[0030] FIGS. **1**A and **1**B are schematic illustrations useful in describing multi-point input techniques;

[0031] FIGS. **2**A, **2**B, **2**C and **2**D are schematic illustrations useful in describing various user interface techniques employing five inputs (e.g., fingers) simultaneously in accordance with the present invention;

[0032] FIGS. **3**A and **3**B schematically illustrate techniques for implementing rotation in accordance with an embodiment of the present invention;

[0033] FIGS. **4**A and **4**B schematically illustrate techniques for 3D object movement/scaling/rotation in accordance with further embodiments of the present invention;

[0034] FIG. **5** schematically illustrates techniques for controlling a displayed globe, including tilt control, in accordance with yet another embodiment of the present invention;

[0035] FIGS. **6**A and **6**B schematically illustrate techniques for controlling globe tilt in accordance with yet a further embodiment of the present invention; and

[0036] FIG. **7** is a block diagram of a system including a display device and a controller for carrying out the various techniques of the present invention.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

[0037] The present invention pertains to techniques for interfacing with multi-point input devices, including multi-point input displays, multi-touch displays/screens, multi-point input capable touch tablets (e.g., without a display integrated), multi-point input devices that receive inputs via a human finger, a stylus or other mechanical, electro-mechanic, magnetic, etc., device, and any other device or apparatus capable of sensing simultaneous multiple inputs. As used herein, the contacting object, whether it is a human finger or stylus or other device, also is referred to herein (primarily in the claims) as an "element." The multi-point input displays/screens may be in the form of a computer monitor, a television, a telephone display, etc. As used herein, the terms "multi-point input device" or "multi-touch device" or "multi-point device" or the like (or, for convenience herein, "input device") shall refer to any of the above-mentioned devices.

[0038] Generalized 2D Object Movement/Scaling/Rotation Control

[0039] Referring first to FIGS. **1**A and **1**B of the drawings, two inputs A and B are schematically shown. Inputs A and B are contact points by, for example, the fingers of a user's hand **10**, on a multi-point input device, such as multi-point input touch-sensitive display **12**. For example, inputs A and B may correspond to a user's thumb and index finger, respectively. As another example, inputs A and B correspond to a user's index finger from each hand. Other finger combinations, from one or multiple hands, may be employed. Further, and as discussed below, a different number of fingers (e.g., 3 fingers, 4 fingers, 5 fingers) may be employed.

[0040] As is known, such as disclosed in G. Kurtenbach, G. Fitzmaurice, T. Baudel, and B. Buxton, "The design of a GUI paradigm based on Tablets, Two-hands, and Transparency," CHI '97: Proceedings of the SIGCHI conference on Human factors in computing systems, 35-42 (1997), cited above, and incorporated herein by reference, two input points may be utilized to effect the 2D position, uniform scaling, and 2D rotation of a 2D object on a display in a straightforward 4 degree-of-freedom ("DOF") operation. This also is known as pan-zoom-rotate, or "PZR," a term generally used when the camera is implied to be being manipulated rather than the object (though there is no functional difference). Here, two 2D points specify the 4-DOF exactly. The operation may be either based on a change from the initial positions of the points (i.e. when first contacting the surface), or based incrementally based on the changes in successive readings of the sensor.

[0041] Referring to FIG. **2**A, five inputs A, B, C, D and E are schematically shown. In accordance with the present invention, the PZR can be generalized to control the same 4 degrees of freedom (2D translation, scaling, rotation) when more than two (i.e. N>2) inputs (e.g., touch points) are used. For example, translation can become generalized to the motion of the centroid of the positions of all N points. As another example, scale can be generalized by averaging the ratios in distances from each input to the centroid or, alternatively, be based on an area defined by the inputs (e.g., where the inputs represent the corners of a polygon). As a further example, rotation can be generalized by averaging the changes in angle each input has with the centroid. Accordingly, such a variant is referred to herein as "N-point-PZR" control.

[0042] In a more mathematically-based approach, each 2D input point on the object can be considered a geometric position constraint, and a numeric optimizer solves (at interactive rates) for the object's **4** orientation parameters to match the new positions of the touch points, while minimizing some error metric in the case it is overdetermined. For example, this can be setup as a system of linear equations, and solved with a method such as SVD.

[0043] 3D Object Movement/Scaling/Rotation Control

[0044] Three-dimensional (3D) object movement/scaling/rotation control in accordance with the present invention entails use of one or more inputs to a multi-point input device to effectuate movement/scaling/rotation of a 3D object or scene that is displayed on a display device. The display device may or may not be the multi-point input device receiving the inputs. As an example, if the multi-point input device is a multi-touch display, then a 3D object or scene displayed on the multi-touch device may be controlled, as described herein, by one or more finger contacts with that device. For convenience, references to a "3D object" shall include either a displayed 3D object or a displayed 3D scene, unless otherwise stated herein. And for convenience, the X/Y axes of the 3D space typically lay within the display screen plane, unless otherwise stated herein.

[0045] In accordance with the present invention, a user controls various movements of a displayed 3D object (or scene) using one or more inputs. As set forth in the various embodiment and variations described herein, the position (along the x, y and z axes), scale (size) and/or orientation of a 3D object is controlled through the user's placement/movement/pressure of one or more inputs to (e.g., fingers on) the input device (e.g., multi-point input touch screen).

[0046] The user can effect a standard "trackball" (i.e. "arcball" or "virtual sphere")-style rotation by placing and moving a single input point on the 3D object. Alternatively, the single input point can be used to control vertical/horizontal movement (i.e. panning) of the 3D object instead.

[0047] The use of multiple (2 or more) input points simultaneously by the user allows for additional 3D control operations to be performed at once.

[0048] The user controls vertical/horizontal movement (i.e., panning) of the 3D object by vertically/horizontally moving some of the inputs (e.g., fingers). The precise location