may be compared in subsequent steps in order to control various aspects of a computer system.

[0080] The above methods and techniques can be used to implement any number of GUI interface objects and actions. For example, gestures can be created to detect and effect a user command to resize a window, scroll a display, rotate an object, zoom in or out of a displayed view, delete or insert text or other objects, etc. Gestures can also be used to invoke and manipulate virtual control interfaces, such as volume knobs, switches, sliders, handles, knobs, doors, and other widgets that may be created to facilitate human interaction with the computing system.

[0081] To cite an example using the above methodologies, and referring to **FIGS. 6A-6G**, a rotate gesture for controlling a virtual volume knob **170** on a GUI interface **172** of a display **174** of a tablet PC **175** will be described. In order to actuate the knob **170**, the user places their fingers **176** on a multipoint touch screen **178**. The virtual control knob may already be displayed, or the particular number, orientation or profile of the fingers at set down, or the movement of the fingers immediately thereafter, or some combination of these and other characteristics of the user's interaction may invoke the virtual control knob to be displayed. In either case, the computing system associates a finger group to the virtual control knob and makes a determination that the user intends to use the virtual volume knob. This association may also be based in part on the mode or current state of the computing device at the time of the input. For example, the same gesture may be interpreted alternatively as a volume know gesture if a song is currently playing on the computing device, or as a rotate command if an object editing application is being executed. Other user feedback may be provided, including for example audible or tactile feedback.

[0082] Once knob **170** is displayed as shown in **FIG. 6A**, the user's fingers **176** can be positioned around the knob **170** similar to if it were an actual knob or dial, and thereafter can be rotated around the knob **170** in order to simulate turning the knob **170**. Again, audible feedback in the form of a clicking sound or tactile feedback in the form of vibration, for example, may be provided as the knob **170** is "rotated." The user may also use their other hand to hold the tablet PC **175**.

[0083] As shown in **FIG. 6B**, the multipoint touch screen **178** detects at least a pair of images. In particular, a first image **180** is created at set down, and at least one other image **182** is created when the fingers **176** are rotated. Although only two images are shown, in most cases there would be many more images that incrementally occur between these two images. Each image represents a profile of the fingers in contact with the touch screen at a particular instant in time. These images can also be referred to as touch images. It will be understood that the term "image" does not mean that the profile is displayed on the screen **178** (but rather imaged by the touch sensing device). It should also be noted that although the term "image" is used, the data may be in other forms representative of the touch plane at various times.

[0084] As shown in **FIG. 6C**, each of the images **180** and **182** is converted to a collection of features **184**. Each feature **184** is associated with a particular touch as for example from the tips each of the fingers **176** surrounding the knob **170** as well as the thumb of the other hand **177** used to hold the tablet PC **175**.

[0085] As shown in **FIG. 6D**, the features **184** are classified, i.e., each finger/thumb is identified, and grouped for each of the images **180** and **182**. In this particular case, the features **184**A associated with the knob **170** are grouped together to form group **188** and the feature **184**B associated with the thumb is filtered out. In alternative arrangements, the thumb feature **184**B may be treated as a separate feature by itself (or in another group), for example, to alter the input or operational mode of the system or to implement another gesture, for example, a slider gesture associated with an equalizer slider displayed on the screen in the area of the thumb (or other finger).

[0086] As shown in **FIG. 6E**, the key parameters of the feature group **188** are calculated for each image **180** and **182**. The key parameters associated with the first image **180** represent the initial state and the key parameters of the second image **182** represent the current state.

[0087] Also as shown in **FIG. 6E**, the knob **170** is the UI element associated with the feature group **188** because of its proximity to the knob **170**. Thereafter, as shown in **FIG. 6F**, the key parameter values of the feature group **188** from each image **180** and **182** are compared to determine the rotation vector, i.e., the group of features rotated five (**5**) degrees clockwise from the initial to current state. In **FIG. 6F**, the initial feature group (image **180**) is shown in dashed lines while the current feature group (image **182**) is shown in solid lines.

[0088] As shown in **FIG. 6G**, based on the rotation vector the speaker **192** of the tablet PC **175** increases (or decreases) its output in accordance with the amount of rotation of the fingers **176**, i.e., increase the volume by 5% based on rotation of 5 degrees. The display **174** of the tablet PC can also adjust the rotation of the knob **170** in accordance with the amount of rotation of the fingers **176**, i.e., the position of the knob **170** rotates five (5) degrees. In most cases, the rotation of the knob occurs simultaneously with the rotation of the fingers, i.e., for every degree of finger rotation the knob rotates a degree. In essence, the virtual control knob follows the gesture occurring on the screen. Still further, an audio unit **194** of the tablet PC may provide a clicking sound for each unit of rotation, e.g., provide five clicks based on rotation of five degrees. Sill yet further, a haptics unit **196** of the tablet PC **175** may provide a certain amount of vibration or other tactile feedback for each click thereby simulating an actual knob.

[0089] It should be noted that additional gestures can be performed simultaneously with the virtual control knob gesture. For example, more than one virtual control knob can be controlled at the same time using both hands, i.e., one hand for each virtual control knob. Alternatively or additionally, one or more slider bars can be controlled at the same time as the virtual control knob, i.e., one hand operates the virtual control knob, while at least one finger and maybe more than one finger of the opposite hand operates at least one slider and maybe more than one slider bar, e.g., slider bar for each finger.

[0090] It should also be noted that although the embodiment is described using a virtual control knob, in another embodiment, the UI element can be a virtual scroll wheel. As an example, the virtual scroll wheel can mimic an actual scroll wheel such as those described in U.S. Patent Publication Nos: 2003/0076303A1, 2003/0076301A1, 2003/