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Link to Video:

https://drive.google.com/file/d/1ToF3bzKA_RXMu1rE2eaHoM5-8XRvqtkn/view?usp=share_link

Links to Github Repo:

1. https://github.com/tomqiluo/Blockchain-Monitor.git
2. https://github.com/tomqiluo/Interactive-Metaverse-Project.git

Robots Interact with a Metaverse in a Cyber-Physical Approach

Introduction

The integration of cyber-physical systems with metaverse technologies offers a unique opportunity to create innovative connections between the real and virtual worlds. This project aimed to develop a cyber-physical system linking a robotic dog to its 3D model in the metaverse, allowing users to interact with the virtual model and observe the corresponding behaviors in the physical robot.

Throughout the project, we focused on the following key aspects:

1. Establishing a communication interface: We developed a Python program to test the API, which is intended to facilitate communication between the metaverse and the robotic dog. Our tests provided valuable insights into how the API could be used in a real-world application, laying the groundwork for future projects in this domain.
2. Developing a user interaction mechanism: Although we couldn't create a 3D model of the Spot robot, we implemented a button as an alternative

interface for user interactions. This allowed us to explore the potential of user-driven commands in the metaverse, even though the interaction was more simplistic than initially planned.

3. Investigating metaverse integration: Despite lacking access to metaverse land for testing, our project explored the requirements and challenges of integrating a cyber-physical system into a virtual environment. Our findings offer guidance for future projects seeking to create similar connections between physical and virtual worlds.
4. Evaluating system performance: We assessed the performance of the Python-based API and the user interaction mechanism, identifying potential improvements and limitations. This evaluation process provided valuable feedback on our project and informed possible directions for future research and development in cyber-physical systems and metaverse applications.

In this final report, we will detail the various components of the project, the strategies we employed to address challenges, and the insights we gained throughout the process. By sharing our experiences and discoveries, we hope to contribute to the growing body of knowledge on cyber-physical systems and their potential integration with metaverse technologies.

<u>Investigating Metaverse integration:</u>

Decentraland uses the Ethereum blockchain to record the ownership of digital assets in the metaverse. To integrate the metaverse interactions into a cyber-physical system, we needed to monitor the Ethereum blockchain and execute code in a physical system. For this reason, we investigated Amazon Web Services (AWS).

AWS Lambda is a serverless computing service that enables developers to run event-driven code without the need to provision and manage servers. With AWS Lambda, we can write code that responds to transactions on Ethereum. We can trigger the AWS Lambda function to run every 30 seconds and use the Infura API to track balance changes in an Ethereum wallet. When a certain amount of ethers is sent to the wallet address, we can trigger the ESP32. For this step, we needed AWS IoT. AWS IoT (Internet of Things) is a platform that creates gateways for devices to interact with cloud services. AWS Lambda can interact with the ESP32 by publishing a message through the gateway provided by AWS IoT.

This part of the technology stack heavily relies on Application Programming Interfaces (APIs) to function. We had success with AWS Lambda and AWS IoT, but we struggled with integrating the two services due to lackluster documentation.

<u>Markelbot Spot</u>

Taking our cue from the innovative work of MerkleBot and Spot, we set out to deepen our understanding of cutting-edge robotics. Spot, a highly advanced and versatile robot designed by renowned company Boston Dynamics, is capable of performing an impressive array of movements, making it ideal for various applications. It has garnered attention for its agility, adaptability, and seamless integration into diverse environments.

MerkleBot is an enterprising startup that has made significant strides in the field of robotics and IoT. They have pioneered a decentralized platform based on the robust and secure foundation of blockchain technology. This revolutionary platform enables seamless communication and control of robots and IoT devices, unlocking new possibilities for applications across multiple industries.

One notable achievement of MerkleBot is the development of a sophisticated application to remotely control Spot. This innovative solution allows users to harness the full potential of Spot's capabilities from a distance, expanding the scope and reach of robotics in everyday life.

With a keen interest in learning from these trailblazers, we scheduled a series of lessons with the expert MerkleBot team. Our goal was to gain in-depth insights into the inner workings of their decentralized application, as well as to uncover the secrets behind the successful integration of blockchain technology into robotics and IoT systems.

Through these educational sessions, we aimed to explore ways in which we could adopt and adapt the principles and concepts demonstrated by MerkleBot to our project. By leveraging their expertise and experience, we hoped to create a solid foundation for our innovations in the rapidly evolving world of robotics and interconnected devices.

Metaverse-API Implementation

Interacting with the API is a major scene in our project, allowing users to make cryptocurrency payments and interact with external APIs. We aim to enable the users to engage with the Spot dog in the metaverse. To achieve this, we first set up our development environment by installing the required tools: Node.js, NPM, and CLI (Decentraland Command Line Interface). Next, we created a new Decentraland scene which is based on SDK and written in TypeScript.

We designed a button that serves as the primary interface for users to initiate cryptocurrency payments. Utilizing the Decentraland SDK, we created the button object and added a text label to communicate its purpose clearly. We also implemented lick event handling to detect the user interaction and trigger the appropriate actions.

For handling cryptocurrency payments, we choose to integrate with the Coinbase Commerce platform, which streamlines the process of accepting various cryptocurrencies. We implemented an asynchronous function to create a new charge and generate a hosted URL for the user to complete the payment. In a real-world scenario, we would verify the payment confirmation either by polling the API or setting up a webhook to receive notifications. However, we only have a dummy API that will be triggered whenever the button is clicked. Once the payment is confirmed, we send out an API request to an external service (more about that later).

Finally, we believe that our scene can now be deployed to Decentraland for more testing.

Conclusion

The integration of a cyber-physical system with metaverse technologies presents a fascinating opportunity to bridge the gap between the real and virtual worlds. Through this project, we explored the feasibility of linking a robotic dog to its 3D model in the metaverse, enabling users to interact with the virtual model and observe the corresponding behaviors in the physical robot.

Despite facing challenges in developing a complete 3D model of the Spot robot and lacking access to Metaverse land for testing, we successfully implemented a button as an alternative interface for user interactions. Furthermore, we established a communication interface using a Python-based API and integrated the metaverse with the Ethereum blockchain and AWS Lambda.

Moreover, we learned from MerkleBot's innovative solutions for controlling Spot and their pioneering work in decentralized platforms for robotics and IoT devices. We believe that our project provides valuable insights into the integration of cyber-physical systems and metaverse technologies and can serve as a foundation for future projects in this domain.

As metaverse technologies continue to advance and more opportunities for integration with cyber-physical systems emerge, we anticipate that the potential applications for these hybrid systems will grow exponentially. The lessons learned from this project and the experiences gained will undoubtedly contribute to the evolution of cyber-physical systems, blockchain technology, and metaverse applications, shaping the future of human-robot interaction and the convergence of the real and virtual worlds.

References

Welcome to Decentraland, https://decentraland.org/. Accessed 15 March 2023.

Using AWS Lambda with AWS IoT. https://docs.aws.amazon.com/lambda/latest/dg/services-iot.html. Accessed April 15, 2023.

The New Dapp of MerkleBot and Robonomics to play with Spot. https://blog.aira.life/the-new-dapp-of-merklebot-and-robonomics-to-play-with-spot-43bf2d92a430. Accessed May 1, 2023.

MerkleBot | data platform for IoT & Robotics, https://merklebot.com/. Accessed 15 March 2023.

Ethereum API | IPFS API & Gateway | ETH Nodes as a Service, https://www.infura.io/. Accessed 15 March 2023.

"Decentraland." *Wikipedia*, https://en.wikipedia.org/wiki/Decentraland. Accessed 15 March 2023.

Németi Florian, et al. "AWS: IoT." *Amazon*, Amazon, 2017, https://aws.amazon.com/iot/.

Hendrix, Roger W. "Lambda." *Amazon*, Laboratory, 1983, https://aws.amazon.com/lambda/.

Perreault, Kristi, and BU ECE. "Cyber-physical Systems with Virtual Reality and Robotics." Edited by Babak Kia. *MS ECE Project Final Paper Summer*, 2020.