X-RAY MONITORING OF THE POSITION OF THE FIBERSCOPE BY MEANS OF COMPUTER CONTROLLED RADIOGRAPHY*

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A new laryngoscopic technique developed at our laboratory makes it possible to observe the larynx during running speech. The method employs a flexible thin fiberoptics cable inserted through the nasal passage into the pharynx of the subject.[1] In the course of this experimental work, it was found desirable to monitor the position of the tip of the fiberscope during utterances for quantitative analyses of the laryngeal images, because the position of the fiberscope may to some extent be affected by the articulatory gestures resulting in some errors in estimations of the laryngeal dimensions. For this purpose, x-ray monitoring of the position of the fiberscope is being tried by means of the computer controlled radiography developed in our laboratory. Details of the radiographic technique have been reported elsewhere.[2) - 5)]

Figure 1 shows an x-ray image obtained by an overall scanning of a rectangular field around the lower pharynx as viewed laterally. The central brighter area in the picture represents the lower pharynx cavity delimited by the posterior pharyngeal wall (and the vertebrae) to the right of the picture, the mandible in the upper portion and the back of the tongue root to the left. The fiberscope is seen as a rectangular shadow hanging down in the pharynx cavity.

It is seen in this picture that the contour of the back pharyngeal wall is the most apparent and at present, our scheme of automatic identification of the fiberscope is performed with reference to this contour.

First, a line scanning is made from front to back at the throat of the subject in search of the back pharyngeal wall. Variations in the x-ray intensities along such a scanning line are shown in Figure 2. As the

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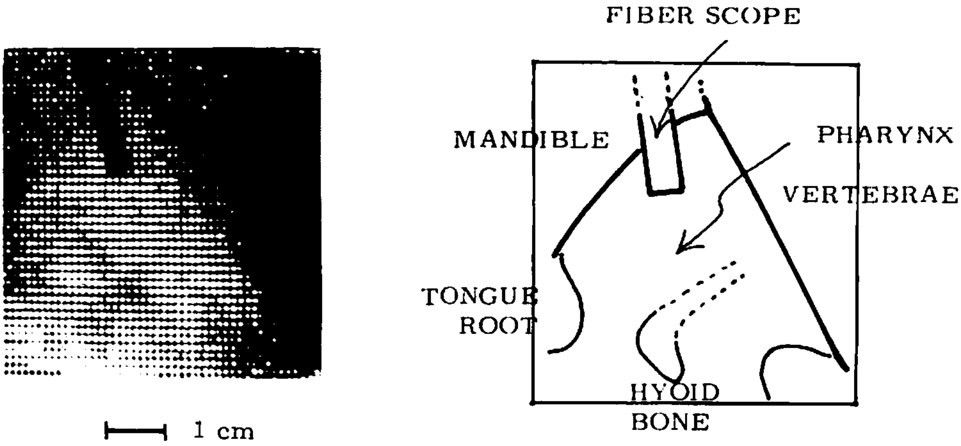

Figure 1. A lateral x-ray view of the lower pharynx obtained by an overall scanning of a rectangular field of 5 cm x 5 cm.

scanning proceeds from left to right (from front to back), a flat plateau is observed on this curve corresponding to the pharyngeal cavity, and beyond this point the x-ray intensity decreases as the scanning point comes close to the back wall of the pharynx. Starting from a sample point selected on this line based on the gradient of radiopacity, an equal brightness contour is traced upwards. With an appropriate threshold value selected, the contour of the posterior pharyngeal wall, the tip of the fiberscope and the inferior margin of the mandible can be traced continuously. When a portion of the contour that is protruding downwards is found, this is taken as a candidate of the

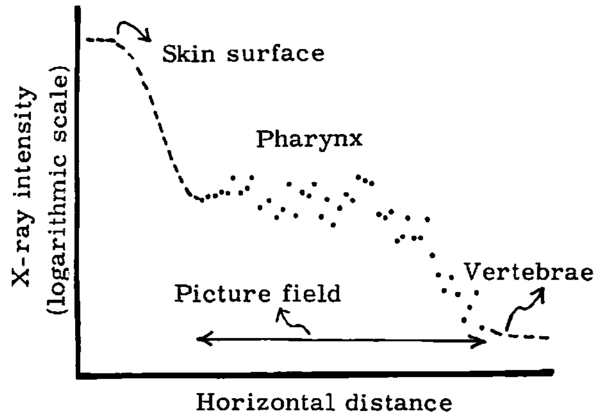

Figure 2. Variations in the x-ray intensity along the horizontal scanning line. The scanning line is located approximately 1 cm above the bottom of the picture in Figure 1.

contour of the fiberscope and the x-ray intensity inside and outside the contour are compared for reconfirmation of the existence of the fiberscope.

In most cases, the fiberscope is located close to the back pharyngeal wall and slight inadequacy in the estimation of the threshold value makes it impossible to trace the contour of the space between the fiberscope and the back pharyngeal wall correctly. In the present computer program, several starting points are selected on the initial scanning line and the contour tracing is repeated with different threshold values until the fiberscope is found. Figure 3 shows the outline of the identified fiberscope obtained by this procedure from the stored intensity data of the picture in Figure 1. The less bright spots represent the entire set of sample points examined for this process of object recognition.

Once the tip of the fiberscope is identified, the x-ray exposures are given only to a minimal number of sample points that are necessary for determining the position of the object, and its movement is automatically tracked. The sample points for the tracking mode are selected as shown in Figure 4. By comparing the intensity values at 9 contiguous sample points

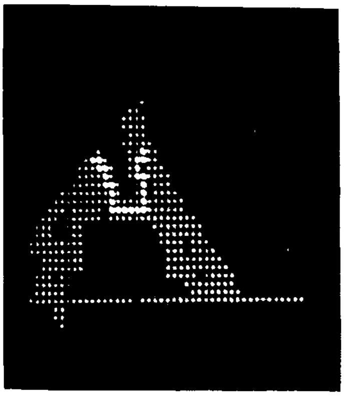

Figure 3. An outline of the identified fiberscope (brighter spots). The less brighter spots represent the entire set of examined sample points during this object recognition process.

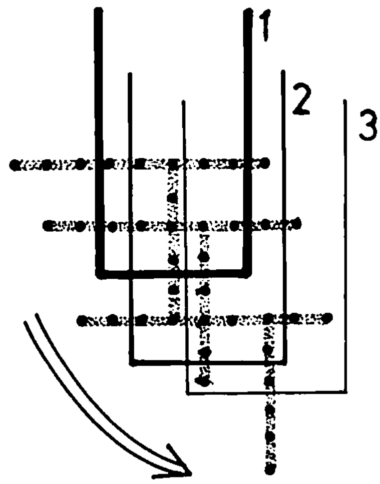

Figure 4. Sample points to be exposed for determination of the position of the fiberscope during the tracking of its movement. Three successive "frames" are shown.

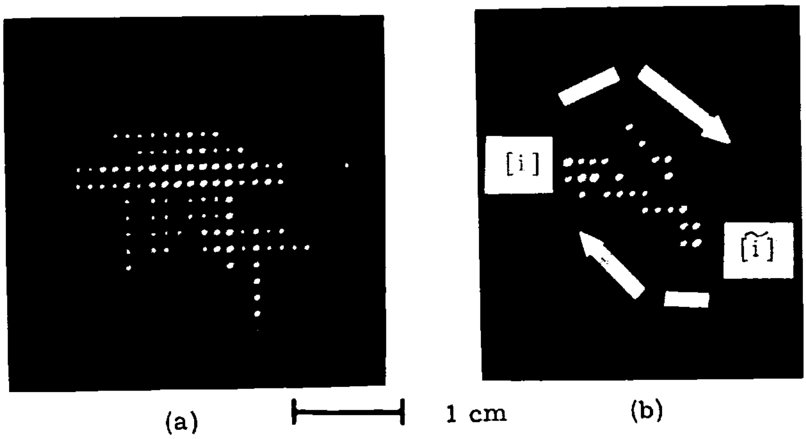

Figure 5. (a) T-shaped arrays of the exposure points over 15 frames during an [i] to [ĩ] transition. (b) The track of the position of the tip of the fiberscope automatically determined in real time over a 1-sec time interval during the test utterance of [i:ĩ:i:].

on a horizontal line, a point on the longitudinal center axis of the fiberscope is determined and starting from this point, 6 sample points in the vertical direction is exposed for determining the lower edge of the fiberscope. The position of the next horizontal scan is updated according to the detected position of the fiberscope.

Among various articulatory gestures, movement of the velum is considered to affect the location of the fiberscope most directly. For the purpose of testing the method described above, the subject uttered a test sound sequence [i:ĩ:i:ĩ: . . .] and the tracking of the position of the fiberscope has been tried. Figure 5 (a) shows the superimposed oscilloscope display of the T-shaped arrays of the exposed sample points for successive 15 time frames duirng an [i] to [ĩ] transition. The track of the determined position of the tip of the fiberscope over a 1-sec time interval is shown in Figure 5 (b). The movement of this identified object can be monitored in a slow motion picture style on the oscilloscope display of the computer.

By the present method, 15 sample points are exposed for one frame determination of the position of the fiberscope, and we need with the presently available pilot x-ray generator an exposure time of approximately 1 msec per sample point.* Thus, the resulting rate is equivalent to approximately 60 frames/sec.

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* We employ a variable exposure method where the exposure time for a sample point is determined depending on the observed radiopacity, so that roughly a constant x-ray intensity is observed regardless of the radiopacity within a certain range of variation.

References

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