

**Combination of Two- and Three-Dimensional Space  
for Solid Modeling**

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This sketch describes a novel hybrid 3-D object modeling system, NIME-NAIST Immersive Modeling Environment, which inherits the advantages of both traditional 2D GUI based interface and 3D immersive modeling environment (fig.1). Figure 2 illustrates the whole system.

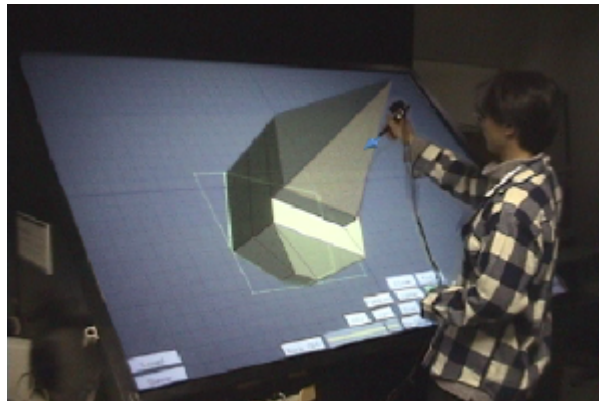


Figure 1: A scene of modeling in NIME

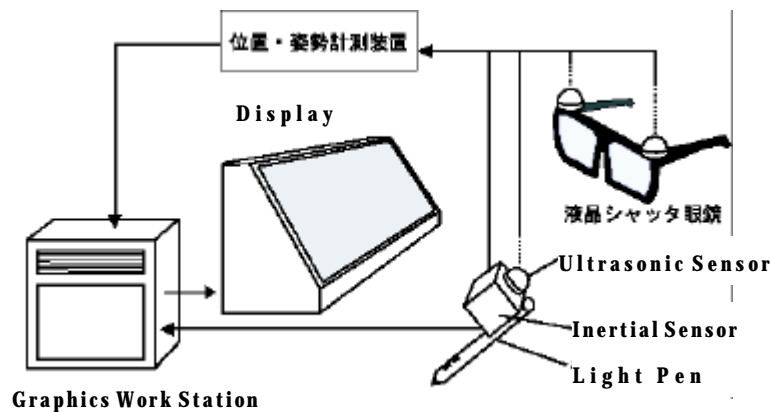


Figure 2: System Configuration of NIME

By employing a slant rear-projection display, NIME integrates 2-D and 3-D modeling environments into a unified modeling space. On the surface of the display, NIME provides a user 2D GUI modeling interface. NIME also provides the 3D modeling environment with a field sequential stereoscopic imaging of objects and 6-DOF pen-type input device. Therefore, a user can create models seamlessly switching between these two modeling environments.

Unlike the conventional 3D CG software systems, which display the projected images

of manipulation targets, NIME provides a user the 2D modeling environment by showing the intersection of targets and the display surface on the screen. By showing both stereoscopically displayed object and its intersection all the time, a user can create objects seamlessly either in 2D or 3D modeling environments without any operation to switch one modeling environment to another.

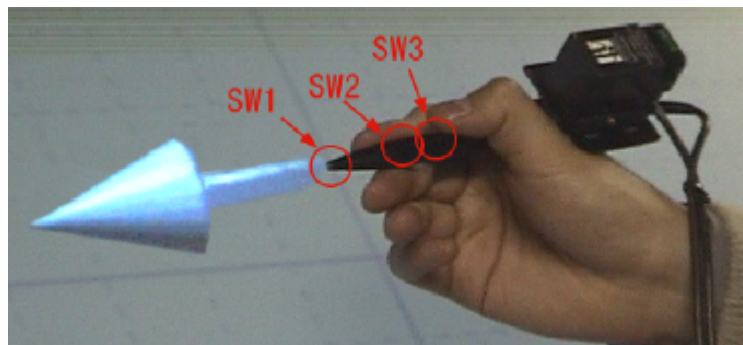
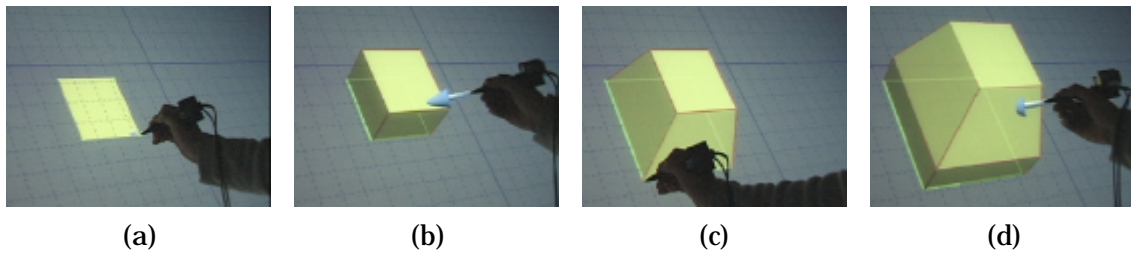


Figure3: Pen-type input device with 3 switches

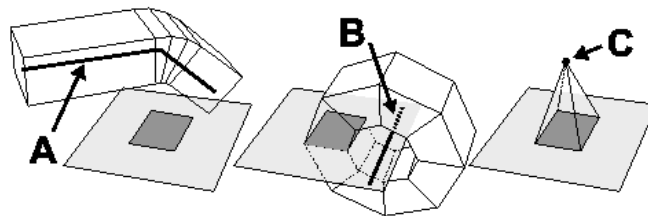
A 6-DOF pen-type input device (fig. 3) is developed and used in this system. The device is a combination of a light pen, an inertial sensor, and an ultrasonic sensor. This pen-type input device can be used in both 2D and 3D modeling environments with the 3 switches arranged at the tip and the side part. By calculating the distance between display surface and the tip of the pen-type input device, NIME detects which modeling environment the user intends to use. When the distance is within 5 mm, the user's operation is considered as for the 2D modeling environment and a dot cursor is shown according to a series of input from the light pen. On the contrary, when the distance is beyond 5 mm, it is considered as for the 3D modeling environment and an arrowhead cursor is shown according to a series of input from the inertial sensor and the ultrasonic sensor.

In NIME, a user can perform a number of modeling operations in both 2D and 3D environments according to the nature of each operation. To create objects, first a user makes 2D plane shape in 2D modeling environment. After creating 2D shape, a user can extrude the 2D shape directly into 3D space. We call this way of creating objects "direct extrude". Once a user extrudes the 2D shape, the intersection of the object becomes to be possible to edit. Fig.4 shows the process of "direct extrude"; (a) a rectangle is created in 2D modeling environment, (b) the rectangle becomes a parallelepiped by "direct extrude", (c) the intersection is edited and (d) "direct extrude" is done again.



**Figure 4: A process of "direct extrude"**

Three more types of shape creation are prepared. They are path-extruded, revolving and pyramidal shapes(Fig. 5).

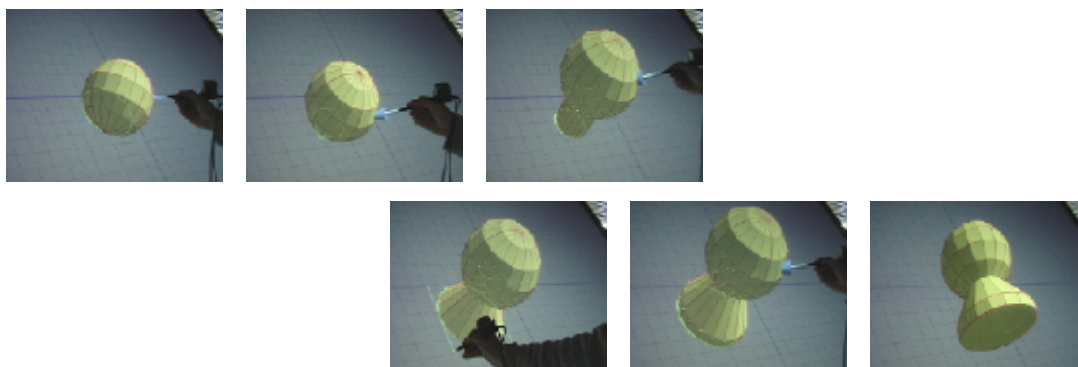


**Figure 5: Three prepared shapes and the referential objects"**

Same as "direct extrude", first a user creates 2D plane shape. After that a user specifies which types of shape a user wants to create through the buttons on the surface of the display, an referential object that correspond to the specified shape appears. The referential object is a extrude path of path-extruded(A), the axis of rotation of revolving(B), or the summit point of pyramidal shapes(C). Users can always edit the referential objects during creation of each object, and at the same time, the original 2D plane shape can be edited. Users can confirm the effects of the change to the referential object and the original 2D plane shape immediately in 3D modeling environment stereoscopically.

To modify the created objects, NIME offers 4 types of operations to users, that is "extrude the intersection", "edit points", "virtual magnet" and "Boolean operation".

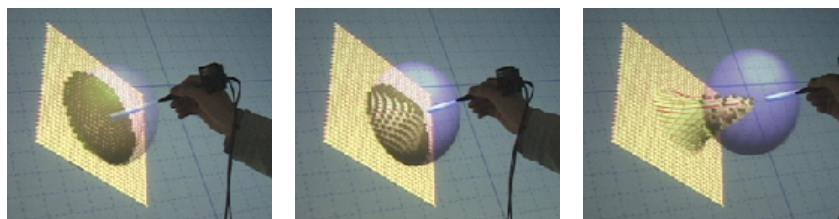
By using "extrude the intersection", users can modify the object as shown in figure 6.



**Figure 6: A process of "extrude the intersection"**

The sphere is arranged so that the bottom part will intersect with the surface of the display. After pushing button of “extrude the intersection”, a user can extrude the intersection by translating the object in 3D space. Same as the “direct extrude”, the intersection is possible to edit. Finally, to make the intersection the base, a user push the button again.

Users can move the selected points of object both in 2D and 3D modeling environments. When users move the pen-type input device in 2D modeling environment, the selected points translate only the 2D direction. When in 3D modeling environment, the selected points translate 3D direction freely.

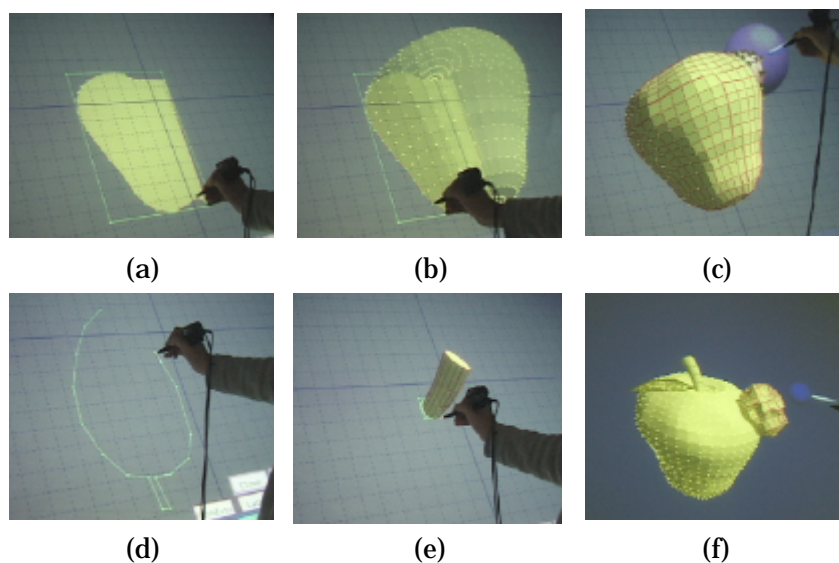


*Figure 7: A process of “virtual magnet”*

The “virtual magnet” is used when a user wants to give the object smooth gradation(Fig. 7). When a user selects “virtual magnet”, the arrowhead of the cursor changes spherical head, which shows the area of influence of “virtual magnet”. A user can modify the object by moving the pen-type input device.

The “Boolean operation” is implemented to perform in 3-D modeling environment, because it becomes easier by giving users ability to understand the relationship between objects and to move objects with 6 degrees of freedom.

Finally, the modeling process of an apple is shown in figure 8.



*Figure 8: A process of modeling an apple*

- a) First, the 2D plane shape, which is the cross section of an apple, is created in 2D modeling environment.
- b) By revolving the 2D plane shape, the body of an apple is created.
- c) The “virtual magnet” is performed to give the body some natural distortion.
- d) A reef is created as 2D plane shape and bended by “virtual magnet”.
- e) Beginning with a circle, repeatedly applying “direct extrude” and editing the intersection create a stem.
- f) To apply “Boolean operation”, each object is arranged at appropriate position.

Figure 9 shows the rendered image of the apple created in NIME.



Figure 9: A photo-realistic rendered apple