Computer Analysis of Radiographic Images

by

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Introduction

The interpretation of radiograms is ordinarily done by the eye of an attending physician or dentist and, for this reason, there is much possibility for subjective difference to creep in this kind of diagnostic information handling. The subjective difference is principally accounted for by the degree of familiarity which the physician or dentist has with his specialized subject and that of his experience in the art of radiographic interpretation. At any rate, it is believed that the physician or dentist will increase his skill in proportion to his exposure to the clinical experience. Although this belief is by no means wrong, there is lacking a definite metrical element in this kind of subjective analysis.

The present report is concerned with our efforts of introducing as much objective interpretation as possible into the radiographic analysis in dental field by the conjoint use of an electronic computer and micro-photometer.

Method

Previous reports dealing with the electronic computer analysis of radiograms in confined to those of the chest film and the number of diagnostic informations is relatively small [1-6]. In addition, in these reports there are found obscure elements arising from the scattering of fluorescence grains out of the intensifying screen in the exposal process of X-irradiation. It cannot be denied that these scatterings certainly affect an adequate interpretation of radiographic images to a considerable degree [7, 8].

By way of a material which did not contain this kind of hindrance to the image analysis, we used an intra-oral radiogram of the normal teeth and their alveoli (Fig. 1). This relatively small radiogram, 40.5 x 30.5 mm, includes two premolars and two molars together with their alveolar bones and part of the mandibular structure. For this reason, our radiogram can be said to give us more definite diagnostic information than a chest radiogram of similar size concerned with just one focus.

Image Analysis Procedures

Our procedures adopted for the present study are schematically given in Fig. 2.

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The gist of the present study was read before the 27th general meeting of Nippon Societas Radiologica in 1968, held in Kyoto.
1. Quantification of relative density.

The above radiogram was continually scanned over its entire surface by the micro-photometer and the output currents of photomultiplier were sent into the analog-to-digital converter, which formed a constituent of the electronic computer system, through the filter. The scan slit of these photo-multipliers was limited to 50 X 50 microns. In the scanning, the distances of sampling points were established in such a manner that they were recorded at intervals of 0.5 mm on the X-axis and 1.0 mm on the Y-axis. In other words, 2400 spots were read on the radiogram altogether which resulted in 2400 different shades of relative density and they were expressed within the scope of bi-quinary notation, 0-155.

2. Retrieval of quantified data.

Data coming out of the A/D converter were sequentially stored in the computer memory unit through the medium of punched paper tape having six-bit holes.

3. Data printout.

Dots indicating different shades of relative density on all the sample elements were automatically printed out on a recording paper. By linking these dots it was possible to obtain a configuration which closely approximated the radiographical pattern of the sample used.
In this operation, there was a possibility that, because of differences in the type writer spacing and the arrangement of numerals, an exact configuration was sometimes difficult to obtain. However, it was rectified by a method to be explained in the ensuing sections.


For the purpose of differentiating the teeth from the bone structure in the original radiogram, it was necessary to establish a certain boundary within the dot range and place all the numerical informations into two divisions. Thus, they were subject to the binary valuation in terms of discriminant functions and were printed out by specific symbols (Fig. 3). It was possible to prepare a visual display in a similar manner by connecting a digital plotter on the on-line basis (Fig. 4).

![Fig. 3. Binary Valuation Display Using Automatic Typewriter](image)

Note: Binary level is the same as in Fig. 4.

Published literature is available which used the same method for the recognition and analysis of tumoral pattern of lung cancers [1-6]. This method is thought to be particularly effective, when a contrast medium is used to bring about pronounced relative density on the part of abdominal organs or a radioisotope is used to analyze the scan image.

However, for the type of study undertaken by us in which the image is made up of numerous varying shades of relative density a more exact method of information retrieval is undoubtedly desired.


The patterns printed out by the output typewriter did not exactly represent those of the original image and it was also true that some other programme of coding the data than the numerals would not satisfy our need in this respect.

From this thinking, we devised a method whereby the quantified data would be classified into certain levels and assign specific symbols to each of these levels for coding purposes.

The following calculation method was adopted to evaluate the different levels established.

Each sampling point was taken to constitute the meshes of $m$ and $n$ with $X_{ij}$ ($i=1, 2, 3, \ldots, m$), ($j=1, 2, 3, \ldots, n$). With this matrix, the vector of sample means was obtained.

$\overline{X_i} = \frac{1}{M} \sum_{i=1}^{m} X_i$, $\overline{X_j} = \frac{1}{N} \sum_{j=1}^{n} X_j$

The result was subjected to weight function, where $w \cdot x = \sum_{i=1}^{m} \sum_{j=1}^{n} x_{ij} \cdot w_{ij}$. After the mean $w \cdot \overline{x_{ij}}$ of the inner area of each sample was calculated, $f(x) = 1$ in case of $w \cdot \overline{x_{ij}} \geq T$ (plus real quantity) or $f(x) = 0$ when $w \cdot \overline{x_{ij}} < T$ was used.

### Table 1

<table>
<thead>
<tr>
<th>(1)</th>
<th>****</th>
<th>0-5</th>
<th>(6)</th>
<th>*</th>
<th>41-50</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2)</td>
<td>***</td>
<td>6-10</td>
<td>(7)</td>
<td>+</td>
<td>51-80</td>
</tr>
<tr>
<td>(3)</td>
<td>**</td>
<td>11-20</td>
<td>(8)</td>
<td>-</td>
<td>81-100</td>
</tr>
<tr>
<td>(4)</td>
<td>***</td>
<td>21-30</td>
<td>(9)</td>
<td>Blank</td>
<td>101-255</td>
</tr>
<tr>
<td>(5)</td>
<td>**</td>
<td>31-40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1. $X_i \ldots X_m = 80$, $X_j \ldots X_n = 30$

$M \times N$ matrix of 2400 elements.

2. $X_{ij}$ mean value = 28, Standard deviation = 13.
7. **Retrieval display of the patterns by means of digital plotter.**

As stated in 3.2, all the shades of relative density from 0 to 255 were classified into 9 levels, to each of which specific codes were assigned. These codes were plotted digitally for the purpose of visual display. The different levels were plotted in a matrix, 2 mm × 4 mm, from the shades of high density to those of low density by the use of *, +, − symbols (Fig. 5).

Fig. 5. Multitudinous Valuation Display

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**Discussion**

The present study is chiefly concerned with an application of the latest A/D electronic computer to the image analysis of radiograms used in dental science. It is to be admitted, of course, that much improvement and new technique are still called for in order to obtain a fully satisfactory technical effect [9, 10, 11].

At any rate, this kind of attempt is not directed at the comparison of a human and a machine concerning the respective skills of perception [12] but its sole purpose is to introduce definite metrical criteria into the interpretative procedures on radiographic images.

Although it takes only 10 microseconds to retrieve a piece of data by the computer used by us, the entire operation will take several hours when the scanning time of microphotometer and plotting of digital display are added.

To top it all, effort and time needed for programming a system which enables us to establish an information retrieval with a minimum of error are quite huge.

However, it is definitely clear that the quantification, though partially, of uncertain elements currently existing in our radiographic interpretation will make tangible contributions to better and more objective diagnosis of radiograms.
Conclusions

As a result of our electronic computer analysis of radiographic image, we arrived at the following conclusions.

1. We succeeded in scanning a standard dental radiogram by the microphotometer and, subsequently, obtained electrically 2400 points representing varying shades of relative density. These were filed in a memory storage through the analogue-to-digital conversion.

2. The varying shades of relative density of each element were quantified and mathematically treated. Through these operations, different patterns could be clusterized.

3. The data were plotted out in the form of digital display. This kind of display is regarded as a useful tool to have better understanding of a radiogram containing uncertain elements.

4. Throughout our experimental stages, it was possible to subject the data to the quantification. On the strength of these findings, we can safely conclude that it is possible to introduce the metrical criteria into the radiographic interpretation in the future.

References