SuperBots – Robotic Context Inference with Through-wall Sensing using Vision and WiFi

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1 Motivation

Context inference is an important enabling capability for many applications. A *complete context inference* would include identifying the people (i.e., who is this person?), inferring their activities, assessing their emotional state (happy, angry, etc), inferring what kind of event is happening, and inferring the type/material of the objects present, among other possibilities. See Fig. 1 for a few examples. In this project, you will develop a **SuperBot**, a robotic system that is capable of context inference, even through walls. The project will focus on a couple of example applications of context inference.

The area of robotics and unmanned vehicles has grown tremendously in the past few years. Unmanned vehicles are starting to materialize in the commercial scenery, with examples such as Alphabet's Wing, or Amazon and Nuro's delivery unmanned vehicle programs. On the other hand, the emergence of AI, along with advancements in vision systems and large language models (LLMs), has opened up significant opportunities for context inference. When coupled with the mobility of unmanned vehicles, this creates unparalleled potentials for sensing, learning, and scene understanding.

Context inference through walls, however, remains a clear challenge with the current sensing modalities. In recent years, sensing with RF signals, such as WiFi, has gained considerable traction. Not only are communication devices ubiquitous, but most smart devices whose main goal is not communication, such as smart speakers or thermostats, are now equipped with communication capabilities. As a result, cheap communication transceivers using WiFi and Bluetooth are readily available and have been envisioned to be utilized beyond communication, and for sensing and learning about the environment. This has resulted in a considerable interest in sensing and learning about the environment with RF signals in recent years.

In this project, you will focus on building a robotic sensing and context inference system using an unmanned ground vehicle (UGV), i.e., the SuperBot. The UGV you will develop will use its navigation system for localization, exploration, and motion planning. Next, you will develop a state of the art vision and AI system for your SuperBot, enabling robotic sensing, exploration and context inference. Finally, to enable through-wall sensing, you will develop a WiFi-based sensing system to complement the other sensors. This then allows your SuperBot to build an understanding of the environment including both line of site and through-wall sensing.

Below, is a more detailed description of the goals of the project.

2 Detailed Descriptions

Here are the steps of the project.

2.1 Phase 1: Robot Setup and Navigation:

You will be using Turtlebot robot, an exciting open-source unmanned ground vehicle platform. In Phase 1, you will first familiarize yourself with ROS 2 operating system, and robot's hardware and software capabilities. You will then configure and successfully demonstrate robot's capabilities in navigation, path planning, exploration, obstacle avoidance, and mapping.

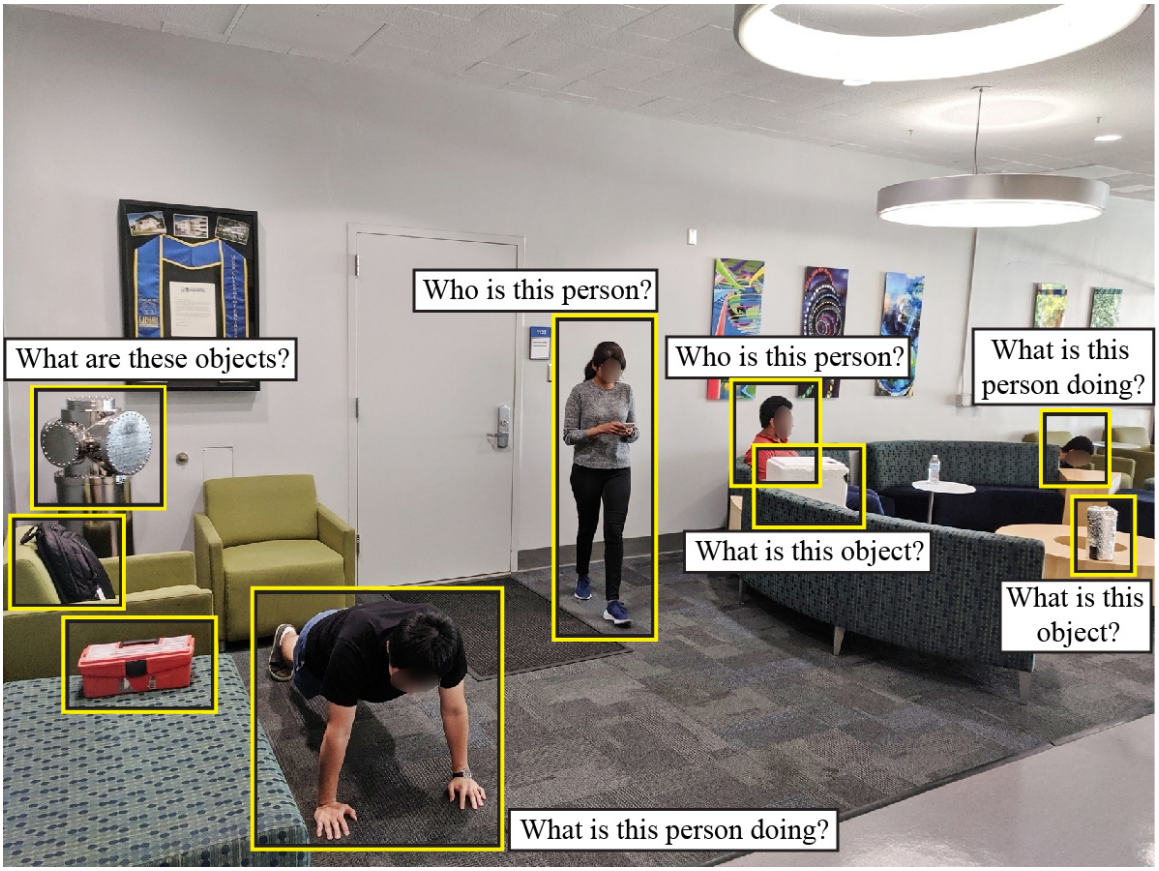

Figure 1: Examples of context inference.

2.2 Phase 2: Enabling Context Inference Using Vision Input:

Once the robot is ready to go from navigation perspective, Phase 2 then focuses on context inference using the onboard vision system of the robot. Specifically, you will use the OAK-D-Lite camera onboard. You will then develop codes and interfaces necessary to enable context inference tasks such as object classification and people detection and successfully demonstrate their performance on your robot. Your implementation will use state of the art AI tools and platforms as well as language models.

2.3 Phase 3: Context Inference Through Walls with WiFi:

Once you have shown the extent of what is possible with the state-of-the-art vision system, you will then address the part of the context inference that still remains challenging, i.e., sensing through walls. To complete your project and enable full context inference, you will then focus on enabling context inference through walls using WiFi signals. More specifically, you will first interface a WiFi card (Intel 5300) with your setup. Then, you will use already-existing codes that will enable processing of the WiFi signals, denoising them, and extracting features relevant to the environment. Finally, you will demonstrate the performance of the developed system by having your robot identify a person through walls.

Overall, the three phases will train the students on the state of the art in robotic navigation, vision and AI, and RF sensing and the union of the three will create SuperBot, a unique and exciting robotic context inference system with through-wall capabilities.