

Autonomous Flying Mini Drone-ball in a Multi-Player AR Superhuman Sports Game

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Final: Practical Course Augmented Reality

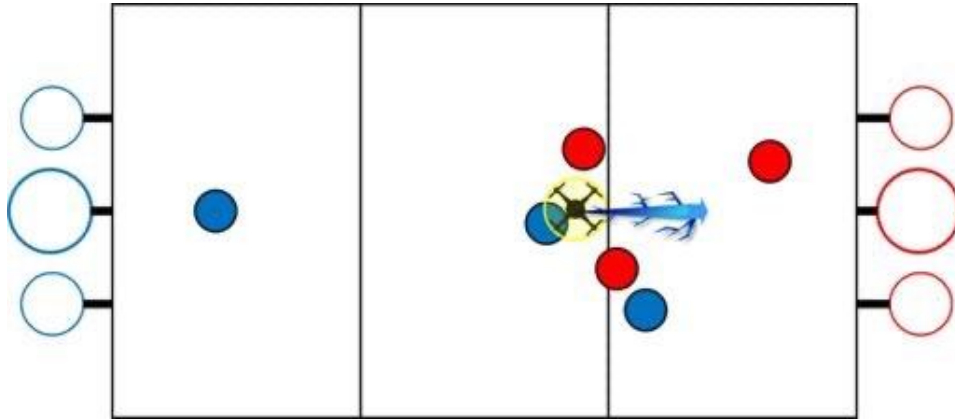
Supervisor: Christian Eichhorn

Motivation



- Superhuman sports game with AR
- Tangible programmable drone
- Immersive gameplay

Catching the Drone - Requirements



1. Safely catchable drone
2. Trackable in AR headsets
3. Win points by throwing through the gates

Existing Solutions - Tangible Drones

“Boxing against drones:
Drones in sports
education”

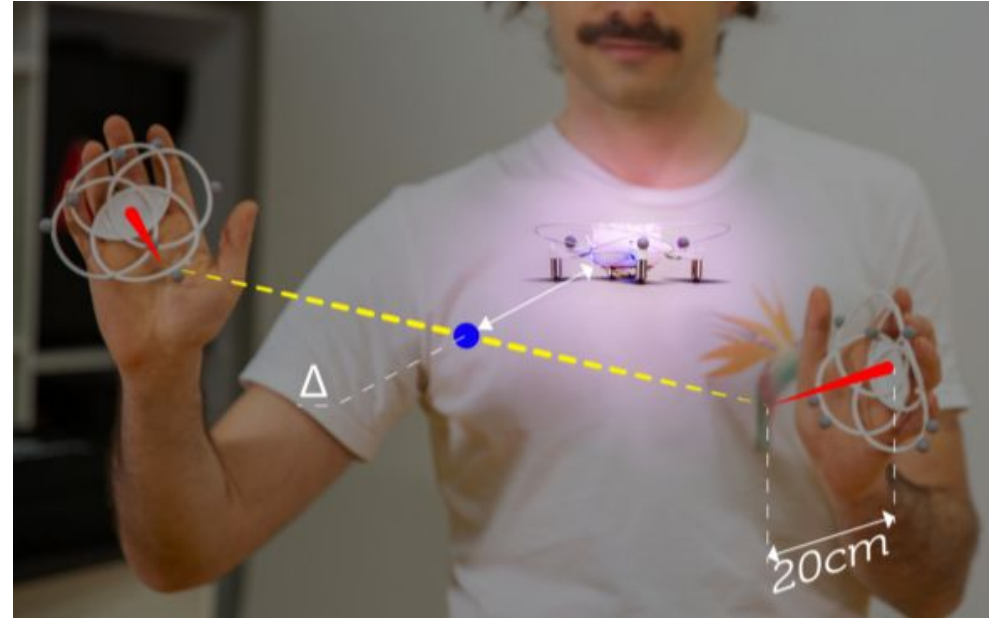
- training partner
- scenarios: minimum physical contact
- autopilot function, body sensors and flight control apps



Existing Solutions - Tangible Drones

“Drone Chi”

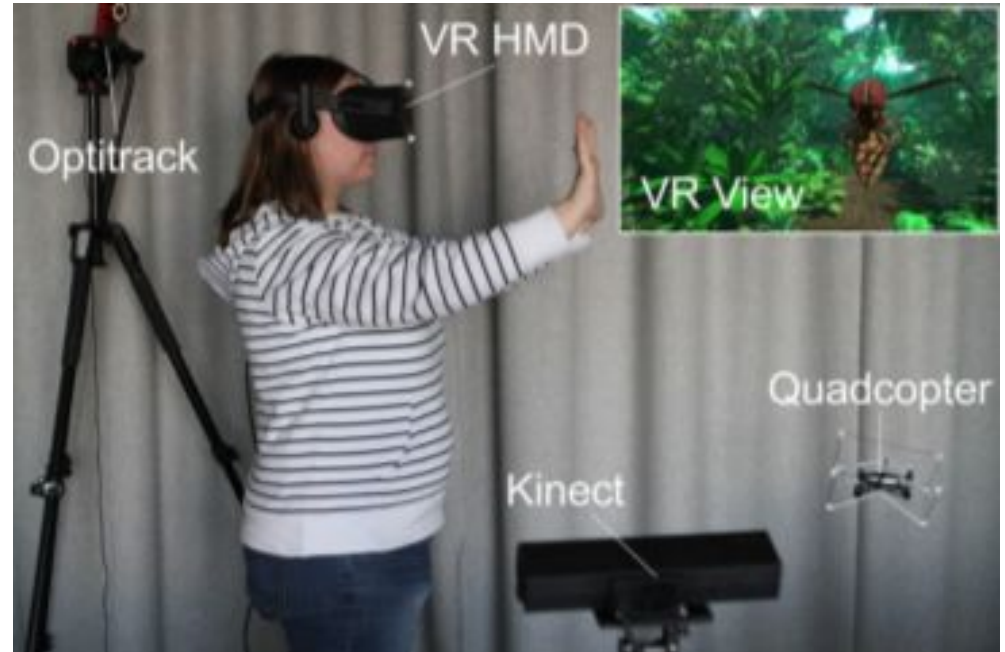
- Inspired by Tai Chi
- Stages:
 - 1) Follow the drone
 - 2) Leading the drone



Existing Solutions - Tangible Drones

“Tactile Feedback in Virtual Reality through Quadcopters”

- VR game
- Full-body tactile feedback
- varying from and speed of the drone



Objectives of this Project

Construction of
a Mini Indoor
Drone-ball

Autonomous
Flight Setup

In-game
Interaction



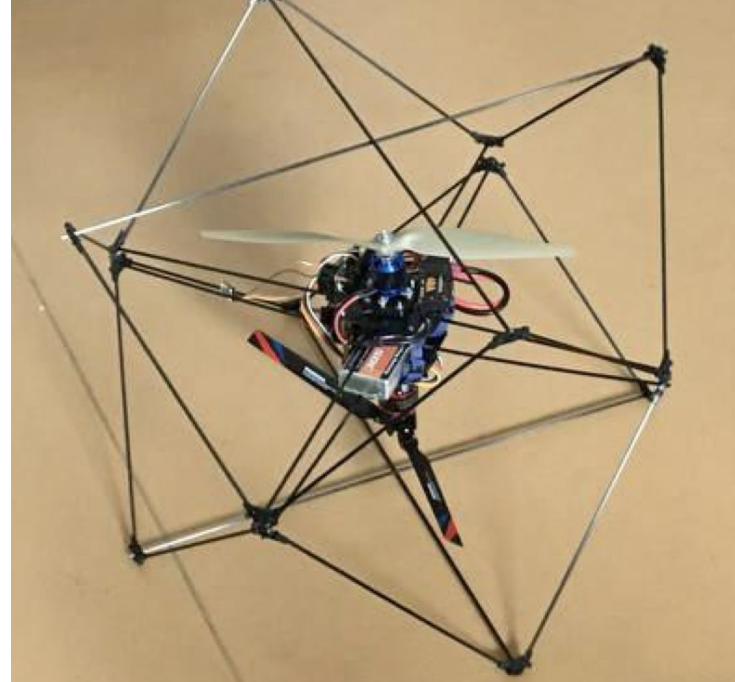
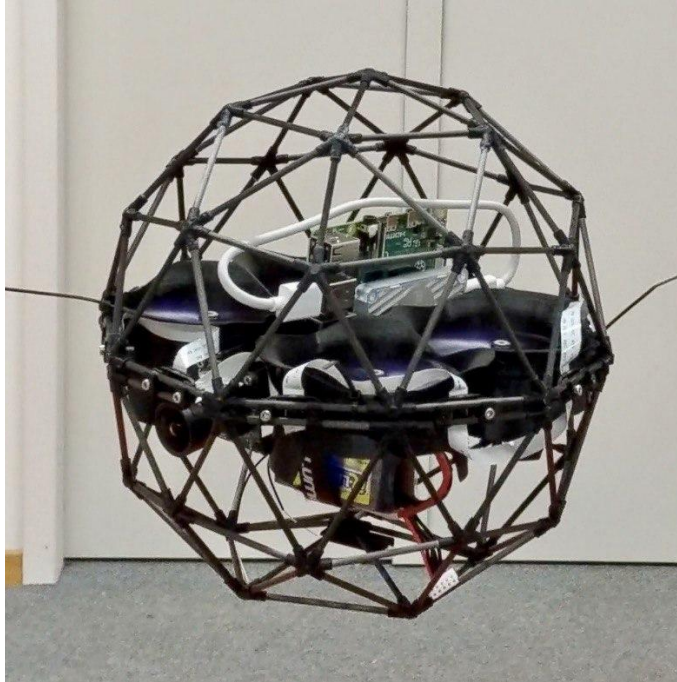
Critical Research Issues

- ... short summary!
-

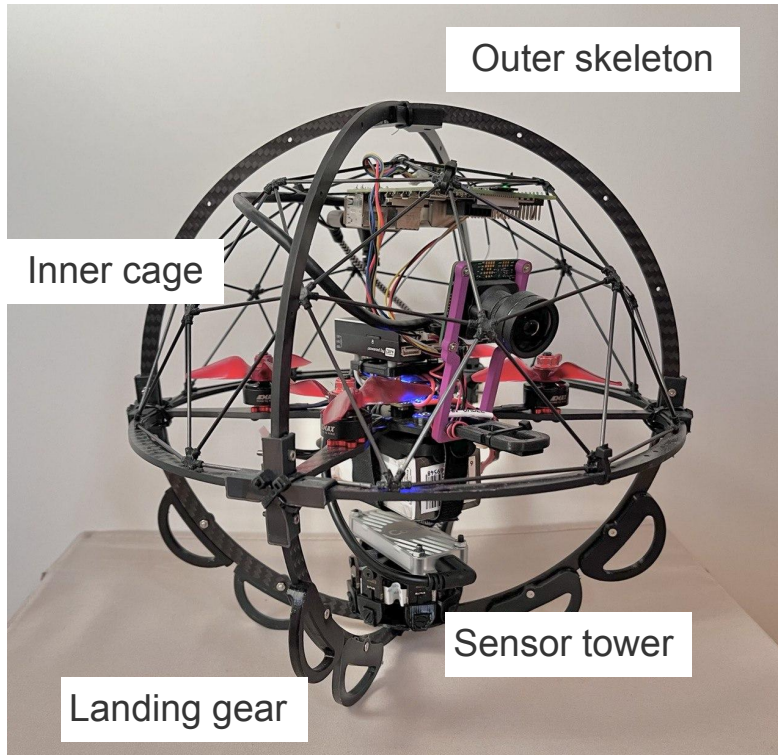


Mini Indoor Drone-ball Construction

Mini Indoor Drone-ball: Pre-work



Mini Indoor Drone-ball: Approach



+:

Crash-resistant cage

Compact sensor tower

Fast access to battery

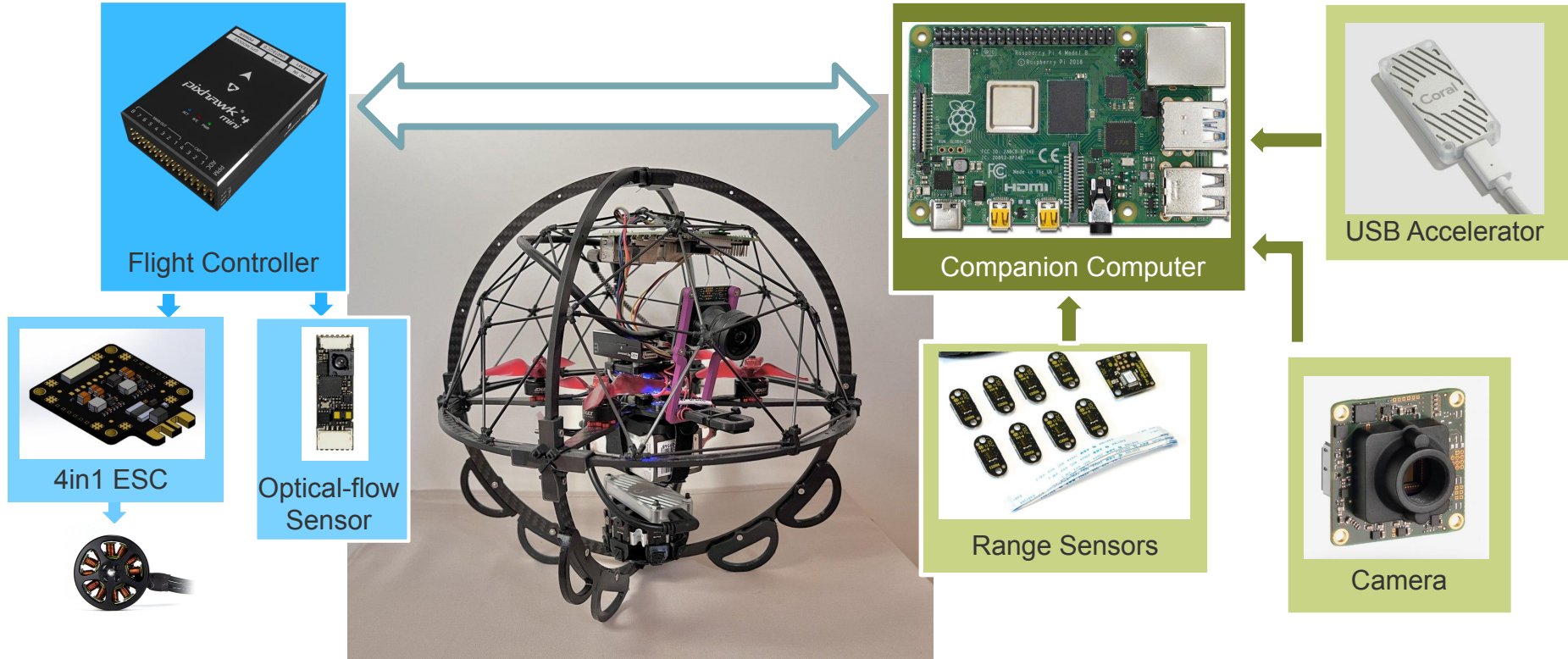
Easier to mount

-:

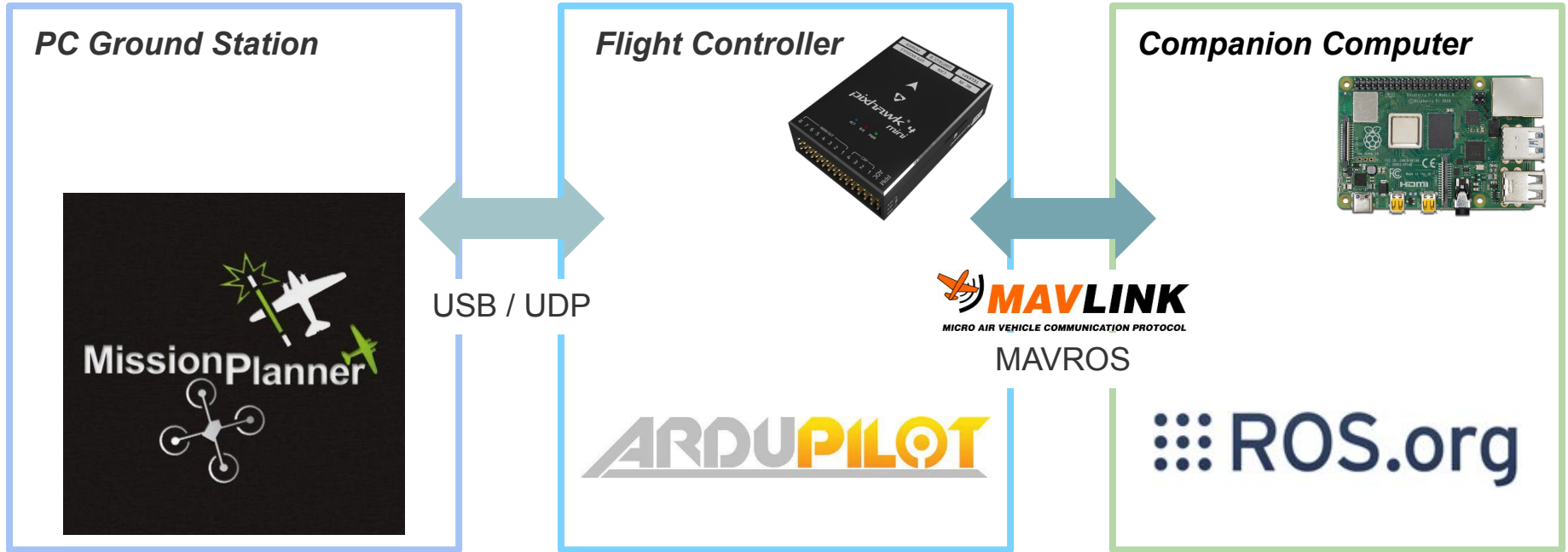
More weight

No ducts

Mini Indoor Drone-ball: Implementation



Mini Indoor Drone-ball: Implementation



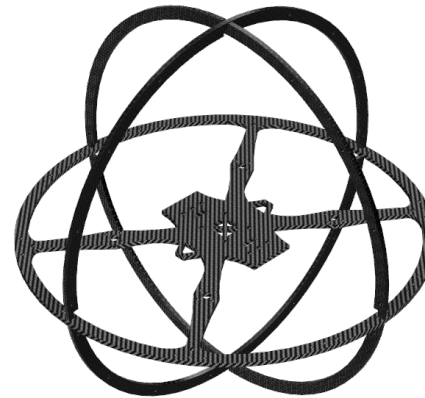
Evaluation - Robust Structure

Crash-resistant outer skeleton



Vulnerabilities:

- Camera holder
- Inner cage rods
- Screws



Evaluation - Flight Time Optimization

Capacity	Weight	Energy	Approx. Flight time
2000 mAh	216 g	29.6 Wh	3'26''
1800 mAh	194 g	26.64 Wh	3'03''
1550 mAh	176 g	22.94 Wh	2'49''
1300 mAh	148 g	19.24 Wh	2'15''

(Total weight without battery: ~ 500g)

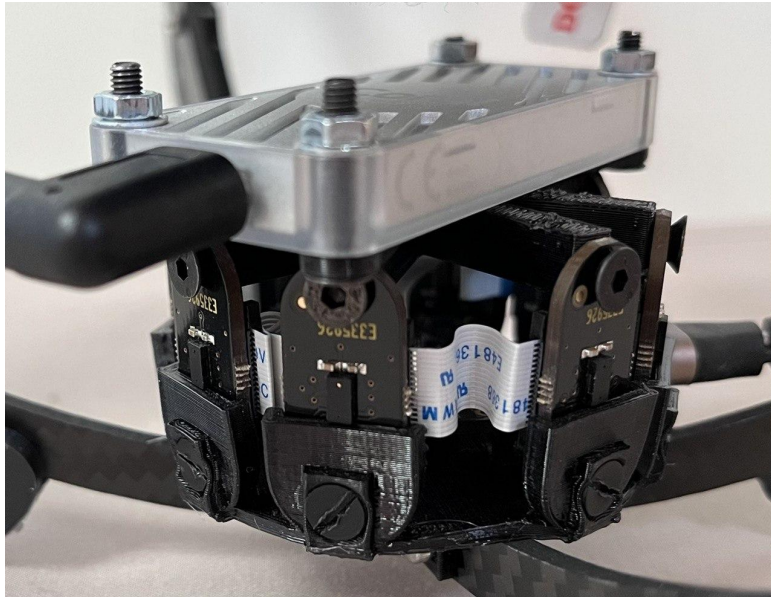
4S 120C LiPo:
16.8V – **15.1V** (14.4V)

It powers:

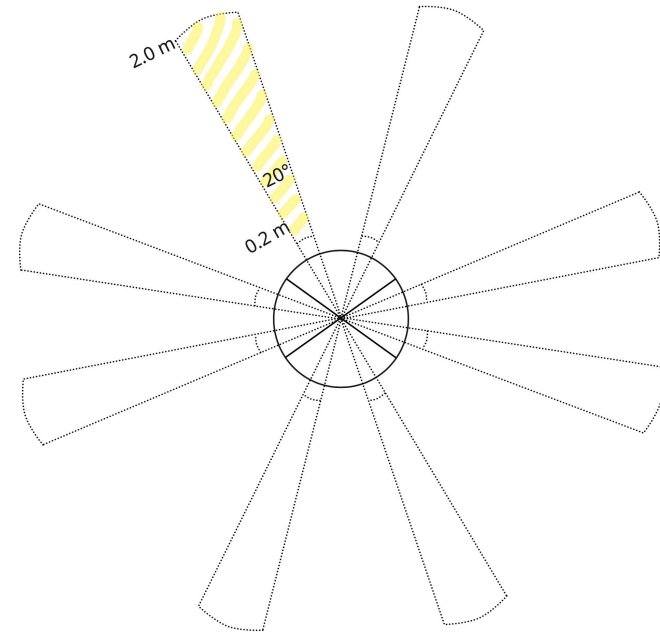
- flight controller
- motors
- companion computer
- sensors

Autonomous Flight: Approach

Range sensor tower



Obstacle avoidance

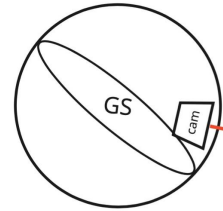


Autonomous Flight: Approach

Camera and optical-flow



Human target tracking



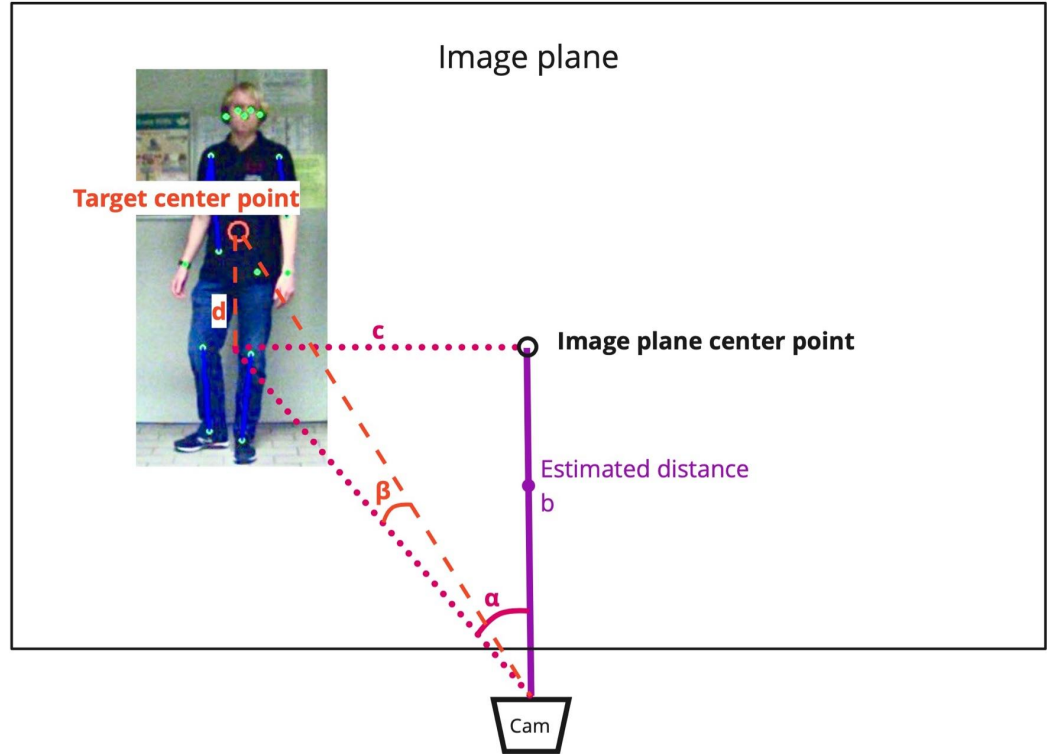
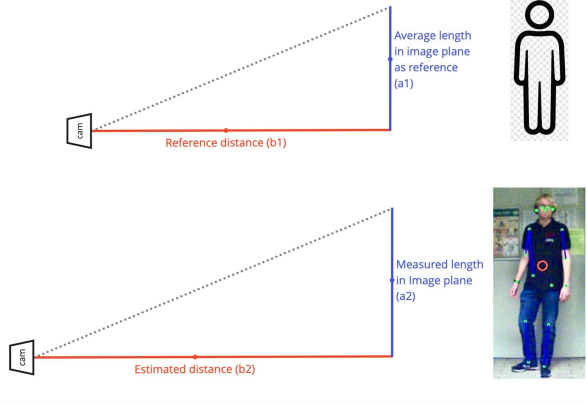
Estimated distance
towards target



Measured upper body
length in camera's
image plane

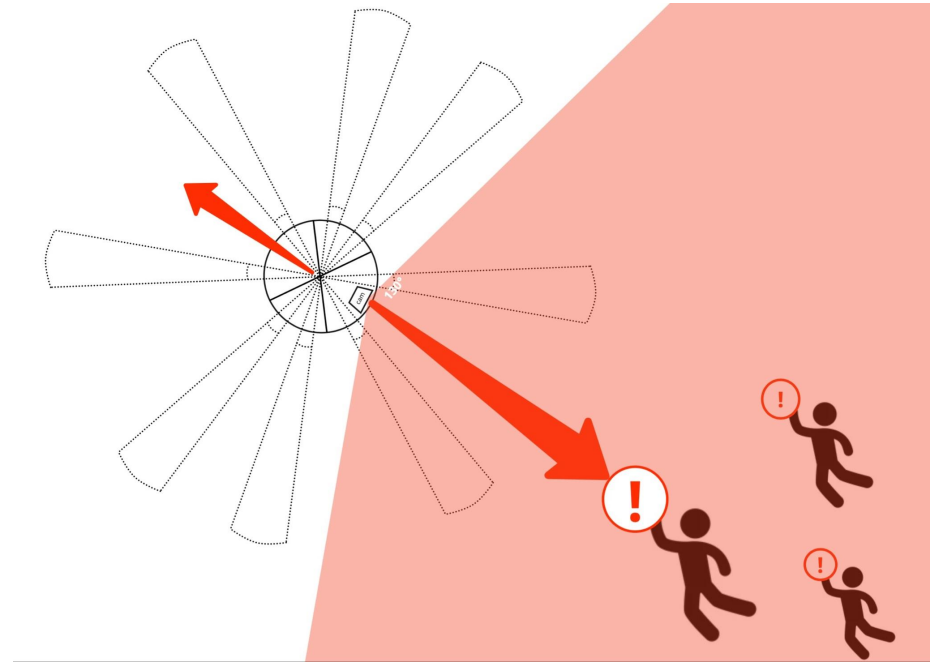
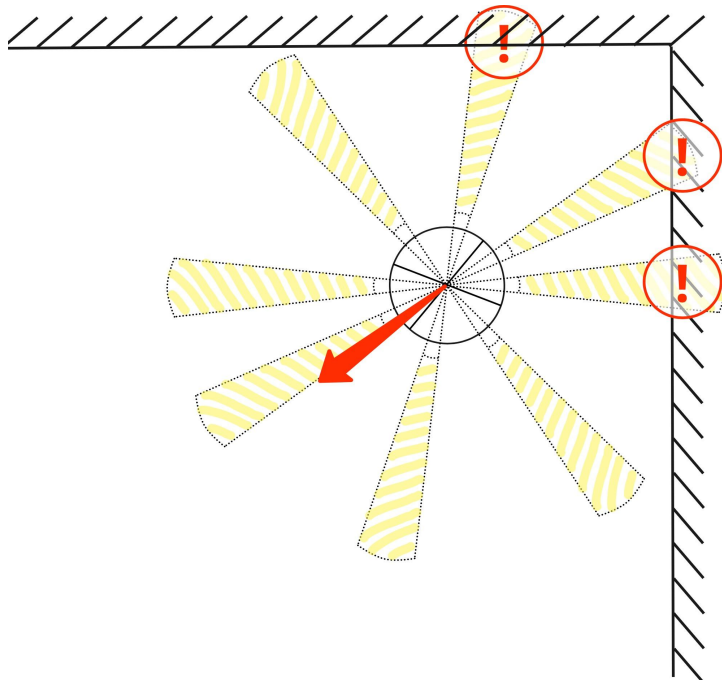
Autonomous Flight: Implementation

Target distance & direction estimation



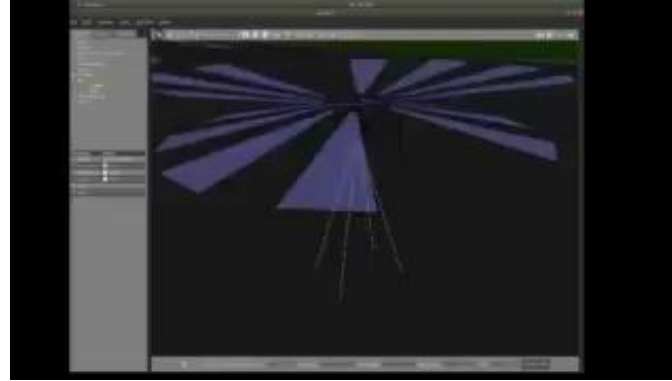
Autonomous Flight: Implementation

Decision making processes



Evaluation - Obstacle avoidance

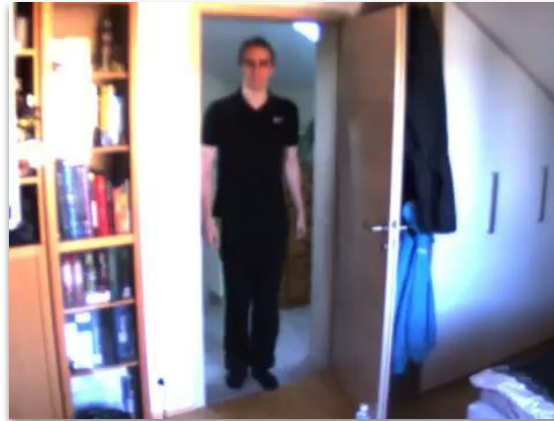
*tested as hold in hand
or while hovering



Reliably detected cases	Unreliably detected cases
<ul style="list-style-type: none">● White walls and corners● Wooden closet	<ul style="list-style-type: none">● Shelves● Windows● Black cloths

*tested in a static position

Evaluation - Target Detection



Reliably detected cases

- Static target
- Slow movement
- Front view

Unreliably detected cases

- Fast movement
- Truncated and occluded
- Side and back view

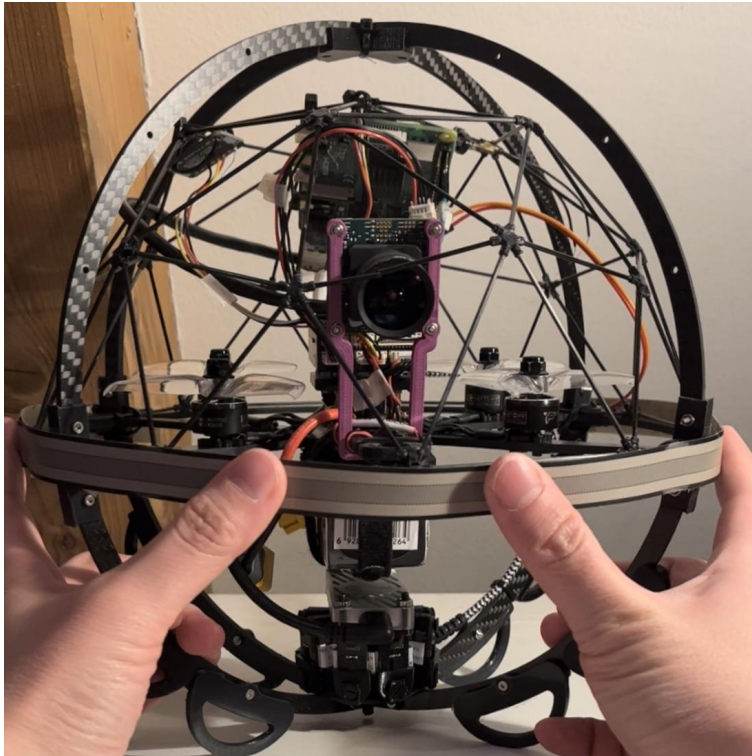


In-game Interaction

Autonomous Flight Setup

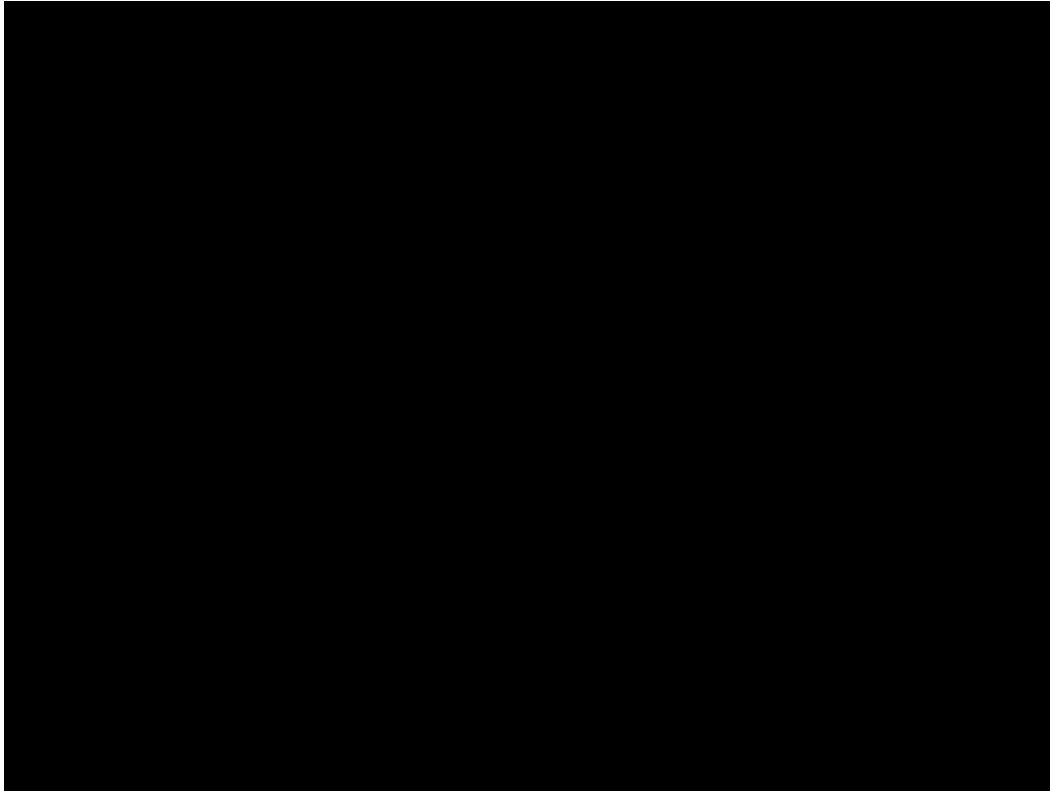


In-game Interaction: Touch Sensing



- Force Sensitive Resistor (FSR)
- Around drone's equator
- Issue: preloading through bending

In-game Interaction: Touch Sensing



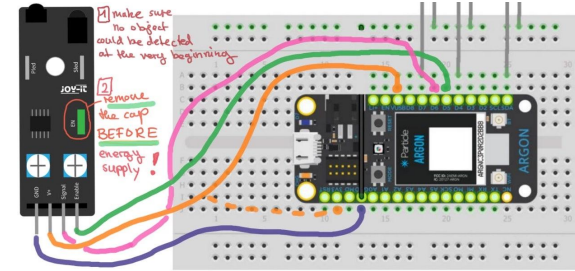
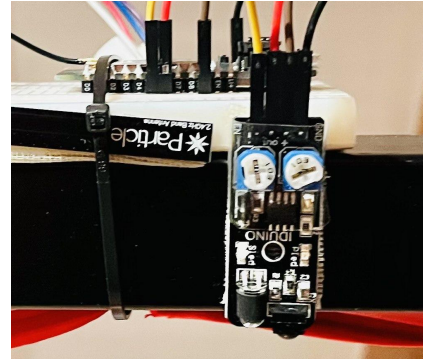
No pressure: counter 0

Touched / Being hold: counter ++

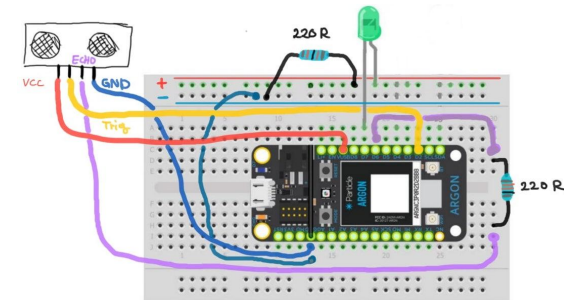
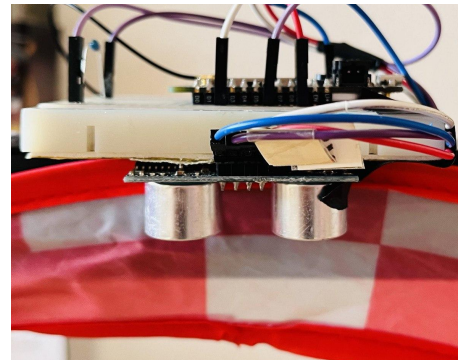
In-game Interaction: Goal Detection



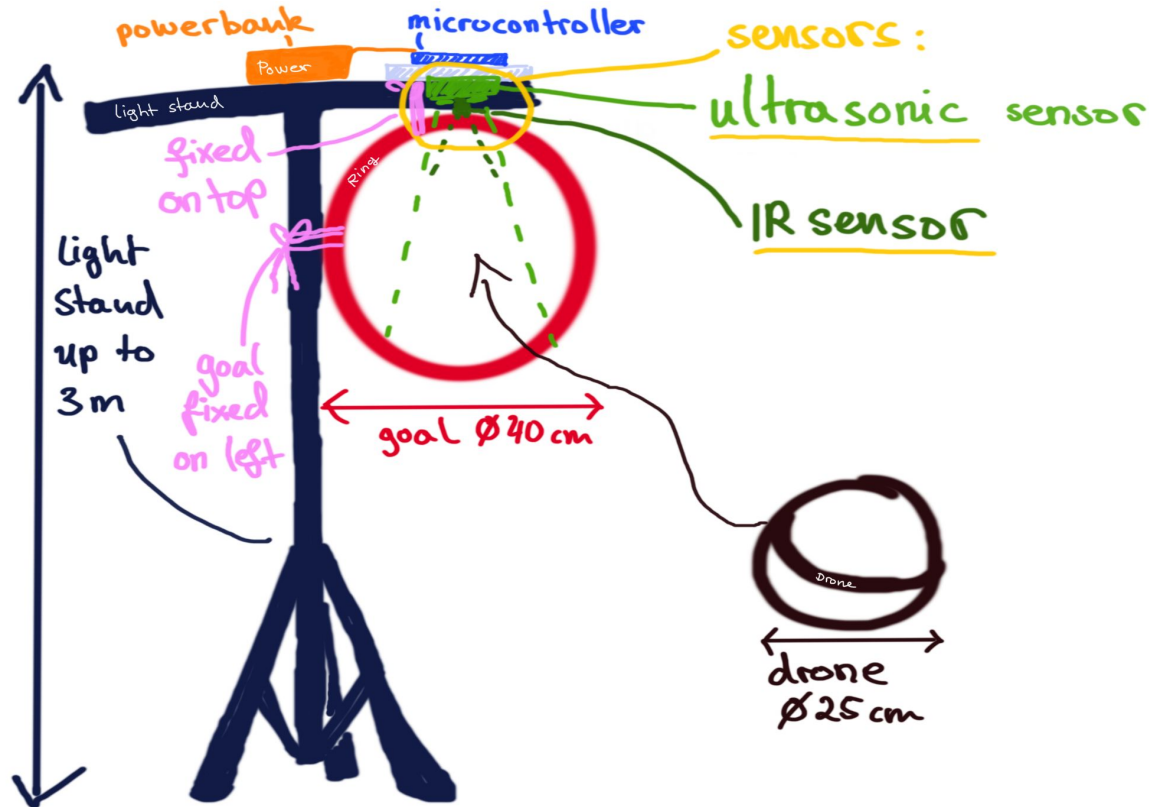
Infrared



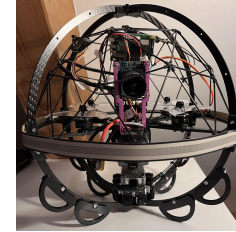
Ultrasonic



In-game Interaction: Goal Construction



Evaluation - Touch Sensing



Normal tests:

Light hold pressure	Hold pressure	Catch pressure
detected occasionally	detected reliably	detected reliably

False-positive tests:

Copter noise	Touch against wall	Touch against people
none	detected occasionally	barely detected

*flown by remote controller

In-game Interaction: Goal Demo

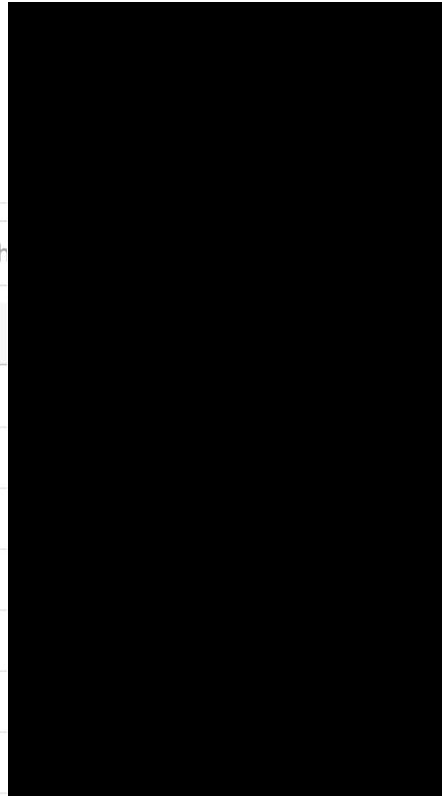
Particle

Sandbox ▾

Events

⏸ ⏪ ⏩ 🔍

NAME	DATA
GoalSensor	Clear
GoalSensor	Goal 3
GoalSensor	Clear
GoalSensor	Goal 2
GoalSensor	Clear
GoalSensor	Goal 1
particle/device/upd...	false

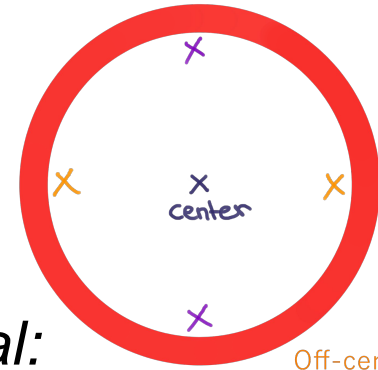


Evaluation - Goal Detection

Test conditions: Stabilize mode or held in one hand

Normal tests:

*Drone flies **through** the goal:*



Off-center horizontal
Off-center vertical

- **IR sensor:**

Centered	Off-center horizontally	Off-center vertically
Detected reliably	detected	detected

- **Ultrasonic sensor: (detection is slower)**

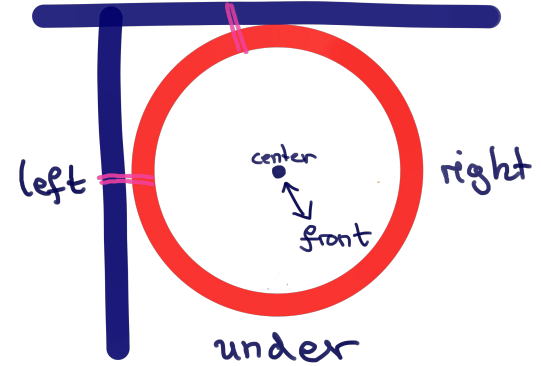
Centered	Off-center horizontally	Off-center vertically
Detected reliably	detected reliably	detected reliably



Evaluation - Goal Detection

False-positives:

*Drone flies **past** the goal:*



- IR sensor:



front	under	on the left	on the right
not detected	not detected	not detected	not detected

- Ultrasonic sensor:



front	under	on the left	on the right
detected X	not detected	not detected	not detected

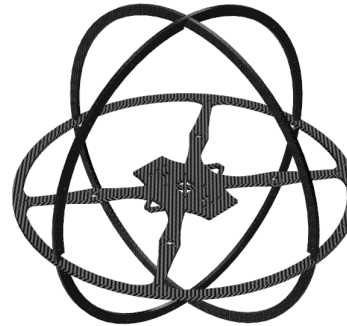
Suggested Future Work

To be finished:

- Embedded LEDs for drone tracking



old cage



new cage:
outer skeleton



new cage:
outer skeleton with inner cage

Suggested Future Work

To be finished:

- Goal: Net, stabilizer, space line
- Catch touch: find perfect timeout count or other solutions

Suggested Future Work

Can be optimized:

- Global space perception
 - Localization and mapping
- Noise reduction of sensor data
 - Parameter tuning, EKF, FFT

Conclusion

- About the drone: A robust open-source prototype.
- About trade-offs: We compromised a lot to gain better result.
- About debugging: We learned much about sensors.
- About the game: Looking forward to a playable AR superhuman sports game!

List of References

1. Christian Eichhorn, Adnane Jadid, David A. Plecher, Sandro Weber, Gudrun Klinker, and Yuta Itoh. Catching the drone – a tangible augmented reality game in superhuman sports, 2019.
2. Zwaan, Sergej & Barakova, Emilia. (2016). Boxing against drones: Drones in sports education. 607-612. 10.1145/2930674.2935991.
3. Joseph La Delfa, Mehmet Aydin Baytas, Rakesh Patibanda, Hazel Ngari, Rohit Ashok Khot, and Florian 'Floyd' Mueller. 2020. Drone Chi: Somaesthetic Human-Drone Interaction. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery, New York, NY, USA, 1–13. DOI:<https://doi.org/10.1145/3313831.3376786>
4. Pascal Knierim, Thomas Kosch, Valentin Schwind, Markus Funk, Francisco Kiss, Stefan Schneegass, and Niels Henze. 2017. Tactile Drones - Providing Immersive Tactile Feedback in Virtual Reality through Quadcopters. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (*CHI EA '17*). Association for Computing Machinery, New York, NY, USA, 433–436. DOI:<https://doi.org/10.1145/3027063.3050426>



~ Thank you for listening ~

Questions?