Magic Skydio

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Abstract

As autonomous robots increasingly integrate with our daily lives, systems that foster accessible Human-Robot Interaction (HRI) become crucial. This is an active area of research which, though exploration into HRI with less collaborative robots, has many opportunities for advancement. Recently, Skydio released the R1 drone platform, for which we have SDK access. This enables us to research collaboration between humans and possibly less collaborative robots. Along this thread, we present Magic Skydio, an augmented reality (AR) interface for the Skydio R1 drone. Magic Skydio both supplies the user with information about the robot's state and accepts gesture commands for movement control. Through this interface, the user is empowered to collaborate with R1.

1 Introduction

Collaborative robots are growing in popularity across consumer and enterprise domains. From household robots like Roomba to assembly line robots like Baxter, collaboration between robots and humans is frequent.

However, many robots are not designed to collaborate with humans. Nonetheless, with cognizance of the increasing presence of robots, we believe in the importance of developing systems that allow humans to safely interact with and leverage a wider class of robots.

We want to empower collaboration between humans and 'non-collaborative' robots.

Our "non-collaborative" robot of choice for this project is a drone. For the purposes of this project, we selected Skydio R1, a drone equipped with an autonomy engine designed to avoid collisions with humans [3] (Figure 5).

R1 is traditionally controlled with a smartphone, though recently the Skydio team released an SDK that allows for control via a basestation connected to R1's network. For communication, we chose the Magic Leap AR headset (Figure 2). The Magic Leap can recognize gestures and display information in the user's field of vision. Thus, it was a natural candidate for our application. Our goal is to enable control of drone using gestures and inform the user if the given command was successfully received.

Figure 1: Skydio R1

Figure 2: Magic Leap

We have achieved communication between the R1 and the Magic Leap. Specifically, the R1 can be controlled using gestures, and the Magic Leap can display the state of R1, including pose and gesture recognition. Additionally, we have ROS-enabled R1 for future research.

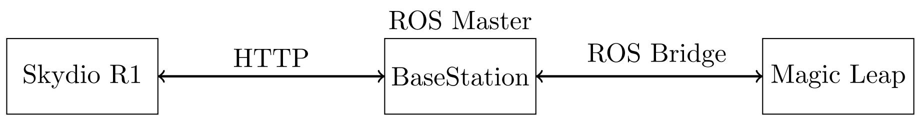
2 Related Work

There have been a number of research papers on human-robot collaboration through Virtual or Augmented Reality (VR or AR). For example, Whitney et al. ([10],[11]) use a VR headset to control Baxter. Zhang et al. [12] also use VR to teleoperate a PR2 robot. Walker et al. [9] suggest that human-robot communication using AR is more efficient than traditional methods.

There has been less, though still noteworthy, exploration into coupling VR/AR with drones. Huang et al. [2] use AR along with natural language to control drones. Omidshafiei et al. [7] also use AR to efficiently communicate the drone's intentions to humans. We plan on furthering the work in this area by using human gestures and AR to improve collaboration between humans and drones.

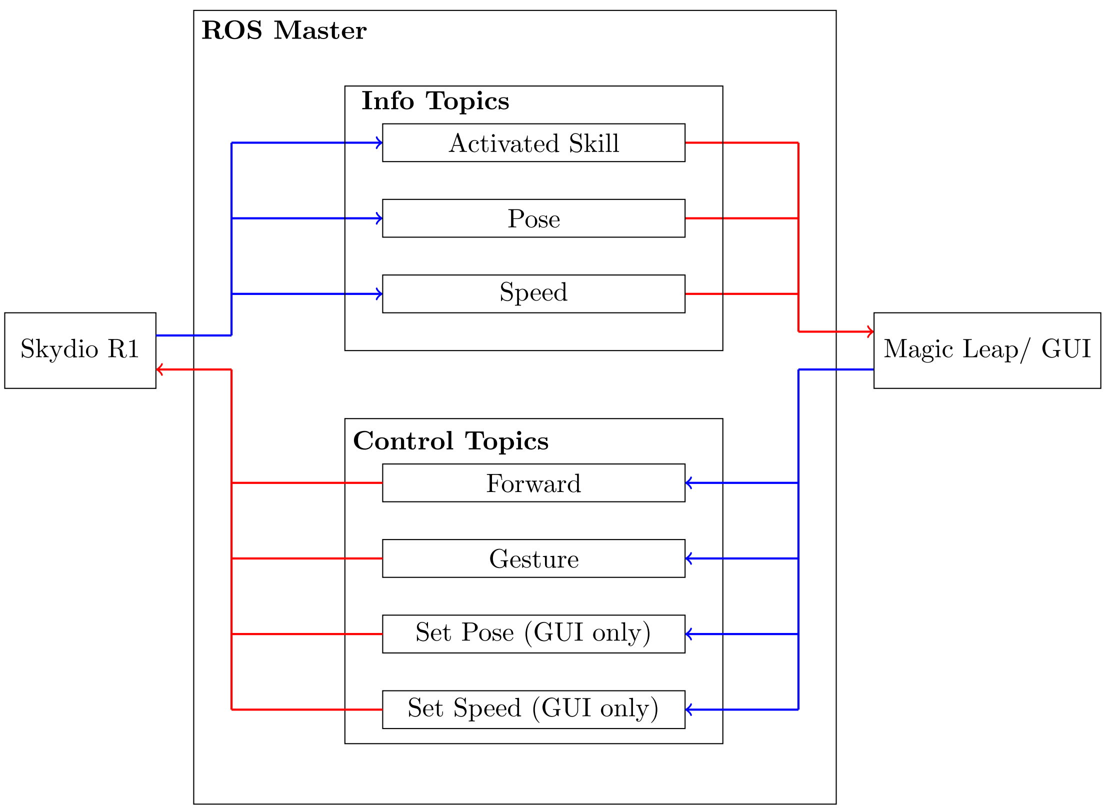
3 Technical Approach

Our goal for this project is to enable communication with the drone using gestures, and provide feedback to the user through AR. To accomplish this goal we connected ROS [8] to Skydio R1 through a base station. The Magic Leap connects to the base station using ROS Bridge.



The ROS network contains seven topics, split into two categories:

- **Information**: *Activated Skill*, *Pose* and *Speed* topics relate to the current state estimate of the drone. The Skydio R1 acts as publisher (via ROS-enabled basestation), and control interfaces (such as Magic Leap, or a GUI) act as subscriber.
- **Control**: *Forward*, *Gesture*, *Set Pose*, and *Set Speed* topics relate to control of the drone state. The control interface acts as publisher, and Skydio R1 acts as subscriber (via ROS-enabled basestation).

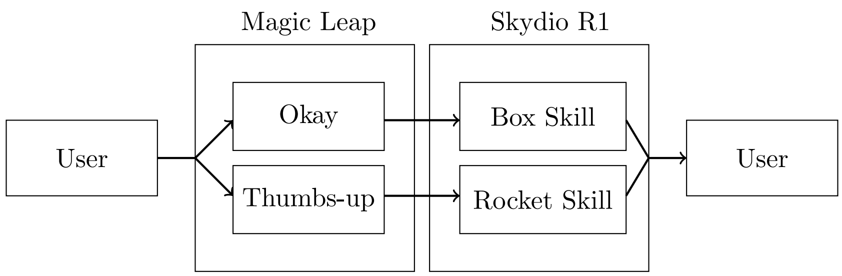


The user can issue two commands to the R1 using gestures. Further, we wrote a GUI to listen to and publish pose and speed updates to R1.

1. *Box Skill.*
   The user can make an "okay" gesture. The Magic Leap will then recognize this gesture and tell the Skydio to perform its box skill, which will make it fly in a box formation.

2. *Rocket Skill.*
   The user can make a "thumbs-up" gesture. The Magic Leap will then recognize this gesture and tell the Skydio to perform its rocket skill, which will make it fly up in the air.

In both cases, if the Skydio succeeds, it will initiate the task, and send a success message to the Magic Leap. The Magic Leap will then display a success message.



4 Evaluation

The goal of this project was two-fold: develop the ROS pipeline for R1 to enable future research with the drone, and use this pipeline to demonstrate the collaborative capabilities of R1. In our view, we have met this goal.
Quantitatively:
At the midterm checkpoint, R1 could listen and publish to ROS topics using our framework. We created an AR app for Magic Leap that displayed R1's state estimate to the user, demonstrating publishing capability, and responded to a trigger command for movement, demonstrating listening capability. We have written up a guide on Github for other interested users to follow [4]. For the final, we enabled R1 to respond to user gestures. When given a "thumbs up", R1 activates its rocket skill. When given an "okay", R1 activates a box motion.

Qualitatively:
We produced videos of our midterm and final work, posted on Youtube ([1], [5], [6]).

5 Conclusion

We aim to foster HRI with a broad of range of robots. In this light, we have developed a system that enables humans to control a drone via gesture recognition. We are using a Magic Leap to determine the user's gestures and map

Figure 3: Set-up outside the CIT

Figure 4: Activating Rocket

Figure 5: Activating Box

these gestures to motion commands for a Skydio R1 drone. To accomplish this, we have established bi-directional communication between the Skydio R1 and Magic Leap, via ROS. Support for both TCP and UDP communication has been implemented.

ROS-enabling the Skydio opens the potential for many new research opportunities. We would be interested to explore pushing the AR interface further, creating 3D maps where R1's position can be viewed and programmed. This would enable exploration of interface designs where R1 is not in Magic Leap's field of view.

On a broader note, the Skydio platform presents many exciting opportunities for research into multiple domains of collaborative robotics. Of particular interest is integrating LTL commands with Skydio, both in the fully and partially observable environment.

The importance of developing new and improving existing methods of collaboration between robots and humans continues to grow. More natural and intuitive collaboration is an exciting area of current research, and we look forward to continuing our efforts in this area.

References

[1] Matthew Berg and Evangelia Anna Markatou. Magic skydio in action (midterm), 2019. https://www.youtube.com/watch?v=90FIUimE__o.

[2] Baichuan Huang, Deniz Bayazit, Daniel Ullman, Nakul Gopalan, and Stefanie Tellex. Flight, Camera, Action! Using Natural Language and Mixed Reality to Control a Drone. In *IEEE International Conference on Robotics and Automation (ICRA)*, 2019.

[3] Skydio Inc. Skydio website, 2019. https://www.skydio.com/.

[4] Evangelia Anna Markatou and Matthew Berg. Magic skydio, 2019. https://github.com/markatou/magic-skydio/tree/ros-skydio.

[5] Evangelia Anna Markatou and Matthew Berg. Magic skydio box skill, 2019. https://www.youtube.com/watch?v=TgQ11kiqacc.

[6] Evangelia Anna Markatou and Matthew Berg. Magic skydio rocket skill, 2019. https://www.youtube.com/watch?v=-N5s-X4kExw.

[7] S. Omidshafiei, A. Agha-Mohammadi, Y. F. Chen, N. K. Ure, S. Liu, B. T. Lopez, R. Surati, J. P. How, and J. Vian. Measurable augmented reality for prototyping cyberphysical systems: A robotics platform to aid the hardware prototyping and performance testing of algorithms. *IEEE Control Systems Magazine*, 36(6):65–87, Dec 2016.

[8] Morgan Quigley, Ken Conley, Brian P. Gerkey, Josh Faust, Tully Foote, Jeremy Leibs, Rob Wheeler, and Andrew Y. Ng. Ros: an open-source robot operating system. In *ICRA Workshop on Open Source Software*, 2009.

[9] Michael Walker, Hooman Hedayati, Jennifer Lee, and Daniel Szafir. Communicating robot motion intent with augmented reality. In *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction*, HRI '18, pages 316–324, New York, NY, USA, 2018. ACM.

[10] David Whitney, Eric Rosen, Elizabeth Phillips, George Konidaris, and Stefanie Tellex. Comparing robot grasping teleoperation across desktop and virtual reality with ros reality. In *Proceedings of the International Symposium on Robotics Research*, 2017.

[11] David Whitney, Eric Rosen, Daniel Ullman, Elizabeth Phillips, and Stefanie Tellex. Ros reality: A virtual reality framework using consumer-grade hardware for ros-enabled robots. *IEEE/RSJ International Conference on Intelligent Robots and Systems*, 07 2018.

[12] Tianhao Zhang, Zoe McCarthy, Owen Jowl, Dennis Lee, Xi Chen, Ken Goldberg, and Pieter Abbeel. Deep imitation learning for complex manipulation tasks from virtual reality teleoperation. In *2018 IEEE International Conference on Robotics and Automation (ICRA)*, pages 1–8. IEEE, 2018.