Affective Wings: Exploring Affectionate Behaviors in Close-Proximity Interactions with Soft Floating Robots

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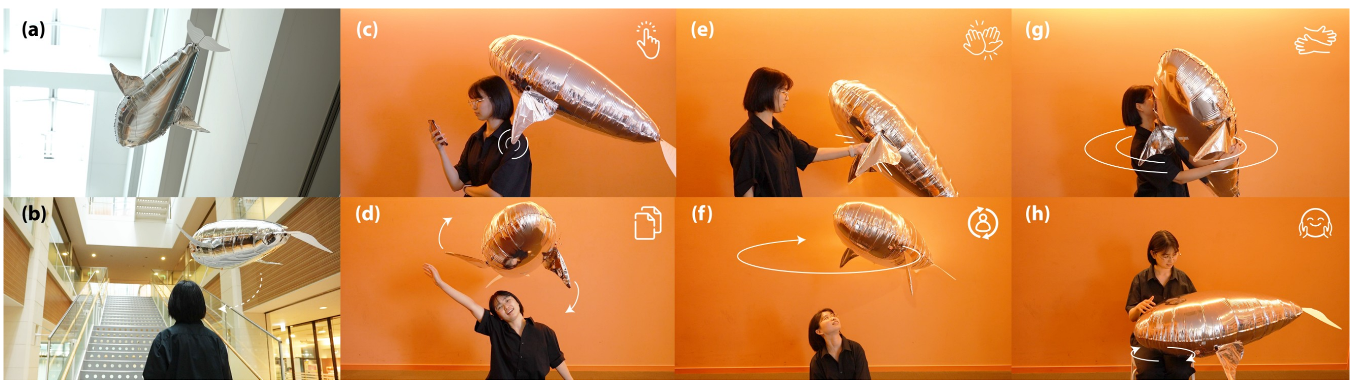

Figure 1: Affective Wings: (a) A soft floating robot flies mid-air in an indoor environment, moving gracefully like a whale swimming through a sea of air. (b) The robot moves across different terrains and follows people upstairs. The robot can interact closely with people through various behaviors, including (c) tapping a person's shoulder to gain attention, (d) mimicking a person's movements, (e) giving high-fives, (f) circling above a person's head, (g) hugging, and (h) perching on a person's legs.

Abstract

This study presents "Affective Wings," a concept involving a soft floating robot designed to enable proximal interactions and direct physical contact with humans to support emotional connection in an indoor environment. Leveraging the capabilities of lighter-than-air robots combined with a controllable wing mechanism, we provide a novel approach to human-robot interaction prioritizing safety and rich dynamic movements. The robot, designed to fly freely within human living spaces, can engage in both physical contact and non-physical contact behaviors, such as hugging, tapping, perching, mimicking, and waving.

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CCS Concepts

• **Human-centered computing** → *Interaction techniques.*

Keywords

Affectionate behavior, Positive affection, Close-proximity interaction, Soft floating robot, Flapping-wing robot

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1 Introduction

Affectionate interaction between humans and robots can foster emotional connections and enhance user experiences [Cooney et al. 2014]. Integrating emotions into robots has been extensively studied, particularly in the context of companion robots [Hsieh and Cross 2022]. Most existing research on affectionate human-robot interactions has focused on ground-based robots. However, ground robots have limitations in terms of mobility and interaction space. In contrast, flying robots offer enhanced mobility and the ability to interact in three-dimensional space [Herdel et al. 2021]. Despite these benefits, there has been limited research on affectionate flying robots, with most studies focusing on multi-rotor drones. These are often unsuitable for indoor environments because of concerns around safety, noise, and limited flight duration [Yamada et al. 2019]. Particularly, fast-spinning blades can potentially cause injuries. In contrast, soft materials can support safe interaction, and be used to create hardware that is harmless to humans.

Lighter-than-air flapping-wing floating robots [Festo 2007] presents a promising alternative. These robots are inflatable and quiet, thus more suitable for indoor environments. Moreover, their flexible and dynamic movement capabilities provide a foundation for designing rich and varied affectionate exchanges. Our contribution encompasses the design of a soft floating robot able to perform a series of affectionate gestures through direct physical contact with humans and flight behavior.

2 Design and Implementation

2.1 Soft Floating Robot

Inspired by marine creatures such as manta rays, sea turtles, and whales, which use low-frequency pectoral fin flapping to assist their movement, this study presents a soft floating robot. The robot can "swim" freely in mid-air within human living spaces, utilizing helium for buoyancy and flapping wings for propulsion, without the use of blades. We fabricated the soft envelope and wings using aluminum-metallized film. The robot is propelled by two wings, each driven by a servo motor and connected by a carbon fibre rod. The wings are actuated in an up-and-down rotational motion, mimicking the natural movement of marine animals. The wings are designed to achieve a flapping frequency within the range of 0.3 to 1 Hz, providing thrust for flight while maintaining a natural and gentle movement pattern. The robot is remotely controlled by a handheld device operating on the 2.4 GHz band radio waves.

2.2 Affectionate Behaviors

The three-dimensional and dynamic movement capabilities of the floating robot provide a basis for designing rich affectionate human-robot interactions. We focused on social behaviors to achieve natural exchanges, allowing users to develop emotional connections with the robot. To convey affection from the robot to humans, we select behavioral capabilities based on existing research, including companion robot [Yoshida et al. 2022], affective touch [Guo et al. 2023], and emotional expression in drones [Cauchard et al. 2016]. We proposed and implemented physical contact and non-physical contact affectionate gestures for the soft floating robot, as shown in Table 1. Physical contact behaviors involve direct interaction with the robot's body or wings, while non-physical contact behaviors are expressed through gestures and movements without touch.

Table 1: Behaviors for close-proximity interaction

Behaviors	Descriptions
Physical contact	
Hug	the robot pitches between 60° and 90° to achieve an upright position, then uses its flapping wings to gently press against and hold the sides of someone.
Perch	the robot lands and stops on someone's upper legs while they are sitting.
Tap	the robot uses its head or one wing to touch someone's shoulder with a quick, light blow or blows.
High-five	the robot pitches between 60° and 90° to achieve an upright position, then uses one wing to flap and strike someone's hand with quick, light blows.
Non-physical contact	
Mimic	the robot uses two wings to imitate and follow the movements of someone's arms.
Follow	the robot stays behind and close to someone, following their path.
Circle	the robot flies in circles around someone by controlling the differential flapping of the two wings to create a circular flight pattern.
Wave	the robot pitches 90° to make its body perpendicular to the ground, then flaps one wing.

3 Discussion and Future Work

This study proposes social behaviors for soft floating robots to safely realize affectionate interactions with humans. We believe that soft floating robots have the potential to support affectionate close-proximity interactions through carefully designed social behaviors. In this study, the robot is piloted by an operator through remote control. Future work will focus on developing autonomous systems for more intelligent interactions. Additionally, we plan to carry out user studies to evaluate different behaviors and their impact on a broader audience.

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References

Jessica R Cauchard, Kevin Y Zhai, Marco Spadafora, and James A Landay. 2016. Emotion encoding in human-drone interaction. In *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 263–270.

Martin Cooney, Shuichi Nishio, and Hiroshi Ishiguro. 2014. Affectionate interaction with a small humanoid robot capable of recognizing social touch behavior. *ACM Transactions on Interactive Intelligent Systems (TiiS)* 4, 4 (2014), 1–32.

Festo. 2007. Air_ray. Retrieved August 3, 2024 from https://www.festo.com/us/en/e/about-festo/research-and-development/bionic-learning-network/highlights-from-2006-to-2009/air-ray-id_33851/

Shihui Guo, Lishuang Zhan, Yancheng Cao, Chen Zheng, Guyue Zhou, and Jiangtao Gong. 2023. Touch-and-Heal: Data-driven Affective Computing in Tactile Interaction with Robotic Dog. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 7, 2 (2023), 1–33.

Viviane Herdel, Anastasia Kuzminykh, Andrea Hildebrandt, and Jessica R Cauchard. 2021. Drone in love: Emotional perception of facial expressions on flying robots. In *Proceedings of the 2021 CHI conference on human factors in computing systems*. 1–20.

Te-Yi Hsieh and Emily S Cross. 2022. The role of empathic traits in emotion recognition and emotion contagion of cozmo robots. In *2022 17th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*. IEEE, 802–806.

Wataru Yamada, Hiroyuki Manabe, and Daizo Ikeda. 2019. Zerone: Safety drone with blade-free propulsion. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–8.

Naoto Yoshida, Shuto Yonemura, Masahiro Emoto, Kanji Kawai, Naoki Numaguchi, Hiroki Nakazato, Shunsuke Otsubo, Megumi Takada, and Kaname Hayashi. 2022. Production of character animation in a home robot: A case study of lovot. *International Journal of Social Robotics* 14, 1 (2022), 39–54.