

AUTOMATIC REGISTRATION OF DENTAL RADIOGRAMS

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ABSTRACT:

In this paper we propose a feature based method, which employs a fuzzy reasoning strategy for registration of two different dental radiograms. The fuzzy decision process for conjugate feature determination simultaneously takes advantage of all the influential parameters that contribute during the conjugate feature identification stage, namely: geometrical constraints, radiometric similarities evaluated by correlation coefficient as well as texture differences. Simultaneous combination of these constraints blended into a fuzzy decision making process may offer the potential for reducing the mismatching possibilities. At the end, the registration outputs the set of transformations that can be used to correctly map the input image to the reference image. The tests carried out on registration of real periapical and panoramic dental radiograms demonstrate the high potentials of the proposed strategy.

1. INTRODUCTION

Within the current clinical setting, dental radiography is a vital component of a large number of applications. Such applications occur throughout the clinical track of events; not only within clinical diagnostics settings, but prominently so in the area of planning, consummation, and evaluation of surgical and adiotherapeutical procedures.

Depending on the relative position of the film and the patient and the resolution of the films and the case of exposing the radiograms, dental radiograms are separated into two major groups, *Intraoral* and *Extraoral* radiograms (Woods and Pharoah, 1994; Whaites, 2003).

1.1 Intraoral Radiograms

In this case, the radiogram is made as a double emulsion film (emulsion is on both sides of the base of the film). With this kind of films, less radiation can be used to produce an image, either, the resolution of these kind of radiograms are more in comparison to extraoral radiograms. In this case, the film is placed inside the mouth of patients. Intraoral radiograms can be divided into three categories (Figure. 1).

Periapical: Periapical views are used to show the crowns, roots, and surrounding bone. Each film usually shows two to four teeth. **Bitewing:** Bitewing (Interproximal) views are used to record the coronal portions of the maxillary and mandibular teeth in one image. **Occlusal:** Occlusal views are used to show larger areas of the maxilla or mandible than may be seen on a periapical film. Here, the film is usually held in position by having the patient bite on it to support it

between the occlusal surfaces of the teeth (Woods and Pharoah, 1994; Whaites, 2003).

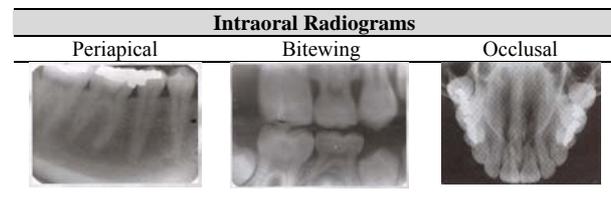


Figure 1. Intraoral radiograms types

1.2 Extraoral Radiograms

These kinds of radiograms include all views made of the orofacial regions with films positioned extraorally. These radiograms are used to examine areas not fully covered by intraoral films or to visualize the skull and facial structures. Extraoral radiograms can be divided into three categories (Figure. 1).

Skull and maxillofacial: Skull and maxillofacial radiograms show different views of the head bones depending on the different projections have had to be devised. **Cephalometric:** Cephalometric radiography is a standardized and reproducible form of skull radiography used extensively to assess the relationships of the teeth to the jaws and the jaws to the rest of the facial skeleton. **Panoramic:** Panoramic (Pantomography) technique is used for producing a single image of the facial structures that includes both the maxillary and mandibular dental arches and their supporting structures.

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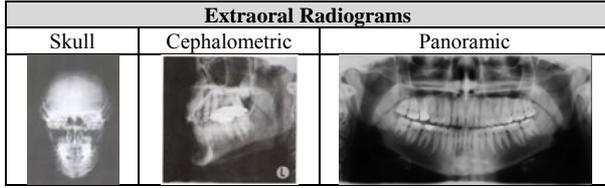


Figure 2. Extraoral radiograms types

2. REGISTRATION OF DENTAL RADIOGRAMS

Since information gained from different dental radiograms acquired in the clinical track of events is usually of a complementary nature, proper integration of useful data obtained from the separate radiograms is often desired. The first step in this integration process is to bring the modalities involved into spatial alignment, a procedure referred to as registration. The goal of image registration is to find a transformation that aligns one image to another. Dental radiogram registration has emerged from this broad area of research as a particularly active field. This activity is due in part to the many clinical applications including diagnosis, longitudinal studies, and surgical planning (Kim and Muller, 2002).

Medical image registration, however, still presents many challenges. Several notable difficulties are a.) the transformation between images can vary widely and be highly nonlinear (elastic) in nature; b.) images acquired from different modalities may differ significantly in overall appearance and resolution; c.) there may not be a one-to-one correspondence between the images (missing/partial data); and d.) each imaging modality introduces its own unique challenges, making it difficult to develop a single generic registration algorithm (Josien *et al.*, 2003).

3. PROPOSED METHODOLOGY

In this paper we propose a feature based hierarchical method, which employs a fuzzy reasoning strategy for digital image matching process and hence the matching operation is designed to be closer to the human operator's decision making approach for the conjugate point identification. The fuzzy decision process for conjugate point determination simultaneously takes advantage of all the influential parameters that contribute during the conjugate point identification stage, namely: geometric constraints, radiometric similarities evaluated by correlation coefficient as well as texture differences. The overall strategy for our proposed registration method may be expressed by the following interrelated procedures:

3.1 Multiresolution representation of information

One of the main requirements needed for all registration algorithms is approximate values of two corresponding points which is related to the interrelation mathematical model of two images (or images and map). The best known solution to derive these approximations is to construct image pyramids and start the matching process at a low resolution level (i.e. from the top of the image pyramids). This can provide rough approximate values for the successive levels of image pyramids.

- *Multiresolution representation of Dental Radiograms:* Construction of image pyramids in this paper is carried out according to wavelet transform. The wavelet transform features are used because wavelet transforms convey both space and time characteristics and their multi-resolution representations enable efficient hierarchical searching.

- *Multiresolution representation of Point Features:* Based on the generated image pyramids, the implemented system also extracts and constructs feature pyramids by applying a Forstner operator to each layer of the image pyramids (Foerstner and Guelch, 1987). The general structure of the normal equation matrix for the intersection points (x_0, y_0) by the Foerstner operator is given by:

$$\begin{bmatrix} \sum I_x^2 & \sum I_x I_y \\ \sum I_x I_y & \sum I_y^2 \end{bmatrix} \cdot \begin{bmatrix} x_0 \\ y_0 \end{bmatrix} = \begin{bmatrix} \sum I_x^2 \cdot x + \sum I_x I_y \cdot y \\ \sum I_x I_y \cdot x + \sum I_y^2 \cdot y \end{bmatrix} \quad (1)$$

where I_x and I_y are the local gradients in x and y directions respectively. The summation is performed over a predefined neighbourhood area.

- *Multiresolution representation of Mathematical Models:* Mathematical modelling approaches for orientation and registration of different dental radiogram have been done based on a multiresolution representation of *Generic Sensor Models* (GSMs), e.g. Rational functions. The Rational function uses a ratio of two polynomial functions to compute the x coordinate in the image, and a similar ratio to compute the y coordinate in the image.

$$x = \frac{p1(X,Y,Z)}{p2(X,Y,Z)} = \frac{\sum_{i=0}^{m_1} \sum_{j=0}^{m_2} \sum_{k=0}^{m_3} a_{ijk} X^i Y^j Z^k}{\sum_{i=0}^{n_1} \sum_{j=0}^{n_2} \sum_{k=0}^{n_3} b_{ijk} X^i Y^j Z^k}$$

$$y = \frac{p3(X,Y,Z)}{p4(X,Y,Z)} = \frac{\sum_{i=0}^{m_1} \sum_{j=0}^{m_2} \sum_{k=0}^{m_3} c_{ijk} X^i Y^j Z^k}{\sum_{i=0}^{n_1} \sum_{j=0}^{n_2} \sum_{k=0}^{n_3} d_{ijk} X^i Y^j Z^k}$$

Where x, y are normalized pixel coordinates on the image; X, Y, Z are normalized 3D coordinates on the object, and a_{ijk} , b_{ijk} , c_{ijk} , d_{ijk} are polynomial coefficients. The polynomial coefficients are called rational function coefficients (RFCs).

3.2 Geometric and Semantic Conditions

Certain factors can be employed to assist the conjugate point determination process. These factors may be categorized into geometric and semantic conditions. *Geometric Conditions:* The geometric parameters are considered to include the object and imaging geometry represented by x and y differences which are related to different mathematical models in each layer of information. *Semantic Conditions:* The semantic conditions are defined based on the radiometric similarities between the conjugate points. This can be determined via different similarity assessment algorithms. Our method takes advantage of two different algorithms, namely: the well known normalized correlation coefficient (NCC) and the rank differences. The so called rank values are computed using window arrays constructed around

already generated salient points. The rank of a window is an integer value denoting the gray shade rank of the central pixel as compared with other pixels of the window. It is assumed that conjugate features should demonstrate a rather similar rank values. Our experiment with different data sets show that the rank values can contribute effectively to the determination of the conjugate features.

3.3 Matching of Corresponding Key Points Based on Fuzzy Logic

Although in the classical image matching approaches radiometric and geometric conditions are effective tools for the determination of the conjugate points, in practice, however, the main problem with these methods is their inability to reliably and realistically fuse these conditions for decision making. There are several schemes for the fusion of different conditions (Strother *et al.*, 1994).

Fuzzy reasoning is one of these methods by which the parameters that influence the decision making process can be realistically fused using a human like reasoning strategy. This is achieved by defining the so called linguistic variables, linguistic labels and membership functions. The fuzzy reasoning process is then realized using the fuzzy if-then rules that enable the linguistic statements to be treated mathematically (Nyongesa and Rosin, 2000). Our proposed linguistic variables (Table 1) are: (a) y-difference, (b) x-difference, (c) correlation coefficient, and (d) rank differences. The first two items control the geometric side and the last two items control the semantic part of the matching operations. For each of these items membership functions are defined by an experienced photogrammetric operator.

TABLE 1. Linguistic variables and labels for the fuzzy based image matching operation.

		Linguistic Variables	Linguistic Labels
Input	Geometric	<i>Y Difference</i>	<i>Very Small, Small, Large, Very Large</i>
		<i>X Difference</i>	<i>Very Small, Small, Medium, Large, Very Large</i>
	Radiometric	<i>Correlation</i>	<i>Very Weak, Weak, Medium, Good, Fine, Excellent</i>
		<i>Texture Diff</i>	<i>Very Small, Small, Medium, Large, Very Large</i>
Output	Conjugate	<i>Conjugation</i>	<i>Not, Probably Not, Probably Yes, Yes</i>

4. EXPERIMENTS AND RESULTS

The potential of the proposed method is evaluated using a real periapical and panoramic dental radiograms (Figure. 3). Registration process is performed hierarchically using five-layer image pyramids. Each pyramid layer has four times reduced resolution in relation to its previous layer.

Table 2 shows the independent results for each pyramid layer obtained by the fuzzy logic process. A comparison between the number of the detected features in each layer and the number of matched points (see Table 2) clearly indicates how the fuzzy reasoning process has eliminated some of the points in each layer. These are the points for which the geometric and the radiometric conditions have not been satisfied according to the fuzzy parameters settings.

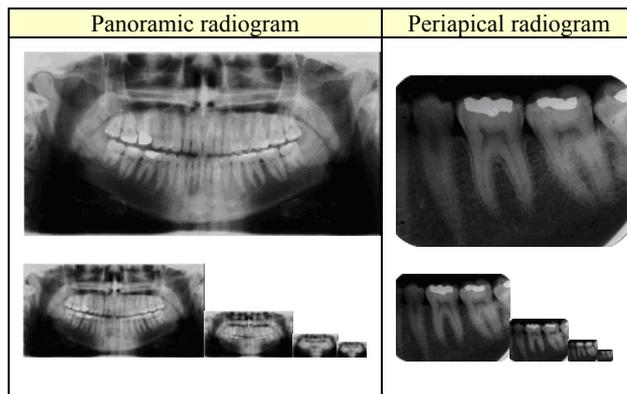


Figure 3. Evaluation data set

Table 2. The number of matched points and the corresponding residual errors on different layers

Layer	Reference Image Points	Target Image Points	Match Points	Method	Order
5	10	7	5	P2=P4	1
4	19	13	11	P2=P4	2
3	28	25	19	P2=P4	2
2	37	32	29	P2≠P4	2
1	49	41	38	P2≠P4	2

Figure 4. shows the final result of registration of prepaical radiogram to panoramic radiogram base on the formulation of last layer of matching process (layer -1).



Figure 4. Registration result

5. CONCLUSION

The proposed automatic image registration method discussed in this paper, has proved to be very efficient and reliable for automatic registration of different dental radiograms. The implemented methodology has characteristics of a) Utilization of a multiresolution representation of information and mathematical models, b) Employing a fuzzy reasoning system for conjugate feature identification and modelling.

In spite of the success which is gained in the implementation of the presented method, the topic by no means is exhausted and still a great deal of research works are needed. These research works should be focused mainly on the development of a more sophisticated fuzzy reasoning system, interest operator and matching strategy. All of these are currently under investigation in our institute.

6. REFERENCES

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