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Low cost, high quality vein pattern recognition device with liveness Detection. Workflow and implementations

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ABSTRACT

Vein pattern recognition in biometric applications has been researched and applied for the last two decades. However, while the methods do exhibit significant improvements over other- more prominent - biometric parameters, the influence of vein recognition systems in the biometric world is stalling. The problems are multiple, starting from the severe lack of databases containing both real and simulated blood vessel to no stimulation of algorithm creation in the absence of standardized hardware scanning modules. Most research is performed on close datasets acquired with makeshift devices that cannot be reproduced by other researches or several constraints are applied to the original data that limit the real-world applicability of the feature extraction software application or scanning hardware modules. This paper aims to propose and implement a robust, modular hardware device that retains the low-cost entry barrier for academic experiments while providing high-quality scans of the blood vessels with significant improvements over traditional scanning systems. The inclusion of a powerful liveness detector using additional raw image calculations and external parameter monitoring (image contrast, temperature or skin reflexivity) completes a possible roadmap for an open-source vein pattern device. Experiments have also shown that the resulting scans are more resilient to hand orientation and position changes due to the data provided by a real-time stereoscopic device attached to the system.

1. Introduction

The importance of biometrics in a unified, networked society has been thoroughly assessed and confirmed in numerous studies [1–3]. The domain has slowly progressed and various verification and identification methods have reached a satisfying degree of maturity.

One of the relatively new techniques used for biometric detection is the extraction of unique features from the geometric arrangement of blood vessels. Due to specific radiation absorption constrains, veins are usually prime candidates for scanning and detection [4,5].

Vein pattern biometrics research can be observed in numerous articles from the last two decades and is often described as a very promising and attractive parameter [6–8]. The model of the veins offers several advantages over traditional biometrics such as fingerprints, iris and voice, mainly due to the covert location and vascularization requirements for the acquisition of the relevant data out of the blood vessels. Concerns such as hygiene, direct spoofing or the stigma associated with several biometric methods can be greatly diminished in devices using vein recognition [4,2,9]. In addition, vein patterns often exhibit increased accuracy rates and improved usability [2,10,11].

Theoretically any part of the body could be used for the visual extraction of vein patterns, but the hand is preferred since it's usually an uncovered part of the body with reduced pilosity and the veins are at a shallow depth [12]. In order to maximize the amount of viable data, the vast majority of scientific articles have described methods of extraction from the finger veins [13–15], palm veins [16–18], or veins in the back of the hand [19–22]. Commercial scanners using this technology have also been available from the early days of the technology, employing the preferred areas of interest in the hand: finger [23], palm veins [24], dorsal veins [25] as seen in Fig. 1.

While several methods of extraction and feature collection are now established, vein patterns as a biometric parameter still struggle to gain acceptance and enter mainstream applications. This inability can be attributed to a host of factors, starting from the relative novelty of the methods to the lack of logistics support for algorithm creation and testing. Previous research has determined that there is a severe lack of databases containing both real and simulated blood vessel patterns as it is the case with other, more

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Fig. 1. Left: Hitachi finger vein scanner. Center: Fujitsu palm vein scanner. Right : Techsphere VP-II dorsal vein scanner [23–25].

prominent biometric technologies [22,26]. In addition, most research is performed on close datasets acquired with makeshift devices that cannot be reproduced by other researches or several constraints are applied to the original data that limit the real-world applicability of the feature extraction software application or scanning hardware modules [22,26]. Most of the issues plaguing the technology are difficult to solve without a concerted effort. Research has shown that the implementation of a high-quality hardware acquisition chain using a modular approach is a viable first step in stimulating the creation of accurate software algorithms [11,12,22,26]. Pushing lower-cost but accurate hardware solutions as potential standards allows for the proliferation of vein pattern datasets, thus closing the gap toward more established biometric solutions.

An accurate and standardized hardware detection workflow allows for the introduction of additional modules in the biometric system. With the advent of digital theft and impersonation attempts, the importance of liveness detection in a biometric system has increased substantially [5,27,28]. Since liveness detection is the ability of a system to determine if the sample is alive or not there are four possible classes of fraud attempts [29,30]:

– False artefacts can be presented to a system in order to gain access to protected/secured areas.
– Additional biometric credentials attached to a registered user allowing access to information normally inaccessible to the clearance level of the original registered user.
– False samples enrolled in the system and shared by several perpetrators thus shunting the system.
– Authentication or transaction rejection from malevolent users due to the system's inability to protect itself from spoofing attacks, therefore false attacks can be artificially attributed to bogus attackers.

Given these scenarios, and considering the fact that biometric control systems are used in essential processes (informational and financial security, access to private property, etc.), spoofing prevention and general sample viability checks should be paramount in any biometric system.

The main scope of the paper is to provide an updated view on possible modular hardware design for vein pattern recognition devices that use the dorsal venous arch as a biometric parameter.

2. Vein pattern background and considerations

Since the vein arrangement has been touted as being a unique trait in both hand and retina -as shown by various research [4,23–25,31] - it can be accepted as a viable biometric parameter. It also shows various strengths over other biometric techniques due to the relative permanence and discrimination rate [26].

The visual scanning process employed in the acquisition of vein patterns relies on the optical absorption properties of the hemoglobin. Near infrared radiation is strongly absorbed by both veins and arteries and using a narrow radiation window of 750–950 nm, water has a reduced influence on the scanning. Fig. 2 depicts the behavior of oxidized and deoxidized hemoglobin together with water when illuminated with visible and infrared radiation.

As mentioned in the introduction, upper extremities veins are preferred over arteries due to their relative size and volume of blood carried, together with the closeness to the surface of the skin. In addition, most superficial veins do not have accompanying arteries.

A depiction of a dorsal vein arch arrangement can be observed in Fig. 3.

While the infrared scanning technology provides accurate contrast between the veins and the surrounding tissue, there is a number of potential issues that can affect the quality of the resulting images.

Since radiation is strongly absorbed or scattered by the various types of hand tissues, the amount of penetration is very small, usually 0.5–2 mm, and a vein pattern scanner can only visualize very shallow depth veins [12,22]. Furthermore, the vein model can shift due to the hand movements when scanning the veins in the back of the hand or the palm. Clenching the fist or extending the fingers also affects the segment angles and overall model length. Other undesirable scanning factors related to human anatomy and behavior include:

- Excessive hair
- Permanent tattoos
- Adipose tissue that can reduce the veins visibility
- Small age children with difficult to identify veins
- Blood loss, excessive physical exercise or altitude changes
- Hand position and orientation when scanned

Even in almost perfect conditions, environmental or systemic influences can alter the quality of a vein pattern recognition device. The scanning accuracy strongly depends on several factors

- Imaging device quality and responsivity to the desired wavelength, ability to control exposure, shutter speed and ISO. Negative influences can be described as camera noise, resolution artefacts, unfocused images, etc.
- Lighting system quality, uniformity -hotspots or uneven distribution, adjustability to environment changes and specificity for the vein model.
- Sample placement, controlled or unconstrained, each with their own array of difficulties having a significant impact on the repeatability of measurements.
- Environmental radiation pollution (external infrared sources).