SwarmFidget: Exploring Programmable Actuated Fidgeting with Swarm Robots

Samira Pulatova, Jiadi Luo, JangHyeon Lee
Simon Fraser University
Burnaby, British Columbia, Canada
{samira_pulatova,jiadi_luo,jla465}@sfu.ca

Veronika Domova, Yuqi Yao
Stanford University
Stanford, California, USA
vdomova@stanford.edu,
yuqiyao2@gmail.com

Parsa Rajabi, Lawrence H. Kim
Simon Fraser University
Burnaby, British Columbia, Canada
{parsa_r,lawkim}@sfu.ca

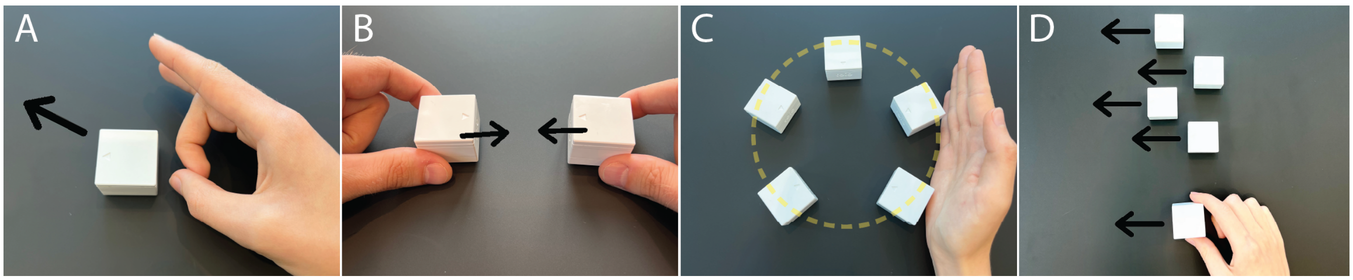

Figure 1: Example Fidgeting Interactions: A) *Flicking* where the robot returns after being flicked or displaced, B) *Magnet* where robots are either attracted to or repelled from one another, C) *Circle* where the robots form a shape and return to the shape when disturbed, and D) *Remote Control* where moving the robot on the bottom moves other robots correspondingly.

ABSTRACT

Fidgeting is a common behavior that one tends to engage in during periods of inattention or mind wandering. Although attempts were undertaken to enhance fidget devices with advanced technology, such as sensors and displays, no works exist that explored fidgeting with actuated devices. To fill this gap, we introduce the concept of programmable actuated fidgeting and the design space for SwarmFidget. Programmable actuated fidgeting is a type of fidgeting that involves devices integrated with actuators, sensors, and computing to enable a dynamic and customizable interactive fidgeting experience. SwarmFidget is an instance of a platform where tabletop swarm robots are used to facilitate programmable actuated fidgeting. To engage with actuated fidgets, users can input commands through various modalities such as touch or gesture, and the actuators in the fidgeting device will respond in a programmable manner to provide haptic, visual, or audio feedback.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**; *Collaborative interaction.*

KEYWORDS

fidgeting, swarm robots, tangible user interface

UIST '23, October 29-November 1, 2023, San Francisco, CA, USA

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/nnnnnnn.nnnnnnn

ACM Reference Format:
Samira Pulatova, Jiadi Luo, JangHyeon Lee, Veronika Domova, Yuqi Yao, and Parsa Rajabi, Lawrence H. Kim. 2023. SwarmFidget: Exploring Programmable Actuated Fidgeting with Swarm Robots. In *The 36th Annual ACM Symposium on User Interface Software and Technology (UIST '23), October 29-November 1, 2023, San Francisco, CA, USA.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/nnnnnnn.nnnnnnn

1 INTRODUCTION

During periods of what is perceived to be inattention or mind wandering, people commonly engage in fidgeting [4]. Fidgeting is a non-goal-directed activity, which is usually repetitive or patterned and is typically initiated subconsciously. A growing body of studies reports a variety of beneficial effects caused by fidgeting. In particular, authors advocate that fidgeting can assist in sustaining focus and optimizing attention [2, 7], reducing stress [16], increasing playfulness and creativity [15]. Moreover, fidgeting can act as a means of exercising [12] and improving motor skills [5], as a mechanism to trace depression [17], and as a tool to track mental states [18]. People often gravitate towards fidgeting with surrounding multi-purpose objects (e.g., pens, keys, fidget toys, etc.). However, we envision that people may fidget with the robots that surround them as autonomous robots become more common in our daily lives due to advances in technology and the exponential growth of artificial intelligence.

For this project, we focus on tabletop swarm robots - robots resting on the top of the desk while people engage with knowledge work at that desk. The fact that both grown-ups and kids tend to fidget with surrounding objects (e.g., pens, clippers, erasers) while performing knowledge work [6, 7] makes us believe that people might fidget with co-present tabletop robots.

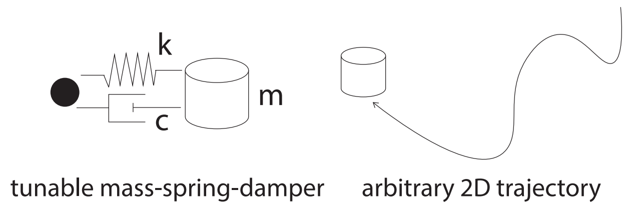

Figure 2: Programmable Behavior is one of the primary features of programmable actuated fidgeting. In the context of SwarmFidget, as shown on the left, we show that a robot can be programmed to behave as if it was connected to a point via virtual spring and dampener where the mass (m), spring constant (l), and damping coefficient (c) are allprogrammable. As shown on the right, robots could also move in any arbitrary 2D trajectory.

Swarm robots are autonomous robots with sensing and communication capabilities that can act on tasks collaboratively. Swarm robots exist in a variety of designs and implementations [3]. Tabletop swarm robots are small wheel-propelled robots with position and touch-sensing capabilities capable of acting as a display, initiating actions, and reacting to the user's input. Several projects highlight that fidgeting preferences are very personal and propose customized or adjustable fidgeting artifacts. The utilization of tabletop swarm robots for fidgeting will provide a customizable, more engaging and interactive fidgeting experience due to the programmability of their collective movement and dynamic physicality. Swarm robots also offer additional advantages, such as swarm intelligence, flexibility, and robustness to failure.

2 DESIGN SPACE OF SWARMFIDGET

Through rapid ideation sessions, we explored the unique design space and affordances of fidgeting with swarm robots compared to commercial fidgeting devices like fidget spinners. As we used the definition of fidgeting from Carriere et al. [4], repetitive non-goal-directed action, any ideas that involved an explicit purpose or goal (e.g., any game-like interaction), or were non-repetitive (i.e., one-time action) were discarded. For the complete design space, refer to the full paper [8].

2.1 Programmable Behavior

Conventional fidgeting tools are limited in their behavior, as they rely on passive mechanical components such as springs. In contrast, swarm robot-based fidgeting allows for programmable behaviors not limited by the passive mechanical components. For example, a robot can be programmed to behave as if it were connected to a specific point by a spring, and when displaced from the equilibrium point, it will return to equilibrium as shown in Figure 2. The spring constant of this virtual spring can also be fixed or variable depending on the situation.

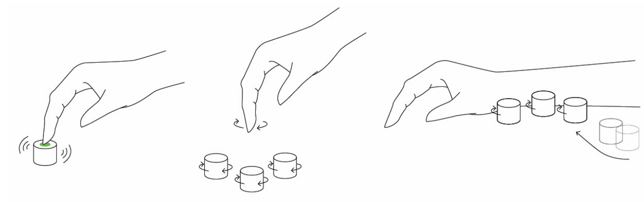

Figure 3: SwarmFidget allows fidgeting through different modalities including touch, gesture, color, and visual motion

2.2 Interaction Modality

The design space of SwarmFidget offers a range of modalities for both user input and robot feedback [8], as shown in Figure 3, extending its potential use scenarios and catering to users' different preferences and needs. Users can choose to interact with the robots directly through touch or indirectly through gestures with their hand or other body parts similar to prior work [1, 9, 11]. In terms of robot feedback, the modality options include active or passive haptic feedback, meaning that the robots can initiate the interaction or the person can start it themselves. Additionally, visual feedback can be conveyed through the use of colors and motion of the robots as used in prior work [1, 10]. Audio feedback can be provided both intentionally through external speakers and unintentionally through the sounds of the motors as discussed in [14].

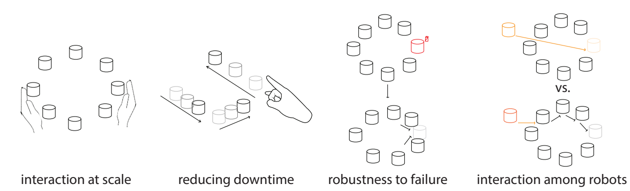

Figure 4: Leveraging Swarmness: having a swarm of robots enable interaction not possible with a robot alone such as interaction at scale, reducing downtime, robustness to failure, and interaction among robots.

2.3 Leveraging Swarmness

Having a swarm of robots dramatically increases the scale of interaction from a simple dyadic interaction making it more interesting or stimulating to fidget. Instead of being limited to just interaction with one robot, users can interact with multiple robots as shown in Figure 4. The robots will have the capacity to form complicated shapes as shown in Figure 4, or patterns that could be dynamic, meaning that the robots are not only forming different shapes but are also constantly moving while maintaining shape. In addition to interaction with users, interaction among robots is a design parameter that can be leveraged for fidgeting. Furthermore, the swarm can also reduce any downtimes that may be experienced when interacting with just one robot, allowing users to fidget at a faster pace as shown in Figure 4. Another commonly known benefit of having a swarm of robots is its robustness. When a robot fails (e.g., due to low battery, broken wheels, etc.), the redundancy of

Figure 5: Robots are able to be *proactive* and initiate fidgeting interactions when needed such as when users are under stress

the system allows the remaining robots to adapt and replace the vacancy of the failed robot.

2.4 Interaction Metaphors

Ideas for different ways robots can be used for fidgeting were derived from familiar metaphors such as physics, existing toys or fidgeting devices. As mentioned earlier, the robots can be programmed to behave as if they were a physical system. For example, magnetism where each robot could have a virtual polarity and be attracted or repelled to one another as described in the "Magnet" example fidgeting interaction and shown in Figure 1B.

2.5 React vs. Proact

Interacting with conventional fidgeting devices involves individuals performing an action on the device and receiving feedback in the form of haptic and/or aural responses. Unlike these traditional fidgeting devices, robots can be both reactive and proactive. In situations where a person is feeling stressed or bored and could benefit from a fidgeting break, robots can initiate the interaction instead of waiting for the person to initiate it.

3 DEMONSTRATION APPLICATIONS

Drawing from the design space of SwarmFidget, we programmed six demonstration applications using the small desktop robots (Zooids [13] and Sony Toio Robots [1]) as shown in Figure 1. The position of each Toio robot can be tracked by the system using a tracking mat with printed patterns. Each robot has dimensions of 3.2cm x 3.2cm x 2.5cm and can move up to a speed of 24cm/sec. The tracking mat, which covers an area of 30cm x 42cm on top of the table, is capable of tracking the position with an error margin of 1mm. Due to the portability of the Sony Toio platform, Toio is used for most applications except for the "tap & rotate", which is implemented using the Zooids platform without the projector for localization.

3.1 Flicking

The flicking interaction requires users to physically disturb the robot, such as by flicking or pushing it, in order to move it out of its position as shown in Figure 1A. and the robot moves back to its original position.

[1]https://www.sony.com/en/SonyInfo/design/stories/toio/

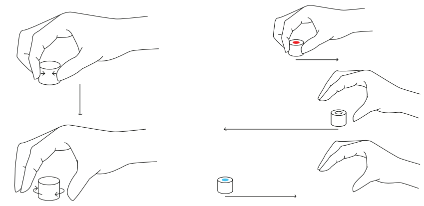

Figure 6: Left: Tap & Rotate interaction where the robot will rotate after being grabbed by the user. Right: Spring-loaded car interaction where the robot will propel forward after being pulled back similar to a spring-loaded car toy.

3.2 Tap & Rotate

The tap & rotate interaction requires the user to grab the robot and release it, causing the robot to rotate, as shown in Figure 6.

3.3 Spring-loaded Car

The spring-loaded car interaction is akin to the action of a pull-back toy car, where a user grabs and pulls the car to wind up the torsion spring. Upon release, the toy car will move forward, utilizing the energy stored in the torsion spring as shown in Figure 6.

3.4 Magnet

The magnet interaction is based on magnetism. As shown in Figure 1B, robots with opposite programmed polarity will be attracted to each other once they are within a threshold, while those with the same programmed polarity will be repelled from one another.

3.5 Circle

The circle interaction is similar to the flicking interaction in that the robots are programmed to stay in a specified position as shown in Figure 1C. In addition to properties relevant to the flicking interaction, we can modify additional properties for this interaction, such as the size and shape of the formation as well as the interaction among the robots. For instance, the robots can either return to a specific position every time or return to a position that optimizes the distance traveled by all robots.

3.6 Remote Control

The remote control interaction, like the circle interaction, also involves multiple robots. As shown in Figure 1D, the user controls the robots indirectly by manipulating a single robot designated as the control knob.

4 CONCLUSION

We introduced *programmable actuated fidgeting*, a new type of fidgeting that involves devices integrated with actuators, sensors, and computing to enable a customizable interactive fidgeting experience. In particular, we described and explored the use of tabletop swarm robots to enable programmable actuated fidgeting. We illustrated the design space of *SwarmFidget* and presented several demonstration applications with the robots highlighting the potential of SwarmFidget for facilitating fidgeting.

REFERENCES

[1] Javier Alonso-Mora, S Haegeli Lohaus, Philipp Leemann, Roland Siegwart, and Paul Beardsley. 2015. Gesture based human-multi-robot swarm interaction and its application to an interactive display. In *Robotics and Automation (ICRA), 2015 IEEE International Conference on*. IEEE, 5948–5953.

[2] Jackie Andrade. 2010. What does doodling do? *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition* 24, 1 (2010), 100–106.

[3] Manuele Brambilla, Eliseo Ferrante, Mauro Birattari, and Marco Dorigo. 2013. Swarm robotics: a review from the swarm engineering perspective. *Swarm Intelligence* 7 (2013), 1–41.

[4] Jonathan SA Carriere, Paul Seli, and Daniel Smilek. 2013. Wandering in both mind and body: individual differences in mind wandering and inattention predict fidgeting. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale* 67, 1 (2013), 19.

[5] Erez James Cohen, Riccardo Bravi, and Diego Minciacchi. 2018. The effect of fidget spinners on fine motor control. *Scientific Reports* 8, 1 (2018), 3144.

[6] Suzanne B da Câmara, Rakshit Agrawal, and Katherine Isbister. 2018. Identifying Children's Fidget Object Preferences: Toward Exploring the Impacts of Fidgeting and Fidget-Friendly Tangibles. In *Proceedings of the 2018 Designing Interactive Systems Conference*. 301–311.

[7] Michael Karlesky and Katherine Isbister. 2016. Understanding fidget widgets: Exploring the design space of embodied self-regulation. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*. 1–10.

[8] Lawrence H Kim, Veronika Domova, Yuqi Yao, and Parsa Rajabi. 2023. SwarmFidget: Exploring Programmable Actuated Fidgeting with Swarm Robots. In *The 36th Annual ACM Symposium on User Interface Software and Technology (UIST '23)*. ACM.

[9] Lawrence H Kim, Daniel S Drew, Veronika Domova, and Sean Follmer. 2020. User-defined swarm robot control. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.

[10] Lawrence H Kim and Sean Follmer. 2017. UbiSwarm: Ubiquitous Robotic Interfaces and Investigation of Abstract Motion as a Display. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 1, 3 (2017), 66.

[11] Lawrence H Kim and Sean Follmer. 2019. Swarmhaptics: Haptic display with swarm robots. In *Proceedings of the 2019 CHI conference on human factors in computing systems*. 1–13.

[12] Gabriel A Koepp, Graham K Moore, and James A Levine. 2016. Chair-based fidgeting and energy expenditure. *BMJ open sport & exercise medicine* 2, 1 (2016), e000152.

[13] Mathieu Le Goc, Lawrence H Kim, Ali Parsaei, Jean-Daniel Fekete, Pierre Dragicevic, and Sean Follmer. 2016. Zooids: Building blocks for swarm user interfaces. In *Proceedings of the 29th annual symposium on user interface software and technology*. 97–109.

[14] Dylan Moore, Hamish Tennent, Nikolas Martelaro, and Wendy Ju. 2017. Making noise intentional: A study of servo sound perception. In *Proceedings of the 2017 ACM/IEEE international conference on human-robot interaction*. 12–21.

[15] Rebecka Nyqvist. 2016. Fidgeting for creativity. (2016).

[16] Kelsey Perrykkad and Jakob Hohwy. 2020. Fidgeting as self-evidencing: A predictive processing account of non-goal-directed action. *New Ideas in Psychology* 56 (2020), 100750.

[17] Katharina CH Reinecke, Daniela Dvoretska, Peter Joraschky, and Hedda Lausberg. 2020. Fidgeting behavior during psychotherapy: Hand movement structure contains information about depressive symptoms. *Journal of Contemporary Psychotherapy* 50, 4 (2020), 323–329.

[18] Kieran Woodward and Eiman Kanjo. 2020. iFidgetCube: Tangible Fidgeting Interfaces (TFIs) to Monitor and Improve Mental Wellbeing. *IEEE Sensors Journal* 21, 13 (2020), 14300–14307.