D7.1 Management Report for Y1

Partner Responsible	UTH-ECE
Other Contributors	UTH-SED, AthenaRC
Document Reference	**D7.1**
Dissemination Level	Public
Version	1.0 (Final)
Due Date	January 2021 (**M12**)
Date of Preparation	January 2021

Contract No.: HFRI-FM17-2456

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Executive Summary

The SL-ReDu project aims to advance the state-of-the-art in the automatic recognition of Greek Sign Language (GSL) from videos, while focusing on the education use-case of standardized teaching of GSL as a second language. In this deliverable (D7.1) we overview the progress during the first year (Y1) of the SL-ReDu project in its various workpackages (WP1-WP7) that has led to the successful completion of the first project milestone (MS1 – M12). The deliverable will be updated in the future as D7.2 and D7.3, each summarizing the SL-ReDu activities during the second and third year of the project, respectively.

Table of Contents

1 Introduction

This deliverable (D7.1) constitutes the management report for the first year of the SL-ReDu project. It is structured as follows:

- Section 2 reports an overview of the project work in each of the seven workpackages of the Technical Annex. For each one, the presentation commences with a summary of workpackage activities, followed by a more detailed presentation of the work conducted in each task, and the future work planned immediately ahead (during the second year of the project);
- Section 3 provides a list of the produced deliverables and the accomplished milestone (MS1);
- Section 4 reports any deviations from the workplan and corresponding mitigation action; and
- Section 5 concludes the deliverable.

2 Progress in the Individual SL-ReDu Workpackages

The SL-ReDu project work is structured along seven workpackages. In the following subsections, we report the main activities and achievements in each of them during the first year of the project.

2.1 WP1 Progress in Y1 (Visual Tracking and Feature Extraction)

This workpackage concentrates on the development of computer vision algorithms for visual tracking and feature extraction, and it consists of two tasks: Task T1.1, concerning the detection and tracking of the signer's visual articulators in SL video, as well as Task T1.2, which focuses on the extraction of visual features from the tracked articulators in order to provide input to WP2. During Y1 of the project, we have worked on both tasks, reporting our efforts in **Deliverable D1.1** [1]. Additional Y1 work conducted after the submission of Deliverable D1.1 will be reported in Deliverable D1.2, during Y2.

Progress on Task T1.1: Detection and Tracking of the Visual Articulators in SL Video

We have considered two approaches for the task of signer detection and tracking in SL videos. First, a "light-weight" scheme was explored, where facial information accomplished by an efficient off-the shelf detector drove skin-tone based hand segmentation and was complemented by motion tracking to localize the signer hands. Second, the OpenPose framework was explored (see also Figure 1), which represents a more computationally demanding, deep-learning based approach. Both methodologies were evaluated on data from three isolated-sign GSL databases, which we harvested as part of WP3 activities. As reported in Deliverable D1.1, the obtained results demonstrated the second approach (OpenPose) to be more accurate.

Beyond Deliverable D1.1 that was finalized during M06 of the project, additional Y1 work on Task T1.1 involved the 3D representation of the signer skeleton (including the signer hands). This was achieved by learning to regress the OpenPose-based detected articulators from the 2D to the 3D space.

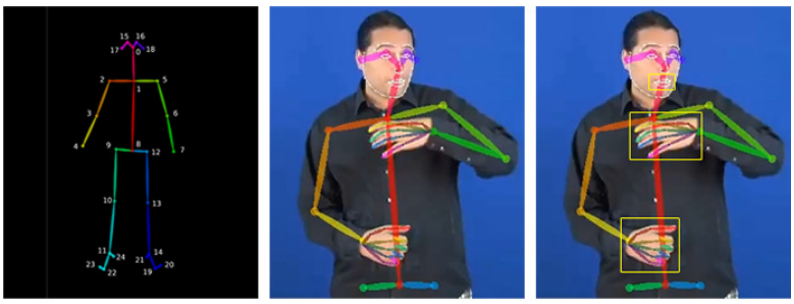

Figure 1: Visual articulator detection using the OpenPose framework.

Progress on Task T1.2: Extraction of Visual Features of Tracked Articulators

Exploiting the tracked visual articulators of the signer, we have considered a number of visual feature representations of such articulators and evaluated their GSL recognition performance. Specifically, we considered traditional appearance schemes such as principal component analysis based representations of the regions-of-interest, and more advanced feature sets such as Gabor filterbank energies, the scale-invariant feature transform, linear binary patterns, histograms of oriented gradients, and optical flow representations (see also Figure 2). Further, we pursued deep learning-based representations using convolutional neural networks (CNNs) as well as deep auto-encoders, thus providing a multitude of visual streams to be utilized in the GSL recognizer of WP2. The feature extraction approaches were evaluated on three isolated-sign GSL databases, employing a recurrent neural network classifier for sign prediction.

As reported in Deliverable D1.1, the obtained results demonstrated that the CNN based feature extractor was superior.

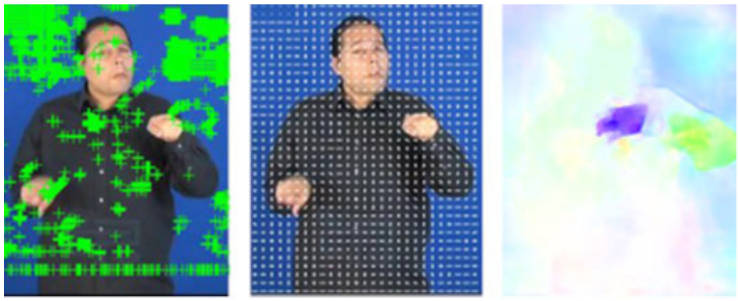

Figure 2: Various feature representations considered in Deliverable D1.1 [1].

WP1 Planned Work in Y2

During Y2 of the project, additional visual feature streams will be considered to improve the 2D-CNN based feature representation that was deemed best among the baseline features of Deliverable D1.1. Among them, various CNN architectures will be investigated for the most appropriate representation of appearance information of the various articulators, optical-flow approaches to best capture motion information, as well as methodologies to allow incorporating the signer 3D pose, such as the ExPose approach. The work will be reported in Deliverables D1.2 (Y2) and D1.3 (Y3), and will be evaluated on isolated-signing GSL data in D1.2 and on continuous-signing GSL data in D1.3.

2.2 WP2 Progress in Y1 (Machine Learning for GSL Recognition)

This workpackage concentrates on the development of machine learning algorithms for the automatic recognition of GSL, and it consists of two tasks: Task T2.1, concerning the recognition of lower-level basic signing units, as well Task T2.2, which focuses on fusing lower-lever results for the recognition of complex signs both for isolated and continuous GSL. During Y1 of the project, we have worked on both tasks, reporting our efforts in **Deliverable D2.1** [2].

Progress on Task T2.1: Articulation and GSL Subunit Recognition

For Task T2.1, we have considered the problem of recognizing hand-shapes when fingerspelling, in which case they correspond to signing units of alphabet letters. For this purpose, we have employed visual feature representations developed in Deliverable D1.1 [1] and fed them to a suitable encoder-decoder architecture for recognizing fingespelling. The developed approach allowed decoding continuous sequences of fingerspelled words.

Progress on Task T2.2: Fusion for GSL Recognition

To recognize complex signs, we, again, followed the best performing approaches of Deliverable D1.1 [1], starting with the OpenPose framework to detect the human skeleton in the 2D image plane and from it the regions-of-interest for the signer hands and mouth. Subsequently, we extracted visual features from these, employing 2D CNNs (residual networks – ResNets), as well as normalized skeleton keypoints of the signer's upper body and hands, and we combined these representations by early fusion (concatenation). We then passed the fused vectors to deep-learning based techniques suitable for spatio-temporal classification problems, focusing on attentional encoder-decoder models (see also Figure 3). Specifically, we investigated five recognition approaches within this framework, incorporating temporal convolutions,

uni-directional or bi-directional long short-term memory models (BiLSTM), gated recurrent units, and the transformer model. We evaluated the considered algorithms on three isolated-sign GSL databases, and we determined that the encoder-decoder approach with attention and temporal convolutions was the best, followed by the BiLSTM method.

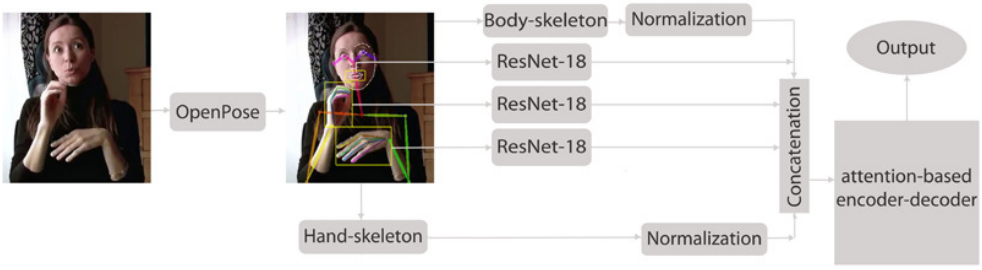

Figure 3: Overview of the GSL recognition framework developed in Deliverable D2.1 [2].

WP2 Planned Work in Y2

During Y2 of the project, additional visual feature streams and recognition approaches will be investigated in order to further improve the results reported in Deliverable D2.1. Indicatively, the connectionist temporal classification approach will be employed in conjunction with BiLSTM encoders, or in combination with the attentional encoder-decoder models already considered. Further, decision fusion methods will be considered for combining the various visual feature representations, in place of the simpler feature concatenation of D2.1. The work will be reported in Deliverables D2.2 (Y2) and D2.3 (Y3), and will be evaluated on isolated-signing GSL data in D2.2 and on continuous-signing GSL data in D2.3.

2.3 WP3 Progress in Y1 (Training Data and Language Model)

This workpackage concentrates on securing training data for the GSL machine learning algorithm (Task T3.1), organizing the language material for the project platform (Task T3.2), and developing a linguistic model (Task T3.3). During Y1 of the project, we have worked on all three tasks, reporting our efforts in **Deliverable D3.1** [3] and **Deliverable D3.2** [4] for the first two tasks, respectively, while a third deliverable (D3.3, due in early Y2) will report our progress on the third task.

Progress on Task T3.1: GSL Corpora Harvesting and Collection

To allow progress early in the project in both WP1 and WP2, we have looked for possible resources of GSL data, already available in the literature. This yielded three datasets (see Figure 4), which we used to evaluate our developed algorithms in Deliverables D1.1 [1] and D.1.2 [2]. In addition to harvesting existing corpora, we have commenced our own data collection efforts, placing a more direct focus on the education use-case of the project. For this purpose, we have determined the data content appropriate for SL-ReDu and the adopted data elicitation procedures, developed the studio setup at the AthenaRC premises (shown in Figure 5) and the recording protocol for data acquisition, designed the data post-processing pipeline, and conducted a dry run of data recording, as described in Deliverable D3.1 [3]. Unfortunately though, due to the pandemic restrictions, we have been unable to gear up the planned data collection to multiple signers, postponing such action to Y2, once conditions allow the presence of unmasked signers in the AthenaRC recording studio for long periods of time.

Figure 4: Example video frames from three publicly available datasets, harvested for use in SL-ReDu.

Figure 5: Two views of the studio setup at AthenaRC, developed for data collection in Task T3.1.

Progress on Task T3.2: Evaluation Language Material Organization

In Task 3.2 that concluded in Y2, we designed the language material for the purposes of the specific education use-case of the SL-ReDu project, taking into account the idiosyncrasy of SLs and GSL in particular, as well as the time-span and learning units allowed for a course that takes place over a single university semester, attended by true GSL beginners. We specified both content and form of such language material, with the manual sign productions in it comprising single-sign manual productions, short phrases in the form of sequences of signs, and finally sets of phrases with non-sequential contrastive morpho-syntactic features. The material has been presented in detail in Deliverable D3.2 [4].

Progress on Task T3.3: Linguistic Model for GSL Recognition

During Y1, we have initiated work on the linguistic model of the project. Our focus lies on its structure methodology and content, in order to support automatic GSL recognition, as well as the design and development of the SL-ReDu platform in respect to its functionalities that serve self-monitoring and testing activities of the end-users, in association with each module content. Such work follows on the footsteps of Deliverable D3.2, and it will be reported in upcoming Deliverable D3.3, due in early Y2.

WP3 Planned Work in Y2

During Y2 of the project, only Tasks T3.1 and T3.3 will remain active, according to the plan in the SL-ReDu Technical Annex (Task T3.2 has concluded in Y1). Specifically, concerning Task T3.1, we plan to speed-up our data collection effort, with the results reported in Deliverables D3.4 (Y2) and D3.6 (Y3). Further, for Task T3.3, we will report ongoing work in Deliverable D3.3 (due in early Y2), and

subsequently focus on statistical modeling approaches for continuous GSL that we will report in Deliverable D3.5 (Y3).

2.4 WP4 Progress in Y1 (Human-Computer Interface)

This workpackage concentrates on the design of an appropriate human-computer interface for the SL-ReDu prototype system (Task T4.1), employing a suitable dialog-management strategy to accommodate both self-monitoring and objective evaluation system modules (Task T4.2). During Y1 of the project, we have initiated work on both tasks, which will be reported in Deliverable D4.1 that is due in Y2 (M16).

Progress on Task T4.1: Human-Computer Interface Design

During Y1, work has been initiated in the design of the human-computer interface design, in accordance with the educational material developed as part of Task T3.2 that has been reported in Deliverable D3.2 [4]. Specifically, mockups of the SL-ReDu platform interface have been developed to accommodate both "passive"-type questions (multiple-choice) and "active"-type drills (GSL production) in both self-monitoring and objective evaluation modules of the system (see also Figure 6), while also allowing navigating of all educational material for its better comprehension by the learner. This design work has progressed well, and it will lead to the finalization of the human-computer interface for the first version of the SL-ReDu system that will be reported in Deliverable D4.1 in the early part of Y2.

Figure 6: Mockups of the human-computer interface of the SL-ReDu platform, designed to accommodate multiple-choice single-answer questions (**left**) and GSL production drills (**right**) for both its self-monitoring and objective evaluation modules.

Progress on Task T4.2: Dialog Management Component

Various aspects of the dialog management component between the user (learner or instructor) and the SL-ReDu system have been designed, taking into consideration the nature of the specific educational material for each type of question / drill (passive vs. active) and operation mode of the platform (self-monitoring vs. objective evaluation). For example, several options for displaying educational material have been considered (text, icons, images, signing avatar videos, or pre-recorded signing videos) in accordance with Deliverable D3.2 [4], and preparation of the corresponding files has commenced.

WP4 Planned Work in Y2

The initiated work of Y1 on WP4 will continue during Y2 of the project, culminating in Deliverable D4.1 (due in M16). In addition, during the second half of the year, preliminary work will be conducted on enhancing the designed human-computer interface, progressing towards the completion of its second version (Y3).

2.5 WP5 Progress in Y1 (System Implementation and Evaluation)

This workpackage aims at the system implementation based on an appropriately defined architecture (Task 5.1), as well as at the system evaluation for the education use-case (Task 5.2). During Y1 of the project, we have worked on both tasks, reporting our efforts in **Deliverable D5.1** [5] concerning the second task, while preparing an additional deliverable (D5.2) that will report our work on the first task at the very beginning of Y2 (M13).

Progress on Task T5.1: System Architecture Definition and System Implementation

We have progressed significantly in defining the SL-ReDu system architecture, and we will report the respective work very soon, in Deliverable D5.2 that is due in M13 of the project. Specifically, we have defined the functional requirements of the platform that the architecture should meet, and we have converged on a solution that adopts a hybrid architecture, employing a server-hosted web-based application that communicates appropriately with the learner-side device where the GSL recognizer will be run. A schematic is shown in Figure 7.

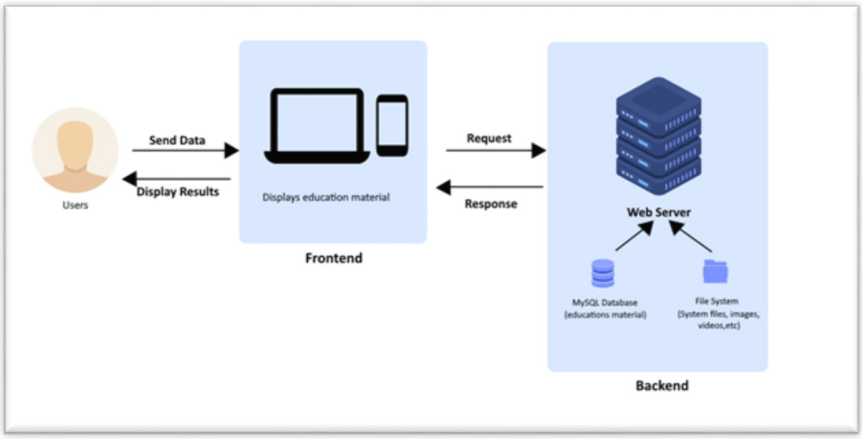

Figure 7: Schematic of the planned web-application based SL-ReDu architecture.

Progress on Task T5.2: System Evaluation

During Y1 of the project, we have concentrated on defining the procedures that will be followed in the evaluation of the SL-ReDu prototype system. These concern the recruitment strategy of the evaluation participants, the protocol that will be followed in the evaluation, as well as the subjective and objective data that will be collected to judge the success of the SL-ReDu approach, in accordance with the evaluation content of Deliverable D3.2 [4]. The work has been reported in Deliverable D5.1 [5].

WP5 Planned Work in Y2

During Y2 of the project, our work will concentrate on both of the WP5 tasks. In particular, in Task T5.1, we will be implementing the first version of the SL-ReDu prototype system, following the architecture that we have been finalizing and be very soon reporting in Deliverable D5.2. We will present the implemented system in Deliverable D5.3. In addition, concerning Task T5.2, we will be conducting a small-scale evaluation (Phase A) of the system with end-users, following the processes outlined in Deliverable D5.1 [5]. The results of this evaluation will be reported in Deliverable D5.4.

2.6 WP6 Progress in Y1 (Dissemination and Exploitation)

This workpackage consists of two tasks: Task T6.1 concerning project publicity and dissemination, as well as Task T6.2 that focuses on exploitation activities of the project results. During Y1 of the project, we have focused exclusively on Task T6.1, since exploitation activities are expected to commence later in the project. We have reported the project publicity and dissemination activities of Y1 in **Deliverable D6.1** [6].

Figure 8: The English version of the SL-ReDu home page.

Progress on Task T6.1: Project Publicity and Dissemination

In more detail, during Y1 of the project, the following dissemination activities have taken place:

- A logo has been designed for the project.
- The project website has been set up (https://sl-redu.e-ce.uth.gr) – see also Figure 8.
- Five scientific publications of SL-ReDu work have been published in the proceedings of well-established international conference with stringent review procedures
- Five presentations of project work have been given at international conferences (corresponding to the above papers).
- A brochure and a poster have been produced, describing the project.
- Student education activities have taken place on the project topics, with one Ph.D. Thesis currently ongoing, one Diploma Thesis successfully defended, and two more Diploma Thesis in progress (expected defense in June/July 2021).
- In additional dissemination activities, the project appears at the website of the host institution (UTH-ECE) under the department active research projects (in both Greek and English), while the project has provided dissemination information to H.F.R.I. in November 2020 (in both Greek and English) using the PowerPoint presentation format provided by the funding agency.

The five project publications during Y1 are the following:

- K. Papadimitriou and G. Potamianos, "Multimodal sign language recognition via temporal deformable convolutional sequence learning," in *Proceedings of the Annual Conference of the International Speech Communication Association (Interspeech)*, pp. 2752–2756, 2020 (DOI: 10.21437/Interspeech.2020-2691).
- K. Papadimitriou and G. Potamianos, "A fully convolutional sequence learning approach for cued speech recognition from videos," in *Proceedings of European Conference on Signal Processing (EUSIPCO)*, pp. 326–330, 2020 (DOI: 10.23919/Eusipco47968.2020.9287365).
- M. Parelli, K. Papadimitriou, G. Potamianos, G. Pavlakos, and P. Maragos, "Exploiting 3D hand pose estimation in deep learning-based sign language recognition from RGB videos," *Computer Vision – ECCV 2020 Workshops Proceedings, Part II*, A. Bartoli and A. Fusiello (Eds.), pp. 249–263, LNCS/LNIP vol. 12536, 2020 (DOI: 10.1007/978-3-030-66096-3_18).
- V. Tassopoulou, G. Retsinas, and P. Maragos, "Enhancing handwritten text recognition with N-gram sequence decomposition and multitask learning," in *Proceedings Int. Conference on Pattern Recognition (ICPR)*, pp. 10555–10560, 2020 (DOI: 10.1109/ICPR48806.2021.9412351).
- G. Potamianos, K. Papadimitriou, E. Efthimiou, S.-E. Fotinea, G. Sapountzaki, and P. Maragos, "SL-ReDu: Greek sign language recognition for educational applications. Project description and early results," in *Proceedings of the ACM International Conference on PErvarsive Technologies Related to Assistive Environments (PETRA)*, 2020 (DOI: 10.1145/3389189.3398006).

WP6 Planned Work in Y2

During Y2 of the project, publicity and dissemination activities will continue with additional publications, as well as participation in a series of events that attract heavy interest by the general public, project stakeholders, and policy makers. These actions will be reported in Deliverable D6.2. Further, initial work will commence on an exploitation plan that will be reported in Deliverable D6.3, as envisaged in the SL-ReDu Technical Annex.

2.7 WP7 Progress in Y1 (Project Management)

This workpackage focuses on management activities of the project. These involve: (a) the communication between the project PI and the Special Account for Research Grants at the host institution (University of Thessaly), as well as the use of the software platform of the latter for entering project requests; (b) the communication between the project PI and the funding agency; (c) the coordination of the project team; and (d) the review of all project deliverables.

In particular, it should be noted that the project members have been holding frequent Skype calls, typically once every week or two weeks, depending on the project workload and time period. Further, a project kick-off meeting has been held at the very beginning of the project, on January 24, 2020 (M01) at the AthenaRC premises in Maroussi. Of course, in addition to the above, individual project partner teams have been meeting regularly at their premises in Volos and Athens.

The workpackage activities also include the compilation of this deliverable (**Deliverable D7.1**).

3 Achieved Deliverables and Milestones in Y1

A list of the project deliverables that have been prepared according to the project Technical Annex are listed in Table 1. Brief overviews of the work reported in these documents has been provided in the previous section (within the corresponding workpackage or task descriptions of Y1 work).

In addition, the first of the three milestones (**Milestone MS1**) has been achieved on schedule (M12). The particular milestone is titled:

- **MS1:** Basic Version of Resources and Components for System Implementation.

MS1 primarily involves workpackages WP1, WP2, and WP3, and it is verified by means of Deliverables D1.1 [1], D2.1 [2], and D3.1 [3], all produced on time (M12).

Num	*Deliverable Title*	*WP*	*Level*	*Type*	*Due*	*Ready*	*Lead*
D1.1	First version of visual tracking and feature extraction components	**1**	**PU**	**R**	**M06**	**M06**	UTH-ECE
D2.1	First version of GSL recognizer	**2**	**PU**	**R**	**M12**	**M12**	UTH-ECE
D3.1	First version of data resources	**3**	**RE**	**R**	**M12**	**M12**	AthenaRC
D3.2	Evaluation language material organization	**3**	**RE**	**R**	**M12**	**M12**	UTH-SED
D5.1	Definition of evaluation procedure	**5**	**PU**	**R**	**M12**	**M12**	UTH-SED
D6.1	Publicity and dissemination report for Y1, incl. project website	**6**	**PU**	**R/O**	**M12**	**M12**	UTH-ECE
D7.1	Management report for Y1	**7**	**PU**	**R**	**M12**	**M12**	UTH-ECE

Table 1: Project deliverables planned and completed during Y1 of the SL-ReDu project, specifying corresponding workpackage, dissemination level (PU: public, RE: restricted), type (R: report, O: other (e.g., project website)), planned and actual delivery date, and lead partner responsible.

During the second year of the project, a number of additional deliverables will be produced as indicated in Table 2. Further, the second project milestone is due to be reached, namely:

- **MS2:** Phase-A System Implementation and Evaluation (due in M20).

Num	*Deliverable Title*	*WP*	*Level*	*Type*	*Due*	*Lead*
D1.2	Intermediate version of visual tracking and feature extraction components	**1**	**RE**	**R**	**M16**	UTH-ECE
D2.2	Intermediate version of GSL recognizer	**2**	**RE**	**R**	**M18**	UTH-ECE
D3.3	First version of linguistic model	**3**	**RE**	**R**	**M16**	AthenaRC
D3.4	Second version of data resources	**3**	**RE**	**R**	**M24**	AthenaRC
D4.1	First version of human-computer interface	**4**	**PU**	**R**	**M16**	AthenaRC
D5.2	Technical specifications and system architecture definition	**5**	**PU**	**R**	**M13**	UTH-ECE
D5.3	First version on system implementation	**5**	**RE**	**P**	**M19**	AthenaRC
D5.4	Evaluation of first system version	**5**	**RE**	**R**	**M20**	UTH-SED
D6.2	Publicity and dissemination report for Y2	**6**	**PU**	**R**	**M24**	UTH-ECE
D6.3	First version of exploitation plan	**6**	**PU**	**R**	**M24**	AthenaRC
D7.2	Management report for Y2	**7**	**PU**	**R**	**M24**	UTH-ECE

Table 2: Future project deliverables planned during Y2 of the SL-ReDu project, specifying corresponding workpackage, dissemination level (PU: public, RE: restricted), type (R: report, P: prototype), planned delivery date, and lead partner responsible.

4 Deviations from Workplan during Y1 and Mitigation

Overall, the SL-ReDu work has been progressing according to the project Technical Annex and the conceived implementation plan, as also evidenced by the prepared deliverables (listed in Table 1) and the timely accomplishment of Milestone MS1.

The only difficulty that the project has faced so far is that, due to the pandemic restrictions, we have been unable to gear up our planned GSL data collection to multiple signers, as already mentioned in Section 2.3. We have chosen to postpone such action to Y2, once conditions allow the presence of unmasked signers in the AthenaRC recording studio for long periods of time. We have mitigated this problem with the use of already available GSL datasets, that we have harvested from existing data collections, as reported in Deliverable D3.1 [3], thus allowing us to achieve MS1. In the likely event of continued pandemic pressure and extended mobility constraints during the first half of Y2, we may request a four-month project extension to allow data collection during the second half of Y2, resulting to a corresponding time-shift of the due date of the remaining project deliverables and milestones. Such action may be taken around July 2021.

5 Conclusions

This deliverable has presented an overview of the SL-ReDu project activities and progress during its first year. Two additional management deliverables will be produced concerning the second and third year of the project.

References

[1] K. Papadimitriou, G. Potamianos, E. Efthimiou, S.-E. Fotinea, and P. Maragos, "D1.1: First version of visual tracking and feature extraction components," *Tech. Report, SL-ReDu Project Deliverable*, Volos, Greece, 2020.

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[5] G. Sapountzaki, E. Efthimiou, and S.-E. Fotinea, "D5.1: Definition of evaluation procedure." *Tech. Report, SL-ReDu Project Deliverable*, Volos, Greece, 2021.

[6] G. Potamianos, K. Papadimitriou, E. Efthimiou, S.-E. Fotinea, P. Maragos, and G. Sapountzaki, "D6.1: Publicity and dissemination report for Y1, including project website," *Tech. Report, SL-ReDu Project Deliverable*, Volos, Greece, 2021.