of the 3D object along the X/Y plane may be implemented in various manners. In one version, motion of the centroid of all the inputs (such as the exemplary downward motion shown in FIG. 2B) controls movement of the centroid of the 3D object along the X/Y plane (translation).

[0049] The user controls the scale of the 3D object (i.e., zooming) by modifying the relative size/area of the inputs. For example, the 3D object's scale may be a function of the average of the distances of each input to the centroid or be a function of the area of the convex hull of the points defined by the inputs. FIG. 2C schematically illustrates moving the inputs in an outward direction (stretching the fingers). For a hand contacting a multi-point input touch screen with multiple fingers, stretching the fingers corresponds to increasing the scale of the 3D object, whereas bringing the fingers together causes a decrease in scale.

[0050] In a variation, rather than changing object scale, moving out (stretching) and moving in the inputs controls the position of the 3D object along the Z axis. Thus, the 3D object's position along the X, Y and Z axes may be controlled in the manner described herein. As understood herein, various other techniques described herein for changing scale may be modified to control Z-position. Conversely, other techniques described herein for controlling/changing Z-position may be modified to control scale.

[0051] FIG. 2D schematically illustrates user rotation, in the clockwise or counter-clockwise direction, of the inputs to control rotation of the 3D object about the Z axis (i.e. within the X-Y plane). For example, rotation of the 3D object may be a function of the average of the changes in the angle each input has with the centroid.

[0052] Referring next to FIG. 3A, which shows three inputs A, B and C, rotation of the 3D object about an axis "r" embedded in the view (i.e. X-Y) plane (i.e., the display surface) is carried out by the user exerting additional pressure at one or more of the inputs. As an example, the user may exert additional pressure at input A (e.g., by the thumb) to cause the 3D object to rotate in one direction about axis r, or may exert additional pressure at inputs B and C (e.g., by the index and middle fingers) to cause the object to rotate in the opposite direction about axis r.

[0053] Preferably, the multi-point input device is a pressure sensitive type device capable of ascertaining changes in pressure and/or measuring true force. High resolution multi-touch sensing devices, with or without true force sensitivity, also can derive similar force-like data by evaluating each contact area, which may increase with force due to the pliability of the human finger. Such evaluation can be carried out using any suitable technique (sometimes called Simulated Pressure techniques). One example of a suitable technique is discussed in the publication H. Benko, et al., "Precise Selection Techniques for Multi-Touch Screens," Conference on Human Factors in Computing Systems, Proceedings of the SIGCHI conference on Human Factors in computing systems, 1263-1272 (2006), which is incorporated herein by reference. For purposes herein, pressure detection, pressure measurement and the like shall include techniques that derive force-like data.

[0054] Referring to FIG. 3B, one manner of calculating the amount of rotation includes interpreting pressure as "depth" below the input surface, resulting in a set of 3D points (e.g., points A', B' and C' in FIG. 3B). A best-fit 3D plane is computed to these 3D points. The best-fit plane will appear to tilt towards the inputs having greater force. Mathematically, there is a direction and angle between the normal vector of the best-fit 3D plane, and the normal of the screen (X-Y) plane (e.g., Z-axis), and this direction/angle specifies an incremental rotation operation on the 3D object. In other words, a "tilt" transform is applied as an incremental rotation about the in-plane axis R that maps the Z-axis to n. Preferably, to ensure that n is well-defined, a set of weak constraint points k are included around the circular boundary of the control with depth equal to zero.

[0055] FIGS. 3A and 3B show three inputs (e.g., three fingers contacting the input device). However, as mentioned above, the user may employ a different number of fingers (i.e., inputs or elements). For example, the user may press the input device with five fingers of a hand, as shown in FIG. 2A. Regardless of whether three inputs are employed, five inputs, or another number of inputs, if the fingers (inputs) that are touching the right side of the 3D object are pressed harder than the other fingers, the object is controlled to tumble left-to-right. As another example, if only a single finger is pressing harder on the left side of the 3D object, the object is controlled to tumble right-to-left. For consistency, solution parameters are adjusted when input points are added or removed, that is, when more or less fingers contact the display, in order to maintain a constant transformation.

[0056] As a particularly useful feature of the present invention, rotation preferably is engaged only when the forces on all inputs exceed a predetermined "deadband" threshold, thus preventing unintended rotation during other movement control of the 3D object (e.g., panning, zooming, rotating about the Z plane).

[0057] The above-described 3D object movement/scaling/rotation control techniques combine isotonic controlled rotation (along the input plane) with isometric controlled tilt (about a variable axis r). The present invention further entails 3D object movement/scaling/rotation control without employing pressure measurement, as described below.

[0058] 3D object movement/scaling/rotation control in accordance with another embodiment of the present invention entails usage of a first set of inputs (e.g., inputs A and B shown in FIG. 4A), temporally followed by a third input (e.g., input C), where the 3D object rotates about axis R during the existence of input C, and axis R is defined as being embedded within the XY plane and whose angle within that plane is specified by the positions of A and B. Thus, the amount of rotation is a function of the amount of time input C is received. Preferably, input C's location is within a suitable control area (e.g., within a predetermined distance from the other inputs) so to prevent rotation by inputs relatively remote from inputs A and B. The rate of rotation may be constant (e.g., angularly) or progressively increases while input C is received. In any case, the axis R can be continuously adjusted by the user during the rotation operation by moving the positions of inputs A and B.

[0059] The direction (clockwise or counterclockwise) of rotation about the axis R may be controlled by input C's position relative to A's and B's positions. In one variation, an input C to the right (or above) line segment A-B causes the 3D object to rotate in one direction, while an input C to the left (or below) line segment A-B causes the 3D object to rotate in the opposite direction. In another variation, the relative distance of input C to line segment A-B designates tilt direction. Different control areas may be designated visually upon receipt of inputs A and B, assisting the user as to the appropriate locations where input C may be received to initiate rotation in one direction or rotation in the opposite direction, as shown in