Proceedings of the 2013 Federated Conference on
Computer Science and Information Systems pp. 179–182

Medical Decision Support System Architecture for Diagnosis of Down's Syndrome

Hubert Wojtowicz*, Jolanta Wojtowicz*, Wojciech Koziol* and Wieslaw Wajs†
*University of Rzeszow
Faculty of Mathematics and Nature
Institute of Computer Science
Email: hubert.wojtowicz@gmail.com
† AGH University of Science and Technology
Faculty of Electrical Engineering
Institute of Automatics
Email: wwa@ia.agh.edu.pl

***Abstract*—The paper presents the development of a new system that is used to solve the problem of the recognition of the dermatoglyphic pattern and the understanding of the classification process of the symptoms of Down's syndrome. The method used in the system for diagnosing Down's syndrome in infants is based on the combination of text knowledge found in the scientific literature describing Down's syndrome with the knowledge obtained from the analysis of dermatoglyphic indices characteristic of Down's syndrome with the use of digital pattern recognition techniques. The scientific goal is to design a classifier system that realizes automatic medical diagnosis through the application of an expert system designed on the basis of knowledge included in the scientific text descriptions of the Down's syndrome. One other aim is the application of the pattern recognition algorithms to the analysis of indices present in the images of dermatoglyphic patterns. This approach, similar to the approach used by anthropologists, is realized by the system through the juxtaposition of the knowledge described in the form of expert system rules and the information provided by the appropriate digital equipment, and on the basis of this juxtaposition an arbitrary classification of the investigated patterns is performed.**

I. Introduction

THE present state of knowledge in the discipline of medical pattern recognition allows the extraction of image features using computer methods and data processing algorithms. The results obtained using these methods are presented to an expert who affirms in an arbitral way his understanding of the pattern presented to him as an after-effect of the occurrence of a pathological process and describes it using terms established in the scientific medical literature. In the present state of science and technology development the number of available patterns and the amount of information included in the scientific literature is constantly increasing. It can be assumed with certainty that both of these elements will have a tendency to increase in a hard to predict tempo. The community of medical experts copes with the high increase in information by dividing medical knowledge into many new specializations. The main and basic source of professional knowledge is the knowledge written in the form of natural language sentences. The attempt described in the project is to combine knowledge extracted from scientific medical literature with features extracted and classified by pattern recognition algorithms in the process of analyzing digital images of infants' dermatoglyphic patterns. In its basic form this approach is based on building a hybrid decision support system that comprises an expert system module inferring the occurrence of a genetic disorder on the basis of the results passed from pattern recognition modules that analyze the dermatoglyphic images automatically without the participation of a human expert. The success of this approach may lead to the application of a computer technique to achieve near complete automation of screening tests for the detection of Down's syndrome in infants.

II. The Aim of the Work

The tasks of the recognition and understanding of dermatoglyphic patterns, whose results form the basis for inferring the occurrence of a genetic disorder in infants, are complex issues. The classification of the patterns and the diagnosing of the presence of a genetic disorder on the basis of recognitions is carried out by professional anthropologist. The service of automatic pattern recognition and clinical decision support designed in the form of a telemedical system can perform specialized screening tests of dermatoglyphic data delivered from medical centers that do not employ anthropologists. The data is collected in a non-invasive manner using touch scanners or specialized cameras and then sent to a distant server that is running the telemedical system via the Internet. The uploaded data is then subject to a detailed analysis whose aim is the extraction of features from the collection of images on the basis of which the classification of the case is carried out. It should be emphasized that it is possible to implement and use the designed system with the use of the existing IT infrastructure of local hospitals.

The design of the system involves the following information processing scheme:

1. The analysis of texts containing specialized field knowledge in the form of natural language sentences, arithmetic expressions and arithmetic-logic relations leads to the formulation of conditions which are basis for the conclusion.

978-1-4673-4471-5/$25.00

2. The synthesis of partial information contained in the digitally stored image leads to the generation of features that represent characteristic image patterns.

As a result of the proposed scheme application a set of rules for the expert system is obtained, on the basis of which the probability of the occurrence of a genetic disorder in infants is determined. The calculation of the values of premises for the expert system is realized through the determination of the classes of the analyzed patterns of particular dermatoglyphic areas and through the assessment of other features of dermatoglyphs. The values of the conclusions of the expert system that was built on the basis of a text analysis allow for the qualification of the medical case to the group of healthy infants or to the group of infants with a genetic disorder. Undertaking the research topic results from the difficulty in the direct access to the screening tests that are carried out by an anthropology specialist. The proposed decision support system allowing for remote access to these tests overcomes limitations that result from the shortage of employment of specialists in small medical centers. Therefore it brings a new substantial value into social life and helps in the task of improving the accessibility to specialized medical services. It is assumed that the application of the system will improve the effectiveness of the treatment, i.e. the number of complications due to improper treatment of infants with certain genetic defects will decrease and thus the costs of the treatment and the length of hospital care will also decrease. The authors believe that the system will prove particularly useful as a support system for doctors working in small hospitals which do not employ anthropologists and as an automatic system for screening tests of infants performed on a large scale. The device for the analysis of dermatoglyphs will consist of an average desktop computer with a touch scanner or a digital camera attached to it. Depending on the computing capabilities of the workstation, it can serve as an independent unit performing diagnosis or as a terminal used for the acquisition of and for sending data over the Internet and for displaying the results of the analysis.

III. Design of the Medical Decision Support System

The project of the decision support system is of interdisciplinary character as it combines the achievements of modern sciences in the fields of computational intelligence, digital image processing, pattern recognition and the design of expert systems containing medical knowledge. The design proposed by the author assumes the modular architecture of the diagnostic system. Based on the design of dermatoglyphic nomogram [4] the system consists of four main modules. One may distinguish three modules that realize the pattern recognition of medical images. Another superior module in the form of an expert system generates diagnosis on the basis of recognition results that come from pattern recognition modules.

The role of the first of the pattern recognition modules is the classification of fingerprints. Fingerprint classification is one of the fundamental tasks of dermatoglyphic analysis. Several

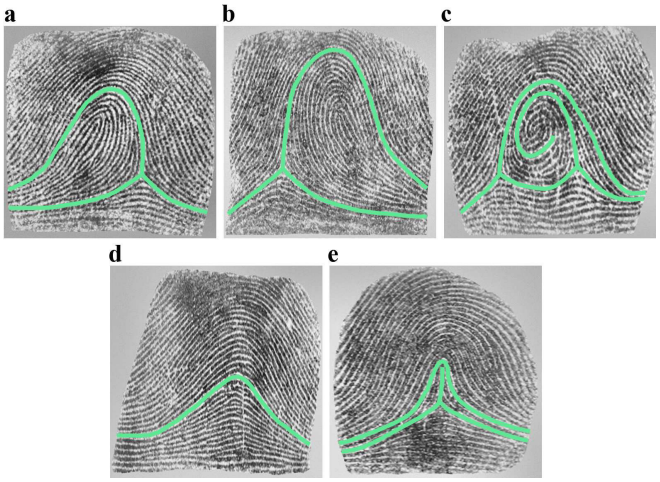

Fig. 1. Classification scheme of fingerprints: (a) left loop (LL); (b) right loop (RL); (c) whorl (W); (d) plain arch (A); (e) tented arch (TA). (The green lines traced on the prints are the type lines, which define the unique skeletons of the patterns.)

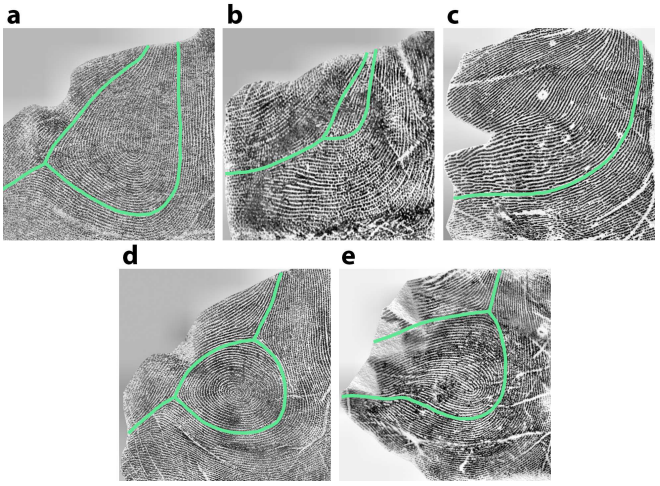

Fig. 2. Classification scheme of the hallucal area of the sole prints: (a) large distal loop (LDL), (b) small distal loop (SDL), (c) tibial arch (TA), (d) whorl (W), (e) tibial loop (TL).

methods of fingerprint classification have been proposed in scientific literature and are used for a variety of applications relating to the analysis of fingerprints [2]. The classification method used in the dermatoglyphic analysis is called Henry's classification method after the name of the originator of this method. It distinguishes between the following five classes of fingerprint patterns: left loop (LL), right loop (RL), whorl (W), plain arch (A) and tented arch (TA) Fig. 1.

The second module performs the classification of patterns of the hallucal area of the sole. A classification scheme of hallucal area patterns includes the following classes: large distal loop (LDL), small distal loop (SDL), tibial arch (TA), whorl (W) and tibial loop (TL) Fig. 2.

Both pattern recognition modules employ the image pro-

cessing algorithms for the segmentation of the background and contrast enhancement of the analyzed images. An important element of enhancement of the local ridge structures of dermatoglyphs is the application of contextual image filtration, which is realized by STFT algorithm [1]. In the classification process, the features extracted from the enhanced images represent the unique properties of the patterns contained within the images. The features used by the classification modules are local ridge flow directions of dermatoglyphic patterns. The classification is accomplished by an ensemble of SVM classifiers that make use of the RBF kernel functions in the learning process and that are trained with the use of the one vs. one voting scheme. Both classification modules recognize the patterns of appropriate dermatoglyphic areas with 90% accuracy ratio.

The third pattern recognition module is used to determine the ATD angle of the right palm print Fig. 3. The value of this angle is determined by the location of digital triradii A and D and the axial triradius t. A reliable and accurate identification of the location of the characteristic points is a complex issue, therefore the algorithm devised for finding these points uses two independent local image descriptors calculated in different ways. The first of these descriptors is an improved variant of the Poincare index [7] that is determined from the ridge flow directions map calculated by the algorithm based on the image pyramid decomposition and PCA [3]. The second of the determined descriptors is a local coherence map calculated from the image texture. For each point of the image containing the analyzed pattern, the values of eigenvectors which create the coherence map are calculated. Eigenvectors are calculated from the confusion matrix that contains the values determined for each image pixel with the use of multiplication of a local image segment centered in pixel (i,j) and the combination of two dimensional Gauss-Hermite moments [7]. The information in the form of the Poincare index and the information in the form of a coherence map are compared for all pixels of the image that contains the dermatoglyphic pattern. The points of the image in which the values of both of these descriptors simultaneously indicate the occurrence of a characteristic point are considered to be the true characteristic points.

The fourth module implemented as an expert system is superior to the modules that carry out the pattern recognition tasks. On the basis of the recognition results that come from pattern recognition modules this module carries out an automatic diagnosis which determines the qualification of the infant to a group of healthy children or to a group of children with Down's syndrome. The basis of the design of an expert system is a dermatoglyphic nomogram. The dermatogram was created on the basis of statistical test results. The statistical test allowed for selecting, from the group of all known dermatoglyphic features that indicate the presence of a genetic disorder, the four most significant features on the basis of which a credible diagnosing of the likelihood of the presence of Down's syndrome in newborns is possible [4].

The premises in the rules of an expert system are the recognized types of patterns of the dermatoglyphic areas that

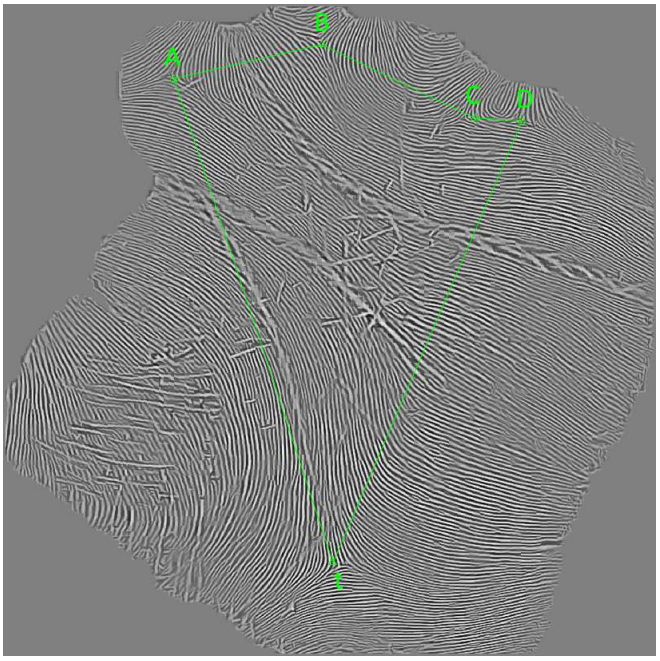

Fig. 3. Singular points of the palm print located with the use of a two stage algorithm that use the improved Poincare index and Gauss-Hermite moments.

contain the four significant features which are: pattern types of index fingers of the left and right hand, pattern type of the hallucal area of the right sole, value of the ATD angle of the right palm. The conclusions of the expert system are diagnostic values determined for diagnostic criterions of the dermatogram that result from the types of dermatoglyphic patterns and from the value of the ATD angle. A combination of these diagnostic criteria values determines the value of the dermatogram diagnostic score and the fact of Down's syndrome occurrence in the newly-born. For the dermatogram 125 possible combinations of patterns exist, which corresponds to the same number of expert system rules.

Table I presents a set of premises and diagnosis results for the rules that correspond to the combination of the recognition of the left and right hand index fingerprints patterns UL - UL (denoting the left loop pattern type on the index finger of the left hand and the right loop pattern type on the index finger of the right hand) and all the possible combinations of the hallucal area of the sole pattern types and the ranges of the ATD angle values.

IV. Results

In the course of the research carried out, components of the system have been designed and implemented. The system will allow for an automatic diagnosis of the occurrence of genetic disorders in infants on the basis of sets of dermatoglyphic images. The system has a modular design. The implementation of the system required the application of numerous computer technologies. The modules responsible for carrying out image processing, feature extraction and pattern recognition tasks

TABLE I
A PARTIAL SET OF EXPERT SYSTEM RULES FOR THE EXAMPLE COMBINATION OF DERMATOGLYPHIC PATTERNS

Combination	Right Index Finger	Left Index Finger	Right Hallucal Area	Right ATD Angle	Diagostic Line Index
1	UL	UL	LDL	⟨15;28⟩	Normal
	UL	UL	LDL	(28;78⟩	NN
	UL	UL	LDL	(78;120⟩	Down
2	UL	UL	Other	⟨15;37⟩	Normal
	UL	UL	Other	(37;88⟩	NN
	UL	UL	Other	(88;120⟩	Down
3	UL	UL	SDL	-	Normal
	UL	UL	SDL	⟨15;58⟩	NN
	UL	UL	SDL	(58;120⟩	Down
4	UL	UL	TbA	-	Normal
	UL	UL	TbA	⟨15;31⟩	NN
	UL	UL	TbA	(31;120⟩	Down
5	UL	UL	W or FL	⟨15;34⟩	Normal
	UL	UL	W or FL	(34;85⟩	NN
	UL	UL	W or FL	(85;120⟩	Down

have been implemented with the use of the Matlab and C languages. The database containing dermatoglyphs was designed and implemented with the PostgreSQL database management system. In the database, collections of images are stored along with their descriptions. The diagnostic module in the form of an expert system has been implemented in the Prolog language. The analysis of the collection of images realized by pattern recognition modules allows for the classification of fingerprint patterns [5], for the classification of the hallucal area of the sole patterns [6] and the determination of the value of the ATD angle of the palm print. The outcomes of the classifications and image features calculations are passed to the set of rules of the expert system which on their basis calculates the value of the diagnostic score that determines to which of the three groups the diagnosed infant belongs: healthy infants, infants with Down's syndrome, or infants for whom the value of the diagnostic index does not give a clear answer as to the occurrence of a genetic disorder. The client application implemented in the project is equipped with typical useful capabilities such as enabling users to search and view data. It also provides scientific capabilities allowing for the following: sending requests to the decision support server to perform a dermatoglyphic analysis, the visualization of analysis outcomes in a numerical form and the visualization of the diagnosis results, generated by the explanation facilities of the expert system module in the form of a text description.

V. SUMMARY

The paper presents the architecture of the medical decision support system for the diagnosis of Down's syndrome in infants on the basis of collections of images. The results of the research on the system have reached a high level of advancement. From the technical standpoint, the modules responsible for the pattern classification of the fingerprint and hallucal area of the sole impressions were accomplished. A procedure for the calculation of the ATD angle of the palm has been proposed and implemented. A decision module that determines the diagnostic index value on the basis of the results passed from pattern recognition and image parameters analysis modules has also been implemented. The intention of the authors is an implementation of the system in a form that is useful for public institutions (hospitals, health care institutions, etc.) and for medical universities that use the advisory nature of the diagnostic system to assist in the education of medical students. A client application will be installed in dedicated terminals as a tool that supports the process of infants' diagnosis. A stand-alone application designed for personal computers, having the functionality of the above-mentioned application, is also planned. This software will serve the public as a free to use assistance for those interested in performing a stand-alone diagnosis. After a full implementation of the system, its further development is assumed depending on the degree of extension of the dermatoglyphic database used as a knowledge base. The users of the system (medical doctors, other medical personnel) will be encouraged to upload the data collected in their daily work to the database and thus improve its efficiency and thereby contribute to the development of the system.

REFERENCES

[1] S. Chikkerur, A. N. Cartwright and V. Govindaraju, "Fingerprint image enhancement using STFT analysis," *Pattern Recognition,* vol. 40, pp. 198–211, Elsevier (2007).
[2] H. Cummins and C. Midlo, "Fingerprints, palms and soles - Introduction to Dermatoglyphics," Dover Publications Inc., New York (1961).
[3] X. G. Feng and P. Milanfar, "Multiscale principal components analysis for image local orientation estimation," *Proc. of the 36th Asilomar Conf. on Signals, Systems and Computers,* vol. 1, pp. 478–482, (2002).
[4] T. E. Reed, D. S. Borgaonkar, P. M. Conneally, P. Yu, W. E. Nance and J. C. Christian, "Dermatoglyphic nomogram for the diagnosis of Down's syndrome," *The Journal of Pediatrics,* vol. 77, no. 6, pp. 1024–1032, (1970).
[5] H. Wojtowicz and W. Wajs, "Intelligent Information System for Interpretation of Dermatoglyphic Patterns of Down's Syndrome in Infants," *Proc. of 4th Asian Conference on Intelligent Information and Database Systems (ACIIDS),* Springer - Verlag, LNAI vol. 7197, pp. 284–293, (2012).
[6] H. Wojtowicz and W. Wajs, "Classification of Plantar Dermatoglyphic Patterns for the Diagnosis of Down's Syndrome," *Proc. of 5th Asian Conference on Intelligent Information and Database Systems (ACIIDS),* Springer - Verlag, LNAI vol. 7803, pp. 295–304, (2013).
[7] Y. Yin and D. Weng, "A New Robust Method of Singular Point Detection from Fingerprint," *Proc. of Int. Symposium on Information Science and Engieering,* IEEE, (2008).