2015 IEEE International Conference on Systems, Man, and Cybernetics

On Clinical-Data-Based Personal Identification for Ophthalmological Patients

Naotake Kamiura, Manabu Nii,
and Takayuki Yumoto
Dept. of Electronics and Computer Science
Graduate School of Engineering, University of Hyogo
Himeji, Japan
{kamiura, nii, yumoto}@eng.u-hyogo.ac.jp

Tomofusa yamauchi and Hitoshi Tabuchi
Department of Ophthalmology
Tsukazaki Hospital
Himeji, Japan
{T.Yamauchi, h.tabuchi}@tsukazaki-eye.net

***Abstract*—In this paper, a system of personal identification using data associated with corneal thickness is presented for ophthalmological patients. The data are measured by OCT (Optical Coherence Tomography). The proposed method equally divides the cornea into thirty-two fan-shaped segments, using thirty-two radiuses. It generates a couple of thirty-two-dimensional vectors (or a sixty-four-dimensional vector) for some test subject as the registered data, and adds it to a set. Each of the data consists of element values associated with minimum values and/or maximum values on the above radiuses. When the test subject takes medical practice, the proposed method generates two thirty-two-dimensional vectors (or a sixty-four-dimensional vector) for the corresponding test subject as the collation data. Then, the proposed method calculates the distance between the collation data with each of the vectors in the set. It judges the test subject corresponding to the given collation data to be that of the registered data with the shortest distance to the given data. Experimental results establish that the proposed method achieves 100 percent as the identification rate on assumption that the number of subjects is at most 45.**

Keywords-component; Personal Identification; Optical Coherence Tomography; Cornea; Pachymetry

I. INTRODUCTION

Recently, the dependability of medical instruments has been remarkably enhanced. The number of medical accidents caused by human errors therefore has increased, compared to that of accidents for which the malfunction of instruments is considered to be a main cause. A number of works have been proposed to cope with human errors. A method of preventing misidentification caused by confusing blood samples between some patients [1], [2] is an example of such works.

In Japan, the number of ophthalmological patients and that of ophthalmic surgeries have rapidly increased. Ophthalmologists and nurses must face up to heavier stress as these numbers become larger, to prevent medical accidents from occurring. The misidentification of patients and misrecognition of treatment sites are considered to be the most severe incident. Health professionals are therefore anxious for the development of convenient personal identification systems with high accuracy.

Retina verification [3]-[5] and iris verification [6]-[8] are representative personal identification based on anatomical and morphological information associated with eyes. The former generates registered data and collation data from patterns of blood vessels on retinas, whereas the latter depends on random and unique patterns of irises. Some medical practices possibly require medicines that make it impossible to analyze the above patterns. On the other hand, Optical Coherence Tomography (OCT) has recently attracted much attention as a high-performance inspection instrument. It can visualize microstructures associated with corneal clouding, conjunctivas, the backs of irises, and corner angles unobserved by a normal slit lamp system. In addition, it can quantitatively analyze corneal thickness, anterior chamber depth, corneal radiuses, and stored amount of tear fluid. Some ophthalmologists believe that employing the above clinical data measured by OCT's would be promising for the personal identification under the condition that neither retina verification nor iris verification is applicable. To the best of our knowledge, however, there exist no works proposing the identification based on the above data.

In this paper, the personal identification is presented, using the data associated with corneal thickness obtained by OCT (model name: SS-1000, manufacturer: TOMEY corporation). SS-1000 provides matrices, each of which consists of thirty-two rows and two-hundred and fifty-six columns, to users as output sequences for test items. The proposed method generates two thirty-two-dimensional vectors (or a sixty-four-dimensional vector) from the matrix associated with a test item for a test subject, and adds it to a set of registered data. When identifying some test subject, the proposed method obtains a 32×256-sized matrix by OCT and generates the collation data as well as when registering the corresponding subject. SS-1000 does not always measure the test item value at the identical point on the cornea. In other words, the point at which the item value is measured when generating the registered data tends to differ from the point at which the item value is measured when generating the collation data, even if these item values are specified by the same row and the same column in the two matrices. To cope with the issue associated with the gap occurring on the cornea when generating registration data and collation data, the proposed method focuses on test items of which values are not only enough

978-1-4799-8697-2/15 $31.00 © 2015 IEEE
DOI 10.1109/SMC.2015.405

different among subjects but also have comparatively low dependency on measuring points for the identical subject. It employs Axial Keratometric, Axial Posterior, and Pachymetry as candidate items fulfilling the above restriction, and examines the identification rate achieved when registration and collation data are generated from the 32×256-sized matrix for each of the three items.

The proposed method picks up the maximum value and the minimum value on each row in the matrix corresponding to one of the test items, and generates the data with the maximum value and/or the minimum value for elements. The three types of the distance are defined, and the proposed method calculates the distance between each of the members in the registered data set and the given collation data. It judges the test subject corresponding to the given collation data to be that of the registered data with the shortest distance to the given data. Experimental results establish that the proposed method achieves 100 percent as the identification rate, provided that registered and collation data are generated from the matrix associated with Pachymetry and that the number of subjects is at most 45.

II. Optical Coherence Tomography

A. *Measurements of Test Items*

In this paper, the data provided from Tsukazaki Hospital in Japan are used for the personal identification. They are measured by Optical Coherence Tomography (OCT) with SS-1000 as a model name. SS-1000 is a non-contact, non-invasive three dimensional imaging system based on the principle of Swept Source OCT [9]. OCT generally makes it possible to examine anterior segments including corneas, irises and so forth in detail. In addition to the information on corneal thickness and height, it can give ophthalmologists refractive powers measured at both anterior and posterior surfaces of corneas. It has been considered that the measurements made by conventional instruments (e.g., slit lamp systems) have difficulties in examining corneal clouding and local thickness of the cornea, and in analyzing situations associated with corner angles and irises of patients with glaucoma. OCT can overcome these difficulties, and provides quantitative information associated with the above items to ophthalmologists.

The test items of which the values are measured by SS-1000 are tabulated in TABLE I. The term “Axial” in TABLE I means the curvature radius map structured under the assumption that the center of curvature is defined on the axis for measurement. The term “Refractive” means the curvature radius map based on the calculation according to Snell's law by considering a cornea to be a lens. The term “Instantaneous” means the curvature radius map to express the local change on the cornea shape.

SS-1000 equally divides the cornea into thirty-two fan-shaped segments, using thirty-two radiuses as shown in Fig. 1. These radiuses are indexed, and considered to be thirty-two directions in the following discussions. In addition, a direction is equally divided into two-hundred and fifty-six line segments, setting Radius in TABLE I as a reference. SS-1000 measures values of the test items in TABLE I at the points specified by directions and line segments. Let directions and line segments correspond to rows and columns, respectively. SS-1000 then provides a matrix with thirty-two rows and two-hundred and fifty-six columns as measured values associated with each of the test items except Radius. The proposed method generates a couple of thirty-two-dimensional vectors (or a sixty-four-dimensional vector) from the matrix associated with a test item for a test subject as registered data and collation data.

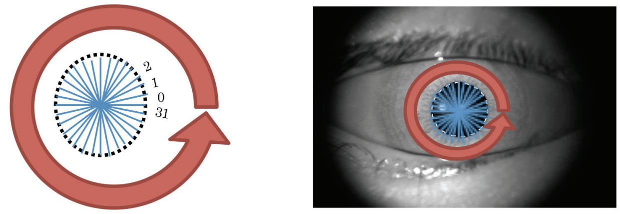

Figure 1. Cornea divided into equal-area fan-shaped segments, using thirty two radiuses.

B. *Test Items Suitable for Personal Identification*

SS-1000 is not designed so that the alignment of measurement positions can be perfectly made for an identical test subject. In other words, for the some subject to which SS-1000 has been applied twice, the position where a direction and a Radius specify on his/her cornea at the first measurement does not always accord with the position where the same direction and the same Radius specify at the second measurement. Therefore, if the gap between measurement positions courses a serious fluctuation for some test item, employing this item is considered to be unsuitable for the personal identification. In addition, the item of which values are almost same among some test subjects is clearly unsuitable.

Figs. 2-6 depict variations in item values associated with Axial Keratometric, Axial Posterior, Instantaneous Keratometric, Height Posterior, and Pachymetry for right eyes of two test subjects indexed as A and B. These variations were measured along one of the thirty-two directions shown in Fig. 1. One subject is a male in his twenties; the other is also a male in his forties. They have healthy right eyes. The measurements were conducted two times at certain time intervals. A set of item values obtained by the first (or second) measurement is considered to be for the registration (or collation).

For item values associated with Height Posterior, a coincidence degree is extremely high between the two measurements for each subject. This means Height Posterior values are robust for the gap caused by the above-mentioned measurement positions. However, since the difference is very small between subjects A and B, it seems that the personal identification using the data generated form Height Posterior matrix would be disappointed. The above tend to apply to the cases where Instantaneous Posterior, Height Anterior, and Elevation Posterior vales are examined.

For item values associated with Instantaneous Keratometric, a clear gap between two subjects appears as shown in Fig. 4.

TABLE I. TEST ITEMS THAT OCT (SS-1000) IS AVAILABLE TO MEASURE

Test items	Definitions
Radius	Distance from the center of the cornea[mm]
Axial Keratometric	Power of the anterior surface of the cornea in Axial [D]
Axial Posterior	Power of the posterior surface of the cornea in Axial [D]
Reflective Keratometric	Power of the anterior surface of the cornea in Refractive [D]
Instantaneous Keratometric	Power of the anterior surface of the cornea in Instantaneous [D]
Instantaneous Posterior	Power of the posterior surface of the cornea in Instantaneous [D]
Height Anterior	Distance from the reference plane in the anterior surface of the cornea [μm]
Height Posterior	Distance from the reference plane in the posterior surface of the cornea [μm]
Elevation Anterior	Distance from the reference spherical surface in the anterior surface of the cornea [μm]
Elevation Posterior	Distance from the reference spherical surface in the posterior surface of the cornea [μm]
Pachymetry	Vertical thickness of the cornea in its anterior surface [μm]

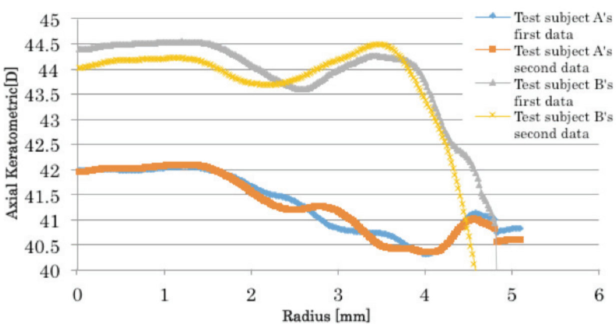

Figure 2. Variation of Axial Keratometric along a direction for two test subjects.

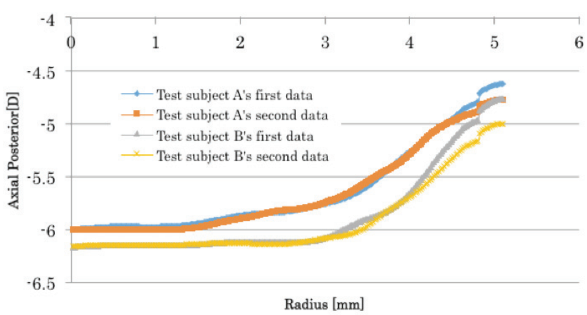

Figure 3. Variation of Axial Posterior along a direction for two test subjects.

On the other hand, in the range where Radius takes the value more than 4 mm, first Instantaneous Keratometric values of subject B are markedly different to the values measured for subject B at the second time. This will correspond to the case where the gap caused by the measurement positions strongly affects the identification rate if the data are generated form Instantaneous Keratometric matrix. A similar tendency with respect to the dependency on measurement positions holds when Reflective Keratometric and Elevation Anterior are employed to generate the data.

Axial Keratometric, Axial Posterior, and Pachymetry remain in TABLE I. In this paper, these items are considered to be promising, and the cases where each of them is employed to generate the data are examined in terms of identification rates achieved.

III. PERSONAL IDENTIFICATION USING DATA GENERATED FROM INFORMATION ON CORNEAL THICKNESS

The proposed method generates either a couple of thirty-two-dimensional data or a sixty-four-dimensional data as the registered data (or collation data), provided that a 32×256-sized matrix associated with one of the three test items, Axial Keratometric, Axial Posterior, and Pachymetry, is used for a given test subject to be identified. Some ophthalmologists demand to incorporate the function of personal identification into OCT. This requires reducing the load imposed on OCT as much as possible, and hence the above vectors are employed for the identification instead of the matrices.

The case of using sixty-four-dimensional data is first discussed. The proposed method searches the minimum (or maximum) value on the *i*-th row in the matrix associated with the given test item at the stages both of the registration and of the collation, where $0 \le i \le 31$. Recall that the cornea is equally divided into fan-shaped segments with thirty-two radiuses (i.e., directions) as shown in Fig. 1. The above search corresponds to find the minimum (or maximum) test item value along the direction *i*. The proposed method employs the minimum value on the direction *i* as the $(i+1)$-th element value, and the maximum value on it as the $(i+33)$-th element value in the data. When identifying some subject, the proposed method calculates the standard Euclidean distance between each of the registered data and the collation data for the subject. It then judges the subject corresponding to the collation data to be that of the registered data with the shortest distance to the collation data. From now on, identification methods using sixty-four-dimensional data associated with Axial Keratometric, Axial Posterior, and Pachymetry are referred to as AK_{64}, AP_{64}, and P_{64}, respectively.

Let us next discuss cases of using a couple of thirty-two-dimensional data. In these cases, the minimum (or maximum) value on the *i*-th row in the matrix associated with the given test item is set to the $(i+1)$-th element value at the stages both of the registration and of the collation. In other words, the data with minimum values and the data with maximum values are generated a subject at each stage. Let d_{min} (or d_{max}) denote the

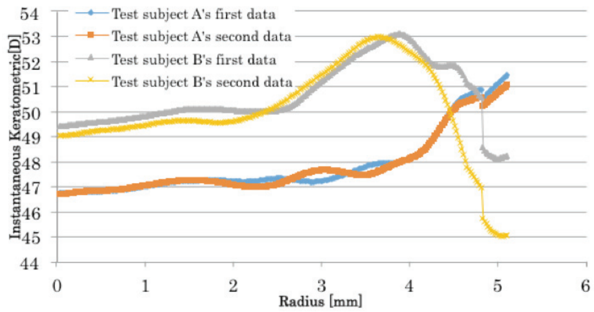

Figure 4. Variation of Instantaneous Keratometric along a direction for two test subjects.

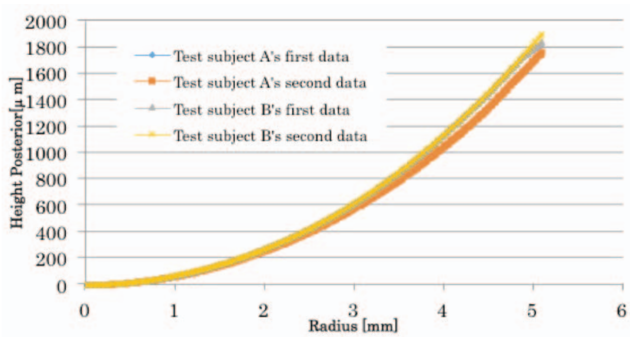

Figure 5. Variation of Height Posterior along a direction for two test subjects.

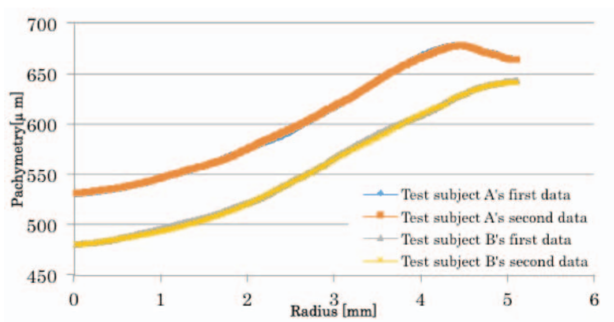

Figure 6. Variation of Pachymetry along a direction for two test subjects.

standard Euclidean distance between the registered data with minimum (or maximum) values and the collation data with minimum (or maximum) values. Besides, let d_{sum} (or d_{prod}) denote the sum (or product) of d_{min} and d_{max}. The proposed method also calculates them as criteria for the identification, and judges the subject corresponding to the collation data to be that of the registered data with shortest d_{sum} (or d_{prod}) to the collation data. Assuming that the calculation of d_{sum} is made, the methods using data associated with Axial Keratometric, Axial Posterior, and Pachymetry are hereinafter referred to as AK_{sum}, AP_{sum}, and P_{sum}, respectively. On the other hand, in the case of calculating d_{prod}, the methods using data associated with Axial Keratometric, Axial Posterior, and Pachymetry are referred to as AK_{prod}, AP_{prod}, and P_{prod}, respectively.

IV. EXPERIMENTAL RESULTS

The proposed method has been applied to the data of forty-five medical staffs working in Tsukazaki Hospital. The data are measured for their both eyes. The measurements are conducted two times a test subject. The data obtained from the first (or second) measurement is considered to be the registered (or collation) data. The time interval between two measurements is about an hour for each subject. The age structure of subjects is tabulated in TABLE II. In the following discussions, the identification rate is equal to the number obtained by dividing the total number of eyes into the number of eyes of the subjects accurately identified. Besides, there are the case where data of the right and left eyes are separately stored and the case where they are stored without distinction. In the former case, the comparison with each member of the set with registered data of right (or left) eyes suffices when the target of the identification is the collation data associated with the right (or left) eye. This case is hereinafter referred to as Identification A. On the other hand, in the latter case, the proposed method must calculate the distance between the target of identification and each of the members in the set of data associated with both eyes. This case is hereinafter referred to as Identification B. Since the total number of data belonging to the set on Identification B is ninety, it can be safely considered that Identification B clearly has double difficulty compared to Identification A.

Results achieved by AK_{64}, AP_{64}, and P_{64} are tabulated in TABLE III. Each of the entries associated with AK_{64} and AP_{64} are less than 80 percent. The identification rates achieved by AK_{64} and AP_{64} especially imply that considerable eyes are misjudged on Identification B. P_{64} fails to accurately identify a subject for right eyes, while it achieves 100 percent for left eyes on Identification A and Identification B.

Let us next discuss results achieved by AK_{sum}, AP_{sum}, and P_{sum}. AK_{sum} is approximately equal to AK_{64} in terms of identification rates as shown in TABLE IV. AP_{sum} achieves high identification rates compared to AP_{64}. Those rates in TABLE IV are however around 80 percent, and the number of right eyes misjudged on Identification B is larger than that misjudged on Identification A. P_{sum} can perfectly judge left eyes both on Identification A and on Identification B as well as P_{64}. Entries for P_{sum} in TABLE IV equal those in TABLE III. In other words, the rates for right eyes slightly fail to reach 100 percent, because a misidentification occurs for a right eye.

Results achieved by AK_{prod}, AP_{prod}, and P_{prod} are finally shown in TABLE V. Though results achieved by AK_{prod} are higher than those achieved by AK_{64} and AK_{sum}, it is impossible to evaluate that they reach practical levels. AP_{prod} is also superior to AP_{64} and AP_{sum}. The rate for right eyes on Identification B is however less than 90 percent. P_{prod} perfectly succeeds in judging all eyes both on Identification A and on Identification B. Achieving 100 percent on Identification B specially means that the executed method can precisely distinguish right eyes from left eyes without generating a data set exclusive for right eyes (or left eyes) in advance. It is revealed that the identification based on P_{prod} will result in improving quality of the system to the level of practical use.

TABLE II. AGE AND GENDER COMPOSITION OF TEST SUBJECTS

Generations	Number of males	Number of Females
Twenties	8	12
Thirties	5	5
Forties	2	5
Fifties	1	1
Sixties	3	1
Seventies	1	1

TABLE III. IDENTIFICATION RATES ACHIEVED BY AK_{64}, AP_{64}, AND P_{64} METHODS

Methods	Eyes	Identification A	Identification B	
AK_{64}	Right eyes	28/45 (62.2%)	26/45 (57.7%)	52/90 (57.7%)
	Left eyes	29/45 (64.4%)	26/45 (57.7%)	
AP_{64}	Right eyes	34/45 (75.5%)	34/45 (75.5%)	65/90 (72.2%)
	Left eyes	32/45 (71.1%)	31/45 (68.8%)	
P_{64}	Right eyes	44/45 (97.7%)	44/45 (97.7%)	89/90 (98.8%)
	Left eyes	45/45 (100.0%)	45/45 (100.0%)	

TABLE IV. IDENTIFICATION RATES ACHIEVED BY AK_{SUM}, AP_{SUM}, AND P_{SUM} METHODS

Methods	Eyes	Identification A	Identification B	
AK_{sum}	Right eyes	28/45 (62.2%)	27/45 (60.0%)	56/90 (62.2%)
	Left eyes	31/45 (68.8%)	29/45 (64.4%)	
AP_{sum}	Right eyes	37/45 (82.2%)	36/45 (80.0%)	72/90 (80.0%)
	Left eyes	36/45 (80.0%)	36/45 (80.0%)	
P_{sum}	Right eyes	44/45 (97.7%)	44/45 (97.7%)	89/90 (98.8%)
	Left eyes	45/45 (100.0%)	45/45 (100.0%)	

TABLE V. IDENTIFICATION RATES ACHIEVED BY AK_{PROD}, AP_{PROD}, AND P_{PROD} METHODS

Methods	Eyes	Identification A	Identification B	
AK_{prod}	Right eyes	39/45 (86.6%)	35/45 (77.8%)	65/90 (72.2%)
	Left eyes	33/45 (73.3%)	30/45 (66.6%)	
AP_{prod}	Right eyes	41/45 (91.1%)	40/45 (88.8%)	81/90 (90.0%)
	Left eyes	41/45 (91.1%)	41/45 (91.1%)	
P_{prod}	Right eyes	45/45 (100.0%)	45/45 (100.0%)	90/90 (100.0%)
	Left eyes	45/45 (100.0%)	45/45 (100.0%)	

As mentioned above, the data of forty-five test subjects have been employed for the experiments. The number of these subjects is close to the number of patients undergoing ophthalmic surgeries a day at Tsukazaki Hospital. It is thus expected that the P_{prod}-based system will be promising in controlling access to comparatively small-scale rooms (e.g., operating rooms in hospitals).

V. CONCLUSIONS

In this paper, the personal identification has been presented, using the data associated with corneal thickness obtained by OCT (model name: SS-1000). When identifying some test subject, the proposed method generates the collation data with thirty-two element values or sixty-four element values from a 32×256-sized matrix obtained by OCT. SS-1000 does not always measure the test item value at the identical point on the cornea. To overcome this problem, the proposed method focuses on Axial Keratometric, Axial Posterior, and Pachymetry of which item values are not only enough different among subjects but also have comparatively low dependency on measuring points for the identical subject. It defines three types of the distance. It calculates the distance between each of the members in the registered data set and the given collation data, and judges the test subject corresponding to the given collation data to be that of the registered data with the shortest distance to the given data. It has been established that the proposed method achieves 100 percent as the identification rate, when a couple of thirty-two dimensional data associated with Pachymetry is employed a subject both at the registration stage and at the collation stage, and d_{prod} is calculated as distance between the registration data and the collation data.

It remains as the future study to improve the identification rate achieved by the proposed method. In addition, the proposed method must be evaluated in terms of rejection capability for unregistered subjects and time dependence associated with the period between the first measurement to generate registered data and the second measurement to generate collation data.

REFERENCES

[1] A. Ohtsuka, N. Kamiura, T. Isokawa, I. Nakagiri, H. Nishimura, and N.Matsui, "Multiple-SOM-Based Detection of Confusion between

Blood Samples," Proc. of the first Int. Conf. on Complex Medical Engineering, pp.428-433, May 2005.

[2] A. Ohtsuka, N. Kamiura, T. Isokawa, N. Minamide, M. Okamoto, N. Koeda, N. Matsui, "A Self-Organizing Map Approach for Detecting Confusion between Blood Samples," Trans. of the Society of Instrument and Control Engineers, Vol.41, No.7, pp. 587-595, 2005.

[3] H. Oinonen, H. Forsvik, P. Ruusuvuori, O. Yli-Harja, V. Voipio, and H. Huttunen, "Identity Verification Based on Vessel Matching from Fundus Images," Proc. of 2010 17th IEEE Int. Conf. on Image Processing, pp. 4089-4092, Sept. 2010.

[4] S. M. Lajevardi, A. Arakala, S. A. Davis, and K. J. Horadam, "Retina Verification System Based on Biometric Graph Matching," IEEE Trans. on Image Processing, Vol. 22, Issue 9, pp. 3625-3635, Sept. 2013.

[5] H. Farzin , H. Abrishami-Moghaddam, and M. S. Moin, "A Novel Retinal Identification System," EURASIP J. Adv. SignalProcess., Vol. 2008, pp. 1-10, 2008.

[6] S. Viriri and J. R. Tapamo, "Improving Iris-Based Personal Identification Using Maximum Rectangular Region Detection," Proc. of 2009 Int. Conf. on Digital Image Processing, pp. 421-425, March 2009.

[7] L. Ma, T. Tan, Y. Wang, and D. Zhang, "Personal Identification Based on Iris Texture Analysis," IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. 25, Issue 12, pp. 1519-1533, Dec. 2003.

[8] Y. Zhou and A. Kumar, "Personal Identification from Iris Images Using Localized Radon Transform," Proc. of 2010 20th Int. Conf. on Pattern Recognition, pp. 2840-2843, Aug. 2010.

[9] http://www.tomey.com/Products/OCT/SS-1000CASIA.html.