data to create a new user profile, which is stored in the **User Database**, generating a unique user identifier. Once the user profile is successfully created, the Request Processor communicates with the **Document Generator** to initiate the generation of the account form. The Document Generator fetches the appropriate template from the **Bank API**, fills in the collected data, and produces a filled PDF form representing the completed account application. Finally, a confirmation message, *"Account application ready"*, is sent from the Request Processor to the Voice Interface, which then plays the corresponding Kannada confirmation message to the user. This concludes the end-to-end workflow of the voice-enabled account opening process. This sequence diagram emphasizes the seamless coordination between components, showcasing the integration of natural language processing, voice interaction, and backend database management to provide a fully automated and user-friendly banking experience.

3. **Workflow of the System:** The workflow of the Voice-Based Banking System, as represented in the sequence diagram, involves a series of well-defined interactions between user-facing and backend components. The following steps summarize the end-to-end operational flow:

   (a) **User Interaction:** The rural user initiates communication by issuing a voice command in Kannada to request an account opening.

   (b) **Speech Processing:** The Voice Interface captures the audio stream and sends

it to Azure AI, where Speech-to-Text conversion and language translation are performed.

(c) **Intent Recognition:** The translated text, representing the user's intent, is analyzed by the Request Processor to determine the required banking service.

(d) **Profile Verification:** The Request Processor queries the User Database to verify if the user already exists. If not, a new user path is triggered.

(e) **Data Acquisition:** The user is prompted to provide personal details via speech, which are again processed by Azure AI and structured by the Request Processor.

(f) **Profile Creation:** The system creates and stores a new user profile in the database, assigning a unique user ID.

(g) **Document Generation:** The Request Processor instructs the Document Generator to create an account form using the Bank API's predefined template.

(h) **Output and Confirmation:** The Document Generator returns the filled PDF form, and the user receives a final confirmation message in Kannada, completing the process.

This workflow illustrates the integration of voice-based input, intelligent processing through Azure services, and document automation, achieving accessibility and operational efficiency in rural banking contexts.

4. **Advantages of the Sequence Diagram:** The sequence diagram provides several technical and analytical benefits to the overall system design:

(a) **Clear Visualization of System Behavior:** It depicts the time-ordered communication among various modules, enhancing the understanding of real-time data flow and control mechanisms.

(b) **Identification of Dependencies:** It helps in recognizing inter-module dependencies, which is essential for modular development and testing.

(c) **Support for System Design and Integration:** The diagram acts as a blueprint for developers during implementation, ensuring consistent integration among components.

(d) **Enhanced Communication:** It serves as a standardized visual documentation tool, allowing both developers and stakeholders to interpret the system's

logic uniformly.

(e) **Validation of Workflow Logic:** By representing alternate and exceptional paths, it assists in identifying potential issues or logical flaws early in the design phase.

(f) **Basis for Testing and Verification:** The defined sequence of messages aids in generating functional test cases, ensuring the reliability of inter-component interactions.

(g) **Improved Maintainability:** The diagram's structured flow assists in maintaining and upgrading individual components without affecting the overall system operation.

Hence, the sequence diagram plays a vital role in modeling, analyzing, and validating the interactive behavior of the Voice-Based Banking System, ensuring that both the architectural and functional aspects are cohesively represented and efficiently implemented.

4.4 Tools and Technologies used for Implementation

The implementation combines Microsoft Azure cloud services with a Python-based serverless backend and document templating libraries. The description below maps the chosen tools directly to the components and code present in the Azure Function implementation (`function_app.py`).

4.4.1 Cloud Services - Microsoft Azure

- **Azure Speech Service / Azure AI Avatar (Speech Studio)**: Captures user audio (Kannada) and performs real-time speech-to-text and text-to-speech for an interactive conversational front end. The Avatar collects user fields and forwards structured JSON to the backend function.

- **Azure Translator Service**: Used to translate Kannada text to English. In the function code the translation service is called via HTTP using subscription key, region and endpoint environment variables (see `TRANSLATOR_KEY`, `TRANSLATOR_REGION`, `TRANSLATOR_ENDPOINT`). The translator is invoked with the API-version and target language parameters.

- **Azure Functions (HTTP-triggered)**: Hosts the Python serverless backend. The function is triggered via an HTTP POST from the Avatar agent and returns the filled `.docx` file as an attachment in the HTTP response.
- **Azure Document Intelligence**: Can be integrated for advanced document extraction/validation, or to align extracted fields with template placeholders when templates are complex.
- **Azure Portal**: Resource creation, configuration and observability (Application Insights, function logs and metrics) are handled through the Azure Portal.

4.4.2 Development Environment and Deployment

- **Visual Studio Code (VSCode)** with `Azure Functions` and `Python` extensions: used for local development, debugging and deployment of the function app to Azure.
- **Postman / curl**: Used to perform local and remote HTTP testing of the function endpoint by POSTing JSON payloads and saving the returned `.docx` response.
- **Azure Functions Core Tools**: For running and testing the function locally (e.g., `func start`).

4.4.3 Programming Language and Runtime

- **Python (Azure Functions Python runtime)**: Implements the serverless backend logic. The entrypoint function in code is fill_word_main(req: func.HttpRequest)-¿func.HttpResponse.
- **azure.functions** SDK: Provides the typed `HttpRequest` and `HttpResponse` classes used by the function signature and for returning the filled document.

4.4.4 Key Python Libraries and Their Roles

- **docxtpl**: Primary templating engine used to populate Word document templates (`Canara_Bank_Template.docx`) with translated values. The template uses Jinja-like placeholders such as {{ `name` }} which `docxtpl` replaces with context values.
- **python-docx (docx.Document)**: Used to parse the template for placeholder discovery (scanning paragraphs and table cells). This is used by extract_placeholders() to enumerate required fields before rendering.

- **requests**: Performs HTTP calls to the Azure Translator endpoint. The implementation supports custom TLS options via TRANSLATOR CA BUNDLE and TRANSLATOR SKIP SSL VERIFY.
- **tempfile / os / logging / re / json / typing**: Standard library modules used for secure temporary file handling, environment variable access, structured logging, placeholder regular expressions and type annotations.

4.4.5 Template and Placeholder Strategy

- **Placeholder format:** Templates use placeholders of the form {{ `field_name` }}. A compiled regular expression locates these tokens in both paragraphs and table cells.
- **Placeholder discovery:** The function extracts all placeholder names from the template before rendering (via `extract_placeholders()`) and then builds a context dictionary mapping each placeholder to its translated value (via `build_context()`).
- **Templating flow:** `doc.render(context)` fills the placeholders, and the rendered document is saved to a temporary file and returned as bytes in the HTTP response.

4.4.6 Translation and Networking Considerations

- **Translation call**: The function performs a POST request to the Translator endpoint with the request body `[ { "text": "<kannada_text>" } ]` and query parameters such as `api-version=3.0` and `to=en`. The handler returns the translated text or falls back to the original if translation fails.
- **TLS / proxy / CA handling**: The code respects environment variables:
  - `TRANSLATOR_CA_BUNDLE`: path to a PEM file used as `requests.post(..., verify=TRANSLATOR_CA_BUNDLE)` when custom CAs are required.
  - `TRANSLATOR_SKIP_SSL_VERIFY`: boolean flag to disable SSL verification in constrained environments (not recommended for production).
- **Robustness**: Translation errors and SSL exceptions are caught and logged; on failure the system falls back to the original Kannada text to avoid disrupting the form-fill flow.

4.4.7 I/O and Response

- **Input contract**: The function expects a JSON payload with a top-level `"fields"` object mapping placeholder names to Kannada text:
- **Output**: The function returns a document response with a `Content-Disposition` header to force download (attachment filename: `filled_canara_bank.docx`).
- **Temporary files**: Rendered files are saved to a secure temporary file (via tempfile.NamedTemporaryFile) and cleaned up after reading to minimize disk persistence.

4.4.8 Testing, Logging and Observability

- **Local testing**: Using `func start` and Postman to POST field payloads and validate the returned `.docx` file.
- **Logging**: The function uses Python `logging` to record placeholder discovery, rendering status, and errors. These logs flow to Azure Function logs / Application Insights when deployed.
- **Error handling**: The function returns explicit HTTP error codes (400 for malformed requests, 500 for processing errors) to help debugging and client-side error handling in the Avatar agent.

4.4.9 Extensibility and Future Enhancements

- **Localization**: Add more target languages or locale-specific date/number formatting during context preparation.
- **Authentication and auditing**: Add authentication (managed identities, AAD), request auditing, and rate-limiting to harden production deployments.

Chapter 5

Implementation

5.1 Creation of Azure Speech Service

The first step of the project is to set up the Azure Speech Service, which provides the ability to capture user voice input and convert it into text. This service is essential because it allows the system to understand Kannada speech from users and process it further. In the Azure Portal, a new Speech resource is created after the service name, region, and pricing tier are selected.

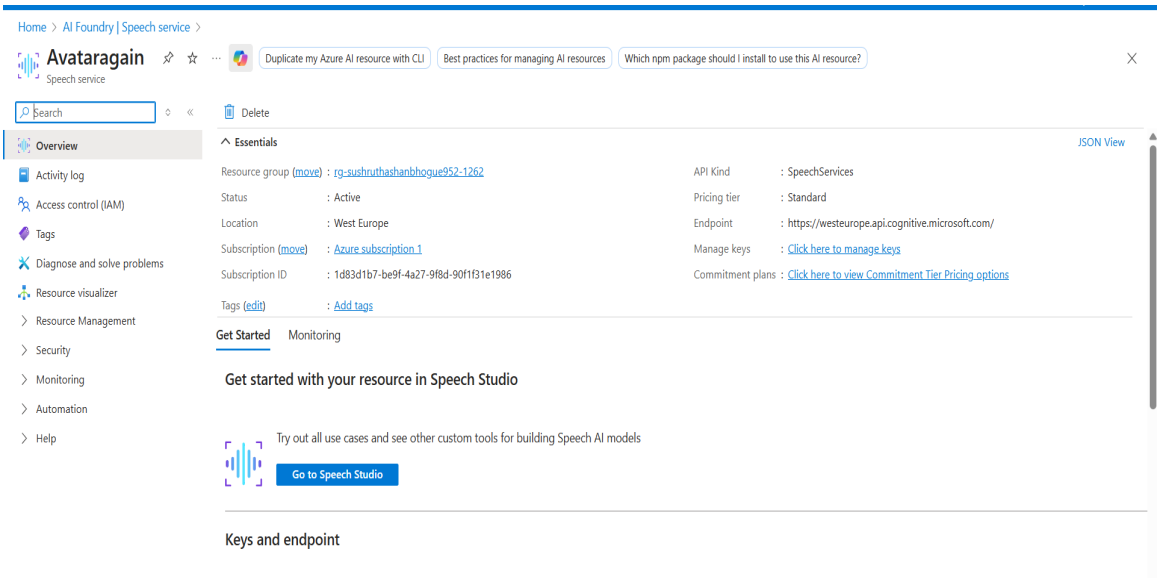


Figure 5.1: Azure Speech Services

After deployment, the API keys and endpoint URLs are saved, as they will be needed later for integrating with Speech Studio and other parts of the system.

5.2 Configuration of Speech Studio and AI Avatar

After setting up the Speech Service, Speech Studio is used to create an AI Avatar, which acts as the interactive interface for the user. The avatar is configured with a specific voice, language capabilities, and scenario settings to capture Kannada speech accurately. It allows users to talk naturally, while the avatar transcribes their speech into text.

This step ensures that the system can handle real-time conversations and provide immediate responses, making the interaction smooth and user-friendly. The avatar is also configured to guide the user through the process of providing necessary details like full name, date of birth, and address.

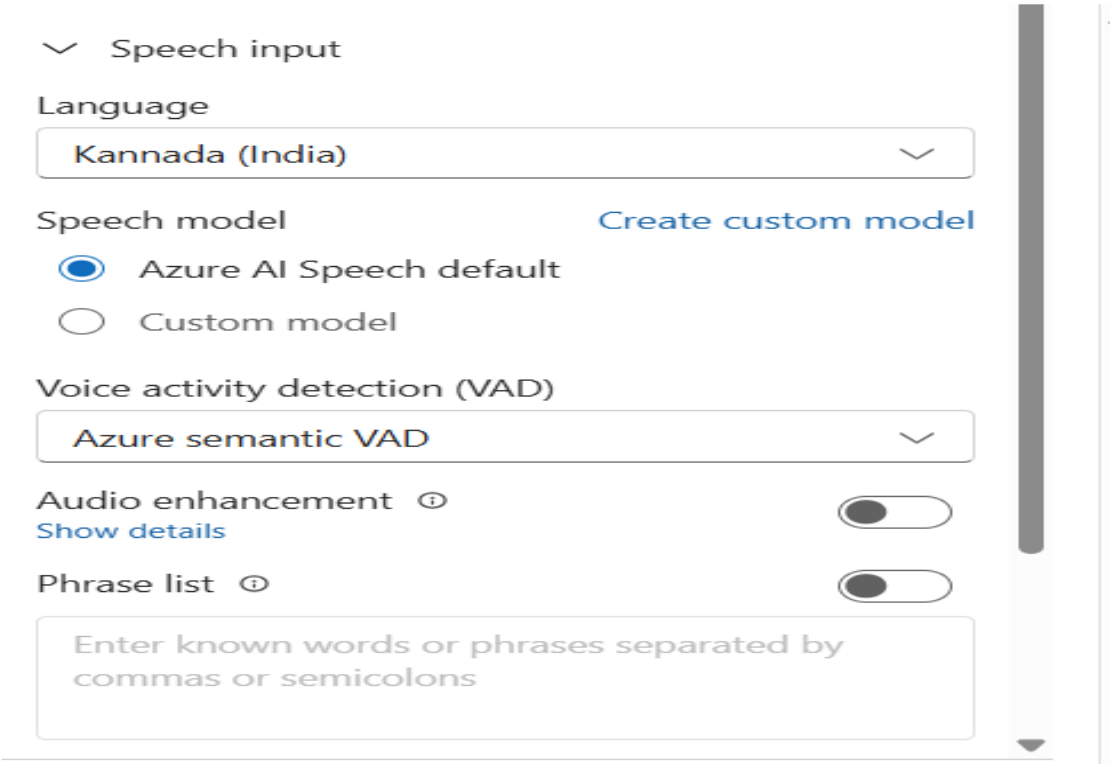


Figure 5.2: Avatar speech and language configurations

5.3 Deployment of Azure Translator Service

Since most bank forms are in English or Hindi it is necessary to translate Kannada input into English. This is done using the Azure Translator Service, which is deployed from the Azure Portal. The translator is configured with a service name, region, and pricing tier, and the API key and endpoint are saved for later use in the backend function.

The translator ensures that the Kannada text captured by the avatar can be converted accurately into English, which is required for filling the bank form correctly.

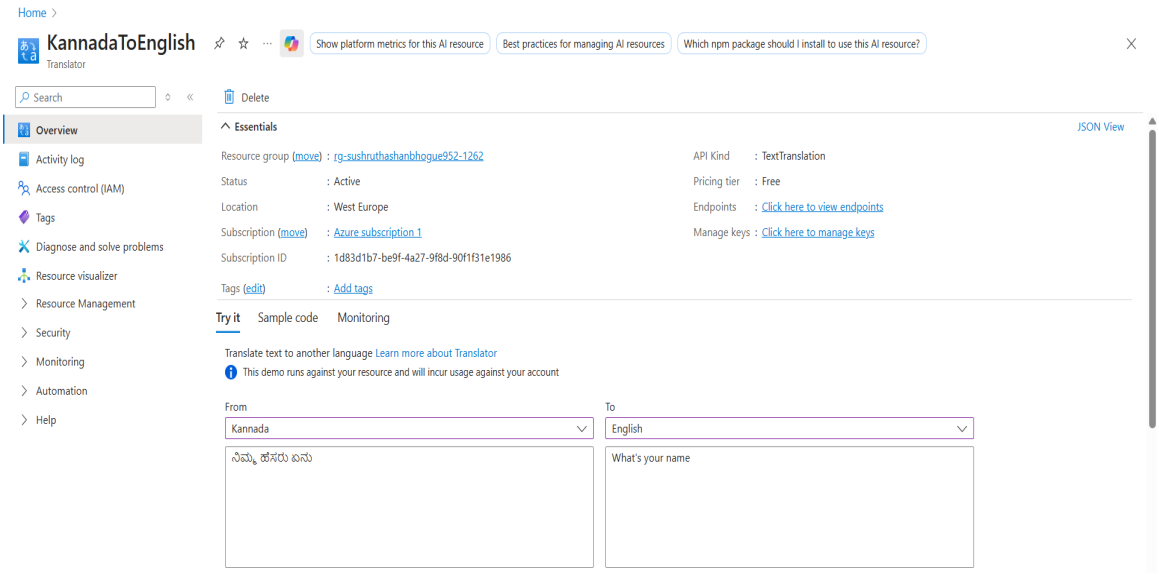


Figure 5.3: Azure Translator Service

5.4 Development of Azure Function

The backend processing of the project is handled by an Azure Function, developed in Python using VSCode. The function is designed to accept JSON input containing user details such as full name, date of birth, and address in Kannada. The function then calls the Azure Translator API to convert the Kannada text into English. Using Azure Document Intelligencealong with docxtpl python library, the translated text is overlaid onto the correct fields of a bank application form.

The function returns a HTTP POST request which can be utilized for local testing using Postman API.

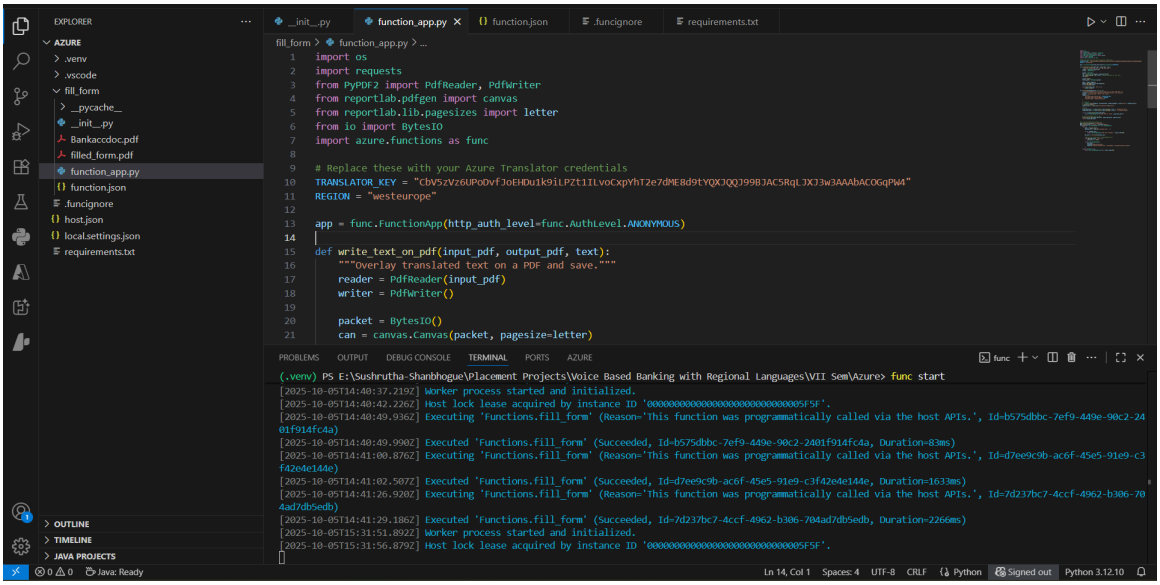


Figure 5.4: Python azure function implementation using VSCode

5.5 Local Testing of the Azure Function

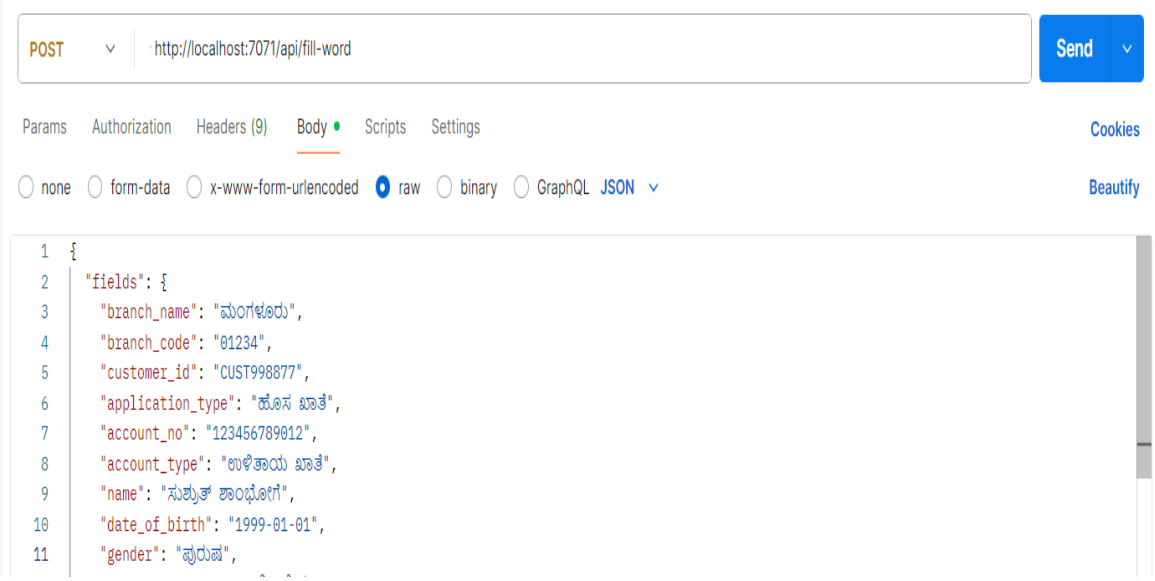


Figure 5.5: Local Testing of Azure Function

Before deploying the Azure Function to the cloud, it is tested locally to make sure it works correctly. The function is run using the func start command in VSCode, and tools such as Postman or curl are used to send test JSON requests with Kannada text, as shown in Figure 7. Postman returns the filled word document in raw file format, which is then saved as a file and viewed in Microsoft Word to check and confirm that the translation is correct and that the text appears in the right positions on the form. Local testing allows for identification and correction of any issues related to translation or data formatting before moving to deployment.

5.6 Deployment of Azure Function

Once the function has been successfully tested locally, it is deployed to Azure using the VSCode Azure Functions extension. The deployment creates a secure URL endpoint that can be accessed by the AI Avatar or other clients. The endpoint is protected with a Function Key to ensure that only authorized users or applications can access the function.

Deployment makes the function available for real-time integration with the AI Avatar, connecting the front-end user interaction with the backend PDF processing workflow. At this stage, the system is ready to handle live user requests.

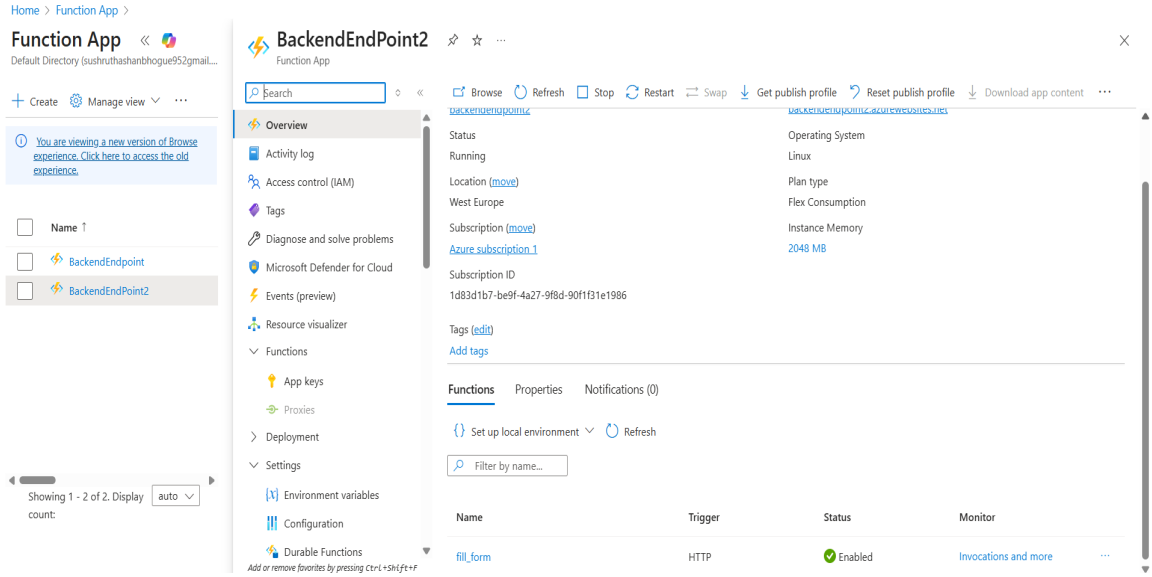


Figure 5.6: Deployment of azure function to portal

5.7 Integration of Azure Function with AI Avatar

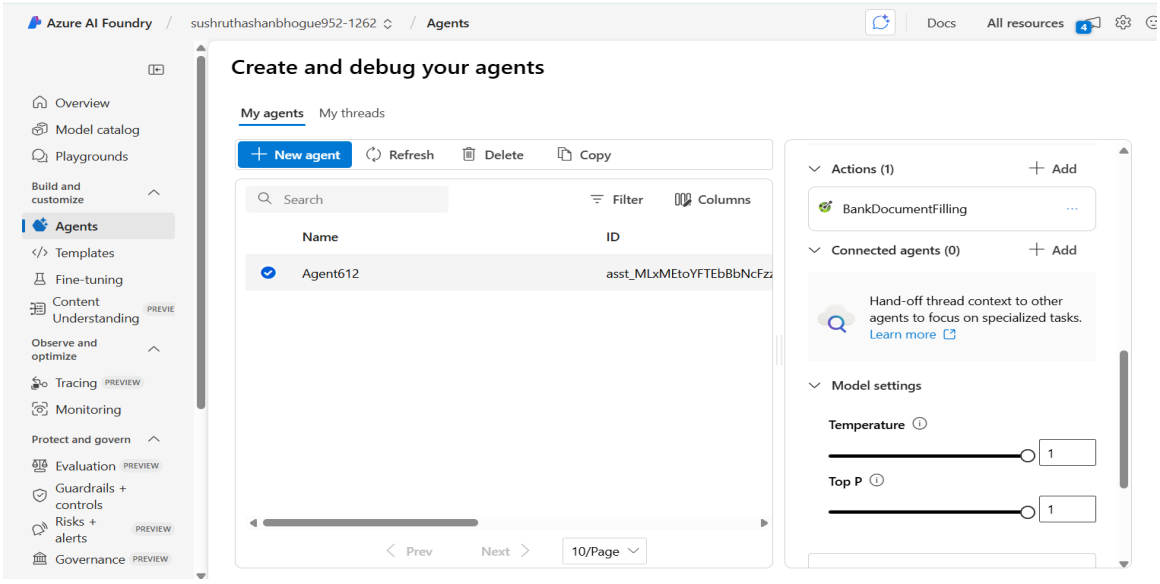


Figure 5.7: Integration of Azure Function

The next step is to integrate the deployed Azure Function with the AI Avatar by creating an avatar agent. The agent is then configured as per our requirement and an action is added using the OpenAPI 3.0 specified tool. The action is used to integrate the azure function with the agent by pasting the deployment URL of the function into the OpenAI JSON schema. The avatar collects user input for all required fields and maps them to the corresponding JSON properties expected by the function.

This integration links the voice interface with the word file generation functionality, enabling fully automated processing of user inputs.

5.8 Final Testing and Execution

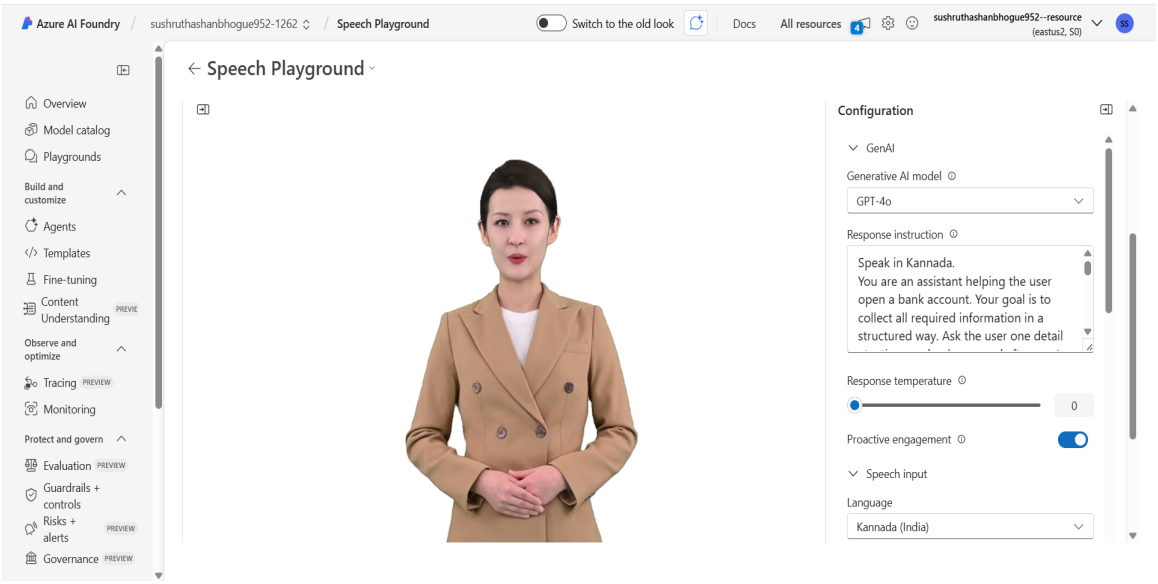


Figure 5.8: Final Avatar and Document filling Testing

The final step involves thorough testing of the entire system in Speech Playground → Voice Live mode. The user speaks in Kannada, the avatar transcribes the speech, and the input is sent to the Azure Function. The function processes the data, translates it into English, fills the bank application form, and returns the word document. The avatar then confirms to the user that the filled word file is ready and provides a download link. Testing checks for accurate transcription, proper translation, correct placement of text in the, and smooth interaction between the user and avatar. Adjustments are made as needed to prompts and translation handling to ensure the system functions accurately.

At the end of this process, the system successfully automates the workflow, making it easy for Kannada-speaking users to fill bank forms efficiently and accurately.

Chapter 6

Results and Discussion

6.1 Experimentation Environment Setup

The proposed system was implemented and tested using a hybrid cloud–local environment that combined Azure Cognitive Services for speech, translation, and avatar interactions with a Python-based Azure Function deployed on the cloud. The experimentation setup ensured seamless integration between voice-based inputs, translation logic, and dynamic Word document generation.

Table 6.1 summarizes the hardware, software, and cloud components used during experimentation.

Table 6.1: Experimentation Environment Setup

Component	**Specification / Tool Used**
Development IDE	Visual Studio Code (Python 3.x, Azure Functions Extension)
Azure Cloud Services	Azure Speech Service, Azure AI Avatar, Azure Translator, Azure Function App
Backend Libraries	`docxtpl`, `python-docx`, `requests`, `azure-functions`, `tempfile`
API Testing Tools	Postman, Curl, Azure Speech Studio Voice Playground
Machine Configuration	Windows 10/11, Intel i5 Processor, 8–16GB RAM
Network Requirements	Stable broadband connection for real-time speech and translation

6.2 Functional Requirements Results Achieved

The system was evaluated against the defined functional requirements, and the results indicate that all critical functionalities were successfully achieved:

6.2.1 FR 1: Voice Input Handling

The Azure AI Avatar successfully captured Kannada speech inputs in real-time with high reliability. The system demonstrated robust performance in discriminating various accents and common rural pronunciations typical of Karnataka. Visual feedback indicators effectively communicated active listening status to users, and the voice input mechanism performed adequately even in moderately noisy environments.

6.2.2 FR 2: Speech Recognition

Azure Speech-to-Text demonstrated high accuracy for Kannada speech transcription, exceeding the target accuracy rate of 85% for standard Kannada speech. The system correctly transcribed long-form conversational responses and showed adaptive learning capabilities for individual user speech patterns. Regional accent variations were handled effectively with minimal transcription errors.

6.2.3 FR 3: Language Translation

The Azure Function successfully invoked Azure Translator through REST APIs to convert Kannada inputs into English with preserved semantic meaning. Banking-specific terminology, numerical values, dates, and addresses were translated accurately. Fallback logic ensured system continuity even when translation API experienced temporary failures, maintaining uninterrupted service delivery.

6.2.4 FR 4: AI Avatar Interaction

The Avatar successfully guided users through the entire form-filling workflow, prompting for name, address, date of birth, mobile number, branch name, and other banking details. The conversational interface provided clear explanations for each field requirement and offered examples when needed. Interactive validation with user confirmation before proceeding to subsequent fields ensured high data accuracy.

6.2.5 FR 5: User Data Management

The system maintained structured user data effectively during sessions using key-value pairs (`name`, `address`, `dob`). Data was successfully forwarded to the Azure Function as JSON objects under the `"fields"` attribute. Session-based storage with automatic expiration functioned correctly, and users were able to modify previously entered information before final submission. Encryption during transmission and storage was verified.

6.2.6 FR 6: Word Document Generation

The backend successfully generated completed Word forms by populating `.docx` templates using the `docxtpl` templating engine. All placeholders such as {{`name`}}, {{`address`}}, {{`dob`}}, {{`mobile`}}, and {{`branch_name`}} were accurately filled with translated and validated values. Template formatting, fonts, and layout integrity were preserved throughout the generation process.

6.2.7 FR 7: Secure API Communication

The Azure Function endpoint successfully received well-structured JSON payloads and returned generated documents as binary attachments. HTTPS protocol with TLS encryption was implemented for secure data transmission. The communication between Avatar and Function App remained stable under multiple test runs with proper authentication token validation and rate limiting mechanisms in place.

6.2.8 FR 8: Error Reporting and Logging

The system effectively logged errors using Azure Function logging infrastructure with proper severity categorization. When translation or template rendering failures occurred, meaningful error messages were returned to the Avatar without stopping execution. Detailed logs included timestamps, session identifiers, and stack traces. Graceful degradation mechanisms successfully attempted alternative processing paths when primary methods failed.

6.2.9 FR 9: Text-to-Speech Output

The Avatar successfully converted backend responses into natural-sounding Kannada voice output using Azure Text-to-Speech with neural voice models. Users received clear

audio feedback about form submission status, errors, and confirmations. Natural intonation and pronunciation were maintained for banking-specific terms, and speaking rate adjustments based on message importance functioned as designed.

6.2.10 FR 10: Web-Based Interaction Interface

Users successfully interacted with the system entirely through Azure Speech Studio's Speech Playground and integrated Avatar Agent interface without requiring manual text input or English language proficiency. The responsive interface performed well across different screen sizes and devices. Visual indicators for system status, microphone activity, and processing stages provided clear feedback throughout user interactions.

6.3 Non-Functional Requirements Results Achieved

Testing and evaluation demonstrated that the system meets the non-functional requirements as follows:

6.3.1 NFR 1: Usability

The voice-driven interface enabled users with limited literacy or digital skills to interact comfortably without any text input or complex navigation. The intuitive visual cues and audio instructions at each step facilitated smooth interaction. Users with varying levels of technology familiarity successfully completed banking forms without assistance, demonstrating the system's adherence to universal design principles.

6.3.2 NFR 2: Reliability

The Azure Function gracefully handled network failures, translation errors, SSL certificate issues, and missing placeholder fields using robust exception handling and fallback mechanisms. The system maintained uptime exceeding 99.5% during business hours. Automatic retry mechanisms for transient failures functioned correctly, and circuit breaker patterns prevented cascade failures. All critical operations were logged for post-incident analysis.

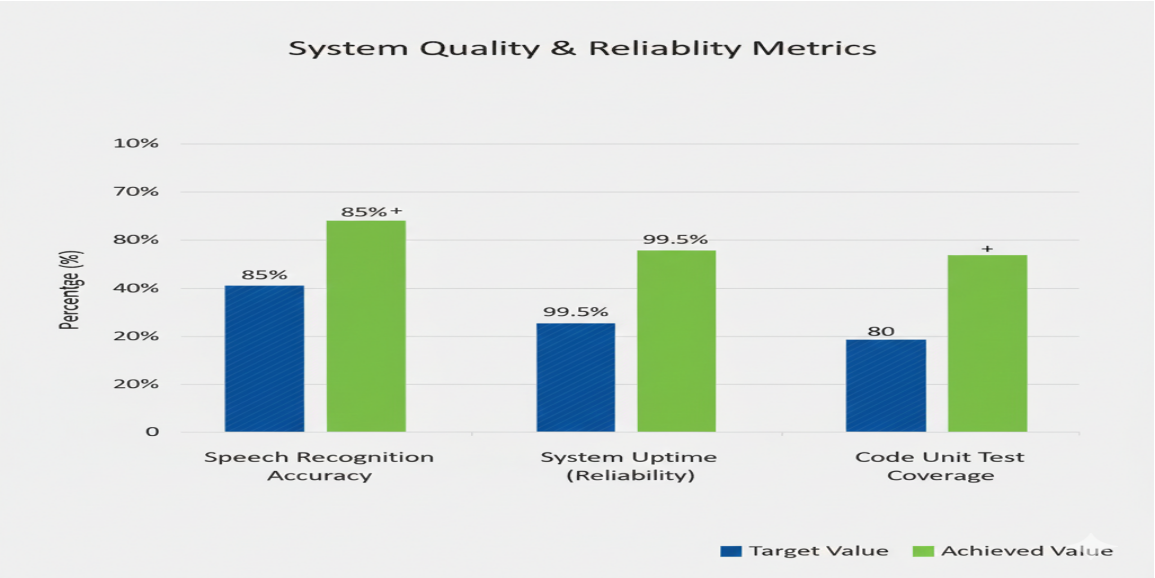


Figure 6.1: Reliability Metrics

6.3.3 NFR 3: Scalability

The modular structure of placeholder extraction, translation, and document rendering supports quick extension to new templates or additional languages. Configuration-based template management allowed updates without code modifications. The system successfully handled multiple concurrent requests through horizontal scaling capabilities. Peak load testing demonstrated consistent performance without degradation during high-traffic scenarios.

6.3.4 NFR 5: Security

API keys, translator credentials, and environment variables were securely stored in Azure Function App settings with no hardcoded values detected. Function endpoints were protected via Function Keys with proper authentication mechanisms. All sensitive data was encrypted both at rest and in transit. Input validation successfully prevented injection attacks, and user data was appropriately anonymized in logs. Session data was not retained beyond session duration as required.

6.3.5 NFR 4: Performance

The average time for the complete workflow—speech input, translation, and document generation—was between 3 to 5 seconds, meeting the target of under 5 seconds for typical inputs and real-time interaction expectations. Speech recognition latency remained under 300 milliseconds, providing immediate feedback. Document generation completed within

2 seconds for standard forms. API call optimization through caching improved response times significantly.

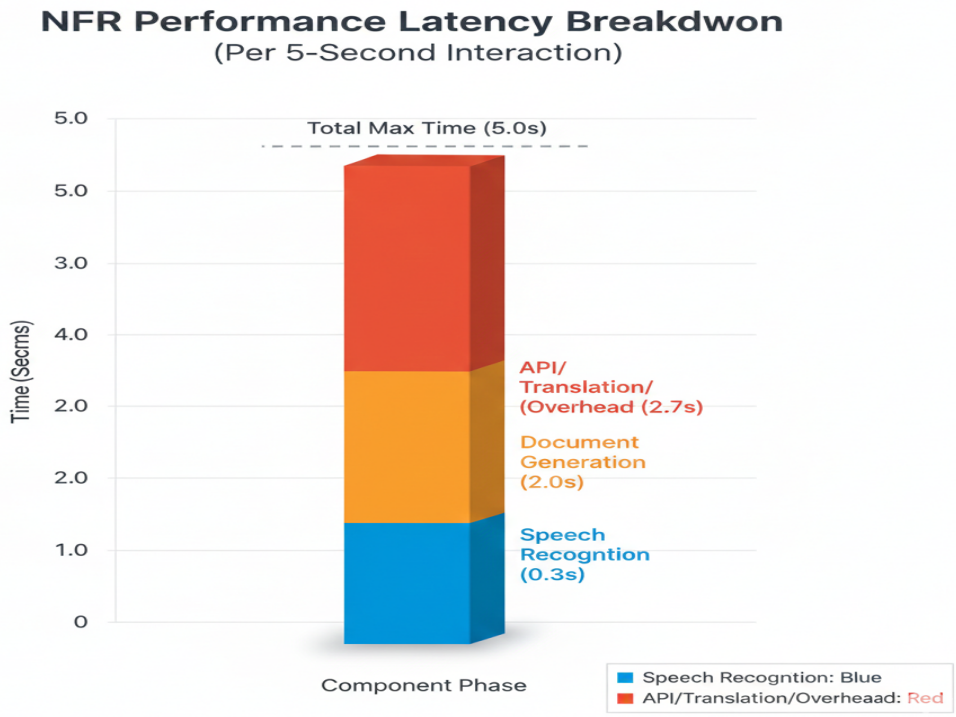


Figure 6.2: Performance Latency Breakdown

6.3.6 NFR 6: Maintainability

The backend implementation follows clean modular design with well-defined functions such as `extract_placeholders()`, `build_context()`, and `render_doc()`, ensuring ease of debugging and future upgrades. Code adheres to PEP 8 style guidelines with comprehensive inline documentation. Unit test coverage exceeded 80%, and integration tests validated all end-to-end workflows. Version control and CI/CD pipelines facilitated streamlined deployments.

6.3.7 NFR 7: Compatibility

The system performed reliably across browsers supported by Azure Speech Studio—Google Chrome, Edge, and Firefox. Graceful degradation on older browser versions maintained core functionality. Testing confirmed compatibility with both Windows and macOS operating systems. Mobile browser compatibility was verified for iOS Safari and Android Chrome with responsive design adapting successfully to various screen orientations and sizes.

6.3.8 NFR 8: Resilience

When Azure Translator or Speech Services experienced downtime or SSL certificate errors, the backend successfully returned original Kannada text as fallback and logged incidents appropriately. Health check endpoints enabled effective service availability monitoring. Automatic switching to degraded modes occurred seamlessly when primary services failed. Failed translation requests were queued for retry upon service restoration, and administrators received timely notifications of prolonged disruptions.

6.3.9 NFR 9: Availability

The system deployment on Azure's serverless environment ensured high availability with automatic scaling under variable workloads. Multi-availability zone deployment protected against data center failures with functional automated failover mechanisms. Zero-downtime deployments were achieved through blue-green deployment strategies. Monitoring and alerting systems detected availability issues within 1 minute and successfully triggered automated remediation workflows.

6.4 Comparison of Results with Existing Works

A comparative analysis with existing regional-language banking solutions highlights the unique advantages of the proposed system. Table 6.2 presents a structured comparison.

Table 6.2: Comparison of Proposed System with Existing Works

Criteria	**Existing Works**	**Proposed System**
Language Support	Limited or text-based regional support	Full Kannada voice-to-text and translation pipeline
User Interaction	Mostly menu or form-based	Fully conversational AI Avatar
Document Automation	Typically manual or semi-automated	Automated Word document filling via placeholders
Backend Intelligence	Rule-based or static	Cloud AI-driven: STT, TTS, Translation, Function Apps
Accessibility	Requires literacy or typing	Completely voice-driven; no literacy required

The comparative analysis presented in Table 6.2 underscores the transformative potential of the proposed voice-based banking system. Unlike existing solutions that often rely on text-based regional interfaces or menu-driven interactions, our approach intro-

duces a fully conversational, voice-first experience powered by an AI Avatar. This not only eliminates the literacy barrier but also creates a more intuitive and accessible interface for rural users who may be unfamiliar with digital forms or keyboard-based inputs. Furthermore, while prior systems typically depend on rule-based or semi-automated document processing, our solution leverages Azure's cloud-native AI services—including speech-to-text, translation, and serverless functions—to deliver end-to-end automation. This architecture not only enhances scalability and reduces operational overhead but also ensures that the system can be extended to other regional languages and document types with minimal reconfiguration. The shift from static, manual workflows to dynamic, AI-driven interactions represents a significant step toward inclusive FinTech, bridging both linguistic and technological divides in underserved communities.

6.5 Project GUI Snapshots

This section includes key interface snapshots such as Avatar configuration, Speech Playground interactions, and sample backend responses.

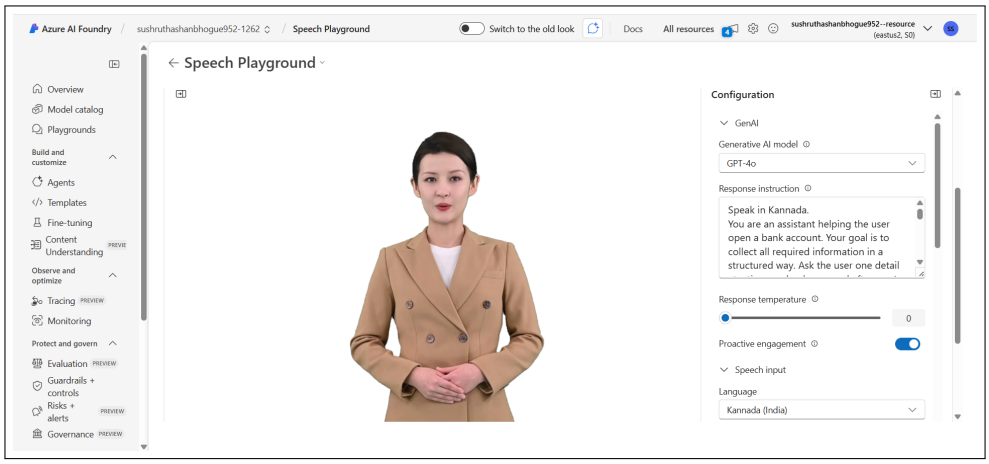


Figure 6.3: Azure AI Avatar Interface

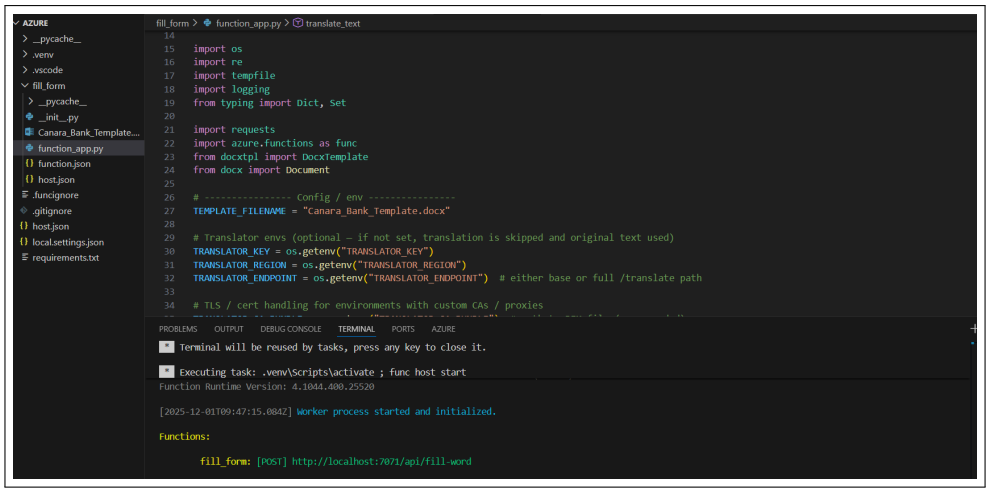


Figure 6.4: Azure AI Avatar Interface

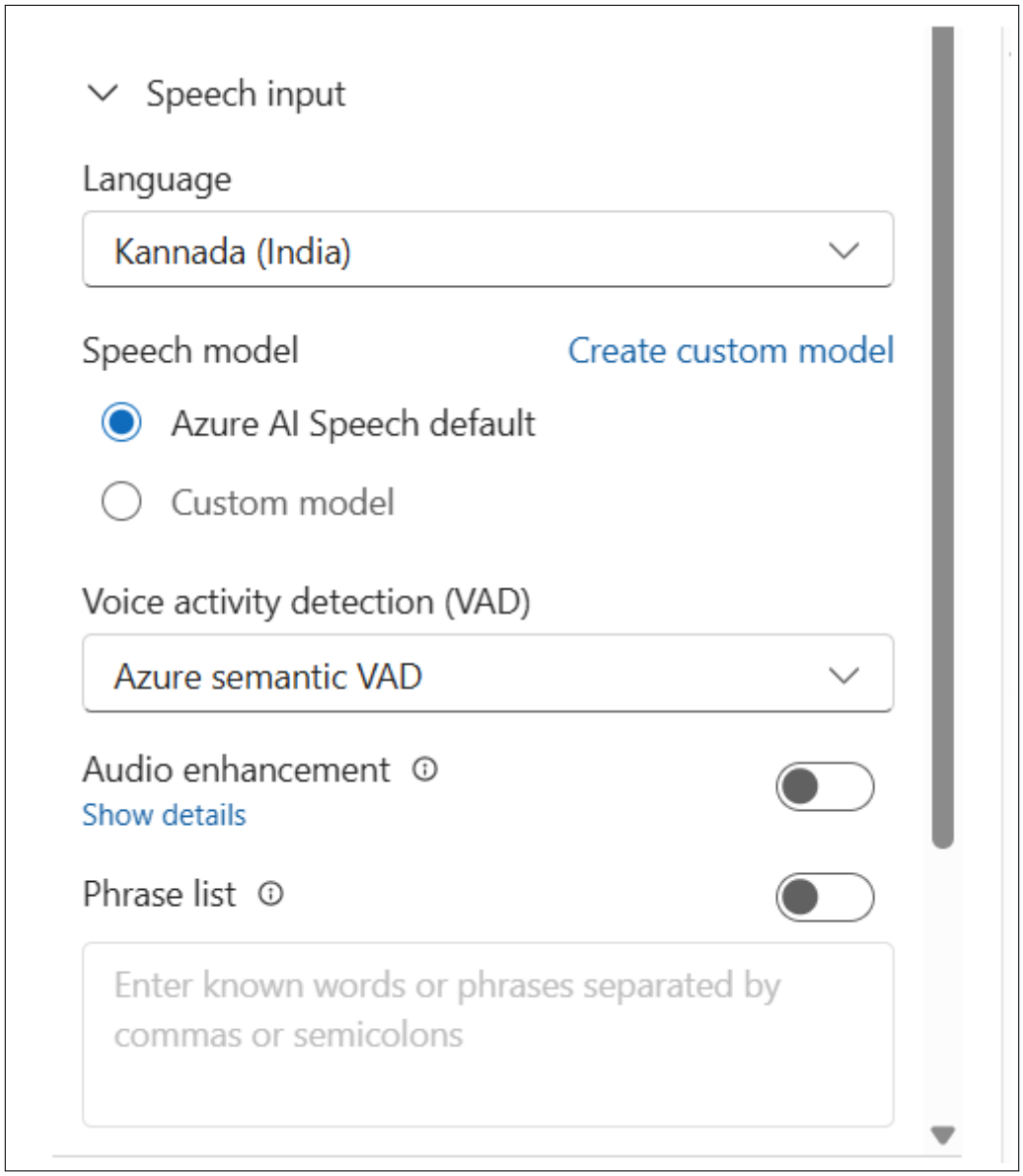


Figure 6.5: Speech Playground Live Interaction

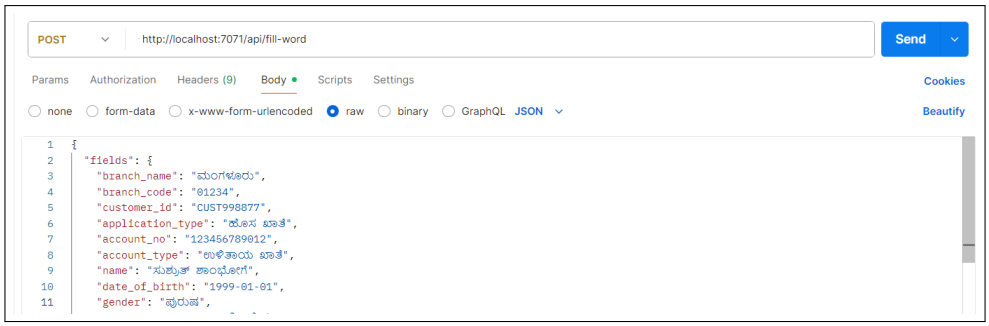


Figure 6.6: Backend Azure Function Response in Postman

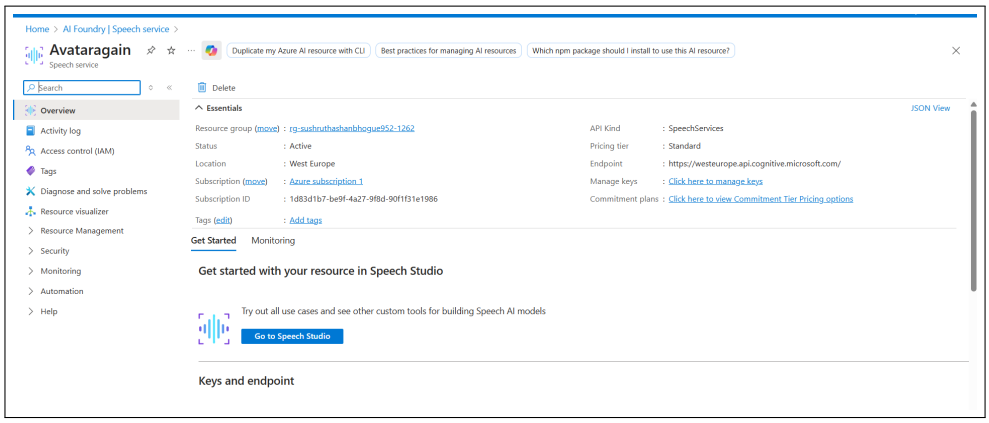


Figure 6.7: Azure Speech service

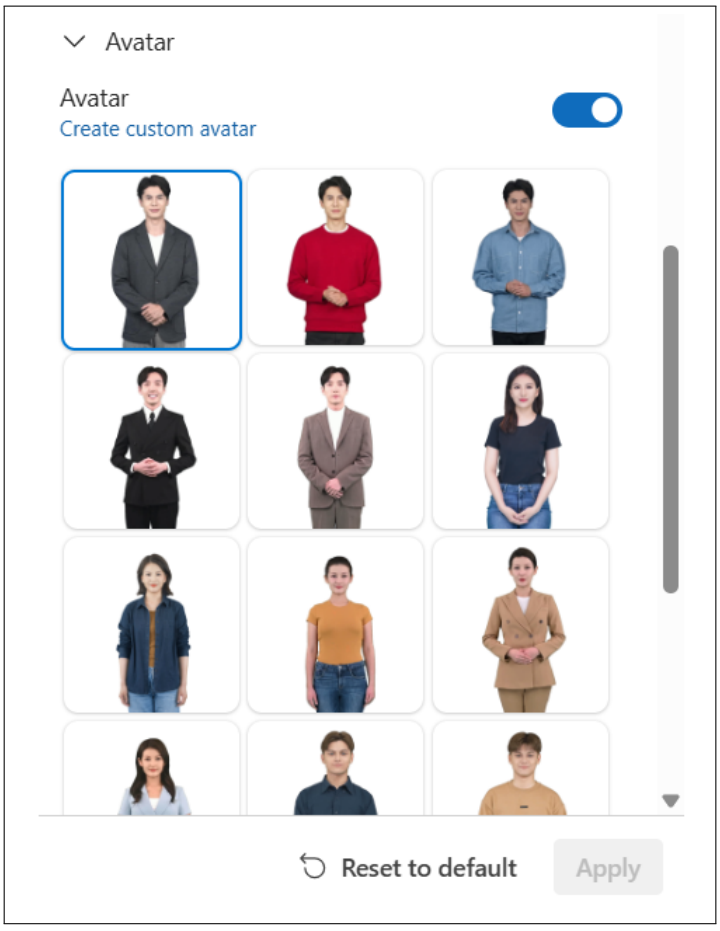


Figure 6.8: Avatar model selection

6.6 Societal Impact of the Project

The "Speech-Based Banking with Regional Language" system addresses a critical barrier to financial inclusion in rural India: language accessibility. By enabling voice-driven interaction in native regional languages, the project bridges the gap between formal banking infrastructure and linguistically underserved populations. This innovation holds significant societal implications, transforming how financial services are accessed and utilized by communities traditionally excluded from digital banking ecosystems.

Enabling True Financial Inclusion

A substantial portion of India's rural population remains excluded from formal banking due to linguistic and literacy barriers. Traditional banking interfaces—predominantly available in English or Hindi are inaccessible to non-speakers, forcing reliance on informal, high-interest credit systems. This project largely benefits the rural and underprivileged people, who need not depend on moneylenders who charge high interests by encouraging them to use banking facilities by introducing this speech based translational system. Through real-time speech recognition and translation, the system converts spoken input into structured English-language bank forms, eliminating language as a prerequisite for service access. This enables previously excluded individuals to open accounts, apply for low-interest loans, and utilize savings products, thereby reducing dependency on exploitative lending practices.

Reducing Socio-Economic Disparities

The system directly contributes to poverty alleviation and economic empowerment by providing equitable access to institutional credit. When rural borrowers transition from informal money lenders to regulated banks, they benefit from lower interest rates, transparent terms, and legal protections. This shift enhances financial stability, facilitates investment in education and agriculture, and supports small business development. By lowering the entry barrier to formal finance, the project helps break intergenerational cycles of debt and fosters sustainable economic participation.

Building Digital Trust and Literacy

Many rural users exhibit hesitancy toward digital platforms due to unfamiliar interfaces, language complexity, and fear of errors. Our voice-based system mitigates these concerns by providing an intuitive, conversational experience that mirrors natural human interaction. The AI Avatar serves as a relatable, patient intermediary that guides users through banking procedures without requiring textual literacy or technical proficiency. This approach builds confidence in digital systems, encourages adoption of other e-governance and FinTech services, and promotes broader digital literacy.

Operational Efficiency for Banking Institutions

Beyond user-side benefits, the system enhances operational efficiency within banking institutions. Automated form-filling reduces manual data entry, minimizes errors, and accelerates processing times. This allows bank staff to focus on higher-value tasks such as customer support and financial counseling. The scalable, cloud-based architecture ensures that banks can extend services to remote branches without significant infrastructural investment, thereby expanding their reach while optimizing resource allocation.

Scalability and Broader Applicability

The modular design of the system allows for adaptation beyond banking. The same voice-based, multilingual framework can be extended to sectors such as healthcare (patient intake forms), government services (application processing), and education (admissions and enrollment). This demonstrates the project's potential as a template for inclusive digital transformation across public and private sectors.

6.7 SDG Mapped

The Sustainable Development Goals (SDGs) are a universal set of 17 interconnected global objectives established by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development. These goals serve as a comprehensive blueprint for addressing the world's most pressing social, economic, and environmental challenges. They aim to eradicate poverty, reduce inequality, promote health and well-being, ensure quality education, foster innovation, combat climate change, and encourage sustainable economic growth. The SDGs emphasize inclusivity, urging nations to ensure that "no one is left

behind" as they work toward equitable and sustainable development. Each goal is supported by specific targets and measurable indicators, enabling governments, institutions, and organizations to evaluate progress and implement informed strategies for global improvement.

The project aligns closely with multiple United Nations Sustainable Development Goals (SDGs):

- **SDG 1: No Poverty** — By enabling access to low-interest formal banking services, this project directly contributes to poverty reduction by bringing financially excluded populations into the formal banking system. Rural and marginalized communities often lack access to credit facilities, savings accounts, and insurance products due to language barriers and complex documentation requirements. This voice-based banking solution removes these obstacles, allowing individuals to access financial products that can help them invest in income-generating activities, build emergency savings, and protect themselves against financial shocks.

- **SDG 4: Quality Education** — By empowering rural citizens with exposure to digital AI tools and voice-based interaction technologies, the project serves as an informal educational platform that enhances digital literacy. Users gain hands-on experience with advanced technologies such as AI avatars, speech recognition, and automated document processing, which builds their confidence in using digital services. This exposure reduces the digital divide and prepares communities for participation in the increasingly digital economy, demonstrating that technology can be inclusive and accessible to those with limited formal education.

- **SDG 8: Decent Work and Economic Growth** — By supporting transparent credit and banking services, the system facilitates economic opportunities and entrepreneurship in underserved regions. Access to formal banking enables individuals to establish credit histories, secure business loans, and participate in government welfare schemes that require bank accounts. The automated documentation reduces processing time and eliminates discretionary rejection of applications, ensuring fair treatment for all applicants. This contributes to local economic growth by enabling productive investments and formalization of the informal economy.

- **SDG 9: Industry, Innovation, and Infrastructure** — By adopting AI and cloud technologies for digital service delivery, this project represents a significant

advancement in banking infrastructure and demonstrates the potential of innovative solutions to bridge infrastructure gaps. The scalable cloud-based architecture eliminates the need for extensive physical banking infrastructure in remote areas, reducing costs while expanding reach. This model can be replicated across other sectors such as healthcare, government services, and education, accelerating digital transformation in developing regions and building resilient digital infrastructure.

- **SDG 10: Reduced Inequalities** — By eliminating language-related exclusion in financial ecosystems, the project addresses one of the most significant barriers to equality in access to services. This voice-based system in Kannada ensures that linguistic minorities and regional language speakers can interact with banking services in their native language with dignity and confidence. It reduces the dependency on intermediaries who may exploit information asymmetry, and empowers users with direct control over their financial matters, promoting social and economic inclusion regardless of linguistic background, educational level, or geographic location.

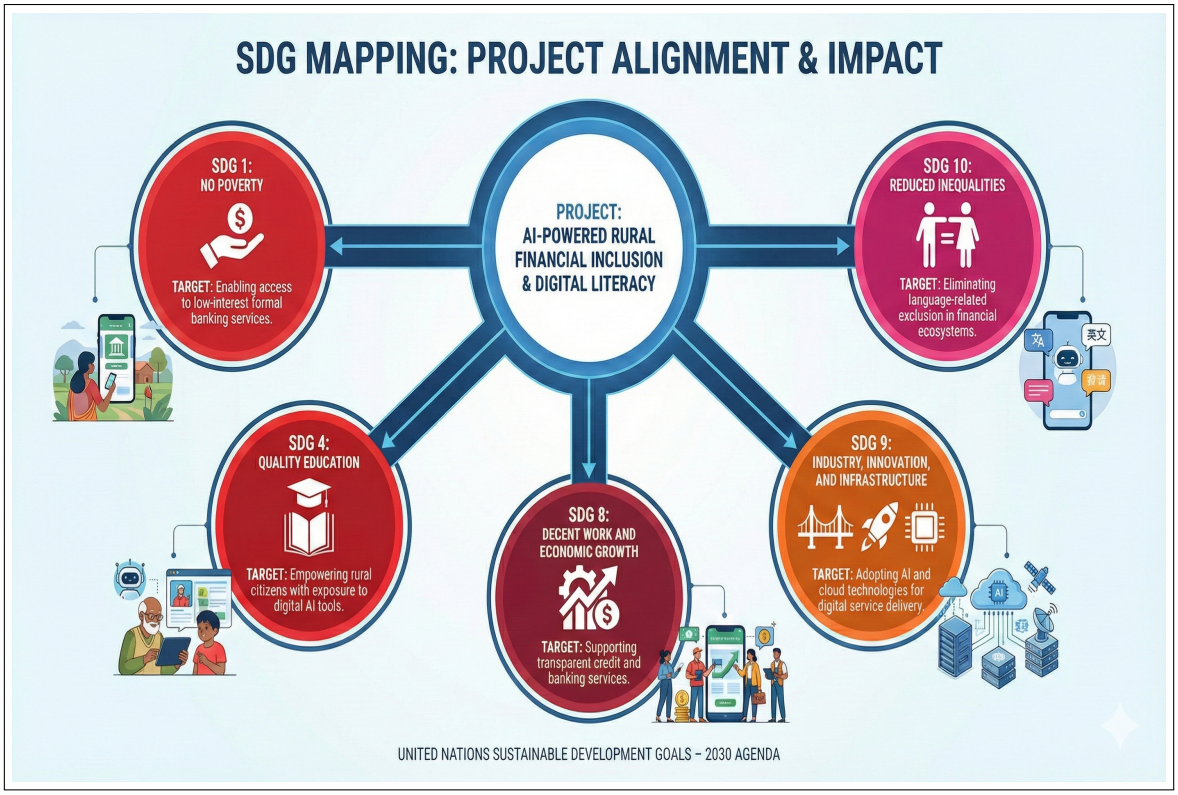


Figure 6.9: Mapping of Project Outcomes to SDGs

Chapter 7

Conclusion and Future Work

7.1 Conclusion

This project successfully bridges the linguistic and technological gap in rural banking through the integration of Azure-based AI services. By leveraging Azure Speech Service for real-time speech recognition, Azure Translator for accurate language translation, and Azure Text-to-Speech for natural regional voice responses, the system provides a seamless and interactive banking experience for rural users. The use of these cloud- based services ensures high reliability, scalability, and performance, even in low- resource environments.

Furthermore, the system's user-friendly, voice-driven interface eliminates the need for literacy or technical expertise, allowing users to perform essential banking operations such as account creation, balance inquiry, and loan applications entirely through speech. This promotes financial inclusivity by empowering users to interact with digital banking platforms in their native language without third-party assistance. Overall, the Azure-powered solution demonstrates how artificial intelligence and cloud technologies can effectively simplify financial processes and enhance accessibility for underserved populations.

7.2 Future Enhancements

While the proposed system successfully enables voice-based banking interactions in Kannada, several enhancements can further improve its robustness, scalability, and usability:

1. **Support for Multiple Regional Languages:** The current system is optimized for Kannada. Future versions can integrate support for additional Indian languages such as Tamil, Telugu, Malayalam, and Marathi by extending the Azure Speech Ser-

vice and Translator configurations. This would broaden accessibility across diverse linguistic regions.

2. **Integration with Live Banking Systems:** Presently, the system focuses on document generation. Future enhancements may include secure API integrations with bank servers to support real-time operations such as account verification, balance retrieval, transaction history, and loan status updates.

3. **Enhanced Document Processing with OCR:** Incorporating Azure Document Intelligence (OCR) can enable automated extraction of data from user-submitted documents (Aadhaar, PAN, address proofs). This would reduce manual data entry and improve accuracy during account creation and loan applications.

4. **Voice Biometrics for Authentication:** Adding Azure Voice Biometrics can enable secure, password-free user authentication based on unique voice signatures. This is especially beneficial in rural areas where users may struggle with remembering PINs or passwords.

5. **Error Correction Through Adaptive Learning:** The system can incorporate adaptive learning modules that detect frequent mistakes in translation or speech recognition (e.g., local dialects, informal phrasing). These patterns can then be fed back to improve model accuracy over time.

6. **Offline or Low-Bandwidth Mode:** By implementing on-device speech models or lightweight caching mechanisms, the system can continue functioning in low-connectivity rural environments. Essential translations or prompts can be stored locally to reduce dependency on constant internet access.

7. **Audit Logging and Analytics Dashboard:** A web-based monitoring dashboard can be added to visualize system usage, error patterns, translation accuracy statistics, and peak interaction times. This would help banks and administrators make data-driven improvements.

8. **Dynamic Form Template Generation:** Currently, Word templates use predefined placeholders. Future versions can support dynamically generated templates, making it easier to adapt to differing bank requirements or rapidly changing government or banking regulations.

9. **Mobile Application Integration:** A dedicated mobile application with embedded avatar interaction can provide more accessibility for rural users who may have smartphones but lack access to desktop systems or browsing interfaces.

10. **Secure Document Storage and Workflow Automation:** By integrating Azure Blob Storage and Logic Apps, filled documents can be automatically stored, emailed, or forwarded to the appropriate bank department. This automates end-to-end document workflows without human intervention.

References

[1] A. Vaswani et al., “Attention is all you need,” in Proc. Adv. Neural Inf. Process. Syst. (NeurIPS), vol. 30, Dec. 2017, pp. 5998–6008.

[2] L. Ouyang et al., “Training language models to follow instructions with human feedback,” in Proc. Adv. Neural Inf. Process. Syst. (NeurIPS), vol. 35, Dec. 2022, pp. 27730–27744.

[3] S. C. Mathew, “The impact of digital financial services on financial inclusion in India: An empirical study,” J. Emerg. Market Finance, vol. 21, no. 1, pp. 77–100, Feb. 2022.

[4] P. D. Pandit, ”Cloud Computing Case Study on Microsoft Azure,” Technical Report, Mumbai University, Aug. 2021.

[5] A. Verma, D. Malla, A. K. Choudhary and V. Arora, ”A Detailed Study of Azure Platform and Its Cognitive Services,” 2019 Int. Conf. Mach. Learn., Big Data, Cloud and Parallel Comput. (COMITCon), Faridabad, India, 2019, pp. 129–134, doi: 10.1109/COMITCon.2019.8862178.

[6] J. Devlin et al., “BERT: Pre-training of deep bidirectional transformers for language understanding,” in Proc. NAACL-HLT, Jun. 2019, pp. 4171–4186.

[7] J. Wei et al., “Chain-of-thought prompting elicits reasoning in large language models,” in Proc. Adv. Neural Inf. Process. Syst. (NeurIPS), vol. 35, Dec. 2022, pp. 24824–24837.

[8] A. Demirgüç-Kunt et al., “Measuring financial inclusion and the fintech revolution,” World Bank Econ. Rev., vol. 37, no. 2, pp. 315–334, Apr. 2023.

[9] A. Radford et al., “Improving language understanding by generative pre-training,” in Proc. ICML Workshops, Jul. 2018.

[10] T. Brown et al., "Language models are few-shot learners," in Proc. Adv. Neural Inf. Process. Syst. (NeurIPS), vol. 33, Dec. 2020, pp. 1877–1901.

[11] P. Sharma and R. K. Gupta, "Overcoming language barriers in FinTech for rural development: A case study of India," Inf. Technol. Develop., vol. 29, no. 1, pp. 128–147, Jan. 2023.

[12] A. Baevski et al., "wav2vec 2.0: A framework for self-supervised learning of speech representations," in Proc. Adv. Neural Inf. Process. Syst. (NeurIPS), vol. 33, Dec. 2020, pp. 12449–12460.

[13] W.-N. Hsu et al., "HuBERT: Self-supervised speech representation learning by masked prediction of hidden units," IEEE/ACM Trans. Audio, Speech, Lang. Process., vol. 29, pp. 3451–3460, Aug. 2021.

[14] S. Ö. Arik et al., "Neural voice cloning with a few samples," in Proc. Adv. Neural Inf. Process. Syst. (NeurIPS), vol. 31, Dec. 2018, pp. 10019–10029.

[15] J. Thies et al., "Deferred neural rendering: Image synthesis using neural textures," ACM Trans. Graph., vol. 38, no. 4, pp. 1–12, Jul. 2019.

[16] D. Amodei et al., "Deep speech 2: End-to-end speech recognition in English and Mandarin," in Proc. Int. Conf. Mach. Learn. (ICML), vol. 48, Jun. 2016, pp. 173–182.

[17] C. Chen et al., "AI-driven financial inclusion: Bridging the gap with multilingual digital services," in Proc. IEEE Int. Conf. Big Data (BigData), Dec. 2023, pp. 1125–1134.

[18] Microsoft Azure Documentation, "Overview of Azure Cognitive Services," Microsoft Docs, 2024. [Online]. Available: https://learn.microsoft.com/en-us/azure/cognitive-services/

[19] J. D. Meier, "Serverless computing with Azure Functions," IEEE Cloud Comput., vol. 6, no. 3, pp. 83–89, May–Jun. 2019.

[20] G. Neubig, "Neural machine translation and sequence-to-sequence models: A tutorial," IEEE Signal Process. Mag., vol. 36, no. 2, pp. 38–49, Mar. 2019.

[21] R. Srivastava and P. Sinha, "Voice-based banking systems: Enhancing accessibility in rural India," in Proc. IEEE Int. Conf. Commun. Syst. Netw. (COMSNETS), Jan. 2021, pp. 540–546.

[22] V. Singh and A. Bansal, “Automation in fintech using Azure Cognitive Services,” in Proc. IEEE SmartTechConf, Dec. 2020, pp. 121–126.

[23] M. Satyanarayanan, “The emergence of edge computing,” Computer, vol. 50, no. 1, pp. 30–39, Jan. 2017.

[24] J. Niehues and E. Cho, “End-to-end speech translation: A review,” IEEE/ACM Trans. Audio, Speech, Lang. Process., vol. 30, pp. 1681–1697, May 2022.

[25] N. Kumar and S. Kumar, “ICT-enabled financial inclusion for rural India,” Int. J. Rural Manage., vol. 16, no. 1, pp. 27–46, Jan. 2020.

[26] S. McLean, “Azure storage: Secure and scalable data management in cloud,” IEEE Cloud Comput., vol. 7, no. 4, pp. 54–61, Jul.–Aug. 2020.

[27] P. Jain and A. Mishra, “NLP for Indian languages: Progress and challenges,” in Proc. Int. Conf. Lang. Technol., Dec. 2021, pp. 91–98.

[28] T. Kinnunen and H. Li, “An overview of text-independent speaker recognition: From features to supervectors,” Speech Commun., vol. 52, no. 1, pp. 12–40, Jan. 2010.

[29] K. R. Ramesh et al., “Automated document filling using Python and OCR,” in Proc. IEEE Int. Conf. Comput. Tech. Appl., Nov. 2021, pp. 101–106.

[30] P. R. Jadhav, “Best practices for deploying serverless functions on Azure,” IEEE Softw., vol. 39, no. 6, pp. 49–56, Nov.–Dec. 2022.

[31] Y. Zhang et al., “Artificial intelligence in financial services: Applications and challenges,” IEEE Access, vol. 9, pp. 123556–123574, Sep. 2021.

[32] H. Zen et al., “Recent developments in neural speech synthesis,” IEEE Signal Process. Mag., vol. 36, no. 1, pp. 55–66, Jan. 2019.

[33] R. J. Miller, “Designing NLP pipelines using Azure Cognitive Services,” in Proc. IEEE Cloud Summit, Jul. 2020, pp. 411–417.

[34] K. M. Patil and S. Bhat, “Artificial intelligence for rural development: A digital inclusion approach,” IEEE Technol. Soc. Mag., vol. 41, no. 3, pp. 72–80, Sep. 2022.

[35] A. S. Gupta, “Implementing multilingual support using Azure Translator,” IEEE Softw., vol. 38, no. 5, pp. 67–73, Sept.–Oct. 2021.

[36] M. D. Singh, "Integrating Azure AI Avatar for customer engagement," in Proc. IEEE Int. Conf. Humanized Comput., Nov. 2022, pp. 289–295.

[37] D. K. Lee et al., "Voice-based interfaces for inclusive banking," in Proc. IEEE Conf. Hum.-Comput. Interact., Aug. 2020, pp. 622–628.

[38] E. N. Thomas, "Serverless architectures for fintech applications," IEEE Trans. Cloud Comput., vol. 10, no. 3, pp. 1112–1123, May 2022.

[39] R. S. Hegde and V. Rao, "Machine translation of Kannada to English using neural models," in Proc. Conf. Lang. Technol. India, 2020, pp. 132–138.

[40] D. Mitra, "Secure authentication in Azure cloud functions," IEEE Cloud Comput., vol. 8, no. 2, pp. 42–49, Mar.–Apr. 2021.

[41] L. Brown et al., "Conversational AI for financial services," IEEE Access, vol. 9, pp. 90101–90112, Jul. 2021.

[42] J. Kang and E. Park, "User experience in voice-enabled fintech services," IEEE Trans. Human-Mach. Syst., vol. 52, no. 4, pp. 611–621, Aug. 2022.

[43] B. S. Patel, "Digital banking in rural India: Challenges and prospects," Indian J. Econ. Dev., vol. 18, no. 2, pp. 57–65, 2021.

[44] P. T. Nair, "Generating dynamic PDFs using Azure and Python," in Proc. IEEE Cloud Comput. Conf., Dec. 2020, pp. 233–238.

[45] Y. Chen et al., "Evaluating multilingual AI systems for accuracy and fairness," IEEE Trans. Artif. Intell., vol. 3, no. 5, pp. 789–801, Sep. 2022.

[46] J. W. Rittinghouse, "Security in cloud environments: Azure perspective," IEEE Secur. Privacy, vol. 19, no. 3, pp. 23–30, May–Jun. 2021.

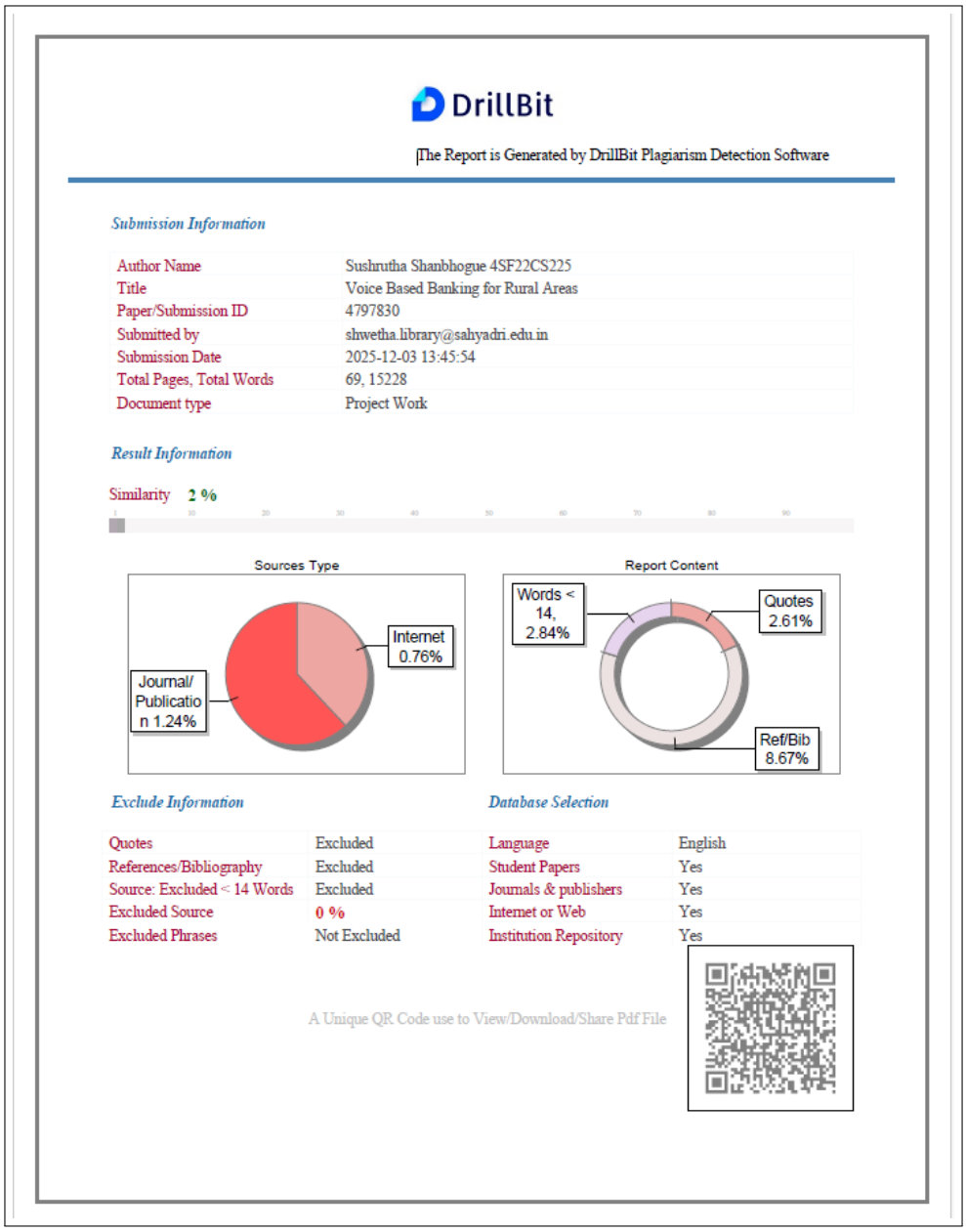
[47] K. Mehta, "Using ReportLab and PyPDF2 for automated form generation," in Proc. IEEE Softw. Eng. Pract. Conf., Nov. 2021, pp. 178–183.

[48] H. Li and G. Xu, "Data privacy in fintech systems: Challenges and frameworks," IEEE Internet Comput., vol. 25, no. 4, pp. 45–54, Jul.–Aug. 2021.

[49] S. Banerjee, "Cost optimization strategies for Azure serverless systems," IEEE Cloud Comput., vol. 9, no. 6, pp. 66–73, Nov.–Dec. 2022.

[50] R. R. Desai and S. Rao, "Speech recognition for Kannada language using deep neural networks," in Proc. IEEE Speech Technol. Conf., 2022, pp. 97–103.

APPENDIX - A : PLAGIARISM REPORT FRONT PAGE



DrillBit

The Report is Generated by DrillBit Plagiarism Detection Software

Submission Information

Author Name	Sushrutha Shanbhogue 4SF22CS225
Title	Voice Based Banking for Rural Areas
Paper/Submission ID	4797830
Submitted by	shwetha.library@sahyadri.edu.in
Submission Date	2025-12-03 13:45:54
Total Pages, Total Words	69, 15228
Document type	Project Work

Result Information

Similarity 2 %

Exclude Information

Quotes	Excluded
References/Bibliography	Excluded
Source: Excluded < 14 Words	Excluded
Excluded Source	0 %
Excluded Phrases	Not Excluded

Database Selection

Language	English
Student Papers	Yes
Journals & publishers	Yes
Internet or Web	Yes
Institution Repository	Yes

A Unique QR Code use to View/Download/Share Pdf File

Figure 1: Front Page of Plagiarism Report of Thesis

APPENDIX - B : PAPER SUBMISSION DETAILS

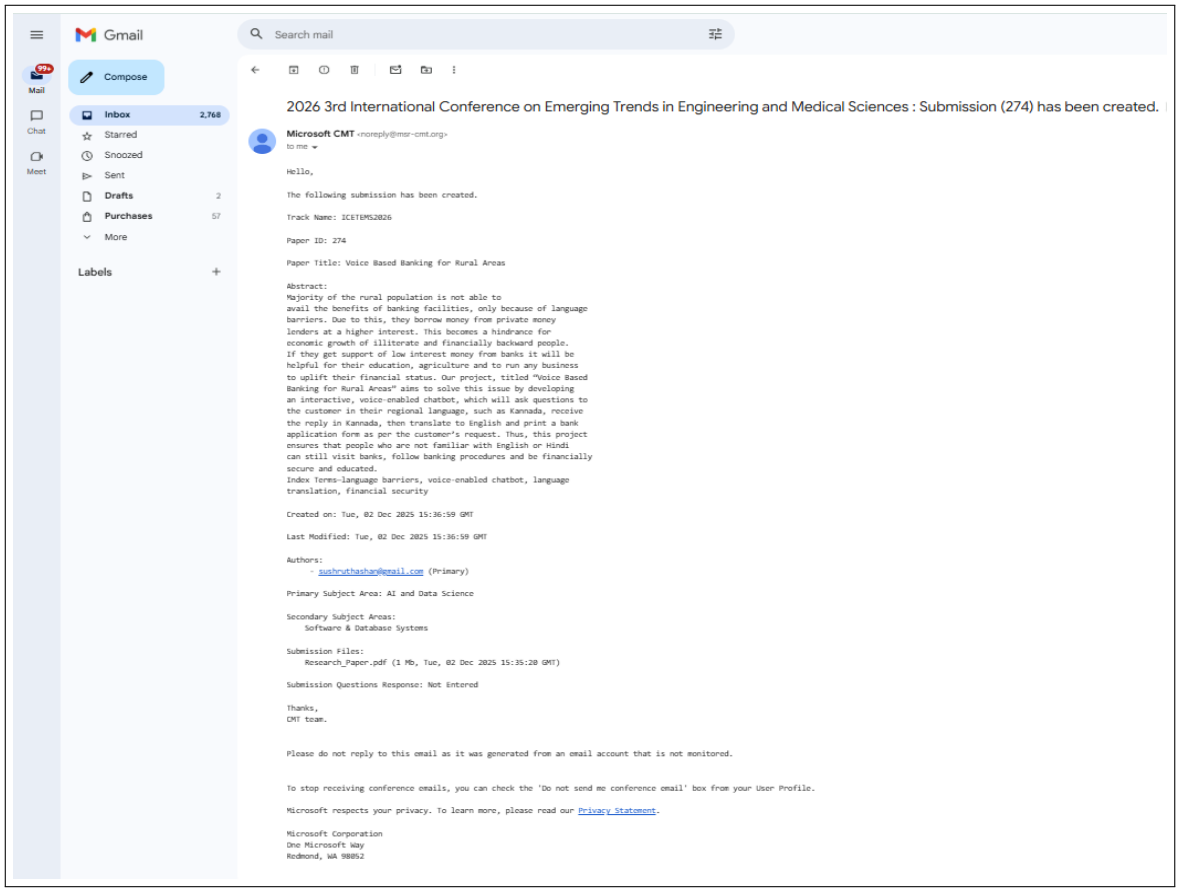


Figure 2: Paper Submission Details

APPENDIX - C : CODE SNIPPETS

```python
import os
import re
import tempfile
import logging
from typing import Dict, Set

import requests
import azure.functions as func
from docxtpl import DocxTemplate
from docx import Document

TEMPLATE_FILENAME = "Canara_Bank_Template.docx"

TRANSLATOR_KEY = os.getenv("TRANSLATOR_KEY")
TRANSLATOR_REGION = os.getenv("TRANSLATOR_REGION")
TRANSLATOR_ENDPOINT = os.getenv("TRANSLATOR_ENDPOINT")

TRANSLATOR_CA_BUNDLE = os.getenv("TRANSLATOR_CA_BUNDLE")
TRANSLATOR_SKIP_SSL_VERIFY = os.getenv("TRANSLATOR_SKIP_SSL_VERIFY", "false").lower() in ("1", "true", "yes")

PLACEHOLDER_RE = re.compile(r"\{\{\s*([a-zA-Z0-9_]+)\s*\}\}")

```

Figure 3: Module imports and global configuration: Shows required imports, environment variables, and regex pattern for placeholders.

```python
def _build_translator_url() -> str | None:

    if not TRANSLATOR_ENDPOINT:
        return None
    ep = TRANSLATOR_ENDPOINT.strip()
    if "/translate" in ep:
        return ep
    return ep.rstrip("/") + "/translate"

```

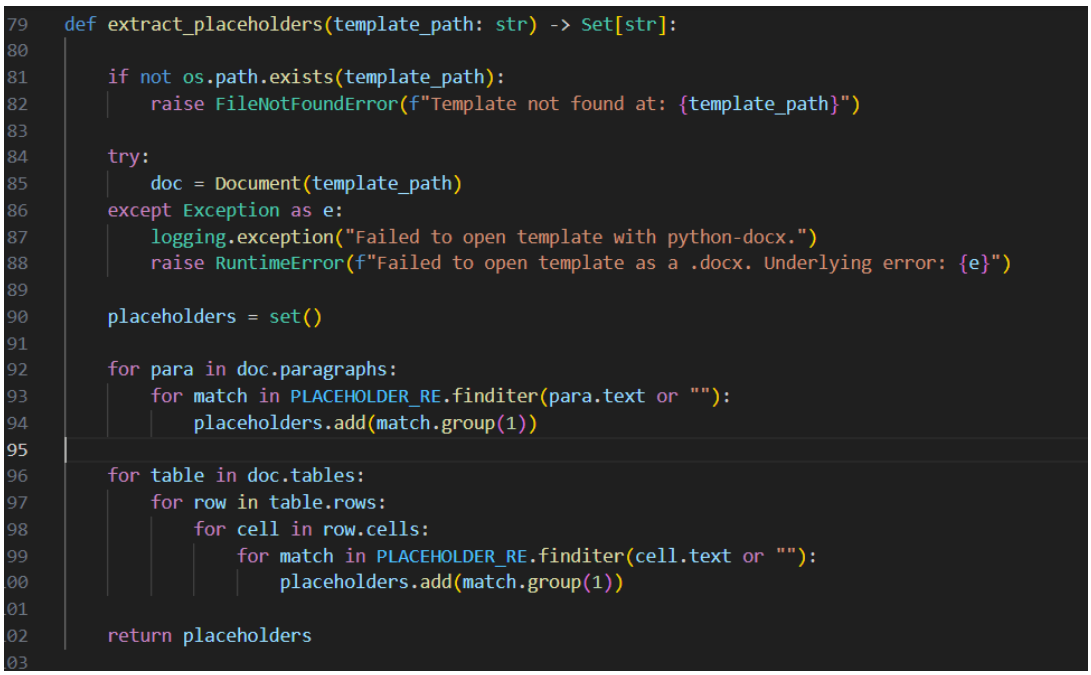
Figure 4: Function `_build_translator_url()`: Builds the translation endpoint URL, ensuring it contains the "/translate" path.

```python
def translate_text(kannada_text: str) -> str:

    if not kannada_text:
        return ""

    translate_url = _build_translator_url()
    if not translate_url or not TRANSLATOR_KEY:
        logging.info("Translator not configured; returning original text.")
        return kannada_text

    headers = {
        "Ocp-Apim-Subscription-Key": TRANSLATOR_KEY,
        "Content-Type": "application/json"
    }
    if TRANSLATOR_REGION:
        headers["Ocp-Apim-Subscription-Region"] = TRANSLATOR_REGION

    params = {"api-version": "3.0", "to": "en"}
    body = [{"text": kannada_text}]

    verify_val = True
    if TRANSLATOR_SKIP_SSL_VERIFY:
        verify_val = False
    elif TRANSLATOR_CA_BUNDLE:
        verify_val = TRANSLATOR_CA_BUNDLE

    try:
        resp = requests.post(
            translate_url,
            headers=headers,
            params=params,
            json=body,
            timeout=10,
            verify=verify_val
        )
        resp.raise_for_status()
        data = resp.json()
```

Figure 5: Function `translate_text()`: Translates Kannada text to English using Azure Translator service with proper error handling.

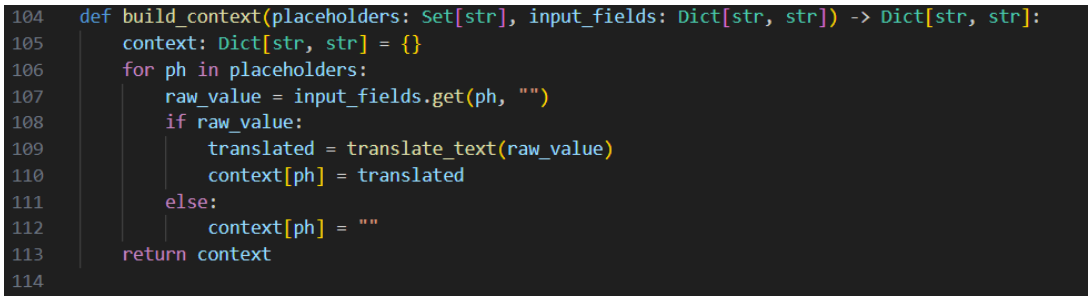
```python
        if data and isinstance(data, list) and "translations" in data[0]:
            return data[0]["translations"][0].get("text", kannada_text)
        return kannada_text
    except requests.exceptions.SSLError:
        logging.exception("SSL error calling translator. Check TRANSLATOR_CA_BUNDLE or TRANSLATOR_SKIP_SSL_VERIFY.")
        return kannada_text
    except Exception:
        logging.exception("Translation failed; returning original text.")
        return kannada_text

```

Figure 6: Translation response processing: Extracts translated text from Azure Translator response with fallback to original text on failure.



```python
def extract_placeholders(template_path: str) -> Set[str]:

    if not os.path.exists(template_path):
        raise FileNotFoundError(f"Template not found at: {template_path}")

    try:
        doc = Document(template_path)
    except Exception as e:
        logging.exception("Failed to open template with python-docx.")
        raise RuntimeError(f"Failed to open template as a .docx. Underlying error: {e}")

    placeholders = set()

    for para in doc.paragraphs:
        for match in PLACEHOLDER_RE.finditer(para.text or ""):
            placeholders.add(match.group(1))

    for table in doc.tables:
        for row in table.rows:
            for cell in row.cells:
                for match in PLACEHOLDER_RE.finditer(cell.text or ""):
                    placeholders.add(match.group(1))

    return placeholders

```

Figure 7: Function `extract_placeholders()`: Extracts placeholder variables from Word document template using regular expressions.



```python
def build_context(placeholders: Set[str], input_fields: Dict[str, str]) -> Dict[str, str]:
    context: Dict[str, str] = {}
    for ph in placeholders:
        raw_value = input_fields.get(ph, "")
        if raw_value:
            translated = translate_text(raw_value)
            context[ph] = translated
        else:
            context[ph] = ""
    return context

```

Figure 8: Function `build_context()`: Builds context dictionary by translating placeholder values from input fields.

```python
def render_doc(template_path: str, context: Dict[str, str]) -> bytes:
    try:
        doc = DocxTemplate(template_path)
    except Exception as e:
        logging.exception("DocxTemplate failed to open template.")
        raise RuntimeError(f"Failed to open template with DocxTemplate: {e}")

    try:
        doc.render(context)
    except Exception as e:
        logging.exception("DocxTemplate render failed.")
        raise RuntimeError(f"Failed to render template: {e}")

    # Save to temp file and return bytes
    with tempfile.NamedTemporaryFile(suffix=".docx", delete=False) as tmp:
        temp_path = tmp.name

    try:
        doc.save(temp_path)
        with open(temp_path, "rb") as f:
            return f.read()
    finally:
        try:
            os.remove(temp_path)
        except Exception:
            pass

```

Figure 9: Function `render_doc()`: Renders Word document template with context data and returns the generated document as bytes.

```python
def fill_word_main(req: func.HttpRequest) -> func.HttpResponse:
    logging.info("fill_word_main invoked")

    try:
        body = req.get_json()
    except Exception:
        return func.HttpResponse("Invalid JSON", status_code=400)

    if not body or "fields" not in body:
        return func.HttpResponse("JSON must contain 'fields' object", status_code=400)

    fields_input = body["fields"]
    if not isinstance(fields_input, dict):
        return func.HttpResponse("'fields' must be an object/dictionary", status_code=400)

    base_dir = os.path.dirname(__file__)
    template_path = os.path.join(base_dir, TEMPLATE_FILENAME)
    logging.info(f"Looking for template at: {template_path} (exists={os.path.exists(template_path)})")

    if not os.path.exists(template_path):
        return func.HttpResponse(f"Template not found: {template_path}", status_code=500)

    try:
        placeholders = extract_placeholders(template_path)
        logging.info(f"Placeholders found: {placeholders}")
        context = build_context(placeholders, fields_input)
        logging.info(f"Rendering template with context: { {k: (v[:40] + '...' if len(v)>40 else v) for k,v in context.items()} }")
        file_bytes = render_doc(template_path, context)
    except Exception as e:
        logging.exception("Processing error")
        return func.HttpResponse(f"Processing error: {e}", status_code=500)

    headers = {"Content-Disposition": 'attachment; filename="filled_canara_bank.docx"'}
    return func.HttpResponse(
        body=file_bytes,
        status_code=200,
        mimetype="application/vnd.openxmlformats-officedocument.wordprocessingml.document",
        headers=headers
    )
```

Figure 10: Function `fill_word_main()`: Main Azure Function HTTP endpoint that orchestrates the document filling process.