# INVESTIGATING TRACE TRANSFORM ARCHITECTURES FOR FACE AUTHENTICATION

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## 1. INTRODUCTION

Face recognition and authentication is an active research field in the computer vision community. Its implications for security, surveillance and identification systems are significant. The majority of the literature deals with systems that are based on feature extraction or image transformation. However, many of these feature extraction methods focus primarily on properties seen from the human perspective. It is, though, useful to expand the horizon, using features which may not have meaning to humans, but which perform well in characterising complex images. Often, the difficulty is in balancing the strength of the algorithm in separating faces from different people, while still combining those from the same person. A novel algorithm, the Trace Transform [1, 2, 3, 4], has been proposed for use in visual recognition systems. The Trace Transform maps an image to another domain, with parameters $\phi$ and $p$, by applying a defined "functional" on the intensity function of a line that crosses the original image tangential to an angle $\phi$ and at a distance $p$ from the centre of the image. This is illustrated in Figure 1. The result of this process can be called the "Trace".

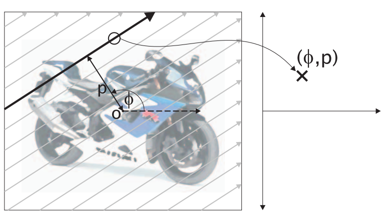


**Fig. 1**. Parameters of a Trace line

For feature extraction, further steps are needed, as shown in Figure 2. Firstly, a "diametrical" functional ($D$) is applied to the columns of the Trace image, reducing the space to a single vector. Finally, a "circus" functional ($C$) is applied to this vector to yield a single value feature. By combining a number of functionals at each stage, numerous features can be extracted. Careful selection of the functionals allows for these features to be translation, rotation and scaling invariant, or measurably sensitive, as well as robust to non-linear deformations [4].

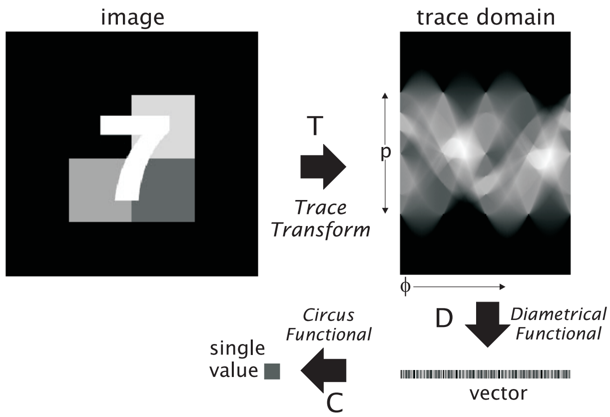


**Fig. 2**. An image, its trace, and the subsequent steps of feature extraction

The primary obstacle to further investigation of applications of this algorithm has been the computational complexity. Acceleration of the Trace Transform in FPGAs will allow for further investigation of the transform in terms of both functionals and applications.

## 2. ALGORITHM EXPLORATION

Application of the transform to face authentication has been implemented in software by Srisuk *et al.* [5, 6]. They construct a trace image of the original face, then threshold it, before applying a shape-matching algorithm to compare against a database of thresholded traces. They have shown results that exceed those of many more popular face authentication systems. Their system uses a set of 22 functionals selected for their texture classification properties. However, no investigation was made into which functionals are important

This work was partially funded by the UK Research Council under the Basic Technology Research Programme (GR/R87642/02) and by the EPSRC Research Grant (EP/C549481/1).

to the recognition process; some functionals may be superfluous or duplicative in their results. Considering that the number of functionals adversely affects the computational complexity of the software implementation, it seems prudent to investigate different combinations of functionals and their efficacy. However with each image taking 30 seconds to recognise and a training time of 100 hours for one functional configuration on a full dataset, it would be a mammoth task to conduct this research in software. It is also necessary to consider that a recognition system based on the Trace Transform, but used for other objects, would have to be trained from the ground up. If this process can be accelerated, a general purpose system could be implemented then trained in a short time to the required object domain.

By accelerating the Trace Transform in hardware, and designing a flexible architectural framework to accommodate various combinations of functionals, we aim to thoroughly research the functional selection problem to allow us to identify the best combination of functionals in terms of performance, area and speed. We will use the face authentication problem as a test case while developing the system.

## 3. WORK COMPLETED

So far, we have completed a hardware implementation of the Trace Transform framework. We have designed it in such a way that it can accommodate many functionals without adverse performance costs. The system runs on an FPGA board, taking images from an onboard RAM and applying a number of Trace functionals in parallel to produce the corresponding Trace images. Acceleration of the system was achieved through optimisation of the line-tracing algorithm, parallelising rotations and parallelising as well as optimising functionals. The system runs faster than realtime, and so could be used for video processing. The details of that implementation have been separately accepted for publication in the Proceedings of FPL 2006[7]. The architecture facilitates the computation of up to 36 parallel functionals (fully-pipelined) in realtime (26fps) on a $256 \times 256$ image. The implementation will serve as a flexible framework for the full investigation of functionals to be used in a face authentication system.

We have also implemented an efficient architecture for median and weighted median calculation [8]. Since this function features in 14 of the 22 originally proposed functionals, we can work with those and develop many more. It may well be possible to use a higher number of simpler functionals.

## 4. FURTHER WORK

The first step is to identify some standard blocks that can be used to construct functionals. This will allow us to create a library of functionals. We can then apply each of these functionals individually to a large selection of faces from a standard face authentication database.

Armed with a large database face traces, as well as the knowledge of which faces are related, we can apply standard computer vision techniques to investigate which functionals are most effective in the face authentication task. The existing software face authentication application of the Trace Transform uses shape matching on a thresholded version of the trace image. We aim to investigate this, as well as algorithms such as Support Vector Machines and Linear Discriminant Analysis when applied to the trace rather than the main image.

## 5. CONCLUSION

The overall aim of this research is to thoroughly investigate which functionals are able to provide the best performance for the Trace Transform. The resultant framework can be applied generally to other domains too. This will be an example of how the rapid prototyping afforded by FPGAs and the performance advantages serve as the ideal platform for algorithmic exploration. Furthermore, the power of runtime-reconfigurability will assist further in the investigation.

## 6. REFERENCES


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