Above-the-Table Interactions for Intelligent Sensing Systems

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***Abstract*—We discuss in this paper above-the-table interactions as they were implemented in order to provide enhanced human-computer interfaces for several commonly encountered application scenarios: manipulating virtual objects, playing computer games and working collaboratively with robotic systems. We present the benefits of above-the-table interactions achieved in the context of video-based acquisition and discuss simple implementation techniques for each of the applications scenarios.**

***Index Terms*—computer vision, HCI, image processing, robotics, tabletop interaction**

I. INTRODUCTION

Applications today require more appropriate interaction techniques due to the specific tasks, scenarios or workloads they implement, beyond the interactions commonly provided by standard input devices. Common examples are virtual environments that require proper pointing, selection or manipulating techniques that would not importunate, add extra cognitive load or distract users from the actual task to accomplish [1, 2]. Computer games are also good examples of applications that would benefit from advanced interaction techniques beyond standard controllers [3, 4, 5] when addressing issues such as characters control, degree of immersion or level of reality. Controlling robots and even more, working in collaboration with robotic systems, are in demand of interaction techniques that need as well to prove easy to perform, achieve and master.

Human gestures as natural means for human-computer interaction have been given attention in the last decades since the very first Bolt's demonstration of put-that-there [6]. Gestures present the inherent advantage of natural and flexible interaction which leads to experiences that are similar to what people are used with when carrying out their everyday work [7, 8]. More recently, tabletop systems allow for on-table interactions by mixing gestures, direct touch and video projections which in the end lead to natural, intuitive and flexible interactions [9, 10, 11].

The focus of this paper is to discuss specific implementations of above-the-table interaction techniques and how they enhance standard interfaces. We bring into discussion for this purpose three application scenarios that were developed along the years in our laboratory for which the novel above-the-table approach brought a new level of interactivity.

This paper is organized as follows: section 2 describes the working scenario that we used in order to acquire the above-the-table interactions for all our implementations; chapter 3 deals with manipulating virtual objects using simple gesture commands whilst working at the interaction table; chapter 4 discusses an interesting enhancement that an intelligent desk brings to computer games that allows context information from the real world, as presented on the interaction desk, to become virtual context inside the game; chapter 5 presents an above-the-table collaborative working scenario with a static manipulation arm-robot. We present our conclusions in the last section of the paper.

II. WORKING SCENARIO

We start by describing the general acquisition scenario that we use through all of our experiments: users sit in front of a table while a video camera permanently monitors a working area on the table surface. Visual feedback of the user's actions is available on the display monitor located at the opposite end of the interaction table. The working scenario is illustrated in Figure 1.

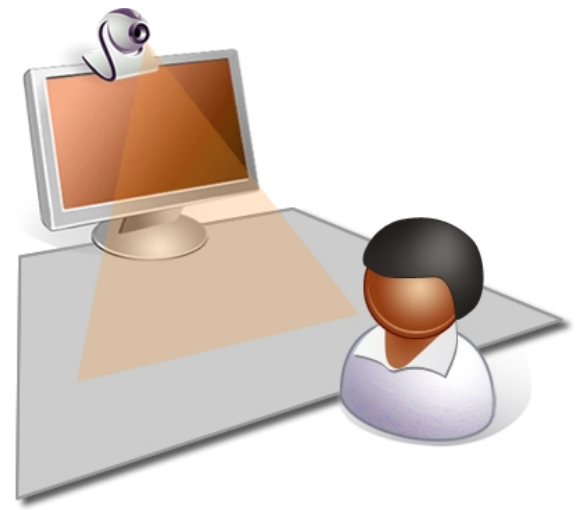

Figure 1. Interaction scenario: users sit comfortably in front of the working table facing the monitor screen while a video camera monitors the interaction area on the table surface.

The setup approaches somewhat the same scenarios specifics to tabletops [9, 10] and assures a non-fatiguing interaction due to the comfortable sit position whilst the arms may rest as well on the surface of the desk. Allowing hands to rest reduces the fatigue factor that may intervene for longer working intervals. Also, the scenario has the advantage of being similar to others that users are already accustomed with such as working with objects on a desk or typing at a keyboard while watching the monitor screen.

The video camera monitors the desk as well as the users' hands, the various gestures they may execute. Various objects may be placed, removed or translated on the surface of the desk with a direct correspondence within the application and with a permanently visual feedback on the monitor screen.

III. MANIPULATING VIRTUAL OBJECTS

Working with virtual objects may be performed naturally and intuitively using hand postures and gestures while sitting comfortably at the interaction desk.

Hands may be detected above the desk by making use of a skin filter algorithm [12] and ensuring that a certain amount of contrast exists between the hands skin and the table color. Detected blobs may be further filtered by geometric constraints such as minimum and maximum width, height, area or aspect ratio [13] in order for only the hands objects to be identified in the end. Many techniques are available for posture and gesture recognition [8, 14, 20] hence simple postures such as point (forefinger pointed), grab or pinch (thumb touching the forefinger) or hand open or closed may be easily recognized. Neural networks may be used in order to discriminate between previously learned postures [19].

In order to perform simple manipulation of virtual objects, a basic set of operations such as selection, translation, rotation and rescale have been implemented [21]. Manipulations are carried out with one or both hands as Figure 2 and 3 illustrate. By keeping all the processing at a low level of complexity and by considering an appropriate control of the environment, we obtained a real-time 25 fps functional system with high detection and recognition accuracy results.

The result in the end is natural interaction with operators using their hands only in order to select, move, rotate or change the scale of virtual objects.

IV. ENHANCING GAME INTERACTION

Computer games are another example of application type that would benefit from appropriate interactions. They represent an important part of the computer industry which has consequently led to many devices and techniques being developed over the years: dedicated hand-held controllers, gesture acquisition using accelerometer-based devices [5] or video cameras that bring the actual players' images and movements into the game: the EyeToy [15] device.

Current available devices are designed to capture users' intentions and transpose them accordingly into the corresponding action of the controlled character in the game. Users only have control over their characters and are not provided with means of changing the game's environment. Dealing with this limitation may be done by implementing context-based interaction [16] in an on-table like scenario as the one presented in Figure 1.

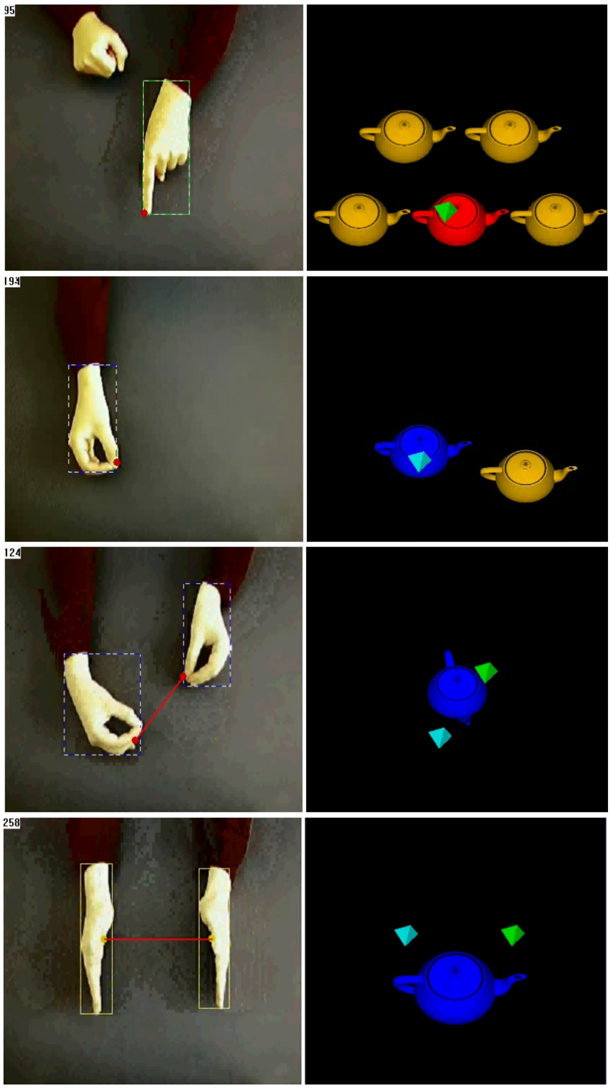

Figure 2. Interacting with virtual objects (teapots) using hand postures above the table. Starting from top: selecting one virtual object amongst many; moving the object in the virtual space; rotating the object; changing the scale of the virtual teapot are demonstrated.

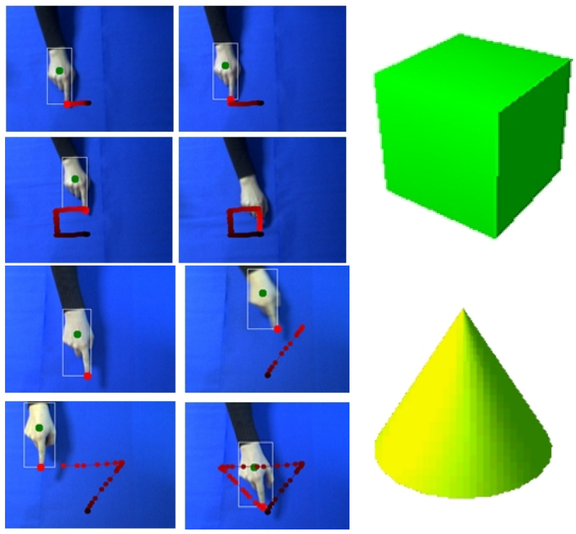

Figure 3. Creating virtual objects using simple hand movements above the table surface: a cube is created when the user performs a rectangle shape while the cone corresponds to the triangle gesture.

During context interaction the video camera monitors the surface of the table on which various real objects may be placed. Using simple computer vision techniques such as color filtering and segmentation against the table's homogenous background, the objects are detected and transformed into elements of context in the game.

A simple example of above-the-table interaction may be discussed for the classical Pong game. In the original game, players control palettes on the left and right sides of the board, trying to return the ball back to the opponent. Objects that are placed on the interaction table are translated into walls of bricks that make the ball bounce more quickly and even before reaching the opponent player. Even more, by changing the position of the objects across the table, the corresponding walls of bricks in the game will change position as well. Adding or removing objects determine similar context changes on the Pong board.

Such on-table interactions prove to be simple and intuitive and, very important, may be performed with no effort and no extra cognitive load at all. Players can very well carry on with their game while they simply add or move walls of bricks into the game. The effect in the end is that above-the-table and on-table interactions lead to an intuitive and flexible interface which brings a new dimension for the Pong game. The concept may be very well extended to other gaming scenarios besides board-like games.

We have presented our interaction technique to several people and we received a very positive feedback in what concerned their reaction. During the "Open Doors" action organized at the Faculty of Electrical Engineering and Computer Science (Suceava, Romania) during 31 March – 4 April 2008, approximately 100 pupils from the terminal grade together with accompanying teachers visited our laboratory and we introduced them to a promotional video of our game prototypes. Their reaction was one of pleasant surprise due to the novelty of the interaction we proposed and one of excitement - "where can I get this from?" one of them asked. They showed themselves interested in the technology which motivates us to further continue our work as, in the end, they represent a considerable part of the target of the computer games industry (ages between 16 and 18).

V. COLLABORATIVE WORKING WITH ROBOTS

Appropriate user interfaces are required for robot controlling applications as well. Requirements may vary from case to case however a few of them seem to apply to all cases: commands that are easy to describe, graphical interfaces, a minimum amount of system knowledge required. The interfaces should be easy-to-use, as friendly and familiar to the users as possible and should allow users to concentrate on the task rather on how to achieve it.

We present in this section a simple and easy-to-use interface for working together with a manipulating arm-robot. Minimum knowledge is assumed from the user although rather complex operations of detection, grabbing and moving objects in the working area are performed from the robot's side.

The interaction scenario is illustrated in Figure 4 where the work-partner, the robot, was added. The same comfortable scenario applies with direct correspondence in the real world: users face the robot working together just like they would share tasks with a real person.

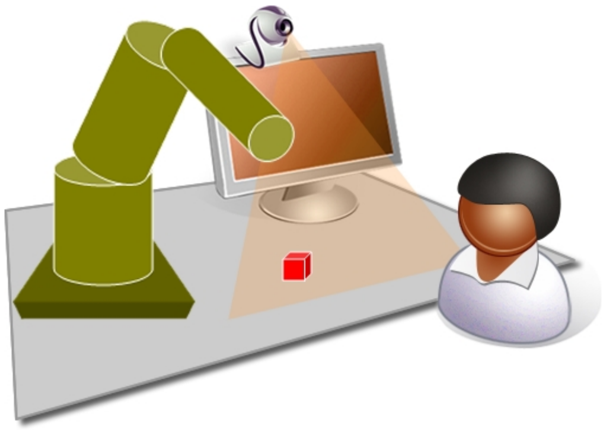

Figure 4. Interaction scenario for working with a robot in a collaborative environment across the table.

The robot was designed and developed at the laboratory [17, 18] in order to detect, pick up and move objects in its reach area. The robotic arm posses 5 DOFs allowing it to control its base, arm, elbow, wrist and claws (open / close). The robot's "eyes" are represented by the information delivered by the top-mounted video camera. Using image processing techniques such as threshold-based segmentation, light-colored objects (4 cm wide white cubes) are spotted against the darker color of the desk. In the end, both users and the robot may place, remove or move cube objects in the working area in a collaborative scenario. Figure 5 presents a snapshot of the actual interaction process: the user places an object on the working desk in the robot's reach. The semi-circular region represents the lower and higher bounds the robot is physically able to reach. Interactions take place on the working desk using the same comfortable on-table techniques.

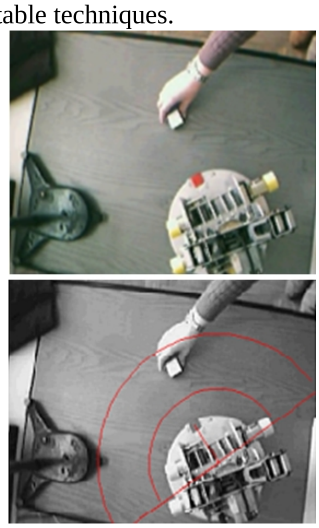

Figure 5. Collaborative working. Top: user placing an object on the table. Bottom: robot detecting the object inside its reaching area.

VI. CONCLUSION

We presented in this paper several implementations of applications that were enhanced with on-table and above-the-table interactions. Such novel interfaces add to existing ones and provide intuitive, natural and flexible interactions by the use of postures and gestures (when manipulating virtual objects) or direct-touch (for game and collaborative working interactions). The direct-touch and use of every day gestures make them attractive as alternative or complementary techniques with respect to currently existing devices.

As future work we envisage applying on-table and above-the-table interactions to other application scenarios. We already demonstrated how games or virtual reality are appealing candidates but what are types of applications may also benefit from this type of interactions? It would also be interesting to see if on-table interactions are better suited for providing complementary interfaces or whether they should replace existing ones. Proper studies on the actual usability of these novel interfaces should be performed in order to measure their actual effectiveness in comparison to other techniques.

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