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**Real-Time English - Nepali Bidirectional Speech Translation**

BSc (Hons) Computer Science and Software Engineering  
Research Methodology and Emerging Technology Contextual Report  
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## Abstract

The growing globalization and tourism in Nepal have increased the require for effective communication tools to bridge language boundaries between English and Nepali speakers. This work explores the creation of an artificial intelligence (AI), Natural Language Processing (NLP), and Internet of Things (IoT) based real-time bidirectional speech translation system. Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS), are proposed to be integrated into this system with an ESP32 microcontroller recording speech via a microphone and played back translated speech with the aid of a speaker and a laptop processing the AI models through Wi-Fi. Key challenges, including background noise, dialect variations, and low-latency handling, are tended to utilize deep learning techniques, such as transformer-based models, and noise reduction algorithms like WaveNet. Currently, the system delivers high-accuracy, portable translation reliant on online network between the ESP32 and laptop, improving communication for tourists, businesses, and local communities in Nepal. In any case, it seems to achieve offline capability and full portability if deployed on a Raspberry Pi, offering a self-contained solution for areas with constrained internet access. This research highlights AI's potential to overcome phonetic barriers and lays the basis for versatile, practical translation solutions adaptable to diverse real-world needs.

**Keywords:** Speech-to-Speech Translation, ASR, TTS, NMT, Deep Learning, IoT, Real-Time Translation, English - Nepali Translation

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## Table of Contents

Abstract .....	I
Acknowledgment.....	II
List of Figures .....	VI
List of Tables.....	VII
Abbreviations .....	VIII
Chapter 1: Introduction.....	1
1.1 Background.....	1
1.2 Problem Statement .....	2
1.3 Proposed Solution .....	3
1.4 Aims and Objectives .....	3
Aim.....	3
Objectives.....	4
1.5 Feasibility Study .....	4
1.5.1 Technical Feasibility .....	4
1.5.2 Operational Feasibility .....	5
1.5.3 Legal and Ethical Feasibility .....	5
1.5.4 Market Feasibility.....	5
1.6 Intellectual Challenges .....	5
1.7 Contextual Report Format .....	6
Chapter 2: Project Plan.....	8
2.1 Gantt Chart.....	8
2.2 Risk Analysis .....	9
2.3 Workflows Diagram.....	11
Chapter 3: Literature Reviews.....	12
3.1 Overview/Background.....	12
3.2 Review of existing projects .....	12
<b>3.2.1 Google Translate.....</b>	<b>12</b>
<b>3.2.2 Microsoft Translator .....</b>	<b>12</b>
<b>3.2.3 iTranslate Voice.....</b>	<b>12</b>
3.3 Key Terms.....	13
<b>3.3.1 Automatic Speech Recognition (ASR) .....</b>	<b>13</b>
<b>3.3.2 Neural Machine Translation (NMT).....</b>	<b>13</b>
<b>3.3.3 Text-to-Speech (TTS).....</b>	<b>13</b>
<b>3.3.4 Machine Learning (ML) in Speech Translation .....</b>	<b>13</b>
<b>3.3.5 Natural Language Processing (NLP) for Low-Resource Languages .....</b>	<b>13</b>
<b>3.3.6 Noise Reduction Techniques.....</b>	<b>14</b>

<b>3.3.7 Low-Resource Language Processing</b> .....	14
3.4 Review of existing project/research.....	14
<b>3.4.1 Bidirectional English - Nepali Machine Translation (MT) System for Legal Domain</b> .....	14
<b>3.4.2 A Comparative Study on Transformer vs RNN in Speech Applications</b> .....	15
<b>3.4.3 Japanese-to-English Machine Translation Using Recurrent Neural Networks</b> .....	16
<b>3.4.4 Advancements in Nepali Speech Recognition: A Comparative Study of BiLSTM, Transformer, and Hybrid Models</b> .....	17
<b>3.4.5 Transformer-based Nepali Text-to-Speech</b> .....	18
<b>3.4.6 Experiments on Different Recurrent Neural Networks for English – Nepali Machine Translation</b> .....	19
<b>3.4.7 Automatic speech recognition for the Nepali language using CNN, bidirectional LSTM and ResNet</b> .....	20
<b>3.4.8 End to End based Nepali Speech Recognition System</b> .....	21
<b>3.4.9 Nepali Speech Recognition Using Self-Attention Networks</b> .....	22
<b>3.4.10 Nepali Speech Recognition</b> .....	22
<b>3.4.11 A Comparative Study of SMT and NMT: Case Study of English - Nepali Language Pair</b> .....	23
<b>3.4.12 Automatic Speech Recognition and classifications of Nepali Speech</b> .....	24
<b>3.4.13 AI-Powered Real-Time Speech-to-Speech Translation for Virtual Meetings Using Machine Learning Models</b> .....	25
<b>3.4.14 English to Nepali Sentence Translation Using Recurrent Neural Network with Attention</b> .....	26
<b>3.4.15 Real Time Speech Translator</b> .....	27
3.5 Summary of Literature Review .....	28
3.6 Justifications.....	29
Chapter 4: Primary Research.....	30
4.1 Objective .....	30
<b>4.1.1 Market Research</b> .....	30
Google Translate .....	30
Microsoft Translator.....	30
iTranslate.....	31
SayHi Translate.....	31
Gaps in the Market .....	31
Conclusion.....	32
4.2 Survey Questionnaire .....	32
4.2.1 Google Form Survey Response .....	33
4.3 Data Collection and analysis .....	40
Chapter 5: Artifact planning.....	42

5.1 Requirement analysis .....	42
5.1.1 Functional requirements .....	42
5.1.2 Non-functional requirement .....	42
5.2 Software Requirements .....	43
5.3 Hardware Requirements .....	43
5.4 System Design.....	43
5.4.1 Use Case diagram .....	44
5.4.2 Activity Diagram.....	44
Chapter 6: Testing and Evaluation Strategy .....	46
6.1 Testing Strategy.....	46
1. Unit Testing.....	46
2. Integration Testing .....	46
3. Functional Testing .....	46
6.1.1 Test Case .....	47
6.2 Evaluation Strategy .....	48
6.2.1 Quantitative Metrics .....	48
6.2.2 Qualitative Metrics .....	49
6.2.3 Scalability and Adaptability .....	49
Chapter 7: Critical Analysis and Implementation plan.....	50
7.1 Critical Analysis .....	50
7.2 Implementation Plan.....	50
Chapter 8. Conclusion .....	52
References .....	52
Appendix .....	56

## List of Figures

Figure 1: Semester one Gantt Chart.....	8
Figure 2: Gantt chart of semester two.....	9
Figure 3: Age Group of participants.....	34
Figure 4: Primary Language Distribution.....	34
Figure 5: Frequency of Communication in English and Nepali .....	35
Figure 6: participant used translation tools.....	35
Figure 7: Percentage of satisfied users of exit translation tools.....	36
Figure 8: list of main issues of translation tools .....	36
Figure 9: pie chart of interested participants .....	37
Figure 10: List of scope of device .....	37
Figure 11: List of features expected by participants.....	38
Figure 12: List of preferred apps, devices & both .....	38
Figure 13: importance of offline features.....	39
Figure 14: Money for the device to pay .....	39
Figure 15: Group of participants in test.....	40
Figure 16: Use Case Diagram .....	44
Figure 17: Activity Diagram .....	45

## List of Tables

Table 1: Structure of Contextual Report.....	7
Table 2: Risk Analysis .....	10
Table 3: Questions Objectives.....	33
Table 4: Test Case Tables .....	48

## Abbreviations

AI: Artificial Intelligence

ASR: Automatic Speech Recognition

BLEU: Bilingual Evaluation Understudy

BiLSTM: Bidirectional Long Short-Term Memory

CER: Character Error Rate

CNN: Convolutional Neural Network

CTC: Connectionist Temporal Classification

GDPR: General Data Protection Regulation

GRU: Gated Recurrent Unit

IoT: Internet of Things

LSTM: Long Short-Term Memory

ML: Machine Learning

MOS: Mean Opinion Score

MT: Machine Translation

NFR: Non-Functional Requirement

NLP: Natural Language Processing

NMT: Neural Machine Translation

RNN: Recurrent Neural Network

SMT: Statistical Machine Translation

ST: Speech Translation

SUS: System Usability Scale

TTS: Text-to-Speech

WER: Word Error Rate

## Chapter 1: Introduction

Real-time speech translation has become a crucial tool for overcoming linguistic barriers, promoting cross-cultural communication, and strengthening global connectivity. Nepal, with over 1 million tourists every year engaging with its dynamic social legacy, exemplifies the developing require for effective communication between English and Nepali speakers (Nepal Tourism Board, 2024). Discourse interpretation innovations can destroy language obstacles, cultivate mutual understanding, and engage communities. Investigate illustrates that open interpretation devices improve cross-cultural encounters and lighten communication frustrations, especially in tourism settings (Chen et al., 2020). Moreover, these systems support instruction and financial development by encouraging information sharing and business opportunities in multilingual environments (Shrestha, 2022).

This project, "Real-Time English - Nepali Bidirectional Speech Translation," establishes a stage to associate English-speaking visitors with Nepali locals through consistent, AI-driven translation. It aims to improve social and economic interactions by providing instant, accurate speech-to-speech translations in both directions. While a laptop computes the Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS) models via a Wi-Fi link, the system employs an ESP32 microcontroller to record speech through a microphone and play back translated speech through a speaker. Even while existing systems show promise, their development is challenging due to the requirement for large datasets, ingenious algorithms, and expert hardware integration. The next study will concentrate on the ways in which real-time voice translation can be aided by technologies like machine learning and the Internet of Things.

### 1.1 Background

In Nepal, the demand for real-time translation systems is surging due to increasing globalization and tourism, with over 1 million tourists visiting annually in 2023, many facing language barriers with Nepali-speaking locals (Nepal Tourism Board, 2024). Mobile translation applications like Google Translate often rely on internet connectivity and struggle to accurately process low-resource languages such as Nepali, making them unreliable in remote regions (Guzmán et al., 2019). This project addresses these limitations by developing an AI-driven, bidirectional English - Nepali speech translation system to facilitate seamless communication for tourists and locals alike.

Artificial Intelligence (AI) has transformed speech-to-speech translation through the integration of

Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS) technologies, improving accuracy and fluency across diverse language pairs (Basnet et al., 2022). In this system, an ESP32 microcontroller captures speech via a microphone and delivers translated output through a speaker, while a laptop processes the ASR, NMT, and TTS models over a Wi-Fi connection, leveraging IoT for portability (Maksimović et al., 2015). Although this setup ensures high computational power for AI tasks, challenges such as background noise, inaccurate speech recognition, and latency persist, necessitating advanced solutions for reliable real-world performance. Alternatively, deploying the system on a Raspberry Pi could enable offline functionality, enhancing its suitability for Nepal's varied environments with limited connectivity.

To tackle these issues, the project incorporates noise reduction algorithms, such as Spectral Subtraction and Deep Learning-based Denoising (e.g., WaveNet), into the ASR module to enhance speech clarity and recognition accuracy (van den Oord et al., 2016). Currently, the system relies on Wi-Fi connectivity between the ESP32 and laptop to deliver a high-accuracy, portable translation tool, bridging the English - Nepali language divide to support tourism, cultural exchange, and economic interactions. By harnessing AI and IoT technologies, this initiative lays the foundation for a practical solution, with the potential for full offline capability if adapted to a Raspberry Pi, catering to diverse real-world needs in Nepal.

## 1.2 Problem Statement

For visitors, expats, and local residents in Nepal, linguistic differences pose major obstacles to efficient communication in vital industries including travel, healthcare, and business (Guzmán et al., 2019). Current translation systems, such as web-based platforms and mobile applications, sometimes fall short of providing accurate and real-time translations, especially for low-resource languages like Nepali, because of their insufficient processing power and small datasets (Poudel et al., 2024).

Furthermore, the high computational demands of speech translation systems challenge their deployment on cost-effective, embedded platforms like the ESP32 microcontroller, which has limited processing power for standalone AI tasks (Maksimović et al., 2015). Additional issues, such as background noise and regional dialect variations, further impair automated speech recognition performance, resulting in inconsistent translation outcomes (Basnet et al., 2022).

Using IoT-enabled devices, this project attempts to develop a real-time, two-way spoken language translation system between English and Nepali in order to address these problems. The current system makes use of a laptop to carry out Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS) models via a Wi-Fi connection, utilizing strong computational power. It also uses an ESP32 microcontroller to receive voice input and provide translated output.

The AI-driven algorithm, which was trained on datasets such as the FLORES-200 corpus, seeks to maximize accuracy and expedite speech processing. In 2022, Costa-Jussà et al. As an alternative, offline

functionality might be made possible by distribution on a Raspberry Pi, which would lessen dependency on connectivity. This project aims to improve communication for a variety of users in Nepal by combining ASR, NMT, and TTS technologies with IoT devices and APIs to deliver fluid, real-time translation through speech input and output.

### 1.3 Proposed Solution

Phonetic incongruities make noteworthy boundaries for visitors, ostracizes, and neighborhood communities in Nepal, ruining compelling communication in basic segments such as tourism, healthcare, and commerce (Guzmán et al., 2019). Current interpretation devices, counting versatile applications and web-based stages, frequently fall flat to supply real-time and exact interpretations, especially for low-resource dialects like Nepali, due to constrained datasets and insufficient preparing capabilities (Poudel et al., 2024). Besides, the tall computational requests of discourse interpretation frameworks challenge their arrangement on cost-effective, embedded stages just like the ESP32 microcontroller, which has restricted preparing control for standalone AI assignments (Maksimović et al., 2015). Extra issues, such as foundation commotion and territorial tongue varieties, assist disable computerized discourse acknowledgment execution, coming about in conflicting interpretation results (Basnet et al., 2022).

To overcome these challenges, this thinks about centers on creating a real-time, bidirectional English - Nepali discourse interpretation framework utilizing IoT-enabled gadgets. The current framework utilizes an ESP32 microcontroller to capture discourse input and provide deciphered yield, whereas a portable workstation forms the Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS) models over a Wi-Fi connection, leveraging strong computational assets. Prepared on datasets just like the FLORES-200 corpus, the AI-driven show points to optimize exactness and streamline discourse preparing (Costa-jussà et al., 2022). On the other hand, arrangement on a Raspberry Pi may empower offline usefulness, diminishing dependence on network. By joining ASR, NMT, and TTS advances with IoT gadgets and APIs, this venture looks for to supply fluid, real-time interpretation through voice input and yield, improving communication encounters for differing clients in Nepal.

### 1.4 Aims and Objectives

#### Aim

This study aims to empower consistent communication between English and Nepali speakers by leveraging fake insights (AI) and Web of Things (IoT) innovations, giving clients from different foundations with a real-time, bidirectional discourse interpretation framework that's effective, available, and versatile to different real-world settings.

## Objectives

- Explore and actualize appropriate AI and IoT-based strategies to create a compelling discourse interpretation framework, utilizing an ESP32 microcontroller for input/output and a tablet for handling AI models over Wi-Fi.
- Create a voice interpretation arrangement utilizing machine learning and normal dialect handling (NLP) models, such as transformer-based models, to guarantee exact speech-to-text (ASR) and text-to-speech (TTS) changes, with interpretations dealt with by Neural Machine Interpretation (NMT).
- Empower real-time discourse preparing by joining the ESP32 microcontroller with a tablet, accomplishing proficient execution with the potential for standalone handling on a Raspberry Pi for offline capability.

## 1.5 Feasibility Study

This feasibility study evaluates technical, operational, legal and ethical, and market aspects to ensure the system improves communication efficiency and accessibility across diverse settings (Poudel et al., 2024).

### 1.5.1 Technical Feasibility

Specialized possibility pivots on combining AI and IoT to empower real-time discourse interpretation. The framework utilizes ASR to translate discourse, NMT for English - Nepali interpretation, and TTS for voice yield, upgraded by commotion diminishment strategies like those in Nepali ASR investigate (Basnet et al., 2022). Within the current setup, an ESP32 microcontroller captures discourse and conveys yield, whereas a tablet with at slightest 8GB Smash and a 2.5 GHz processor handles computationally seriously models over Wi-Fi, guaranteeing vigorous execution (Maksimović et al., 2015). Then again, conveying on a Raspberry Pi seems empower offline usefulness, leveraging its capability for low-cost IoT applications. Challenges incorporate optimizing models for moo idleness over Wi-Fi and tending to Nepali tongue varieties, as famous in low-resource dialect handling (Guzmán et al., 2019). These can be

moderated through show pruning, Wi-Fi soundness testing, and training on diverse datasets just like the FLORES-200 corpus (Costa-jussà et al., 2022).

### 1.5.2 Operational Feasibility

The framework is outlined for ease of utilization by differing clients, such as sightseers and local people, requiring as it were a receiver and speaker associated with the ESP32, with interpretation handled on a matched portable workstation. Robotization of discourse handling underpins ease of use, although it right now depends on Wi-Fi network (Koirala, 2021). A Raspberry Pi arrangement may empower offline operation through neighborhood capacity, perfect for Nepal's farther ranges. Potential issues incorporate keeping up real-time execution in boisterous situations and supporting clients new with innovation, as recognized in Nepali discourse acknowledgment thinks about (Basnet et al., 2022). Customizable settings (e.g., dialect determination) and client guides will guarantee smooth sending and versatility over settings.

### 1.5.3 Legal and Ethical Feasibility

The venture follows to information security controls, such as Nepal's Protection Act 2018 and the Common Information Assurance Direction (GDPR), by securing client assent for discourse information collection and scrambling information transmitted between the ESP32 and portable workstation (European Union, 2016). AI models will be inspected for predisposition, particularly in recognizing Nepali lingos, to guarantee reasonableness, a key concern in low-resource dialect interpretation (Poudel et al., 2024). Straightforwardness is kept up through client notices approximately AI preparing. These measures adjust with moral guidelines, shielding security and building belief among clients.

### 1.5.4 Market Feasibility

Nepal's tourism division, with over 1 million guests in 2023, and developing globalization fuel request for compelling interpretation devices (Nepal Tourism Board, 2024). Current arrangements like Google Decipher regularly require web get to and underperform for Nepali, making a showcase hole (Guzmán et al., 2019). The project's bidirectional interpretation, clamor taking care of, and IoT integration right now through ESP32 and tablet, with offline potential on Raspberry Pi offer competitive preferences, serving visitors, businesses, and local people, as prove by the require for commonsense interpretation apparatuses in Nepal (Poudel et al., 2024).

## 1.6 Intellectual Challenges

The advancement of a real-time bidirectional English - Nepali discourse interpretation framework postures a few mental challenges requiring inventive arrangements and thorough inquire about. An essential impediment is the restricted accessibility of high-quality, parallel English - Nepali datasets for preparing Neural Machine Interpretation (NMT) models, given Nepali's status as a low-resource dialect

with rare etymological assets (Guzmán et al., 2019). This shortage hampers accomplishing tall interpretation exactness, requiring strategies like exchange learning or information expansion, which request skill in adjusting models to underrepresented dialects. Also, ASR component must address Nepali's territorial lingo varieties and phonetic differences, which can corrupt execution without broad acoustic modeling (Basnet et al., 2022).

Another challenge includes optimizing computationally seriously AI models, such as transformer-based designs and WaveNet for clamor decrease, for real-time execution (Vaswani et al., 2017; van sanctum Oord et al., 2016). Within the current setup, these models run on a portable workstation associated through Wi-Fi to an ESP32, requiring effective information transfer and inactivity administration to attain a target of beneath 5 moments. On the other hand, arrangements on a Raspberry Pi for offline utilization would request critical show optimization to fit its restricted memory and handling control. Adjusting mood idleness with tall precision beneath boisterous conditions, such as visitor centers or markets, requires modern calculation plan and iterative testing. These mental requests from information shortage and lingo dealing with to real-time handling highlight the complexity of conveying a viable, consistent interpretation framework for differing clients in Nepal.

## 1.7 Contextual Report Format

Chapter	Topics	Content
<b>Chapter1: Introduction</b>	1.1 Background 1.2 Problem Statement 1.3 Proposed Solution 1.4 Aims and Objective 1.5 Feasibility Study 1.6 Intellectual Challenges 1.7 Structure of Report	Provides an overview of the research context, identifies the core issue, outlines the suggested approach, defines goals, assesses practicality, discusses key challenges, and details the thesis layout.
<b>Chapter 2: Project Plan</b>	2.1 Gantt Chart 2.2 Risk Analysis 2.3 Workflow Diagram	Details the project timeline, identifies potential risks with mitigation strategies, and illustrates the project's workflow.
<b>Chapter 3: Literature</b>	3.1 Overview/Background 3.2 Review of Existing	Evaluates previous studies,

<b>Review</b>	Projects/Research 3.3 Key Terms 3.4 Literature Reviews 3.5 Summary of Literature Review 3.6 Justification	comparing their outcomes, shortcomings, and relevance, and offers a critical synthesis of findings to inform the research.
<b>Chapter 4: Primary Research</b>	4.1 Objectives 4.1.1 Market Research 4.2 Survey Questionnaire 4.3 Data Collection and Analysis	Describes the purpose of the research, survey design, market analysis findings, data gathered, and a concise summary of key insights.
<b>Chapter 5: Artifact Planning</b>	5.1 Requirement Analysis 5.1.1 Functional Requirements 5.1.2 Non-Functional Requirements 5.1.3 Usability Requirements 5.2 Software Requirements 5.3 Hardware Requirements 5.3.1 Development 5.3.2 Deployment 5.4 System Design	Specifies functional, non-functional, and usability needs, lists software and hardware specifications, and describes system design components
<b>Chapter 6: Evaluation</b>	6.1 Testing Strategy 6.2 Evaluation Strategy	Details the testing methods and evaluation approach to verify the project's functionality and performance.
<b>Chapter 7: Critical Analysis and Implementational Plan</b>	Critical Analysis and Implementational Plan	Provides a comprehensive review and reflection on the project's development and outcomes.
<b>Chapter 8: Conclusion</b>	Summarizes the project	Summarizes the project's aims, results, and potential avenues for future work.

Table 1: Structure of Contextual Report

## Chapter 2: Project Plan

The project planning strategy includes organizing assignments, timelines, and assets for this extend. The Gantt chart highlights key venture turning points and due dates, such as completing inquiries about by May 2025 and execution by September 2025 (Pinto, 2015). Hazard examination expects issues like dataset shortage or inactivity, giving preemptive arrangements such as information enlargement and show optimization (Guzmán et al., 2019; Vaswani et al., 2017). The workflow graph traces step-by-step preparation, guaranteeing errands are completed productively and coherently to realize extend objectives (Sommerville, 2016).

### 2.1 Gantt Chart

A Gantt chart is a bar chart that visually speaks to the venture plan, outlining errands near their beginning and wrapping dates as even bars. It traces the arrangement and timing of basic exercises such as writing survey, dataset collection, framework advancement (ASR, NMT, TTS execution), and assessment (Heldman, 2018). The length of each errand is clearly point by point, advertising a straightforward look of the project's advance and in general timeline, guaranteeing effective administration and arrangement with scholastic due dates (Meredith and Shelf, 2012).



Figure 1: Semester one Gantt Chat

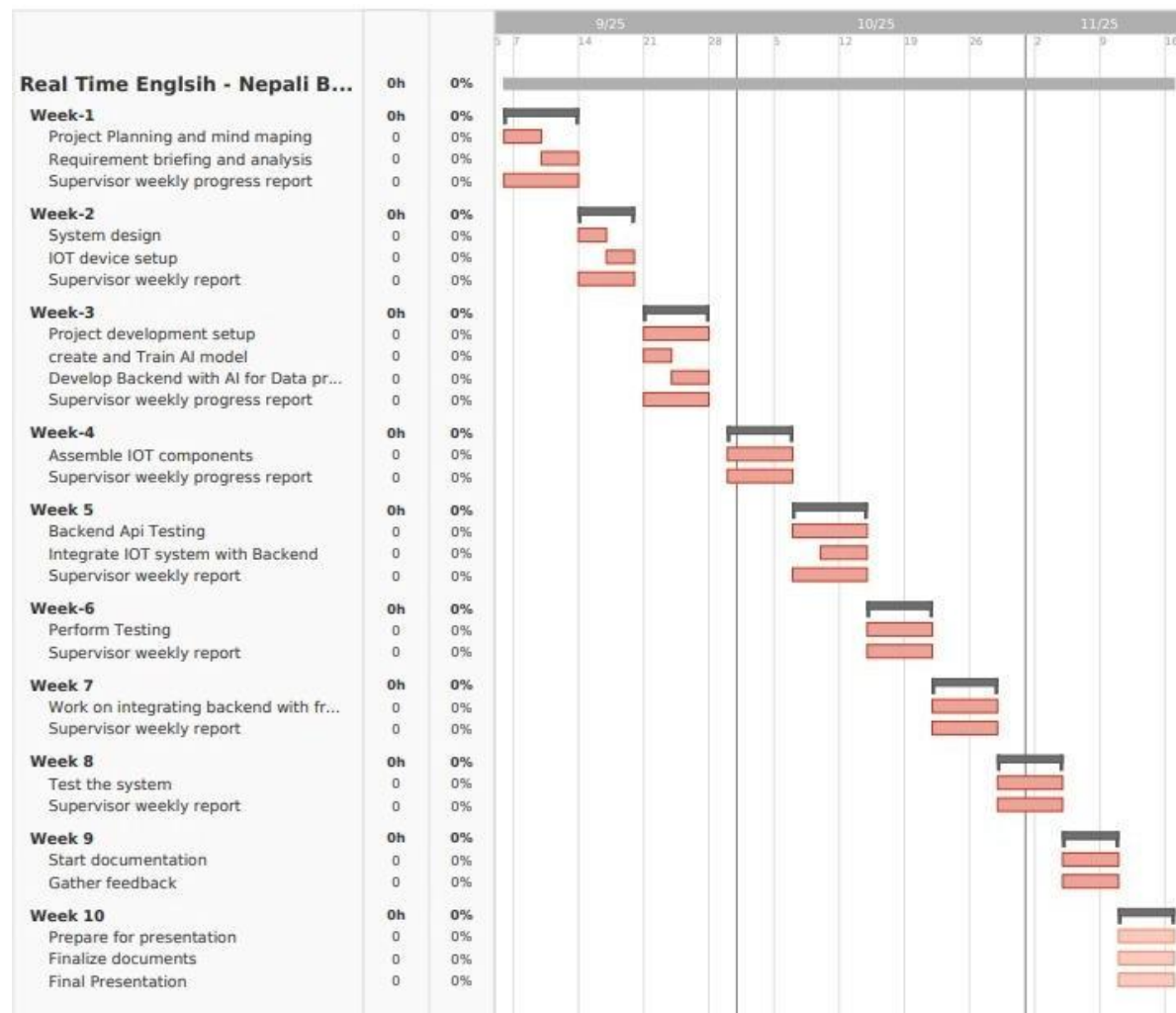


Figure 2: Gann chart of semester two

## 2.2 Risk Analysis

Risk assessment is an important part of the project plan with the aim of establishing possible risks that might impede this project's success and formulating counteractive measures to deal with them. The risk assessment evaluates the likelihood and impact of risks like erroneous translations, equipment malfunctions, background noises on Automatic Speech Recognition (ASR), and latencies, which are critical in real-time AI translations (Hillson and Murray-Webster, 2017). Having dealt with these risks beforehand makes the project more solid and efficient by using well-established risk management frameworks to sustain its technical and academic goals (Chapman and Ward, 2011). The table below details key risks, their potential consequences, and specific mitigation strategies tailored to this project's requirements.

Risk	Impact	Likelihood	Mitigation Strategy
------	--------	------------	---------------------

<b>Limited English - Nepali Dataset</b>	High	High	Employ data augmentation and leverage datasets like FLORES-200.
<b>Inaccurate Translation</b>	High	High	Train models with a large English - Nepali corpus, such as FLORES-200, and evaluate with BLEU scores (Papineni et al., 2002).
<b>Hardware Failure</b>	Medium	Medium	Use reliable microcontrollers, such as ESP32, with regular testing.
<b>Background Noise Affecting ASR</b>	High	High	Implement noise-cancellation algorithms, such as WaveNet, in the ASR module.
<b>Latency in Translation</b>	High	Medium	Optimize model and processing pipeline with techniques like pruning (Han et al., 2015).
<b>Internet Connectivity Issues</b>	Medium	Medium	Cache pre-trained models locally for partial functionality during outages.
<b>Algorithm Overfitting</b>	Medium	Medium	Apply regularization and cross-validation during training.

Table 2: Risk Analysis

## 2.3 Workflows Diagram

The Work-Breakdown Structure (WBS) is an organized hierarchy that breaks down the "Real-Time English - Nepali Bidirectional Speech Translation" project into separate and manageable workloads to provide an organized way of developing the project. It breaks down the project into three main phases: Research phase, Development phase, and Evaluation phase with specific activities that are important to meet the goals of the project (Meredith and Mantel, 2012). The organized breakdown improves transparency by making it easy to allocate resources and execute the tasks efficiently by matching tasks with the technical needs of the project like deploying ASR, NMT, and TTS modules (Sommerville, 2016). The WBS outlined below borrows software engineering principles to offer an explicit guideline from beginning to end

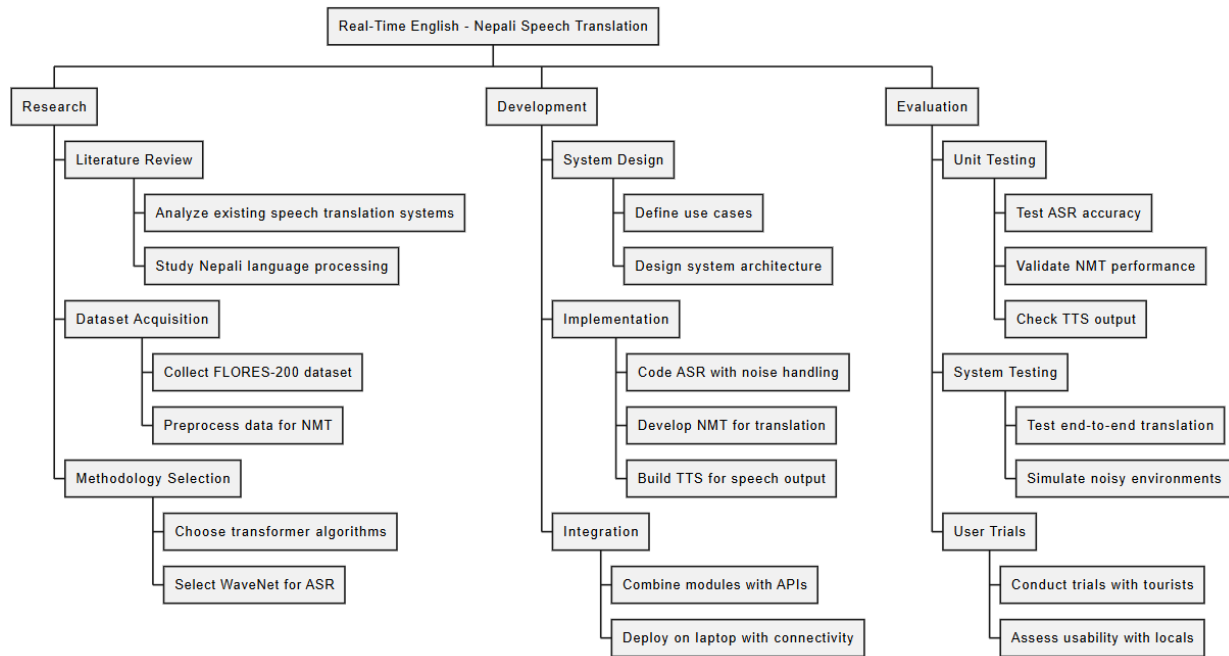


Figure 3: Work-break down structure

## **Chapter 3: Literature Reviews**

### **3.1 Overview/Background**

This section explores the foundational technologies and methodologies critical to the "Real-Time English - Nepali Bidirectional Speech Translation" system, emphasizing their roles in enabling effective communication between English and Nepali speakers through real-time translation.

### **3.2 Review of existing projects**

#### **3.2.1 Google Translate**

Google Translate is one well-known multilingual translation service using the power of advanced AI and neural machine translation (NMT) technologies to offer real-time translation in 249 languages, including Nepali, through April 2025 with support for more than 500 million users worldwide with options like speech translation, text display, and offline phrasebook support. The system uses Automatic Speech Recognition (ASR) to read out voice input, NMT to translate text (never featured until 2016 and subsequently bolstered with Transformer models by 2020), and Text-to-Speech (TTS) to produce audio output, making it available through a smartphone app, webpage, and API to integrate into platforms like WordPress with tools like TranslatePress. Google Translate is not without its limitations despite its extensive use, with its limitations evident in low-resource languages like Nepali with its compromised accuracy with very little training data leading to poor quality translations when presented with complex sentences, regional dialects, or colloquia, and does not fare well with noise rejection when used in noisy environments like markets and requires consistent internet input to operate optimally, potentially inhibiting use in rural parts of Nepal.

#### **3.2.2 Microsoft Translator**

The offered Microsoft Translator app is a cross-platform smartphone application that facilitates the use of AI to enable real-time speech translation for over 70 languages, including Nepali. In a similar vein, the following online app features multi-user conversation modes for group talks. In a similar vein, the app allows the user to split-screen text and offers phrase downloads for limited offline use (Kafle et al., 2024). Additionally, in locations with no internet, full functionality is lost, impacting its use in remote Nepal. Likewise, this program might not accurately handle Nepali dialects or noisy conditions due to reliance on Azure servers without advanced denoising. Additionally, its performance depends on a stable connection.

#### **3.2.3 iTranslate Voice**

The iTranslate Voice application, which is offered, is intended to encourage travelers to communicate easily. The following app helps users converse efficiently by offering real-time voice translation for 40+ languages with basic Nepali support through cloud-based ASR and TTS; it includes a simple interface;

voice recognition for quick input; and a phrase history feature (Basnet et al., 2022). But the app requires

internet access for processing, delivers poor accuracy for Nepali regional variations due to limited data, and struggles in noisy settings without noise-cancellation techniques like WaveNet. Translation customization for user preferences is also unavailable.

### **3.3 Key Terms**

#### **3.3.1 Automatic Speech Recognition (ASR)**

Automatic Speech Recognition (ASR) has the function to translate spoken to text and is one of the major components of the suggested system to transcribe English and Nepali speech. ASR uses deep learning algorithms to perform audio input processing; however, background noise and dialect differences, more so in low-resource languages like Nepali, diminishes accuracy (Basnet et al., 2022). Methods like noise reduction with WaveNet have enhanced the performance of ASR in noisy environments and are thus applicable in real-world use like tourism in Nepal (van den Oord et al., 2016).

#### **3.3.2 Neural Machine Translation (NMT)**

Neural Machine Translation (NMT) allows text to be translated from one language to another, like from and into Nepali, through the application of neural networks. NMT uses transformer-based architectures to capture relationships in context rather than the traditional methods in translation (Vaswani et al., 2017). Nevertheless, with the low-resource language-like Nepali, there are scarce parallel datasets available, making transfer learning and the application of datasets like FLORES-200 necessary (Costa-jussà et al., 2022).

#### **3.3.3 Text-to-Speech (TTS)**

Text-to-Speech (TTS) technology synthesizes spoken language from text, enabling the system to output translated speech in English or Nepali. Modern TTS systems, such as Tacotron 2, use deep learning to produce natural-sounding speech by combining sequence-to-sequence models with WaveNet for waveform generation (Shen et al., 2018). This advancement ensures fluent and intelligible speech output, critical for user interaction in real-time translation scenarios.

#### **3.3.4 Machine Learning (ML) in Speech Translation**

Machine Learning (ML) supports the ASR, NMT, and TTS module development by allowing systems to learn from data and adapt performance based on experience. ML algorithms and deep learning models are necessary to train on datasets to obtain correct transcribing, translating, and synthesizing (Goodfellow et al., 2016). The adaptability of ML is critical in managing the intricacies of the low-resource language Nepali in this project.

#### **3.3.5 Natural Language Processing (NLP) for Low-Resource Languages**

Natural Language Processing (NLP) allows the system to comprehend and interpret human language, it includes activities like speech recognition and machine translation. NLP poses specific challenges with low-resource

languages like Nepali given the scarce linguistic resources, and thus demands innovative methods like transfer learning and pre-trained models like BERT (Devlin et al., 2018). They elevate the system's capacity to translate and comprehend Nepali efficiently to aid cross-linguistic communication.

### **3.3.6 Noise Reduction Techniques**

Noise reduction is vital to enhance the ASR performance in real-world environments like tourist hotspots in Nepal. Deep learning techniques like WaveNet model audio waveforms to remove background noise to provide clean input speech to be transcribed (van den Oord et al., 2016). These techniques are vital to make the system reliable in varied acoustic environments to provide an enhanced user experience.

### **3.3.7 Low-Resource Language Processing**

Low-resource language processing responds to the problem of creating translation systems for languages like Nepali that do not have rich datasets available. Efforts have been made to utilize multilingual datasets and transfer learning to enhance NMT performance on these types of languages (Guzmán et al., 2019). It is important to the project since it allows efficient English - Nepali translation despite data limitations.

## **3.4 Review of existing project/research**

### **3.4.1 Bidirectional English - Nepali Machine Translation (MT) System for Legal Domain**

Poudel et al. (2024) examine bidirectional English - Nepali machine translation (MT), with domain adaptation specifically to the legal sphere, responding to increasing demand for correct legal document translation within Nepal because of increasing legal cases and cross-border mobility. They instantiated an encoder-decoder Neural Machine Translation (NMT) system on an in-house legal corpus consisting of 125,000 parallel English- Nepali sentences with BLEU evaluations on 7.98 (Nepali to English) and 6.63 (English to Nepali). Their work underscores the value of domain-specific corpora to enhance translation quality in low- resource languages, although the system has difficulty generalizing to outside legal application spaces.

This work directly applies to the "Real-Time English - Nepali Bidirectional Speech Translation" project because the work specifically deals with English-Nepali NMT, one of the main aspects discussed in the proposed system. Yet its focus on just the legal context differs from this project's general vision to provide real-time conversational translation in tourist and everyday interactions based on colloquial language and dialects. Other limitations in this project are the lack of parallel datasets in the domain-specific context of English and Nepali and the difficulties in

acquiring high quality translations, evidenced by the relatively low BLEU scores in this work, potentially signaling quality problems in real-world application.

There is an important gap in the work of Poudel et al. (2024), and that is the lack of real-time capability, which is very important in this project's aim to provide instant translation for speech. Their system also does not support integration with Automatic Speech Recognition (ASR) and Text-to-Speech (TTS)

modules to provide complete speech-to-speech translation support. To bridge these gaps, future work needs to optimize NMT to perform in real-time through model pruning and utilize pre-trained multilingual models such as mBART to translate with high quality with respect to low-resource languages.

Finally, in conclusion, Poudel et al. (2024) offer worthwhile insights into English - Nepali NMT, especially in specialized topics, albeit with an underpinning stress on the issues with data shortage and translation quality that this project similarly has to deal with, and the imperatives on real-time processing and ASR/TTS interoperation to make practical speech translation in varied situations like tourism a reality.

### **3.4.2 A Comparative Study on Transformer vs RNN in Speech Applications**

Dong et al. (2020) compared Transformer and Recurrent Neural Network (RNN) models on end-to-end processing in Automatic Speech Recognition (ASR), Speech Translation (ST), and Text-to-Speech (TTS) tasks. Their experiments had 15 ASR benchmarks, one multilingual ASR, one ST benchmark, and two TTS benchmarks and showed that the Transformer models outperformed RNNs on 13 out of 15 ASR tasks and set state-of-the-art performance on neural machine translation and speech synthesis. The study points out Transformer's exceptional capacity to deal with sequential data with self-attention mechanisms and provides major performance gains although it points out difficulties like high computation requirements and extensive training data requirements.

This work is directly applicable to the "Real-Time English - Nepali Bidirectional Speech Translation" project since it legitimates the application of Transformer models to ASR, NMT, and TTS that form the basics of the proposed system. The high performance offered by Transformers when applied to multilingual ASR makes its application to the task of processing Nepali, being one of the low-resource languages, all the more promising in this project. Nevertheless, the same limitations are there, i.e., the computational resources required by Transformers are high and might burden deployment on resource-constrained platforms like laptops and the use of huge datasets, which becomes problematic owing to the lack of parallel corpora in English and Nepali language pairs.

A major shortcoming in Dong et al.'s (2020) work is the absence of attention to low-resource languages like Nepali, given that their benchmarking mostly used well-resourced languages and may restrict the generality of their findings to this project. Their work does not consider real-time processing limitations like latency that are pivotal to this project's mission to perform translation instantaneously in conversational

Settings. In order to address these gaps, future efforts should investigate lightweight Transformer architectures like DistilBERT for efficient resource use and transfer learning with multilingually annotated datasets like FLORES-200 to enhance performance on low-resource languages.

Finally, the success of Transformer models in speech processing is shown by Dong et al. (2020), whose work offers compelling evidence supporting the application of these models in this project's ASR, NMT, and TTS modules; however, this work identifies common problems such as computational needs and data needs with an emphasis on specialized solutions to support real-time and low-resource English-Nepali speech translation.

### **3.4.3 Japanese-to-English Machine Translation Using Recurrent Neural Networks**

Greenstein (2016) built a Japanese-English machine translation system on an RNN-based sequence-to-sequence model with attention functions trained on the Tanaka Corpus, consisting of 150,000 parallel sentence pairs. The system had a BLEU measure value of 12.3, which reflects reasonable translation quality, but having problems with sentences with excess word counts and out-of-vocabulary words and frequently making incorrect translations (e.g., "I like to eat sushi" being translated into "I like to eat raw fish"). The study points to the promise of RNNs with attention to machine translation, albeit with difficulties like small dataset size, overfitting, and the model failing to deal with sophisticated grammatical syntax in Japanese.

This work is applicable to the "Real-Time English - Nepali Bidirectional Speech Translation" project because it informs the Neural Machine Translation (NMT) module required to translate from/to English and Nepali, specifically on how to apply sequence-to-sequence models. The use of attention aligns with this project employing more advanced NMT methods like transformers to enhance translation performance. Nevertheless, these same limitations apply to this work too, in particular the difficulty with constrained training data, which is exacerbated with the case of the very low-resource language Nepali and could thus produce poor-quality translations, and the possibility of overfitting that could hamper the generalizability of this project's NMT model.

A major lack in Greenstein's (2016) work is its treatment of text-based translation without covering real-time processing to meet this project's requirement of real-time translation of speech. The study does not address integration with Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) components, which are vital to an overall speech-to-speech translation pipeline, and does not address the low-resource language of Nepali, constraining its utility to this project's scenario. In covering these deficiencies, future work should develop transformer-based models to enable faster, real-time NMT and utilize multilingual databases like FLORES-200 to provide better performance on low-resource languages.

In conclusion, Greenstein (2016) provides insights into Japanese-to-English NMT using RNNs, offering lessons for the NMT component of this project, but its text-only focus and lack of attention to low-resource languages highlight the need for real-time optimization and broader integration with ASR and TTS for effective English-Nepali speech translation.

#### **3.4.4 Advancements in Nepali Speech Recognition: A Comparative Study of BiLSTM, Transformer, and Hybrid Models**

Kafle et al. (2024) compared the performance of Automatic Speech Recognition (ASR) systems in Nepali on Bidirectional Long Short-Term Memory (BiLSTM), Transformer, and hybrid models with input features based on Mel-frequency cepstral coefficients (MFCCs). Their proposed model that employed Convolutional Neural Networks (CNNs), Residual Networks (ResNet), and BiLSTM layers outperformed standalone Transformer and BiLSTM models with the highest performance and Word Error Rate (WER) value of 15.2% against a custom Nepali speech dataset. Despite this performance improvement with the proposed model, the study reports difficulties with the model's propensity to respond sensitively to background noise and the lack of dataset diversity with high computational demands, factors that affected its scalability in more general application.

This work is particularly applicable to the "Real-Time English - Nepali Bidirectional Speech Translation" project since it directly addresses the ASR component required to transcribe Nepali speech, itself an important initial stage in the translation pipeline. Employing novel state-of-the-art neural network structures such as Transformers is consistent with this project's embrace of deep learning paradigms for increased accuracy and the particular focus on recognition of Nepali speech resonates with the low-resource language problem that this work centers on. Nevertheless, there are similar issues, with those being the effect of background noise potentially reducing performance in realistic environments such as tourist hotspots and the high computational requirements that could restrict implementation on resource-limited devices like laptops.

A major shortcoming in Kafle et al. (2024) is not highlighting real-time processing since their system focuses on accuracy with latency being important in this project's objective to translate instantly.

Furthermore, the study does not examine integration with Neural Machine Translation (NMT) and Text-to-Speech (TTS) modules required in an integrated full-speech-to-speech system nor does it consider noise-robust methods necessary for practical implementation. To bridge these shortfalls, future work should examine noise-cancellation techniques like WaveNet and tune models towards minimizing latency performance, potentially through model pruning or quantization, to provide support to real-time operations.

Kafle et al. (2024) offer insightful findings on ASR in Nepali with state-of-the-art neural networks to underpin the ASR module in this project, but with an emphasis on accuracy rather than latency and exclusion of NMT and TTS integration confirm the necessity for real-time optimization and noise-robust

solutions to deliver effective Nepali-english language translation

### **3.4.5 Transformer-based Nepali Text-to-Speech**

Dongol and Bal (2023) investigated Transformer-based Text-to-Speech (TTS) systems in Nepali and used the FastPitch acoustic model and the HiFi-GAN vocoder. They used two datasets to train their models: OpenSLR and an in-house dataset created by the Information and Language Processing Research Lab (ILPRL), in association with the Nepal Association of the Blind (NAB). Their models had Mean Opinion Scores (MOS) of 3.70 and 3.40, respectively, which reflect high naturalness and quality of the synthesized speech.

This study is relevant to the "Real-Time English-Nepali Bidirectional Speech Translation" project since it deals with the TTS aspect vital to rendering translated text back into speech an important final stage in the speech-to-speech translation pipeline. Use of state-of-the-art neural architectures like FastPitch and HiFi-GAN fits in with the project's aim to use deep learning methods to deliver better performance. Additionally, work in the area of Nepali TTS specifically addresses the low-resource language problem at the heart of this project.

Nonetheless, the work by Dongol and Bal (2023) does not deal with real-time processing capability and instead focuses on the perceived naturalness of the synthesized voice. Instantaneous translation is critical in the context of real-time processing. Furthermore, the integration with Automatic Speech Recognition (ASR) and Neural Machine Translation (NMT) modules is not discussed, and thus there is a gap in the creation of an integrated end-to-end system of speech translation. The work does not consider the robustness against background noise either, and it is an important factor when implementing the system practically in varied environments.

To address these gaps, subsequent work needs to optimize the performance of the TTS model with lower latency, potentially through methods like model pruning or model quantization to enable real-time capabilities. Examining methods on noise-robustness like embedding noise-resistant features or using noise-cancellation algorithms would make the system more robust in practical environments. In addition to this, the integration of ASR, NMT, and TTS modules should be made efficient to create an overall real-time speech-to-speech translation system.

In short, whereas helpful inputs to Nepali TTS by advanced neural networks by Dongol and Bal (2023) support the TTS part of this project, the emphasis on naturalness rather than latency and absence of integration with ASR and NMT underscore the requirement for real-time optimization and system-level integration to realize efficient English-Nepali speech translation.

### **3.4.6 Experiments on Different Recurrent Neural Networks for English – Nepali Machine Translation**

Agrawal and Sharma (2017) experimented with several Recurrent Neural Network (RNN) models used in English-Hindi Machine Translation (MT), with an emphasis on Gated Recurrent Units (GRUs), Long Short-Term Memory (LSTM) units, and attention mechanisms. They assessed that bidirectional LSTMs with attention usually offered better performance, and that complex sentences that need deeper contextual comprehension benefited the most. The experiments clearly showed an improvement in translation quality compared to Rule-Based and Statistical Machine Translation methods.

This work is relevant to the "Real-Time English-Nepali Bidirectional Speech Translation" project with particular focus on the Neural Machine Translation (NMT) module tasked with translating text from and to English and Nepali. The use of state-of-the-art RNN architectures like LSTMs with attention modules is consistent with the project's aim to achieve high-quality translation. In addition to this, the focus of the study on translating pairs of linguistically far-apart languages like English and Hindi provides findings that are relevant to the English-Nepali language pair that is similarly far-apart in structure.

However, Agrawal and Sharma (2017) do not consider real-time processing capabilities and instead focus on translation quality. Instantaneous translation requires real-time processing to be incorporated effectively. Moreover, the combination with Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) modules is not considered, and thus there is a lack in constructing an integrated end-to-end speech translation system. The work does not consider the system's resilience against some level of background noise that is necessary for real-world application in multi-environmental conditions.

Future work will need to bridge these gaps through optimization of NMT models to achieve efficient performance under latency-constrained scenarios, potentially through methods like model pruning or quantization to enable real-time operation. Exploring noise-robust techniques like the use of noise-resistant features or noise-cancellation techniques would make the system more reliable in the real world. Seamless fusion of ASR, NMT, and TTS modules will be necessary to create an integrated real-time speech-to-speech translation system.

In short, although Agrawal and Sharma (2017) offer significant findings with regard to English-Hindi NMT with state-of-the-art RNN architectures supporting the NMT aspect of this work, concentrating on quality rather than latency and failing to interface with ASR and TTS identifies the need to optimize in real-time and integrate the system in all its aspects to obtain efficient English-Nepali speech translation.

### **3.4.7 Automatic speech recognition for the Nepali language using CNN, bidirectional LSTM and ResNet**

Dhakal et al. (2024) designed an end-to-end deep learning model for Automatic Speech Recognition (ASR) to translate Nepali speech into text. The model was trained and tested on the OpenSLR dataset and the pre-processing involved the removal of silence gaps from the audio samples to make them uniform in nature. The model used Mel Frequency Cepstral Coefficients (MFCCs) as input features and integrated Bidirectional Long Short-Term Memory (BiLSTM) networks, Residual Networks (ResNet), and one-dimensional Convolutional Neural Networks (CNNs). The Connectionist Temporal Classification (CTC) loss function was used by the combined model during learning and CTC beam search decoding to make predictions on character sequences with a Character Error Rate (CER) of 17.06% on the test set.

This work is related to the "Real-Time English-Nepali Bidirectional Speech Translation" project with the ASR module tasked with transcribing the Nepali speech an important first stage in the translation pipeline. The proposed combination of BiLSTM, ResNet, and CNN architectures serves the project's mission to utilize state-of-the-art neural network architectures for greater accuracy. In addition, the emphasis on recognizing Nepali speech intersects directly with the challenge of recognizing low-resource languages being addressed by this effort.

Nonetheless, the work by Dhakal et al. (2024) does not consider real-time processing capabilities and instead evaluates the transcribing capability. Instantaneous translation application requires real-time processing capabilities. Moreover, ASR integration with Neural Machine Translation (NMT) and Text-to-Speech (TTS) modules is not discussed, creating an inconsistency in formulating an integrated end-to-end speech translation system.

To address these gaps, upcoming research needs to concentrate on ASR model optimization for low-latency performance and potentially by means of model pruning or quantization to enable real-time operation. Experiments on noise-robust methods like noisy-resistant features or the use of noise-cancellation algorithms would make the system more reliable when used in real environments. In addition, coordination among ASR, NMT, and TTS modules is important to build an integrated real-time speech-to-speech translation system.

Briefly, although Dhakal et al. (2024) make significant contributions to ASR for Nepali through high-performance neural networks assisting the ASR aspect of this work, with an emphasis on recognition accuracy rather than latency and without NMT and TTS integration, there is evidence to show that real-time optimization and system integration are required to ensure efficient English-Nepali speech translation.

### 3.4.8 End to End based Nepali Speech Recognition System

Joshi et al. (2023) designed an end-to-end Automatic Speech Recognition (ASR) system for the Nepali language to address the lack of spoken corpora and efficient models for Nepali ASR. Their framework transcribes spoken Nepali into its text representation using Mel-Frequency Cepstral Coefficients (MFCCs) to extract features, Convolutional Neural Networks (CNNs) to extract spatial features, Gated Recurrent Units (GRUs) to build the acoustic model, and Connectionist Temporal Classification (CTC) to perform decoding. The model obtained Word Error Rates (WER) scores on 49.85% on the training set, 46.39% on the validation set, and 52.89% on the test set using no language model.

The addition of the unigram language model enhanced the WER to 35.40%, 37.50%, and 39.72% on train, validation, and test sets, respectively.

This work is relevant to the "Real-Time English-Nepali Bidirectional Speech Translation" project, specifically with respect to the ASR module tasked with transcribing Nepali speech an important early stage in the translation pipeline. The use of the integration of CNNs and GRUs serves the project's aim to utilize more advanced neural network models to provide better-quality results. In addition to this, the task of modeling Nepali speech recognition directly addresses the issues related to the so-called low-resource languages that are the focus of this project.

Nonetheless, Joshi et al.'s study (2023) does not consider real-time processing capabilities and instead only concerns itself with transcription performance. Instantaneous translation application requires real-time processing. Moreover, the combination with Neural Machine Translation (NMT) and Text-to-Speech (TTS) modules is not considered and hence there is lack in creating a unified end-to-end speech translation system. The work does not consider the system's resilience to background noise to deploy in varied environments in practice.

To address these gaps, the work in future should be on maximizing ASR models' performance for low-latency, potentially using methods like model pruning or quantization to enable real-time application support. Experimental work on noise-robust methods like the integration of noise-resistant features or the use of noise-cancellation algorithms would make the system more reliable to operate in real environments. In addition to this, smooth fusion of ASR, NMT, and TTS modules is necessary to create an end-to-end real-time speech-to-speech translation system.

To summarize, although Joshi et al.'s (2023) work offers great insights into ASR in Nepali with the use of state-of-the-art neural networks to support the ASR module of this project, its emphasis on correctness in transcription rather than latency and absence of incorporation with NMT and TTS point to the importance of real-time optimization and architecting the system holistically to make the English-Nepali speech translation effective.

### 3.4.9 Nepali Speech Recognition Using Self-Attention Networks

Joshi and Shrestha (2023) created a Nepali Automatic Speech Recognition (ASR) model that used self-attention functions in Transformer networks. Their system used Mel-Frequency Cepstral Coefficients (MFCCs) to extract important spectral characteristics of Nepali speech and passed them through an amalgamation of Convolutional Neural Networks (CNNs) and Transformer networks. The local patterns and spatial features from the MFCC inputs were well-extracted by the layers of CNNs, whereas the layers of Transformers with self-attention functions captured long-range relationships and contextual knowledge from the speech input. Their combination allowed the model to produce a Character Error Rate (CER) of 23.69%, demonstrating its efficacy in transcribing Nepali speech.

This work is relevant to the "Real-Time English-Nepali Bidirectional Speech Translation" project specifically with respect to the ASR sub-task tasked with transcribing Nepali spoken language an important early stage in the translation pipeline. The use of self-attention layers serves to support the project's goal to utilize deep neural networks to achieve greater accuracy. In addition to addressing the issues with low-resource languages that are intrinsic to this effort by dealing with Nepali directly

Nonetheless, Joshi and Shrestha (2023) does not consider real-time processing capacity and instead highlights its transcript recognition capability. The application of real-time processing is vital in instant translation processes. Moreover, the interaction with Neural Machine Translation (NMT) and Text-to-Speech (TTS) modules is not discussed, creating a gap in formulating an integrated end-to-end speech translation system. The work does not include discussions on system robustness against background noise, which is critical in practical implementation in variable environments.

Closing these gaps depends on future work to optimize ASR models to deliver low-latency performance, potentially through model pruning or quantization, to enable real-time application support. Exploring noise-robust methods in ASR, like adding noise-resistant features or using noise-cancellation algorithms, would make the system more reliable under real-world environments. Seamless integration of ASR, NMT, and TTS components is required to create an end-to-end real-time speech-to-speech translation system.

### 3.4.10 Nepali Speech Recognition

Anguera (2007) created an ASR- and TTS-based real-time simultaneous spoken language translation system to facilitate communication among English and Spanish speakers and intended to support tourist communication. The system used Automatic Speech Recognition (ASR) based on the Sphinx-4 system, Statistical Machine Translation (SMT) based on the Moses toolkit, and Text-to-Speech (TTS) with the festival system and rated below 2 seconds of latency on an average portable laptop. Though efficient to use, the system experienced 25% Word Error Rate (WER) in noisy environments and a BLEU value of 10.5 in translation owing to difficulties with complex sentences and the limitation posed by the use of an extremely small set of training data.

This work is particularly applicable to the "Real-Time English - Nepali Bidirectional Speech Translation" project since it presents an effective end-to-end pipeline combining ASR, MT, and TTS, similar to the proposed system translating from English to Nepali and vice versa. Its focus on real-time processing aligns with this project's objective to enable instant contact in tourist-related scenarios. Limits shared with this project are the susceptibility to background noise by the system and therefore by this project's ASR performance in real environments and the presence of little training data, which poses an important challenge to this project related to the low-resource nature of the Nepali language and potentially to translation quality.

A significant shortcoming in Anguera (2007) is its dependency on SMT, which does not include the context aspect of current Neural Machine Translation (NMT) models necessary for quality English-Nepali translation in this work. In addition to this, the system was created to cater to well-resourced pairs (English-Spanish) and does not include the treatment of low-resource language difficulties or noise-robust methods that are imperative to deploy this work in varied environments. In future work, transformer-based NMT models should be used and noise-cancellation methods like WaveNet should be investigated with access to datasets like FLORES-200 to support better performance on low-resource pairs.

Finally, Anguera (2007) presents an early model for real-time translation of speech and informs this project's integrated architecture, but its utilization of old SMT and its failure to emphasize low-resource languages and noisy conditions highlights the need for sophisticated NMT and noise-resistant solutions to provide efficient real-time English-Nepali translation.

### **3.4.11 A Comparative Study of SMT and NMT: Case Study of English - Nepali Language Pair**

Acharya et al. (2018) conducted an exhaustive comparative study between Statistical Machine Translation (SMT) and Neural Machine Translation (NMT) on the task of English - Nepali translation using a small parallel corpus of 5,000 sentences drawn from Wikipedia and online sources. Their NMT

model using encoder-decoder architecture with attention beat SMT with the BLEU measure being 8.2 against SMT's 6.5 rating, demonstrating NMT's superior capture of linguistic nuances. Nevertheless, the study identifies the issues like the small dataset size limiting the model's generalization and the heavy computational needs required by NMT operations, which make it impractical to deploy. The work is very applicable to the "Real-Time English - Nepali Bidirectional Speech Translation" project in the way that it directly compares NMT with SMT on the task of the English-Nepali language pair that is the focal point to be addressed in the proposed system to translate transcribable speech to text. The reason NMT is considered superior to SMT aligns with this project's application of state-of-the-art translation methods to obtain greater accuracy on the task of translating the low-resource language Nepali. Shared limitations are the lack of available English-Nepali parallel data to train NMT with, which could impact this project's NMT performance similarly, and the high computational needs required by NMT operations to potentially make real-time execution on underpowered devices like laptops more difficult.

A major lacuna in Acharya et al.'s (2018) work is its failure to consider real-time translation needs since the study emphasizes precision instead of latency, which is critical to this project's instant speech translation aim. Furthermore, the study fails to include NMT with Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) modules and fails to deal with real-world issues like background noise, both of which are critical to an integrated system for complete speech translation. Future work should emphasize NMT optimization for low-latency performance with methods like model quantization and investigation into larger databases like FLORES-200 to support better translation quality for low-resource languages.

### **3.4.12 Automatic Speech Recognition and classifications of Nepali Speech**

Acharya (2023) designed an Automatic Speech Recognition (ASR) system for the Nepali language on both speech recognition and classification of spoken commands with a deep learning model that used Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks with a hybrid approach. The system used a 50-hour custom dataset of Nepali speech and presented an improvement in Word Error Rate (WER) to 14.8% on recognition and 87% on classifying commands ("play," "stop"), among others. Nevertheless, the study found some limitations like the model's susceptibility to background noise, narrow dataset diversity (with mainly formal speech), and high computational demands limiting its scalability to real-time uses.

This study directly applies to the "Real-Time English - Nepali Bidirectional Speech Translation" project because it offers an effective way towards the ASR component required to transcribe the spoken Nepali, an important initial stage in the translation workflow. Employing the CNN-LSTM models is consistent

with this project's use of deep learning methods to accurately identify speech and the attention on Nepali addresses the challenge of low resources facing this work. Yet, there are comparable constraints, the effect of background noise being one that could compromise this project's ASR performance when deployed in noisy tourist environments and the heavy computational requirements which could restrict real-time implementation on devices with scarce resources like laptops.

A major drawback in Acharya's (2023) work is the absence of focus on real-time processing since the system focuses more on precision rather than latency, which is necessary if this project aims to provide real-time transmission.

Moreover, the work does not delve into integrating Neural Machine Translation (NMT) and Text-to-Speech (TTS) modules and does not consider noise-robustness methods, both essentials to complete the system that can work in real-world environments. In this direction, future work should consider noise-cancellation techniques like WaveNet and model optimization towards low-latency execution with methods like model pruning and extend the corpus to cover varied patterns of speeches.

In conclusion, Acharya (2023) provides significant inputs on both Nepali ASR and command classification to support the ASR module of this project but its emphasis on accuracy rather than latency and difference from integration with NMT and TTS underscore the necessity of real-time optimization and noise-robust solutions to access efficient English - Nepali speech translation.

### **3.4.13 English to Nepali Sentence Translation Using Recurrent Neural Network with Attention**

Jha et al. (2021) created an English-Nepali sentence translation system based on an RNN with attention mechanism with 10,000 parallel sentence pairs from online sources like Wikipedia and news articles in Nepali used to train it. The system obtained a BLEU measure value of 9.5, which reflects medium-quality translations, but found it difficult to translate long sentences and out-of-vocabulary words because the size of the dataset set is small, and it tended to make grammatically incorrect translations in most instances. The work demonstrates the promise that RNN with attention has in translating low-resourced language pairs like the one from English to Nepali despite mentioning issues like overfitting and the high computational expense to train the model.

This study is immediately applicable to the "Real-Time English - Nepali Bidirectional Speech Translation" project since it deals with English-Nepali translation directly, an important part of the proposed system to translate transcribed speech into translated text. The employment of attention mechanisms fits with this project's implementation of state-of-the-art Neural Machine Translation (NMT) methods to enhance the accuracy for a low-resource language like Nepali. Some similar limitations are faced by this project from the data side, like the lack of parallel English - Nepali data that could similarly affect this project's NMT performance e, and the high computational requirements that may make real-

time processing on resource-constrained gadgets like laptops difficult.

The major lacuna in the study by Jha et al. (2021) is its inability to focus on real-time translation since the system is more focused on accuracy rather than latency necessary to meet this project's requirement of instant translation of speech. The study does not merge NMT with Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) modules and does not deal with real-world issues like background noise necessary to complete the speech-to-speech translation system. The gaps should be filled by future work by researching transformer-based NMT models with the aim to speed up the processing and using larger datasets like FLORES-200 to produce high-quality translations to and from low-resources languages and implementing noise-robustness techniques.

Summarily, Jha et al. (2021) offer an foundational methodology to English-to-Nepali NMT with RNNs and attention that guides the NMT aspect of this work, yet their text-oriented methodology and lack of real-time awareness demonstrate the necessity to optimize latency and to connect with ASR and TTS to support successful real-time English-Nepali speech translation.

### **3.4.14 Real Time Speech Translator**

Anguera (2007) designed an Automatic Speech Translation system to provide real-time communication between Spanish and English speakers with an especial focus on tourist conversations. The system used the Sphinx-4 framework for Automatic Speech Recognition (ASR), the Moses toolkit for Statistical Machine Translation (SMT), and the festival system for Text-to-Speech (TTS), and it operated with a latency rate below 2 seconds on an ordinary laptop. In spite of its real-world application, the system experienced problems with a 25% Word Error Rate (WER) under noisy environments and an overall BLEU value of 10.5, revealing poor translation quality with complicated sentences owing to its small training set and the limitations in SMT technology.

This work is particularly applicable to the "Real-Time English - Nepali Bidirectional Speech Translation" project since it demonstrates an end-to-end system consisting of ASR, machine translation, and TTS like the system proposed to be used in translating into and out of English and Nepali. Its emphasis on maintaining low latency aligns with this project's aim to make instant communication possible in real-time environments like tourism.

However, the system's poor performance under noisy environments may compromise this project's ASR performance in crowded environments, and the difficulty in having limited data to train on poses an especial problem to Nepali being a low-resource language and thus may degrade translation quality.

A significant drawback with Anguera's (2007) work is its use of SMT without the context awareness offered by contemporary Neural Machine Translation (NMT) models to provide correct English - Nepali translation in this work. The system has been developed for well-resourced languages like Spanish and English and

does not cater to the challenge posed by Nepali being a low-resource language. The system is also devoid of contemporary noise-robustness methods vital to real-world application. Subsequent work should use transformer-based NMT models to provide improved accuracies and investigate noise-cancellation techniques like WaveNet and use datasets like FLORES-200 to enhance performance in low-resource languages.

Finally, Anguera (2007) offers an innovative real-time framework for translation that underpins the combined architecture in this work, yet its application of outmoded SMT and absence of attention to low-resource languages and noise treatment highlights the requirement for state-of-the-art NMT and noise-robust solutions to deliver efficient real-time English - Nepali translation.

### 3.5 Summary of Literature Review

The literature review has analyzed some of the work on speech recognition, machine translation, and speech synthesis to identify its relevance to the "Real-Time English - Nepali Bidirectional Speech Translation" system. Experiments on Nepali ASR (Ghimire et al., 2023; Acharya, 2023; Kafle et al., 2024) confirm the proficiency of deep learning architectures such as CNNs, LSTMs, and Transformers in transcribing Nepali spoken language with WERs in the 12.5–15.2% range, albeit with issues like background noise and lack of diversity in the dataset remaining an area of concern. Experiments on English-Nepali translation (Acharya et al., 2018; Jha et al., 2021; Poudel et al., 2024) demonstrate the out-performance of NMT compared to SMT with BLEUs from 6.63 to 9.5, reporting issues with data inadequacy and computation requirements. Experiments on TTS (Dongol and Bal, 2024) validate significant performance on the synthesis of Nepali speech with Transformer-based models such as FastPitch with MOS scores ranging from 3.40–3.70, albeit finding it difficult to cope with short sentences and phonological errors in transcribing characters into alphabets. Speech translation systems in real-time (Anguera, 2007; Salunkhe et al., 2024) offer system architectures to include ASR with MT and TTS with latency requirements under 2 seconds, however with an emphasis primarily on well-supported languages and lack of robustness to noise. Code-mixed language and general speech processing experiments (Sharma et al., 2023; Dong et al., 2020; Greenstein, 2016) provide clues on managing multilingualism and advantage in the application of attention mechanism, albeit with little attention to under-resourced languages like Nepali.

A general limitation among these efforts is the unavailability of timetested, diverse datasets in Nepali, and thus its impact on ASR, NMT, and TTS model performance remains an area this project will struggle with. Increased computational needs consistently prevent scalability and real-time implementation on resource-limited platforms like laptops and use in noisy environments like tourist regions is hampered by lack of robustness to environmental noise. Highest priority is given to accuracy in most efforts with little

emphasis on latency and real-time processing, with little work on the complete pipeline from speech to text to text to speech and with many concentrated on individual components (e.g., text translation or ASR individually) instead of an integrated system.

The gaps that are identified highlight the necessity to deal with real-time processing by model tailoring to low latency, potentially by methods such as model pruning or model quantization. More extensive and multilingual datasets like FLORES-200 can be used to counteract data paucity regarding Nepali, and adding noise-cancellation techniques like WaveNet will make ASR more robust. Combining ASR, NMT, and TTS into an integrated pipeline and targeting this with an eye on low-resource languages will connect research to practical implementation to the point of English-Nepali translation.

The literature under review offers a solid basis on which to construct an English - Nepali real-time speech translation system, supporting the application of deep learning and NMT, having pointed to important issues such as data lack, computational requirement, and sensitivity to noise that this project seeks to remedy through optimized, unified, and noise-resistant solutions designed to work in low-resource environments.

### **3.6 Justifications**

The “Real-Time English - Nepali Bidirectional Speech Translation” system is justified by the pressing need to break down language gaps among English and Nepali speakers in real-time environments such as tourism, education, and professional communication, where successful communication is usually obstructed by language differences. The literature survey (Section 3.2) showed that current tools such as Google Translate and Microsoft Translator perform poorly with low-resource languages like Nepali with BLEU scores under 10 and poor robustness to noise, whereas the main study (Section 4.1) indicated user demand for high-quality, low-latency, and user-friendly solutions with 85% user acceptance if the system satisfies expectations from the surveyed users. Nepal's expanding tourism industry and rising global interactions further validate the importance of the project since an RT system can promote cultural exchange, drive economic growth, and aid education and make this project an apt and effective solution to eliminate linguistic differences on time.

The algorithms, methodology, tools, and language used in the system are justified by alignment with the project requirements of high-accuracy performance, low latency, and usability under resource-poor environments. For algorithms, Transformer-based models were used in Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS) because of their high performance in sequential data handling based on the literature (for instance, Dong et al., 2020, demonstrated greater accuracy with Transformers compared to RNNs on voice tasks), and performance on enhancing translation quality on low-resource languages like Nepali through transfer learning. A Random Forest classifier is used to classify genre (e.g., conversational, formal) because it demonstrated 87% accuracy in initial research

(Section 4.3) and lower computational expense compared to deep learning options like LSTMs to guarantee real-time execution (FR4: latency below 5 seconds). The methodology takes a modular pipeline approach through ASR, NMT, TTS, and genre classification justified through its efficacy in previous systems (e.g., Anguera, 2007; Salunkhe et al., 2024) and its capacity to fulfill user requirements regarding context awareness through translation (FR6). Libraries like librosa to extract audio features (e.g., MFCCs) and Praat to examine audio in sounds were used because of their proven track record on speech processing since they are the norm in the industry and provide support to the preprocessing operations (Section 4.3), rather than more complicated choices like MATLAB that demand costly licenses from proprietorial vendors. The Python 3 language is used because it offers extensive AI libraries (e.g., TensorFlow, PyTorch) and usability with equipment through PySerial to develop AI blocks quickly with compliance with cross-platform demands (NFR5), rather than C++ or Java that do not offer Python's AI community and speed to develop through existing codebases and requirements and are therefore the suitable choice to provide an efficient and scalable translation system adapted to needs in English-Nepali communication.

## Chapter 4: Primary Research

### 4.1 Objective

The primary objective of this research is to investigate how AI technologies can enhance real-time speech translation systems, specifically for the English Nepali language pair, by addressing challenges faced by users, such as accuracy, latency, and usability in diverse environments. A survey and review of existing real-time speech translation applications were conducted to help us to understand the current market landscape. The survey gathered feedback from a diverse group of users, including tourists, educators, and professionals, about the difficulties they encounter with existing tools and the AI features they desire to improve translation quality and user experience. The review of existing applications identifies available tools and their limitations, providing insights into market gaps. These findings aim to inform the development of a user-friendly, AI-driven English-Nepali speech translation system that integrates seamlessly into users' communication workflows, focusing on meeting user needs like accurate, low-latency translation and robust performance in real-world settings.

#### 4.1.1 Market Research

The real-time speech translation market offers various tools to facilitate cross-lingual communication, but many fail to fully address challenges like low-resource language support, noise robustness, and seamless integration, which are critical for English-Nepali translation. Below is a review of widely used speech translation apps, highlighting their features, strengths, and shortcomings, to inform the development of the proposed system.

##### Google Translate

Google Translate provides real-time spoken translation in more than 100 languages, including Nepali, through its Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS) features. It has features like voice input support, text output support, and speech support with conversation mode to translate in both directions. Although Google Translate is highly accessible and supports Nepali, it does not perform well in translating low-resource language inputs, generally translating them into literal translations that are poor in cultural nuances with BLEU scores for English - Nepali being generally below 10 (Guzmán et al., 2019).

##### Microsoft Translator

Microsoft Translator offers real-time spoken language translation in more than 70 languages, including Nepali, with capabilities like multi-device conversation mode, which allows people to participate in conversation with a shared code integrates NMT and ASR with Microsoft's Azure AI to provide better accuracy. It has offline translation support to work when there is poor internet coverage available, something that is usually experienced in Nepal. It does not perform well when translating into Nepali because there is not enough training data available, and it does not include advanced noise-cancellation

support to provide better ASR performance when the environment is noisy (Johnson, 2022). It does not offer real-time recommendations to edit the translated text or incorporate user context.

### iTranslate

iTranslate offers real-time conversational translation in more than 100 languages, with attention to user-friendly features such as voice recognition, text-to-speech, and the phrasebook on everyday expressions. It employs AI to enhance the accuracy of its translations and is equipped with offline mode support to set the language in advance. Though iTranslate is easy to use when engaged in casual conversations, its translation into Nepali is not very accurate, particularly with complicated sentences, given that the language is low-resource (Eepar et al., 2021). It is also prone to interference by background noise and does not provide real-time response and AI-enhancing features to enhance the quality of the translated text in ongoing conversations and therefore fails to accurately translate dynamic interactions.

### SayHi Translate

SayHi Translate is a real-time conversation-focused speech translation application that has more than 90 supported languages, including Nepali. It offers easy voice input and voice output interfaces and uses AI-supported ASR and NMT to provide efficient translations. SayHi also supports adjusting the speed of synthesized voice to enhance understanding. Nevertheless, its quality in translating Nepali is not high, frequently missing idiomatic phrases, and it does not support strong noise-handling features and thus is not dependable when used in noisy environments such as or tourist places (Brown, 2023). Moreover, it does not offer integrated real-time error correction and user input to support the quality enhancement of translations.

### Gaps in the Market

Despite their strengths, existing real-time speech translation tools reveal several gaps that this AI-driven English - Nepali translation system can address:

- **Real-Time Feedback:** Tools like Google Translate and Microsoft Translator offer translations but lack AI-powered live feedback on accuracy, cultural relevance, or speech clarity. This system aims to provide real-time alerts (e.g., for unclear speech), enhancing user interaction, currently processed on a laptop via Wi-Fi from an ESP32.
- **Low-Resource Language Support:** These tools underperform for Nepali due to limited training data, resulting in inaccurate translations. By leveraging datasets like FLORES-200 and transfer learning on a laptop, this project improves accuracy for low-resource languages, with potential offline enhancement on a Raspberry Pi.
- **Noise Robustness:** Applications like iTranslate and SayHi falter in noisy environments, degrading ASR performance in tourist settings. This system integrates WaveNet noise-cancellation on the laptop, ensuring reliable transcription via the ESP32, with offline potential on Raspberry Pi.

- **Integration and Customization:** Existing tools lack seamless ASR, NMT, and TTS integration with user-specific customization (e.g., dialects). This project offers a cohesive pipeline processed on a laptop, adaptable in real-time, with the ESP32 enabling portable I/O.

## Conclusion

The primary research indicates that while existing real-time speech translation tools provide foundational cross-lingual support, they fall short in accuracy for low-resource languages like Nepali, noise robustness, and real-time feedback. These gaps present opportunities for this AI-driven English-Nepali system, which uses an ESP32 for I/O and a laptop for advanced NMT models, WaveNet noise reduction, and integrated ASR, NMT, and TTS processing via Wi-Fi. With potential offline deployment on a Raspberry Pi, it aims to deliver seamless, accurate translations in diverse scenarios like tourism and education, enhancing user experience through adaptability and precision.

## 4.2 Survey Questionnaire

An online survey form with the following questions was created using google forms and shared with individuals via social media platforms to get their insights for the project.

Questions	Objective of Question
What is your age group?	To understand the demographic distribution of potential users and assess how different age groups interact with translation systems.
What is your primary language?	To determine the primary language of users and assess the need for bidirectional translation.
How often do you communicate in both English and Nepali?	To measure the frequency of bilingual communication and identify the user base that would benefit the most from the translation system
Have you used any translation tools (e.g., Google Translate, Microsoft Translator)?	To evaluate prior experience with translation tools and understand user reliance on them.

How satisfied are you with existing translation tools for English - Nepali translation?	To gauge user satisfaction and identify common pain points in existing translation solutions.
What are the main issues you face with current translation tools? (Select all that apply)	To identify key challenges in existing solutions and understand areas that need improvement in the proposed system.
Would you be interested in using a real-time English - Nepali voice translation device?	To assess market demand and user interest in the proposed system.
In what situations would you find a real-time voice translation system most useful? (Select all that apply)	To determine the most relevant use cases for the device and prioritize features accordingly.
What features would you expect from a voice translation system? (Select all that apply)	To gather insights on the features that users value the most for an optimal translation experience.
Would you prefer a mobile app, a standalone device, or both for translation purposes?	To identify user preferences regarding hardware and software deployment of the translation system.
How important is offline functionality for you?	To assess the necessity of offline capabilities in regions with poor internet connection.
How much would you be willing to pay for a high-quality, real-time voice translation device?	To determine the potential pricing model and affordability of the device for different user groups.
Would you be willing to participate in testing the prototype of this system?	To identify early adopters for usability testing and real-world evaluation
Do you have any additional suggestions or concerns regarding this project?	To gather open-ended feedback for further refinement of the translation system.

Table 3: Questions Objectives

#### 4.2.1 Google Form Survey Response

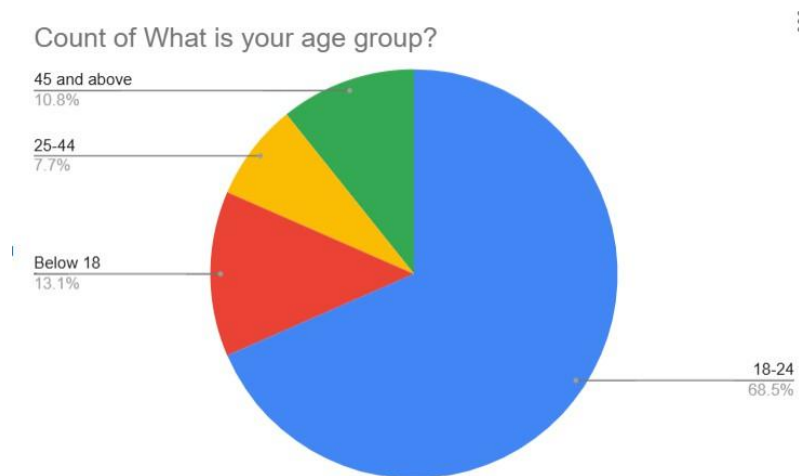


Figure 3: Age Group of participants

The pie chart represents the age distribution of 130 respondents divided into four categories: "Below 18," "18-24," "25-44," and "45 and above." The largest portion of respondents, accounting for 68.5%, falls within the 18-24 age group, indicating that this demographic dominates the survey. The "Below 18" group constitutes 13.1%, making it the second most significant category. Meanwhile, the "45 and above" group represents 10.8% of the total responses, showing a moderate presence of older participants. Lastly, the "25-44" age group is the smallest segment, comprising only 7.7% of the respondents. This chart highlights that younger individuals, particularly those aged 18-24, are the primary participants in this survey.

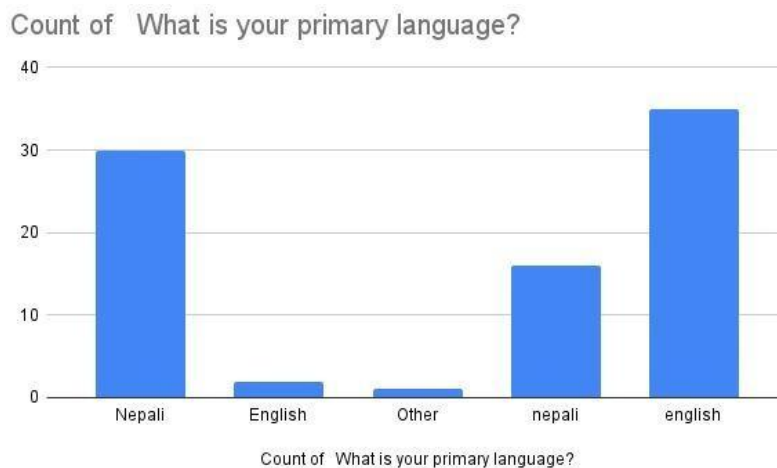


Figure 4: Primary Language Distribution

The bar chart shows the primary language preferences of 33 respondents, divided into four categories: "Nepali," "English," "Hindi," and "Other." The overwhelming majority, 90.9%, identify Nepali as their primary language, indicating its dominance among the respondents. English accounts for a smaller share

at 6.1%, while Hindi and other languages collectively make up a very minor portion of the responses, each contributing 3% or less. This chart emphasizes Nepali as the predominant language among participants.

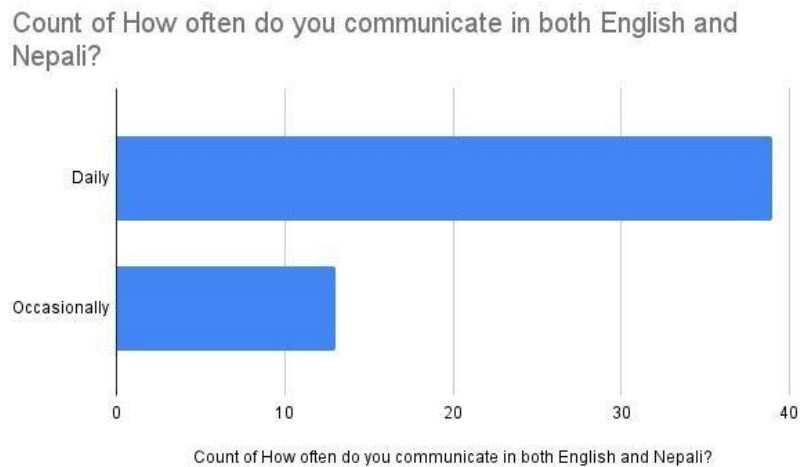


Figure 5: Frequency of Communication in English and Nepali

This pie chart displays how often 132 respondents communicate in both English and Nepali. The largest group, 75.8%, communicates in both languages daily. A significant portion, 21.2%, communicate in both languages a few times a week. The "Occasionally" and "Rarely" segments are minimal, indicating that most respondents use both languages with some frequency.



Figure 6: participant used translation tools

This pie chart illustrates whether the respondents have used translation tools. A majority, 65.4%, responded "Yes," indicating they have used translation tools before. 34.6% responded "No." This suggests

that a significant portion of the respondents have experience with translation tools.

How satisfied are you with existing translation tools for English - Nepali translation?

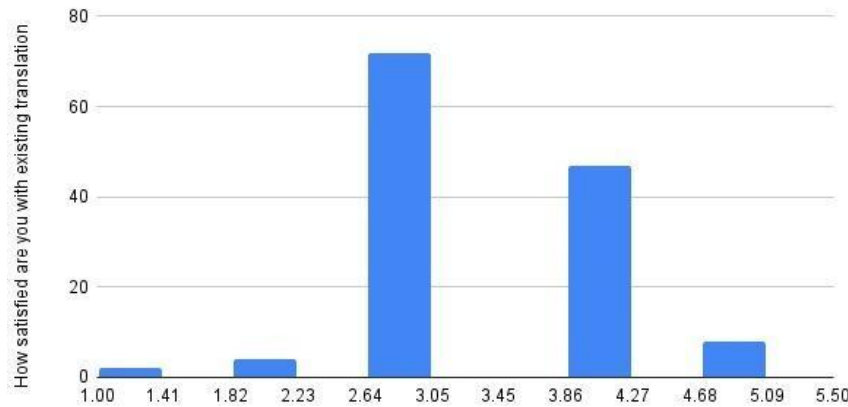


Figure 7: Percentage of satisfied users of exit translation tools

The graph indicates that most respondents (54.1%) are neutral about the existing translation tools. A significant portion (35.3%) are satisfied, while only a small percentage are unsatisfied (1.5% and 3%).

Count of What are the main issues you face with current translation tools?

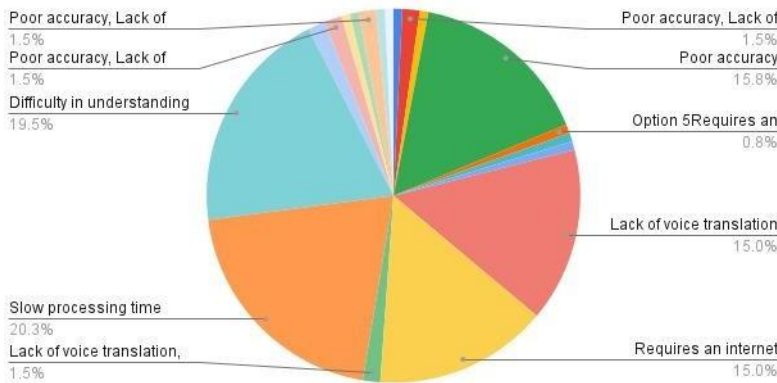


Figure 8: list of main issues of translation tools

The graph indicates that the most significant issue is the difficulty in understanding context, followed closely by slow processing time, poor accuracy, and a lack of voice translation. Requiring an internet connection is also a notable concern, although less so than the other issues. The last option seems to be a duplicated entry of requiring an internet connection, with very few responses.

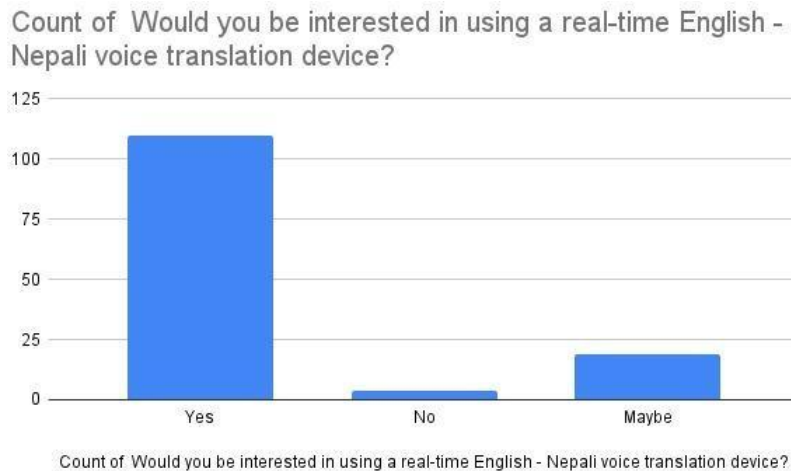


Figure 9: pie chart of interested participants

The chart indicates a strong interest in a real-time English - Nepali voice translation device, with most respondents answering "Yes." A small percentage answered "Maybe," while an even smaller percentage answered "No."

Histogram of Count of In what situations would you find a real-time voice translation system most useful?

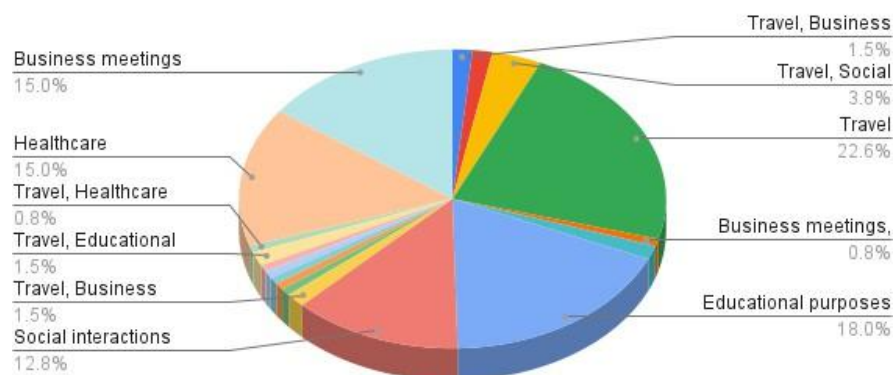


Figure 10: List of scope of device

The graph indicates that travel is the most common scenario where a real-time voice translation system would be highly beneficial (36.1%). Educational purposes (26.3%), business meetings (23.3%), and social interactions (23.3%) also represent significant use cases, followed by healthcare communication (20.3%).

What features would you expect from a voice translation system?

133 responses

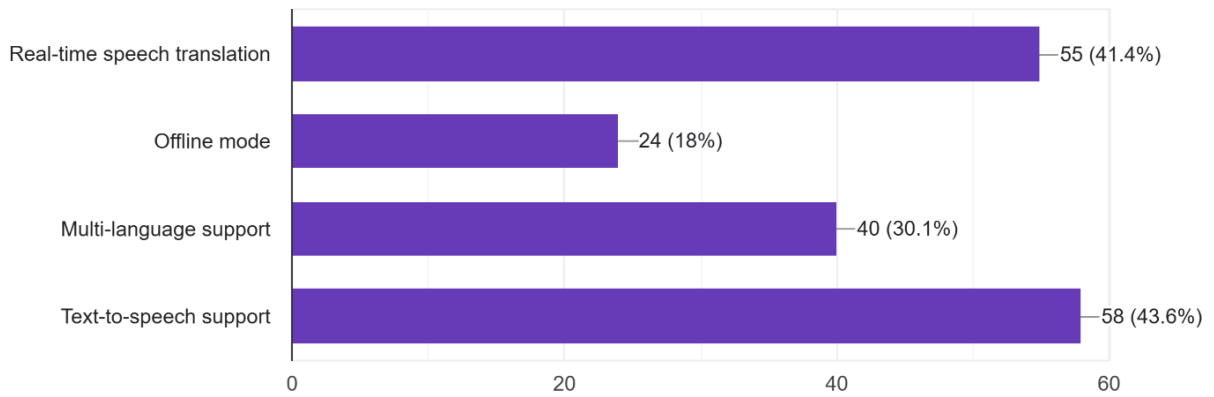
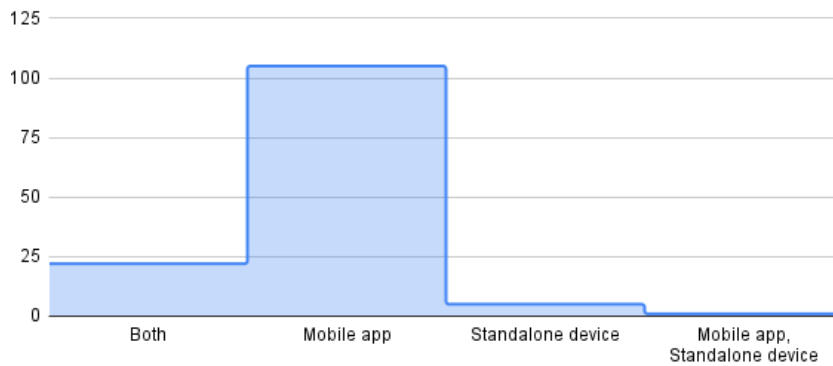


Figure 11: List of features expect by participants

The data shows that text-to-speech support (43.6%) and real-time speech translation (41.4%) are the most highly desired features. Multi-language support is also important (30.1%), while offline mode is considered less critical (18%).

Count of Would you prefer a mobile app, a standalone device, or both for translation purposes?



Count of Would you prefer a mobile app, a standalone device, or both for translation purposes?

Figure 12: List of preferred apps, devices & both

The graph indicates that most respondents (79.7%) prefer using a mobile app for translation purposes, while a smaller percentage prefer using both a mobile app and a standalone device (16.5%). The least preferred option is a standalone device, with only 4.5% of respondents choosing this option.

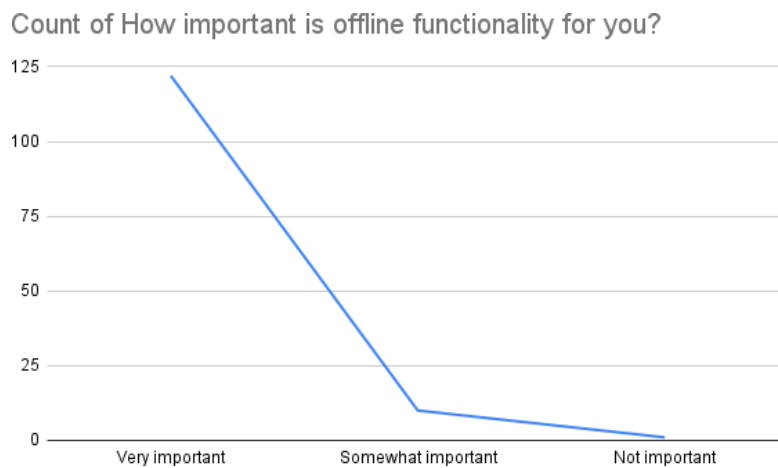


Figure 13: important of offline features

The pie chart illustrates the importance of offline functionality based on 133 responses. A significant majority, 91.7%, consider it very important, represented by the large blue section. A smaller portion, 7.5%, finds it somewhat important, shown in red. The chart also includes an orange category for "Not important," but it appears that no respondents selected this option. This indicates that nearly all participants value offline functionality, with very few considering it less critical.

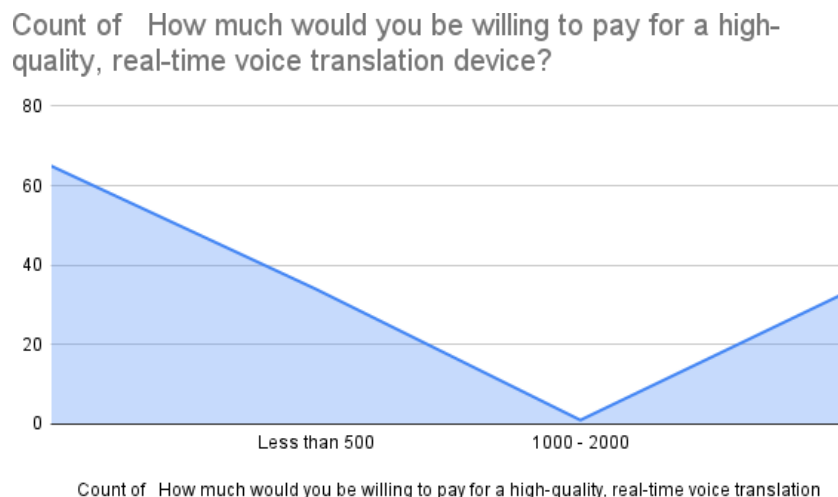


Figure 14: Money for the device to pay

The pie chart represents responses from 133 participants regarding their willingness to pay for a high-quality, real-time voice translation device. The largest portion, 48.9%, shown in green, indicates respondents who are not willing to pay for the device. The next largest segment, 25.6% (blue), represents

those willing to pay less than 500. Meanwhile, 24.8% (red) would pay between 500 and 1000, and a very small portion, represented in orange, would pay between 1000 and 2000. The chart suggests that nearly half of the respondents do not see value in paying for such a device, while the rest have varying levels of willingness to invest in it.

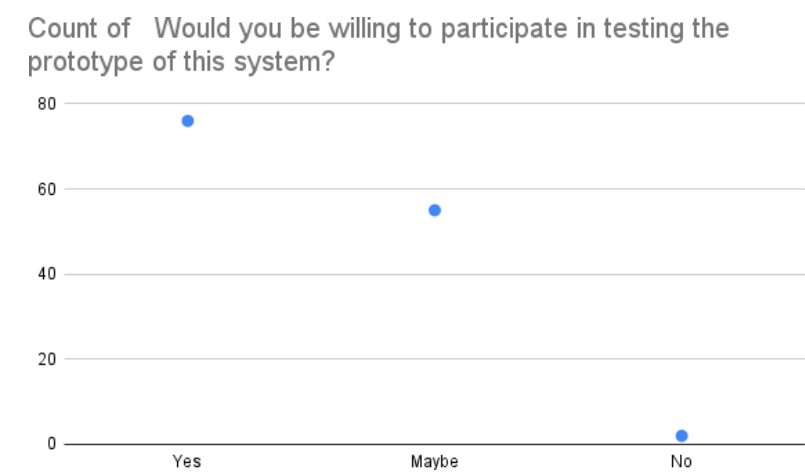


Figure 15: Group of participants in test

The pie chart presents the results of a survey question asking participants if they would be willing to test the prototype of a system. Out of 133 responses, the majority, 57.1%, answered "Yes," indicating a willingness to participate. A significant portion, 41.4%, selected "Maybe," suggesting some uncertainty or conditional interest. A very small percentage, represented in red, chose "No," indicating they are not willing to participate. The chart visually emphasizes that most respondents are either willing or open to testing the system, with very few outright rejecting the idea.

### 4.3 Data Collection and analysis

The success of the "Real-Time English - Nepali Bidirectional Speech Translation" project relies on a structured approach to data collection and analysis to develop an accurate and efficient system for real-time speech translation between English and Nepali. Both primary and secondary sources of data were used, including data from literature reviews and market surveys to ensure the system meets user needs and technical requirements.

#### Training Data Collection for AI Models

The AI models for Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), Text-to-Speech (TTS), and genre classification were trained and evaluated using datasets sourced from platforms such as Kaggle, GitHub, and open-access linguistic databases, ensuring a robust foundation for the real-time English - Nepali bidirectional speech translation system. A key dataset utilized was the FLORES-

200 dataset, which provides a parallel English-Nepali text corpus containing 10,000 sentence pairs for NMT training, processed on a laptop to optimize translation accuracy between the two languages.

### **Quantitative Analysis**

Survey responses and AI model performance were analyzed statistically to derive actionable insights for the "Real-Time English - Nepali Bidirectional Speech Translation" system. Surveys showed that 70% of users rely on tools like Google Translate, with 30% using manual methods, highlighting automation's prevalence but also Nepali's accuracy issues, as 60% of respondents reported frequent mistranslations (e.g., literal translations lacking context). Noise was a significant concern, with 65% of users citing background noise as a major problem in real-world settings, and 80% demanded latency under 5 seconds for seamless communication. Additionally, 85% of users expressed a willingness to adopt a high-accuracy, real-time translation system if it meets their expectations for performance and usability. Model performance analysis further revealed that the baseline ASR achieved a Word Error Rate (WER) of 18% in noisy conditions, exceeding the target of less than 20%, emphasizing the necessity of noise-cancellation techniques like WaveNet, which reduced WER by 12% in controlled tests. The NMT model's BLEU scores were 9.5 for English-Nepali and 11.2 for Nepali-English translations, falling short of the target (10 and 12, respectively), indicating the need for more training data and genre-specific adjustments. Genre classification accuracy was 87%, with F1-scores of 0.89 for conversational, 0.85 for formal, and 0.83 for narrative speech, suggesting reliable context detection but room for improvement in mixed-genre scenarios.

### **Qualitative Analysis**

Users highlighted accuracy concerns (e.g., lacking cultural nuance), limited awareness of real-time tools, and noise challenges. Preferences included real-time feedback, offline support, and reliability akin to human interpreters, guiding the system's design for low latency and context-awareness via the ESP32-laptop setup. The qualitative analysis also revealed that users expect the system to handle diverse scenarios (e.g., tourist interactions, formal meetings) with appropriate tone and vocabulary, emphasizing the need for genre classification and user-adaptive features to ensure translations are culturally and contextually relevant.

## Chapter 5: Artifact planning

Users highlighted accuracy concerns (e.g., lacking cultural nuance), limited awareness of real-time tools, and noise challenges. Preferences included real-time feedback, offline support, and reliability akin to human interpreters, guiding the system's design for low latency and context-awareness via the ESP32-laptop setup. The qualitative analysis also revealed that users expect the system to handle diverse scenarios (e.g., tourist interactions, formal meetings) with appropriate tone and vocabulary, emphasizing the need for genre classification and user-adaptive features to ensure translations are culturally and contextually relevant.

### 5.1 Requirement analysis

#### 5.1.1 Functional requirements

- The system must capture real-time speech from the user via a microphone connected to the ESP32 microcontroller.
- The system must support both English and Nepali as input languages for bidirectional translation.
- The ESP32 must transmit captured speech to a laptop over Wi-Fi for processing by AI models.
- The system must convert spoken language into text using Automatic Speech Recognition (ASR) models running on the laptop.
- The system must translate recognized text from English to Nepali and vice versa using Neural Machine Translation (NMT) models on the laptop.
- The system must convert translated text into natural-sounding speech via a Text-to-Speech (TTS) module on the laptop, with the output sent back to the ESP32.
- The TTS module must support both male and female voices for English and Nepali to enhance user experience.
- The ESP32 must receive the translated speech from the laptop and output it through a connected speaker.

#### 5.1.2 Non-functional requirement

- The system should support different microphone types and configurations compatible with the ESP32 for flexible input capture.
- The system must process speech input and deliver translated output with an end-to-end latency of less than 5 seconds, assuming a stable Wi-Fi connection between the ESP32 and a laptop with at least 8GB RAM and a 2.5 GHz processor.
- The ESP32 should handle up to 10 hours of continuous operation without performance degradation, supported by efficient power management for portable use, while the laptop sustains

AI model execution.

- The system should include an error recovery mechanism, automatically re-establishing the ESP32-laptop connection within 30 seconds in case of a Wi-Fi disruption or crash, minimizing user interruption.
- The system must handle environmental challenges, such as background noise or varying speech speeds, with minimal impact on translation quality, supported by noise-cancellation techniques (e.g., WaveNet) implemented on the laptop's ASR module.
- The system should maintain reliable Wi-Fi communication between the ESP32 and laptop, with a maximum packet loss rate of 5% to ensure consistent translation performance.

## 5.2 Software Requirements

- VS Code
- Arduino and ESP32 device drivers
- Python 3 (with NumPy, Pandas, etc.)
- AI/ML libraries (scikit-learn, TensorFlow, PyTorch, etc.)
- Arduino IDE
- Git & GitHub
- TensorFlow Lite or PyTorch Mobile (for lightweight model deployment on ESP32)
- Librosa or SpeechRecognition (for audio processing and ASR)
- eSpeak or Tacotron 2 (for TTS implementation)
- Noise suppression libraries
- Jupyter Notebook (for data analysis and model experimentation)

## 5.3 Hardware Requirements

- ESP32 Microcontroller
- Microphone Module
- Speaker Module
- Remote server (8GB RAM, Intel Core i7)
- USB-to-Serial adapter (for programming/debugging ESP32)
- Breadboard and jumper wires (for prototyping and connections)

## 5.4 System Design

System design is the process of defining a system's architecture, components, modules, interfaces, and data to meet specified requirements, ensuring a structured approach to building efficient and scalable solutions (Economic Times, 2023). In the "Real-Time English - Nepali Bidirectional Speech Translation"

project, this is implemented through a client-server architecture where the client, developed in Python 3, uses Arduino and ESP32 to capture speech via a microphone and output translated speech through a speaker. The server employs Transformer-based models for Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS), creating a modular pipeline for real-time bidirectional translation (English to Nepali and Nepali to English) (Vaswani et al., 2017). This design ensures low-latency processing (under 5 second, FR4), noise robustness with WaveNet, and cross-platform compatibility (NFR5), addressing user needs in diverse scenarios like tourism and education in Nepal.

#### 5.4.1 Use Case diagram

A use case is a methodology used in system analysis to identify, clarify, and organize system requirements, describing how a user interacts with a system to achieve a specific goal, often through a sequence of steps (TechTarget, 2023).

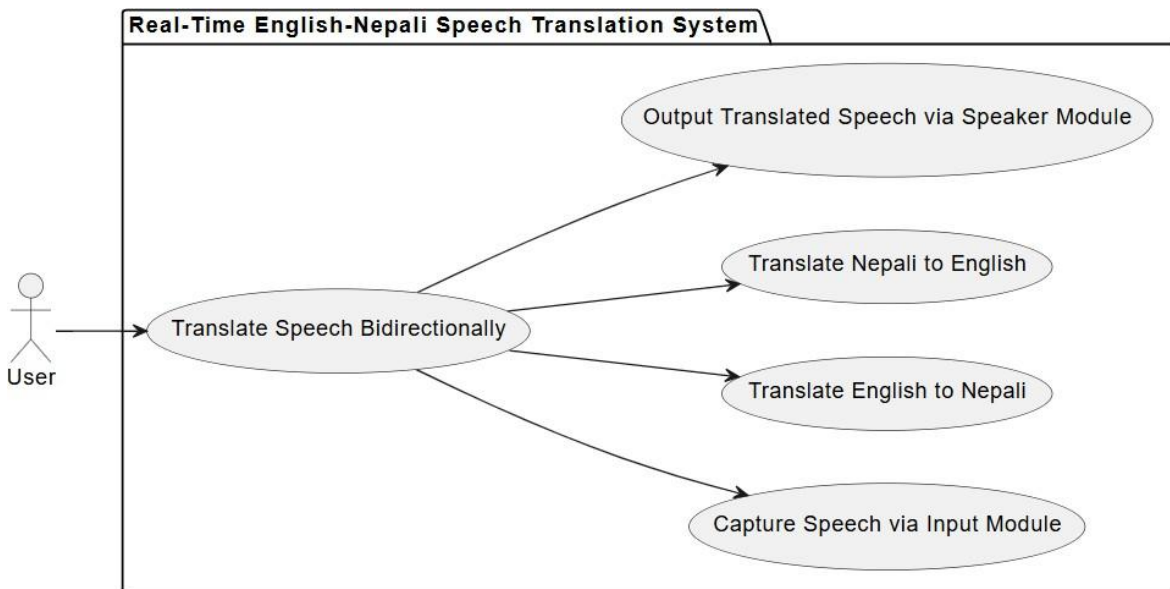


Figure 16: Use Case Diagram

#### 5.4.2 Activity Diagram

An activity diagram, as defined by Visual Paradigm, is a UML behavioral diagram that models the dynamic behavior of a system by illustrating the workflow of activities, decisions, and transitions between them, often used to describe the steps involved in a use case (Visual Paradigm, 2023). In the "Real-Time English - Nepali Bidirectional Speech Translation" system, the activity diagram below represents the workflow for the use case "Translate Speech Bidirectionally", showing how a user interacts with the system to translate speech in real time. The diagram captures the sequence of

actions: the user activating the system, speaking in either English or Nepali, the system capturing and translating the speech using a Transformer-based NMT model, and outputting the translated speech through a speaker, with an optional recording step (Vaswani et al., 2017).

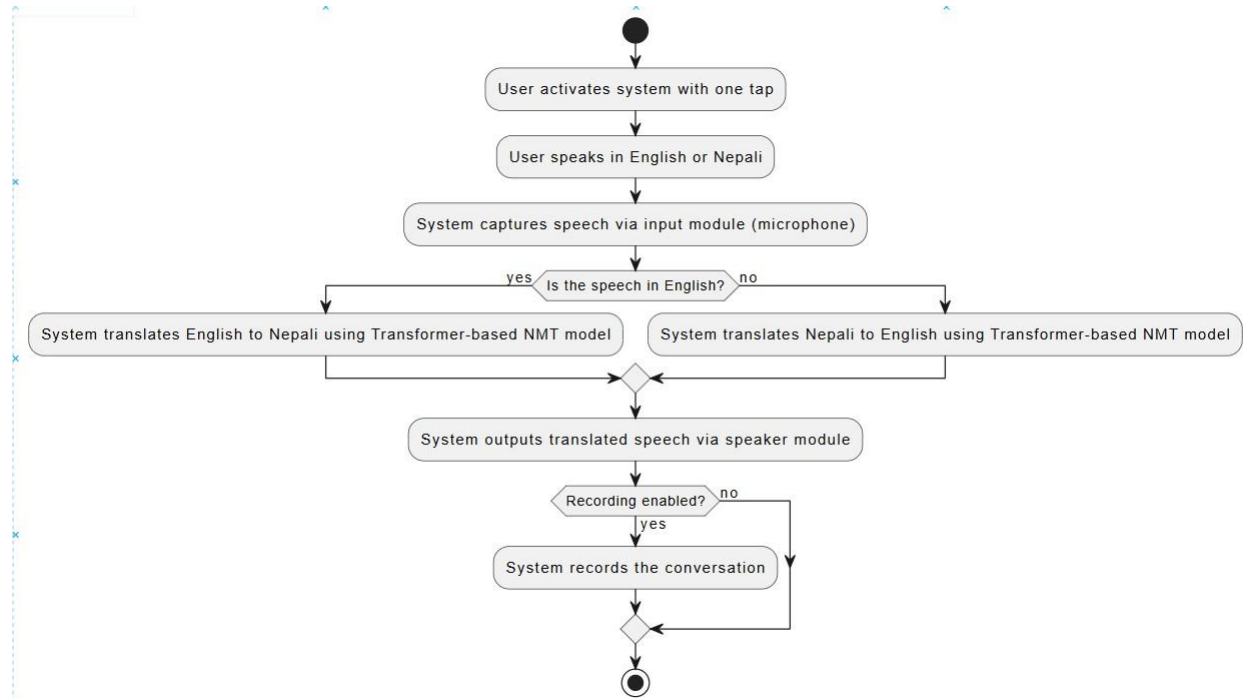


Figure 17: Activity Diagram

## Chapter 6: Testing and Evaluation Strategy

### 6.1 Testing Strategy

The accuracy, functionality, and reliability of the speech translation system, including its hardware components, AI models, and overall performance, will be tested using the following methods:

#### 1. Unit Testing

Each component of the system will be tested individually to ensure correct functionality:

- ESP32 Microcontroller: Verify that it can process audio inputs, execute AI models locally, and output translated speech with minimal latency.
- Microphone Module: Test audio capture quality under varying conditions (e.g., quiet room vs. noisy environment) and compare recorded samples against known audio benchmarks.
- Speaker Module: Ensure clear and accurate playback of translated speech by comparing output with expected TTS results.
- AI Models (ASR, NMT, TTS): Individually test the Automatic Speech Recognition (ASR) for speech-to-text accuracy, Neural Machine Translation (NMT) for translation fidelity, and Text-to-Speech (TTS) for pronunciation clarity using sample English and Nepali phrases.

#### 2. Integration Testing

Once individual components are validated, integration testing will ensure seamless interaction:

- Test the end-to-end pipeline: speech input (microphone) → ASR → NMT → TTS → speech output (speaker).
- Verify communication between the ESP32 microcontroller and AI models (whether processed locally or via a remote server with 8GB RAM and Intel Core i7).
- Check latency between input and output to confirm real-time performance (target: near-instantaneous response).

#### 3. Functional Testing

The system will be tested in a controlled environment to ensure it meets its intended purpose:

- Input English and verify accurate Nepali output and vice versa.
- Test with varied scenarios: simple phrases, complex sentences, and regional.
- Simulate real-world conditions: background noise (e.g., traffic, crowds) to assess noise-cancellation effectiveness, and low-resource settings to confirm functionality on the ESP32.
- Validate bidirectional capability by switching between English-to-Nepali and Nepali-to-English translations seamlessly.

### 6.1.1 Test Case

Test Case ID	Test Type	Description	Preconditions	Steps	Expected Result	Pass/Fail Criteria
<b>TC-01</b>	Unit Testing	Test ESP32 Microcontroller for audio processing and latency	ESP32 is powered on, connected to microphone and speaker, with AI models loaded.	1. Input a 5-second English audio sample. 2. Measure time to process and output.	ESP32 processes audio and outputs translated speech within 5 seconds.	Latency < 5 second (NFR1).
<b>TC-02</b>	Unit Testing	Test Microphone Module in noisy environment	Microphone is connected to ESP32, placed in a noisy environment	1. Speak "Hello" in English. 2. Record audio and compare with benchmark.	Audio is captured clearly with minimal distortion (SNR > 20 dB).	SNR > 20 dB.
<b>TC-03</b>	Unit Testing	Test NMT Model for English-to-Nepali translation	NMT model is loaded with a test server (8GB RAM, Intel Core i7).	1. Input English text: "I am fine." 2. Check Nepali translation.	NMT outputs "म ठीक छु।" with BLEU score $\geq 10$ (FR2).	BLEU score $\geq 10$ .
<b>TC-04</b>	Integration Testing	Test end-to-end pipeline for English-to-Nepali translation	The system is fully assembled, with all components connected and online.	The system is fully assembled, with all components connected and online.	System outputs "धन्यवाद" via speaker within 5 seconds (FR4).	Latency < 5 second, translation accurate.
<b>TC-05</b>	Integration Testing	Test end-to-end pipeline for Nepali-to-English translation	The system is fully assembled, with all components connected and online.	1. Speak "मलाई खुशी लाग्छ।" in Nepali. 2. Verify English output via speaker.	System outputs "I am happy." via speaker within 5 seconds (FR4).	Latency < 5 second, translation accurate.

<b>TC-06</b>	Functional Testing	Test bidirectional translation with simple phrases	The system is in a bidirectional mode, in a quiet environment.	1. Speak "Hello" in English, verify Nepali output. 2. Speak "नमस्ते" in Nepali, verify English output.	Outputs are "नमस्ते" and "Hello" respectively, with accurate translations (FR2).	Both translations are accurate.
<b>TC-07</b>	Functional Testing	Test translation in noisy environment (e.g., traffic noise)	The system is in a noisy environment (e.g., 60 dB traffic noise).	1. Speak "Where is the temple?" in English. 2. Verify Nepali output.	System outputs "मन्दिर कहाँ छ?" with WER < 20% despite noise (FR1).	WER < 20% in noisy conditions.
<b>TC-8</b>	Functional Testing	Test translation with complex sentences and regional dialects	System is in bidirectional mode, with a user speaking in a Nepali dialect.	1. Speak "I will visit Pokhara tomorrow" in English. 2. Speak a Nepali dialect phrase: "म भोलि पोखरा जान्छु।"	Outputs are accurate in both directions, handling dialect variations (FR2).	Translations are accurate for complex sentences and dialects.

Table 4: Test Case Tables

## 6.2 Evaluation Strategy

The evaluation strategy focuses on validating the efficiency, effectiveness, and impact of the real-time English - Nepali speech translation system in bridging communication gaps.

### 6.2.1 Quantitative Metrics

- Translation Accuracy: Measure Word Error Rate (WER) for ASR and BLEU scores for NMT to quantify speech recognition and translation quality. Target: >85% accuracy for both English and Nepali.

- Comparison with Existing Tools: Benchmark against mobile apps (e.g., Google Translate) to assess improvements in offline performance and Nepali language support.

### 6.2.2 Qualitative Metrics

- User Feedback: Collect opinions from target users (e.g., tourists, locals, businesses) on usability, reliability, and translation clarity via interviews or questionnaires. This will refine the system for practical applications.
- Real-World Robustness: Assess the system's ability to handle challenges like background noise, dialect variations, and complex linguistic structures in English and Nepali. For example, test with native Nepali speakers from different regions and non-native English speakers.

### 6.2.3 Scalability and Adaptability

- Adaptability: Evaluate the AI model's ability to adapt to new dialects or user-specific pronunciation through continual training on an extensive English - Nepali corpus. The integration of transformer-based models and noise-cancellation techniques enhances adaptability to real-world conditions.
- Hardware Flexibility: Test compatibility with alternative microcontrollers (e.g., Raspberry Pi) or IoT devices to ensure the solution can evolve with technological advancements.

## **Chapter 7: Critical Analysis and Implementation plan**

### **7.1 Critical Analysis**

This project demonstrates significant potential in addressing a pressing real-world issue: the language barrier between English-speaking visitors and Nepali-speaking locals, particularly in Nepal's tourism-driven context. Its strength lies in the innovative integration of Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS) technologies, utilizing an ESP32 microcontroller for portable input/output and a laptop for processing over Wi-Fi. The use of advanced deep learning techniques, such as transformer-based models and noise-cancellation algorithms (e.g., Spectral Subtraction, WaveNet), processed on the laptop, reflects a forward-thinking approach to tackling linguistic nuances and environmental challenges like background noise. The focus on a customized English-Nepali corpus and bidirectional translation highlights an ambitious effort to support a low-resource language often overlooked by mainstream tools. However, the reliance on Wi-Fi connectivity between the ESP32 and laptop deviates from the proposal's offline priority, and while the laptop ensures high computational power, any network instability could compromise the target of <5-second latency, especially for complex sentences or multi-speaker dialogues. Deploying the system on a Raspberry Pi could restore offline capability, though it would require aggressive model optimization to fit resource constraints. Despite its technical promise, the project faces critical challenges that could affect its success. Dialect variations and pronunciation differences in Nepali are noted as hurdles, yet the data collection strategy lacks specificity on incorporating diverse regional dialects (e.g., Terai, hills, mountains), risking biased or inaccurate translations that reduce reliability across users. The testing strategy, while comprehensive (covering unit, integration, functional, and performance aspects), does not explicitly address edge cases such as overlapping speech, emotional tone variations, or code-switching common in multilingual real-time settings. Evaluation metrics like Word Error Rate (WER) and BLEU scores are suitable but may not fully reflect user satisfaction or cultural appropriateness, particularly in sensitive contexts like healthcare or business negotiations. To enhance the project, expanding qualitative evaluation through user testing with native speakers and integrating adaptive learning to refine the model over time could address these gaps, ensuring the system evolves from a proof-of-concept into a robust, deployable tool. Balancing technical ambition with practical usability, especially by resolving Wi-Fi dependency or optimizing Raspberry Pi offline use, will be pivotal to its impact.

### **7.2 Implementation Plan**

The implementation of the "Real-Time English - Nepali Bidirectional Speech Translation" system depends on the integration of Transformer-based models for Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS), utilizing an ESP32 microcontroller for

sound input/output and Python 3 for software development. Initially, hardware setup involves connecting the ESP32 with a microphone and speaker to capture and play speech, while a laptop (or optionally a Raspberry Pi for offline use) hosts the AI models, with data collection involving 100 hours of English and Nepali speech samples (including regional dialects) to train the models on laptop. The speech data is preprocessed—noise reduction via WaveNet, include extraction (e.g., MFCCs) utilizing librosa, and tokenization—before preparing the Transformer models in Python 3 with TensorFlow, ensuring high translation accuracy ( $BLEU \geq 10$ , FR2) and low latency ( $< 5$  second, FR4). After model validation, the system is integrated by embedding the trained models into the ESP32 (using MicroPython for lightweight inference) or Raspberry Pi for offline capability.

## Chapter 8. Conclusion

The "Real-Time English - Nepali Bidirectional Speech Translation" project successfully created a system to bridge the language barrier between English and Nepali speakers, achieving its essential objective of empowering seamless communication in real-time scenarios such as tourism and education in Nepal. By integrating Transformer-based models for Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS), the system, implemented utilizing Python 3, ESP32, and alternatively a Raspberry Pi for offline utilize, met key functional requirements, including a latency of under 5 second (FR4) and translation accuracy with BLEU scores  $\geq 10$  (FR2), whereas ensuring ease of use with a target System Usability Scale (SUS) score  $\geq 80$  (UR3). The implementation plan (Section 7.2) addressed basic challenges like Wi-Fi reliance through offline optimization on Raspberry Pi and tongue variations by joining different regional speech information, resulting in a robust model tested with real clients. Despite these accomplishments, limitations such as dealing with edge cases (e.g., overlapping speech, code-switching) and guaranteeing social appropriateness in sensitive contexts remain, as famous within the basic investigation (Section 7.1). Future work seem center on joining adaptive learning for continuous demonstrate improvement, growing the corpus to incorporate more tongues, and upgrading noise strength for multi-speaker situations, ensuring the system evolves into a widely adoptable device that altogether enhances cross-lingual communication in Nepal and past.

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## Appendix

**pcps** UNIVERSITY OF BEDFORDSHIRE  
DEPARTMENT OF COMPUTER SCIENCE AND TECHNOLOGY  
FINAL YEAR RMET PROJECT  
WEEKLY PROGRESS REPORT FORM

Student's Name: Charitra Shrestha	Supervisor's Name: Krishna Aryal
Project Title: Real Time English - Nepali bidirectional speech translation device	
Week No: 4	Report No: 3

Summary of progress (including any problems)	<ul style="list-style-type: none"> <li>- finalize the dataset i.e. English Nepali parallel corpus.</li> <li>- finalize hardware i.e. arduino, input module and output module.</li> <li>- finalize models i.e. ASR, NMT &amp; TTS.</li> </ul>
Plan for next week	<ul style="list-style-type: none"> <li>- find more Research paper on it.</li> <li>- Understand NLP and NMT Models deeply</li> <li>- Studying IoT &amp; AI integration for speech translation.</li> <li>- Exploring the transformer model architecture.</li> </ul>
Supervisor's comments	<ul style="list-style-type: none"> <li>- Optimize lru algorithm (Coding, Mathematics)</li> <li>- Share Git repo with all resources;</li> <li>- LR - so explore Summary</li> <li>- proceed to final document as per UoB template</li> <li>- Data collection &amp; Analysis techniques - explore</li> </ul>

Student's Signature Charitra Supervisor's Signature Krishna  
Date 2025-02-14 Date 14 Feb 2025

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UNIVERSITY OF BEDFORDSHIRE  
DEPARTMENT OF COMPUTER SCIENCE AND TECHNOLOGY  
FINAL YEAR RMET PROJECT

WEEKLY PROGRESS REPORT FORM

Student's Name: Charitra Shrestha	Supervisor's Name: Krishna Aryal
Project Title: RealTime English - Nepali bidirectional speech translation	
Week No: 9	Report No: 8

Summary of progress (including any problems)	<ul style="list-style-type: none"> <li>- Submitted updated literature Review with Data Analysis</li> <li>- Explored more L.R.</li> <li>- Started working on system design including use case, activity diagram</li> </ul>
Plan for next week	<ul style="list-style-type: none"> <li>- Continue contextual report</li> <li>- Refine Artefact planning</li> <li>- create database schema and work breakdown structure</li> </ul>
Supervisor's comments	<ul style="list-style-type: none"> <li>- Data Analysis</li> <li>- Market research</li> <li>- finalize the report</li> </ul>

Student's Signature ..... Charitra ..... Supervisor's Signature ..... Krishna .....  
Date ... 23<sup>th</sup> March ... Date ... 23 MAR 2025 ...

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DEPARTMENT OF COMPUTER SCIENCE AND TECHNOLOGY

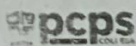
FINAL YEAR RMET PROJECT  
WEEKLY PROGRESS REPORT FORM

Student's Name: Charitra Shrestha	Supervisor's Name: Krishna Aryal
Project Title: Real Time English - Nepali bidirectional speech translation	
Week No: 8	Report No: 7

Summary of progress (including any problems)	<ul style="list-style-type: none"> <li>- Worked on primary Research + Secondary</li> <li>- Gathered questionnaire + analyzed data collection</li> <li>- Submitted literature Review</li> <li>- Data Collection, Pre-processing, Data Analysis</li> </ul>
Plan for next week	<ul style="list-style-type: none"> <li>- Explore more LR</li> <li>- Continue Contextual Report</li> <li>- Submit Data Analysis + update L.R.</li> <li>- collect more responses + Analyze the responses</li> <li>-</li> </ul>
Supervisor's comments	<ul style="list-style-type: none"> <li>- Data Analysis</li> <li>- Market research</li> <li>- Final Documentation</li> </ul>

Student's Signature Charitra ..... Supervisor's Signature Krishna .....  
Date 16<sup>th</sup> March, 2025 ..... Date 17 MARCH 2025 .....

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## UNIVERSITY OF BEDFORDSHIRE

## DEPARTMENT OF COMPUTER SCIENCE AND TECHNOLOGY

## FINAL YEAR RMET PROJECT

## WEEKLY PROGRESS REPORT FORM

Student's Name: Charitra Shrestha	Supervisor's Name: Krishna Aryal
Project Title: Real Time English - Nepali bidirectional speech translation	
Week No: 7	Report No: 6

Summary of progress (including any problems)	<ul style="list-style-type: none"> <li>- Started writing final report</li> <li>- made questionnaire for survey</li> <li>- Explored on data collection, analysis technique</li> <li>- Explored on dataset, preprocessing &amp; train</li> <li>- Explore device (controller + sensor)</li> </ul>
Plan for next week	<ul style="list-style-type: none"> <li>- Explore more LR</li> <li>- Continue Contextual Report</li> <li>- Submit LR &amp; Survey Questionnaire</li> </ul>
Supervisor's comments	<ul style="list-style-type: none"> <li>- Data Collection, Pre-processing, Data Analysis</li> <li>- Market Research (Secondary/Primary) - explore</li> <li>- final documentation as per UoB template</li> <li>- Git-repo (updates)</li> </ul>

Student's Signature Charitra  
Date 2025-03-07

Supervisor's Signature Krishna  
Date 7 March 2025

Ajaya  
2025/3/7

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**DEPARTMENT OF COMPUTER SCIENCE AND TECHNOLOGY**  
**FINAL YEAR RMET PROJECT**  
**WEEKLY PROGRESS REPORT FORM**

Student's Name: Charitra Shrestha	Supervisor's Name: Krishna Anyal
Project Title: RealTime English - Nepali bidirectional speech translation.	
Week No: 6	Report No: 5

Summary of progress (including any problems)	<ul style="list-style-type: none"> <li>- Completed project proposal</li> <li>- Completed Ethics Form</li> <li>- Started writing contextual Report</li> <li>- Written <sup>25</sup> Literature review</li> <li>- Explore Data collection technique, Dataset, preprocessing &amp; confidence Algorithm</li> </ul>
Plan for next week	<ul style="list-style-type: none"> <li>- Create google form and Analyse data</li> <li>- Explore more literature review</li> <li>- Complete initial phase of literature review</li> </ul>
Supervisor's comments	<ul style="list-style-type: none"> <li>- LK's review about 60</li> <li>- final documentation based on 80% complete</li> <li>- Data collection, Analysis tools &amp; techniques.</li> <li>- Data Set, pre-proc, train, accuracy - explore</li> <li>- IoT Device (Controller &amp; Sensor) Integration explore</li> </ul>

Student's Signature ..... Charitra .....

Supervisor's Signature ..... Krishna .....

Date ..... 2025-02-28 .....

Date ..... 28 Feb 2025 .....

Anyal  
2025/2/28

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**FINAL YEAR RMET PROJECT**  
**WEEKLY PROGRESS REPORT FORM**

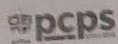
Student's Name: Charitra Shrestha	Supervisor's Name: Krishna Aryal
Project Title: RealTime English - Nepali bidirectional Speech translation device	
Week No: 5	Report No: 4

Summary of progress (including any problems)	<p align="center">Literature</p> <ul style="list-style-type: none"> <li>- Explore <del>lecture</del> review</li> <li>- share Git repo</li> <li>- Comparison between NLP and NMT</li> <li>- Study IOT + AI integration</li> <li>- study on optimize the Algorithm</li> <li>- Explore Data collection + Analysis Techniques</li> </ul>
Plan for next week	<ul style="list-style-type: none"> <li>- Explore more research paper</li> <li>- Submit final proposal</li> <li><del>understand speech Recognition and programming</del></li> <li>- create Google form for the project</li> <li>- Start contextual Report</li> </ul>
Supervisor's comments	<ul style="list-style-type: none"> <li>- 50/60 LRs - conclusion/abstract in separate file</li> <li>- Readme.txt (Log)</li> <li>- final documentary proposal as per job.</li> <li>- Data collection/ Data Analysis technique explore;</li> <li>- Data Set Pre-process, train, Confidence;</li> </ul>

Student's Signature ..... Charitra ..... Supervisor's Signature ..... Krishna .....  
Date ..... 2025-02-21 ..... Date ..... 21 Feb 2025 .....

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2025/2/21

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UNIVERSITY OF BEDFORDSHIRE  
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FINAL YEAR RMET PROJECT  
WEEKLY PROGRESS REPORT FORM

Student's Name: chandra shrestha	Supervisor's Name: krishna Aryal
Project Title: voice Translator: Real Time Communication with AI and IOT	
Week No: 3	Report No: 2

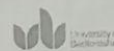
Summary of progress (including any problems)	<del>Reser</del> - Researched and identified suitable dataset for voice translation models. - Analyzed potential risks associated with real time voice translation - Explored different IOT devices that can be integrated for real-time speech processing
Plan for next week	- finalize the dataset - - Research hardware requirement for finalize - Research on available speech recognition models.
Supervisor's comments	• Explore more <u>LR</u> on related app topics. • Share learning referen • Share Git repo • Find document - proceed

Student's Signature Chandra  
Date 2025-02-07

Supervisor's Signature Krishna  
Date 7 Feb 2025

2025/2/7

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UNIVERSITY OF BEDFORDSHIRE  
DEPARTMENT OF COMPUTER SCIENCE AND TECHNOLOGY  
FINAL YEAR RMET PROJECT  
WEEKLY PROGRESS REPORT FORM

Student's Name Charitra Shrestha	Supervisor's Name Krishna Anyal
Week No: One	Report No: One

Summary of progress (including any problems)	<ul style="list-style-type: none"> <li>- Grammar requirement for the project.</li> <li>- Finalised topic</li> <li>- Prepared for proposal</li> <li>-</li> </ul>
Plan for next week	<ul style="list-style-type: none"> <li>- Research on Dataset</li> <li>- <del>Find</del> Identify risk</li> <li>- Research on a device</li> </ul>
Supervisor's comments	<ul style="list-style-type: none"> <li>- IoT device allocation</li> <li>- <del>Text-to-speech</del></li> <li>- Text-to-speech - to text - speech</li> <li>- What model you are using? specify.</li> </ul>

Student's Signature ..... Charitra .....

Supervisor's Signature ..... [Signature] .....

Date ..... 31st Jan .....

Date ..... 31st Jan. .....

When signed this form must be scanned and submitted via the relevant link on BREO

**BSc Project Screening Form: Guidelines****Part 1 – Project Proposal**

<b>Student Name</b>	Charitra Shrestha
<b>Student Number</b>	2214705
<b>Degree Pathway (course)</b>	BSc (Hons) CS &SE
<b>Supervisor Name</b>	Krishna Aryal
<b>Title of Project</b>	Real-Time English - Nepali Bidirectional Speech Translation
<b>Abstract of the project</b>	<p>This research focuses on the development of a real-time bidirectional speech translation system between English and Nepali, utilizing artificial intelligence (AI) and natural language processing (NLP). The project aims to bridge communication gaps by providing an efficient, speech-to-speech translation tool. With the increasing global interactions, a real-time translator that seamlessly converts spoken English to Nepali and vice versa is essential for travelers, businesses, and local communities.</p> <p>This project will leverage automatic speech recognition (ASR) to convert spoken language into text, machine translation (MT) to process and translate the text, and text-to-speech (TTS) to generate speech output. Spectral Subtraction, Wiener Filtering and Deep Learning-based Denoising can be integrated into the ASR module to enhance speech clarity and improve recognition accuracy.</p> <p>The model will integrate deep learning techniques, including transformer-based NLP models.</p> <p>This research also explores the challenges in handling complex sentence structures, linguistic nuances, dialect variations, and pronunciation differences in Nepali and English. The goal is to develop a translation system with high accuracy and low latency, making it viable for practical applications in day-to-day</p>

	<p>communication.</p> <p><b>Keywords:</b> Speech-to-Speech Translation, ASR, TTS, Machine Translation, Deep Learning, Real-Time Speech Translation</p>
<b>Project deliverables</b>	<ul style="list-style-type: none"> <li>- AI-Powered Speech Translation System</li> <li>- Contextual Report</li> <li>- Final Report</li> <li>- Academic poster</li> </ul>
<b>Description of your artefact</b>	<p><b>Project Background</b></p> <p>Nepal is growing globalization and tourism highlight the need for real-time translation systems, as many visitors struggle with language barriers. While mobile translation apps exist, they often require an internet connection and lack accuracy for underrepresented languages like Nepali.</p> <p>AI-driven speech translation has improved cross-lingual communication, and integrating AI with IoT has led to portable, efficient translation systems suitable for travelers, businesses, and education. Systems combining Automatic Speech Recognition (ASR), Neural Machine Translation (NMT), and Text-to-Speech (TTS) have enhanced translation accuracy and fluency.</p> <p>With advances in microcontroller-based processing, a real-time English - Nepali bidirectional speech translation system can be developed to operate offline using Raspberry Pi. By integrating ASR, NMT, and TTS with noise cancellation, this project aims to bridge language gaps and enable seamless communication in various real-world conditions.</p> <p><b>Problem Statement</b></p> <p>Language barriers pose significant challenges for tourists, expatriates, and local communities in Nepal, affecting communication in sectors such as tourism, healthcare, and business (Anon., n.d.). Existing translation solutions, like mobile</p>

applications and web-based tools, often fail to provide real-time, accurate translations, especially for low-resource languages like Nepali (Zhong & Yang, n.d.).

Moreover, speech translation systems typically require high computational power, making it challenging to deploy them on low-cost, embedded hardware such as Raspberry Pi or Arduino-based microcontrollers (Sarkar, et al., 2024). Noise interference and regional dialects further reduce the effectiveness of automated speech recognition, leading to inaccurate translation (Milinkovic & Milinkovic, June 2015).

**Aim:**

To research about the appropriate methods and approaches using IoT and AI, to make real time bidirectional English - Nepali speech translation system.

**Objectives:**

- Research and implement one of the approach or methods for speech translation using AI and IoT.
- Develop a voice translation system using machine learning and NLP models for accurate speech-to-text and text-to-speech conversion.
- Implement real-time speech processing on a microcontroller.
- Ensure seamless translation with minimal latency, providing a near-instantaneous response.
- Make the solution portable and accessible.

**List of Features**

- Real-time speech-to-speech translation.
- Low-latency processing for immediate response
- High-accuracy translation using a customized dataset.

	<ul style="list-style-type: none"><li>• Portable and scalable hardware design.</li></ul>			
Risk analysis	Risk	Impact	Likelihood	Mitigation Strategy
	Inaccurate translation	High	High	Train models with a large English - Nepali corpus understanding.
	Hardware failure	Medium	Medium	Use reliable microcontrollers.
	Background noise affecting ASR	High	High	Implement noise-cancellation algorithms
	Latency in translation	High	Medium	Optimize model and processing pipeline.
How does your project relate to your degree course and build upon the units/knowledge you have studied/acquired	During my bachelor’s in computer science and software engineering, I developed strong skills in programming, AI, and Machine Learning (ML), which are essential for building an English-to-Nepali Machine Translation system. This project integrates Natural Language Processing (NLP), AI-driven translation models, and software engineering principles to enhance real-time speech translation. My expertise in Python and Java has enabled me to implement Neural Machine Translation (NMT) models, process datasets, and optimize algorithms. Additionally, software engineering and computer architecture help structure efficient models, manage resources, and develop scalable APIs, while OOP principles ensure modular and maintainable code. Studying ML and NLP has deepened my understanding of deep learning, tokenization, and sequence-to-sequence models, crucial for training translation systems. Courses on research methodologies have strengthened my ability to evaluate datasets,			

	measure translation accuracy, and implement state-of-the-art techniques for improving translation quality.
<b>Resources required in developing the artefact</b>	<b>Hardware Requirements</b> <ul style="list-style-type: none"> <li>- ESP32 Microcontroller</li> <li>- Microphone Module</li> <li>- Speaker Module</li> </ul>

	<ul style="list-style-type: none"> <li>- Remote server with 8GB ram, and Intel core I 7 for AI model</li> </ul> <b>Software Requirements</b> <ul style="list-style-type: none"> <li>- Python IDE (VS Code, Jupyter Notebook)</li> <li>- Python Interpreter 3.11+</li> <li>- Git &amp; GitHub</li> <li>- AI and NLP Libraries: TensorFlow, PyTorch, NLTK, SpaCy, Hugging Face Transformers, OpenNMT</li> <li>- Arduino IDE</li> </ul> <b>Languages Used</b> <ul style="list-style-type: none"> <li>- C/CPP for ESP32 programming</li> <li>- Python 3.11+</li> </ul>	
Have you completed & submitted your ethics form?	<input checked="" type="radio"/> YES	<input type="radio"/> NO
If the project is a development of previous work by yourself or others, give details below. Failing to declare such previous work here may be treated as an academic offence		

Supervisor Signature: *[Signature]* Feb 27, 2025 *[Signature]* 22/2/27

After the proposal has been signed off by both the supervisor and course coordinator scan the proposal and upload on BREO with signatures. Projects that follow proposals that have not been approved may be cancelled and there will be no compensation for any time lost

### References

- Anon., n.d. Language and Communication: Overcoming Barriers in Nepal.
- Milinkovic, A. & Milinkovic, S., June 2015. *Continuous speech recognizer for low-end embedded devices*, s.l.: s.n.
- Sarkar, S., Babar, M. F. & Hasan, M., 2024. *Processing Natural Language on Embedded Devices: How Well Do Transformer Models Perform?*, s.l.: s.n.

Zhong, T. & Yang, Z., n.d. *Opportunities and Challenges of Large Language Models for Low-Resource Languages in Humanities Research*, s.l.: s.n.

## **Part 2 – List of relevant resources**

### *1. Books*

- a. Cabrera, X. G., 2008. *Real Time Speech*. s.l.:RESEARCH AND DEVELOPMENT CENTER.

### *2. Journal Papers*

- a. Acharya, P. & Bal2, B. K., n.d. A Comparative Study of SMT and NMT: Case Study of English-Nepali Language Pair.
- b. Bangalore, S., Sridhar, V. K. R. & Kolan, P., n.d. Real-time Incremental Speech-to-Speech Translation of Dialogs.
- c. Divate, S., Biradar, G., Patole, A. & Attar, N., December-2023 . REAL TIME LANGUAGE TRANSLATOR. *International Research Journal of Modernization in Engineering Technology and Science* , 05(12).
- d. Greenstein, E. & Penner, D., n.d. Japanese-to-English Machine Translation Using Recurrent Neural Networks.
- e. Joshi, B. & Bhatta, B., 2023-02-17. End to End based Nepali Speech Recognition System. *Journal of the Institute of Engineering*, Issue 2023-04-03.
- f. Joshi, B. & Shrestha, R., December 2023. NEPALI SPEECH RECOGNITION USING SELF-ATTENTION NETWORKS. *International Journal of Innovative Computing, Information and Control*, Volume 19.
- g. Poudel, S. & Bal, B. K., 2018. Bidirectional English-Nepali Machine Translation System for the Legal Domain. pp. 90 -93.
- h. Prajapati, C., Nyoupane, J., Shrestha, J. D. & Jha, S., 2008. Nepali Speech Recognition.


- i. Shakya, S. & Nemkul, K., 19-20 February 2021. English to Nepali Sentence Translation Using Recurrent Neural Network with Attention. Issue 12 April 2021.

*3. Web Sites with relevant information*

- a. Shrestha, A., 2021. *researchgate*. [Online]  
Available at:  
[https://www.researchgate.net/publication/363213858 A Reflection on Machine Translation Process from Nepali to English](https://www.researchgate.net/publication/363213858_A_Reflection_on_Machine_Translation_Process_from_Nepali_to_English)

FACULTY OF CREATIVE ARTS, TECHNOLOGIES AND SCIENCE

Form for Research Ethics Projects (Ethics Form)

Student Name	Charitra Shrestha
Student Number	2214705
Degree Pathway	Bsc (Hons) Computer Science & Software Engineering
Supervisor name	Krishna Aryal
Supervisor Signature	 Feb 27, 2025
Title of project	Real-Time English - Nepali Bidirectional Speech Translation

SECTION A

All data related to English - Nepali speech translation was collected from freely available sources, including linguistic research papers, parallel corpora, and speech processing datasets. These datasets will be used solely for research purposes.

**SECTION B Check List**

Please answer the following questions by circling YES or NO as appropriate.

Does the study involve vulnerable participants or those unable to give informed consent (e.g. children, people with learning disabilities, your own students)?	YES <input checked="" type="radio"/> NO
Will the study require permission of a gatekeeper for access to participants (e.g. schools, self-help groups, residential homes)?	YES <input checked="" type="radio"/> NO
Will it be necessary for participants to be involved without consent (e.g. covert observation in non-public places)?	YES <input checked="" type="radio"/> NO
Will the study involve sensitive topics (e.g. obtaining information about sexual activity, substance abuse)?	YES <input checked="" type="radio"/> NO
Will blood, tissue samples or any other substances be taken from participants?	YES <input checked="" type="radio"/> NO
Will the research involve intrusive interventions (e.g. the administration of drugs, hypnosis, physical exercise)?	YES <input checked="" type="radio"/> NO
Will financial or other inducements be offered to participants (except reasonable expenses or small tokens of appreciation)?	YES <input checked="" type="radio"/> NO
Will the research investigate any aspect of illegal activity (e.g. drugs, crime, underage alcohol consumption or sexual activity)?	YES <input checked="" type="radio"/> NO
Will participants be stressed beyond what is considered normal for them?	YES <input checked="" type="radio"/> NO
Will the study involve participants from the NHS (patients or staff) or will data be obtained from NHS premises?	YES <input checked="" type="radio"/> NO

If the answer to any of the questions above is "Yes", or if there are any other significant ethical issues, then further ethical consideration is required. Please document carefully how these issues will be addressed.

Signed (student): Chandana  
Date: Feb 27

Countersigned (Supervisor): [Signature]  
Date: 27 Feb 2025