Design of an Ultrasonic Lingual Profilograph (ULP)

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Abstract

This communication presents the first results of a project carried out jointly by the LIEN (Univ. Nancy) and the LISIF (Univ. Paris) concerning the design of a lingual ultrasonic profilograph ULP. The study is concerned with the possibility of acquiring and visualizing the movement of the tongue during pronunciation and swallowing - in real time - using a simplified portable echograph. The medical interest of such a system stems from pioneering work of Pr. Maureen Stone (U. of Maryland, USA) on tongue contour measurement. The operating principle of the ULP consists of placing an ultrasonic sensor under the chin of the patient and exciting it with pulses. The echoes returned by the upper surface of the tongue, received by the same sensor, enable to rebuild the surface profile.

Introduction

Since nearly 20 years several teams of research, of which animated by Pr Maureen STONE in Baltimore, study the movements of the tongue during the pronunciation, the absorption of food and the swallowing [1, 2, 3]. These studies are carried out by techniques of ultrasonic echography which are non invasive and allows an analysis of the movements in real time. The major applications interested by the study of the dynamic behavior of the tongue are :

- the functional re-education of tongue ;
- orthophonic re-education in some pronunciation disturb ;
- establishment of models for the voice synthesis ;
- as well as the majority of the medical applications treating of the lingual problems.

These teams showed the interest of a portable lingual profilograph. In this communication, we study the design of such a system and propose solutions for its realization.

The first part is devoted to the preliminary study which made possible

- on the one hand to check the feasibility of the project ;
- on the other hand to specify the principal parameters of a simplified ultrasonic transducer, adapted to the application concerned.

The analogical conditioning of the signals delivered by the transducer is the subject of the second part. Finally we propose an numerical architecture of control and treatment which can be implanted on circuits FPGA.

Preliminary study

Echographic statements of the oral cavity were carried out using a medical echograph ATL Philips HDI 3000. The apparatus is placed under the chin with various angles of incidence and for various positions of the tongue during pronunciation (figure 1).

The purpose of this preliminary study is:

- to check the contrast and the reproducibility of the lingual profiles ;
- to define the geometrical parameters and the constitution of a simplified transducer ;
- to define the angle of incidence more adapted.

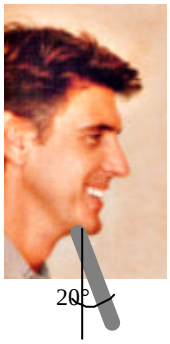

Figure 1

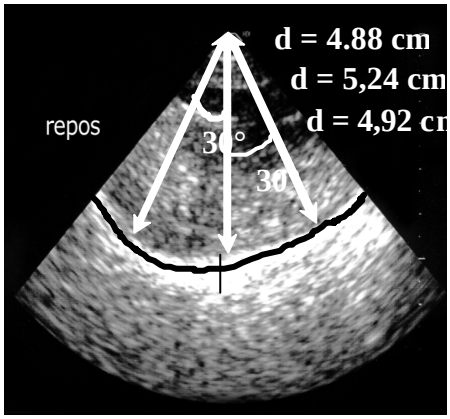

Figure 2. Tongue in median position

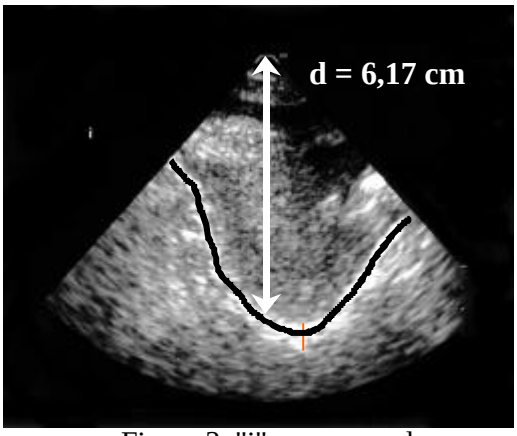

Figure 3. "i" pronounced

This first study highlighted the dependence of the profiles with the pronounced phonemes (figures 2 and 3). It showed that the lingual profile can be rebuilt by interpolation of approximately 8 points. We plan to work with a convex transducer (radius of curvature 1 inch) equiped with 16 active elements which seem to be well adapted to the application concerned. Finally the maximum depth of exploration is about 8 cm.

ULP configuration

The general device that we propose is described in figure 4.
The ULP electronic command and processing system is composed of 3 independent modules:

- an impulse generator
- an amplification and conditioning stage for backscattered echoes
- a computational module using FPGA circuits for the following functions:
  - determination of the temporal positions of received echoes
  - mathematical interpolation of intermediate positions
  - information transfer via the computer parallel port control of a matrix display for visualization of the lingual profile.

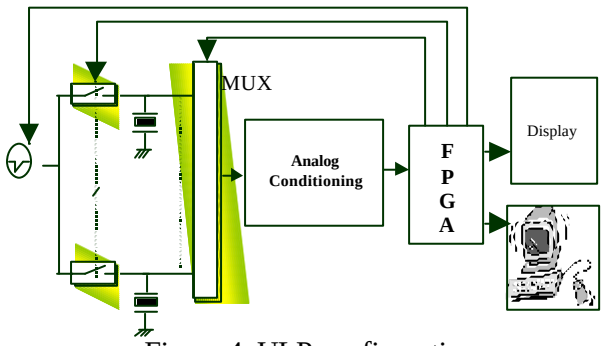

Figure 4. ULP configuration.

Analog conditioning

The conditioning chain of the signal we tested [4], with one mono-element transducer of central frequency 1 MHz, is described in figure 5. For reasons of simplification, the excitation is carried out by an external ultrasonic generator.

- Upstream: a directional coupler which temporaly switches the signal of excitation towards the transducer then which connects the last one to an amplifier
- The time gain amplifier: the nominal gain is applied just after the coupling of the amplifier to the transducer. This method eliminates a significant part of the switching parasites. The Logarithmic amplifier provides two significant functions:
  - It compresses the dynamic of the received echoes what decreases the sensitivity of measurements to the experimental conditions.
  - It carries out the amplitude demodulation of the signal.

  At the end of the chain, a threshold detector delivers a binary signal relating to the position of the echoes. This signal is directed towards the architecture of numerical processing.

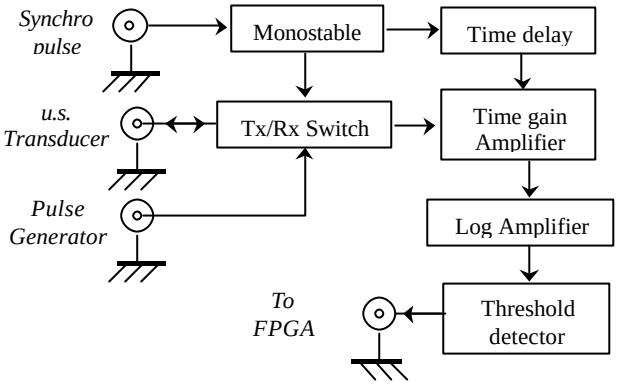

Figure 5. Analog conditioning

Numerical architecture.

The control and treatment modules are currently implanted on a development board "Excalibur®" containing a FPGA (Field Part Gate Array) Altera APEX 20K200E 484-3.

The module built around a circuit FPGA is in charge of the following functions:

- determination of the temporal position of the received echoes ;
- mathematical treatment (interpolation) ;
- transfer of the data on the parallel port of a computer ;
- visualization of the lingual profile on a matrix display :
- management of the transducer excitation.

The general architecture is represented on figure 6.

The position of the language will be visualized in real time with 30 images a second by 16 points of measurements from the ultrasonic sensors.
The principle selected corresponds to a chronometric measurement. We measure the time between the ultrasonic impulse and the reception of the backscattered echo. A counter working at a frequency of 1.33 MHz provides this measurement of the time passed on 8 bits. The whole datas from the counter is then stored in a buffer memory.

An algorithm of interpolation (linear or cubic spline) implanted in the FPGA allows the representation of the tongue profile in the shape of a smoothcurve. This curve thus obtained is visualized on a matrix display and recorded in a computer of the type PC.

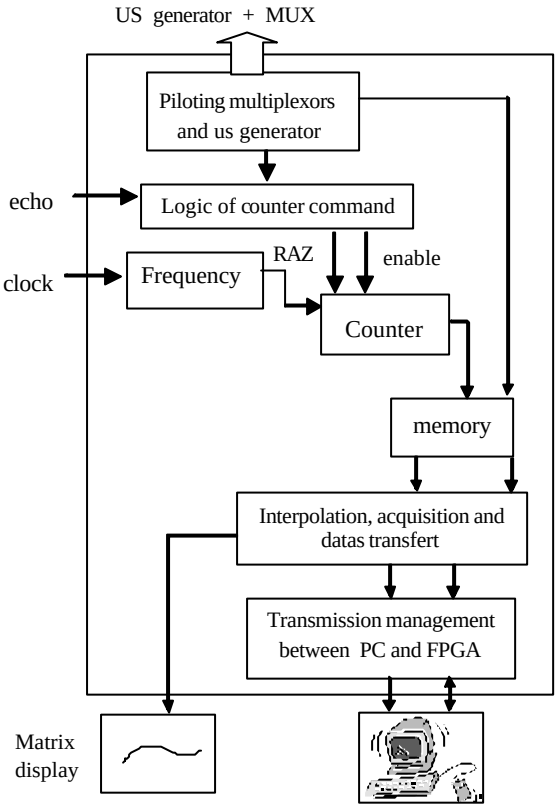

Figure 6 : FPGA architecture

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Conclusion

We presented an original configuration of a simplified portable echograph for tracking the tongue surface, recording and visualizing in real time the tongue movement.
This configuration, we propose, is characterized by :
A curved ultrasonic transducer with 16 elements
A reduced analogical conditioning chain (multiplexer, log amplifier, threshold detector).
A unity of control, treatment and visualization which can be implanted on a FPGA circuit.
To date, the tests of the various modules have showed the feasibility of the unit.

References

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