RFIDesk: An Interactive Surface for Multi-Touch and Rich-ID Stackable Tangible Interactions

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ABSTRACT

This work introduces RFIDesk, an interactive surface that enables both multi-touch and rich-ID stackable tangible interactions. By using ultra-high frequency (UHF) radio-frequency identification (RFID) technology, the RFIDesk can effectively identify the elements of a stack. Furthermore, this system integrates capacitive multi-touch sensing based on indium tin oxide (ITO) to effectively detect touch events while preserving the interface transparency, thus enabling rich visual feedback to be displayed under the stackable objects. The interference between the two sensing technologies is resolved by applying time-division multiplexing sampling. We use a tangible tower-defense game to demonstrate the interaction possibilities of this system.

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**;

KEYWORDS

interactive surface; stackable; transparent

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1 INTRODUCTION

Interactive surfaces improve user experiences by enabling users to interact with digital information through touch events and even tangible interaction [Ullmer and Ishii 1997]. The interaction space of the surface can be further extended from 2D to 3D by enabling stacking operations. However, the existing solutions have not yet effectively integrated stacking and touch detection. Studies have enabled stacking interaction on a touchscreen [Baudisch et al. 2010; Chan et al. 2012; Liang et al. 2014], but the ID space and stacking height have been limited. The RFIBricks [Hsieh et al. 2018] system enables rich-ID stacking by using ultra-high frequency (UHF) radio-frequency identification (RFID) technology; however, it does not support touch interaction.

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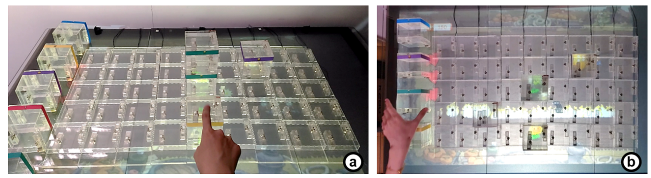

Figure 1: (a) RFIDesk is an interactive surface supporting both multi-touch and rich-ID stackable tangible interactions. (b) Tangible tower-defense game.

This work introduces RFIDesk, an interactive-surface system that supports rich-ID stacking and multi-touch interactions (Figure 1). RFIDesk enables the sensing of rich-ID stacking by using UHF RFID switches. It also integrates capacitive touch detection. In the following sections, we describe the two solutions major technical challenges offered by this system: 1) reducing the occlusion of the RFID switches and 2) mitigating the interference between the capacitive and radio-frequency (RF) sensing methods.

2 DESIGN AND IMPLEMENTATION

Rich-ID Stacking. The UHF RFID contact switch [Hsieh et al. 2018] (Figure 2a), comprising a counterpart of RFID antenna and a chip attached to a magnet at each endpoint, can be deployed as a pair on the top and bottom surfaces of each stackable object. When one of the objects is stacked on another, two RFID contact switches can be activated simultaneously with a single physical contact. To reduce the occlusion problem of the RFID contact switches, we reversed the design proposed in the RFIBricks system by only placing these switches on the top and bottom surfaces of the block (Figure 2b) and the top surface of the tiles (Figure 2c). We deployed the tiles as a 2D grid and placed them on the projection desktop (Figure 2d).

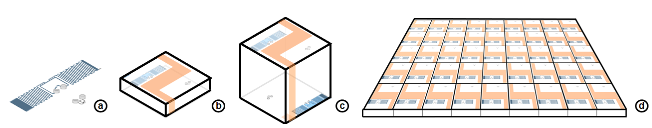

Figure 2: (a) RFID contact switch. (b) Tile. (c) Block. (d) 9 × 5 interactive surface. ITO patches are marked in orange.

The RFID contact switches on each block and tile were registered with the corresponding Cartesian coordinates. The system could then determine the 3D coordinates of the block on the interactive surface through the pair of correlated IDs generated from stacking one block on another. For example, when block A is stacked on floor tile B, which is at the location $l_B = (x,y,z)$, the two RFID contact switches located at the top of tile B and the bottom of block A are activated simultaneously. With the two IDs, the system can identify this stacking event and register the spatial position of block A as $l_A = (x',y',z') = (x,y,z+1)$. One block can therefore be removed from another by eliminating the pair of IDs in a similar manner.

Multi-Touch Sensing. For touch detection, an ITO patch was deployed on the surface of each tile. Each ITO patch was connected to an ATMega 328P micro-controller through an MPR121 module. We also applied one ITO patch on the top of each building block, and connected it to the bottom by using low-ohmic copper tapes on the sides of the blocks. When a block is stacked on a tile or another block, the ITO patches of the stacking block extends the touch-sensing area. Therefore, touch input can be detected when performed by touching the top of the stack or grasping the stack.

The dense electric field generated by the capacitive touch sensor could interfere with the transmission of the RF signals. Therefore, time-division multiplexing sampling was applied to mitigate the interferences. We first categorized the gridded tiles into two sets that were mutually exclusive in their 4-connectivity, and then alternatively (de)activated the touch sensors between the two sets to ensure that the adjacent capacitive touch sensors would never be activated simultaneously.

Hardware Implementation. The implementation of the system included gridded 9×5 tiles and dozens of blocks. The dimensions of each tile and block were 72.1 (W) × 72.1 (L) × 14.1 (T) mm^3 and 72.1 (W) × 72.1 (L) × 72.1 (T) mm^3, respectively. AZ-9610 RFID tags (44.45 (W) × 10.33 (L) mm^2), which had a sensing range of 3 m, were used for implementing the tiles and blocks. Each tag was modified through a vinyl cutter, and 4 mm (T) × 3 mm (D) cylindrical neodymium magnets were used as magnetic connectors. An Impinj Speedway Revolution R420 UHF RFID reader was used for tag reading. The reader can be connected to four 260 (W) x 260 (H) x 40 (T) mm^3 YAP-101CP circularly polarized antennas. The signal coverage of each antenna is approximately 3 (W) × 3 (H) m^2. The signal band is set to 902 MHz to 928 MHz, and the signal amplitude is set to 8 dBi. An Epson EB-530 projector placed under a table, which is mounted a 100 (W) × 75 (L) × 2 (T) mm^3 projection screen, is used for providing 1920 × 1080 px display with dimensions of 71 (W) x 49 (L) mm^2.

Demo: Tangible Plants vs. Zombies Game. In Emerging Technologies, attendees can experience the interactions of the RFIDesk by playing a physical tower-defense game, Plants vs. Zombies[1], using the physical blocks. They can deploy weapons and defenses by stacking different blocks (Figure 3a-b), collect coins by touching the tiles or a stack of blocks to collect coins (Figure 3c), and upgrade their weapons by stacking the blocks differently (Figure 3d-h).

3 DISCUSSION

RFIDesk is an interactive-surface system that supports both multi-touch input and rich-ID stacking and therefore enables novel interaction experiences. The tiles and blocks also retain their transparency and therefore can also provide rich visual feedback. However, the proof-of-concept system implementation, which could inform future research directions, remains limited in several ways.

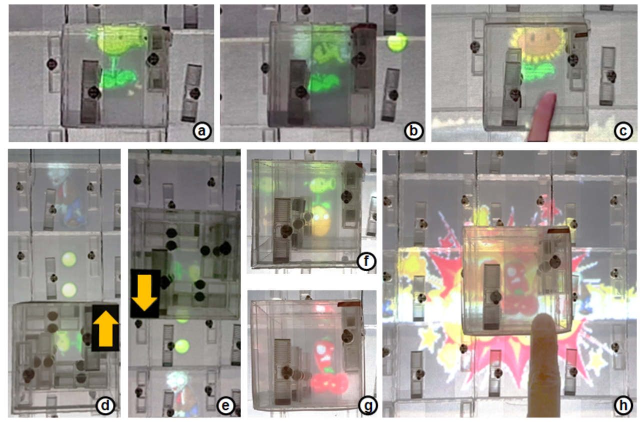

Figure 3: (a) Deploying a shooter block at the desired location. (b) Stacking one shooter block on another to upgrade it. (c) Collecting a bonus by touching the sunflower block. (d-e) Changing the attack direction by reorienting a special shooter block, which supports stacking in four directions. (f) Enhancing a shooter block with a shield. (g-h) Combining the attack area by stacking multiple bomb blocks, and igniting the bombs by touching the stack.

Regarding visual feedback, the graphical fidelity of the display is affected by the occlusions introduced by the antenna of the RFID tag. Using ITO as the antenna could be a plausible solution, but the design must be scrutinized to achieve the desired performance. The stacking of the blocks also introduces visual parallax problems that may degrade the coherence between the input and output spaces; this can be mitigated by either reducing the height of the blocks or lowering the table surface to enable users to play with it from the top. Regarding input, the resolution of the multi-touch sensing is limited to the granularity of the tile grid because each grid can only detect the presence of touch events, rather than the location. Although deploying a higher-resolution ITO touch panel on the tile surface could enable finer-grained touch input capabilities, it may require further investigation on the interference issues.

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