3D Palatography

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Abstract

Static palatography has been widely used to investigate consonant articulation. The method is based on the observation of the tongue print (a black paste is spread on the tongue before the production) either directly onto the palate (direct palatography) or onto a pseudo palate (indirect palatography).

This study has two main objectives. The first one is to provide an automatic analysis of the tongue print characteristic (size, shape, position onto the palate,...) in order to allow an objective description of the linguopalatal contact.

The second one concerns the shape of the palate. Indeed, a simple picture (2D) analysis does not take into account the shape (3D) of the palate vault. To alleviate this 2D limitation, we propose a method based on the use of structured light which enables the computation of the palate shape.

1 Introduction

Static palatography is an old method which has been used over years to study consonants articulations during speech production [1].

The method consists of analyzing the contact area where the tongue touches the palate during the articulation. In order to visualize this contact area, before the consonant production, a paste made half of charcoal and half of olive oil is painted over the tongue. After the consonant production, the articuloratory contact leaves a dark print onto the palate which is analyzed to characterize the articulation.

Palatography is said direct if the tongue touches the real palate. In this case, the tongue print is observed using a mirror (see figure 1). Palatography is said to be indirect, if an artificial palate is used. In this case, once the palate is placed in the mouth, the consonant is produced, and the artificial palate is then removed for its analysis.

Static Palatography (direct and indirect) had been used in many studies for more than a century, but in the sixties Electropalatography (EPG) came in [2,3], and permitted the study of dynamic contacts tongue/plate.

Electropalatography permits contact analysis over time, but it also shows limitations. Indeed, only points of the palate where electrodes are located are considered, the artificial palate can disturb the speaker. Lastly, as an EPG plate is expensive, so it makes difficult the proposition of studies which would require a large number of speakers [4]. On the other hand, static palatography takes into account the whole tongue print onto the palate. Moreover, the low cost associated to such studies permits to consider a large number of speakers.

The ensuing study has two main objectives. The first one is to propose an automatic analysis of the tongue print with the extraction of its characteristics. The analysis of characteristics of the print leads to efficient comparisons of production achieved by a given speaker but is also useful when comparing several speakers' productions.

The second one aims at knowing the shape of the palate without making an impression of the speaker's palate. Information about the palate shape is quite important to understand specificities of certain articulators behavior as previous studies pointed it out [5]. Knowing the palate shape also permits to compensate an intrinsic limitation due to the picture (2D) analysis whereas the palate is not flat. In order to permit palate classification we propose extraction of the 3D shape to make palate comparison possible.

2 Method

2.1 Shooting system

The shooting system used is inspired from the one described by Anthony [6]. We have slightly modified it (see figure1), keeping only the main mirror, and we have added a system to project the structured light in order to determine the palate's shape.

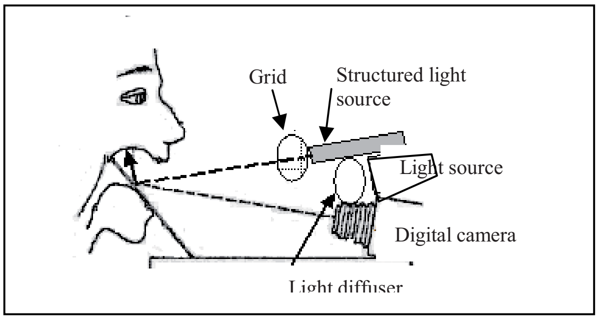

Figure1: *Static direct Palatography, shooting system (inspired from the one described by Ladefoged, 1957)*

In order to be able to extract real dimensions from the picture, a calibration target is present on each picture taken. This permits a conversion pixel to mm, even if camera adjustments are not recorded.

In case of indirect static palatography the shooting system is much simpler, as the artificial palate is removed from the mouth and set on a table to take the picture.

2.2 Picture analysis

Before any information extraction from the picture, the operator has to set three markers, thus in order to define automatically sixteen areas to perform tongue print shape analysis (see Figure 2).

The first marker is set between the two incisors and the two other markers, on the rear side of last molars.

In both case of direct or indirect palatography, the procedure to set markers and the picture analysis are identical. As analysis of the picture is essentially based on pixel counting, this is why the required format for pictures is BMP (BitMaP).

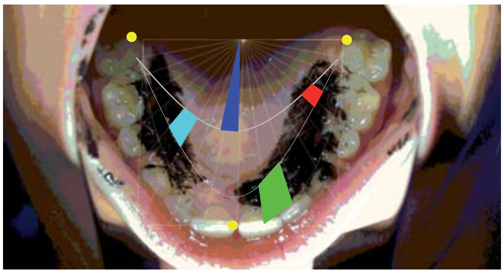

Figure 2: *Palatogram with the 3 yellow markers and 16 analysis areas (3 areas are coloured to highlight them)*

Pictures processed must be 256 color BMP pictures. This palette size is large enough for color analysis in case of palatography study. If one wants to process pictures with a larger palette, then a palette conversion must be first performed.

Various characteristics of the tongue print can be provided like its location onto the palate (referred to markers) and its "shape". To extract information about the print shape, for each area (16 in total, see figure 2) are computed: the center of gravity, the percentage of the considered area touched. Combining information for each of the sixteen areas, it is possible to determine symmetry parameters for the whole print (front/back, left/right). An average pattern can be computed over several pictures.

The proposed division of the palate (16 areas) can be overlaid on the one described by Lenz [7] which distinguished 6 different areas: alveolar, palatal (pre, medio, post) and two velar areas (pre and post).

3 Palate shape calculation

Knowing the palate shape is quite important, and Ladefoged in 1957, already emphasized that the study of the plate's impression was mandatory to get a better estimate of the print than the one we can extract from a picture (2D).

Moreover, several studies have previously pointed out that the palate shape impact articulator's behavior. So, once being able to classify palates' shape, then it is possible to run studies with atypical palates (wide, narrow, arched, flat, cleft) including the palate shape as a factor.

3.1 Principle

The principle consists of a projection of a structured light (a grid) onto the palate.

As the palate is not flat, columns and rows of the grid are distorted. Taking into account these distortions enables computation of the palate shape which caused the observed distortions.

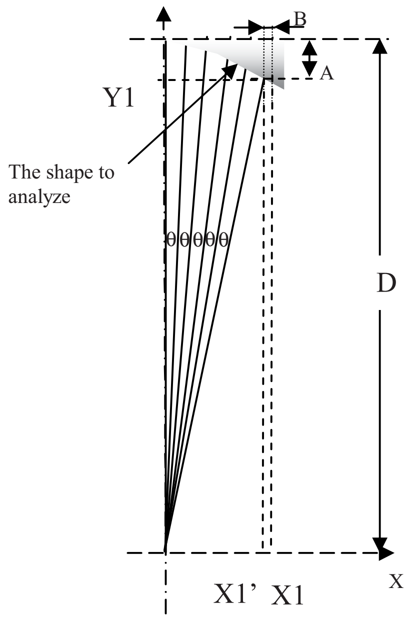

Figure 3: *Use of a structured light projected on the shape. Angle θ and the distance D are controlled parameters.*

The shape we want to measure is placed at a distance D from the light source. Each beam of the light source is separated by an angle θ. To do so, we have tested a laser source which by construction projects a matrix 7*7, and also tested the use of a strong white LED behind a screen drilled.

From figure 3 it appears that the information we want to get is the height of the shape (A) at a certain abscise X1'. If the shape was flat and thin then the spot would have hit it at abscise X1.

To calculate the height (A) the principle is to measure the gap between X1 and X1', respectively the expected abscise in case of the shape would be extremely fine, and the observed abscise where the spot hits the real shape.

The following equation permits to calculate A, from controlled parameters (θ, D) and from the observed gap spotted B on figure 3.

$$\mathbf{A=B.(\tan\theta)^{-1}} \qquad \textbf{Equation 1}$$

We can see that for a given horizontal axis (X1), a height of +A or –A leads to the same gap B. To deal with this ambiguity, we introduce a constraint that concavity is the expected global shape instead of convexity.

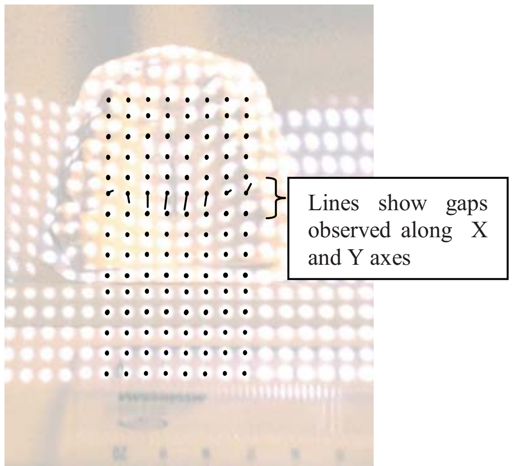

Figure 4: *View of an impression of a palate with a structured light grid projected on it. Lines show shifts between expected spots (if the palate was flat) and observed spots on the shape to reconstruct.*

To generalize Equation 1, to all spots of the grid:

Xs.DEFx=Xo DEFx: distortions matrix along X
Ys.DEFy=Yo DEFy: distortions matrix along Y

With:

Xs,Ys,Xo,Yo : matrix of coordinates respectively of the structured light grid without distortions (Xs and Ys) and of the observed grid with distortions (Xo and Yo).

Measuring distortions of the grid (gaps between the original grid and the observed one) enables the computation of the shape. To validate this method we used it successfully to characterize known shapes like a ball.

Once tested, this method had been used on a real impression of a palate. This configuration corresponds to the case of indirect static palatography when the palate is removed from the mouth and set in front of the picture shooting system (see figure below).

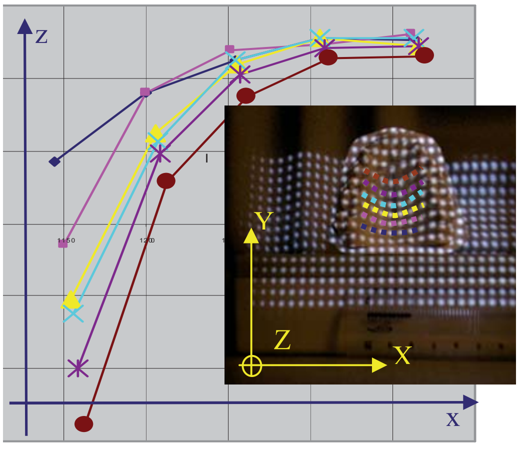

Figure 5: *View of a palate impression lighted by the structure grid. For lines drawn on the picture, the profile of the vault was rebuilt.*

This test shows that the method permits using structured light to obtain "Z information" from a picture (2D).

3.2 Use of the 3D shape

Many studies consider the shape of the palate as valuable information for the optimization of the analysis of palatograms. In order to describe palates or to classify them according to the shape of their vault we propose parameters (for some of them previously described).

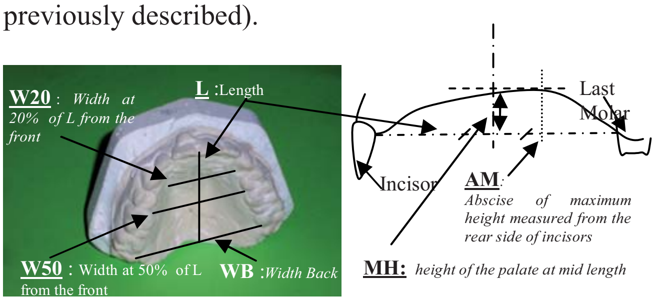

Figure 6: Palate description parameters.

4 Conclusion and perspectives

The automatic analysis of palatograms may revive interest in static palatography, as it provides an accurate description of the tongue print and then permits comparisons of several productions of a given speaker, but also helps when comparing several speakers' productions.

The knowledge of the palate shape can be a key point to understand certain consonant productions. Several tests performed on known shapes and on artificial palates have validated the method. It can be used for static direct and indirect palatography.

For Electropalatography studies, the description of the palate can also help. A set of virtual electrodes laid out on a palatogram provides an interesting overlap with usual EPG studies. When EPG gives a digital pattern of contacts (tongue/electrodes), static palatography takes over, going beyond the electrodes lay out and consider the whole print.

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