[0015] FIG. **5**A shows an illustrative keycap that is arranged to appear to have a dimension of depth when in its un-actuated state;

[0016] FIG. **5**B shows the illustrative keycap as it appears in its actuated state;

[0017] FIG. **6** shows an illustrative portable computing device that provides a combination of tactile, audio, and visual feedback to a user when a keycap is actuated using the device's touch screen;

[0018] FIGS. **7**A and **7**B show respective front and orthogonal views of an illustrative vibration motor and rotating eccentric weight;

[0019] FIG. **7**C is a top view of a vibration unit as mounted in a device shown in a cutaway view;

[0020] FIG. **7**D is an orthogonal view of a vibration unit as mounted to a touch screen in a POS terminal;

[0021] FIGS. **8**A and **8**B show respective top and side views of an illustrative virtual keycap for which a tactile feedback force profile is applied in response to touch to impart the perception to a user that the keycap has a depth dimension;

[0022] FIG. **9** shows an illustrative application of 3-D object simulation using audio, visual, and tactile feedback;

[0023] FIG. **10** shows another illustrative application of 3-D object simulation using audio, visual, and tactile feedback; and

[0024] FIG. **11** shows an illustrative architecture for implementing 3-D object simulation using audio, visual, and tactile feedback.

[0025] Like reference numerals indicate like elements in the drawings.

DETAILED DESCRIPTION

[0026] FIG. **1** shows an illustrative portable computing environment **100** in which a user **102** interacts with a device **105** using a touch screen **110** which facilitates application of the present three-dimensional ("3-D") object simulation using audio, visual, and tactile feedback. Device **105**, as shown in FIG. **1**, is commonly configured as a portable computing platform or information appliance such as a mobile phone, smart phone, PDA, ultra-mobile PC (personal computer), handheld game device, personal media player, and the like. Typically, the touch screen **110** is made up of a touch-sensor component that is constructed over a display component. The display component displays images in a manner similar to that of a typical monitor on a PC or laptop computer. In many applications, the device **105** will use a liquid crystal display ("LCD") due to its light weight, thinness, and low cost. However, in alternative applications, other conventional display technologies may be utilized including, for example, cathode ray tubes ("CRTs"), plasma-screens, and electroluminescent screens.

[0027] The touch sensor component sits on top of the display component. The touch sensor is transparent so that the display may be seen through it. Many different types of touch sensor technologies are known and may be applied as required to meet the needs of a particular implementation. These include resistive, capacitive, near field, optical imaging, strain gauge, dispersive signal, acoustic pulse recognition, infrared, and surface acoustic wave technologies, among others. Some current touch screens can discriminate among multiple, simultaneous touch points and/or are pressure-sensitive. Interaction with the touch screen **110** is typically accomplished using fingers or thumbs, or for non-capacitive type touch sensors, a stylus may also be used.

[0028] While a portable form-factor for device **105** is shown in FIG. **1**, the present arrangement is alternatively usable in fixed applications where touch screens are used. These applications include, for example, automatic teller machines ("ATMs"), point-of-sale ("POS") terminals, or self-service kiosks and the like such as those used by airlines, banks, restaurants, and retail establishments to enable users to make inquiries, perform self-served check-outs, or complete other types of transactions. Industrial, medical, and other applications are also contemplated where touch screens are used, for example, to control machines or equipment, place orders, manage inventory, etc. Touch screens are also becoming more common in automobiles to control subsystems such as heating, ventilation and air conditioning ("HVAC"), entertainment, and navigation. The new surface computer products, notably Microsoft Surface™ by Microsoft Corporation, may also be adaptable for use with the present 3-D object simulation.

[0029] It is also emphasized that the present arrangement for 3-D object simulation is not necessarily limited to the consumer, business, medical, and industrial applications listed above. A wide range of uses and applications may be supported including, for example, military, security, and law enforcement scenarios for which robust and feature-rich user interfaces are typically required. In these demanding environments, more positive interaction and control for devices and systems is enabled by the enhanced correlation and disambiguation of objects displayed on a touch screen provided to the user using a combination of audio, visual and tactile feedback.

[0030] FIG. **2** shows an illustrative touch screen **110** that supports user interaction through icons **202** and a virtual keyboard **206**. Icons **202** are representative of those that are commonly displayed on the touch screen **110** to facilitate user control, input, or navigation. Icons **202** may also represent content such as files, documents, pictures, music, etc., that is stored or otherwise available (e.g., through a network or other connection) on the device **105**. The virtual keyboard **206** includes a plurality of icons that represent keycaps of a conventional keyboard, as shown. Touch screen **110** will typically provide other functionalities such as a display area or editing window (not shown in FIG. **2**) which shows the characters (i.e., letters, numbers, symbols) being typed by the user on the virtual keyboard **206**.

[0031] FIGS. **3**A and **3**B show an alternative illustrative form-factor for a portable computing device **305** which uses physical controls **307** (e.g., buttons and the like) to supplement the user interface provided by the touch screen **310**. In this example as shown in FIG. **3**A, several pieces of media content (indicated by reference numerals **309** and **312**), which can represent photographs or video, for example, are displayable on the touch screen **310**. FIG. **3**B shows a page of an exemplary document **322** which is displayable on the touch screen **310**.

[0032] As shown in FIGS. **3**A and **3**B, device **305** orients the touch screen **310** in "portrait" mode where the long dimension of the touch screen **310** is oriented in an up-and-down direction. However, some portable computing devices usable with the present arrangement for 3-D object simulation may be arranged to orient the touch screen in a landscape mode, while others may be switchable between portrait and landscape modes, either via user selection or automatically.