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LAMPIRAN

Synchronous Distance Learning Using Virtual Reality in Low Bandwidth Condition

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Abstract

The COVID-19 pandemic has forced most learning facilities to close and change the learning method using distance learning and online lecture. While some universities might already have an online learning platform, the lower education level might not and having difficulties in adapting. Synchronous distance learning method, being the closest to face-to-face interaction normally occurring in the classroom, is currently the preferred method, mainly using video conference with Zoom or Google Hangout or chat app such as WhatsApp Group (WAG) as an alternative.

This synchronous method comes with their own set of problem, especially in the less developed area due to the lack of ICT infrastructure and educational resources. One of those problems are the required bandwidth and data usage. To reduce this bandwidth usage, some student would turn off their camera feed, which would reduce its main advantage as a synchronous learning method and may induce feeling of isolation. With the constrain of low bandwidth and data cap, the main concern lay in the ability to provide smooth direct many to many interaction without raising the feeling of isolation and minimal delays. In this paper, we explore the possibilities of using virtual reality classroom by taking advantage of its avatar-based interaction and immersion, focused on its flexible capabilities to change from synchronous to asynchronous learning with relatively low bandwidth and data usage.

Keywords— distance learning, virtual reality, avatar-based interaction, cyber presence, COVID-19

Introduction

Distance learning where the learning process occurred without the student being physically present on-premise are said to have revolutionized the learning process, whether in universities or corporation landscape (Kaplan & Haenlein, 2016). Massive Open Online Course (MOOC) being the most common method implemented in universities while Small Private Online Course (SPOC) is more likely used in the corporation. With the advent of the internet new method started to be used like distributed learning, e-learning, m-learning, and virtual classroom.

This distance learning method directly widens access to education. With the limitation of distance removed and a far more flexible scheduling, a new chance opened up for people with other time commitments or geographical barriers to learn with relative ease.

The importance of a good implementation of distance learning was made clear at the onset of the COVID-19 pandemic. With almost every country affected at 116.874.912 confirmed cases, including 2.597.381 death (WHO, 2021), most learning facilities were forced to close and continue using distance or online lectures. While some universities might already have an online learning platform whether in the form of MOOC or SPOC, this situation is a problem for universities without one.

In Indonesia, The Ministry of Education and Culture with the cooperation of online learning platforms, are focusing to provide asynchronous learning methods as widely as possible (Abidah, et.al., 2020). Although the asynchronous method had a negligible difference in learning retention(Jordan, et.al., 2013), the interactive synchronous learning method was still more popular. However, implementing synchronous distance learning using the traditional face-to-face class as a base model was proved difficult due to the lack of ICT infrastructure and educational resources (Basilaia & Kvavadze, 2020) . Another obvious limitation is it's almost impossible to teach practicals and labs, music, and art course using current distance learning method available (Sahu, 2020).

On the other side, reports from UNICEF show that 66% of 60 million students across 34 provinces felt uncomfortable learning from home during the Covid-19 pandemic. 87% of that student wishes to go back to school. While so, the student, realizing the effect of the pandemic, still chooses to wait for the pandemic effect to reduce before doing so (UNICEF, 2020). There is a difficulty in understanding the online lesson caused by the lesson delivery thus being a heavier burden to the students compared to face-to-face offline learning (Sadikin & Hakim, 2019). The situation made worse with the high cost of internet access and uneven accessibility to the ICT infrastructure in some areas (Sadikin & Hamidah, 2020).

Distance Learning During COVID-19 Pandemic

Looking at current online learning method, namely synchronous, asynchronous, and the hybrid of the two, each has its own advantage and disadvantage. The synchronous method whether it is via chatroom or video conference, although more preferably, was hard to use in low bandwidth conditions and students complained about running out of the internet data cap. While the asynchronous method seems feasible in this situation, the feeling of isolation due to the lack of interaction tends to makes students feel frustrated (Khotimah, 2020). Due to this, WhatsApp was one of the most popular applications used as synchronous learning method (Pramana, et.al., 2021).

While using WhatsApp Group (WAG) may reduce the imminent use of bandwidth and data cap, the fast velocity nature of synchronous distance learning will cause problems in the long run. Especially in the case of learning which needs near-instantaneous voice interaction. This is due to WAG video call limitation. As an alternative, while not nearly as effective, students and lecturers might use the file-sharing or voice note feature which in turn would be limited by the smartphone memory and data cap (Afifah, 2021).

Video conference is the other preferred method as synchronous distance learning method though the problem remains the same. Zoom, one of the most popular video meeting software during the COVID-19 pandemic requires at the lowest quality need 600kbps (up/down) for 1:1 video calling and 3.8Mbps/3.0Mbps (up/down) for 1080p HD video. For group video calling it need 1.0Mbps/600kbps (up/down) and 3.8Mbps/3.0Mbps (up/down) for 1080p HD

video. In addition, the gallery view receiving in group video calling requires 2.0Mbps for 25 views or 4.0Mbps for 49 views. Screen sharing need an additional 50-75kbps and 60-80kbps for audio VoiP (Zoom, 2021).

Depending on the stream quality, a 1:1 Zoom meeting will use somewhere around 540 MB to 1.62 per hour. While during a group call it use around 810 MB to 2.4 GB per hour just for the video feed alone. This bandwidth usage would be a problem to students with a weak internet connection. And to reduce the bandwidth usage, some student would turn off their camera feed (Castelly & Sarvary, 2021). This, in turn, would reduce the main advantage of video conference as a synchronous learning method which is allowing the participant to feel a direct many to many communication (Beutner & Echterling, 2019).

Virtual reality (VR) as a relatively new rising technology has the ability to simulate real environment onto a digitized three-dimensional space. According to Coburn (2017), the very basic definition of a VR experience is the replacing of one or more physical senses with virtual senses. With the constrain of low bandwidth conditions, the main concern of synchronous distance learning lay in the ability to provide a smooth direct many to many interactions without raising the feeling of isolation. The system needs to provide a sense of presence with the ability to interact with minimal delays even under limited bandwidth. So we propose the usage of avatar-based interaction as a replacement for the video feed and a virtual reality environment to provide the interactive media.

Related Works

Xue-qin Chang, Dao-hua Zhang, Xin-xin Jin (2017) proposed a model of web based multi-user virtual campus (WMUVC) system as a way to simulate three-dimensional world as a learning environment. The concept combines virtual reality three-dimensional environment with traditional website information such as video chat, email, VOIP to make the teaching resource browsable.

Another research in the viability of virtual reality as a distance learning platform was done by Leanne Coyne, Jody K. Takemoto, Brittany L. Parmentier, Thayer Merritt, and Rachel A. Shapton (2018). They found that 94.44% of the participant would prefer to use VR media if offered. It was identified that the interactive tools provided in VR environment were useful in this use case and the engagement provided made the participant felt more confident to express their ideas with their team.

Yiqun Liu, Xuanxia Fan, Xiaojing Zhou, Meiqin Liu, Jianfeng Wang, and Tao Liu (2019) proposed five application modes of VR in its usage as a distance learning method in higher education. These modes include self-exploration learning, distance group discussion, open learning, and experiment learning. They identified the main challenge in this implementation was the cost and portability of the VR system and the difficulty in adapting current teaching resources to the VR environment.

In this paper, we explore the possibilities of applying VR environment as a virtual classroom in a low bandwidth situation. Taking advantage of its avatar-based interaction and the adaptability of the learning method, focused on its synchronized learning capabilities in comparison to the current widely used method.

Proposed Method

a. *Virtual Reality Classroom Environment*

The main goal of a virtual classroom environment is simulating a real classroom for remote participants by providing the ability to participate and interact in the class (Deshpande & Jenq-Neng Hwang, 2001). With its fully immersive nature (Bowman & McMahan, 2007), virtual reality also could give nearly the same effect as doing face-to-face learning in the real world (Blume, et.al., 2019). A Virtual reality environment with a full 6 degrees of freedom (6DoF) movement would give students chances to visualize, explore, manipulate, and interact with a virtual objects which in turn would add student ability to respond to instruction inside the classroom (Crumpton & Harden, 1997).

Using virtual reality to simulate the class classroom could also be directed to another way. One of the main limitations of video conference as a synchronized learning method is its inherent lack of ability to provide “lab experience”. Virtual reality on the other hand could provide an interactive experience akin to using real tools and experiments.

Inside this virtual classroom, every student and teacher would be represented with a 3-dimensional avatar tracked to their device. Since the avatar only loaded once at the initialization, the movement could be controlled only by its coordinate in the virtual 3d space. In comparison, a video conference would need to broadcast every single video frame which needs more bandwidth in the long run.

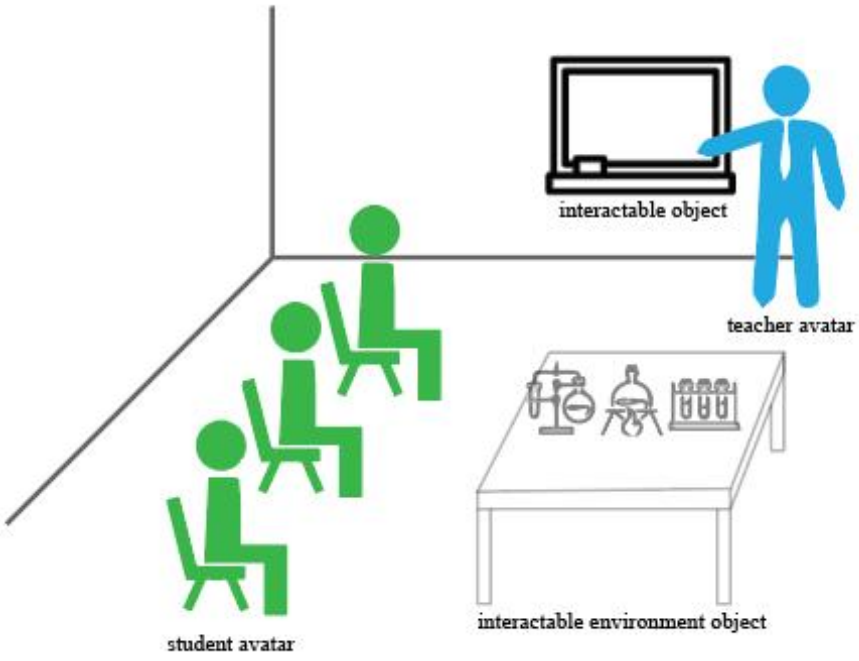

Fig. 1: virtual classroom mockup composition

b. *Avatar-based Interaction*

In an avatar representation, take for example a rigged bipedal human avatar with 20 pivot points, the movement of this avatar could be controlled just by sending the coordinate location and its rotation relative to each other. Since most consumer VR headsets used only 3 tracking points, head and both hands, the

movement data need to be broadcast would be far smaller. The server could skip any processing to this data and directly broadcast it. The client would then process this coordinate and location individually to do the movement or interaction.

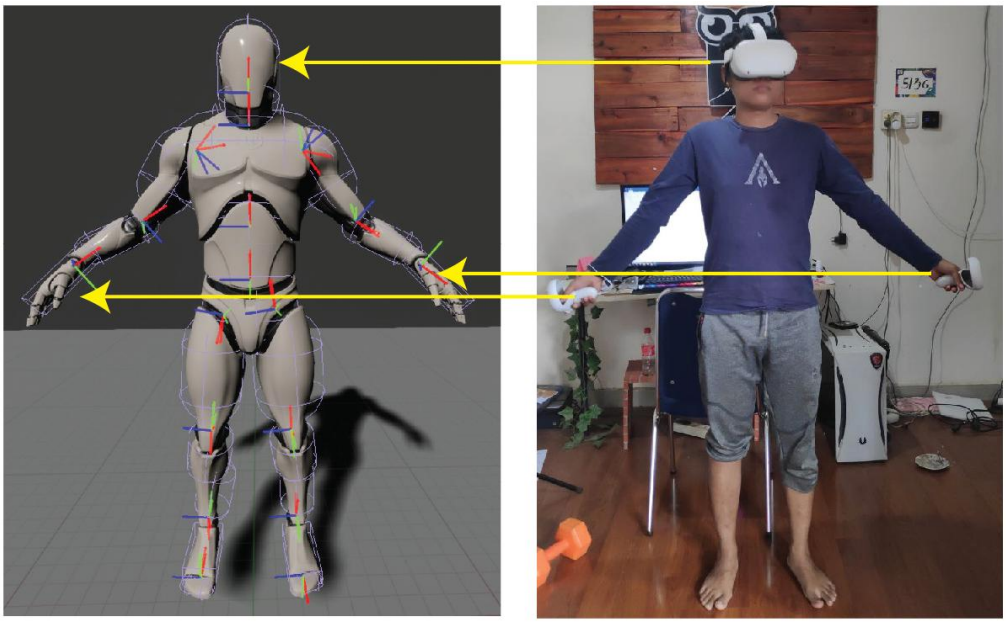

Fig. 2: Human-Avatar Three-Point Motion Tracking

c. *Bandwidth Optimation*

A system made using Unreal Engine 4 defaulted in 10kbps bandwidth limit in the UNetDriver config. This setting of course could be changed to accommodate our needs. In our preliminary testing, sending movement through multicast RPC to about 100 actors uses around 20kbps - 30kbps without any optimization. In comparison, Zoom 1:1 video calling needs 600kbps at the lowest resolution and up to 3.8Mbps at the highest resolution. Since in vr environment, the render resolution are dictated by the client, this means that the bandwidth usage would stay mostly the same across any resolution in the clients.

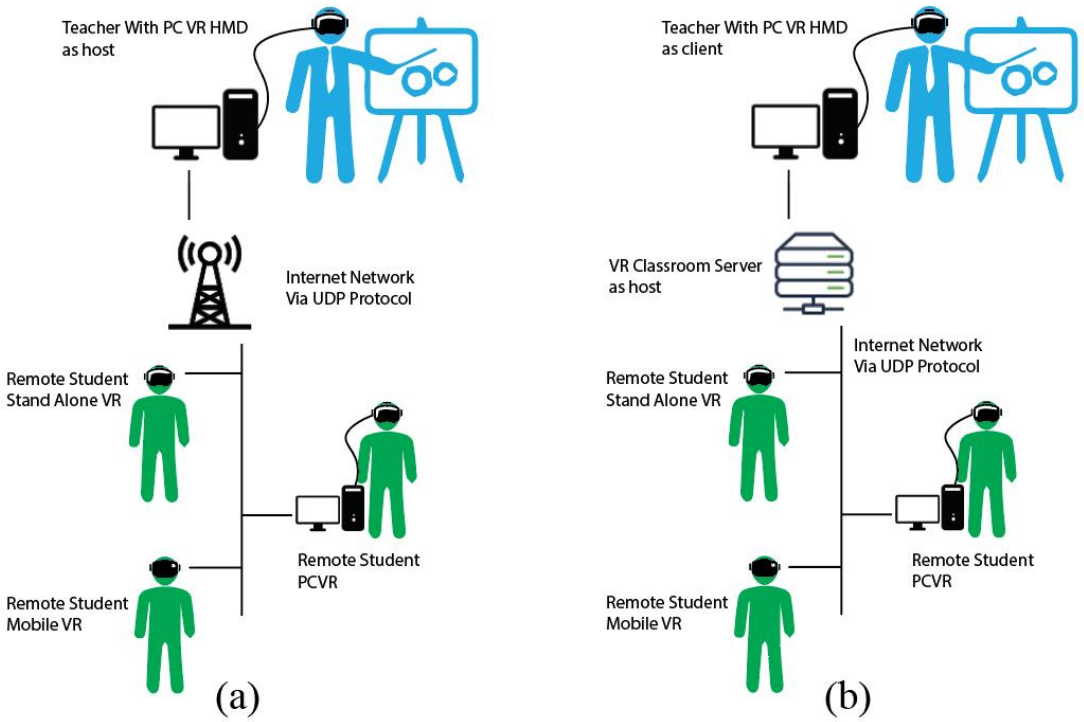

Fig. 3: System architecture (a) peer-to-peer with the teacher as host. (b)client-server with teacher & students as clients

To further reduce the bandwidth usage, we could reduce the transmission frequency and let the client interpolate the coordinate by itself. This would result in the same movement with an imperceivable motion delay and a smaller bandwidth usage. This would also mean that the transmission could be done with UDP protocol which won't guarantee the error but compensate in less delay. By default, an avatar-based interaction using VR environment don't need that much bandwidth.

Furthermore, a VR system could also be used as an asynchronous method if needed, switching it to self-exploration learning.

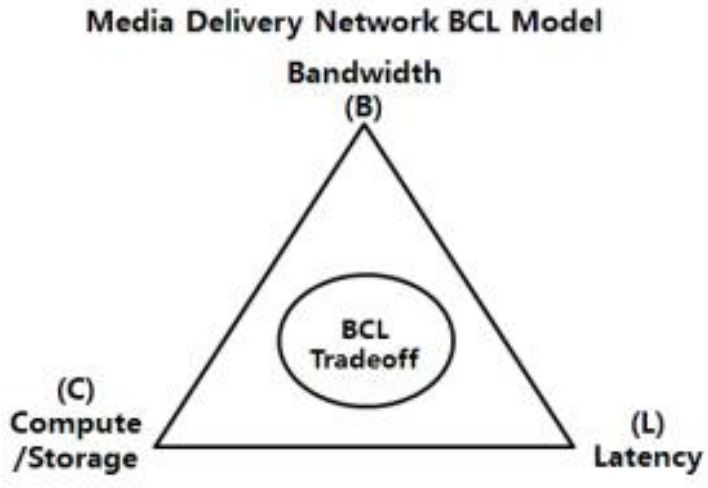

Fig. 4: Media Delivery Network BCL Model (Mangiante, et.al., 2017)

According to Magiante et.al. (2017) Media Delivery Network BCL Model, by moving to one extreme end of the BCL tradeoff triangle, in this case, the compute/storage angel, thus eliminating the real-time bandwidth usage. This could be done by allowing the client to download content individually and allowing the student to explore the provided content by themselves.

If we compare this to video conference, in this case a pdf presentation file over Zoom video call, we could predict the bandwidth usage difference just in the presentation sharing alone. Zoom bandwidth requirement use 50-150kbps for screen sharing with no video thumbnail and this usage increase to 50-150kbps with video thumbnail.

Take the 10-page pdf file without embed image at 300kb size. By pre-downloading and displaying it in the VR environment, the bandwidth usage would only need that 300kb. On the other hand, by using zoom screen sharing the bandwidth usage would increase by the time it's displayed.

Method	Data Usage		
	20 minutes	60 minutes	120 minutes
predownload	300 kb	300 kb	300 kb
Zoom (min, no thumbnail)	60 mb	180 mb	360 mb
Zoom (max, no thumbnail)	90 mb	270 mb	540 mb
Zoom (max, with thumbnail)	180 mb	540 mb	1.08 gb

Table 1. theoretical data usage overtime for screen sharing small pdf file (300kb)

As we could see, the data usage for predownload would remain the same no matter how long the session takes since the weight was moved to compute/storage side. The client would need to store and render (compute) the file by themselves. In theory, there would be a point where the shared file would be too big to handle effectively by the client itself in comparison to screen sharing method, but at that point, there is also a time factor and the bandwidth limitation that we need to consider. For example, sharing an HD video for 20 minutes via screen sharing would use less data on zoom, but when we factor in the video compression (50-150kbps limit on zoom screen sharing), the resulting video stream could be less than optimal.

Conclusion

The fast growth of VR technology in the recent year and with devices getting relatively cheaper in the consumer market opens up new chances of widespread adoption and implementation, especially in the education field. Meanwhile, the COVID-19 pandemic forcing learning institutions to quickly adopt distance

learning even without an adequate infrastructure also pushing new method to be considered further.

Solving the feeling of isolation in a distance learning environment is an advantage we should take seriously, especially if this “forced” long-distance learning situation would need to be prolonged further. As shown above, in a low bandwidth situation, this virtual reality environment could be a better solution than the currently used method. VR lab also opens up chances for a cheaper experiment learning medium since there is no need to provide physical material use. More research needs to be done in making this technology easier to adopt by the public especially to make the devices cheaper to make adaptation far more widespread.

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