[ST] DOMINO (Do Mixed-reality Non-stop) Toppling

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Abstract

We propose an MR "domino toppling" attraction as a case study of MR systems, focusing on the Real–Virtual (R–V) and Virtual–Real (V–R) continuum. In this attraction, the user experiences that real and virtual domino blocks seamlessly pushes each other through a video-seethrough head-mounted display. Therefore, the user may believe that attractive MR effects happen in the real space. To achieve the seamless R–V/V–R transitions, we implemented simple switching devices. In addition, we use diminished reality techniques to visually remove the devices to make it harder for the user to distinguish R–V/V–R transitions.

Keywords: MR, DR, R-V/V-R transition

Index Terms: [Computing methodologies]: Computer graphics—Graphics systems and interfaces—Mixed / augmented reality.

1 Introduction

A mixed reality (MR) attraction presents users an MR space in which real and virtual objects coexist and interact each other, and provides a new experience by augmenting the real world with the virtual objects [1, 4]. Due to recent advances in head/camera registration technology and CG rendering engines, MR systems can technically easily superimpose moving virtual objects onto static real scenes. However, it still has technical difficulties to switch moving real objects to moving virtual objects seamlessly and vice versa, because geometric, photometric, and time inconsistencies are prominent at the switching point. From this background, we have developed "DOMINO (Do Mixed-reality Non-stop) Toppling" as a case study of MR systems (**Figure 1**).

In DOMINO system, we aim to develop a general MR system rather than a specific domino toppling MR system. The followings are the functions of our MR system focusing on real−virtual (R–V) and virtual−real (V–R) transitions:

(A) R–V/V–R transition continuities
    (1) Geometric and photometric consistencies between real (R) and virtual (V) spaces are accomplished.
    (2) The dynamic characteristics of R space are consistent with that of V space
    (3) The acoustic characteristics of the R space are consistent with that of V space;
(B) R–V switching devices

Another characteristic of DOMINO system is that it combines MR and diminished reality (DR) techniques to provide seamless R–V/V–R transitions to improve user experience [3].

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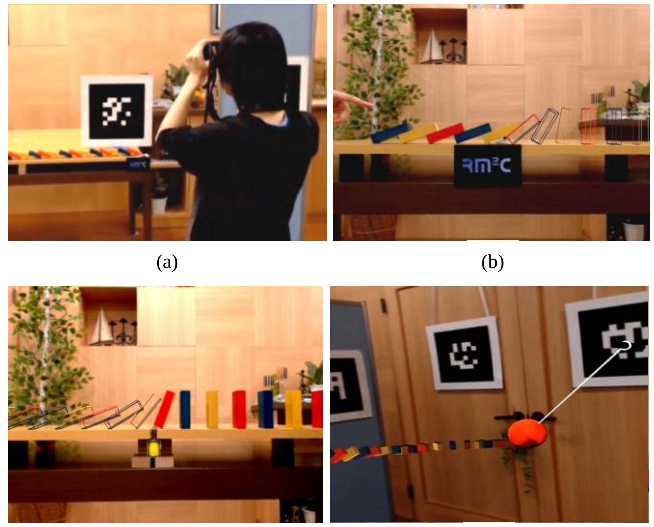

(a) (b) (c) (d)

Figure 1: The proposed MR system provides a unique experience, in which real and virtual domino pieces coexist and interact. (a) The user can observe connections between the real and virtual world directly using a VST-HMD. (b,c) We implemented a real-virtual switching device to seamlessly change real domino blocks to virtual blocks (b) and vice versa (c). (d) A combination of real and virtual domino pieces applied to conventional domino toppling enables attractive domino design and experiences.

2 Domino Toppling in Mixed Reality Space

Jakob et al. [2] proposed a collaborative tabletop game for domino toppling. They created tunnel-shaped special devices as portals for real and digital domino pieces. The devices hide connections between the real and virtual worlds; therefore, in the truest sense, R–V/V–R connections are not seamless. We adopt the following design principal to satisfy the above requirements.

Realistic virtual domino pieces: (A-1) Accurate camera pose estimation and realistic rendering are required, in particular, at the boundary of real and virtual realms. Thus, occlusion culling of virtual domino pieces by real pieces should be implemented. (A-2) Domino toppling must be animated plausibly, but this shall not apply to some parts of the fully virtual realms to show attractive MR effects. Virtual domino pieces have no physical limitations. (A-3) Virtual domino piece toppling sounds are recorded in real space, and the sounds must be presented in real time.

R–V/V–R domino switching: (A-1 and A-2) We deliberately show the user contact parts of real and virtual domino realms to make our MR attraction challenging and attractive. Therefore, the connections must be seamless through a video-seethrough head-mounted display (VST-HMD). (B) Furthermore, our MR system

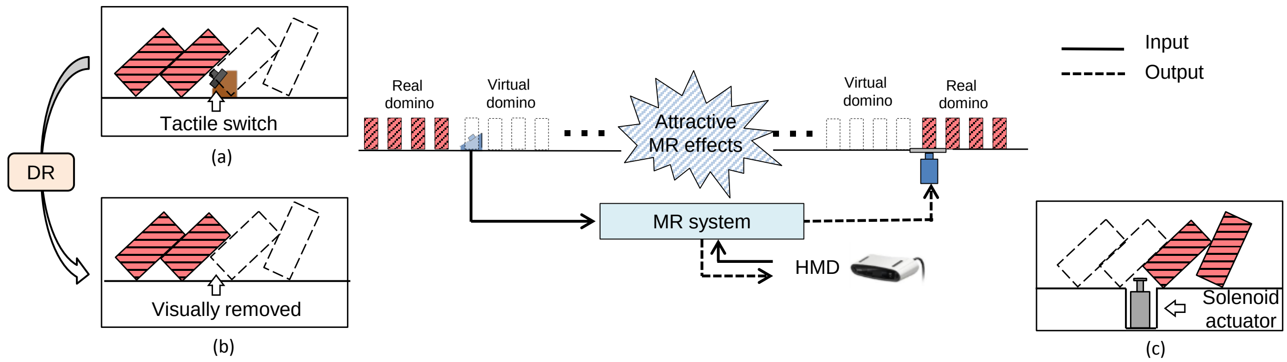

Figure 2: The proposed MR system (the MR experience flows from left to right).

must be able to detect real domino piece topple actions and physically push a real domino piece using devices. These are possibility of user's perception R–V/V–R transition; therefore, we use DR to make these devices invisible.

Flexible virtual domino effects and routing: As mentioned above, virtual domino blocks have no physical limitations; thus, they can move through the air, increase in size, change materials, etc. The routes of virtual domino blocks are read from an external settings file that determines the poses of each domino block.

3 Implementation

3.1 System Configuration

As shown in **Figure 2**, our MR attraction is comprised of a PC as an MR space manager, a VST-HMD (Canon HH-A1), a camera that provides an objective viewpoint for waiting participants, a camera pose tracking system, audio image presentation devices, and real–virtual switching devices and their controllers.

3.2 Domino Blocks

In general, real domino pieces are made of wood or plastic. For our MR attraction, we use wooden pieces to reduce undesirable reflection, simplify the photometric parameters of virtual domino blocks, and for light and preferable sound characteristics. Currently, we use $40 \times 80 \times 20$ mm domino blocks that can be viewed through the VST-HMD at any position in the 5×5 meter experiencing space.

3.3 R-V Switching

We use tactile switches to detect when a real domino piece topples over (Figure 2 (a)). When a real piece topples, it pushes a tactile switch; thus, the detected signal is transmitted to the MR space manager. At this time, a virtual domino toppling animation is initiated. The tactile switch serves as a physical stopper that keeps the leaning real domino block still; thus, domino blocks are not buried within virtual blocks in the MR space. When the virtual domino chain begins, the proposed system produces domino toppling sounds using the audio image presentation devices. Switching devices are hidden using a DR technique. We capture the background to be hidden in advance and overlay it in run time (Figure 2 (b)).

3.4 V-R Switching

When a virtual domino line reaches a real domino realm, a solenoid actuator under the first real domino block knocks the bottom of the first real domino (Figure 2 (c)). Virtual domino animations are managed in the proposed system. As a result, the system transmits a trigger signal to a device controller to activate the solenoid actuator when the last virtual domino piece falls. We place the solenoid actuators under real domino pieces to hide them from view. The proposed system stops producing virtual domino toppling sounds when the last virtual domino piece falls.

4 User Experience

The MR experience is initiated by the user touching the first real domino. In the following chain reaction, the user observes the reaction through the VST-HMD. In a virtual domino realm, digital domino pieces interact with each other in attractive ways (Figure 1 (d)). Finally, the virtual domino blocks reach the last real domino realm and return to the user. We expect that this series of R–V–R domino chains will provide the user with a believable augmented domino experience with the abovementioned MR stage effects in V space that is consistent with R space.

5 Conclusion

We have developed "DOMINO (Do Mixed-reality Non-stop) Toppling" as a case study of MR systems. We have focused on the R–V continuum. We use DR to make switching devices invisible. The results of our test indicated that most participant reactions were positive. However, some users found it difficult to follow the quick flow of the domino chain.

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Demo Video URL
http://www.rm.is.ritsumei.ac.jp/~hirata/ISMAR2015_Hirata.wmv