sheet must be rigid enough to apply uniform pressure to all of the pins in the display. The locking sheet can be made of compressible material, with an internal support frame of rigid material. Alternatively, the locking sheet can be made primarily of rigid material, with compressible material attached just at the openings where it contacts the pins.

[**0060**] Another pin locking alternative would be to place a textured structure such as ridges of compressible material on the shafts of the pins for contact at openings in a locking layer **43**.

[**0061**] A rotary pin retention approach could also be utilized. Utilizing this approach, pins **21** would each have individual locking structures built into them that interact with the surrounding matrix when the pins are individually rotated. An example of this approach would be pins that are threaded part way along the shaft, mounted in a threaded matrix. Rotating a pin along its axis in one direction causes the head of the pin to extend by an amount proportional to the angle of rotation. Another approach uses a cross-piece in each pin (oriented perpendicular to the axis of the pin) that can be rotated with the pin to lock in slots (parallel to the surface of the display) to hold the pins at one or more heights. The control system keeps track of the current positions of all the pins, and returns them all to the default position when resetting the display.

[**0062**] A click-lock device could be utilized and adapted so that a button on one end that is clicked once extends a tip from the pin, the tip being retracted when the button is clicked a second time. A similar design approach can be used for setting and resetting the pins in an extended array tactile graphic display.

[**0063**] A feature of the pin locking mechanisms hereinabove described is that they provide for incremental drawing capability. In accessibility applications, it is often useful to be able to draw part of a tactile figure, allow the user to read the tactile image, then add to the tactile drawing and permit a second reading, and so on. Two main uses for incremental drawing are: 1) in the presentation of complex tactile images, where the basic features are drawn first then details added, to aid the user in interpreting the image, and 2) in design work, where the user specifies incremental changes to the drawing. As may be appreciated, the two-stage pin retention approach supports incremental drawing since, while the pin locking mechanism is released, temporary pin retention holds previously set pins in place, allowing additional pins to be set before the pin locking mechanism is once again shifted for engagement and locking of the pins.

[**0064**] Pin setting and resetting for the apparatus of this invention utilize approaches that reduce the number of actuators needed by a very large factor compared to heretofore known devices and include a one-dimensional scanned actuator array. Each of the various approaches taught herein has its own advantages and, thus, applications for which it is most effective.

[**0065**] A first embodiment utilizes a one-dimensional scanned array of actuators with spacing matching that of the pins. The array is passed across the display (e.g. contacting the bottom portions **35** of pins **21**) and each actuator sets the selected pins that it encounters. The entire display is written in a single pass, and the number of actuators needed to set the pins is greatly reduced. For example, in a display with an m by n array of pins, and an m×1 actuator array, the number of actuators needed is 1/n of the number needed using the conventional approach of one actuator per pin. The additional time needed to scan the actuator array across the display will not be an issue for many applications, since the tactile reading of two-dimensional images is a relatively slow process. This approach requires precision 1-dimensional tracking of the actuator array and placement to align it with the pins that each actuator must control.

[**0066**] Raster scanning of the display could be utilized. A monochrome CRT (cathode ray tube) monitor uses an electron beam that sweeps across each row of the visual display in turn, until all the rows have been traced, allowing one beam to drive every pixel in the display in sequence. A similar approach can be used in setting pins **21** in the extended array tactile graphic display of this invention, wherein one actuator is moved across all the pins in the display, setting the selected pins to form a pattern. Since there may be many thousands of pins and the mechanical setting process is much slower than the writing process of an electron beam, the process may be speeded by raster scanning using a 1-dimensional array that in length is an integer fraction of one of the dimensions of the pin array. For example, in a display of m rows and n columns, an m/8 by 1 array of actuators can scan ⅛ of the rows at a time, so that the entire display is written in 8 passes. Raster scanning requires precision 2-dimensional guidance of the actuators.

[**0067**] Another approach utilizes vector drawing. Most tactile graphic drawings for accessibility place an emphasis on lines and curves, since these are easier to interpret using the sense of touch than area fills. It is possible to take advantage of this tendency by designing a tactile graphic display that employs vector drawing methods to set pins **21**, with as little as one actuator setting all the pins for the drawing. Rather than systematically scanning all the pins on the display, the drawing is specified in terms of a set of lines and curves (vectors), and the actuator is made to draw out these lines and curves on the display by following the vectors and setting the pins that are encountered. The vectors are followed using a precision 2-dimensional guidance system comparable to that of a 2-dimensional graphic plotter used for making visual plots on paper. Selected pins can be explicitly set by precision placement of the actuator, or the actuator can be made to set all those pins it happens to encounter in its passage. The latter method works especially well if the writing process is performed by pressing against the ends of the pins opposite the ends that the user reads, and facilitates very fast vector writing of the image (since the positioner does not have to pause at each selected pin). It also facilitates scaling of images to larger or smaller sizes, since it is not necessary to calculate in advance a mapping between the vectors needed and the physical placement of the pins in the display (though such calculation may result in an improved tactile graphic image).

[**0068**] When using the vector drawing approach, the time to complete a drawing is no longer a constant: it becomes proportional to the complexity of the drawing. The drawing is a set of straight or curved vectors, each of which is made by positioning the actuator at the starting point, engaging the actuator, following the specified vector, then disengaging the actuator. This approach lends itself very well to incremental drawing (described above), since individual increments that involve a few vectors may take a very short time to write