University of Padova

Department of Information Engineering

Master Thesis in ICT for Internet and Multimedia

Traffic Source Modeling in Interactive Virtual Reality

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Academic Year: 2023-2024
Date of Graduation: 27-02-2024

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Whispers of Destiny: Maidens' Odyssey Amidst Rural Reverie

In villages nestled by streams serene,
Where life's rhythm flows in tranquil scene,
There dwell the girls with dreams untold,
Whose spirits shine like purest gold.

Amidst the fields and meadows green,
Their aspirations, a beacon keen,
They yearn for more than fields and toil,
To grasp the world, to till the soil.

With eyes that gleam with fires bright,
They weave their dreams through darkest night,
Though paths seem rough, and skies seem grey,
They hold on tight, they find a way.

Though trials come, and hardships press,
They rise above, they do not regress,
For in their hearts, a flame ignites,
A fervent spark that forever ignites.

So let them not despair or weep,
For in their dreams, their hopes they keep,
To soar beyond the village bounds,
And reach the stars with joyous sounds.

O girls of villages, stand tall and true,
Your dreams are valid, your journey too,
Through education's sacred door,
You'll find the keys to life's grandeur.

Abstract

Virtual Reality (VR) stands as a pivotal technology merging computer science and human-computer interaction, rooted in immersive experiences. However, the analysis of large sets of traffic measurements in its development is challenged by high variability and limited datasets. This study aims to establish valuable data sets in VR development and analyze the data traffic to see the influence of nature of players and games during the gameplay. Sixty participants aged 18 to 35, having passed standard visual acuity and color blindness screenings, with diverse gaming backgrounds, were randomly divided into two groups. Each group, consisting of 30 individuals, engaged in VR experiences via Oculus Meta 3. Group 1 played Cooking Simulator and Beat Saber, while Group 2 experienced Forklift Simulator and Medal of Honor. Utilizing box plots, the data rate distribution reveals varying ranges among traces, with lowest data rates observed in two traces of Cooking Simulator and Beat Saber. Total Variation Distance (TVD) displayed the similarity between probability distributions, indicating higher TVD values for lower data rates, suggestive of concentrated data around a central point. Conversely, lower TVD values correlated with less centralized points in lower data rates. Furthermore, the detection of gaps and small frames led to a left-skewed frame distribution, while the highest frame size reached is not more than around 320kb in all games. Despite each game having certain ways to guide the players to play in a specific way, TVD values show that there is a difference when same player playing different games and different players played same games.

Contents

Listing of figures

Listing of tables

Listing of acronyms

AR . . . . Augmented Reality

CDF . . . . Cumulative Density Function

CSV . . . . Comma-Separated Values

DL . . . . Downlink

FTC . . . . Fundamental Theorem of Calculus

Gbps . . . . Gigabit per second

HIT . . . . Human Inspired Technology

IFI . . . . Inter-Frame Inter-Arrival

Mbps . . . . Megabits per second or MB/s

PC . . . . Personal Computer

PDF . . . . Probability Density Function

PTSD . . . . Post-Traumatic Stress Disorder

RAM . . . . Random-access Memory

SPARCS . . . . Space, Aerial and Ground Control Systems

SSQ . . . . Simulator Sickness Questionnaire

TVD . . . . Total Variation Distance

UL . . . . Uplink

USB . . . . Universal Serial Bus

VR . . . . Virtual Reality

6DOF . . . . Six Degrees of Freedom

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Introduction

1.1 Background

In the digital era, Virtual Reality (VR) has rapidly evolved into a groundbreaking technology that integrates computer science, human-computer interaction, and a rich history of experimentation with immersive environments. It is commonly well-known as a tool used for entertainment purpose. Over time, VR has been used for some beneficial applications not only for entertainment like gaming with Meta Quest 3, but also for education and training aim such as in occupational health and safety training in underground mines [1], and even for clinical medicine purpose such as reducing fear and anxiety during operating room transfer surgery [2]. One of the strengths of VR lies in its ability to deliver a high level of immersion through more realistic graphics and precise simulation, especially compared to mobile applications. However, due to its immersive nature, it requires devices capable of handling large transmission of data to support its performance. Despite its potential, current research on this field remains relatively novel, with limited dedicated sources for exploration. Consequently, there is a pressing need to dig in more into data transmission with a broader spectrum of data sources to enhance VR capabilities. This research seeks to contribute to the ongoing discourse surrounding VR by examining the dynamics of data transmission.

1.2 Objectives of Research

The primary objectives of this research are to provide a valuable dataset that can contribute to support VR development and to analyse the nature of players and games based on the data traffic. The experiment was carried out at the Laboratory of Space, Aerial and Ground Control Systems (SPARCS) in the Department of Information Engineering at the University of Padova. Sixty participants played the games using Oculus Meta Quest 2 in which its headset was connected to the Personal Computer (PC) via a Universal Serial Bus (USB) cable. Data traffic was recorded during the experiment using Wireshark and Oculus Monitor software respectively.

1.3 Work Structure

The work structure of this study is divided into several chapters. Following the Introduction, Chapter 2, known as "Literature Overview", presents the brief definitions of VR, the history of VR, USB, and prior works related to the analysis of data traffic of VR. Chapter 3, "Data Acquisition" outlines an overview of comprehensive details of how the data is gained during the experiments then followed by the final results presented in Chapter 4. Lastly, Chapter 5 summarizes the conclusion and suggests future work.

2
Literature Overview

2.1 VR Development

"Experience is a cover-all term for the various modes through which a person knows and constructs reality. These modes range from the more direct and passive senses of smell, taste and touch to active visual perception and the indirect mode of symbolisation." [3]

Virtual reality has various definitions. Steuer in 1992 proposed a fundamental concept that highlights the definition of VR: the notions of "presence" and "telepresence". These terms relate to the sensation of being immersed in an environment, whether it arises naturally or through mediated methods. Telepresence, specifically is described as a form of presence induced by the medium itself. This is attained through the quality of sensory richness (vividness) and the level of interactivity (the ability to exert influence) within the virtual environment. Additionally, Slater also defined immersion as a significant aspect of VR, which is closely linked to presence of sensorimotor contingencies [4]. According to Slater [5], immersion is the term used to describe the physical actions and interactions within a specific virtual environment in order to perceive and interact with that environment effectively. These actions may include actions like bending and shifting to gain a better view beneath an object or reaching out to grasp an object. Such actions are typically acquired through the use of head-mounted displays.

As mentioned by Sherman and Craig [6], virtual reality can be defined as a technology built by interactive computer simulations capable of detecting participants' positions and actions.
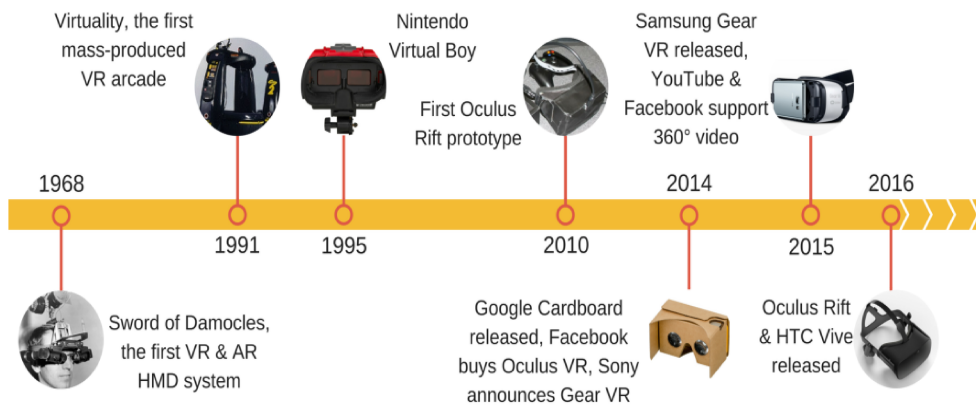
Figure 2.1: VR Timeline [7]

It then offers artificial sensory feedback to one or more of the senses, creating a sensation of complete immersion or presence within the simulation. Nowadays, VR has gained prominence across various industries, owing its success to decades of continuous research and development as shown in Figure 2.1.

Among the various definitions of Virtual Reality, it refers to the application of computer modelling and simulation to extend human sensory perception and it can enable users to interact with immersive virtual environments, facilitated through the use of a headset that projects the digital environment.

Dating back in the 1950s, Morton Heilig, and an American cinematographer and inventor, conceived the idea of the Sensorama machine. His inspiration came from his belief that theatre could evolve into an experience that engaged all the senses and immersed viewers in onscreen activities. Later on, his concept was documented in a 1955 paper titled *"The Cinema of the Future"* [8]. By 1962, he had constructed a prototype of his immersive multi-sensory Sensorama showed in Figure 2.2 along with five short films designed for its presentation. Sensorama featured a stereoscopic color display, fans, odor emitters, a stereo-sound system, and a motion chair. This setup enabled viewers to embark on a simulated motorcycle journey through New York City, allowing them to sit in an imaginary motorcycle while experiencing the city streets through a screen, feeling the wind from the fans, and immersing themselves in the simulated sounds and scents of the city [9]. Nonetheless, the pre-recorded motorcycle route resulted in a non-interactive experience for the user.

In 1965, Ivan Sutherland conceptualized an "ultimate" display, envisioning a room where the computer could control various sensory elements, including graphics, force-feedback de-

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Figure 2.2: Sensorama machine [10]
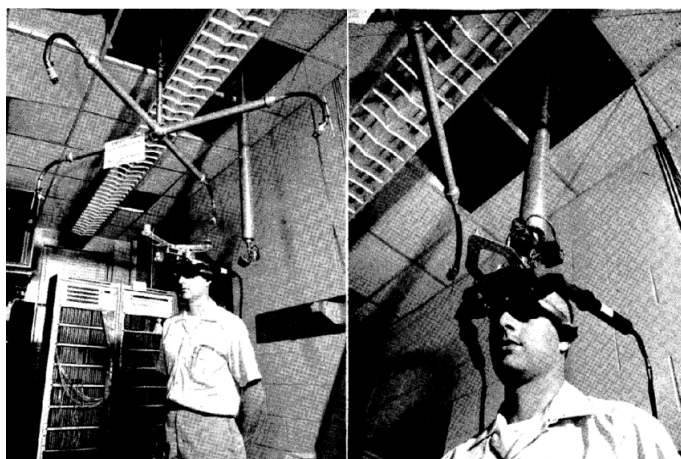
Figure 2.3: Sword of Damocles [10]

vices, sound, taste, and smell [11]. Three years later, he and his student Bob Sproull at the University of Utah developed the first VR headset, famously known as "Sword of Damocles", as depicted in Figure 2.3. The headset featured head tracking, which accurately adjusted the stereo view based on the user's head position through the use of a pair of half-silvered mirrors [12].

Since that pivotal moment, VR research has progressed rapidly. In 1978, Aspen MoviMap hypermedia experiment project was conducted in Aspen, Colorado, USA. This project employed panoramic and moving stop-motion photography, simultaneous recording systems, computers with laser players and a touchscreen playback system to create a virtual reality environment of the world [13].

From 1980 to 2007, there were some other research and developments such as one of the first VR products sold to the market by VPL research founded by Janor Lanier (1987) [14], Vituality as first VR arcade machine produced by Virtuality group (1991) [15], Sega's VR-1 motion simulator arcade (1994) [16], a VR headset dubbed Nintendo Virtual Boy released by Nintendo (1995), and three-dimensional positioning from Google Street View with panoramas [17] (2007).

In 2010, Palmer Lucky introduced the concept of Oculus Rift and Oculus Touch controllers, along with the first test series. Afterwards in 2012, a fundraising campaign on Kickstarter successfully garnered approximately $ 2.4 million, which provided Oculus with the necessary funds to develop two pre-production models for developers to utilize. However, before the hardware's full realization, Facebook Inc. acquired Oculus in March 2014 for a total of $ 2.3 billion, encompassing both cash and stock [18]. In the same year, Cardboard was introduced by Google as well as Sony which was introducing Sony Gear VR [19]. Thenceforth in 2015, Gear VR by Samsung was introduced to the market [20] along with YouTube [21] and Facebook [22] that started to support the 360° video. Subsequently, in March 2016, Oculus launched the initial consumer version of the VR Rift headset, enabling more developers to experiment with VR applications [18], while HTC launched Vive's first generation one month later [23].

2.2   VR Application

Initially recognized for its entertainment applications, particularly in gaming, VR application has been developed for other purposes such as healthcare and training-education. In the field of healthcare, VR has been applied across different stages, from treatment, counselling and rehabilitation, and to the designing of hospitals. Particularly notable is its role in psychiatry, where VR is used for Post-Traumatic Stress Disorder (PTSD) treatment, especially caused by the battlefield. Nevertheless, a substantial challenge looms in the form of potential side effects, including but not limited to dizziness, nausea, headache, eye strain, and others [24].

Another study investigated the application of immersive VR for colonoscopy screening [25]. Colonoscopy is a medical procedure where a doctor checks the inside of the entire colon (large intestine), traditionally employs optical colonoscopy which is an uncomfortable and invasive technique commonly used for colon cancer (Colorectal cancer/CRC) screening. On the other hand, virtual colonoscopy was proposed as a non-invasive, comfortable, rapid, and cost-effective alternative for mass screening when compared to optical colonoscopy. This approach aids in a

meticulous examination of user-defined regions of interest with an intuitive zoom feature.

For training and education purposes, Walmart (a big company in the United States) has been adapting VR as a tool for their training program [26]. Furthermore, VR also has been used for cabin safety training procedures by utilizing a serious game that simulates a runway overrun accident. The study shows that VR was more engaging than safety cards and proved to be more effective in helping users to keep acquired knowledge a week after training [27].

2.3   USB

USB (Universal Serial Bus) is an external bus architecture designed for connecting USB-capable peripheral devices to a host computer. It stands out as the most successful personal-computer interface since it is used not only for linking to PCs but also for mobile phone connectivity and some various other devices. USB presents numerous advantages for users [28]:

- **User-Friendly**
  Its singular interface accommodates many devices through different ports. With automatic configuration, there is no need for users to do specific settings.

- **Multiple speeds**
  USB facilitates various speeds (bus speeds): low speed (1.5 Megabits per second or Mbps), full speed (12 Mbps), high speed (480 Mbps), SuperSpeed (5 Gigabit per second or Gbps), and SuperSpeedPlus(10 Gbps).

- **Reliable**
  USB protocols let the error detection in received data, notifying the sender so it can retransmit without software or user intervention.

- **Power Conserving**
  Efficient power-saving circuits and protocols minimize a device's power consumption while maintaining the device's readiness to communicate when necessary leading to more environment-friendly, cost-effective, long-time charges for battery-powered devices.

- **Low Cost**
  As the host computer predominantly supplies the intelligence to control the interface, components for USB devices remain efficient.

USB Type-C cable is used in this experiment. Offering rapid data transfer speeds up to 10 Gbps, it boasts ultra-high bandwidth video capabilities and enables a continuous power flow of 100 Watt through a single connection. The main goal of the USB Type-C cable is to supersede all preceding versions of the USB cable and significantly enhance overall capabilities as shown in Figure 2.4 [29].
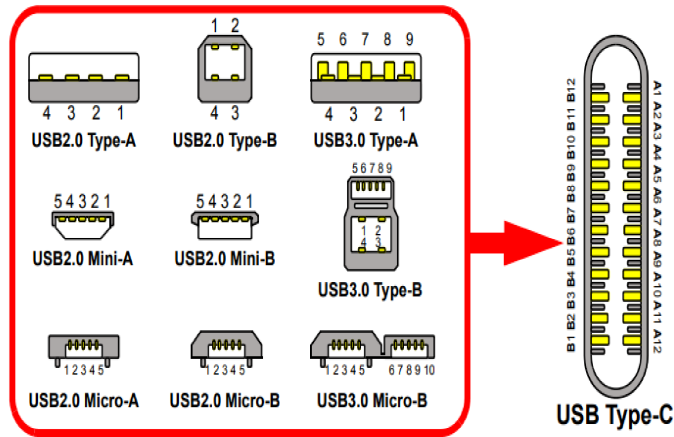
Figure 2.4: USB Plug Form [29]

2.4 Related Works

In prior research on VR analysis, diverse methodologies have been proposed. A study in *"Temporal Characterization of VR Traffic: A Network Slicing Use Case"*, for instance, introduced an analysis of rate distribution using empirical Cumulative Density Function (CDF) applied to *Virus Popper* resulting in a significant variation in the rate (MB/s) for various number of frames. The research also proposed models that can predict the future frames size and it can be generalized to other traces[30]. Another study in *"An Open Framework for Analyzing and Modeling XR Network Traffic:*, applied to *Minecraft*, *Virus Popper*, *Google Earth VR - Tour*, and *Google Earth VR - Cities*, suggested that by narrowing the focus on Downlink (DL) video traffic, the researchers ignored the less impactful non-video traffic so that they could concentrate on understanding and representing the data. The non-video traffic, which includes head tracking, was found to have a low data usage. For example, non-video DL traffic only accounted for 3 to 5 kilobit per second and Uplink (UL) traffic for about 135-140 kilobit per second. These were relatively low compared to their target rates. Moreover, the non-video traffic flows were consistent and did not vary much[31]. Additionally, examining in trace of *Star Wars IV* encoded at medium quality MPEG-4 shows remarkable challenge to analyze large sets of traffic measurements due to high variability. The study recommends having data sets collected from diverse sources or time periods can enhance the probability of identifying common aspects in behavior of videos. Furthermore, it suggests viewing traffic rate as a continuous-time process for more effective analysis. An initial crucial step in traffic analysis involves utilizing Probability Density Function (PDF) estimated by histograms to discern peak rate and mean

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rate of traffic[32].

In modern machine learning, a key idea is using probability distributions to describe data. Data sets are often represented by these distributions, which are like patterns showing how different parts of the data relate to each other. The main problem here is figuring out the distance between two distributions, called P and Q. This distance, denoted as $\rho(P, Q)$ or $d_{TV}(P, Q)$ helps to measure how different they are. For example, if P and Q are the results of two learning algorithms, it might be necessary to know how much they differ from each other. The Total Variation Distance (TVD) quantifies the discrepancy between two probability distributions which makes it a versatile metric for comparing and assessing the similarity of various distributions. P and Q, defined over a finite domain D, the statistical difference is determined by [33]:

$$d_{TV}(P, Q) = \frac{1}{2} \sum_{x \in D} (|P(x) - Q(x)|) \tag{2.1}$$

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Data Acquisition

3.1 Participants

Around 60 people from various backgrounds and experiences in gaming and who were in the range between 18 to 35 years old participated to play the games with VR as a part of the research. It took around one and a half hours for each person to be involved in the whole activity. Before starting to play the game, the researchers informed the participants about the research such as the main goals of the research, the procedures that they needed to follow, and checked if they were eligible to participate. Upon receiving all the explanations, the participants proceeded to sign the consent form (see **Appendix A** for Consent Form). This document signifies that the research has been authorized by the Ethical Committee of Human Inspired Technology (HIT) Research Centre at the University of Padova. Moreover, people with a history of vertigo, inner ear problems, balance issues, epileptic attacks or seizures, and brain injuries could not participate to the research. Therefore, before starting the game, the participants was asked to do the visual acuity test using the Snellen chart and the blind colour test on the Ishihara website [34]. The participants were allowed to continue to the next step if only they passed the visual acuity test at least with a 5/11 score. The blind colour test result determined the eligibility of participants in playing the Beat Saber game since it has some colours to follow in the game.

3.2 Setting Environment

Before starting the research, it was necessary to do the initial preparation such as setting the room and devices to be used so that future problems regarding to the technical issues such as low battery for the controllers could be avoided.

3.2.1 Location

The environment was set up carefully and cleared of obstacles that potentially disturbed or harmed the participants. The experiments were conducted at the SPARCS laboratory of Department of Information Engineering, University of Padova as shown in Figure 3.1.

Figure 3.1: SPARCS Lab

3.2.2 Computer

The research employed two monitors supported by a desktop computer (system unit) that is equipped with Windows 10 Home X64. The computer is powered by an Intel i7-9700k processor with speed 3.60 GHz across 8 cores and 8 threads, along with 2400 Hz of 64 GB Random-access Memory (RAM). The system is also enhanced by the graphic processing unit of NVIDIA GEFORCE RTX 2080 Ti. The first monitor served the purpose of executing the recording software (Oculus Monitor and Wireshark) and it simultaneously facilitated file management throughout the experimental process, while the second monitor was exclusively operated in running VR applications. The VR headset was connected to the computer via a Meta Quest Link cable (type C), illustrated in Figure 3.2.

Figure 3.2: Meta Quest Link Cable [35]

3.2.3 Oculus Meta Quest 2

The Oculus Meta Quest 2 consists of a headset and a pair of controllers enabling coverage of Six Degrees of Freedom (6DOF) movement of the body and head which subsequently translates into a virtual reality experience. The headset is equipped with an adjustable soft strap designed for user comfort purpose. Built-in 3D positional audio enhances the immersive experience with the headset and a 3.5 mm audio port is available when playing with headphones [35]. Moreover, the device has a Qualcomm Snapdragon XR2 processor with 6GB of RAM. The device is also provided with two controllers that require 2AA batteries for each controller [36]. For this experiment, the selected refresh rate was 72 Hz with display resolution 4128x2096 per eye aligning with the automatic recommendation provided by the Oculus based on the specifications of computer. To establish the connection between the VR headset and the computer, the Meta Quest Link cable (type C) was utilized and the Oculus Link (Quest 2 app) was initiated. By using this app, all devices (headset and controllers) could be monitored including connection status and tracking the battery percentage for each controller. Furthermore, the setup on the app was needed to choose the connection of the device via Link (cable). It was essential to launch the Steam VR in the Oculus Link menu, before commencing any gaming activities.

Another critical aspect of the setup involved defining the boundaries in a virtual box of 3 meters x 3 meters using the controllers as illustrated in Figure 3.4a. It was also crucial to ensure the safety of the participants and prevented any inadvertent collisions with the limited space. As the participants navigated closer to these boundaries, the participants would see a blue net

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as visually represented in Figure 3.4b. Hence, the participants could be aware when they got closer to the boundaries and could go back to the safe area.

Figure 3.3: Oculus Meta Quest 2 [37]

(a) Boundary 3x3m [35]
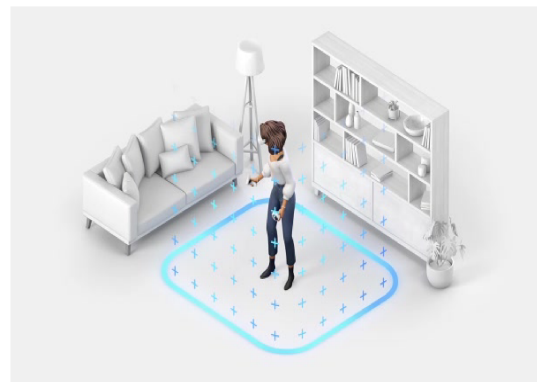
(b) Net Boundary [35]

Figure 3.4: Boundary Setting

3.3   Setting Recording Software

Within this research, the data is obtained through recording interactions between the headset and the computer via Meta Quest Link cable. The software used to record the data are Wireshark and Oculus Monitor. In general, the Wireshark functions as a tool to record the traffic of the data while the Oculus Monitor is utilized simlutaneously to record the movement of the headset.

3.3.1 Wireshark

When the participants started to play the game, the Wireshark was run first before the Oculus Monitor to prevent any bugging or delays as was observed during the trial when the Oculus Monitor was operated first. According to Walter Goralski [38], Wireshark functions as a program to analyze network protocols and it keeps a duplicate of each data packet that originates from or enters the system through a specific interface. The captured packet stream is saved in .pcapng format due to its improved capability, especially in time stamp precision of nanoseconds [39]. The packets are captured through USBPcap which is USB Packet capture for Windows. It captures the packets based on the USB protocol traffic since we use the Meta Quest Link cable to connect the headset to the computer [39]. Figure 3.5 shows the display for stored pcapng file from Wireshark where the recorded time is in nanoseconds, the source and destination represent the connection between the headset and the computer, the protocol is USB because of cable link usage, the length of each frame, and it also shows the total number of packets. The URB on the display represents the transferred message that encapsulates comprehensive information necessary for the execution of USB transactions and delivery of data and status back. It plays a pivotal role in transferring some various types of data transfer, including bulk transfers. Bulk transfers excel their capacity for dependable data movement, especially for handling large data volumes, facilitated hardware error detection, and involving restricted number of retries in hardware. BULK IN refers to direction of data transfer from a USB device to the host (computer), while the BULK OUT refers to the opposite direction where data is transferred to a USB device from the host (computer) [40].
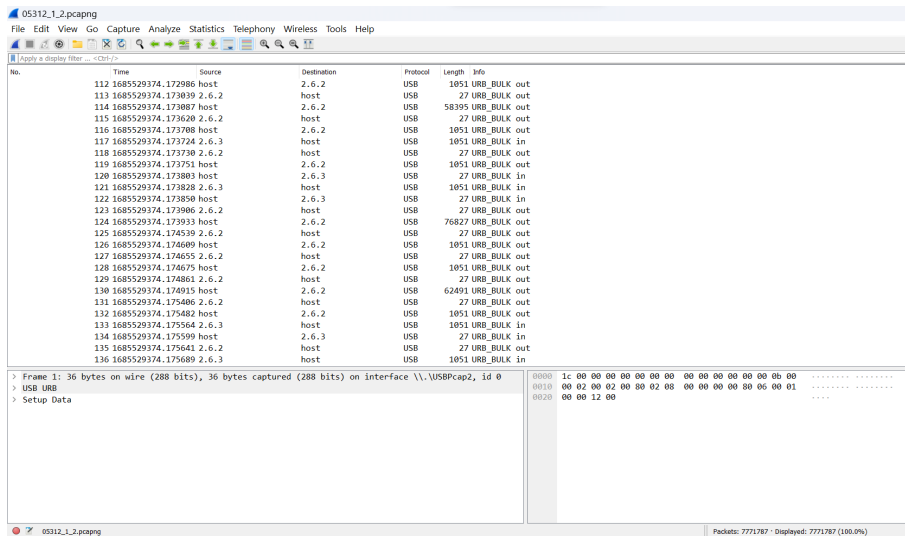
Figure 3.5: Wireshark Display

3.3.2 Oculus Monitor

According to Rajetic [41], Oculus Monitor is a software deisgned to monitor the real-time status of various aspects of the Oculus VR environment. It renders the room layout, alongside with the sensors metrics derived from movements such as rotation, acceleration, position, and others, originating from the headset and each controller as shown in Figure 3.6. All of those values is logged using the software and stored in Comma-Separated Values (CSV) text file format. The recorded data then later is associated with the data from Wireshark for further analysis.

Figure 3.6: Oculus Monitor

3.4 Games Used

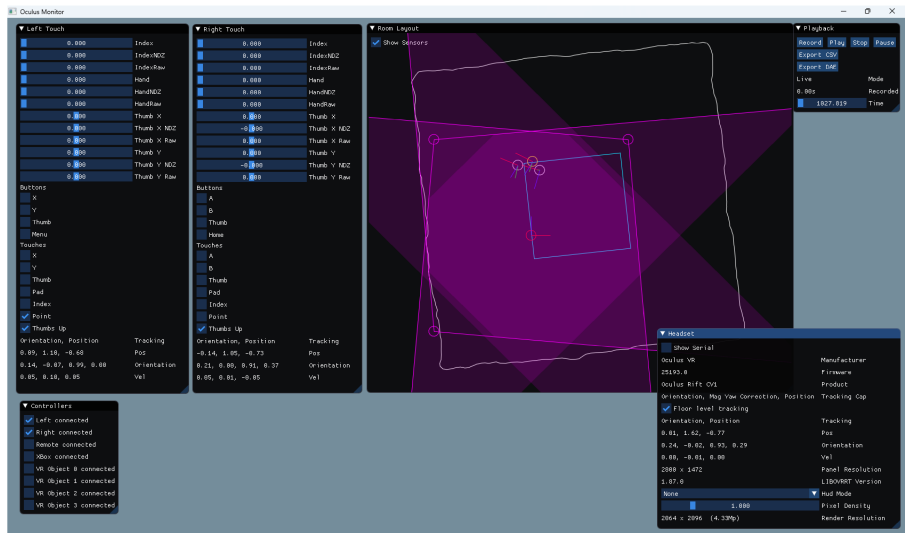In this research, 60 participants were randomly selected to play in two different groups of games, where 30 individuals played for each group of the games. Group 1 consists of two games: Cooking Simulator and Beat Saber. Cooking Simulator was chosen for its relative simpleness and real-life relevance, especially for the individuals without prior experience in gaming. It was paired with Beat Saber game played by the participants with no severe color blindness since the game-play heavily relies on distinguishing colours.

The second group of games consists of the Forklift Simulator and Medal of Honor. The game-play in Forklift Simulator predominantly hinges on the movement of the headset and the control of the joysticks, similar to the Cooking Simulator. However, participants are required to sit on a chair to play the game. The Medal of Honor, on the other hand, is a type of war game that encourages the participants to engage in more extensive movements, such as walking, turning around, or even extending their arms. Participants with colour blindness are advised to play the second group of games.

3.4.1 Cooking Simulator

Cooking Simulator, shown in Figure 3.7, is a game in which the players can prepare various recipes. In this study, the participants take part in a tutorial session for a maximum of around 15 minutes to familiarize themselves with the game mechanics such where the place to get the

utensils, how to open the fridge, how to turn on the stove, how to chop a lemon, and others. Additionally, their task involves in playing two recipes: Fried Shrimp and Baked Cod recipes, each for a combined maximum duration of 20 minutes.

Figure 3.7: Cooking Simulator [42]

3.4.2 Beat Saber

Beat Saber is a game that heavily relies on colour in its game-play. The players take maximum 10 minutes to become accustomed to the game, such as in which direction they should swing the joysticks to cut the cube, in tutorial session. Subsequently, they play several types of levels based on different songs and levels of movement complexity. For the Beat Saber Original song, the levels include *Easy* 0°, *Easy* 90°, and *Easy* 360°. Similarly, the $100Bills song consists of *Normal* 0° (as revealed in Figure 3.8), *Normal* 90°, *Normal* 360°, and *Hard* 0° levels.

Figure 3.8: Beat Saber - $100Bills Hard [43]

3.4.3 Forklift Simulator 2019

Forklift Simulator 2019 is a gaming application which provides users an environment to simulate forklift operation, closely mimicking reality as shown in Figure 3.9. In this experiment, the participants play in various types of driving scenarios, each encompassing distinct difficulty levels. Player plays Controls session as a part of tutorial to develop familiarity with operational aspects like machine activation, light management, wheel control, and other related functions. For the Starting and Driving session, it has 2 levels, Driving Forward session has 4 levels, and the Driving Backward session has 4 levels.

Figure 3.9: Forklift Simulator 2019 - Controls

3.4.4 Medal of Honor

Medal of Honor is a war-type game where the participants utilize joysticks to navigate and engage in firearm combat. The tutorial session takes in the Firing Range level, where the players allocate approximately 10 minutes to acquaint themselves with movement dynamics, then object interaction or how to grab things, firearm loading, and accurate shooting techniques. After the tutorial, the participants are challenged to survive for 5 minutes in the Bullets and Bulkheads level as represented in Figure 3.10 by evading their or neutralizing their enemies.

Figure 3.10: Medal of Honors - Bullets and Bulkheads

3.5 Questionnaire

In this study, two types of questionnaire forms were used, which participants were required to complete. First, the Initial Survey form was filled out before the participants played the game (see **Appendix B** for Initial Survey). This survey collects information related to the ID number assigned by the researchers, date of research session, gender, prior experience with 2D or 3D or VR or Augmented reality (AR) technologies, and whether they had undergone the visual tests.

Another questionnaire used was Simulator Sickness Questionnaire (SSQ) (see **Appendix C** for SSQ). This questionnaire was designed to collect the information about symptoms experienced by participants before and after engaging in first game, and also before after playing the second game. The symptoms covered are general discomfort, fatigue, headache, eyestrain, difficulty focusing, increased salivation, nausea, difficulty concentrating, fullness of the head, blurred vision, dizziness when eyes opened and closed, vertigo, stomach awareness, and burping. Gathering these information allowed the researchers a link between playing VR and the

sickness for further analysis.

3.6 Data set

In this research, the data sets are obtained from 60 experiments in total split by two groups of games. Group 1 as included Cooking Simulator and Beat Saber consist of 30 experiments each, as well as Group 2 that includes Forklift Simulator and Medal of Honor. These data sets contains two type of data: data traffic and data movement. Data traffic has been aligned accordingly to data movement. Since this study focuses on frame analysis, only data traffic is considered.

4
Results

4.1 Data Rate Distribution

Data rate represents the amount of data transmitted over a specific period which is crucial in assessing the efficiency of data transmission influencing the quality of experience for the players during the game-play. In this section, the individual data rate is presented for each experiment along with the average of data rate from each game. In this research, data rate is analyzed over a 500-second time frame for computational ease purpose in MB/s unit.

For Cooking Simulator as shown in Figure 4.1, 50% of data rates median from 12 out of 30 experiments is in interval around 19MB/s. For all experiments, the data points do not extend beyond the upper fence, except for experiment 07044 and 07265. This result reveals that the data points for the two experiments are significantly higher than most of data. Moreover, numerous experiments exhibits data points touching the lower fence implying the data points are significantly lower than the majority of data. Specifically in experiment 07252 and 07253, the range of data rates are relatively lower than the others. In experiment 07252, the length of box is shorter and grouped outliers touch lower fence which suggests the majority of data points are clustered within a narrow range indicating the presence of certain extreme values lower than the central bulk of data. Conversely, although data rate range of player 07253 also lower, the size of the box is not relatively small and there is one extreme value in the lower data.
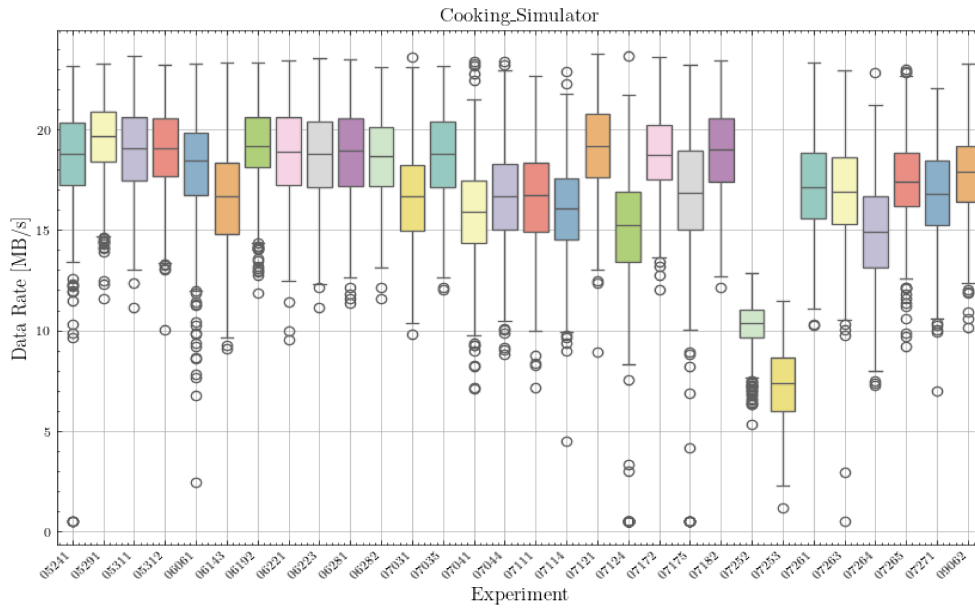
Figure 4.1: Cooking Simulator Data Rate

For Beat Saber in Figure 4.2, the data rates tend to be more diverse than Cooking Simulator. There are almost half of experiments where the outliers touch the lower fence indicating extremely lower data rates among the most of data. In addition, experiments 07252 and 07253 also show remarkably low data rates compared to others. The box size of experiment 07252 playing Beat Saber is also shorter similar as in playing Cooking Simulator, while experiment 07253 has no outliers around the upper and lower fences. Generally, the median of data rates in Beat Saber is more various compared to Cooking Simulator and specifically player 05291 has longer size of upper box showing that the values above median (19MB/s) are more dispersed compared than the values below median. It may indicates that the distribution of data rates is skewed towards higher values.
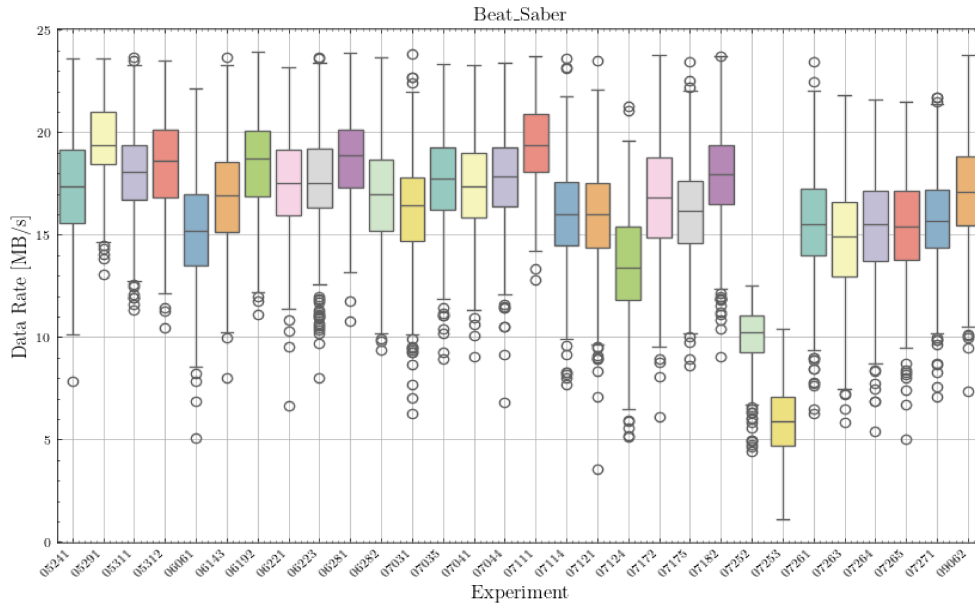
Figure 4.2: Beat Saber Data Rate

Moving to Forklift Simulator (Figure 4.3), the majority of experiments have outliers in the upper fence and also in the lower fence with median around 14MB/s. The highest data rate is reached by experiment 06141 and the lowest one is achieved by experiment 06142. For experiment 06142, the upper box is longer indicating that the values beyond median (10MB/s) are more spread than the values below the median. In contrast for Medal of Honor (Figure 4.4), experiment 06141 and 06142 have lower range of data rates. Then, the general medians are more various compared to Forklift Simulator with fewer outliers in upper parts. For experiments 06141, 06142, and 06274 the length of the boxes are longer than other experiments. It informs that there is more dispersion in the data rates of the two experiments compared to other experiments. In general, most of the experiments has more extreme values in the bottom 50% of data rate than top of 50% of data which means that majority of the experiments has skewed left distributions which will be explained further in the following section. The difference of data rates, particularly in extreme values such as in experiment 07252 and 07253, can be influenced by many factors such as the possible movement of individuals and potential undetected/missing frames. When players are standing without much movements, reading the instructions, or in the menu, there is a probability that there is less transmission during the period. Thus, further analysis will be discussed in the Frame Size Analysis Section.
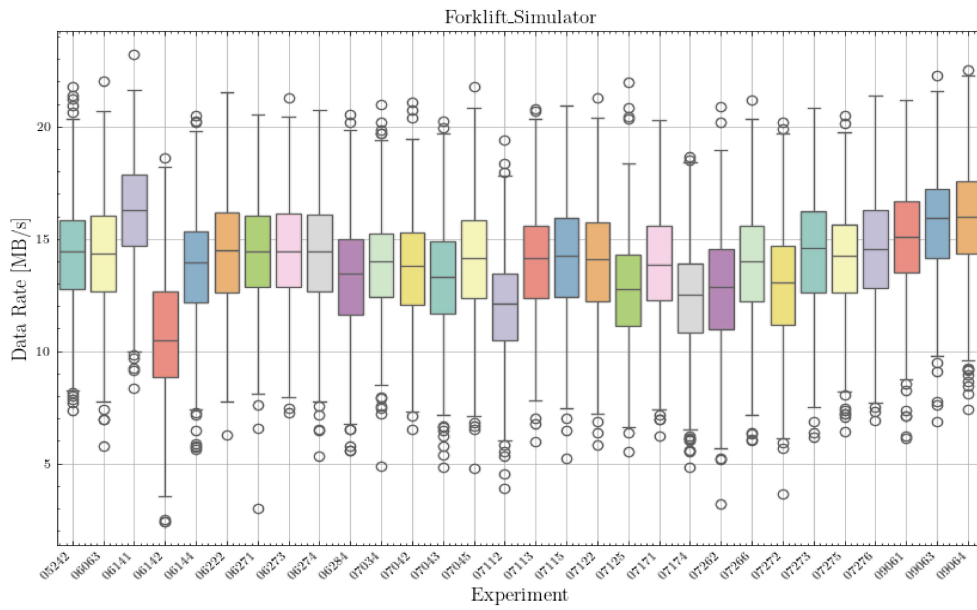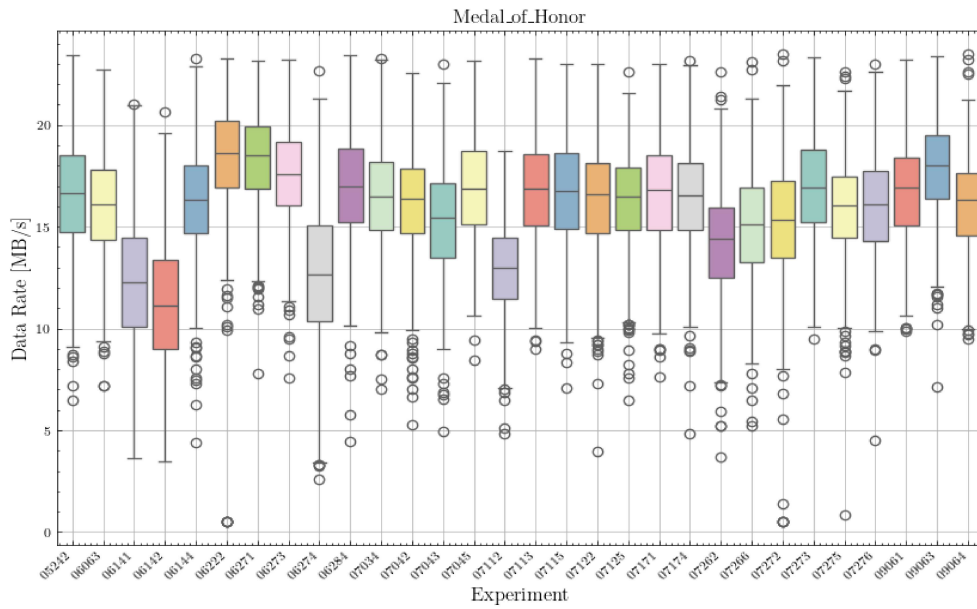
Figure 4.3: Forklift Simulator Data Rate

Figure 4.4: Medal of Honor Data Rate

4.1.1 Mean and Peak Average of Data Rate for Each Game

In addition, Figure 4.5 illustrates the average of mean and peak of data rate for each game, with Cooking Simulator having highest values of the mean followed by Beat Saber, Medal of Honor, and Forklift Simulator. The peaks of data rates of all games are less significantly different, except Forklift Simulator with around 1MB/s lower than other games. While the data rates can surpass 20MB/s in specific instances, the collective average from all experiments for each game are unable to reach 20MB/s. In spite of that, pinpointing exact reasons for these numerical differences proves challenging due to the diverse nature of the players.
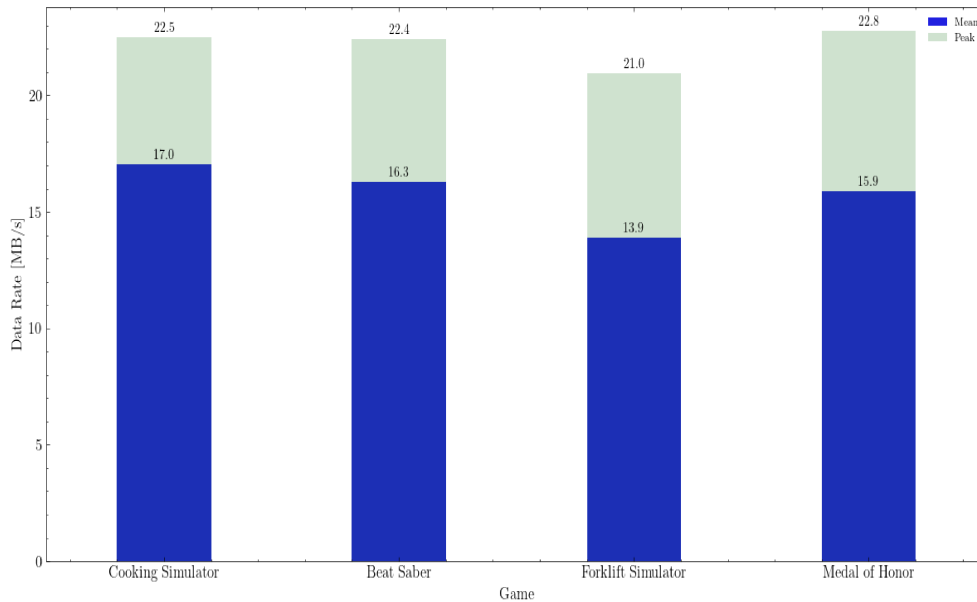
Figure 4.5: Average Mean and Peak of Data Rate for Every Game

For instance, Table 4.1 presents how average data rate of Medal of Honor for player 06274 is lower than Forklift Simulator, contrary to the overall average data rate. In the context of Medal of Honor, when a player allocated more time in hiding rather than engaging actively, reduced data transmission occurs, and it impacts the data rate even though it is a type of war game which involves high-speed movements like explosions and gunfire. Therefore, despite each game having instructions directing the players to perform specific actions, the participants' behavior during game-play also plays a pivotal role in determining the data rate.

Table 4.1: Mean Data Rate from Samples Experiments 07175 and 06274

Experiment	Group	Game	Mean Data Rate [MB/s]
07175	1	Cooking Simulator	16.7
		Beat Saber	16.1
06274	2	Forklift Simulator	14.3
		Medal of Honor	12.6

4.2 Total Variation Distance (TVD)

As observed in the previously presented data rate box-plots, certain experiments show a similar trend across various games. To effectively compare data rates among these experiments, it is essential to measure the similarity between probability distributions, specifically in this experiment using Total Variation Distance (TVD) in which the probabilities are computed from among experiment pairs.

4.2.1 TVD for Each Game

Despite most of the experiment pairs among games are slightly different, there are some instances where the difference is outstandingly significant. In Cooking Simulator, the data rate of players 07252 and 07253 playing Cooking Simulator are exceptionally lowest compared to the rest. However, Figure 4.6 reveals that probability distribution of data rate from experiment 07252 is not significantly different from others. Meanwhile, the total variation distance of player 07124 and 07253 are the most remarkably unlike from others. In Beat Saber, the most pronounced different total variation distance is exhibited by experiment 07253. Similarly to Cooking Simulator, the data rates of players 07252 and 07253 are the lowest. The probability distribution of data rate from experiment 07253 is the most significant different because the distribution of data rate even with low range is more concentrated around a central point than the distributions for the other experiments. This is also because the other experiments have more data points at the extremes of the range. If the distributions have similar shapes, the total variation distance may not vary much despite the differences in the range.
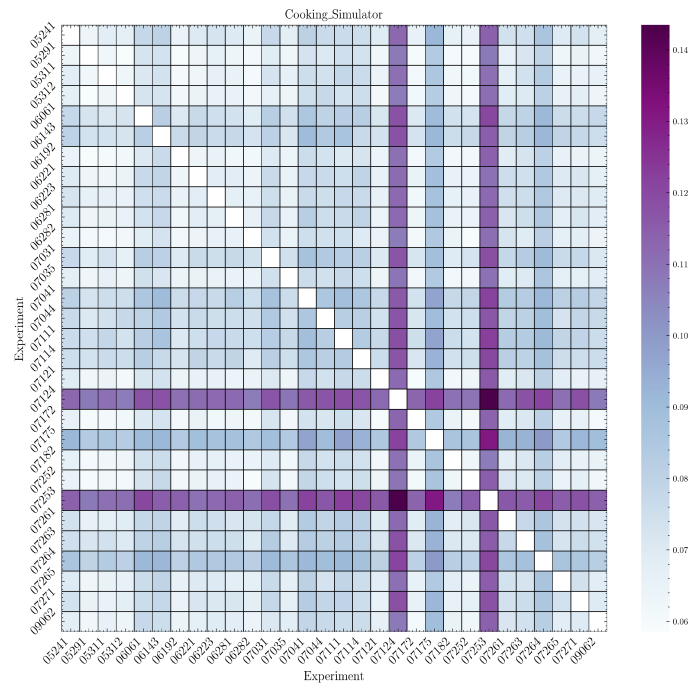
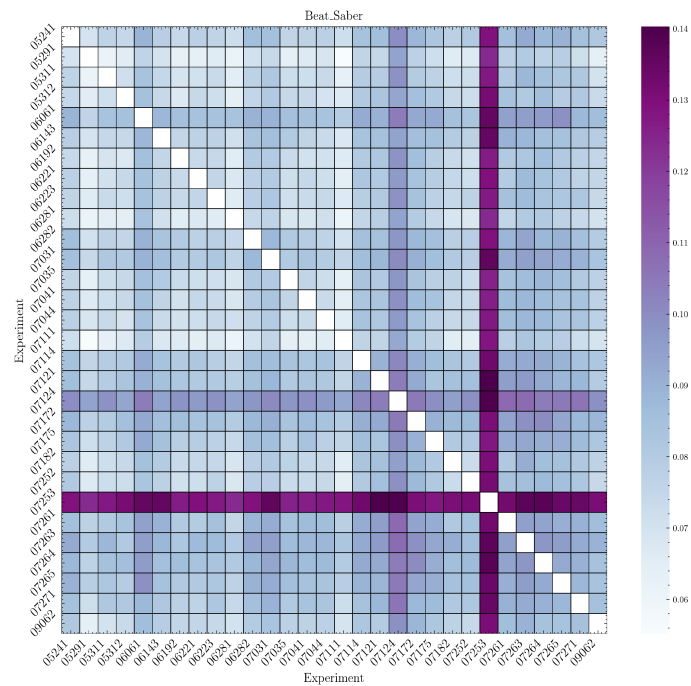**Figure 4.6:** Total Variation Distance of Data Rate in Cooking Simulator Experiments

Figure 4.7: Total Variation Distance of Data Rate in Beat Saber Experiments

Furthermore, the most notable different of total variation distance in Forklift Simulator is in experiment 06142 in which the range of data rate is also the lowest. In this case, there is possibility where the data points distribution is concentrated in a central point, similar to instances in Cooking Simulator and Beat Saber. In addition, there are three experiments in Medal of Honor exhibiting the most outstanding difference which are 06141, 06142, and 06274.

Hence, the most significant disparities in total variation distance of data rate among the games are observed in Cooking Simulator for experiments 07124 and 07253, Beat Saber for player 07253, Forklift Simulator for 06142, and Medal of Honor for experiments 06141, 06142, and 06274. In the case of Forklift Simulator, Figure 4.8 displays deeper colors, signifying a greater diversity compared to other games. This describes that in Forklift Simulator experiments, the total variation of distance is slightly more varied.
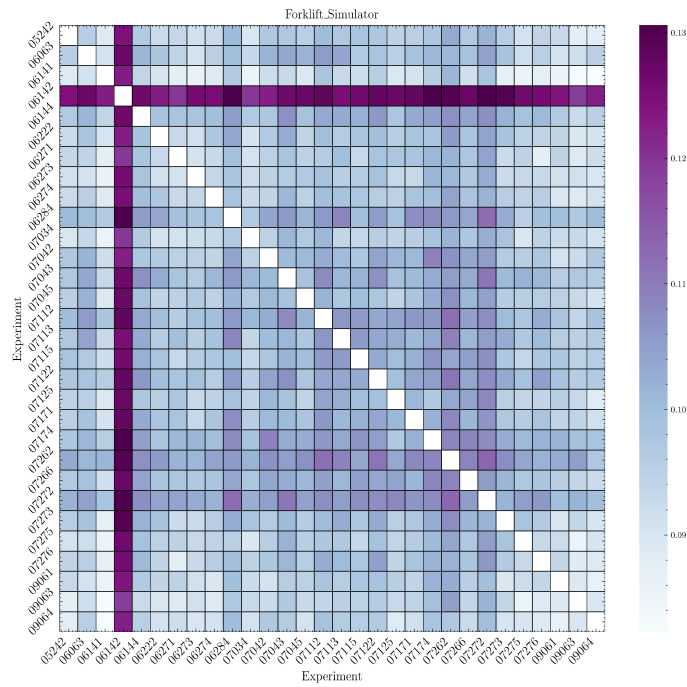

Figure 4.8: Total Variation Distance of Data Rate in Forklift Simulator Experiments
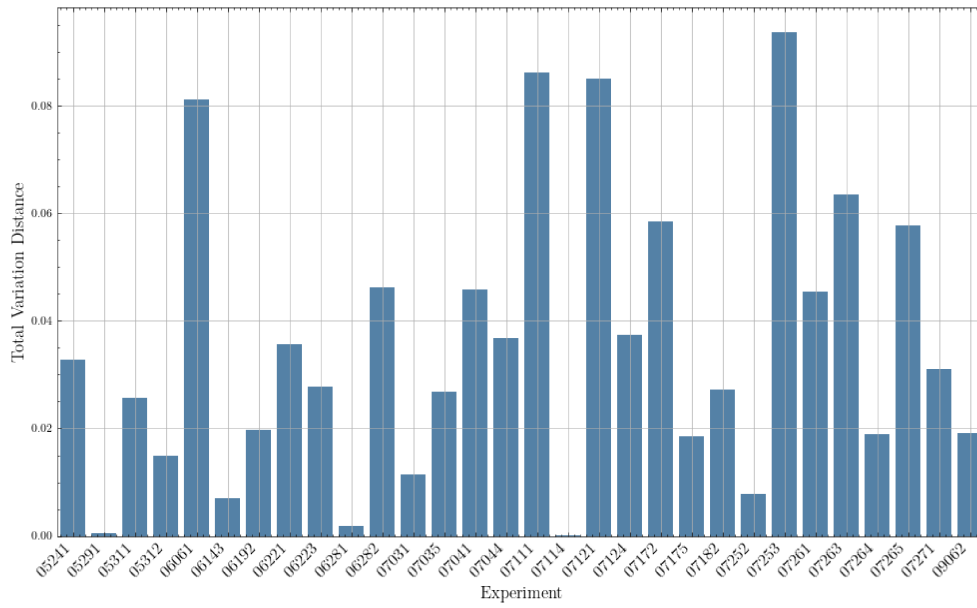
Figure 4.9: Total Variation Distance of Data Rate in Medal of Honor Experiments

4.2.2 TVD for Each Player

An examination of players who engaged in both Cooking Simulator and Beat Saber shown in Figure 4.10 depicts that player 07253 has the most significant difference in total variation distance, followed by player 07111, 07121 and 06061. On the other hand, player 07114, 05291, and 06821 manifest lowest differences, implying a similarity in their game-play behaviors across the two games. Regarding individuals participating in both Cooking Simulator and Beat Saber, it is noticeable that player 07114 demonstrated a consistent gaming approach, while player 07253 demonstrated a distinctly divergent gaming style.

For players playing Forklift Simulator and Medal of Honor, Figure 4.11 illustrates that player 09064 has the lowest total variation distance. Meanwhile, experiment 07174 demonstrates the most notable distance. Thus, player 09064 played with a higher degree of consistency across both Forklift Simulator and Medal of Honor games, whereas the game-play behaviors for player 09064 differed when engaging with these two games.

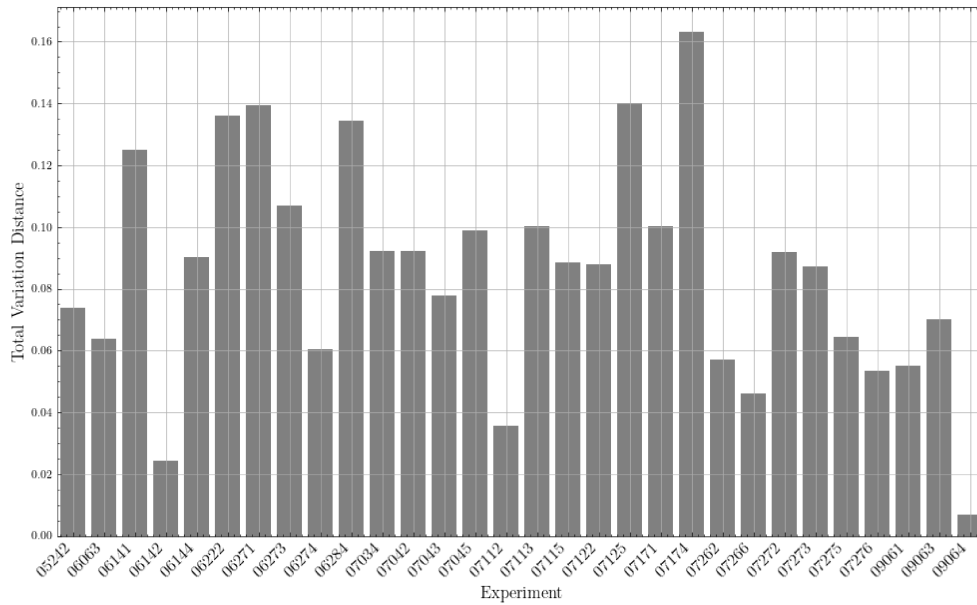**Figure 4.10:** Total Variation Distance of Data Rate for Same Players playing Cooking Simulator and Beat Saber

Figure 4.11: Total Variation Distance of Data Rate for Same Players playing Forklift Simulator and Medal of Honor

4.3 Frame Size Analysis

4.3.1 Frame Size Distribution

Another visualization method is used to analyze individual experiment deeper by using histogram. This visual exploration determines the shape, skewness, and presence of outliers in the data rates and to see if the distribution follows a normal pattern (Gaussian distribution) in which the majority of observations cluster around the center, called mean. In this study, packets that arrive with interval times below 0.05 seconds are considered as the same frame and this study only focuses on analysing the frames instead of packets since information of frame will be more useful despite of various network used. As discussed in the data rate distribution before, there are two experiments in Cooking Simulator and Beat Saber that have the lowest range of data rate: 07252 and 07253. It is necessary to analyze the frame in order to understand the low rates of those traces.
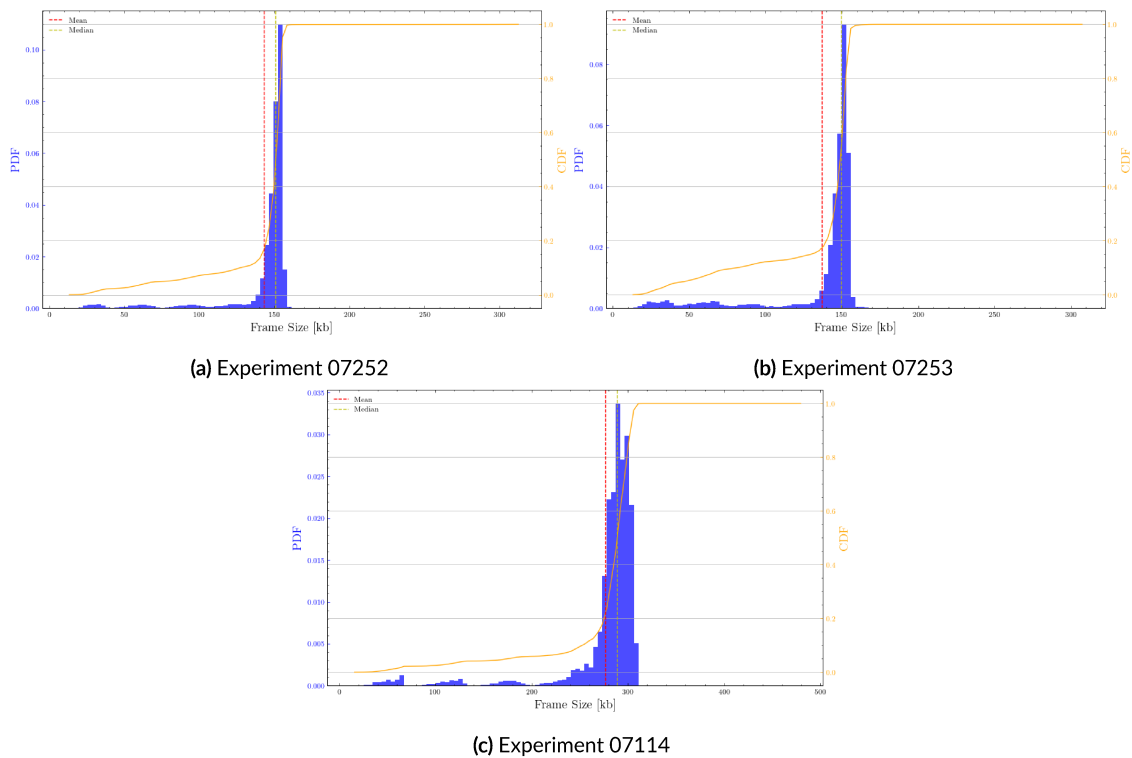

(a) Experiment 07252

(b) Experiment 07253

(c) Experiment 07114

Figure 4.12: Frame Size Distribution using PDF and CDF in Cooking Simulator

It can be seen in Figure 4.12a and Figure 4.12b that 75% of data falls in the big values of frame size in experiments 07252 and 07253 playing Cooking Simulator which is around 150kb. In contrary, most of experiments such as in experiment 07114 as shown in Figure 4.12c informs that the third quartile of data lies on big frames around 300kb. The left tail in the histograms suggests the presence of a few data points with low values which significantly influences the mean and causes it to be lower than the median.. Moreover, higher values are more prevalent as indicated by the concentration of data points toward the right side of histograms. This phenomenon also occurs in Beat Saber, as displayed in Figure 4.13, where player 07252 and 07253 have very low data rates but only observation 07253 has significant dissimilarity. Thus, this leads to the low data rates in the two experiments in both games.
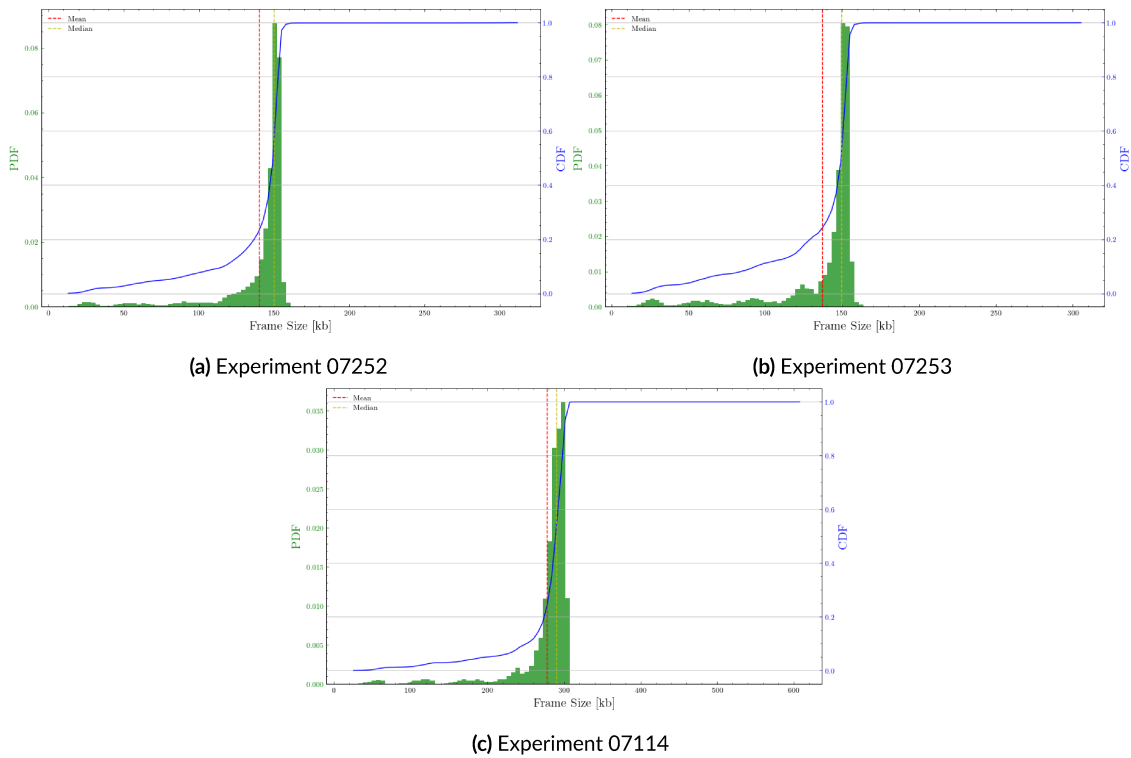

(a) Experiment 07252

(b) Experiment 07253

(c) Experiment 07114

Figure 4.13: Frame Size Distribution using PDF and CDF in Beat Saber

Moving to Forklift Simulator as illustrated in Figure 4.14a, there is a probability between 0 to 0.03 where the frame size is in range 20 to 50kb. According to TVD result, player 07174 in Forklift Simulator exhibits most significant dissimilarity of distributions among other experiments such as experiment 09064 showed in Figure 4.14b. It can be seen that even though quartile of experiment 07174 achieved 290kb as well as in experiment 09064, the distribution of smaller sizes is higher. Moreover, the probability of frame 290kb in experiment 07174 is 0.036 slightly lower than in experiment 09064 (0.039). Similar to Forklift Simulator, observation 07174 in Medal of Honor also exhibits higher value of total variation distance when compared to 09064. Figure 4.14c depicts that 75% of data has lower probability to reach close to 300kb, which is around 0.056, while in observation 09064 in Figure 4.14d, it can achieve nearly 300kb with probability of 0.058. Hence, this results contribute to the high different in total variance distance of 07174 and less for 09064 which shows that player 07174 played the most inconsistently in both games.
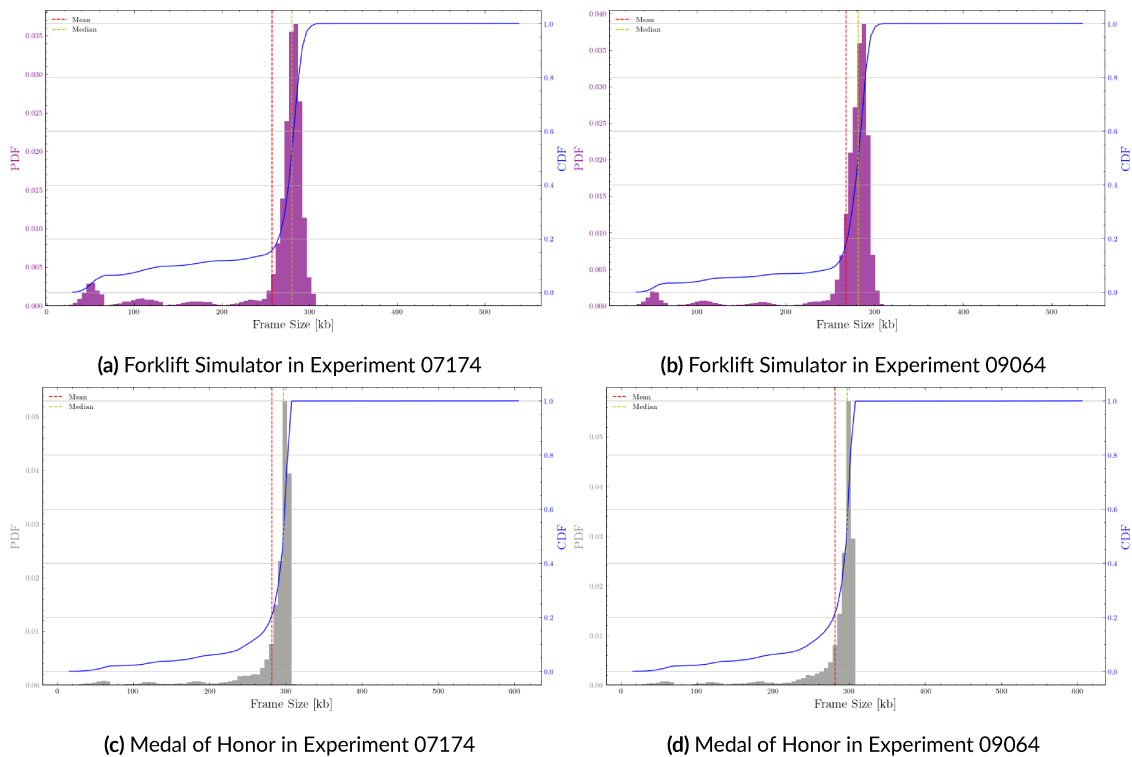

(a) Forklift Simulator in Experiment 07174

(b) Forklift Simulator in Experiment 09064

(c) Medal of Honor in Experiment 07174

(d) Medal of Honor in Experiment 09064

Figure 4.14: Frame Size Distribution using PDF and CDF in Forklift Simulator and Medal of Honor

4.3.2 Missing Frames

In this research, the expected frame per second is 72Hz. In order to investigate the presence of missing or undetected frames, the frames that did not appear in the time period where Inter-Frame Inter-arrival (IFI), which is time duration between two consecutive frames around 13.8ms (1/fps), exceeds 20.8ms (1.5/fps). If the IFI is larger than 20.8ms, it is sure that there is at least one empty frame in between. The missing frames were filled with synthetic zero values to be visualized better. In Cooking Simulator, although the big frames of observation 07252 is low 150kb, which explains the low data rates, the frequency of missing frame is lower than experiment 07253 leading to the low TVD value as seen in Figure 4.15a and Figure 4.15b. Figure 4.15b also indicates the higher frequency of missing frames which significantly contradicts the big frames group causing the significant value of TVD. The significant missing frames affect the overall distribution of frames.
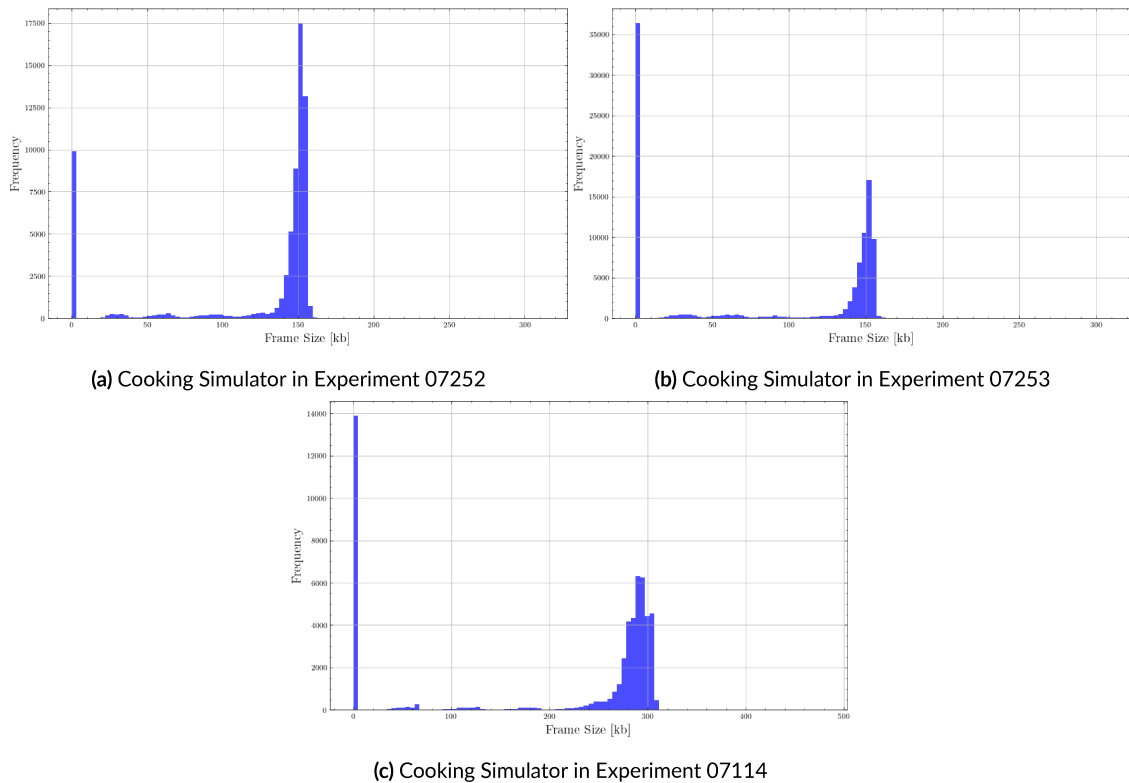

(a) Cooking Simulator in Experiment 07252

(b) Cooking Simulator in Experiment 07253

(c) Cooking Simulator in Experiment 07114

Figure 4.15: Missing Frames in Cooking Simulator

For Beat Saber, trace 07253 in Figure 4.13b displays that the frequency of missing frames is extremely high more than 40000 compared to other experiments such as in 07252 showed in Figure 4.16a. Then, although the 07252 also has low data rate and small frames size, the frequency of 150kb frames is higher than the missing frames. Hence, the observation 07253 has the most significant dissimilarity of distributions among the experiments. Comparing trace 07114 in Cooking Simulator (Figure 4.15c) with trace 07114 in Beat Saber (Figure 4.16c), it shows that regardless the difference between the frequency of missing frames, the overall distribution between two traces are similar.
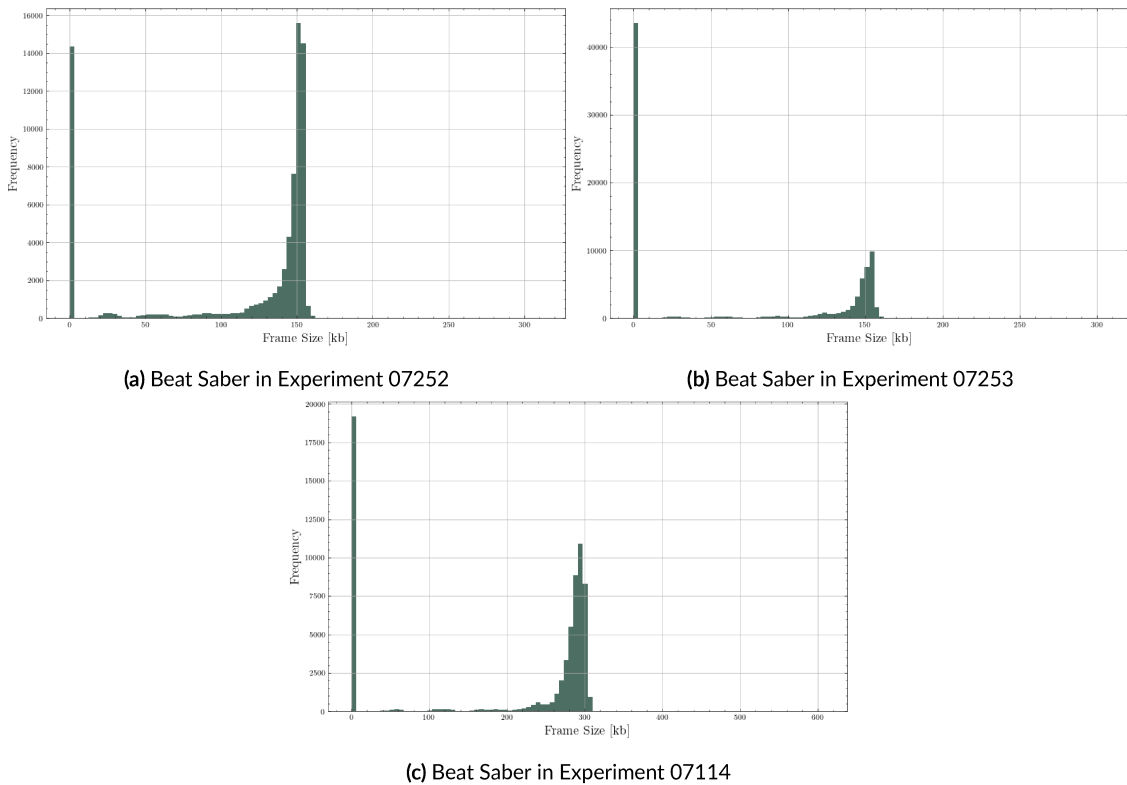

(a) Beat Saber in Experiment 07252

(b) Beat Saber in Experiment 07253

(c) Beat Saber in Experiment 07114

Figure 4.16: Missing Frames in Beat Saber

According to TVD result, player 07174 played most inconsistently in Forklift Simulator and Medal of Honor when compared to other observations such as experiment 09064. Figure 4.17a shows that the frequency of bigger frames is dominated extremely by missing frames, whilst in 09064 the frequency of bigger frames is higher than in 07174 showed in Figure 4.17b. Similarly, Figure 4.17c and Figure 4.17d depict that even though both traces present the high frequency in around 300kb frames in Medal of Honor, frequency of missing frames in player

07174 is outstandingly higher than the bigger frames. Consequently, player 07174 exhibits high significant different behaviour while playing both games among the rest of observations.
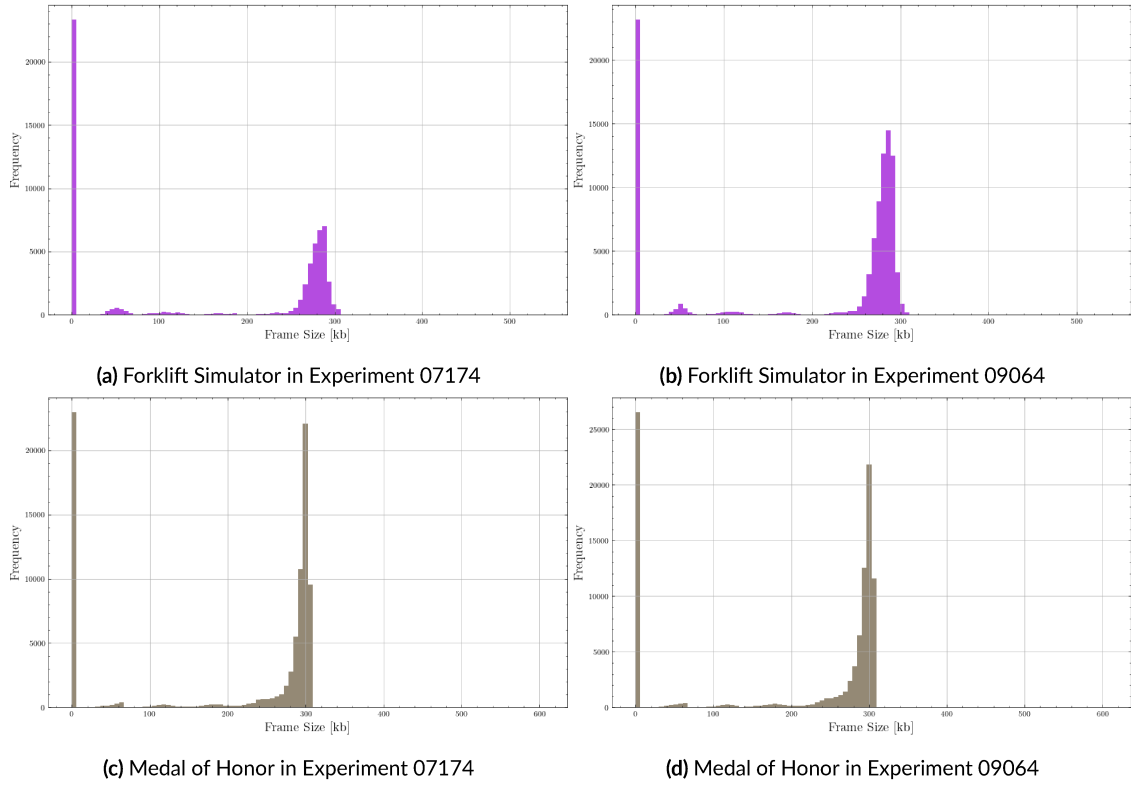

(a) Forklift Simulator in Experiment 07174

(b) Forklift Simulator in Experiment 09064

(c) Medal of Honor in Experiment 07174

(d) Medal of Honor in Experiment 09064

Figure 4.17: Missing Frames in Forklift Simulator and Medal of Honor

5
Conclusion

This research provides valuable data sets obtained from 60 experiments for exploring the traffic in Virtual Reality within Cooking Simulator, Beat Saber, Forklift Simulator, and Medal of Honor games. Even though every game has certain ways to lead the players to play in a specific way, the nature of players during game-play also plays a pivotal rule in influencing the data traffic distribution. In general, Total Variation Distance (TVD) results describe that the total variation distance may not remarkably similar regardless of the range differences. The higher TVD results imply the more dissimilarity between distributions, meaning that the higher TVD value indicates the more different behaviour between players playing same game or same player playing different games. In different games and different players, more than 90% players' nature results in slightly distinct distribution of data rates with more various dissimilarity in Forklift Simulator. For same players playing same games, more than 50% of players played in slightly different behavior for Cooking Simulator and Beat Saber. Similarly, players in Forklift Simulator and Medal of Honor also played slightly differently except for one player that played extremely dispersed when compared to other players.

Furthermore, the distinction of data rates, specifically in extreme values might be influenced by various factors. The data rate distributions of the games are vary with the noticeable low range in data rate of two traces in Cooking Simulator and Beat Saber such as individual behaviour and possibility of missing frames. When players are standing without much movements, reading the instructions, or in the menu mode, there is a possibility that there is less transmission during the period. Moreover, presence of small frames and extreme missing

frames also contribute to the low data rates since they appear when the data rate range is in the lowest ones. As consequence of the gaps and small frames, the distribution of frames tends to get close to skewed-left, which is notably unique in the context of traffic analysis. Therefore, it becomes imperative to investigate deeper into the development of predictive model for handling the missing frames and conduct a thorough analysis in movement traces. Through this study, the aim is to contribute to broader exploration in immersive Virtual Reality analysis.

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A
Consent Form

HIT Research Centre, University of Padova - Ethical Committee - Informed Consent template
(adapted from Standard EUR Informed Consent Form template *version 0.2*)

Version March, 2022

<table>
<tr><td></td><td align="center">INFORMATION NOTE</td></tr>
<tr><td>Project Title</td><td>VR traffic analysis</td></tr>
<tr><td>Purpose of the Study</td><td>This research is being conducted by Andrea Zanella (andrea.zanella@unipd.it), Department of Information Engineering (DEI), University of Padova (https://www.dei.unipd.it/~zanella/)

This research is sponsored by the National Institute of Standards and Technology (NIST), USA (https://www.nist.gov/)

The research has no commercial purpose.

The purpose of this research project is to measure Virtual Reality (VR) traffic, i.e., how much data the computer and the VR headset need to exchange for common applications, and how this affects the quality of the user experience and the risk of cybersickness (a temporary condition caused by exposure to a virtual environment and symptoms similar to motion sickness). The physical movements during the game will also be recorded directly from the computer, in order to measure possible links with the data traffic and quality of the user experience. Its larger implications are in the future design of networked VR systems, as the models resulting from the study may be used in the future generation of headset to provide a better experience to users.</td></tr>
<tr><td>Data collection procedure</td><td>If you decide to participate, you will be asked by Federico Chiariotti, Federica Battisti, Sara Baldoni, Paolo Testolina, Alessandro Traspadini, Alfi Baqiatus Shofi, or Fabio Mistrorigo to play 2 VR games (selected by the researchers) for approximately 20 minutes each, with a 15 minute break in between, and to fill in a questionnaire before and after each session. Aside from the data in the questionnaire, your movements and actions with the controller will be automatically recorded by the computer, along with the content that you will see on the headset. In the questionnaires, we will ask you about your age, gender, and vision issues, along with your previous experience with VR and gaming. We will also record your score and time in each level. After the sessions, we will ask you about any cybersickness-related symptoms you might feel.

The data collection session takes place in a laboratory at the DEI department, which has a wide area for you to play the game safely, and lasts approximately 1 hour, including the break and questionnaires.

The data collected will be used exclusively to fulfill the scientific purpose described above. Anonymized data, without any identifying information, will also be published as a freely available dataset for the scientific community.</td></tr>
</table>

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	To participate, you must be between 18 and 35 years old, with no history of balance issues, brain injuries, inner ear problems, or vertigo. As the games will involve flashing lights and rapid movements, you must also have no history of epileptic attacks or seizures. If you do not satisfy any of these criteria, you should inform the researchers immediately that you cannot take part in the experiment, but you do not have to say which.
Compliance statement	"This project complies with the current pertinent regulations related to research ethics and professional deontology, such as: The General Data Protection Regulation (EU) 2016/679 ("GDPR"), the decree "Regole deontologiche per trattamenti a fini statistici o di ricerca scientifica pubblicate ai sensi dell'art. 20, comma 4, del d.lgs. 10 agosto 2018, n. 101 - 19 dec 2018", and the European Convention on Human Rights (1950), the EU Charter on Fundamental Rights (2000), World Medical Association (WMA), Declaration of Helsinki (2008).
	The principal investigator declares to comply with the measures to contain the contagium from Covid-19 in place at the time of the data collection, and to inform the participant about the risks of contagion depending on the participation to the present study, as well as about the measures to prevent them. The headset will be covered with a disposable mask to minimize the risk of exposure, and the controllers will be sanitized before each experiment.
Incidental findings	You will be able to see your score in the games.
Potential Risks and Discomforts and related minimization procedures	The main risk during the experiment is the advent of cybersickness, a temporary condition caused by exposure to a virtual environment and symptoms similar to motion sickness. A secondary risk is that you may injure yourself by falling or losing your balance.
	To minimize these risks, the laboratory environment will be clear of any objects and surrounded by netting, so as to minimize the risk of tripping up or hitting walls or other objects while playing. If severe cybersickness symptoms arise, or you feel intense discomfort at any point during the experiment, you should interrupt the session and take off the headset immediately. The researchers will also interrupt the experiment if they detect balance issues or erratic movements.
	One of the games (Medal of Honor: Above and Beyond) is in a war setting and involves scenes of violence, in which the player must shoot guns and fight in a war setting. If you are not comfortable with the content of the game, you may opt out and play an alternative game, which does not involve violence of any kind.
Potential Benefits	You will contribute to the advancement of research on VR technology, and have

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	fun playing video games during the experiment.
Compensation	There is no compensation for participating in the study.
Right to Withdraw and Questions	Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time, even if you gave consent. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized in any way. In case of withdrawal before the end of the experiment, the recorded data will be erased. If you decide to stop taking part in the study, if you have questions, concerns, or complaints, or if you need to report an injury related to the research, please contact the principal investigator.
Confidentiality and anonymization procedure	The research team has the following components: Andrea Zanella (full professor, Department of Information Engineering, University of Padova), Michele Zorzi (full professor, Department of Information Engineering, University of Padova), Federica Battisti (associate professor, Department of Information Engineering, University of Padova), Federico Chiariotti (assistant professor, Department of Information Engineering, University of Padova), Sara Baldoni (assistant professor, Department of Information Engineering, University of Padova), Paolo Testolina (research assistant, Department of Information Engineering, University of Padova), Alessandro Traspadini (PhD student, Department of Information Engineering, University of Padova), Alfi Baqiatus Shofi (student, Department of Information Engineering, University of Padova), Fabio Mistrorigo (student, Department of Information Engineering, University of Padova). All components commit to treat the data collected with confidentiality and have received proper instruction about the specific nature of this commitment and of the project approved by the HIT Ethical Committee. Your privacy will be protected to the maximum extent allowable by law. Processed data including statistics about the data traffic, your movements during the games, and your answers to the questionnaires will be published as a freely available dataset on the Unipd data portal (https://researchdata.cab.unipd.it/). No personally identifiable information will be reported in any research product or in the public dataset, and all identification data will be destroyed. As no identifying information about you, aside from your age and gender, will be recorded in the experiment, the data will be fully anonymous (to the researchers as well as users of the dataset).
Data protection rights	By signing this form, you consent to the processing of personal data, which you can revoke at any time during the experiment. As no personal identification data will be kept, and all collected data are fully anonymous, you will not be able to erase your data afterwards (art. 11 GDPR).

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Data controller (Titolare del trattamento) + institutional privacy referent (referente per la privacy)	The data controller ("Titolare del trattamento") is the University of Padova. As PI of the project, Andrea Zanella is the institutional privacy referent for the project ("referente organizzativo per la privacy"). He may be contacted by phone (+39 049 827 7770) or email (andrea.zanella@unipd.it).
Autorizzati al trattamento	Michele Zorzi (full professor, Department of Information Engineering, University of Padova) Federica Battisti (associate professor, Department of Information Engineering, University of Padova) Federico Chiariotti (assistant professor, Department of Information Engineering, University of Padova) Sara Baldoni (assistant professor, Department of Information Engineering, University of Padova) Paolo Testolina (research assistant, Department of Information Engineering, University of Padova) Alessandro Traspadini (PhD student, Department of Information Engineering, University of Padova) Alfi Baqiatus Shofi (student, Department of Information Engineering, University of Padova) Fabio Mistrorigo (student, Department of Information Engineering, University of Padova)
ETHICAL APPROVAL	This study has been reviewed and approved by the HIT Ethical Committee on May 30th, 2023, with protocol number 2023_204R1.

	CONSENT STATEMENTS
Statement of Consent to participate	I agree to participate in the research project described in the information note attached here and led by Andrea Zanella. 1. I have been given sufficient information about this research project and my questions has been answered to my satisfaction. The purpose of my participation has been explained to me and is clear. 2. My participation is voluntary. There is no explicit or implicit coercion whatsoever to participate. 3. I am at least 18 years of age.

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	4. I have the right not to answer any of the questions. If I feel uncomfortable in any way during the interview session, I have the right to withdraw from the interview.
	5. I have been given the explicit guarantee that the researcher will not identify me by name or function in any reports based on this study, and that my confidentiality as a participant in this study will remain secure. In all cases subsequent uses of records and data will be subject to standard data use policies at the EU (Data Protection Policy).
	6. I have been given the guarantee that this research project has been reviewed and approved by the HIT Ethical Committee
	7. I have been given a copy of this consent form co-signed by the interviewer.
Signature and Date	NAME PARTICIPANT / NAME PRINCIPAL INVESTIGATOR SIGNATURE / SIGNATURE DATE / DATE
Consent to data processing	1. I was explained and I understood the full goal of the study. 2. I consent to the processing of the personal data collected during the session in which I participated for the project led by Andrea Zanella 3. I am aware that the data erasure from the dataset is not possible, because of the impossibility of identifying the data subject due to a process of anonymization (Art. 11 GDPR)
Signature and Date	NAME PARTICIPANT / NAME PRINCIPAL INVESTIGATOR SIGNATURE / SIGNATURE DATE / DATE

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B

Initial Survey

Initial survey

Accedi a Google per salvare i risultati raggiunti. Scopri di più

* Indica una domanda obbligatoria

ID *

La tua risposta

Experiment date *

Data

, dd-----yyyy

Age *

La tua risposta

Gender *

La tua risposta

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Rate your previous VR experience *

None

1 ◯

2 ◯

3 ◯

4 ◯

5 ◯

Expert

Rate your previous gaming experience (2D, 3D, VR, AR) *

None

1 ◯

2 ◯

3 ◯

4 ◯

5 ◯

Expert

I have completed the visual tests (Ishihara and Visual acuity) *

◯ Yes

◯ No

Invia   **Cancella modulo**

⚠ Non inviare mai le password tramite Moduli Google.

C

Sickness Simulator Questionnaire

SSQ

Simulator Sickness Questionnaire for the VR experiment

Accedi a Google per salvare i risultati raggiunti. Scopri di più

* Indica una domanda obbligatoria

ID *

La tua risposta

Experiment group number *

◯ 1

◯ 2

◯ Altro:

Date *

Data

, dd-----yyyy

Questionnaire number *

◯ 1 - Before the first test

◯ 2 - After the first test

◯ 3 - Before the second test

◯ 4 - After the second test

Symptoms

In the following, you will find a set of questions concerning the symptoms you may have experienced during the Virtual Reality experiment. Please indicate the level of relevance for each symptoms. There are four possible levels:

1. None - the symptom has not been experienced
2. Slight - slight presence of the symptom
3. Moderate - moderate presence of the symptom
4. Severe - severe presence of the symptom

For every symptom, a single answer is allowed.

Symptoms *

	None	Slight	Moderate	Severe
General discomfort	○	○	○	○
Fatigue	○	○	○	○
Headache	○	○	○	○
Eyestrain	○	○	○	○
Difficulty focusing	○	○	○	○
Increased salivation	○	○	○	○
Nausea	○	○	○	○
Difficulty concentrating	○	○	○	○
Fullness of the head	○	○	○	○
Blurred vision	○	○	○	○
Dizziness (eyes closed)	○	○	○	○
Dizziness (eyes open)	○	○	○	○
Vertigo	○	○	○	○
Stomach awareness	○	○	○	○
Burping	○	○	○	○

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Sweating

⬭   ⬭   ⬭   ⬭

Write down every symptoms that you experienced while playing the game.

La tua risposta

Invia   Cancella modulo

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Questo modulo è stato creato all'interno di Università degli studi di Padova. Segnala abuso

Google Moduli

Acknowledgments