Perspective-dependent Indirect Touch Input for 3D Polygon Extrusion

Henri Palleis
University of Munich (LMU)
Munich, Germany
henri.palleis@ifi.lmu.de

Julie Wagner
University of Munich (LMU)
Munich, Germany
julie.wagner@ifi.lmu.de

Heinrich Hussmann
University of Munich (LMU)
Munich, Germany
hussmann@ifi.lmu.de

ABSTRACT
We present a two-handed indirect touch interaction technique for the extrusion of polygons within a 3D modeling tool that we have built for a horizontal/vertical dual touch screen setup. In particular, we introduce perspective-dependent touch gestures: using several graphical input areas on the horizontal display, the non-dominant hand navigates the virtual camera and thus continuously updates the spatial frame of reference within which the dominant hand performs extrusions with dragging gestures.

Author Keywords
3D polygon modeling; extrusion; bimanual interaction; perspective-dependent gestures;

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION AND RELATED WORK
Extrusion in conventional 3D authoring tools (e.g. Blender) requires users to frequently switch modes resulting in a sequential workflow of alternating selection, extrusion, transformation as well as navigation commands. While in WIMP environments these commands are invoked by selecting menu items, applying keyboard shortcuts or operating graphical handles, multi-touch input for 3D interaction faces fundamental challenges: apart from fatigue effects, touch imprecision and occlusion issues [1], the mismatching *degree of integration* [2] has inspired different approaches for basic 3D object manipulation (e.g. [5, 4]) and navigation (e.g. [3]).

We approach these challenges by exploring indirect touch input techniques in a horizontal/vertical dual touch-display setup. In this context, we have developed a 3D polygon modeling tool called FAD (Finger-Aided Design) that includes a novel approach towards polygon extrusion. Our main design goal was to reduce activation costs [2] and encourage bimanual operation: we consider the horizontal display as a *tool space* that can display several spatially multiplexed and task-dependent UI elements and input areas with direct mappings to task functions. In our extrusion tool, the non-dominant hand controls the camera viewpoint and frames the scope of potential extrusions performed with the dominant hand using dedicated *graphical input areas* (see figure 1). Further, the spatial multiplexing also allows to operate tools simultaneously, e.g. enabling the extrusion of bent shapes through concurrent extrusion and scene navigation.

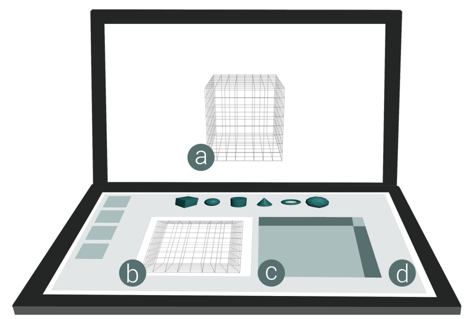

Figure 1. Our notion of the horizontal display as *tool space*: graphical input areas (b-d) with direct mappings to operations allow spatial activation and encourage two-handed interaction.

In general, we see the following benefits of our approach: (1) indirect touch improves ergonomics, precision and occlusion, (2) the spatial multiplexing of graphical input areas allows a restriction to simple one- and two-finger gestures instead of introducing complex gesture sets and (3) our design encourages but does not enforce bimanual input, allowing flexible hand/task-relationships.

PERSPECTIVE-DEPENDENT EXTRUSION WITH FAD
Figure 1 gives an overview of FAD's *tool space* for the extrusion task: (a) the scene object, (b) the polygon selection tool, (c) the extrusion touch pad, and (d) the base layer for scene navigation.

Basics. One-finger touch gestures on the base layer (d) orbit the camera around the selected object (a), two-finger pinch gestures control the zoom level.

Selecting Surfaces and Polygons. Users select a surface of the scene object on the vertical screen (a) via direct touch. Then, the *polygon selection tool* (b) displays an animated virtual camera motion towards the selected surface (point-of-interest, similar to Navidget [3]). Inside the polygon selection tool, users can select and deselect single polygons of the object by tapping and dragging.

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Perspective-dependent Polygon Extrusion. Once a set of polygons of an object is selected, the selection can be extruded up, down, left or right via dragging gestures on the extrusion touch pad (c) with the dominant hand. The interpretation of the gestures depends on the orientation of the scene controlled with the non-dominant hand on the *tool space's* base layer (d).

The extrusion touch pad consists of a square area containing a horizontal and a vertical bar. Gestures within the horizontal and vertical bar extrude the selection along the respective surface normal in a constrained manner depending on the scene camera's orientation: for example, figure 2 (1) shows the interpretation of the rightward gesture in a side-view: visual feedback shows alternative selection areas on the up- and down-side of the extruded end indicating how a subsequent up- or down-ward gesture would be interpreted in the current camera orientation. The visual feed is continuously updated with the manipulation of the camera viewpoint (see figure 2 (3) to (4)).

Gestures outside the constraining bars also extrude the selection along the respective axis. However, an additional translation is applied by considering both translation deltas from the touch input. The additional translation vector is also dependent on the camera perspective and is parallel to the surface normals of the polygons contained in the alternative selections.

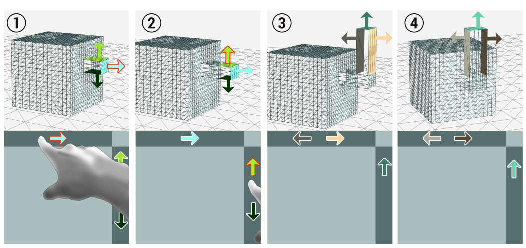

Figure 2. Extrusion workflow: arrows in the diagram indicate perspective-dependent polygon selections and the according gestures on the extrusion touch pad. (3) and (4): polygon selections flip when the view is rotated.

Implementation of the Extrusion

The extrusion logic is handled by an event handler that divides touch events on the extrusion pad in three phases: During the first phase (100 ms), touch deltas are summed up to determine the direction of the extrusion (up, down, left or right). Then, the extrusion is executed once (new geometry is created) and finally, the continuing touch input controls the translation of the newly created polygons. This results in a fluent movement, that enables users to extrude selected polygons by simple one-finger dragging gestures. Implementation details and code are made available at http://www.medien.ifi.lmu.de/fadextrusion.

After each extrusion movement and after each change of the camera viewpoint, all newly created polygons are assigned to one of the following directions: left, right, up or down. This is done by constructing local coordinate axes of the camera and calculating angles between them and the polygons' surface normals.

The initial extrusion of polygons selected in the polygon selection tool is a special case in FAD, as there are no other polygons facing in other directions that can be extruded yet. In this case, the touch input of the extrusion pad is used to insert the new geometry into the mesh and to translate the new polygons in the manner described above.

Bent Extrusion with Scene Navigation

We also explored a more integral way of extruding bent shapes compared to existing tools that allow to specify a path and then extrude along that path. Building upon the two-handed control of extrusion and navigation, our workflow allows to create bends and twists by rotating the camera with the non-dominant hand while extruding polygons with the dominant hand. Figure 3 illustrates the interaction technique: while the right hand extrudes to the left, the left hand performs a camera rotation around the object's Y-axis. During the camera movement the right hand continues the extrusion movement.

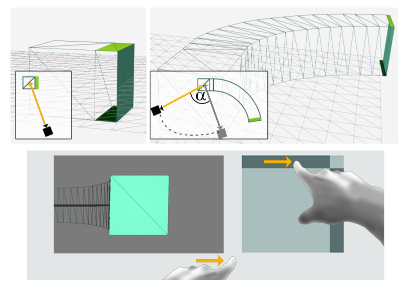

Figure 3. Creating bent shapes with simultaneous extrusion and camera control. α is the angle of camera rotation and corresponds to the sum of rotation angles of the automatically extruded polygons.

FUTURE WORK

We plan the evaluation of our technique regarding the general usability, the required learning for bimanual operation as well as its influence on the exploration of 3D shapes during modeling. Further, we will enhance our technique with the ability to immediately rotate and scale extruded polygons with two-finger gestures.

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