Physical-Gestural-Parametric: Learning through graceful transition

Chreston Miller, Yannick Verdie, Francis Quek, Anurodh Joshi, and Roger Ehrich

Introduction:

We are interested in the use of tabletop surfaces for interactive manipulations. We focus on the implementation of Image Processing algorithms and techniques in two projects exploiting a horizontal surface: 'Tangram Project' and 'MirrorTrack'. The 'Tangram Project' studies children's mathematical skills when manipulating geometrical shapes. This project is supported by NFS (NSF 0736151) based on the proposal 'Social Organization, Learning Technologies & Discourse: System Features for Facilitating Mathematical Reasoning in PreK-3 Students' by M. Evans, F. Quek, R. Ehrich and J. Wilkins.

The motivation of the technical work described here is to bridge between direct interaction with physical manipulatives that emphasizes geometric intuition and problem solving and indirect virtual manipulation of geometric forms through control of parameters. While the former encourages geometric reasoning and conceptualization, it hides the details of geometric formalization. The latter requires conceptualization of parameters and operations, but may impede development of problem solving intuitions.

Our contribution is the design and realization of vision-based tracking software that could be used in a classroom, and that transitions gracefully between physical interaction, gestural manipulation, and indirect interaction through the control of parameters. Our implementation offers three modes of interaction making it easier to study the children's behaviors in specific situations and constraints.

Overview:

Our goal is to design a system supporting three modes of interactions. Those modes are chosen in order to study the Mathematical reasoning of children confronted to geometrical games and puzzles. The system runs on a custom-designed display table that features a 30" display embedded in a coffee-table-sized interaction surface.

The first mode emphasizes the physical manipulative by supporting tracking and manipulation of physical objects laying on the table. These objects could be manipulated by the children. The system tracks the objects as they are manipulated and places 'graphical shadows' of the objects on the table.

The second mode emphasizes the virtual manipulative by supporting fingertip-tracking, allowing manipulation of virtual objects displayed on the table. These objects can be rotated, or translated based on the gesture. In this mode, the student has to think of the 'kind of operation' to perform on the virtual tangrams, but the actual degree of transformation and the decomposition of coordinate systems is not made explicit.

The third mode emphasizes the parametric manipulative by supporting physical proxy – a physical object with a symbol on top of it. The symbol indicates the 'kind of operation' supported by the proxy (known to the student as the 'magic controller'). By placing the object on the table, and rotating it, the student may, for example, be able to move the selected virtual tangram object horizontally, vertically, or rotationally. The degree of movement of the proxy controls the quantity of the specific parameter.

Setup and design:

To allow the use of these three modes, we design a tabletop table with a LCD screen and a overhead camera on top of it. This LCD screen is horizontally mounted inside the table allowing users to gather all around for collaborative use the device. A dedicated computer processes the camera frames to supply real time interaction for users. Our system can recognize up to four distinguish users.

The Tangram software implementation is structured in two layers. The low layer is composed of the Image Processing algorithms that recognizes and localizes monochromatic plastic shapes, user's fingertips, and stands for the proxies. The top layer provides placement of virtual tangrams on the table based on the location of the physical tangrams. These virtual tangrams, or shadows of the physical tangrams, can be interacted with by the user through gesture recognition and the provision of a virtual physics engine that enforces inter-object interaction (e.g. collision, and pushing of other objects). These capabilities of the top layer provide manipulation and gesture interaction in the form of highlighting, selecting, moving, and rotation of the virtual tangrams. Moreover, the proxies can be placed on the table to manipulate a virtual objects. Indeed the direct manipulation of these proxies allow a control of the virtual objects displayed on the table.

In short, the low layer scans each frame grabbed by the camera to detect tangrams on the table based on their color and shape. A tangram database is used to reconstruct the shape in case of occlusion of the tangrams. Depending on mode of operation, either tangram positions, fingertip locations, or proxy configurations are communicated to the top layer to allow interaction with the virtual tangrams.