pins be settable to multiple levels, and the resulting tactile image is comparable to relief sculpture (with the requirement that there be no undercutting of the raised portions of the image). Relief in non-refreshable media such as plastic is currently used for accessibility purposes, but use is limited by cost (much higher than 2-level embossed paper) and volume storage requirements.

[0077] If a multiple-level display has large intervals between the allowed levels (required by some of the locking mechanisms described hereinabove), then the stepwise nature of the depth presented may impede the reading of the display. This difficulty may be alleviated by measures to smooth the apparent surface of the display, for example by use of a flexible sheet as described above and shown in **FIG. 13**. As described for two-level displays, a multi-level display can also be designed for occasional use as a form for molding of permanent copies of the image displayed, by the application of a heated thermoplastic sheet.

[0078] An extended array tactile graphic display must follow a specified sequence of actions in order to ensure correct operation and to prevent harm to the user or damage to the display. In production design it is desirable to include layer interlock mechanisms to make sure that the allowed operational sequences are followed. For example, in a display with a two-stage pin retention, a sensor should detect whether the pins are locked (e.g., sensing position of the pin locking mechanism employed) and no effort to set or reset the pins while the lock is engaged should be supported. If a roller or other device is passed over the reading surface to reset the pins, then a sensor should detect whether or not the user is currently touching the reading surface—this could be implemented by requiring the user to press buttons (and therefore remove the hands from the display), or by use of position detection sensors, or by requiring that a cover be placed over the display during reset, or by a combination of the above. The specific interlocks needed depend on the specific implementation details of the display.

[0079] For computer implementation of the array of this invention, the following is a normal sequence of operations. The user first issues a command for the display of a tactile graphic image. The system converts the graphical image to a format suitable for the display, e.g. raster or vector format, and if necessary converts the image to a map for setting of individual pins. The system determines that the pins are unlocked (if two-stage pin retention is used) and ready for setting. If there is an undesired image already on the display, the pins are reset. The selected pins are set to produce the desired tactile graphic image and, if two-stage pin retention is used, the pins are then locked. The user is given a signal that the display is ready to read and the user reads the display. If desired and if the display has the capability, a permanent hardcopy of the displayed image can be made. If the user so desires, one or more incremental additions can be made to the displayed image. If two-stage pin retention is used, the pins are unlocked before each incremental addition, then re-locked, and the user signaled that the display is again ready for reading. Finally, when the user signals that the displayed image is to be erased or replaced, if two-stage pin retention is used the pins are unlocked and the pins are reset to the default position. The display is now ready to display a new graphic image.

[0080] Computer control is not necessary for implementation of the extended tactile graphic array. There can be considerable value for accessibility in a low-cost device that lets the user draw and read tactile images, then erase the images to enable further drawing. To be economically attractive, a non-computer-driven implementation of this technology must be extremely low in cost. In this cost range, the favored method is likely to be pin pop-through (elastic sheet), with a user-operated roller to erase tactile images. In the simplest implementation, the user writes on the back of the display with a free hand version of the tracker (roller pen described previously), and the displayed tactile image is a mirror image of what was written by the user. It is possible to employ a two-step writing process that reverses the image a second time and provides the user with a non-mirrored image to view.

[0081] All mechanical systems exposed to the environment experience wear and sometimes need repair. It is therefore important to keep in mind the ability to refurbish or repair, when designing production devices. There is significant value to the intended users in designing a tactile graphic display so that some of the repairs can be carried out by a blind or visually impaired user; this must be balanced against the complexity of various types of repair and the additional production cost associated with user-serviceable designs. Specific features that can enhance the ability to repair devices using this invention include the ability to disassemble the stack that forms the display matrix, the ability to replace worn pins, and the ability to detach the display matrix from the driving mechanism.

[0082] There are many situations in which the user may want to interact with the graphic image displayed rather than entering all commands by other methods such as voice or keyboard. Examples include the interactive addition of elements to a drawing, and clicking on graphically displayed control buttons. A number of control mechanisms have been incorporated in graphic tablets for use by sighted users, and many of these are applicable for use with a tactile graphic display. The basic requirements are position detection and sensing that an action should be taken. Position detection could be performed by incorporating pressure sensors in the display if sensitive enough to operate with the pin locking mechanisms herein disclosed. Alternatively, ultrasonic or optical pickup could be utilized. The use of a stylus simplifies the detection of a command to perform an action, but since the user reads the display with the fingertips, there may be an advantage to implementation of a system that can be controlled by a fingertip on the display. A simple example of this would be optical detection of finger position, and acoustic pickup of a fingernail clicked at a selected point on the display.

[0083] A conventional optical scanner is a useful accessory for obtaining images to be represented on the tactile graphic display. An additional possibility is a tactile scanning device that collects tactile images of real objects, for immediate display or for storage and later playback.

[0084] It is possible to use a mechanical linkage (e.g. a buckle) for the pin locking mechanism that remains stable after locking without the need to supply power. With this type of lock, the display surface is essentially independent of the display driving and control systems until it is time to unlock the pins. Therefore, the extended array tactile graphic display can be configured with a detachable display surface that maintains a stable tactile graphic image on the detached