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LEAD ME Winter Training School Madrid 2021

Media Accessibility Training: Sign Language and Subtitling for the Deaf and Hard-of-hearing

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Virtual Signers generation within SignON

Víctor Ubieto, Pablo García, Josep Blat // UPF-GTI
(victoremilio.ubieto@upf.edu, pabloluis.garcia@upf.edu, josep.blat@upf.edu)

upf. GTI Interactive Technologies Group

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LEAD ME Winter Training School Madrid, 15-17 November 2021

SIGNON

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017255

Overview

Sign Languages as Context

SIGNON

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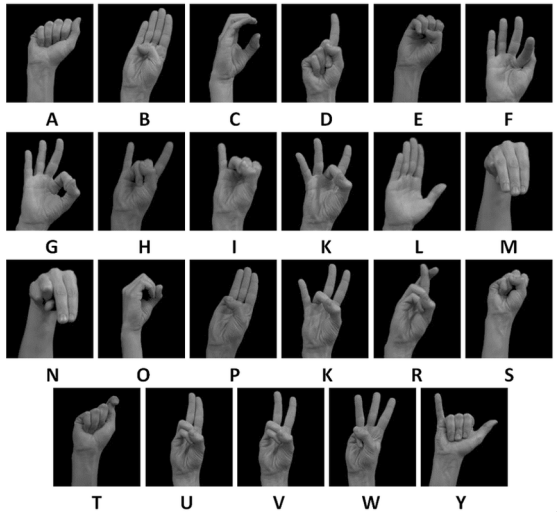
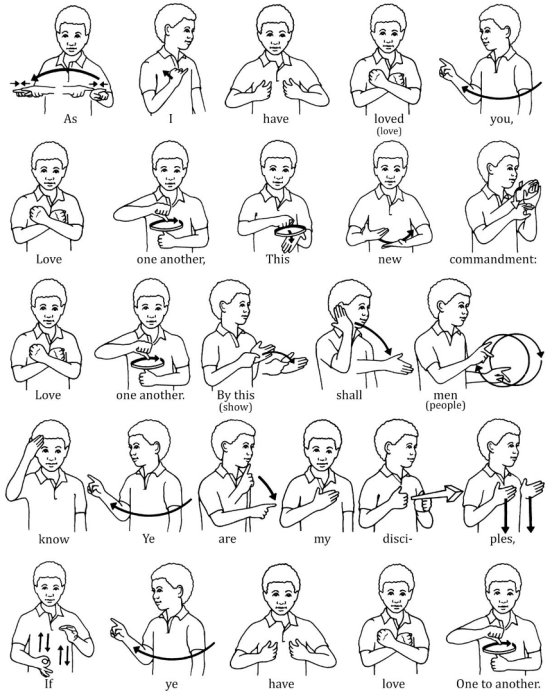
SIGNON





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"Sign language: A language that employs signs made with the hands and other movements, including facial expressions and postures of the body, used primarily by people who are deaf." [1]

"SLs are visual gestural languages articulated in a signing space. SLs have no written form." [2]

"Sign languages are, after all, complex visual languages. Generally, one can say that sign languages have five parameters. A sign is distinguished by hand shape, hand orientation, movement, location, and non-manual components such as mouth shape and eyebrow shape." [3]

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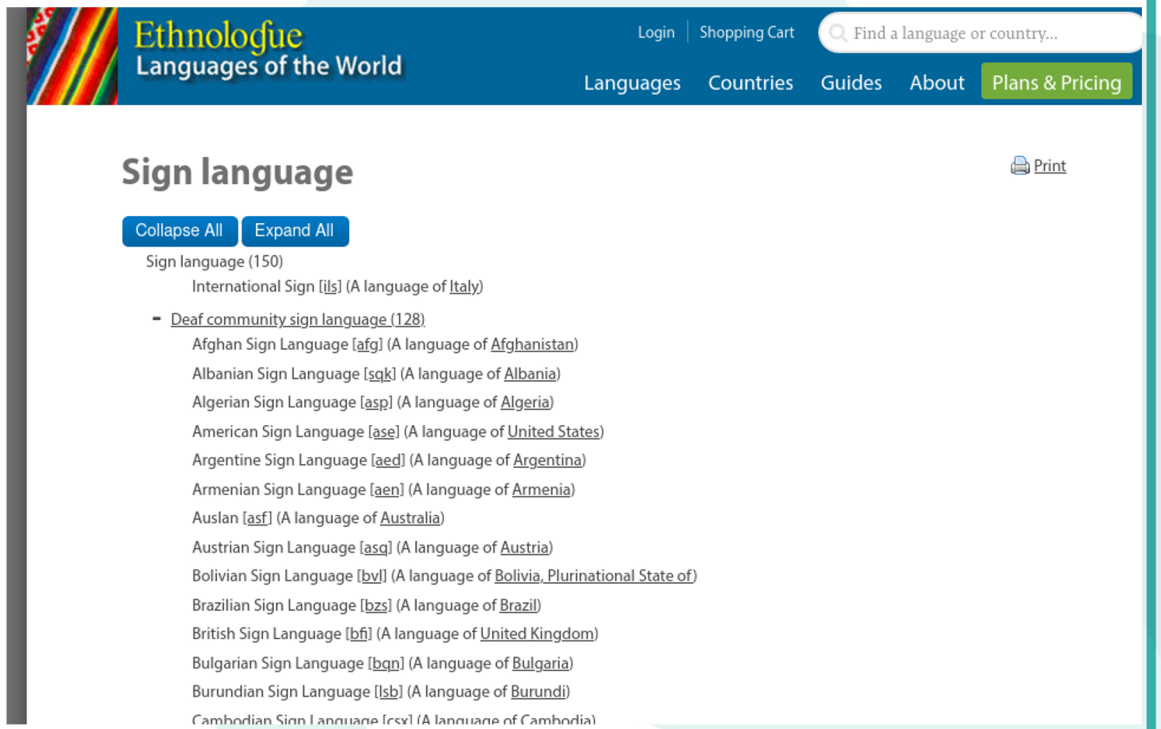
[1] https://www.medicinenet.com/sign_language/definition.htm
[2] Murtagh, Irene (2019), *A Linguistically Motivated Computational Framework for Irish Sign Language*, PhD thesis
[3] De Coster, Mathieu, Van Herreweghe, Mieke and Dambre, Joni (2020) Sign Language Recognition with Transformer Networks, Proceedings of the 12th Conference on Language Resources and Evaluation (LREC 2020)

"One of the most common misconceptions about sign language is that it's the same wherever you go. That's not the case. In fact, there are somewhere between 138 and 300 different types of sign language used throughout the world today. New sign languages frequently evolve amongst groups of deaf children and adults." [4]



https://www.ethnologue.com/subgroups/sign-language

[4] https://www.k-international.com/blog/different-types-of-sign-language-around-the-world/

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Overview

Complementing Human Translators - Interpreters

SIGNON

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- Currently, human interpreters are the main medium for signed-to-spoken, spoken-to-signed and signed-to-signed language translation.
- The availability and cost of these professionals is often a limiting factor in communication between signers and non-signers.

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SIGNON

Main Objective

SignON aims to reduce the gap between the three stakeholder communities (deaf, hearing and hard of hearing) through a user-centred and community-driven research and development approach, involving stakeholder-led user profiles from its inception.

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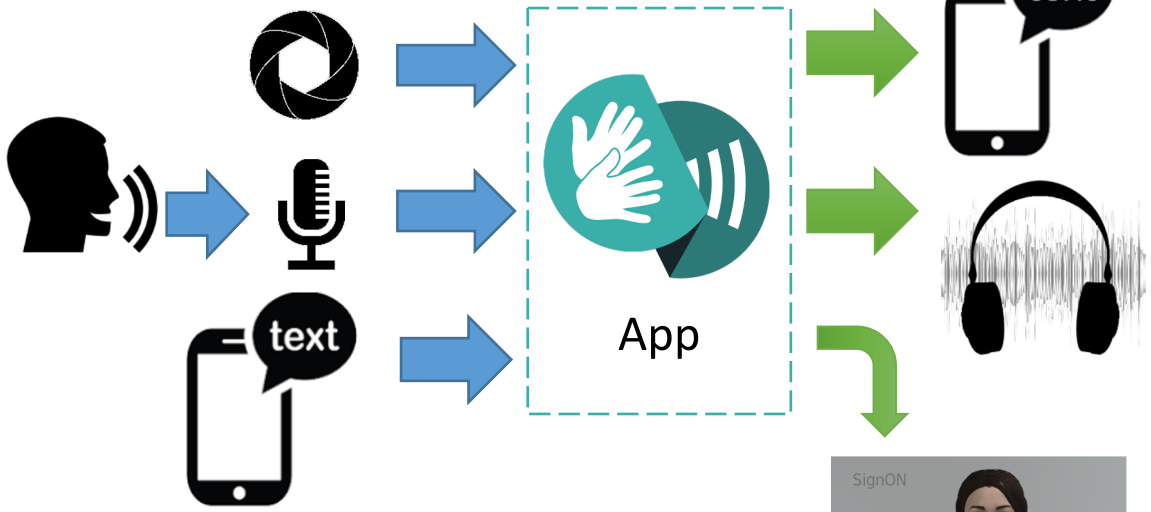
Use Case



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Objectives

OBJECTIVE 1: **Co-creation Workflow and Community.** We aim to bring researchers and developers into a close collaboration with the main stakeholder groups to drive the research and development in SignON.

OBJECTIVE 2: **SignON Framework and Mobile Application.** Design and development of a framework and a mobile application which will deliver the SignON service to the user.

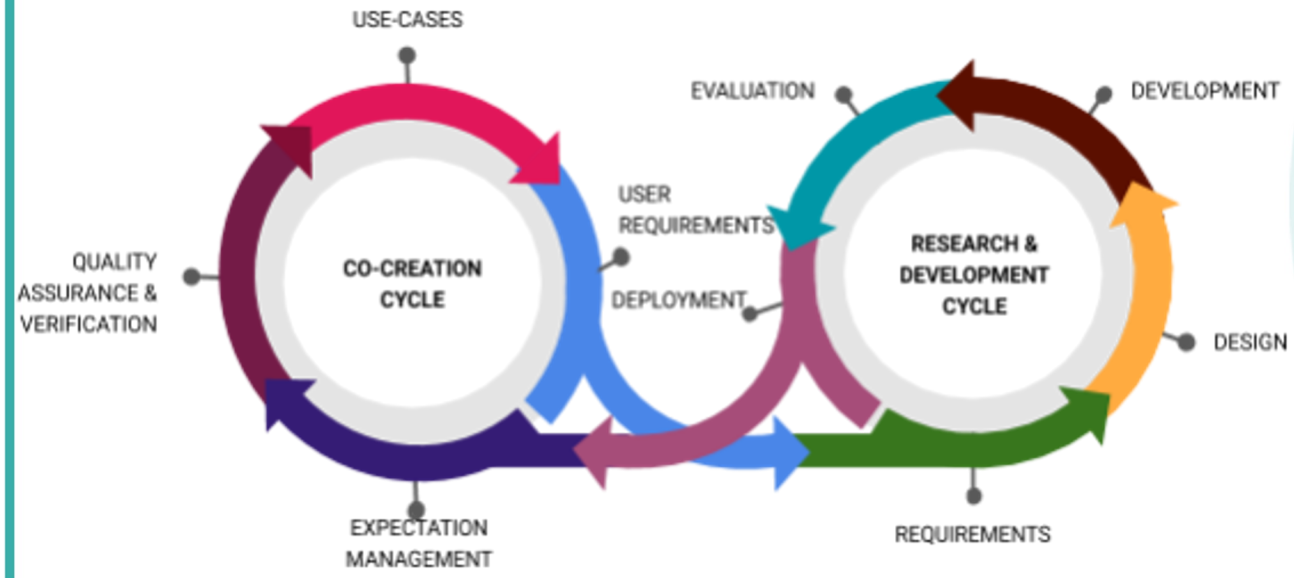
OBJECTIVE 3: **Automated Recognition and Understanding of SL and Verbal Language Input** through advanced sign language recognition (SLR), automatic speech recognition (ASR), and natural language understanding (NLU).

OBJECTIVE 4: Research and Development of a Novel **Language Independent Meaning Representation** for interlingua M, based on current vector representations, symbolic components or hybrid representations of the input/output message.

OBJECTIVE 5: **Sign, Speech and Text Synthesis.** SignON will convert a SL specific syntactic-semantic representation in the target SL via a customizable 3D virtual signer (i.e. avatar). It will also produce text output in the different oral languages adapted to the user, by, for example, simplifying the text.

OBJECTIVE 6: **Wide-range of Supported Languages and Extensibility of the Framework.** During the project we will provide support for the following SLs: Irish SL (ISL), British SL (BSL), Flemish SL (VGT), Dutch SL (NGT) and Spanish SL (LSE) as well as English, Irish, Dutch and Spanish verbal languages. However, we will design the SignON application and framework to be extensible to new sign and verbal languages.

Nothing about us without us
=> co-creation



Co-creation cycle

- **Expectation management**: The SignON service (at its present stage) will be outlined along with its intended use for the defined use-cases and the benefits for the users.
- **Quality assurance and verification**: The quality of the SignON service will be tested by the user community. The defined expectations will be confirmed/discarded. The QoS will be reevaluated and verified.
- **Use-cases**: The quality and functionality of the SignON service will be considered in redefining currently addressed use-cases (if needed) and defining new ones.
- **User-requirements**: The collection of evaluation metrics and statistics, reviews, and use case (re)definitions will be translated into user requirements to drive the development cycle.

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Scope and Extensibility

Wide-range of Supported Languages and Extensibility of the Framework.

During the project we will provide support for the following SLs:

- Irish SL (ISL)
- British SL (BSL)
- Flemish SL (VGT)
- Dutch SL (NGT)
- Spanish SL (LSE)

As well as English, Irish, Dutch and Spanish verbal languages.

However, we will design the SignON application and framework to be extensible to new sign and verbal languages.

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The SignON framework and Mobile Application

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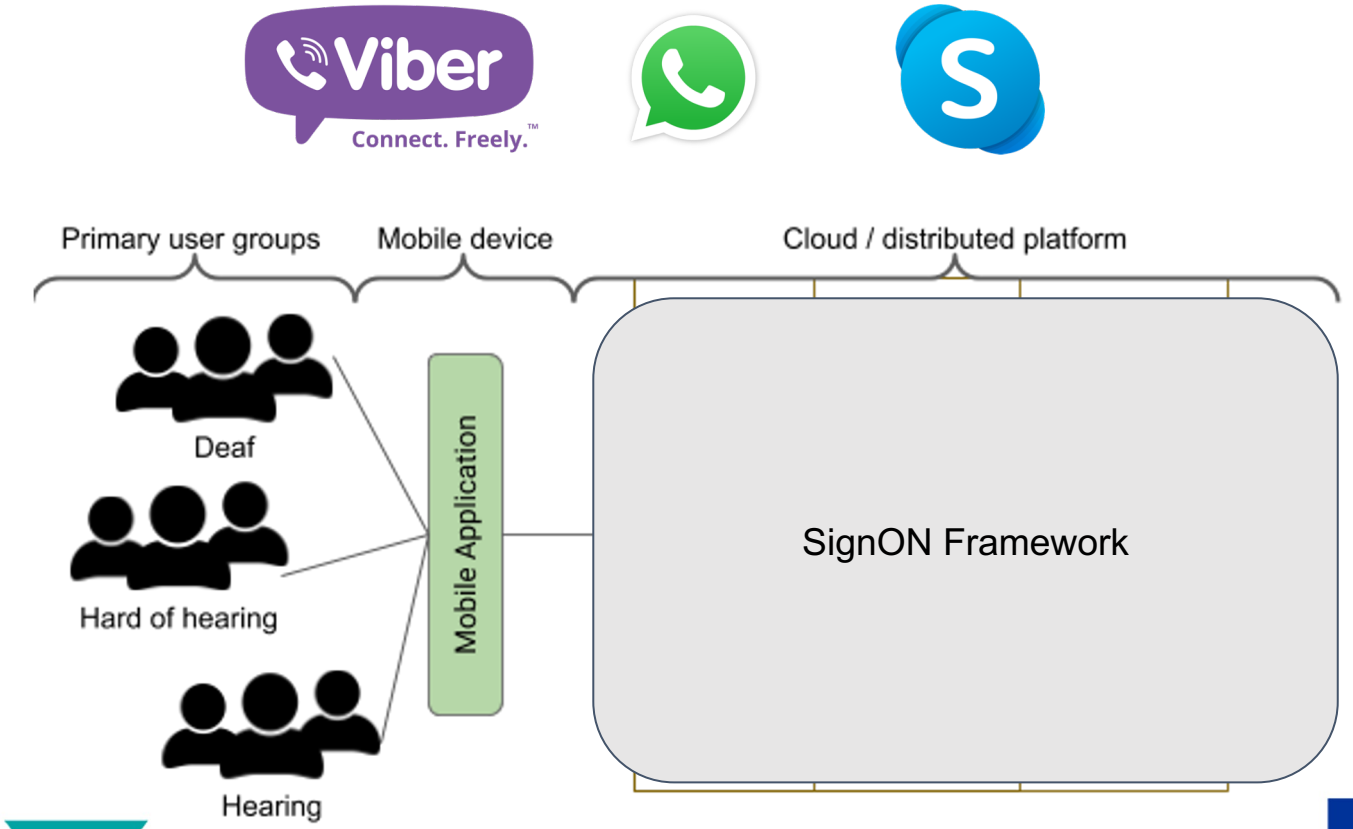
The SignON framework and Mobile Application



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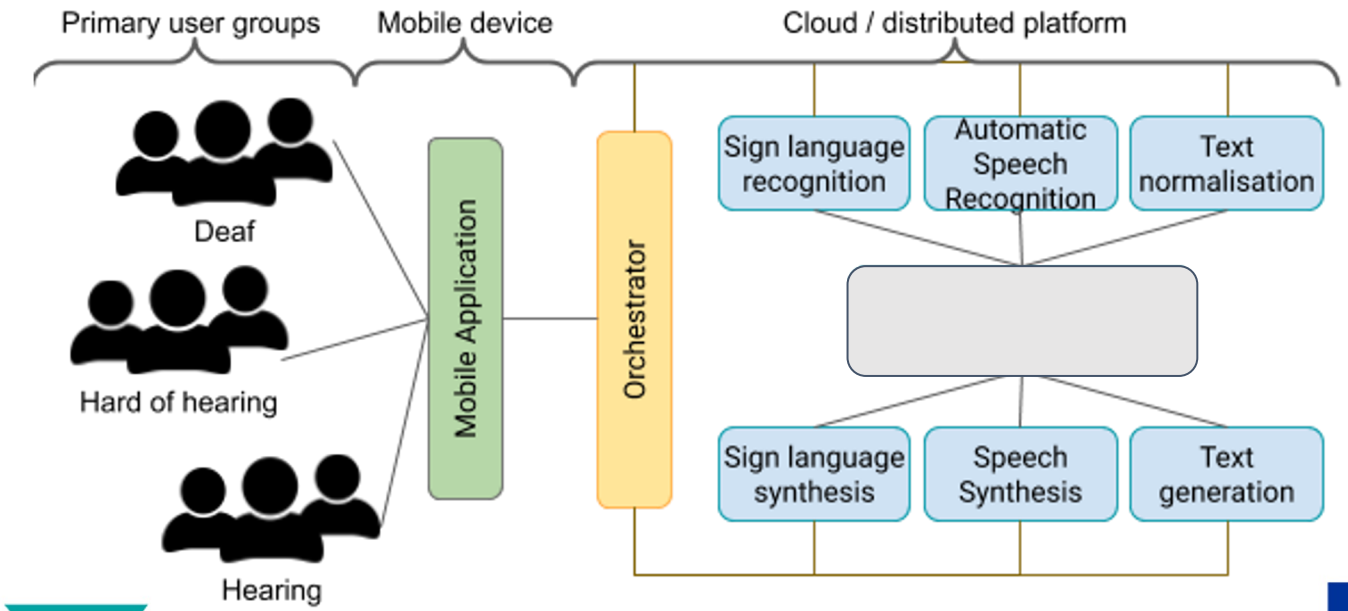
Automated Recognition and Understanding of signed and spoken Language Input through advanced sign language recognition (SLR), automatic speech recognition (ASR), and natural language understanding (NLU).

Sign, Speech and Text Synthesis.



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Sign language recognition

Given an input video, generate a sequence of tokens that are representative

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Sign language recognition

Why not end to end?

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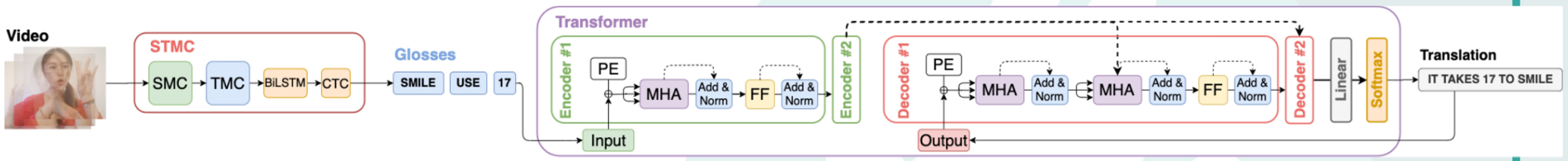
Sign language recognition

Why not end to end?



[5] Yin, Kayo and Read, Jesse (2020) *Attention is All You Sign: Sign Language Translation with Transformers*

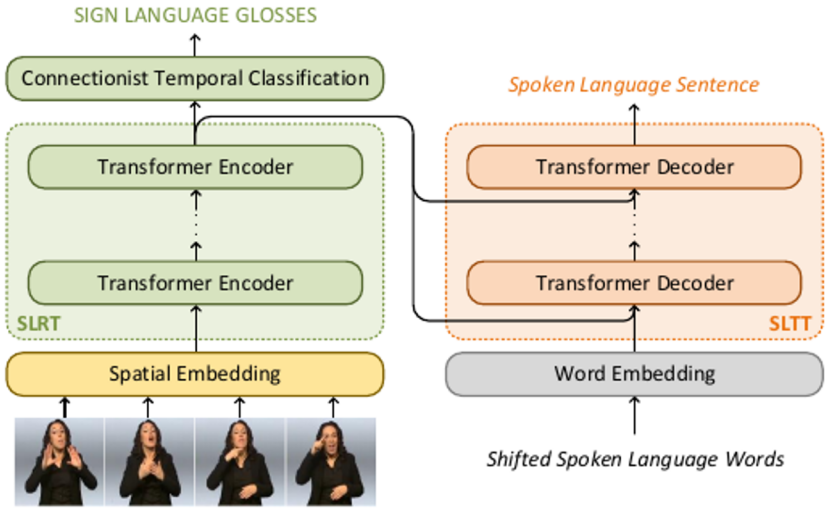


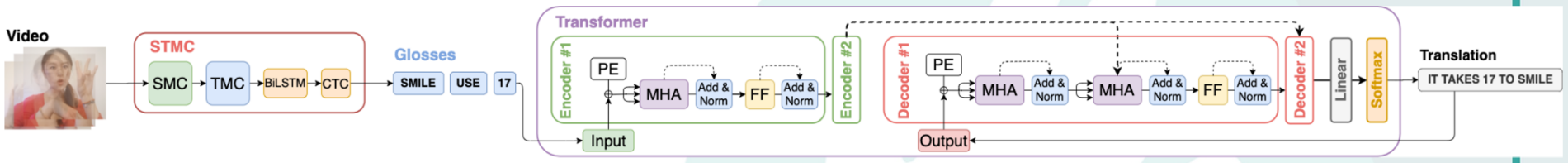
Figure 1: An overview of our end-to-end Sign Language Recognition and Translation approach using transformers.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017255

[6] Camgöz, Necati Cihan; Koller, Oscar; Hadfield, Simon and Bowden, Richard (2020) *Sign Language Transformers: Joint End-to-end Sign Language Recognition and Translation*

Sign language recognition

Why not end to end?



[5] Yin, Kayo and Read, Jesse (2020) *Attention is All You Sign: Sign Language Translation with Transformers*

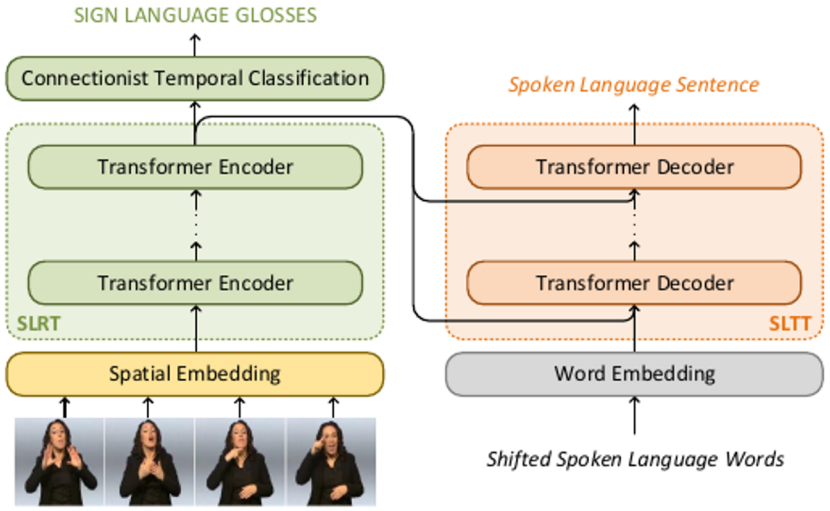


Figure 1: An overview of our end-to-end Sign Language Recognition and Translation approach using transformers.

- **Data is scarce**
- **Multiple languages**
- **Computational complexity**

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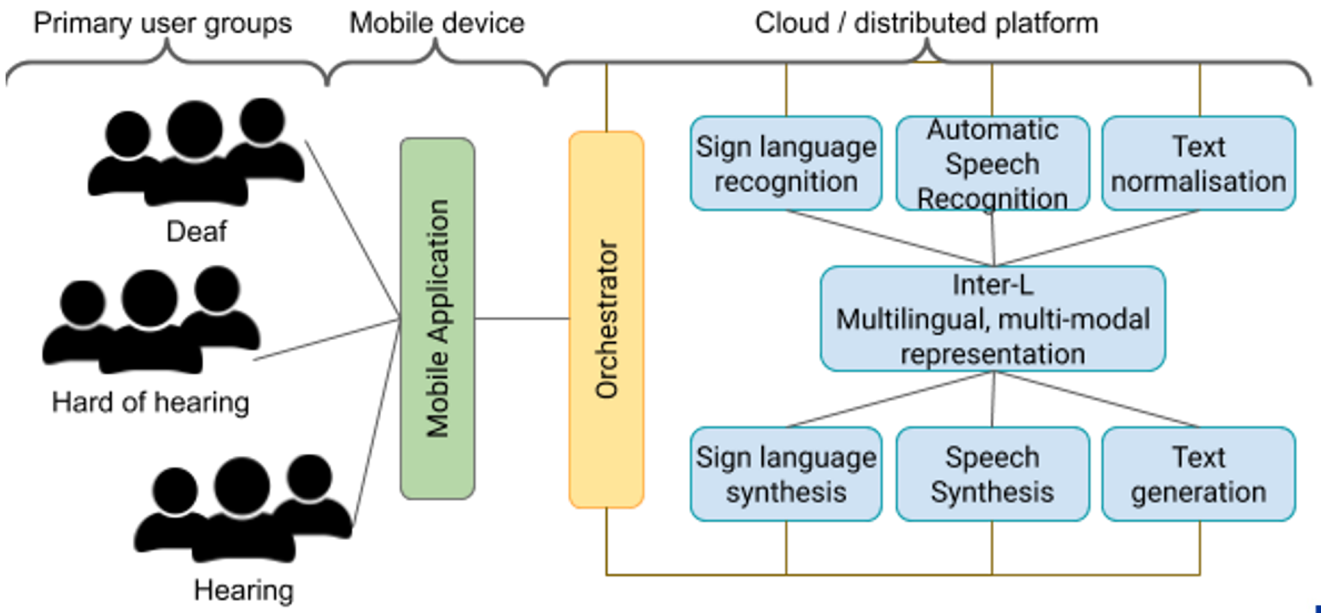
[6] Camgöz, Necati Cihan; Koller, Oscar; Hadfield, Simon and Bowden, Richard (2020) *Sign Language Transformers: Joint End-to-end Sign Language Recognition and Translation*

Translation

Research and development of a novel language-independent meaning representation for multilingual machine translation, based on word or sentence embeddings, symbolic components or a combination of both, i.e. a hybrid representation.



Inter-L

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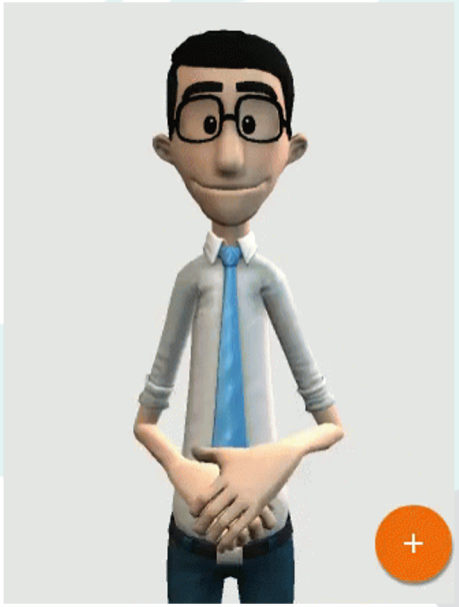
Sign language synthesis

Given textual or another encoded representation of an output message generate its sign language alternative through the movements of a 3D virtual character

Interactive visualization!



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Sign language synthesis

This virtual character is named EVA (Embodied Virtual Agent) and signs "good". EVA is still in the early stages now and will be fine-tuned throughout the project.

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Sign language synthesis

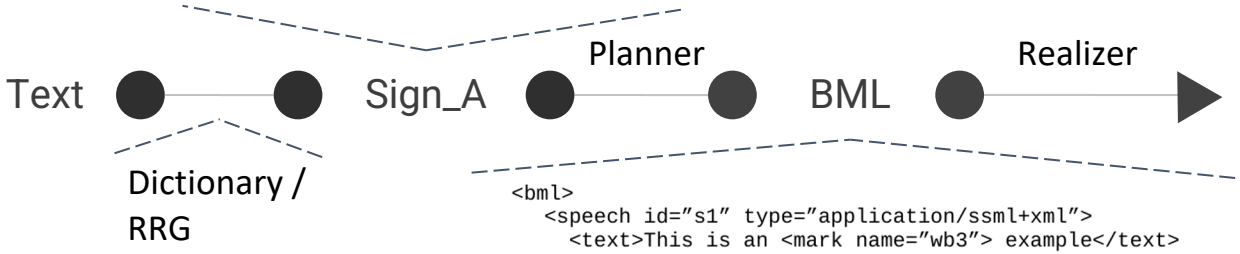
a) State ← Event/Situation Type

REAL LIKE MY JOB ← Gloss

'I really love my job' ← English Translation

LIKE′ <TLine><MF><NMF> (1sg, JOB) ← Sign_A + RRG logical Structure

SOI Corpus Noeleen (03) Personal Stories (Dublin)




```
<bml>
  <speech id="s1" type="application/ssml+xml">
    <text>This is an <mark name="wb3"> example</text>
  </speech>
  <head id="h1" type="NOD" stroke="s1:start"/>
  <gesture id="g1" stroke="s1:wb3" relax="s1:end" type="BEAT">
    <description level="1" type="MURML">...
    </description>
  </gesture>
  <gaze id="z1" target="PERSON1" stroke="g1:stroke-0.1"/>
  <body id="p1" posture="RELAXED" start="after(s1:end)"/>
  <cadia:operate target="SWITCH1" stroke="p1:ready"/>
</bml>
```

This virtual character is named EVA (Embodied Virtual Agent) and signs "good". EVA is still in the early stages now and will be fine-tuned throughout the project.

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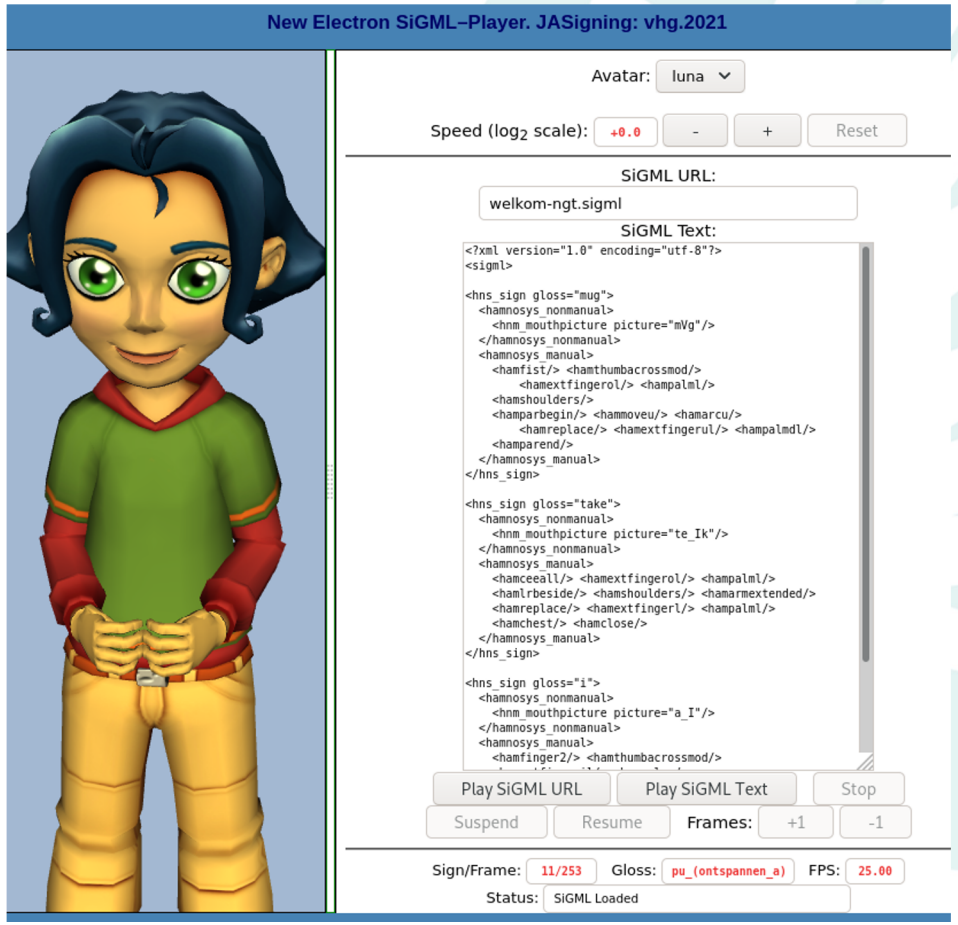
Sign language synthesis

How is this computational representation written?



Link →

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Insights of the project and tasks

How is this computational representation written?

There is a common way to specify the movement (the **behaviour**) of an character animating.

Markup Languages → Behaviour Markup Language (BML)

```
<bml xmlns="http://www.bml-initiative.org/bml/bml-1.0"
        character="Alice"
        id="bml1">
    <head id="behavior1" lexeme="NOD" repetition="2" start="1" end="3"/>
</bml>
```

Cool Demo

Idea: *we can extend the BML and create a new unique specification for Sign Language animations.*

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UPF-GTI Contribution Importance

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Avatar Synthesis

1. Creation a representative avatar
2. Making it visually realistic
3. Applying natural and realistic animations

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017255

(Interdisciplinary) Survey on SotA and Challenges

Danielle Bragg Oscar Koller Mary Bellard Larwan Berke Patrick Boudreault Annelies Braffort Naomi Caselli Matt Huenerfauth Hernisa Kacorri Tessa Verhoef Christian Vogler Meredith Ringel Morris: Sign Language Recognition, Generation, and Translation: An Interdisciplinary Perspective, *ASSETS '19*, October 28–30, 2019, Pittsburgh, PA, USA

Three **questions** addressed

Q1: What is the current state of sign language processing, from an interdisciplinary perspective?

Q2: What are the biggest challenges facing the field, from an interdisciplinary perspective?

Q3: What calls to action are there for the field, that resonate across disciplines?

Issues discussed:

Datasets

Recognition & Computer Vision

Modeling & Natural Language Processing

Avatars & Computer Graphics, following **challenges** identified

Uncanny Valley
Realistic Transitions
Modeling Modulations
Finding Model Holes
Public Motion-Capture Datasets

UI/UX Design

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Our work in SignON addresses some of the challenges identified (and other ones)

Avatar Synthesis

1. **Creation a representative avatar**
2. Making it visually realistic
3. Applying natural and realistic animations

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Personalised Design of Characters (Ref: Llorach et al 2019)

Pipeline for participatory design of personalisable characters:

1. Virtual character creation
1.1. *Adobe Fuse CC*.

2. Blender: improving the model
2.1 Import into *Blender*.
2.2 In Blender we separate the head from the body (which appears as a single mesh in most cases) and remove blend shapes from body parts that are actually not deformed.
2.3 We create other necessary blend shapes by mixing existing blend shapes/facial bones or manually.
2.4 Usually small corrections are needed to fix errors of the model or to improve the character.
2.5 Further file size reduction for better loading process performance can be achieved by lowering the resolution of the textures, simplifying or deleting geometries that are not going to be seen or do not take part in the final scene.

3. Mixamo / Blender with Makehuman plugin for animations
3.1We perform the preprocessing of the animations in *Blender* and/or in *Mixamo*.

4. WebGLStudio for integration and control

Table 8.1. Comparative analysis of different tools to create virtual humans

	High-level geometry control	Detailed geometry control	Clothes, hairstyles	Textures	Facial blend shapes and skeleton	Realism
MakeHuman 1.1.0	++ Ethnicity, age, gender	+ Feature modification through sliders	- Small set	Diffuse, normal map	+ Facial bone rig	+ Medium
Autodesk Character Generator	+ Blending between two predefined geometries	- Blending of predefined geometries	+ Medium-to-large set of hairstyles and clothes	Diffuse, normal map, specular map	+ Facial bone rig or facial blend shapes	- - Low
Adobe Fuse CC 2017.1.0	- 3D scans of real humans	++ Feature modification through sliders or directly on the mesh	++ Highly customizable medium-to-large set of hairstyles and clothes	Diffuse, normal map, specular map, gloss map, opacity map	+ Facial blend shapes	++ Medium-to-high
Daz Studio 4.10 Pro	- - Predefined models	- - Feature modification through sliders	- - Very small set, but dependent on the predefined model	Diffuse, opacity map	+ Facial bone rig	++ High

Figure 8.1. Pictures of characters created (with, from left to right, Makehuman, Autodesk Character Generator, Adobe Fuse CC and Daz Studio) and rendered on the web. The quality of the final rendering is only indicative, as it could be improved using custom shaders and additional textures when possible.

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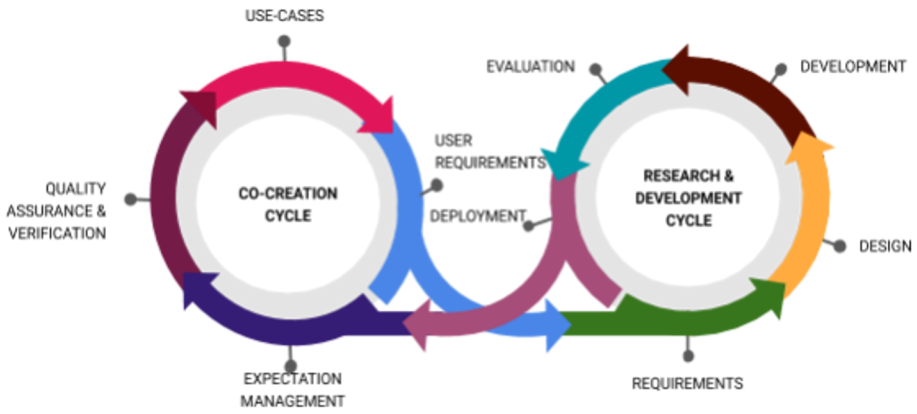
(1) G. Llorach, J. Agenjo, J. Blat and S. Sayago. "Web-Based Embodied Conversational Agents and Older People." In *Perspectives on Human- Computer Interaction Research with Older People*, pp. 119-135. Springer, Cham, 2019

1. Creation a representative avatar

This task is fundamented by the three following concepts:

- Co-design work



Implementation defined by use-cases

↓

User community will test the quality of service

↓

Redefinition of use-cases given the review, new user-requirements

What happens in most projects is that they try to outclass and go far away but they don't take into account the opinions of the community, therefore it ends having bad critics.
With this workflow we can correct this problem and have the certain of going to the right path.

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1. Creation a representative avatar

This task is fundamented by the three following concepts:

- Co-design work
- Personalisable avatar

- ❖ Gender
- ❖ Skin Color
- ❖ Clothes
- ❖ Hair Style

Being represented by the avatar

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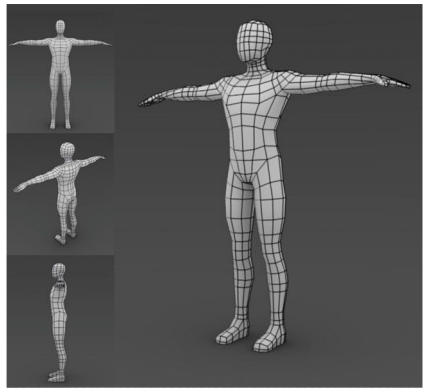
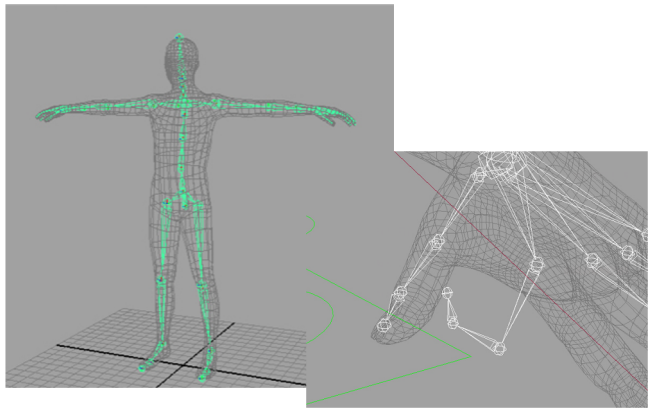
1. Creation a representative avatar

This task is fundamented by the three following concepts:

- Co-design work
- Personalisable avatar
- Prepared to perform signs



Mesh



Skeleton

We need to define a generic body proportions.
Maybe we might want to have bigger hands in order to visualize better the signs.

High definition in face and hands, the lower body is unnecessary.

Needs to be prepared to support sign animations more than typical locomotion animations.

→ Additionally: **BlendShapes**

Demo1 - Demo2

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Avatar Synthesis

1. Creation a representative avatar
2. **Making it visually realistic**
3. Applying natural and realistic animations

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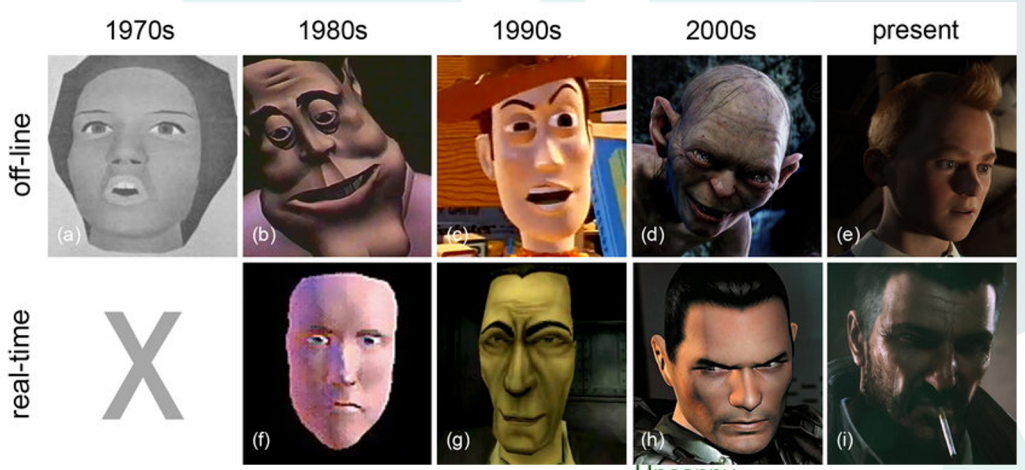
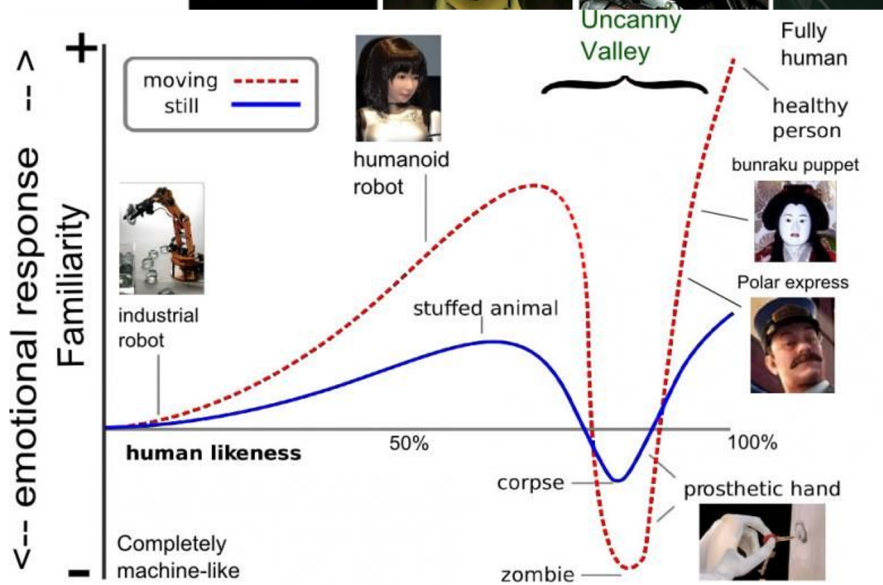
2. Making it visually realistic

The visual fidelity of 3D characters has increased considerably over the years. Despite that, this technology seems that has not reached Sign Language (SL) avatars.

Performing signs introduce a high complexity in the realism of an avatar. This is due to the fact that a small unprecise behaviour is felt weird if it is done by a very realistic character. → Uncanny Valley effect

That is why in most cases we can hear the statement:
"Acceptance before Realism"
(But don't leave the realism too low.)





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2. Making it visually realistic

Complexity (Realism) ⟷ Accessibility (Natural)

- Decide our final way to go.
- Related avatar rendering difficulties:
  Hair, skin, clothes, mouth, eyes, ...

(?)

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Avatar Synthesis

1. Creation a representative avatar
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Animating Signing Avatars (Ref: Naert et al 2020)

Linguistics

Sign: lexical unit.
Utterance: close to “sentence”.

Isolated sign **representation** is complex: **Hand configuration, Hand placement**, **Hand orientation, Non-manual features** (NMFs) as facial expressions, mouthing, gaze and torso direction; utterances add grammar complexity.

Scripting languages for SL (see right)

Sign synthesis

Keyframing (manual, automatic)
Procedural (continuous motion, realism added)
Data driven

Utterance synthesis

Concatenative
Coarticulatory
Hybrid

Lucie Naert, Caroline Larboulette, Sylvie Gibet: A survey on the animation of signing avatars: From sign representation to utterance synthesis, *Computers & Graphics*, **92**, 76-98, 2020, https://doi.org/10.1016/j.cag.2020.09.003
For NMF, see Kacorri Hernisa: Tr-2015001: A survey and critique of facial expression synthesis in sign language animation; 2015. CUNY Academic Works. https://academicworks.cuny.edu/gc_cs_tr/403

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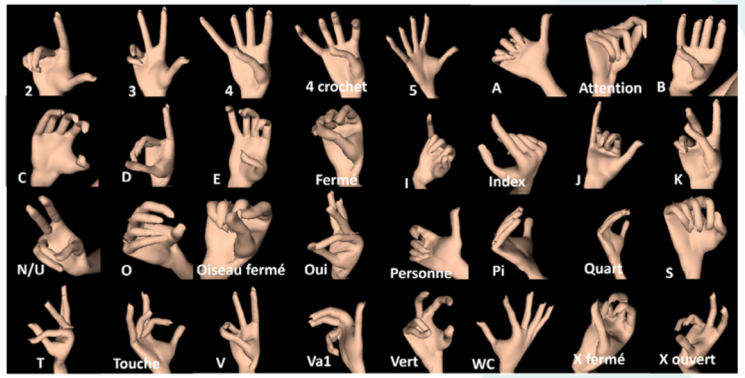
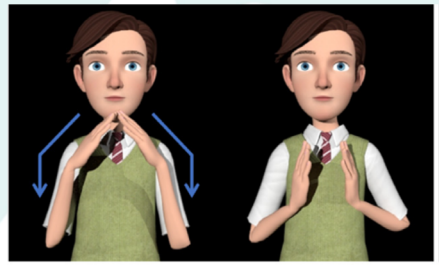
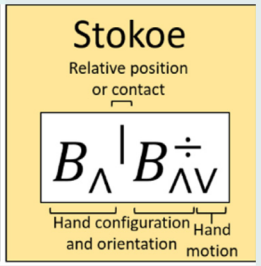
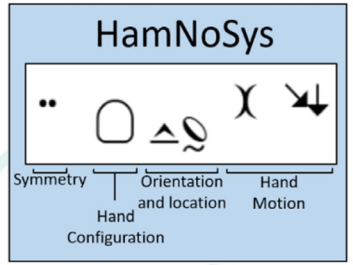








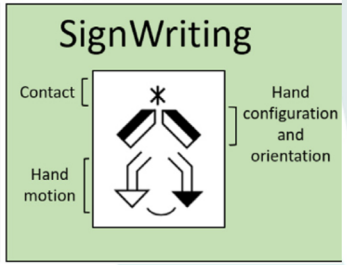


Table 1
Comparison of the sign representation.

Category	Name	Fidelity	Temporal aspects, synchronization	Non manual features	Flexibility	Understandable by a computer
Visual Representation	Drawings	✓	✗	✓	✗	✗
	Video recordings	✓✓	✓✓	✓✓	✗	✗
Parametric Notation	Stokoe [32]	(✓)	✗	✗	(✓)	✗
	HamNoSys [26]	✓	(✓)	(✓)	(✓)	(✓)
	SLPA [37,39]	✓	✓	✗	(✓)	(✓)
	SignWriting [33]	✓	(✓)	(✓)	(✓)	✗
Scripting Language	SiGML (extended) [42]	✓	✓	(✓)	(✓)	✓✓
	QualGest [25]	✓	✓	✗	✓	✓✓
	Losson [43]	✓	✓	(✓)	✓	✓✓
	Zebedee [44]	✓	✓	✗	✓✓	✓✓
	EMBRScript [45]	✓	✓	✓	(✓)	✓✓

Fidelity: absence of ambiguity, fidelity to the original movement, precise description of the sign, preservation of the intent of the signer. **Temporal aspects, synchronization**: the dynamics of the movement is specified, the synchronization between the different channels is managed. **Non manual features**: the status of non-manual components (facial expressions, gaze, etc.) is specified/visible. **Flexibility**: the ease with which the representation of a sign is modified to take into account the context of the sentence. A purely visual representation will make the transformation fastidious while some linguistic representations are highly flexible. **Understandable by a computer**: it can be reused as it is at the input of an automatic synthesis engine.

3. Applying natural and realistic animations

★ We aim for realistic animations:

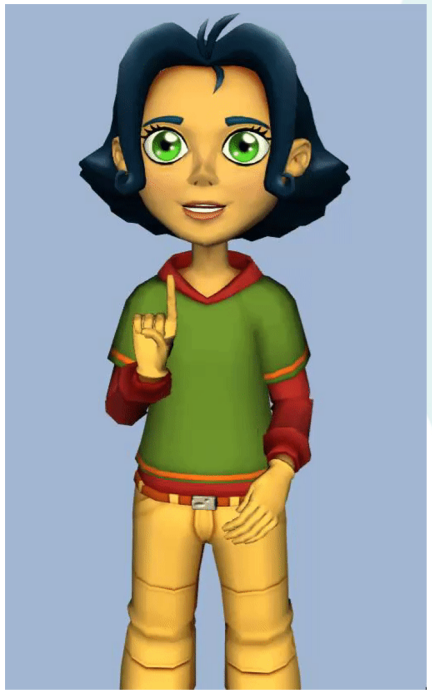
Synthetic

+ **Easy to generate**
- **Robotic looking**

Motion Capture

+ **Realistic**
- **Animation for each sign**

Synthetic Animations vs **Motion Capture** (from real person)



Links

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017255

Collaborative Authoring System (Ref:Heloir-Nunnari 2016)

Online collaborative framework allowing Deaf individuals to author intelligible signs using a dedicated 3D animation authoring interface.

Design of a dedicated User Interface assisted by novel input devices (Leap-Motion and Kinect-like).

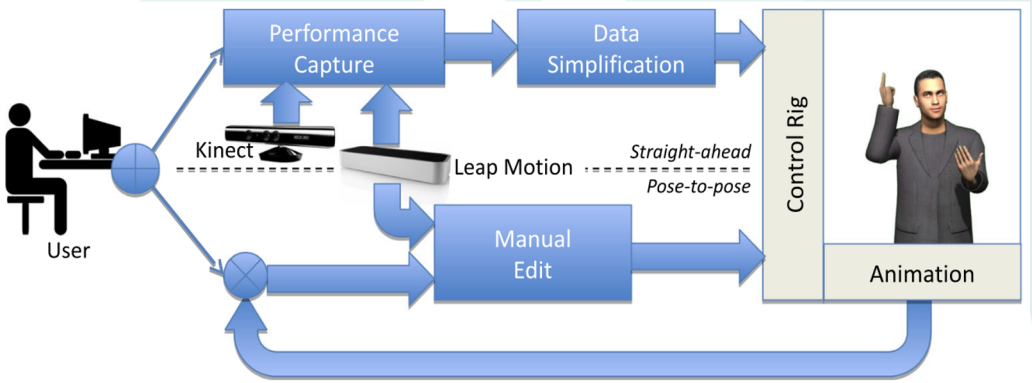
Result: symbolic representation of intelligible sign language animations together with a fine-grained log of the user's edit actions.

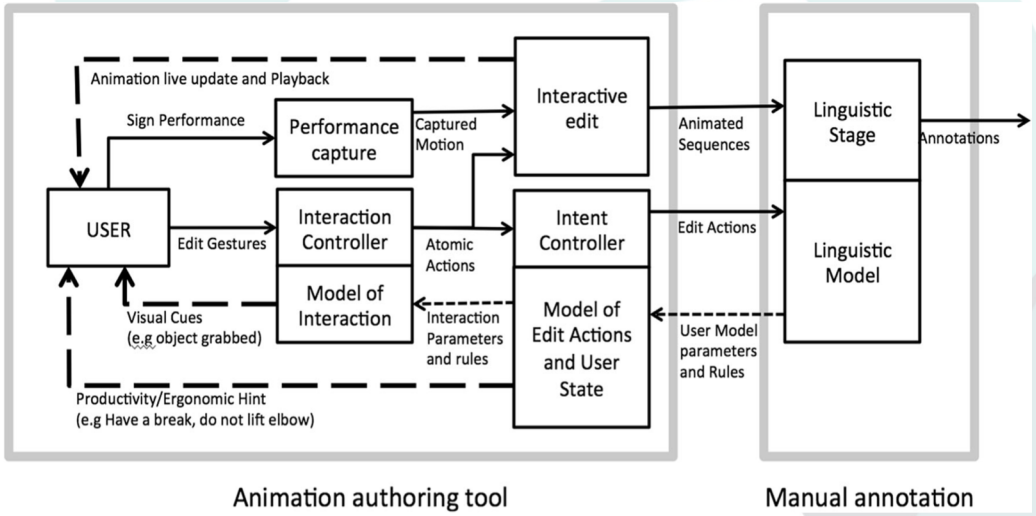
Heloir, A., Nunnari, F. Toward an intuitive sign language animation authoring system for the deaf. Univ Access Inf Soc 15, 513–523 (2016). https://doi.org/10.1007/s10209-015-0409-0

Top-right: pipeline

Bottom-right: details of system

Left: look of the system





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3. Applying natural and realistic animations

★ Best approach to obtain natural animations? → Obtaining them directly from a real person.

Motion Capture (MoCap) possibilities specifically for hand capture:

- **Marker-based methods.**
- Sensors-based methods.
- Machine Learning methods.

High Intrusivity

Difficult to perform signs correctly

Errors in signs that blocks markers

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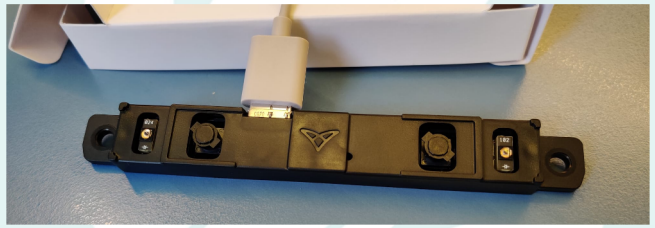
3. Applying natural and realistic animations

★ Best approach to obtain natural animations? → Obtaining them directly from a real person.



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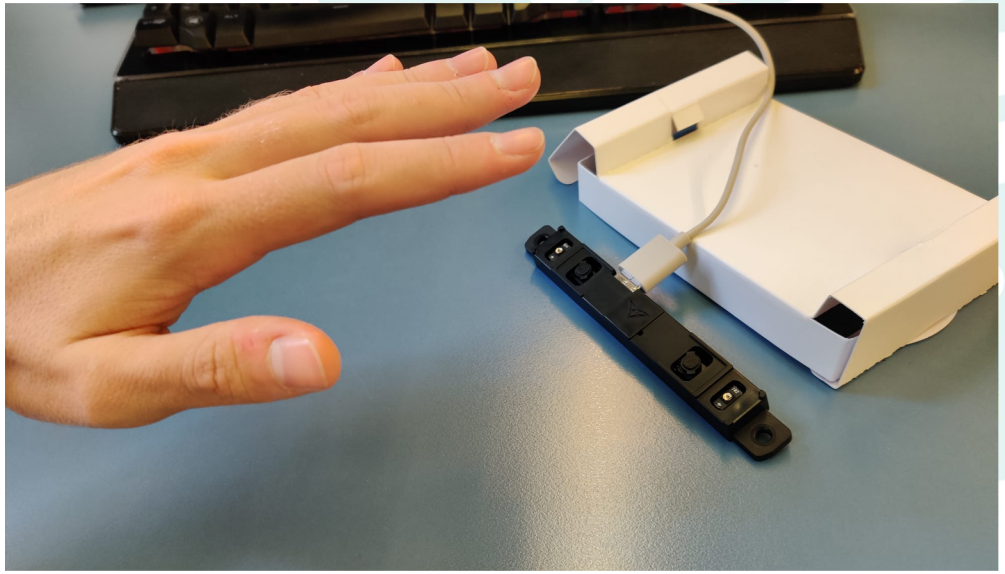

Limited range of action

Good to capture only depth

Unnatural station to perform signs

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3. Applying natural and realistic animations

★ Best approach to obtain natural animations? → Obtaining them directly from a real person.

Motion Capture (MoCap) possibilities specifically for hand capture:

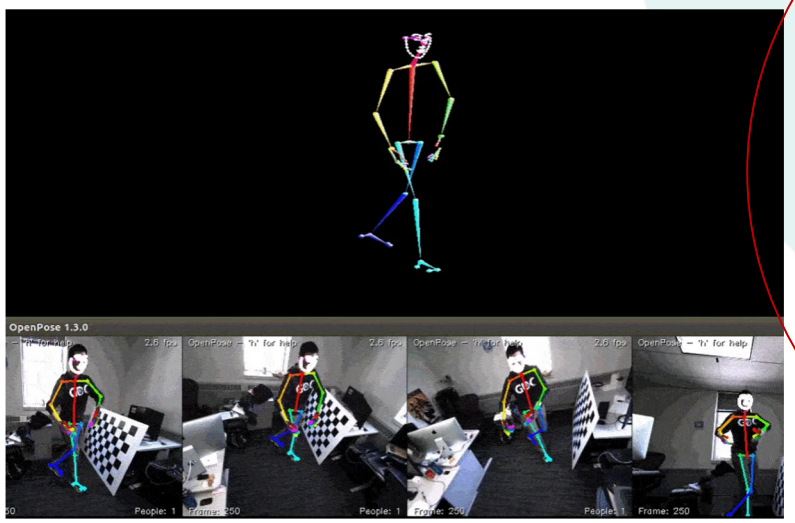
- Marker-based methods.
- Sensors-based methods.
- **Machine Learning methods.**

New research field

Reconstruction from models

Good to occlusions

OpenPose



MediaPipe

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017255

3. Applying natural and realistic animations

Creating a skeleton from MediaPipe:

- MediaPipe → Markers in space → Location
- 3D models → Hierarchy of bones → Rotation

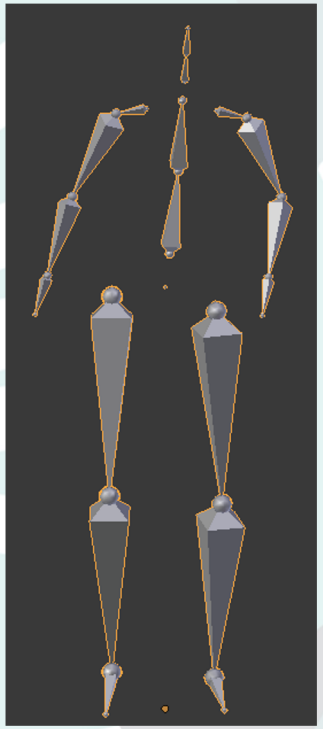
We need to convert markers location to hierarchy of rotations

BVH Format

+ Widely supported
+ Retargeting (adapt to different 3D models)

MediaPipe

BVH Skeleton



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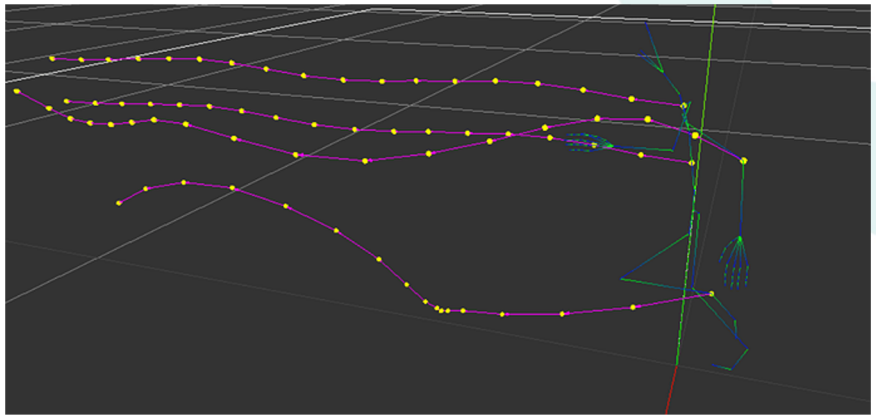
3. Applying natural and realistic animations

★ Best approach to obtain natural animations? → Obtaining them directly from a real person.
★ Which method to use? → MediaPipe

Now we need provide an edit station to the user. Need to think the most intuitive and manageable mode.

- Track the path of the joints.
- Select the bones in the scene to edit them.
- Edit the rotations of the selected joints.

User Interface



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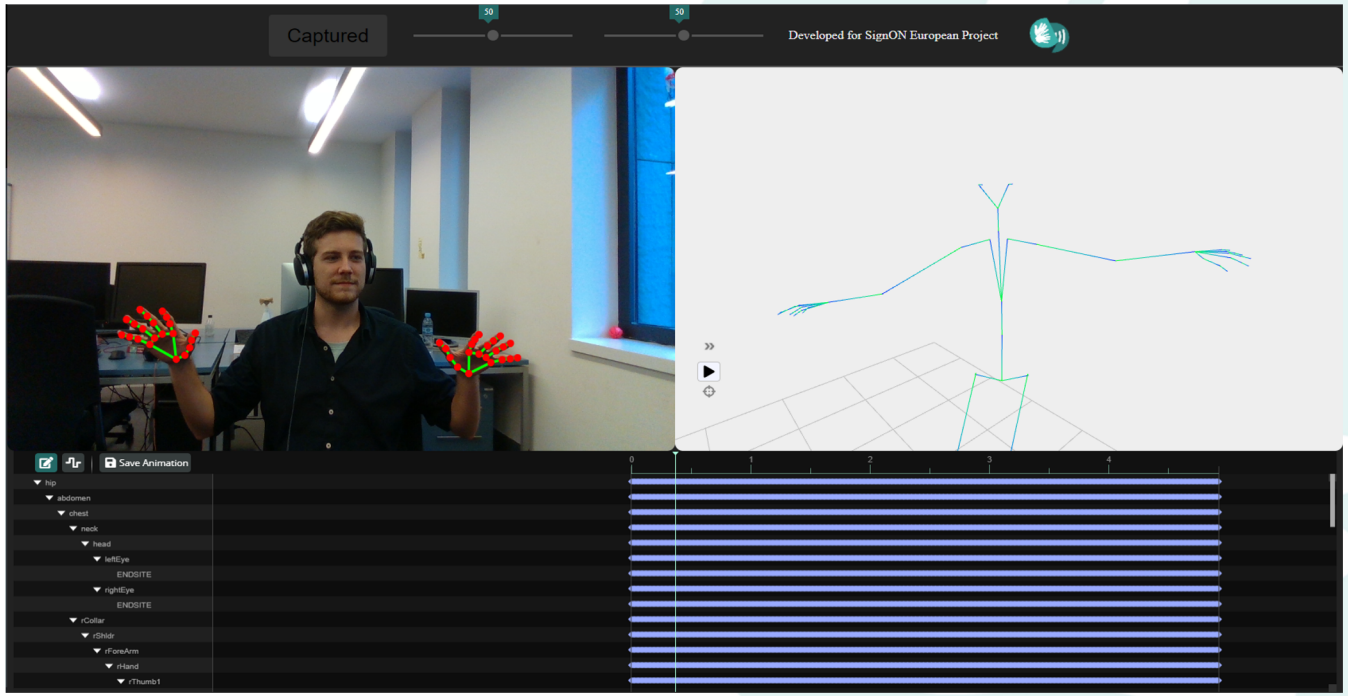
3. Applying natural and realistic animations

Evaluation of our end result



Demo

+ Editor of animations →
+ High challenge
+ Creation of a dataset of sign animations → Innovative, none existing right now

USEFUL WORK

- Dataset performed in 5 SL → Extensible to more sign languages

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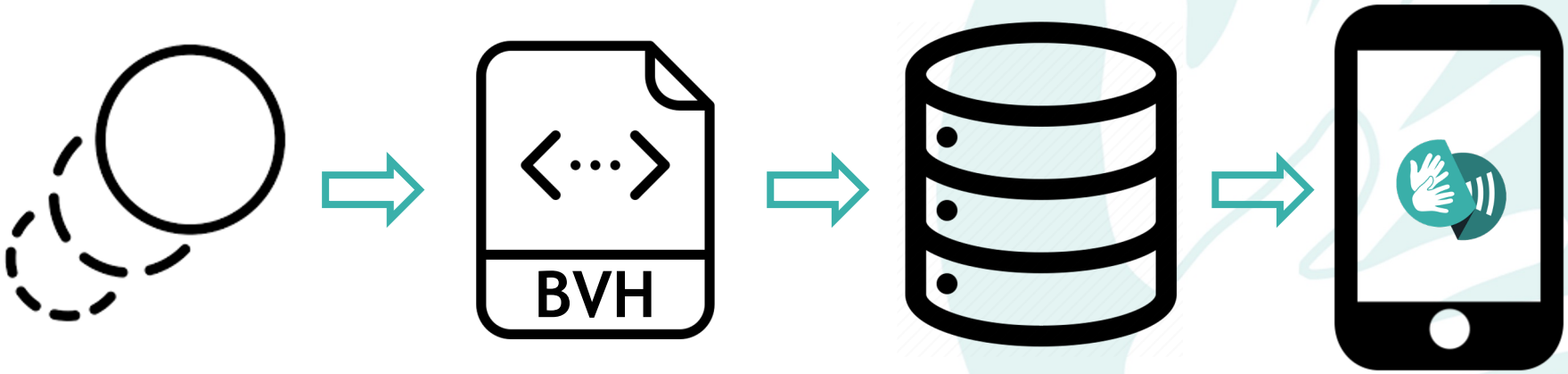
Insights of the project and tasks



Animations Gathering
Usage in SignON app

Animation Data

Database

Complete Tasks Integration Pipeline in the Projects

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