skin comprises pores distributed over the skin surface and the image includes an image of these pores which is then used to generate the skin deformation signal.

The skin surface imaging means may be based upon a prism, a light source and an optical imaging device or may rely on acoustic or other known imaging means. In the case where the contacting surface is textured the light source preferably provides diffuse light, including, for example, light provided by a scialitic mirror.

The electronic processing means may provide the output skin deformation signal from said image signal by comparison with a known image of the skin in a relaxed state, or it may operate by receiving a plurality of images obtained from skin surface which is in motion in respect of said contact surface. This latter procedure is particularly suited to the case where the contacting surface is textured to provide changes in the deformation of the human skin when such skin is in moving contact with the contacting surface.

The tactile sensing transducer may be employed in combination with a tactile stimulation display transducer having a common base support and a plurality of individually actuatable bendable cantilevered arms mounted in line on said base support, each of the arms having tip ends which are displaceable, upon actuation, from their initial positions in the line of arms. In one preferred variant the tip ends are displaceable, upon actuation, laterally. i.e. transversely, to the line of arms.

According to another preferred the arms each have a base end at which the arms are mounted on the common base support, the arms being wider at their base ends than at their tip ends. Additionally, the tip ends may be aligned along a straight line, or they may be aligned along a curved line.

According to one aspect, the invention an area tactile stimulation display device, or “area tactile displace device”, is formed by assembling a plurality of tactile stimulation display devices arranged in first and second sub-arrays wherein respective member devices of the first and second sub-arrays are positioned to intersect with each other. Such intersection may be at a range of angles, but preferably is orthogonal.

By a further feature of the invention the tactile sensing transducer and tactile stimulation display transducer may be combined, with the tactile stimulation display transducer being in the form of the preferred tactile stimulation display transducer as described above.

The foregoing summarizes the principal features of the invention and some of its optional aspects. The invention may be further understood by the description of the preferred embodiments, in conjunction with the drawings, which now follow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a first finger whose owner experiences tactile sensations arising from contacting a surface and a recording device capable of measuring the deformation of the skin of the first finger. The signals indicative of this deformation are recorded or processed. A display device uses these signals to causing similar deformations at the surface of the skin of second finger whose owner in turn experiences sensations that are similar to those experienced by the owner of the first finger.

FIG. **2** shows a finger experiencing skin deformation caused by a display device receiving signals which have been previously recorded and processed or are artificially produced.

FIG. **3** shows a finger contacting a surface and device capable of measuring and recording these deformations.

FIG. **4** shows the principle of an optical device capable of measuring the deformation of the skin of a finger.

FIG. **5** shows a device similar to that of FIG. **4** but with interchangeable contacting surfaces.

FIG. **6** shows a device similar to that of FIG. **4** but with the diffuser replaced by a plurality of light sources.

FIG. **7** shows a device similar to that of FIG. **4** but with the diffuser replaced by a light panel.

FIG. **8** shows the principle of an ultrasonic device capable of measuring the deformation of the skin of a finger.

FIG. **9** shows skin deformation measuring devices utilizing capacitive, thermal or electro-optical polymers sensors.

FIG. **10** shows various surfaces which are appropriate for recording via frustrated total internal reflection.

FIG. **11** shows various surfaces which are marginally appropriate for recording via frustrated total internal reflection.

FIG. **12** shows the disposition of a skin deformation inducing device made of stacked comb-like piezoelectric multiple benders.

FIG. **13** shows the manner in which the skin deformation inducing device can cause either principal strain or shear strain.

FIG. **14** shows how each comb-like piezoelectric multiple bender may be realized from a single plate.

FIG. **15** shows how a comb-like piezoelectric multiple bender may be shaped to increase its strength.

FIG. **16** shows how a comb-like piezoelectric multiple bender may be shaped to vary its response.

FIG. **17** shows various shapes of skin contactors.

FIG. **18** shows skin contactors separate from the benders themselves.

FIG. **19** shows how comb-like piezoelectric multiple bender can be shaped to be interlocked for form a grid.

FIG. **20** shows a grid of interlocked comb-like piezoelectric multiple benders

FIG. **21** shows digital circuitry to drive a large number of actuators.

FIG. **22** shows a modulation amplifying circuit utilizing only one transistor.

FIG. **23** represents diagrammatically the effect of modulating the duty cycle of the driving pulsing signal.

FIG. **24** shows the steps needed to convert signals indicative of skin deformation to signals appropriate for driving a tactile display.

FIG. **25** shows an alternate sequence of steps needed to convert signals indicative of skin deformation to signals appropriate for driving a tactile display.

FIG. **26** shows corrections automatically made to features detected in fingerprint images.

FIG. **27** show a grey level fingerprint image which is processed to extract features.

FIG. **28** show a triangulation of detected features to be tracked over time.

FIG. **29** illustrates the process of tracking features over time to detect deformation.

FIG. **30** exemplifies the deformation of one’s finger pad skin when touching an object.

FIG. **31** shows a detailed sequence of steps to measure skin deformation.

FIG. **32** shows a detailed sequence of steps needed to extract features from an image of a fingerprint.

FIG. **33** shows an alternate sequence of steps to measure skin deformation.