Multimodal Sign Language Translator

FACULTY OF INFORMATION ENGINEERING, INFORMATICS AND STATISTICS

COMPUTER SCIENCE DEPARTMENT

MULTIMODAL INTERACTION

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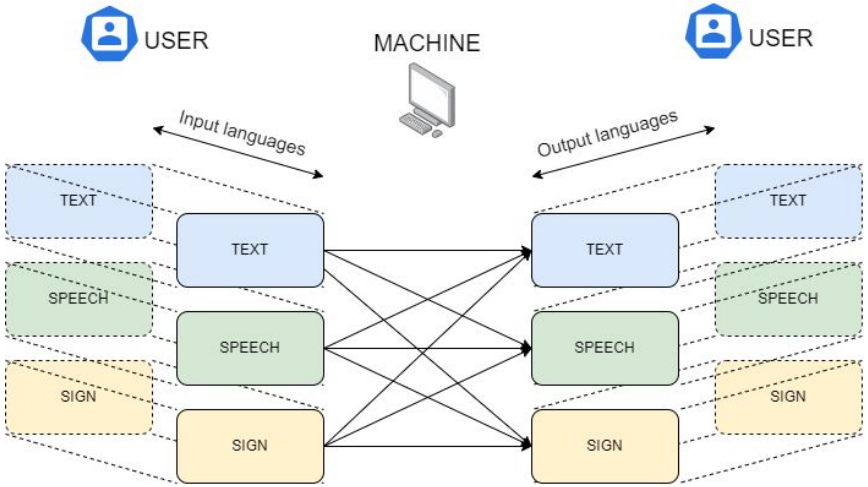


High-level view

Sign language (SL) translations

- **Multimodal**
  - Tactile, Speech and Visual
- **Polyglot**
  - 🇮🇹, 🇬🇧, 🇺🇸 and 🇪🇸
  - Spoken & Signed languages
- **Bidirectional**
  - {speech, text, sign} ⟷ {speech, text, sign}

MMST development timeline

- **Domain** focus: sign language
- Domain **understanding** and knowledge gathering
- Real-world scenarios and **use-cases**
- **Theoretical** modeling and design
- **Practical** modeling and design

Real-world scenarios

Conversations between

- Two people using two different Sign Languages
- Person unable to use Sign Language, person only able to use Sign Language

No need for a physical **interpreter**

Conversion of material to sign language

Sign Language **learning**

- Test current knowledge
- Learn new signs

From scenarios to actual use-cases

Text-to-Sign translation

Speech-to-Sign translation

Sign-to-Text translation

Text-to-Speech translation

Text-to-Text translation

Sign-to-Sign translation

Speech-to-Speech translation

All modalities are valid and applicable in reverse as well!

Actors

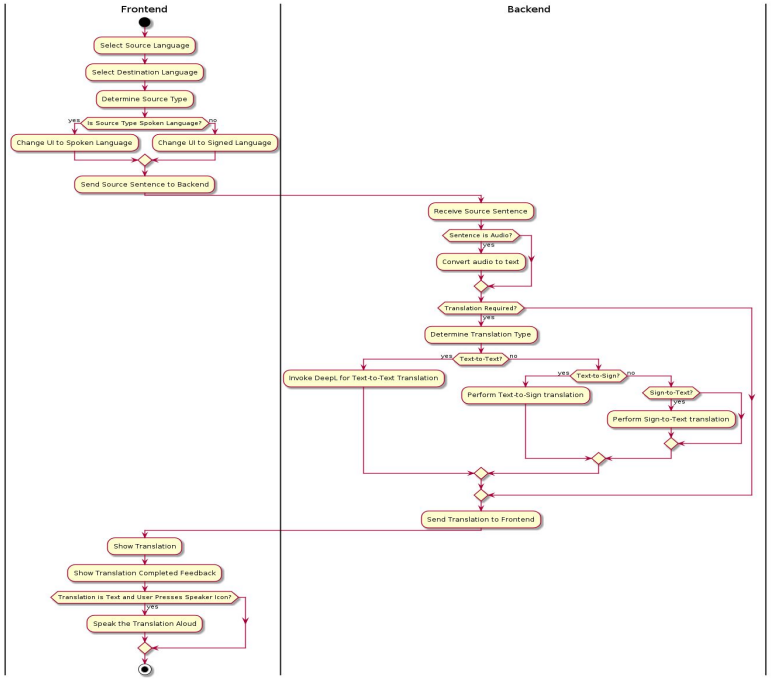
Preconditions

Main flow

Postcondition

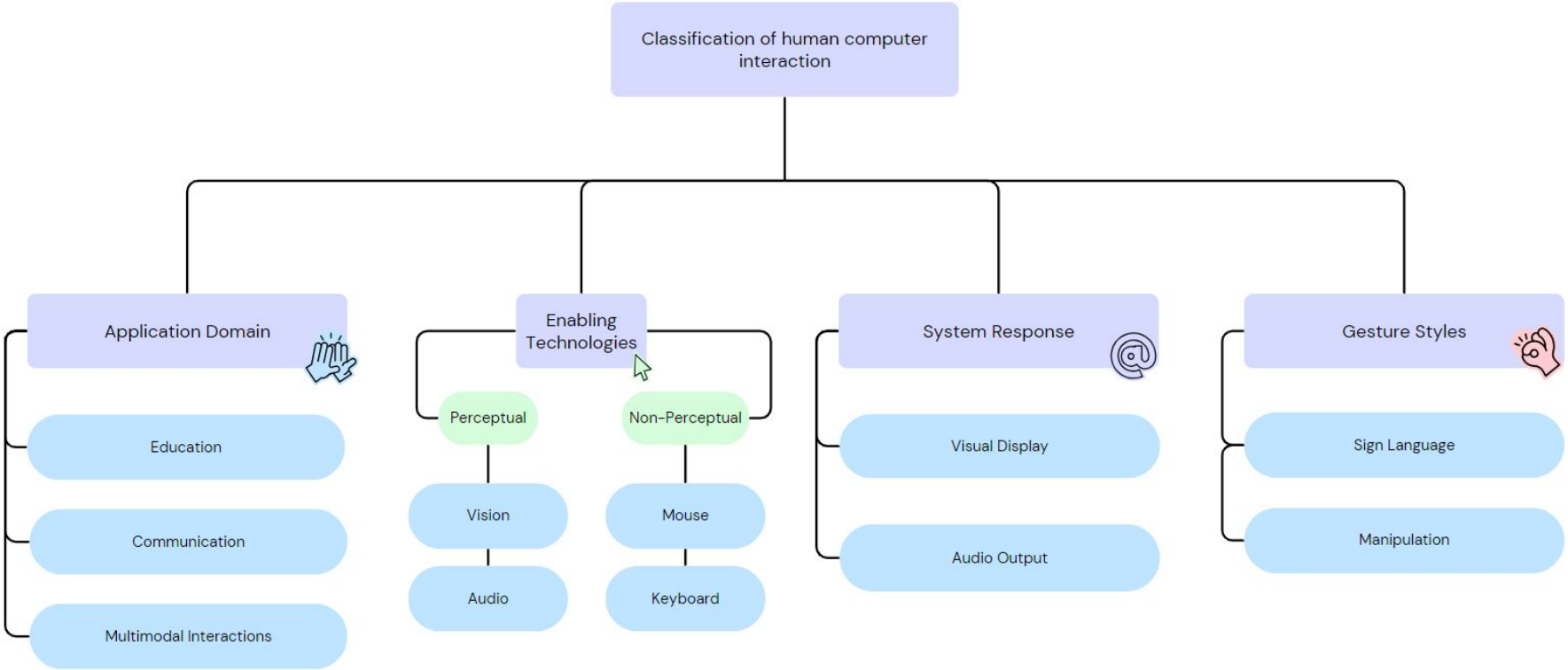
Theoretical Design Modeling

Activity diagram




```
@startuml
|Frontend|
start
:Select Source Language;
:Select Destination Language;
:Determine Source Type;

if (Is Source Type Spoken Language?) then (yes) :Change UI to Spoken Language;
else (no) :Change UI to Signed Language;
endif

:Send Source Sentence to Backend;

|Backend|
:Receive Source Sentence;

if (Sentence is Audio?) then (yes) :Convert audio to text;
endif

if (Translation Required?) then (yes) :Determine Translation Type;
  if (Text-to-Text?) then (yes) :Invoke DeepL for Text-to-Text Translation;
  else (no)
    if (Text-to-Sign?) then (yes) :Perform Text-to-Sign translation;
    else (no)
      if (Sign-to-Text?) then (yes) :Perform Sign-to-Text translation;
      endif
    endif
  endif
endif

:Send Translation to Frontend;

|Frontend|
:Show Translation;
:Show Translation Completed Feedback;

if (Translation is Text and User Presses Speaker Icon?) then (yes)
  :Speak the Translation Aloud;
endif
stop
@enduml
```

Human-Computer Gesture Interaction



Human-Computer Interaction

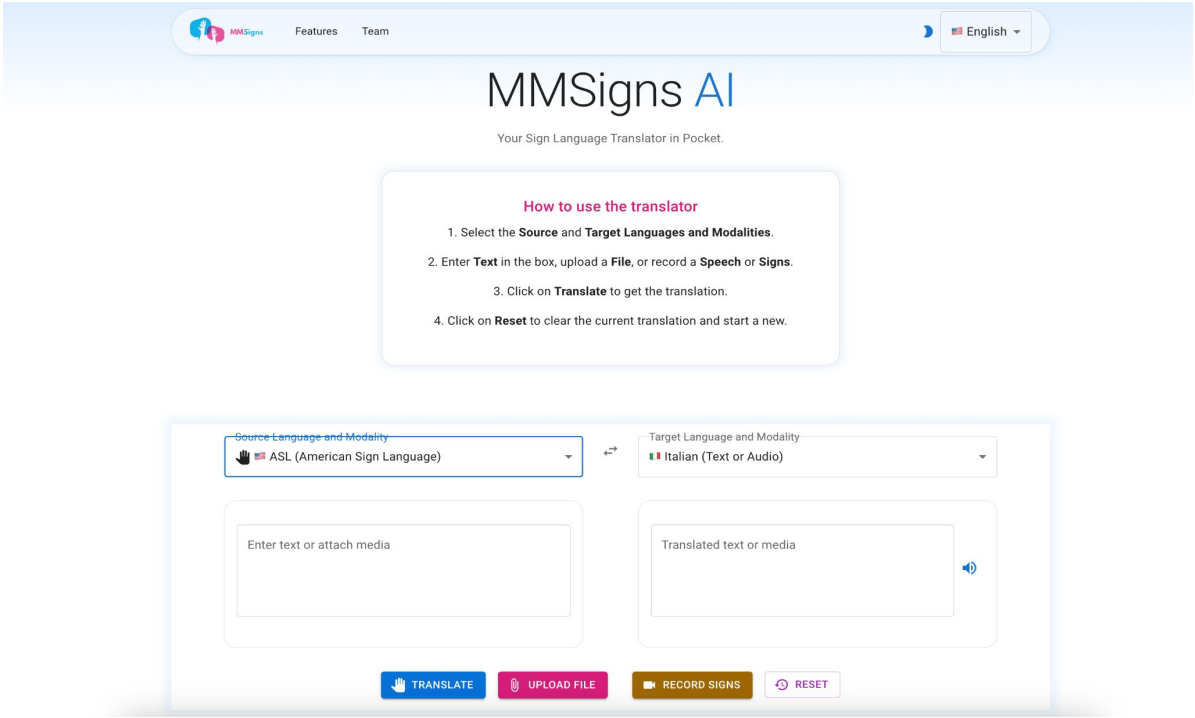
User Interface

- **Usable**
  - Requires < 2 mins to learn
- **Accessible**
  - Multi-language support
  - Comply with accessibility requirements
    - **WCAG 2.2**., A and AA (certain cases)

User Experience

- **Intuitive**
  - Buttons, drop down menus, text boxes
- Step-by-step **instructions**
- Browser- and OS-**agnostic**

Human-Computer Interaction



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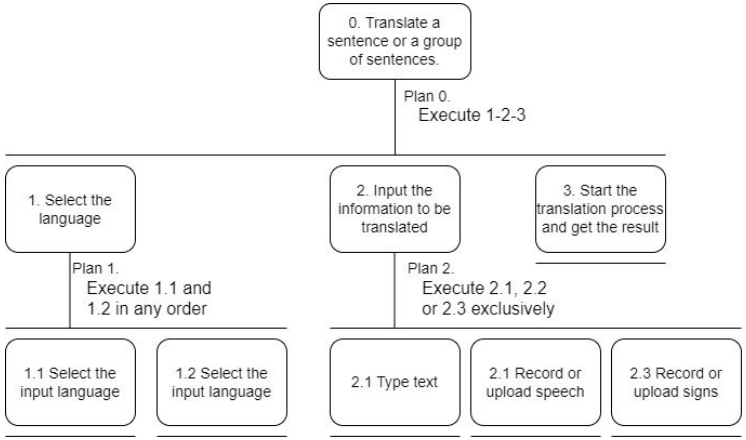
Separable Interface Design

Theoretical **desideratum** → keep presentation and functionality separate

Practical implementation → stay tuned…

Task Analysis

- **H**ierarchical **T**ask **A**nalysis
  - CTT logical-temporal operators not required
- Three-level **hierarchy**
  - Task → Sub-tasks → Sub-sub-tasks
- Three **plans**
  - Fixed
  - Discretionary
  - “Alternative”



Multimodal Coordination

- **Alternative/Equivalent** (Bernsen and Dybkjær /Martin) → inputs
  - Semantic content **invariant** w.r.t. modality
    - “apple”, [pronunciation of “apple”], [sign language video of “apple”] → always refers to 🍏
- **Transfer**
  - In some cases, input modality ≠ output modality

- **No Specialization**
  - Incompatible with full equivalency

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Multimodal Fission

- **Fission** (Foster) ⟶ outputs
  - **Implicit** message ⟶ translation done
  - Distributed across multiple channels ⟶ audio and visual **feedbacks**
    - Multimodal feedbacks used to **highlight new content** and **explain context**

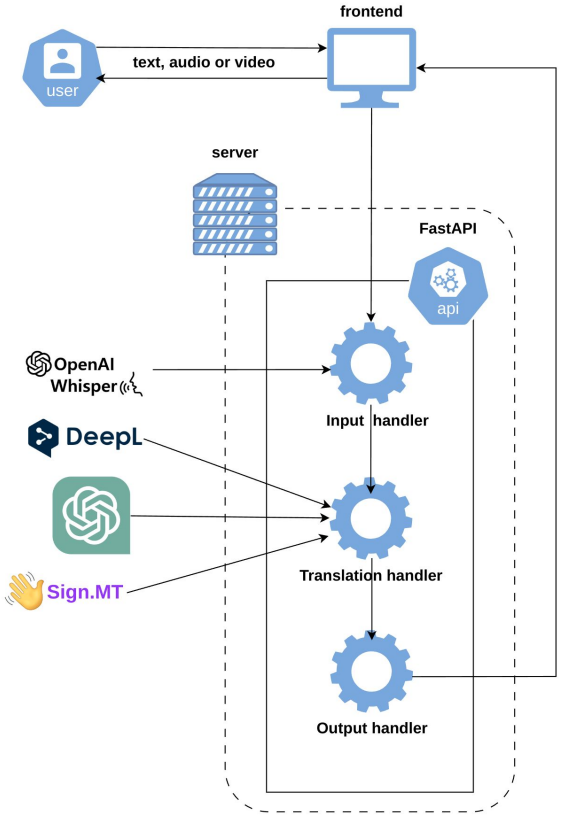
  - **Gestalt Laws**
    - **Proximity, Closure and Continuity** laws to avoid artifacts and ambiguity
    - Used **Similarity** law to separate different components, for example closed box to distinguish “instructions block” and “translation block”

Practical Design Modeling

Separable Interface Design

Theoretical desiderata → keep presentation and functionality separate

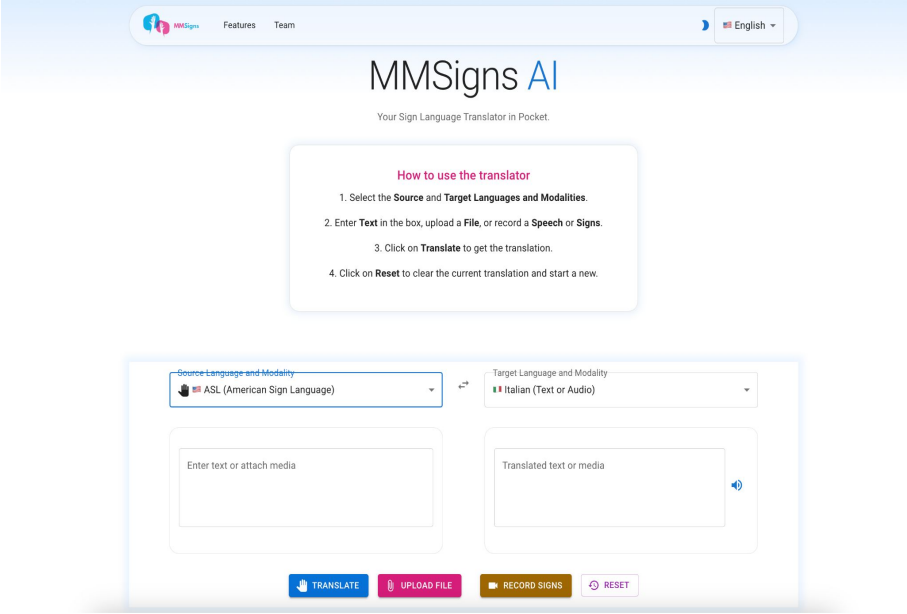
Practical **implementation** → now! 🎉



Separable Interface Design

Seehein Model

- Presentation component
  - **Frontend**
- Application interfaces components
  - **Backend**
- Dialogue component
  - Frontend⟵ ⟶backend HTTPS requests



Frontend

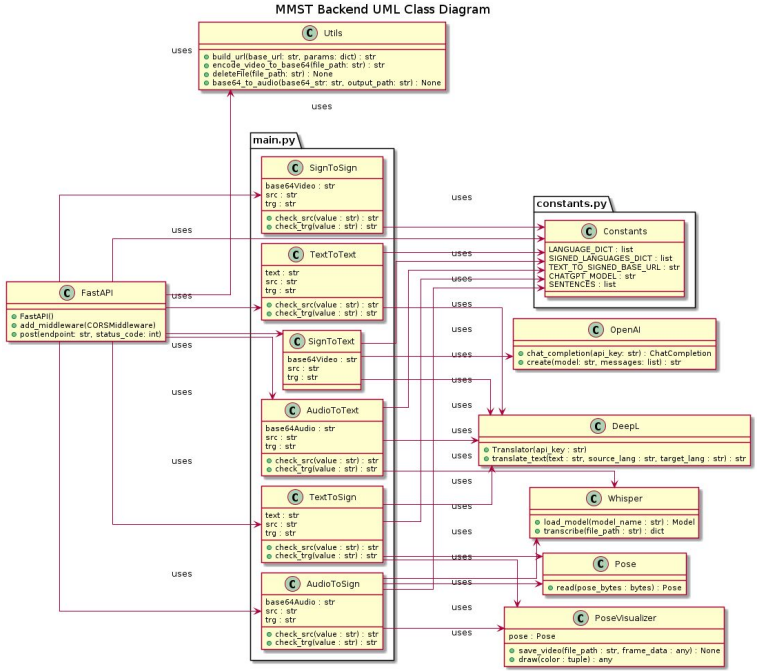
Presentation component

- Show app **logo** and **tutorial**
- Select source and destination languages
- **Input** source sentence
- **Output** translation
- Select preferred **modality**

Backend

Application component

- Input **pre-processing**
- **Calls** to external services
  - OpenAI Whisper, ChatGPT, DeepL, Sign.mt
- Output **post-processing**



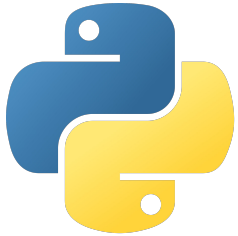
Frontend ⟷ Backend

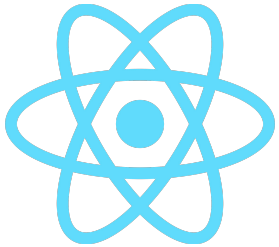
Dialog component

- **Bidirectional** communication
  - Frontend ⟶ Backend
  - Backend ⟶ Frontend
- Input **validation**
- **API** entry points
  - {audio, text, sign}-to-{audio, text, sign}

```python
@app.post("/translate/text_to_text", status_code=200)
async def text_to_text(req: TextToText):
    translator = deepl.Translator(os.getenv("DEEPL_API_KEY"))
    text_info = translator.translate_text(
        req.text,
        source_lang=req.src,
        target_lang="en-us" if req.trg == "en" else req.trg,
    )
    return {"result": str(text_info)}
```

Frameworks and libraries





Future Works

- Expand
  - Multimodal **coordination**
    - Complementarity & redundancy
    - Ambiguous translations & reinforce SL concepts
  - More signed and spoken languages
  - Mobile and tablet apps
- Include
  - **Real-time** capabilities → AR overlay of SL translations
  - Natural Language **Understanding**

Conclusion and Recap

- **Sign language** translations
- **Multimodal**
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- **Polyglot**
  - 🇮🇹, 🇬🇧, 🇺🇸 and 🇪🇸
  - Spoken & signed languages
- **Bidirectional**
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- Activity Diagram and use-cases
- UI and UX design
- Separable Interface Design
  - Backend, Frontend and Communication
- Task Analysis
  - Task Hierarchy
  - Fixed, discriminative, “alternative” plans
- Multimodal coordination
  - Alternative/Equivalent and Fission
  - Complementarity and Redundancy 🔮

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THANKS FOR THE ATTENTION!

MMST – Multi**m**odal **S**ign **L**anguage **T**ranslator