Model Of 2D Optical Correlator For Fingerprint Identification

Miloš Klíma[1], Jiří Rott[1], Pavel Dvořák[1]
Susan McKenna-Lawlor[2], Daniel Gleeson[2]
John Keating[3]

[1]Dept.of Radioelectronics, Faculty of Electrical Engineering,
Czech Technical University, Technická 2, 166 27 Prague 6, Czech Republic
[2]Dept.of Experimental Physics, St.Patrick's College, Maynooth, Co. Kildare, Rep. of Ireland
[3]Dept.of Computer Science, St.Patrick's College, Maynooth, Co. Kildare, Rep. of Ireland

Abstract - This paper is devoted to the problems of fingerprint identification and experimantal models of relevant optical setups. As published last year there exist some possibilities of fingerprint identification by means of 1D cut correlation. The first part deals with an improvement of our previous method based upon 1D cut correlation. Originally, a fingerprint photographic film record was used. Recently, the finger prints are displayed on a 2D high-resolution SHARP LCD panel .
The second part of the paper is oriented to a comparative experimental verification of widely used JTC as a reference 2D correlation method.
Finally, a set of experimental data for both techniques is presented.

Previous Results

As we published in our paper in the Carnahan Conference in 1995 our identification model was based upon the evaluation of correlation of particular linear fingerprint cuts. In the first step we applied a linear cut of a fingerprint and a linear 1D LCD array to create an analyzed picture. In both cases an acoustooptic 1D SLM (spatial light modulator) formed a reference image. During the initial period the optical setup with a fingerprint photographic record was tested also for an identification - see Fig.1.

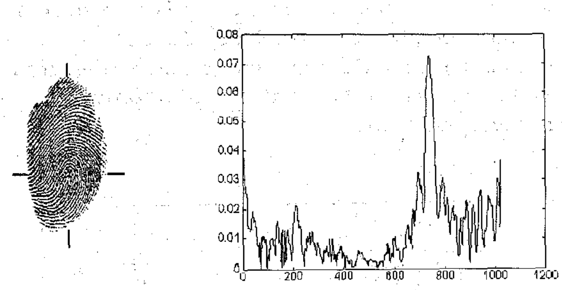

Figure 1: Correlation with a slide reference

This simplest correlator setup was chosen according to our idea to construct a massively parallel but low cost optical system. The technical aim is to verify some techniques suitable for very fast performance (real or near real time) for identification in a limited size database of e.g. authorized personell (several hundreds of individuals). The fingerprint was chosen because of expected simplicity of required sensing device but in the future it is possible to introduce some other anthropometric or technical evaluation such as spectroscopic patterns, DNA fingerprints, chromatograms etc.

One-Dimensional Correlator with a High-resolution 2D LCD Reference - Experimental Results

Based upon the above mentioned results we designed and assembled the second generation of an optical correlation setup. The crucial part of this optical system a high-resolution active LCD panel from SHARP company originally used in TV projectors. The parameters of the LCD panel are shown in Table 1.

Resolution:	382.5 x 264 (approx. 100,980 pixels)
Dimensions:	7.6 cm diagonally (3 inch)
Contrast:	100:1
Refresh rate:	50 Hz

Table.1: Technical parameters of used LCD panel SHARP model XV 330H

The overall optical setup of our experimental model was modified as sketched in Fig.2. The laser beam from an argon laser ILA 120 (wavelength 541 nm, manufacturer Karl Zeiss Jena) is expanded by a beam expander 1:20. The output beam is vertically polarized and the residual light from the discharge tube is suppressed by an interference filter. Then the laser beam passes through the LCD panel. To avoid extra noise produced by reflected beams the LCD panel is slightly tilted from vertical direction. The 2D image of a fingerprint is supplied to the LCD panel from a computer and a particular horizontal cut is separated by a single slit. The fingerprint is displayed in inverse mode (white lines on black background) in order to reduce the level of scattered light as much as possible. The real rather complex grid structure of TFT LCD panel introduces a significant number of diffracted beams. The switch rate of the TFT LCD panel limits the overall computational power. Our LCD panel has been designed for a

0-7803-3537-6-9/96/$4.00 ©1996 IEEE

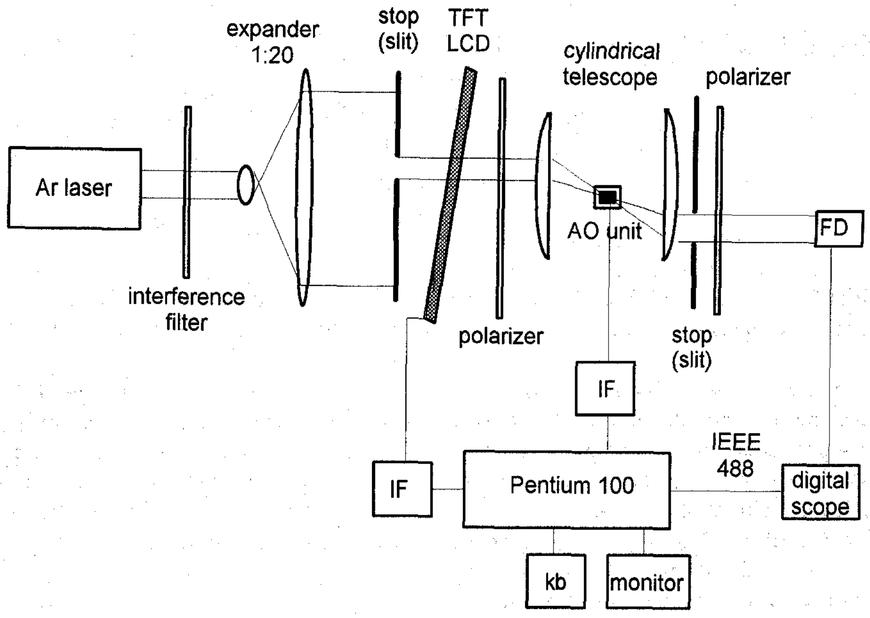

Fig.2: Correlator with LCD 2D panel

standard TV operation mode - one frame per 40 msecs, one field per 20 ms. Because the panel resolution is roughly 300 pixels only, both fields are identical and we can use it as a noninterlaced raster scan with half resolution.

After the slit the fingerprint cut image passes through the acoustooptic SLM. We have applied a high resolution SLM acoustooptic unit made by Isle Optics, U.K. The unit is manufactured from a single crystal of mercurous chloride and exhibits the parameters given in Table 2.

acoustic wave velocity:	347 m/sec
optical aperture:	approx. 30 mm
acoustic aperture:	85 msec
theoretical resolution:	2550 pixels
acoustic central frequency:	60 MHz
acoustic bandwidth:	30 MHz
driving power:	600 mW

Table 2: Paramesters of the used acousto-optic cell

A cylindrical telescope is used for better geometrical matching of the beam's vertical dimension and the optical aperture of the acoustooptic unit. Theoretically, the LCD panel is the resolution limiting element. According to our experiments an actual resolution of 100 pixels is sufficient for this particular purpose of fingerprints comparison. The acoustooptic unit is supplied with AM signal. The modulation relief is given by a particular fingerprint cut. We can provide a new sample every 100 msec - it means that we can compare 10,000 fingerprint cuts from a database per second. For the resolution limit of 100 pixels per cut we can estimate the required signal dataflow at around several Mbits per second. To avoid significant intermodulation effects due to nonlinear transfer function, the operational value of diffraction efficiency was reduced to approx. 1% and thus a high-power argon laser was used.

After having left the acoustooptic unit the laser beam energy is integrated and finally detected by a photomultiplier.

Experimental results of optical calculation of the correlation function are shown in Fig.3. Figure 3a displays an output of the optical detector when identical cuts are compared. The multiplying effect of the Gaussian laser beam profile is apparent. Figure 3b shows the same correlation signal when the Gaussian beam profile is compensated.

Pseudo 1D (Multichannel 1D Version) Correlator With LCD Reference

An optical setup similar to that shown in Fig.2 can be used as a pseudo 2D correlator when the multiline version is used. Both slits are removed and instead of the integral photodetector a 1D linear detector array is placed. In such a case we can compute the correlation function for all LCD image lines in parallel with the same common reference in the acoustooptic unit. This configuration will improve the overall performance significantly.

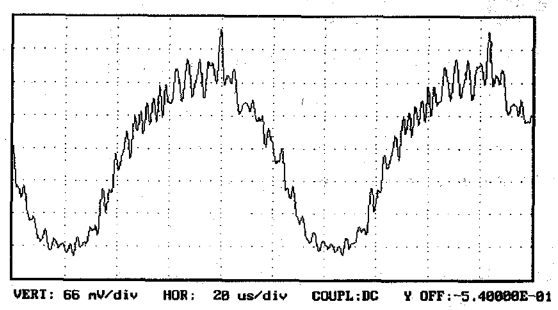

Figure 3a: Correlation of fingerprint cut, uncompensated

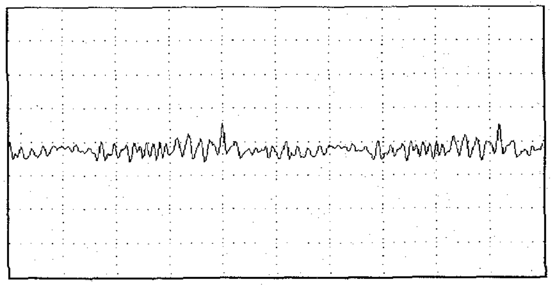

Figure 3b: Correlation of fingerprint, compensated

Another possible modification is the application of a multichannel acoustooptic SLM in order to provide several sets of data from a database. This configuration will compare one line on LCD panel with several references in parallel.

JTC (Joint Transform Correlator)

The most interesting technique for optical fingerprint identification was introduced at the beginning of the eighties and is still further developed. We have tested the performance of a simple configuration for this truly two-dimensional technique.

The principle optical setup is sketched in Fig.4. Basically, it forms an optical Fourier transform system. Two compared images r(x,y) and s(x,y) are displayed on the same SLM side by side shifted by a and -a respectively from the central position (see [2]) and the forward Fourier transform is performed by the first transforming lens. Then, the spatial spectrum created in the spectral plane has to be modified by quadratic function. It can be done by various methods e.g. photographic record, photorefractive material etc. In our case we simulate this quadratic function in a computer in this phase of experiment. The output intensity in the Fourier plane is given by

$$I(u,v) = |FT[(r(x-a,y)+s(x+a,y))]|^2 = |R(u,v)+S(u,v)|^2 =$$
$$= R(u,v).R^*(u,v) + S(u,v).S^*(u,v) + R(u,v).S^*(u,v).\exp(i2\pi ua) +$$
$$+ S(u,v).R^*(u,v).\exp(-i2\pi ua)$$

The square of the original FT is inversely transformed by the second transforming lens. According to the convolution (correlation) theorem after the inverse Fourier transform there exist several local intensity maxima in the output plane. Table 3 shows their positions and interpretation.

Horizontal shift of the maximum	Interpretation
0	$r(x,y) \otimes r(x,y) + s(x,y) \otimes s(x,y)$
+2a	$s(x,y) \otimes r(x,y)$
-2a	$r(x,y) \otimes s(x,y)$

The first term are the autocorrelation functions but the second and the third term are the required cross-correlation peaks.

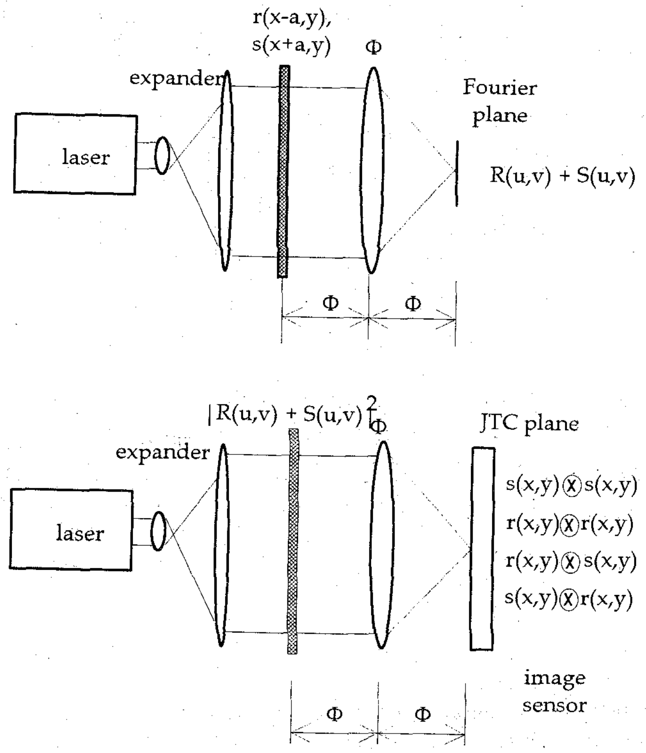

Fig.4: JTC optical setup - principle

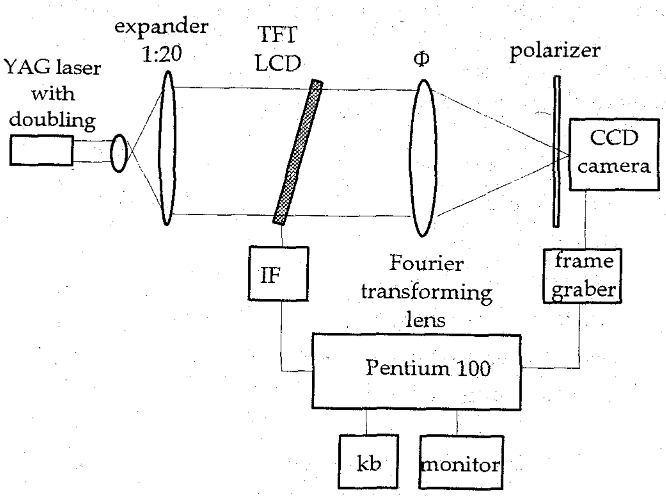

Fig.5: JTC optical setup

Experimental JTC Verification

Experimental verification of the JTC technique has been performed with the modified optical setup as shown in Fig.5. The above mentioned LCD SLM SHARP XV 330 H was used again. Because the required optical power is reduced significantly we used a pocket-sized YAG (solid state) laser with optical frequency doubling model No.LL-01cc manufactured by Laser-Compact Co. with a nominal output power of 0.3 mW. A positive lens with a focal distance 300 mm, diameter 60 mm was used as a transforming lens.

The output image sensor was a TV rate CCD camera MTV - 231CM with a 1/3" chip.
The detailed configuration of our test images is shown in Figure 6a. On the left side of the test image three objects are placed - two patterns of the original reference fingerprint (producing a normalising constant) and one pattern of a modified test fingerprint. Figure 6b demonstrates the final JTC output picture obtained by JCT correlating the original reference fingerprint and the same fingerprint rotated by 5 degrees anticlockwise.
Figures 7, 8 and 9 show results obtained with similar configuration of input patterns but with the different test fingerprint:
Figure 7: test fingerprint of different person
Figure 8: test fingerprint of the same person rotated 20 degrees anticlockwise
Figure 9: test fingerprint of the same person rotated 1 degree anticlockwise.
All 2D JTC patterns are accompanied by the intensity profile cuts through both identical and test correlation maxima.

Comparison of Both Approaches

It is apparent that both approaches can be hardly compared. The JTC method is fully two dimensional and insensitive to rotation up to 25 degrees. The optical system requires very high optical quality of elements to achieve reasonable signal to noise ratio.
The cut correlation method is relatively simple but very sensitive to any geometrical deformation and/or transformation and both test image and reference image have to be precisely positioned.

Conclusion

The field of optical information processing is expanding dramatically. Inherent massive parallelism, 3D interconnections and very high speed of computational

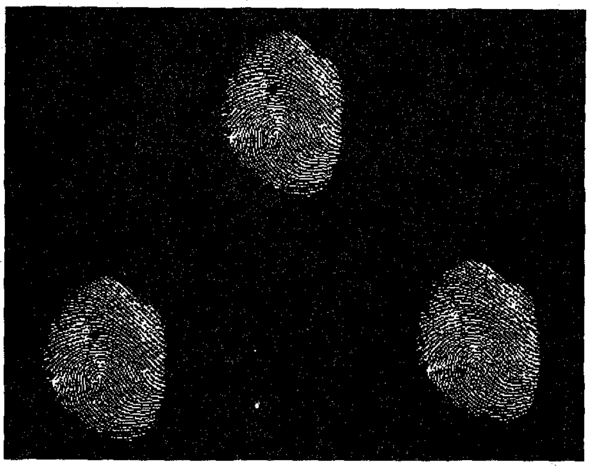

Figure 6a: The arrangement of tested fingerprints

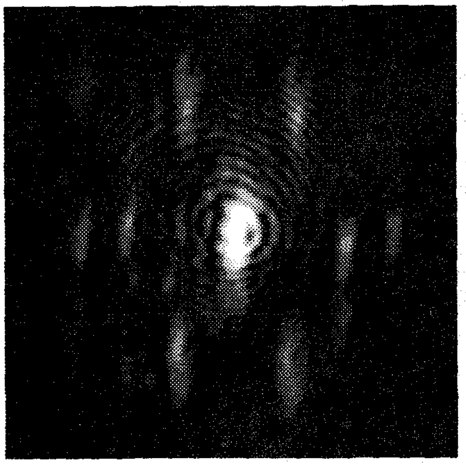

Figure 6b: The full output of the JT correlation of fingerprints in Fig.6a

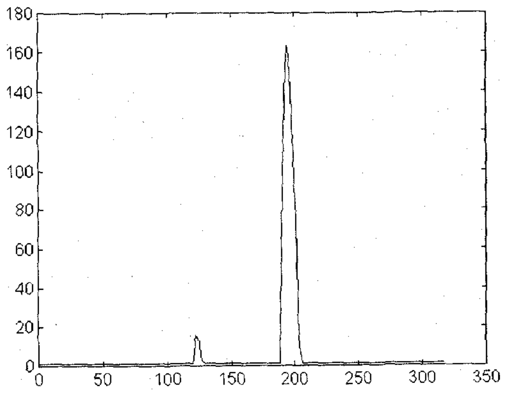

Figure 7: Correlation between the reference fingerprint and a fingerprint of a different person. The JTC output and a cross section through the correlation peaks.

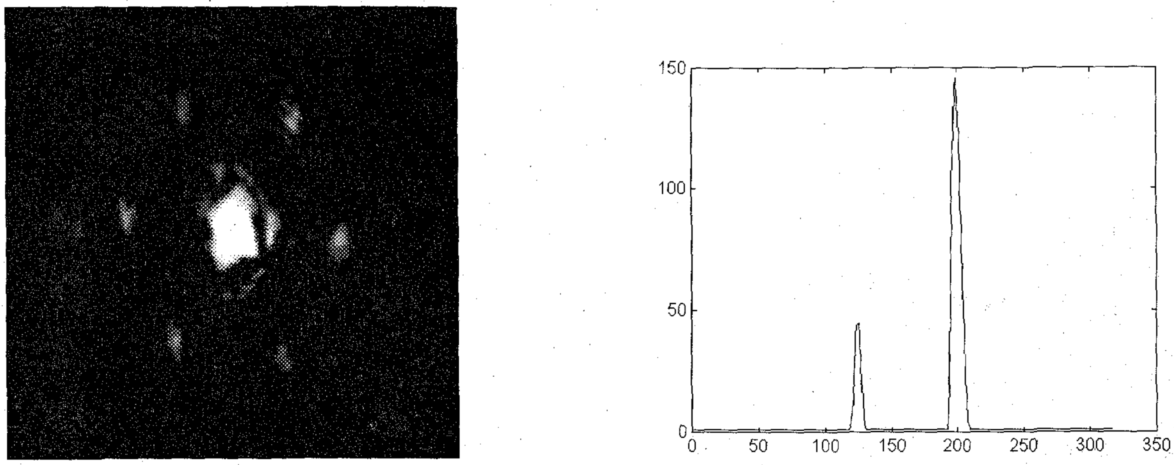

Figure 8: Correlation between the reference fingerprint and a fingerprint of of the same person rotated by 20 degrees anticlockwise. The JTC output and a cross section through the correlation peaks.

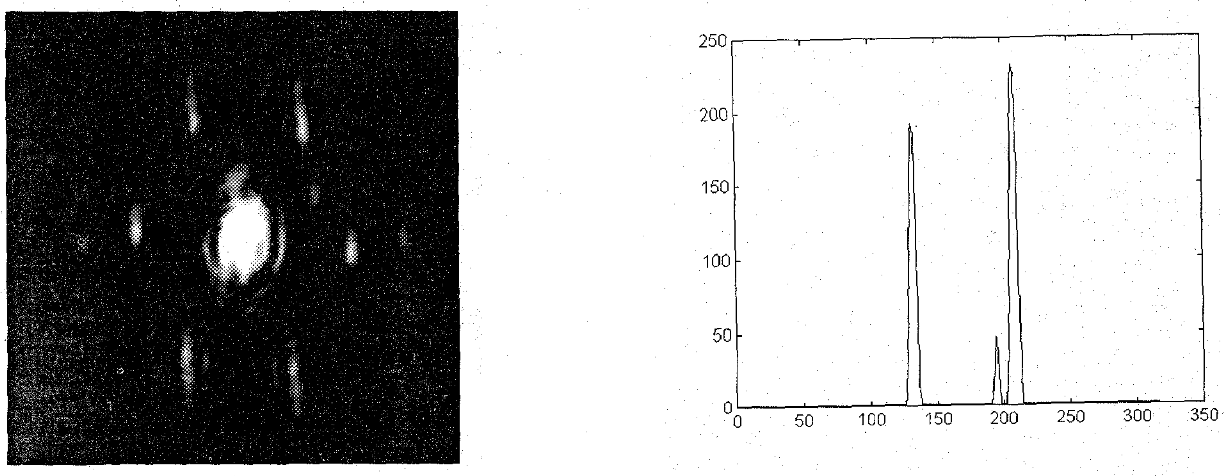

Figure 9: Correaltion between the reference fingerprint and the fingerprint of the same person rotated by 1 degree anticlockwise. The JTC output and a cross section through the correlation peaks.

performance exceed in many cases possibilities of electronic systems. Some operations as analog multiplication, convolution, correlation and Fourier transform are based upon natural properties and principles of optical processing systems. The wide selection of applications is described in [3], [4].

Acknowledgement

This work has been supported by the research grant No.102/955/1157 of the Czech Grant Agency and by the research grant No.13031030 of the Czech Technical University.

References

[1] Klíma M., Dvořák P., Rott J., McKenna-Lawlor S., Gleeson D., Keating J.,*Experimental Model of a Combined Optical Processing Correlation System,* Proc. 29th Int. Carnahan Conference on Security Technology, Sanderstead, U.K., 1995

[2] Rodolfo J., Rajbenbach H., Huignard J.P., *Performance of a photorefractive joint transform correlator for fingerprint identification,* Optical Engineering, 34, 4, Apr.95, pp 1166-1171

[3] Vanderlugt A., *Optical Signal Processing,* A Wiley Interscience Publication, John Wiley & Sons, New York, 1992

[4] Lee J.N., *Design Issues in Optical Processing,* Cambridge University Press, 1995

[5] Volner R., Trunkvalter M., *Interactive communications in CATV,* Proceedings of Int. Conf. Electro95, Žilina, Slovak Republic, pp. 252-256