Lateral Skin Stretch Measurement by Fingerprint Minutia Tracking

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Abstract

This poster proposes a technique for the measurement of lateral skin stretch on the fingertip. A sequence of images is acquired as the fingertip moves across a transparent surface. Fingerprint minutia are detected using techniques borrowed from the fingerprint identification field (Stosz and Alyea, 1994) and tracked between pairs of successive images. Variations in inter-minutia distance are used to evaluate lateral skin stretch.

Motivation

The Stimulator of Tactile Receptors by Skin Stretch (S.T.Re.S.S.) is a tactile display that exploits sensations caused by lateral skin stretch at the fingertip. Measurement of local skin stretch by visual tracking of fingerprint minutia can be used to determine the varying 2D strain pattern applied by the S.T.Re.S.S. to display textures and surfaces. This method eliminates the need for computationally expensive models of fingertip tissues.
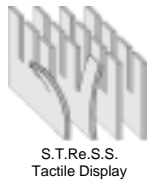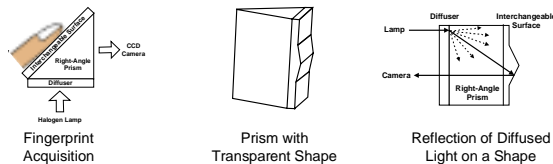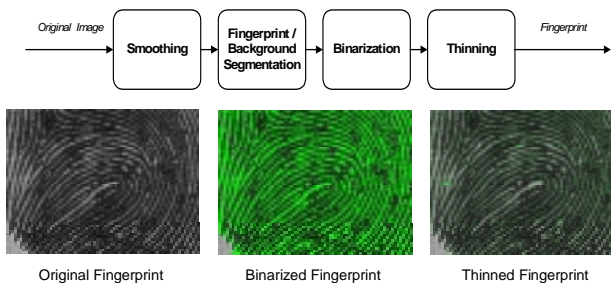
S.T.Re.S.S. Tactile Display

Image Acquisition

High-contrast fingerprint images are acquired through the principle of frustrated total internal reflection (FTIR). The fingertip is pressed against the surface of a right-angle prism as shown below. Fingerprint ridges come in contact with the prism and prevent the total internal reflection, resulting in a dark pattern. The fingerprint valleys and pores do not contact the prism and appear bright. A large prism and a diffuser allows the use of 3D surfaces as shown below.
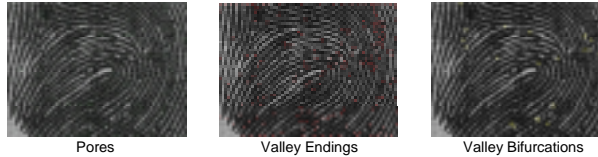
Fingerprint Acquisition

Prism with Transparent Shape

Reflection of Diffused Light on a Shape

Fingerprint Pre-Processing

Four pre-processing operations improve and simplify the fingerprint images.

Original Image → Smoothing → Fingerprint / Background Segmentation → Binarization → Thinning → Fingerprint

Original Fingerprint

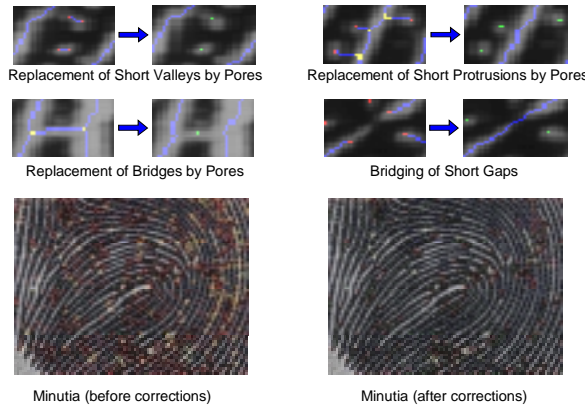Binarized Fingerprint

Thinned Fingerprint

Minutia Extraction

Fingerprints identification is often carried out by matching discontinuities in the ridge or valley pattern called minutia. Three types of minutia are considered here: pores, valley bifurcations and valley endings. Valley endings and bifurcations are characterized by an angle relative to the nearby valley(s).

Pores

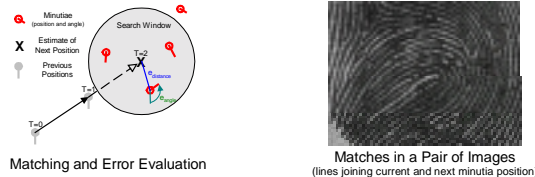Valley Endings

Valley Bifurcations

Minutia Editing

The image acquisition and pre-processing steps introduce errors in the valley pattern that result in false minutia. The following heuristic steps eliminate most false minutia.

Replacement of Short Valleys by Pores

Replacement of Short Protrusions by Pores

Replacement of Bridges by Pores

Bridging of Short Gaps

Minutia (before corrections)

Minutia (after corrections)

Minutia Matching

Fingerprint images are recorded at 60 frames per second resulting in short minutia displacements between successive frames. Minutia are tracked by searching a small window around the expected next position for the best possible match. Each candidate match is evaluated based on the error in position and the error in minutia angle (when applicable).
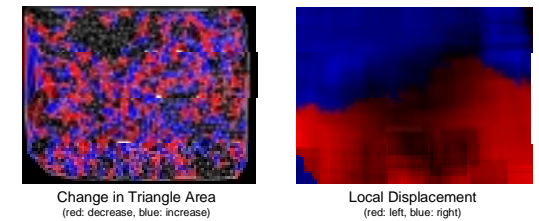
Matching and Error Evaluation

Matches in a Pair of Images
(lines joining current and next minutia position)

Lateral Skin Stretch Measurement

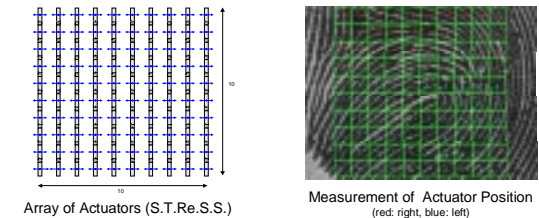Two skin stretch measurement methods were investigated.

Change in triangle area: A Delaunay triangulation is constructed with matched minutia as vertices. Local skin stretch is measured using triangle areas.

Local displacement: The displacement of a skin region can be estimated by computing its local average of minutia displacement vectors relative to the fingertip. The skin stretch is obtained from the local displacement by differentiation.

Change in Triangle Area
(red: decrease, blue: increase)

Local Displacement
(red: left, blue: right)

Tactile Display Mapping

The S.T.Re.S.S. tactile display consists of an array of 10x10 piezoelectric actuators moving laterally in one axis. The field of local displacements obtained from the matched minutia is used to determine the appropriate position of each actuator on the tactile display at different points in time. An array of 10x10 blocks is tracked through the image sequence. The local displacement inside each block is mapped directly to an actuator to reproduce the sensation caused by the surface or texture.

Array of Actuators (S.T.Re.S.S.)

Measurement of Actuator Position
(red: right, blue: left)

Future Improvements

This project is currently in progress. Preliminary results with flat surfaces are encouraging. Further work remains to be done:

• Extensive testing of the system with a variety of surfaces.

• Validation of the method as a signal generator for the S.T.Re.S.S. tactile display.

• Calibration to obtain absolute displacements in physical units.