Real World Third-Person with Multiple Point-of-Views for Immersive Mixed Reality

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Abstract. Technologies of Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) are increasingly applied in urban construction and smart cities. As one of the high fidelity revivification methods, the purpose of these applications is to provide a better immerse experience over the combination of realistic and virtual interactions. Numerous methods and models are adopted to simulate real life scenarios. Regularly, first-person perspective (1PP) is a spontaneous way to revive reality virtually, and this is also what most manufacturers do. In a different way, we tend to verify the feasibility of a new perspective for VR, AR or MR: a third-person perspective (3PP) with multiple Point of View (PoV) from different fixed cameras. We implemented an immersive AR environment for users to control or view themselves in a third person perspective. They are able to switch among different perspectives in different angles, including a first-person view. We developed a simple game based on this environment and conducted user study with this implementation. The result shows that people will generally be intrigued and willing to pay for a new MR experience (like 3PP) if the process is effortless and pleasurable. The most welcomed thing is the ability to switch perspectives during a VR or AR experience. This environment can be extended to real world services such as interviewing, dating and picnic, etc. or future smart cities services that use VR and AR, such as VR traffic management, VR communities empathetic planning and AR navigation, etc.

Keywords: Virtual Reality · Augmented Reality · Third person view · Future cities · Video games

1 Introduction

Today, the diversity of Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) applications enters the field of urban settlements and smart cities [1, 2]. Prolificacy in similar patterns of AR and VR applications, coupled with constantly changed future possibilities produces a great demand of novel experiences. While AR and VR hardware are augmented from time to time, the design of Head-Mounted Display (HMD) spontaneously inspires the same pattern: first-person perspective (1PP) centered with the HMD. For example, Minecraft VR [3], an exploratory VR game with a low-poly aesthetic, Pokemon Go [4], an AR game for capturing Pokemon or battling gyms, Fragments

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[5], a mystery-solving MR game for Hololens, and researches like [6, 7], are all designed in the classic first-person view. However, first-person perspective sometimes cannot adequately tender horizon or information for virtual or augmented realities, especially in cases that require a macroscopic view, such as VR or AR tools for self-validation, rehabilitation, traffic detection, safety instruction or education [8–11]. We believe essential future smart cities services would be energized and consummated with these AR or VR enhancement.

With the question of perspective comparison [12] and the intention to explore potential AR/VR modes, we tend to probe into different applicable perspectives for MR users. Specifically, we verify the capability of fixed-camera third-person perspectives (3PP) for immersive AR applications and the ability to switch between different perspectives. In order to implement the fixed-camera third-person views for MR applications, we set up a rectangle room with cameras attached at different positions and use it as the experiment space. Each position of the cameras represents a different perspective for the user. The display of the VR HMD will show the live video footages from these cameras. When the user enters the room, he/she is able to see himself/herself from one of the perspectives created by these cameras. What the user does in the room represents what he/she operates to the virtual world and he/she is able to view all the actions from the HMD in real time. Moreover, we augment the video contents from the cameras, adding augmented and mixed realities to the environment. We set up action triggers in the room: when the user ‘touches’ one of these triggers, corresponding event will be operated. For example, when the user touches a locker, information of the locker owner will show up. Ultimately, content shown in the HMD will be automatically switched to another camera/perspective when the system detects the vision of the user may be blocked by his/her own body. It will be easier for the user to finish certain tasks in this way. In the case of Fig. 1, when the user steps through the trigger, the viewpoint will be switched to the right perspective from the left one.

This paper aims to create a third-person immersive environment for the upon features and verify the effectiveness of this perspective for AR, VR and MR. The prototype is built upon Unity 3D [13] and we use several webcams as the sources of different perspectives. Video stream of the right camera will be shown in HMD and serve as the current perspective. HTC VIVE [14] is used as the VR headset and TPCAST [15] is adopted to make the whole process wireless. TPCAST is a wireless adapter attached to the HMD, broadcasting the content from PC to the VR headset, removing the need for transmitting cables, which can also be done by the wireless adapter from VIVE [16].

Beyond entertainment, VR, AR and MR is likewise significant for many scenarios, especially for future smart cities services [10, 17]. Derivative applications of the third-person view environment can be of great help in these scenarios. For example, recent treatment approaches with virtual reality in stroke rehabilitation is rapidly adopted in clinical settings [18], and virtual reality researches on urban safety for preventing child pedestrian injury come into notice [10]. With the perspectives of multiple Point of View (PoV), in future cities, users may be able to observe themselves in a third-person view timely, anywhere and anytime, if the involved devices become perfectly wireless and portable, or the city gives the effort to open the CCTV (Closed-Circuit Television) for limitary public access.

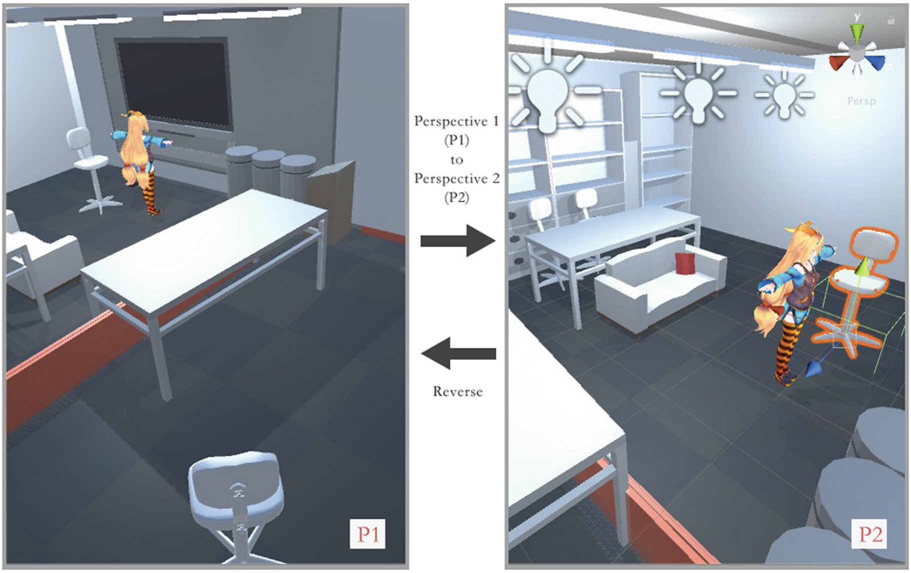


Fig. 1. Perspective switching

In the following sections, Sect. 2 describes several related works. Section 3 introduces the prototype implementation. Section 4 proposes the design and results of the user study. Section 4 describes limitations and challenges. Lastly in Sect. 5, we give conclusion and future possibilities.

2 Background and Motivation

In terms of the great attention paid to the ability of VR to immerse people into another reality, it seems to imply that first-person perspective is the perfect option for VR. As more and more AR or MR headsets come into mass production, such as HoloLens 2 [19], the ability to augment reality is also attached to the first-person perspective. We believe it can be more than like that. Playing in multiple perspectives in mixed realities is not always a second rate experience. For example, Chronos [20] uses a third-person perspective in the VR game by following the protagonist in a third-person camera. In many cases, it is more comfortable for a user to keep distance from the action. In this way, the user may feel less of the VR Sickness [21]. Based on the products of first-person and third-person view with a virtual main character, we tend to research and verify the combination of multiple perspectives in AR/VR. Further, we make the virtual protagonist real by using real-time video feeds from a fixed-camera, creating an immersive mixed reality in a real world third-person perspective: the protagonist is you and you are in a third-person point of view. To verify this two aspects, we developed a prototype and conducted user study with it.

2.1 Related Work

Third-person perspective has appeared in video games and AR/VR applications for years. This perspective seems preferable in action games with a protagonist roaming in a virtual world [3]. There are roughly two types of third-person perspectives in video games: a following PoV behind the protagonist like GTA [27], or a fixed-camera PoV attached from a distance, containing the character and a range of the environment where the character operates in, such as Biohazard 2 [28]. All of these perspectives are important for video games, and in [4], the authors check whether the GTA kind third-person perspective in AR/VR could share a preference. We tend to verify the availability of fixed-camera PoV with a perspective switching strategy: third-person perspectives from different angles (as shown in Fig. 1) and a first-person perspective (the classic AR perspective like Hololens 2).

A research of vision-based wearable device proposes dynamic gestures to interact virtual objects in the scene, in order to create a pervasive and interactive AR experience [5]. It provides a new way to interact with objects in augmented reality, using technologies of image processing to recognize different gestures. It inspired us to adopt similar solutions to indoor localization and body gesture detection. Since we tend to verify the effectiveness of the new perspectives in this research, instead of interaction gestures at this moment, we did not implement gesture based interaction in our prototype. Instead, we use VIVE Tracker [22] to implement an approximate indoor localization and use Vuforia Engine in Unity [23] to recognize markers in the scene, which play the role of the perspective switching and action triggers.

In [8], authors mention the technological impact of third-person perspective on daily life and its adoption on therapy and rehabilitation, especially coupled with virtual reality. We share the same idea on the impact of VR, AR and MR on the case of medication. In our future works, we plan to adapt our implementation to the scenario of medication and rehabilitation and verify the effectiveness of fixed-camera third-person view in this way. The implementation of this research is compatible with most indoor situations with proprio-perception intention, such as self evaluation of dancing, exercising, doing work out or other behaviors. We believe multiple perspectives for VR and AR have incremental weight on diversifying people's daily lives in future smart cities.

2.2 Motivation

As more AR/VR applications and more gameplay modalities emerge due to the demanding market, people may suffer from the gap between themselves and the points of view in the virtual or augmented reality. For example, a fast action will be quite difficult to track on a standard first-person perspective or a classic following third-person view [4]. Manufacturers will probably need some extra effort before adding this category of virtual ingredients to the virtual or augment reality. On the other hand, when inventing a teleport characteristic for the protagonist, such as teleport between dimensions in Halo 5 [24], the suddenly switch of camera to a different context is easy to leave a sense of disorientation. A fixed camera third-person perspective does not have these problems. Within the current field of view, it is spontaneous to implement any fast action or teleport features. With a fast pace and fiercely competitive AR/VR market, one more effective choice is always safe to have. Thus, we want to verify the availability of this perspective and multiple PoV in VR, AR and MR implementations.

To tackle this, we create a mixed reality environment with multiple selectable PoV, including first-person perspective and fixed camera perspective from different angles. These points of view are implemented as camera footages streaming to a wireless VR HMD. With this environment, we tend to verify two things: the acceptance of fixed camera third-person perspective in virtual reality and the preference of the ability to change perspective in virtual reality.

3 Design and Implementation

In order to verify the availability of fixed camera third-person perspective and the ability of selectable PoV, we implemented a prototype based on Unity 3D and HTC VIVE, and invited people to try it and participate in the experiment. In this section, we introduce the settings of hardware and software configuration of our prototype.

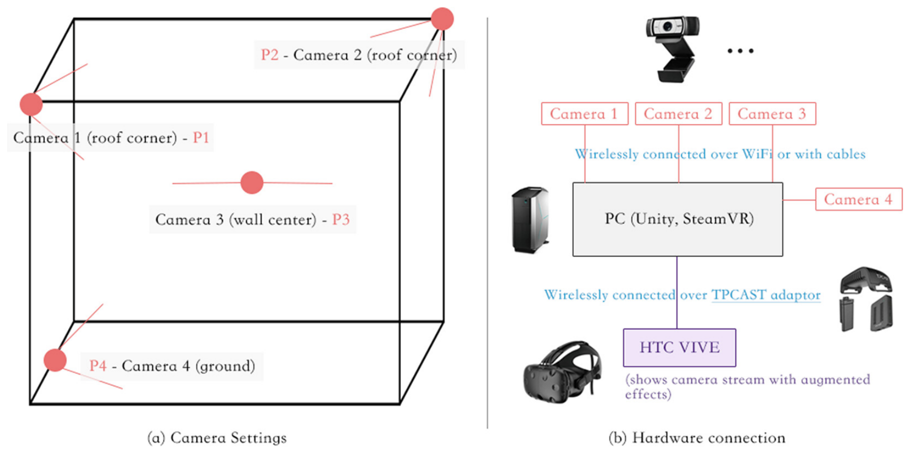
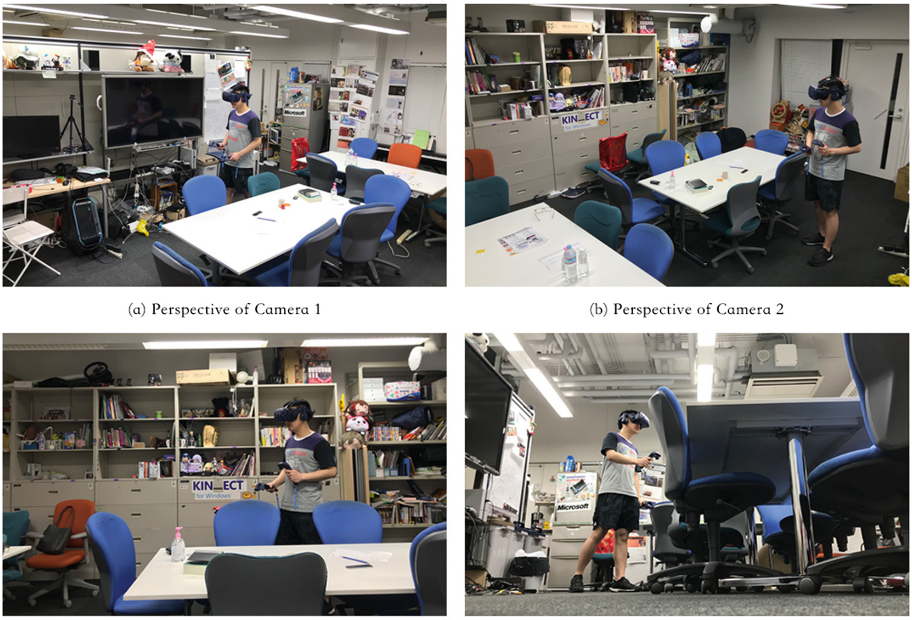


Fig. 2. Space and hardware setup

3.1 Hardware Setup

We set up a rectangle room (As shown in Fig. 2a) as the experiment space, which is covered by the field of view of four cameras. Two of the four cameras are attached diagonally to the corner of the roof while one of the rest is attached to the middle of the longer wall and the last one is set on the ground of the shorter side. With these four cameras, we simulate four different PoV from different angles. As shown in Fig. 2b, all of these cameras are connected to a PC that runs the Unity project. Footage of the current camera selected by the user will be processed by Unity and eventually streamed to the HTC VIVE headset. We use Logitech Wide Angle Webcam and Broadcaster Wi-Fi Webcam [25] for these perspectives.

The selection of these four camera positions corresponds to the four angles that video games frequently used in fixed camera third-person perspective. The correlation between these four positions and perspectives is shown on Fig. 3. The two cameras at the corners of the roof are considered to have the widest range of FoV (Field of View) and contain the most information in the space. The one at the middle of the wall provides a horizontal view and the one at the ground looks up at the user and provides the information under any covers like the table top or upper side of the shelf, which is blocked when using the looking down cameras.



(a) Perspective of Camera 1

(b) Perspective of Camera 2

(c) Perspective of Camera 3

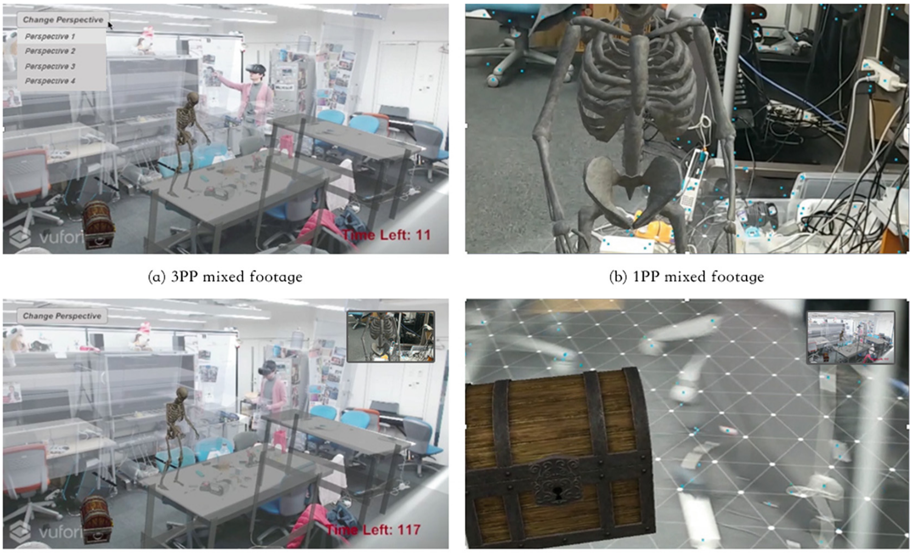
(d) Perspective of Camera 4

Fig. 3. Correlation between the four positions and perspectives

On the other hand, considering the flexibility of the experiment process, we need to allow the user to move freely in the room. This require the headset to be wirelessly connected, instead of letting it drag behind or probably trip over the user. In order to effectuate a wireless headset, we originally tried to process the Unity game or the PC desktop as video stream and project it to a smart phone and use Cardboard [26] to visualize the VR content. However, this process is laborious and turned out with bad performance because of the limited computing power of a smart phone. Instead, we use a third-party gadget called TPCAST to wirelessly transmit VR content to HTC VIVE headset with an integrated router, a transmitter and a receiver, substituting the cable transmission. Likewise, another option could be the wireless adapter from VIVE [16].

We set up markers in the room for mixed reality effects. The markers serve as the interactive objects in the game and are rendered as virtual objects like treasures, keys or any other necessary props in the virtual world. Users can interact with these objects with the VIVE controllers or directly touch them. Besides, there are some virtual triggers and objects in the game without physical markers for implementing virtual interactive objects, for example, a moving ghost. In future works, we may also use markers to set up some critical triggers in the room. Perspective will be automatically switched when one of these triggers is touched off. The positions of triggers and the way to touch off them should be selected and tested discreetly and deliberately because a wrong trigger would be a huge shock for the user.

3.2 Implementation



(a) 3PP mixed footage

(b) 1PP mixed footage

(c) 3PP with secondary 1PP

(d) 1PP with secondary 3PP

Fig. 4. The game scene mixed with camera footage

Based on the above hardware configuration, we developed a simple game with Unity 3D and run it with HTC VIVE. The game is designed simple for proof of concept. The user is supposed to avoid a moving skeleton and get to the treasure box in a limited time. As shown in Fig. 4, we reconstruct a rectangle space of our lab into a Unity scene and make some of the objects in the space appear with virtual effects. The skeleton is a trigger in game moving back and forward in front of the start point and the treasure box is a marker in game placed behind the skeleton. If the user collides with this skeleton or does not finish the game within the limited time (120 s), the game is over and shows a failure interface with a restart button. If the user goes through the skeleton and touches the treasure box with the VIVE controller, the game is completed successfully and a success interface shows up. The virtual effects to the reconstruction of the experiment space is raw and unripe, but it proofs the feasibility of virtual reconstruction and the availability of the augmented real life experience. To guide the user through the experiment, we let one of our researchers stand inside the FoV of the cameras. He shows up in the game scene and serve as a RPG (role-playing games) instructor.

By default, we provide the camera 1 (fixed camera third person perspective (3PP)) perspective in the experiment. To finish the task, the user can switch to first-person perspective (1PP) or other angles of the third-person perspectives manually. We encourage users to use all of these perspectives, and compare the feedback of different angles and views. Users can change the current perspective by clicking on the buttons listed at the left top side of the screen (Fig. 4a) with the VIVE controller.

4 Initial User Study

In order to conduct an evaluation and assessment to our approach, we have developed an experiment that measures user scores based on various indicators of our implementation. We asked participants to do questionnaires and interviews after the experiment and drew conclusion from the statistical result and feedback records. We aim to verify the approach in two respects: the fixed-camera third-person view for MR and the ability to switch perspectives in an immersive experience.

4.1 Participants and Procedure

We invited 12 college students (age m = 23.80, SD = 1.84, six men, six women) to participate in the user study. We set up the demonstration environment described in Sect. 3, and helped the participant to reset the experiment and wear the headset. We introduced the experiment, the perspectives and the objective task to the participants individually, and taught them how to interact with virtual objects. We showed them how to switch perspective and how to deal with triggers and markers. Participants are encouraged to use as many perspectives as possible before finishing the experiment and asked to successfully finish the task for at least one time. We observed the participants aside and stood by in case they have any problems. Users could actually see one observer in the game scene because the observer stood inside the FoV of the cameras. Users can turn to this 'RPG character' for instructions, just like interacting with virtual characters in classic role playing games, for example, GTA 5 [27]. Each participant was asked to fill out a questionnaire after the experiment, followed by a one-on-one interview.

4.2 Results and Feedback

We adopted the five-point Likert scale (1 - disagree/bad, 5 - agree/good) to develop ten rating queries. We asked the participants to complete the questionnaire right after the experiment. We observed that each experiment cost about 10 min averagely and the questioning and interview cost roughly 15 min for each participant. From the result of the questionnaire (as shown in Table 1), we know 91.7% of the participants have used VR devices before. The participants rated highest for the ability of changing perspectives in an immersive process (83.3% rated over 3 points).

From Table 1, we know P1 and P2 cameras (diagonal roof corners in Fig. 2) are the most welcomed perspectives among the four fixed camera third-person views in the

Table 1. Result of rating questions. (P1–P4 cameras are explained in Fig. 2)

	Average points	Standard deviation
Classic 1PP VR	3.83	0.58
Classic 1PP AR	3.92	0.67
Fixed camera 3PP (P1 + P2) in the demo	3.68	0.99
Fixed camera 3PP (P3) in the demo	3.61	0.90
Fixed camera 3PP (P4) in the demo	3.42	0.89
Fixed camera 3PP (Overall) in the demo	3.57	0.90
1PP AR in the demo	4.42	0.51
Able to switch perspectives	4.50	0.74
3PP with secondary 1PP (Fig. 4c)	3.87	0.63
1PP with secondary 3PP (Fig. 4d)	4.49	0.79
Generally about the experience	4.00	1.02
Willing to pay if well-developed	3.75	0.62

prototype, but collectively lower than the traditional first-person perspectives. However, when the fixed camera 3PP is combined with the classic 1PP, the ratings generally become higher. Specifically, rating of 1PP with secondary 3PP (Fig. 4d) is significantly increased and even surpass the classic VR and AR 1PP.

Moreover, P3 camera is rated slightly lower than P1 and P2 while P4 is the lowest. Overall, fixed camera third-person perspective is no better than the classic first-person perspective in AR/VR, but the P1 and P2 perspectives are generally accepted and could be a practical extra perspective for VR or AR applications. For example, use fixed-camera third-person views in indoor occasions and first-person in outdoor environments, having the secondary first-person and third-person attached correspondingly. Also, the rating for the ability of changing perspective during a gameplay is high. We speculate that people enjoy the freeness of selecting their own preferable perspective, instead of having what a system defines for them.

On the other hand, from the answers of multiple selection questions and interviews with the participants, we find that most participants (83.3%) consider the ability to switch perspectives is the best feature of this immersive MR environment and as a fresh experience, this third-person view is generally novel and acceptable to them. 66.6% of them are willing to pay for applications with such perspectives involved if the applications are fully developed. The most critical problem of this environment is the unnatural perspective. Users are worried that they may feel dizzy in this perspective if playing with it for long. ‘Easy to block the vision’ and ‘hard to control’ are ones of other concerns. We select the most typical ones and list them in Table 2.

Based on the result, we speculate that immersive third-person has incremental values to VR or AR applications, especially when it is combined with a natural perspective and serve as a supplementary perspective, providing more information and feedbacks for the users. The participants generally approve of the concept of this MR experience

Table 2. Pros and Cons.

Type	Description	Percentage
Pros	Be able to switch perspectives	83.3%
Pros	A fresh experience with AR/VR	41.7%
Pros	Be able to observe yourself	62.3%
Cons	May feel dizzy because of the unnatural perspective	58.3%
Cons	Easy to block the vision behind you	33.3%
Cons	Hard to control	33.3%

(4.00 points out of five in Table 1) and we believe the acceptability of such products is dependent on the experience, operability, how entertained the game is or how effective the application is, which demands reliable and fail-proof future implementations.

5 Current Limitations and Challenges

From the fixed camera 3PP demonstration, we see possibilities and limitations of this perspective and we summarize the challenges of similar kinds of implementation. The most critical problem of the fixed camera 3PP is the unnatural view of oneself. Users will hesitate to move at the beginning because they feel unreliable in an unnatural perspective. They are afraid to collide something unintentionally and feel hard to control themselves. A possible scenario is to use 1PP mainly and give a smaller rectangle view of the fixed camera 3PP at the corner as a secondary perspective (Fig. 4d). Users can use this extra perspective to obtain more information and don't have to stay in an unnatural perspective. They can switch the perspectives if they get used to the fixed camera 3PP and want to have a more macroscopic view.

On the other hand, fixed camera 3PP only provides one side view of objects or people in the room, so if you can see the front, you can not see the back, and vice versa. To overcome this constrain, users will have to switch between the diagonal perspectives to see the whole thing. The actions of switching between perspective can be automated and triggered at proper conditions such as when the user turn around, when the user's face is blocked by a table surface (when the user is trying to look below the table), or track the user's eyesight. This automation can be a challenge on development involved with image processing, face/motion detection, real time video processing and machine learning.

Compared with the following 3PP, fixed camera 3PP is more suitable for a complementary macroscopic view, instead of a sole perspective. Following 3PP is more spontaneous while multiple fixed camera 3PPs contain more information. Users will always prefer more customized options. Multiple fixed camera 3PPs will give incremental value to immersive experience when united with other perspectives, but they have difficulty serving as the only perspectives. Generally, people will get uncomfortable if using these perspectives for a long time. Solutions to avoid this uncomfortableness could be a challenge. One possible method is to combine these perspectives to a natural perspective like 1PP or following 3PP.

Moreover, this approach adopts commonly-used webcams to explore the efficacy of gaming perspectives for real world scenarios while leaving the camera variables out. The influence of camera variables in real life scenarios such as concave or convex viewpoints, mirroring effects and coverage issues, etc. could be explored accordingly.

6 Conclusion and Future Direction

We present a mixed reality indoor environment with multiple fixed camera third-person perspectives and a first person perspective for AR/VR applications, which can be extended to outdoor environments in future smart cities with ambient accessible intelligent cameras. We implement a prototype and conduct user study with this environment. Through the process, we speculate that immersive third-person has incremental values to VR, AR or MR applications. We consider the feasibility of such applications is up to their maneuverability, entertainment and effectiveness, which requires more fail-proof future researches. Basically, people will generally accept and be willing to pay for the new VR experience (fixed-camera third-person) when the process is effortless and pleasurable. We also conclude limitations and challenges of our implementation. A critical problem of this perspective is the unaccommodated view, which proof this perspective is not suitable for long-term use. Nonetheless, these perspectives provide a more macroscopic information of the environment and fresh angles for observing oneself. It is beneficial to combine fixed camera third-person view with classic first-person or following third-person perspectives. Additionally, the ability to choose a favorite perspective is generally a good option. In a such background of highly diverse immersive experiences, a novel perspective or angle will invariably be a fair alternative.

In the future, the interaction of perspective switch would be refined by motion detection such as detecting motions of raising head or pointing to the camera that provides the perspective you want to use. The game plot should be enriched and real people could show up and interact with users in the room, acting as interactive non-player characters (NPC). Beyond entertainment, we would verify the possibilities of multiple fixed camera 3PP usage in rehabilitation, education, self behavior analysis like dressing, dancing, etc., or smart cities services such as traffic management, urban safety instruction, etc. We want to adapt the 3PP environment to outdoor scenario with newly set-up or existing cameras (e.g. CCTV) and check on the potential derivatives.

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