Face Recognition Methods by Using Low Resolution Devices

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***Abstract* - This paper focuses on the face recognition based on low-cost devices. It contains the modern forms of the face processing in 3D. The first part of the paper shows the comparison of the portable scanners. In the next section the face recognition process is split into three phases – capturing, processing and classifying. The options how to capture the face are listed and also the common processing methods for the face recognition are described. The classification methods are showed at the end of the section. In the last part of the paper we present our design of face recognition based on the face profile line, the face polygon and the color features of the face.**

***Keywords* – Face recognition; Multimodal Interface, User Identification**

I. Introduction

Face recognition is still very popular in science. The first attempt to process a face by computer was in the 90s [1]. Since then there has begun an idea to determine a user by a computer through the user's face. However, nowadays, new approaches have still been arising. The reason is that 3D scanners are cheaper and more available than before. One of the milestones in the 3D scanning was an introduction of the Kinect on November 2010[1], which offers a low cost 3D capturing. This step has brought 3D devices from laboratories to people´s living rooms.

The face recognition is resolved and in use, but there are still many factors like a facial position, capturing conditions, a quality of the device, a mimicry, a facial motion and the others, which have an impact on the results. Thus the aim is to use the low cost devices which the wide public can afford to get the relevant results and to increase a ratio of a cost and a quality.

II. Comparision of Scanning devices

Scanning devices are used to get an object from the reality to the virtual reality. Their purpose is to digitize a scanned object. The technologies are being improved every day and a trend of a device quality is rising up. Today, there are lots of scanning devices based on different technologies and used for various aims, so there are many approaches how to scan an object. Most of them use laser or optical sensors. The quality of scanning devices is related to their accuracy. The more accurate the device is, the higher quality of the result is. Today, the most accurate devices use laser but these devices are the most expensive. In the case that quality of the scan is not the highest priority there is another approach – IR sensor.

TABLE I. Table of scanning devices

Properties	Devices		
	3D scanner XYZ printing[2]	***Sense 3D scanner***[3]	***iSense***[4]
Resolution	1,5mm	0,9mm @0,5m	0,9mm @0,5m
Depth resolution	1,5mm	1mm @0,5m	1mm @0,5m
Distance	15 - 25cm	0,2 – 1,6m	0,4 – 3,5m
Size of object	10 - 70 cm	0,2 - 2m	0,2m – 3m
Depth image size	640x480px	640x480px	640x480px
Color image size	640x480px	1920x1080px	320x240px
Released	2015	2014	2014
Price	$ 199	$393,14	$393,14

TABLE II. Table of scanning devices II

Properties	Devices	
	Microsoft Kinect 2[5]	***HandySCAN 700™***[6]
Resolution	0,75mm@0,5m	0.050 mm
Depth resolution	1,5mm@0,5m	0.030 mm
Distance	0,5-4,5m	0,1 – 4m
Size of object	?	? – 2,75m
Depth image size	512x424px	?
Color image size	1920x1080px	?
Released	2014	2014
Price	$ 199	$56 900

[1] https://news.microsoft.com/2010/11/04/the-future-of-entertainment-starts-today-as-kinect-for-xbox-360-leaps-and-lands-at-retailers-nationwide/#sm.0000qhc77310vddx1sfyoh54mrmxo

[2] http://us.xyzprinting.com/us_en/Product/3D-Scanner
[3] http://www.3dsystems.com/shop/sense/techspecs
[4] http://www.3dsystems.com/shop/isense/techspecs
[5] https://developer.microsoft.com/en-us/windows/kinect/hardware
[6] http://www.creaform3d.com/en/metrology-solutions/products/portable-3d-scanner/technical- specifications-handyscan- 3d

IR sensor captures bounced infrared waves emitted from an IR active emitter. Many of the low cost scanning devices use this approach to get a 3D scan. In the Table I, the comparison of few devices is shown. All of them except of HandySCAN 700™ use the infrared principle. The HandySCAN uses the lasers. The precision of the result depends on a distance of the object and the scanner. The closer the object is, the better the result is.

HandySCAN is used in industry for precision work and it is one of the high-end solutions in contrast of the other scanners. 3D scanner XYZ printing is used for a portable scan of various small objects for post-processing and 3D printing. The purpose of Sense 3D scanner and iSense is to digitize and to post-process 3D data. Microsoft Kinect 2 has many usages, like gaming, human-computer interaction, gestures and the other.

III. FACE RECOGNITION PROCESS

The process of the face recognition includes many algorithms and methods. Each method is responsible for some part of the process, but in common there are three main steps how to recognize a face – capturing, processing and classification.

A. Capturing methods

A face can be captured in different ways. It has many unique characteristics and each approach tries to capture the most significant trait of the face.

Firstly, when the face is captured, we get a depth map as an output. The depth map is a map of the points where each of them has its own depth information. It is a 2D array of the depth points. From this map it is necessary to get face data because the obtained map contains points of a whole captured screen. To achieve the face data we need to detect a face area and determine a nose tip.

The nose tip can be detected in different ways. Above all, Microsoft offers The Microsoft Face Tracking Software Development Kit for Kinect for Windows, which allows getting face points from Kinect data[7]. In [7] authors consider the nose tip as a point of the face profile with the longest distance from the base.

When the nose tip is detected, the face is cropped from the map. In [2] authors used 80mm radius around the nose and they determine this area as face data. A nose is a good fixed point to align faces so it allows a comparison of faces in the same way.

There are many methods how to capture and store the face data. Below the most common approaches are listed [8].

1) Depth map and point cloud

This map served as an input for other capturing approaches which are mentioned below. However, it can be used as standalone face data for the processing and the classification.

The depth map can be easily converted into point clouds where each point has 3D coordinates, unlike the map where the third dimension is stored in the 2D array. Different processing algorithms are used for both representations. A disadvantage of this capturing method is a data size of the sample. It needs a bigger space for a face database and so it involves a longer processing time. On the other hand it contains the raw face data and it supports a robust solution [3].

a) Symmetry of the face

In this work [3] a usage of the symmetry feature of a human face is described in a detail. It allows solving a face position problem. This problem is about a turning head out of the front view. When the head is turned left, left part of the face is behind the right side and the left side cannot be captured. It causes lack of data for the face recognition. This feature makes the whole recognition process proof against face position because the data, which are missing, can be copied from the captured face side. The symmetry feature supports the robustness to disguise for example caused by wearing glasses. A capturing ability of the scanning device can widely pass through the sunglasses. The holes in a face data caused by glasses can be filled in by face data from the other side of the face where the face data are not omitted under the glasses.

2) Texture

The texture contains only 2D data of a color representation. Only using of the texture as a capturing method is equal to face recognition in 2D. The main problem of this approach is an illumination and a face position. In case of the overexposure or the darkness is the face recognition unable. However, there arises another feature of the texture in combination with depth map. The texture can be processed in other way as it was in default flat face recognition. Firstly, color data have to be normalized. In [4] researchers highly recommend to convert RGB for the face recognition to another color space with higher discriminating power like $I_1I_2I_3$, YUV, YIQ and LSLM color space. After this preprocessing the texture is ready. From the texture we can extract color characteristic features of human face to enhance the face recognition. It is possible to get the color of the skin, eyes and hairs. This information can be useful for the face database where face samples can be sorted by this feature. Certainly, the texture can be used as additional recognizer, which can help in case of a hole in depth map or another gap in depth data.

3) Facial curves

This approach works with human facial geometry. It focuses on shapes from which the face consists of. On the face are many edges. Some of them are typical for human face and some of them are special. However every edge of every face has unique curvature. The facial curves approach is based on this assumption. Its behalf is that curves can be described by mathematical functions. This can speed up comparing time and decrease the data size of the face sample.

The most valuable information carries a profile curve. The profile covers whole face height and it is the longest line of the face. It is proof against glasses disguises, forasmuch as the glasses minimally involve in profile curve and it is partially robust to expression because a nose line is not so changeable unlike a mouth part. On the other hand it is sensitive on an accuracy of the sensor because the profile covers thin part of the face data.

[7] https://msdn.microsoft.com/en-us/library/jj130970.aspx

In [5] authors search for plane of facial symmetry by using three profiles separated by 3cm. After these cuts they use the normalization procedure with translations and orientations. The result is two profiles. The first is a central profile and the second is a lateral profile. The other profile approach proves that vertical planes between the eye edges are used in common [6].

4) Polygones

There is another solution how to process the face edges and features. When the common face points are detected, the distance and their position can be stored in a shape – polygon. It follows many combinations which face points should be selected and included to the polygon. Geometrical operations and properties are associated with the shape. It allows getting a surface or a center of the polygon, or a center of gravity. These properties can be used in comparison and in classification.

5) Differential geometry

This purpose is focused on depth zones of the face. There is an ambition to select in sequence those face data which match with a selected depth interval. By changing depth interval we can get more face regions. These regions are used in comparison of face samples. The advantage of this approach is that the regions of the same object with different expression are similar [9].

There exists several methods how to capture a face than it was mentioned above. These methods are called free-form description.

B. Processing algorithms

Processing methods are algorithms to preprocess captured face data for effective storing in database and to process actual face sample and compare it with a sample from database. These well-known algorithms are commonly used for face recognition.

1) ICP

The Iterative closest point algorithm is a very common method to find the best position of the object to match with another object. In face recognition, especially with point clouds it is used to fit two samples to prepare for compering or to compare. It costs lots of computing power. It uses mostly translation and rotation transformation [8].

2) PCA

Face data contain information, which can be correlated. To get linearly uncorrelated variables it is possible use principal component analysis. It decreases a number of the values and it decomposes the properties to uncorrelated values from which the most significant features can be taken to the next process.

a) Eigenfaces

The name Eigenface is derived from eigenvector which is used in the PCA. From face database is computed set of the Eigenfaces. By linear combination of this set, it is possible to get each face from the database.

3) SVM

Support vector machine is classifying algorithm. This method is safe for situations where samples are near to a dividing plane which divides a space into two sides. It finds the best definition of the plane to maximize distance of two sample groups of the training set. This type of algorithm can face the non- linear problem. It uses a Kernel trick by mapping the inputs into high-dimensional space.

We have listed and have shortly described the most common and well-known algorithms in a connection to face recognition. There are still many more algorithms like ICA, LDA or many variations of mentioned methods how to process and compare the face data, but it is out of the scope of this paper.

C. Classification process

This step is essential to effectively get a match of a taken sample with a sample from the database. The stored face data should be prepared for the comparison. We can classify the data in many ways. In [10] are mentioned this registration architectures.

1) One-to-all architecture

The one-to-all registration means to compare the sample face to each face from the database. It is very time-consuming, especially when it is used with complex method like ICP algorithm on the other hand it is accurate.

2) AFM or ICS architecture

Average Face Model or Intrinsic Coordinate System is indirect registration and it enables to use the comparing algorithm only once. However, it requires well-prepared face data, good land-marking and high quality of the samples.

3) Proposed registration architecture

An idea of the architecture of proposed registration is to define some canonical faces which represent each group of the faces in the database. It is possible to make more layers of the canonical faces and thus it decreases the number of the queries in an optimal way.

IV. Design of Face recognition

Our purpose is to create a face recognition system based on low-cost device and despite it to make this system robust to the position of head and partial proof against a disguise.

A. Chosen approaches

1) Device

To our design we take Microsoft Kinect 2 as a capturing device. Kinect is relatively cheap and it has a wide background of solved algorithms, prepared frameworks and programmer communities. The depth resolution is quite fair and for the texture extraction it is equipped with high resolution camera. The ratio of a quality and a price is high. We would like to integrate the device into the living room and make the room smart and the capturing distance up to 4,5m is enough to cover the whole room. Kinect supports also other types of projects for the smart room by gesture process assistance, four microphones, quality camera and the others.

2) Capturing method

By the chosen device we have decided to capture a face profile combined with polygons and texture. It is an ambition to take more faces of more objects in the living room at a same time from various positions because in the room are grouped more people than one. We want to create simpler deciders and make their results to join by fuzzy logic to get a proper decision. The simply deciders are not time-consuming and allow to get a quick response for more users.

Face profile has an advantage of being head position proof, especially in horizontal way. The whole profile line can be split into more sections because parts of the profile line represent bow, nose, mouth and chin and every part is unique. On the other hand the face data from Kinect have not high depth resolution and they are noisy, so not each part can be captured correctly.

We also take another method to distribute responsibility of the result – polygon method. Its task is to bring a new point of view in the face recognition. The polygon should be simple due to the low quality of data. If the profile line fails, the polygon can hold the result in the correct way.

If the illuminance is balanced, it is possible to use texture. An idea of the texture is to extract color information of the face. After normalization and conversion to better color space, the color of hair, skin or eyes can be stored. There is a potential to rapidly decrease a number of possible matching face samples. However, normalization of colors is difficult in various illuminance, brightness and contrast.

3) *Process algorithm*

The face profile line is similar to a mathematical function. We have an ambition to describe a face profile with the set of known functions. After conversion we can get mathematically described signal which includes signal properties. Using the signal processing algorithm we can extract main components which is possible to compare.

A polygon method allows to use geometrical properties to process the face from angles, surface, center point etc. It is possible to compare the samples by mathematical operation.

The processing of the texture is designed to extract color of the eyes, skin and hair. These features of the face are very clear and in a case of an ambiguity they can be crucial

The outputs of all listed methods are not very complex, thus we consider the combination of these methods as fast for the computing and suitable for our purpose. It is necessary to set the proper rules for the fuzzy logic, which joins the outputs. When one of the methods fails due to an inadequacy of the capturing conditions, it is possible to rely on the other methods.

4) *Clasification process*

As authors in [10], we are engaged to use sorted database with canonical data. It can be helpful to split the database according to the color features of the face which can speed up the registration process. However, this splitting rule has no impact in case of the bad illuminance conditions. So we choose the other classification rule as main. The sharpness of the profile line is characteristic feature of the human face and can be easily computed. It is able to split the samples of the face equally.

V. CONCLUSION

We compared the newest portable devices for the scanning of the real objects in 3D. We described common capturing methods and we mentioned the features of human face like a symmetry, color, curvature and we showed according to them how the face is processed. It was listed the well-known algorithms to compile the face data and it was described the classification methods. We presented our design of the face recognition based on the low-cost device.

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REFERENCES

[1] C. Beumier, “3D face recognition,” in Industrial Technology, 2006, ICIT 2006, IEEE International Conference on, 2006, pp. 369–374.

[2] A. Mian, M. Bennamoun, and R. Owens, “An efficient multimodal 2d-3d hybrid approach to automatic face recognition,” IEEE Trans. on Pattern Anal. and Machine Intel., 29(11):1927–1943, 2007

[3] B. Y. Li, A. Mian, W. Liu, and A. Krishna, “Using kinect for face recognition under varying poses, expressions, illumination and disguise,” in Applications of Computer Vision (WACV), 2013 IEEE Workshop on, 2013, pp. 186–192.

[4] J. Yang, C. Liu, and L. Zhang, “Color space normalization: Enhancing the discriminating power of color spaces for face recognition,” Pattern Recognition, 43(4):1454–1466, 2010

[5] Ch. Beumier, “3D Face Recognition.” In Industrial Technology, 2006, ICIT 2006. IEEE International Conference on, 369–374, IEEE, 2006, http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4237707.

[6] J. Cartoux, J. T. LaPreste, M. Richetin, “Face authentication or recognition byprofile extraction from range images.,” in Workshop on Interpretation of 3D Scenes, 1989, pp. 194–199.

[7] G. Pan, S. Han, Z. Wu, Y. Wang, "3D Face Recognition using Mapped Depth Images," *2005 IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR'05) - Workshops*, San Diego, CA, USA, 2005, pp. 175-175. doi: 10.1109/CVPR.2005.560

[8] D. Petrovska-Delacrétaz, B. Dorizzi, G. Chollet, eds., „Guide to Biometric Reference Systems and Performance Evaluation,“ London: Springer London, 2009, http://link.springer.com/10.1007/978-1-84800-292-0., p.p 270, 277

[9] C. Samir, A. Srivastava, M. Daoudi, "Three-Dimensional Face Recognition Using Shapes of Facial Curves," in *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 28, no. 11, pp. 1858-1863, Nov. 2006.

[10] M. Rui, J. Choi, G. Medioni, and J. L. Dugelay, “Real-Time 3D Face Identification from a Depth Camera.” In Pattern Recognition (ICPR), 2012 21st International Conference on, 1739–1742. IEEE, 2012. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6460486.