Down with Sound
The Story of Silent Speech

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Speech Communication

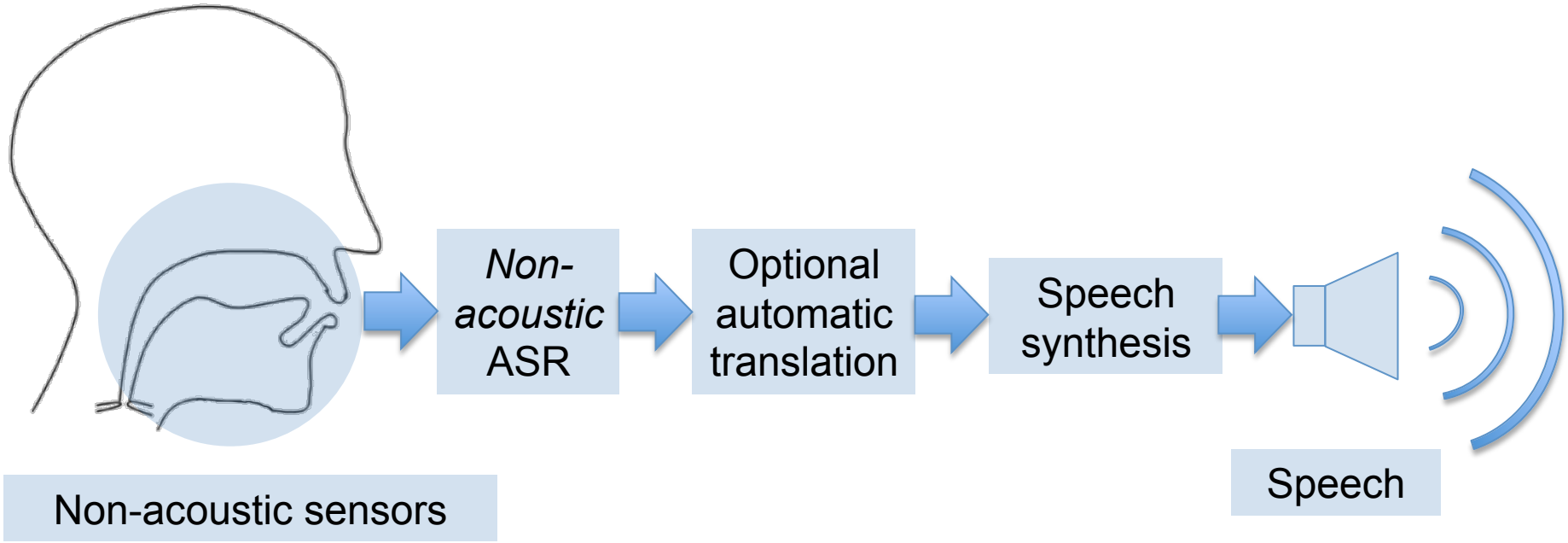
- Speech has always been the most natural and spontaneous modality for communication between human beings (and machines…?)

But speech has certain problems

- Noise sensitivity
  - ASR performance degrades very rapidly in the presence of background noise
- Airborn nature of speech signal
  - Interference with other communications
  - Security problems
- Inaccessibility for certain populations
  - Laryngectomy
  - Paralysis, pulmonary insufficiency, etc.
- Language dependence…

The *Silent Speech Interface* (SSI) Idea

- Use non-acoustic sensors to augment or completely replace the acoustic speech signal



SSI Application Areas

- In medicine
  - Give back original voice to voice-handicapped persons: laryngectomy or other pathologies
- In telecommunications
  - Telephone securely without disturbing others
  - Silent Man-Machine Interface (data entry, etc.)
  - Communicate verbally even in very noisy environments
  - Automatic translation

SSI – *"a hot new area"*

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Available online at www.sciencedirect.com

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www.elsevier.com/locate/specom

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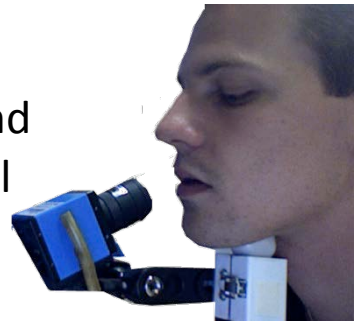
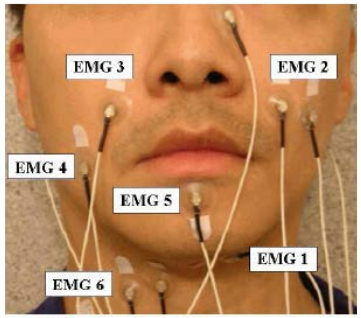
Special Issue: "Silent Speech" Interfaces
Guest Editors: B. Denby, T. Schultz and K. Honda

Variety of Approaches

Ultrasound + Optical

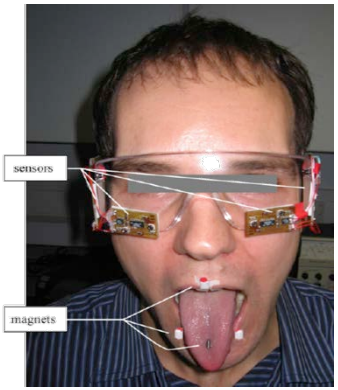


EMG



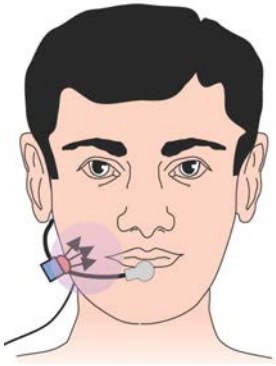
NAM

EMA

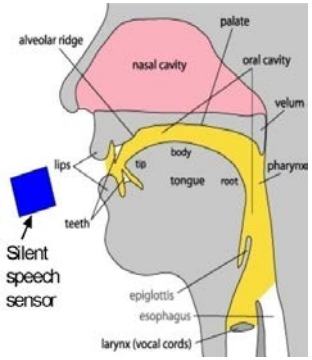


Vibration Sensors

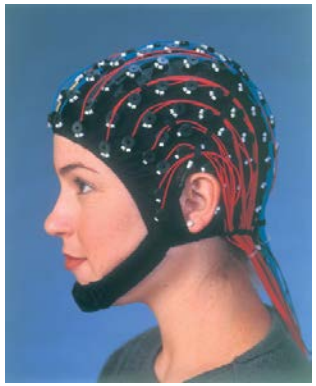
Radar



Low Freq. Ultrasound In Air



BCI EEG

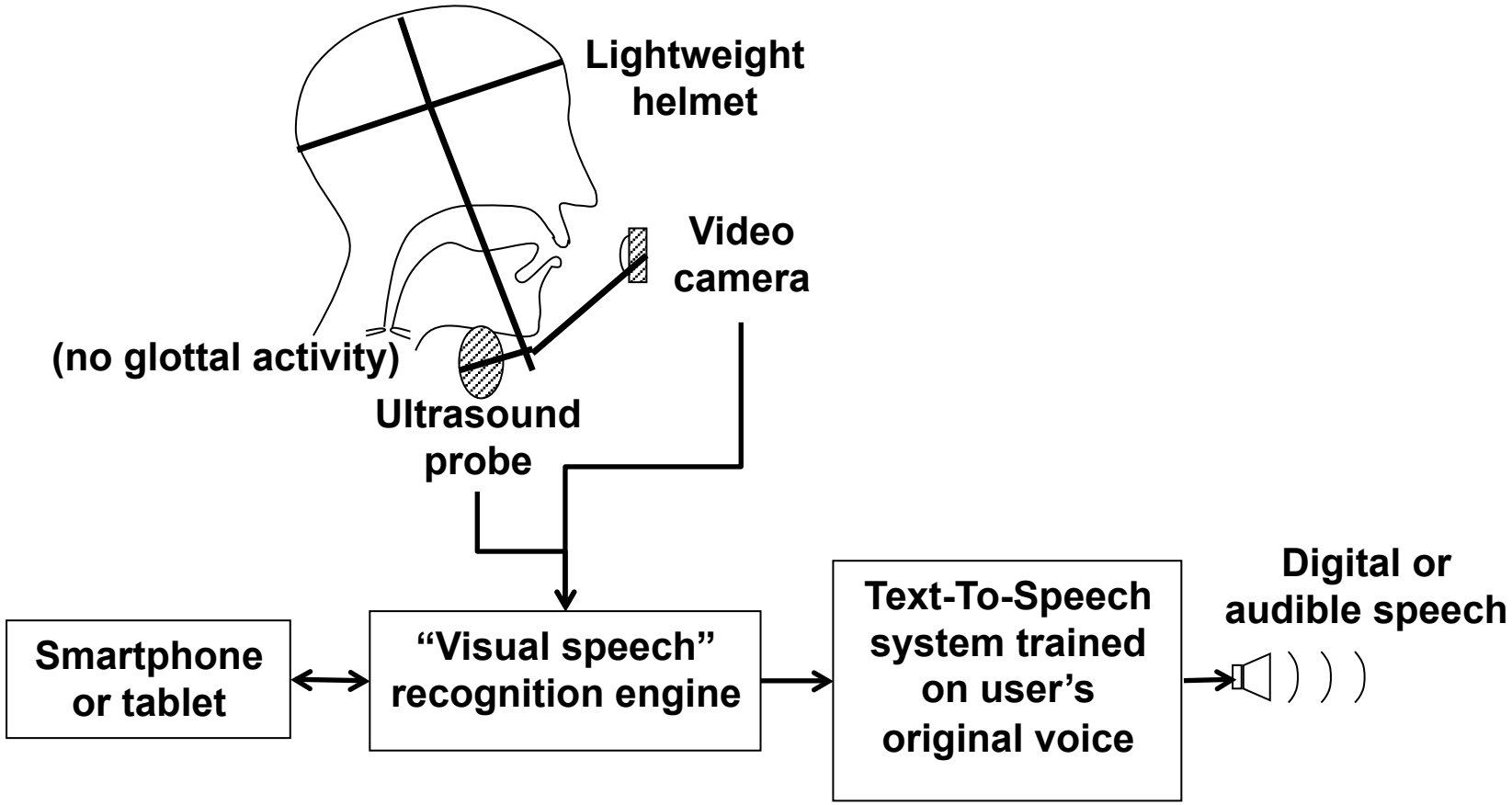


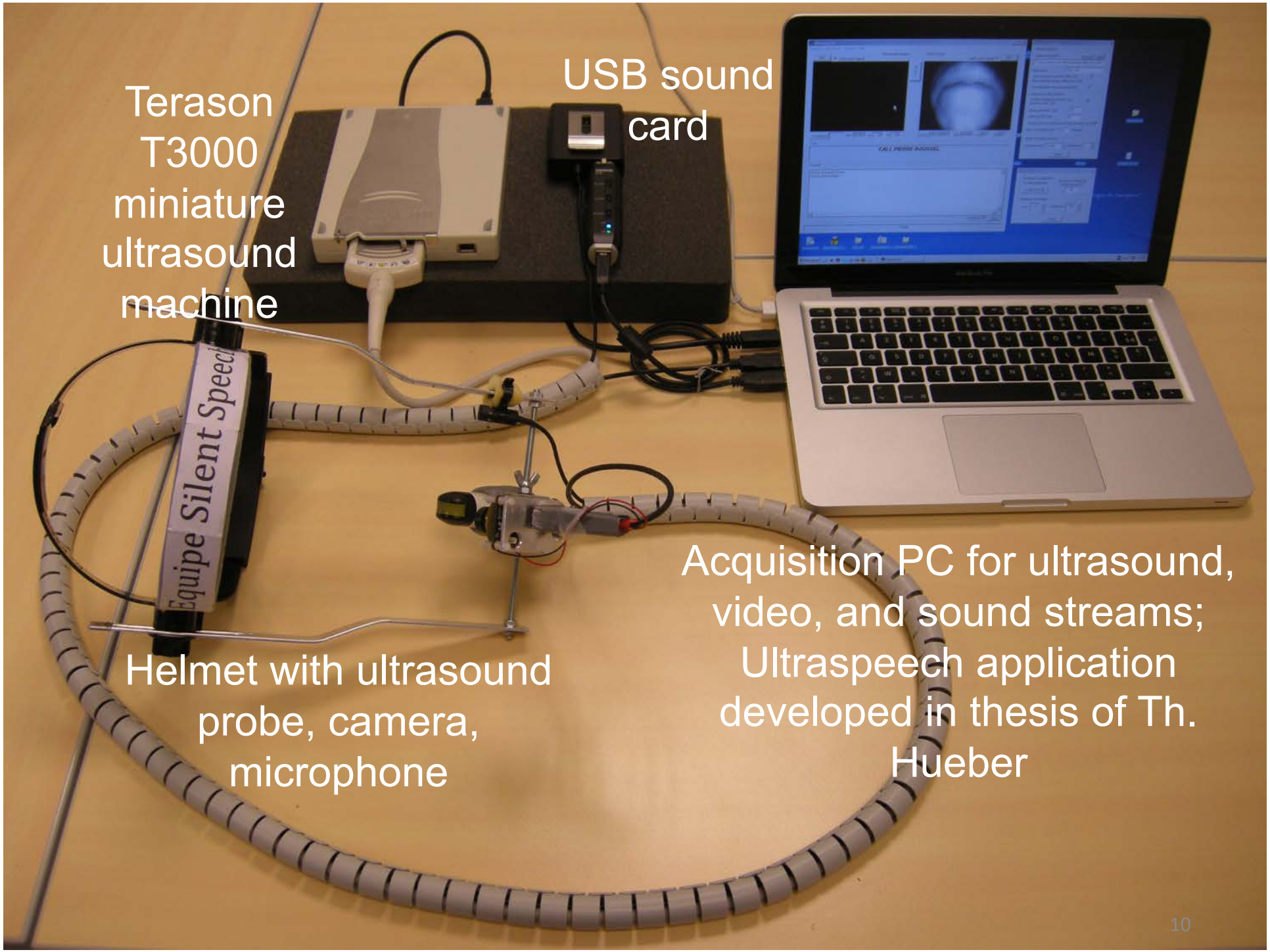
BCI cortical

Ultrasound data acquisition

- a) Classic cart-based multi-probe machine
- b) Siemens Acuson P10 ultra-miniaturised
- c) Terason solution – support PC/Windows
- Price: 20 000 € (small, 30 Hz) to 200 000 € (standard, high speed and/or 3D)

SIGMA Lab SSI: Ouisper Overview

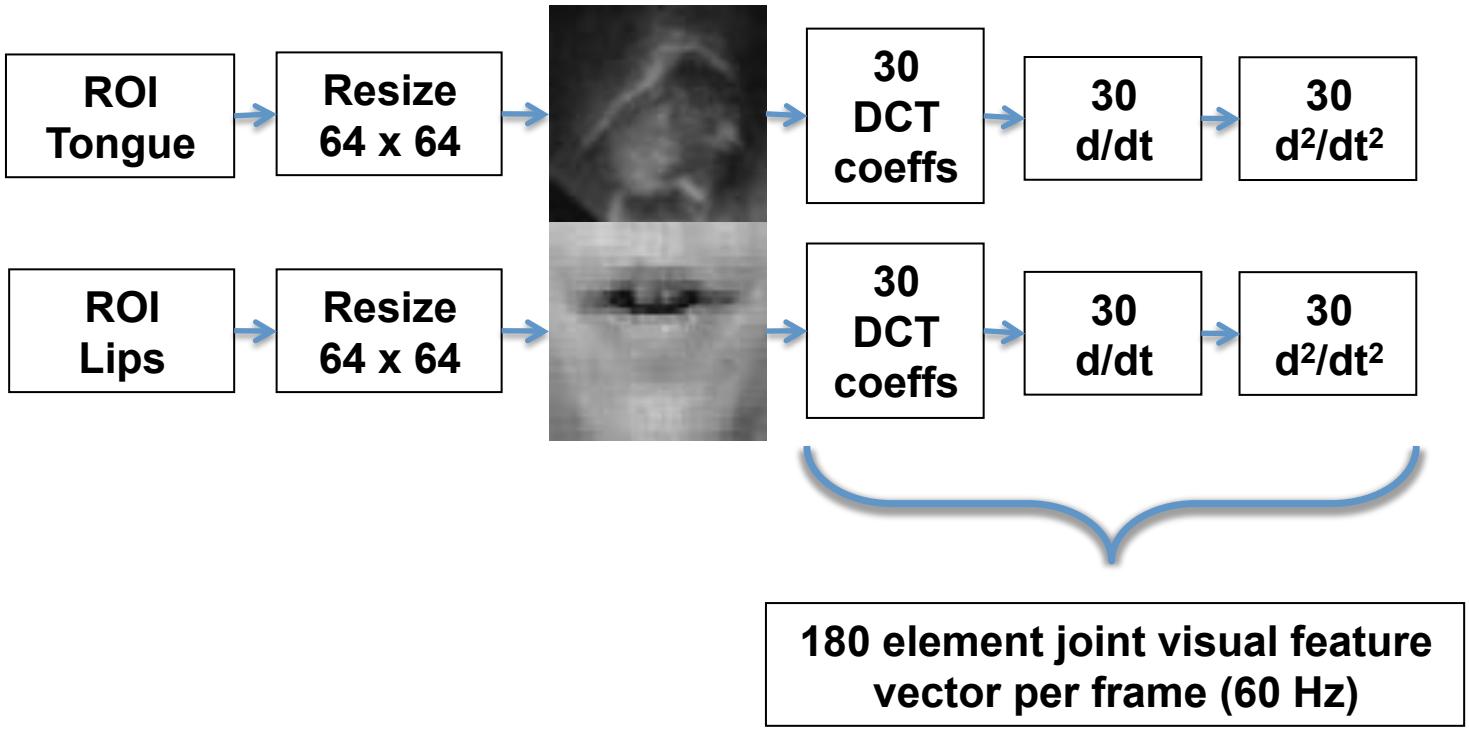



Terason T3000 miniature ultrasound machine
USB sound card
Equipe Silent Speech
Helmet with ultrasound probe, camera, microphone
Acquisition PC for ultrasound, video, and sound streams; Ultraspeech application developed in thesis of Th. Hueber

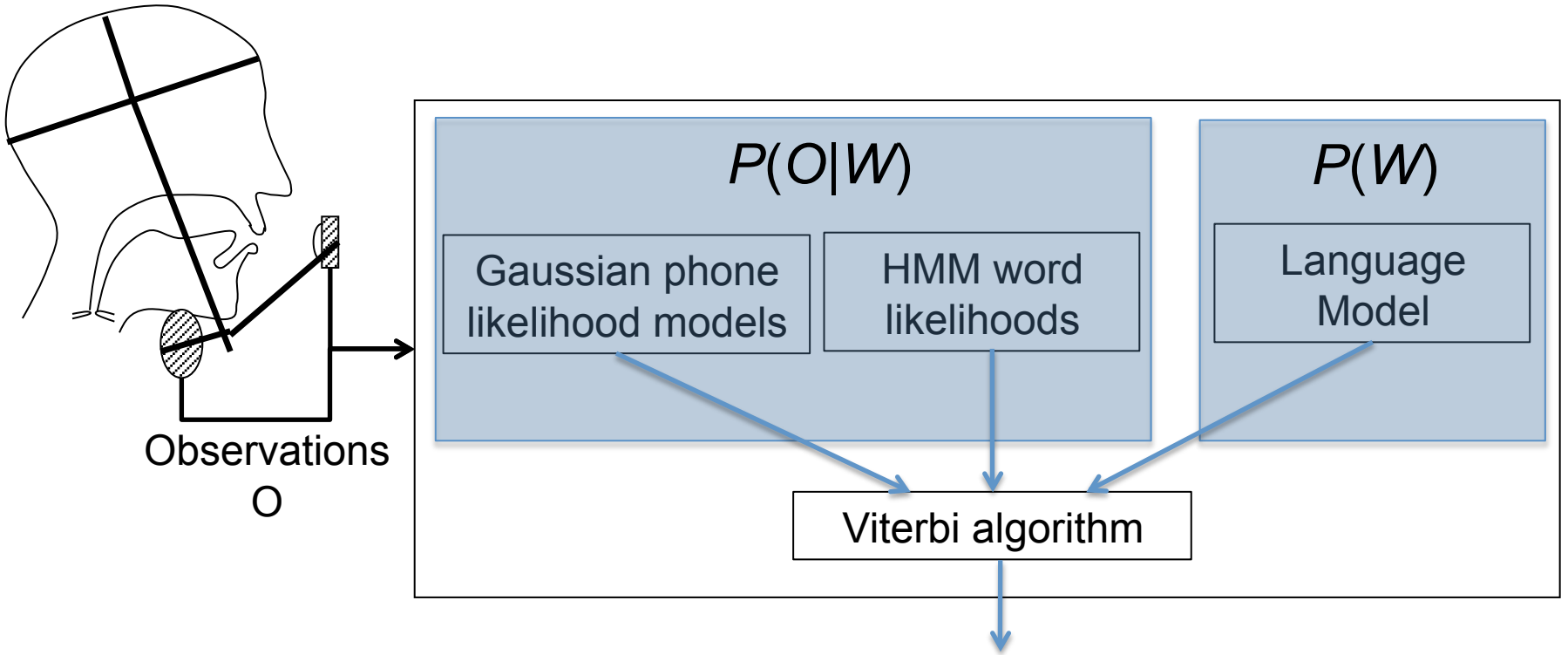
Example: laryngectomy voice recovery with phrasebook (French)

Example of captured data (English)

Visual Feature Extraction: selected method for Ouisper SSI



Continuous Non-Acoustic Speech Recognition: Overall Decoding Strategy



Estimated sequence:

$$\hat{W} = \underset{W \in dictionary}{\arg\max}\, P(O \mid W) P(W)$$

Recognition Results for English

- DARPA TIMIT corpus used for training triphone HMMs
- 3000 sentences, 2 months of recording
- Accuracy = (N – D – S – I) / N

Test Set + Language Model	Recognition Accuracy (%)	
	Word Level	Phone Level
Visual WSJ0 5k + WSJ0 5k NVP bigram	84	93
Visual Gigaword 20k + Gigaword 20k bigram	77	90
Visual Gigaword 20k + Gigaword 20k trigram	86	94

Presented at Interspeech, Sept. 2011, Florence, Italy

Real Time Recognition with Julius

- HMMs implemented with HTK toolkit
- This is slow
- Julius HMM code is available
- Developed in Japan
- Uses 2-path search
  - Initial search with reduced number of Gaussians in GMM
  - Full search on reduced set of paths
- Allows faster than real time recognition even on visual speech

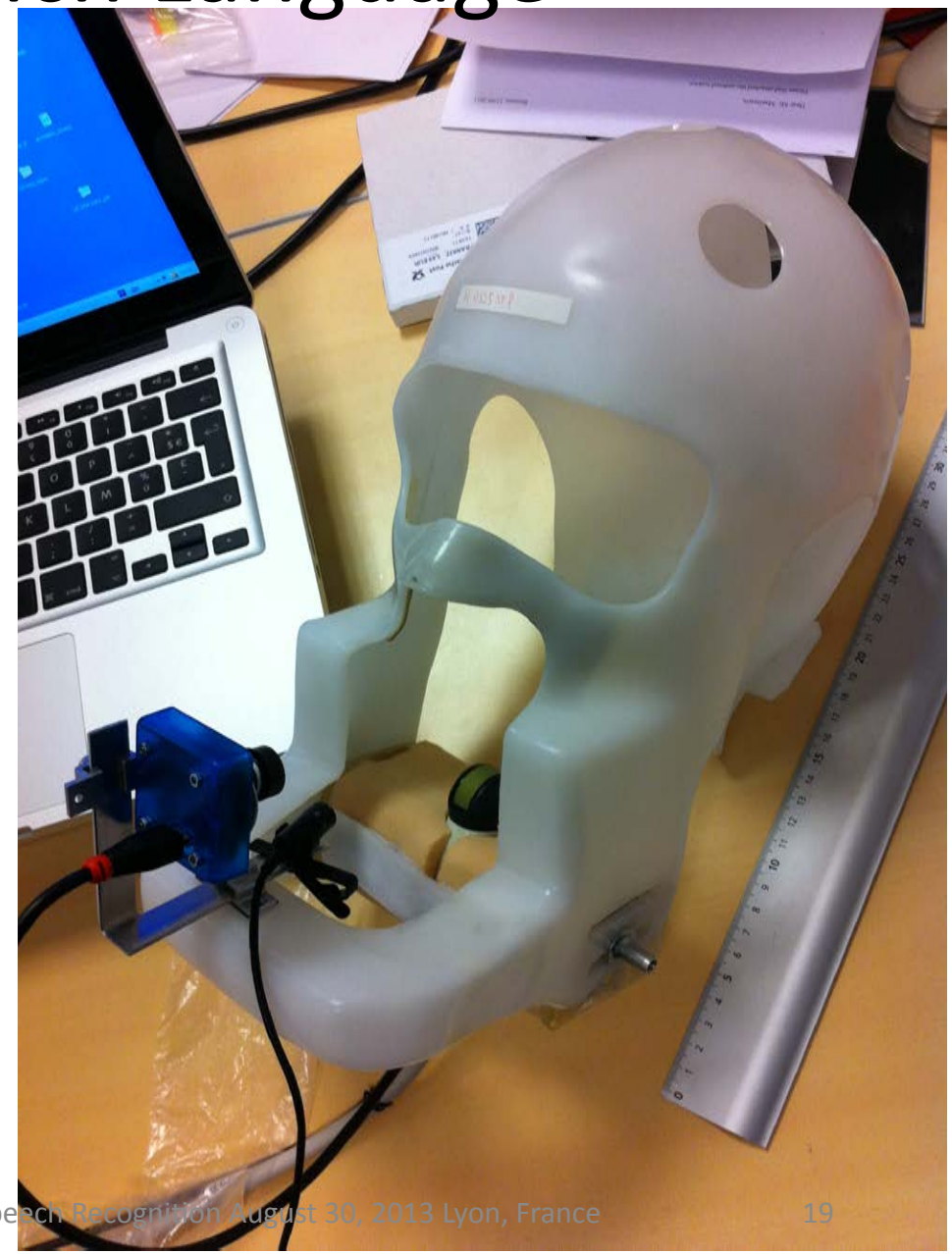
Synthesis Step: Chosen Method for Ouisper SSI

- Train Text-To-Speech (TTS) on speaker's voice
- Use OpenMary open source TTS tools
- Record 1500 triphone-rich sentences in sound cabin (microphone only)
- TTS resides on a server accessible via Internet
- Laryngectomy case:
  - Ideally pre-op voice if good quality recordings exist
  - If not, we have found a voice imitator is a good solution

Demo at ISSP, June 2011, Montréal

Move to French Language

- Individually thermoformed plastic helmets
- French is hard!
  - Corpora, LM, tools less available
  - Liaisons, variants, nasality, etc.
  - New synthesis module!
- Recording 3 speakers one of whom is post laryngectomy



Recognition Results for French

Table 2. *Word and phone level recognition accuracy in % for the 3 speakers and 2 LMs, with 95% c.l. intervals.*

Triphone enriched Polyvar training set and Polyvar Language Model (train set excluded)

Speaker	Recognition Accuracy in %			
	Word Level		**Phone Level**	
	Word Loop bigram	Polyvar bigram	Word Loop bigram	Polyvar bigram
PRR	10.1±2.4	**64.0**±3.8	62.1±2.0	**77.9**±1.7
LCB	12.4±3.2	**65.7**±4.5	65.0±2.4	**78.7**±2.1
JCD*	29.0±4.3	**65.4**±4.5	71.3±2.3	**74.6**±2.2

*post-laryngectomy speaker

Presented at I2MTC, Minneapolis, USA, May 2013

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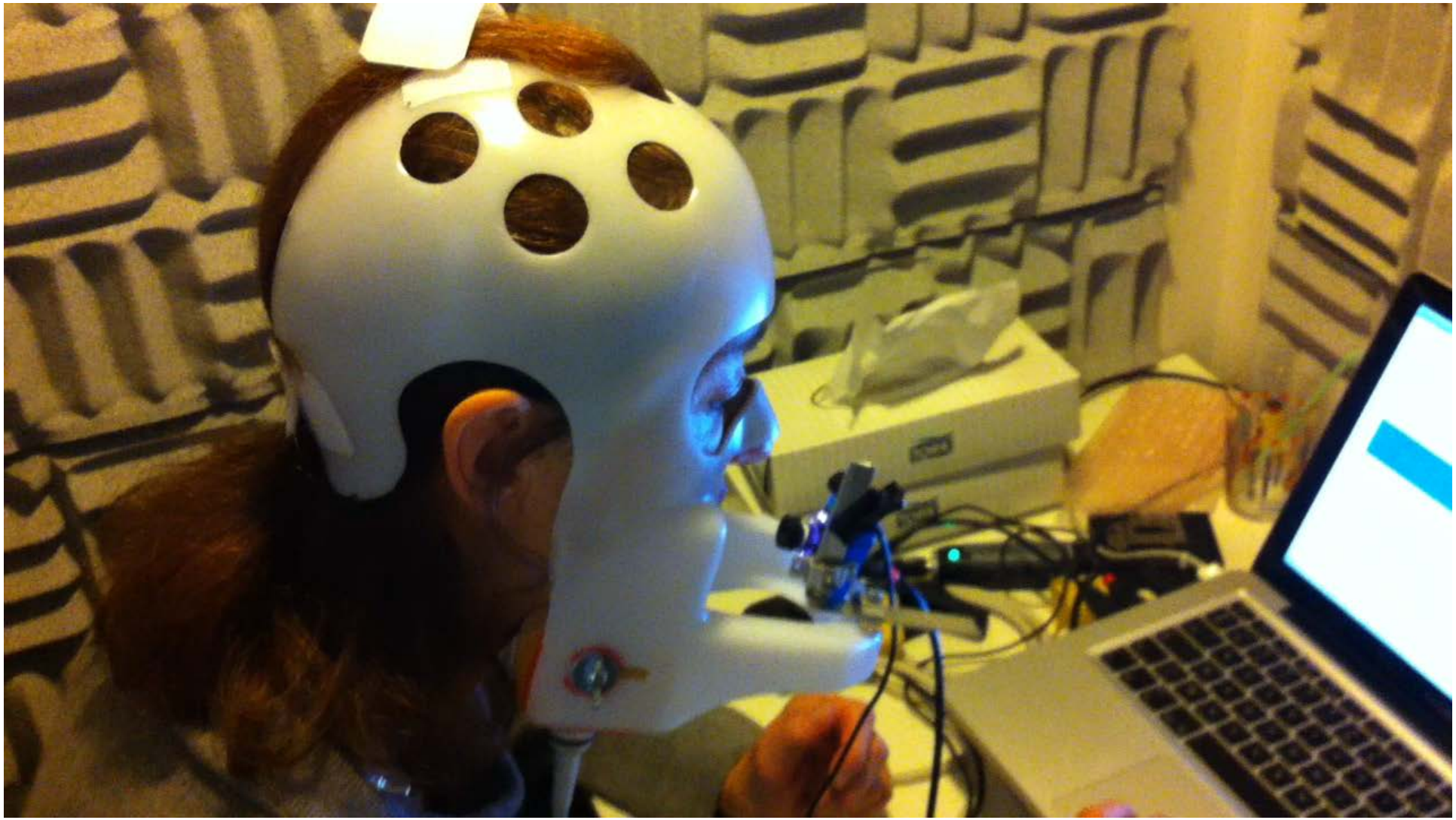
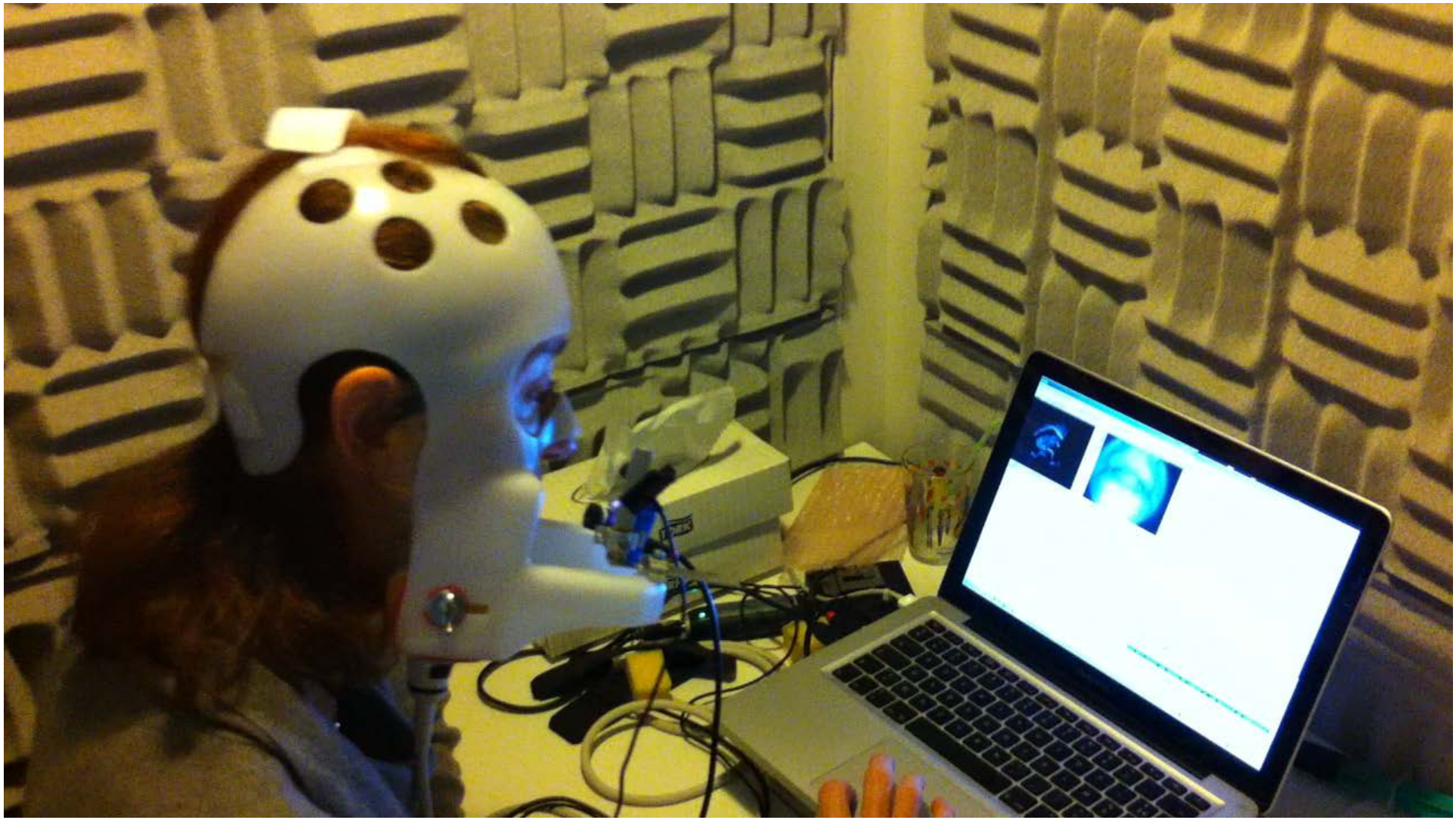
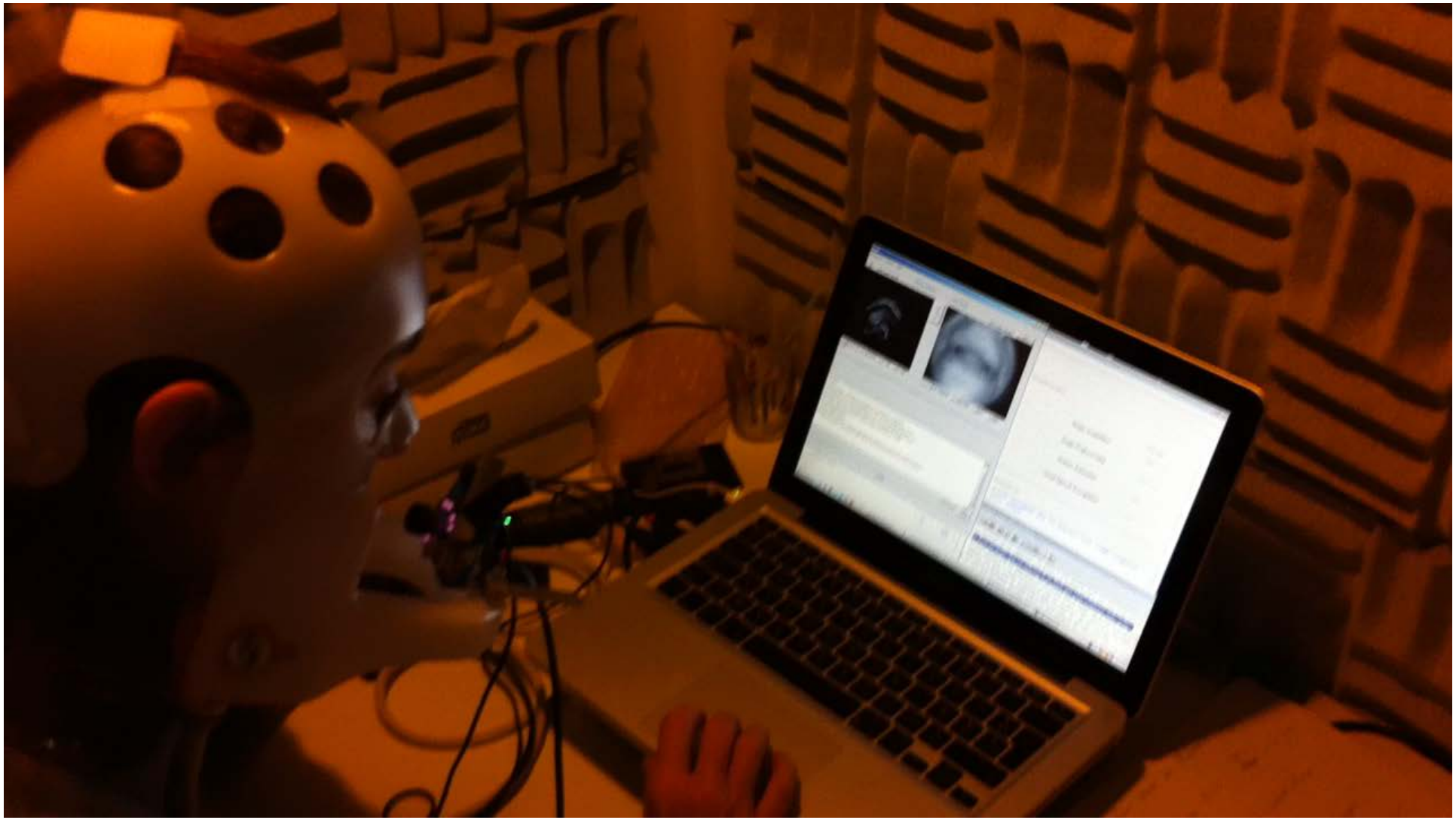
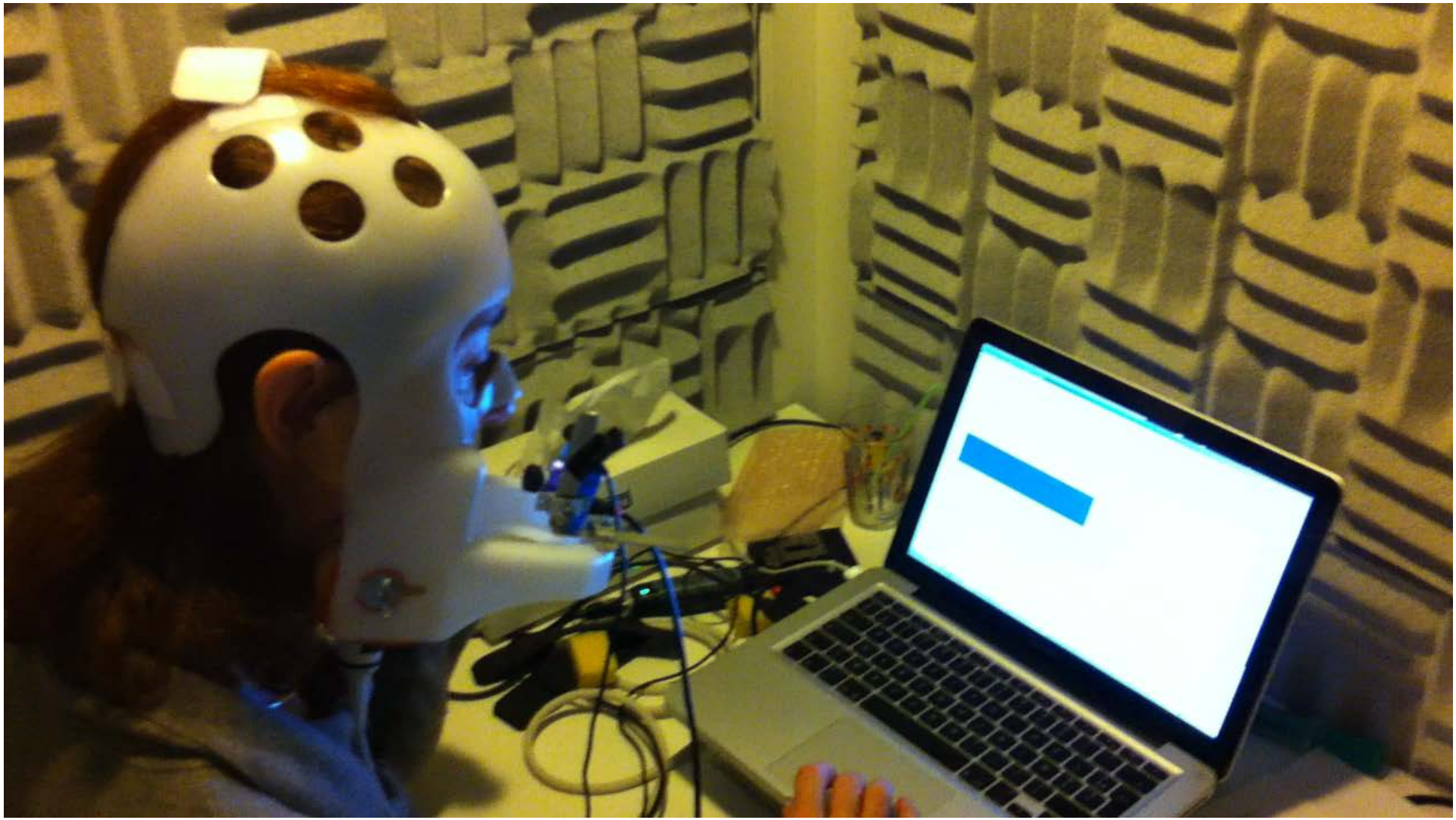
Real Time Tests in French
(text output only, no synthesis)

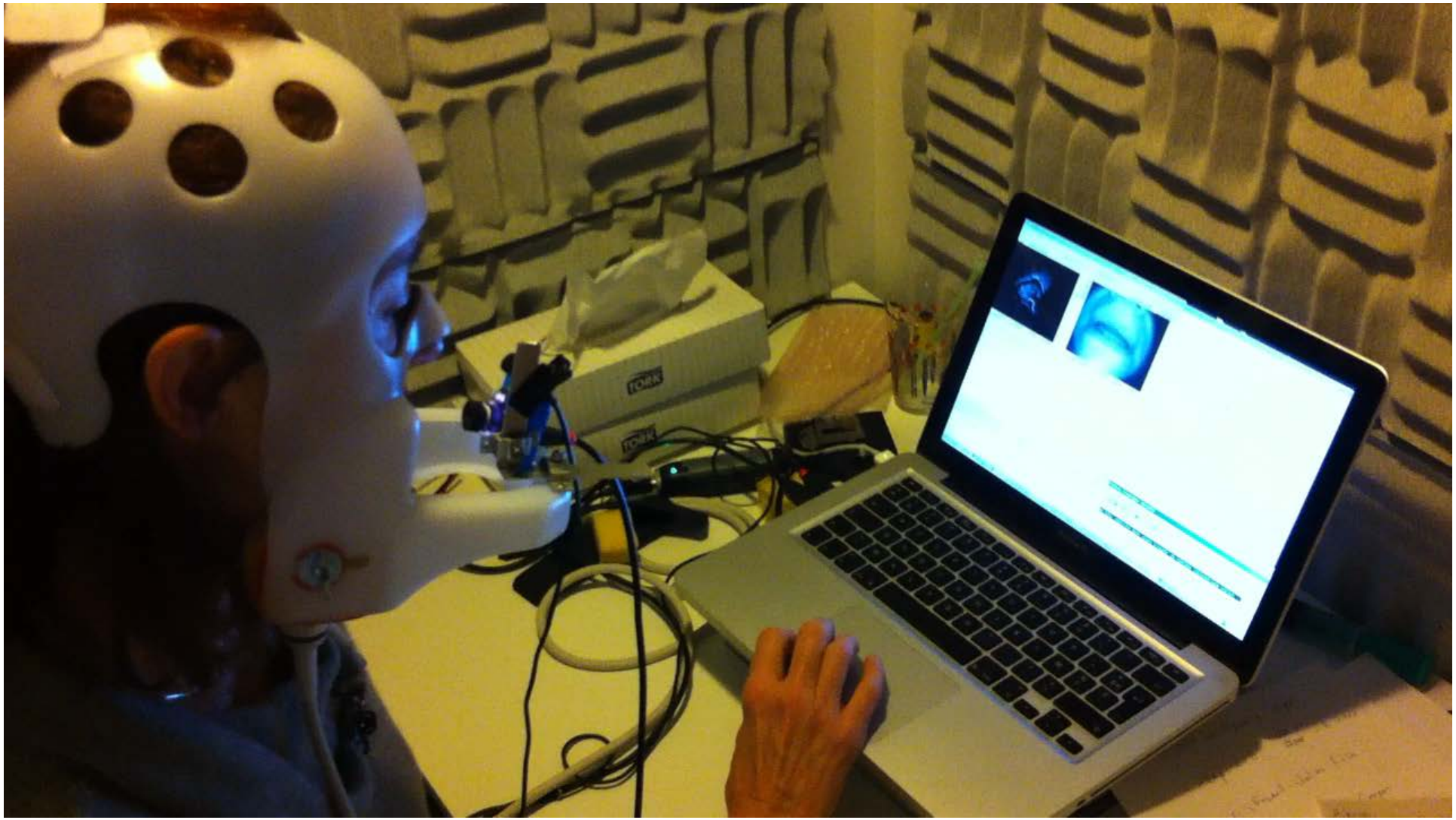

TORK
TORK











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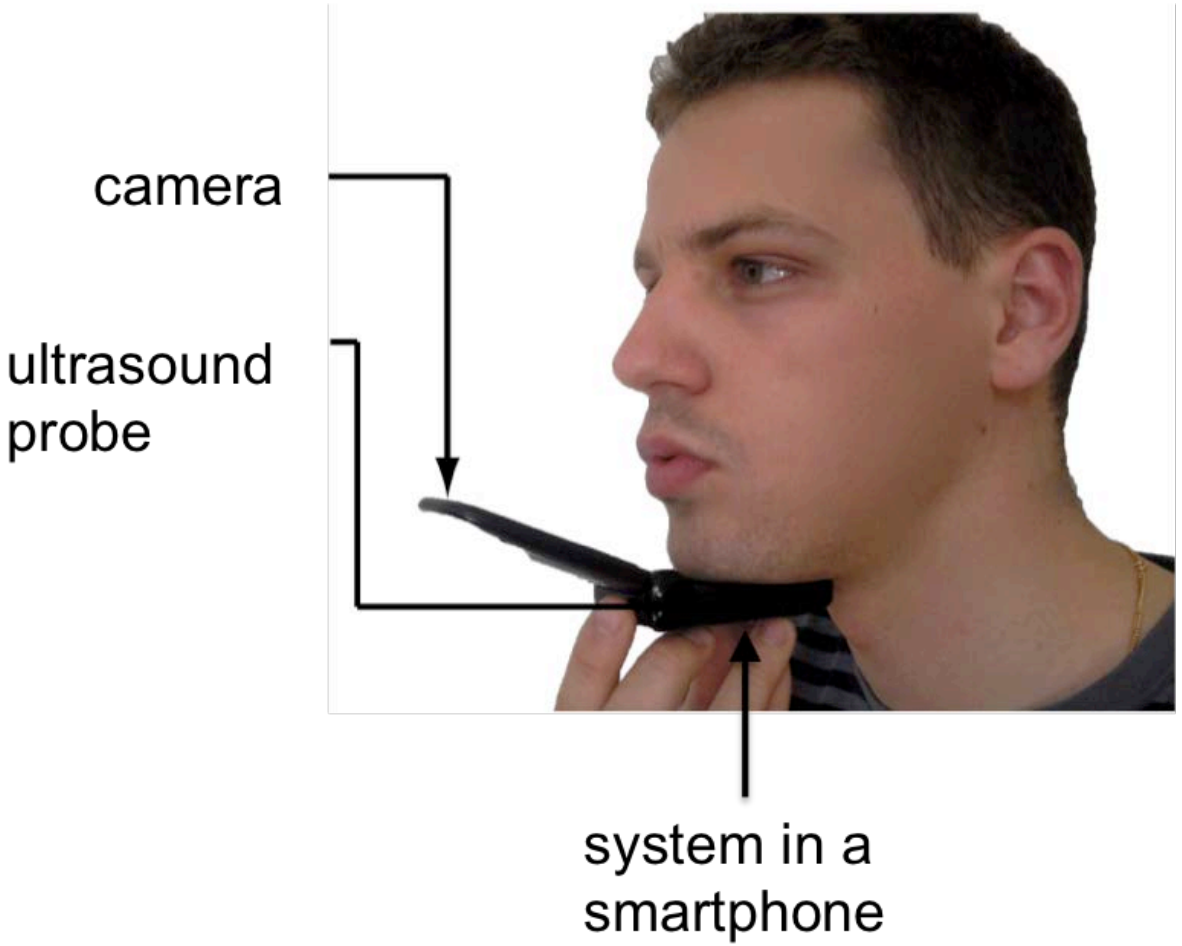
Silent Speech Challenge

- English multimodal silent speech data are available online for others to try!!
- Includes raw single speaker ultrasound and lip images plus text of sentences pronounced (no sound: silent speech!)
- Hundreds of Gbytes of data!
- Includes TIMIT training/development corpus plus WSJ0 test corpus (100 sentences) and language model.
- Benchmark: 93% phone recognition, 84% word recognition on WSJ0 set
- Available by anonymous ftp at ftp.espci.fr (login anonymous, password your email address)
- Go to pub, sigma, then TIMIT_Training or WSJ05K_Test, then to Ultraspeech Capture

More Recently

- Specially manufactured miniature US probe

Perspective



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SPINOFF

i-Treasures Project

- FP7 IP project
- 12 Partners
  - CERTH, UOM, AUTH (Greece)
  - UPMC, ARMINES/ENSMP, LPP/CNRS (France)
  - UCL (UK)
  - CNR (Italy)
  - UMONS, Acapela (Belgium)
  - Turkish Telecom
  - University of Maryland (observer)
- Propose novel multisensory technologies to safeguard and transmit ICH (Intangible Cultural Heritage)

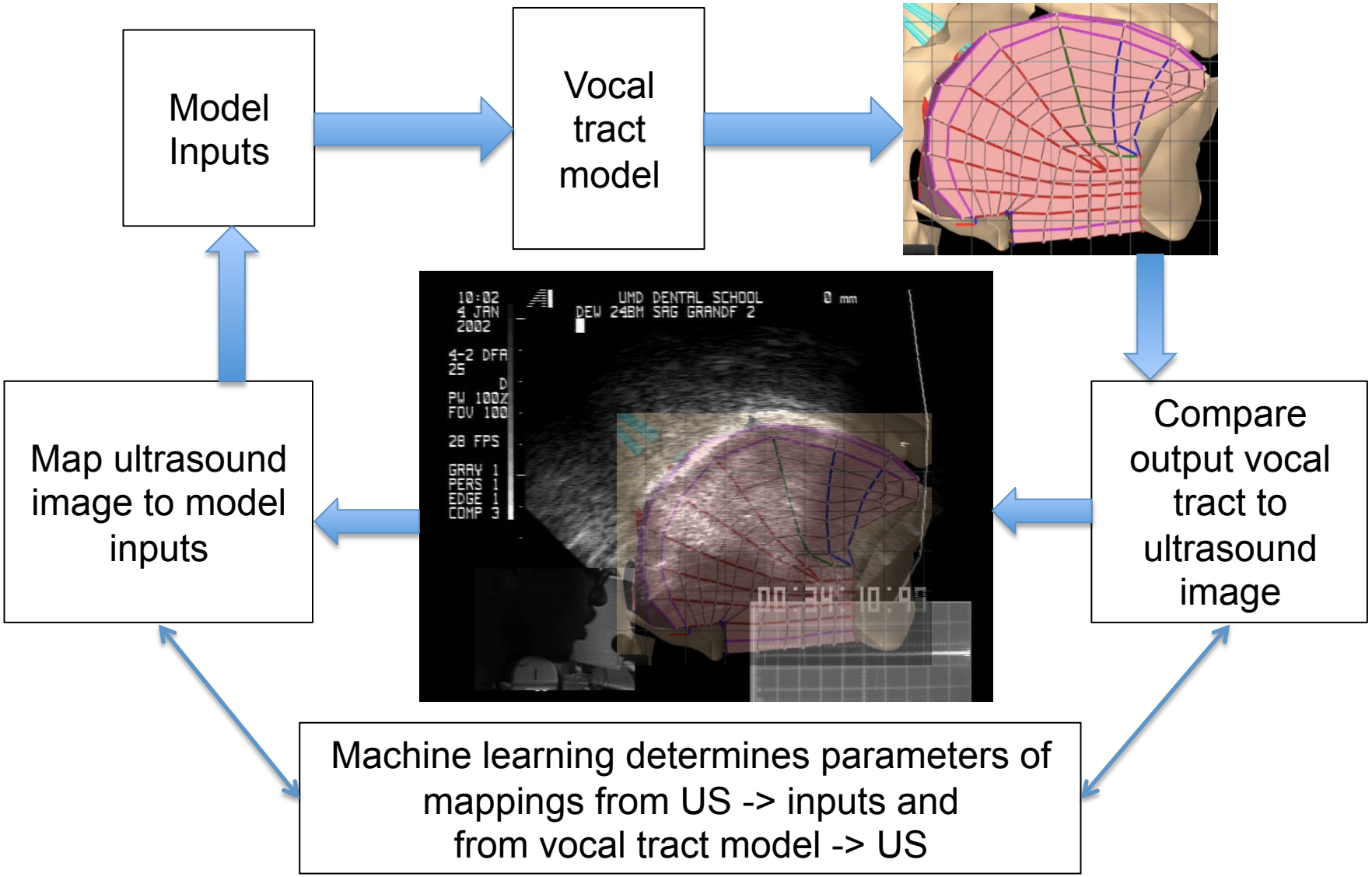
i-Treasures

- Four use cases in different ICH domains:
  - Rare traditional songs
  - Rare dance interactions
  - Traditional craftsmanship
  - Contemporary music composition
- Capture and analyze Intangible Cultural Heritage:
  - Facial expression analysis
  - Body and gesture recognition
  - Vocal tract modeling
  - Sound processing
  - Electroencephalography

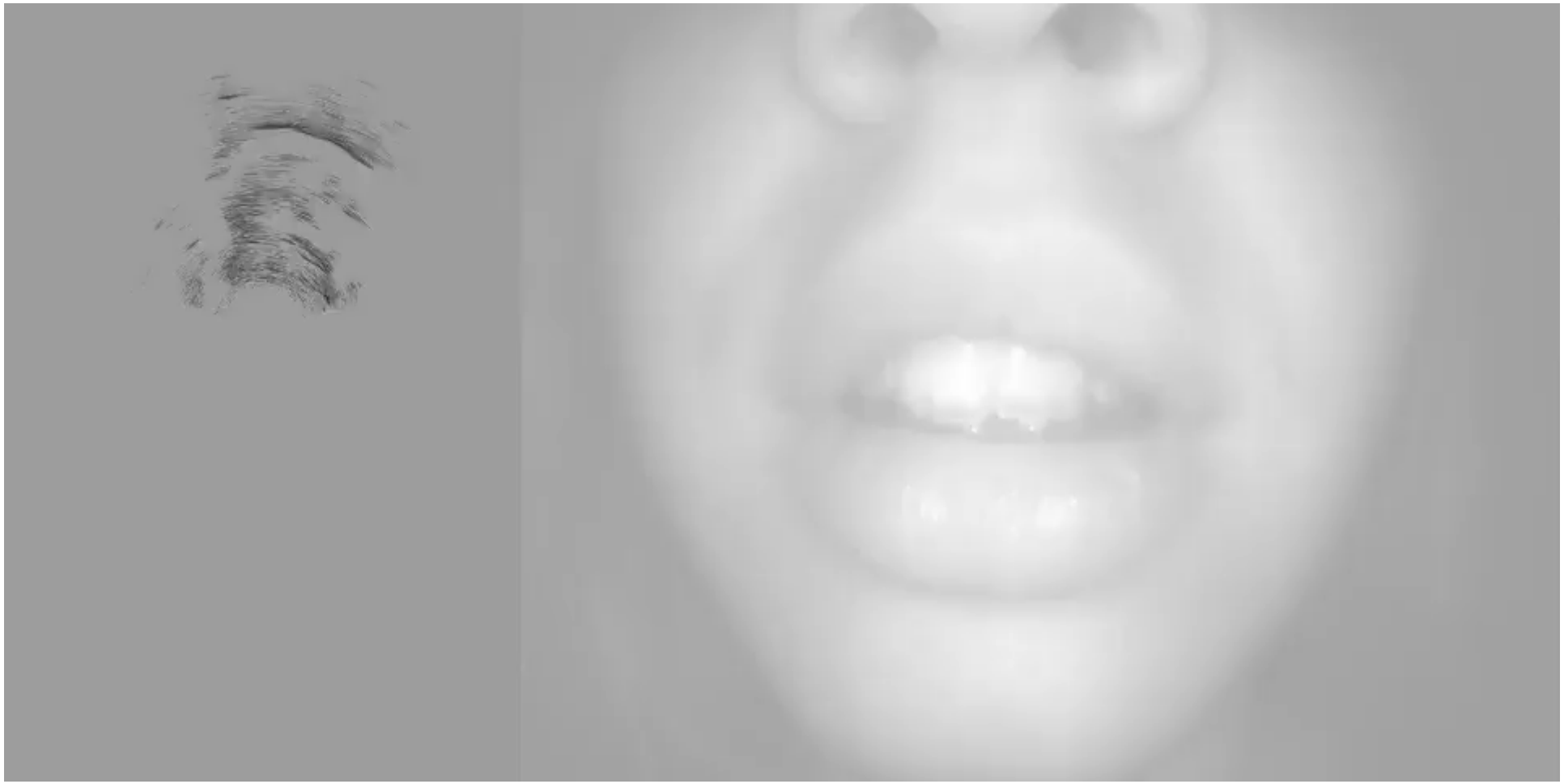
Rare traditional song use case

- Capture and analyze vocal tract of expert singers and use to create an independent 'avatar' of the singer
- Student displays expert avatar and tries to match his own to it in real time, in order to learn the technique
- Targeted rare singing techniques:
  - Corsican cantu in paghjella
  - Sardinian canto a tenore
  - Byzantine singing
  - Human beat box

Possible Strategy



First recording of singing data



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The End
Thank you!