Effective Strategies for ROI and Image Matching

Dr. Khaled M. G. Noaman
Associate Professor
Department of Distance Learning
Deanship of E-Learning and Distance Learning,
Jazan University
Jazan, Kingdom of Saudi Arabia (KSA)

Dr. Jamil Abdulhamid M. Saif
Associate Professor
Information Systems Department
Community College of Bisha, Bisha University
Bisha, Kingdom of Saudi Arabia (KSA)

***Abstract*—The paper presents an exceptional four matching strategies: systematic, random, gradient and simulated annealing using diferent metrics. We consider two kinds of image matching algorithms. The first one oriented on the whole image matching where we compare corresponding pixels or chosen image characteristics. The second one is oriented on finding the region in the target image (region of interest ROI) , which match best the ROI given in the template image. For our experiments we take the list of target images, directly from the atlas, and a subset of these images as the template images.**

Keywords—systematic; random; gradient; simulated annealing

I. Introduction

Presently digital image processing has a broad spectrum of applications, such as multimedia systems, business systems, monitoring and inspection systems, archiving systems. Architectures of such systems are much complex (see Fig. 1). In spite of digitisation, storage, transmission, and display operations, extra functions are considered. They are as follows: image data compression and representation, image enhancement and reconstruction, image indexing retrieval and matching, etc. and they are executed on application oriented servers.

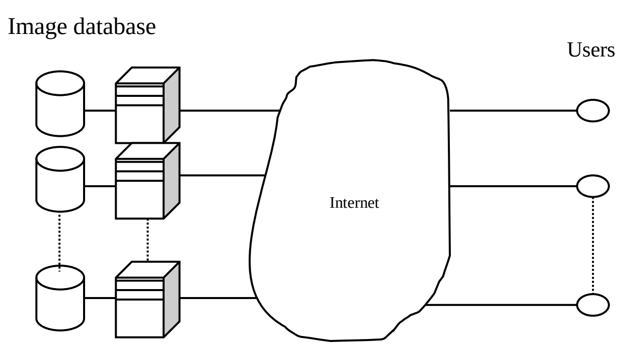


Fig. 1. Modem digital image processing system

In medical applications clinical diagnosis as well as evaluation of therapy is often supported by image processing systems. Such techniques as SPECT (Single Photon Emission Computed Tomography), PET (Positron Emission Tomography), MRS (Magnetic Resonance Spectroscopy), MRI (Magnetic Resonance Imaging), or ultrasound and X-ray scanning are largely used and developed [1,2]. The Internet creates a new possibilities for medicine diagnosis. Application of multiedia systems provides a real-time medical monitoring multi-party consultations and distance collaborations. Examples of such solutions are the following systems:

1) MedNet - used in brain surgery [3],

2) Telematic microscopy system used in diagnostics of histopathology [4],

3) Medinet - used in diagnostics of teleradiology [5].

The rest of this paper is organized as follows: section 2 presents the matching problem and defines the similarity for Whole image and region-based image matching. In section 3, experimental results are presented and discussed, also the effectiveness of our proposed method are discussed. The conclusion and the proposal of future works are given in Section4.

II. Image Matching Problem

A digital image (I(m,n), m, n-integers) [6,7,8] is usually the result of discretization process of a continuous image function I(x, y) x, y ∈ R, and it is stored in a computer memory as a two dimensional array A, where A=[A(m, n)], m= 1, 2, ..., M, n=1, 2, ..., N; i.e:

We limit our considerations to the discrete image describing by two dimensional array A. However, other image dimensions can be taken into account (1D, 3D, ..., etc.) [9,10], depending on what kind of imaging systems is used to create digital images. Each A(m, n) element of the array A corresponds to a pixelwhich describes some properties of the image. We can use many shades of grey typically 16 or 256 to represent the pixels. However, grey scanning requires larger amounts of memory. In spite of a greyscale images are simple and have less information in comparison to colour images. It is possible to construct all visible colours by combining the three primary colours: red, green and blue (RGB colour image).

A. Image Matching Algorithms and related definitions

Theimage matching algorithms for the compared images or ROIs regarding the accuracy can be evaluated by the similarity degree, therefore we give the following definition that is needed for the matching problem.

<u>*Def*inition 2.1.</u>

Let be given matrix A1 representing a template image I1 and matrix A2 representing a target image I2. For images I1 and I2 the following three cases should be considered:

1) Images are the same (A1=A2) if and only if similarity criteria SC (A1, A2)=1.

2) Images I1 and I2 are similar if and only if $\Delta \leq SC(A1, A2) < 1$.

3) Images I1 and I2 are different if and only if $0 \leq SC(A1, A2) < \Delta$.

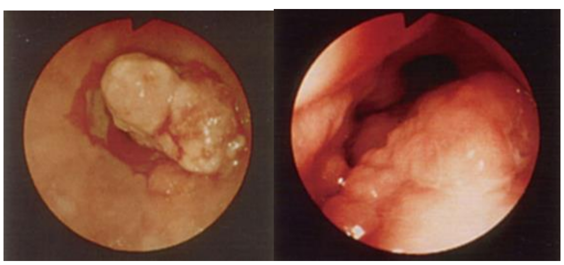
Similarity criteria SC and threshold Δ (SC ε < 0, 1> and Δ ε < 0, 1>) can be chosen arbitrarily for each class of matching algorithms.

In case of pixel to pixel comparison [11,12], we can define similarity criterion SC(Ik, Ik+1) as the following formula:

$$MS = SC\left(I^{k}, I^{k+1}\right) = \sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\left[A^{k}(i,j) - A^{k+l}(i,j)\right]^{2}}$$

(2.1)

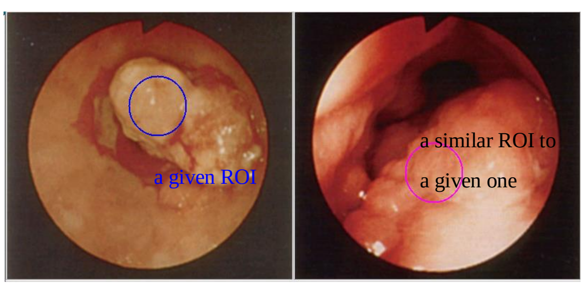
where $A^x(i, j)$ is the pixel digital value for x^{th} image, it can be referred either to the whole image or to its ROI (see Fig. 2, 3). In many cases the similarity degree MS is higher for ROI than for the whole images. In case of ROI the similarity criterion should be suitable modified (i.e. proper pixels are only compared).



a b

similarity degree = 0.8394

Fig. 2. Example of matching two images, a) template, b) target



a b

similarity degree = 0.8718

Fig. 3. Example of matching two ROI, a) template, b) target

B. Image Matching Algorithms

To solve the matching problem we propose four algorithm[13], systematic (lexicographical) searching, gradient searching, random searching and simulated annealing searching, that define the methods of searching the ROI in the target image that is best match the one specified in the template image. In systematic searching algorithm an initial location of the ROI is assumed to be on the left top corner of the target image, the the center of the ROI is moved from left to right and up to down in the target image with specific step of pixels, for each location of the ROI the relative similarity degree is calculated, at the end the location with the best similarity degree is pointed out as the best solution. Gradient searching algorithm can assume a random choice of the initial location of the ROI in the target image, next we calculate the step and the direction of the ROI movement, to find the best matching location we decrease the step twice in each iteration that returned the optimal location, and from that location we repeat this process of searching we get the best matching location. In random searching we determine only the number of iterations and every iteration the location of the ROI is randomly selected, after such process the optimal location with the best matching similarity of the ROI in the target image is returned. Finally in simulated annealing searching algorithm also the initial location of the ROI in the target image is selected randomly with a given number of iterations and with high starting temperature which is reduced in each iteration according to the annealing scheme, the location of the ROI in each location then is changed with probability determined by the generation function and the similarity degree is calculated for the new location with probability determined by the acceptance. After reaching the maximum iteration, we choose the optimal solution the found solutions.

III. Experimental Results and Discussion

Experiments are carried out for endoscopic and the obtained results discussed in order to evaluate the different searching procedures, that helps choosing the best procedure of matching the whole endoscopic image, as well as ROI searching. The representative benchmarks for illustration of our considerations is presented in table 1., where there are different endoscopic images (size of 800 x 720 pixels), chosen from endoscopic atlas [14] among 1500 available images. We concentrate on stomach diseases, and include five images (from 1 to 5), corresponding to healthy patients, next nine images (from 6 to 14) contains some changes referring to typical (representative) stomach diseases. The last five images from 15 -19 represent similar changes regarding to appearance.

TABLE I. Detailed Description of the Endoscopic Images Belonging to the Test Benchmark

The number of image in Fig. 5.1	**Its atlas number**	**Description of changes in the endoscopic images**
1	1_24	Formix fundus, healthy
2	1_25	Corpus venriculi, healthy
3	1_26	Corpus ventriculi, healthy
4	1_27	Antrum, anqulus, healthy
5	1_32	Antrum, healthy
6	6_15_a	Ventriculus, cancer
7	6_18_a	Ventriculus, cancer
8	6_18_b	Ventriculus, cancer
9	6_18_c	Ventriculus, cancer
10	6_23	Ventriculus, cancer
11	6_25_b	Ventriculus, cancer
12	6_5	Corpus, cancer
13	6_8_a	Corpus, cancer
14	6_8_b	Corpus, cancer
15	6_27	Fundus ventriculus, cancer
16	6_30_b	Fundus ventriculus, cancer
17	6_32_c	Corpus ventriculus, cancer
18	6_3_a	Corpus, antrum, cancer
19	6_6	Cardia, cancer

A. Image and ROI matching strategies

We consider two kinds of image matching algorithms. The first one oriented on the whole image matching where we compare corresponding pixels or chosen image characteristics.

The second one is oriented on finding the region in the target image which matches best the ROI given in the template image. In our experiments we take the list of target images, directly from the atlas, and a subset of these images as the template images. In case of simple matching criteria (MS – formula (2.1), IF - formula [13] the similarity degree for the whole image gives value 1 for the same image. Table 2. confirms such cases.

Let consider ROI - oriented matching for the same set of template and target images. Note that even in case of the same compared images values of similarity degree are not equal to 1. Moreover, we can find higher value of these criteria for different images than for the same images see the first and the column of Table 3. However, it does not mean that this kind of matching is not practically acceptable.

TABLE II. THE SIMILARITY DEGREE VALUES FOR THE WHOLE IMAGE MATCHING

No of template images / No of target images	1	2	7	11	16	17
1	**1.0000**	0.7910	0.6744	0.7353	0.8140	0.6342
2	0.7910	**1.0000**	0.7529	0.7583	0.7792	0.7437
3	0.7715	0.8285	0.7465	0.7512	0.7945	0.7461
4	0.7479	0.8515	0.7985	0.7351	0.7617	0.7591
5	0.8185	0.8385	0.7415	0.7460	0.8062	0.7311
6	0.6928	0.7135	0.7637	0.7617	0.7734	0.7442
7	0.6744	0.7529	**1.0000**	0.7421	0.7211	0.7845
8	0.7142	0.7805	0.7859	0.7695	0.7562	0.7649
9	0.6677	0.7925	0.7453	0.6623	0.6703	0.7463
10	0.7232	0.7870	0.6684	0.7332	0.7623	0.7463
11	0.7353	0.7583	0.7421	**1.0000**	0.7949	0.7133
12	0.7429	0.8167	0.7500	0.7342	0.7790	0.7706
13	0.6685	0.7579	0.7860	0.7338	0.7417	0.8343
14	0.7964	0.8451	0.7704	0.7711	0.8210	0.7728
15	0.8016	0.8232	0.7691	0.7739	0.8049	0.7482
16	0.8140	0.7792	0.7211	0.7949	**1.0000**	0.7044
17	0.6342	0.7437	0.7845	0.7133	0.7044	**1.0000**
18	0.6478	0.7337	0.7873	0.6771	0.6847	0.7252
19	0.7520	0.7841	0.7450	0.7753	0.8010	0.7500

TABLE III. SIMILARITY DEGREE VALUES FOR ROI - ORIENTED MATCHING

No of template images / No of target images	1	2	7	11	16	17
1	**0.9082**	0.8465	0.7406	0.7566	0.7600	0.7739
2	0.9068	**0.9689**	0.8229	0.8755	0.8177	0.8804
3	0.8553	0.7815	0.7982	0.8021	0.7820	0.8159
4	0.8598	0.8828	0.8513	0.8612	0.8516	0.8752
5	0.8468	0.9031	0.7488	0.7721	0.7768	0.7703
6	0.8710	0.8400	0.8681	0.8895	0.8903	0.9046
7	0.8696	0.8289	**0.9514**	0.9101	0.8708	0.9153
8	0.8799	0.8163	0.8751	0.9002	0.8893	0.9282
9	0.8860	0.8252	0.9297	0.8807	0.8812	0.9041
10	0.8837	0.8299	0.8703	0.8839	0.8715	0.9004
11	**0.9089**	0.8086	0.8616	**0.9262**	0.8830	**0.9401**
12	0.8619	0.8337	0.8878	0.9097	0.8907	0.9359
13	0.8549	0.8253	0.8804	0.8978	0.8852	0.9104
14	0.8671	0.8455	0.8168	0.8849	0.8737	0.8566
15	0.8500	0.8227	0.7825	0.8117	0.8021	0.8238
16	0.8661	0.8164	0.8480	0.8614	**0.9374**	0.8698
17	0.8463	0.8213	0.9023	0.9033	0.8900	**0.9375**
18	0.8657	0.8073	0.9195	0.9183	0.8819	0.9263
19	0.8954	0.8276	0.8842	0.8882	0.8559	0.8989

B. Evaluation of searching procedures

We consider four sequential procedures: systematic, random, gradient and simulation annealing defined in [13]. They operate only on pairs of target/template images where ROI's are determined by experts. In our experiments we assume that the target image is the same as the template one, but without ROI. We made many such experiments, but representative results are shown in Table 4. and Fig. 4., the best results we obtained for simulation annealing procedure, then for gradient procedure, we also note that random and systematic procedures give nearly the same level of the mean accuracy, however they are a bit a lower than the first two procedures.

TABLE IV. THE MEAN IMAGE MATCHING ACCURACY OF SEARCHING PROCEDURES

Searching procedure / No of compared image	Systematic	Gradient	Random	Simulated annealing
4	0.7446	0.6729	0.8416	0.8721
5	0.6297	0.5815	0.5851	0.7792
10	0.7688	0.7648	0.7556	0.8426
16	0.8407	0.8153	0.8276	0.9210
17	0.8265	0.9508	0.8459	0.8556
19	0.7827	0.8910	0.7448	0.7920
Mean value	0.7655	0.7794	0.7648	0.8437

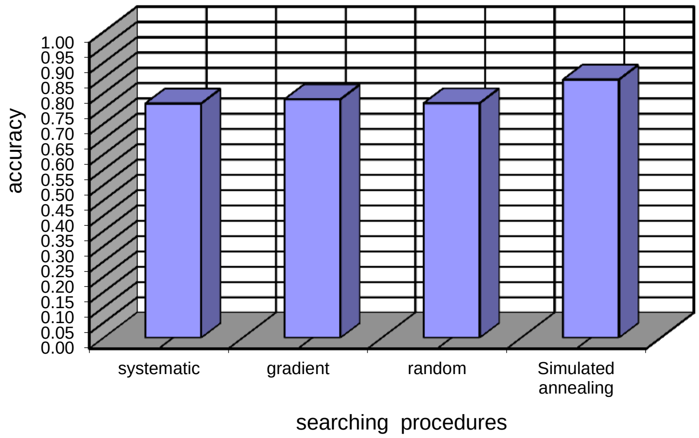


Fig. 5. The mean image matching accuracy of searching procedures

IV. CONCLUSION

In our paper four searching procedures were investigated and analyzed for the endoscopic images. Such images are very heavy for analysis owing to some deformations made during their registrations. Therefore we decide to construct four such algorithms different from each other by use of systematic random, gradient and simulation annealing searching methods. All versions are so flexible that can be tune to improve quality of searching and matching in accordance to specific features of endoscopic images.

For future work further improvement of the algorithms should be done. As well as parallelization of searching procedures will be presented and the version parallel matching algorithms will be described, analyzed and evaluated.

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AUTHOR PROFILES

Khaled M. G. Noaman received the PhD degree in Artificial Intelligent (artificial neural networks) from Wroclaw University of Technology, Wroclaw, Poland, in 1999. In July 2006 he got promoted to associate professor at the Faculty of Computer Science and Information Technology, Sana'a University, Sana'a, Yemen. From 2012 till now he is working in the department of Distance Learning, Deanship of E-Learning and Distance Learning, Jazan University, Jazan, Kingdom of Saudi Arabia.

Jamil A. M. Saif received the Msc degree in telecommunication engineering, from the Department of telecommunication, Faculty of Automatic Control, Electronics and Computer Science , Silesian University of Technology, Gliwice, Poland, in 1993, the PhD degree in Computer Science from the Department of Computer Architecture, Faculty of Electronics, telecommunications and Informatics, Gdansk University of Technology, Gdansk, Poland, in 2004. In May 2012 he got promoted to associate professor at the Faculty of Computer Science and Engineering, Hodeidah University, Hodeidah, Yemen. From 2013 till now he is working in the Department of Information Systems, Community College of Bisha , King Khalid University, Kingdom of Saudi Arabia.