surface. This capability provides two benefits to the user. First, the user may wish to work on a project that requires simultaneous access to more tactile graphic information than can be displayed on a single display surface of the size that the user possesses. Rather than pay the price of two or more complete displays, the user can pay for one display driving system and multiple display screens (or display matrices), and write each screen in turn until all the needed information is displayed on one or another of the screens. Second, if the display surface becomes defective due to damage or wear, the user can attach a replacement screen and send the defective screen away for repair, thus minimizing the amount of time that the user does not have access to a working display.

[0085] Since the non-computer-driven extended tactile graphic array could be used as a sketchpad for hand drawing, the addition of elements to sense the positions of the pins will allow the user to connect the array to a computer system and capture the tactile image drawn, for further processing or storage.

[0086] With computer driven applications, the user can make permanent hardcopies of displayed images by attaching a commercially available tactile graphic embosser to the computer system. Examples of applications are the desire of the user to simultaneously access multiple screens of images (similar to the use of detachable screens described above), and tactile image distribution, for example handouts for a class.

[0087] In an extended array tactile graphic display, the tactile image created on the display is a real physical structure that the user reads by moving the fingers over the surface. The realism of such a display is the extent to which the user can easily receive the intended tactile impressions from the display. A primary issue is the spatial resolution of the display, which affects the user's ability to perceive lines and curves as continuous objects. If future technological advances make higher pin resolutions practical, it is likely that displays using the higher pin resolutions will provide increased functionality, including a greater sense of realism and the ability to display more detailed tactile graphic images. Similarly for multi-level displays, the number of depth levels determine the amount of relief that can realistically be portrayed.

[0088] It is fortunate that generic drawings do not have to conform to a particular scale. If there is a need for the user to feel a particular feature of an image, then the image can be scaled (or zoomed) to the point at which the feature can be displayed with the resolution available on the display. In this sense, the amount of detail that can be shown on a tactile graphic display is more a function of the total number of pins than of the pin spacing, unless the pin spacing is significantly closer than 20 pins per linear inch.

[0089] While the primary intended use of the extended array tactile graphic display is the display of images, it is expected that many users will also want the display device to show Braille text in addition, for example Braille labels on portions of a diagram. Unlike graphics, Standard Braille text has specific preferred dimensions, which can not be exactly reproduced on a tactile graphic array unless the pin spacing of the array corresponds to those dimensions. The spacing between dots in a Braille cell, the spacing between Braille cells in a row, and the spacing between rows of Braille cells are all different, so Standard Braille can not be presented on a regular rectangular array. "Dithering" displayed Braille text (shifting the pin positions or using multiple pins to map the desired dimensions of the text to the pin array) is not recommended because the relative spacing of the dots in Braille is also very important, and the user needs to be able to feel each Braille dot as a distinct point. The most effective solutions appear to be: 1) position the pins in the layout of the extended array in the proper configuration to display Braille, with additional pins as needed to obtain relatively uniform pin spacing for graphics applications (as shown in **FIG. 4**), or 2) adjust the dimensions of the Braille text so that while it no longer exactly matches Standard Braille dimensions, the match is as close as can be achieved with the available pin array, and so that the individual Braille cells displayed can be clearly distinguished from the neighboring cells.

[0090] The driving algorithm to be used for the extended array tactile graphic display or this invention must consider conversion of images to the tactile domain. Tactile graphic images have significant differences from visual graphic images, because the sense of touch uses different methods from the sense of sight to detect, identify, and organize object features. The greatest priority for a tactile graphic display is to allow the identification of distinctive features such as lines, curves, and borders between regions, and to provided differentiation between different regions by means of tactile cues such as textures.

[0091] The first step in tactile display of a visually oriented image is to convert it to a format that displays well on the tactile display. Conversion of visual cues may include the use of varying line widths to convey emphasis. If the tactile display uses vector drawing to set the pins, then part of this conversion implements a way to efficiently express the desired image in terms of vectors.

[0092] The extended tactile graphic array is constrained to place the stimulus points at the physical locations of the pins **21** that make up the array. If the image to be displayed has features that are not exactly aligned with the pin array, then the driving algorithm must determine how these features are to be displayed. An example of such a decision is to offset the displayed features slightly to align them with the pins in the display array. Display of diagonal lines offers the choice of setting only those pins that fall exactly on the desired line (which may leave many gaps in the line and produce a result that is difficult to interpret as a line), or setting a sufficient number of pins to produce the perception of a continuous line, which may result in a slightly jagged (stair step) line that is of varying apparent width depending on the angle of the line relative to the layout of the pin array. These issues do not interfere with the production of usable tactile graphic images, however, and the effects can be reduced as advances in the technology permit design of the display with closer pin spacing.

[0093] If the tactile graphic array does not use a regular pin pattern (e.g., using instead an array which includes dots spaced for the display of Standard Braille), then the driving algorithm must take into account the physical locations of these pins in the array, unless the pins are set by vector drawing, in which case the driving algorithm is less sensitive to the physical pin layout.

[0094] As may be appreciated from the foregoing, apparatus and methods in accord with this invention provide new