ROBOTIC IOT SMARTSPACE TESTBED

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RUTGERS
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PROJECT OVERVIEW

Abstract
The project focuses on the Internet of Things (IoT) intertwined with Machine Learning (ML). The group continues the *SenseScape Testbed*, an IoT experimentation platform for indoor environments containing a variety of sensors, location-tracking nodes, and robots. The *SenseScape Testbed* provides an adaptable environment for labeling/testing advanced ML algorithms centered around IoT.

The Project's Three Phases

Phase One:
- MAESTROs recognize **predetermined set of activities** in office
- Set in **coordinate system**
- Cameras capturing video data of human activity
  - **Automatic labeling**

Phase Two:
- MAESTROs communicate with each other about what is happening in space using **zero-shot** or **few-shot** recognition.

Phase Three:
- MAESTROs communicate with each other to **create a narrative** of given space
  - **"memory"** of the space
  - descriptions based on scope of time
- LLM is core of project

HARDWARE

Raspberry Pi Model 3B+: Microcomputer with Raspberry Pi OS Lite (Legacy)

Raspberry Pi Camera Module: data for labelling purposes

MAESTRO: a custom multi-modal sensor. Has **NINE** distinct sensors

WEBSITE

Real-time information on the sensors: Name of sensor, online status, & continuous data

Reservation system for robot
- Client sends Python script for robot that will be carried out if accepted
- **User-friendly:** easy for user to execute commands & restricts change

PRECISION TIME PROTOCOL

Synchronizes clocks in network
- Sychronize Raspberry Pis with sensors or cameras attached
- Essential for **connecting** sensor data to the camera input **at the same timestamp**
- Using ethernet to connect to boundary server - less latency than a wireless connection

SERVER/DATABASE ARCHITECTURE

Here is the location of where the sensor data is being sent.
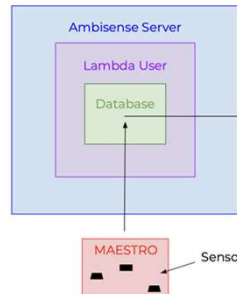
Server: Ambisense
User: "lambda"
- Contains **smartbox database** where the MAESTROs' send information
- Data accessed by **Jupyter Notebook,** manipulated using Postgresql commands

Web App created using **Dash by Plotly**
- easier way to **visualize & label** data

UNITY/ROBOTICS

- Explored **Unity** for human centered design
  - **Avatar mirrors** webcam feed
  - **VSeeFace**: sends webcam data to IP address
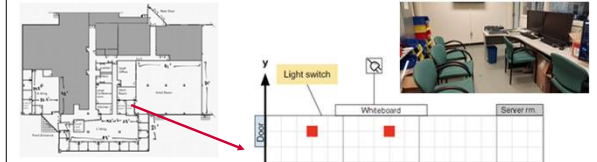   - Multiple users in testbed

- **VR** through **Meta Quest 2**
  - User can move & interact with **digital twin** room in headset
  - Demo: table and 3 blocks → grabbed using controllers

- Explored ROS Point Clouds
  - **LIDAR** generated **point clouds**
  - Explore room using **first person camera**
  - Point cloud sent in **real-time** through ROS **rviz** (3D visualizaition tool)

COORDINATE SYSTEM

Measurements taken of WINLAB. Focus on smaller **control room**. Map to be **included on website**.
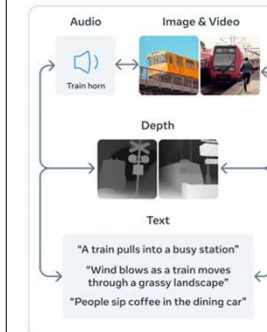
FUTURE WORK

Hardware for PTP: **TimeCard mini Platinum Edition** from OCP-TAP
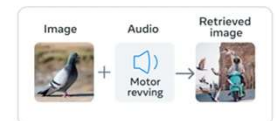
Data Collection: Set up MAESTROS & cameras in grid and collect data
- Data is uploaded on website

Source: https://imagebind.metademolab.com/

Automatic labelling: Label activity within environment using natural language descriptions of video data
- Train neural networks in encoder-decoder architecture for feature extraction
- Bridge the gap between sensor-to-text

ACKNOWLEDGMENTS

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