Chapter 6
Evolution of Finger Vein Biometric Devices in Terms of Usability

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Abstract In this chapter, the usability of finger vein biometric devices is reviewed and discussed from various viewpoints. Since the usability requirements vary on both the applications and the situations in which the device is used, the requirements need to be carefully reviewed in light of each viewpoint and reflected to the product design.

Keywords Usability · Anti-vandalism · Compactness · Compliance · Durability · High throughput · Mobility · Portability · Universal design · Universality

6.1 Introduction

The term usability is defined as follows:

> the fact of something being easy to use, or the degree to which it is easy to use [1]

Obviously, most industrial products are designed in light of usability in order to meet users' various requirements. These requirements are characterised by factors such as use cases, user profiles, security requirements or local regulations. Since all of these requirements cannot be satisfied by a single device, a variety of devices has been developed and provided to the users who can choose the product's usability features to fit their needs.

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The usability factors of biometric devices include the following:

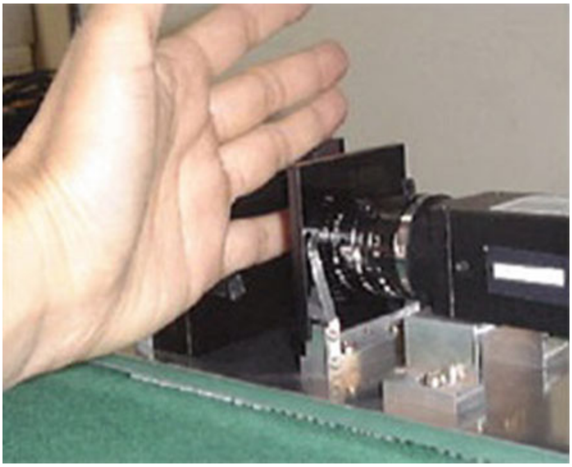
- Compliance with regulations,
- Compactness,
- Portability and mobility,
- Universal design,
- Durability and anti-vandalism,
- High throughput and
- Universality.

In the following sections, the first experimental implementation of the finger vein biometric technology with a very primitive user interface is introduced. The details of each usability factor considered at the time of industrialisation of the technology are then reviewed and discussed by illustrating use cases in the real world. The key factors how the usability requirements were achieved in the product design are also discussed later in this chapter.

6.1.1 Early Implementation

The basic principle of the finger vein biometrics was discovered in a research on vascular pattern visualisation for medical purposes [2]. Since the primary purpose of the research was to obtain high contrast images that can be used for medical diagnostics, the researchers focused on the image quality rather than the usability of the device in the early stage of the development. As a consequence, the prototype device was large and heavy, and thus not suitable for general public use. One of the first implementations of such experimental equipment is shown in Fig. 6.1.

Fig. 6.1 Prototype finger vein reader



6.1.2 Commercialisation

In order to utilise the technology originally developed for medical equipment for commercial biometric devices, there were a lot of factors to consider. The following three minimal usability features were particularly focused at the time of development.

- Intuitive operation

One of the major issues was the ease of use. As biometric devices are sometimes used as a modality alternative to existing rather complicated authentication procedures (e.g. long passwords which are frequently asked to change, or USB tokens that users are required to type the challenge and response codes every time), the operation of the device is expected to be simple and intuitive. To achieve this goal, the appearance of the device needed to be designed carefully so that users can present their fingers properly without any effort or training.

- Compact design

The device dimension is another factor to consider. Many biometric devices are used in an office environment where the desktop spaces are limited and thus the size of the biometric device needs to be as small as possible.

- Universal design

As a commercial product, it is important to design the device so that it is accepted by various types of users. This means that the size and shape of the image scanning platen need to be designed to be suitable for the majority of fingers. The length and the thickness of fingers of the target users are collected, and the device is designed so that it can accept more than 90% of the user population.

One of the most successful finger vein devices was developed and released by Hitachi, Ltd. in 2006. The device was designed to be used on desktop computers and connected to a PC via USB cable. The vein images were captured by the infrared camera embedded in the bottom part of the device and the comparison process was executed on the connected PC [3]. Its compact body and the intuitive design were widely accepted and employed for many use cases such as logical access control, physical access control or time and attendance systems. This model became a benchmark for other finger vein devices developed later as well as the origin of the following usability evolutions.

6.1.3 Evolutions of the Finger Vein Biometric Devices

The H-1 finger vein device was designed bearing the above-mentioned basic usability requirements in mind and successfully accepted in the market (Fig. 6.2). In the course of the worldwide deployment of the biometric devices, some users pointed out the possibility of further optimisation in terms of usability in order to meet various requirements specific to the use case [4]. In the following sections, the usability

Fig. 6.2 Hitachi finger vein reader H-1

requirements are summarised, and the optimisations applied to the finger vein biometric devices are described.

6.2 Compliance with Regulations

6.2.1 Use Case/Background

In some use cases, the authentication/transaction process needs to be compliant with Public Key Infrastructure (PKI) by law or by regulation. Especially in the banking sector, PKI transactions are widely adopted for both corporate and retail online banking and it is necessary to incorporate PKI functionality into the device.

6.2.2 Usability Requirement Details

In the PKI scheme, every user needs to keep a private key in a secure storage. Typically, private keys are stored in a tamper-proof smart card, in which the key is activated by a PIN number. This scheme is widely employed by credit card transactions and sometimes referred to as “chip-and-pin” scheme. In order to apply biometric authentication in this scheme, the following requirements needed to be satisfied:

- A smart card reader must be equipped in a single body.
- Communications between the biometric reader and the card reader must be secured.
- The “Challenge-Response” protocol must be supported.
- The RSA signing functionality is required.

6.2.3 Challenges

The layout of the smart card reader was the most significant challenge for this implementation. In order to protect the communication between the biometric device and the smart card reader, it was necessary to integrate both components in a single tamper-proof enclosure. Attaching a smart card reader on the hood of the scanner was the easiest option; however, this idea was not employed because the increased height and the weight of the upper part of the device reduced the physical stability.

6.2.4 Implementation

For a stable use on the desktop and consistent user experience with the precedent finger vein devices, a small micro-SIM card reader is embedded under the finger scanning platen. The internal structures around the bottom part of the device were drastically reviewed and redesigned so that the card reader could be embedded without changing the height of the finger presentation. The card slot is accessible from the front of the device so users can visually confirm that the card is properly set. The card can be inserted or removed just by a simple “push-push” action for convenience, which is effective especially when the device is shared by other users. The PKI-enabled finger vein reader B-1 is shown in Fig. 6.3.

6.3 Compactness

6.3.1 Use Case/Background

One of the most common feedbacks from the users concerns the dimension of the device. Although the H-1 device was made compact, some users find the upper hood relatively bulky especially when compared with fingerprint readers.

6.3.2 Usability Requirement Details

The height of the finger vein reader needed to be reduced. The footprint (the area occupied on the desktop) also needed to be as small as possible. The requirements to satisfy are as the following:

- A small and flat form factor with a minimum footprint is needed.
- Practical authentication accuracy must be achieved without the hood.

6.3.3 Challenges

Since the scanning platen is exposed to the outside, the lighting conditions cannot be controlled. The image contrast is largely influenced by the ambient light and the captured finger vein images can be easily saturated under a strong light such as direct sunlight.

Due to the small form factor, the area available for the scanning platen is very limited. On the other hand, the physical finger area to scan needs to be larger than a certain size in order to achieve practical authentication accuracy.

Fig. 6.3 PKI-enabled finger vein reader B-1

6.3.4 Implementation

In order to suppress the influence of the uncontrollable ambient light, the enclosure is carefully designed. The finger rest is made narrow so that the entire platen is covered with the presented finger. The enclosure is painted in matt black to avoid any undesirable light reflected on its surface. These measures prevent the ambient light from getting into the camera, which largely contributes to the stable image capturing.

The scanning platen was made smaller than the H-1 device by reducing the marginal area of the captured image. This reduces the tolerance of the finger positioning, which affects the usability; however, the narrow finger rest and the newly designed fingertip stop help users to present fingers in a consistent manner. A couple of notches are added to both sides of the front part so that users can place their index finger and ring finger for better stability.

The small factor finger vein reader S-1 is shown in Fig. 6.4.

Fig. 6.4 Finger vein reader S-1

6.4 Portability and Mobility

6.4.1 Use Case/Background

One of the most preferred features is the portability of the device. It is not difficult to imagine a situation where users need to authorise transaction requests when they are out of office and do not have any office environment.

6.4.2 Usability Requirement Details

In the mobile computing scene, the size of the device is an important factor. Especially when users need to authenticate transactions immediately wherever they are, the authentication device needs to be compact enough to bring with. Also, it is inconvenient to work with hardware that requires cable connections. It is quite often the case that no mains are available when working outside the office. Although there are some technologies to reduce the number of wired connections such as PoE (Power over Ethernet) or USB bus power, the user experience is not satisfactory for the mobile use. Taking these factors into account, the following requirements are preferred:

- The dimension must be compact enough to fit in a pocket.
- The device must be powered without a lead.
- Cable connections are not appropriate.

6.4.3 Challenges

In order to reduce the height of the first-generation device H-1, the hood needed to be removed. Since the infrared light source is embedded under the hood, the optical system layout has to be changed. After a careful technical consideration, two infrared LED arrays are placed on both sides of the scanning platen.

6.4.4 Implementation

In order to produce the illumination powerful enough to penetrate the presented finger, a large-capacity lithium–ion rechargeable battery is employed. For the wireless connectivity with small power consumption, the Bluetooth® Low Energy technology was employed.

The mobile finger vein reader B-2 is shown in Fig. 6.5.

Fig. 6.5 Mobile finger vein reader

6.5 Universal Design

6.5.1 Use Case/Background

Unauthorised cash withdrawals from ATMs with counterfeit cards, stolen cards and stolen PINs became a serious social issue about 15 years ago in Japan. Many account holders used a vulnerable PIN such as a birthday, a phone number and a car registration number and financial institutions were expected to introduce countermeasures to reduce the fraud risk promptly. In response to this movement, many financial institutes in Japan decided to introduce finger vein biometrics for ATM transactions [5].

6.5.2 Usability Requirement Details

Since ATM users are general public, it is not realistic to expect all users have received sufficient training before using biometric devices. Therefore, an external design that implies intuitive operations is very important. Biometric ATMs should also be highly accessible for physically challenged people. Thus, the following usability requirements are needed:

- Users need to be able to present their fingers intuitively and straightforwardly without a special training.
- Fingers must be always visible through the authentication process.
- The shape of the enclosure must be friendly for visually impaired users.

6.5.3 Challenges

Since the infrared light source was embedded under the hood of the device in the H-1 device, users could not see their fingers whilst having them scanned. In the course of the proof-of-concept study, some users found it uncomfortable or even scary to insert their fingers into the tunnel under the hood. In order to reduce this psychological stress, the hood needed to be removed and the layout of the light source had to be changed to enhance the usability.

The height of the device should be as low as possible so that users on a wheelchair can easily access the bank card reader and the cash outlet over the biometric device. The device shape itself needs to give an intuitive guide to visually impaired users so that they can understand the proper finger positioning only by touching the device.

6.5.4 Implementation

The hoodless "open-type" finger vein device was developed by introducing a pair of infrared LED arrays embedded on both sides of the scanning platen (Fig. 6.6). An inverted U-shaped fingertip guide was employed to enhance the usability for visually impaired users. The accessibility of the biometric device and other ATM components such as a card reader is carefully checked with a help of handicapped users (Fig. 6.7). The open-type finger vein devices and an implementation example on an ATM are shown in Figs. 6.8 and 6.9, respectively.

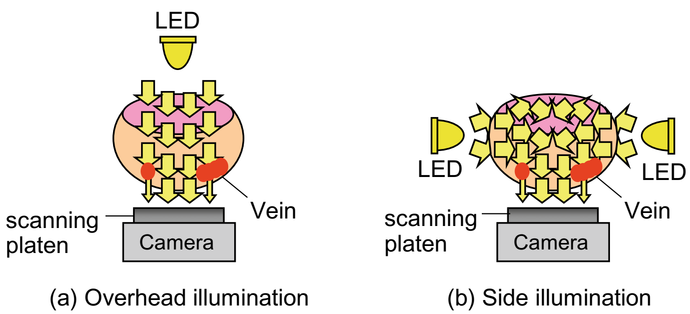


Fig. 6.6 Comparison of finger illumination

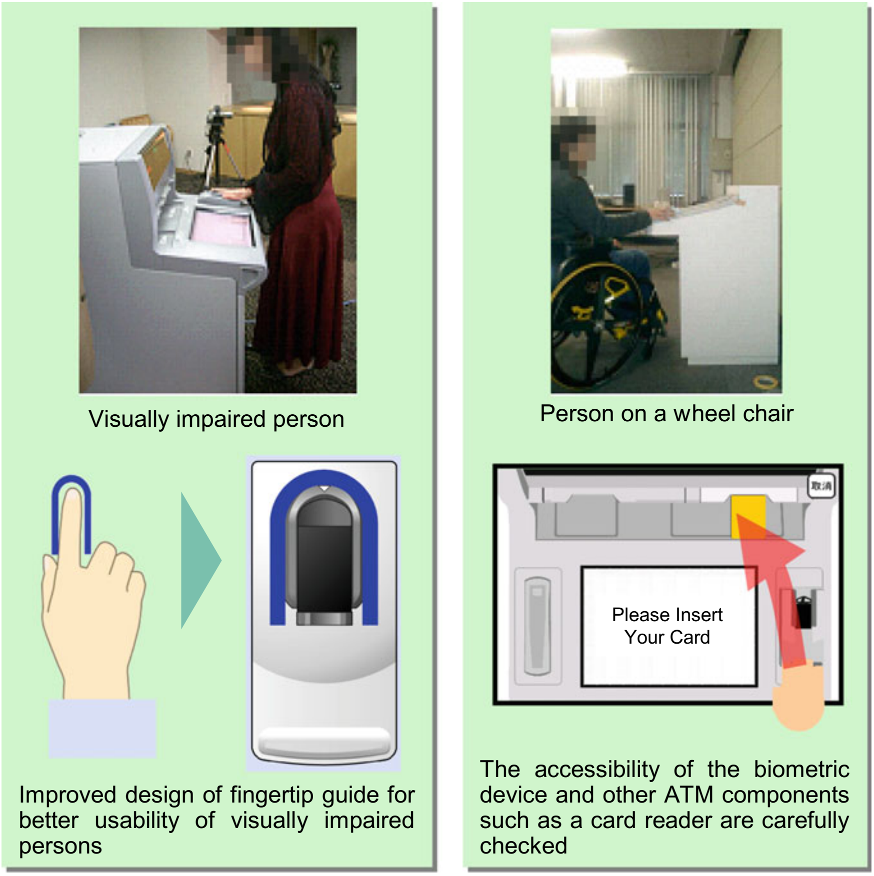


Fig. 6.7 Accessibility tests at the user experience

6.6 Durability and Anti-vandalism

6.6.1 Use Case/Background

In many cases, ATMs are located outdoors to provide users with 24/7 financial services. The environmental conditions of outdoor use cases are much more challenging than indoor use cases.

(a) Desktop device (b) Enrolment device

Fig. 6.8 Open-type finger vein reader

Fig. 6.9 Finger vein device installed on ATM

6.6.2 Usability Requirement Details

In order to embed the device on outdoor ATMs, the device needed to be robust against rough ambient conditions. The following requirements needed to be satisfied:

- The device needs to be operable under severe weather such as rain, snow or direct sunlight.
- The enclosure of the device must withstand vandalism.

6.6.3 Challenges

As ATM users are general public, the balance between the user-friendliness and the durability is a key factor. The open-type finger vein readers are widely accepted in Japan because users feel less psychological stress as described in the previous chapter. In some countries, however, there are not so many users to feel such stresses and the durability has more importance than the psychological factor.

6.6.4 Implementation

The enclosure of the finger vein device was redesigned to cope with the outdoor ATM use case scenarios. A hood to protect the scanning platen was added to increase the durability. The round ABS enclosure shown in Fig. 6.10 is designed to withstand vandalism and can hold a weight of an adult male. In the case where the see-through materials are preferred rather than the durable reinforced plastic (see Sect. 6.5.3), the hood can be replaced with the one made of tinted clear plastic as shown in Fig. 6.11. The curvature of the hood is carefully designed to reduce unwanted infrared light reflection inside the tunnel. The hood also acts as a platen protector from dirt, which is effective to maintain the performance and to reduce the number of cleaning visits.

Fig. 6.10 Finger vein enclosure for outdoor ATMs (prototype)

Fig. 6.11 Outdoor ATM finger vein reader installed on an ATM

6.7 High Throughput

6.7.1 Use Case/Background

For physical access, control use cases such as entry to an office building or a ticket barrier in a station, the authentication processing time is a critical factor. Instead of holding a proximity ID card to touch in, it is obviously more convenient if users just need to present their fingers on a reader installed at the entrance. This means that the comparison process needs to be done in the identification mode, or also known as one-to-many authentication.

6.7.2 Usability Requirement Details

In the case of office building scenario, the entrance gate is heavily used typically at the time of open and close of business. The access to the building needs to be granted within the time the existing entrance system (e.g. proximity cards) requires. Otherwise, a long queue will develop at the busiest time.

The following features are needed for this application:

- The authentication must be fast enough to accommodate a large number of visitors.
- One-to-many authentication functionality is required.
- Fingers presented in various manner need to be accepted.

6.7.3 Challenges

In order to maximise the throughput, i.e. the number of successful entry permissions per unit time, it is necessary to design a physical access control system that does not require users to stop at the gate. This means that finger rests employed for other models to encourage users to position their fingers correctly cannot be used and thus the presented fingers cannot be completely stationary.

6.7.4 Implementation

The presented fingers are automatically located in the camera's field of view so that users do not need to place their fingers always in the same position [6]. The distance between the camera and the presented fingers is measured by a range finder so that the captured images have sufficient image resolutions for the following comparison process. The optical system layout of the walk-through finger vein technology and its prototype implementation used in a proof-of-concept are shown in Figs. 6.12 and 6.13, respectively.

6.8 Universality/Availability

6.8.1 Use Case/Background

Biometric authentication is becoming very common in our daily life. One of the most familiar use cases is the logical access control for mobile devices such as smartphones. Biometric modalities such as fingerprint, facial or iris recognitions are

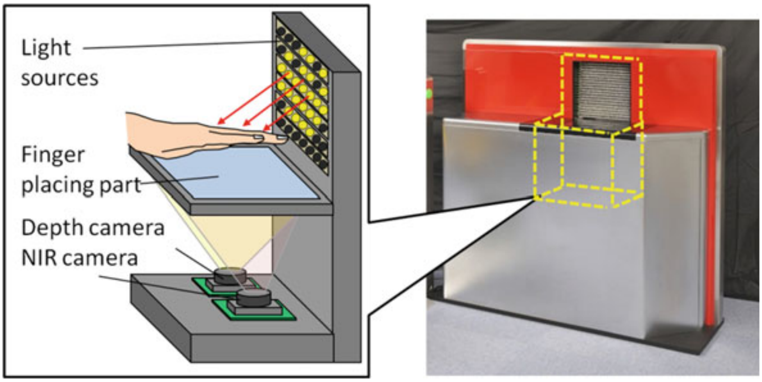


Fig. 6.12 Optical system layout of the walk-through finger vein technology

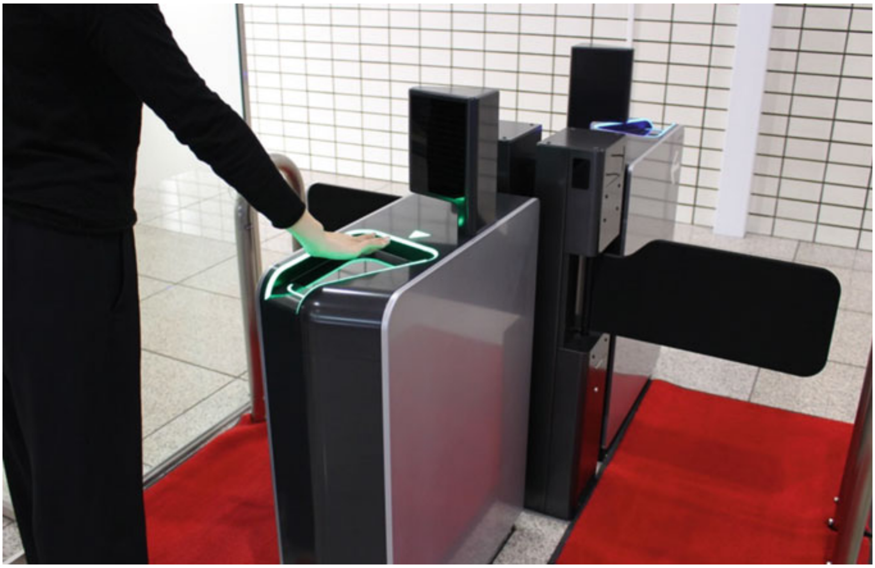


Fig. 6.13 Walk-through finger vein entrance gate used in a proof-of-concept

widely used; however, these technologies typically require a dedicated sensor, which is a hurdle for smartphone manufacturers in terms of cost.

6.8.2 Usability Requirement Details

Since majority of the smartphone users are general public, it is almost obvious for them to expect the following features:

- The form factor must be comparable to fingerprint sensor modules.
- The weight must be minimal for better portability.
- The authentication process should not consume a lot of battery power.
- The cost must be minimal for general public use.

6.8.3 Challenges

Miniaturisation has been a long-awaited evolution for finger vein devices. Although it may be technically possible to achieve the form factor, it is hard to be competitive in terms of cost comparing with the existing biometric readers such as capacitive or swipe fingerprint readers.

6.8.4 Implementation

In order to meet the above-mentioned requirements, the finger vein device was fully implemented by software [7]. The authentication algorithm uses the camera and the System on Chip (SoC) on the smartphone to authenticate the user. The vascular pattern extraction process is drastically re-engineered so that it can locate the internal structure even from images captured by an ordinary visible light camera embedded on the mobile device. The Android™[1] implementation of the finger vein software is shown in Fig. 6.14.

[1] Android is a trademark of Google LLC.

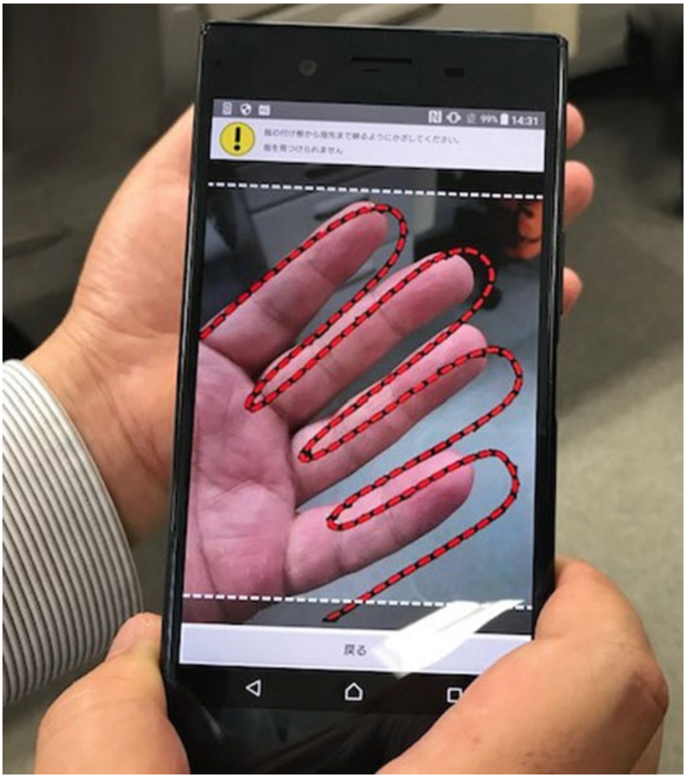


Fig. 6.14 Finger vein software working on Android smartphone (prototype)

6.9 Summary

In this chapter, the user requirements expected for finger vein biometric devices are summarised and reviewed in terms of usability. The backgrounds of the usability requirements are illustrated by quoting real use cases and the product design approaches to satisfy such requirements are discussed. The usability requirements vary over time or by region together with ever-evolving technologies and need to be reviewed time to time in order to satisfy the needs of the mass-market.

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