

## **FINGERPRINT STRUCTURE IMAGING BASED ON AN ULTRASOUND CAMERA**

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### **ABSTRACT**

This paper describes the design of an ultrasound camera which has a resolution of 0.1mm. The camera allows the observation of the near surface structures of solid objects and is suitable for the finger ridge pattern imaging (i.e., pattern which is reflected in a fingerprint). The device can be used for a biometric identification of individuals (for access verification). It can also be employed for all other sorts of structures which have ultrasound detectable changes in the near surface structure, both natural and artificial (e.g., created for information recording). The paper describes the current version of the camera and the physical phenomena behind its operation. Presented are also perspectives of further development of the device.

### **INTRODUCTION**

Over the last few years, a new area of engineering science has been established whose products are likely to create a large market in the near future. It has been called "biometrics." The pioneers of this new domain intend to construct devices which would allow identification of a person on the basis of his/her "biological" characteristics: voice, dynamics of movements, features of face and other parts of the body, retina or iris pattern. However, the greatest hope seems to be lying in the possibility of the fingertip structure recognition (this structure is reflected in the fingerprint pattern).

It is well known that the finger ridge pattern is different for each individual and that it does not change over the life time. Touching of a sensor surface is a simple act. Many inventors of biometric devices hope to develop a button which would "know" by whom it has been pressed and which finger has been used. A button used for the door unlocking would of course let in only authorized people and this is what the whole new area is about.<sup>1,2,3</sup>

Systems for the ridge pattern imaging with the optical acquisition of data have been investigated for a number of years. They show "live" fingerprint images directly from a finger without the need for ink and paper which have been traditionally used by police since Galton times.<sup>3,4</sup> The systems with optical data acquisition, however, have a number of drawbacks: the direct image of the fingertip has a very low contrast and it is easier to see the dirt than the ridge pattern. In turn, methods employing the reflection from the surface are very sensitive to grease, dirt, and water. A three-dimensional image is difficult to create and does not provide satisfactory results for damaged fingers.<sup>2</sup> Furthermore, no method allows to decide, in an easy way, whether the object under observation is a real finger, an imitation, or perhaps a greasy residue of a finger on the sensor. The description of a typical optical fingerprint imaging system is given in Reference 6.

Hence, it should not be surprising that there has been interest in alternative methods of the ridge pattern imaging. For instance, Constantine Tsikosa proposed a capacitive method,<sup>7</sup> further developed recently by SGS-Thomson,<sup>8</sup> [8] Siemens, and Veridicom.<sup>3,9</sup> So far, only prototypes of such devices have been presented and there is little known about their practical usefulness.

## PERSPECTIVES OF ULTRASOUND DEVICES DEVELOPMENT

In 1986, the author of this paper proposed a method based on ultrasound data acquisition.<sup>14</sup> This approach allows to distinguish between real living fingers and any imitations. Furthermore, it is not sensitive to any dirt, grease etc. There is also a completely new perspective, unthinkable in the case of other methods. It is possible to create a device with a surface reacting to a finger touch (or a number of fingers) which would be able to decide where the finger has been placed, identify it, and register its movements. Such a device would not have any moving parts and could replace today's keyboards, mice, graphic pads, and fingerprint identification systems, though this is not the limit of its potential applications. To complete the picture, it is worth knowing that it is feasible to create a device which would be small, inexpensive (a kind of a chip), and could really fit in a button. Such a device would have another interesting property. It would enable us to devise a system for remote people identification (through a network) which cannot be cheated, even if a person sitting at a remote terminal has unlimited possibilities of carrying out a fraud.

A number of papers have been published describing our method,<sup>10-13</sup> a few patents have been granted, and a few other patents are pending<sup>14-16</sup> (the owner of the patents and commercial rights to the device is Sonident, Vaduz). This work is aimed to be a brief presentation of the key aspects of the method employed by us which have not been described in detail in the previous papers. The paper is also intended to present the subject to the readership of this journal.

## THE IDEA OF THE ULTRASONIC CAMERA OPERATION

The operation of our devices is possible thanks to the phenomenon, which apparently has not so far been employed by anyone and perhaps not even noticed (to the best of our knowledge). It can be summarized in the form of the following rule.

Consider a surface of a solid object against which another object has been placed, so that the contact between the two objects is not ideal, i.e., there are some inhomogeneities. The sound wave which reaches such a place not only passes from one environment to the other, become reflected and diffracted in the contact area as described by classical theory, but it also is subject to some additional scattering and transformation into different kinds of waves. This phenomenon is the effect of disturbance in the sound propagation conditions in the contact area between two objects; hence, it will be referred to as the contact scattering. It is sure that this kind of scattering is the result of, not only the contact area of the two objects, but also the area near the objects' surface (henceforth it will be referred to as the near surface structure). It is likely that, for this reason, the contact scattering is strongly dependent upon the substance of the placed object.

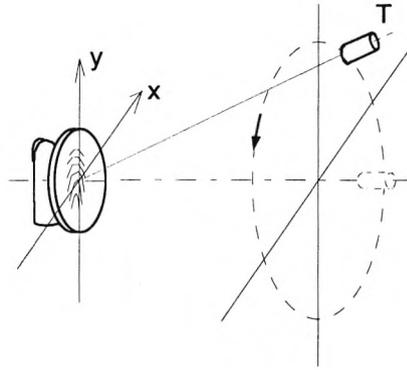
Experiments show that the transition of the wave from one environment to the other may practically not occur at all and observed are only the contact scattering and generation of other types of waves (it is particularly conspicuous for transversal waves). It is likely that the disturbances of the wave occurring in the contact areas are mainly in the phase (the phase front is spatially distorted) and they are responsible for the observed contact scattering. At the moment, the research is being carried out to develop a theory adequately describing this phenomenon. We shall devote further publications to this subject.

## DESIGN OF THE ULTRASONIC CAMERA

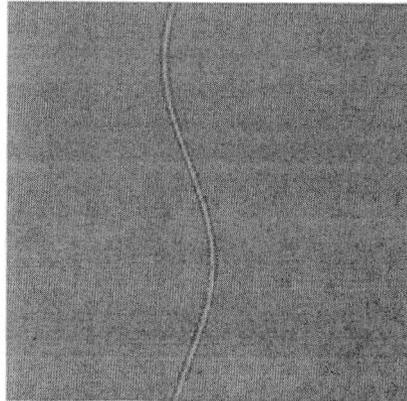
Employing the phenomenon described in the previous section, we have designed a device for measuring and analysis of the signals being the result of the contact scattering of objects placed against a plastic window. The device is designed mainly for the near surface observation of the finger ridge patterns. A detailed description of our device has been presented in the aforementioned papers. For all those readers who are not familiar with the subject, we offer a brief description.

An acoustic wave is sent in the direction of the surface against which an object has been placed (see Fig. 1). The signals which are scattered by the object are received by the transducer (T), which is moving along a circular trajectory whose axis is perpendicular to the contact surface ( $x$ - $y$ ). The same element can be used both as an emitter and a receiver. Alternatively, instead of one moving transducer it is possible to employ a number of fixed transducers.

For the object analysis with a resolution of around 0.1 mm, it is necessary to collect scattered signal data from about 256 different angles. At the moment, our device sends, in each of the 256 directions, a short pulse and receives the impulse response (in the case of a finger, the signal spectrum is in the range from 4 to 16 MHz and it is dependent on the device design).



**Figure 1.** Schematic diagram of the device.

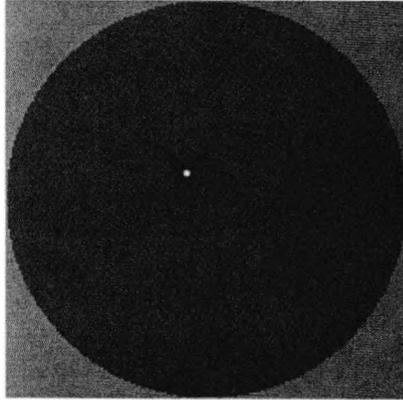


**Figure 2.** Impulse response of a ball.

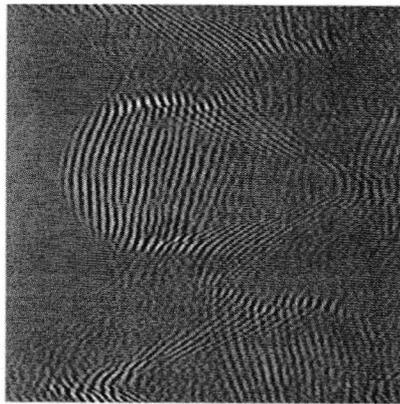
Figure 2 shows the set of impulse responses for a small ball, whereas Fig. 4 for a finger (vertical axis corresponds to time, horizontal axis corresponds to angle, the value of the signal is represented through the grey level). In order to obtain the observed structure from the collected data, a reconstruction procedure is used which is similar to methods used in ultrasound reflection tomography.

A set of programs have been written, aimed at achieving high quality and high speed reconstruction.

The algorithms developed at Optel enable image reconstruction based on a set of 256 impulse responses each containing 256 samples in about 20 ms (using a standard PC based on the Cyrix 6x86 P200+ processor). The reconstructions for the impulse response from Figures 3 and 5, are presented in Figures 3 and 5, respectively.



**Figure 3.** Reconstruction of a ball.



**Figure 4.** Impulse response of a finger.

### **TECHNICAL SOLUTIONS EMPLOYED IN THE CAMERA'S DESIGN**

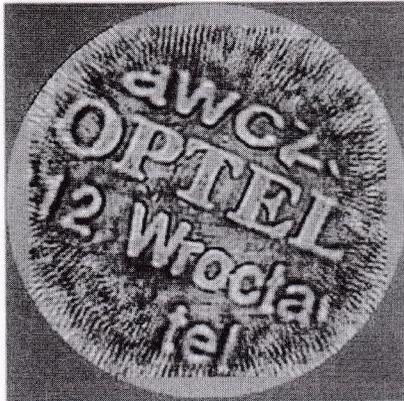
The use of the contact scattering phenomenon discovered by us and computer tomography methods was not enough to construct an ultrasound camera. We had to solve a few other problems.

In order to obtain the required resolution it was necessary to develop a circuit which, having a relatively small diameter, would emit a Gaussian ultrasound beam of high amplitude and have a high sensitivity as a receiver. Such a circuit has been developed and patented<sup>16</sup> and we intend to present its construction in a separate paper.

It was also necessary to develop a transducer which would be able to emit a short pulse and, as a receiver, would have the required bandwidth (4-16 MHz). Moreover, its phase function was required to have the smallest possible variance. It was also important



**Figure 5.** Reconstruction of a finger.



**Figure 6.** Reconstruction of a stamp.

that such a transducer would have to be cheap and have repeatable parameters. The final effect of our research is to be a device suitable for mass production whose price has to be reasonable. The researchers at Optel managed to develop a transducer which has a completely new design (a patent application has been submitted). It is able to emit very short pulses (in the range of 20ns - see Fig. 8 ) and has very wide bandwidth as receivers (ca 4-25 MHz).

The amplitude of the signal emitted by the new transducers is about two times higher than for classical pulse transducers. Their sensitivity as receivers is, however, slightly lower which, in the measurement cycle, gives a comparable result.

Nevertheless, the idea behind the new transducers opens a new path in the design of the ultrasound transducers and it is fair to expect significant improvement in their parameters. Again, we wish to devote a separate paper to this subject.



Figure 7. Appearance of the camera.

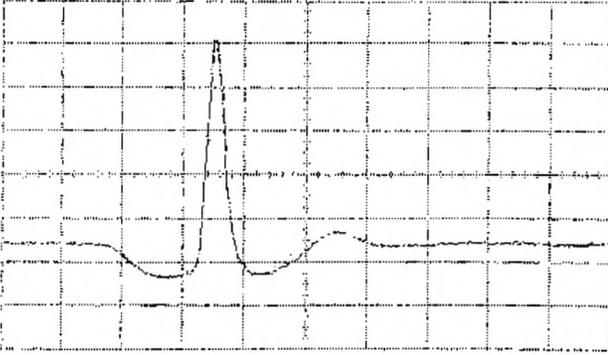


Figure 8. The shape of a pulse generated by our transducer.

The design of our ultrasound camera would not have been possible had we not developed our own electronic circuitry, which includes the transceiver circuit and an oscilloscope card. These elements are also based on our own original ideas. The pulse generator is capable of generating pulses as short as 20 ns which have the amplitude of ca. 600 V; the receiver has the sensitivity of  $5\mu\text{V}$  for the frequencies in the range 4-16 MHz, and the dynamic range of 60 dB. The oscilloscope card enables sampling at up to 200 MS/s and is specifically dedicated for processing sets of ultrasound signals (it satisfies some strict timing parameters).

It should also be noted that our ultrasound camera would not be of much use if there were no methods for the finger ridge pattern analysis. Also, in this area, we have some original solutions though, perhaps, they are of less interest to the readers of this journal. It is, however, worth mentioning that the algorithms which have been developed allow not only fingerprint recognition but also significant compression of the fingerprint data. For example, the finger ridge pattern can be synthesized from the information contained in as few as 30 bytes.

## OBSERVATIONS WITH THE USE OF THE CAMERA

Objects of similar structure, but made of different substances, give significantly different signals (both in amplitude and in character). The structure of the objects is nevertheless visible. Hence, it is possible to distinguish between "real" and "artificial" fingers.

Spreading gel on the surface of an object, soaking it in water or covering with dirt, does not result in significant changes of the signal.

A fingerprint is hardly noticeable because the signal level it gives is at least 30 dB lower than the signal given by a real finger (in contrast to this, for optical devices this level does not change significantly). The above observation is also true when soot or metal powder is used in order to enhance the fingerprint.

A fingerprint left on a thick (ca 0.5 mm) layer of gel or grease is noticeable but it is very different when observed directly.

Fingers which have damaged surface still give relatively clear image. Their internal structure seems to be visible, since the phenomenon on which our observations are based applies to the near surface layer.

## FUTURE WORK

In the near future, we plan to develop a new model of the camera, which will be based on fixed transducers and will be capable of showing "live" pictures of objects at 25 frames per second. It will be a kind of a "real-time" ultrasound camera which can see the near surface structures of objects placed against its sensitive surface. The camera will contain its own electronic circuit for reconstruction and it will have an output for a standard monitor. The camera used at present is based on a moving transducer and can produce a few frames per second. It also needs a computer which does the signal processing and displays the image on its screen. In 1999, we plan to develop an integrated version of the device. Eventually, we hope to implement it in a kind of a chip.

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