Biometric identification and LoRaWAN communication problems in remote health monitoring

Marcell Szántó

University of Óbuda Kandó Kálmán Faculty of Electrical Engineering Institute of Instrumentation and Automation, Tavaszmező street 15, 1084, Budapest, Hungary

marci199803@gmail.com

Consultant: Tamás Sándor. Döníz Borsos

Abstract: Biometric identification is no longer an idea of the future, it's a possibility of the present. It's enough to think about everyday things like the new ID card, some laptops, and most cell phones. We can see that the use of biometric-based identification systems is growing on a large scale. Behind the rapid spread is both demand and offer. On the demand side, there is a demand for security. For example, states want to know who is crossing their borders, and companies want to know who is entering their buildings. On the supply side, compact and inexpensive devices appear that can be easily integrated into any system. Although experts believe that biometric identification can be considered extremely secure, these systems also have weaknesses. In the course of my research, I examine fingerprint-based recognition among biometric identification types in more depth. There are also two types of errors that affect system reliability. One is FAR, i.e. false acceptance, the other is FRR, i.e. false rejection. In my work, I would like to find a solution to how we can best reduce the first and second type errors (FAR and FRR) by changing the number of samples and tuning the acceptance threshold. The biggest difficulty with this is finding the EER (Equal Error Rate) point, as deviating from this point, the error rates show an increasing trend. Another topic of my research is the examination of LoRaWAN technology for reliability. The health and remote monitoring armband I designed uses LoRa communication to transmit information. The biggest advantage of the technology is the long-range, which is significantly influenced by environmental variables and current terrain conditions. I would like to find out what range the LoRa module I use can operate in different noise-laden environments, under different weather and terrain conditions. This can be used to establish a coverage area within which the exchange of information between the LoRa device and its associated gateway can be guaranteed.

Keywords: LoRaWAN, biometric, fingerprint, communication, identification

1 Three basic methods of personal identification

Personal identification can be divided into active and passive methods depending on whether the involvement of the person to be identified is required. Based on the information used for identification, there are three basic ways to identify people:

- knowledge based
- property based
- biometrics

In the case of knowledge-based identification, the person is aware of information that can be verified during the identification procedure, such as a password or a PIN code.

In the case of estate-based identification, identification is done by a device that is in the person’s possession, such as a key, barcode, or magnetic card.

The third option is to use biometrics when the verification is done using some physical or biological characteristics of the person.

As all three methods also have unavoidable drawbacks, neither alone provides sufficient protection. Therefore, it is recommended to use at least two of the three methods together, but independently of each other.

Of the three types of identification, biometric identification is the most reliable. In this method, we use a physical or biological feature of the human body that can be interpretable by machines. Examples are the uniqueness of the fingerprint, the ear, or the retina. Compared to the previous two methods, it is not a tool or information that is the basis for identification, but the person to be identified. This guarantees that the property on which the identification is based cannot be stolen and, in some cases, even a silent alarm can be activated by the person forced to identify. For example, you use another finger that also activates an alarm for authentication.

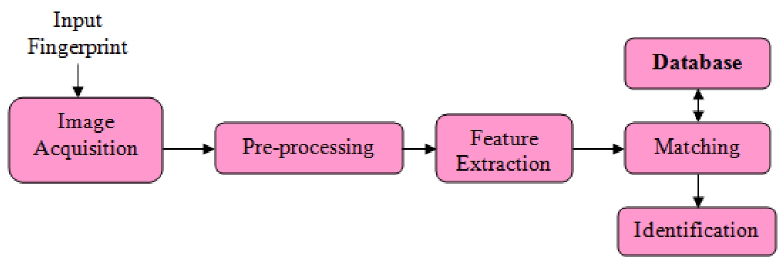

Figure 1

The process of biometric identification

1.1 Biometric identification [3] [4] [7]

The purpose of biometric systems is to determine whether the person to be identified is the same as a person already in the database. In the case of authentication, this means a comparison with a specific sample, while in the case of identification, the system must quickly search the database for the matching person or indicate that the person sought is not in the database.

The extraction of features differs for different biometric features. In the case of fingerprint identification, the goal is to find different patterns on the bitmap and to extract the characteristics of the given print from all of them. The comparison practically means the calculation of a similarity index, the value of which expresses the similarity of the two samples.

Examples of the reliability of biometric systems built with the appropriate features:

- Voice recognition: 1:50
- Fingerprint identification: 1: 500
- Iris identification: 1: 131.000
- Retinal identification: 1: 10.000.000+

Examples of asset rating indicators are ACOM[1] and MOA[2].

ACOM will tell you to what extent the working principle of the device can exclude counterfeit samples. The MOA, as an indicator, refers to the security needs of a given device.

[1] ACOM: AntiCloning Operation Methods
[2] MOA: Mission Oriented Application

1.2 Fingerprint identification [2] [8]

The uniqueness of the fingerprint is given by the pattern of folds and grooves on the surface of the skin. These folds, also known as ruffled fibers, form different patterns that can be divided into larger units. Such are the vault, vortex, and loop.

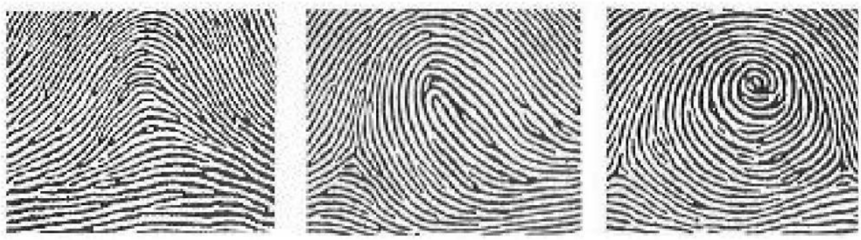

Figure 2

Vault, loop, swirl ruffle thread pattern

Typical points are hook, end, point, island, bridge, junction, intersection. The branching, end, or confluence of ruffled fibers is also called the minutia point.

Figure 3

Characteristic points formed by ruffled threads

There are distinguished points and lines for fingerprint processing that should be mentioned by all means. An example is a feature line. The feature line is essentially the innermost groove that surrounds the sample area. The sample area contains global characteristics, such as the base point, which is located in the center of the sample area and is also treated as a reference point. A delta is a curve with all three sides as a starting groove. It is fairly easy to determine the point, so it is excellent for groove counting. The furrow number covers the number of furrows in the sample area.

1.3 Devices and operating principles [4]

There are several technical solutions for scanning fingerprints, in which the similarity is that each examines the uniqueness of the ruffled fiber patterns found on the fingers. There are tools that, in addition to scanning the fingerprint, can also check to see if the finger is alive. This is done by testing for temperature and humidity. Among fingerprint reading devices, the greatest achievement is in reading techniques. There are two ways to do this. Optical and non-optical scanning.

Optical devices:

- Chip sensor
- Diffraction
- Total reflection

With this technology, the fingerprint to be processed is imaged on the surface of an image resolution device (CMOS, CCD element) using an optical system (prism, Fresnel lens).

Non-optical devices:

- Thermal analysis
- Radio frequency principle
- Ultrasonic principle
- Capacitive principle
- Pressure sensor principle

Devices operating on this principle create a fingerprint image from different pressure, capacity values, or reflected waves.

1.4 Preparing and processing the scanned image [5]

We need to improve the image from the sensor so that we can separate the pleat and grooves well and reduce the noise. We use adaptive filters for this. We are helped by the parallel redundancy of the ruffled threads, according to which, although there is a rupture in the ruffled thread, we can also tell the orientation of the given groove about the smaller units. An adaptive filter is applied based on this parallel redundancy, which is then used to perform spatial convolution throughout the image. As a result, we will get an orientation map in which the direction of the ruffled fibers is marked with lines. The most commonly used algorithm to perform this operation is the hierarchical orientation field-defining algorithm.

The steps of hierarchical orientation field-defining algorithm:

Step 1: Divide the image into W × W blocks.

Step 2: Calculate the gradient (Gx and Gy) for each pixel of each block.

Step 3: Determine the local orientation of each pixel (i, j). We can use the following equations for this

$$(1.1) \quad V_x(i,j) = \sum_{u=i-\frac{W}{2}}^{i+\frac{W}{2}} \sum_{v=j-\frac{W}{2}}^{j+\frac{W}{2}} 2G_x(u,v)G_y(u,v)$$

$$(1.2) \quad V_y(i,j) = \sum_{u=i-\frac{W}{2}}^{i+\frac{W}{2}} \sum_{v=j-\frac{W}{2}}^{j+\frac{W}{2}} (2G_x^2(u,v) - G_y^2(u,v)$$

$$(1.3) \quad \theta(\mathrm{i,j}) = \frac{1}{2} tan^{-1}(\frac{V_x(i,j)}{V_y(i,j)})$$

Step 4: Calculate the consistency level of the orientation field for the neighborhood of the current (i, j) block. To do this, we use the following equations, where N is the number of blocks in d, θ i', j', and θ i, j are the ruffle fiber orientations in the (i', j'), and (i, j) blocks.

$$(1.4) \quad C(i,j) = \frac{1}{N}\sqrt{\sum_{(i',j')\in D} |\theta(i',j') - \theta(i,j)|^2}$$

$$(1.5) \qquad |\theta' - \theta| = \begin{cases} d \; ha \; (d = (\theta' - \theta + 360) mod\, 360) < 180 \\ \qquad d - 180 \qquad különben \end{cases}$$

Step 5: If the consistency level is above a certain threshold, the value of C (i, j) must be recalculated with a lower resolution.

After preparing the image, we need to select the ruffled fibers. This is done by the so-called binarization method, which makes 2 of the 256 kinds of color intensity. The difficulty is that we cannot apply a constant threshold, since different images, but even the same two different sides of an image have different contrast values. To solve this, we use the Niblack algorithm, which examines the environment of a given pixel and determines the threshold value for each pixel based on its mean and standard deviation.

Once we have sorted the ruffles, we need to reduce their width to 1 pixel. This makes it easier to notice the branches and ends.

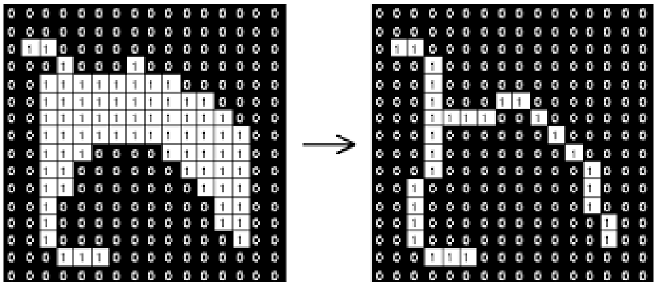

Figure 4

Thinning result on a binary image

When we scan an image and want to identify a person with it, we perform the above-mentioned operations on the new image and compare the neighborhoods of the minutiaes. A neighborhood can contain at least 3 adjacent minutiaes. They are spaced apart and have a relative orientation. In addition, we can even compare the type of minutiaes in question if they are stored. If the comparison does not show a big difference, then the neighborhoods are considered the same.

1.5 Biological changes in the fingerprint [1] [6]

According to a 2012 study in Denmark, about 15% of people in the world suffer from manual dermatitis.

Figure 5

Hand dermatitis

The reasons for this are still debated, but it certainly contributes to damage to the skin barrier, the malfunction of the immune system, and prolonged or regular contact with substances that cause an allergic reaction. A study in Malaysia looked at 200 people, 100 of whom had manual dermatitis and 100 were completely healthy. Fingerprint samples were taken from all 200 participants and during the experiment they had 3 opportunities to identify themselves using a fingerprint reader. Of the 100 participants with dermatitis, 27 failed to identify themselves.

Figure 6

Fingerprint of people with mild dermatitis

The article concluded that the larger the area of dystrophy (squamous cell disorder), the more likely the system will not recognize the fingerprint and thus cause a second type of error. There were areas on the fingers of 84 members of the patient group where fringe patterns were missing or the skin surface appeared stained due to the formation of a rough skin layer. People whose hands are exposed to constant irritation at work are much more likely to suffer from manual dermatitis. This layer includes healthcare workers who wash their hands very often, mechanics who come into contact with various oils and chemicals during physical work where their hands are used, and cooks, and kitchen workers.

1.6 My fingerprint comparison program [9] [10]

In my research, I would also like to use several fingerprint reading sensors based on the principle of operation to get an even more comprehensive picture of the quality of the samples produced and their dependence on the type of sensor. I decided to test an optical device and a non-optical device. Of the devices operating on the optical principle, I chose the GTS-511E2 based on chip sensor technology, which is included in a Mikroe Fingerprint click. The other fingerprint reader is a capacitive Sparkfun SEN-15338 system. The Fingerprint click features the world's smallest optical fingerprint sensor, the GTS-511E2. The sensor uses digital light to capture a digital image of the fingerprint pattern. To distinguish between 2-dimensional images and real fingerprints, the CMOS image sensor has a special lens and cover. Considering how dark the lens is when a person presses their finger against the lens, an LED illuminates the lens from one side. The device can be communicated via SPI. Using the Windows application for Fingerprint click, I took pictures of my own fingerprints and used these pictures as a sample to create the image processing programs.

Figure 7

Image of Fingerprint click utility and a completed sample

The sensor provides an image that displays a relatively small area of the fingerprint and does not contain unnecessary information, so the segmentation step can be omitted. With segmentation, the part that does not contain a fingerprint is omitted from the image and the image is cropped only along the outline of the useful area. For the scanned samples to be comparable, they must first be processed. To do this, I wrote the image processing algorithms in C #, which performed the following tasks:

1. grayscale
2. ridge detection

3. enhancement
4. binarization
5. thinning
6. minutia-based comparison

The result of image processing is shown in Figure 8.

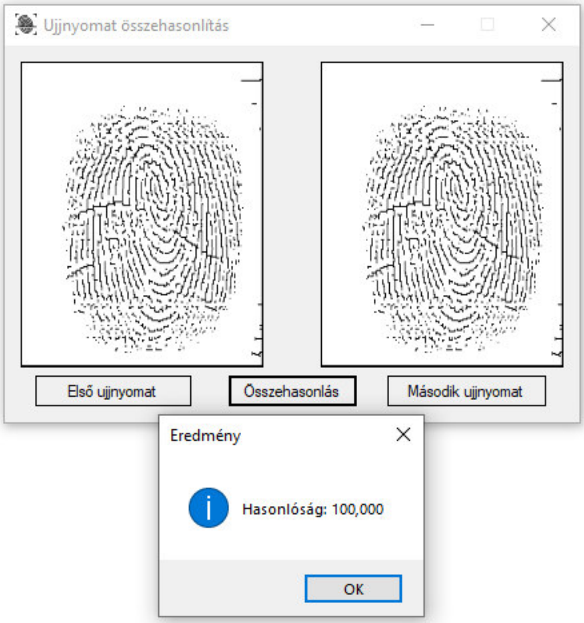

Figure 8

Sample comparison application user interface

Of the minucia searches, I'm basically just dealing with finding the bifurcation and the ending, because all the other minucias can be put together from these two.

The method of searching for minutes is to look at all 8 neighbors of a given pixel in the image of a line tapered 1 pixel wide. We take the sum of these pixels, and if this sum is equal to zero, there is no minucia. If only one of the adjacent points exists, we found an ending, and if two, a branch. The only flaw in the algorithm is that it can produce false minutes at both image errors and the edge of the sample. For this reason, we need to pay attention to the edge of the sample so as not to lay out minucias there. This can also be solved by subsequent minucia deletion.

1.7 Results

So far, I have taken fingerprint samples from 17 people of nearly the same age (21–23 years). From everyone, the thumb, index, and little finger were the sample samples selected. The first two have a damaged and worn pattern in most people due to very frequent use. In contrast, the little finger carried a completely intact and easily removable ruffle pattern on its surface in almost all subjects. There were 4 samples of each finger, two completely well-calibrated, clean-surface, fingerprint images placed in the center of the sensor, one image of a finger not placed in the center of the sensor but clean, and one image of an uncleaned finger not placed in the center of the sensor. Based on the tests performed so far, the comparative application successfully determines how much two samples match and also displays its percentage value. Comparison of the images taken with the sample bases of different qualities yielded the expected results in all three cases. This means that when comparing a good quality image to a good quality one, the similarity was greater than when comparing good quality and medium or good and poor quality images. A graphical representation of this is shown in Figure 9.

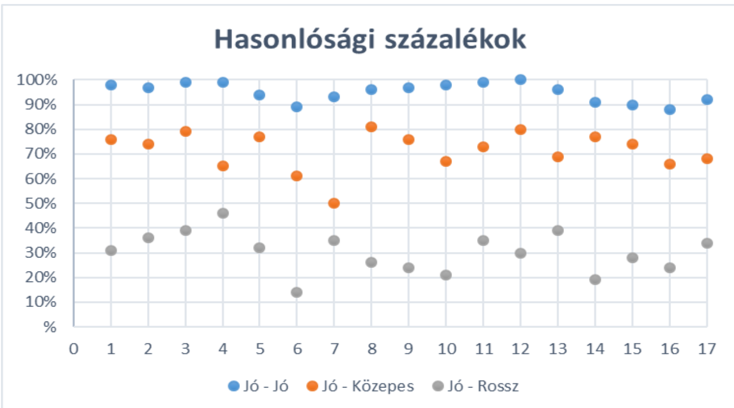

Figure 9

Percentages of similarity for each subject

The diagram in the figure shows a comparison of the samples taken from the index finger of each subject. The blue dots show the similarity of the two good quality samples, the yellow the good and medium quality, and the gray the good and poor quality samples. On the X-axis I displayed the number of subjects and on the Y-axis the percentage of similarity.

References

[1] Martin Drahansky Michal Dolezel, Jaroslav Urbanek, Eva Brezinova, and Tai-hoon Kim - Influence of Skin Diseases on Fingerprint Recognition – 26 February 2012

[2] Tajti Balázs - A BIOMETRIKUS UJJNYOMAT AZONOSÍTÁS ALKALMAZÁSÁNAK ÚJ LEHETŐSÉGEI – Hadmérnök VII évfolyam 1. szám -2012 március

[3] Lajkó Dóra – BIOMETRIA VILÁGA

[4] Kovács Tibor, Milák István, Otti Csaba - A BIZTONSÁGTUDOMÁNY BIOMETRIAI ASPEKTUSAI

[5] Venczel Viktor - Fingerprint Identification System – 2007 október

[6] Chew Kek Lee, Choong Chor Chang, Asmah Johar - Fingerprint Changes and Verification Failure Among Patients With Hand Dermatitis – 2013

[7] Venkata Krishna - Fingerprint enhancement and compression method using Morlet wavelet - 11 January 2011

[8] Luca Didaci, Gian Luca Marcialis. Fabio Roli - Modelling FRR of Biometric Verification Systems Using the Template Co-update Algorithm -

[9] Octavio Loyola-González, Miguel Angel Medina-Pérez, Andres Eduardo Gutierrez Rodriguez, Milton García Borroto: Framework in C# for Fingerprint Verification

[10] Shlomo Greenberg, Mayer Aladjem, Daniel Kogan and Itshak Dimitrov: Fingerprint Image Enhancement using Filtering Techniques