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Definition of Tactile Interactions for a Multi-Criteria Selection in Learning Geometry Application

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ABSTRACT

Tablets, smartphones are becoming increasingly common, and interfaces are predominantly tactile and often multi-touch. More and more schools are testing them with their pupils in the hope of bringing pedagogic benefits. With this new type of device, new interactions become possible. A lot of studies have been done on the manipulation of 3D objects with 2D input but we are only at the beginning of studies coupling pedagogical needs and the possibilities of these new interactions. FINGERS© is an application for learning spatial geometry. It's developed for pupils from 9 to 12 years old. Interactions have been designed with teachers. Some interactions are specifics for 3D geometry (3 DOF translations, rotations, nets, combinations of cubes, etc) and some are general like designation or multi-selection. Many grammars of gestures propose a set of interactions to select an object or a group of objects. Multi-taps and lasso around an area are commonly adopted interactions. Performing geometry exercises requires new interactions. For example how selecting all Cubes, how selecting all green objects. The real question is how to introduce a parameter in selection. After presenting the limits of current solutions we present the solutions developed in FINGERS©. We explain how they allow a "parameterized" selection.

Keywords: Tactile Surface, Tablets, Gestures, Cognitive, Human-centered design, iPad

INTRODUCTION

The commercial success of tablets requires researchers in human-computer interaction to imagine new ways to interact with tactile surfaces. Today, we can use it in an individual way (Wellner 1993), in groups (Martinet et al. 2010), as part of multi-display environments (Forlines et al 96), and for fun and entertainment (Wilson, 2005). These devices provide interaction techniques that are often intuitive and easy to use in 2D. However, manipulation of objects in 3D is still a challenge. Manipulations in 2D have been defined very simply (selection, moving, designation). Things become more complex when we needed to perform manipulations in space. In a 3D environment, widgets (Morris et al. 2006) have been largely used to make 3D manipulation easier. Moscovich (Moscovich, 2009) had shown how to design touchscreen widgets that respond to a finger's contact area. Designating an object in 2D or 3D is relatively simple. A user would naturally choose a direct touch on an object. Selecting a group of objects can be done either by increasing touches or by drawing an area around a group of objects (the lasso technic or selection box). Both approaches seem to meet all the needs and few works propose solutions for more complex designations. For example, what grammar of gestures to select all objects with the same geometric shape? What grammar of gestures to select objects with the same color? This paper proposes to explore innovative and intuitive solutions to provide simple solutions to a problem that can be complex.

Related Works

Multi-touch surface computing provides a set for interactions that are closer analogs to physical interactions. Building natural and intuitive gestures is sometimes a difficult problem. Sometimes the gesture is not natural. How to define a gesture to move an object in a virtual world along 3 directions with only one hand? (Bertolo et al. 2013 b) or two-handed (Martinet et al. 2010). When you have only one hand to point, to move, and to turn an object, your possibilities to interact with its entity are poor. In 2009 Moscovich (Moscovich, 2009) shows how to design touchscreen widgets that respond to a finger's contact area and gives limitations on the design of interactions based on sliding Widgets. Imagining new interactions (grammar of gestures) became a necessity. Schmidt (Schmidt et al. 2008). present an interface for 3D object manipulation in which standard transformation tools are replaced with transient 3D widgets invoked by sketching context-dependent strokes. Many works try to define affording gestures that reduce learning and memorization of the interaction. Understanding users' mental models will improve a better knowledge of relationships between technology and users. From an analysis of people collaborating around a drawing table, Tang (Tang 1991) observes that gestures appear as an element of simulation for operations, referring to an area of interest in connection with users.

Some studies focus more specifically on handling objects in a workspace in 3D. Gestures are more complex and less intuitive. It is common to incorporate the users to involve the input systems and mainly grammars gestures (User-centered design). Cohé (Cohé, Hachet. 2012) conducted a user study to better understand how non-expert users interact with a 3D object from tactile inputs. Users defined gestures to perform rotations, scaling, and translations (RST) of a cube displayed on the screen. Their study shows a wide disparity for gestures suggested by users. The most suggested gesture by users represents only 17.9% of proposals. The sixth gesture gets even 8.6% of suggestions. In 1986, Bier (Bier, 1987) introduces two classes (two widgets): "anchors" and "end condition" to precise placement of shapes relative to each other. Since this first definition and tactile interface building, widgets used in 3D manipulation are in rapid succession. But, when you use your finger to point, to move, and to turn, your possibilities to interact with an entity are reduced. Some studies explore multi-touch controls to manipulate several degrees of freedom at the same time. Hancock (Hancock et al. 2009) (Hancock et al. 2019) proposed to use from one to three fingers to handle objects in shallow depth. Martinet (Martinet et al. 2010) explored the

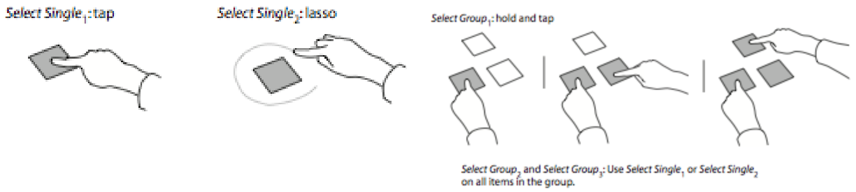

Figure 1: Wobbrock's propositions for select single or select group.

design of free 3D positioning techniques for multi-touch displays to exploit the additional degrees of freedom provided by multi-touch technology. Their contributions are twofold: in a first time an interaction technique to extend the standard four viewports technique found in commercial CAD applications by adding a teleportation system, and in a second time, they introduce a technique designed to allow free 3D positioning with a single view of the scene: The Z-technique. From a short preliminary study, Cohé (Cohé et al. 2011), shows that selection of the DOF controls is difficult as soon as the graphical elements project close to each other on the screen. They note that it is difficult to control all the DOF when they are displayed at the same time. They propose an alternative approach and build a tBox controlled with a finger. User-centered design is a way of designing human-computer interfaces. But you have a gap between users and designers. Users' behaviors are often complex to develop and often inefficient for design. Foley (Foley et al.) observes that a user-computer dialogue is at the beginning of all languages of inputs and outputs. As in speech recognition, feedback is inevitable to develop an exchange between two entities (humans or not). In its work on user-defined gestures, Wobbrock (Wobbrock et al. 2009) tries to control this feedback to prevent revision by the user of his mental model. Participants perform a gesture to pan a field of objects after a learning animation. The initial hypothesis is that any action or command cannot be performed by a gesture. "So what is the right number of gestures to employ?" He developed a field experience with 20 participants. They presented to users a set of actions, such as Cohé (Cohé, Hachet 2012) a set of 27 commands and then asked them to imagine the corresponding gesture.

PROBLEMS WITH CURRENT SOLUTIONS

With a small number of objects or in specific situations the problem of multi-selection is always simple. The gesture created, to solve this problem, are easy to understand, simple to realize, and very efficient. The two main options use a lasso or a designation by multi-touch (Figure 1).

These object selection gestures are often presented as effective and affordable solutions, but they are not suitable when complexity increases. They do not answer the following questions

- How select all the squares/cubes/circles?
- How select all red objects?
- How select all wired objects?

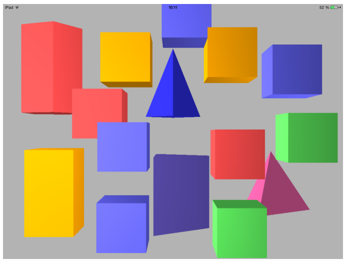

Figure 2: Example of situation containing multiple objects in FINGERS©.

If we extend the question, how selecting objects by providing parameters like form, color, or representation. According to teachers of primary school, we have included in our application FINGERS© different categories of selection. After presenting FINGERS© and its functionalities we describe the solutions adopted for the selections of objects.

FINGERS APPLICATION

FINGERS© (Find INteractions for Geometry learNERS) is an application on tactile tablets that help young students to learn geometry in 3D space (Bertolo et al. 2013 a) (Bertolo et al. 2013b) (Bertolo et al. 2013c). We have restricted our study to mobile devices like the iPad (This tablet is present in many schools in France). The main goal is to manipulate a solid accurately even if one. Moreover, the scene can contain several mathematical objects like Cube, Sphere, Pyramid, and parallelogram. To permit the largest possibilities of manipulation, each solid had to be independently manipulated as well as the entire scene. To test potential pedagogic benefits of our set of interactions we have implemented a prototype with different functionalities:

- Creation and suppression of solids with tangible objects
- Selection
- Translation
- Duplication
- Manipulation of a net of a polyhedron
- Rotation
- Changing the position of observer with gyroscopic sensor and video camera metaphor.

PROPOSITIONS FOR MULTI-SELECTION

Figure 2 shows a simple example of problematic. Imagine that the user wishes to select all blue cubes or all parallelograms of different colors (green, red, yellow, and blue). Using Lasso technic or selecting one by one objects is difficult indeed impossible. We can also argue by subtraction. How to select all objects except the pyramids or all green cubes except the one in the bottom left corner?

The generalization of the problem is how to introduce a parameter like a number, color, form, representation indeed position in a tactile selection

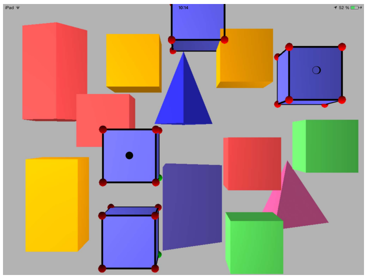

Figure 3: Gesture to select all blue cubes.

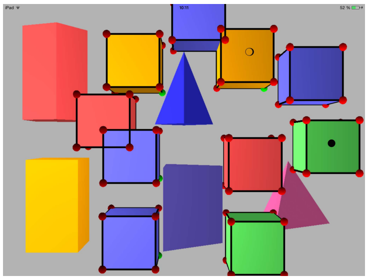

Figure 4: Gesture to select all cubes

query. In FINGERS© application, a long touch is used to select an object. A simple tap is not used as a principal action on an object. The easiest way was using these interactions to build action of multiple selections. We maintain consistency with the other actions, the interaction is easy to remember and very efficient. According to Kammer (Kammer et al. 2010) we define the syntax of our grammar gesture that is an extended Backus Naur Form. A small proportion of this grammar used for selection ⊙ is: for a long touch, ● for a tap, + Two gestures performed in an asynchronous manner, * Two gestures performed in a synchronous manner

A multiple-selection can be written: Multi::=(Initial object) + ● (Destination object).

Selecting all Same Objects

For example, to select all blue cubes you perform a long touch on an initial object and a tap on the destination object. Initial and final objects have the same form, same color, same representation (plain or wire), and different positions in space. FINGERS© understands that selection must be realized for all blue cubes and select them with only one gesture (Fig 3).

Selecting all Same Forms

To select objects with the same shape (not necessarily the same color) you must apply the same interaction of selection on the two objects (Long touch on one and a tap on the other one). Figure 4 shows for example how to select all colored cubes.

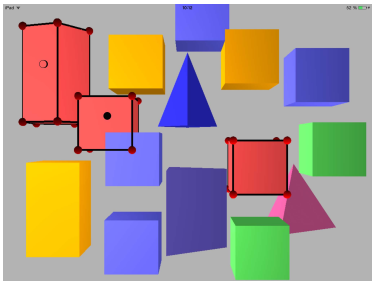

Figure 5: Gesture to select all red objects.

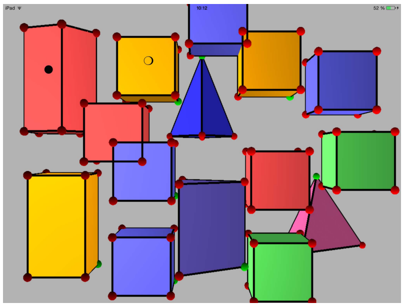

Figure 6: Gesture to select all objects.

Selecting all Same Colors

Similarly, we can select all objects with the same color (whatever their form or modeling). Figure 5 presents the selection of red objects.

Selecting all Objects

There is still a function that is the selection of all objects. When the action involves two unrelated objects, interaction must be applied for all objects of 3D space. A long touch on an object and a tap on another one (having no common features) will select all elements (Figure 6).

Unselect One Object from the Selection

Sometimes it's necessary to realize an incomplete selection. For example, we need to delete all green cubes except the cube localized at the left-down corner. The intuitive step is:

- Selection all objects
- Unselect one cube (left-down corner)
- Delete all selected cubes.

From a selection mode, an object has two states. On one hand a state is "selected" on other hand an "unselected" state (it's a binary state).

⊙(blue cube) + ● (blue cube): It's interaction to do to select all objects. This final state is shown (Fig. 7a) by a symbolic red vertex on all green cubes.

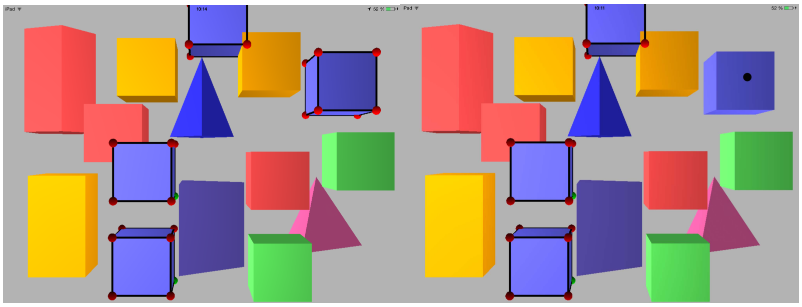

Figure 7: a) All blue cubes selected. b) Only one cube unselected (at right).

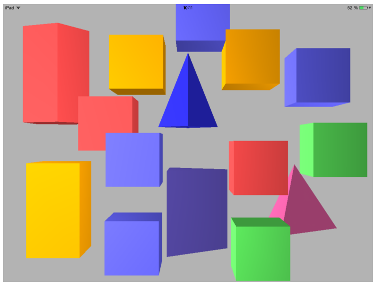

Figure 8: Back to start situation.

● (blue cube): a tap on a selected cube changes his state only. All similar objects stay selected, and we can manipulate them in only one interaction (Fig. 7b).

A long touch on an empty space unselecting all objects (Figure 8).

CONCLUSION

With the development of tactile devices, software designer has imagined interactions to perform complex tasks. Sometimes, an action deemed simple has not been of particular attention. The problem of selecting multiple items is a good example. This paper shows that the problem may be more complex, and the solutions developed are insufficient. We propose a simple and effective approach based on two common gestures a long touch and a tap. The proposed actions are intuitive. We can select groups of objects by varying different criteria. Our selection mode allows designation with three different criteria (shape, representation, color). Without common criteria, our gesture will be interpreted as a selection of all the elements. We could imagine other criteria such as position, orientation, or size by changing only a small part of the interaction. This solution is integrated soon into our FINGERS© and tested in the actual software.

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