안전 출입 시스템을 위한 체적 홀로그래픽 광지문인식

Volume Holographic Optical Fingerprint Identification for Secure Entry System

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ABSTRACT

We propose an optical fingerprint identification system using volume hologram for database of matched filter. Matched filters in VanderLugt correlator are recorded into a volume hologram that can store data with high density, transfer them with high speed, and select a randomly chosen data element. The multiple reference fingerprint photographs of database are prerecorded in a photorefractive material in the form of Fourier transform images, simply by passing the image displayed in a spatial light modulator through a Fourier transform lens. The angular multiplexing method for multiple holograms of database is achieved by controlling the reference directions with a step motor. Experimental results show that the proposed system can be used for secure entry systems to identify individuals for access to a restricted area, security verification of credit cards, passports, and other IDs.

국 문 요 약

본 논문에서는 정합필터의 데이터 베이스로 체적 홀로그램을 사용한 광 지문 인식 시스템을 제안하였다. VanderLugt 상관기에 사용되는 정합필터는 방대한 저장 능력과 실시간 랜덤 엑세스의 장점을 갖는 체적 홀로그램에 기록된다. 데이터 베이스로 사용되는 지문 영상들은 각각 공간광변조기에

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디스플레이 되어 퓨리에 변환 렌즈를 통과한 후 퓨리에 변환된 공간정합필터의 형태로 광굴절매질에 기록된다. 대용량의 데이터 베이스를 구성하기 위한 다중화 방법으로 스텝 모터를 이용하여 기준파의 각도를 회전하는 각다중화 기술을 사용하였다. 실험을 통해 본 시스템이 제한된 영역의 접근을 통제하기 위한 개인 인증용 안전 출입 시스템 및 크레디트카드, 여권, ID등의 위조방지에 이용이 가능함을 제시하였다.

1. Introduction

In accordance with rapid development of information-oriented society, a concern for individual information management is increased day by day. Credit card fraud is a serious problem facing many banks, businesses, and consumers. Counterfeit parts such as computer chips, machine tools, etc. are arriving on our shores in great numbers. With a rapid advances in computers, CCD technology, image processing hardware and software, printers, scanners, and copiers, it is simple to reproduce pictures, logos, symbols, money bills, or patterns. Presently, credit cards and passports use holograms for security which are inspected by human eye and can be easily reproduced. What is needed to thwart this fakery is a code pattern that cannot be seen, copied scanned or read by conventional methods. Most of the work in biometric identification has gone into the fingerprint. Also, it is well known that fingerprints have been used as a unique identifier of individuals. Fingerprints are used for general security, military facilities, government facilities, banks, jails, and businesses. Fingerprint patterns are relatively stable and have unique features. There is only one in a billion chance of fingerprints of two different people being identical. Identification of fingerprints is user-friendly.

Personal identification by fingerprint recognition is of great interest in biometrics, and optical correlation offers attractive perspectives. Optical correlation as one important field of optical signal processing has wide applications in pattern recognition, image processing, target tracking and optical computing[1~4]. The key function of an optical correlator is that simple lenses perform the two-dimensional Fourier transform and multiplication required for the correlation. These operations are performed with massive parallelism and at the speed of light. To verify a fingerprint, minutiae that are the end points and junctions of print ridges are examined. In another methods, the number of ridges between the minutiae are counted. Other approaches use image processing and pattern recognition techniques including neural networks[5]. Many fingerprint recognition systems by optical correlator have already been proposed since Vander Lugt correlation[6~9]. In the conventional matched filter system the reference filter was stored on a holographic film plate that is a small reference bank[3].

In this paper, we use a photorefractive crystal as a database of matched filter in Vander Lugt correlator. Photorefractive materials can store optical images using variations in the index of refraction through the electro-optic effect. A photorefractive material, upon exposure to a light beam or an image, generates free charges such as electrons or holes. These charges redistribute and charges fall into trapping sites which create a charge distribution. The trapped charge distribution results in a non-uniform space charge field that is stored in the material. The space charge field produces a spatially-dependent electric field that changes the index of refraction of the material through the electro-optic effect. The variations in the index of refraction result in the diffraction. of light. The image stored in the photorefractive material can be reconstruct by an optical beam. Recently, many new developments and demonstrations have encouraged volume holographic memory systems[10~13]. The optical correlation system using a volume hologram has a capability of high speed and parallel processing as well as merits of large reference bank and real-time access. Each of the database images is displayed at the SLM and passed through the Fourier transform lens and interferes with the reference beam. Then the pattern is recorded into a crystal. We use angular multiplexing technique to make a large reference bank that is prerecorded in a photorefractive crystal in the form of Fourier transform images. The control of the reference beam, template images update, and exposure time to recording are processed automatically by a computer. When the input and the reference images are the same, the multiplied spectrum will be reconstructed at that angle. This spectrum will pass another Fourier transform lens and the correlation result between input and the reference image will appear at the output plane.

This system is ideally suit for secure entry systems to identify individuals for access to a restricted area or for mobile and remote surveillance by law enforcement agencies.

2. Optical correlation using a volume hologram

Optical correlator is an optical system in which an input image is compared to a previously stored reference or template, which is known as a matched filter. A large output in the form of peak light from the correlation operation indicates a high degree of similarity between the input and the reference.

Figure 1(a) shows the recording operation of matched filter. The object beam is focused into a crystal through a Fourier transform lens and interferes with the reference beam of a plane wave. Figure 1(b) shows the reconstruction, that is, the correlation operation. The readout from the crystal passing through the Fourier transform lens is the inverse Fourier transform of a product of two Fourier

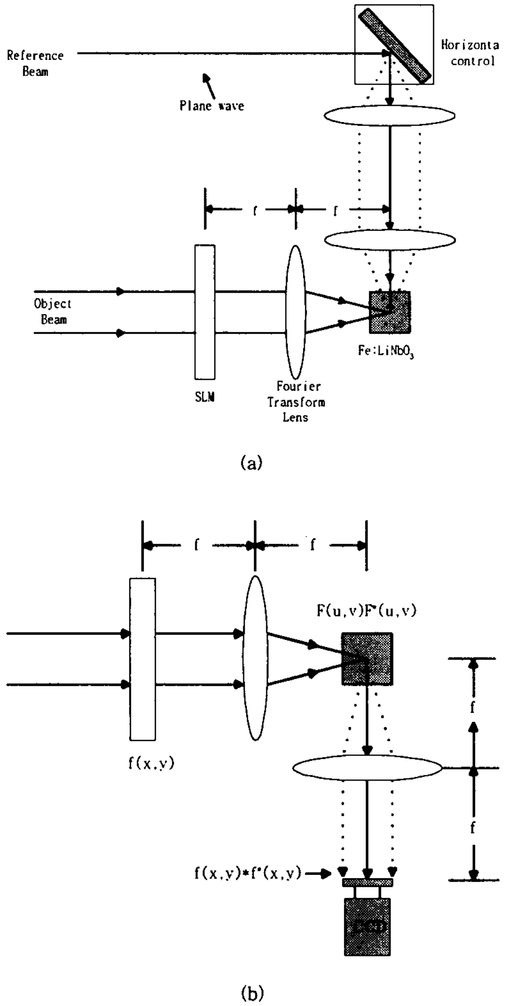

Fig. 1 (a) Recording and (b) readout operation of spatial matched filter transformations. It is the correlation between input image and the prerecorded templates. Accordingly, if the input image is the same as the template, the correlation peak will appear at the output plane.

To store multiple templates of the matched filter, angular multiplexing is used. To store each template in a crystal, the reference beam is to be controlled by a motor.

3. Experiments

An optical correlation system utilizing a volume hologram is shown in Fig. 2. In this system, the images from a computer are fed into the SLM one after the other. To record one template image of matched filter, the step motor sets M1 at a certain angle. Simply controlling M1 allowing the reference beam to project itself onto the crystal at a different angle does another template recording.

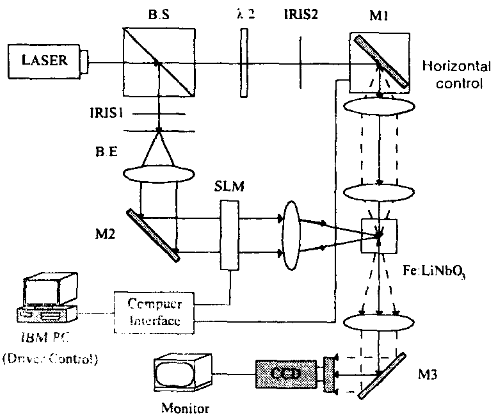

Fig. 2 An optical correlation system using volume hologram

Accordingly, we can record lots of templates for matched filter into a volume hologram using angular multiplexing technique like this. At this point in the experiment we *have recorded 100 fingerprints into a volume* hologram. In this process of recording templates of matched filter, two IRIS switches are necessary. IRIS1 allows the reference beam to project onto the crystal. IRIS2 is located between the beam splitter and M2. These IRISs are opened and closed synchronously to record each template image. The actual recording of templates takes place in the following way. First, M1 is set at a certain angle. Then, the first template is fed from the computer onto the SLM. This step is carried out with both IRIS switches turned on. For the display and recording of the second template the IRIS switches are turned off. Then, the second template is fed into the SLM and the angle of M1 is changed. At this point, the IRIS switches are turned on allowing the second template to be recorded. The display and recording of each subsequent template is to be done using the procedure described above. This procedure is electronically controlled.

To test the correlation of the input fingerprint and templates, we close IRIS1. IRIS1 is not needed in reconstruction. The input image from a computer is fed into the SLM. This image is Fourier transformed by a lens and focused into the crystal. Then the correlation

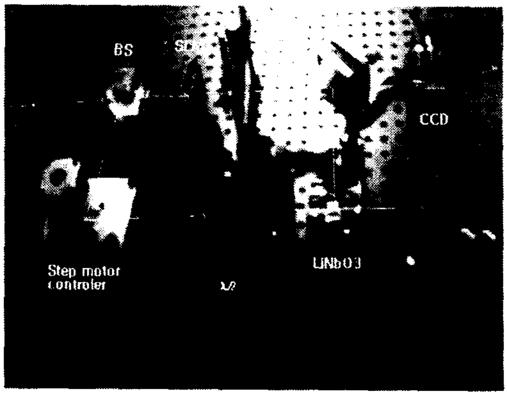

Fig. 3 The photo of optical correlation system based on volume hologram

output will be monitored. If the input fingerprint and one of the templates are identical the correlation peak will appear on the monitor. Also, we can know exactly which template is being identified by the position of the peak on the monitor.

The important step to record templates lies in recording time schedule, step motor control, and updating SLM image. That is, the recording time dependant on the sequence of recording. We have to find the recording time relation to the number of templates and erasing time. In this system, the computer automatically controls IRIS1, IRIS2, M1 and SLM display. We use a 10mm cubic Fe : $LiNbO_3$ crystal, 100mw Nd : YAG laser and 640×480 pixels Epson LCD as the SLM. Figure 3 is the picture of correlation system. Figure 4 shows 10 typical fingerprint images recorded into a Fe : $LiNbO_3$. Figure 5 shows the correlation peak takes place at the 50th template. The plot shows that the peak intensity is normalized. The input fingerprints and corresponding correlation peaks are shown in Fig. 6.

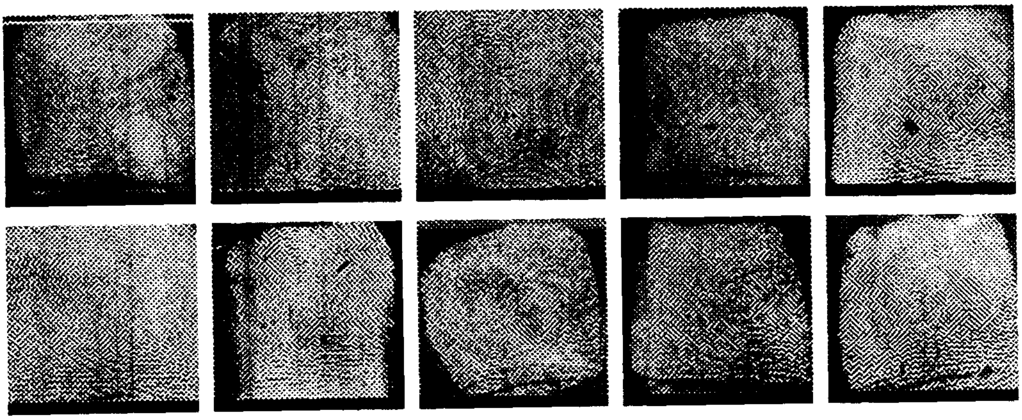

Fig. 4 10 fingerprint images from the database of 100 fingerprints

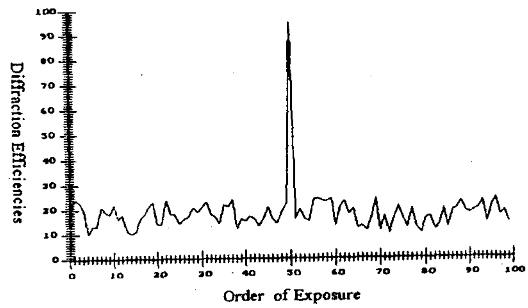

Fig. 5 Normalized correlation peak intensities as to 50th fingerprint image

4. Conclusion

We present an optical fingerprint identification system that can be used for secure entry systems to identify individuals for access to a restricted area. The massive database of matched filter in an optical correlation system can be used with a volume holographic memory. Angular multiplexing technique was used to record multiple holograms. This system enables faster data transfer and access from a large database for security check. Future experiments with this system will attempt to recognize rotated or partially distorted fingerprints.

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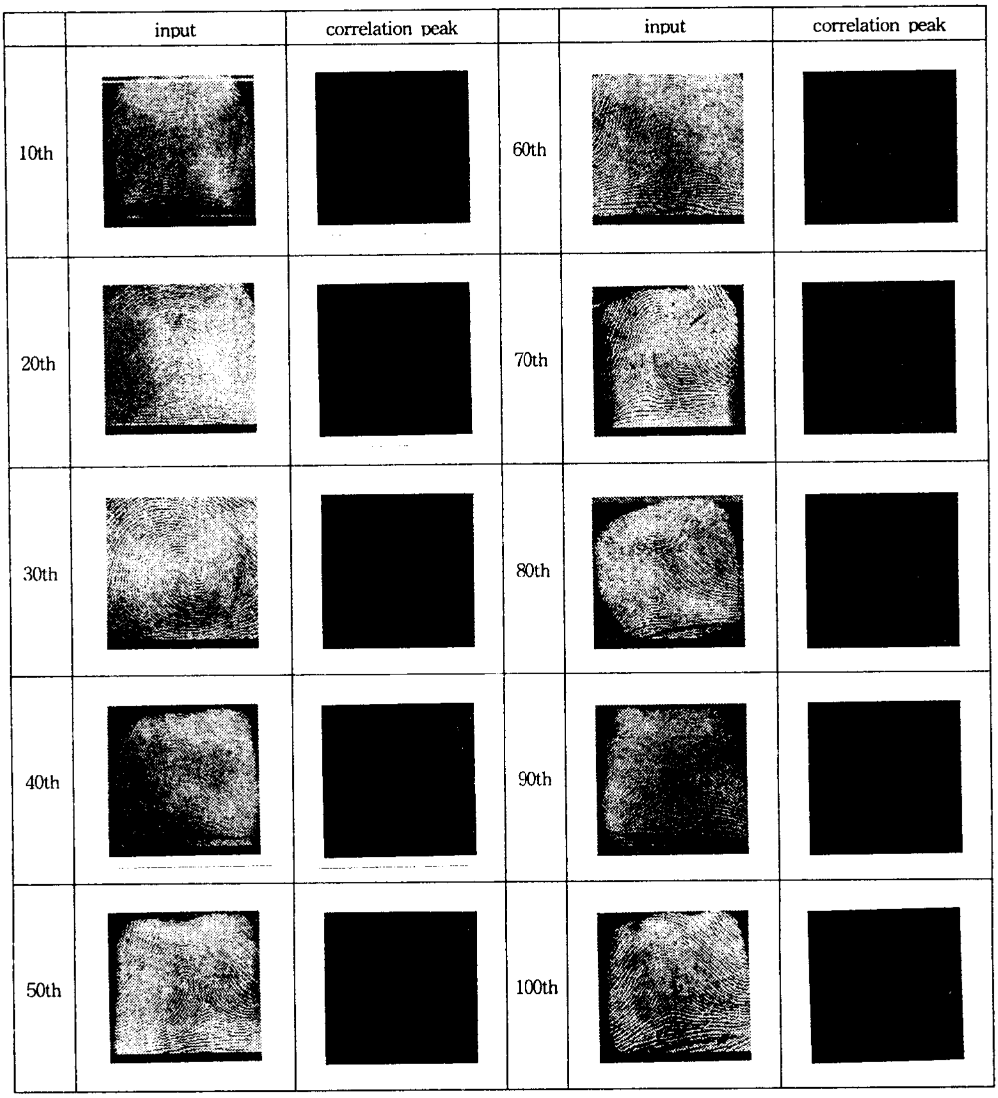

Fig. 6 The input fingerprints and corresponding correlation peaks

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