D20: Interaction with Multifaceted Display Devices

Ivan Poupyrev
Interaction Lab, Sony CSL
3-14-13 Higashigotanda, Shinagawa,
Tokyo, 141-0022 Japan
poup@csl.sony.co.jp

Henry Newton-Dunn
SET Design Studio,
Sony Creative Center,
1-15-5 Jingumae, Shibuya-ku
Tokyo, 150-0001 Japan
henry@dc.sony.co.jp

Olivier Bau[†]
Institut National Polytechnique de Grenoble
46 avenue Felix Viallet
Grenoble cedex 1, 38031 France
bauo@ufrima.imag.fr

Abstract

In this paper we investigate the principles for desiging multifaceted displays and their potential interfaces. D20 is a prototype of a handheld digital device which has an icosahedron shape. Each face of the device is a triangular display, the entire surface of the device forms one continuous multisided display. The user interacts with the device by manipulating it. The principles that we develop can be applied to other non-rectilinear multifaceted displays.

Keywords

mobile and gestural interaction, multifaceted displays.

ACM Classification Keywords

H.5.2 [Information interfaces and presentations (e.g., HCI)]: User Interfaces---input devices and strategies, interaction styles, screen design; B.4.2 [Input/output and data communication]: Input/Output Devices---image display; C.5.3 [Computer system implementations]: Microcomputers---portable devices.

Introduction

This paper presents D20, a design of a handheld digital device that has a regular icosahedron shape (figure 1). An icosahedron is a polyhedron with 20 faces, all of which are equilateral triangles. Each triangular face of our device is a display, therefore, the entire surface of the device forms one continuous, curved multifaceted display surface. There is no space for buttons or key-

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[†] Currently at Project In Situ, LRI/INRIA Futurs, Paris, France

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boards, the entire interaction is conducted by manipulating the device, observing the interface response and touching the device faces to initiate functions.

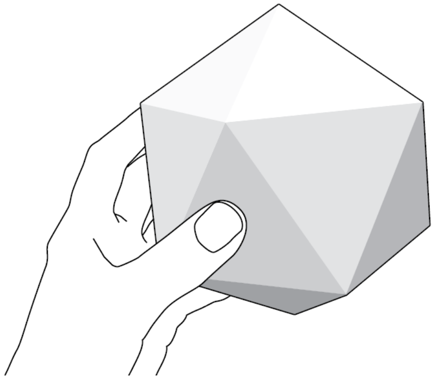

figure 1: D20 is a design of multifaceted handheld display device, shaped as regular icosahedron.

The main goal of the D20 project was to investigate handheld devices with multifaceted displays. We are interested in such devices for a number of reasons. Firstly, there has been a rapid progress in the new display technologies, such as electronic ink and organic light-emitting diode (OLED) displays. These technologies potentially allows to make displays with arbitrary pixel order and 2D shapes, e.g. triangles or circles. Such displays can be assembled into many shapes, forming continuous curved or convex 3D display surfaces. We believe that for the first time in the history of computing, there is a real opportunity to break away from traditional flat and square displays and investigate completely new display shapes and interactions.

Secondly, with market saturated with digital devices, the physical design as well as the user experience are becoming more important than the features, the technical and the functional characteristics [1]. However, the current interaction design and user experiences are limited by the WIMP interfaced paradigm, designed specifically for flat rectilinear displays. We are interested in the potential of displays that have complex shapes. In the future any shape around us or any object might have an inexpensive and high-quality display wrapped around it. This opens an exciting opportunity for designing new experiences and applications. In particular, we are interested in handheld digital devices.

This paper presents the design of one possible device, and reports a set of user interface principles that we developed. These principles can be generalized and used for the design of other multifaceted devices and their user interfaces.

Related work

The importance of a control's shape has been long understood in human factors and user interface research and practice. The shape of hand tools, for example, is optimized to maximize user performance while minimizing human wear and tear. In desiging human-machine interfaces, the shape coding has been extensively used to improve the accuracy of control identification either visually or through touch [2].

A control's shape effects user experience in at least two ways. Firstly, the shape of the device directly defines the muscles groups that are involved in manipulation: We can influence the grasp of a control by carefully designing its shape [3]. Secondly, a control's shape can inform the user about its functionality. This approach has been popular in tangible and 3D user interface design[4, 5].

Although the effect of a control's shape on user performance and comfort has been extensively investigated there were only few attempts to learn how a *display's shape* effects the user performance and the experience. Tan [6] investigated the effect of the display size on user performance, but his work focused on desktop interaction and only on the size of the display.

The closest research that we aware of is Z-agon device designed at the Keio University, Japan [7]. Z-agon is a cuboid handheld device where each face is a display. The interaction with Z-agon, however, is still limited to the rectilinear paradigm and at each moment of time the user can interact with only one individual face, rather than with the shape as a whole. On the contrary, we are proposing an interaction style that works across the entire display surface of the multifaceted device, specifically taking advantage of its complex shape.

Design and interaction for multifaceted displays

If we can make an arbitrarily shaped display what would be the optimal interaction for that shape? Our basic guiding observation is that *the physical shape of the display influences the structure of the displayed information.* Indeed, in the case of traditional flat displays their physical shape is irrelevant: We observe only the displayed information. However, if a display has a complex 3D shape the user perceives *both* the shape of the display and the displayed information at the same time. Hence, when we design the structure of the information we should also think about the display shape. Vice versa, by designing a certain display shape we can influence how the information will be structured.

Perception of the display shape

We can effortlessly recognize forms and images from individual parts, such as lines, curves and dots. Gestalt psychologists proposed a number of principles to explain how we perceive forms. For example, in figure 2a we naturally group the black and white dots into lines, this is known as *grouping by similarity* [8]. We can also perceive shapes from partial or incomplete information, for example on figure 2b we can see a triangle and a sphere even though they are not drawn explicitly. This principle is known as *closure*. Presented with ambiguous visual stimuli we are able to see two or more interpretations by switching back and forth between them. For example, on figure 2c we can see two faces or a vase. This principle is called *multistability*. Importantly, by altering the image we can make one of the interpretations dominant, i.e. if we decrease the distance between faces, then the vase is more likely to be seen.

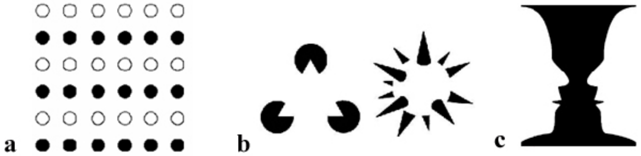

figure 2: Perception of form.

We apply these simple principles to the design of the shape of multifaceted displays. First, we chose the shape whose sides *naturally form multiple visual patterns* that can be easily perceived by the user.

For example, in case of icosahedron, its faces can naturally form a *strip*, a *pentagon* and a *rhombus* (figure 3). With little effort we can also see more complex shapes, such as the shape in figure 3 on the right. Each of these shapes can be used as *containers* for user interface elements, as we demonstrate later.

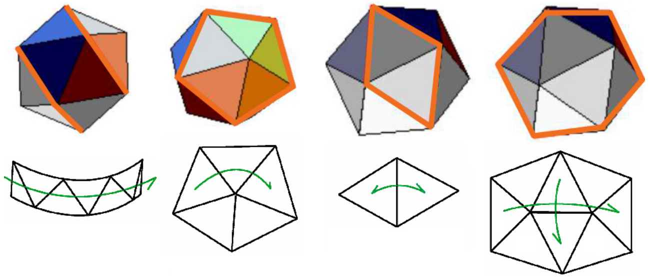

figure 3: Basic visual elements in the icosahedron.

Furthermore, we can *see several shapes at the same time* and switch between them as we did in the case of the image of the vase. For example, on figure 4 we can see a pentagon, a strip and a rhombus at the same time.

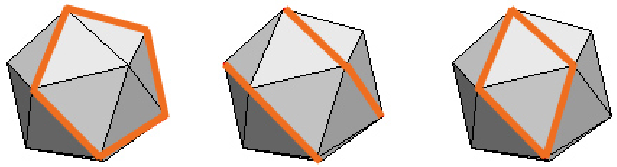

figure 4: Multistability in display shape: we can see several basic shapes at the same time.

Furthermore, because each face is a display we can alter the image shown and make one of the shapes *dominant*. Hence the displayed images are used to prompt the user to see a certain shape.

Gesture control, air bubble pointer

In the case of a traditional rectilinear display the entire image is always visible. With multifaceted displays, however, we can not assume that the whole display surface is visible at the same time, some of the faces might be occluded. This prompts the user to rotate the device, which makes gestural interaction (such as [9]) a natural technique to control the interface.

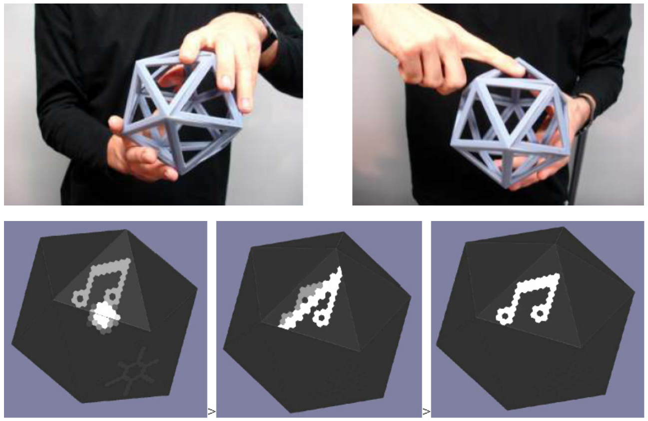

figure 5: Top: Interacting with the device using gestures; Bottom: selecting an icon using the air bubble pointer.

The interaction with D20 is based on an *air bubble* metaphor. Imagine a glass ball filled with water with a small bubble of air inside. As we rotate the ball the air bubble moves to the top. If the bubble is a pointer and there are images on the surface of the ball, i.e. icons, we can select one by aligning the bubble with the icon. Selection can then be confirmed by touching the icon as demonstrated in figure 5. Consequently, different icons can represent different functions which use different gestures for their interaction.

D20 interaction techniques

We implemented a number of basic interaction techniques, such as hierarchical menu navigation, pie menu, continuous control, and a switch.

figure 6a demonstrates hierarchical menu navigation: the strip shape is used to contain menu items. We scroll through the menu by rotating the device. As the device is curved we can have an *infinite* number of the menu items. When the desired icon is selected the submenu appears on an orthogonal strip intersecting the selected icon (figure 6a right). To indicate the transition, the entire strip flashes once before displaying the new submenu (figure 6a middle). To return back to the top-level menu we simply shake the device.

figure 6b shows how a pentagon shape is used to implement a pie menu. The illuminated face represents the current selection, the user rotates the device around the vertical axis to switches between items. We illuminate the corners and the center of the pentagon to help the user to see the pie menu clearly.

figure 6c shows continuous control using a pentagon. The size of the illuminated area corresponds to the value we are controlling. We change the value by rotating the device around the vertical axis, which decreases or increases the controlled value depending on the direction of rotation.

Finally, figure 6d shows continues control using a rhomboid. The zero value is presented as a line in the middle, by tilting the device to the left or to the right we can increase or decrease the controlled value.

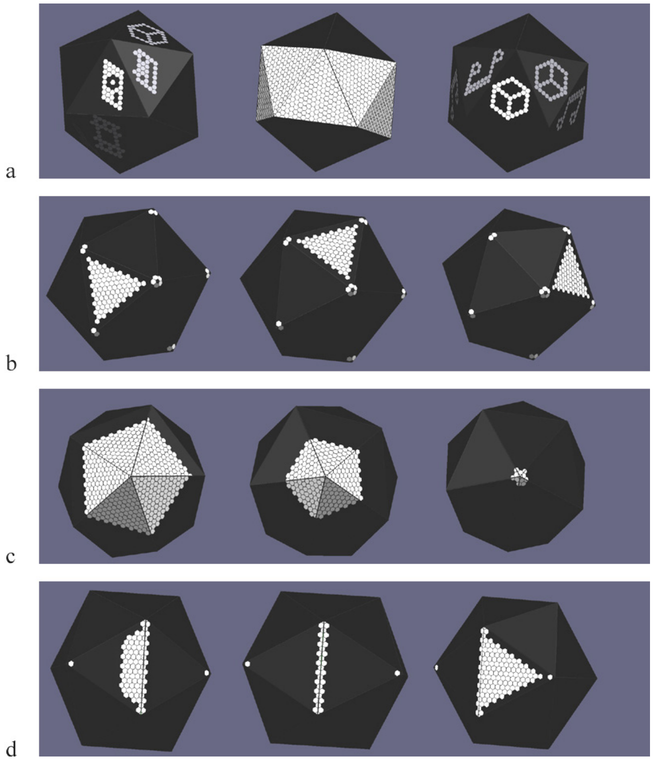

figure 6: Basic interactions: menu navigation, pie menu and two continuous control techniques.

D20 prototype

To evaluate our ideas we implemented an early prototype of D20. We made a physical 3D model of the icosahedron (figure 5), and attached a Polhemus Fastrack 6DOF magnetic sensor which reported the 3D orientation of the model. We simulated an icosahedral display device using 3D computer graphics and the user observed the interaction on a screen. A mouse button was used to simulate the touch input.

Discussion and conclusions

We reviewed a number of shapes, both regular and irregular polyhedra. The icosahedron was chosen because of its regularity, simplicity and because it contained easily perceived shapes that allowed us to illustrate our ideas clearly.

We also explored very irregular shapes, such as figure 7, where we attempted to design a number of basic interaction blocks and then combine them together. However, we found that the resulting shape was too specifically oriented toward certain interactions or difficult to understand.

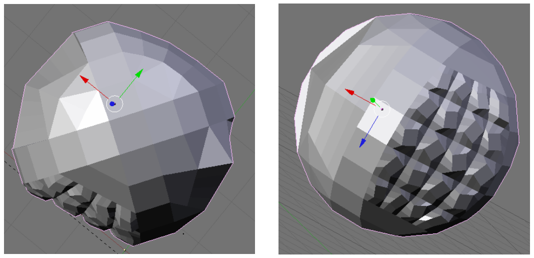

figure 7: Irregular multifaceted displays

We are not suggesting that the icosahedron is the "best" shape; there are many possible shapes that can be explored and all of them might have applications and interesting uses. The icosahedron is a single point in this large design space.

The main contribution of this work is to propose a set of basic principles for desiging multifaceted displays devices and their interfaces. Although we are currently looking at handheld devices, we believe that the same principles can also be applied to any multisided interactive display including large environmental displays or deformable displays, where the shape can be changed to change the function.

This, of course, is a work in progress. We are currently building a physical D20 device using LEDs arrays for displays and 3D rotational gyro sensor to track rotation. We will, however, continue to use our simulation platform to design new interaction scenarios and uses for multifaceted displays.

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