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# SuperVision: Spatial Control of Connected Objects in a Smart Home

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**Abstract**

In this paper, we propose SuperVision a new interaction technique for distant control of objects in a smart home. This technique aims at enabling users to point towards an object, visualize its current state and select a desired functionality as well. To achieve this: 1) we present a new remote control that contains a pico-projector and a slider; 2) we introduce a visualization technique that allows users to locate and control objects kept in adjacent rooms, by using their spatial memories. We further present a few example applications that convey the possibilities of this technique.

**Author Keywords**

Smart Home; Pico-projector; Spatial memory; Visualization; SuperVision

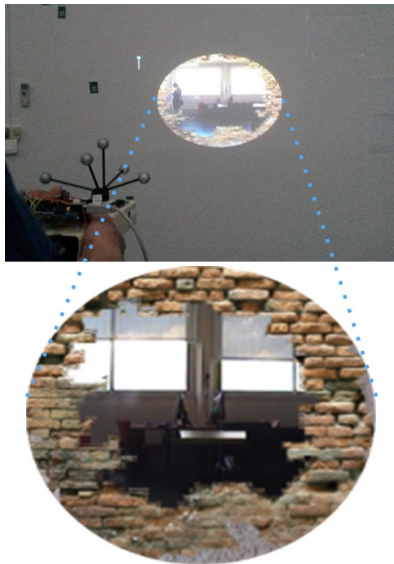
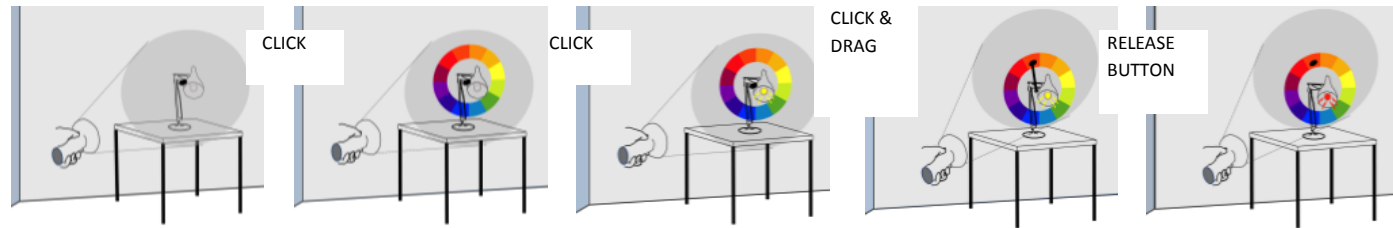
**ACM Classification Keywords**

H5.2 [Information interfaces and presentation]: User Interfaces – Input Devices and Strategies.

**Introduction**

A smart home contains devices that control various aspects of a home, such as room temperature, humidity, ambient light, security locks etc. These new possibilities offer enhanced services to the user and also help in better energy management or optimization

**Figure 1:** Concept of SuperVision. From left to right, the various stages of interaction with a lamp



**Figure 2:** “Looking” through the wall using SuperVision.

of shared resources [8]. However, the question of how to allow users to easily access and control these innumerable services still remains challenging.

A common approach for smart home control is to use an application on a smartphone or tablet (e. g. [3]). However a smartphone offers a limited interaction space and these applications often require the user to select an appliance by searching through menus or long lists of available devices.

Our technique called SuperVision is based on the ability of users to locate objects by using their visuospatial memory, even if they are hidden from view [1]. With SuperVision, users simply need to point in the direction of an object, (which needs not be in the line of sight) using a mobile device in order to control this object (Figure 1). This mobile device has a pico-projector fitted in it, which serves to display useful information and graphical widgets on and around objects.

SuperVision also offers users the power of “looking through” walls. This unique feature has been designed to allow controlling of objects outside the user’s field of view (typically behind a wall). In order to do this, we have developed an animated visualization (which is projected on the wall) that creates the illusion of gradually

creating a tunnel in the wall (Figure 2), thus allowing the users to “see behind the wall”. Users can control the size of this virtual hole in real-time -this is reminiscent of the super power (X-Ray Vision) of the fictional Superman character, hence the name of the technique. Such an idea of looking through a wall has been recently explored in [15] albeit not in the same context. We also suggest that the use of an animated visualization can make the interaction more intuitive and easily adaptable.

### Related Work

Several techniques have been provided for distant control of objects in a smart home. A few of the solutions are based on direct pointing with laser pointers [9] or infrared pointers [10]. However such techniques are only suitable for un-obstructed objects that are near to the user. Recently, PICOntrol [12] and RFIG lamps [11], have demonstrated how a handheld projector can serve as a suitable pointing device. However unlike these, SuperVision does not need a tagged environment. Other interesting approaches include object control from a video on a computer screen [13] or a table top display [5]. However, these approaches tend to divide the user’s attention from the controlled object to the controlling device. SuperVision proposes a more direct approach by projecting the control interface directly on or around the object to be controlled, ensuring the undivided attention of the user.

## **SuperVision**

Supervision (Figure 1) introduces a novel remote control to manage connected objects in a Smart home. This remote control acts like a “spotlight” (akin to [16],[17]) that selectively lights up parts of a virtual world. It displays virtual information on or around a real world object. Interaction with projected interfaces takes place by using a slider on the remote control and by making mid-air gestures.

### *Visualization*

Augmenting Objects: The handheld projector displays different types of information on and around the selected object, for example: the current status of an object (temperature of the heater, volume information of a stereo system) or general information about the house (total energy consumption of the house and the individual contributions of different appliances). While the shape or color of an object can make it unsuitable as a projection surface, it is generally possible to find an adequate surface for video projection in its vicinity (e.g. a wall behind it, the ceiling, the floor etc.).

Semantic zoom: The slider located on the remote control makes it possible to reveal different amounts of information through semantic zooming. For example: when a room heater is selected, it displays the current temperature. Upon zooming in further, more information is displayed, like energy consumption, the history of usage or the contribution of the pointed device to the total energy consumption of the house, in order to encourage reduction in usage.

### *Interaction with Objects*

SuperVision supports two types of interaction: pointing and gestural interaction.

Pointing: When the user points at an object and presses the button on the remote control, suitable control widgets are projected on or around it. When several commands are displayed in the projection area, the one that is closest to the center of the projection is highlighted (center of the projection is marked with a circular cursor). Users can activate this command by pressing the button. Users can also zoom using the slider to show only parts of the interface, in order to select a command with better accuracy.

Gestural interaction: Instead of pointing, users can input a command using a crossing gesture (as demonstrated in Figure 1): users first press the device button and then drag the cursor towards the projected command. Selection is done upon crossing the visual representation of the command, reducing the level of precision required to invoke it [14].

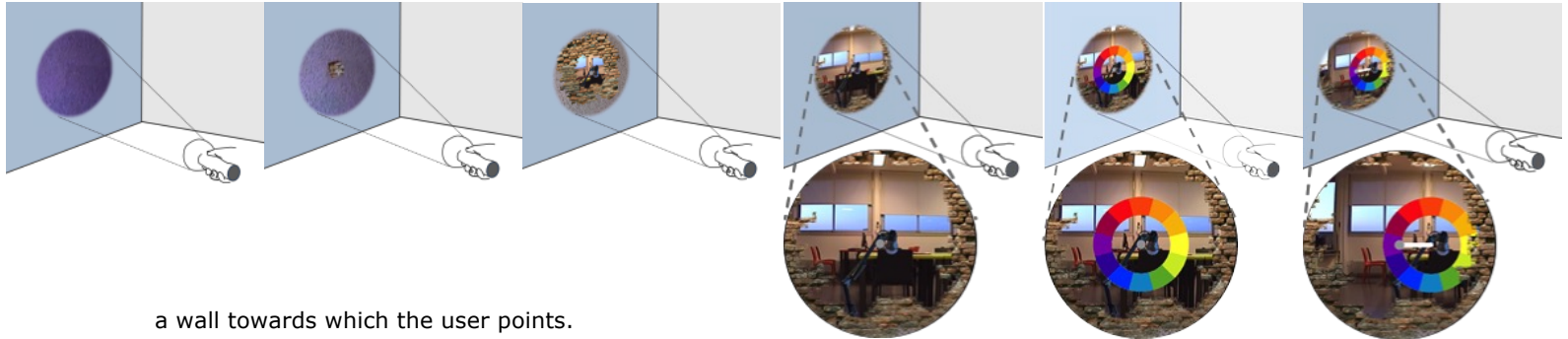
### *Expert Interaction*

Different arrangements of control widgets are designed depending on the kind of device being controlled (e.g. a circular color wheel for the lamp). Once users get used to the interfaces, they can use mid-air gestures to perform eyes-free selection as in Marking Menus [4]. In default mode, the user interface is displayed after pressing a button for a short interval (300 ms). However, if users perform a quick gesture while pressing the button for more than 300 ms, then the suitable control gets activated without the display of the user interface (expert mode).

### *Objects in Adjacent Rooms*

SuperVision allows users to interact with objects in other rooms. This requires the presence of a camera whose image is projected using the remote control, on

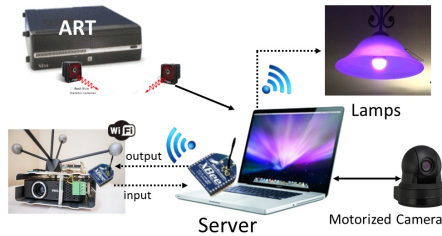
**Figure 3:** The figures from left to right show the various stages of the animation that is displayed, as the slider is moved up. Once the user locates a lamp behind the wall, it can be controlled in identical fashion, as if it was inside the same room.



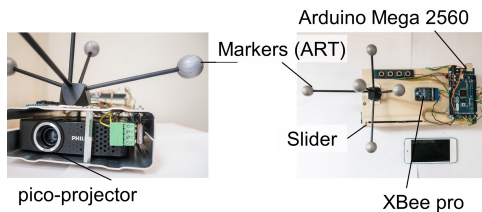
a wall towards which the user points.

Smooth transition: To allow the user to interact with objects in another room, we propose the metaphor of Superman's "Xray vision" (Figure 3). The same slider that serves the function of semantic zooming (when an object is selected) can also be used to "zoom" out of the room and "see" through a wall when no object is selected. An animation controlled by the position of the slider prompts the user to continue with the interaction once he/she has discovered how to harness the metaphor of "X-ray vision". The user first sees the wall texture which gives way to the bricks inside, as the virtual "hole" appears in the wall. Upon further "zooming", this "hole" gains more depth and gradually tunnels through the wall, revealing the scene behind it.

Interaction with objects behind the wall: The user retains identical interaction methods to control objects inside the room or in another room. Moreover the same metaphor of X-Ray Vision can also be applied to look through several walls, simply by engaging cameras kept in different rooms, according to the users pointing **direction and the position of the slider.**



**Figure 4:** System Architecture



**Figure 5:** Remote Controller Prototype

### *Implementation*

The architecture of the system is illustrated in Figure 4. The details of the proof of concept are as follows :

Remote control: Our remote (24×12cm) contains an off the shelf pocket projector (Philips PicoPix). The position and orientation of the remote is sensed using Advanced Real-time Tracking (ART) technology [2] and some retro-reflective markers.

The number of physical control options on the controller is minimized to facilitate eyes free interaction. A button serves to activate the controls and a slider serves to adjust the zooming level and the depth of view (Figure 5). The other buttons visible in Figure 5 have been included for future use. An Arduino microcontroller controls the button, the slider and a XBee module.

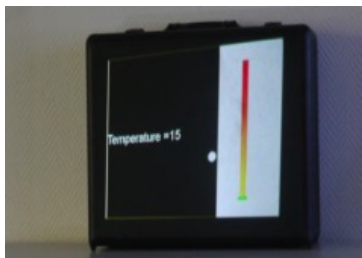
Camera: We used a Sony (EVI D90 PTZ) camera that is capable of panning, tilting and zooming. This camera is kept outside the room where the user is located. The video feed from the camera is projected on a wall (the wall between the user and the object to be controlled), to implement the "X-ray Vision" metaphor.



A



B



C

**Figure 6:** A) Display of TV channel logos around the screen. B) Lamp control using projected color-wheel. C) Crossing Widget for setting temperature of heater

Communication: The pico-projector is Wi-Fi enabled. We use the ZigBee protocol to transmit the values of the button and the slider. Moreover, a simple UDP protocol controls the smart lamps wirelessly.

Software: The GUI relies on C++/Qt. Image distortions are handled using OpenCV. Objects in the environment are currently assigned coordinates during an initial calibration process and are deemed to be stationary.

Distortions: Our system has to account for several types of distortions: 1) keystone distortions resulting from the oblique orientation of the projector with respect to the projection surface; 2) Distortions due to the difference between the user's view and the camera's point of view and 3) Distortions due to the difference between the position of eyes of the user and the position of the hand-held projector.

In our proof of concept implementation, distortions of type 1) vary greatly depending on the position of the projector. They are corrected through an algorithm relying on motion capture.[6][7]. Distortions of type 2) are compensated to a great extent by making use of the "pan, tilt and zoom" capabilities of the camera. Distortions of type 3) are considered negligible in the current proof-of-concept.

### Applications

Many applications are possible using SuperVision, varying from simple security applications or monitoring babies in the nursery, to controlling numerous appliances in the house (eg. setting the temperature of a heater, Figure 6-C).

### Interactive TV

The number of TV channels and the complexity of the control menus in televisions continue to increase. To tackle this, we propose to use the space located around the TV: upon pointing towards TV and selecting it, the user discovers the possible choices,( channel logos, or menu items) as shown in Figure 6-A. This allows the user to navigate through the different programs without altering the one that is on-going.

### Ambient Light Control

SuperVision displays a color circle around each lamp. A radial drag crossing gesture allows the user to choose a particular color from the color wheel .The user's choice is immediately reflected in the lamp, which glows with the selected color and helps to set up the desired mood (Figure 6-B).

### Visualization of Distant Objects

SuperVision lets users visualize and monitor appliances from far away. For example, while sitting in the living room, the user can not only monitor the cooking oven in the kitchen, but also control the heat settings as needed.

### Gaming

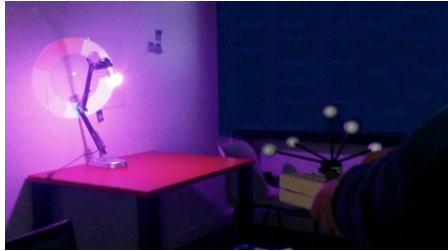
SuperVision also offers the possibility of development of games that rely on spatial memory. For example, a Memory Game in 3D whereby virtual information can be attached to real world objects across many rooms and users need to identify matching pairs of information.

### Conclusion and Future Work

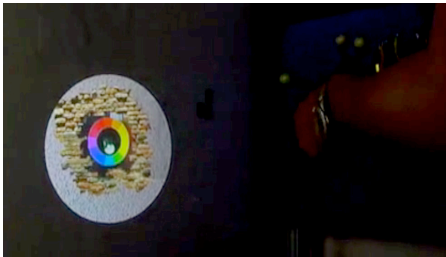
We have presented a new technique to visualize and control connected objects in a smart home (Figure 7).



A



B



C

**Figure 7:** SuperVision in a nutshell: A)The controller B)Controlling an object inside the room C)Controlling an object outside the room

This technique is able to control both objects in the user's field of view and also outside it, such as in other rooms or behind a wall. A prototype has been developed to realize this concept.

In future we wish to 1) miniaturize the controller 2) reduce the motion tracking infrastructure 3) undertake user studies to better understand the possibilities offered by the technique as well as the effect of distortions on the user experience 4) understand and tackle the possible privacy issues that may arise due to the use of video cameras. One possible solution is to use static images to cover up parts of the video stream, in a way that does not affect the interaction.

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