Sign Language Translation Mobile Application and Open Communications Framework

Deliverable 7.4: Final Report

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Overview: This report provides an accurate detailed description of the work carried out in this project in the three years that it was active.

Revision History

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V1.0	The SignON Consortium	20/12/2023	Final revision
V0.1	The SignON Consortium	21/11/2023	First Draft

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V0.1	D7.4	Irene Murtagh	TU Dublin	15/12/23
V0.1	D7.4	Jorn Rijckaert	VGTC	16/12/2023
V0.1	D7.4	Vincent Vandeghinste	INT	18/12/2023
V0.1	D7.4	Josep Blat	UPF	20/12/2023
V0.1	D7.4	Gorka Labaka	UPV/EHU	20/12/2023
V0.1	D7.4	Dimitar Shterionov	TiU	20/12/2023
V0.1	D7.4	Lorraine Leeson	TCD	20/12/2023

Acronyms

The following table provides definitions for acronyms and terms relevant to this document.

Acronym	Definition
DHH	Deaf and Hard of Hearing
DoA	Description of Action
WP	Work Package
MT	Machine Translation
UI	User Interface
SLR	Sign Language Recognition
ASR	Automatic Speech Recognition
SL	Sign Language/s
REC	Research Ethics Committee
DMP	Data Management Plan
SLMT	Sign Language Machine Translation
NLU	Natural Language Understanding
SOI	Signs of Ireland
CL	Computational Linguistics
SOTA	State Of The Art

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1. Executive Summary

SignON is a EU-funded project that was designed to develop a mobile application for translation between different European signed and spoken languages. It aims, on the one hand, to address a communication gap and on the other, to facilitate the fair and unobstructed exchange of information between deaf, hearing and hard of hearing individuals. Despite the overarching objective (developing a translation mobile application) being stated as highly technical, this three-year project, instead of contrasting technical and societal, aligned these two dimensions in an unprecedented collaborative workflow. With co-creation embedded from its inception, SignON is the first large-scale project to (i) rely on the inputs, requirements and desires of deaf and hard-of-hearing communities and (ii) openly inform its stakeholders, addressing their reservations, fears and suspicions and disseminate its outputs fairly in signed and spoken languages.

This SignON project started in January 2021 and is about to end in December 2023. At the time of writing this report, we are almost at the project's end. In this report, we trace its execution, its evolution, how its objectives have been addressed, its operation, management and future perspectives. This project targets a wide range of tasks. The work we conducted adequately addresses these tasks through a very broad spectrum of activities addressing every aspect of automatic translation between signed and spoken languages – from recognition of signed utterances to synthesis, from light-weight mobile applications to heavy modern cloud-based solutions to service the apps, from data collection to ethics and legislations, from the individual to society. The progress we have made within SignON is summarised in this deliverable. We present summaries of all deliverables, outlining the work conducted within each work package (WP) addressing each task towards achieving our objectives.

2. Introduction

The SignON Consortium consists of seventeen members from five different countries, with the required track record and expertise to achieve the objectives of the project. The members of the consortium are shown in Table 1.

No	Name	Short Name	Country
1	Dublin City University	DCU	Ireland
2	Fincons Group AG	FINCONS	Switzerland

3	Stichting Instituut Voor De Nederlandse Taal	INT	Netherlands
4	Universidad Del País Vasco / Euskal Herriko Unibertsitatea	UPV/EHU	Spain
5	The National Microelectronics Applications Centre Ltd	MAC	Ireland
6	Universitat Pompeu Fabra	UPF	Spain
7	Technological University Dublin	TU Dublin	Ireland
8	The Provost, Fellows, Foundation Scholars & the College of the Holy & Undivided Trinity of Queen Elizabeth Near Dublin (Trinity College Dublin)	TCD	Ireland
9	De Vlaamse Radio En Televisieomroeporganisatie NV	VRT	Belgium
10	Universiteit Gent	UGent	Belgium
11	Vlaams Gebarentaalcentrum VZW	VGTC	Belgium
12	University College Dublin, National University of Ireland, Dublin	NUID UCD	Ireland
13	Stichting Katholieke Universiteit	RU	Netherlands
14	Nederlandse Taalunie	TaalUnie (NTU)	Netherlands
15	Katholieke Universiteit Leuven	KU Leuven	Belgium
16	European Union of the Deaf AISBL	EUD	Belgium
17	Stichting Katholieke Universiteit Brabant	TiU	Netherlands

Table 1: Partners in the SignON Consortium

3. Overview of Project Objectives

The SignON Project started with the goal of fulfilling six objectives, with the overall aim being to develop a solution to help to bridge the communication gap between DHH and hearing people through the provision of an accessible translation service. The six objectives are summarised below and are presented as they were in the Grant Agreement:

1. **Co-creation workflow and community**: A co-creation workflow will be established for: (i) the identification, collection and analysis of existing practices, translation requirements, needs and gaps, as well as the production of user requirements, performance indicators and recommendations to drive the development of the SignON framework, service and application; and (ii) an ongoing feedback loop from DHH and hearing stakeholders back to the consortium to ensure user responses are woven into the ongoing plans for the project, expectations are met and issues related to diversity and bias are explicitly addressed.

2. **SignON Framework and Mobile application**: (i) Design, development and release of the free, open-source SignON Framework and SignON smartphone application for effortless access to Machine Translation (MT) between signed and spoken languages, i.e. the SignON service; and (ii) Each user will be unrestricted by the source and target modalities and languages and can choose their preference via the mobile app's user interface (UI).

3. **Automated recognition and understanding of signed and spoken/written language input**: To facilitate recognition and understanding of signed and spoken/written language input SignON will encapsulate: (i) Sign Language Recognition (SLR), handling lexical and productive signs as well as fingerspelling; (ii) Advanced Automatic Speech Recognition (ASR) tuned to the user, the topic and the context, responding to atypical speech from DHH speakers.

4. **A language independent meaning representation (InterL)**. Design and develop a language independent meaning representation to facilitate the encoding and decoding of input/output messages: (i) language- and modality-specific Natural Language Understanding (NLU) layers capable of capturing the meaning of the input message; (ii) a vector space, symbolic or hybrid meaning representation of the input message and its context; (iii) procedures for mapping from NLU to Language Independent Meaning Representation and from Language Independent Meaning Representation to Generation modules.

5. **Sign, speech and text synthesis**: (i) SignON will convert a sign language (SL) specific syntactic-semantic representation in the target SL via a 3D virtual signer. The 3D virtual signer will be driven by a real-time computational system translating the syntactic-semantic representation into a suitable timed list of specific signs in the target SL to be played (planner)

and a real-time computational system that visually renders the list generated by the planner into web-based virtual signer animations. This real-time computation system fixes potential conflicts while providing continuity and smooth transitions of the animations (realiser); (ii) SignON will convert language specific representations into surface text in the appropriate register, taking special care to avoid linguistic bias; and (iii) Protocols will be defined for connecting to external, cloud-based text-to-speech service and synthesis of speech based on surface text.

6. **A wide range of supported languages and extensibility of the framework**: (i) Through a phased development cycle, we aim to provide support for the following SLs: Irish Sign Language (ISL), British Sign Language (BSL), Flemish Sign Language (VGT), Dutch Sign Language (NGT) and Spanish Sign Language (LSE) as well as the English, Irish, Dutch and Spanish spoken languages. The support of these languages is driven by the expertise of the consortium members and aims to showcase the applicability and usefulness of the SignON framework; (ii) Develop a system that is **flexible**, i.e. can accommodate different user requirements and preferences, and **extensible**, i.e. new languages (signed and spoken) can be integrated and the support of existing ones can be updated.

4. Detailed Progress Report per Work Package

The work conducted in SignON was divided into nine work packages, in order to ensure a clear and well-organised distribution of tasks, and to facilitate an orderly and timely execution of the project goals.

The goals and scope of each work package are laid out in detail in the Grant Agreement (GA), including a list of the specific tasks that belong to them. The main aims of the nine work packages can be summarised as follows (taken directly from the Grant Agreement):

- **Work Package 1 (Co-creation and User Response)**, led by the European Union of the Deaf (EUD), will engage with potential users to co-design and co-develop the SignON framework and application and will lay out a roadmap of KPIs to guide their development. Through openness, fairness and gender equality we will also establish a user community with hands-on experience with realistic expectations towards the SignON service.

- **Work Package 2 (SignON Service and Mobile App)**, led by FINCONS GROUP AG, will encapsulate the technical activities of designing and developing the SignON framework that will incorporate components delivered through WP3, WP4 and WP5 and the SignON mobile app. The framework and the app will be free and open-source to allow for easy adoption and evolution during and after the life cycle of the project. WP2 is also concerned with the instantiation and utilisation of the cloud-based platform and the creation of a repository for storing and organising collected data.

- **Work Package 3 (Source Message Recognition, Analysis and Understanding)**, led by Ghent University (UGent), research and develop efficient methods for recognition and analysis of the input message in the source language: (i) SLR, (ii) ASR for typical and atypical speech and (iii) input and recognised text analysis and processing through a set of NLU pipelines. The outcomes of the involved research and development will be components for SLR, ASR and NLU, which will be adaptable (to the user and the use-case). The work will be conducted in parallel, and led by different partners, in order to achieve a synchronous delivery of source message understanding of both spoken and sign languages in accordance with the DesignForAll methodology.
- **Work Package 4 (Transfer and Interlingual Representation),** led by Tilburg University (TiU), will formulate and implement a multimodal and multilingual intermediate representation - InterL - to bridge sign and spoken languages handled in the project as well as the transformation processes from and to InterL. It will start with two different representations - a symbolic one and a representation based on embeddings - that will be merged into a hybrid representation.
- **Work Package 5 (Target Message Synthesis),** led by Universitat Pompeu Fabra (UPF), is devoted to real-time target message synthesis in sign and spoken languages. A personalisable 3D virtual signer to convey the translated message in the target SL will be developed. This will be co-designed with and verified by the users (WP1). WP5 will also encapsulate the work for written language synthesis and normalisation based on the representation in InterL (WP4). Thereafter this text will serve as the basis for the synthesis of spoken language through a commercial text-to-speech platform. WP5 will also deliver a pipeline for sending the target message to the user through the SignON app (WP2).
- **Work Package 6 (Communication, Dissemination and Exploitation)**, led by Vlaams Gebarentaalcentrum VZW (VGTC), aims to raise awareness on the outcome of the project. SignON will offer innovative opportunities to exploit and promote its results and WP6 will develop business plans and advance exploitation for the project, including joint and individual

opportunities, maximising opportunities for the dissemination of project results and ensuring effective communication procedures are in place. The project will draw on significant media networks and established contacts to promote awareness, adoption, and further development of the SignON services and application.

- **Work Package 7 (Coordination and Management)**, led by Dublin City University (DCU) as coordinator of the project, will manage and coordinate the overall project with WP leaders managing their own work-packages and contributing to project management (meetings, reviews, reports). DCUs extensive experience in managing and collaborating in multidisciplinary research as well as experience in organising multidisciplinary research-industry events will ensure smooth and productive work throughout the project.

- **Work Package 8 (Ethics requirements)**, led by Dublin City University (DCU), will set out the 'ethics requirements' that the SignON project must comply with.

- **Work Package 9 (Ethics)**, led by Trinity College Dublin (TCD), will oversee and coordinate all ethical aspects of the project and provide ethical guidelines and protocols for identification and recruitment of participants. It will also ensure all consortium members abide by the EU Code of Research Integrity and provide support and advice to members of the community as well in terms of the use of their personal data.

4.1 Work Package 1: Co-creation and User Response

4.1.1 Introduction

Work Package 1 (Co-creation and User Response), led by the European Union of the Deaf (EUD), engaged with potential users to co-design and co-develop the SignON framework and application and laid out a roadmap of KPIs to guide their development. Through openness, fairness and gender equality we also established a user community with hands-on experience with realistic expectations towards the SignON service. Therefore, the work of WP1 from M1 to M36 was essential to the development process within SignON.

4.1.2 Work Package Objectives

The overall objectives of WP1 were :

- Identification, collection and analysis of existing practices, translation requirements, needs and gaps in current software solutions and services, as well as to produce recommendations and performance indicators to bootstrap and support the development of the SignON service, framework and application.
- To establish an effective continuous communication between DHH and hearing stakeholders on the one hand and the consortium on the other, in order to define requirements for the SignON services, framework and application and to ensure these are woven into the ongoing plans for the project.
- To ensure that SignON addresses relevant use-case scenarios and its range and quality of services is in line with stakeholders' expectations and that stakeholders' expectations are in line with the capabilities of the SignON framework.
- Through the community iteratively interacting with the SignON application, to test and validate the SignON service and to improve it (and its underlying components) via its machine learning capabilities, ensuring that it reaches indicated quality standards.
- To explicitly address diversity and bias by ensuring that stakeholders involved in ongoing co-creation events represent the diversity of the stakeholder groups.
- To ensure the efficient and effective adoption of the SignON communication services among the stakeholders, leveraging its beneficial impact on DHH users.

4.1.3 Tasks

Task 1.1: Case Studies and Evidence Analysis

This task gathered evidence, lessons learned and best/worst practices of sign language translation with a particular emphasis on the adoption of application-based technologies and services while paying particular attention to data protection. The output of T1.1 was translated into D1.1.

This deliverable was submitted in March 2021 and described lessons from projects on sign language machine translation to date as well as highlighting deaf community perspectives towards machine translation software or/and devices with attention to ethical considerations and data management. Particular emphasis was also dedicated to key challenges in order to meet potential user's expectations and ensure effective communication between the user community and the SignON Consortium.

Task 1.2: (re)define and (re)evaluate target usage domains and use-case scenarios

This task aimed to assess the validity of the use-cases and use-domains before using the results of D1.1 to update the use-cases and use-domains and, eventually, to extend the application domain of SignON. A working group was set up to define use cases for specific application domains. The working group set up a list of potential use cases and a set of criteria to assess the suitability of the individual use cases for the SignON project and the SignON app. Among these criteria was the appraisal of the use cases by the DHH and hearing communities as collected in a survey designed by KU Leuven and distributed across five sign language communities (VGT - Flanders, NGT - the Netherlands, ISL - Ireland, BSL - Ireland and LSE - Spain). At the SignON project meeting in Tilburg in June 2022 it was decided to select the hospitality domain as a use case. Further discussions addressed the acquisition of train and test data for the hospitality domain from a technical, ethical and legal point of view, which eventually led to the SignON ML App (see D2.9).

A dedicated report was devoted to the use-cases and usage domains and stakeholders' acceptance in D1.2, which was submitted in September 2023. We have also produced a report on the Flemish Survey in Dutch which is currently being translated into VGT with the aim of informing the Flemish Deaf community (and the hearing and hard of hearing participants).

Task 1.3: User Requirements, Needs and Gaps

This task defined the user requirements, needs and gaps for the new translation technology based on the data from tasks T1.1 and T1.2. For this purpose, communication with DHH citizens helped to refine the outline of end-user requirements, as well as exchanges with industry stakeholders (media, translation service, public authorities) to identify professional user requirements. Details of the results of this quantitative and qualitative user requirements research were reported in D1.3.

D1.3 was submitted in June 2021 and contained a description and analysis of the findings of focus group interviews with deaf participants and detailed analysis of user requirements alongside a list of recommendations. A distinction has been made between recommendations coming from the community that are within the scope of the SignON project and recommendations that are outside the scope of the SignON project.

Deliverable D1.7 was the second iteration of D1.3 and further built upon this. The deliverable contained further end-user research and was submitted in June 2022, and yet another iteration with even further end-user research was submitted in June 2023 as D1.8.

Task 1.4: Technical user Requirements, Iterative design process (UX)

This task defined the technical requirements to support the application development, integration and testing of SignON. These technical requirements were based on the work of T1.3 (user requirements) for the best possible implementation of the SignON application in WP2 (task T2.3). To ensure that the needs of each user group were considered throughout the development cycles, this task was a reference intermediary to moderate the execution of each cycle.

The work of T1.4 was documented in D1.4, the first version of which was published in June 2021. The second and third versions (D1.9 and D1.10) were published in June 2022 and June 2023, respectively.

Task 1.5: Building a bias-free community within and outside the SignON project

This task aimed to engage all stakeholders through the organisation of co-creation events. Focus groups were organised with deaf users in Spain, Flanders (Belgium), Ireland and the Netherlands, along with European-wide focus groups with deaf people from specific minorities, such as deafblind and ethnic minorities, as the enlargement of the user community is the key to T1.5 to help determine/validate some of the objectives recorded by the different tasks of WP1 (T1.2, T1.3, T1.4). Attention was given to the sign languages studied as well as to the best possible representation of users regardless of gender, ethnicity, religion, etc. There are also other methods of community building outside of focus groups for user research that are visited in D1.5, such as the physical co-creation events in the form of roundtables and workshops that were carried out, the science communication strategy and SignON attendance on academic events.

D1.5, which contained the first iteration of the Community Building Report, was submitted in June 2022, while the second iteration of the Community Building Report (D1.11) was submitted in September 2023.

Task 1.6: Human-centric testing, validation and upgrade

During the second half of the project, the cycles of testing, validation and upgrade continued in this user-centric project. The final, mostly qualitative assessment of the project results is contained in D1.6, *Quality Assessment Report*, submitted in M35 instead of M30 as initially foreseen to enable the gathering of summative feedback from stakeholders on the latest version of the SignON SLMT app and service. This summative evaluation is based on analysing how (much) the current version of the app meets the KPIs of the project; users found that the app has positive aspects related to ease of use, while the accuracy and effectiveness of the sign language translation and the avatar's signing accuracy was criticised by several users. From this feedback, specific recommendations to support improvements of the app with regard to SLMT are provided. The app integrates multiple subsystems including a sign language recognition subsystem, a machine translation subsystem, a synthesis subsystem and others. The synthesis (sub)system only achieved enough maturity by the end of the project, and users' feedback is pending, but a comparative evaluation with alternative systems of similar approaches has been carried out and is reflected in D1.6 (November 2023), showing that similar coverage and some improvements have been achieved.

Task 1.7: Key Performance Indicators

Using the results from Tasks 1.1 - 1.5 as input, we defined the Key Performance Indicators (KPIs) related to quality (e.g. of the animated signer), performance (e.g., speed of the SignON service), acceptance (e.g. minimum translation quality), etc. D1.13 was submitted in June 2021.

4.1.4 Deliverables Submitted

D1.1: Case studies and evidence analysis

This deliverable draws on available literature that describes, documents and interrogates best practices with respect to sign language machine translation (MT) with a particular emphasis on the adoption of application-based technologies and services. Firstly, we addressed DHH stakeholders' views towards MT, drawing on the limited literature available. This set the scene for work in progress to document current attitudes and perceptions of European deaf signers vis-a-vis a range of MT approaches including sign languages, a theme we report on later in the SignON project.

Here, we also considered data available to our project and outlined key considerations relating to data protection during and into the post-project deployment phase of the SignON project. A number of projects that entail sign language translation have been supported over the past decade or so. Here, we summarised a sample to indicate the current state of the art.

Against this backdrop, we explored deaf community responses to these developments, identified other key challenges (e.g. range of data available, limited documentation of sign languages, insufficient sign language repertoires in many teams, and crucially, lack of engagement with Deaf communities and limited involvement of deaf scientists on many (most) teams).

D1.2: Report on Use cases & Usage Domains and Stakeholders' Acceptance

This report provided an outline of the research on potential use cases for the SignON application. This research was conducted using a broad online survey in the different partner countries. In this way, the expectations, wishes and needs of the DHH and hearing community were polled according to the co-creation principles of the SignON project. The report explains in detail what the objectives, methodology and results of this research were. The findings and lessons learned were, and still are, an important input for further developments of the SignON app and similar, future projects.

D1.3: First User Requirements Report

This report provided a first overview of the user requirements for the SignON project. The information in this overview was gathered during focus group interviews and individual interviews with members of the DHH community. Afterwards we provided an analysis of user requirements, followed by a list of recommendations for SignON. We also presented an overview of recommendations which are not immediately tied to the SignON project, but may prove to be interesting for future projects and/or research. This way, no information could get lost, and every opinion receives a proper follow-up. The end of the report consisted of information about possible future cooperation with the focus group participants for app prototype evaluations, and a general conclusion of the report.

D1.4: First Technical User Requirements and User Research (UX Design) Report

The technical requirements of SignON were derived by mapping the end user requirements (Task 1.3) onto the technical implementation of the SignON application, based on a structured formative evaluation of users' technical requirements using an initial fast prototype of the SignON mobile application. This mobile app prototype demonstrated early SignON features, allowed users to begin to see, hold and feel something tangible and provide realistic inputs on what they want, and for the developers to get an appreciation of the realities of the mobile app platform and cloud requirements. This app continued to be improved driven by users' feedback and suggestions.

D1.5: Interim Community Building Report

This report provided a current overview of our initiatives to build out our community with co-creation events, detailing the co-creation events we carried out. Other avenues of community building were also explored, such as the use of our social media channels and the building of a scientific community.

D1.6: Quality Assessment Report

As foreseen in the Description of Work of the project, this deliverable on *Quality Assessment* focuses on two aspects: (i) the summative evaluation by stakeholders of the performance of the SignON service and the SignON SLMT app, and (ii) the evaluation of stakeholders of the sign language production by means of an avatar. Other deliverables report on the quality of partial aspects, such as Sign Language Recognition (D3.2 *"Sign language recognition component and models"*), or translation (for example D4.5 "*A hybrid intermediate representation"* which reports on the quality of the translation pipelines). To provide this final evaluation, the submission has been on M35. It contains some perspectives towards the future derived from the results of the evaluation.

D1.7: Second User Requirements Report

This report provided an update to the first overview of the user requirements for the SignON project, which contained insights from focus groups conducted with two of the project's target sign language communities (VGT and LSE). This report added further insights from focus groups conducted in two more target sign language communities (NGT and ISL).

D1.8: Final User Requirements Report

This report provided a final update to the overview of the user requirements for the SignON project, which contains insights from all co-creation events conducted throughout the SignON project. The methodology was explained to clarify our way of working, then there was an analysis of the user requirements, followed by a list of recommendations for both in SignON and beyond. The end of the report contains a general conclusion with key take-aways.

D1.9 Final Technical Requirements & User Research (UX design) Report

The technical requirements were derived by mapping the end user requirements (Task 1.3) onto the technical implementation of the SignON application, based on a structured formative evaluation of users' technical requirements using the first release of the SignON mobile application, and building on *D1.4: First Technical Requirements and User Research (UX design) Report*. The resulting updated definition of the SignON Mobile App's user technical requirements were tabulated and continued to be updated based on further user feedback, evaluation and SignON Framework system development that was documented in the final iteration of this report as D1.10 in June 2023.

D1.10 Final Technical Requirements & User Research (UX design) Report

These technical requirements continued the D1.9 structured formative evaluation of users' technical requirements using the latest version of the SignON mobile application. Overall, users saw the SignON SLMT App's potential, and agreed that it is a good foundation for the future evolution of the SignON service for all users, however it needs improvement in terms of speed, accuracy, customization, and user interface. These were tabulated in an updated definition of the SignON Mobile App's user technical requirements, which continued to be updated based on further user feedback, evaluation, and SignON Framework system development. This fed into the summative evaluation of *D1.6: Quality Assessment Report* just before the end of the project.

D1.11: Final Community Building Report

This report was the second iteration of D1.5 and expanded the overview of our initiatives to build out our community with co-creation events, detailing the co-creation events we carried out. Other avenues of community building were also explored, such as the use of our social media channels, via creative arts practices, and the building of a scientific community.

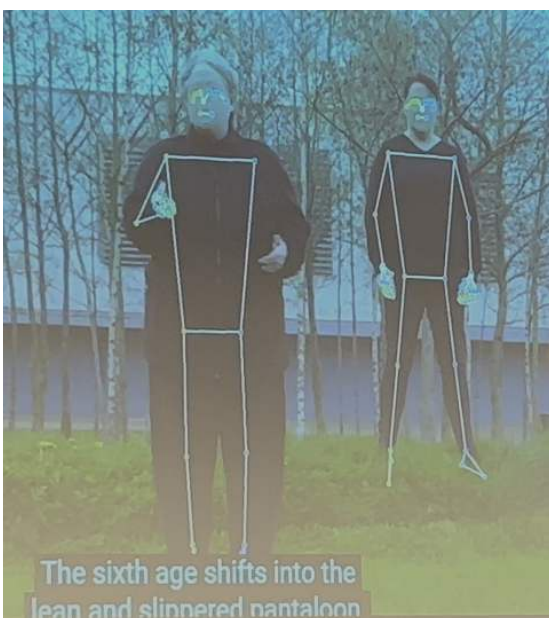

Figure 1: Image of Alvean Jones and Lianne Quigley, two Irish Deaf actors, from a recorded performance of "All the World's a Screen - A Shakespeare performance in Irish Sign Language" in Irish Sign Language for people and artificially intelligent machines[1]*.*

[1] Additional funding to support this initiative was secured by Shaun O'Boyle, DCU from Science Foundation Ireland and the ADAPT Centre and is based on a format developed by TRACES as part of SISCODE.

D1.12: User-generated data

This deliverable reported on the task to support data generation by users undertaken within the SignON project. Data generation is essential to enhance Machine Learning strategies. Within this perspective, two complementary systems have been developed, which are expected to be useful beyond the life of the project. The initial data obtained or re-used by the project is discussed, as well as details of one of the systems, which are not reported elsewhere.

D1.13: KPIs

This document presented the Key Performance Indicators (KPIs) as indicated by each WP lead, offering a comprehensive overview of how we seek to evaluate our success across the life of the SignON project.

4.1.5 Deviations and Corrective Actions

With the agreement of the Project Officer, the final, mostly qualitative assessment of the project results in *D1.6: Quality Assessment Report*, was submitted in M35 instead of M30 in order to allow time to gather summative feedback from the stakeholders on the latest version of the SignON SLMT app and service.

4.1.6 Conclusions

From EUD's experiences throughout WP1, we conclude that co-creation is very welcomed by the deaf communities, and that sign language research projects must have deaf professionals at the steering wheel to keep them going in the right direction and to alleviate the distrust for "hearing researchers". Furthermore, transparent and trustworthy co-creation and science communication strategies, led and carried out by deaf professionals, are essential to build a relationship with deaf communities. The key is direct communication in sign language.

While co-creation is an excellent and much needed first step, it is not enough. "Hearing researchers" must also be aware of their social responsibility. Throughout our work, deaf communities continuously expressed the same concerns: there are fears that governments and other hearing decision-makers decide SLMT is a cheaper alternative than human interpreting, deciding to invest in these technologies and divest in human interpreters causing deaf communities to have to rely on technology only for accessibility, even when it is against their wishes. Will hearing academics actually be allies of the deaf communities to clarify that humans are more important than machines when it comes to accessibility, or are they going to take a neutral stance when these discussions begin?

While the SignON project aims to achieve a sign language machine translation tool to bridge the communication between hearing and deaf interlocutors, during our co-creation it came to the forefront that deaf communities have many ideas to use (parts of) sign language technologies for a plethora of other uses outside of the communication domain, e.g. as tools to make work or life easier. Many of these ideas parallel the way text to text machine translation is used in daily life (by both deaf and hearing people), such as translating websites/emails or automatically transcribing (sign) language.

In any case, the deaf end-user should decide what method of communication is best for them/the situation. There is a strong tendency towards live human interpreters first as preferred communication method between signed and spoken languages. The gap left by this could be filled by VRS/VRI services. Then the gap left by these might eventually be filled by SLMT, but not in its current state. The deaf communities are open to use sign language technologies, but also have very high expectations before they consider it usable.

4.2 Work Package 2: SignON Service and Mobile App

4.2.1 Introduction

WP2, SignON Service and Mobile App, aims at designing and developing the SignON Services Framework, which integrates components from the SignON processing pipeline delivered through WP3, WP4 and WP5 with the SignON Mobile App. This integration is made possible with the instantiation and utilisation of the SignON Open Cloud Platform, which hosts the SignON Services Framework, together with the creation of a repository for storing and organising collected data, and with the design and development of the SignON Mobile App. The framework and the app are free and open-source to allow for easy adoption and evolution during and after the life cycle of the project.

4.2.2 Work Package Objectives

- Implementation of the SignON Open Cloud Platform and the SignON Services Framework;
- Integration of the services and components developed in WP3, WP4, WP5;
- Development of the SignON mobile application to support translation as well as user input for

service upgrade;

- Delivery of the SignON services through a hybrid remote-local service delivery platform i.e. cloud (remote) and mobile (local).

4.2.3 Tasks

T2.1: Design and implementation of the SignON Open Services Framework

This task is focused on the definition of the SignON Development Repository and on the design of the SignON Services Framework architecture.

For the SignON Development Repository, a GitLab platform was adopted for hosting the codebase of the project and a container registry for the Docker images, and later on moved to GitHub, due to changes in licensing terms. Furthermore, structure organisation and shared patterns (versioning, branching, etc.) were agreed among partners. The results were formalised in the deliverable *D2.1: SignON Development Repository*.

For the design of the SignON Services Framework architecture, the input and output requirements of the SignON App and the SignON Pipeline were used as a starting point to define the SignON Orchestrator, i.e. the component that will take care of dispatching information between the various components of the system. Furthermore, technical details about the component interaction were agreed with the technical WPs (WP3, WP4 and WP5) in order to support the foreseen workflows. The results have been formalised in the deliverable *D2.2: SignON Services Framework Architecture*.

T2.2 Development of the SignON Cloud platform

Task 2.2 defines and implements the open cloud-infrastructure and the cloud-storage (for the large data hosting) and defines the SignON Open Cloud Platform, which hosts the SignON free and open-source Service Framework. The repository for large data storage and the platform hosting the SignON Services Framework have been deployed at INT, and the software and hardware infrastructure has been deployed and tested.

The architecture of the SignON Framework has been structured into several components, each of them with a specific purpose in the platform (see Figure 2).

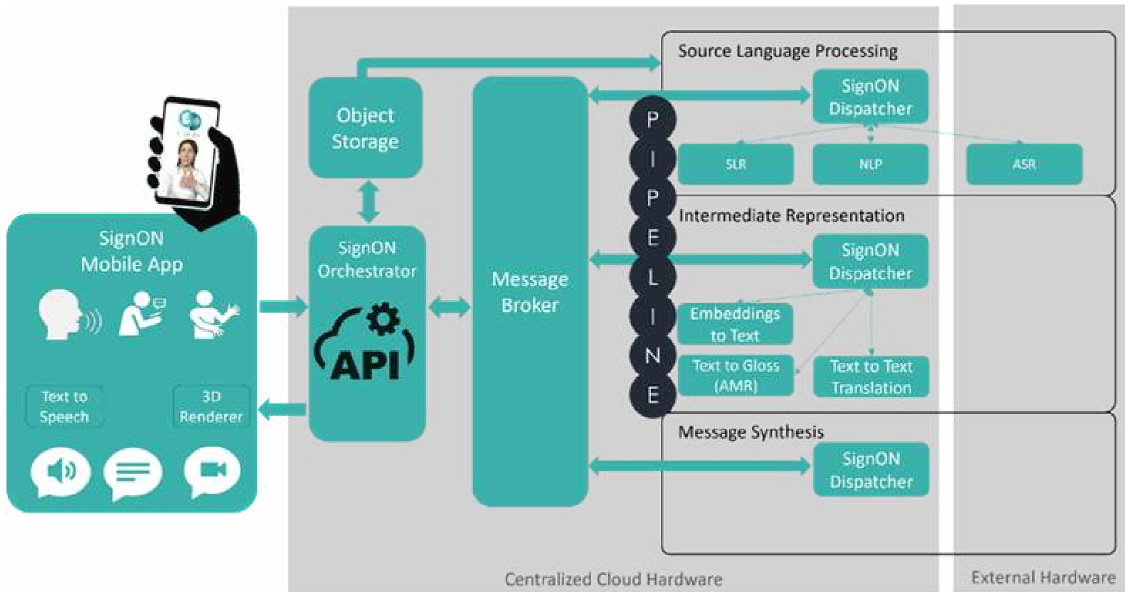

Figure 2: SignON Framework final architecture

The SignON Orchestrator works as the central control hub, managing and coordinating incoming requests from the SignON Mobile App (developed in T2.3), to forward incoming requests to the SignON Dispatchers. The SignON Dispatchers work as specialised components to distribute incoming requests towards the relevant SignON Pipeline components for execution. The Object Storage component is used to transfer audio or video files from the Mobile App to the relevant Pipeline components; once processed, such audio and video files are deleted. Finally, SignON Pipeline components are in charge of implementing the specific source language processing, intermediate representation or synthesis functionalities implemented in WP3, WP4 and WP5.

The SignON Framework APIs (described in D2.4 and D2.5) allow communication between the SignON Apps, the SignON Orchestrator, and the SignON Pipeline components (through the SignON Dispatchers).

The SignON Framework can handle different inputs and return different outputs depending on the request made through the SignON Mobile App. Three different types of input and output are available, namely: text, audio, video/avatar (see Figure 3). For each one of those it is possible to choose a different source and translation language. Due to the complexity of the "X to Sign" pipeline, three different approaches were formulated; out of the three available options, the third one (i.e., Text to Gloss followed by 3D Engine) was implemented. Detailed sequence diagrams for all I/O combinations are described in D2.5.

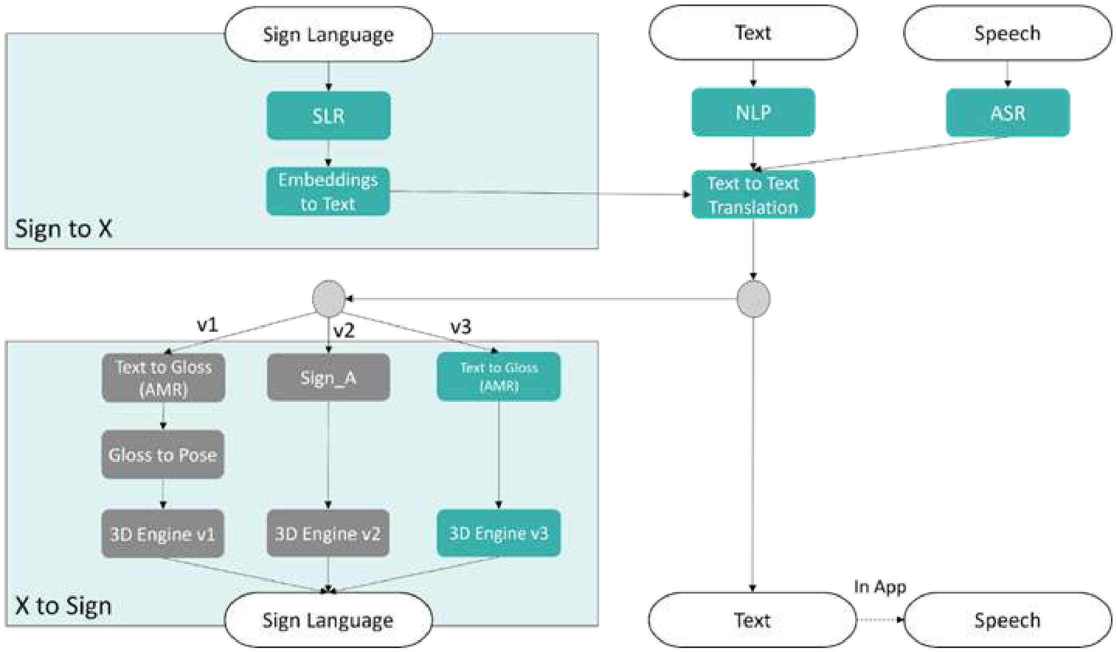

Figure 3: SignON Framework final data flow. The integrated components are highlighted in green.

Network security on the exposed systems is established by using multiple layers of network filtering using firewalls and exposing as little as possible to the internet to minimise the attack surface.

During the initial stage of development, an ESX based virtualization was chosen to facilitate development and isolation of different WPs. However, the GPU ability could not be shared among WPs' VMs on native ESX VMs without a substantial investment in licences from ESX and Nvidia. The hardware was reinstalled with an Ubuntu 22.04 LTS operating system. A new Docker environment with GPU support was installed from the native Ubuntu repositories and the data location for the Docker associated files were moved to the local datastore, to allow for GPU acceleration in the new configuration.

Public access to the new containers was set up in the same way as on the ESX system: endpoints in the Docker containers are exposed on the DMZ network of INT and made public by a reverse proxy.

Task 2.3 Design & Development of the SignOn Communication Mobile Application

This task developed and supports the SignON SLMT mobile App as a TRL6[2] pre-commercial prototype that has been validated and "demonstrated in relevant environment". The

[2] TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies) h2020-wp1820-annex-g-trl_en.pdf (europa.eu)

functional status of the SignON SLMT App and Framework services is described in D2.7 and D2.5.

SignON is a free, open-source prototype application and framework for conversion between video (capturing and understanding Sign Language (SL)), audio and text and translation between signed and spoken languages (see Figure 4). To ensure uptake, improved SL detection and synthesis, as well as multilingual speech processing on mobile devices for everyone, the SignON service is a smartphone application running on standard modern devices.

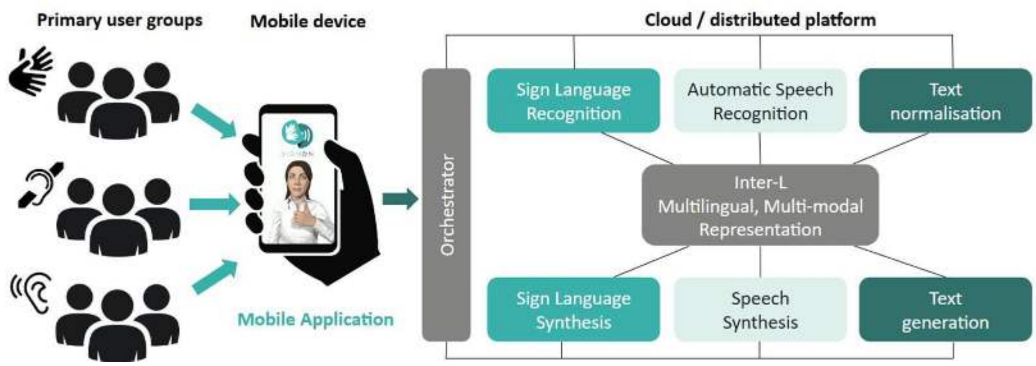

Figure 4: SignON SLMT application and framework of services

In line with User Experience (UX) Design and Design Thinking[3], this task used an Agile DevOps approach[4], with iterative fast prototypes that enabled users to become actively involved in the co-creation process of its functional specification and its co-development (through formative evaluation in WP1) from early in the project. This process followed and promoted best practices on SL technology R&D practices[5] by actively addressing: (1) knowledge of the specific SL at the centre of the research and of SLs more generally; (2) involved deaf people at the centre of research, including researchers who are themselves deaf; (3) motivations of the researcher and the relationship to the views of the SL community; (4) what SL data needs to be considered; (5) full recognition of the challenges posed by such research[6]. This co-creation approach now facilitates uptake, improved SL detection and multilingual speech processing on mobile devices for everyone.

Task 2.4 Machine Learning extension for the SignOn Service

[3] See D1.4 "First Technical Requirements & User Research (UX design) Report", June 2021
[4] https://devops.com/how-to-combine-devops-and-agile/
5 Best practices for sign language technology research | Universal Access in the Information Society (springer.com)

[6] See SignON *D9.4: Final Annual Ethical Report on Practices Towards the Stakeholder Communities* and *D9.7: Final Annual Ethical Report on Internal Affairs*

SignON ML

The SignON Machine Learning (ML) Training App and System was developed as a complementary but separate App and service to train and improve the SignON SL and atypical ASR Machine Translation Learning systems. The main functionalities of this interface allow users to capture data and permanently store them on the Object Storage in the backend of the SignON Services framework. The SignON ML App enables SignON Approved Users to:

1. Record Task Messages in SL video or speech audio inputs from predefined use case storyline tasks, as shown in D2.9.
2. Review and Edit their Messages,
3. Tag their Messages with Text translation/identification, and upload them to the SignON Server.

The SignON ML App aims to be easy and intuitive to use as illustrated in Figure 5 and explained in D2.9.

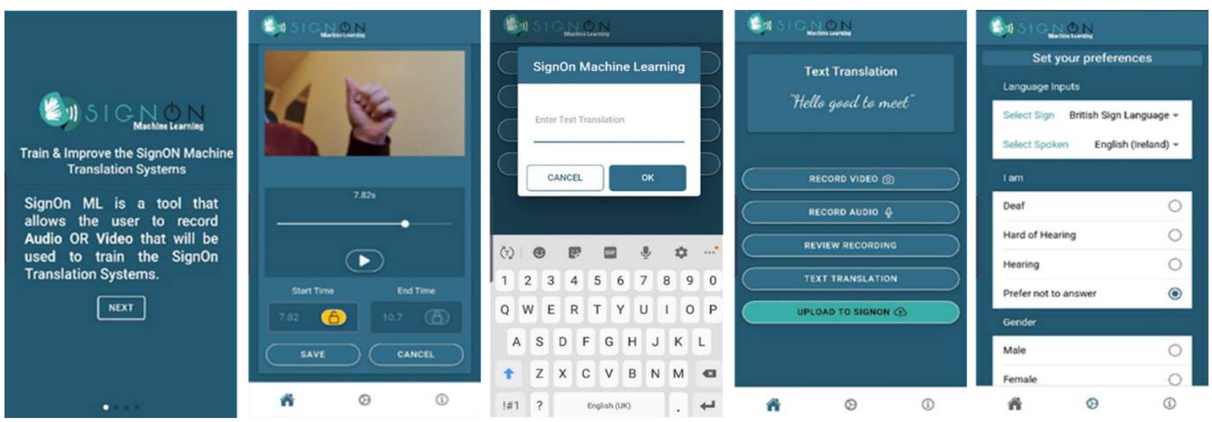

Figure 5: SigON ML Training App

The SignON ML App is published on the Google Play Store and Apple App Store, for Android and iOS phones, respectively. It operates in all of languages specified in the SignON DoA (i.e. Text: Dutch, English, Irish and Spanish; signed languages: British, Dutch, Flemish, Irish and Spanish; spoken languages: Northern Dutch, Southern Dutch, English (Ireland), Irish, and Spanish), and adheres to all of the SignON ethical and GDPR requirements.

To meet its requirements and ensure the security and quality of SignON MT training, the SignON ML App is used by Users approved by SignON, as explained at [Speech Recordings English](#) (Figure 6).

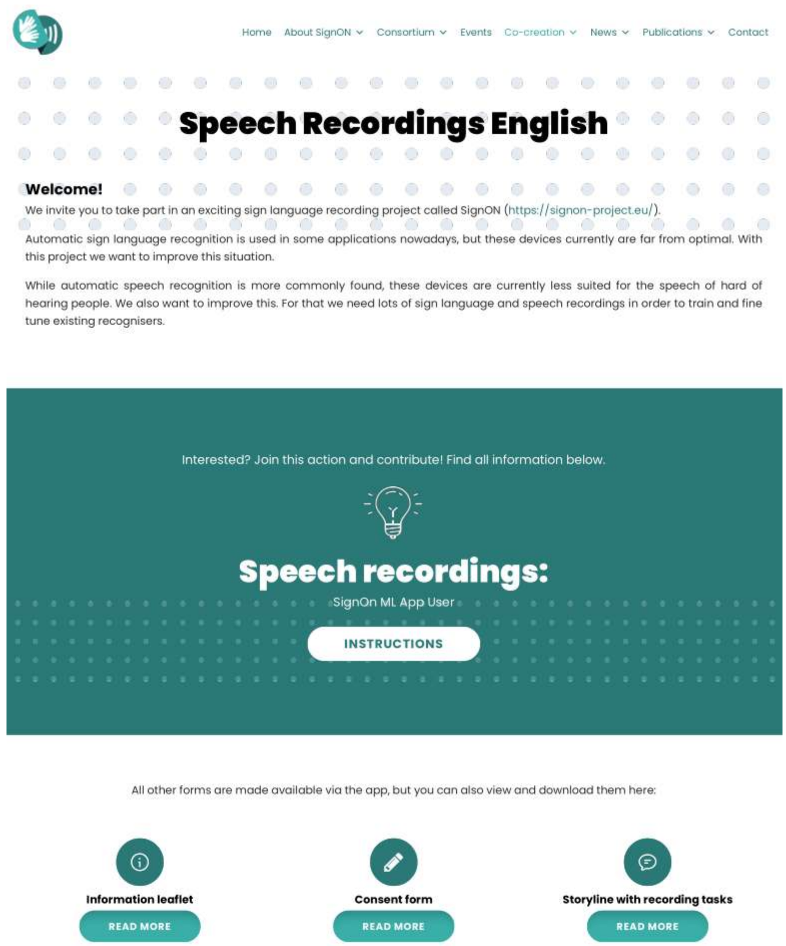

Figure 6: Screenshot of the SignON Project website section dedicated to Speech Recordings English.

The collected data are encoded according to the EAF Annotation Format for ELAN, an XML-based annotation format widely used in linguistic research datasets, to facilitate the tasks of enriching and extending the models and intermediate representations as described in WP3, WP4 and WP5. The services implemented in this task are connected with the SignON Services Framework (T2.1) that runs on the SignON Open Cloud Platform (T2.2), by means of suitable APIs to interact with backend services. The results obtained in this Task are reported in Deliverables *D2.8: First Machine Learning interface* and *D2.9: Second Machine Learning interface.*

4.2.4 Deliverables Submitted

D2.1: SignON Development Repository

The deliverable D2.1 describes the definition of a SignON Development Repository, hosted on the GitHub platform and suitably structured to be used by all members of the SignON distributed development team. The SignON Development Repository enables incremental development, testing and issue management of the SignON Services Framework and of the SignON App. Furthermore, once the basic system is proven in the current project, the SignON Development Repository will support the subsequent publishing and use by the wider open-source community.

D2.2: SignON Services Framework Architecture

The deliverable D2.2 describes the SignON Services Framework architectural design, including a specification of an appropriate storage for the large data (e.g. audio, video, other media, etc.). Interfaces are defined between The SignON Mobile App and the SignON Framework: the SignON Orchestrator exposes a RESTFul API to allow communication between the SignON Mobile App and the SignON Processing Pipeline. Information that needs to be transferred to and between pipeline modules are detailed in the definitions of input-output interfaces. Another goal of the SignON Orchestrator is decoupling the communication flow between the SignON Mobile App and the SignON Processing Pipeline, which is accomplished by means of a message broker.

D2.3: First release of the Open SignON Framework

The deliverable D2.3 describes the process of the design and implementation of a shared platform (located at INT) on which to host developing or developed parts of the SignON software and data. The implemented platform allows to store the reference data and training data on a dedicated repository, and to host, on a virtual environment, the SignON Services Framework (according to the architecture described in D2.2) with the required computational power and network security.

D2.4: Intermediate release of the Open SignON Framework

This was the intermediate release of the Open SignON Framework as a demonstrator. This report describes the progress of the shared SignON platform, which consists of two separate entities: the repository with reference data and training data, and the platform with processing space to host both developing and developed/production components of the SignON Framework service, software, and data, since *D2.3: First release of the SignON Open Cloud platform* was delivered in January 2022.

D2.5: Final release of the Open SignON Framework

This deliverable is the final release of the Open SignON Framework as a demonstrator. This report describes the progress and final implementation of the SignON platform, with a particular focus on the architecture, the data-flow, the infrastructure, the deployment and the testing implementations.

D2.6: First Release of the SignON Communication Mobile Application

This was the first Release of the SignON Transmodal Machine Translation Mobile Application. The SignON Communication App aims to be an intuitive, easy-to-use user input and output interfacing with the cloud-based SignON Service platform (T2.1 and T2.2) where the computationally intensive tasks (of WP3, 4 & 5) are executed. This first release of the App enabled the WP1 formative evaluation pilot trials to take place, as reported in D1.9, and evolving it to its Final Release, as D2.7. This co-creation approach aims to ensure wide uptake, improved sign language detection and multilingual speech processing on mobile devices for everyone. The SignON App V1.0 was published for both Android and Apple mobile devices on the Google Play Store and Apple App Store as "SignONMobile".

D2.7: Final release of the Communication Mobile Application

This deliverable is the SignON project's final major release of the SignON Sign Language Machine Translation (SLMT) Mobile Application pre-commercial prototype (see Figure 7). This V3.0 release of the app enabled the WP1 summative evaluation to be undertaken and reported in D1.6 .

Version V3.0 of the SignON Mobile App for Android and iOS based phones, includes Sign Language Recognition (SLR), Automatic Speech Recognition (ASR), Sign Language Translation (SLT), Spoken Language Machine Translation and Sign Language Synthesis (SLS) functionality, as described in *D3.2: Sign language recognition component and models*, *D4.8: Final Routines for transformation of text from and to InterL*, *D4.10: Final Routines for transformation of SL representations from and to the InterL*, and *D5.1: First version of virtual character*. The App includes the Acapela TTS[7] for natural speech synthesis and SignON ASR[8] "atypical speech" recognition, as described in the DoA.The App is simple to use, but powerful.

[7] [Acapela Group: Text To Speech (TTS) solutions, personalized voices based on neural technology. (acapela-group.com)](acapela-group.com)

[8] As described in *D3.4: Automatic speech recognition component and models*

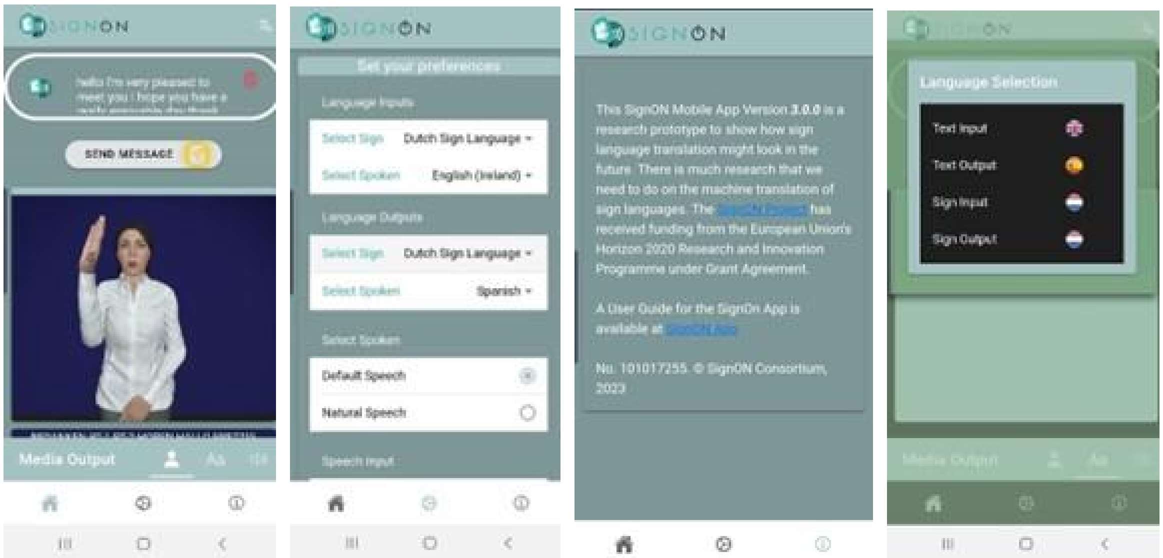

Figure 7: SignON Mobile App V3.0 Translation, Preferences & Information Screens

This third major release of the prototype mobile app demonstrates the SignON SLMT features, so that users can see, hold, and feel something tangible and provide realistic inputs on what they want, and for the developers to get an appreciation of the realities of the mobile app platform and cloud requirements.

The SignON SLMT App V3.0 is available for both Android and Apple mobile devices on the Google Play Store and Apple App Store as “SignONMobile”.

D2.8: First Machine learning interface

This deliverable proposes and designs a first draft of a new feature of the SignON Framework that is aimed at collecting new data that contribute to enriching and extending the Machine Learning (ML) models and intermediate representations used in the SignON Project. Firstly, the requirements from the SignON standardisation of the ML training process and the related user’s involvement are presented to define the working background. Then the initial design is presented with an overview of the system architecture and with further details related to the backend components involved. Detailed explanations are provided regarding the interfaces and the internal components of the solution, and some example cases are presented.

D2.9: Second Machine Learning interface

D2.9 provides an update on the new features implemented for collecting new data for enriching and extending the Machine Learning (ML) models and intermediate representations used in the SignON project. Updates to functionalities are shown in accordance with requests from involved users, and a general update on the backend, introducing re-designed REST APIs and upgrades regarding the Object Storage component is described. Frontend functionalities implemented in the SignON infrastructure are then presented, followed by a description of a complementary tool with a command-line interface, the so-called SignON Extractor that can be utilised to easily filter and download users' contributions from the backend components where they are stored.

4.2.5 Deviations and Corrective Actions

To improve system performances, it was proposed and approved by the entire consortium to embed the SignON Pipeline WP5 Message Synthesis component (i.e., the 3D Engine) directly in the SignON Mobile App. This solution has proven to be very effective, as the avatar scene is no longer downloaded to the end-user device, but it is directly loaded from within the SignON Mobile App. Moreover, with this approach, only a sequence of glosses are sent from the SignON Pipeline to the SignON Mobile App, greatly reducing also the used bandwidth.

With the agreement of the Project Officer, *D2.7: Final release of the Communication Mobile Application*, was submitted in M33 instead of M30 in order to allow time to integrate the findings from *D1.8: Final User Requirements Report* and *D1.10: Final Technical Requirements and User Research (UX Design) Report*, which were both submitted in M30. This allowed time to create a more impactful and useful application which was then described in D2.7.

4.2.6 Conclusions

WP2 has implemented the SignON Open Cloud Platform and the SignON Services Framework, which has allowed for integrating all services and components developed in WP3, WP4 and WP5. The architecture of the SignON Services Framework, based on dockerized components, allows for updates to the models embedded in pipeline components, and supports a wide range of input and output combinations. This Framework supports the functionalities exposed in the SignON Mobile Applications, which offer translation services (through the Sign ON Mobile App) as well as user input for service upgrade (through the SignON ML Training App).

4.3 Work Package 3: Source Message Recognition, Analysis and Understanding

4.3.1 Introduction

Work Package 3 (WP3) groups the tasks related to the processing of source messages within the SignON application and framework. This includes sign language recognition (SLR), automatic speech recognition (ASR) and natural language understanding (NLU). These tasks are supported by two other tasks, one on data collection and organisation, and the other on linguistic analysis of the sign languages within the SignON project. WP3 is first and foremost a research oriented work package, but it also includes tasks related to the development of components that fit within the SignON framework.

4.3.2 Work Package Objectives

The overall objectives of WP3 were:

- Collection, organisation and disclosure of existing source language datasets
- The development of a generic component for real-time sign language recognition supporting multiple SLs and supporting continuous learning through user feedback
- Linguistic analysis and understanding of SLs
- Real-time processing of spoken language input using ASR
- Development of natural language processing pipelines for the analysis (POS tagging, parsing, etc.) of the spoken languages of the project.

4.3.3 Tasks

Task 3.1: Data collection and organisation

Task 3.1 handled the collection and organisation of datasets that have been used for training and evaluating machine learning models in SignON. In addition, several other existing datasets were collected and prepared for research use. Together, the bulk of collected data will provide a valuable resource for future research on sign language recognition, translation and linguistic analysis.

A password protected SFTP server has been set up for the publicly available data, so that every partner has easy access to the datasets and can upload the datasets they get hold of.

A lot of effort has been put in trying to convince organisations of the benefits of making their datasets available for the project, or for research in general, but there are several ethical and intellectual property (IP) restrictions that need to be overcome for many datasets, which require negotiations with legal departments about IP, about anonymisation and privacy; and setting up procedures for the sign language interpreters to sign informed consent forms or contracts, which need to be made available not only in writing but also in the respective sign language.

Deliverable 3.1 (D3.1) describes in detail which datasets were collected at the time of writing that deliverable (December 2022). In the paper by De Sisto et al (2022)[9] and book chapter by Vandeghinste et al. (in press),[10] we describe the issues and difficulties we overcame for these datasets. Our experiences with the datasets for sign languages in the project led to the coordination of writing an overview paper of the status of sign language technology in Europe, together with partners from the EASIER project (Vandeghinste et al. 2023),[11] which has also lead to a book chapter (Vandeghinste et al. *in press*)[12].
Datasets explicitly created within the project and since the writing of D3.1 are the BeCoS corpus (Vandeghinste et al. 2022)[13], for which a lot of effort was put in exploring and developing tools for automatic annotation/transcription of this corpus, the NGT/VGT HoReCo corpora (De Sisto et al. 2023),[14] for which extra funding was secured through the European Language Equality SRIA project funding,

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[9] Mirella De Sisto, Vincent Vandeghinste, Santiago Egea Gómez, Mathieu De Coster, Dimitar Shterionov and Horacio Saggion (2022). Challenges with Sign Language Datasets for Sign Language Recognition and Translation. *Proceedings of the 13th International Conference on Language Resources and Evaluation (LREC).* Marseille, France.
[10] Vincent Vandeghinste, Mirella De Sisto, Santiago Egea Gómez and Mathieu De Coster (in press). Challenges with Sign Language Datasets. In Andy Way et al. (eds) *Sign Language Machine Translation*. Springer.
[11] Vincent Vandeghinste, Mirella De Sisto, Maria Kopf, Marc Schulder, Caro Brosens, Lien Soetemans, Rehana Omardeen, Frankie Picron, Davy Van Landuyt, Irene Murtagh, Eleftherios Avramidis, Mathieu De Coster (2023). Report on Europe's Sign Languages. *ELE Project Deliverable 1.40*. https://zenodo.org/record/8047005
[12] Vincent Vandeghinste, Mirella De Sisto, Maria Kopf, Marc Schulder, Caro Brosens, Lien Soetemans, Rehana Omardeen, Frankie Picron, Davy Van Landuyt, Irene Murtagh, Elefterios Avramidis, Mathieu De Coster (in press). Language Resources for European Sign Languages. In Andy Way et al. (eds) *Sign Language Machine Translation*. Springer.
[13] Vincent Vandeghinste, Bob Van Dyck, Mathieu De Coster, Maud Goddefroy and Joni Dambre (2022). BeCoS corpus: Belgian Covid-19 Sign language corpus. A corpus for training Sign Language Recognition and Translation. Computational Linguistics in the Netherlands Journal. Vol. 12. pp. 7–17.
[14] Mirella De Sisto, Dimitar Shterionov, Lien Soetemans, Vincent Vandeghinste, Caro Brosens (2023). NGT-HoReCo and GoSt-ParC-Sign: Two new Sign Language - Spoken Language parallel corpora. In *Proceedings of the CLARIN Annual Conference* . Leuven.

GoStParC Sign (De Sisto et al. 2023)[15] for which translation funding was secured from the European Association for Machine Translation, and the BSL-Hansard corpus which contains 88h of parallel utterances in interpreted BSL video and time-aligned English text from parliamentary debates[16].

Several of the already existing datasets that were not easily available for research, and all of the newly created datasets have been made available for download for further research through the CLARIN depositing centre at the Instituut voor de Nederlandse Taal, and can be retrieved through the CLARIN Virtual Language Observatory (https://vlo.clarin.eu/).

Task 3.2: SLR component development and model training, evaluation and release

Sign language recognition (SLR) is the task of identifying and classifying sign language linguistic elements such as signs or glosses from video streams. The goal of Task 3.2 was to develop a component for SLR model training and inference and to integrate this into the SignON framework. The purpose of this component is to extract information from sign language video data and to pass this information onto the Sign Language Translation (SLT) models.

The models in this component are deep neural networks that output, given input video data, a sequence of *embedding vectors* that summarise the information contained in the video. The component itself is a web service which wraps these models and is integrated into the SignON application framework (see Deliverable 2.2). With this web service, the trained models can be used to perform inference on data submitted by users of the application. Language specific models were trained, with additional investigation into cross-lingual training or cross-language knowledge transfer.

All aspects of this component (training data, design choices and evaluation) were extensively described in D3.2. In what follows, we briefly summarise the main messages of that deliverable.

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[15] Mirella De Sisto, Vincent Vandeghinste, Lien Soetemans, Caro Brosens, Dimitar Shterionov (2023). GoSt-ParC-Sign: Gold Standard Parallel Corpus of Sign and spoken language. *Proceedings of the 24th Annual Conference of the European Association for Machine Translation. pp.* 501–502, Tampere, Finland, June 2023. pp. 503-504

[16] Euan McGill and Horacio Saggion (2023). BSL-Hansard: A parallel, multimodal corpus of English and interpreted British Sign Language data from parliamentary proceedings. *Proceedings of the Second International Workshop on Automatic Translation for Signed and Spoken Languages.* pp. 43-48. Tampere, Finland

Dataset	# samples	#distinct glosses	# participants	Min #samples /gloss
NGT	68854	458	82	20
VGT	24967	292	112	20
ISL	4013	224	37	3
BSL: D3.2 / now	2416 / 2568	123 / 132	44 / 49	3
LSE: added since D3.2	589	35	4	5

Table 2. SignON SLR final dataset statistics.

Within the SignON project, we train our SLR models with the objective of recognising individual glosses that were extracted from continuous signing video streams. This requires training data with annotations that identify the individual glosses in a video, including their start and end times. Unfortunately, for the sign languages addressed in SignON (VGT, NGT, ISL, BSL, LSE), only very little training data of that nature was available. In addition, the data that does exist only covers a very small fraction of the total vocabulary in these sign languages: only 458 distinct glosses for the largest training set, NGT and no more than 35 for the smallest one (LSE). Table 2 summarises the datasets we had available for training. A detailed description of the origin and the properties of these datasets can be found in D3.2. Note that the data for LSE has only become available very recently (i.e., after the publication of D3.2). After the publication of D3.2, additional data has been collected for BSL, leading to a slightly larger dataset.

Figure 8 (copied from D3.2) shows an overview of the SLR pipeline. The models in this component are deep neural networks. They are trained to predict individual glosses, given input video data. As a first step, to reduce the complexity of the problem for our networks, each videoframe is converted into a set of keypoint coordinates by a pose extraction tool. These keypoints are the characteristic points of the human body that are most representative for sign language recognition: the joints of the hands and upper body and key elements of the face. We chose MediaPipe Holistic[17] to extract these poses because it is freely available and supports full body pose estimation in almost real-time. Besides being small, the vocabularies available for training SLR models have almost no overlap with the specific topics that occur in either the SignON hospitality use cases (see deliverable D1.2 "*Report on the use-cases and usage domains and stakeholders' acceptance*" and the corresponding discussion in Section 4.1.4), or the data that is used for training the translation models (see the deliverables related to the interlingua from WP4,

[17] https://github.com/google/mediapipe/blob/master/docs/solutions/holistic.md

summarised in Section 4.4.4). Because of this, and because a sequence of predicted glosses would always be restricted to the (very limited) vocabulary such a model is trained on, the SLR component forwards embeddings, not glosses, to the translation models. These are less specific than the gloss outputs and contain generic information relating to face, body, and hand morphology and movement. The use of embeddings also allows for knowledge transfer between different sign languages to mitigate the lack of training data.

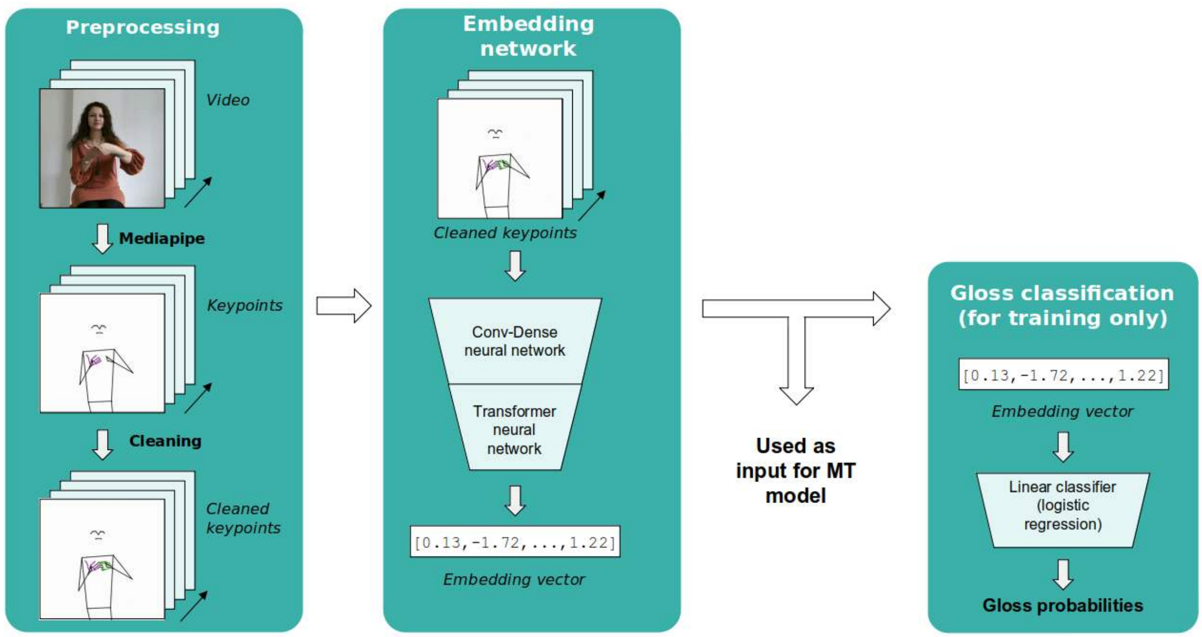

Figure 8: The SLR pipeline: (left) keypoint extraction & cleaning; (middle) Extraction of embedding (used as input for the SLT component); (right) gloss classification (used to train embedding network).

For each language, a language-specific model was trained by only using the training data for that language. In addition, two approaches to knowledge transfer were tried: a single multilingual model that combines all available SignON SLR datasets, and the fine tuning of the best language-specific model (NGT) for each of the other languages. The second approach yielded the best results and was retained. Table 3 summarises the final evaluation results on the test set for each language. In comparison to D3.2, the results for BSL were improved and results for LSE were added, both following the addition of new data. In all cases, the NGT-transfer model was incorporated in the SLR component, as it outperformed the model without transfer. Note that some care must be taken when interpreting and comparing the final accuracies for the different languages, since they were trained and evaluated on very different vocabulary sizes.

Dataset	No transfer	NGT transfer (fine-tuning)	#glosses in test set
NGT	**51.9%**	-	458
VGT	47.7%	**50.8%**	292
ISL	22.1%	**30.1%**	224
BSL - improved since D3.2	18.8%	**31.9%**	132
LSE - added since D3.2	41.4%	**54.4%**	35

Table 3: Accuracy of SLR models. All reported results use the same neural network architecture. The training data depends on the chosen source language and the training approach depends on whether or not knowledge transfer is used.

In order to assess the inherent quality of the neural network model design that is used in the SLR component, it was separately evaluated on a large ASL (American Sign Language) data set that was provided through a recent SLR Kaggle competition.[18] This was highly relevant to the SignON use-case, as it also used MediaPipe keypoints as inputs and was aimed specifically at the development of lightweight models for edge devices. In this competition, our models achieved an accuracy of 87% on the test set (this was within the top 2% of the competition competitors).

The transferability of our embeddings to signs outside the training set was evaluated by implementing a prototype vector-based dictionary search module that can be used to look up signs in the Flemish Sign Language online dictionary[19], managed by VGTC, based on a video recording of a sign.[20] We evaluated this approach for a small subset of signs that did not occur in the training set and found an accuracy that is not that far below that for the signs used in training. UGent and VGTC have secured follow-up funding (starting in January 2024) to further develop and scale up this particular application and integrate it into the dictionary.

[18] https://www.kaggle.com/competitions/asl-signs
[19] https://woordenboek.vlaamsegebarentaal.be/
[20] Mathieu De Coster and Joni Dambre (2023). Querying a Sign Language Dictionary with Videos using Dense Vector Search. *Proceedings of the Eighth Workshop on Sign Language Translation and Avatar Technology.* Rhodos, Greece.

Task 3.3: Linguistic investigation of supported sign languages

The goal of Task 3.3 was to provide a linguistic analysis of Irish Sign Language (ISL), British Sign Language (BSL), Sign Language of the Netherlands (NGT), Flemish Sign Language (VGT) and Spanish Sign Language (LSE). Our research was driven by the needs and requirements for linguistic insides to aid the translation. We focused on constituent order, on gerund constructions, on contrasting older and younger generations of signers, on the impact of video-mediated conversations on (sign) language, on neologisms and other linguistic aspects that we deem important for better understanding how to model sign languages to support the process of translation.

This task also facilitated various consultations where linguists provided linguistic advice to the "technical partners" (working within WP3, WP4 and WP5). This often concerned constituent order and sentence structure, but also e.g. the use of non-manual features, challenges concerning meta-data for signed languages, and the annotation and translation of signed production in glosses and written language. In some cases, specific questions led to small-scale research activities, e.g. on complex sentence structures, and the use of ID-glosses. This task has one relevant deliverable (D3.3), which is summarised below.

In the context of MT applications, and within the framework of SignON specifically for WP4 "Transfer and InterLingual Representations" and WP5 "Target message synthesis", there was a need for information on sentence structure, and particularly on constituent order. First focusing on Flemish Sign Language (VGT) we initially inventorised the results of previous research by Vermeerbergen (1996; 1997; 2010; Vermeerbergen et al., 2007).[21] Given the strong suspicion of age-related variation in VGT, especially concerning constituent order, we conducted a new study of constituent order in younger signers (age 12 to 18). The in-depth analysis resulted in a very detailed description of constituent order in locative and non-locative sentences, demonstrating indeed the presence of age-related variation (Soetemans & Janssens, 2023)[22].

[21] Vermeerbergen, M. (1996). ROOD KOOL TIEN PERSOON IN. Morfo-syntactische aspecten van Gebarentaal. [Doctoraatsproefschrift, Vrije Universiteit Brussel].
Vermeerbergen, M. (1997). Grammaticale aspecten van de Vlaams-Belgische Gebarentaal. Gentbrugge: Cultuur voor Doven.
Vermeerbergen, M. (2010). Onderzoeksrapport: Woordvolgorde in de Vlaamse Gebarentaal. Vlaams GebarentaalCentrum.
Vermeerbergen, M., Van Herreweghe, M. Akach, P. & Matabane, E. (2007). Constituent order in Flemish Sign Language (VGT) and South African Sign Language (SASL): A cross-linguistic study. Sign Language & Linguistics, 10(1), 23-54.

[22] Soetemans, Lien and Janssens, Margot. 2023. *Onderzoek naar constituentenvolgorde in Vlaamse Gebarentaal. Enkelvoudige zinnen bij jongeren van 12- tot 18 jarigen.* Onderzoeksrapport in het kader van het SignON project, KU

Given the importance of video in MT applications, we also investigated the potential impact of video-mediated and video-recorded communication on sign language production and structure. In the corresponding study we compared VGT production in five different settings: 1) face-to-face communication; 2) real-time online communication via laptop; 3) real-time online communication via smartphone; 4) video-recorded VGT production on a laptop; and 5) video-recorded VGT production on a smartphone. A first analysis showed that the use of online tools does indeed affect the signed production of VGT users compared to face-to-face communication. Following this exploratory study, two new related studies were set up. A first follow-up study further explores the topic of referent tracking and analyses in detail which forms of referent tracking are used more and which less in the five different settings. A second follow-up study focuses on the lexicon and examines the extent to which the use of video has an impact on the number of one-handed versus two-handed signs. Results indicate that signers do tend to opt for one-handed signs more frequently when conversing through their laptop or smartphone. Future research steps include investigating whether, when switching from two-handed to one-handed signs, Flemish signers are more likely to choose to perform a two-handed signs with one hand, or to choose a one-handed synonym. For both follow-up studies a publication is in preparation.

With respect to the Sign Language of the Netherlands (NGT) we investigated the order of signs to aid the translation/synthesis pipeline. We drew from existing research and identified that both subject - object - verb (SOV) and subject - verb - object (SVO) orders are attested in the language. This duality is also influenced by simultaneity, where V and O can be articulated at the same time (for example when O is expressed with a classifier). Next, we looked at negation, WH- elements, topicalisation and focalisation that can affect constituent order.

With respect to Irish Sign Language (ISL) we focused on two different research directions: (i) neologisms and depiction in ISL and (ii) gerunds. Depiction can have a significant semantic role in a sentence and is a ubiquitous phenomenon in the production of sign languages. We conducted new research on the topic using methods from cognitive (sign) linguistic research to better support our understanding of these phenomena and to inform SLMT work that will go beyond the life of the SignON project. We analysed data from several recently developed domain-specific glossaries including Science Technology Engineering Math, Covid-19, the political domain, and Sexual, Domestic and Gender Based Violence

Leuven Campus Antwerpen & Vlaamse GebarentaalCentrum (42 pages) (https://www.vgtc.be/onderzoek/publicaties/onderzoek-naar-constituentenvolgorde-in-vlaamse-gebarentaal/)

(SDGBV) related vocabulary and found out that a deliberate focus on iconicity - specifically elements of depiction - appears to be a primary linguistic driver for these new terminologies.

With respect to the aforementioned analysis of depiction strategies, the following findings need to mentioned: (1) thus far, depiction has co-occurred with embodiment 100% of the time in the neologisms examined; (2) thus far we have not observed instances of 'drawing' or 'other' (presenting, beats, pointing) in the glossaries examined. Instead, enactment is the most common depiction strategy (50%) in this glossary.

When it comes to investigating gerund constructions in ISL, our research is motivated by the challenging nature of those constructions in linguistic terms and the lack of research with regard to this linguistic phenomenon across many sign languages.[23] We investigate the existence in sign languages of constructions similar or equivalent in functionality to gerunds in spoken language, in particular, English. We focus on aspect and aspectual marking in ISL, as both gerund constructions and progressive aspect share the use of the same construction type i.e. the verb. In addition, the internal structure of both gerunds and progressive aspect is similar. Within this research we analyse the Signs of Ireland (SOI) corpus[24,25] with a focus on the occurrence of reduplication of verb signs. While this research is still ongoing, our current findings indicate the existence of constructions similar or equivalent to gerund constructions in spoken language. Next we aim to investigate these constructions further by including the different forms that these constructions may take. This research will serve as an invaluable resource in the computational modelling and processing of signed language, providing a more comprehensive understanding of how this challenging linguistic phenomenon manifests itself.

When it comes to British Sign Language (BSL) the constituent order is particularly interesting from a typological perspective. The predominant basic order of constituents in a declarative phrase is said to be object - subject - verb (OSV) (Sutton-Spence and Woll, 2007)[26] - an order which is vanishingly rare

[23] From a linguistic perspective, a gerund is a form of verb that functions as a noun. In English, they are represented using the suffix -ing at the end of verbs.
[24] The SOI corpus consists of data that is collectedfrom 40 participants (males and females) from many parts of the Republic of Ireland, including Dublin, Cork, Galway, Waterford, and Wexford. Participants shared two forms of stories: frog story (used in cross-linguistic studies), and a personal story from the participant's life.
[25] Leeson, L., Saeed, J., Byrne-Dunne, D., Macduff, A., & Leonard, C. (2006). Moving Heads and Moving Hands: Developing a Digital Corpus of Irish Sign Language. The 'Signs of Ireland' Corpus Development Project. Proceedings of Information Technology and Telecommunications Conference, Carlow, Ireland.
[26] Sutton-Spence, R., & Woll, B. (2007). The Linguistics of British Sign Language: An Introduction. In Language (8th ed.). Cambridge University Press.

amongst the world's languages (Dryer, 2013).[27] However, as described for NGT, and as is the case in many SLs, topicalisation plays an important role in shaping the order of BSL constituents. BSL employs the fronting of constituents which are new or pertinent to the discourse. As is attested in other SLs, often a spatio-temporal framework is set up before the referents within it are introduced and commented upon. This means it would be more accurate to state that its order is 'Time - location - object - subject - verb - question'.

When it comes to LSE, during SignON, we conducted research into creating text-to-gloss and gloss-to-text SLMT models between LSE and Spanish. These models are first pre-trained on parallel Spanish/synthetic LSE gloss data, before being fine-tuned on the small amount of available, real parallel data between these two languages (described in detail in Chiruzzo et al., 2022;[28] McGill et al., 2023[29]). The synthetic glosses were created by means of a rule-based approach based on our knowledge of the grammar and unique features of LSE. They were also chosen because they were reflected clearly in a text form - glosses - and appeared in the target datasets on which we were testing these translation models.

For comparison with the other SLs covered in SignON, it has been noted that the canonical constituent order of LSE is Subject-Object-Verb but topicalisation has a strong effect on the order of constituents in a phrase in context. Noun phrases are also said to have a specific order of components if they are included: noun, demonstrative, possessive, numeral, indefinite. Finally, as with other SLs, LSE uses reduplication to mark plurals and for emphasis.

Also within this task we worked on the set-up of a lexical-semantic database for Sign Languages, by analogy with Wordnet: a SignNet. It entails more than just linking signs with a WordNet, more specifically Open Multilingual Wordnet, as we also cover cases in which a word expressing the concept behind a sign is lacking in spoken language, or the other way around, when there is no sign covering the meaning of a word, or when such a sign is only available for some regions (as regularly is the case for VGT). Such situations would lead to translation issues, especially as long as no large parallel corpora SL-SpL are available. And such corpora should also contain enough rather recent data, as due to the extended use

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[27] Dryer, M. S. (2013) Order of Subject, Object and Verb (v2020.3) In: Dryer, M. S. and Haspelmath, M. (Eds.) World Atlas of Linguistic Structures. Online: Zenodo.

[28] Chiruzzo, L., McGill, E., Gómez, S. E., & Saggion, H. (2022) Translating spanish into spanish sign language: Combining rules and data-driven approaches. In Proceedings of the Fifth Workshop on Technologies for Machine Translation of Low-Resource Languages (LoResMT 2022), pp. 75-83.

[29] McGill, E., Chiruzzo, L., Egea-Gómez, S., and Saggion, H. (2023) Part-of-Speech tagging Spanish Sign Language data and its applications in Sign Language machine translation. In: Proceedings of the Second Workshop on Resources and Representations for Under-Resourced Languages and Domains (RESOURCEFUL-2023), pp. 70-76

of smartphones for visual remote communication, the lexicon of signs is changing rapidly, for example from two-handed signs to one-handed ones. In such cases a SignNet may come to the rescue as these will be easier (and cheaper) to extend than corpora are.

In summary, within Task 3.3 we conducted a wide spectrum of research and analysis of the involved Sign Languages, mainly focusing on aspects and features that are important for informing the translation process. These include constituent order, analysis of gerunds, informing rule-based systems and others. We also conducted work on the development of SignNets which can be used to inform the translation process with a wider semantic representation.

Task 3.4: ASR component development and model training, evaluation and release

The goal of task 3.4 was the development of an ASR component that converts oral messages into their textual form. For this purpose, state-of-the-art ASR models are trained and fine-tuned. Initially, we developed and implemented the first versions of the required ASR components for Dutch, English, Spanish, and Irish using a hybrid/modular ASR approach with Kaldi ASR[30]. This approach involved creating acoustic models, language models, and pronunciation lexicons separately and integrating them for the ASR task. For Dutch, two variants have been implemented: one for Northern Dutch (as spoken in the Netherlands) and one for Southern Dutch (Flemish, as spoken in Belgium). The main reason for this distinction is the considerable difference in pronunciation that requires different acoustic models. In our tests, the developed ASR components achieve word error rates (WERs) of around 15%. All these hybrid ASR models were deployed via a web service[31] and integrated with the SignON mobile application framework as version 1.

In version 2 of the ASR models, we employed an end-to-end approach. We used pre-trained transformer-based ASR models, namely wav2vec 2.0 XLS-R[32], and fine-tuned them with the same audio training data used in the development of the version-1 hybrid ASR models. With this end-to-end approach, we achieved a significant improvement in recognition. In our tests, the developed end-to-end

[30] https://kaldi-asr.org/
[31] https://restasr.cls.ru.nl/api-docs/
[32] https://huggingface.co/docs/transformers/model_doc/xls_r

ASR models achieve word error rates (WERs) of around 10%. Next to wav2vec 2.0, we also explored robust and multilingual open-sourced OpenAI's Whisper[33] ASR models.

We deployed all end-to-end wav2vec 2.0 XLS-R models and the OpenAI Whisper model via a RESTful API web service[34]. The REST API framework is developed with FastAPI.

We tested all our ASR models (hybrid and end-to-end models) using test recordings from the HoReCo test sets which for ASR refers to the audio recordings of 30 test speakers in the use case domain of hospitality described in more detail in section 3.4 of D4.5.

Based on the test results, we eventually employed a medium-sized Whisper ASR model for English ASR and wav2vec 2.0 XLS-R model for Dutch-Flemish and Spanish ASR. It is important to note that a single model now caters to both Dutch (Netherlands Dutch) and Flemish (Southern Dutch). Based on our results, we continued using a hybrid ASR model based on Kaldi for the Irish ASR only. Representative test results are given in the table below.

Language	Test Set	ASR V1 WER	ASR V2 WER
English	Common Voice Test	23.69%	10.30%
Spanish	Common Voice Test	15.69%	6.73%
Dutch (Netherlands	Common Voice Test(NL Dutch)	24.78%	4.06%
Flemish (Southern Dutch (Flanders, Belgium)	Common Voice Test(VL Dutch)	14.02%	
Irish	Common Voice Test	22.69%	13.78%

Table 4:Performance of Speech Recognition component on our internal testsets. The V1 of ASR represents hybrid ASR models integrated with SignON mobile application initially. The V2 of ASR models represents the current state of art end-to-end ASR models.

[33] https://openai.com/research/whisper
[34] https://signon-wav2vec2.cls.ru.nl/docs

Language	ASR V1 WER	ASR V2 WER
English	24.23%	5.15%
Spanish	12.82%	9.48%
Dutch (Netherlands	15.61%	5.23%
Flemish (Southern Dutch (Flanders, Belgium)	20.29%	7.79%
Irish	39.46%	42.77%

Table 5: The performance of the Speech Recognition component on the HoReCo test set refers to the audio recordings of 30 test speakers in the hospitality domain. Based on the results below, in the SignON mobile application, English ASR is served via the Whisper medium model. Spanish and Dutch-Flemish ASR are served via the wav2vec 2.0 XLS-R model, while Irish is served via a Kaldi-based hybrid ASR model.

The reported WER scores are well in line with the target values outlined in the SignON project proposal, with the exception for Irish on the HoReCo use case related task, where the model was underperforming for the data for two out of four speakers. It is important to note that although the recorded speakers in this testset spoke Irish, these speakers are not native speakers of the Irish language.

Detailed information about train/test audio corpora, speech and pronunciation data, ASR models and the set-up of the ASR webservice have already been described in detail in SignOn deliverable *D3.4: Automatic Speech Recognition Component and Models*.

Task 3.5: Implementing language-specific NLU pipelines

Natural language processing capability is a requirement for the spoken languages of the SignON project: Dutch, English, Irish, and Spanish. The NLU pipelines process text from spoken or written input into the app with the aim of preparing it for the InterL-S representation used in translation models. According to the Grant Agreement, SignON's NLP module must contain text normalisation, spelling correction, sentence identification, tokenisation, PoS tagging, lemmatisation, named entity recognition, coreference resolution, entity linking, and figurative language handling - with a preference for statistical and less data-demanding methods in low-resource settings.

The first iteration of the NLU pipeline, as reported in D3.5 in M16 (April 2022) described the module's place in the project infrastructure, its input/output specification, and its features. Language models for Dutch, English, and Spanish were sourced from spaCy, while for Irish a Stanford NLP stanza model is used through spaCy architecture. For all languages, the pipeline supports tokenisation, PoS-tagging, dependency parsing, lemmatisation, named entity recognition, and sentence identification. The pipeline module was made available as a Docker container for integration in the SignON framework.

In the final iteration of the NLU pipeline - as reported in D3.6 in M36 (December 2023) - functionality for text normalisation, spell-checking was added, as well as an expansion of capabilities in word sense disambiguation for Dutch, English, and Spanish. Figure 9 shows the module's architecture, and position in the project infrastructure.

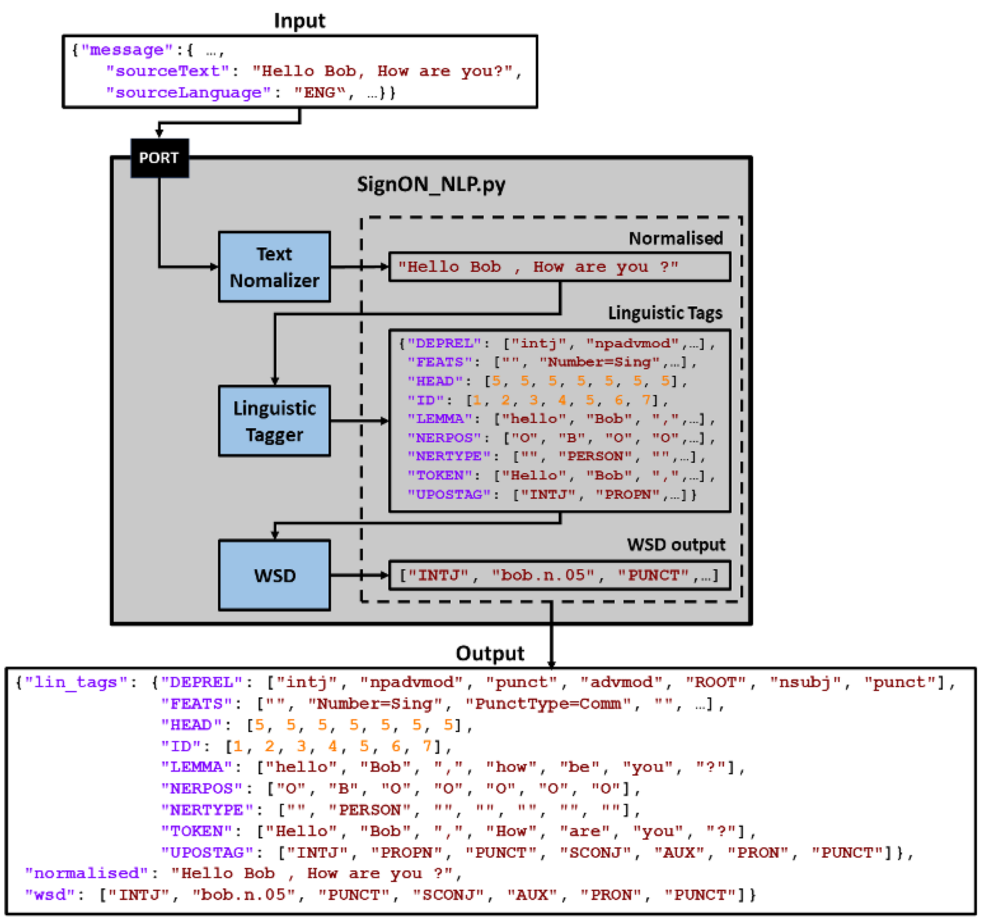


Figure 9: Block diagram of the NLP pipeline

Input to the NLU module comes from user-input as text, or text from speech processed by the ASR module (described in Task 3.4). In terms of the output, processed text from the NLU is no longer informing the interlingua (InterL-S) as was initially anticipated. Text used for SLMT is now translated into English through a third party application, and then fed through AMR before being translated into a representation for SL production. Therefore, in D3.6, we explore using the functionality of the NLU pipeline for other SL processing tasks such as text-to-gloss and gloss-to-text translation using linguistic feature representations, generating synthetic SL gloss data from monolingual spoken language corpora, and developing NL tagging and parsing capabilities for SL glosses.

In terms of the requirement set out in the Grant Agreement, the NLU pipeline fulfils the brief in terms of its place in the SignON ecosystem. We opted for statistical and less computationally-demanding methods for linguistic tagging and parsing such as by using the 'medium' or 'small' models provided by SpaCy[35], as well as for text normalisation and word sense disambiguation. It was, however, not possible to provide figurative language handling or coreference resolution as these models are either incompatible with our pipeline architecture, only available for English, and/or only available in computationally-demanding large neural models.

4.3.4 Deliverables Submitted

D3.1: Internal repository with language data resources (sign and oral)

Deliverable 3.1 describes the internal data repository that was set up for the SignON consortium, to ensure that all the consortium partners have easy and secure access to the datasets that have been collected for the project. It also contains a short description of the datasets themselves.

D3.2: Sign language recognition component and models

Deliverable 3.2 describes the Sign Language Recognition (SLR) models and the SLR component. The difference between model and component is the following. The models are the actual deep neural networks that predict, given input video data, the sign corresponding to the video. The component is a web service which wraps these models and is integrated into the SignON application framework (see Deliverable 2.2). With this web service, the trained models can be used to perform inference on data

[35] https://spacy.io/models

submitted by users of the application.

D3.3: Linguistic description for ISL, BSL, VGT, NGT and LSE

Deliverable 3.3 provides a linguistic analysis of Irish Sign Language (ISL), British Sign Language (BSL), Sign Language of the Netherlands (NGT), Flemish Sign Language (VGT) and Spanish Sign Language (LSE). We provide a broad overview of existing literature with regard to the linguistics of each of the SLs. Driven by the needs and requirements for linguistic insides to aid the translation, we analysed sign languages focusing on constituent order, on gerund constructions, on contrasting older and younger generations of signers, on the impact of video-mediated conversations on (sign) language and on neologisms, depiction. We also developed the concept of SignNets which, similar to WordNets for words (spoken language / written form) are semantic networks of signs.

D3.4: Automatic Speech Recognition component and models

This deliverable provides a comprehensive overview of the automatic speech recognition (ASR) component developed within the SignON project. It focuses on the development and implementation of ASR models for the supported languages, namely English, Spanish, Dutch, and Irish, using a modular/hybrid approach with Kaldi ASR, as well as an end-to-end deep learning approach using wav2vec 2.0 and Whisper ASR. The document offers detailed insights into the audio, text, and pronunciation lexicon datasets utilised during the training of the ASR models. Additionally, it presents a comprehensive outline of the training procedures with Kaldi ASR, including the fine-tuning process with wav2vec 2.0. The deliverable evaluates the performance of the ASR model developed through the modular Kaldi approach and compares its Word Error Rate (WER) with both end-to-end systems i.e. wav2vec 2.0 and Whisper ASR. Finally, it described the deployment of all ASR models and their integration within the SignON orchestrator system.

D3.5 and D3.6: Natural Language Processing pipelines

Deliverable 3.5 reports on the functionalities of the Natural Language Understanding pipelines developed in the context of the SignON project. It introduced processes for tokenising, tagging, and parsing text data from all four spoken languages of the project (Dutch, English, Irish, and Spanish) under one unified architecture had been constructed - as well as some initial experiments on rule-based Word-Sense Disambiguation for Dutch. It was initially planned for the NLU output to be fed to the symbolic representation in the interlingua (InterL-S).

Deliverable 3.6 saw the NLU pipeline being substantially upgraded to enable text normalisation and WSD. We were able to provide support to English, Spanish, Irish and Dutch for text normalisation and English, Spanish and Dutch for WSD. Text normalisation is implemented to remove non-informative characters and punctuations, and to correct some typos that the user could accidentally produce while writing.

4.3.5 Deviations and Corrective Actions

In the project plan we had not foreseen the creation of new datasets. Extra funding was acquired to create new high quality datasets for translation, such as GoSTParC Sign and NGT HoReCo.

The lack of annotated training data for SLR in the targeted sign languages strongly impacts the quality of the SLR models: while the models themselves were shown to be sufficiently powerful for a language with a large training set (for example, ASL), significant effort was dedicated in Task 3.2 to the mitigation of this through maximally using knowledge transfer. This was the main motivation behind the choice for a keypoints-based approach and for the models that use NGT-transfer. Since we found that no suitably annotated data existed for LSE, a small dataset was collected for this sign language. Through the excellent performance of the SLR model architecture on the ASL (American Sign Language) dataset, we confirmed that lack of data is the main (only) bottleneck at this point. Through our participation in another Kaggle competition, we found that current technical solutions (very similar to what we used for SLR) can achieve very high accuracy, but this only works when a large set of continuous fingerspelling data is available because the transients between spelled symbols cause a lot of variability. Since such datasets are not available for any of the SignON Sign Languages, we did not proceed with this topic.

With regard to task 3.3, the linguistic analysis of five different SLs supported by the SignON project was a very broad topic. The approach taken was to provide a broad overview of the literature in relation to the linguistics of the five sign languages. We conducted new research on gerund constructions, on contrasting older and younger generations of signers, on the impact of video-mediated conversations on (sign) language and on neologisms, depiction. We also developed the concept of SignNets which, similar to WordNets for words (spoken language / written form) are semantic networks of signs. First linguistic analyses of productive lexicon were performed in Task 3.3 which can lead to some level of machine understanding in the future.

For task 3.4, ASR models were developed for Dutch, English, Spanish and Irish as planned. For Dutch we added a variant for Southern Dutch (Belgium) with help from our colleagues at KU Leuven, to cater for speakers of the Flemish variant of Dutch, which was an addition to the task in the original project proposal.

For all these languages we implemented ASR models in two stages. In the first half of the project we concentrated on the classic modular approaches using the Kaldi framework. In the second half of the project we explored the emerging transformer based approach with wav2vec 2.0 and whisper, using our own implementations of these approaches, and running the resulting recognizers on our own secure servers. This approach led to substantially better recognition performances, except for the under-resourced Irish language for which the modular approach performed best. With these best recognizers we achieved Word Error Rates at the level outlined as target values in the SignON project proposal. This also held for the test with the Horeco use case recordings (only for Irish was the performance lower). These best models were connected to the SigON Mobile application using Rest API.
One deviation from the proposal is what we could achieve for the atypical speech of DHH speakers. In co-creation with the consortium we set up a special version of the SignON app to record 30 prompted tasks in the hospitality use case scenario. Such a use case recording initiative was not part of the original SignON proposal but was considered necessary in the light of the hospitality use case and the lack of existing recordings of DHH speakers. The full set up of this initiative is described in D1.12. Speaker recruitment campaigns were set up for all languages targeting interest groups and DHH organisations in all countries participating in SignON. These efforts entailed getting in touch with personal contacts, DHH support and interested organisations, including hospitals. We offered personalised help to make the recordings and had contact with various organisations and prospective participants about this.

However, responses in terms of completed recordings were minimal. We identified a number of causes for this:

- The use case data collection was not budgeted in the project (there was no time budgeted for it, nor there was money budgeted to set it up, nor to pay participants)
- The recruitment was not led by role models from the DHH community which the participants trust.

- To ensure the quality and GDPR compliance of the SignON MT training data, users had to be first approved by SignON, to access the prototype recording app, which was felt as an initial obstacle by participants.
- The instructions were fine grained but therefore not sufficiently user-friendly for the target group.

As a consequence we could not finetune our ASR training for these speakers, nor test with these. We are confident that the final versions of our ASR engines perform much better for this speaker group than our first modular versions, but cannot substantiate this currently with experimental results.

In terms of T3.5, it was originally anticipated that NLU output would be fed to the symbolic representation in the interlingua (InterL-S). However, it turned out that text is directly passed to AMR during translation, so the NLU pipelines solely serve the purpose of tokenising, tagging and normalising text for all spoken languages of SignON - as well as WSD for Dutch, English, and Spanish.

With the agreement of the Project Officer, the deadline for MS5: Sign Language Recognition Model for VGT/NGT and ISL/BSL was moved from M18 to M22 as the work on SLR models was ongoing.

4.3.6 Conclusions

Work Package 3 (WP3) has addressed the processing of the different types of sources for the SignON pipeline: sign language videos, spoken language audio signals and written language text. From a research perspective, for each of these modalities, the project has focused on resolving or mitigating the remaining open problems, adding to or adapting the evolutions in the state-of-the-art. From the technical perspective, for each modality, processing components for the SignON framework were delivered. The linguistic expertise represented by the partners in Task 3.3 provided valuable knowledge about sign languages to all technical partners. The knowledge about the Sign Languages involved in SignON was further increased for various aspects that are important for informing the translation process. These include constituent order, analysis of gerunds, informing rule-based systems and others. We also conducted work on the development of SignNets which can be used to inform the translation process with a wider semantic representation.

One of the main bottlenecks in this work package was the lack of data for “low resource” language modalities: all sign languages, as well as atypical speech. Task 3.1 focused on collecting, cleaning and disclosing existing datasets, but the resulting amount of labelled data is still orders of magnitude below what is available for written and spoken modalities. Small additional datasets have been created, and some additional labelling for existing datasets has been performed. However, large scale dedicated data collection for source message extraction (sign language videos or atypical speech) with gloss- or word-level annotations, would require considerable time and resources. This was not possible within the scope of the SignON consortium agreement. Instead, we focused on maximally reducing the data needs through knowledge transfer, and on identifying the data needs for future projects. Several project proposals for data collection projects have meanwhile been submitted by SignON partners (and a few have already been granted). Meanwhile, the data that has been collected and disclosed through the SignON project will present a valuable resource for future research.

4.4 Work Package 4: Transfer and Interlingual Representation

4.4.1 Introduction

The core aim of this Work package (WP4) is (i) the research and development of multimodal and multilingual intermediate representation(s) of signed and spoken languages that facilitate the (automatic) translation of utterances / sentences in those languages (in all possible directions) included in the SignON project and (ii) the development of software pipelines that can update these representations and / or utilise them for the task of translation. In particular, these include the InterL (InterL-E and InterL-S) models along with the machine translation (MT) training (fine-tuning) and inference pipelines, the language specific to language agnostic (and vice-versa) mapping routines, e.g. from SLR internal representations to InterL-E and from text to AMR to gloss to avatar (WP5), and their quality assessment. The objectives are detailed below (Section 4.4.2) followed by the work description along the different tasks (Section 4.4.3) and the submitted deliverables (Section 4.4.4), followed by a short conclusion in Section 4.4.5 along with a discussion on any deviations.

4.4.2 Work Package Objectives

1. Definition and implementation of multimodal and multilingual intermediate representations which include an abstract interlingual symbolic meaning representation (InterL-S) and a distributional representation based on embeddings (InterL-E), that are capable to represent words, signs, sentences and utterances of spoken and signed languages.

2. Hybridisation of symbolic and embedding-based representations combining their strong sides (InterL).

3. Advancing from language specific meaning representations to language independent meaning representations. That is, defining (i) a mapping between language specific NLU analyses (WP3) and the InterL and (ii) a mapping between the InterL and a form that is needed as input for the output module: text representation suitable for text to speech synthesis or for sign language synthesis (WP5).

4. Development of a pipeline for updating the intermediate representation with new data: a framework that can be updated with new data to support new sign, spoken or written languages.

4.4.3 Tasks

The tasks addressed within WP4 are:

Task 4.1: Development of a symbolic intermediate representation (InterL-S), led by KULeuven.

For the development of InterL-S we explored three different approaches (summarised in *D4.1: First symbolic intermediate representation - InterL-S*): (i) a rule-based system for generating glosses from spoken language, (ii) WordNets and SignNets and (iii) Abstract Meaning Representation (AMR). While Sign_A is another interlingual representation targeting signed languages it finds its place in the work on synthesis (WP5) and thus, in the context of WP4, we involve it only in the step of translation into sign language.

Task 4.2: Development of an intermediate representation based on distributional semantics / embeddings (InterL-E), led by UPV/EHU.

Starting from the state-of-the-art in language modelling at the beginning of the project, we found that the multilingual BART (mBART) is most suitable for our needs. As such we adopted mBART as the core model for our InterL-E. The initial work is described in deliverable *D4.3: First distributional intermediate representation based on embeddings*. As a text-based model we first expanded its capacity to cover Irish (GA). Then, we extended it to support the encoding and decoding of both signed and spoken language representations, as shown in *D4.4: Second distributional intermediate representation based on embeddings - InterL-E*.

Task 4.3. Evaluation of the two representations and hybridisation, led by TiU

Following the assessment of rule-based systems and SignNet it was determined that such a language-specific solution would require a lot of human effort to cover all languages of our project than what was anticipated. While continuing the work on the aforementioned methods, we delved into automating the process of generating symbolic semantic representations which was tied to the InterL-E for language support and automation. An overview of the different models and representations and the corresponding translation pipelines, along with empirical evaluations is presented in *D4.5: A hybrid intermediate representation*.

Task 4.4: Source or recognised text transformation from and to InterL, led by UPF.

Translating spoken language, audio or text, is a simpler process (than that of sign-to-text, see Task 4.5). The speech-to-text pipeline first converts the speech input into text which is then translated through the InterL-E. The text-to-speech pipeline sends text to the external text-to-speech framework provided by www.acapela-group.com.

The input to the Machine Translation pipeline is text, which is the natural modality accepted by the mBART model as input. This text can be transformed to the InterL space in the form of numerical vectors (embeddings) representing the meaning of the sentence by the mBART encoder. In order to generate the translated message, the encoded sequence is passed through the mBART decoder to generate the output. In order to implement this process, mBART has been finetuned to generate spoken text from glosses and vice versa (see D4.7 *“Second Routines for Transformation of Text from and to InterL”* and D4.8 *“Final Routines for transformation of text from and to InterL”*). With this aim, we had to expand the mBART and include control tokens (one per SL covered in SignON), also we experimented with different model architectures and training parameters.

The text input to the mBART can have different sources: (1) text directly typed by the users, (2) recognised glosses coming from the SLR module and (3) recognised speech from the ASR. In the regard that the target language is a SL, the sequence of glosses generated by the mBART decoder will be the input to the SL synthesis module. Finally, the output message can be shown as text in the application or be passed through the Speech Synthesis module to reproduce the message with voice.

Task 4.5: Sign language recognition form transformation to InterL and from InterL to Sign_A, led by UCD

With respect to Task 4.5 we connected the SLR model with the InterL-E by aligning their embedding spaces. The work on the SLR component and models as well as on the MT pipeline and the InterL-E were conducted in parallel and once the required models were tested and available we combined the two. Before pipelining the SLR component with the InterL we tested the aforementioned approach using visual embeddings from prior work and reached state-of-the-art results, supporting the validity of the proposed approach. However, using the SignON SLR models led to very low translation quality. We thus tested several other approaches leading to similar results. However, comparing these results to the state-of-the-art results from the two shared tasks on sign language translation (WMT 2022 and WMT 2023) our systems are (i) quite similar to the other approaches and (ii) their performance is on par with the submitted ones, indicating that it is not the models nor the pipeline, but rather data-scarcity is the main source of the problem.

When it comes to text-to-sign, i.e. generating signed utterances via our 3D virtual signer (for the final updates see deliverable *D5.2: Final version of virtual character) we utilise both a symbolic approach as well as the InterL-E*. In a nutshell, the mBART model (embedding-based representation) has been developed to automatically generate Abstract Meaning Representation (AMR) graphs (symbolic representation) which, after linearisation and post-processing, are used to determine a sequence of glosses that describe the utterance which is then used as input to the planner of the virtual signer. We deviated from the initially proposed Sign_A-based approach due to the low coverage and computational complexity and developed a data-driven approach (mBART-to-AMR-to-glosses) which, naturally, has a wider language coverage and can be easily updated / upgraded.

Task 4.6: Development of an approach for automatic updating of the InterL based on new data, led by UPV/EHU.

To address this task we developed a software pipeline for training and updating / fine-tuning the InterL. This work is described in deliverables *D4.11: First adaptable pipeline for training and updating the InterL* and *D4.12: Second adaptable pipeline for training and updating the InterL*. We first started with the fine-tuning of the basic mBART model (D4.11). The pipeline can be broken down into a three-step process that involves data preparation, fine-tuning and translation/evaluation. Then we expanded towards adding support for training and updating AMR (see D4.12). These pipelines are available at: https://github.com/signon-project-wp4/second-adaptable-pipeline

4.4.4 Deliverables Submitted

D4.1: First symbolic intermediate representation - InterL-S

This document presents the first steps in creating a symbolic language-independent intermediate representation (interL-S), including (1) the creation of a rule-based system for data augmentation with synthetic glosses, (2) the implementation of a word sense disambiguation (WSD) scheme to link to WordNet and the creation of SignNets and (3) the investigation of a language-independent representation of the meaning of input sentences (abstract meaning representation, AMR).

D4.2: Second symbolic intermediate representation - InterL-S

This deliverable describes the text-to-AMR-to-gloss pipeline that is implemented in the SignON app as a bridge component between the “text” modality and the avatar for the text-to-sign and sign-to-sign translations, but also covers Abstract Meaning Representation (AMR; Banarescu et al., 2013)[36] as used in SignON more broadly.

D4.3: First distributional intermediate representation based on embeddings - InterL-E

This deliverable describes the first version of the embedding-based interlingual model – InterL-E. In SignON we adopted the multilingual BART model as our interlingua aiming to represent different languages in a common way. In this deliverable we presented the process of adapting mBART to the (spoken) languages included in SignON, as well as the results obtained by the fine-tuned model in the translation task for these languages.

D4.4: Second distributional intermediate representation based on embeddings - InterL-E

This deliverable builds on D4.3. It focuses on extending the input and output of the InterLingua from supporting only text (both as input and output) to supporting both SL and text as input and glosses (or text) format as output. The output glosses can be then used to produce an avatar animation of the translated SL utterance. This new translation pipeline is divided into the following steps: the Sign Language Recognition (SLR) module, the Machine Translation (MT) module and the AMR-to-Gloss module (where AMR is the acronym used for Abstract Meaning Representation).

[36] Banarescu, L., Bonial, C., Cai, S., Georgescu, M., Griffitt, K., Hermjakob, U., Knight, K., Koehn, P., Palmer, M., & Schneider, N. (2013). Abstract Meaning Representation for Sembanking. Proceedings of the 7th Linguistic Annotation Workshop and Interoperability with Discourse, 178–186. https://aclanthology.org/W13-2322

D4.5: A hybrid intermediate representation

This deliverable presents the work on the different interlingual representations and their utilisation in translation pipelines. It covers the work we conducted with different models and model combinations to address the targeted translation tasks. It takes the perspective of the interlingual representations and does not focus on the recognition or synthesis components. In this deliverable we report our quality findings with respect to the InterL, which encapsulates both the InterL-E and the InterL-S models, and the combination with other models and pipelines.

D4.6: First Routines for transformation of text from and to InterL

This document presents (i) an overview of the work we conducted in implementing routines for inference with the first InterL-E (D4.3) and (ii) proof of concept (PoC) experiments that aim to assess the validity of our approach. At this stage, four months into the project, the work on InterL was very much focused on spoken languages. The practical potential was tested in the two PoC experiments. The first PoC deals with the translation of English into Spanish for which we fine-tuned the mBART model. The second PoC uses mBART for English text simplification. In the first case we aim to quantitatively assess the performances of mBART for translation between two languages in a particular speech context (parliamentary proceedings from the European Parliament are used as the domain). The second PoC assesses mBART performance for simplification between a reference text in natural language and a simplified form of the same text. These PoCs complement the experiments presented in D4.3 following which we had the justification to proceed with mBART as our InterL-E model.

D4.7: Second Routines for transformation of text from and to InterL

This document presents (i) the evolving work we conducted in implementing routines for inference with the InterL-E (D4.7) and (ii) experiments to assess the validity of the approach. It is an increment of deliverable *D4.6: First Routines for transformation of text from and to InterL*. The experiments presented here are also complementary to the ones presented in *D4.3: First distributional intermediate representation based on embeddings - InterL-E*, in which the mBART neural transformer is trained to translate between different spoken languages. D4.7 reports results on including SLs within the InterL. The InterL-E is computationally very heavy but at the same time is expected to run in a real-time environment and in this deliverable we described how the model is optimised to accelerate training and translation processes. Additionally, it covers our study on linguistic features computed by the WP3 pipeline and the potential to produce more accurate translations and our work on data preprocessing.

D4.8: Final Routines for transformation of text from and to InterL

Continuing the work on translation routines, in this deliverable, we study several strategies to adapt the InterL-E to bidirectional text to sign language gloss translation under different settings: including a variety of language pairs with different degrees of data sparsity and several model architectures. Both translation directions are explored in two types of experiments, namely, text-to-gloss and gloss-to-text. While the work presented in this deliverable focuses on SL translation, it differs from the one described in D4.9 and we need to point that out. In D4.8 we focus on textual representation of signs, i.e. glosses and the translation between these and text. In D4.9. (see below) we focus on the translations of sign language recognition representations into text through the InterL which are then further advanced in D4.10.

D4.9: First Routines for transformation of SL representations from and to the InterL

This document provides a bridge between WP3 and WP4 in the context of SL translation. In particular it presents the first routines to transform sign language representations, that originate from the sign language recognisers, to InterL. It describes the sign language recognition system first, technical specifications of the data pipeline, its output representations and the requirements for these representations to be transformed to InterL.

D4:10: Final Routines for transformation of SL representations from and to the InterL

This deliverable describes the final pipeline to convert between SL representations and Interlingua (InterL). This process comprises a number of components, namely sign language recognition (SLR), embedding generation and machine translation (MT).

D4.11: First adaptable pipeline for training and updating the InterL

Considering that language is constantly changing as well as the fact that more and more data becomes available, we have implemented routines to easily adapt our InterL to new data. In D4.11 we present the first iteration of this work. It presents the processes involved in data preparation, fine-tuning and translation/evaluation. Our code and models, accessible via SignON's github repository, allows anyone with sufficient data resources to train/fine-tune their own model(s).

D4.12: Second adaptable pipeline for training and updating the InterL

Following deliverable 4.11, this deliverable presents the second adaptable pipeline for training and updating the InterL. It introduces a pipeline to generate Abstract Meaning Representation (AMR; Banarescu et al., 2013) outputs from text that are used for describing sign languages.

4.4.5 Conclusions

Work package 4 is devoted to the intermediate language representations that can act as a translation bridge between the languages of the project both signed and spoken (in written form). It also covers all the routines, methods and methodologies to facilitate the training and updating of these models as well as the translation pipelines.

The work objectives as per the grant agreement and the Tasks of this work package have been achieved to a high degree – while the translation quality of the pipeline is not sufficient for real use, we have built pipelines and models that, given enough data, will produce sufficiently high results (as was demonstrated on the limited use-case of whether predictions and given that we show that our approach is at a par with other state-of-the-art ones). In the three years of the project we deviated slightly from the original plan. These deviations are linked to two main issues: lack of data and complexity of Sign_A which led to reducing the focus on Sign_A (in the context of InterL and the transformation from and to Sign_A) and to exploring an alternative solution with AMR and the text-to-AMR-to-gloss approach for synthesis.

4.5 Work Package 5: Target Message Synthesis

4.5.1 Introduction

This WP is devoted to the synthesis of the target messages, with most of the work focused on the production of 3D virtual characters able to sign (signing avatars or virtual signers), and a smaller part to text and speech generation.

In terms of the virtual signers, the first 18 months of the project resulted mainly in 1) the design of a better quality character; 2) the first version of an end to end system based on Machine Learning that allows us to capture (Manual Features of) signs and turn them into rendered animations of the signing avatar, including manual edition to improve quality; and 3) a parser from Sign_A to a BML extension (the BML extension has already been turned into a mouthing system for Non Manual Features of signs). The second half of the project has resulted in 1) the completion of a better quality character, the creation of a pipeline and revamping of the system to support multiple customisable character; 2) the extension to Non Manual Features of the ML based system to capture signs and turn them into rendered animations of the signing avatar that can be edited; 3) a fully symbolic driven sign synthesis system supporting both a further BML extension and SiGML; and 4) the articulation of the realiser into a very flexible autonomous component which supports simple customisation and easy landing in multiple outputs. In particular, there has been a major re-organisation of the system leading to a set of usable interfaces for final users, from which crowd contributions can be expected in the near future.

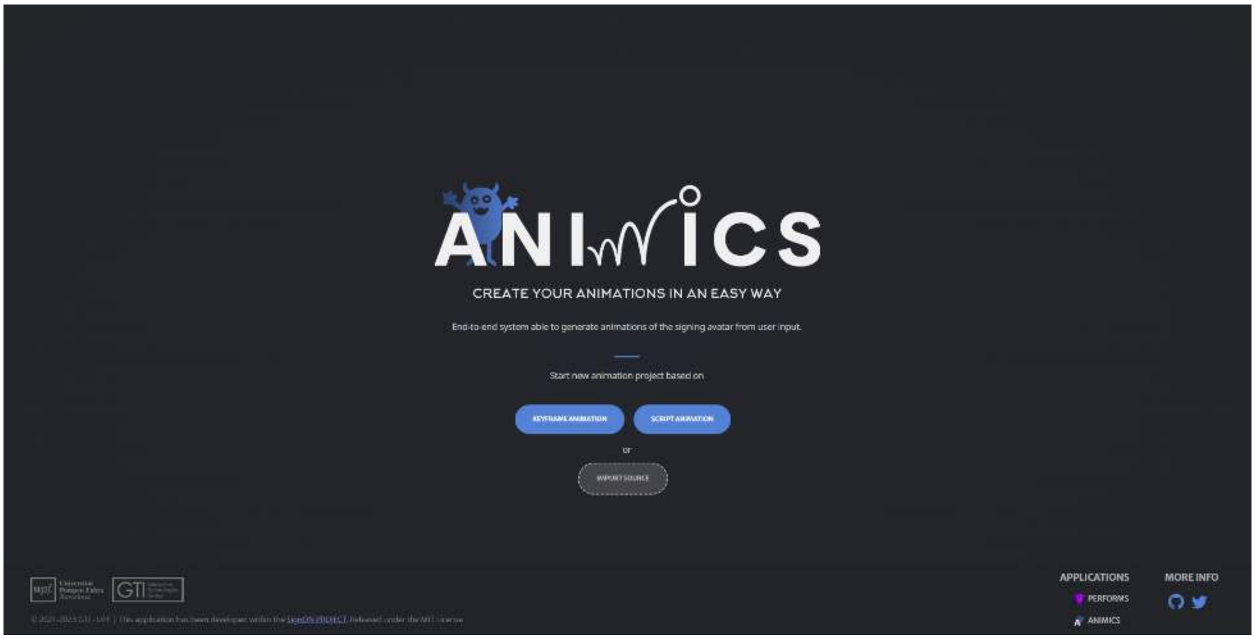


Figure 10: Screenshot illustrating the major re-organisation of the system.

The goal of task 5.3 has been to provide the sign language specific lexicon and structure for Irish Sign Language (ISL), British Sign Language (BSL), Sign Language of the Netherlands (NGT), Flemish Sign Language (VGT) and Spanish Sign Language (LSE). D5.4 provided initial steps in terms of the development of a linguistically motivated lexicon and architecture, which relied heavily upon manual evaluation and annotation of the input into the language processing pipeline. D5.5 provided a shift in focus from a linguistically informed approach to a symbolic approach, which aligned itself better to the goals of the project. The benefits to this approach is that the lexicon semantic representations can be derived independently from a syntactic representation and it can also be generated through an adaptation of the mBART model, which drives the InterL-E within the NLU pipeline of the project. Finally D5.6 provides a description of the final SL lexicon and structure for the project.

4.5.2 Work Package Objectives

As indicated earlier, this WP is devoted to the synthesis of the target messages, with most of the work focused on the production of 3D virtual characters able to sign (signing avatars or virtual signers), and a smaller part to text and speech generation. This is articulated in different tasks: 5.1 to the creation of a virtual character that can be suitably animated, whose visual quality is high, and supports diversity; 5.2 addresses the scarcity of data to support the synthesis of signs, through development of ML and symbolically driven systems; 5.3 to support the rich representation and generation of the machine translated messages in a way that can be used to drive the synthesis of the animations of a signing avatar; 5.4 is intended to bridge this representation within a sign synthesis system; 5.5 actually provides the system allowing for the generation and visualisation of the signing avatar; and finally 5.5 addresses the text and speech rendering of messages (as alternative output).

4.5.3 Tasks

During the second half of the project considerable consolidated advances have been made within WP5. These include:

Task 5.1: Co-designing a personalisable virtual animated signer

Based on a co-creation approach where users from the target communities provide requirements and feedback, this task consists of the design and implementation of customisable virtual avatars that can support diversity and inclusion, possess high visual quality and support sign language production, and their adaptation to low-end devices,

The single character approach of the first half has evolved to a system supporting diverse characters. We have proposed a standardised skeleton, a standardised facial representation, and refactored the system, including configuration files for each character. We have created a pipeline to generate a wide variety of high quality characters, based on Open Source models and software, the supporting tools to easily create configuration files and a final step supports the adaptation of characters to mobile use. All of this enables the co-design of avatars with users in the future. We have finalised within this framework another character of very high quality. D5.2 discusses how this approach meets the requirements of the users.

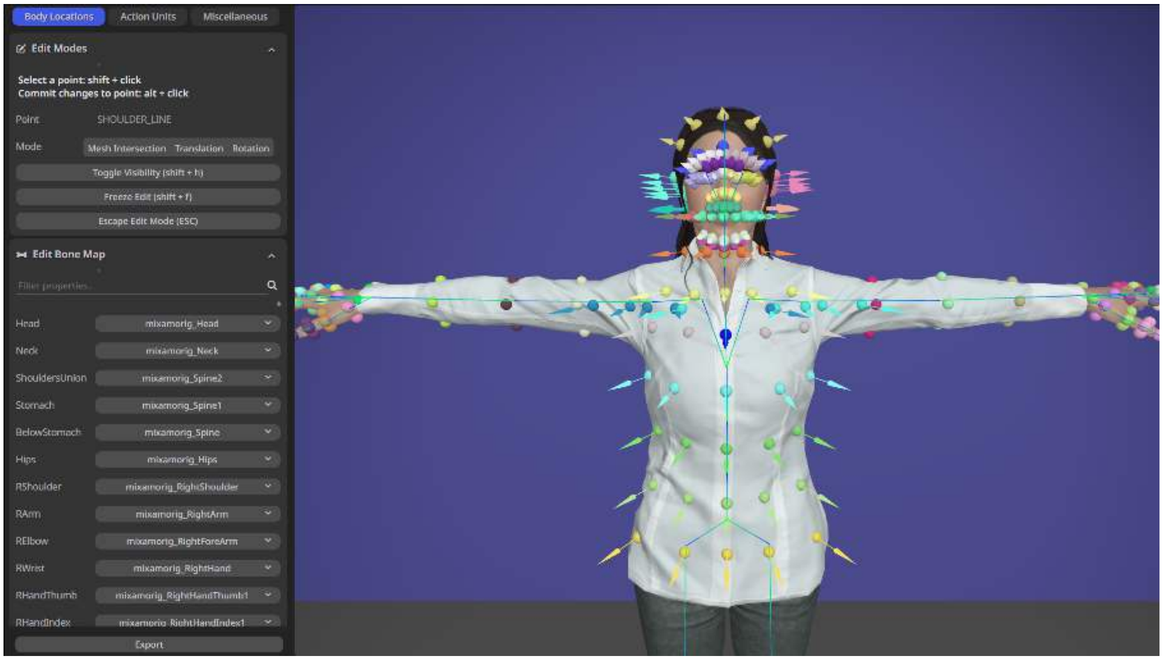


Figure 11: Body Locations editor.

Figure 12: Side-to-side comparison of the heads between the new (left) and old (right) avatar.

Figure 13: Side-to-side comparison of the whole body between the new (left) and old (right) avatar.

Task 5.2: Developing an interactive system of learning from user generated signed content

This task proposed the development of a system capable of capturing, generating, and storing signed content.

In the second half of the project, the (ML based) system allowing to obtain sign animations from single video or webcam input, which addressed only Manual Features (MFs) has been completed by including as well Non-Manual Features (NMFs).

Figure 14: Blendshapes edition view.

In the second half of the project, the animation of signs from symbolic descriptions has been extended to MFs. This has been a major advance, which is discussed in more detail in Task 5.4, as it fits better, although this complementary system allows a major avenue towards user generated sign content.

Task 5.3: Development of a Sign_A lexicon and language-specific structure

The objective of task 5.3 was to develop an appropriate sign language lexicon and an architecture for this lexicon. The SL lexicon and architecture are leveraged by the SL synthesis pipeline. Our first deliverable in D 5.4 was submitted in M8 and focused on the development of a linguistically motivated lexicon and architecture, which relied heavily upon manual evaluation and annotation of the input into the language processing pipeline. We provided an XML description for the Sign_A computational framework, for use within the lexicon entry descriptions. This specification was used to inform the development of a markup language, in particular, Extended Behavioural Markup Language, which provides an interface between the lexicon and the realiser on the SL synthesis facing pipeline. The paper by Murtagh et al. (2022)[37] provides an overview of this work.

The second deliverable for this task was submitted in M28, and this deliverable provided a description for a newly proposed symbolic approach to the SL lexicon and architecture, based on Abstract Meaning

[37] https://aclanthology.org/2022.amta-research.18/

Representation (AMR) and the use of landmarks[38]. Due to the substantial overheads involved with the development of Role and Reference Grammar (RRG) + Sign_A logical structures to represent SL lexicon entries, we turned our focus to AMR, which allowed us to automatically generate a semantic structure. The benefits to this approach is that it can be derived independently from a syntactic representation and it can also be generated through an adaptation of the mBART model, which drives the InterL-E within the NLU pipeline of the project. Within this deliverable we provide the tools to generate lexicons for different SLs from monolingual (videos) and parallel (videos aligned with lexicon entries) data. We also provide the pipelines for the synthesis of SL avatars. D5.6 provides a report on the final SL lexicon and structure.

Task 5.4: Development of a planner for translating from Sign_A representation to BML-based script

The goal of this task was to create a planner to use as a bridge to translate between the Sign_A representation and (an extended) Behavior Markup Language (BML). Generating enough (lexical and grammatical) representations in the target sign languages has not been achieved, while there existed symbolic repositories in SiGML, specifically of NGT, the Sign Language of the Netherlands. Thus, a complementary SignON system has been developed which both addresses the scarcity of (symbolic) data and scalability of the sign synthesis system, which represents a major addition. It allows the re-use of existing datasets containing symbolic descriptions of signs so that at least minimal automated sign language output within the Machine Translation (MT) app can be provided. The BML extension proposed has been further extended to match, and, if possible, improve, the SiGML descriptions, through an Inverse Kinematics based synthesis system. Indeed, it has been successfully tested by incorporating two diverse datasets of very different origin (NGT, LSF-CH).

[38] In this deliverable we use the term lexicon to represent a collection (or repository) of sign-label pairs which are stored (electronically). The way we use it here differs somewhat from the notion of lexicon in its linguistic definition as the set of signs/words of a language.

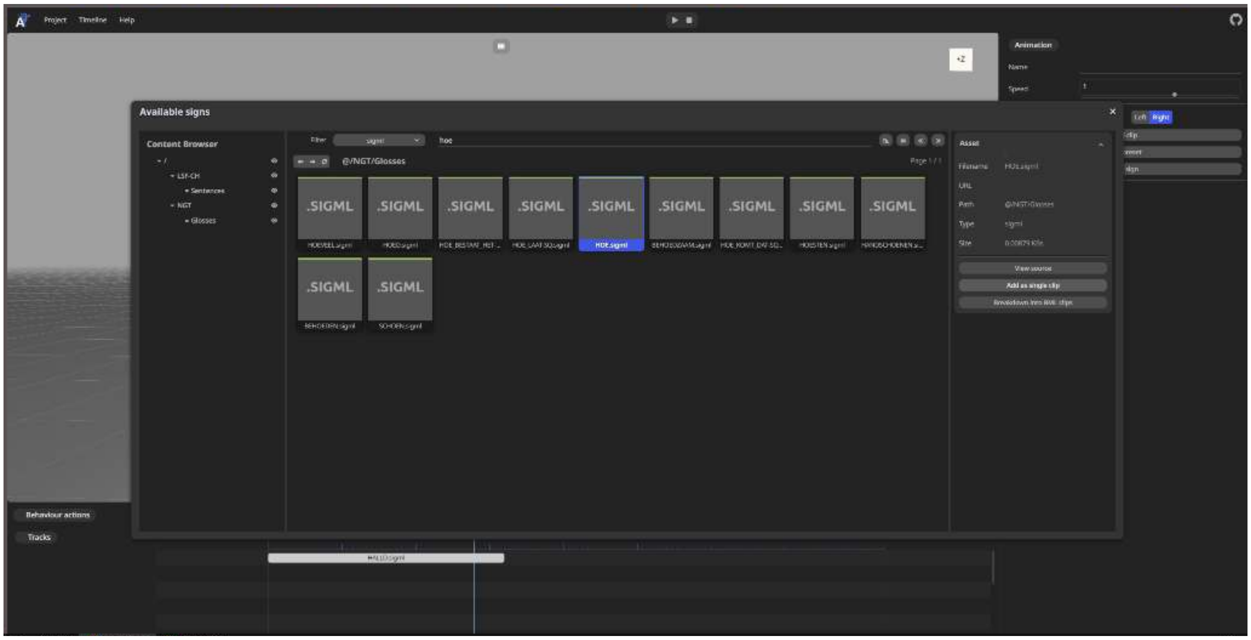


Figure 15: Adding "Hoe" gloss from the NGT-SiGML repository panel.

The system allows for symbolic editing of signs as well as creating novel ones, with import and export capabilities.

Figure 16: Clip edition view of the hand orientation. On the right, the panel with the properties of the selected clip.

The system deals with both glosses and sentences, with support for integration and smooth transitioning, as well as the integration with pre-sets to support expressive templates and, possibly, prosody.

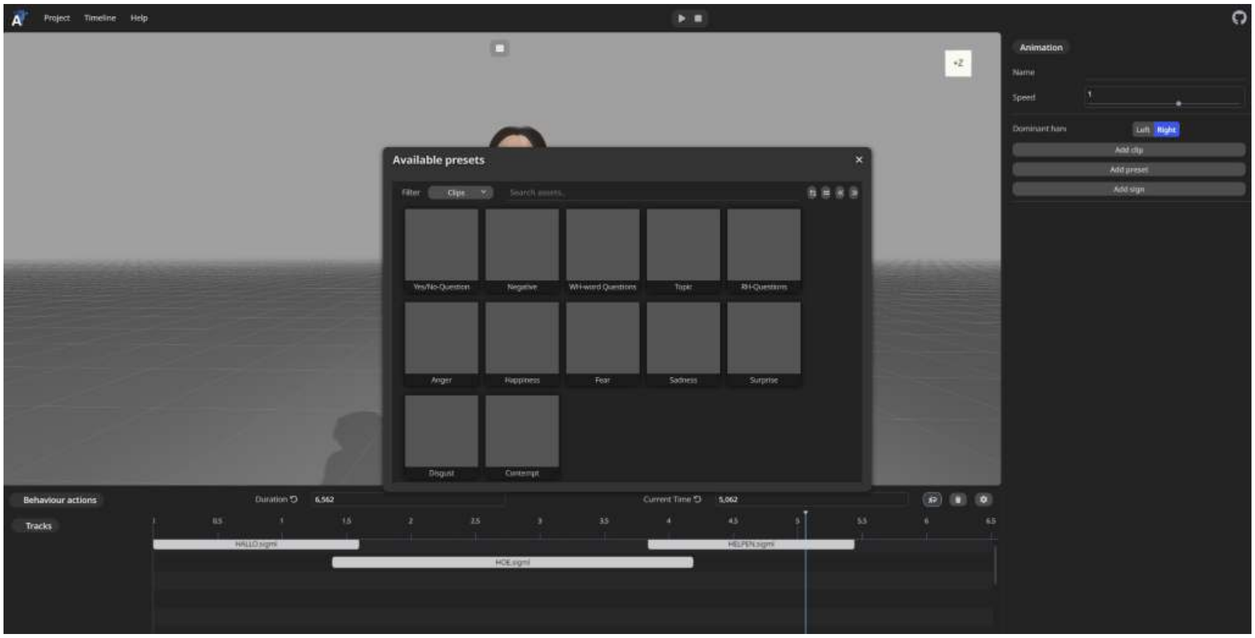


Figure 17: Panel for selection of a common behaviour from available presets on Animics.

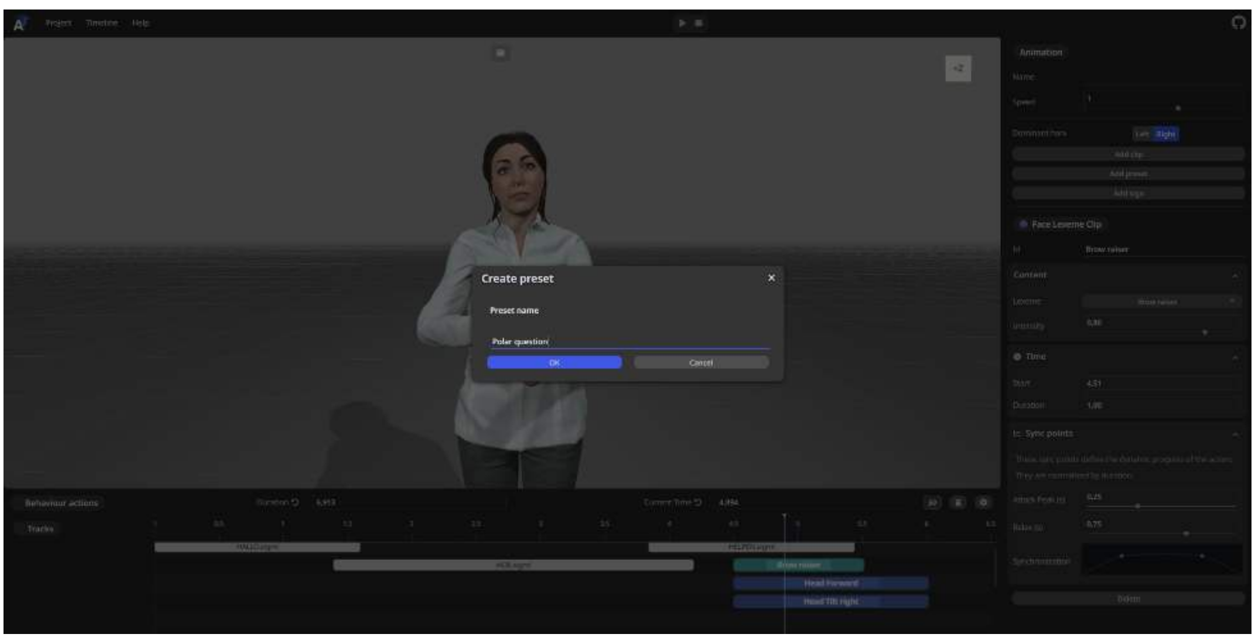


Figure 18: Creation of a custom preset from selected clips.

Task 5.5: Real-time synthesis and delivery of target SL

This task involves the development of a *realiser* (a component of the BML methodology that is in charge of carrying out the actions specified in the BML message), that receives the input message created by the planner (from T5.4) and calls the orders to move the virtual avatar. The realiser has required very substantial work to support the major extensions carried out during the second half of the project, e.g., 1) interoperable support for multiple high quality characters (task 5.1); 2) realising the major advances in both the symbolic and ML driven synthesis (tasks 5.2 and 5.4): providing support for the most extensive set of symbolic representations of sign languages (SiGML) has been a major milestone. The real-time rendering is interactively provided within *Animics*, as it shows the animations resulting from the input and edition in both ML and symbolic modes. In this sense *Animics* integrates the realiser, as the end-to end system did in the past. However, a major software re-organisation has taken place, and an autonomous rendering component, *Performs*, supports customisable visualisation of input coming from *Animics* as well as other sources. It supports customising the scene, clothes, mood, changing avatar, and the easy integration in multiple platforms as shown in the different pictures that follow.

Figure 19: Customising mood (left), avatar (centre) and integration support within Performs.

Task 5.6: Generating output in the target language and modality - sound or text

This task focuses on the module responsible for processing the translated text generated by the translation model (WP4). Its purpose is to normalise the text output for presentation to the user and to convert it into speech. The normalisation task is conducted as part of our research project, while the synthesis of speech is handled by an external contractor.

The process of text normalisation involves post-processing the raw output of the translation model (WP4) to a format that can be sent as output to the SignON mobile application, which will then be returned to the user. Experiments were conducted to address the challenge of proper sentence separation and punctuation integration within the context of a mobile phone application limited by space constraints. The goal was to enhance the readability and comprehension of the translated text by refining its structural aspects. Despite the successful outcome of these experiments, the unmodified outputs of the translation model were found to be satisfactory. Consequently, the final results of the text normalisation process have not been integrated into the system.

Although speech synthesis is not a research objective of the project, it is necessary to include it in the mobile application. Therefore, the task of speech synthesis within the SignON project is outsourced to the Acapela Group, an industrial contractor. Acapela offers a cloud-based solution for speech synthesis in multiple languages, such as English, Spanish, and Dutch, which can be accessed through an API. After consulting with partners from WP2, the decision was taken to integrate the speech synthesis directly within the mobile application, either by utilising Acapela's API or by utilising the speech synthesis capabilities of the mobile device itself. As a result, the output of WP5 will be in text form, and any conversion to speech will be performed within the mobile application based on the user's preferences.

4.5.4 Deliverables Submitted

During the second reporting period (M19-M36), all foreseen deliverables were submitted:

D5.1: First Version of a Virtual Character

In this deliverable the requirements and specifications of virtual avatars for this project's use were presented, both in terms of mesh (surface), and the skeleton (internal structure). The improvements of the base avatar that we were using were also discussed, and we showed render screenshots of the new details of the virtual avatar.

D5.2: Final Version of a Virtual Character

In this M36 deliverable, continuation of D5.1 previously submitted, we focus on character customisation, and the approach followed to support a multiplicity of diverse avatars, the adaptation when integrating high quality avatars in mobile devices and the final improvements in the high quality avatar.

D5.3: Interactive co-creation web-based platform for learning from user input

This deliverable presented the first prototype of the tool for capturing, editing and storing SL animations. We provided a detailed explanation and implementation of each module, and a comparison between different strategies for the Motion Capture problem. The plan of reformulating the system and improving it as future work was also outlined.

D5.4: First Sign language-specific lexicon and structure (Sign_A)

In this deliverable we provided a description of the SignON sign language lexicon and its architecture. This deliverable also provides an XML description for the Sign_A computational framework, which we will leverage both within the lexicon entry descriptions and also, within the development of a markup language that will interface with a realiser on the SL synthesis facing pipeline.

D5.5: Second Sign language-specific lexicon and structure

In this deliverable, submitted in M28, we described the second sign language (SL)-specific lexicon and structure together with (i) the tools to generate lexicons for different SLs from monolingual (videos) and parallel (videos aligned with lexicon entries) data; (ii) the pipelines for synthesis of SL avatars (two approaches – the one described in D5.4 and a newly proposed approach based on AMR and landmarks), and the perspectives for the remainder of the project.

D5.6 Final Sign language-specific lexicon and structure

In this deliverable, submitted in M36, we describe the final sign language (SL)-specific lexicon and structure. This deliverable is a continuation of D5.5, submitted in M28, and it focuses on the final iteration of the SL lexicon and structure, providing a symbolic approach to SL generation. The linguistically informed approach proved to be very manually intensive with regard to development and challenging in terms of automation and scalability, whereas the symbolic approach supports the re-use of existing repositories and allows for scalability. This was our focus for the final iteration of the sign language specific lexicon and structure.

Additionally, it is worth mentioning that qualitative assessment of the symbolic driven sign synthesis is extensively provided and discussed in Section 2 of *D1.6: Quality Assessment Report* submitted in M35; while sections 2 and 3 of *D1.12: User-generated data*, submitted in M36, report on both the ML- and symbolic- driven sign synthesis systems

D5.7: A planner for translating from Sign_A to BML-based script

In this deliverable we presented the collaborative work with the Sign_A team to create a computational representation that could retrieve the key information that represents the sign movement from Sign_A. For understanding purposes, comparison tables between Sign_A and the parsed data, and from BML to our extended BML were presented in the Annexes.

D5.8: A realiser of BML-based script to 3D animated character

This deliverable presented the process of generating sign animations. With specific explanation of the proposed end-to-end system to create the Manual Features of the sign, and the addition of the Non-Manual Features with BML descriptors.

D5.9: InterL to Text to speech pipeline

This deliverable presented the textual post-processing module, in order to normalise the textual output yielded by the translation model (WP4) into an output format that is suitable for presentation to the user, and the subsequent synthesis of text into speech output. The former task is carried out as part of our research project, while the latter task is outsourced to an industrial contractor.

4.5.5 Deviations and Corrective Actions

While not actually a deviation from the project description, it is worth mentioning that the symbolic driven sign synthesis was prioritised in the second half of the project, both to provide automated SL output in the MT app, and to support both re-use of existing repositories, and scalability. Another relevant aspect is the major re-organisation of systems for much enhanced usability and diverse use. In a similar vein, the synthesis pipeline (and the related Task 5.3) adopted mainly an approach based on AMR to provide the SL lexicon and structure. The decision to prioritise symbolic methods, specifically utilising Abstract Meaning Representation (AMR), is further supported by the availability of sufficient training data for AMR representations. The ample supply of training data for AMR allows for more robust and accurate synthesis of sign language, contributing to the enhanced usability and adaptability of the system. By leveraging available AMR training data, the project was able to overcome the challenge of limited resources often encountered in the domain of sign languages. This strategic approach aligns with the project's objective of developing a high-quality and reliable sign language translation system.

With the agreement of the Project Officer, *D5.5: Second Sign language-specific lexicon and structure*, was submitted in M28 instead of M24 to allow for some unforeseen circumstances that were discussed with the PO.

4.5.6 Conclusions and Perspectives

At M36 the SignON project has provided an extensive set of extensively documented Open Source tools for production of signing avatars that currently support 1) alternative pipelines of MT within SignON; and 2) diverse approaches, including extensive re-use of repositories, and prosody research. However, extensive testing is needed, and a lot more improvements need to be carried out.

4.6 Work Package 6: Communication, Dissemination and Exploitation

4.6.1 Introduction

SignON focuses mainly on deaf and hard-of-hearing people, who are minority groups in society. Therefore, it employs a strong "nothing about us without us" principle. Through the co-creation events, DHH people are involved in the SignON process. Communication and dissemination of the progress and the results are also an important aspect in the transparency between DHH and the researchers and developers of the SignON consortium. SignON also offers innovative opportunities to exploit and promote its results and develops business plans, looks in advance at exploitation of the project, including joint and individual opportunities. Listed below are tasks performed by VGTC (Task 6.1 and 6.3), DCU (Task 6.2) and MAC (Task 6.4).

4.6.2 Work Package Objectives

The overall objectives of WP6 are to maximise the innovation impacts of the project and contribute to the uptake of the project results by the deaf and hard of hearing communities as well as creating a new market with the creation of jobs. This objective is key to achieving lasting implementation of the outputs of SignON.

To achieve these goals, the team will:

1. Manage the knowledge generated in the project and adequately protect project IP where possible.
2. Produce high-quality accessible communication and dissemination materials to the target groups.
3. Actively disseminate the non-confidential results to the target audiences.

4. Design and implement a powerful communication campaign for engagement with key stakeholders.
5. Coordinate the dissemination of research papers, presentations, demos at conferences, journals and other similar venues.
6. Oversee the organisation of workshops, to bring MT, ASR and Sign Language research communities closer together in a cross-field workshop.
7. Develop, implement and update a business plan to demonstrate the socio-economic feasibility of the results.
8. Contribute to market uptake of project results taking into account commercial interests and IPR rules.

4.6.3 Tasks

Task 6.1: Create, implement and update the dissemination and communication plan

The aim of this task was to put together a communication and dissemination plan for the SignON project, with the intention of structuring, coordinating and overseeing the communications concerning the project. The first output of this task was translated into D6.1 where the PDCA-principle (Plan, Do, Check and Adjust) was applied, proposing a seven-step method of continuous improvement in our communication and dissemination approach. In this deliverable, the project context was defined first and then a SWOT analysis was performed, which led to the creation of our target group analysis. Communication strategies and tools were selected. An overview of strategic (over a period of three years) and operational (short term) objectives was drawn up.

Task 6.2: Review communication and dissemination activities

In a fortnightly meeting between the coordinator of the SignON project (DCU) and the coordinator of WP6 (VGTC), all communication and dissemination activities are reviewed.

Task 6.3: Organisation of workshops

This task coordinated all workshops and activities for communication and dissemination to the researchers and our target groups. The overview of all these workshops is listed in D6.5.

Task 6.4: Sustainable Exploitation of the SignON Services and Mobile Apps

This task researched the potential and created exploitation, IPR and innovation management plans for the SignON services and mobile apps. This has allowed the consortium to estimate the potential commercial value, as well as a pricing model and business plan which has been continuously updated. They are now concluded, agreed, and presented in D6.8 as the final sustainable exploitation and IPR plans at the end of the project. These plans are built on

- *D6.7: First SignON Sustainable Exploitation, Innovation and IPR Plans* and *D6.6: SignON Market Analysis* (delivered during Period 1),
- The status of the SignON (SL Machine Translation) SLMT Apps and Framework services, as described in *D2.7: Final release of the Communication Mobile Application* and *D2.5: Final release of the Open SignON Framework*,
- The user feedback as described in *D1.8: Final User Requirements Report* and *D1.10: Final Technical requirements and user research (UX design) report*,
- The R&D project progress and experience as described in *D1.6: Quality Assessment Report*
- Developments in the SLMT market during this R&D project,
- The partners' intentions now at the end of the R&D project

4.6.4 Deliverables Submitted

The 8 deliverables submitted from WP6 during three project years were as follows:

D6.1: SignON Communication and Dissemination Plan

Opting for a publicity-oriented approach in which informing, giving insight, motivating and "selling our idea" are key, this deliverable lists a number of strategic and operational objectives that have to be followed up on and implemented. Four strategic objectives were drawn up: (1) Increase visibility of the SignON project, (2) Disseminate information about and results of the SignON project, (3) Raise positive attitude about and foster engagement with SignON, (4) Align visions between project partners internally. For each strategic objective, a list of operational objectives was made with the aim of practical implementation. The operational objectives are formulated in terms of SMART (Specific, Measurable, Acceptable, Realistic and Time-related) in order to constantly evaluate the communication and dissemination plan and update it if necessary (see D6.2). In this deliverable, a timeline for the implementation of these operational objectives is also formulated in terms of the three project years.

D6.2: First Annual reports on communication and dissemination activities

This deliverable gives an overview of the communication and dissemination activities in the first project year. Each operational objective was evaluated towards the second year of the project. Objectives that could not be implemented were evaluated according to SMART criteria and adjusted. New operational objectives were added and the timing was adjusted.

D6.3: Second Annual reports on communication and dissemination activities

This deliverable gives an overview of the communication and dissemination activities in the second project year. Because the communication and dissemination plan is iterative, D6.3 is a new working tool for the last project year as it replaces the previous communication and dissemination plans (D6.1 and D6.2).

D6.4: Final Annual reports on communication and dissemination activities

This deliverable gives an overview of the communication and dissemination activities in the third and last project year. This deliverable also lists which strategic and operational objectives (originally planned in D6.1 or added later) have been implemented and which have not. Evaluation of these objectives is followed by recommendations on efficient scientific communication with DHH for future projects.

D6.5: Workshops, Showcases & Demonstrations Report

This report provides an overview of all workshops, showcases, and demonstrations that have been organised and/or attended by the members of the SignON consortium. Furthermore, it offers recommendations for a targeted communication approach towards various target audiences, based on the organised communication events and feedback received from our stakeholders.

D6.6: SignON Market Analysis

This deliverable introduces the SignON user-centred co-created next-generation Sign Language Machine Translation service and an analysis of its intended markets and policy contexts. The initial core market of potential users for SignON are people who use SL as their first language, their family, friends and co-workers, as well as interpreters, NGOs, the scientific community, regulators, policy makers and external service providers, estimated to be 2.5 million in the EU and 10 million globally. This report discusses various policies, strategies and initiatives over the coming years, that indicate a very significant and active opportunity for the SignON Framework, App and services to have a major impact in Europe's Digital Future[39], and also provide exploitation opportunities for the outcomes of the project.

D6.7: First SignON Sustainable Exploitation, Innovation and IPR Plans

This deliverable provides an initial description of the potential and innovation management plans for the IPR of the SignON services and mobile apps, and potential sustainable exploitation commercial value and pricing model with an appropriate business plan (Sponsorship, freemium model, paid advertisements, paid offer without advertisements). These elaborate and build on the plans described in the DoA and market analysis of D6.6. Management and protection of the project's Intellectual Property Rights are described. During the remainder of task T6.4, this document and its plans were updated and refined to its final version, as *D6.8: Final SignON Sustainable Exploitation, Innovation and IPR Plans* at the end of the project, based on (a) DHH users' feedback and experience in WP1, (b) the technical development work in WP2, WP3, WP4 and WP5, (c) the evolving ecosystem of SL MT tools and services and (d) partners' exploitation plans at that point.

D6.8: Final SignON Sustainable Exploitation, Innovation & IPR Plans

This deliverable describes the post-project plans for the IPR of the SignON services and mobile apps, including its sustainable exploitation, commercial value and pricing model with an appropriate business plan. Management and protection of the project's Intellectual Property Rights (IPR) are explained. These plans and procedures were continuously updated throughout task T6.4 of the project based on development of the SignON App and Framework services, users' feedback, and operational experience during the project, and agreed by all Partners as the project ends.

4.6.5 Deviations and Corrective Actions

In the middle of the project, it was determined that we needed to create realistic expectations within DHH communities in our communications and dissemination activities. Despite what originally sounded like only negative resistance from the communities towards Sign Language Technology, there were also positive (high) expectations. Transparent communication, but also honest communication about expectations from both sides became important. Expectation management was given a place within our operation and in the second annual report (D6.3). In our communication we changed from claiming that

[39] Shaping Europe's digital future | Shaping Europe's digital future (europa.eu)

Sign Language Technology is the solution to communication barriers that DHH experience in society, but rather saying that it contributes to a repertoire of different communication methods and language choices of DHH and hearing interlocutors.

With the agreement of the Project Officer, *D6.5: Workshops, Showcases & Demonstrations Report*, was submitted in M35 instead of M30 in order to allow us to include the large workshop for World Deaf Day that was held in Bruges at the end of September.

4.6.6 Conclusions

Scientific communication for DHH individuals and communities is very new. Thanks to the SignON project, especially within VGTC, we have explored and applied new communication and dissemination methods, especially with regard to the strategic use of deaf presenters versus translators, the language choice of national sign languages versus International Sign. From this we (VGTC) learned a lot and this was a very nice opportunity from the SignON project. This led to a white paper under the initiative of VGTC entitled "Sign Language Technology: Do's and Don'ts - A Guide to Inclusive Collaboration Among Policymakers, Researchers, and End Users." which serves as a helpful guide for internal operations and upcoming projects specifically on Sign Language Technology.

The white paper advises that Sign Language Technologies should:

1. Acknowledge ‘Deaf’ issues
2. Avoid technosolutions
3. Be aware of potential Cultural Appropriation
4. Embrace the principle of ‘Nothing About Us Without Us’
5. In their Communication and Dissemination
    a. Exercise caution in how you communicate about sign language technologies
    b. Manage expectations in the media
    c. Promote transparency and accessibility in communication and dissemination

While Sign Language Research and Development should

1. Utilise a co-creation strategy for collaborative design and development
2. Incorporate insights into the attitudes of deaf sign language users
3. Invest in education and training for deaf signers
4. Work on use-cases determined by deaf communities
5. Involve deaf employees and researchers
6. Work interdisciplinarily with Deaf Studies

7. Avoid tokenism
8. Avoid linguicism
9. Ethically
    a. Recognize that sign language data is scarce and scattered
    b. Be aware of bias in sign language data
    c. Be aware of risks of using L2 / non-native signers' data

4.7 Work Package 7: Coordination and Management

4.7.1 Introduction

Work Package 7 (*Coordination and Management*) ran for the entire duration of the project and aimed to ensure the smooth running of the project. This work package provided the overall administrative management of the SignON project to ensure that it achieved its objectives, including progress monitoring, report preparation, meeting organisation and ensuring that there was regular contact with the European Commission on behalf of the SignON Consortium. The work of this Work Package will continue for some time after the completion of the project in order to ensure that the final reporting and the project review process runs without issue.

Establishing productive communication channels between the partners was the most important first step in this work package. This has ensured that effective collaboration was achieved in order to fulfil the obligations of each task and project deliverable and to deliver the expected outcomes of the project on time and in scope.

The work undertaken in Work Package 7 covers everything involved in managing the project, including taking prompt corrective measures in case of deviations from the work plan, with effective remedial measures put in place to prevent or reduce to the minimum extent possible any disruption to the timely and successful execution of the project.

4.7.2 Work Package Objectives

The work package performed the overall administrative and technical management of the SignON project to ensure that it achieved its objectives and was scheduled to run throughout the whole project, from its start until the very end, and beyond as described above.

To achieve the desired level of effectiveness, the management team operated to the best international practice and built on DCU's experience of managing complex programmes and projects with wide ranging partners from varying backgrounds (work, focus, cultural, resources, etc.), large budgets and tight deadlines.

DCU led the consortium in:

- Carrying out a comprehensive series of consortium management activities to optimise the application of resources by creating an appropriate management framework, linking together all project components and ensuring all contractual requirements are met, incl. but not limited to communication and reporting.
- Ensuring project management procedures were implemented.
- Coordination with and reporting to the European Commission.

4.7.3 Tasks

Task 7.1: Project Coordination

This task handled all of the coordination and administrative activities within the project and ran for the duration of the project.

This work package started out by establishing the coordination and management processes of the project. Once the project was up and running, DCU continued monitoring the execution of the tasks as well as the day to day running of the project, setting up meetings, helping out with internal communications within the project and liaising with the EU Commission when necessary.

The management structure had been previously defined, with each work package being managed by a Work Package Lead (WPL) and supported by the Project Management Board (PMB). The PMB is made up of 20 participants from the 17 consortium partners, and is the ultimate decision-making authority of the project.

Meetings

A kick-off meeting took place virtually on the 21st of January and set the expectations for the start of the project. A monthly WP leads meeting was established to allow for any issues or blockers to be raised and discussed. Minutes were taken at each meeting and shared on Google drive.

Figure 20: SignON Consortium Meeting, June 2022, Tilburg

Project Management Board meetings were held on the 28th April 2021, 6th July 2021. 5th November 2021 and 7th February 2022. In lieu of a virtual PMB meeting in Q2 2022, the first SignON face-to-face meeting took place in Tilburg University from the 15th-16th June 2022, which incorporated the PMB meeting. This meeting was well attended by the consortium partners and consisted of discussions about the various topics of interest within the project, led by experts in each topic. Again, as preparations for the midterm review in September 2022 took precedence, a PMB was merged into these preparations with several all-partner meetings taking place. Another face-to-face consortium meeting took place in Dublin in February 2023, with another review and all of the preparations meetings associated with this in June 2023. The final face-to-face meeting then took place in Bilbao in November 2023.

Figure 21: SignON Consortium Meeting, February 2023, Dublin

A Scientific Advisory Board meeting was scheduled for 6th July 2021, but unfortunately, the Sign Language Interpreter who was due to attend was sick so it was decided to postpone the meeting until after the summer break. This then took place on the 5th November 2021, with another meeting taking place on the 27th June 2022. Valuable feedback on the direction and progress of the project has been given to the consortium members as well as suggestions on how better to run these meetings in order to get the most out of them. SignON SAB Members were invited to various SignON events - the EU Parliament Workshop in September 2022, the Dublin workshop in February 2023 and the workshop at the European Commission in November 2023. The final SignON SAB meeting took place on the 20th June 2023.

Figure 22: SignON Consortium Meeting, November 2023, Bilbao

After the first SAB meeting, one of the SAB members, Dr Ádam Kosa, an MEP, invited the SignON project to present a workshop at the European Parliament. This workshop took place on the 28th September 2022, and was followed by more information workshops in the afternoon. More details about this can be found in *D6.5: Workshops, Showcases & Demonstrations Report*. From the perspective of WP7, the main focus of the PM activities were focussed on the organisation and logistics of this workshop, liaising with the hosts in the European Parliament.

Reviews

Two reporting periods were planned for SignON (RP1 ran from M1 to M18; RP2 ran from M19 to M36). A third, intermediary review that was not linked to a payment period, took place remotely on 15th October 2021. This followed the submission of *D7.1: Interim Progress Report* which was submitted at the end of September 2021. The Project Officer stressed the importance of working with the deaf community as closely as possible and welcomed any feedback we can receive from the community that may influence policy. This has always been fundamental to the partners and objectives of the SignON project and continues to be so.

The first reporting period ended on 30th June 2022 and an official review took place on the 30th September 2022. Feedback was received and addressed by the project consortium. As a result of this another progress check was scheduled for the 9th of June 2023; this went ahead as planned and feedback was received in December 2023.

Monitoring of Progress

An internal report has been prepared monthly for the SignON project. This report has been made available to all of the members of the SignON consortium on the shared Google Drive.

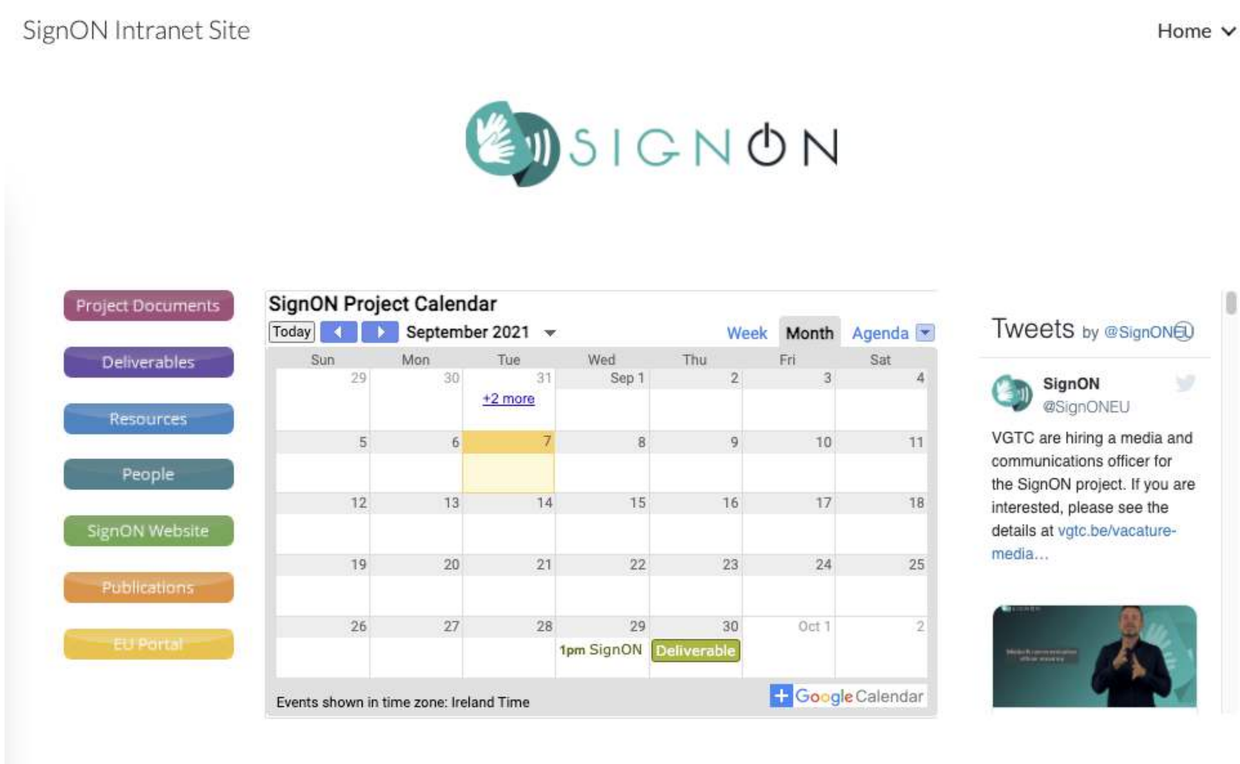


Figure 23: SignON Intranet Landing Page

A Quality Assurance Plan (D7.2) and Risk Management Plan (D7.3) were created and submitted in March 2021. A risk register was established and a process for ensuring quality deliverables was outlined. More details on these can be found in the relevant deliverables.

A project handbook which includes all of project policies, procedures and reporting templates, was developed and shared with all of the partners in March 2021. This was a milestone that was achieved in M3.

As an addition to the project handbook, an Intranet site was created and access was given to all of the people involved in the project. This Intranet site provides an interface to all of the documents, resources, templates and tools available to the consortium members. An overview of the front page of the Intranet site can be seen in Figure 23.

Internal SignON Communications

Thirteen Internal project seminars have been held for the members of the consortium since Q3 2021. These have been very well attended and have been recorded and can be accessed on the Intranet page (see Figure 24) and the shared Google drive folders. The seminars to date have covered the following topics:

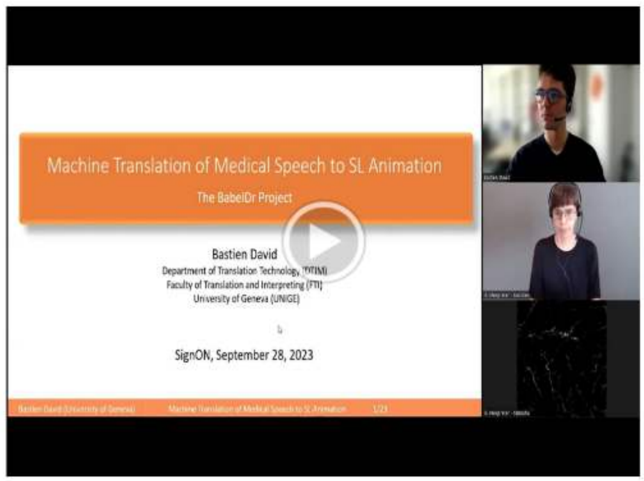
- #notoavatars: why is there a resistance from the deaf communities? (Jorn Rijckaert, November 2021)
- Innovations in Deaf Studies (external speaker Maartje De Meulder, December 2021)
- Introducing Sign Languages. Simultaneity, Multimodality and Other Characteristics (Myriam Vermeerbergen & Lorraine Leeson, March 2022)
- Depiction in Irish Sign Language (Rachel Moiselle, May 2022)
- SciComm & SignON (Shaun O'Boyle, July 2022)
- Describing the Lexicon of a Sign Language (Caro Brosens, October 2022)
- Signer Independent Sign Language Recognition (Ruth Holmes, November 2022)
- Text-to-text Machine Translation (Dimitar Shterionov, January 2023)
- Exploring Models for Sign Language Phonology (Lee Kezar, March 2023)
- Scientific Communication Training (Shaun O'Boyle, April 2023)
- An Overview on Sign Language Recognition(Santiago Egea Gómez, May 2023)
- Machine Translation of Medical Speech to SL Animation (Bastien David, September 2023)
- Text-to-AMR-To-Gloss (Bram Vanroy, November 2023)

An Overview on Sign Language Recognition: Santiago Egea Gómez

22nd May 2023

Machine Translation of Medical Speech to SL Animation: Bastien David

28th September 2023



Text-to-AMR-To-Gloss: Bram Vanroy

9th November 2023

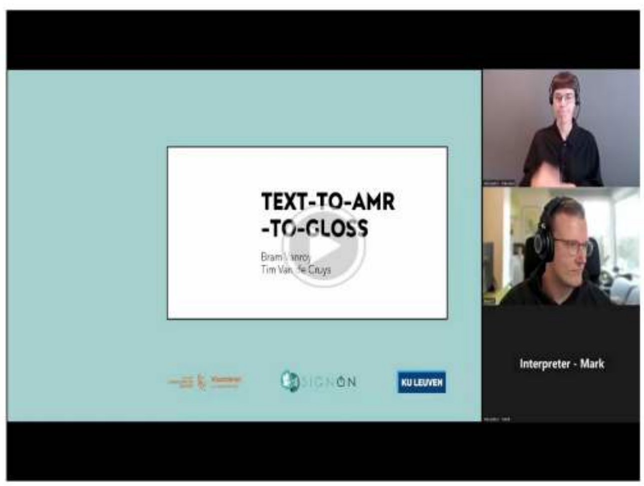


Figure 24: SignON Intranet Internal Seminars Page

A Slack[40] Workspace was set up for use by members of the project. This allowed for instantaneous communications in a less formal manner than email. Channels were established for each work package.

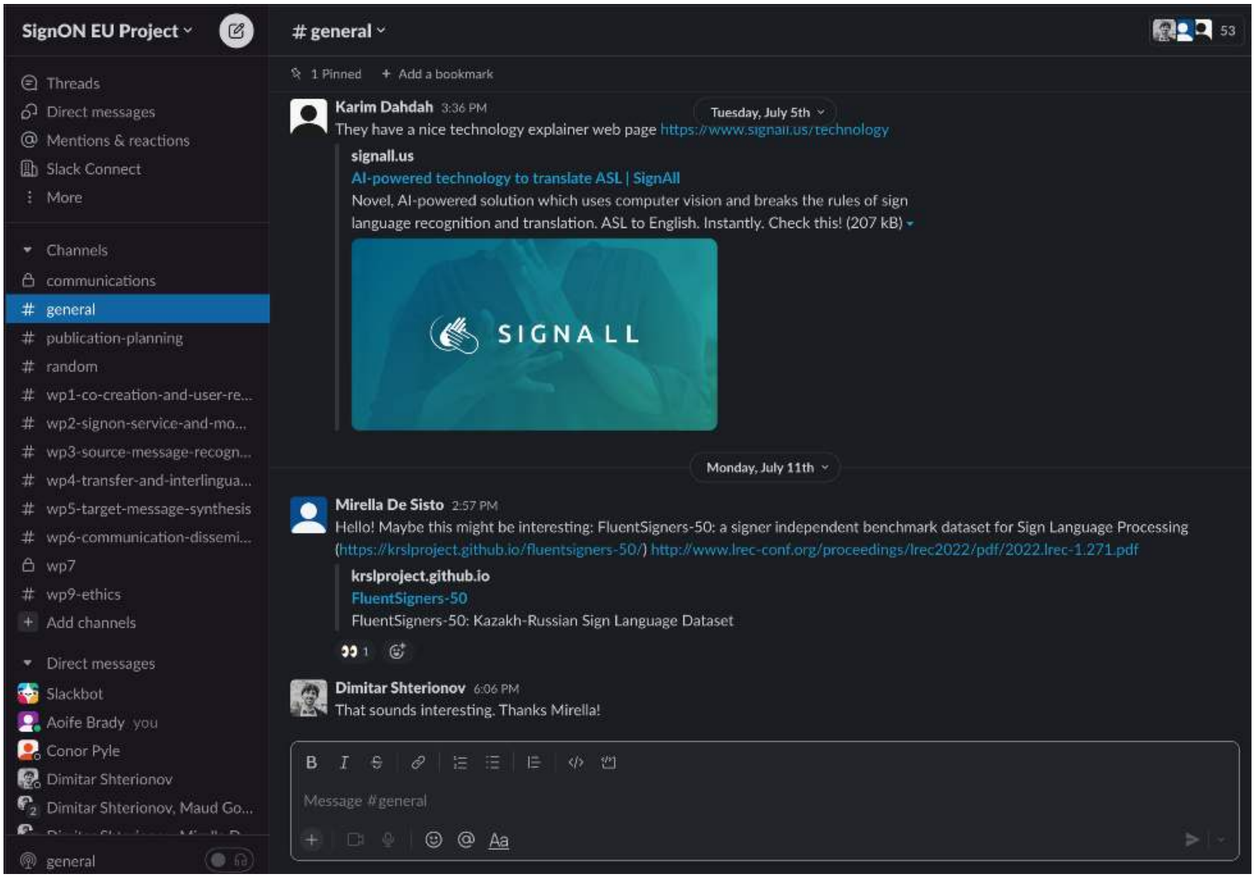


Figure 25: SignON Slack Workspace

Mailing lists were created and utilised. A number of work packages have specific mailing lists, as well as more focussed lists, e.g. for the communications team and the ethics committee.

The Intranet site provides the contact details for all of the members of the consortium, as well as an overview of the topics that each member is working on. This was a great resource for people joining the project to know who to contact about various issues.

Task 7.2: Financial Management

This task looked at the management of and reporting of the project finances for the duration of the project. This task involved setting all of the partners up on the DCU system, in order to be able to

[40] https://slack.com/intl/en-ie/

transfer the appropriate payment to them on the commencement of the project. To date, all partners have received the initial payment and the midterm payments.

In anticipation of the ending of both reporting periods, details for putting together the financial reporting for the project were shared with all partners several months in advance with a deadline of a month before the submission deadline, in order to have enough time for the DCU Research Accountant to review these in full in advance of submission. Instructions for filling this out were provided over email and on the SignON Intranet site with the Research Accountant making himself available to help with any queries which came up during this process.

For the end of the first reporting period, the Research Accountant engaged with all of the partners, at some level, to assist them with their queries in relation to their submission on the EU portal. He reviewed the figures against the budgets and advised the partners of their current standing at the half-way point in the project. He also checked all the Financial Statements sent to him before consolidating them for submission to the PO.

There is now a new person in this position in DCU and we anticipate that the final financial reporting will take the same form as that of the midterm financial reporting.

Task 7.3: Quality Assurance and Risk Management

Quality Assurance and Risk Management were defined at the start of the project during the Kick-off meeting and a Quality Assurance Plan and a Risk Management Plan were delivered (D7.2 and D7.3) in March 2021. The risks have been encapsulated in a Risk Register which is available to each consortium partner and is actively monitored throughout the project lifecycle. Quality assurance of the deliverables is ensured by facilitating the review of the deliverables by each consortium partner. This ensures that a comprehensive and rigorous review of each deliverable is carried out before submission.

Task 7.4: Project Assessment

This task involved the assessment of the project's results and its direction. In December 2021 and 2022 we conducted the first (D7.5) and second (D7.6) impact reviews for the project and provided an assessment of the overall direction of the project and its impact for the user groups. In December 2023, at the same time as the submission of this deliverable, we will submit the final version of the impact review (D7.7).

The SignON Project is a fundamental step towards a new vision for Speech and Sign Language Recognition and translation between sign and spoken languages. It employs a user-centric approach to draw use-cases, to validate quality, to ensure acceptance based on continuous communication with the stakeholders. As such SignON aims to become a stepping stone to foster communication, information exchange, business creation, learning and knowledge acquisition within an inclusive and open society.

- Co-creation events: WP1 (EUD and the Centre for Deaf Studies (CDS) in TCD, as well as VGTC, UPF, TiU & DCU) has organised several interviews, focus groups, workshops, round tables and surveys across the target communities. Dialogue was a core principle of our co-creation events. The outcome was that the SignON team received input from potential users at an early stage, and the impact of this was a research and development process that was immediately informed by deaf and hard of hearing perspectives and expertise. More long-term, we hope that the co-creation process will lead to technologies that are useful and beneficial to DHH users. The co-creation events were also an opportunity for the SignON team to provide deaf and hard of hearing users with more information about the technologies that underpin SLMT. These conversations highlighted to us which aspects of the technology DHH users are most interested in (or concerned about), and they created opportunities for users to become more informed, and to realign their expectations for SLMT with a realistic time frame for its development. Overall, the potential (DHH) users felt informed and involved from an early stage in the research process resulting in a strong willingness to follow-up further stages of SignON development (e.g. to test each component of the SignON services if they have the opportunity). The impact is the positive view on the SignON project, thanks to being aware that deaf people are involved from the start this time and that we will actually listen to them. More details on the co-creation events are presented in Section 4.1.
- Scientific and popular publications: The members of the SignON consortium have had numerous papers published in addition to providing presentations on the project at various venues. The details of these can be seen on the portal as well as in *D6.4: Final Annual Report on Communication and Dissemination Activities*.
- Wide-ranging media content: SignON content is disseminated via its channels on Facebook (SignONEU), LinkedIn (SignON (EU project)) and Twitter (@SignONEU). A great success is the SignON encyclopaedia which presents videos containing information about sign language, avatars, deafness, machine translation and other interesting and related to the project topics (including a series of short films in collaboration with deaf artists and performers). A newsletter

is released every quarter (since Q4 2021) and keeps followers informed about all of the project news.

- Since the major update of the website and its publication, and the launch of the social media channels of SignON, our target groups are aware of our project. Several name-signs for SignON were suggested by the deaf community. Voting was enabled on social media and the name-sign for SignON was confirmed. This was made public in June 2021.
- The first (Beta) version of the app was released at the end of June 2022 for use which impacts the direct stakeholder communities. Reciprocally their feedback provided new insights and impacted the continuous development of the SignON application and service leading to the final version of the application released towards the end of the project. Not only that, we released an application for data collecting and processing to act as a data-hub for user-generated content closing the loop of a self-evolving framework.
- Existing data has been collected and processed and, as long as licences allow, any derivatives will be released to aid the future development in this field. In addition new data has been collected, a great example is the (NGT) HoReCo corpus. The HoReCo has had a snowball effect - after the initial release of the corpus, different partners decided to extend it to other sign and spoken languages. And while it is not yet fully processed to accommodate for the needs of ML / DL models we plan to do that in the future.
- The machine translation approach of SignON leads to state-of-the-art results as shown by our empirical results and the comparison to other state-of-the-art models. In addition, our InterLingua approach reduces the needs for individual / dedicated models for each language pair and modality. Through the automated learning process, when more data is available, it can be used directly to fine-tune the underlying models to improve the quality for the supported languages or even add new ones. Our code and models will be released upon completion of the project with a direct impact on the research community in this field and indirect, through the application and other translation services, on the end-users.
- We conducted a wide research along the sign language synthesis axis. We came across several obstacles mostly related to automation, data and lack of common language between the synthesis (sub)system and the InterLingua. These obstacles we overcame through investigating and developing different approaches and methodologies. We developed the Animics and Performs systems which have already made an impact outside of SignON.

- Through SignON we developed a robust ethics assessment approach which was observed by the research ethics committee. The activities of the SignON REC impacted the data collection and management, the intra and inter-team interactions between individuals and groups, the collaborations, and the fairness and openness in communication and dissemination. The produced guidelines and best practices will have a long-lasting impact in the research community.
- The communication and dissemination, led by VGTC, were conducted with respect to the deaf and hard of hearing communities. Through targeted events tailored content in regional and international sign languages could reach a wide spectrum of stakeholders. Not only did the communication and dissemination activities inform the communities but also managed the users expectations.

Task 7.5: Data Management

A Data Management Team was established and, with their help, the Data Management Plan (D7.8) was created and delivered in June 2021. This deliverable set out the principles for Research Data Management in the SignON project. It addressed the project's Open Access publication policy and how the project will meet the FAIR principles for sharing data, models and software after the lifetime of the project. It also explains how the collection and sharing of data (in a GDPR compliant way) during and after the lifetime of the project will be dealt with, as well as data security issues and ethical aspects.

In order to accommodate for the dynamic nature of the DMP, intermediate versions of these were scheduled for M12, M24 & M36. Project partners could use the DMP tools and templates provided by their own organisations as long as the guidelines outlined in this report are followed. Partners then provided individual plans to the SignON's Research Ethics Committee (REC) by the middle of November in each project year and these were then reviewed and suggestions made. These project plans were then added to *D7.10: Data Management Report* which will be submitted at the same time as this report.

Data Protection training was provided to all partners in May 2021 by the DCU Data Protection Unit. For those who could not attend, recordings were shared in the project Google drive and links are provided on the Intranet site.

In June 2021, a template for the Data Transfer Agreement (D7.9) was created and shared to lay out the conditions of the transfer of data between consortium members. In collaboration with the DCU Data Protection Unit, it was agreed that all partners would be data controllers and this agreement would be signed by all partners. Negotiations for the exact wording for this were lengthy but it was fully executed in 2023.

4.7.4 Deliverables Submitted

D7.1: Interim Progress Report

This report provided an accurate detailed description of the work carried out in this project in the period (M1-M9).

D7.2: Quality Assurance Plan

This document described the quality assurance approach for the SignON project. The Quality Assurance Plan (QAP) defines the overall policies, the participant roles and responsibilities, the quality procedures and the means of ensuring that all the activities (R&D activities, deliverable writing, etc.) are in conformance with the contract provisions and specifications.

D7.3: Risk Management Plan

The Risk Management Plan described the risk management framework for the SignON project, ensuring that adverse situations will be managed accordingly during the project lifecycle.

D7.4: Final Report

This document.

D7.5: First Impact Review

This report provided an overview of the impact of the SignON project to date. It gives an outline of the impact that was described in the Grant Agreement and how this impact has been seen at the end of the first year of the project.

D7.6: Second Impact Review

This report provides an overview of the impact of the SignON project to date. It gives an outline of the impact that was described in the Grant Agreement and how this impact has been seen at the end of the second year of the project.

D7.7: Final Impact Review

This report provided an overview of the impact of the SignON project. It gives an outline of the impact that was described in the Grant Agreement and how this impact has been seen at the end of the project.

D7.8: Data Management Plan

D7.8 outlined the framework and the principles which individual DMPs in the project should meet in line with the contract obligations stipulated in Article 29.3 of the Grant Agreement of the project. D7.8 is complemented by the specific DMPs for each partner. These will be delivered in D7.10 which is due in M36. In order to accommodate for the dynamic nature of DMPs, intermediate versions of D7.10 are scheduled for M12 and M24.

D7.9: Data Transfer Agreement

This deliverable set out the template for the data transfer agreement between all partners on the transference of data. The purpose of this document is to provide the template for the Data Transfer Agreement which will be in place in order to facilitate the sharing of data between the partners in the SignON consortium.

D7.10: Data Management Report

D7.8 outlined the framework and the principles which individual DMPs in the project should meet in line with the contract obligations stipulated in Article 29.3 of the Grant Agreement of the project. D7.8 is complemented by the specific DMPs for each partner. These have now been delivered in D7.10 which will be submitted at the same time as this report.

4.7.5 Milestones Achieved

MS1: Project Handbook (DCU, Month 3): The Project Handbook describes in detail the plan to implement and execute the project; providing an overview of the management framework that the Consortium has established to guide all the project activities and tasks, with a view to ensuring smooth and effective collaboration amongst the partners, so that the overall project is successfully executed. The Handbook was prepared and shared with the consortium members in March 2021.

4.7.6 Conclusions

WP7 progressed as planned. All deliverables have been submitted to date and the tasks progressed as planned. Any deviations from the plan were flagged with the Project Officer and changes approved.

The next steps involve preparing for and attending the project review meeting with the Commission at the start of February 2024 as well as coordinating the final reporting of the project that is due 60 days after the project finishes.

4.8 Work Package 8: Ethics Requirements

4.8.1 Introduction

When the details of the project were being added into the EU portal, this Work Package was automatically generated. It focuses on the Ethics Requirements for the project and runs for the duration of the project. The ethics requirements that the project must comply with are included as a deliverable in this WP. There was one deliverable due in this work package (D8.1) and this was submitted in June 2021.

4.8.2 Work Package Objectives

The objective of this work package is to ensure compliance with the ethics requirements of the project.

4.8.3 Tasks

The preparation of the deliverable D8.1 aimed to emphasise how all of the data that will be processed as part of the SignON project is relevant and limited to its purposes in accordance with the 'data minimisation' principle.[41] The details for this were submitted as deliverable *D7.8: Data Management Plan*. D7.8 contains the framework and requirements for the Data Management Plans (DMPs) of each project partner and were complemented by the specific DMPs for each partner. These are delivered in D7.10 which is due in M36. In order to accommodate the dynamic nature of the DMPs, intermediate versions of D7.10 were scheduled for M12 and M24. Each partner's DMP was reviewed and approved by SignON's Research Ethics Committee, and served as the framework to ensure the protection of personal data (POPD) within the project. All of our work was conducted in accordance with the EU Code of Conduct for Research Integrity.

[41] Data minimisation as defined by GDPR, art. 1, section 1, c) https://gdpr-info.eu/art-5-gdpr/

4.8.4 Deliverables Submitted

D8.1: POPD (Protection of Personal Data) - Requirement No. 2 (TCD, June 2021): This deliverable D8.1 was requested by the European Commission. This deliverable points to *D7.8: Data Management Plan* which details how, in accordance with the 'data minimisation' principle, the data that would be processed as part of the project is relevant and limited to the purposes of the research project. It also references *D9.1: Ethical Guidelines and Protocols*, which describes the ethical guidelines and processes that we applied across the execution of our project.

4.9 Work Package 9: Ethics

4.9.1 Introduction

Work package 9 set out to ensure that all work carried out under the auspices of the SignON project was in accordance with the European Union's Code of Conduct for Research Integrity and to provide ethical guidance to consortium members with regard to our project work. We established a SignON Research Ethics Committee, drawing on expertise from across the consortium. We also worked to ensure that we incorporated clear guidance to the consortium regarding best practices in working with Deaf, hard of hearing and other minority communities, drawing on Deaf studies literature (See D9.1). Data management was also dealt with in this WP in accordance with the General Data Protection Regulation (GDPR). Plan S principles were applied and we provided guidelines around how we should approach publications in our consortium that supported transparency and protection of results. We liaised with WP6 in this regard.

4.9.2 Work Package Objectives

This work package ensured that the work carried out in SignON was in accordance with the EU Code of Conduct for Research Integrity and provided ethical guidance to consortium members in conducting the research plan and in the identification and recruitment of participants for the use cases.

4.9.3 Tasks

Task 9.1: Development of Ethical Guidelines and Protocols

Task 9.1 was concerned with the development of ethical guidelines and protocols for the consortium, in line with the EU Code of Conduct for Research Integrity. We embedded best practices for researchers working with Deaf communities, including the need for co-creation of research protocols, a central tenet of our approach (as outlined in WP1). We produced protocols for the identification and recruitment of participants, a description of the consenting procedures that we adopt, and an annex that includes templates of participant information leaflets, consent forms and other relevant documentation for stakeholders. Sample content in a sign language is also included. This information is available in *D9.1: SignON Ethical Guidelines and Protocol* document, which was submitted in M6.

Task 9.2: Provide Ethical Support to Members of Stakeholder Communities

Through Task 9.2, we oversaw the management of information provided to stakeholder communities that related to their engagement with the SignON project's research teams.

A SignON Research Ethics Committee (REC) was established, comprising the following members:

	Name	**Institution**	**Country**
1	Prof Lorraine Leeson	TCD	IE
2	Dr Dimitar Shterionov	TiU	NL
3	Dr Vincent Vandeghinste	INT	NL
4	Dr Henk van den Heuvel	RU	NL
5	Prof Josep Blat/Prof Horacio Saggion (shared the position)	UPF	ES
6	Jorn Rijkaert	VGTC	BE
7	Prof Dr Myriam Vermeerbergen	KUL	BE

8	Dr Catia Cucchiarini	DLU	NL
9	Aoife Brady	DCU	IE

Table 8: SignON REC Members

The team met regularly, allowing for ongoing review of ethics documentation from partners as they were prepared for submission to their local university REC, or, in the case of industry and NGO partners, to the DCU REC. We reviewed and offered feedback on 12 ethics applications for DCU (2), TCD (3), KU Leuven (3), UPF (1) and Tilburg (3).

Task 9.3: Ethics Monitoring

As noted above, the SignON REC met regularly and evaluated how privacy, ethics, legal and societal impact factors were approached within the consortium, monitoring our approach as we worked on the SignON project tasks. This supported our co-creation goal by ensuring that the SignON protocols along with other best practice guidelines were mirrored in local REC applications and subsequent research processes. For example, this included considering how we embed a research integrity culture in our work (e.g. see LERU 2020).

Task 9.4: Ethics training, organisation of ethical committee meetings and ethical approvals

The SignON ethics committee supported partners in the development of REC applications for their local institutions, offering input, feedback and guidance as appropriate. We reviewed each ethics application prior to submission at the partner institutions, kept a record of all ethics applications submitted to us, and noted the institutional approvals, once they were confirmed. We ran an online training session on GDPR for researchers by Joan O'Connell in the DCU Data Protection Unit in 2021 and have had a number of within consortium sessions that address key ethical considerations from a Deaf community perspective (e.g. Dr Maartje De Meulder presented on "Keeping up with Deaf Studies" on 16/12/2021; at our Consortium meeting in Tilburg, June 2022, Prof Leeson presented an overview of some key considerations that are important to deaf community stakeholders, e.g. understanding of what kinds of data we are drawing on, why, and for what purposes).

4.9.4 Deliverables Submitted

D9.1: Ethical Guidelines and Protocols

This report presented guidelines and protocols that will be followed throughout the SignON project. All of our work was conducted in accordance with the EU Code of Conduct for Research Integrity. This documentation provides guidance and reference for all members of the consortium.

D9.2: Annual Ethical Report for Stakeholder Communities

This report offered an overview of the work that the SignON Research Ethics Committee (REC) completed over the first year of the project.

D9.3: Second Ethical Report for Stakeholder Communities

This deliverable is an exact copy of *D9.6: Second Annual Ethical Report on Internal Affairs*. For this reason, and after discussion and approval by the Project Officer it was agreed that a dummy deliverable (this) would be prepared and submitted for D9.3 in order to avoid redundancy. For the content for this deliverable, please refer to D9.6 (submitted on the same date).

D9.4: Final Ethical Report for Stakeholder Communities

This deliverable is an exact copy of *D9.7: Final Annual Ethical Report on Internal Affairs*. For this reason, and after discussion and approval by the Project Officer it was agreed that a dummy deliverable (this) would be prepared and submitted for D9.4 in order to avoid redundancy. For the content for this deliverable, please refer to D9.7 (due to be submitted on the same date).

D9.5: First Annual Ethical Report on Internal Affairs

This report offered an overview of the activities of the SignON Ethics Committee over year 1 of the project.

D9.6: Second Annual Ethical Report on Internal Affairs

This deliverable provided an overview of the activities of the SignON Research Ethics Committee across 2022. It also briefly outlined some plans for 2023. Please note that D9.3 and D9.6 are mirror copies, as there are no issues arising that require handling in an internal versus external facing document. For this reason, Deliverable *D9.3: Second Annual Ethical Report on Practices Towards the Stakeholder Communities*, was delivered as a dummy document. This decision was made after discussion and approval by the Project Officer in order to avoid redundancy. Both deliverables were submitted at the same time.

D9.7: Final Ethical Report on Internal Affairs

This document presented the final annual ethical report on internal affairs. It documented the listing of all ethics applications that were supported across the life of the project. Please note that D9.4 and D9.7 are mirror copies, as there are no issues arising that require handling in an internal versus external facing document. For this reason, Deliverable *D9.4: Final Annual Ethical Report on Practices Towards the Stakeholder Communities*, was delivered as a dummy document. This decision was made after discussion and approval by the Project Officer in order to avoid redundancy. Both deliverables were due at the same time.

D9.8: Report on Ethical approval

This document presented an overview of the research ethics applications that have been submitted and approved to date, supporting and underpinning data collection for the SignON project. This included focus groups with deaf and hard of hearing people that supported our co-construction approach and data that supported our hospitality use case goal.

4.9.5 Deviations and Corrective Actions

There were no deviations from the original plan. However, we noted that D9.2 and D9.5 would, necessarily, include the same information, resulting in reduplication of content in each of the deliverables. We suggested that we collapse subsequent annual reports D9.3 and D9.6 (due M24) and D9.4 and D9.7 (due M36) into single annual ethical reports. Due to issues removing deliverables from the portal, the Project Officer for the EC has approved the submission of a "dummy" document for deliverables D9.3 & D9.4, which will indicate that the content of D9.3 and D9.4 have been integrated into D9.6 and D9.7, respectively. This is in order to avoid redundancies.

4.9.6 Conclusions

Through this WP, we have steered our SignON research work in a way that places our co-construction principles at the heart of our ethical practices. This work has also provided us with the opportunity to engage in the ongoing highly topical conversation around the ethics of SLMT with Deaf communities, which also sits within the thematic domain of ethics and AI more generally. The SignON REC supported consortium partners as they prepared REC documentation, and, as necessary, provided advice and guidance during the planning phase of research activities. We also recruited a (deaf) research assistant to work on aspects of the ethics of SLMT with Deaf communities, an area that is under-explored in an empirical way in the European context. A publication has been submitted for review in this regard (Loughrey et al.) Our goal is that findings emerging from this work will inform practice across the field at large.

5. Summary of Deliverables and Milestones

Deliverable	Title	Lead Beneficiary	Due Date	Status
D1.1	Case studies and evidence analysis	TCD	3	Delivered
D2.1	SignON Development Repository	FINCONS	3	Delivered
D6.1	SignON Communication and Dissemination Plan	VGTC	3	Delivered
D7.2	Quality Assurance plan	DCU	3	Delivered
D7.3	Risk Management Plan	DCU	3	Delivered
D4.3	First distributional intermediate representation based on embeddings - InterL-E	UPV/EHU	4	Delivered
D4.6	First Routines for transformation of text from and to InterL	UPF	4	Delivered
D1.13	KPIs	TCD	6	Delivered
D1.3	First user Requirements Report.	EUD	6	Delivered
D1.4	First technical requirements and user research (UX design) report.	MAC	6	Delivered
D4.11	First adaptable pipeline for training and updating the InterL.	UPV/EHU	6	Delivered
D7.8	Data Management Plan	DCU	6	Delivered
D7.9	Data Transfer Agreement	DCU	6	Delivered

D8.1	POPD - Requirement No. 2	TCD	6	Delivered
D9.1	Ethical Guidelines and Protocols	TCD	6	Delivered
D2.2	SignON Services Framework Architecture	FINCONS	8	Delivered
D5.4	First Sign language-specific lexicon and structure	TU Dublin	8	Delivered
D7.1	Interim progress report	DCU	9	Delivered
D5.3	Interactive co-creation web-based platform for learning from user input	UPF	12	Delivered
D5.7	A planner for translating from Sign_A to BML-based script	UPF	12	Delivered
D6.2	First Annual reports on communication and dissemination activities	DCU	12	Delivered
D6.6	SignON Market Analysis	MAC	12	Delivered
D6.7	First SignON Sustainable Exploitation, Innovation and IPR Plans	MAC	12	Delivered
D7.5	First Impact Review	DCU	12	Delivered
D9.2	First Annual Ethical Report on Practices Towards the Stakeholder Communities	TCD	12	Delivered
D9.5	First Annual Ethical Report on Internal Affairs	TCD	12	Delivered
D2.3	First release of the SignON Open Cloud platform, including the Open Cloud Platform design	INT	13	Delivered
D3.5	First Natural Language Processing Pipelines	UPF	16	Delivered
D1.5	First Interim Community building Report.	EUD	18	Delivered
D1.7	Second User Requirement Report	EUD	18	Delivered
D1.9	Second Technical requirements and user research (UX design) report.	MAC	18	Delivered
D2.6	First release of the SignON Communication Mobile Application	MAC	18	Delivered
D2.8	First Machine learning interface	FINCONS	18	Delivered
D4.1	First symbolic intermediate representation - InterL-S	KU Leuven	18	Delivered

D4.7	Second Routines for transformation of text from and to InterL	UPF	18	Delivered
D5.1	First version of virtual character	UPF	18	Delivered
D5.8	A realiser of BML-based script to 3D animated character	UPF	18	Delivered
D5.9	InterL to Text to speech pipeline	KU Leuven	18	Delivered
D4.9	First Routines for transformation of SL representations from and to the InterL	NUID UCD	22	Delivered
D3.1	Internal repository with language data resources (sign and oral)	INT	24	Delivered
D4.12	Second adaptable pipeline for training and updating the InterL.	UPV/EHU	24	Delivered
D5.5	Second Sign language-specific lexicon and structure	TU Dublin	24	Delivered in M28 as agreed with the PO
D6.3	Second Annual reports on communication and dissemination activities	DCU	24	Delivered
D7.6	Second Impact Review	DCU	24	Delivered
D9.3	Second Annual Ethical Report on Practices Towards the Stakeholder Communities	TCD	24	Delivered
D9.6	Second Annual Ethical Report on Internal Affairs	TCD	24	Delivered
D2.4	Intermediate release of the SignON Open Cloud Platform	MAC	26	Delivered
D1.10	Final Technical requirements and user research (UX design) report.	MAC	30	Delivered
D1.6	Quality Assessment Report	UPF	30	Delivered in M35 as agreed with the PO
D1.8	Final User requirements report	EUD	30	Delivered
D2.7	Final release of the Communication Mobile Application	MAC	30	Delivered in M33 as agreed with the PO
D2.9	Final Machine Learning interface	FINCONS	30	Delivered

D3.2	Sign language recognition component and models	UGent	30	Delivered
D3.4	Automatic speech recognition component and models	RU	30	Delivered
D4.4	Second distributional intermediate representation based on embeddings - InterL-E	UPV/EHU	30	Delivered
D6.5	Workshops, showcases, demonstrations report	VGTC	30	Delivered in M35 as agreed with the PO
D9.8	Report on Ethical approval	TCD	30	Delivered
D4.10	Final Routines for transformation of SL representations from and to the InterL	NUID UCD	32	Delivered
D4.2	Second symbolic intermediate representation - InterL-S	KU Leuven	32	Delivered
D4.8	Final Routines for transformation of text from and to InterL	UPF	32	Delivered
D1.11	Final Interim Community Building Report	MAC	33	Delivered
D1.2	Report on the use-cases and usage domains and stakeholders' acceptance.	KU Leuven	33	Delivered
D1.12	User generated data	UPF	36	Pending
D2.5	Final release of the SignON Open Cloud Platform	MAC	36	Pending
D3.3	Linguistic description for ISL, BSL, VGT, NGT and LSE	TU Dublin	36	Pending
D3.6	Second Natural Language processing pipeline	UPF	36	Pending
D4.5	A hybrid intermediate representation	TiU	36	Pending
D5.2	Final version of virtual character	UPF	36	Pending
D5.6	Final Sign language-specific lexicon and structure	TU Dublin	36	Pending
D6.4	Final Annual reports on communication and dissemination activities	DCU	36	Pending
D6.8	Final SignON Sustainable Exploitation, Innovation and IPR Plans	MAC	36	Pending

D7.10	Data Management Report	DCU	36	Pending
D7.4	Final Report	DCU	36	Pending
D7.7	Final Impact Review	DCU	36	Pending
D9.4	Final Annual Ethical Report on Practices Towards the Stakeholder Communities	TCD	36	Pending
D9.7	Final Annual Ethical Report on Internal Affairs	TCD	36	Pending

Table 9: Summary of SignON Deliverables

Milestone Number	**Milestone Title**	**WP**	**Lead Beneficiary**	**Due Date**	**Means of Verification**	**Status**
MS1	Project handbook	WP7	DCU	3	Project handbook with details on the overall project management procedures delivered	Reached
MS2	Sign Language Data	WP3	UGent	12	Sign language data available for initial languages (VGT, NGT, ISL, BSL)	Reached
MS3	Verbal Language Data	WP3	UGent	12	Verbal language data available for initial languages (Dutch, English)	Reached
MS4	Sign Language Recognition Component	WP3	UGent	13	Sign language recognition component is ready for training and inference	Reached
MS5	Sign Language Recognition Model for VGT/NGT and ISL/ BSL	WP3	TU Dublin	18	Sign language recognition models have been trained for VGT, NGT, ISL and BSL	Reached in M20 instead of M18 with the agreement of the PO
MS6	Automatic Speech Recognition Component	WP3	RU	13	Automatic speech recognition component is ready for training and inference	Reached

MS7	Automatic Speech Recognition Model for Dutch and English	WP3	RU	18	Automatic speech recognition models have been trained for Dutch and English	Reached
MS8	First version of pipeline to convert the recognised or input text into the InterL and from the InterL to representation suitable to be output to the user	WP4	UPV/EHU	20	First version of pipeline available and ready.	Reached
MS9	A set of routines to convert the recognised WP4 sign language into InterL.	WP4	UPF	14	First set of routines identified	Reached
MS10	A set of routines to convert encoded message from InterL to a SRSL representation	WP4	NUID UCD	14	First set of routines identified	Reached

Table 10: Summary of SignON Milestones

6. Status of the Objectives

Objective 1: Co-creation Workflow and Community

Expected outcomes	Status	
A co-creation development workflow through co-creation events - workshops, round-tables interviews, surveys	Achieved	12 co-creation activities, over all countries with a sign language covered in SignON, with exception to the UK.
A proactive user community (WP1)	Achieved	User community is informed and engaging.

Success measures	Status	
At least 75% average user satisfaction rating with the overall operation of the SignON service.	Partially achieved	Acceptable usability, but limited (60%) user satisfaction for overall operation, see D1.6
Steady increase of users involved in co-creation events	Achieved	

Objective 2: SignON Framework and Mobile Application

Expected outcomes	Status	
A service accepted and validated by its user community	Partially achieved	Acceptable usability, but limited (60%) user satisfaction for overall operation, see D1.6
A smartphone application providing the SignON service to its users, running on standard modern	Achieved	SignON SLMT V3.0 app, see D2.7

mobile devices		
The open-source SignON Framework, running on a cloud service platform	Achieved	Described in D2.5

Success measures	**Status**	
Application and Service at TRL 7 running on standard modern mobile devices without the need for additional special equipment.	Partially achieved	But TRL 6, see D6.8
Respond with user-acceptable accuracy for 75% of users.	Not achieved	Achieved translation accuracy 55%, see D1.6
The SignON Framework, Application and cloud platform, specification, implementation documentation and source code will be published free and open-source.	In progress, planned for the end of the project	Completed activities: - published specifications, architectures and documentation in public WP2 deliverables; - published public SignOn repository: https://github.com/signon-project Planned activities: - all partners review their codebases and take decisions about what shall be published; -all partners clean and upload code with the proper licensing.

Objective 3: Automated Recognition and Understanding of Signed and Spoken/Verbal Language Input

Expected outcomes	**Status**	
SLR component and models for multiple SLs	Achieved	Planned for the end of the project as with the last success measure of Objective 2
A smartphone application providing the	Achieved	A translation application and a

SignON service to its users, running on standard modern mobile devices		data-collection and processing application
The open-source SignON Framework, running on a cloud service platform	Achieved	An architecture that employs modern cloud-based solutions with dedicated servers as well as external APIs.

Success measures	**Status**	
SLR component & models for multiple SLs	Achieved	SLR models for all languages are available. Fingerspelling recognition work has been conducted but fingerspelling is not integrated in the translation application.
ASR component & models for typical & atypical speech	Achieved	Models based on different methodologies are accessible via the application for every language.
Text normalisation component	Achieved	NLP models have been developed but not integrated in the MT pipeline accessible via the application.
NLU components for the different languages	Achieved	NLP models have been developed but not integrated in the MT pipeline accessible via the application.

Objective 4: Language Independent Meaning Representation

Expected outcomes	**Status**	
InterL - a robust and reliable Language Independent Meaning Representation in vector space, symbolic and hybrid format	Achieved	Fine-tuned models for signed and spoken languages have been developed and integrated.
Tools that map from NLU to Language Independent Meaning Representation	Achieved	Recognition is linked to translation directly.

(WP4)		
Tools that map Language Independent Meaning Representation into input format for Generation modules (WP4)	Achieved	A pipeline from the InterL through AMR to the synthesis component has been developed and deployed within the application.

Success measures	**Status**	
Capability to represent full meaning in meaning transfer between languages	Achieved	Two types of models - for text and for sign; symbolic representation to bridge the data gap
Accuracy of the entire processing pipeline	Partially achieved	We did not achieve a user-acceptable translation quality. However, our results are state-of-the-art and are limited by the lack of data.
Robustness against noisy input due to inaccurate NLU	Not achieved	

Objective 5: Sign, Speech and Text Synthesis

Expected outcomes	**Status**	
3D virtual signer and a component for SL output synthesis	Achieved	A virtual signer is deployed with the mobile application.
Text synthesis component	Achieved	A simple process to decode into text
Generic TTS system for speech synthesis (WP5)	Achieved	Using either the phone TTS system or the one provided by the https://www.acapela-group.com/

Success measures	Status	
Robustness of the tools in case of wrong input	Partially achieved, in progress	The main goal for the virtual signer is to increase coverage of SLs
Language richness, expressivity and intelligibility judged by human assessor.	Not achieved	
Scalability measured as the software and hardware utilisation to synthesis requests	Partially achieved, in progress	Scalable system in terms of symbolic representation
Reusability measured as the post-deployment efforts for extending to new vocabulary, languages and use-cases	Partially achieved, in progress	Existing NGT/SiGML dataset supported, incorporating a new SL, LSF-CH/SiGML, tested

Objective 6: Wide-range of Supported Languages and Extensibility of the Framework

Expected outcomes	Status	
Support for the translation and conversion between ISL, BSL, VGT, NGT, LSE, English, Irish, Dutch and Spanish.	Partially achieved	Sign language recognition for all languages is operational. Translation from SLs to text is operational, despite the low translation quality. Sign language synthesis for NGT only is in place and accessible via the application.
Learning and tuning extensions/support of the SLR, ASR and the virtual signer synthesis.	Partially achieved for sign synthesis	Sign learning system provided, showing extension to other SLs tested
Tuning of the interlingua	Achieved	Fine-tuning pipelines have been implemented and successfully

		used to train / fine-tune the InterLingua models
Information on best practices and possible transfer to languages not involved in the project	Partially achieved for sign synthesis	Ongoing collaboration for LSF-CH in synthesis, documentation generated

Success measures	**Status**	
Translation and conversion between ISL, BSL, VGT, NGT and LSE as well as English, Irish, Dutch and Spanish spoken languages has been showcased and accepted by DHH as well as hearing users.	Partially achieved	Translations from all sign to all spoken languages is possible, but with low quality. Translation from all spoken languages to NGT is possible with low quality. The potential of the application and the SignON services has been acknowledges by the DHH communities but has not reached the expected quality for wide adoption of the service.
The SignON framework is trained automatically to support at least one additional SL and one additional spoken language.	Not achieved	

7. Conclusions

This report presents in detail the work completed during the three years of the SignON Project. It describes the work carried out across all tasks in the nine Work Packages and reports on deviations as well as corrective actions. The established and excellent intra-team collaborations and effective management resulted in 76 deliverables (50 of which are public), 54 articles, a book, 8 workshops, conferences, symposia, and other outreach events such as demonstrations and invited talks. In addition all milestones have been met.

SignON has paved the way for the advancement of SL NLP in the right direction - through inclusive collaboration, fair and open communication and rigorous research and development. This project has provided opportunities to learn from a multidisciplinary team and establish / strengthen a solid network. Many of the members of this consortium have taken actions to keep the momentum of SignON going through new collaborative or individual projects, grants and funding and it is hoped that the effects of these continued collaborations will benefit the DHH community well into the future.