D1.2 SECOND YEAR PROGRESS REPORT

Sten Ternström

Dept of Speech, Music & Hearing
School of Computer Science and Communication,
KTH Royal Institute of Technology
SE-100 44 Stockholm, Sweden
e-mail: stern@kth.se

Oriol Guasch

GTM-Grup de recerca en Tecnologies Mèdia, La Salle,
Universitat Ramon Llull, C/Quatre Camins 2,
Barcelona 08022, Catalonia, Spain
e-mail: oguasch@salleurl.edu

This document summarises the status of the EUNISON project at Milestone 2, month 24, as represented at the second project annual meeting at GIPSA-Lab in Grenoble (participant CNRS) that was held on March 10-11, 2015.

Version	V2
Date	25/11/2015
WP number	1
WP leader	Sten Ternström
WP leader email	stern@kth.se

Contents

1. Introduction

This deliverable documents the project status at month 24, and in section 4 outlines the plans for the third year.

2. Exchange visits and project meetings

Exchange visits and project meetings conducted in year 2 were as follows.

2.1 LaSalle to KTH

November 2013 to May 2014. The six-month visit of doctoral student Marc Arnela was completed, after an important and productive period of exchange.

2.2 LaSalle to GIPSA-Lab

Grenoble, 10 April 2014; topics discussed included (1) finishing measurements vs simulations for static vowels; (2) effects of geometrical simplifications; and (3) dynamic vocal tracts. Minutes are available separately.

2.3 GIPSA-Lab to FAU

All WP6 researchers visited WP3 in Erlangen on 10-12 June 2014. The main topic was to define a common strategy in order to perform the coupling of the vocal tract replicas developed at Gipsa-lab with the artificial vocal folds developed at FAU. Minutes are available separately. Rémi Blandin visited there again on 8-18 February 2015.

2.4 FAU to GIPSA-Lab

During a two-week stay on 13-25 October 2014, the FAU and GIPSA-Lab members met at GIPSA-Lab in order to intensify their collaboration. In preparation for this, a PIV-optimized vocal tract geometry was de-signed and 3D-printed. This geometry was acoustically configured to generate the vowel <a> during phonation. Additionally, optical access was integrated for later optical measurements, especially Particle Image Velocimetry (PIV). During the stay, this new geometry was characterized and integrated with the vocal fold replica of the FAU. The characterization measurements included the determination of acoustic transfer paths within the vocal tract as well as first experiments on the geometry with vocal fold replicas. At the end of the stay, a lecture by Stefan Becker about voice research in Erlangen and a subsequent discussion was held.

2.5 Meeting on the unification strategy

Barcelona (CIMNE), 16 October 2014. In anticipation of the Year 3 task of “grand unification”, a major technical meeting was held, with representatives from the concerned work packages 2, 4, 5, 6 and 7. The scope of the problem was described and three main approaches were considered. Difficulties repeatedly encountered with anomalies arising in moving meshes were discussed. A road map and a set of five test cases were defined. The minutes of this meeting are available in document IR3.300.

2.6 CIMNE to KTH

Héctor Espinoza from CIMNE, made a doctoral stay at KTH from November 1st 2014 to January 31st 2015. (He later defended his PhD on May 8th, 2015, under the supervision on Prof. Ramon Codina.) The objective was to experiment with the implementation of the formulation for wave problems developed at CIMNE in the FEniCS code developed at KTH.

The FEniCS Project is a collection of free software with an extensive list of features for automated, efficient solution of differential equations. The idea is to use FEniCS for the unification part of the EUNISON project. FEniCS-HPC is a C++ only FEniCS version optimized for high performance.

Dr. Espinoza focused on the implementation of the mixed wave equation and domain coupling strategy in FEniCS, but there are some additional requirements such as: Arbitrary Lagrangian-Eulerian formulations (ALE), time-explicit formulations, incompressible Navier-Stokes solver and compressible Navier-Stokes solver. FEniCS developers were contacted about these features and obtained the following answers: 1) FEniCS supports ALE formulations. In this context it has two types of mesh smoothing: one is a Poisson mesh smoother and the other is an inverse mapping method. 2) FEniCS supports time-explicit formulations. It requires just a linear form defined in UFL. About the diagonal mass matrix it is possible to access each element of the matrix to do element-wise operations. 3) FEniCS has an incompressible Navier-Stokes solver with ALE. It is based on a stabilized FE method using first order interpolation for velocity and pressure. 4) FEniCS has a compressible Naver-Stokes solver. It is based on a stabilized FE method. The algorithm is time-explicit and uses Runge-Kutta as time marching scheme. It does not have ALE but it can be added.

The FEniCS finite element collection was examined and Dr. Espinoza learnt how to use it to solve differential equations using stabilized finite element methods. The wave equation in mixed form was implemented in FEniCS including hard wall, soft wall, impedance and non-reflecting boundary conditions. A domain coupling strategy intended to transfer information from a Fluid-Structure interaction solver to a wave propagation solver was developed within FEniCS using a domain interface mesh. Additional developing and testing is needed in the coupling strategy to ensure it is working properly in parallel. In summary, FEniCS is capable of handling some extra requirements of the EUNISON project such as ALE, time-explicit formulations and compressible/imcompressible Navier-Stokes solvers.

2.7 Annual project meeting in Grenoble

The second annual project meeting of the EUNISON project was held at the GIPSA-Lab of partner CNRS in Grenoble, on 10-11 March 2015. All WP leaders and most of the project's researchers were present for the duration of the meeting. Additionally, Dr. Ian Stavness of the University of Saskatchewan attended as an observer, for the ArtiSynth consortium.

Schedule

	Tuesday March 10th	**Wednesday March 11th**
9h20	Welcome	WP7
10h00	Coffee break	Coffee break
10h40	WP1 status	ArtiSynth presentation / Visit to Gipsa-lab
11h20	WP8	
12h00	Lunch	Lunch
13h20	WP2	Scientific discussion "Unification: from muscle activation to emitted voice"
14h00	WP5	Workgroups : PEVOC, remoting, replicas
14h40	WP4	
15h20	WP3	Concluding remarks, Adjourn
16h00	Coffee break	Coffee break
16h30	WP6	
16h50	Scientific Presentation	
17h30	Summing up; Wednesday agenda	
20h00	Dinner in Grenoble	

EUNISON is supported by the Future and Emerging Technologies (FET) programme within the ICT theme of the Seventh Framework Programme for Research of the European Commission

3. Project status

We list here activities performed and goals achieved during months 13-24, per Work Package.

3.1 WP1

3.1.1 General

In addition to the activities as regulated by the Consortium and Grant Agreements, the Management activities in year 2 have concerned the creation of a formal Memorandum of Understanding between the Eunison consortium and the ArtiSynth consortium at the University of British Columbia in Canada. The memorandum was finally done in September 2014.

WP1 started the preparations for a EUNISON workshop/summer school in conjunction with the international voice conferences at the end of the summer of 2015 (Interspeech and/or PEVOC-Maveba). After multiple contacts with the organisers of these conferences, it was decided that EUNISON would locate the thrust of its outreach to the PEVOC+Maveba voice conferences in Florence, Italy, September 2015.

EC funds for Reporting Period 1 were promptly distributed to the partners.

3.1.2 Technical Board meetings

In the period of months 13-24, the EUNISON Technical Board convened by videoconference for its meetings #5 (May 2014), #6 (July 2014) and #7 (November 2014). Minutes of these meetings are in the Box repository. There has also been a major technical meeting of researchers in Barcelona, see Section 2.4.

3.1.3 Executive Board meetings

In project year 2 there have been no issues of governance that could not be dealt with during the Technical Board meetings, and therefore the project's Executive Board (which is a subset of the TB) has not found it necessary to convene separately.

3.2 WP2 Simulation of phonation

Tasks 2.1 (vocal fold model) and 2.2 (contact model) have been completed. The contact algorithm has been further refined. This work has been reported in deliverables D2.1, D2.2 and D2.3, as well as in the associated journal publications.

WP2 has demonstrated dynamic deformation of dense DOLFIN/Unicorn computational volume meshes as controlled by sequences of sparse boundary surfaces meshes from WP7 (ArtiSynth). This means that a one-way control interface from the ArtiSynth domain to the DOLFIN/Unicorn Domain is established. The next step will be to demonstrate self-oscillation of a vocal folds model that is thus controlled.

3.3 WP3 Phonation in replicas

Tasks T3.2 and T3.3 have been completed, as stated in D3.2 and D3.3. Additionally, the work in T3.4 has been started.

Since the phonation process of human vocal folds can be described as a fluid-structure-acoustic interaction, the structural movement of the applied artificial vocal folds and the arising flow field play a significant role. Therefore, we examined the oscillatory behaviour via laser vibrometry, high-speed camera recordings and a hemilarynx experiment. Additionally, we determined the inflow profile using our phase-triggered PIV technique for the results as presented in D3.2.

In general, two oscillation modes could be detected for every vocal fold model that was examined. In a first oscillation mode, the vocal folds oscillate with no contact of the tips of the vocal folds. By applying a slightly larger mass flow, oscillation mode two is generated, where the tips contact during each oscillation cycle. Thus, the glottis is periodically closed in this oscillation mode. The extended inflow boundary revealed a constant flat top inflow profile with a phase angle dependent flow velocity.

As part of T3.3, different configurations of the supraglottal flow boundary conditions as well as the oscillation type of the vocal folds have been investigated to determine its influence on the acoustic outcome.

The acoustic measurements showed strong dependency of the acoustic outcome on the supraglottal channel geometry as well as the oscillation type. When including a smaller supraglottal channel, higher harmonics were more intense and a broadband increase in the spectra was found. Additionally, more intense higher harmonics were found for contacting vocal folds, when compared to non-contacting ones. Subharmonic tonal components within the spectra were found for the configurations including a supraglottal channel. They were assigned to cycle-to cycle variations of the flow field and are typical for diplophonia.

Additionally, the acoustic sources have been determined for the configurations presented in D3.1. Based on the phase-averaged measurement data, the main acoustic source was found right at the glottis for the basic oscillation frequency. This source was one order of magnitude more intense than the sources found within the glottal jet. This accounts for all investigated configurations.

For the task T3.4, the collaboration with GIPSA lab has been intensified. Several vocal tract shapes have been designed to be 3D-printed and incorporated into the existing experimental setup with the vocal fold model. First experiments have been conducted during a two-week stay of the FAU members at GIPSA-lab. There, a PIV-compatible vocal tract geometry has been 3D-printed and characterized by transfer functions.

3.4 WP4 Compressible solver and grand unification

The remaining deliverables of WP4 are not due until the third year; therefore, a detailed itemized account of progress during year 2 is given below. Leading up to the WP4 deliverables, work during the second year has included the following.

3.4.1 Waves

- Full Fourier analysis of the one-dimensional wave equation in mixed form to determine stability and accuracy from a practical point of view. Space discrete, time discrete and fully discrete versions of the problem are being considered.
- Separation of the boundary and volume sound source terms in the wave equation coupled with the incompressible Navier-Stokes equations, using acoustic analogies.
- BDF2 and implicit Newmark integrator for the wave equation.
- Implementation of the Sommerfeld boundary condition for these integration schemes
- Started realistic 3D analyses (real head geometry).

3.4.2 Vocal tract, incompressible flow with acoustic analogies

- Implementation of ALE formulations for incompressible flows including now acoustic analogies. These analogies were implemented in the spring of 2014.
- Development of mesh transfer algorithms to be used in case finite element meshes get too distorted in the ALE scheme and full remeshing is required.
- Acoustic pressure decomposition. The diffracted wave plus the incident one equals the acoustic pressure of the original problem.
- Finite element disconnection for acoustics and Navier-Stokes equations. Selection of surfaces and volumes where the equations must not be solved.
- Definition of geometries for test cases

3.4.3 Compressible flow solver

- Further development of the compressible flow solver, with some improvements in robustness. In particular, discontinuity-capturing techniques are being implemented. Tests to check accuracy and convergence order are being conducted.
- Development of a Variational Multiscale (VMS) formulation of the compressible Navier-Stokes equations in conservative form.
- Validation of the compressible solver, numerical examples (including the implementation of discontinuity capturing methods).
- Validation of the parallel implementation of the compressible solver.
- Convergence estimation for the time integration scheme
- Five benchmark cases for the compressible formulation
- Implementation of high order FEM for the stabilized compressible formulation.
- Started an example to try to model a fricative (agreed in the first grand unification meeting)

3.4.4 Other

- Numerical cases in 2d with semi-realistic geometries, waiting for 3d geometries to be available.
- Transfer of information between meshes
- Parallel scalability test up to 208 processors
- Installed the code in MareNostrum (profiling for running with a large number of processors)
- Started the implementation of parallel adaptive refinement strategy (hierarchichal mesh refinement)
- Obtained access to the KTH cluster for starting the Grand Unification
- Hosting the first grand unification meeting

3.5 WP5 Simulations of the vocal tract

The main activity of WP5 in year 2 of the Eunison project has focused on developing and implementing a finite element (FEM) strategy for the numerical simulation of acoustic waves propagating in a general domain with moving boundaries. This will allow dealing with the production of vowels taking into account flexible walls for the vocal tract, and more significantly, it will allow generating diphthongs. The main outcome of the work has been a stabilized FEM formulation for the wave equation in mixed form with convection, which permits using the same interpolation fields for the acoustic pressure and the acoustic particle velocity. The mixed convected wave equation has been set in an arbitrary Lagrangian-Eulerian (ALE) frame of reference to account for moving vocal tract (VT) walls. The movement of the VT consists of two components, an external prescribed motion and a motion related to the VT wall elastic back reaction to the inner acoustic pressure, in the normal direction. A mass-damper-stiffness auxiliary equation is solved for each boundary node to include this effect. 3D examples have been presented consisting of vowel and diphthong generation. Simple geometries with radial symmetry and zero pressure release boundary conditions at the mouth exit have been used for the moment. Future work will involve more realistic geometries driven by muscle activation and will include outward wave radiation from the mouth.

In addition to the former, a strategy for the generation of diphthongs using tuned 2D vocal tracts that present the same acoustic behavior than 3D simulations has been also developed. Pending work on vowel generation involving comparison with experiments, the effects of lips and the effects of various VT simplifications have been also pursued.

3.6 WP6 Articulation in replicas

The data from a static replica of the fricative /s/ which has been extensively studied experimentally (Fujiso et al. 2015) has been provided to WP4 for comparison with FEM simulations.

The major technical challenge of Task 6.3 was to design, build and control an experimental mechanical set-up able to reproduce articulated sounds. This task was achieved using a flexible silicon tube whose shape can be changed by compressing the tube with rigid bars motioned by step motors. Using two pairs of bars, one can therefore generate a large amount of geometrical configurations. The motion of each bar and the position along the tube length can be varied dynamically and independently so that even eccentric constrictions can be created. In particular, the set-up allows for fricative-like configurations where a jet is generated by a first constriction and encounters the obstacle formed by a second constriction. In addition, this experimental setup is not limited to fricative generation, but can also be used to study vowel articulation. It also allows comparison of experimental measurements with FEM simulations performed by WP5 for the generation of diphthongs.

To be able to compare experiments with the numerical simulations of WP4, a description of the geometry of the tube is necessary. To achieve this, a theoretical approximation of the shape of the tube laterally compressed by two bars has been elaborated and validated experimentally (Van Hir-tum 2015).

The mechanical coupling with this deformable vocal tract replica and the vocal folds replica developed in WP3 has been successfully achieved thanks to the visits of Alexander Lodermeyer at Gipsa-lab and Rémi Blandin at FAU. The results obtained on this unified mechanical replica will be presented in an international conference (PEVOC) and a demo video has been realised.

3.7 WP7 Control architecture

At the request of the project reviewers after Review #1, revised deliverables for WP7 and supplementary documents were submitted to the EC on 31 August, 2014, and subsequently approved (notification of approval received on 31 Oct, 2014).

In year 2, work in WP7 ran along four main threads:

- Generating tongue positions from EMA data (Dabbaghchian, Engwall). This is done by applying EMA data points to an inverse solver for muscle activations. EMA data are available from earlier work, but only for the tongue midline, which for some vowels is recessed; also the biomechanical models and the EMA data originate from different individuals and need to be reconciled.
- Deriving vocal tract airway models from biomechanical models (Widing, Dabbaghchian, Ekeberg). Here the main challenge remained that of finding general and automated ways of laying intermediate meshes, such that they can be deformed sufficiently to model the movements of the voice organ, in sufficient detail, without causing problems of numerical stability. There is currently a simplifying approach of creating a smooth airway mesh from cross-sections, but it would not be able to model multiple cavities that frequently occur in the vocal tract.
- Studying how to adapt ArtiSynth models of laryngeal mechanics for the purposes of EUNISON (Selamtzis). This includes paring down existing models to include only components that are needed for posturing the vocal folds and the adjacent airway walls. A first instance of a moving laryngeal mesh has been provided to WP2 (D2.3).
- Devising ways of interfacing ArtiSynth output and/or code to the DOLFIN/Unicorn FEM-solvers (Widing, Wensby, Selamtzis); by exporting static meshes, dynamic mesh sequences, or representations of model components.

3.8 WP8 Dissemination, Collaboration and Exploitation

3.8.1 Eunison website

- 18 news (about e.g. technical board meetings, presentations on conferences, etc.) and 12 events (also in the calendar) have been generated.
- Publications (journals and conferences) have been updated and links to the webpages where they can be downloaded have been included. All deliverables from the first year are now available in the webpage.

- 3 new videos are available. One from WP7 (tongue EMA) and two from WP8 (Eunison general presentation, and interview for the Barcelona city council).
- New links have been included (2014 world voice day, SkAT-VG, CIMNE press release, new section outreach).

On Twitter, 144 tweets have been written (22 conversations with @FET_eu), there are 44 followers and 66 following. EUNISON has participated in #FETINNOV, where it was discussed how FET projects can move to applications in the market.

3.8.2 Task 8.2 Publications

- 2nd year: 9 conference papers, 10 journal papers plus 5 journal papers submitted. One PhD thesis completed.
- A seminar on voice production using FEM was given by Oriol Guasch at GIPSA-lab.
- EUNISON has been presented during the annual meeting of the Spanish RTSDA network.

3.8.3 Task 8.3 EUNISON with other projects

- As planned, there has been increasingly close collaboration between the Canadian Artisynth consortium and especially WP7 (see also section 3.1.1). WP7 has discussed technical issues with the Artisynth architects on a regular basis, and also participated by teleconference at some of the biweekly research liaison meetings internal to the Artisynth team. This collaboration with the ArtiSynth consortium has resulted also in a doctoral student position at the University of Saskatchewan for Erik Widing, KTH, from the autumn of 2015. WP7 has benefitted from cooperation also with Dr Scott Moisik at the Max Planck Institute of Psycholinguistics in Nijmegen, NL. Although Dr Moisik is not officially part of the Artisynth team, he is developing what is currently the most advanced model of laryngeal mechanics, in Artisynth, and is generously sharing this with Eunison so that models that we derive from his model ultimately can be made to produce sound.

- SkAT-VG (FET-Open 618067): our Project Coordinator Sten Ternström is also the KTH site representative for SkAT-VG. The main goals of Skat-VG project are to create an audio sketching tool and support system for sound designers, and KTH is responsible for its phonetic component. In this sense, SkAT-VG is closely related to WP7. If the EUNISON project's models were already very complete, and fast, they would be a very interesting tool also for the SkAT-VG project. However, the relative timing of the two projects is less than optimal. The main benefit of cooperation has been exchange of phonetic and anatomical expertise, which is still useful.

3.8.4 General outreach

The issue of how best to organise an open workshop and/or summer school somewhere in the period month 26-30 was discussed at intervals during the autumn and spring. The next FET conference is still not announced. Interspeech, PEVOC/MAVEBA and the ICT 2015 in Lisbon 20-22 October 2015 were investigated as alternatives.

3.9 Summary of the project status as a whole

Summary of the project status as a whole

Good progress has been made on most fronts concerning the development of individual foreground contributions to the envisioned simulation framework. At M24/MS2, the prospect of achieving complete dynamic simulations using incompressible flows and acoustic analogies seems to be well within reach, and probably also some basic trials using the compressible solver. Dynamic replicas that are well described mathematically will also be achieved. The project has made interesting and significant advances in fluid-structure simulation techniques, and in the construct ion and measurement of experimental replicas. These advances include the simulation of moving domains to generate diphthongs and vocal folds oscillations, a novel technique for handling the contact problem in 3D, innovations in static and dynamic mechanical replicas, the design of new numerical strategies to distinguish direct and diffracted pressure fields in aeroacoustics, as well as to stabilize the underlying governing equations, and improved strategies for handling systems with hard and soft solids combined with fluids, among many other issues. The project achievements to date have been reflected in a considerable number of scientific publications both in highly reputed scientific journals and at congresses.

The ultimate goal of a complete, unified-domain simulation system, which would also be remotely controllable by non-experts, may yet prove to be too ambitious, in terms of computational loads and of logistic complexities. At this stage, though, the theoretical accuracy and basic science aspects are more important. Apart from the sheer volume of computations required by a complete model, the main challenge remaining at M24 is that of integrating the component systems into a workflow that can produce acoustic output all the way from virtual biomechanical inputs, i.e., from prescribed “muscle activations.” We have met with several practical difficulties in translating static and dynamic 3D models from the biomechanical, non-acoustic domain into mesh representations that can meet a number of topological constraints imposed by the aerodynamic and acoustic modeling techniques. The difficulties stem essentially from three circumstances: (a) the vocal tract airway ‘object’ in the aerodynamic FEM simulations is a ‘non-object’ in the biomechanical domain, defined only as any space(s) *not* occupied by solid structures; (b) that, as meshes are made to move, contacts, intersections and narrow angles inevitably appear that threaten the stability of the FEM solutions; and (c) that developing the control architecture has been a steep learning process: researchers with expertise mainly in voice have needed new skills in tools and techniques that interface to three very different computational domains.

4. Plans for year 3

4.1 Outreach

It was decided in Grenoble that the main thrust of EUNISON outreach will be arranged in connection with the bi-annual Pan-European Voice Conference and MAVEBA workshop in Florence, Italy, September 2015. The WP8 and WP1 leaders are in charge of the practical arrangements.

4.2 Unification strategy

Based on the discussions held at Grenoble, the Scientific Coordinator issued the following strategy for goals in year three.

> Remark 1: The tasks [listed below] are critical for the project success. All task deadlines end before December 2015. It is expected that in the remaining months until the end of the project some additional simulations could be performed. These will depend on the results reached so far. In particular simulations to compare with MR could be performed at that time.
>
> Remark 2: The time schedule for the online platform led by WP7 has not been included in this [strategy].
>
> Recommendation: Be active! Ask for what you need to other partners to achieve the project goals and coordinate with them. Work as a team.

4.2.1 Mechanical Replicas (MR)

Leading partners involved: Gipsa-Lab + FAU

- UMRVow: Unified MR for vowels (Vocal folds (VF) + Vocal tract (VT))
  - Status: to begin
  - Time due: 15 May
  - Partners involved: FAU + Gipsa-Lab
- MRDip: MR for diphthongs (Dynamic VT)
  - Status: MR already built
  - Time due: 15 June
  - Partners involved: Gipsa-Lab
- MRFri: for fricatives (Only VT)
  - Status: MR already built
  - Time due: 15 July
  - Partners involved: Gipsa-Lab
- MRSyll: for syllable /sa/ or /za/ (Only dynamic vocal tract)
  - Status: MR already built
  - Time due: 15 October
  - Partners involved: Gipsa-Lab
- UMRDipSyll: Unified MR for either diphthongs or syllable
  - Status: to begin
  - Time due: 15 December
  - Partners involved: FAU + Gipsa-Lab

EUNISON is supported by the Future and Emerging Technologies (FET) programme within the ICT theme of the Seventh Framework Programme for Research of the European Commission

4.2.2 Unified Numerical Simulation of Vowels

Leading partners involved: KTH (WP2 and WP7) + La Salle and CIMNE (WP4)

- USimVowSG: Unified simulation of vowels using simplified geometries for VF and VT:
  - Status: Mixed wave equation implemented in FEniCS (Hector, CIMNE). Unified geometry and acoustic analogy formulation to be supplied by La Salle. Use of Sommerfeld condition or implementation of PML (to be discussed).
  - Time due: 1 June
  - Partners involved: KTH (WP2) + La Salle and CIMNE (WP4)
- USimVowRG: Unified simulation of vowels using realistic geometries for VF and VT:
  - Status: to begin.
  - Time due: 1 July
  - Partners involved: KTH (WP2 and WP7) + La Salle and CIMNE (WP4)

4.2.3 Unified Numerical Simulation of Dipthongs

Leading partners involved: KTH (WP2 and WP7) + La Salle and CIMNE (WP4)

- USimDipSG: Unified simulation of dipthongs using simplified geometries for VF and VT:
  - Status: Mixed wave equation in an ALE framework to be implemented in FEniCS.
  - Time due: 15 October
  - Partners involved: KTH (WP2) + La Salle and CIMNE (WP4)
- UBioMSimDip: Unified biomechanical simulation of dipthongs using geometries from Artysynth (VF not included):
  - Status: Working on it.
  - Time due: 1 July
  - Partners involved: KTH (WP7) + La Salle and CIMNE (WP4)

4.2.4 Unified Numerical Simulation of Fricatives

Leading partners involved: CIMNE and La Salle (WP4) + Gipsa Lab (WP6)

- SimFriSG: Simulation of fricative /s/ using a simplified geometry for the vocal tract and teeth.
  - Status: On going in FEMUS.
  - Time due: 1 June
  - Partners involved: CIMNE and La Salle (WP4)
- USimFriSG: Unified simulation of fricative /s/ using a simplified geometry for the vocal tract and teeth and including static VF to change the inflow.
  - Status: On going in FEMUS.
  - Time due: 1 June
  - Partners involved: CIMNE and La Salle (WP4) + Gipsa Lab (WP6)

4.2.5 Numerical Simulation of Syllables

Leading partners involved: CIMNE and La Salle (WP4)

- SimSyll: Simulation of syllable /za/ using simplified dynamic geometries for the vocal tract and teeth and a glottal pulse in addition to the aerodynamically generated sound.
  - Status: to begin.
  - Time due: 15 October
  - Partners involved: CIMNE and La Salle (WP4)

EUNISON is supported by the Future and Emerging Technologies (FET) programme within the ICT theme of the Seventh Framework Programme for Research of the European Commission

- USimSyll: Unified simulation of syllable /za/ using simplified dynamic geometries for the vocal tract and teeth, a glottal pulse in addition to the aerodynamically generated sound and inclusion of static VF.
    - Status: to begin.
    - Time due: 1 December
    - Partners involved: CIMNE and La Salle (WP4)

5. PUBLICATIONS

New publications by the project partners, for project year 2, months 13-24, March 2014-February 2015, funded by or otherwise related to the EUNISON project.

1. *Journal papers, accepted or published*

Santiago Badia, Ramon Codina and Héctor Espinoza. Stability, convergence and accuracy of stabilized finite element methods for the wave equation in mixed form. *SIAM J. Numer. Anal.*, 52(4), (2014), 1729–1752.

R. Blandin, M. Arnela, R. Laboissière, X. Pelorson, O. Guasch, A. Van Hirtum, X. Laval. Effects of higher order propagation modes in vocal tract like geometries. *J. Acoust. Soc. Am*. **137** (2), February 2015, 832-843.

R. Codina and J. Baiges. Weak imposition of essential boundary conditions in the finite element approximation of elliptic problems with non-matching meshes. Accepted by *Int. J. Numer. Meth. Engng*.

H. Espinoza, R. Codina, S. Badia. A Sommerfeld non-reflecting boundary condition for the wave equation in mixed form. *Comput. Methods Appl. Mech. Engrg.* Vol. 276 (2014), 122-148.

Y. Fujiso, K. Nozaki, A. Van Hirtum. Towards sibilant physical speech screening using oral tract volume reconstruction: Some preliminary observations. *Applied Acoustics* **96** (2015) 101–107.

A. Lodermeyer, S. Becker, M. Döllinger, Stefan Kniesburges. Phase-locked flow field analysis in a synthetic human larynx model. *Experiments in Fluids* **56** (4).

C. Pocci, J. Izarra, S. Ochoa, G. Pagnini, J. Jansson. Adaptive DNS/LES with applications in gas burners. *Int. J. Numer. Meth. Fluids*. DOI: 10.1002/fld . 19 pages.

A. Van Hirtum, Y. Fujiso and K. Nozaki. The role of initial flow conditions for sibilant fricative production (L). *J. Acoust. Soc. Am*. **136** (6), December 2014, 2922-2925.

A. Van Hirtum. Deformation of a Circular Elastic Tube between Two Parallel Bars: Quasi-Analytical Geometrical Ring Models. *Mathematical Problems in Engineering*, 2015:1-15, http://dx.doi.org/10.1155/2015/547492.

M. Arnela and O. Guasch, “Two-dimensional vocal tracts with three-dimensional behaviour in the numerical production of vowels,” *J. Acoust. Soc. Am.*, vol. **135** (1),369–379, 2014.

2. *Journal papers, submitted before March 2015*

J. Baiges and R. Codina. Analysis of a finite element method to prescribe essential boundary conditions on non-matching meshes for elliptic problems. (submitted)

H. Espinoza, R. Codina, S. Badia. On some time marching schemes for the stabilized finite element approximation of the mixed wave equation. Submitted to *Comput. Methods Appl. Mech. Engrg.*

O. Guasch, M. Arnela, R. Codina, H. Espinoza. A stabilized finite element method for the mixed wave equation in an ALE framework with application to diphthong production. (submitted)

J. Jansson, J. Spühler, C. Degirmenci, J. Hoffman. Automated error control in finite element methods with applications in fluid flow. (submitted)

Widing, E. and Ekeberg, Ö. Tailoring Biomechanical Models for Aero-Acoustic Simulations. Accepted by *Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization.* (Accepted May 2015)

3. Conference papers

M. Arnela and O. Guasch (2014). Validation of the piston set in a sphere model for vowel sound radiation losses against realistic head geometry using time-domain finite-element simulations. 9th International Conference on Voice Physiology and Biomechanics, April 10-12, Salt Lake City, Utah, USA.

M. Arnela and O. Guasch. Three-dimensional behavior in the numerical generation of vowels using tuned two-dimensional vocal tracts. Forum Acusticum, Krakow, Poland, 7-12 September 2014.

M. Arnela, O. Guasch, R. Codina and H. Espinoza (2014). Finite element computation of diphthong sounds using tuned two-dimensional vocal tracts. 7th Forum Acusticum, September 7-12, Krakow, Poland. ("EAA Best Paper and Presentation Award" for young investigators given to first author.)

R. Blandin, X. Pelorson, A. Van Hirtum, R. Laboissère, O. Guasch and M. Arnela (2014). Effet des modes de propagation non plan dans les guides d'ondes à section variable. 12e Congrès Français d'Acoustique, CFA2014 , April 22-25, Poitiers, France. (in French)

R. Codina, O. Guasch, M. Arnela and H. Espinoza (2015). Waves in time dependent domains. 10th International Workshop on Variational Multiscale and Stabilized Finite Elements (VMS2015), February 25-27, Garching / München, Germany.

O. Guasch, R. Codina, M. Arnela and H. Espinoza (2014). A stabilized Arbitrary Lagrangian Eulerian finite element method for the mixed wave equation with application to diphthong production, WCCM XI (11th World Congress on Computational Mechanics), ECCM V (5th European Conference on Computational Mechanics) and ECFD VI (6th European Conference on Computational Fluid Dynamics), July 20-25, Barcelona, Catalonia (Spain).

A. Lodermeyer, S. Becker, S. Kniesburges and M. Döllinger: Phase-locked flow field analysis in a synthetic human larynx model. In *Proc of 17th International symposium on applications of laser techniques to fluid mechanics*, July 2014.

S. Dabbaghchian, I. Nilsson, and O. Engwall, "From Tongue Movement Data to Muscle Activation: A Preliminary Study of ArtiSynth's Inverse Modelling," 2nd International Workshop on Biomechanical and Parametric Modeling of Human Anatomy (PMHA), 22-23 Aug 2014, Vancouver.

4. Ph.D. Thesis

Marc Arnela (February 2015) *Numerical production of vowels and diphthongs using finite element methods*. Supervised by: Oriol Guasch.

EUNISON is supported by the Future and Emerging Technologies (FET) programme within the ICT theme of the Seventh Framework Programme for Research of the European Commission