Buoyancé: Reeling Helium-Inflated Balloons with Swarm Robots on the Ground for Mid-Air Tangible Display, Interaction, and Assembly

AxLab
Actuated Experience Lab

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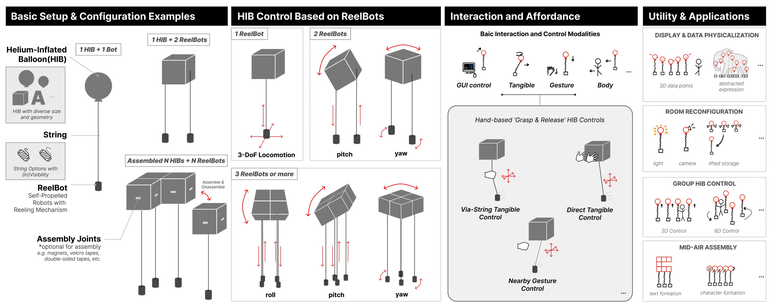
INTRODUCTION

Buoyancé: a novel approach to spatially actuated tangible UI by controlling helium-inflated balloons (HIBs) in mid-air using mobile reeling robots, named ReelBots.

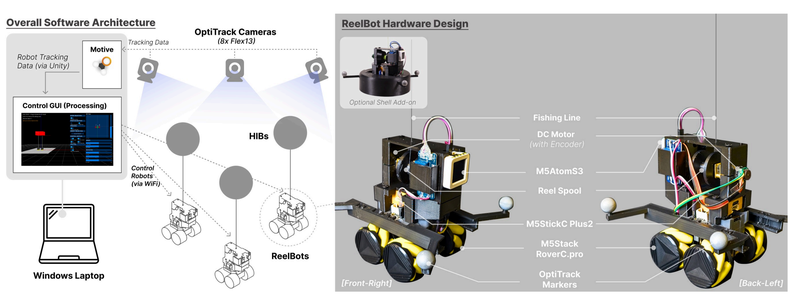
- Our proof-of-concept implementation was developed based on omnidirectional mobile robots and a motion tracking system to demonstrate the novel approach of enriching 3D physical space.
- Our control software is designed to manipulate multiple robots to control the position of HIBs in real time via multiple options ranging from GUI control and tangible and gesture based controls.
- Our system could be deployed in the future of physical environments, spanning across tangible information display, room reconfiguration, group HIB control, and mid-air assembly.



OVERALL SYSTEM SETUP

The overall system consists of ReelBots, HIBs, an optical tracking system (OptiTrack), and a computer to control the system.

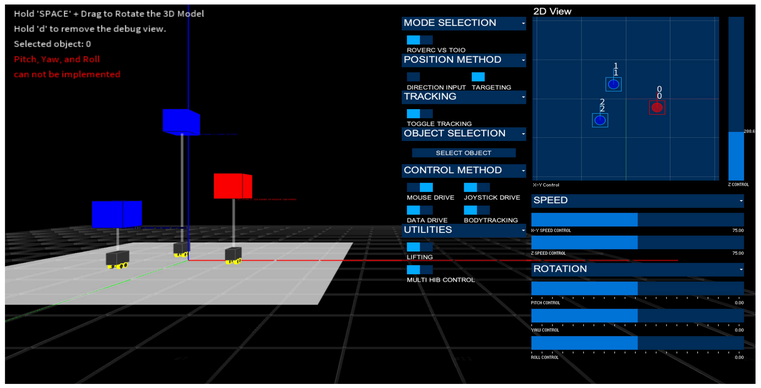
- ReelBots are controlled wirelessly via Wi-Fi using the GUI, which manages their lateral movement and the vertical position of HIBs.
- OptiTrack (8 cameras) tracks positions and sends the data through Motive software to Unity via OSC.
- Unity processes this data and sends it back to the Processing GUI, enabling closed-loop control and centralized coordination of all robots.



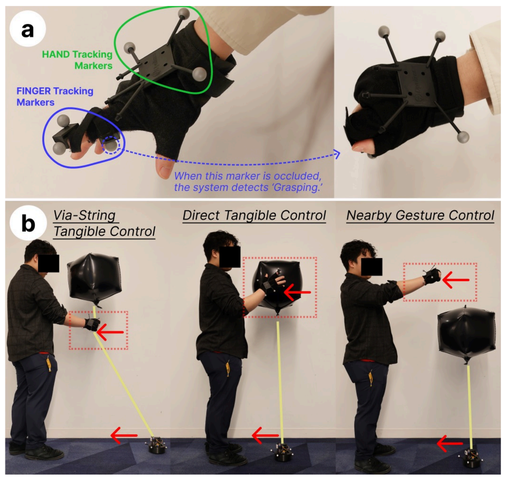
SOFTWARE IMPLEMENTATION

GUI: enable users to flexibly manage the XY movements of ReelBots and the Z-height adjustments of HIBs under various conditions.

Different Control Methods based on GUI: mouse control, joystick controller mode, data input control, hand and body based control.

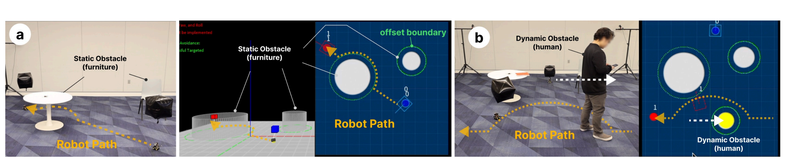


Specifically, for body control, one method we explored is **Hand-based 'Grasp & Release' HIB Controls**.



1. Via-String Tangible control (grasp and drag the string to direct the robot and HIB)
2. Direct Tangible control (directly hold and reposition the HIB)
3. Nearby Gesture control (gesture-based manipulation)

Optional Collision Avoidance Functionality: to mitigate the potential collision risks of on-ground robots with environmental objects and people, we also implemented an optional collision avoidance functionality that is further integrated into our GUI and control system.



TECHNICAL EVALUATION

Robot Control Capability

- The assembly of 2 cubic HIBs provided a buoyant force capable of lifting 11 grams, the lone A-shaped HIB 10 grams, and the assembly of 2 spherical HIBs 10 grams as well.
- With the 24-inch cubic Mylar HIB, it was able to travel around 114.62 meters.
- The speed of the rover is about one-third the speed of the average human walking speed of 1.2-1.4 meters per second.

Reeling Motor

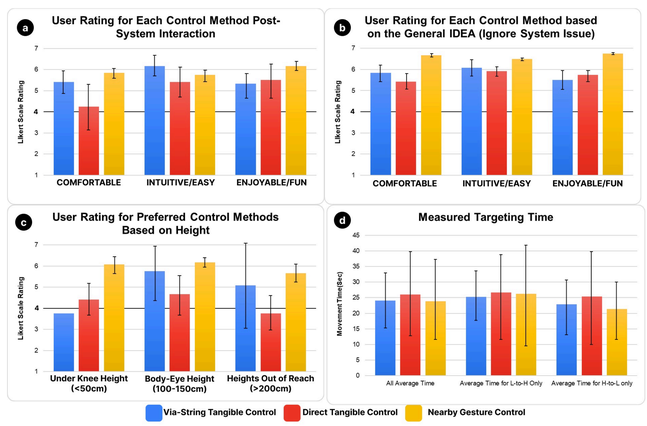
- We found that the 30:1 gear ratio satisfied most of our desires, providing a speed compatible with the HIB and strong enough to lift the ReelBot into the air for docking and storage.

	HIB Reeling Speed		*Lifting Capabilities*		
	Reel Up Speed (cm/s)	Reel Down Speed (cm/s)	Lift Body Speed (cm/s)	Lifting Weight [motor active] (g)	Lifting Weight [motor off] (g)
30:1 Motor	57.28	52.99	46.93	170	N/A (can't hold its own weight)
210:1 Motor	7.55	7.58	8.2	400	230

USER STUDY

We conducted a user study to compare the three hand-based HIB control methods. Tasks were based on a series of spatial targeting tasks to bring the HIB to a designated 3D target in space.

Participants: we recruited 12 participants from UChicago (ages 20–52 [average of 25.75], 7 females and 5 males).



a - c: participant's rating for the 7-point Likert scale questions.
d: the average measured targeting time for each control, based on raising [Low-to-High], or lowering [High-to-Low].

ACKNOWLEDGMENTS

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