otron") are preferable. FIG. **4** is a top-down view of the gel layer **302** providing a better view of the construction of the gel layer.

[0037] As shown in FIG. **4**, the first matrix of electrodes **306** and second matrix of electrodes **308** intersect at points **312** within the perimeter of each cell **310**. The resulting electrode grid is driven with an X-Y drive circuit.

[0038] Each cell **310** is filled with a hydrogel. Polymer hydrogels exhibit large, reversible volume changes in response to various external stimuli, such as temperature, pH, solvent, and electric field. Consequently, when a drive current is applied across any given cell **310**, the cell **310** bulges or contracts based on the polarity of the applied current, thus deforming the outer layer of the screen **304**. As with the magnetic bead embodiment, the drive current in the hydrogel tactile feedback unit can be pulse-width modulated so as to provide modulation of the interface element.

[0039] The benefit of the hydrogel embodiment over the magnetic bead embodiment is in the ability to bulge the cell outward, as well as contract, or dimple, the cell. Moreover, the hydrogel embodiment allows for much finer resolution of the tactile feedback limited only by the size of the individual cells. Additionally, because the hydrogel tactile feedback unit does not require a separate deforming layer as necessary in the magnetic bead embodiment, the overall thickness of the tactile-feedback touch-screen device can be minimized.

[0040] Driving the tactile surface is performed by bringing an electrode of the front electrode layer **306** (i.e., row electrode) to 0V relative to circuit ground. The remaining electrodes of the front electrode layer **306** are floating (i.e., held at high impedance). Individual electrodes of the rear electrode layer **308** (i.e., column electrodes) are set to a positive voltage (+V) greater than 0V if the corresponding cell is intended to be tactile (raised), or set to 0V in cells that are desired to be flat.

[0041] In cases where the hydrogel exhibits contraction properties in the presence of an electric field as well, a column electrode can be set to a negative voltage (−V) in order to dimple the corresponding cell. The dimpling effect in the present embodiment is somewhat limited by the rigidity of the rear electrode layer **308** material as well as the rigidity of the underlying structures.

[0042] As shown in FIG. **5**, the present embodiment can provide a scanning tactile sensation. To perform a scanning process across the surface of the tactile layer, the scanning begins by initializing the row electrode counter N to 1 in step **601**. The row electrodes are floated to have high impedance in step **603**. In step **605** the Nth row electrode is selected and set to a 0V value in step **607**.

[0043] Proceeding to step **609**, all column electrodes corresponding to cells that are to be activated are selected. In the case for providing a scanning sensation, all the column electrodes would be selected in step **609**. The selected column electrodes are then set to +V, which is a positive voltage greater than 0V in step **611**. As discussed above negative voltage vales can be used as well in embodiments where the hydrogel supports contraction.

[0044] This voltage configuration is maintained for a period of time sufficient to allow the cells to respond mechanically in step **613**. Once the cells have responded to the induced electric field, the column electrodes are returned to 0V in step **615**. The Nth row electrode is set to high impedance state in step **617**. A second delay is provided in step **619** to allow the stored charge on the column electrodes to dissipate.

[0045] In step **621** the row electrode counter N is checked to determine if the last row electrode had just been selected. If the last row electrode had just been selected, the process returns to step **601** where the process begins anew. Otherwise, the process continues to step **623** where the row electrode counter N is incremented by 1. From this point the process returns to step **605** and continues as described previously.

[0046] If desired, the height of an individual cell can be varied multiple steps using the technique of Frame Rate Modulation (FRM), which is essentially a special case of pulse-width modulation. A description of LCD grayscaling using FRM is given in U.S. Pat. No. 6,064,359. The technique would be similar for this application, except for not being used to directly drive a display. FRM is valid for any application of this programmable tactile surface.

[0047] FIG. **6** illustrates a representation of an embodiment of the present invention in a typical application. As shown, a tactile feedback touch screen **702** displays a software-implemented graphical user interface having a plurality of defined control elements **704**. These control elements are positioned by the software to overlap regions of active tactile feedback elements **708**. In the shown application, 16 tactile feedback elements are evenly distributed on the display area of the tactile feedback touch screen **702**. However, more or less tactile feedback elements can be provided.

[0048] Of the provided tactile feedback elements, some are active tactile feedback element **708** while others are inactive tactile feedback elements **710**. A tactile feedback element can be switched between active and inactive as needed by the graphical user interface. Thus, when a control element **704** overlaps a tactile feedback element **708**, the tactile feedback element is activated. On the other hand, when no control element overlaps a tactile feedback element as in the case of tactile feedback element **710**, the system switches the tactile feedback element **710** to inactive.

[0049] The described embodiments of the present invention are intended to be illustrative rather than restrictive, and are not intended to represent every embodiment of the present invention. Various modifications and variations can be made without departing from the spirit or scope of the invention as set forth in the following claims both literally and in equivalents recognized in law.

What is claimed is:

1. A touch-screen display, comprising:

a digitizer layer for detecting a contact of a touch-screen display surface by a user;

a gel layer for deforming discrete surface areas of said touch-screen display;

a display layer for generating a display; and

a tactile feedback controller for controlling said deformation by said gel layer.

2. The touch-screen display as in claim **1**, further comprising a deforming layer disposed beneath said display layer, said deforming layer comprising a plurality of electromagnets arranged in a grid, each of said plurality of electromagnets being controllable by said tactile feedback controller.

3. The touch-screen display as in claim **2**, wherein said gel layer is imbued with magnetically attractive particles.

4. The touch-screen display as in claim **2**, wherein said magnetically attractive particles are formed of transparent glass beads containing iron oxide.