Hand Anatomy

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Synonyms

Hand Structure, Hand Physiology

Definition

The **anatomy** of human hand is quite unique and includes the configuration of bones, joints, veins and muscles. The physiological interconnection and structure of these parts are responsible for the structure of the human hand. The functional area of hand includes the five fingers, palm and the wrist. Amongst a number of biometric modalities that are used for human identification, hand-based modalities achieve high performance and have very high user acceptance. A hand-based biometric system integrates several physiological and/or behavioral features that have their individuality in the anatomy of hand. The prime focus of this study is on internal and physiological structure of human hand which defines the uniqueness of various hand related biometric modalities.

Main Body Text

Introduction

The anatomical study of human hand is not new; it dates back to prehistoric times, but it is finding new applications in the field of biometrics. The proper understanding of structure requires the knowledge of function in the living organism. As one of the basic life sciences, anatomy is closely related to medicine and to other branches of biology. The hands of the human being are the two multi-fingered body parts located at the end of each arm. It consists of a broad palm with five fingers, each attached to the joint called the wrist. The back of the hand is formally called the dorsum of the hand. The uniqueness of the human hand, as compared to the other animals comes from the fact that all the fingers are independent of each other and the thumb can make contact with each finger.

The anatomy of hand is the key for individuality of hand-based biometrics. The hand-geometry biometric largely represents the anatomy of hand bones and muscles. The hand-vein biometric represents the uniqueness in the anatomy of hand-veins while the palmprint represents **epiderm** on the palm. The behavioral biometrics like signature is also highly dependent on the anatomy of bones and muscles. Therefore the study of hand anatomy is fundamental to ascertain the individuality of hand-based biometrics.

Structure of the human hand

The internal structure of hand is an assortment of bones, muscles, nerves and veins.

Bones

The structure of the hand is primarily attributed to the bones comprising the human hand. The hand is composed of 27 bones, broadly divided into three groups called carpals, metacarpals and phalanges (Fig. 1). The wrist of the hand consists of a cluster of bones named as carpals. These bones are considered as a part of wrist and are responsible for the to-fro and back-forth movement of the wrist. These are eight in number and are named as:

1. Scaphoid
2. Lunate
3. Triquetrum
4. Pisiform
5. Trapezium
6. Trapezoid
7. Capitate
8. Hamate

Metacarpals are the intermediate part of the fingers and the wrist [1]. This cluster of bones make the central part of the hand called the palm. The metacarpals are five in number and are named as:

9. First metacarpal (Thumb)
10. Second metacarpal (Index finger)
11. Third metacarpal (Middle finger)
12. Fourth metacarpal (Ring finger)
13. Fifth metacarpal (Little finger)

The remaining fourteen bones are called the phalanges. These are named as follows:

14. Proximal
15. Medial
16. Distal

There are two in the thumb, and three in each of the four fingers, as shown in (Fig. 2). The distal phalanges carry the nails, the middle phalanges are in the middle and the proximal phalanges are closest to the palm. Bones are the most important structure of the human hand and responsible for almost all the activities of the hand. Even so, bones structures in the hand are not a popular candidate for biometric authentication. Being a hidden structure of hand, the acquisition of hand bone images is very difficult. However, the hand bone structures are useful in forensic identification especially in situations when other physiological structures are not available, *e.g.* during accidents/fire. The individuality of hand bone structures is believed to be low due to the high similarity in the bone types.

Muscles

Muscles are like the building blocks on the bones. These not only make the hand robust in gripping but also are very helpful in its movement. The muscles of the human hand are composed of two types of tissue, namely the extrinsic muscle groups and intrinsic muscle groups [2]. The extrinsic groups of muscles are generally present in dorsal (back) part of the hand, or palmer (grasping) part of the hand. It is broadly divided into extensors, present on dorsal part and flexors, present on the palmar part of the hand. The extensor muscles are further divided into those whose movement is around wrist as:

1. Extensor carpi radialis longus
2. Extensor carpi radialis brevis
3. Extensor carpi ulnaris

And those whose movement is around digits (the four fingers without the thumb) of hand as:

4. Abductor pollicus longus
5. Extensor pollicus brevis
6. Extensor pollicus longus
7. Extensor digiti minimi
8. Extensor digitorium

All the extensor muscles are shown in (Fig. 3). Unlike extrinsic muscles, the intrinsic muscles of the hand are originated at wrist and hand. It can be divided as: Dorsal and Volar muscles. The dorsal intrinsic muscles (Fig. 4) can be further subdivided into:

1. Dorsal interossei
2. Abductor digiti minimi

The volar intrinsic muscles are present in two layers:
1. Superficial layer

1.1. Abductor digiti minimi
1.2. Flexor digiti minimi
1.3. Lumbricals
1.4. Adductor pollicis
1.5. Abductor pollicis brevis

2. Deep layer

2.1. Oppones digiti minimi
2.2. Palmar interossei

The superficial and deep muscles are shown in Fig. 5 and Fig. 6.

Due to intrinsic features of human hand, the muscles are weak candidate for biometric identification. Muscles are covered by skin and hence it is very difficult for an imaging system to capture muscle structures independently. The acquisition of muscle structure requires very complex imaging techniques, such as magnetic resonance imaging which is very expensive. While capturing hand geometry or palmprint images, the muscles have very little or no effect on hand surface when the user-pegs are employed to constrain the hand movement. However, the peg-free hand imaging introduces some effect due to the independent movement of fingers. One of the major weaknesses with muscles as biometric trait is that with the change in age, it begins to loose its shape and strength. Due to change in shape the hand surface of a young man looks quite different as compared to an old man. However, being an internal part of hand surface, muscles are quite stable with respect to changes in humidity and temperature. Another advantage with the possible usage of muscle as a biometric trait is that being hidden structure it is very difficult to spoof and any change in muscle structure requires very complex surgical operations.

Nerves

The nerves are a very important part of hand and helpful in sensing objects. These internal structures are also responsible for carrying the sensory information from one part of the body to the other. These nerves are quite stable and unique candidate for potential biometric identification. There are two ways of discussing nerve distribution in wrist and hand of human body. These are:

1. Peripheral nerves or
2. Dermatomes nerves

The peripheral nerves are distributed around wrist and hand and can be classified as:

1.1. Median nerve
1.2. Ulnar nerve
1.3. Radial nerves
1.4. Lateral cutaneous nerve of forearm (musculocutaneous nerve)
1.5. Medial cutaneous nerve of forearm

The dermatomic regions of the skin are very sensitive from medical point of view, as pain in this area indicates spinal damage. Nerves in these areas are originated from dorsal root (single spinal nerve root) [3]. These root nerves are:

1.1. C5
1.2. C6
1.3. C7
1.4. C8
1.5. T1
1.6. T2

Nerve root C5 is associated with radial nerve, C6 is associated with median nerve, and C7 is associated with both median and radial nerve. C8 forms the median, ulnar and radial nerve. T1 root is of Medial cutaneous nerve of forearm. All the root and peripheral nerves are shown in Fig. 7.

However, nerves are also the hidden structure and therefore very difficult to be imaged. This is the principal reason why the nerve structures are not yet been explored for biometric identification.

Palmprint

The human *palm* is defined as the inner portion of the hand starting from the wrist to the root of the fingers. The *print* is an impression made when the body part is pressed against some surface. A palmprint therefore illustrates the physical properties of skin pattern such as lines, points and texture [4]. Palmprint identification can be seen as the capability to uniquely identify a person amongst others, by an appropriate algorithm using the palmprint features. The palmprint features are mainly developed during the life processes, due to biological phenomenon, with the growth of fetus in the uterus. Even a minute change in these inherent phenomenon, changes the complete life process and hence the structure of two different palms is expected to be never the same. The main features of concern in a palmprint are:

1. Geometric features like width, length and area
2. Principal lines, which are the most darken lines on the palm
3. The thinner and irregular lines, as compared to principle lines called wrinkles
4. Datum points, which are the end points of principal lines

In the most palmprint recognition approaches, various texture features acquired from the 2D images. However, a limitation of such a system is that the acquired images and hence the accuracy of such systems is highly sensitive to the illumination changes. Recent research in this area has shown promising results using simultaneously acquired 3D palmprint features [5]. A 3D scanner can be used to capture the palmprint surface. Such acquisition not only reduces the effect of illumination, but also provides a better curvature of principle lines, depth and wrinkles of the palmprint. The palmprint systems employing 3D palmar features are certainly more reliable and robust to security threats as compared to those systems employing only 2D features.

Most of the above discussed palmprint features are acquired from low resolution images (approx 100 pixels per inch). Such extracted features and matching algorithms can not suit a typical forensic application. More palmprint features such as: palmar friction ridges, palmar flexion creases, palmar texture, minutiae *etc.*, can be utilized for recognition purposes. Friction ridges are folded pattern of palm skin with sudoriferous gland but without hair. The palmar friction ridges are formed during the embryonic skin development but after the appearance of flexion creases [6], [7]. The palmer friction ridges originate from the deeper **dermis** layer within the first twelve weeks of fetal development.

As shown in Fig. 8, the flexion creases appearing on palmar surface can be grouped in three categories: major flexion, minor flexion and secondary creases. The major flexion creases are the largest creases and include distal transverse (heart-line), radial transverse (life-line) and proximal transverse (head-line). These major flexion creases are highly visible large lines that are often employed as reference while aligning two palmprints for biometric identification. The minor flexion creases, along with the secondary creases and minutiae locations, serve as reliable features for palmprint identification for forensic [6] and civilian applications.

Fingerprint

Like palmprint, fingerprints are highly unique biometrics and have been reliably used for forensic study. The formation of finger tips is similar to the formation of blood vessels or capillaries while the growth of fetus in the uterus. The formation of skin and the volar surface of palm or sole in the fetus are due to flow of amniotic fluids in a micro-environment. With the minor change in the flow of amniotic fluids and the position of fetus in the uterus, the minute skin structures around palm or finger tips begins to differentiate. Thus, the finer details present on fingertips are determined by very minute biological phenomenon in a micro-environment. Even a small difference in micro-environment, changes the process of cell formation completely and these structures vary from hand to hand. The similarity of these minute structural variations is virtually impossible to detect [8]. In biometrics literature, fingerprint is treated as one of the most reliable modality due to its high structural variance from hand to hand as even identical twins have different fingerprints [9]. A fingerprint broadly consists of a pattern of ridges/valleys. Its uniqueness is attributed to the ridge characteristics and their inter-relationship. Minutiae points in the fingerprints are defined as ridge endings, the point where the ridges end abruptly, or ridge bifurcation/trifurcation, where the ridges are divided into different branches. These patterns are life-long and are immune to aging and biological changes. The brief summary of fingerprint features is:

1. Ridge endings are the points where the ridges end abruptly
2. Ridge bifurcations are the point at which one ridge divides into two
3. Crossovers are the points where two ridges meet each other to form one
4. The core is the inner point, generally situated at the centre of the fingerprint
5. Delta is a point normally at the lower left or right side of the fingerprint, around which a triangular series of ridges center.

Hand Geometry

Unlike other biometrics like, fingerprint, iris, palmprint, *etc*, hand geometry depends upon the geometry of personś hand, length, width of fingers, and the span of the hand in different dimensions. The hand geometry biometric is not considered suitable for personal identification for the large scale user population as the hand geometry features are not highly distinctive. However, the low cost imaging and low-complexity in feature extraction makes this biometric highly suitable for small scale applications (office attendance, building access, *etc*). The typical imaging setup for the acquisition of hand geometry images employ pegs to constrain the movement of fingers. However, recent publications have illustrated that the peg-free imaging can also be used to acquire images for hand geometry measurements. Such images can be used to extract length, width, perimeter and area of palm/finger surface. These geometrical features of the hand can be simultaneously extracted with other biometric features, *e.g.* palmprint or fingerprint [10]. The anatomy of two human hands is quite similar and therefore hand geometry features from the left and right hands are expected to be similar. This is unlike the fingerprint or iris which shows characteristic distinctiveness in two separate (left and right) samples. The hand gestures also play very important anatomical representation in our daily life. Some of examples of such activities are, we wave our hand for familiar faces, we make use of our hands to call someone, we represent the sign of victory with hands, fingers are used to point someone, *etc*. The 3D hand gestures are a potential modality for gesture recognition and pose estimation and highly depend on the anatomy of individual's hands [11].

Hand Veins

Veins are hidden underneath the skin, and are generally invisible to the naked eye and other visual inspection systems. The pattern of blood veins is unique to every individual, even among identical twins. The veins are the internal structure responsible for carrying blood from one body part of the body to the other. Veins that are present in the fingers, palmar and back of the hand surface are of particular interest in biometric identification. There are mainly two types of veins found on the dorsum of the hand, namely cephalic and basilic. Basilic veins are the group of veins attached with the surface of the hand. It generally consists of upper part of the back of hand. Cephalic veins are the group of veins attached with the wrist of the hand. It is often visible form the skin. The vein pattern of human hand can also be represented in the same way as fingerprint and palmprint by ridges and bifurcation points [12]. Fig. 9 shows the vein structure on the back of human hand or on the palm dorsum surface. The spatial arrangement of the vascular network in the human body is stable and unique in individuals [13]. The prime function of vascular system is to provide oxygen to body parts. As the human body increases with age it extends or shrinks with the respective change in the body. Thus, the shape of hand vein changes with the physiological growth. During the adult life generally no major growth takes place and hence vein patterns are quite stable at the age of 20-50 years, at a later age the vascular system begins to shrink with the decline in the strength of bones and the muscles. These changes in vascular system make the vein pattern loose earlier pattern. As the vascular system is a large and essential system of the body, it is largely affected by any change in the body; either by nature or by disease. Diabetes, hypertension, atherosclerosis, metabolic diseases or tumors [14] are some diseases which affect the vascular systems and make it thick or thin.

The temperature of veins is quite different from its surrounding skin due to temperature gradient of skin tissues containing veins. This change in temperature can easily be observed in an image, captured by infra red thermal camera. However, such imaging is largely influenced by room temperature and humidity due to sensitivity of thermal cameras to these factors. Incorrect information about any of such factors can result in wrong approximation of temperature and affect the visibility of vein patterns. Based on the fact that the superficial veins have higher temperature than the surrounding tissue, the vein pattern at the back of the hand can be captured using a thermal camera. Other important aspect of vein anatomy relates to their spectral properties. Vein absorbs more infrared light as compared to its surrounding skin. This is due to level of blood oxygen saturation in the vein patterns. Therefore the vein pattern of a human hand can also be acquired using low-cost near infrared imaging [12]. The absorption and scattering property of infrared light depends upon exact wavelength used at the time of imaging, while at some wavelength arteries absorb more light than veins. Thus the same image of veins and arteries,6 acquired at low wavelength generates different intensity images.

The reflectance spectrum of hand skin

Besides the internal inherent structures that constitute the hand anatomy (as discussed above), some other biological properties of human hand can also be utilized to acquire unique features for biometric identification. One of such properties is the existence of distinguishing patterns in skin reflectance. The biological composition of skin and its response varies from individual to individual. The spectral behavior of skin can be quantitatively measured as the ratio of light reflected over the incident light for a particular wavelength. This spectral analysis is one of the most reliable approaches to detect spoof biometric samples; as research in this area shows that the spectrum in the case of a mannequin is quite different from human skin [15]. It is important to note that the spectral characteristics of the palm are quite identical to that of back of hand with little increase in wavelength due its reddish color. The spectral reflectance of skin is quite independent of any particular race or species and therefore it cannot be used for any such classification. However, the darker skin reflects smaller proportion of incident light, therefore the variation in curvature is also low [15].

Conclusions

The structure of human hand is quite complicated and consists of variety of soft tissues and bones. The hand based biometrics system exploits several internal and external features that are quite distinct to an individual. However, some features or traits are highly stable (*e.g.* veins, palmprint, *etc.*) while some are more conveniently acquired (*e.g.* hand geometry). The individuality in the uniqueness of the hand based biometrics is highly dependent on the intrinsic anatomical properties of the hand. There has been very little work to explore several anatomical characteristics of hand, *e.g.* muscles, nerves, *etc.*, for biometric identification. The success of a biometric modality highly depends on its uniqueness or the individuality, which can be better explored from the human anatomy and the biological process that generates corresponding physiological characteristics.

Related Entries

Palmprint Features, 3D Palmprint, Hand Geometry, Hand Vein.

References

1. Pedro Beredjiklian, M.D.: The Structure Of The Hand, available at: http://files.ali-aba.org/thumbs/datastorage/skoob/articles/BK40-CH11_thumb.pdf (2003)
2. Norman, W.: The Anatomy Lesson, available at: http://home.comcast.net/~WNOR/lesson5mus&tendonsofhand.htm (1999)
3. Richards, L., Loudon, J.: Hand Kinesiology. The University of Kansas, available at: http://classes.kumc.edu/sah/resources/handkines/nerves/dermatome.htm (1997)
4. Zhang, D.: Palmprint Authentication. Springer (2004)
5. Kanhangad, V., Zhang, D., Nan, L.: A multimodal biometric authentication system based on 2D and 3D palmprint features. In: Biometric Technology for Human Identification. Volume 6944., Orlando, Florida, Proc. SPIE (Mar, 2008) 69440C–69440C
6. Jain, A.K., Demirkus, M.: On Latent Palmprint Matching. MSU Technical Report (2008)
7. Ashbaugh, D.R.: Quantitative-Qualitative Friction Ridge Analysis: An Introduction to Basic and Advanced Ridgeology. CRC Press (1999)
8. Maltoni, D., Maio, D., Jain, A.K., Prabhakar, S.: Handbook of Fingerprint Recognition. Springer-Verlag, New York (2003)
9. Jain, A.K., Prabhakar, S., Pankanti, S.: On the similarity of identical twin fingerprints. Pattern Recognition **35** (2002) 2653–2663

10. Kumar, A., Wong, D.C., Shen, H.C., Jain, A.K.: Personal Verification using Palmprint and Hand Geometry Biometric. In: Audio- and Video-Based Biometric Person Authentication (AVBPA), Guildford, UK, Proc. 4th Intl. Conf. (June 9-11, 2003) 668–675
11. Guan, H., Rogerio, F.S., Turk, M.: The Isometric Self-Organizing Map for 3D Hand Pose Estimation. In: Automatic Face and Gesture Recognition, Southampton, UK, The 7th International Conference (2006) 263–268
12. Kumar, A., Prathyusha, K.V. In: Personal authentication using hand vein triangulation. Volume 6944., Proc. SPIE Conf. Biometric Technology for Human Identification, Orlando, Florida (Mar. 2008) 69440E–69440E–13
13. Nadort, A.: The Hand Vein Pattern Used as a Biometric Feature. Master's thesis, Netherlands Forensic Institute, Amsterdam (2007)
14. Carmeliet, P., Jain, R.K.: Angiogenesis in cancer and other diseases. Nature **407** (2000) 249–257
15. Angelopoulou, E.: The Reflectance Spectrum of Human Skin. Technical Report MS-CIS-99-29, University of Pennsylvania (1999)

Definitional Entries

Anatomy

The word Anatomy originates from the Old French word Anatomie, or a Late Latin word Anatmia. Anatomy implies, ana meaning up and tomia meaning cutting. It is a branch of natural science concerned with the study of the bodily structure of living beings, especially as revealed by dissection.

Epidermis

This is the uppermost layer of the skin. Its thickness varies depending upon the location of the skin. Generally it is found to be 0.5 nm on the eyelids and (thinnest) and 1.5 nm at palm and sole (thickest). It consists of 5 layers named:

1. Stratum germinatum
2. Stratum granulosum
3. Stratum spinosum
4. Stratum licidum
5. Stratum corneum

Dermis

This is the inner layer of the skin. It varies in the thickness according to the location of skin. It is 0.3 nm on eyelid while 3.0 on back. It is composed of three types of tissues which are present throughout the layers named as: collagen, elastic tissue, and reticular fibers. The two layers of the dermis are the papillary and reticular layers. The upper, papillary layer, which is the outer layer, contains a thin arrangement of collagen fibers. The lower, reticular layer is thicker and made of thick collagen fibers that are arranged parallel to the surface of the skin.

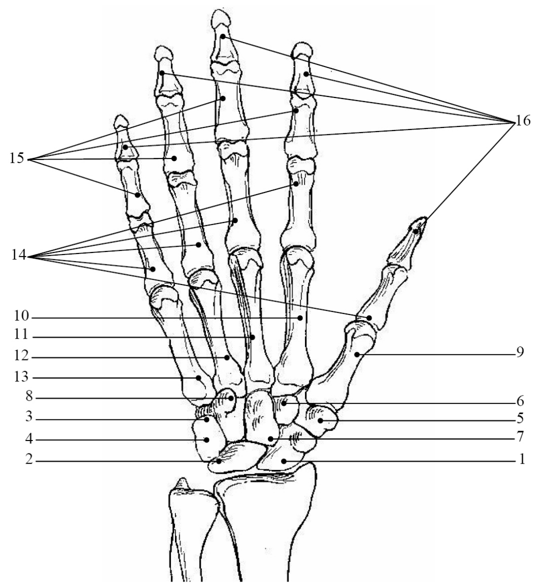

Fig. 1. Skeletal structure of the human hand.

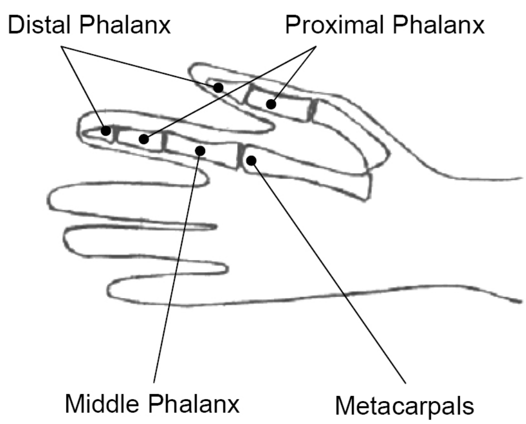

Fig. 2. Phalanx bones of the human hand.

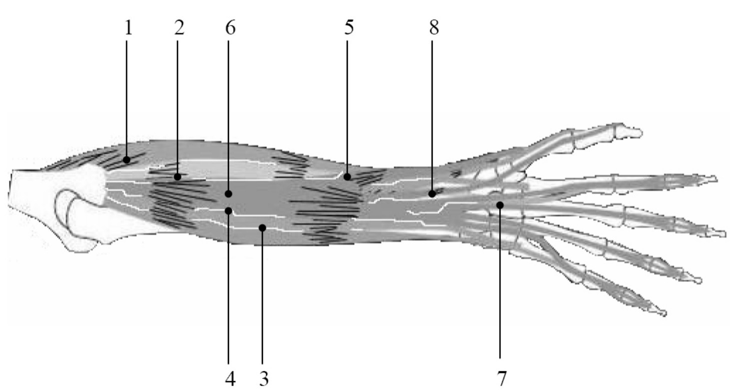

Fig. 3. Extensor muscles of the hand.

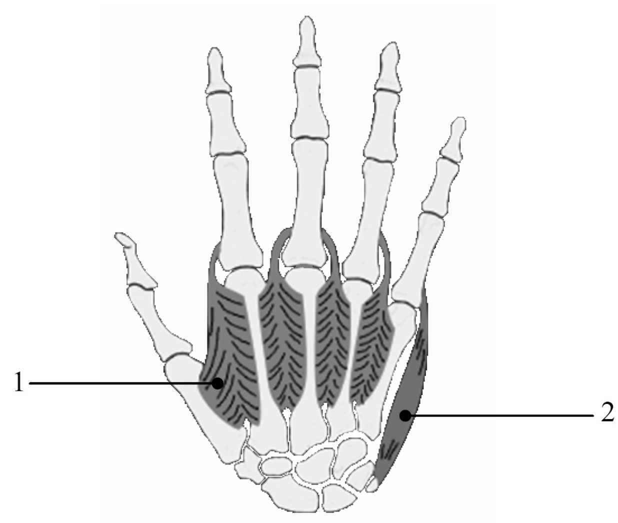

Fig. 4. Dorsal intrinsic muscles.

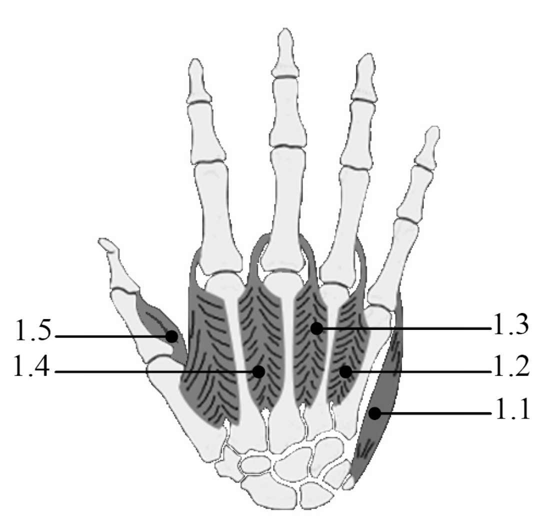

Fig. 5. Superficial layers.

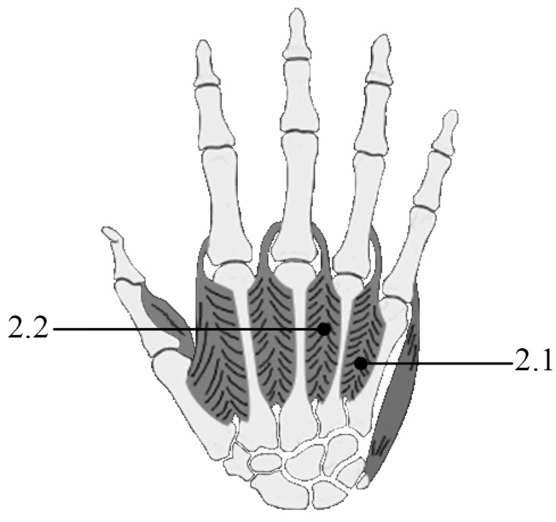

Fig. 6. Deep layer.

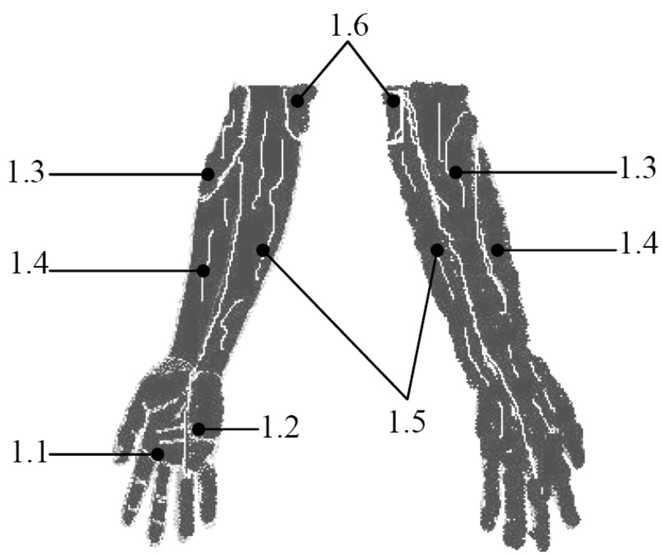

Fig. 7. The peripheral nerves distribution in arm and wrist of human hand.

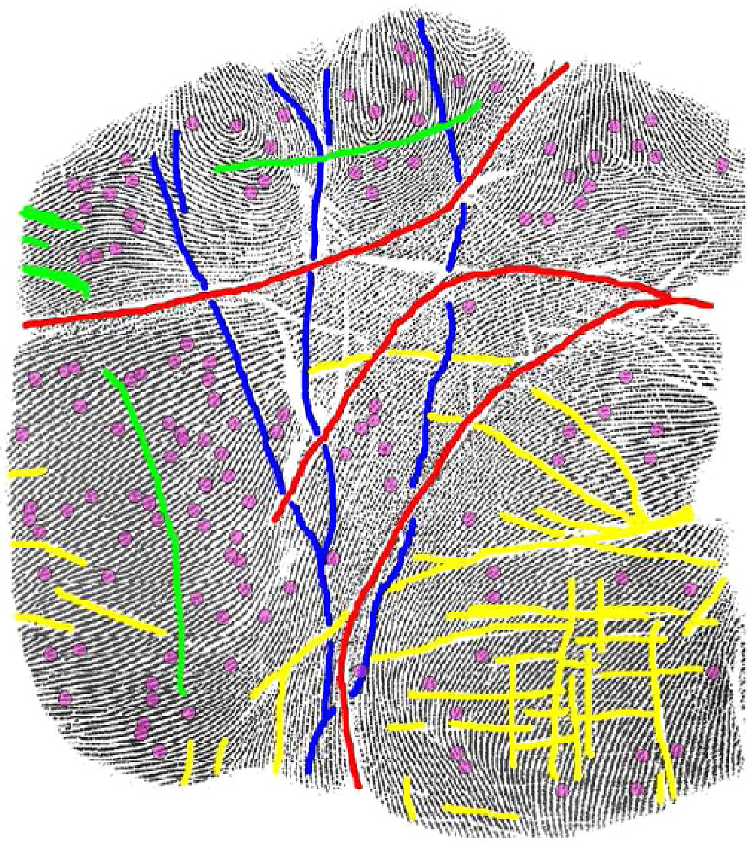

Fig. 8. The palmar flexion creases (adopted from [6]): major creases (red), minor creases (green), minor finger creases (blue), secondary creases (yellow), and minutiae details (magenta).

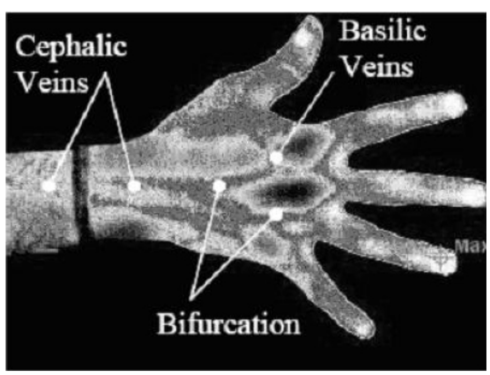

Fig. 9. Veins in the human hand.