Selecting a Function by How Characteristic Shapes Afford Users

Makoto Oka[1], Masafumi Tsubamoto[2], and Hirohiko Mori[1]

[1] Tokyo City University, 1-28-1 Tamadutumi, Setagaya, Tokyo, Japan
[2] YAHOO! Japan, 9-7-1 Akasaka, Minato, Tokyo, Japan
{moka,hmori}@tcu.ac.jp, mtsubamo@yahoo-corp.jp

Abstract. This study focused on shapes in accordance with the affordance theory. We would like to propose as a substitute for a mouse a new interface that enables humans to instinctively select functions. Instead of making the optimally shaped devices for each function of computers, the aim is to instinctively select functions with a minimum device. To this end, we verify what shape of devices would enable humans to imagine and select all the functions. The present study takes a close look at “how devices are held”; and we conduct experiments, focusing on musical instruments that are held in different manners.

Keywords: affordance theory, select function, menu.

1 Introduction

Humans select shapes that are suitable for specific functions. For example, how do humans use sticks? They sometimes write characters and pick up nuts with sticks, but do not use the latter as chairs. As such, constrained by the shape and size of things, humans subconsciously narrow down their functions. As time goes by, originally simple-shaped tools become fragmented depending on their respective functions, and keep evolving until they become the most appropriate shape.

On the other hand, taking a close look at computers, one may notice that they have evolved in the opposite direction of the reality. For example, one computer has multiple functions, such as “drawing pictures”, “writing characters”, and “calculating”. These functions are expressed as icons and hierarchically structured menus, and manipulated with a mouse. Computers are distinct from the history of humans that have essentially conceived functions based on shapes. Humans cannot imagine the usage of mice that they directly touch.

The limitations that humans subconsciously have with respect to shapes are called the affordance theory [1]. Some alternative shapes to a mouse prepared with the use of affordances must enable humans to instinctively select and manipulate functions. Following the current hierarchical menu structure of computers, the phase of selecting the shape of such an alternative mouse would correspond to the first layer, and the phase of holding it in different ways would determine the second layer. Research on such “holding” interactions is underway.

S. Yamamoto (Ed.): HIMI 2014, Part I, LNCS 8521, pp. 621–628, 2014.

We call the “possibility of behavior constrained by the limitations that humans subconsciously have with respect to shapes and sizes” an affordance. To maximize the use of affordances, we would like to propose as a substitute for a mouse a new interface that enables humans to instinctively select functions. Instead of making the optimally shaped devices for each function of computers, the aim is to instinctively select functions with a minimum device. To this end, we verify what shape of devices would enable humans to imagine and select all the functions. The present study takes a close look at “how devices are held”; and we conduct experiments, focusing on musical instruments that are held in different manners. The study verifies whether users can identity a wider range of musical devices when they are given the opportunity to select and combine appropriately shaped devices for many musical instruments, compared to a case in which they are allowed to use a device of one single shape.

2 Related Work

Taylor proposed a function selecting method called “Grasp Recognition” [2]. Taylor made a device equipped with 72 touch sensors on its surface, displays on the front and back, and an acceleration sensor (Fig. 1). Those 72 touch sensors detected the points where fingers were touching the device. He examined how the subjects held the device in cases of a camera, a cell phone and a music player, as examples. He extracted data from 13 subjects, and analyzed the discrimination rates by machine learning. From the way they held the device, 70% of the discrimination rate was obtained for each of a camera, a cell-hone, and a music player. Taylor revealed that grasping could be one of the guidelines in selecting functions.

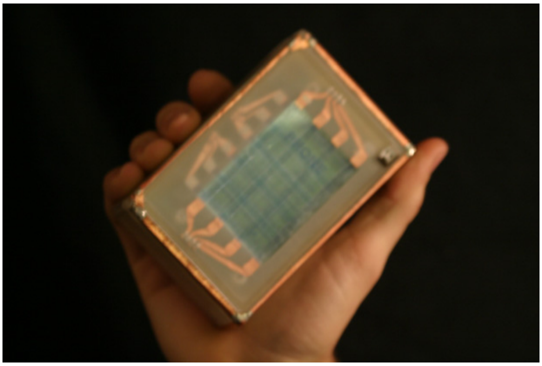

Fig. 1. Taylor's device (The Bar of Soap [2])

There have been studies of selecting the best functions by analyzing the grasping of a single shape of a device with multiple functions added. However, one single shape of a device limits the number of functions available to select from. We think that, thinking in the hierarchical menu, there would be too many functions in one hierarchy to select the functions by ways of grasping.

If we think about things that have evolved into the best shapes, it is difficult to think a knife to have evolved from a ball, or a glass to have evolved from a stick. If we trace things back to their origins, it is unthinkable that they all go back to one shape. Based in the affordance theory, it can be thought, by using a hierarchy of ‘shape’ before the hierarchy of ‘grasping’, we can increase number of functions. We think that combining objects of multiple shapes expands the range of functions and enables intuitive selections of functions.

3 Proposal

In this study, ‘the possibilities of actions determined by the shapes and the mass of objects, which we humans may subconsciously have’ are to be called ‘affordance’. In order to maximize the use of the affordance in digital world, we would like to propose new interface that replaces a mouse, which allows you to select functions intuitively. Instead of using a different device of a different shape to match each function in the computer, we aim to develop a minimal shape of a device that allows you select functions intuitively. For that purpose, we examine what shape of device best enables you to imagine all the functions and select them. In this study, we focused on ‘how to hold’ musical instruments, which people might have diversified ways. For each kind of instrument, users (subjects) were to choose the shape of device or combine some devices of different shapes to best suit to the imagined instrument, and we examined whether the discrimination range widens compared to the case in which one single shape of device was used.

4 Overview of System

We thought that, if we can identify fingers that are touching the device, we could select more functions. ‘Which finger, including palm, is touching where’ is, we call it, ‘finger touch information’; and we conducted function selecting by using the finger touch information. We limited the objects to only musical instruments, and we produced devices that are the supposed-to-be instruments, and glove type devices to obtain touch information. The devices measure the touch information, the tilt and the orientation of the devices.

When we hold something, there are two ways; one way is with fingers, and the other is with whole palm (Fig. 2). The difference is whether the palm is touching the object or not. If we can distinguish these two, then we would be able to judge the way he/she is holding the object.

When the shapes are similar, if we compare the ways of holding them, their postures may be different. In each device, by obtaining three axes of different angels against the ground, we can detect the differences.

Prior, we conducted a simple questionnaire to decide the shapes of the devices to be used in the study. Following the results of the questionnaire, we excluded complicated shapes, and selected five simple shapes of; elliptic column, cubic, circular corn, long and thick stick, and short and thin stick. Probably because sticks are versatile, these two types of sticks were selected, and we prepared both.

Fig. 2. How to hold (left: with fingers, right: with whole palm)

Fig. 3. Five objects (devices) for experimental system

We used two Arduinos to prepare the experimental system. The five devices we prepared were, as mentioned above, an elliptic column, a cubic, a circular corn, long and thick stick, and short and thin stick, and we also prepared gloves for both hands that can discern the fingers and the palm (Fig. 3).

5 Evaluation

We conducted discrimination experiment of the musical instruments as an example of function selection by devices. By discriminating instruments by the ways of holding the multiple shapes, we examined function selection when multiple shapes were used.

5.1 Musical Instrument (Function List)

The subject matters were string instruments, wind instruments and percussion instruments. Eleven instruments were studied. Eleven instruments of cylindrical shapes were; violin, guitar, cello, trumpet, saxophone, flute, piccolo, clarinet, recorder, ocarina and harmonica.

5.2 Evaluation Method

Experiment was conducted with 30 university students as subjects. As an example of single device function selection, we obtained data of the subjects' ways of holding the device imagining each instrument. Then, having the subjects choose a device best suited to each instrument from five devices of different shapes, we obtained data of the subjects' ways of holding device imagining each instrument.

Among those eleven different instruments, if the students (subjects) did not know certain instrument, or how to hold it, we excluded that data. We examined the discrimination rate by the finger touch information, the inclination of the device(s) and the selection and combination of the device(s). In order to validate the advantage of the multiple device function selection in comparison with the single device function selection, we used 'k-nearest neighbor algorithm' to conduct function selection. We used KStar of Weka 3.6 as k-nearest neighbor algorithm[1]. Afterwards, we conducted two-step classification; first by the shapes, using decision tree method; then by the ways of holding, and tried to validate the effectuality of the function selection by the shapes. We validated the data by 'cross validation', which enabled all data to be used as the classification data and the learning data.

6 Result

6.1 Selected Devices

When multiple shapes of devices are used, some instruments had divided tendencies of shape selections. In case of the violin, the selections of shapes were divided into two. One was elliptic column and the other was long stick.

In the case of the guitar, some subjects picked one device, the long stick; and others picked two devices, the long stick and the elliptic column, to express the instrument. The combination of the long stick and the elliptic column were thought to be more accurate for the shape of the guitar, but as it restricted the way of holding, more subjects picked the long stick only to express the instrument. For the cello, most of the subjects used two devices; the long stick and the short stick. Only one device was picked to express; the saxophone, the flute, the piccolo, the clarinet, the recorder, the ocarina and the harmonica. The long stick for the saxophone and the clarinet, the short stick for the flute, the piccolo and the recorder, the elliptic column for the ocarina, and the cuboid for the harmonica.

6.2 Result of One-Step Classification

With all the data obtained from the experiment, we conducted the instrument discrimination. We evaluated the function selection by using k-nearest neighbor algorithm, comparing the multiple shape device selection and the single shape device selection.

[1] http://www.cs.waikato.ac.nz/ml/weka/

In this study, we assumed that the long, thick stick is the most universal shape, and used it as the single shape device experiment.

We output the results of the single device discrimination to a table 1. Then, we studied the finger touch information, the inclinations of the devices, and the device selections and combinations in the feature quantity, and we output the results of the discriminations to the chart. Furthermore, in order to compare both cases, we indicated the conformance rate, the recall factor and the F-measure of each case in the chart.

The F-measure in the single shape device (the long/thick stick) was as low as 38.7. For the reasons of this low F-measure, the mix-up of the flute and the piccolo, and also mix-up of the sax, the clarinet and the recorder could be thought. The errors of recognitions of these instruments lead to the low F-measures. This corresponds to the fact that the subjects were remarking during the experiment, “we don’t know the exact difference of each of these instruments”. When the multiple shapes of devices were used, the F-measure was as high as 64.1. From these results, we can say that the function selection by using the multiple shapes of devices is more effectual than the function selection by simply ways of holding a single shape of a device.

As regard to the piccolo and the clarinet, the F-measure of each was as low as 25.0. It is possible that the subjects did not know the instruments enough. It was noted that, during the experiment, some subjects were holding the piccolo vertically, and holding the clarinet sideways. The data is thought to contain obvious errors of holding the instruments, causing miss-discriminations.

As some of the subjects obviously did not know how to hold some instruments, we, then, conducted a study and discriminations once again with the data of only those who answered ‘they were sure of holding the instrument correctly’ (subjects with high self-evaluations). The result of the learnt data of the subjects with the high self-evaluations was 69.3, and was much higher than the result of all data used for the discrimination.

Table 1. Result of One-step Classification

	Single shape			Five shapes		
	precision	recall	F-measure	precision	recall	F-measure
violin	0.571	0.640	0.604	0.824	0.519	0.636
guitar	0.615	0.615	0.615	0.828	0.857	0.842
cello	0.583	0.824	0.683	1.000	0.526	0.690
trumpet	0.323	0.385	0.351	0.654	0.630	0.642
sax	0.300	0.261	0.279	0.429	0.545	0.480
flute	0.500	0.391	0.439	0.500	0.667	0.571
piccolo	0.067	0.100	0.080	0.286	0.222	0.250
clarinet	0.000	0.000	0.000	0.217	0.294	0.250
recorder	0.294	0.370	0.328	0.633	0.679	0.655
ocarina	0.571	0.462	0.511	0.815	0.815	0.815
harmonica	0.176	0.120	0.143	0.800	0.769	0.784
total	0.387	0.396	0.387	0.670	0.634	0.641

Some of the subjects evaluated themselves high, although they had wrong ways of holding the instruments. We, then, excluded them, too, from the discrimination experiment. The discrimination rate was 71.5, in this case. However, as we have excluded some data, the number of samples turned out to be extremely low.

6.3 Result of Two-Step Classification

From the affordance theory, it can be said that we, humans, were controlled by the shapes of objects. With this in mind, we, first, conducted classification by the shapes, using the decision tree; and then we classified the output by the ways of holding them. The results of this two-step classification show table 2.

Table 2. Result of two-step classification

	One-step			Two-step		
	precision	recall	F-measure	precision	recall	F-measure
violin	0.824	0.519	0.636	0.900	1.000	0.947
guitar	0.828	0.857	0.842	0.947	1.000	0.973
cello	1.000	0.526	0.690	1.000	0.714	0.833
trumpet	0.564	0.630	0.642	0.714	0.714	0.714
sax	0.429	0.545	0.480			
flute	0.500	0.667	0.571	0.875	0.875	0.875
piccolo	0.286	0.222	0.250			
clarinet	0.217	0.294	0.250	0.833	0.833	0.833
recorder	0.633	0.679	0.655	1.000	0.960	0.980
ocarina	0.815	0.815	0.815	1.000	1.000	1.000
harmonica	0.800	0.769	0.784	1.000	1.000	1.000
total	0.670	0.634	0.641	0.919	0.900	0.906

The discrimination rate of the functions was 78.2 after this two-step classification, but the discrimination rates for the piccolo and the saxophone were too low to be classified correctly.

The instruments with low discrimination rates (the piccolo and the sax) were, when the decision tree was used, classified into the same group. The discrimination rates were low as the piccolo confused with the flute, and the saxophone confused with the clarinet. During the experiment, some subjects commented, “there is no suitable shape for the saxophone”.

Having conducted the analysis with the piccolo and the saxophone excluded, we obtained F-measure of 90.6.

7 Discussion and Conclusion

In this study, we focused our attention on the function selection by the shapes based on the affordance theory. We experimented the function selection by the ways of holding multiple devices of different shapes. The functions were limited to the musical instruments of eleven representing instruments. When we compared the discrimination rates of the single device experiment and multiple device experiment, the latter showed higher discrimination rate of 64.1, higher by 26 points.

We, then, conducted classification, using the affordance theory, by shapes first, and then by the ways of holding. The result was, compared to the case we input the data in the classifier based in the shape and the ways of holding together, 78.2 of discrimination rate on the instruments, 7 points higher. As some instruments were similar in shapes and ways of holding, we limited the instruments to 9 different kinds, and re-evaluated the rate, which yielded an extremely high discrimination rate of 90.6 on the instruments.

This result revealed that the shapes are more important than the ways of holding, and the multiple shapes can lead to higher discrimination rate than the single shape, widening the range of functions available to select from.

8 Future Work

Most of the subjects in this study were inexperienced with musical instruments. It is possible that we could not obtain ideal training data. We think it is necessary, by limiting the subjects to those who are experienced with instruments, to obtain ideal training data and create a database. And, as the number of the subjects with experiences with musical instruments was small, the number of the samples and the data quantity was limited. In the future, we should increase the number of the samples.

In this study, we evaluated the selection of the musical instruments. In the future, we think it is also necessary to conduct an experiment and evaluations on more universal functions.

References

1. Gibson, J.J.: The Theory of Affordances: Perceiving, Acting, and Knowing. John Wiley & Sons Inc. (1977)
2. Taylor, B.: Grasp Recognition as a User Interface. In: CHI 2009 Proceedings of the 27th International Conference on Human Factors in Computing Systems, pp. 917–925 (2009)