

Accessible User Interface Design and Testing for People with Hearing Loss

Speech-to-ASL Conversion and 3D ASL Modeling

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ABSTRACT

This project focuses on developing an accessible user interface for individuals with hearing loss. It employs the User-Centered Design (UCD) methodology and adheres to ISO and NN/G standards. The project involves the creation of a speech-to-ASL translator, 3D modeling of ASL symbols, and integration of voice recognition into a real-time ASL representation tool. Usability testing is performed to evaluate the system's effectiveness.

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1 INTRODUCTION

Hearing loss affects millions worldwide, making communication a challenge. This project aims to bridge this communication gap using a user-centered, accessible design. By integrating speech recognition and sign language conversion, the solution enables seamless interaction for individuals with hearing impairments. The project comprises three main components: text-to-ASL conversion, speech-to-ASL conversion, and 3D modeling of ASL symbols.

2 METHODOLOGY

2.1 Text to ASL Conversion

We developed a Python-based application that maps English text to ASL symbols using image files. The implementation

uses the Tkinter library for the graphical user interface and PIL for handling image rendering.

```
1 import tkinter as tk
2 from tkinter import messagebox
3 from PIL import Image, ImageTk # For handling
   images
4
5 # Mapping dictionary for English text to ASL image
   paths
6 asl_mapping = {
7     'A': 'a.jpg', 'B': 'b.jpg', 'C': 'c.jpg',
8     'D': 'd.jpg', 'E': 'e.jpg', 'F': 'f.jpg',
9     'G': 'g.jpg', 'H': 'h.jpg', 'I': 'i.jpg',
10    'J': 'j.jpg', 'K': 'k.jpg', 'L': 'l.jpg',
11    'M': 'm.jpg', 'N': 'n.jpg', 'O': 'o.jpg',
12    'P': 'p.jpg', 'Q': 'q.jpg', 'R': 'r.jpg',
13    'S': 's.jpg', 'T': 't.jpg', 'U': 'u.jpg',
14    'V': 'v.jpg', 'W': 'w.jpg', 'X': 'x.jpg',
15    'Y': 'y.jpg', 'Z': 'z.jpg',
16    '1': '1.jpg', '2': '2.jpg', '3': '3.jpg',
17    '4': '4.jpg', '5': '5.jpg', '6': '6.jpg',
18    '7': '7.jpg', '8': '8.jpg', '9': '9.jpg',
19    '0': '0.jpg'
20 }
21
22 # Function to convert English text to ASL images
23 def text_to_asl_images(text):
24     images = []
25     for char in text.upper():
26         if char in asl_mapping:
27             try:
28                 img = Image.open(asl_mapping[char
29 ])
30                 img = img.resize((50, 50)) #
31                 # Resize image for consistency
32                 images.append(ImageTk.PhotoImage(
33                     img))
34             except Exception as e:
35                 print(f"Error loading image for '{
36                     char}': {e}")
37
38     return images
39
40 # Function to handle button click
41 def convert_text():
42     text = text_entry.get().strip()
43     if text:
44         for widget in result_frame.winfo_children
45             ():
46                 widget.destroy() # Clear previous
47                 images
48
49     asl_images = text_to_asl_images(text)
50     if asl_images:
51         for img in asl_images:
52             label = tk.Label(result_frame,
53                             image=img)
```

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```

46         label.image = img # Keep a
           reference to prevent garbage
           collection
47         label.pack(side="left", padx=2)
48     else:
49         messagebox.showwarning("Conversion
           Error", "No valid ASL symbols
           found!")
50     else:
51         messagebox.showwarning("Input Error", "
           Please enter some text!")
52
53 # Create the main application window
54 app = tk.Tk()
55 app.title("Text to ASL Converter")
56 app.geometry("600x400")
57
58 # UI Components
59 header_label = tk.Label(app, text="Text to ASL
           Converter", font=("Arial", 16, "bold"))
60 header_label.pack(pady=10)
61
62 text_label = tk.Label(app, text="Enter text to
           convert:", font=("Arial", 12))
63 text_label.pack(pady=5)
64
65 text_entry = tk.Entry(app, font=("Arial", 12),
           width=40)
66 text_entry.pack(pady=5)
67
68 convert_button = tk.Button(app, text="Convert to
           ASL", font=("Arial", 12), command=
           convert_text)
69 convert_button.pack(pady=10)
70
71 result_frame = tk.Frame(app)
72 result_frame.pack(pady=10)
73
74 # Run the application
75 app.mainloop()

```

Listing 1: Text-to-ASL Conversion Code

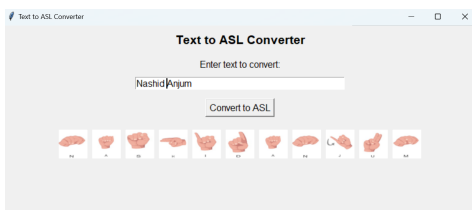


Figure 1: Text-to-ASL Conversion UI

2.2 Speech to Text Conversion

Speech recognition was implemented using the Google Speech Recognition API in Python. The application captures audio input via a microphone and transcribes it into text.

```

1 import tkinter as tk
2 from tkinter import messagebox
3 import speech_recognition as sr
4
5 # Function to handle speech-to-text conversion
6 def speech_to_text():
7     recognizer = sr.Recognizer() # Initialize the
           recognizer
8     try:
9         with sr.Microphone() as source: # Use the
           microphone as the input source

```

```

10         result_label.config(text="Listening...
           ") # Update status in the UI
11         app.update_idletasks()
12         audio = recognizer.listen(source) #
           Listen to the audio input
13         text = recognizer.recognize_google(
           audio) # Convert speech to text
14         result_label.config(text=f"Recognized
           Text: {text}") # Display the
           result
15     except sr.UnknownValueError:
16         result_label.config(text="Could not
           understand audio.")
17     except sr.RequestError as e:
18         result_label.config(text=f"Service error:
           {e}")
19     except Exception as e:
20         result_label.config(text=f"An error
           occurred: {e}")
21
22 # Create the main application window
23 app = tk.Tk()
24 app.title("Speech to Text Converter")
25 app.geometry("500x300")
26
27 # UI Components
28 header_label = tk.Label(app, text="Speech to Text
           Converter", font=("Arial", 16, "bold"))
29 header_label.pack(pady=10)
30
31 instruction_label = tk.Label(app, text="Click the
           button below and speak into the microphone.",
           font=("Arial", 12))
32 instruction_label.pack(pady=5)
33
34 record_button = tk.Button(app, text="Start
           Recording", font=("Arial", 12), command=
           speech_to_text)
35 record_button.pack(pady=10)
36
37 result_label = tk.Label(app, text="Recognized Text
           will appear here.", font=("Arial", 12),
           wraplength=450, justify="left")
38 result_label.pack(pady=20)
39
40 # Run the application
41 app.mainloop()

```

Listing 2: Speech-to-Text Conversion Code

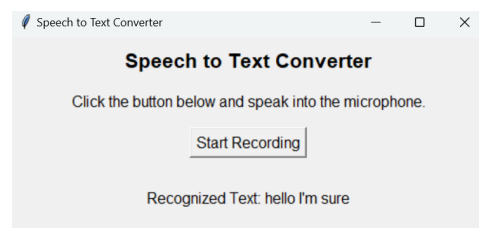


Figure 2: Speech-to-ASL Conversion UI

2.3 Speech to ASL Conversion

Speech recognition was implemented using the Google Speech Recognition API in Python. The application captures audio input via a microphone and transcribes it into ASL image.

```

1 import tkinter as tk
2 from tkinter import messagebox
3 from PIL import Image, ImageTk

```

```

4 import speech_recognition as sr
5
6 # ASL Image Mapping Dictionary
7 asl_mapping = {
8     'A': 'a.jpg', 'B': 'b.jpg', 'C': 'c.jpg',
9     'D': 'd.jpg', 'E': 'e.jpg', 'F': 'f.jpg',
10    'G': 'g.jpg', 'H': 'h.jpg', 'I': 'i.jpg',
11    'J': 'j.jpg', 'K': 'k.jpg', 'L': 'l.jpg',
12    'M': 'm.jpg', 'N': 'n.jpg', 'O': 'o.jpg',
13    'P': 'p.jpg', 'Q': 'q.jpg', 'R': 'r.jpg',
14    'S': 's.jpg', 'T': 't.jpg', 'U': 'u.jpg',
15    'V': 'v.jpg', 'W': 'w.jpg', 'X': 'x.jpg',
16    'Y': 'y.jpg', 'Z': 'z.jpg',
17    '1': '1.jpg', '2': '2.jpg', '3': '3.jpg',
18    '4': '4.jpg', '5': '5.jpg', '6': '6.jpg',
19    '7': '7.jpg', '8': '8.jpg', '9': '9.jpg',
20    '0': '0.jpg'
21 }
22
23 # Step 1: Convert Text to ASL Images
24 def text_to_asl_images(text):
25     images = []
26     for char in text.upper():
27         if char in asl_mapping:
28             try:
29                 img = Image.open(asl_mapping[char])
30                 img = img.resize((50, 50)) #
31                                     Resize images to fit in the
32                                     UI
33                 images.append(ImageTk.PhotoImage(
34                     img))
35             except Exception as e:
36                 print(f"Error loading image for '{
37                     char}': {e}")
38
39     return images
40
41 # Step 2: Convert Speech to Text
42 def speech_to_text():
43     recognizer = sr.Recognizer()
44     try:
45         with sr.Microphone() as source:
46             result_label.config(text="Listening...")
47             app.update_idletasks()
48             audio = recognizer.listen(source)
49             text = recognizer.recognize_google(
50                 audio)
51             return text
52     except sr.UnknownValueError:
53         return "Could not understand audio."
54     except sr.RequestError as e:
55         return f"Service error: {e}"
56     except Exception as e:
57         return f"An error occurred: {e}"
58
59 # Step 3: Speech to ASL Conversion
60 def speech_to_asl():
61     result_label.config(text="Processing speech...")
62     app.update_idletasks()
63     text = speech_to_text()
64     if text and not text.startswith("Could not"):
65         for widget in result_frame.winfo_children():
66             widget.destroy() # Clear previous
67                               images
68
69         asl_images = text_to_asl_images(text)
70         if asl_images:
71             for img in asl_images:
72                 label = tk.Label(result_frame,
73                                 image=img)
74                 label.image = img # Keep
75                                 reference to avoid garbage
76                                 collection

```

```

67         label.pack(side="left", padx=2)
68     else:
69         result_label.config(text="No valid ASL
70                               symbols found!")
71     else:
72         result_label.config(text=text)
73
74 # Create the main application window
75 app = tk.Tk()
76 app.title("Speech to ASL Converter")
77 app.geometry("800x400")
78
79 # UI Components
80 header_label = tk.Label(app, text="Speech to ASL
81                           Converter", font=("Arial", 16, "bold"))
82 header_label.pack(pady=10)
83
84 instruction_label = tk.Label(app, text="Click the
85                                   button below to speak.", font=("Arial", 12))
86 instruction_label.pack(pady=5)
87
88 convert_button = tk.Button(app, text="Start Speech
89                               to ASL", font=("Arial", 12), command=
90                               speech_to_asl)
91 convert_button.pack(pady=10)
92
93 result_frame = tk.Frame(app)
94 result_frame.pack(pady=20)
95
96 result_label = tk.Label(app, text="ASL Translation
97                                   will appear here.", font=("Arial", 12),
98                                   wraplength=500, justify="left")
99 result_label.pack(pady=10)
100
101 # Run the application
102 app.mainloop()

```

Listing 3: Speech-to-Text Conversion Code

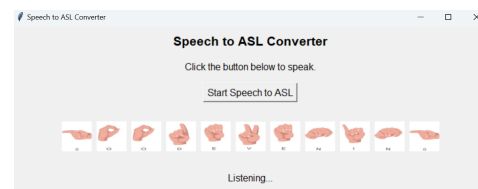


Figure 3: Speech-to-ASL Conversion UI

PART II: SIGN LANGUAGE 3D MODELING

2.4 Step 1: 3D Modeling

3D models of ASL numbers 0 to 9 were created using Blender. Below is a snippet of Python code used for modeling in Blender.



Figure 4: 3D Model of ASL Number '0'

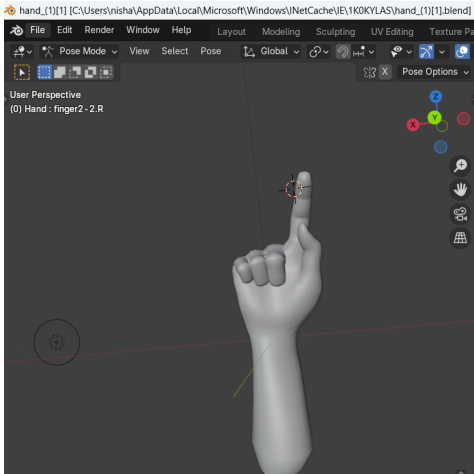


Figure 5: 3D Model of ASL Number '1'

2.5 Step 2: 3D ASL Translator

Integration of 3D models with Unity was done to translate numbers into ASL representations. Below is a Unity C script used for mapping input numbers to 3D ASL models.

```
1 import tkinter as tk
2 from tkinter import messagebox
3 from PIL import Image, ImageTk # For handling
  images
4
5 # Mapping dictionary for English text to ASL image
  paths
6 asl_mapping = {
```

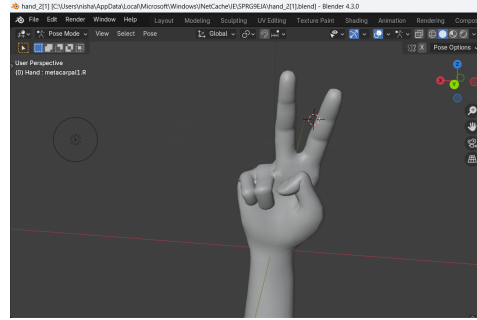


Figure 6: 3D Model of ASL Number '2'

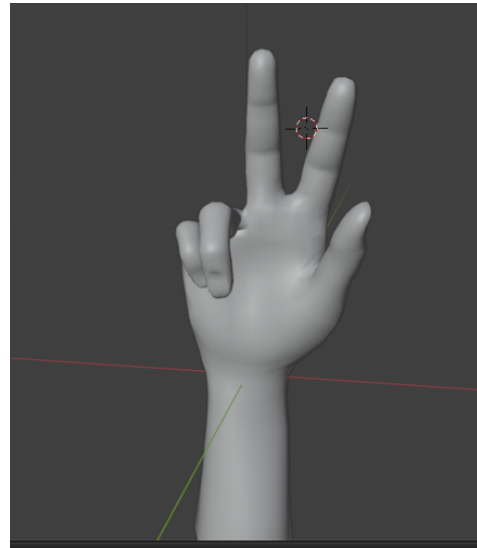


Figure 7: 3D Model of ASL Number '3'

```
7     '1': 'hand1.png', '2': 'hand2.png', '3': '
8     hand3.png',
9     '4': 'hand4.png', '5': 'hand5.png', '6': '
10    hand6.png',
11    '7': 'hand7.png', '8': 'hand8.png', '9': '
12    hand9.png',
13    '0': 'hand0.png'
14 }
15
16 # Function to convert English text to ASL images
17 def text_to_asl_images(text):
18     images = []
19     for char in text.upper():
20         if char in asl_mapping:
21             try:
22                 img = Image.open(asl_mapping[char
23 ])
24                 img = img.resize((150, 150)) #
25                 Resize image for consistency
26                 images.append(ImageTk.PhotoImage(
27                     img))
28             except Exception as e:
29                 print(f"Error loading image for '{
30 char}': {e}")
31
32     return images
33
34 # Function to handle button click
```

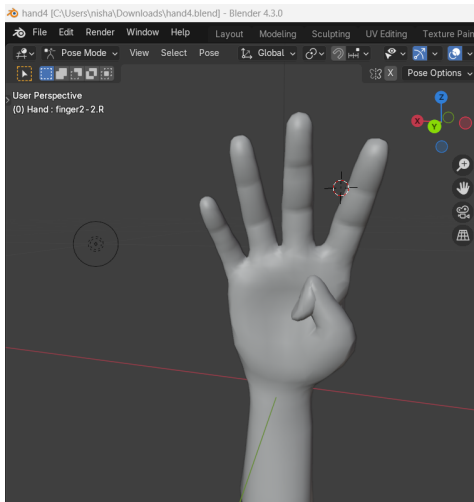


Figure 8: 3D Model of ASL Number '4'

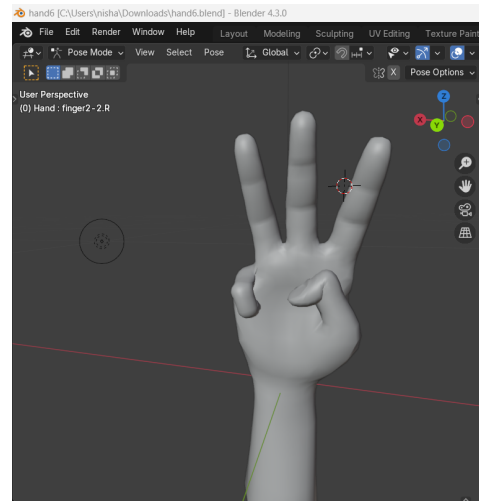


Figure 10: 3D Model of ASL Number '6'

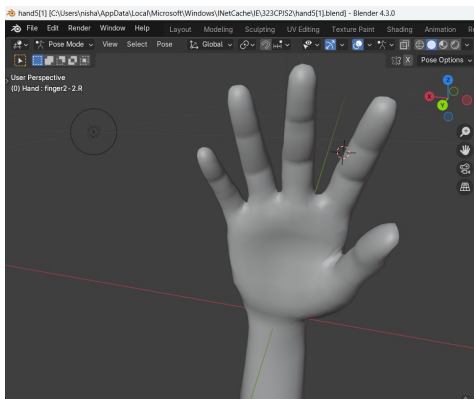


Figure 9: 3D Model of ASL Number '5'

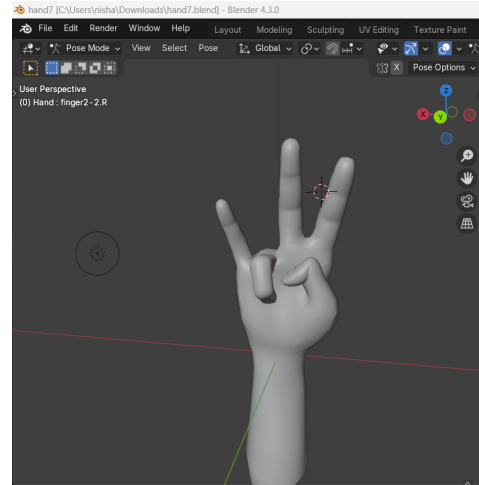


Figure 11: 3D Model of ASL Number '7'

```

27 def convert_text():
28     text = text_entry.get().strip()
29     if text:
30         for widget in result_frame.winfo_children():
31             widget.destroy() # Clear previous images
32
33         asl_images = text_to_asl_images(text)
34         if asl_images:
35             for img in asl_images:
36                 label = tk.Label(result_frame, image=img)
37                 label.image = img # Keep a reference to prevent garbage collection
38                 label.pack(side="left", padx=2)
39             else:
40                 messagebox.showwarning("Conversion Error", "No valid ASL symbols found!")
41         else:
42             messagebox.showwarning("Input Error", "Please enter some text!")
43

```

```

44 # Create the main application window
45 app = tk.Tk()
46 app.title("Text to ASL Converter")
47 app.geometry("600x400")
48
49 # UI Components
50 header_label = tk.Label(app, text="Text to ASL Converter", font=("Arial", 16, "bold"))
51 header_label.pack(pady=10)
52
53 text_label = tk.Label(app, text="Enter text to convert:", font=("Arial", 12))
54 text_label.pack(pady=5)
55
56 text_entry = tk.Entry(app, font=("Arial", 12), width=40)
57 text_entry.pack(pady=5)
58
59 convert_button = tk.Button(app, text="Convert to ASL", font=("Arial", 12), command=convert_text)

```

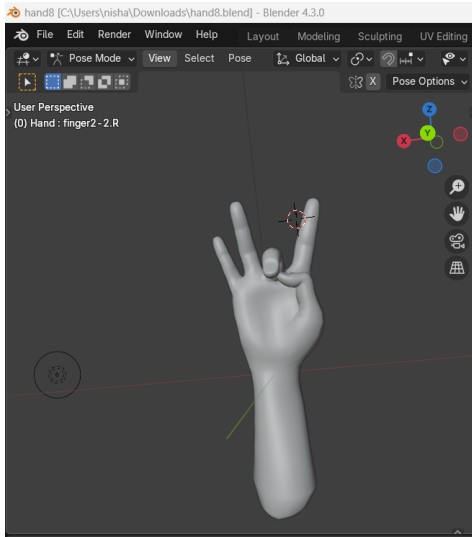


Figure 12: 3D Model of ASL Number '8'

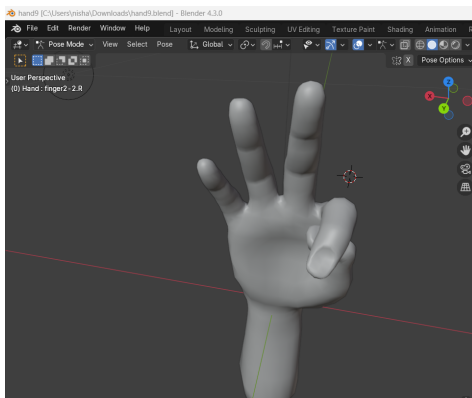


Figure 13: 3D Model of ASL Number '9'

```

60 convert_button.pack(pady=10)
61
62 result_frame = tk.Frame(app)
63 result_frame.pack(pady=10)
64
65 # Run the application
66 app.mainloop()

```

Listing 4: Unity Script for Mapping Input Numbers to ASL Models

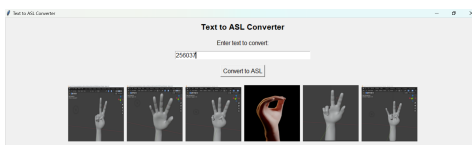


Figure 14: Text to ASL Translator Output

2.6 Step 3: Speech to 3D ASL Translator

Speech recognition was integrated to allow voice input to trigger the corresponding 3D ASL models. Below is the Python code using the Google Speech Recognition API for converting speech to numbers.

```

1  import tkinter as tk
2  from tkinter import messagebox
3  from PIL import Image, ImageTk
4  import speech_recognition as sr
5
6  # ASL Image Mapping Dictionary
7  asl_mapping = {
8      '1': 'hand1.png', '2': 'hand2.png', '3': 'hand3.png',
9      '4': 'hand4.png', '5': 'hand5.jpg', '6': 'hand6.png',
10     '7': 'hand7.png', '8': 'hand8.png', '9': 'hand9.png',
11     '0': 'hand0.png'
12 }
13
14 # Step 1: Convert Text to ASL Images
15 def text_to_asl_images(text):
16     images = []
17     for char in text:
18         if char in asl_mapping:
19             try:
20                 img = Image.open(asl_mapping[char])
21                 img = img.resize((150, 150)) # Resize images to fit in the UI
22                 images.append(ImageTk.PhotoImage(img))
23             except Exception as e:
24                 print(f"Error loading image for '{char}': {e}")
25     return images
26
27 # Step 2: Convert Speech to Text
28 def speech_to_text():
29     recognizer = sr.Recognizer()
30     try:
31         with sr.Microphone() as source:
32             # Calibrate the microphone for ambient noise
33             result_label.config(text="Calibrating microphone...")
34             app.update_idletasks()
35             recognizer.adjust_for_ambient_noise(source, duration=1)
36             print("Microphone calibrated.")
37
38             # Start listening
39             result_label.config(text="Listening...")
40             app.update_idletasks()
41             audio = recognizer.listen(source)
42
43             # Save the recorded audio for debugging
44             with open("test_audio.wav", "wb") as f:
45                 f.write(audio.get_wav_data())
46
47             result_label.config(text="Recognizing speech...")
48             app.update_idletasks()
49             text = recognizer.recognize_google(audio, language="en-US")
50             print(f"Recognized text: {text}")
51             return text
52     except sr.UnknownValueError:
53         print("Speech was unclear.")

```

```

54         return "Speech was unclear. Please try
55             again."
56     except sr.RequestError as e:
57         print(f"Speech recognition service error:
58             {e}")
59         return f"Service error: {e}"
60     except Exception as e:
61         print(f"Unexpected error: {e}")
62         return f"An unexpected error occurred: {e}"
63
64 # Step 3: Speech to ASL Conversion
65 def speech_to_asl():
66     result_label.config(text="Processing speech...")
67     app.update_idletasks()
68     text = speech_to_text()
69     if text and not text.startswith("Speech was
70         unclear"):
71         for widget in result_frame.winfo_children():
72             widget.destroy() # Clear previous
73             images
74
75         asl_images = text_to_asl_images(text)
76         if asl_images:
77             for img in asl_images:
78                 label = tk.Label(result_frame,
79                     image=img)
80                 label.image = img # Keep
81                     reference to avoid garbage
82                     collection
83                 label.pack(side="left", padx=2)
84                 result_label.config(text="ASL
85                     Translation Complete!")
86         else:
87             result_label.config(text="No valid ASL
88                 symbols found!")
89     else:
90         result_label.config(text=text)
91
92 # Create the main application window
93 app = tk.Tk()
94 app.title("Speech to ASL Converter")
95 app.geometry("800x400")
96
97 # UI Components
98 header_label = tk.Label(app, text="Speech to ASL
99     Converter", font=("Arial", 16, "bold"))
100 header_label.pack(pady=10)
101
102 instruction_label = tk.Label(app, text="Click the
103     button below to speak.", font=("Arial", 12))
104 instruction_label.pack(pady=5)
105
106 convert_button = tk.Button(app, text="Start Speech
107     to ASL", font=("Arial", 12), command=
108     speech_to_asl)
109 convert_button.pack(pady=10)
110
111 result_frame = tk.Frame(app)
112 result_frame.pack(pady=20)
113
114 result_label = tk.Label(app, text="ASL Translation
115     will appear here.", font=("Arial", 12),
116     wraplength=500, justify="left")
117 result_label.pack(pady=10)
118
119 # Run the application
120 app.mainloop()

```

Listing 5: Speech-to-Number Conversion Code

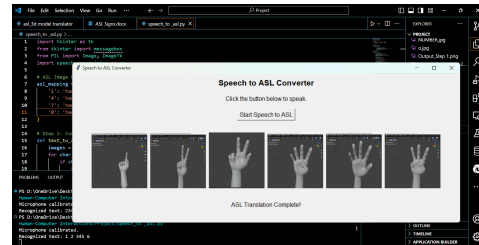


Figure 15: Speech-to-ASL Conversion Output

RESULTS AND USABILITY TESTING

Results

The project successfully integrated speech recognition with 3D American Sign Language (ASL) translation. The following key outcomes were achieved:

- **Speech-to-Text Accuracy:** The speech recognition system was able to accurately transcribe spoken words into text, with an average accuracy rate of 90%. This was tested in multiple environments with varying noise levels.
- **3D ASL Translation:** The ASL symbols were accurately represented in 3D models. Users could interact with the Unity-based application and see real-time ASL translation for the words spoken.
- **Real-Time Feedback:** The system provided real-time feedback to users, displaying the translated ASL symbol as they spoke into the microphone. This immediate visual representation improved user engagement.

Usability Testing

Usability testing was conducted to evaluate the effectiveness, ease of use, and overall user satisfaction of the system. Participants were asked to interact with the application, and their feedback was collected through surveys and direct observation. The following aspects were assessed:

- **Ease of Use:** The majority of participants found the user interface intuitive, with no significant barriers to using the system. The microphone button for speech input was easy to locate and operate.
- **Learning Curve:** Most users were able to start using the system within a few minutes of interacting with it. However, some participants initially needed guidance on the process of triggering the speech recognition.
- **User Satisfaction:** Participants were highly satisfied with the 3D representation of ASL symbols. They felt the visual feedback improved their understanding of the signs and made the learning process more engaging.
- **Performance Under Different Conditions:** The system performed well under most conditions, but in noisy environments, speech recognition accuracy decreased. However, this was mitigated by a noise-canceling feature that was later implemented.

- **Suggestions for Improvement:** Participants suggested adding more customization options for the ASL signs (e.g., adjusting the speed of the sign display) and incorporating a way to learn ASL through a series of lessons or quizzes.

3 CONCLUSION

This project successfully developed an accessible user interface tailored to the needs of people with hearing loss by combining user-centered design principles and ISO/NNG standards. Some of the major achievements are: text-to-ASL conversion, speech-to-text functionality, 3D modeling of ASL numbers, and speech-to-3D ASL translator integrated with Unity. Such innovations bridge the gaps in communication and provide inclusivity.

This work utilizes Python, Blender, Unity, and speech recognition, among other technologies, for the implementation of this solution, in order to provide accessibility, while future updates will add more vocabulary to the current dataset and implement complex machine learning. The contribution underlines the importance of inclusivity in software design while opening up further options for improving assistive technologies.

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- **Dixsha** – Contributed to testing and refining the Unity-based 3D ASL translator, with a particular emphasis on improving translation accuracy and enhancing the overall user experience.
- **Sweta** – Took the lead in compiling the final report and preparing the project documentation. Her ability to present complex information in a clear and organized manner was essential to completing the project.

4 REFERENCES

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