ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ
Қ. И. Сәтпаев атындағы Қазақ ұлттық техникалық зерттеу университеті

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Казахский национальный исследовательский технический университет им. К. И. Сатпаева

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Kazakh national research technical university named after K. I. Satpayev

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

1 (439)

JANUARY – FEBRUARY 2020

THE JOURNAL WAS FO67UNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы "ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы" ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Меншіктенуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).
Қазақстан республикасының Мәдениет пен ақпарат министрлігінің Ақпарат және мұрағат комитетінде 30.04.2010 ж. берілген **№10892-Ж** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Мерзімділігі: жылына 6 рет.
Тиражы: 300 дана.

Редакцияның мекенжайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., 220, тел.: 272-13-19, 272-13-18, http://www.geolog-technical.kz/index.php/en/

Редакцияның мекенжайы: Қазақстан, 050010, Алматы қ., Қабанбай батыр көш., 69а.
Қ. И. Сәтбаев атындағы геология ғылымдар институты, 334 бөлме. Тел.: 291-59-38.

Типографияның мекенжайы: «NurNaz GRACE», Алматы қ., Рысқұлов көш., 103.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан (г. Алматы)

Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан **№10892-Ж,** выданное 30.04.2010 г.

Периодичность: 6 раз в год
Тираж: 300 экземпляров

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, ком. 219, 220, тел.: 272-13-19, 272-13-18,
http://nauka-nanrk.kz /geology-technical.kz

Адрес редакции: Казахстан, 050010, г. Алматы, ул. Кабанбай батыра, 69а.
Институт геологических наук им. К. И. Сатпаева, комната 334. Тел.: 291-59-38.

Адрес типографии: «NurNaz GRACE», г. Алматы, ул. Рыскулова, 103.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)
The certificate of registration of a periodic printed publication in the Committee of information and archives of the Ministry of culture and information of the Republic of Kazakhstan N 10892-Ж, issued 30.04.2010

Periodicity: 6 times a year
Circulation: 300 copies

Editorial address: 28, Shevchenko str., of. 219, 220, Almaty, 050010, tel. 272-13-19, 272-13-18, http://nauka-nanrk.kz/geology-technical.kz

---

Editorial address: Institute of Geological Sciences named after K.I. Satpayev
69a, Kabanbai batyr str., of. 334, Almaty, 050010, Kazakhstan, tel.: 291-59-38.

Address of printing house: «NurNaz GRACE», 103, Ryskulov str, Almaty.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 439 (2020), 14 – 22 **https://doi.org/10.32014/2020.2518-170X.2**

UDC 51-76: 004.6
IRSTI 50.37.23

T. Zh. Mazakov[1,2], Sh. A. Jomartova[1,2], T. S. Shormanov[2], G. Z. Ziyatbekova[2], B. S. Amirkhanov[1], P. Kisala[3]

[1]RSE Institute of Information and Computational Technologies CS MES RK, Almaty, Kazakhstan;
[2]Al-Farabi Kazakh National University, Almaty, Kazakhstan;
[3]Lublin Technical University, Poland.
E-mail: tmazakov@mail.ru, jomartova@mail.ru, tt007@mail.ru, ziyatbekova@mail.ru, 87019931011@mail.ru, amirkhanov.b@gmail.com, p.kisala@pollub.pl

THE IMAGE PROCESSING ALGORITHMS FOR BIOMETRIC IDENTIFICATION BY FINGERPRINTS

Abstract. The article discusses image processing algorithms for biometric fingerprint identification. The identification features of the structure of papillary patterns on the fingers have been studied taking into account the fact that different pressure, speed, direction, ambient temperature and humidity level lead to different images. Due to various digital image processing and analysis algorithms such as: the SIFT descriptor, as well as the closest competitor, the SURF descriptor, it is possible to quickly obtain unique characteristics for each image. This study used a database of photographs obtained from open sources – the Fingerprint Verification Competition 2004 (FVC2004). As a result of the work, the graphic image of the matching key points, as well as the number of matched key points by fingerprints, have been investigated. Search key points is performed using the Hesse matrix. The determinant of the Hesse matrix (Hessian) reaches the extremum at the points of maximum variation of the brightness gradient. Fingerprints were obtained using the optical sensor "Cross Match V300". The experimental study showed that the developed software system has invariance to image rotations.

Key words: biometrics, fingerprints, identification signs, minute, papillary patterns, key point descriptors, image gradient, biometric personality identification, brightness gradient, digital processing algorithm, SIFT, SURF, BRIEF descriptors, database, Hessian matrix, CrossMatch V300 optical sensor, biometric scanner, FPM10A module, Adafruit Arduino library, optical scanner, password for passwords, invariance, uniqueness, volume precedents, Laplace pyramid, octave, key point estimates, Haar filter, Hamming distance sum, electronic fingerprint.

Introduction. Modern image processing algorithms are the main tools to improve performance in a variety of industries [1-3]. Criminology is one of those areas where the use of modern image processing algorithms provides a significant improvement in the results.

Since ancient times, a handprint was used to confirm the authenticity of a document. In VI-VII centuries in China a fingerprint was used to sign documents. The most famous use of the handprint as a confirmation of the document was the Ashtiname of Muhammad, also known as the Covenant or Testament of Muhammad, is a document which is a charter or writ ratified by the Islamic Prophet Muhammad granting protection and other privileges to the followers of Jesus the Nazarene, given to the Christian monks of Saint Catherine's Monastery. It is sealed with an imprint representing Muhammad's hand [4].

Traces of human fingers in their forensic significance occupy the first place in the group of methods of identification, which is explained as the frequency of their detection, and the fact that they can be used quickly enough to identify the person who left the fingerprints, also to identify the relation of this person with other incidents in which the same fingerprints were found. Such possibilities are associated with the features structure of skin on the fingers, namely the uniqueness of papillary patterns. Identification features of the structure of papillary patterns on fingers are divided into global and local signs: Global signs include features that can be seen with unaided eye. These features include: the type and kind of papillary pattern; direction and steepness of the flow of papillary lines; structure of central pattern; structure of delta; the number of papillary lines between the center and delta and many other features. Another type of signs is local. They are also called minutia points (signs or special points) – unique features inherent only in a particular print, determining the points of change in the structure of papillary lines (ridge ending, bifurcation, short or independent ridge, etc.), the orientation of papillary lines and coordinates in these points. Each print can contain up to 70 minutiae or more. The analysis is based on mapping local features – minutia is the most popular approach to identify because of the widespread opinion that minutia are the most discriminating and reliable features [5]. However, this approach faces some serious problems related to large distortions caused by fingerprint matching with different rotation, an example of such matching is shown below (figure 1) distortions from the FVC2004 DB1 (102_3) base.tif and 102_5.tif).

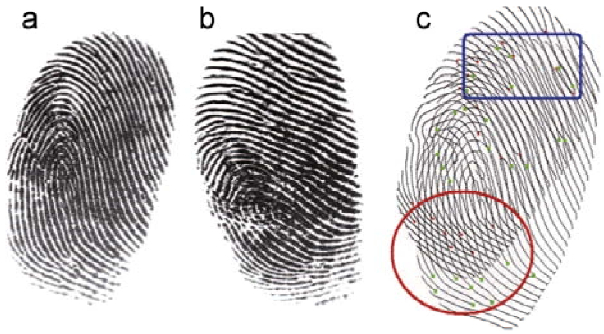


Figure 1 – The result of matching fingerprints with different rotation

The fingerprint of the same person will never look the same in any two readings. Different pressure, speed, direction, ambient temperature, skin moisture and moisture levels will result in different images. Also, in work [13] the example of age-related changes of fingerprints is given, with age fingerprints become less accurate and can change.To solve the above mentioned questions, the researchers proposed various methods of digital image processing and analysis, namely, the description of local vicinity of characteristic points - descriptor.

One of the main requirements for a special descriptor were:

Invariance – for the description of singular points to little change under different geometric and photometric transformations of the image.

Uniqueness – the descriptors of two different images should be markedly different from each other. These image requirements were formulated in [7] on the review of image matching methods.

Through various digital image processing and analysis algorithms such as: the SIFT descriptor, which was proposed in 1999 in article [8], as well as the closest competitor the SURF descriptor, which was proposed in 2008 in work [9], it became possible to quickly obtain unique characteristics for each image. However, none of the existing algorithms is universal, and therefore the search for solutions is an actual task.

The algorithms used to describe local features for biometric fingerprint identification, can be separated into several interrelated tasks:

1. Transformation the fingerprint image to a list of special points in the function (intersections, ridges, etc.), as well as their relative positioning and other parameters.

2. Converting the resulting function vector to a storage object in the database, which can be a row or a data series of column in a tuple.

3. Classification and comparison of the identified unique features of fingerprints with all the data that are already available in the system.

The objects of analysis are photos of fingerprints obtained from open sources, their unique features – a set of characteristics, and the output – comparison with other images and an indication of the coefficient of "similarity" with images that have already been previously identified in the database. Training takes place on a sufficient amount of precedents.

Research methods. In this research, we used a database of photos obtained from open sources - Fingerprint Verification Competition 2004 (FVC2004) [15-16], and the result: a graphical image of matching key points, as well as the number of matching key points on fingerprints. In FVC2004, emphasis is placed on distortion as well as on obtaining images of dry and wet fingerprints. Fingerprints were obtained using the optical sensor "Cross Match V300". Between the identification features of the structure of papillary patterns of the same person, obtained at different times, there are certain dependencies that need to be established. For this purpose, so-called precedents are used, that is, such sets of fingerprint images that are already identified using this algorithm. Such precedents are called training samples. In this study, several types of descriptors such as SIFT, SURF, and ORB descriptors were considered and used.

Descriptor SIFT. The SIFT (Scale Invariant Feature Transform) descriptor was proposed in 1999 by D. Love, University of British Columbia [8]. This descriptor is a local histogram of the image gradient directions. The following steps are required to build an image descriptor:

1. Finding the pyramid of image.
2. Keypoint finding.
3. Keypoint localization.
4. Keypoint orientation.
5. Local descriptor of image.

To find the pyramid of the image, we use the Laplace pyramid, in which we find high-frequency information about the image. The keypoints of the image are mainly located in these high-frequency parts of the image. In fact, the Difference of Gaussian (DoG) is an approximation to the Laplacians of the Gaussian (LoG). It is necessary to build several pyramids with different image scale, each pyramid is called an octave. Pyramids (octaves) is necessary for invariance to changes in scale and also to search for keypoints in different scales. For search keypoints to the DoG pyramid, it is necessary to find maximum / minimum in this scale as well as to find maximum / minimum in the neighboring scales. Refinement of keypoints after finding the maximum / minimum the next step is a detailed alignment with nearby data on the location, scale and ratio of the main curves. Keypoint orientation, gradient histograms are build for each keypoint, and the neighborhood of the special point is divided into four square sectors. In each pixel inside each sector, the gradient of image, direction and modulus are calculated. Next, the modules of the gradients are multiplied by the weight exponentially decreasing with distance from point of interest. For each sector, is created directions histogram of gradients, with each occurrence weighted by modulus of the gradient.

The local SIFT descriptor is a vector derived from the values of all elements of the histograms of directions and consists of 128 components (8 (number of bins) ×4×4 (number of squares)).

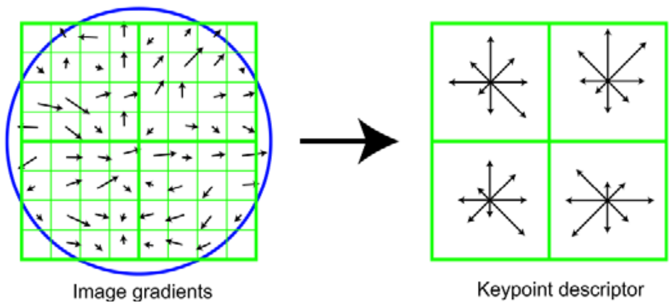


Figure 2 –
The construction of SIFT descriptor

The disadvantage of the system is that the descriptor vector consists of 128 real numbers, that is, it occupies at least 512 bytes per keypoint. That require significantly more processing power from the hardware especially if the image has a large resolution and a large number of details. Below (figure 3) an example of evaluation of key points using the SIFT algorithm is given.

Figure 3 –
Assessment the key points
of the SIFT descriptor

SURF descriptor. Descriptor SURF (Speeded up Robust Features) was proposed in 2008 [9] and is a further development of the SIFT technique. Its descriptor also refers to the number of descriptors that simultaneously search for singular points and construct their description invariant to scaling and rotation. The descriptor has proven itself in the tasks of searching for objects in images and comparing images.

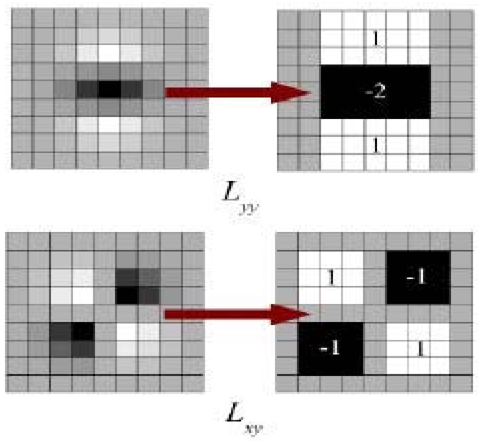
The SHIFT method uses the Difference of Gaussian (DoG) for building pyramids of the images. Different scales of Hessian masks are used to calculate the pyramid of the SURF image, while the scale of the image is always unchanged. This speeds up the calculation time without reducing the image.

Keypoints are searched using the Hesse matrix. The determinant of the Hesse matrix (Hessian) reaches the extremum at the points of maximum variation of the brightness gradient and its determinant is defined as follows:

$$H(f(x,y)) = \begin{bmatrix} \frac{\partial^2 f}{\partial x^2} & \frac{\partial^2 f}{\partial x \partial y} \\ \frac{\partial^2 f}{\partial x \partial y} & \frac{\partial^2 f}{\partial y^2} \end{bmatrix}$$

$$det(H) = \frac{\partial^2 f}{\partial x^2}\frac{\partial^2 f}{\partial y^2} - \left(\frac{\partial^2 f}{\partial x \partial y}\right)^2$$

where H is the Hesse matrix and the $f(x, y)$ is brightness gradient change function. In this case, the SURF algorithm uses different-scale filters to find hessians. For each keypoint, the gradient and scale are calculated. The gradient at a point is calculated using Haar filters. The filter size is taken to be 4s (where s is the scale of the singular point). An example of Haar filters is shown in figure 4. After finding the keypoints, the SURF method generates their descriptors. The descriptor for each key point is a set of 64 (or 128) numbers. These numbers represent the gradient fluctuations around the keypoint. Since the key-point is the maximum of Hessian, thereby is guaranteed that there must be areas with different gradients in the in the neighborhood of the point. Thus, the dispersion (difference) of descriptors for different keypoints is provided, thereby achieving invariance of the descriptor with respect to rotation. The size of the area on which the descriptor is calculated is determined by the scale of the Hesse matrix, which provides invariance with respect to the scale.



(black areas have values of "–1", white "+1")
Figure 4 – Haar Filters

Figure 5 –
Evaluation of kypoints of SURF descriptor

SURF. Advantages of the method: the SURF method has a higher accuracy and speed of recognition in comparison with the SIFT method. The disadvantages of the method are similar to the disadvantages of the SIFT method – it is a requirement for computing power, as well as method is patented and its use is prohibited for commercial purposes, without the consent of the owner. Below (figure 5) an example of evaluation of keypoints using the SURF algorithm is given.

ORB descriptor. The ORB descriptor (Oriented FAST and Rotated BRIEF) is a combination of the detector of keypoints FAST [10] and binary descriptors BRIEF [11], this method was proposed in 2011 [12] as an effective replacement for descriptor SURF/ SIFT.

The FAST detector is used to search for keypoints. To find corner points, comparing the brightness of the surrounding 16 pixels around each pixel p. All 16 pixels are then sorted into three classes (lighter than p, darker than p or similar to p). If more than 8 pixels are darker or brighter than p, this pixel is selected as the keypoint. Thus, the keypoints found with FAST detector give us information about the location of the edge (border) in the image. Selecting only 4 pixels on a circle allows you to quickly weed out the wrong points, but in some cases it is possible to determine different features in the same circle. However, the FAST algorithm does not have orientation component and multi-scale functions. A multi-level in image pyramid is used to solve this problem. By detecting keypoints at each level, the algorithm effectively finds key points at a different scale. Thus, the FAST detector is invariant of partial scale. In the ORB algorithm, the maximum number of special points by default is not more than 500, if there are more, then the Harris angle detector [11] is applied to them, to exclude the least significant ones.

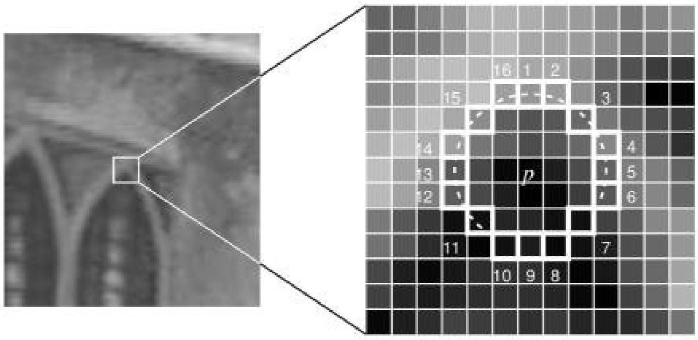


Figure 6 – The considered neighborhood of the p point of the FAST detector

After locating keypoints position, the FAST detector now assigns an orientation to each keypoint, such as left or right, depending on how the intensity levels change around that key point. The Ball uses a centroid of intensity for detect changes in intensity. The intensity centroid assumes that the intensity of an angle is shifted relative to its center, and this vector can be used to calculate orientation.

BRIEF descriptor. This descriptor takes all the keypoints found by the FAST algorithm and converts it to a vector of binary objects so that together they can represent the object. A binary objects vector, also known as a binary objects descriptor, is an object vector that contains only 1 and 0. In brief, each key point is described by a vector of objects, which is a string 128-512 bits long.

The BRIEF handle smoothes the image using a Gaussian kernel to prevent the handle from being sensitive to high-frequency noise. The BRIEF descriptor selects a random pair of pixels in a specific neighborhood around a key point. A certain neighborhood around a pixel is called a patch, which is a square of width and height equal to the selected pixel of the singular point. The first pixel in a random pair is taken from a Gaussian distribution centered around a key point with a spread of σ (Sigma). The second pixel in a random pair is taken from a Gaussian distribution centered around the first pixel with a spread of σ (Sigma)/2. Now, if the first pixel is brighter than the second, it assigns a value of 1 to the corresponding bit, otherwise 0, figure 7 shows an example of estimating the neighborhood of the keypoint.

This descriptor is represented as a 256-length vector consisting of binary tests results around a singular point. To achieve invariance to rotation, the descriptor computation area is oriented by the orientation of the singular point.

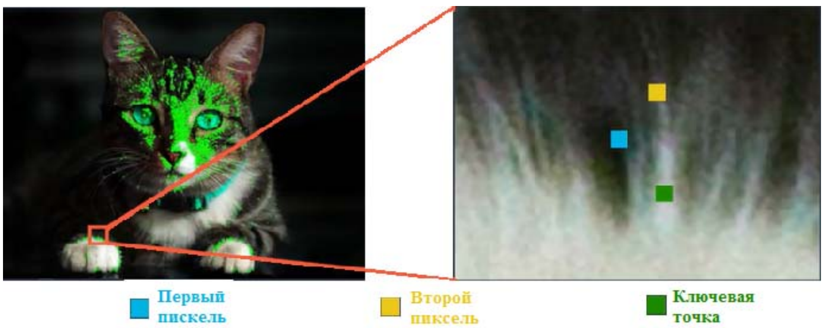


Figure 7 – Considered neighborhood of the keypoint

Advantages of the method: the ORB method has a high speed in comparison with the methods of SIFT/SURF. Disadvantages of the method: This method has a "lower" accuracy of recognition in comparison with the methods of SIFT/SURF. Below (figure 8) an example of evaluation of key points using the ORB algorithm is given.

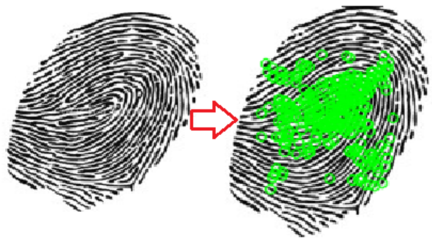


Figure 8 – Evaluation of keypoints of the ORB descriptor

Research results. The analysis of algorithms of search and identification on images showed that for the solution of a problem of identification on fingerprints it is effective to use descriptors of key points because they provide possibility of obtaining the classifier (descriptor) of a fingerprint with high degree of accuracy, and also have good function of identification on an incomplete fingerprint, the example of an assessment of 30 key points is shown on (figure 9).

Figure 9 – Score 30 key points descriptor ORB (left), SIFT (center), SURF (right)

The experimental research of biometric fingerprint identification, created on the basis of the proposed methods of searching for key points, showed that the developed software system has invariance to image rotations. Its software system is able to work in a large range of lighting changes up to 50-70% of the lighting level in the image, and has invariance to zoom and slight distortion.

Discussion. According to the results of the analysis of the efficiency and speed of methods and algorithms of biometric identification of persons, the following conclusions can be drawn:

Algorithms SURF/SIFT have better classifying ability in solving everyday tasks of finding textured images. Both algorithms are more demanding on the hardware and more suitable for other computer vision tasks, and both algorithms are patented and its use is prohibited on commercial use, without the consent of the owner for fingerprint identification task, they have "excess power".

The ORB algorithm has a higher speed in comparison with the above algorithms using SIFT/SURF techniques, and is more suitable for biometric fingerprint identification tasks. The algorithm is freely available. ORB algorithm descriptors are binary descriptors and the matching test for such descriptors is the sum of the Hamming distances for each byte of the descriptor. The use of this algorithm is more suitable for the tasks of searching for fuzzy fingerprint. An example of the use of forensic software systems in which fingerprints were marked out using the proposed algorithm.

Conclusion. In the course of the research work, the following tasks were performed: three algorithms for the identification of key points were investigated and analyzed to solve the problem of biometric identification by fingerprints. A promising area of application of algorithms is the addition into "classic" software products for the creation of electronic dactylocards, to search for incomplete fingerprint, because often in practice there is only a part of the fingerprint to search for matches.

Acknowledgment. The work was carried out at the expense of grant funding for research for 2018-2020 under the project №AP05131027 "Development of biometric methods and means of information protection" at the Institute of Information and Computational Technologies, the Committee of science of the Ministry of Education and Science of the Republic of Kazakhstan.

Т. Ж. Мазаков[1,2], Ш. А. Джомартова[1,2],
Т. С. Шорманов[2], Г. З. Зиятбекова[2], Б. С. Амирханов[1], P. Kisala[3]

[1]Ақпараттық және есептеуіш технологиялар институты, Алматы, Қазақстан;
[2]әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан;
[3]Люблин техникалық университеті, Польша

САУСАҚ ІЗДЕРІ БОЙЫНША ЖЕКЕ ТҰЛҒАНЫ БИОМЕТРИЯЛЫҚ СӘЙКЕСТЕНДІРУ ҮШІН АЛГОРИТМДЕРДІ ӨҢДЕУ

Аннотация. Мақалада биометриялық саусақ ізін сәйкестендіруге арналған суретті өңдеу алгоритмдері қарастырылады. Олар көптеген салалардағы жұмысты жақсартудың негізгі құралы болып табылады. Тану жүйесі деректерді сақтауға, оны ары қарай өңдеуге, саусақ іздерінің суреттерін анықтауға және көрсетуге арналған. Криминалистика (сот сараптамасы) – кескіндерді өңдеудің заманауи алгоритмдерін қолдану және жұмыс нәтижелерін едәуір жақсартатын бағыттардың бірі. Мұнда тәжірибелік зерттеу әдісі қарастырылып, сәйкестендіру нәтижелерін өңдеу процесі сипатталған. Бұл жұмыста FPM10A модулін Adafruit Arduino кітапханасында биометриялық саусақ іздері жүйесін құру үшін пайдалану әдісі көрсетілген. Бұл мәселені шешу үшін деректерді сақтау, одан ары өңдеу, саусақ іздерінің суреттерін анықтауға және көрсетуге арналған тану жүйесі ұсынылды. Олар өте құпия жерлерде, сканерлеу және дерекқордың көмегімен саусақ іздерін тексеруге негізделген парольға қол жеткізу кілтінің бір түрі ретінде қолданылады. Саусақтардағы папил-лярлы өрнек құрылымының сәйкестендіру ерекшеліктері әртүрлі қысымның, жылдамдықтың, бағыттың, қоршаған ортаның температурасы мен ылғалдылық деңгейінің әртүрлі кескіндерге әкелетінін ескере отырып зерттеледі. Олар әдетте жаһандық және жергілікті ерекшеліктерге бөлінеді. SIFT дескрипторы және SURF ең жақын бәсекелесі сияқты әртүрлі сандық өңдеу алгоритмдерінің арқасында әр кескінге ерекше сипат-тамаларды тез алуға мүмкіндік туды. Осы зерттеуде біз ашық көздерден алынған фотосуреттер базасын қолдандық. Ол Fingerprint Verification Competition 2004 (FVC2004) деп аталады. Жұмыс нәтижесінде сәйкестіктің негізгі нүктелерінің графикалық бейнесі, сонымен қатар саусақ іздері бойынша сәйкес келетін негізгі нүктелердің саны зерттелді. Бұл ерекшеліктер үшін әртүрлі мысалдар келтірілген, олардың алгоритмдерінің айырмашылықтары, артықшылықтары мен кемшіліктері көрсетілген. Саусақ іздерін сканер арқылы әртүрлі айналдырумен сәйкестендіру нәтижесі алынды. Негізгі нүктелер Гессе матрицасының көмегімен ізделеді. Гессе матрицасының детерминанты (гессиан) жарық градиентінің максималды өзгеру нүктелерінде экстремумға жетеді. Саусақ іздері «Cross Match V300» оптикалық сенсорының көмегімен алынды. Эксперименталды зерттеуден көргеніміздей, әзірленген бағдарламалық жасақтама кескіннің айналуына тұрақты емес.

Түйін сөздер: биометрия, саусақ іздері, сәйкестендіру белгілері, минуция, папиллярлық үлгілер, түйінді дескрипторлар, сурет градиенті, жеке басын биометриялық сәйкестендіру, жарықтылық градиенті, цифрлық өңдеу алгоритмі, SIFT, SURF, BRIEF дескрипторлары, мәліметтер базасы, Гессе матрицасы, CrossMatch V300 оптикалық сенсор, биометриялық сканер, FPM10A модулі, Adafruit Arduino кітапханасы, оптикалық сканер, парольге арналған кілт, инвариант, бірегейлік, векторлық функция, Лаплас пирамидасы, октава, негізгі нүктелерді бағалау, Хаар фильтрі, Хэммингтің қашықтық сомасы, электронды саусақ ізі.

Т. Ж. Мазаков[1,2], Ш. А. Джомартова[1,2],
Т. С. Шорманов[2], Г. З. Зиятбекова[2], Б. С. Амирханов[1], P. Kisala[3]

[1]РГП Институт информационных и вычислительных технологий КН МОН РК, Алматы, Казахстан;
[2]Казахский национальный университет им. аль-Фараби, Алматы, Казахстан;
[3]Люблинский технический университет, Польша

АЛГОРИТМЫ ОБРАБОТКИ ИЗОБРАЖЕНИЙ ДЛЯ БИОМЕТРИЧЕСКОЙ ИДЕНТИФИКАЦИИ ЛИЧНОСТИ ПО ОТПЕЧАТКАМ ПАЛЬЦЕВ

Аннотация. Рассматриваются алгоритмы обработки изображений для биометрической идентификации личности по отпечаткам пальцев. Они являются основными инструментами по улучшению результатов деятельности в самых различных отраслях. Система распознавания предназначена для хранения данных, дальнейшей ее обработки, идентификации и отображении снимков отпечатков пальцев. Криминалистика является одним из таких направлений, где применение современных алгоритмов обработки изображении дает значительное улучшение результатов работы. Рассмотрена методика экспериментальных исследований, описан процесс обработки результатов идентификации. В этой работе показано, как использовать модуль FPM10A с библиотекой Adafruit Arduino для создания биометрической системы отпечатков пальцев. Для решения данной проблемы была предложена система распознавания, которая предназначена для хранения данных, дальнейшей ее обработки, идентификации и отображении снимков отпечатков пальцев. Они используется в местах строгой секретности, как своего рода паролевый ключ доступа, основанный на сканировании и сверки отпечатков пальцев с базой данных. Исследованы идентификационные признаки строения папиллярных узоров на пальцах с учетом того, что различное давление, скорость, направление, температура окружающей среды и уровень влажности приводят к разным изображениям. Их принято подразделять на глобальные и локальные признаки. Благодаря различным алгоритмам цифровой обработки и анализа изображении таким как: дескриптор SIFT, а также ближайший конкурент дескриптор SURF, появилась возможность быстрого получения уникальных характеристик по каждому изображению. В данном исследовании использовалась база данных из фотографий, полученная из открытых источников – Fingerprint Verification Competition 2004 (FVC2004). В результате работы исследованы графическое изображение совпадающих ключевых точек, а также количество совпавших ключевых точек по отпечаткам пальца. Приведены различные примеры для этих признаков, показывающие их отличия, преимущество и недостатки использованных алгоритмов. Получен результат совпадении отпечатков пальцев с различным вращением через сканер. Поиск ключевых точек производится с помощью матрицы Гессе. Детерминант матрицы Гессе (гессиан) достигает экстремума в точках максимального изменения градиента яркости. Отпечатки пальцев были получены с помощью оптического датчика «CrossMatch V300». Проведенное экспериментальное исследование показало, что разработанная программная система обладает инвариантностью к поворотам изображения.

Ключевые слова: биометрия, отпечатки пальцев, идентификационные признаки, минуция, папиллярные узоры, дескрипторы ключевых точек, градиент изображения, биометрическая идентификация личности, градиент яркости, алгоритм цифровой обработки, дескрипторы SIFT, SURF, BRIEF, база данных, матрица Гессе, оптический датчик CrossMatch V300, биометрический сканер, модуль FPM10A, библиотека Adafruit Arduino, система распознавания, оптический сканер, паролевый ключ доступа, инвариантность, уникальность, объем прецедентов, пирамида Лапласа, октава, оценки ключевых точек, фильтр Хаара, сумма расстояний Хэмминга, электронная дактилокарта.

Information about authors:

Mazakov T.Zh., Dr. Sci. Phys.-math., Institute of Information and Computational Technologies; tmazakov@mail.ru; https://orcid.org/0000-0001-9345-5167

Jomartova Sh.A., Dr. Sci. Tech, Institute of Information and Computational Technologies; jomartova@mail.ru; https://orcid.org/0000-0002-5882-5588

Shormanov T.S., doctoral student, Al-Farabi Kazakh National University; tt007@mail.ru; https://orcid.org/0000-0003-0093-2599

Ziyatbekova G.Z., doctoral student, Al-Farabi Kazakh National University; ziyatbekova@mail.ru; https://orcid.org/0000-0002-9290-6074

Amirkhanov B.S., doctoral student, Al-Farabi Kazakh National University; amirkhanov.b@gmail.com; https://orcid.org/0000-0002-4915-0347

Kisala P., Lublin Technical University, Poland; p.kisala@pollub.pl

REFERENCES

[1] Litvinenko N., Mamyrbayev O., Shayakhmetova A., Turdalyuly M. Clusterization by the K-means method when K is unknown // International Conference on Applied Mathematics, Computational Science and Systems Engineering (AMCSE 2018), 2019. Vol 24. DOI: 10.1051/itmconf/20192401013.

[2] Mamyrbayev O. Zh., Muhsina, K. Zh. Analysis of existing systems for determination of tonnity of text // News of the national academy of sciences of the Republic of Kazakhstan. Series Physico-Mathematical 2017. Vol. 5, N 315. P. 149-155. ISSN 1991-346X http://rmebrk.kz/journals/3432/6180.pdf#page=149

[3] Svyd, I.V., Obod, A.I., Zavolodko, G.E., Melnychuk, I.M., Wójcik, W., Orazalieva, S., Ziyatbekova, G. Assessment of information support quality by "friend or foe" identification systems // Journal Przeglad Elektrotechniczny, Poland. 2019. Vol. 95. Issue 4. P. 127-131.

[4] X. Tan B. Bhanu "Robust fingerprint identification," in International Conference on Image Processing. 2002. Vol. 1. IEEE. P. I–277.

[5] C. Kai, Y. Xin, C. Xinjian, Z. Yali, L. Jimin, and T. Jie, "A novel and colony optimization algorithm for large-distorted fingerprint matching", Pattern Recognition, 2012. Vol. 45. N 1. P. 151–161.

[6] Ethan Rublee, Vincent Rabaud, Kurt Konolige, Gary Bradski: «ORB: an efficient alternative to SIFT or SURF», Computer Vision (ICCV), IEEE International Conference on. IEEE. 2011. P. 2564–2571.

[7] Zitova B., Flusser J. Image registration methods: a survey // Image and Vision Computing. 2003. Vol. 21. P. 977–1000.

[8] Lowe D. G. Object recognition from local scale-invariant features // Proc. Intl. Conference on Computer Vision. 1999. P. 1150–1157.

[9] Bay H., Ess A., Tuytelaars T., Van Gool L. SURF: Speeded up robust features // Computer Vision and Image Understanding. 2008. V. 110. P. 346–359.

[10] Rosten, Edward, Tom Drummond: "Machine learning for high-speed corner detection", 9th European Conference on Computer Vision (ECCV), 2006. P. 430 – 443.

[11] Michael Calonder, Vincent Lepetit, Christoph Strecha, Pascal Fua, "BRIEF: Binary Robust Independent Elementary Features", 11th European Conference on Computer Vision (ECCV). 2010. P. 778–792.

[12] Ethan Rublee, Vincent Rabaud, Kurt Konolige, Gary R. Bradski: «ORB: An efficient alternative to SIFT or SURF». ICCV 2011: 2564-2571.

[13] Soweon Yoon and Anil K. Jain: «Longitudinal study of fingerprint recognition» PNAS 8555 - 8560, 2015.

[14] Chen Y, Jain AK: «Beyond minutiae: A fingerprint individuality model with pattern, ridge and pore features». Third IAPR/IEEE International Conference on Biometrics, Lecture Notes in Computer Science, eds Tistarelli M, Nixon MS (Springer, Berlin). 2009.Vol. 5558, P. 523–533.

[15] Biometric Systems Lab, Pattern Recognition and Image Processing Lab. Biometric Test Center [Online]. Available: http: // bias.csr.unibo.it/ fvc2004/, 2004.

[16] Yavorsky V.V., Utepbergenov I.T., Mamyrbayev O.Zh., Akhmediyarova A.T. Models of analysis of distribution of passenger traffics in routed transport systems // News of the National academy of sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences 2019. Vol. 6, N 438. P. 268-275. ISSN 2518-170X (Online), ISSN 2224-5278 (Print). https://doi.org/10.32014/2019.2518-170X.178

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:

www:nauka-nanrk.kz

ISSN 2518-170X (Online), ISSN 2224-5278 (Print)

http://www.geolog-technical.kz/index.php/en/

Редакторы *Д. С. Аленов, М. С. Ахметова, Т. А. Апендиев*
Верстка *Д. А. Абдрахимовой*

Подписано в печать 05.02.2020.
Формат 70x881/8. Бумага офсетная. Печать – ризограф.
11,0 п.л. Тираж 300. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко 28, т. 272-13-19, 272-13-18