

Proceedings of the 11th International Conference

PRIP'2011

Pattern Recognition and Information Processing

18–20 May 2011, Minsk, Belarus



Belarus, Minsk

UDC 004.93'1
BBC 32.973.26-018.2
P32

Editorial Board:

Prof., DSc Rauf Sadykhov,
Academician of NASB, Prof., DSc Sergey Ablameyko
Ass. Prof., DSc Alexander Doudkin
Leonid Podenok

Pattern Recognition and Information Processing (PRIP'2011) :
proceedings of the 11th International Conference (18 – 20 may, Minsk,
Republic of Belarus). – Minsk : BSUIR, 2011. – 472 p.

ISBN 978-985-488-722-7

The book collects the papers accepted for publication and presentation at the 11th International Conference on Pattern Recognition and Information Processing (PRIP'2011) that will be held at may 18 – 20 in Minsk, Belarus. The proceedings are prepared for publication by PRIP'2009 Program Committee and Belarusian Association for Image Analysis and Recognition .

Proceedings will be useful for students and researchers working in the following areas: pattern recognition and image analysis; knowledge processing and representation; knowledge based decision support system, fuzzy mathematics and systems, applications of pattern recognition and image analysis.

Papers are reviewed by at least two reviewers and approved by Program Committee. All papers have been photographically reproduced exactly as submitted by authors on their own responsibility.

UDC 004.93'1
BBC 32.973.26-018.2

Contributors PRIP'2011

Conference is organized by:

- Belarusian State University of Informatics and Radioelectronics

in cooperation with:

- United Institute of Informatics Problems of the National Academy of Sciences of Belarus
- Belarusian State University, Faculty of Applied Mathematics and Computer Sciences
- Belarusian Association for Image Analysis and Recognition
- Enterprise IT-Park
- Bluemedia Ltd.
- Effective Software Ltd.
- Enterprise ISsoft Solutions
- Enterprise TelesoftService
- Synesis Ltd.

in collaboration with:

- Belarusian Republican Foundation for Fundamental Research
- International Associations for Pattern Recognition

Section list

0	Plenary Papers.....	13
1	Pattern Recognition and Image Processing.....	25
2	Data Analysis.....	149
3	Signal Processing.....	219
4	Systems and Parallel Architectures for Signal and Image Processing	268
5	Knowledge-Based Expert and Decision Support Systems.....	303
6	Application of Pattern Recognition and Informaton Processing	351
7	3D Image Processing and Modeling.....	442

Contents

Committees PRIP'2011	9
Welcome from the Honorary Conference Chair and Co-Chairs	11
Key-note speakers	12
Plenary Papers	13
<i>Robert E. Hiromoto</i> GPU and Multi-cores: Computational Thinking – Art and Science	13
<i>Chanin Joochim, Hubert Roth, Chayakorn Netramai</i> Robust 3D Map Building Using 3D sensors	17
<i>Janusz Zalewski</i> Latest Developments in Artificial Intelligence Techniques for Prognostics – A Brief Survey	21
Pattern Recognition and Image Processing	25
<i>Zalesky B. A., Lukashovich P. V.</i> Scale Invariant Algorithm to Match Regions on Aereo or Satellite Images	25
<i>Alzaabi A., Alquié G., Tassadaq H., Seba A.</i> Harris Extraction and SIFT Matching for Correlation of Two Tablets	31
<i>Aguilar-González P. M., Kober V., Karnaukhov V.</i> Pattern Recognition with Noisy Target	35
<i>Bekhtin Y. S., Bryantsev A. A.</i> Matching Pursuit of Coherent Structures During Wavelet-Based Fusion of Noisy Multi- spectral Images	39
<i>Zharkikh A. A., Bychkova S. M.</i> Modeling of the Recognition Algorithm of Direction of Random Shift of Point on a Plane on a Random Rotations Background	43
<i>Khrustalev P.</i> Method of a Finding of a Skyline on the Image	48
<i>Gorshkova K., Shumsky I., Tsiatlatnikau R.</i> Photo Localization on Identification Documents in Conditions of Incomplete and Noisy Information	52
<i>Kozlovskii V. A., Maksimova A. J.</i> Algorithm of Pattern Recognition with Intra-Class Clustering	54
<i>Verma A., Liu Ch.</i> Fusion of Color SIFT Features for Image Classification with Applications to Biometrics .	58
<i>Vadapalli H. B., Nyongesa H., Omlin C. W. P.</i> Classifying Facial Action Units: Use of Time Variant Data and Recurrent Neural Networks	64
<i>Gubchik I. N., Ivanov N. N.</i> Tracking of an Object in Colony of Sparse Cells	69
<i>Grushetsky Y. E., Tuzikov A. V.</i> Motions Space Clustering for Template-Based Protein Docking	73
<i>Pradun D. V.</i> Block-Parallel Clustering of Multispectral Images Using Max Flow Network Algorithm . .	76
<i>Nedzved A., Nedzved O., Ablameyko S., Uchida S.</i> Object Extraction at Nano-Surface Images	80
<i>Naqvi S. A. Khattak T., Rehan W., Elahi A.</i> A Novel Model for Face Recognition	84
<i>Siddiqi M. H., Truc P. T. H., Lee S., Lee Y.-K.</i> Level Set Based Automatic Human Body Segmentation	88
<i>Farag A., Atta R., Mahdi H.</i> Face Recognition Based on the Statistical Features of BDIP and Wavelet Transform . . .	92

<i>Guzik P., Matiolański A., Orzechowski T. M., Dziech A.</i>	
Evaluation of Parameters for Haar-Like Features Based Face Detection Algorithm	96
<i>Tulyakov S., Sadykhov R.</i>	
Face Recognition on Machine Readable Travel Documents: Algorithms and Results	99
<i>Dvoenko S. D.</i>	
On Clustering of a Set of Members by Distances and Similarities	104
<i>Khatami A., Mirghasemi S.</i>	
A Hybrid Intelligent Algorithm-Based Color Space Conversion for Skin Detection	108
<i>Moreno R., Graña M., Ramik D. M., Madani K.</i>	
Image Segmentation by Spherical Coordinates	112
<i>Lisitsa Y. U., Yatskou M. M., Apanasovich V. V., Rui H., Apanasovich T. V.</i>	
Fully-automated segmentation of tumor nuclei in cancer tissue images	116
<i>Damaratski A., Juodelis A.</i>	
A Novel Technique of Partial Supervision for a Heuristic Algorithm of Possibilistic Clustering	121
<i>Kharinov M.</i>	
Adaptive Dichotomous Image Segmentation	127
<i>Sizov R., Kovalev T., Mironenko V., Prytkov V.</i>	
Algorithms of Searching and Marking Out Biological Objects	131
<i>Trekin A., Matveev I. A.</i>	
Projection Method for Pupil Detection	135
<i>Żywicki M., Matiolański A., Orzechowski T. M., Dziech A.</i>	
Knife Detection as a Subset of Object Detection Approach Based on Haar Cascades	139
<i>Ganchenko V., Petrovsky A., Pawlowski T.</i>	
Special Areas Detection on Agricultural Fields Images Using Color Characteristics and Image Local Variability Evaluations	143
Data Analysis	149
<i>Tarkov M. S., Tikhonov N. V.</i>	
Evaluating the Thermogram Heterogeneity Based on Its Quadtree Representation	149
<i>Stankevich S. A., Starovoitov V. V., Shklyar S. V.</i>	
Joint Subpixel Analysis of Different Spatial Resolution Multispectral and Hyperspectral Imagery	153
<i>Sergeeva K., Vorobejchikov S.</i>	
An Efficient Algorithm for Detecting a Change Point of Autoregressive Parameters of AR(P)/ARCH(Q) Process	156
<i>Burkatovskaya Y., Vorobejchikov S.</i>	
Sequential Procedure of Parameter Change Detection in AR/ARCH Process	159
<i>Dvoenko S. D., Panferov A. V.</i>	
The Problem of Negative Eigenvalues Removing from Matrixes of Pairwise Comparisons	165
<i>Kovalev V., Dmitruk A., Safonau I.</i>	
A Method for Morphological Image Mining	169
<i>Marushko Y.</i>	
Forecasting Multivariate Time Series Using Ensembles of Neural Network	172
<i>Podolskiy V. E.</i>	
Simple Fuzzy Based Optimization Approach to the Problem of Dividing Outliers into Classes of Valuable and Noise Points	176
<i>Dotsenko A. S., Kondratenko Y. P.</i>	
Computer Hand Gesture Recognition Using Fuzzy Logic	179
<i>Arroyo-Cañada F.-J., Gil-Lafuente J.</i>	
Effectiveness of Interactive Advertising Formats Versus Non Interactive in the Television Environment: a Simulation Based in Fuzzy Logic Analysis	183
<i>Viattchenin D. A.</i>	
An Approach to Constructing a Possibility Distribution for the Number of Fuzzy Clusters	188
<i>Liu R., Gillies D. F.</i>	
Feature Selection Using Order Statistics	195

<i>Hancharou D., Nedzved A., Starovoitov V. V.</i>	
Histological Image Stitching Algorithm Based on Normalized Statistical Moment	200
<i>Aliyeva N. T., Ismayilov E. A.</i>	
Research of a Class of Smooth Membership Functions	204
<i>Butkin G., Zhuk D., Tuzikov A. V.</i>	
Nonparametric Transforms for Describing Local Image Features	209
<i>Chernov S., Kharin A.</i>	
Error Probabilities Evaluation in Sequential Testing of Simple Hypotheses for Dependent Observations	213
<i>Myshev A. V., Chunyayev N. V., Shelyakov M. A.</i>	
Cognitive Computer Technologies of Graphic Images Analysis	216
Signal Processing	219
<i>Piunovsky E.</i>	
Using Wavelet Lifting Scheme for Audio Data Compression	219
<i>Aida-Zade K., Sharifova A.</i>	
A comparison Between Allophone, Syllable, and Diphone Based TTS Systems for Azer- baijan Language	222
<i>Fedyayev O. I., Bondarenko I. Yu.</i>	
Segment-Holistic Speech Recognition System Based on Model of Brain Hemispheric Inter- action in Speech Perception	226
<i>Semenchik V., Pahomov V.</i>	
Harmonic Signal Amplitude and Phase Measurement for Microwave Imaging System	231
<i>Bushra J., Fauwet E., Laligant O.</i>	
Piecewise Image De-Noiseing Utilizing Discontinuous Edges	237
<i>Wassermann J., Dziech A.</i>	
New Approach in Video Watermarking Based on DPCM and Transform Coding	241
<i>Stankevich A., Petrovsky Al., Petrovsky A.</i>	
An FPGA-Based CABAC Module for Real-Time H.264/AVC Decoder	245
<i>Novikov A. E., Petrovsky A.</i>	
Embedded DSP Module for Active Noise Control in Ventilation Systems	249
<i>Petrovsky N. A., Parfieniuk M.</i>	
Distributed Arithmetic-Based Quaternion M-Band Wavelets Kernel for Multi-Resolution Analysis of Multimedia Data	253
<i>Klucheniya V.</i>	
FPGA Architecture of DCT Processor Based on Lifting Steps for Real-Time Embedded Applications	259
<i>Golovko V., Apanel E., Mastykin A., Vaitsekhovich H., Eustigneev V.</i>	
Neural Network Model for Transient Ischemic Attacks Diagnostics	263
Systems and Parallel Architectures for Signal and Image Processing	268
<i>Minkevičius S., Kulvietis G.</i>	
A Mathematical Model of the Message Switching System	268
<i>Kulik B., Zuenko A., Fridman A.</i>	
Modified Reasoning by Means of N-Tuple Algebra	271
<i>Archvadze N., Pkhovelishvili M., Shetsiruli L.</i>	
The Complexity of Program Synthesis from Examples	275
<i>Khanh N. Q.</i>	
Security Requirements for SOA on the Base of Security Standards of Web-Service	280
<i>Mustafayev E. E., Hasanov J. Z., Sharifova A.</i>	
The Device of Recognition and Scoring of Printed Texts	283
<i>Timchenko L., Kokriatskaia N., Melnikov V., Ivasyuk I., Makarenko R.</i>	
Training the Parallel-Hierarchical Network for Recognition Static and Dynamic Images	286

<i>Salnikov I. I.</i>	
The Analysis of Distant Objects' Spatio-Temporal Parameters in Information Technical Systems	290
<i>Burmako E., Sadykhov R.</i>	
Conflux: Embedding Massively Parallel Semantics in a High-Level Programming Language	294
<i>Sadykhov R., Uvarov A., Pertsev D.</i>	
Parallel Face Detection Algorithm for GPU Architecture	299
Knowledge-Based Expert and Decision Support Systems	303
<i>Artemieva I. L., Zuenko A., Fridman A.</i>	
Integration of Ontologies, Knowledge and Data Archives into Ontology-Based Modeling Systems	303
<i>Gurevich I.</i>	
Atoms, Molecules and Fundamental Restrictions on Characteristics of Information Systems	307
<i>Mamedova M. H., Djabrailova Z. G., Aliyev H. B.</i>	
The method of Decision-Making Support for Employment of IT-Specialty Personnel Considering the Requirements of Employers	313
<i>Lbov G. S., Polyakova G. L.</i>	
Forecasting Method Based on Logical Regularities	317
<i>Litvinskaya O. S., Salnikov I. I.</i>	
Mathematical Decision Making Model for Selecting Implementation Means of Information Technical System	320
<i>Rusc T., Fornalski P., Dziech A., Slusarczyk P.</i>	
Computer System for Management and Full-text Search of Court RecordsClasses	322
<i>Varlamov O.</i>	
Mivar's Technologies to Development of Intelligent Systems and Project Development Active Multi-Subject Online Mivar's Encyclopedia	326
<i>Djabrailova Z. G., Nobari S. M.</i>	
Defining Methods of Importance Factor of the Criteria in the Solution of Personnel Management Problems and Detection of Contradictions	330
<i>Rustamov S.</i>	
Structure and Contents of the Intellectual Systems, Which Ensure Human-Computer Dialogue	334
<i>Kaliukhovich D.</i>	
Effect of Perceptual Expectancy on Neural Adaptation: Computational Approach	337
<i>Shut O. V.</i>	
Logical and Precedent-related Approaches to Representation of Information in Pattern Recognition Problems: Comparative Analysis and Applications	339
<i>Krasnoproshin V., Obratsov V., Vissia H.</i>	
Knowledge Formalization in Decision Support Systems	342
<i>Kostyukovich N. Yu., Shakah G., Valvachev A. N.</i>	
Modeling of Nature-Territorial Complexes Based on Organizational Structures	347
Application of Pattern Recognition and Informaton Processing	351
<i>Bogush R., Brovko N.</i>	
An Efficient Smoke Detection Algorithm for Video Surveillance Systems Based on Optical Flow	351
<i>Megrelishvili R., Besiashvili G., Shengelia S.</i>	
One-Way Cryptography Function Using $N \times N$ Matrices	355
<i>Kumari L. L., Dharmaratne A.</i>	
A Survey on Age Progression Techniques for Elderly People	358
<i>Antidze J., Gulua N.</i>	
Generalized Tools for Computer Realization of Natural Language Models	362
<i>Ramík D. M., Sabourin Ch., Madani K.</i>	
Hybrid Artificial Vision System Combining Salient Object Extraction and Machine-Learning Skills	366

<i>Myshev A. V.</i>	The Metrological Theory of Information Dynamics for Intelligent Tech-Nologies' Processes of Processing and Analyzing Information	370
<i>Sergeev R. S., Tuzikov A. V., Eremin V. F.</i>	Statistical Approach to HIV-1 Mutation Analysis and Its Application	374
<i>Anfleets S. V., Kasyanik V. V., Shuts V. N.</i>	Application of Algorithms for Searching Motion in the Frame for the Detection of Vehicles	378
<i>Zaitseva E., Rusin M., Levashenko V.</i>	Reliability Analysis of Complex System	381
<i>Pisarenko V., Pisarenko J.</i>	Some Algorithms of UAV's Coordinates Definition by Onboard Processor According to Videocameras	387
<i>Kabysh A., Golovko V., Mikhniayeu A., Rubanau U., Lipnikas A.</i>	Behavior Patterns of Adaptive Multi-Joined Robot Learned by Multi-Agent Influence Reinforcement Learning	392
<i>Vaitsekhovich L., Golovko V., Madani K.</i>	Modeling of Multi-Agent Intrusion Detection System Based on Interaction Graph of Agents	397
<i>Diomin V., Kostyuk D., Nikoniuk A.</i>	Dynamic Windows Scaling in Unix-Like Systems Interface	402
<i>Baranauskas V., Bartkevičius S., Šarkauskas K., Kabysh A.</i>	Using Vector Marks for Robot Navigation	406
<i>Krasnoproshin V., Mazouka D.</i>	Graphics Pipeline Automation Based on Visualization Algebra	410
<i>Liu H., Krasnoproshin V.</i>	Electronic Commerce Websites Evaluation Based on Fuzzy Analytic Hierarchy Process . .	413
<i>Avakaw S., Doudkin A., Voronov A., Orlova T.</i>	Software Applications of Input Data Preparation for Single-Beam Layout Generator of IC Topology	417
<i>Inyutin A.</i>	Algorithm of the PCB Topology Inspection and Defects Classification	422
<i>Kuzmich A. I., Shakah G., Valvachev A. N.</i>	Remote Monitoring System for Mobile Objects	427
<i>Avakaw S. M., Doudkin A., Inyutin A., Rusetsky S. A., Otwagin A. V.</i>	Paralleling Aerial Image Simulation Based Multi-Agent Approach for Photolithography .	431
<i>Podenok L. P.,</i>	On Modular Exponentiation in Residue Number System	438
	Image Processing and Modeling	442
<i>Struts S. V., Matveev I. A.</i>	Reconstruction of 3D Structure of Human Face Using a Pair of Images and 3D Model of Human Face	442
<i>Podkosova Y., Vasiuhova S. A., Varlamov O.</i>	Use of Technologies of the Virtual Reality in Three-Dimensional Visualization of Results and Mivar's Application of Training Systems	447
<i>Amarger V., Ramík D. M., Moreno R., Rossi L., Madani K., Graña M.</i>	Wildland Fires' Outlines Extraction: a Spherical Coordinates Framed RGB Color Space Dichromatic Reflection Model Based Image Segmentation	451
<i>Losik G.</i>	A Recognition Model Using Objects Variability Information	455
<i>Kapura V., Sachenko A., Roth H., Adamiv O.</i>	Method of Stereoimage Fusion for 3D Reconstruction	461
	Subject Index	464
	Author Index	468

Histological Image Stitching Algorithm Based on Normalized Statistical Moment

Dzmitry Hancharou ¹⁾, Alexandr Nedzved ²⁾, Valery Starovoitov ²⁾

1) Belarusian State University, Nezavisimosti avenue 4, goncharovda@gmail.com

2) United Institute of Informatics Problems (UIIP NAS of Belarus), Surganova street 6, valerys@newman.bas-net.by

Abstract: The problem considered in this paper is the automatic histological image stitching. In this paper, invariant local features based on normalized statistical moment are used to select matching points and calculate the translation. This algorithm consists of feature detection, feature registration and spatial transition. The experimental results with histological images in different categories demonstrate this algorithm is fast, effective and does not require human interaction.

Keywords: Image Stitching, Harris Detector, Normalized Statistical Moment (NSM)

1. INTRODUCTION

Stitching techniques have been used to combine overlapped signals into a new one with as little distortion of each signal as possible. Building a stitched image from a sequence of partial views is a powerful means of obtaining a complete, non-redundant view of scene [1]. Image stitching has been applied in medicine, computer vision and photogrammetry.

In general, most image stitching techniques developed in recent years can be divided into two categories: template and feature based. Template based algorithms attempt to correlate the grey levels of image patches in the views, assuming that they present some similarity [2]. Feature based algorithms establish correspondences between points, lines or other geometrical entities and use properties of local intensity values to match them.

In our application, overlapping images are used to construct an image with a far larger field of view. It solves the problem that histological image covers a very small area. The approach proposed in this paper as shown in Fig.1 extracts interesting points by Harris corner detector and then matches them using a NSM technique followed by a statistical procedure. We choose Harris corner detector here due to its invariant to geometric transformations. NSM feature which belongs to invariant image feature is from physical conceptions. Experimental results show that the NSM feature of image has the ability of antitonal and geometric distortion (translation, rotation and scaling, TRS) and its extracting method is simple [3]. Thus, NSM feature offers a solution to correlate interesting points and recover the translation between images.

This work was supported by ISTC project B-1636.

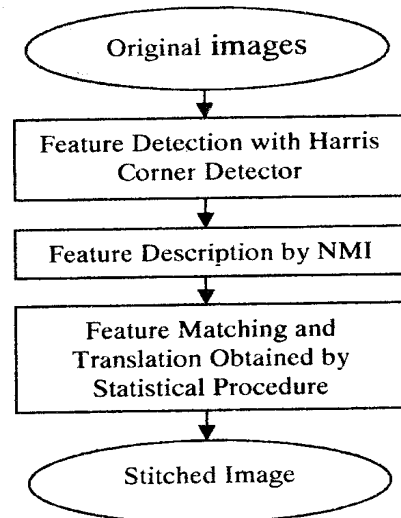


Fig. 1. The pipeline of image stitching

2. FEATURE DETECTION

The Harris measure M is the second moment matrix, describing the curvature of the autocorrelation function in the neighborhood of a point [4].

$$M = w_{u,v} * \begin{pmatrix} L_x^2 & L_x L_y \\ L_y L_x & L_y^2 \end{pmatrix}. \quad (1)$$

where $*$ is convolution operator and $w_{u,v} = e^{-\frac{(u^2+v^2)}{2\sigma^2}}$ a Gaussian smoothing window. We can get image L_x from image I_x smoothed by a Gaussian $L_x^2 = I_x^2 * w_{u,v}$.

And the first gradients I_x and I_y in x , y direction respectively are approximated by

$$I_x = I * (-1,0,1) \approx \partial I / \partial x. \quad (2)$$

$$I_y = I * (-1,0,1)^T \approx \partial I / \partial y. \quad (3)$$

Let α , β be eigenvalues of M . α and β will be proportional to the principal curvatures of local autocorrelation function and form a rotationally invariant description of M [5, 6]. A corner point will have an M with two strong eigenvalues. An edge will present one strong and one weak eigenvalue and a flat region will have two weak eigenvalues.

Now, we can measure the corner response R with eigenvalues α and β , thus

$$R = \text{Det}(M) - k\text{Tr}^2(M). \quad (4)$$

Where $\text{Det}(M) = \alpha * \beta$, $\text{Tr}(M) = \alpha + \beta$. R is positive in the corner region, negative in the edge region, and small in the flat region [5]. An interesting point is selected as a corner pixel by applying high threshold as shown in Fig.2.

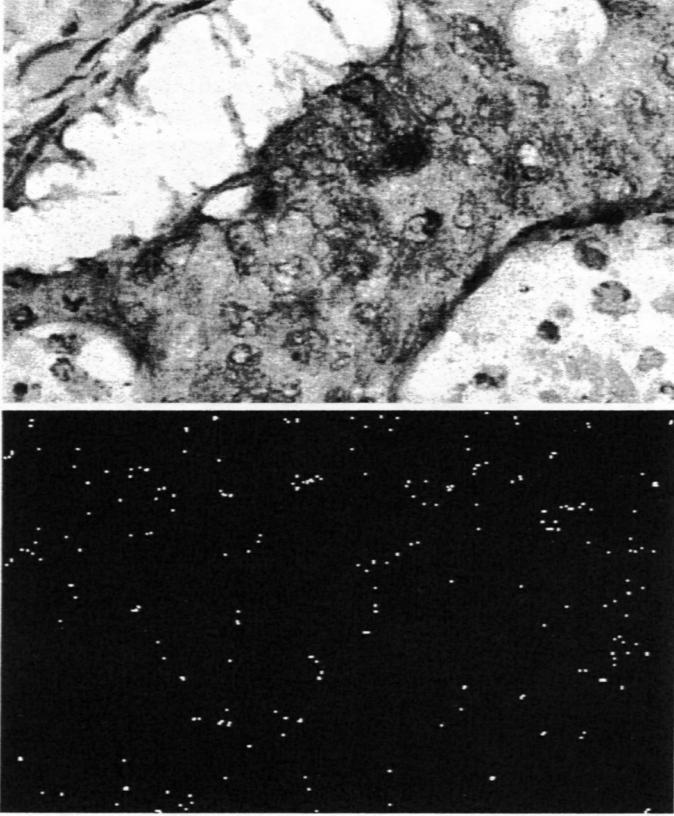


Fig. 2. Histological image with interesting points in blue with the threshold 5000

3. FEATURE DESCRIPTION

The definition of NSM is as follows:

$$NMI = \frac{\sqrt{J_{(cx,cy)}}}{\sum_{x=1}^M \sum_{y=1}^N f(x,y)}. \quad (5)$$

where (cx, cy) is the center of mass of the image and $J_{(cx,cy)}$ the statistical moment.

$$cx = \frac{\sum_{x=1}^M \sum_{y=1}^N x \times f(x,y)}{\sum_{x=1}^M \sum_{y=1}^N f(x,y)}. \quad (6)$$

$$cy = \frac{\sum_{x=1}^M \sum_{y=1}^N y \times f(x,y)}{\sum_{x=1}^M \sum_{y=1}^N f(x,y)}. \quad (7)$$

$$J_{(cx,cy)} = \sum_{x=1}^M \sum_{y=1}^N ((x - cx)^2 + (y - cy)^2) f(x,y). \quad (8)$$

NSM feature is invariant to translation, rotation and scaling. In our application, we use NSM to describe the interesting points in images. The approach calculates NSM for a disk around the points and the same points in different images will have similar properties.

4. FEATURE MATCHING

In our application we only consider translation between images though tiny rotation and scaling may exist from measure errors. Feature matching is performed with NSM and centers of gravity corresponding to interesting points between images. We define a measure of the strength of the match (SM for abbreviation), as

$$SM(NMI_{1i}, NMI_{2j}) = \frac{|NMI_{1i} - NMI_{2j}|}{0.5 * (NMI_{1i} + NMI_{2j})}. \quad (9)$$

NMI_{1i} is the NSM of i -th interesting point in the first image and NMI_{2j} the j -th in the second image. Let $G_{1i}(x, y)$ and $G_{2j}(x, y)$ are the centers of gravity.

If $SM(NMI_{1i}, NMI_{2j}) \leq 0.1$ and $\text{Dist}(G_{1i}, G_{2j}) \leq 0.1$, then the pair of interesting points is a potential match. $\text{Dist}(G_{1i}, G_{2j})$ is defined as follows.

$$\text{Dist}(G_{1i}, G_{2j}) = \sqrt{(x_{1i} - x_{2j})^2 + (y_{1i} - y_{2j})^2}. \quad (10)$$

Until now the match relationship is multi-to-multi and the purpose is to contain correct matches in potential matches. For every pair of math points, calculate translation in x and y directions each, then we can get a statistical char of quantities of matching points at different translation as shown if Fig.4. Correct matching points will result in same translation and others are stochastic, so maximum exists at proper translation between images in theory. In practice, we use following expression to estimate.

$$\text{score} = \frac{\text{Num}_x(\text{best})}{\text{Num}_x(\text{second})} + \frac{\text{Num}_y(\text{best})}{\text{Num}_y(\text{second})}. \quad (11)$$

$\text{Num}_x(\text{best})$ and $\text{Num}_x(\text{second})$ mean the number of best and second best match in x direction in the statistical chart. If the condition $\text{score} > 1.2$ is met, these two images are treated as overlapped and the location of maximum in the chart is the translation between them.

5 EXPERIMENTAL RESULTS

The proposed algorithm has been evaluated by histological images and pathological images and good stitching results have been obtained.

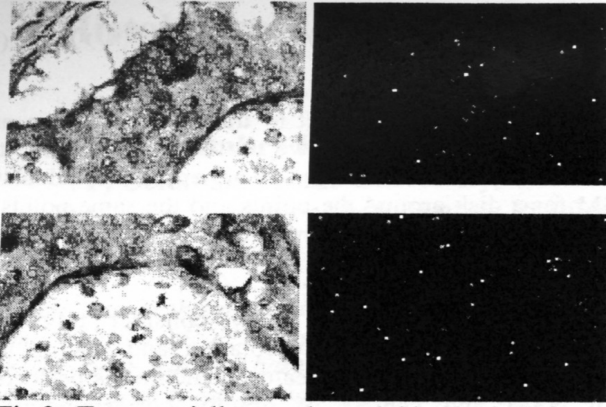


Fig.3. Two partially overlapped histological images (top) and the images with detected interesting points (bottom)

Fig.3 shows two original overlapped histological marrow images and interesting points which are detected by Harris corner detector with the threshold 5000. For such a color image, we only use intensity component to calculate interesting points and NSM.

After feature matching, the statistical chart of distance of matching points is shown in Fig.4. We can easily find maximums in each direction and this can demonstrate the robustness of our algorithm. The location of peak value on x and y axis is the translation between the two images to be stitched and in this case the peak is at (313, 50). The stitching result is shown in Fig.5.

This method can achieve fast image stitching and the time elapsed during the procedure of feature detection and feature matching is theoretical proportional to the number of interesting points. Table 1 compares the time consumed of NSM based method with Zernike moment [4], phase correlation [6] methods in image stitching and the results are average time of experiments on same size images. Fig.6 shows the mosaic results based on these two methods.

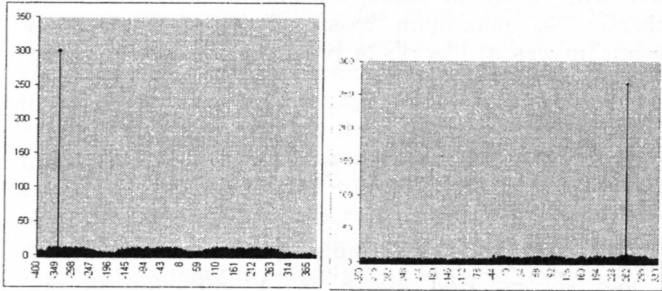


Fig.4. The statistical chart of quantities of matching points at different translation in x direction (left) and y direction (right)

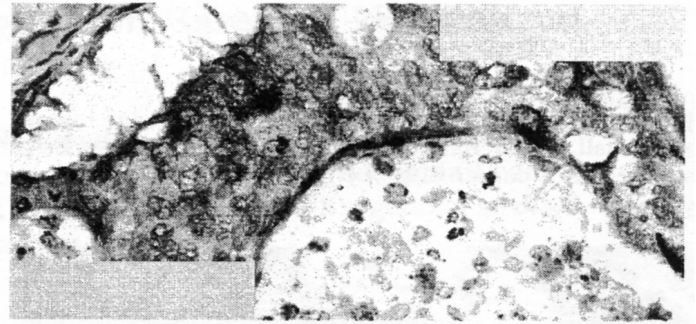


Fig.5. Stitching image by the translation obtained in Fig.4

NSM based mosaic result shown in Fig.5 is almost the same as Zernike moment and phase correlation based results shown in Fig.6, but their efficiency is distinct. Table 1 demonstrates that NSM based method is much faster in stitching images with translation. Its advantage becomes more prominent when the size of images increases. Fig.7 shows image stitching with NSM.

Table 1. A comparison of time-consuming of three different methods (unit: ms)

Image size	NSM	Zernike Moment	Phase Correlation
1798x1438	5601	47631	44692
2592x1944	9659	65798	174676

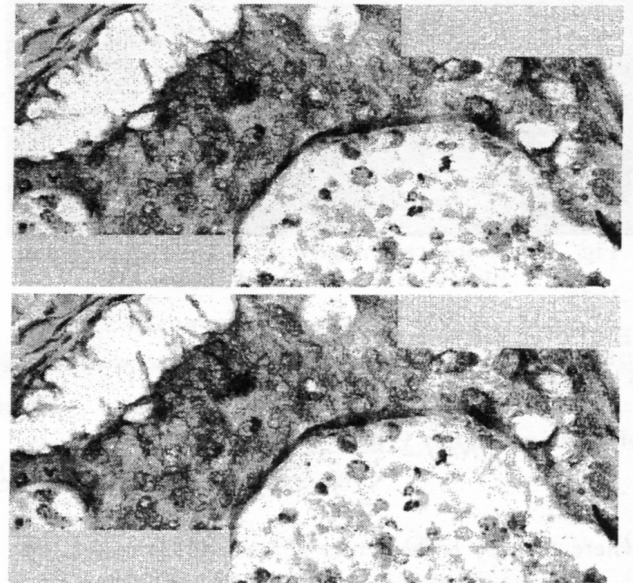


Fig.6. Mosaic based on Zernike moment (top) and phase correlation (bottom)

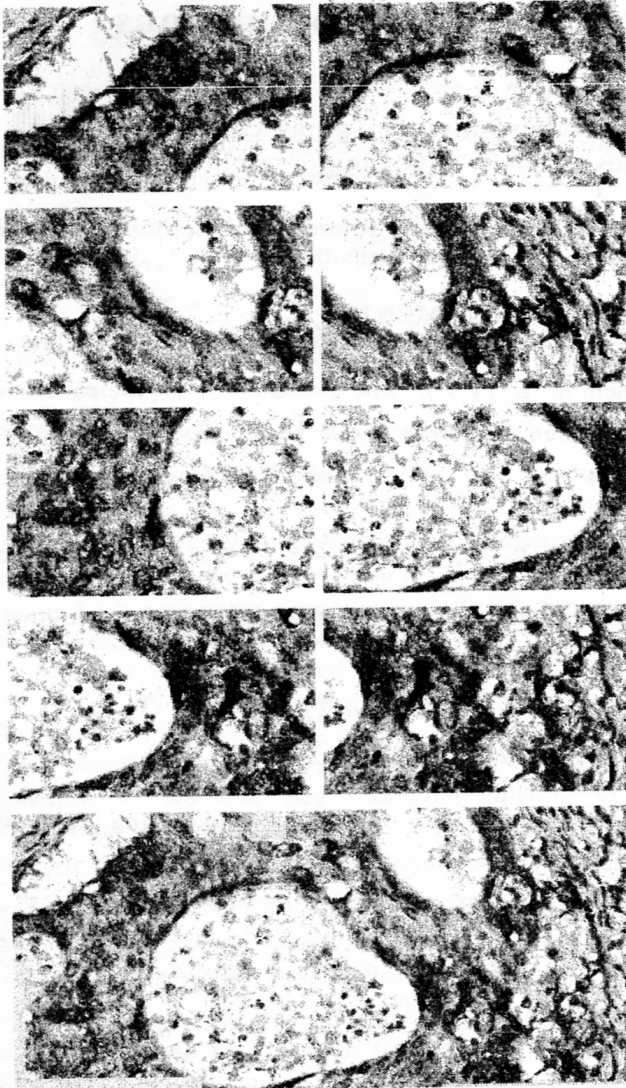


Fig.7. Original partially overlapped images to be stitched (top) and the stitching result with NSM (bottom)

6. CONCLUSION

In this paper, a novel approach based on normalized statistical moment to solve the histological image stitching problem has been proposed. The algorithm can calculate and recover the translation between the images quickly and efficiently to completely meet the demands of stitching histological medical images. Our experiments with histological images in different categories have demonstrated the proposed algorithm's robustness and speed, so it has been successfully integrated in our automatic histological image analysis system.

7. REFERENCES

- [1] M. Irani, P. Anandan, S. Hsu: Mosaic Based Representations of Video Sequences and Their Applications. *Proc. IEEE Int. Conf. on Computer Vision (1995)*, p. 605-611
- [2] Z.Y. Zhang, R. Deriche, O. Faugers, Q.T. Luong: A Robust Technique for Matching Two Uncalibrated Images Through The Recovery of The Unknown Epiipolar Geometry, *INRIA (1994)*
- [3] Yang X.G., Fu G.Y., Miao D., Zhang W.J.: A New Approach to Target Recognition Based on Image NSM Feature, *Computer Engineering (2002)*
- [4] Pizarro O., Singh H.: Toward Large-Area Mosaicing for Underwater Scientific Applications, *IEEE Journal of Oceanic Engineering*, 28 (2003)
- [5] Harris C., Stephens M.: A Combined Corner and Edge Detector, *Proc. Alvey Conf.*, Manchester, U.K. (1988) 189-192
- [6] S. Suen; E. Lam, and K. Wong (2007). "Photographic stitching with optimized object and color matching based on image derivatives". *Optics Express* 15: 7689-7696.