LYU2304

Preliminary Entry into the Metaverse: VR Dataset, Analysis, and Testing

supervisor: Professor Michael Lyu

19/04/2024

CAI Yong Jie
WEI You Lin

香港中文大學
The Chinese University of Hong Kong

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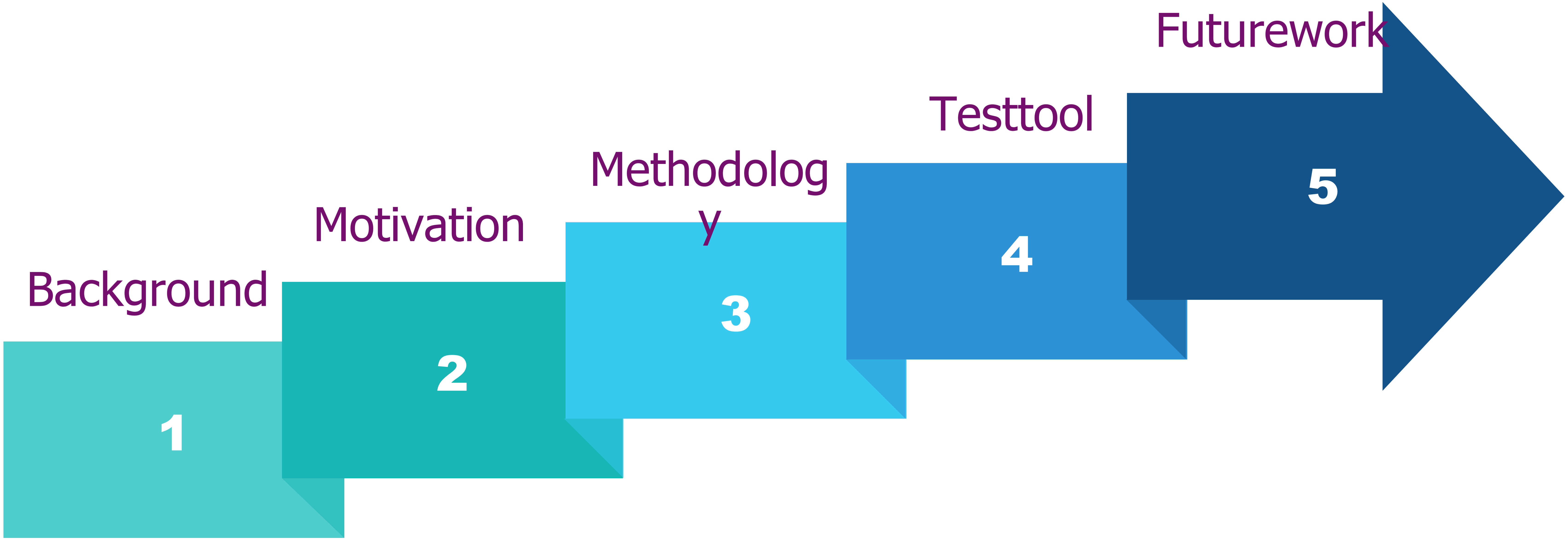

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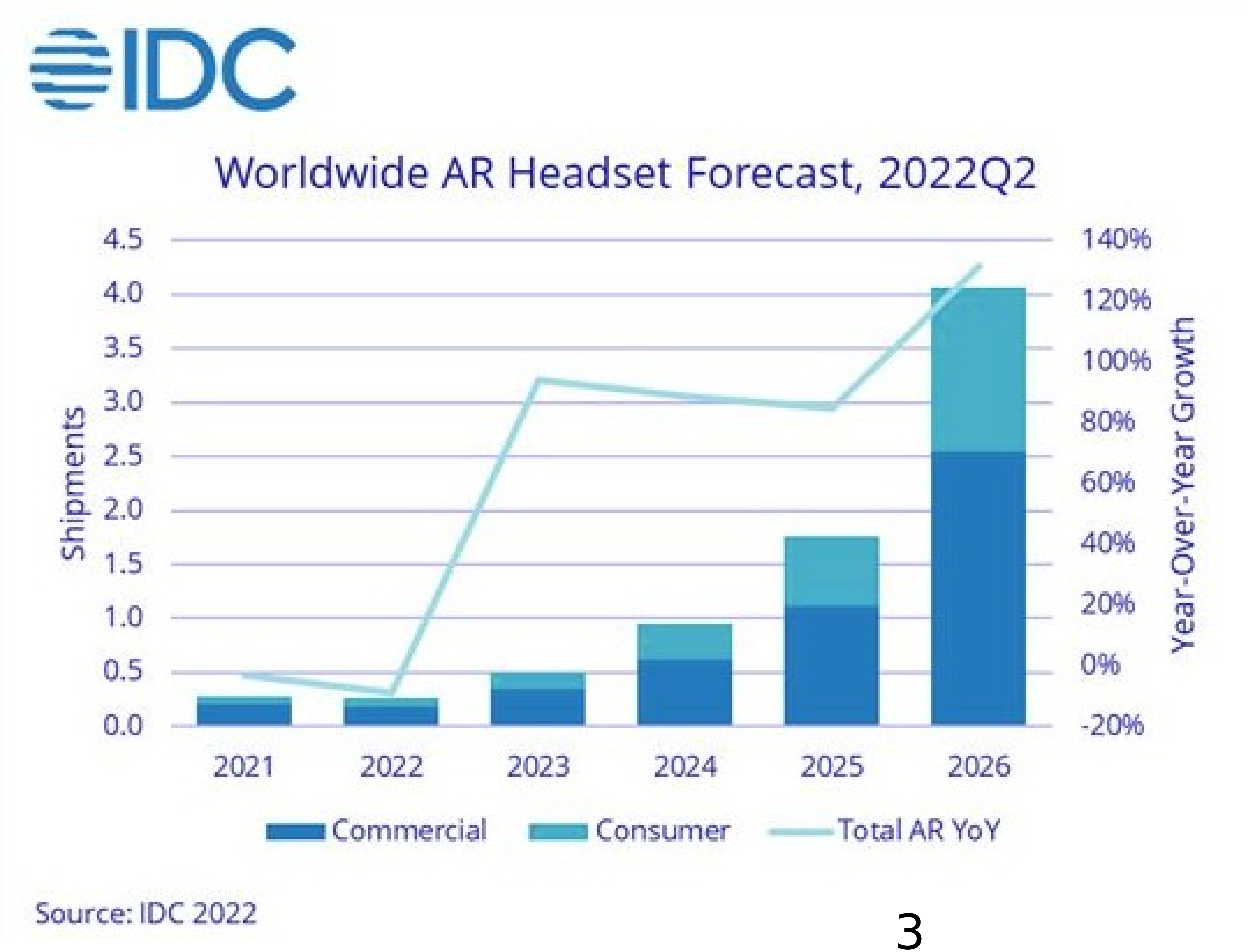
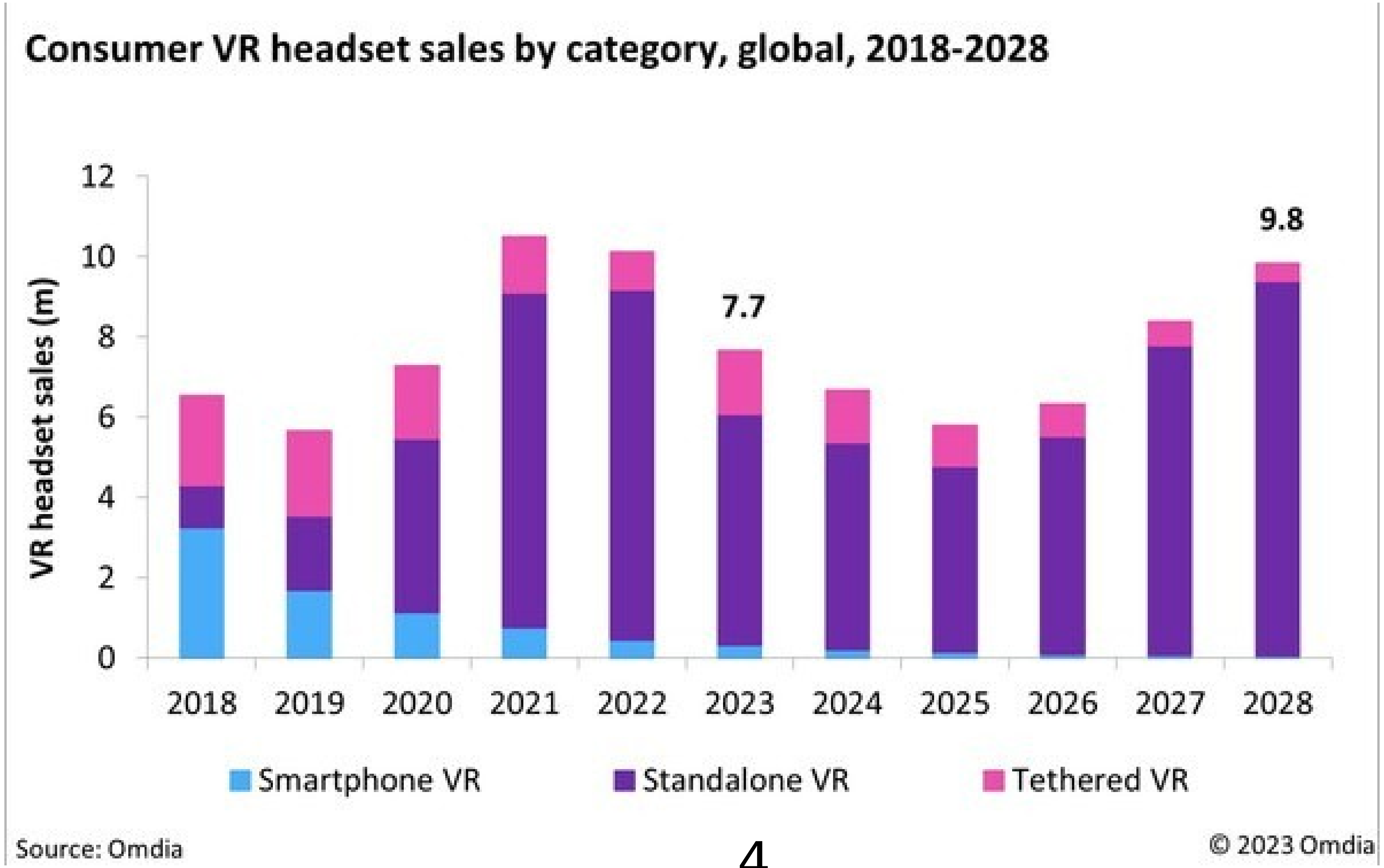
Background


Worldwide AR Headset Forecast, 2022Q2

Source: IDC 2022

VR Headset Market Continues to Decline



Source: Omdia

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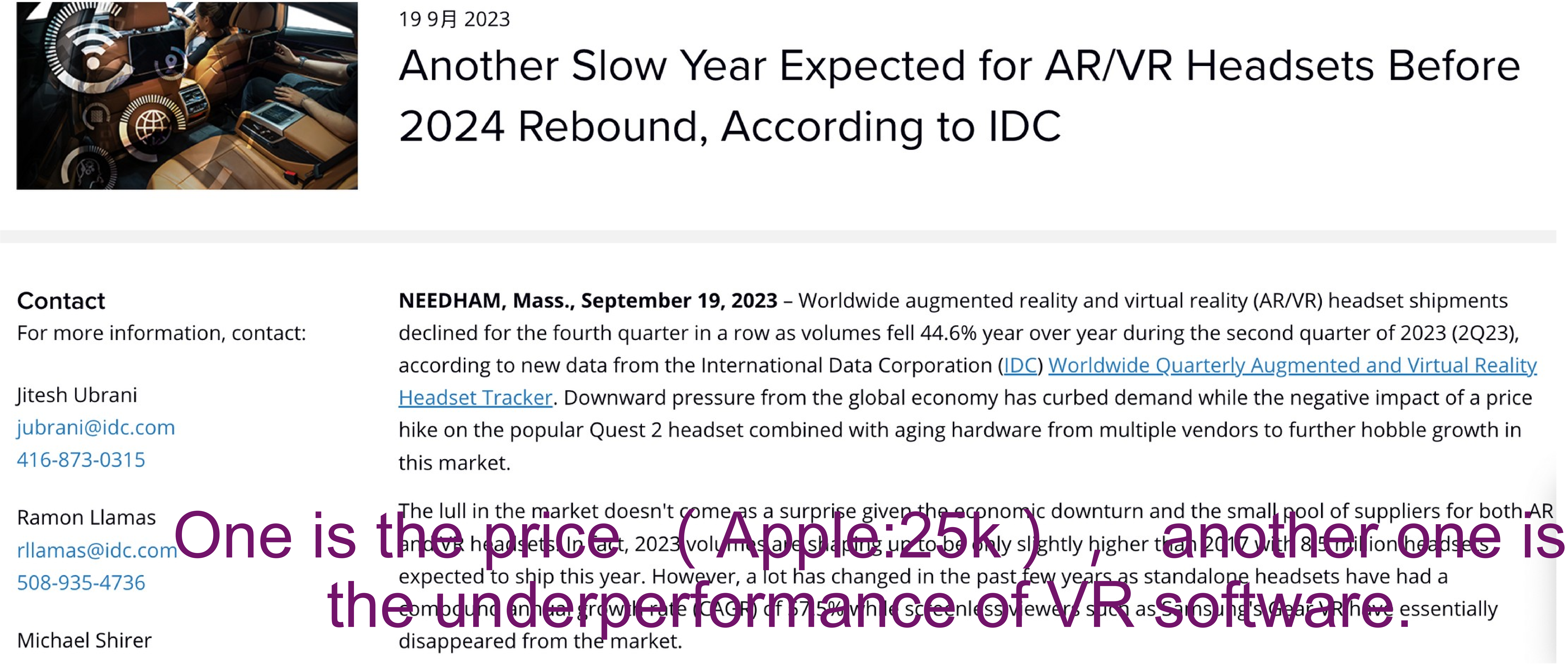
Background



19 9月 2023

Another Slow Year Expected for AR/VR Headsets Before 2024 Rebound, According to IDC

Contact

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Michael Shirer

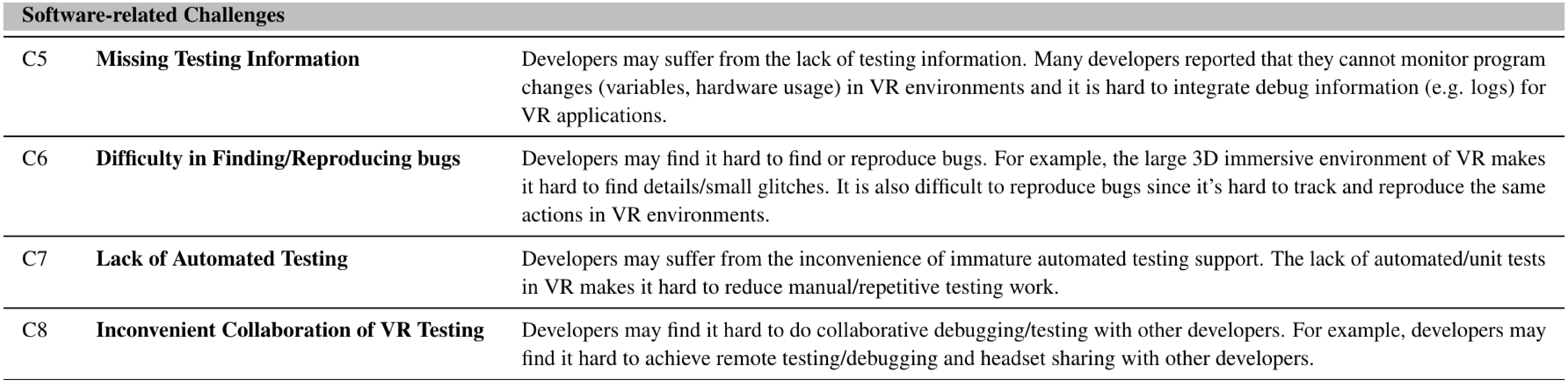
NEEDHAM, Mass., September 19, 2023 – Worldwide augmented reality and virtual reality (AR/VR) headset shipments declined for the fourth quarter in a row as volumes fell 44.6% year over year during the second quarter of 2023 (2Q23), according to new data from the International Data Corporation (IDC) Worldwide Quarterly Augmented and Virtual Reality Headset Tracker. Downward pressure from the global economy has curbed demand while the negative impact of a price hike on the popular Quest 2 headset combined with aging hardware from multiple vendors to further hobble growth in this market.

The lull in the market doesn't come as a surprise given the economic downturn and the small pool of suppliers for both AR and VR headsets. In fact, 2023 volumes are shaping up to be only slightly higher than 2017 with 8.5 million headsets expected to ship this year. However, a lot has changed in the past few years as standalone headsets have had a compound annual growth rate (CAGR) of 67.5% while screenless viewers such as Samsung's Gear VR have essentially disappeared from the market.

One is the price（Apple:25k）， another one is the underperformance of VR software.

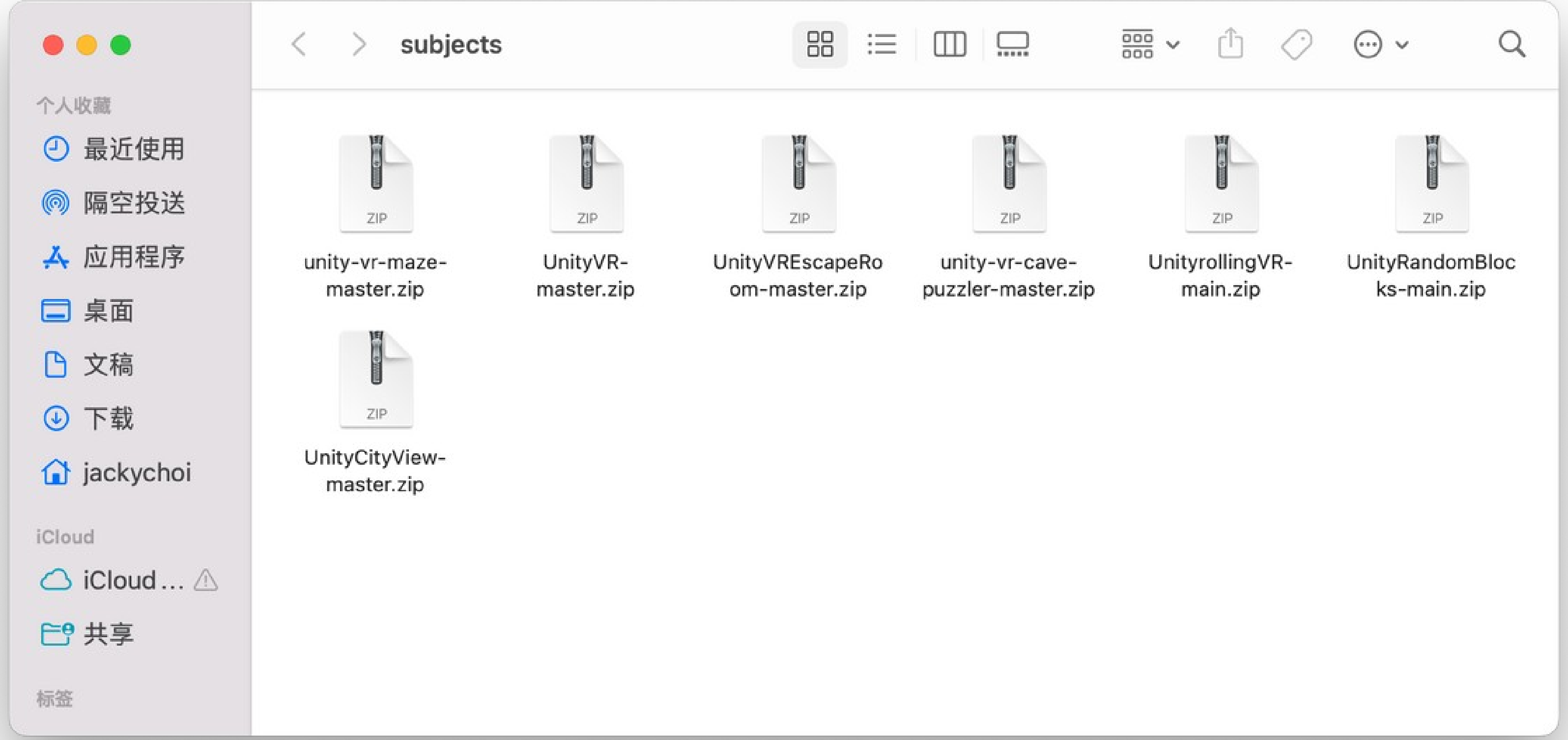
Overview of VR Software and Existing Tools

Lack of Bug Detection and Testing Tools:
Some Challenges for VR Developers

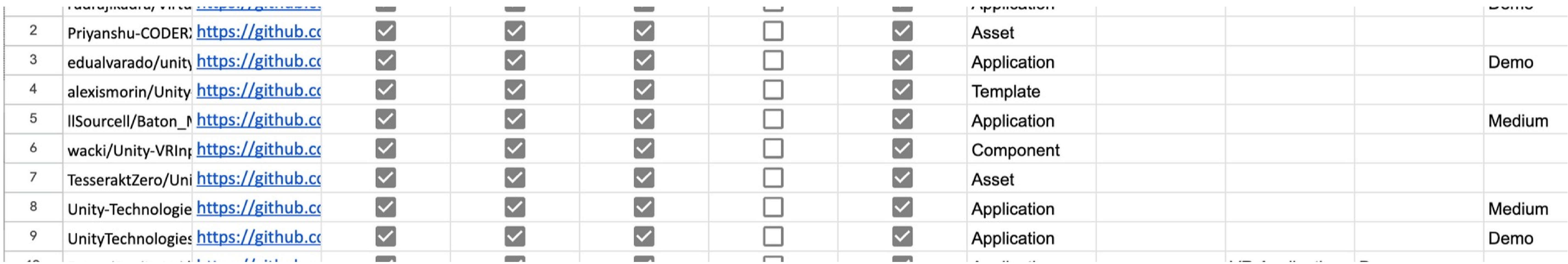


Software-related Challenges		
C5	**Missing Testing Information**	Developers may suffer from the lack of testing information. Many developers reported that they cannot monitor program changes (variables, hardware usage) in VR environments and it is hard to integrate debug information (e.g. logs) for VR applications.
C6	**Difficulty in Finding/Reproducing bugs**	Developers may find it hard to find or reproduce bugs. For example, the large 3D immersive environment of VR makes it hard to find details/small glitches. It is also difficult to reproduce bugs since it's hard to track and reproduce the same actions in VR environments.
C7	**Lack of Automated Testing**	Developers may suffer from the inconvenience of immature automated testing support. The lack of automated/unit tests in VR makes it hard to reduce manual/repetitive testing work.
C8	**Inconvenient Collaboration of VR Testing**	Developers may find it hard to do collaborative debugging/testing with other developers. For example, developers may find it hard to achieve remote testing/debugging and headset sharing with other developers.

Application of Test Tool



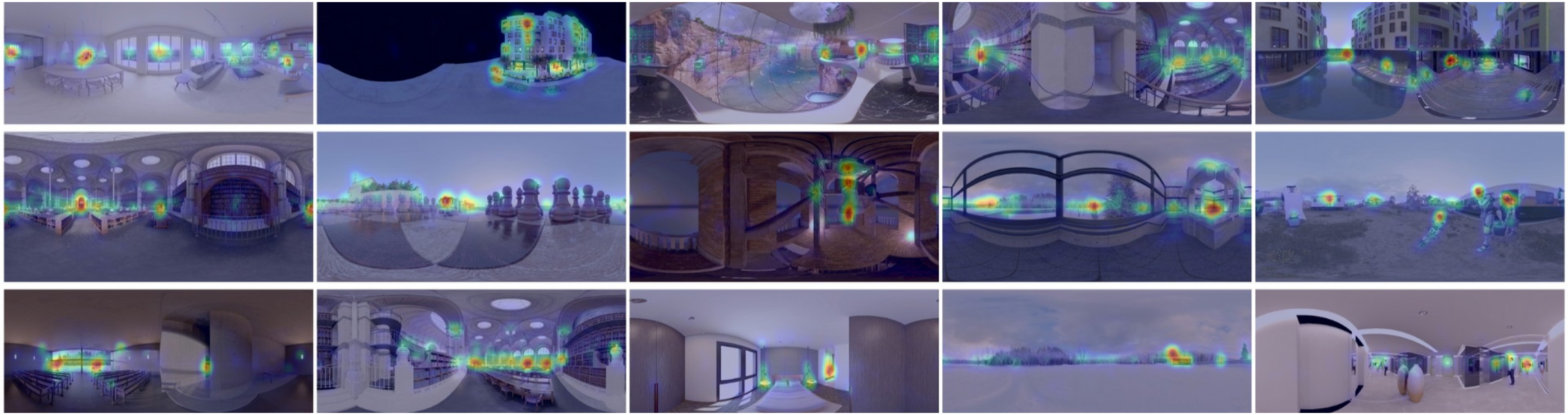
Seven examples provided in the paper, which is so small.



2	Priyanshu-CODER)	https://github.cc	☑	☑	☑	□	☑	Asset				
3	edualvarado/unity	https://github.cc	☑	☑	☑	□	☑	Application				Demo
4	alexismorin/Unity	https://github.cc	☑	☑	☑	□	☑	Template				
5	llSourcell/Baton_M	https://github.cc	☑	☑	☑	□	☑	Application				Medium
6	wacki/Unity-VRInp	https://github.cc	☑	☑	☑	□	☑	Component				
7	TesseraktZero/Uni	https://github.cc	☑	☑	☑	□	☑	Asset				
8	Unity-Technologie	https://github.cc	☑	☑	☑	□	☑	Application				Medium
9	UnityTechnologies	https://github.cc	☑	☑	☑	□	☑	Application				Demo

Purpose of the study - Motivation

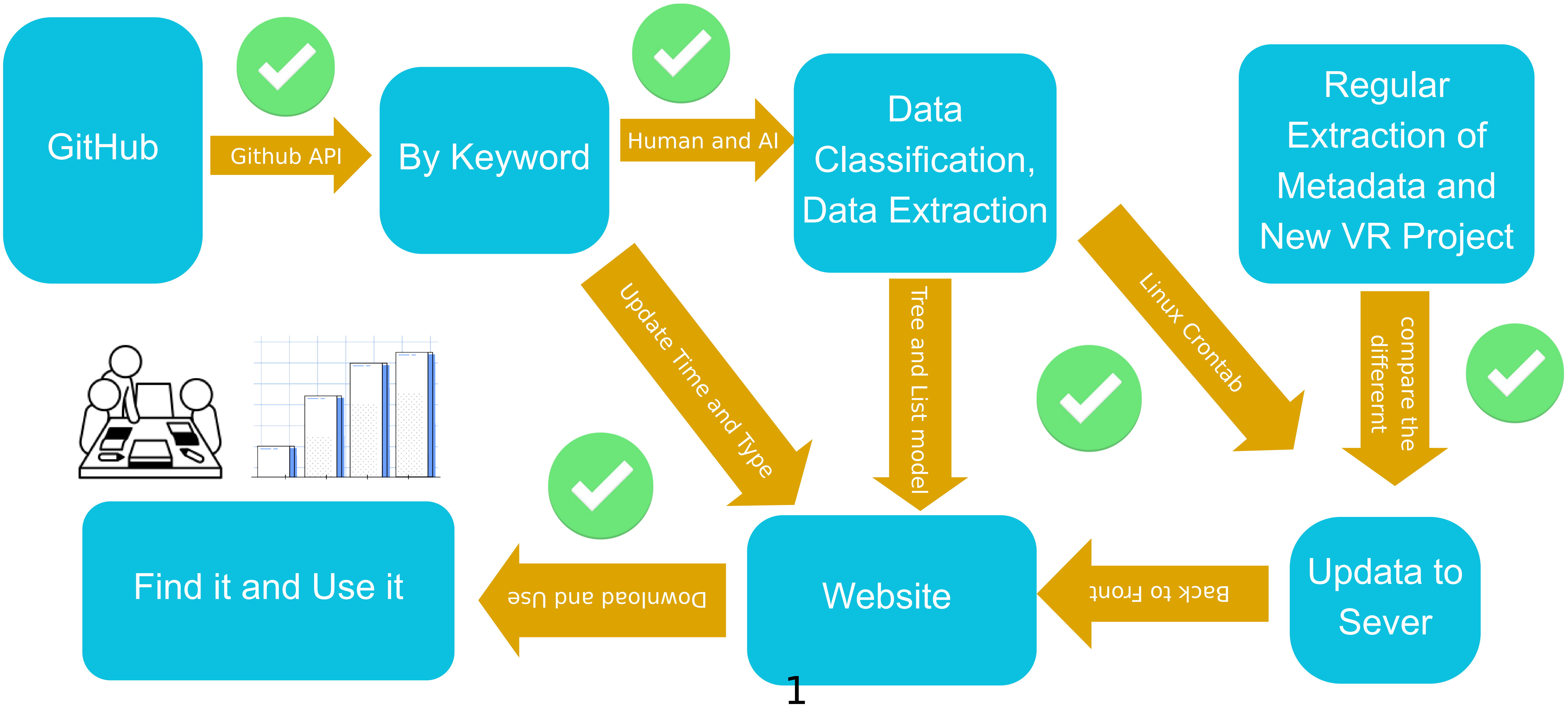
- Virtual reality datasets contain 3D models, motion data, depth maps, audio, script, Unity, and game.
- High-quality datasets are vital for VR but are scarce due to complexity.



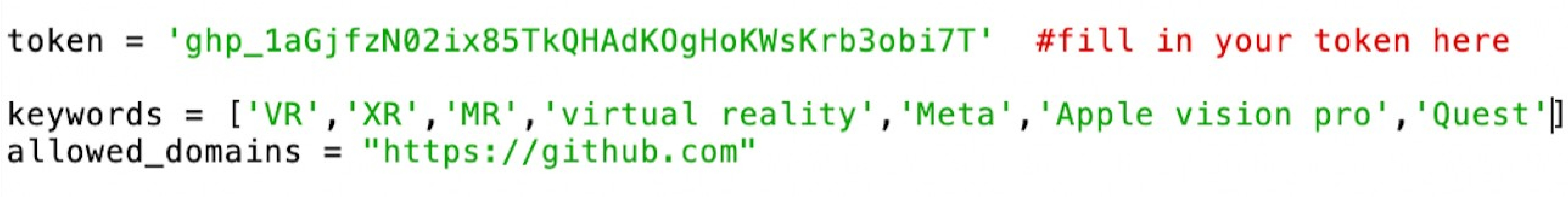
Purpose of the study - Motivation

- Curating VR datasets is crucial for research, testing, and improving VR projects.
- VR datasets will be created to support developers and innovation as the market expands.

Data Collection Process

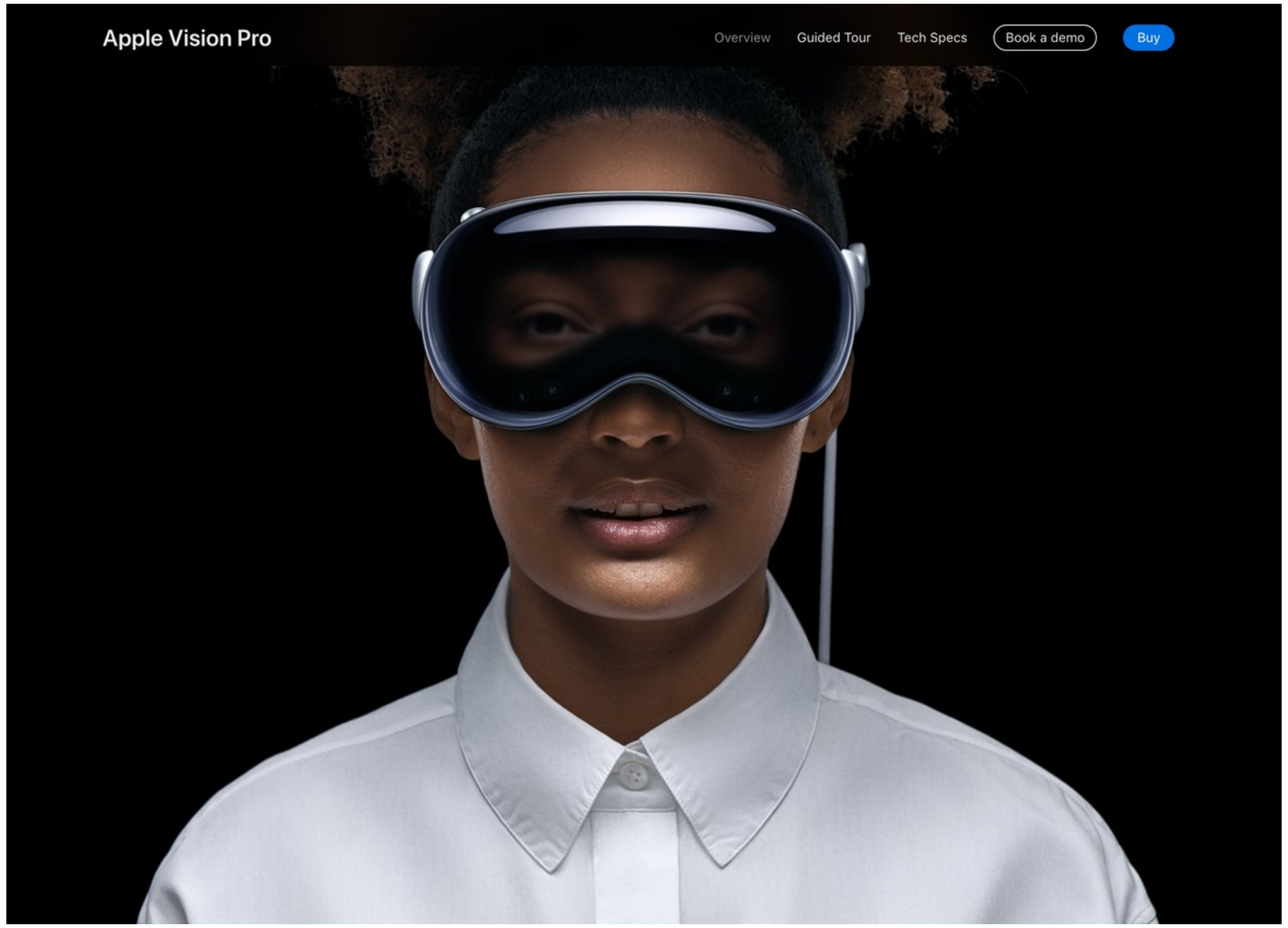


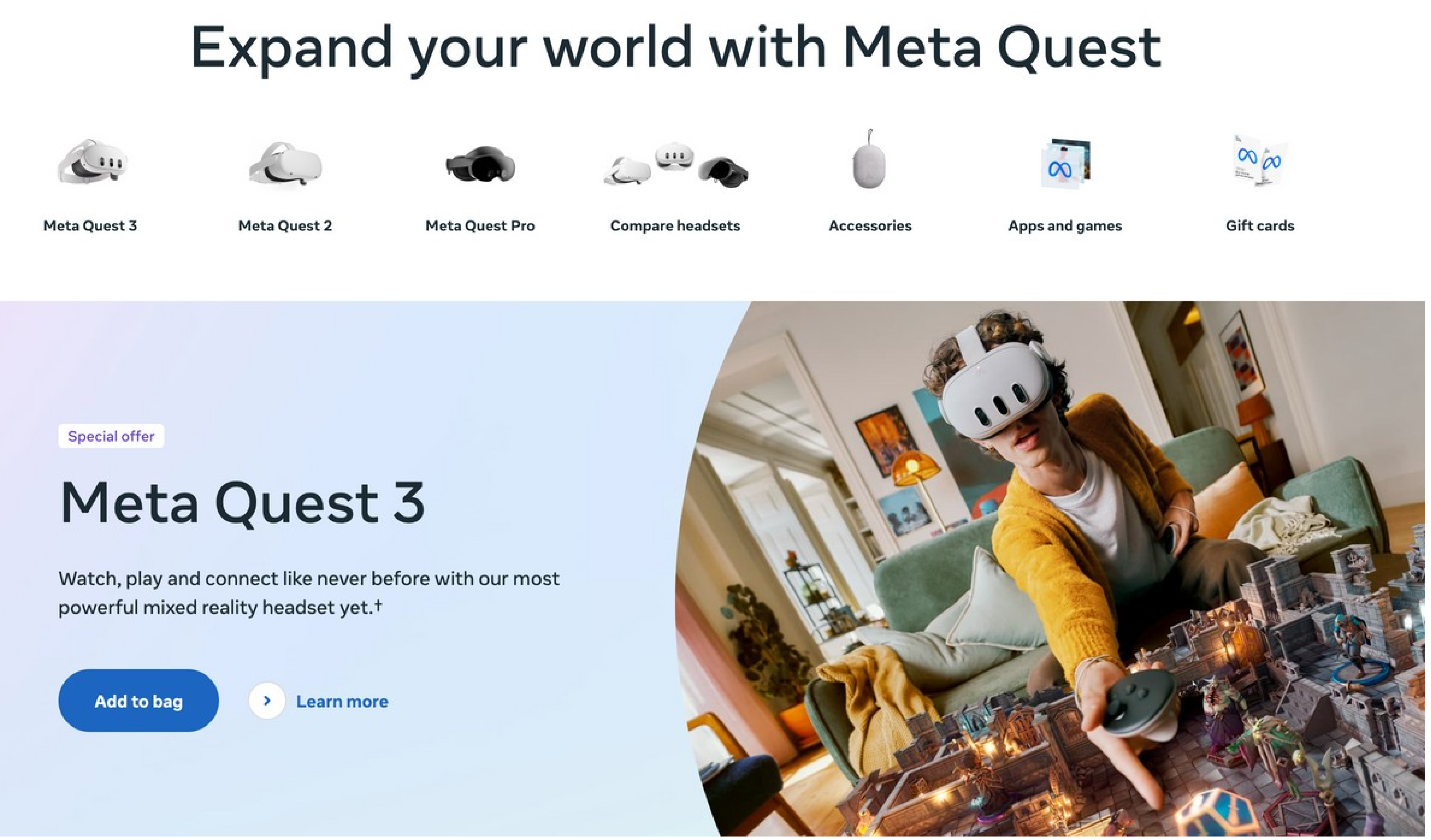
Github Crawler Code and Filter in Keyword



```
token = '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'  #fill in your token here

keywords = ['VR','XR','MR','virtual reality','Meta','Apple vision pro','Quest']
allowed_domains = "https://github.com"
```





Expand your world with Meta Quest

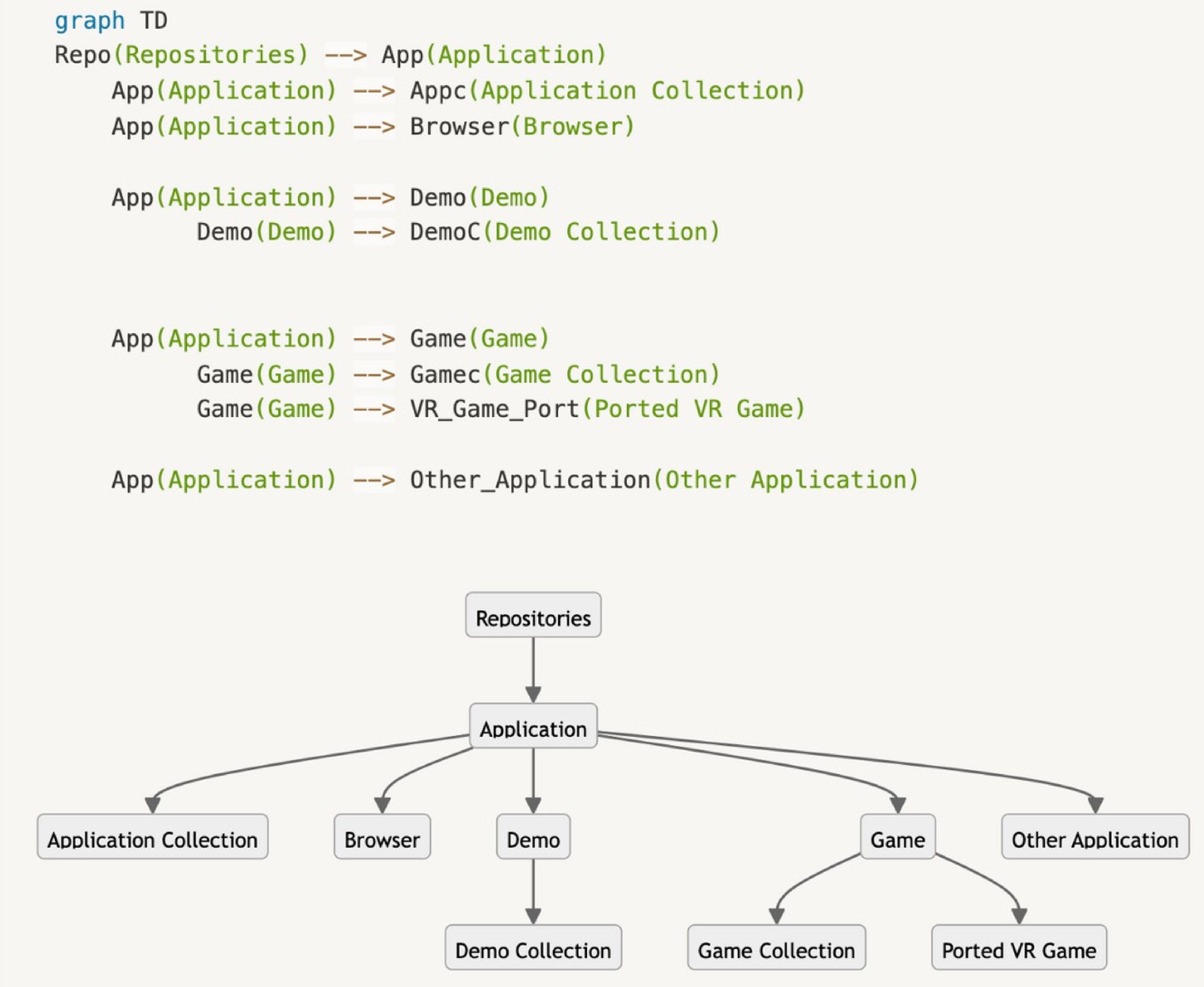
Meta Quest 3

Watch, play and connect like never before with our most powerful mixed reality headset yet.†

Result of the Github Repository

- Selected 1,4 423,
  categorized

- visualized w ols used.



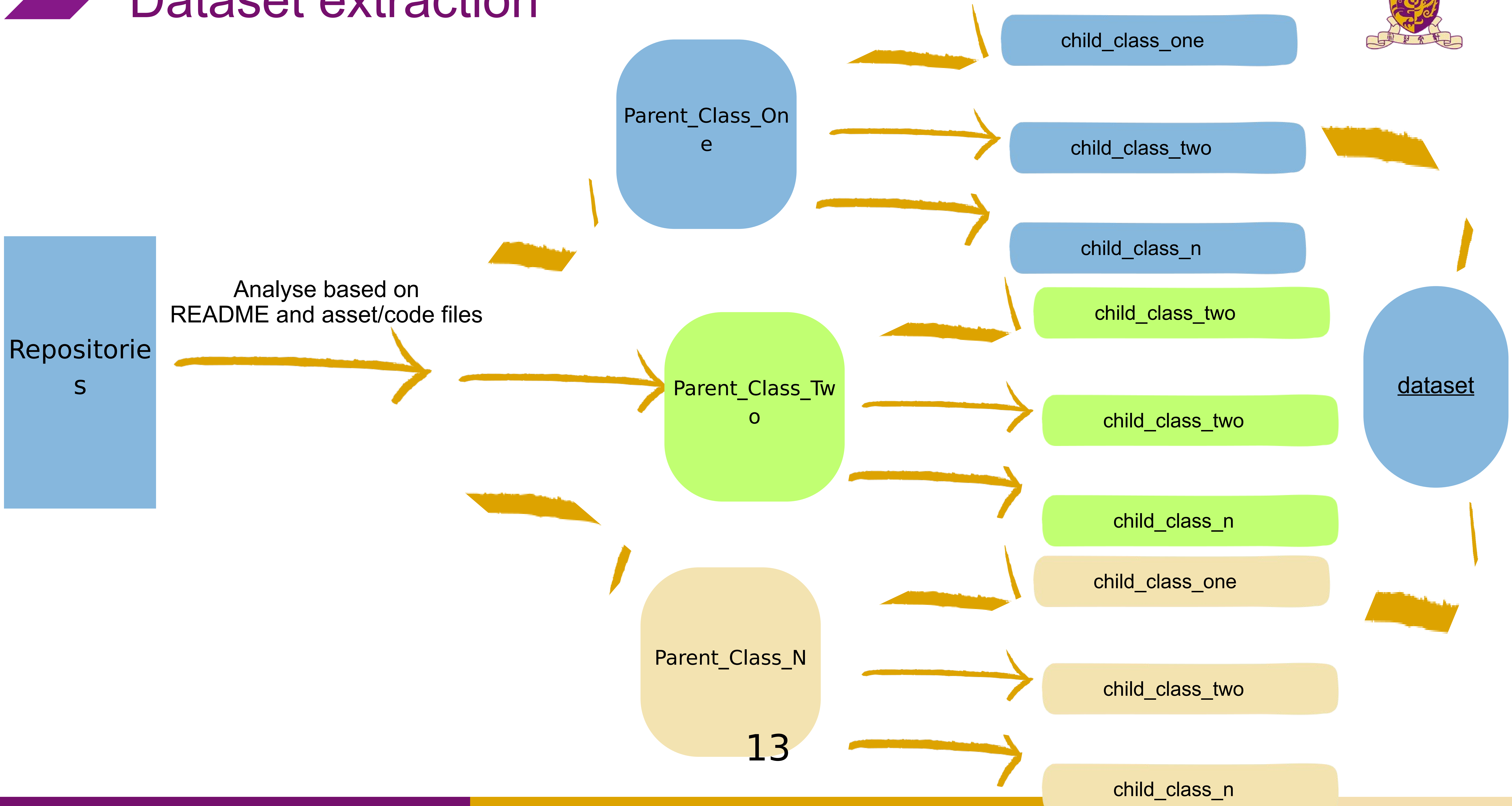
```
graph TD
Repo(Repositories) --> App(Application)
    App(Application) --> Appc(Application Collection)
    App(Application) --> Browser(Browser)

    App(Application) --> Demo(Demo)
          Demo(Demo) --> DemoC(Demo Collection)


    App(Application) --> Game(Game)
          Game(Game) --> Gamec(Game Collection)
          Game(Game) --> VR_Game_Port(Ported VR Game)

    App(Application) --> Other_Application(Other Application)
```

Dataset extraction



Repositories

Analyse based on README and asset/code files

Parent_Class_One

child_class_one

child_class_two

child_class_n

Parent_Class_Two

child_class_two

child_class_two

child_class_n

Parent_Class_N

child_class_one

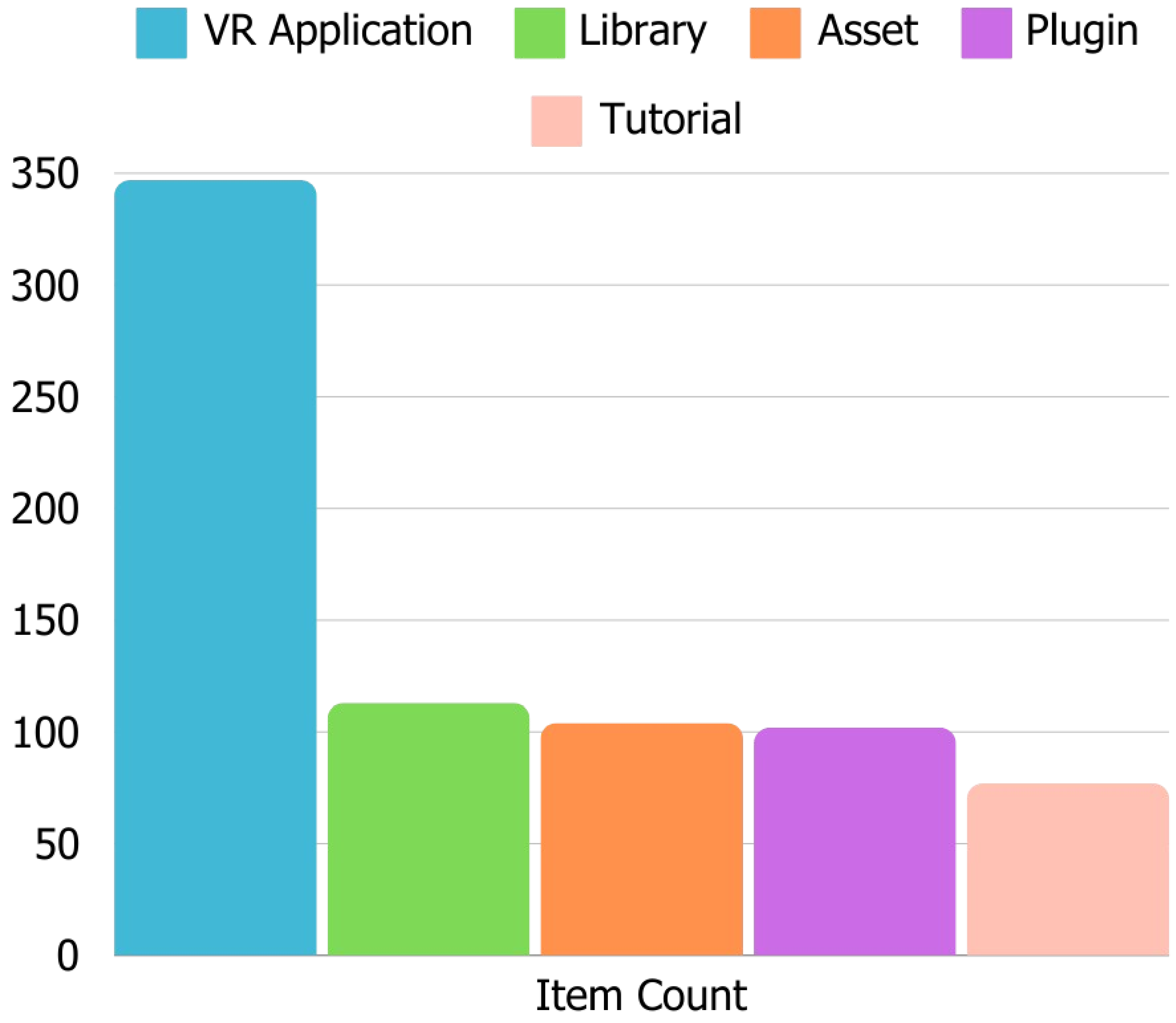
child_class_two

child_class_n

dataset

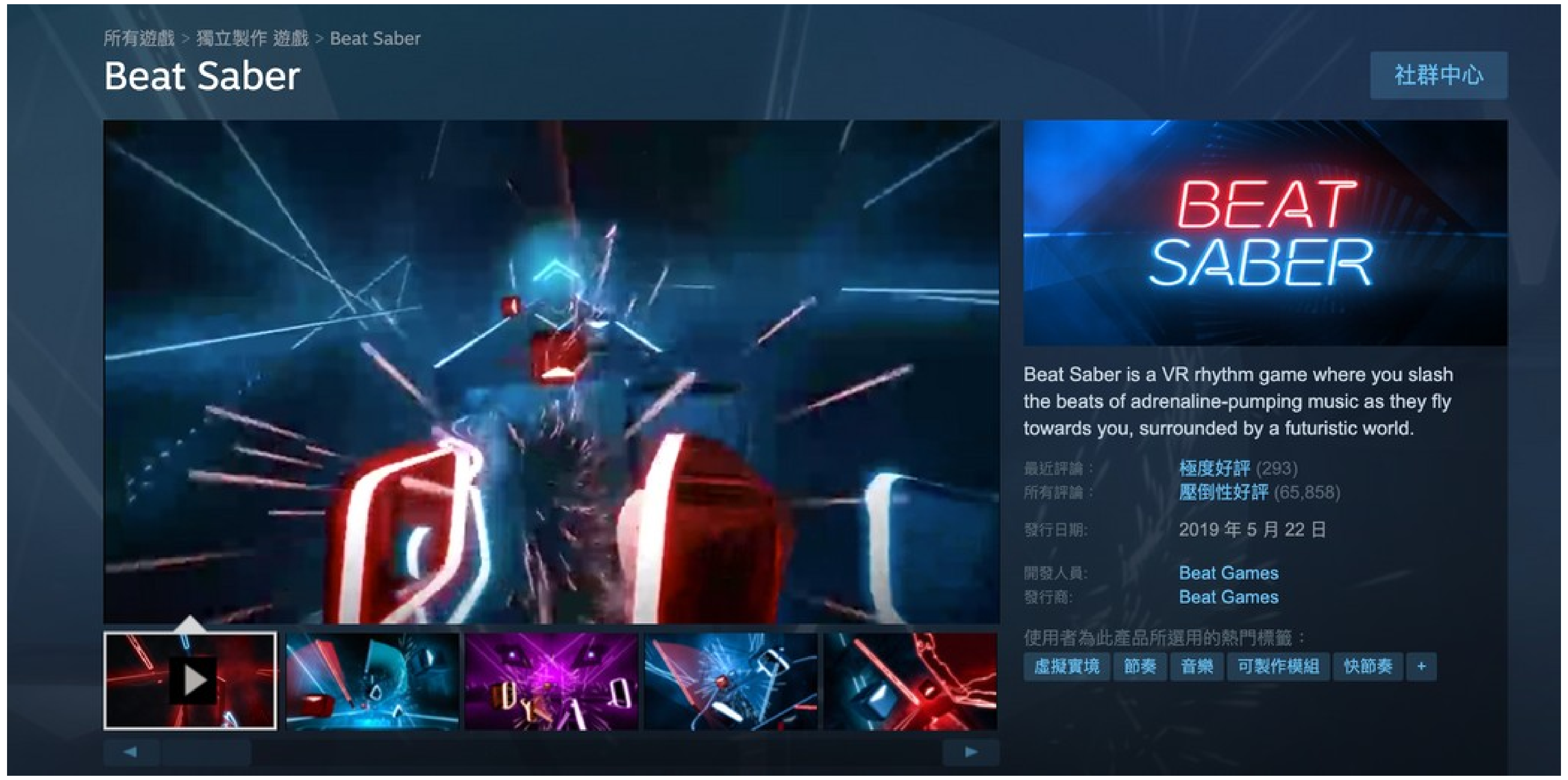
Collected Data Analysis

‘Applications’ is the most prevalent category



Clear Defination

Application:it had to include a set of VR assets and be able to run independently in a VR environment


所有遊戲 > 獨立製作 遊戲 > Beat Saber

Beat Saber

社群中心

Beat Saber is a VR rhythm game where you slash the beats of adrenaline-pumping music as they fly towards you, surrounded by a futuristic world.

最近評論： 極度好評 (293)
所有評論： 壓倒性好評 (65,858)

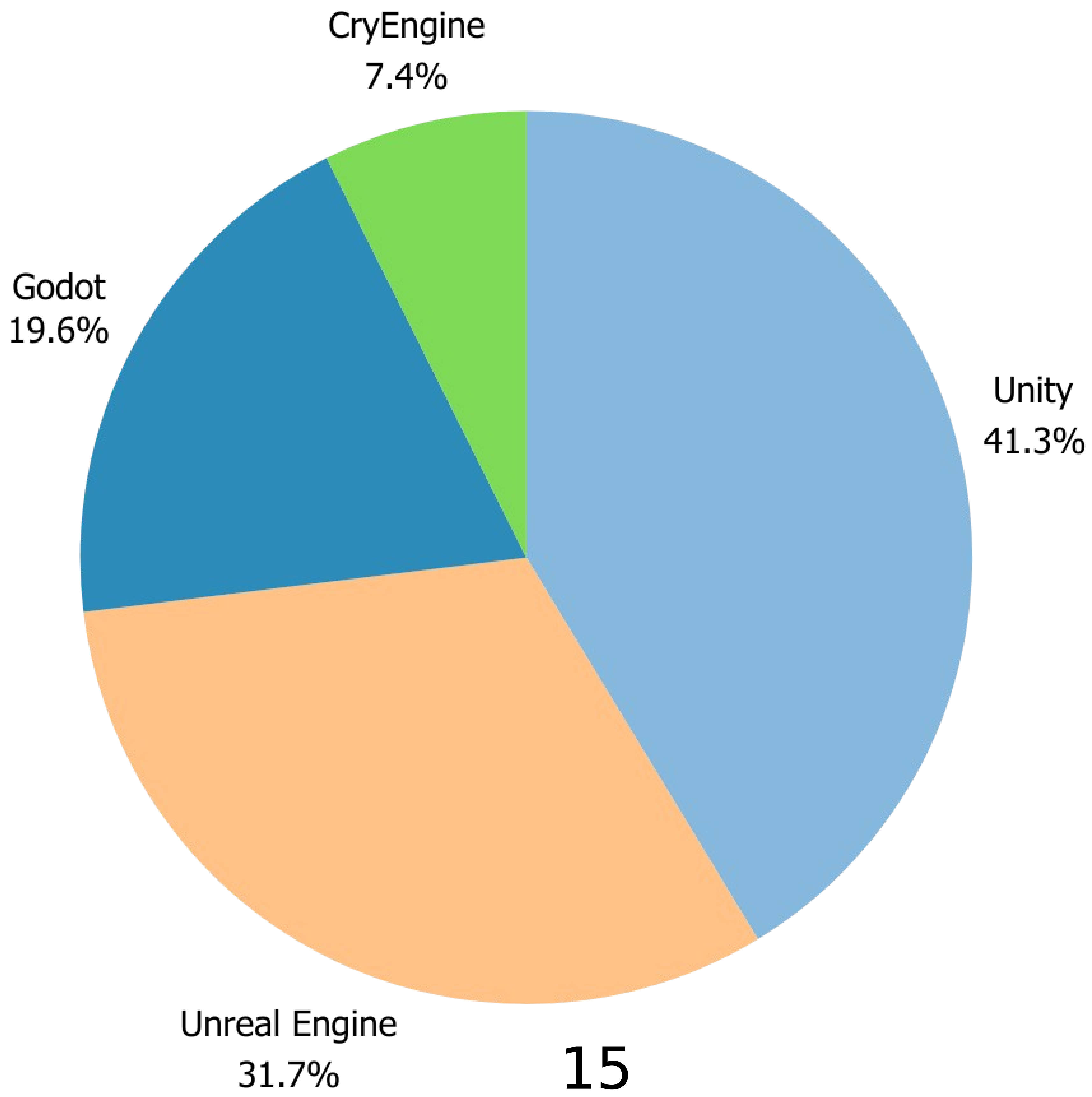
發行日期: 2019 年 5 月 22 日

開發人員: Beat Games
發行商: Beat Games

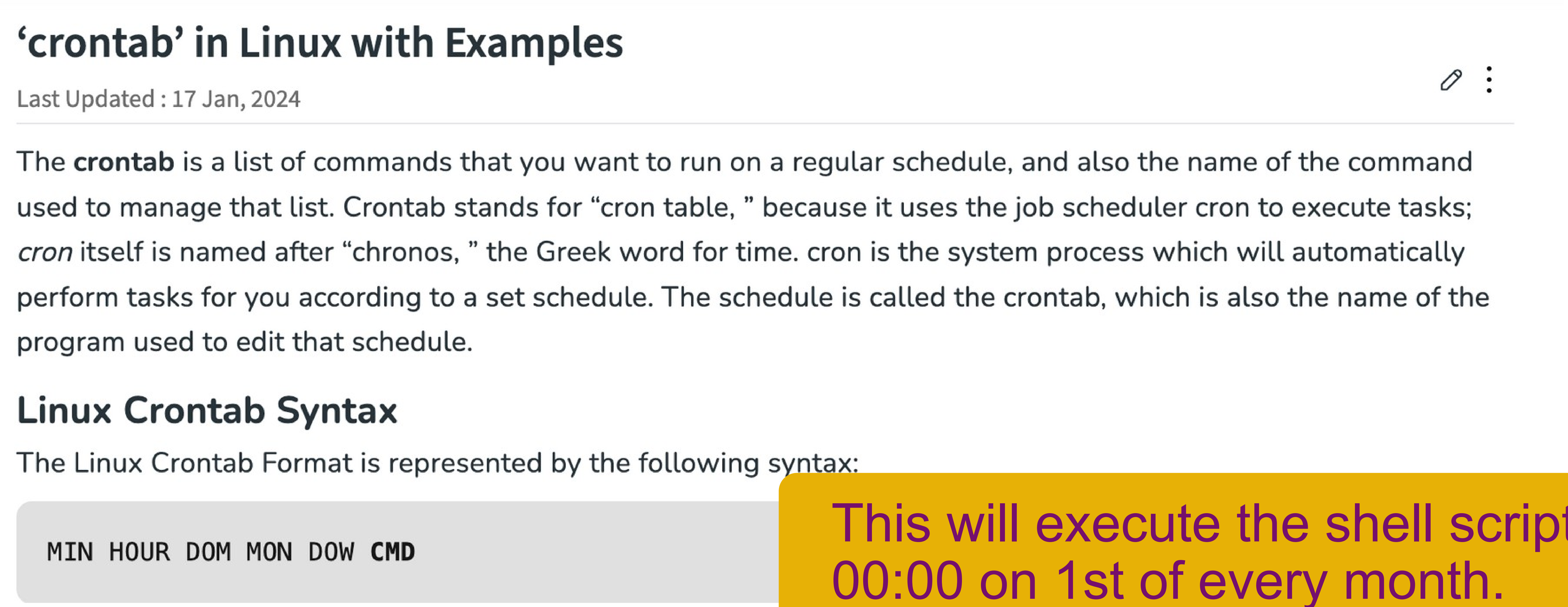
使用者為此產品所選用的熱門標籤：
虛擬實境 節奏 音樂 可製作模組 快節奏 +

Collected Data Analysis

‘Unity’ is the most prevalent engine



Optimized Dataset to Keeping It Update



‘crontab’ in Linux with Examples

Last Updated : 17 Jan, 2024

The **crontab** is a list of commands that you want to run on a regular schedule, and also the name of the command used to manage that list. Crontab stands for “cron table, ” because it uses the job scheduler cron to execute tasks; *cron* itself is named after “chronos, ” the Greek word for time. cron is the system process which will automatically perform tasks for you according to a set schedule. The schedule is called the crontab, which is also the name of the program used to edit that schedule.

Linux Crontab Syntax

The Linux Crontab Format is represented by the following syntax:

```
MIN HOUR DOM MON DOW CMD
```

This will execute the shell script main at 00:00 on 1st of every month.

@monthly /home/maverick/bin/main.shell

Data Visualization

Dynamic Updates

Search Bar

Node Details Module

Introduction Module

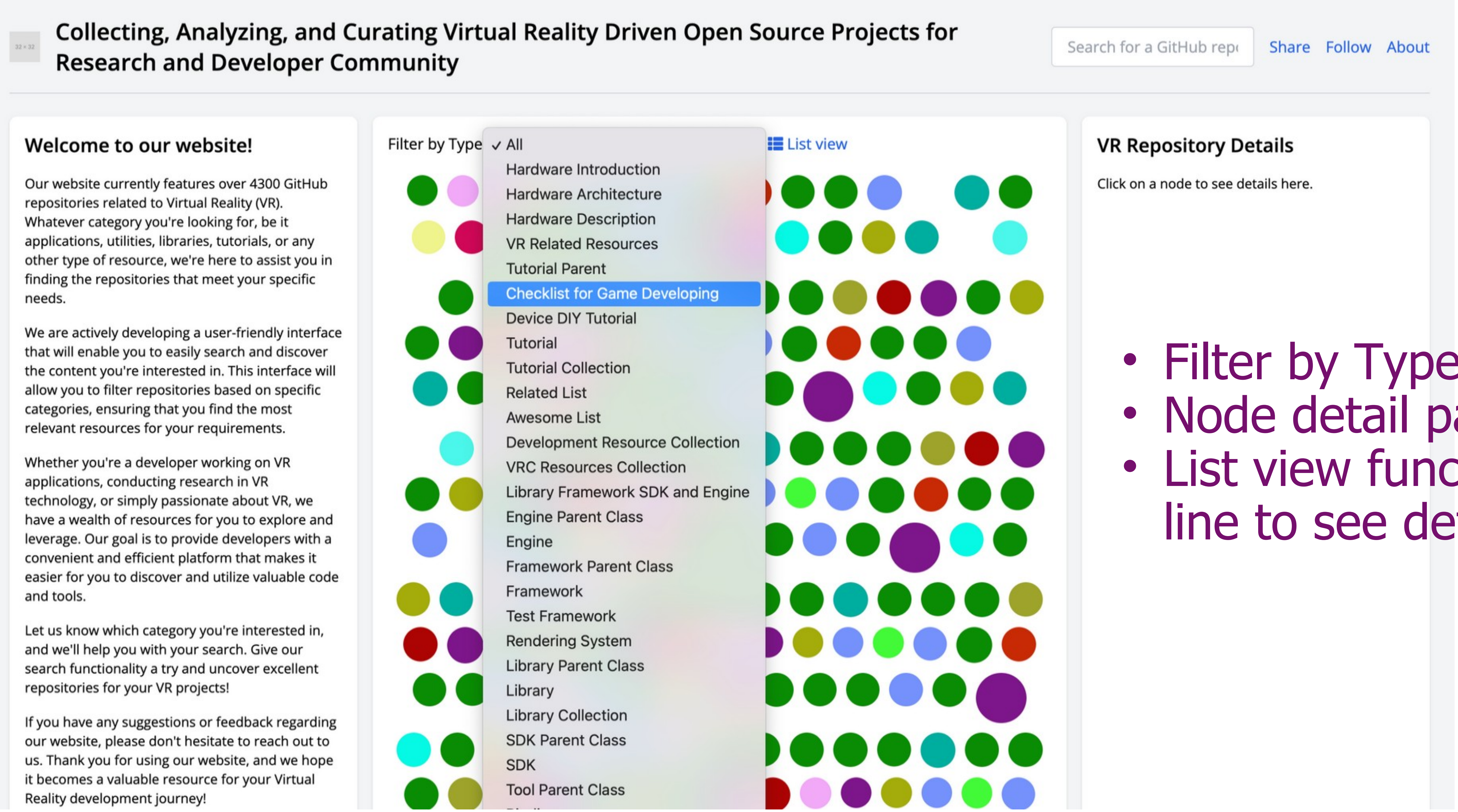
Project Display Module

Demo

Filtering Feature

List View Option

Data visualization



Collecting, Analyzing, and Curating Virtual Reality Driven Open Source Projects for Research and Developer Community

Welcome to our website!

Our website currently features over 4300 GitHub repositories related to Virtual Reality (VR). Whatever category you're looking for, be it applications, utilities, libraries, tutorials, or any other type of resource, we're here to assist you in finding the repositories that meet your specific needs.

We are actively developing a user-friendly interface that will enable you to easily search and discover the content you're interested in. This interface will allow you to filter repositories based on specific categories, ensuring that you find the most relevant resources for your requirements.

Whether you're a developer working on VR applications, conducting research in VR technology, or simply passionate about VR, we have a wealth of resources for you to explore and leverage. Our goal is to provide developers with a convenient and efficient platform that makes it easier for you to discover and utilize valuable code and tools.

Let us know which category you're interested in, and we'll help you with your search. Give our search functionality a try and uncover excellent repositories for your VR projects!

If you have any suggestions or feedback regarding our website, please don't hesitate to reach out to us. Thank you for using our website, and we hope it becomes a valuable resource for your Virtual Reality development journey!

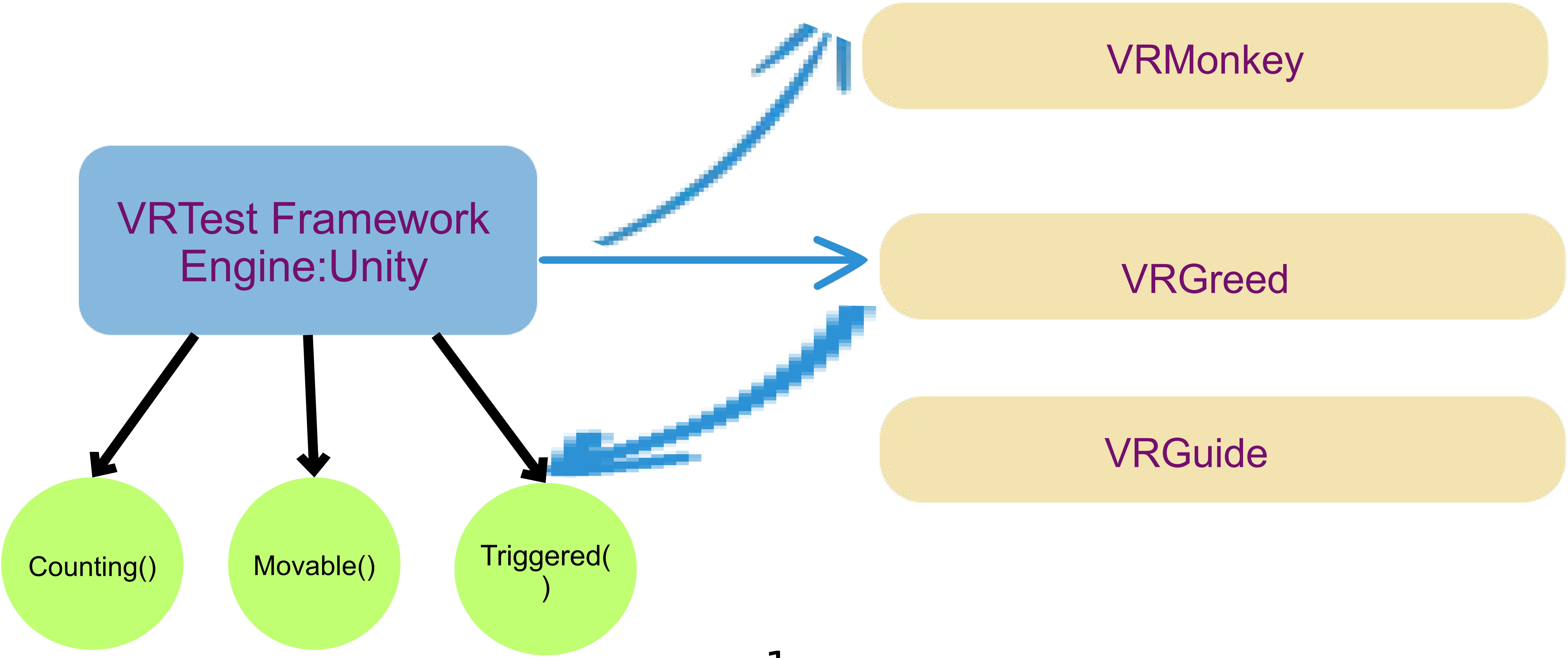
VR Repository Details

Click on a node to see details here.

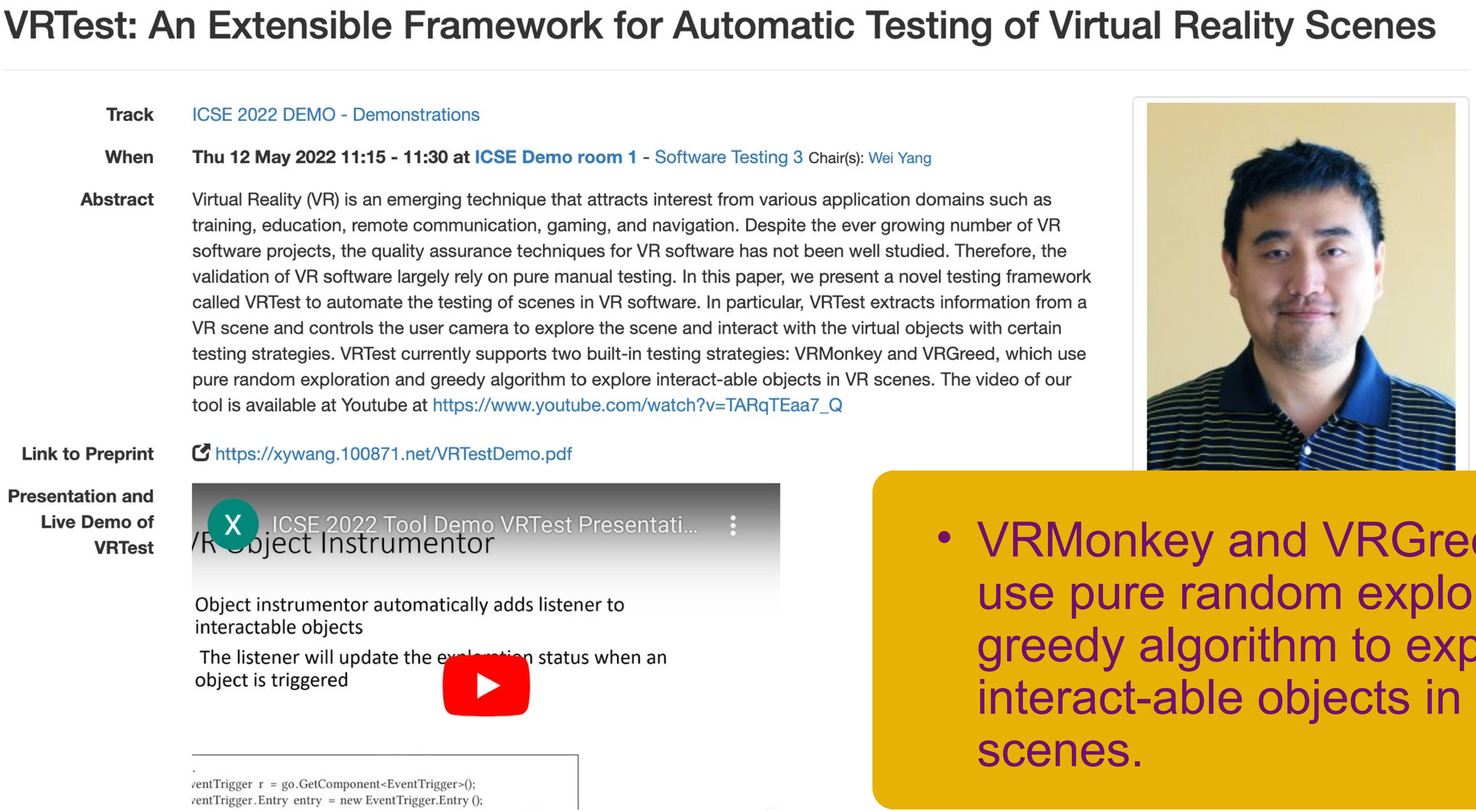
- Filter by Type
- Node detail page
- List view function (you can click on the line to see details)

Enhancing Existing Test Tool: Building on Others' Success

Brief Introduction of Test Scripts from an article



Application of Test Tool



VRTest: An Extensible Framework for Automatic Testing of Virtual Reality Scenes

Track ICSE 2022 DEMO - Demonstrations

When Thu 12 May 2022 11:15 - 11:30 at ICSE Demo room 1 - Software Testing 3 Chair(s): Wei Yang

Abstract Virtual Reality (VR) is an emerging technique that attracts interest from various application domains such as training, education, remote communication, gaming, and navigation. Despite the ever growing number of VR software projects, the quality assurance techniques for VR software has not been well studied. Therefore, the validation of VR software largely rely on pure manual testing. In this paper, we present a novel testing framework called VRTest to automate the testing of scenes in VR software. In particular, VRTest extracts information from a VR scene and controls the user camera to explore the scene and interact with the virtual objects with certain testing strategies. VRTest currently supports two built-in testing strategies: VRMonkey and VRGreed, which use pure random exploration and greedy algorithm to explore interact-able objects in VR scenes. The video of our tool is available at Youtube at https://www.youtube.com/watch?v=TARqTEaa7_Q

Link to Preprint https://xywang.100871.net/VRTestDemo.pdf

Presentation and Live Demo of VRTest

ICSE 2022 Tool Demo VRTest Presentati...

VR Object Instrumentor

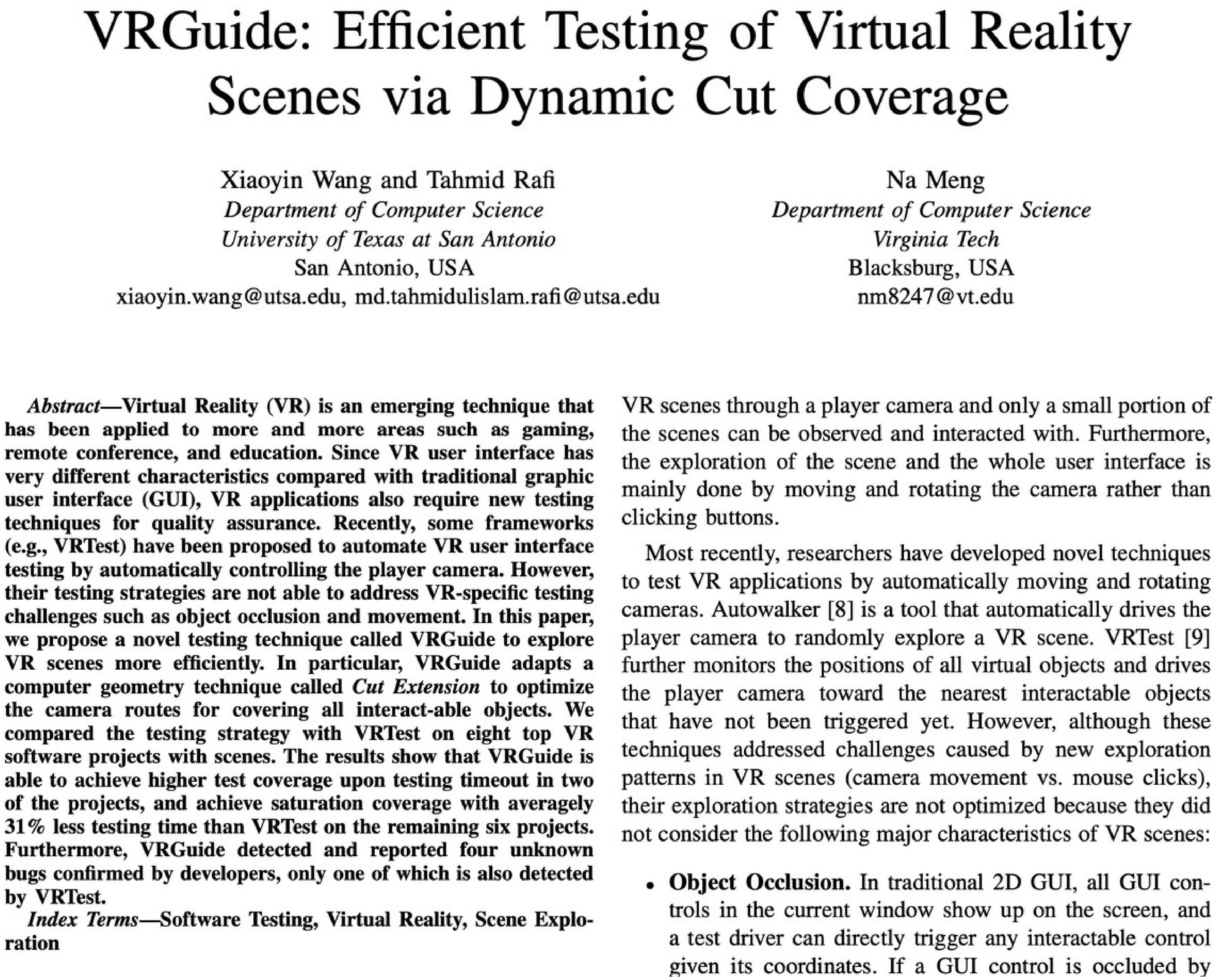
Object instrumentor automatically adds listener to interactable objects

The listener will update the exploration status when an object is triggered

```
ventTrigger r = go.GetComponent<EventTrigger>();
ventTrigger.Entry entry = new EventTrigger.Entry ();
```

- VRMonkey and VRGreed, which use pure random exploration and greedy algorithm to explore interact-able objects in VR scenes.

Application of Test Tool



VRGuide: Efficient Testing of Virtual Reality Scenes via Dynamic Cut Coverage

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San Antonio, USA
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Na Meng
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***Abstract*—Virtual Reality (VR) is an emerging technique that has been applied to more and more areas such as gaming, remote conference, and education. Since VR user interface has very different characteristics compared with traditional graphic user interface (GUI), VR applications also require new testing techniques for quality assurance. Recently, some frameworks (e.g., VRTest) have been proposed to automate VR user interface testing by automatically controlling the player camera. However, their testing strategies are not able to address VR-specific testing challenges such as object occlusion and movement. In this paper, we propose a novel testing technique called VRGuide to explore VR scenes more efficiently. In particular, VRGuide adapts a computer geometry technique called *Cut Extension* to optimize the camera routes for covering all interact-able objects. We compared the testing strategy with VRTest on eight top VR software projects with scenes. The results show that VRGuide is able to achieve higher test coverage upon testing timeout in two of the projects, and achieve saturation coverage with averagely 31% less testing time than VRTest on the remaining six projects. Furthermore, VRGuide detected and reported four unknown bugs confirmed by developers, only one of which is also detected by VRTest.**

***Index Terms*—Software Testing, Virtual Reality, Scene Exploration**

VR scenes through a player camera and only a small portion of the scenes can be observed and interacted with. Furthermore, the exploration of the scene and the whole user interface is mainly done by moving and rotating the camera rather than clicking buttons.

Most recently, researchers have developed novel techniques to test VR applications by automatically moving and rotating cameras. Autowalker [8] is a tool that automatically drives the player camera to randomly explore a VR scene. VRTest [9] further monitors the positions of all virtual objects and drives the player camera toward the nearest interactable objects that have not been triggered yet. However, although these techniques addressed challenges caused by new exploration patterns in VR scenes (camera movement vs. mouse clicks), their exploration strategies are not optimized because they did not consider the following major characteristics of VR scenes:

- **Object Occlusion.** In traditional 2D GUI, all GUI controls in the current window show up on the screen, and a test driver can directly trigger any interactable control given its coordinates. If a GUI control is occluded by

- Paper introduces a new testing technique called VRGuide for VR user interface testing.
- VRGuide utilizes the Cut Extension technique from computer geometry to optimize camera routes and cover all interactable objects.
- VRGuide is a promising tool for improving test coverage and efficiency in VR application testing.

Enhancing Existing Test Tool: Building on Others’ Success

Process

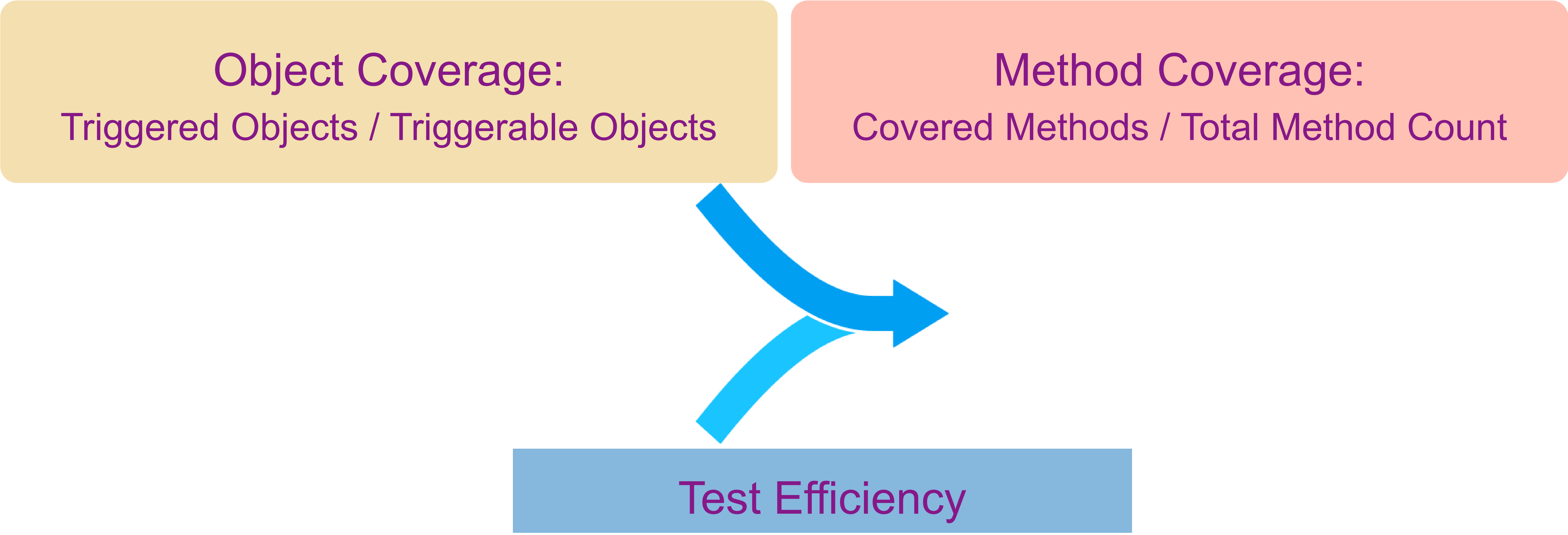
Random Object Initialization

Random Location of Player

Repeat Three Times to Take Average

Enhancing Existing Test Tool: Building on Others' Success

Benchmark



Object Coverage:

Triggered Objects / Triggerable Objects

Method Coverage:

Covered Methods / Total Method Count

Test Efficiency

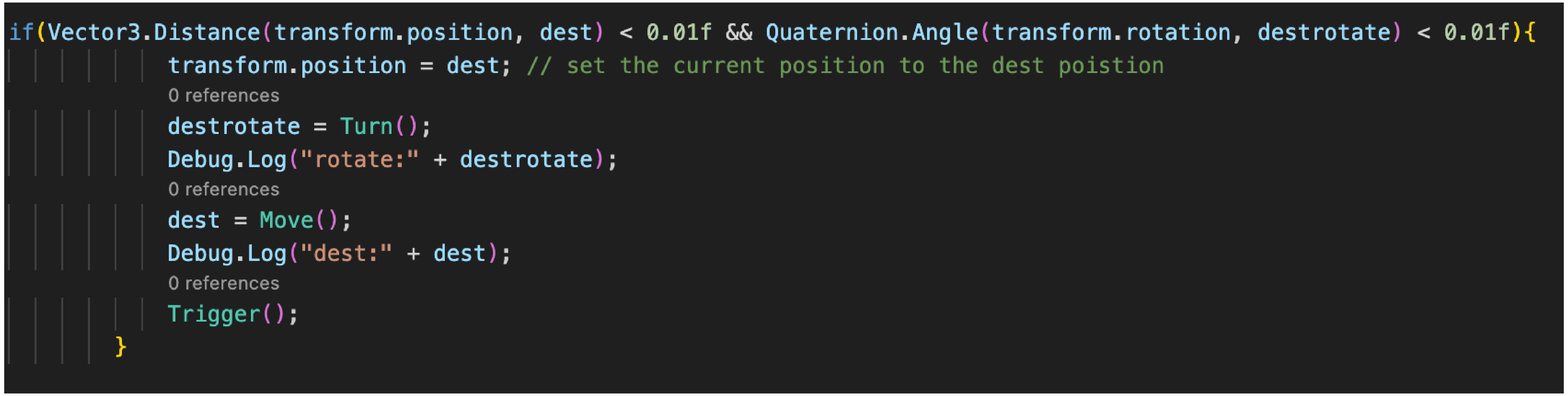
Enhancing Existing Test Tool: Building on Others’ Success

Improve the Test Scripts

After running the Unity project for a while, the object remains stationary.

Enhancing Existing Test Tool: Building on Others’ Success

Improve the Test Scripts

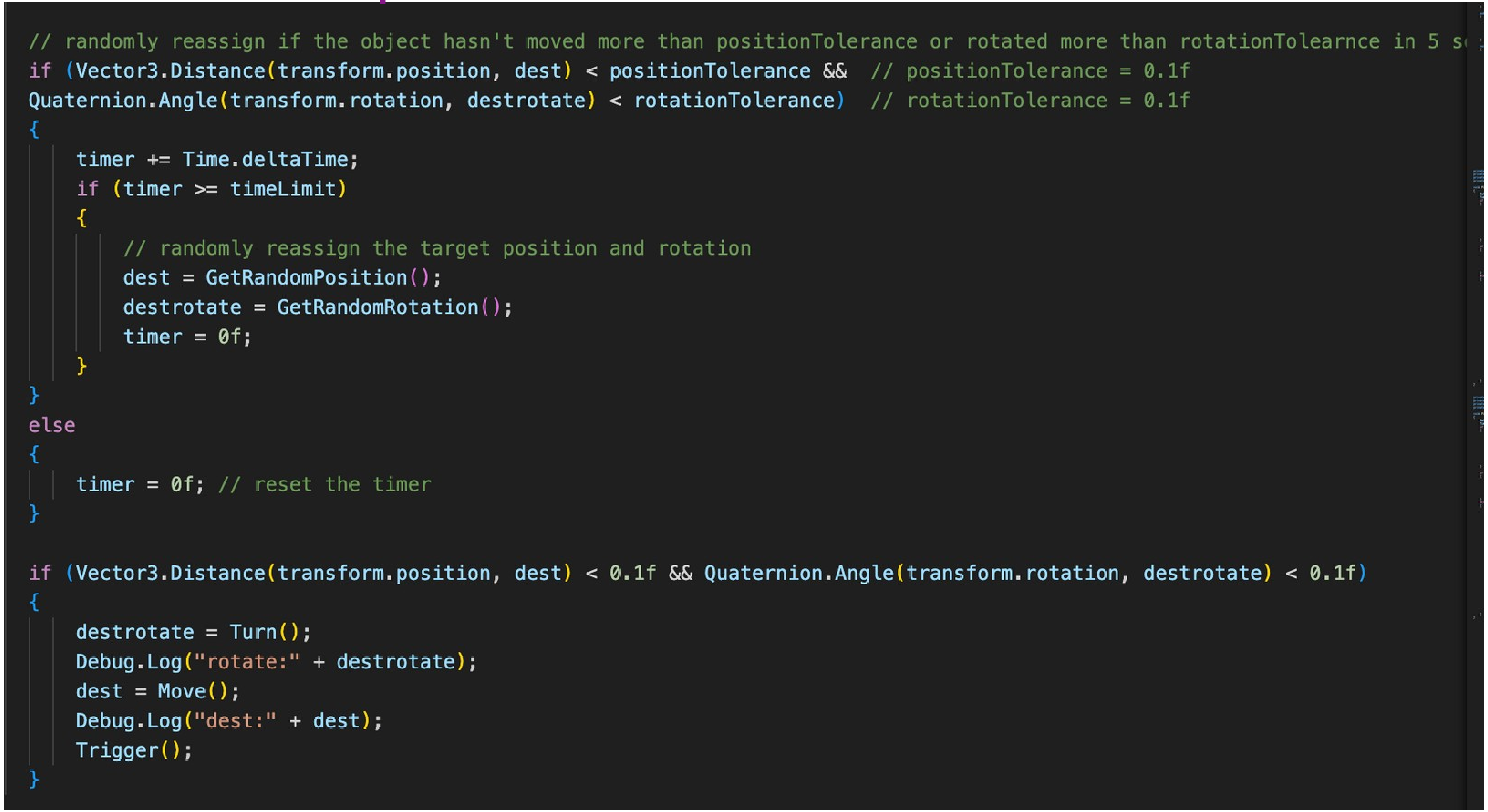


```
if(Vector3.Distance(transform.position, dest) < 0.01f && Quaternion.Angle(transform.rotation, destrotate) < 0.01f){
      transform.position = dest; // set the current position to the dest poistion
      0 references
      destrotate = Turn();
      Debug.Log("rotate:" + destrotate);
      0 references
      dest = Move();
      Debug.Log("dest:" + dest);
      0 references
      Trigger();
    }
```

Check whether the position and rotation angle are close enough.

Enhancing Existing Test Tool: Building on Others’ Success

Improve the Test Scripts

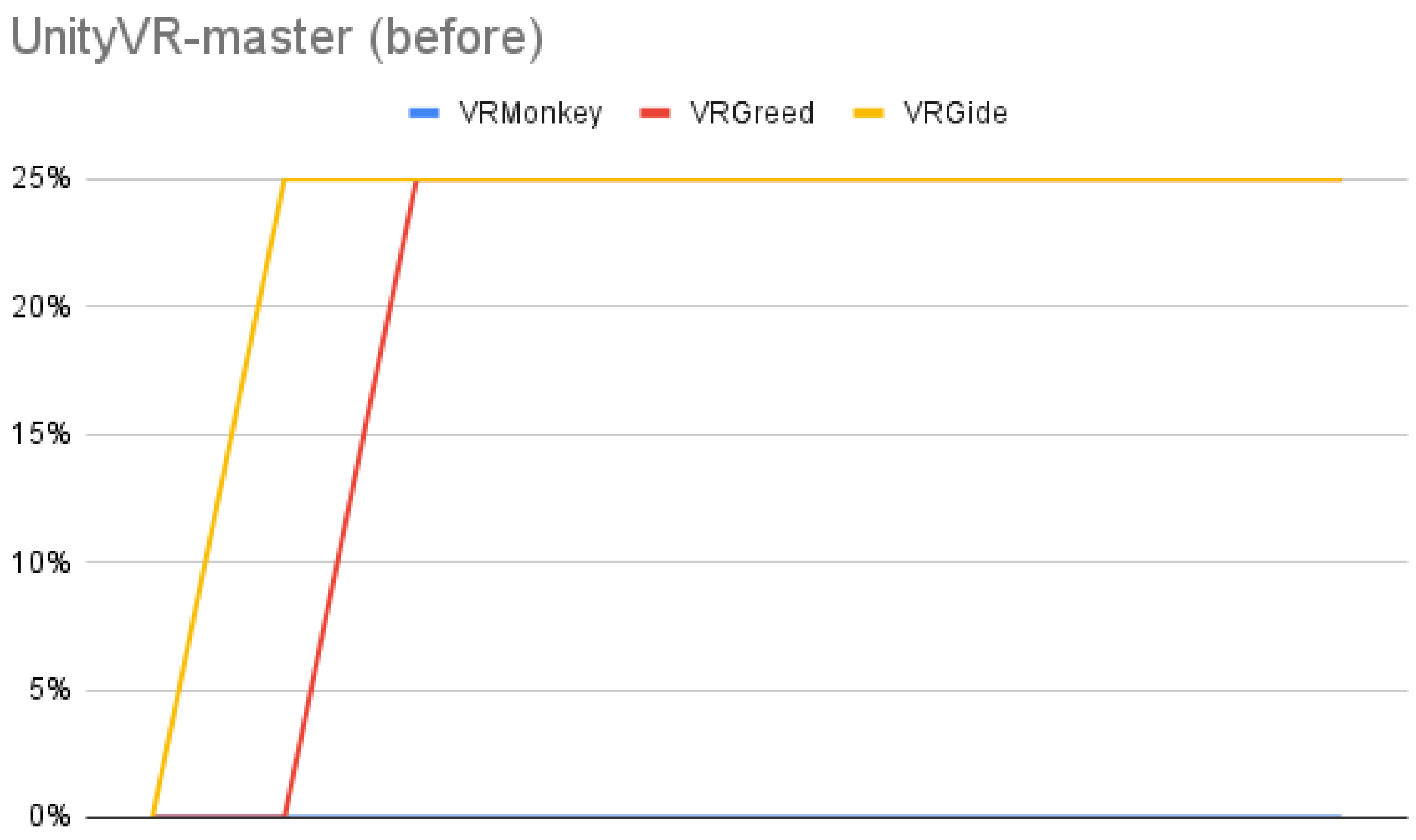


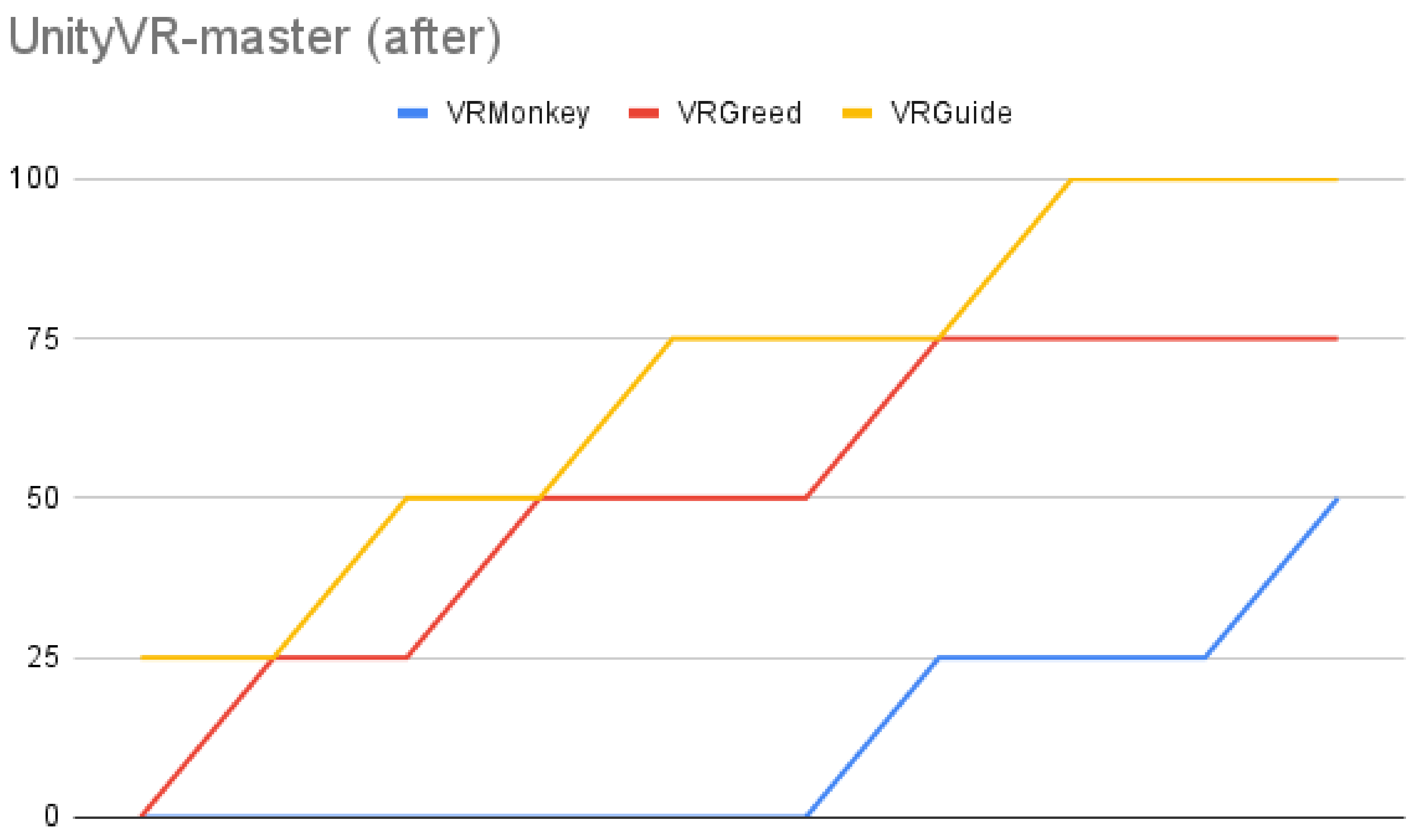
```
// randomly reassign if the object hasn't moved more than positionTolerance or rotated more than rotationTolearnce in 5 s
if (Vector3.Distance(transform.position, dest) < positionTolerance &&  // positionTolerance = 0.1f
Quaternion.Angle(transform.rotation, destrotate) < rotationTolerance)  // rotationTolerance = 0.1f
{
    timer += Time.deltaTime;
    if (timer >= timeLimit)
    {
        // randomly reassign the target position and rotation
        dest = GetRandomPosition();
        destrotate = GetRandomRotation();
        timer = 0f;
    }
}
else
{
    timer = 0f; // reset the timer
}

if (Vector3.Distance(transform.position, dest) < 0.1f && Quaternion.Angle(transform.rotation, destrotate) < 0.1f)
{
    destrotate = Turn();
    Debug.Log("rotate:" + destrotate);
    dest = Move();
    Debug.Log("dest:" + dest);
    Trigger();
}
```

Enhancing Existing Test Tool: Building on Others' Success

Improve the Test Scripts

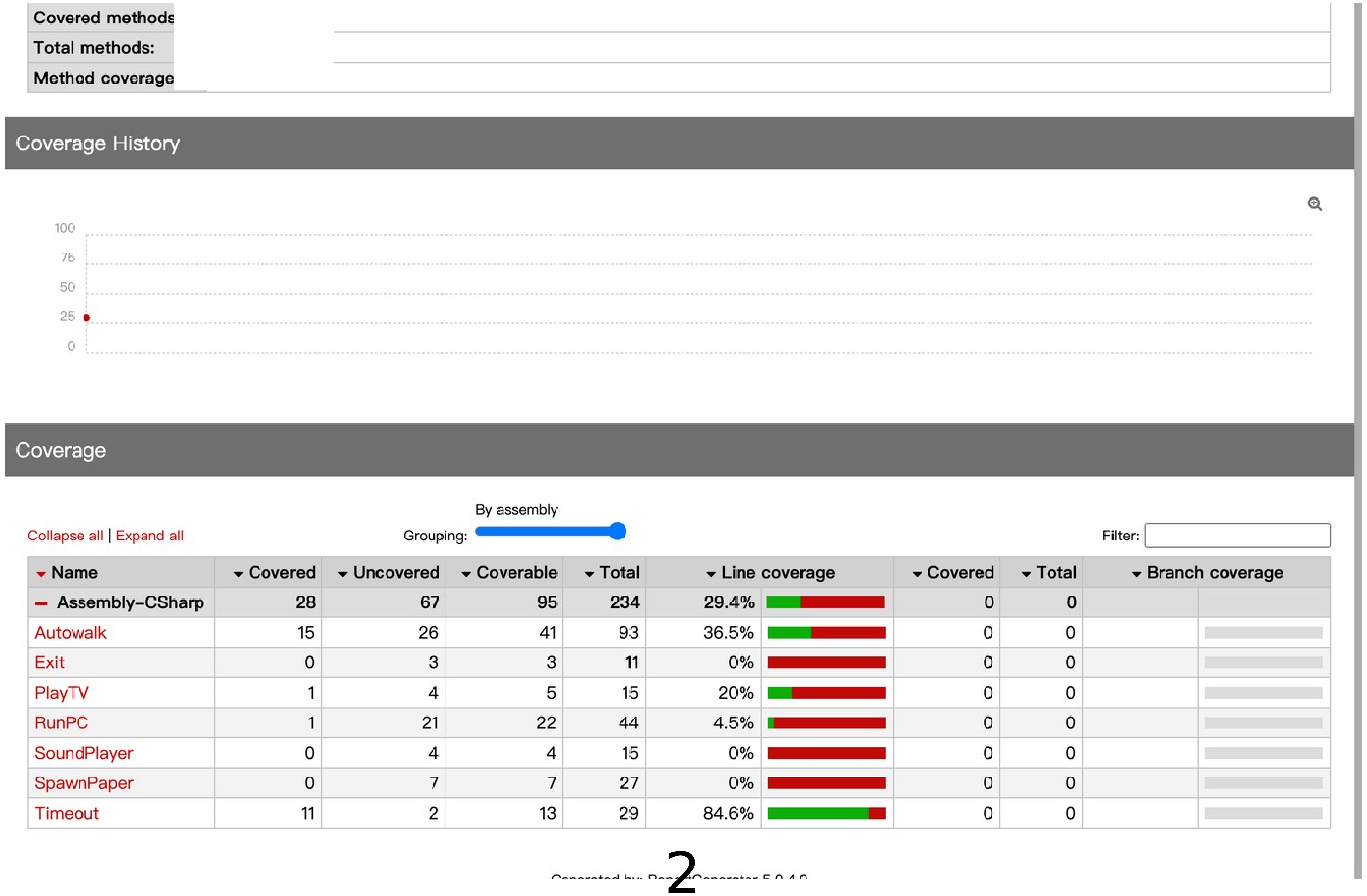




Enhancing Existing Test Tool: Building on Others’ Success

Improve the Test Scripts

Original Method Coverage is only 50.



Covered methods	
Total methods:	
Method coverage	

Coverage History

Coverage

Collapse all | Expand all

Grouping: By assembly

Filter:

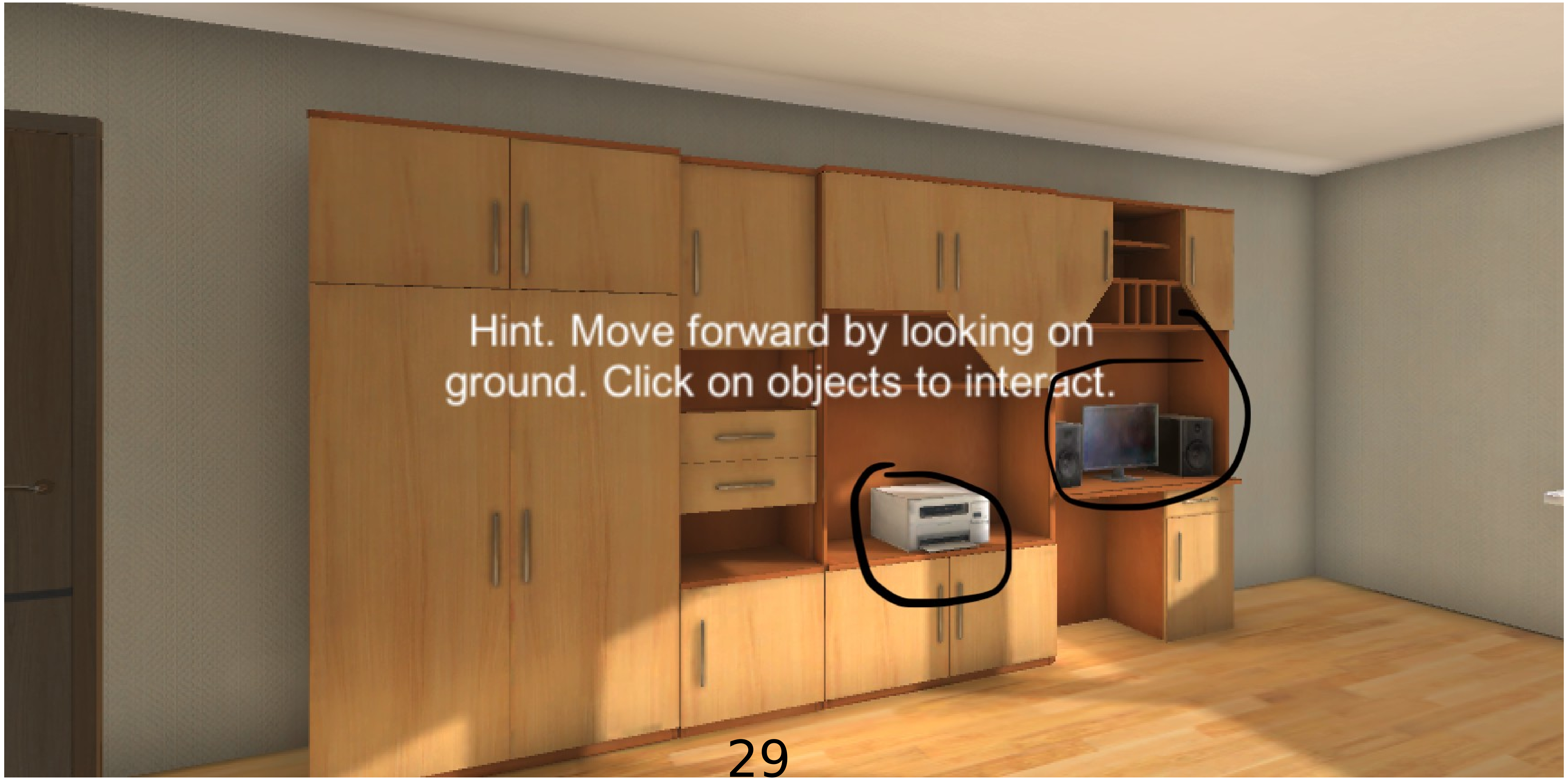
Name	Covered	Uncovered	Coverable	Total	Line coverage		Covered	Total	Branch coverage	
Assembly-CSharp	28	67	95	234	29.4%	🟩🟥	0	0		
Autowalk	15	26	41	93	36.5%	🟩🟥	0	0		
Exit	0	3	3	11	0%	🟥	0	0		
PlayTV	1	4	5	15	20%	🟩🟥	0	0		
RunPC	1	21	22	44	4.5%	🟩🟥	0	0		
SoundPlayer	0	4	4	15	0%	🟥	0	0		
SpawnPaper	0	7	7	27	0%	🟥	0	0		
Timeout	11	2	13	29	84.6%	🟩🟥	0	0		

Generated by: ReportGenerator 5.0.4.0

Enhancing Existing Test Tool: Building on Others' Success

Improve the Test Scripts

Some objects have never been triggered, and methods related to them either.

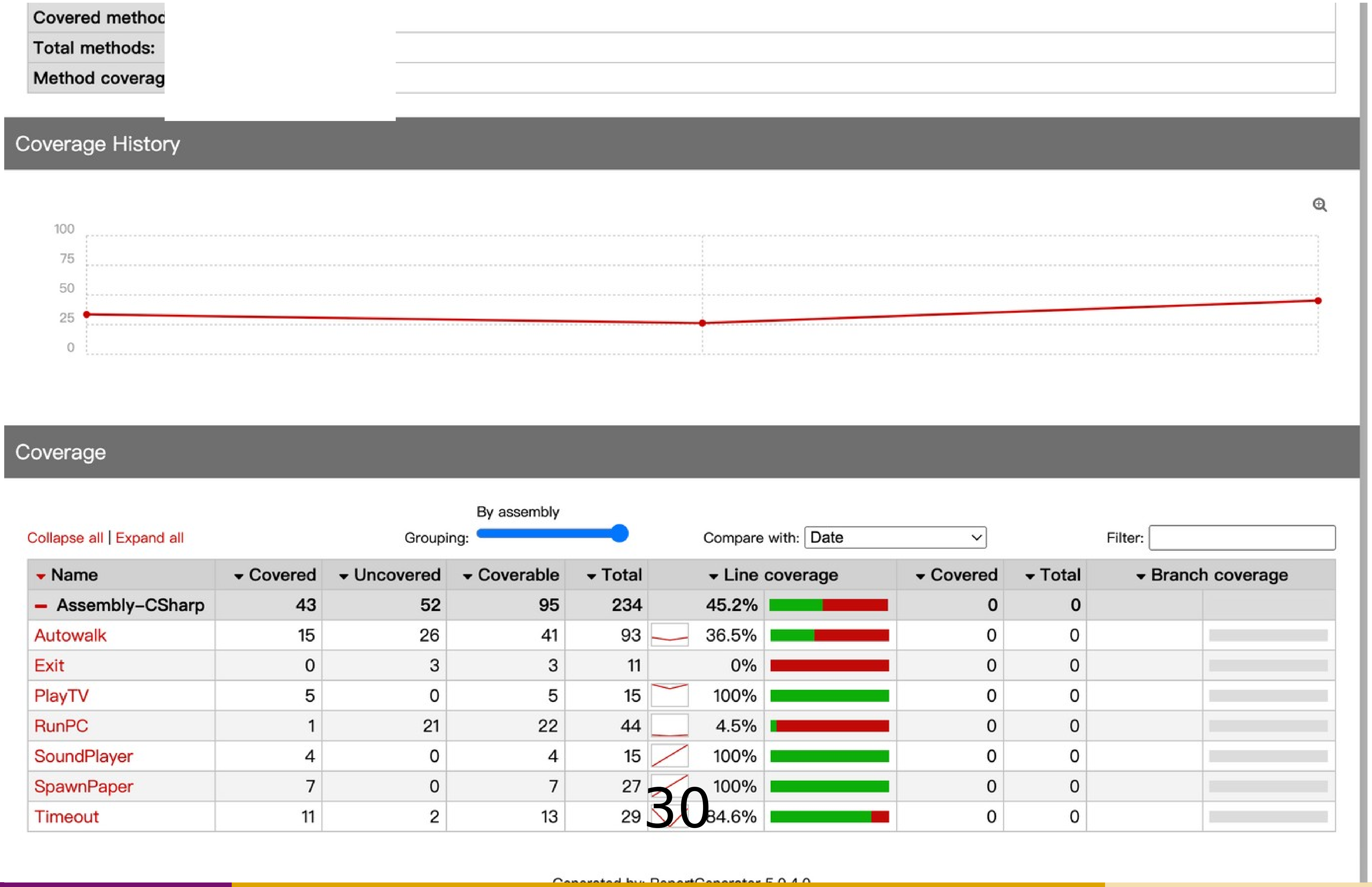


Hint. Move forward by looking on ground. Click on objects to interact.

Enhancing Existing Test Tool: Building on Others’ Success

Improve the Test Scripts

The improved Method Coverage reaches 75.



Covered methoc	
Total methods:	
Method coverag	

Coverage History

Coverage

Collapse all | Expand all

Grouping: By assembly

Compare with: Date

Filter:

Name	Covered	Uncovered	Coverable	Total	Line coverage	Covered	Total	Branch coverage
Assembly-CSharp	43	52	95	234	45.2%	0	0	
Autowalk	15	26	41	93	36.5%	0	0	
Exit	0	3	3	11	0%	0	0	
PlayTV	5	0	5	15	100%	0	0	
RunPC	1	21	22	44	4.5%	0	0	
SoundPlayer	4	0	4	15	100%	0	0	
SpawnPaper	7	0	7	27	100%	0	0	
Timeout	11	2	13	29	84.6%	0	0	

Generated by: ReportGenerator 5.0.4.0

Application of VR Dataset

VR Test Tool

Software Developer

AI Training

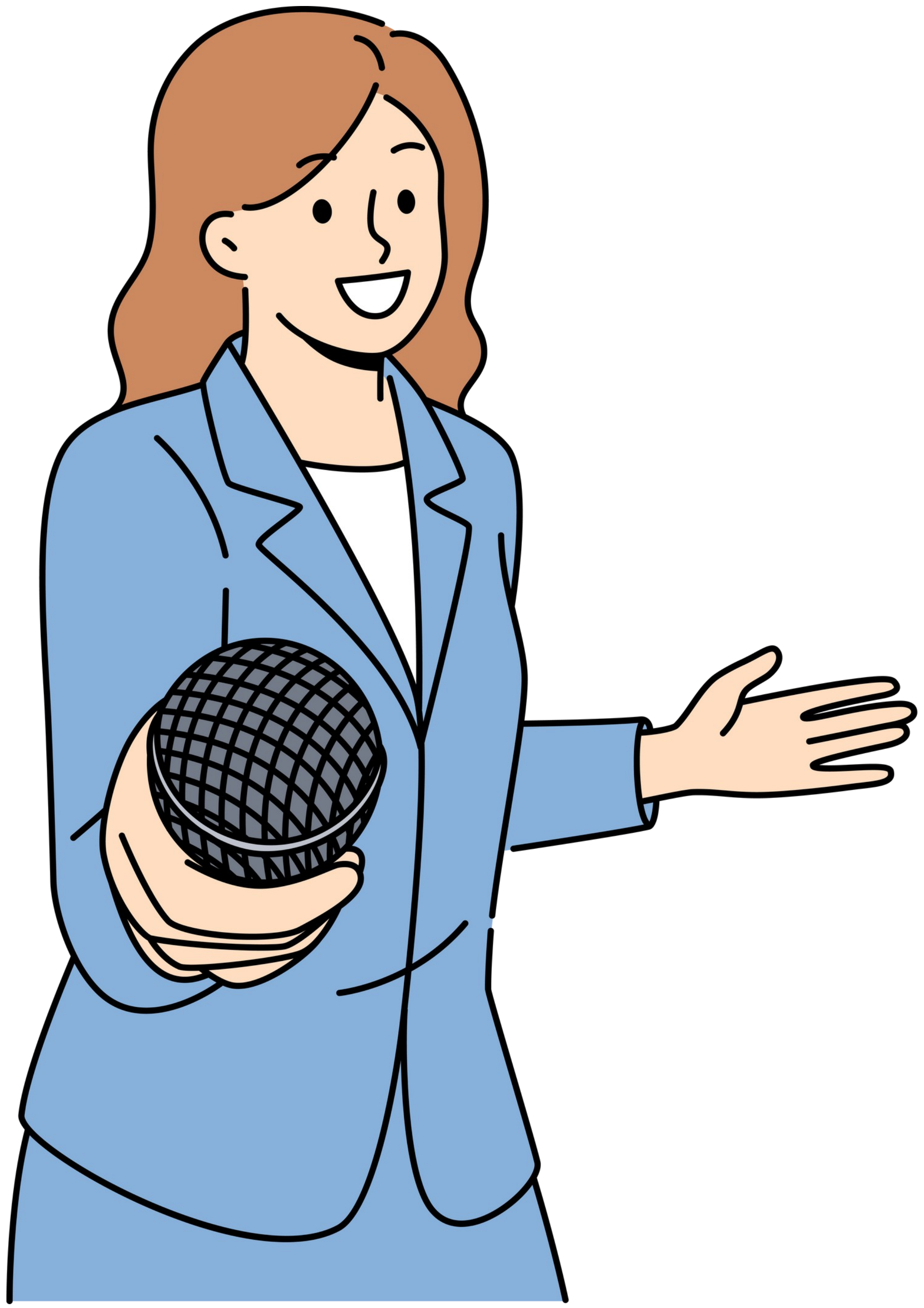
Future Work

- Collect more open-source VR projects and diverse testing scenarios.
- Improve testing tools based on user feedback.
- Integrate AI to enhance VR experiences.
- Collaborate with VR game developers and develop tailored testing tools.
- Continuously seek feedback for ongoing improvement in VR software development.

ACKNOWLEDGEMENTS

We would like to express our deepest gratitude to Professor Michael R. Lyu, our supervisor, and Ms. Shuqing Li, our advisor. Their invaluable guidance and profound insights have significantly contributed to the success of our final year project.

QUESTION & ANSWER SESSION



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