Learning Experience to Improve on the Finch

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***Abstract*—Finch is a small, inexpensive robot used to aid students in learning programming languages at schools of all levels including universities. However, proposals for an integrated system surrounding the Finch and studies to improve the forward movement of the Finch have not been reported in literature. This paper proposes a wireless Finch with an attached camera through mounting a Raspberry Pi and battery on the Finch's back using a unique 3D-printed cover. Furthermore, the research introduces a GUI to control Finch movements and a support wheel at the Finch's back to stabilize the Finch's performance and increase its speed. Experiments have shown that with the back wheel and wireless connection, the Finch can move forward faster and more in a straight line and rotate in a circle faster. This research will impact the application and education design areas. The experience gained could be applied in product design and fabrication, program design, GUI design and implementation and wireless network component set-up. In education design, the scaffolding technique can be employed to create a series of practical exercises for students to gain design, software implementation, and networking knowledge.**

***Index Terms*—finch, wireless, back wheel, GUI, application, education design**

I. Introduction

The Finch robot [1] is especially designed for computer science education. The robot is designed to support over a dozen programming languages and provide students with interactive learning programs. It has built-in accelerometers and sensors such as light sensor, temperature sensor and obstacle sensors. The robot is able to produce sound and light from its beak. Research using the Finch robot in teaching is reported in [2]-[7]. Nevertheless, proposals for an integrated system using the Finch as a central component and explorations for improving the Finch's movement have not been reported in literature.

Currently, the Finch is sold with a wired connection to a personal computer. The USB cable can be easily tangled when the robot turns in a circle. The tail end of the Finch is in contact with the floor and this decreases the speed of the Finch because of friction. As for the holder of wireless Finch devices, there is no unique product which carries the logo of our university, Singapore University of Technology and Design (SUTD).

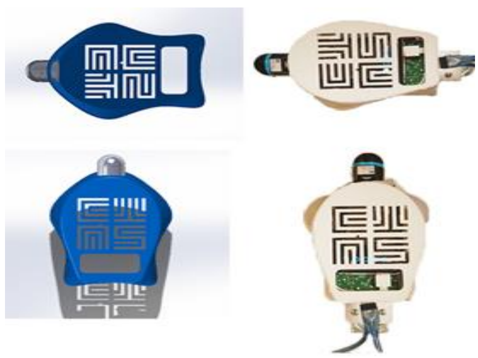

Figure 1. Cover design

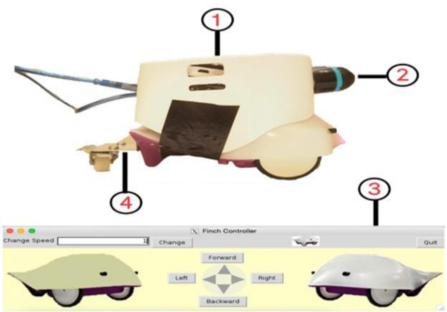

Figure 2. Integrated finch

In this paper, we will be sharing our learning experience in making the Finch move faster, designing a

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holder with the SUTD logo (Fig. 1) for the wireless devices, and implementation of a wireless Finch with a mounted camera and a graphical user interface to control Finch movement (Fig. 2).

The rest of the paper is organized as follows. Section 2 presents the high level architecture of the system. Section 3 briefly describes the design of the cover, GUI panel and support wheel. Section 4 discusses the results of the investigation. Section 5 concludes this paper.

II. Overview Architechture

Fig. 2 depicts the design components of the integrated Finch: ①A back cover mounted by tape to contain a Raspberry Pi [8], a portable power bank as the battery, a cable to connect the Pi to the battery and also a cable to connect the Pi to the finch; ② The wireless camera [9] is mounted in front of the back cover; ③ The GUI panel for the remote control; ④The supporting wheel is attached at the tail of the Finch with industrial tape.

The 3D-printed cover is specially designed using Solidworks software. The cover is used to contain the electronic devices–a small camera, a Raspberry Pi, and a battery. The communication system is shown in Fig. 3. The host computer, the Raspberry Pi and the camera are connected to the router via Wi-Fi. Therefore, these devices are able to communicate with each other through the router. The Raspberry Pi and the camera are set to login into the router Wi-Fi using static Internet Protocol (IP) addresses. Consequently, the host computer is able to Secure Shell (SSH) the Raspberry Pi and connects to the camera without the added hassle of having to locate their IP addresses provided by the router. For wireless communication, the SSH encrypted protocol is used to login on the Raspberry Pi from the host computer terminal which then assesses the coding window on the Pi and controls it. When opening the GUI panel for remote control, we use the SSH-Y (trusted X11 forwarding) to open graphical client via SSH. The step-by-step instructions to set-up Raspberry Pi, SSH remote controlling and file transfer are all available online. The wireless camera Ai-Ball is installed to video stream while the Finch is moving to assist user control. The communication between wireless camera and host computer is through a router and the detailed setup is provided in the device manual and website [7]. The system has been successfully tested using an off-the-shelf router. Moreover, the system can run in the SUTD campus network through Wi-Fi but without the wireless camera due to security protocol procedures.

A graphical user interface (GUI) for the Finch (Fig. 4) is written using Python programming language. The GUI provides functionality for movement of the Finch and two-way communication between the host computer and

Raspberry Pi. Section 3B describes the GUI in more detail.

The supporting wheel of the Finch is designed to stabilize the Finch while moving and to increase its speed. We choose the castor rubber wheel and castor nylon wheel materials due to weight concern and market constraints. The castor wheel can turn 360 degrees. The supported wheel can be easily attached to the Finch or detached from the Finch.

III. Major Design Components

A. Cover Design

The Finch cover is designed to hold the electronic devices and camera that are mounted on the Finch for wireless control. The cover should have sufficient space, accurate openings for the camera and a heat-releasing vent. The Finch robot has a curved shape. Thus, the cover must be able to fit the shape closely and be removed to allow portable power bank to be recharged and reconfiguration or any other necessary changes of the Raspberry Pi settings.

Based on the above requirements, the existing Finch cover (Fig. 3) is customized with the "SUTD" logo at the top with small holes to prevent overheating of the Raspberry Pi and the power bank. We used the Solidwork 3D modeling software to design the cover and printed it out via "3DISON PLUS 3D" printer. The cover is mounted on the Finch using tapes for easy removal.

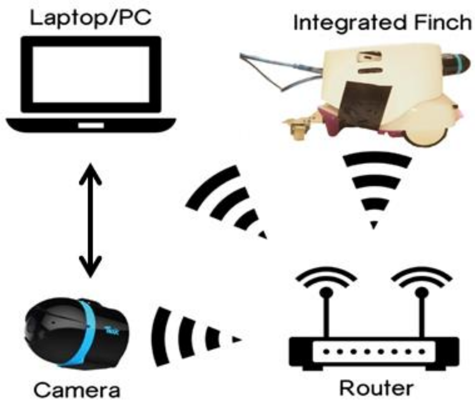

Figure 3. Communication system

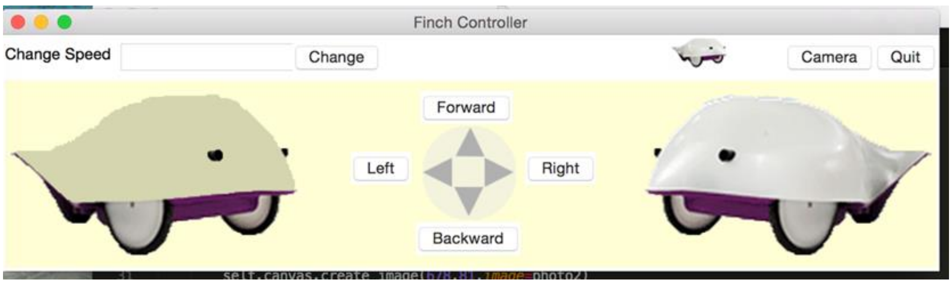

Figure 4. GUI design

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Import finch, sleep, Tkinter, tkMessageBox, pygame modules for the GUI finch control panel
Build a class named mainGUI
Instantiate an object for finch to control movement
Create top canvas for running finch
Create bottom canvas for gif files, buttons, and entries
Initialize pygame to play background music
Bind each button with an event
Start infinite while loop for the running finch animation
Define function for speed entry of finch in top canvas
Define function for movement of finch (right, left, forward, backward)
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Figure 5. High-level GUI pseudo-codes

There are multiple ways of mounting the Raspberry Pi and other components onto the Finch. One particular approach is to mount the Raspberry Pi separately on top of the cover to allow assessed to the Pi without actually opening the cover. Thus, the cover could be fixed on the Finch. However, the current method of mounting is selected due to the aesthetic concern for the overall product. Hiding the Raspberry Pi and most of cables inside the cover would make the system more appealing and presentable.

B. GUI Panel Design

The GUI (Fig. 4) panel is designed to control the Finch remotely from the host computer by SSH and login via the Raspberry Pi. The GUI panel controls the Finch forward, backward, left and right. The GUI is designed for simplicity and friendliness to users. Fig. 5 illustrates the very high-level pseudo-codes of GUI panel design. The design of the GUI panel consists of both the functional and aesthetic factors. Its objective is to generate a more attractive and user-friendly control panel because the main audience of the Finch robot is students.

C. Support Wheel Design

The initial idea of adding a support wheel on the Finch is due to the observation that when the Raspberry Pi and other components are loaded up onto the Finch, the tail of the Finch is actually pressed down against the floor which creates friction. The original Finch may also have such a problem although the design of the tail itself is supposed to work as a castor wheel. However, mounting these devices exaggerates the insignificant friction between the tail and the floor. As the devices are mounted, there is an imbalance of weight distribution at the back of the Finch due to the uneven curved shape of the Finch. Such imbalance aggravates the Finch's ability to move straight. For this reason, the supported wheel is added for two purposes:

a) To lift up the tail of the Finch and reduce the friction between the tail and the floor to increase the speed of the Finch;

b) To balance the Finch and improve its performance of moving in a straight line.

Three initial designs with different supported wheel positions are shown in Fig. 6.

Idea 1: Attach one supported wheel at the back of the tail.

Idea 2: Attach two supported wheels at the back of the tail; each of them is able to rotate freely.

Idea 3: Attach a mini-sized supported wheel below the Finch.

Figure 6. Supported wheel design

IV. RESULTS AND DISCUSSION

Idea 3 in Fig. 6 was not materialized because there was no miniature castor wheel in the hardware market. In addition, the budget was not sufficient to customize a castor wheel to this size. For the Idea 1 and Idea 2 of Fig. 6, we used rubber castor wheel with weight 32g and 36mm in size and can rotate 360 degrees. The attachment component between the wheel and the tail was 3D-printed. In the initial experiment, the same wireless Finch was programmed with a maximum forward throttle of 1.0 for the two models - one supported wheel at the back and two supported wheels at the back. Each experiment model was run 5 times continuously. The wireless Finch with one supported wheel was able to move forward further and straighter compared with the wireless Finch with two supported wheels. In order to reduce the cost, a bent aluminum piece was used instead of a 3D-printed part. The one supported wheel was installed on an aluminum piece (Fig. 7 and Fig. 8). This component was attached to the tail of the Finch using industrial tape which was stronger than normal tape. Then, a series of experiments were conducted to test the function and performance of one supporting wheel on an aluminum piece.

Figure 7. One supported wheel on aluminum piece

Figure 8. Attached one supported wheel on aluminum piece to the Finch

Figure 9. Wireless Finch on rough surface slope

The same wired Finch was set to move forward with full throttle speed of 1.0 for 15 seconds twice - once without a supported wheel and once with a support wheel. The same scenario was also carried out for the wireless Finch. Due to the fact that the original Finch was had difficulty moving straight on a flat floor, the experiments were conducted on a rough surface slope (Fig. 9) with a slight incline. The wired Finch with a supported wheel was able to move a longer distance than the wired Finch without a supported wheel. The wireless Finch also produced the same result. (Table I)

TABLE I. FINCH WITH SUPPORTING WHEEL PERFORMANCE

Model	Wired Finch	Wireless Finch
15s Distance difference	Approximated. 10cm	Approximated. 13cm
Straightness	85% path straight	90% path straight

The performance of the Finch was tested (left wheel 0.2 and right wheel 1.0 throttle) to turn in a circle on a carpet floor for 15 seconds too. For the anti-clockwise direction, the wired Finch with a supported wheel (Fig. 10) was able to turn an average one round more than the one without a supported wheel. Also, a very similar result was recorded for wireless Finch.

Figure 10. Wired Finch on carpet

V. CONCLUSION

This paper proposed an integrated system which includes components such as the Finch, a GUI, a unique holder, a Raspberry Pi, a battery pack, a camera and a support wheel for the Finch. The investigation revealed that a back castor wheel and a wireless or wired connection could help the Finch to move faster and deviate less from the set direction and turn more rounds in a circle. The experience gained by students in this research can be applied in the following areas: product development in particular product design and fabrication and computer science notably python programming, GUI design, and wireless network set up. Furthermore, a series of practical exercises can also be developed for students to acquire design, software development, and networking knowledge.

In the near future, the system may include Internet-Of-Things capability. Software applications like the Finch as an elderly toy could be developed to tackle the loneliness of old people.

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REFERENCES

[1] BirdBrain Technologies. (2010-2016). Finch robot. [Online]. Available: http://www.finchrobot.com

[2] A-M. Eubanks and R. G. Strader, "Introduction to programming with the Finch robot: pre-conference workshop," *Journal of Computing Sciences in Colleges*, vol. 27, no. 4, pp. 5, April 2012.

[3] D. R. Loker, A. Stephen, and S. A. Strom, "Virtual joystick control of finch robot," in *Proc. 121st ASEE Annual Conference & Exposition*, Indianapolis, June 15-18, 2014.

[4] BirdBrainTechnologies. (2010-2016). Scratch 2.0 Programming [Online]. Available: http://www.hummingbirdkit.com/learning/scratch-20-programming

[5] T. Lauwers, "The finch, a robot for the CS classroom," *Journal of Computing Sciences in Colleges*, vol. 29, no. 3, pp. 76-77, January 2014.

[6] C. H. Yoong, *et al*, "Open designettes, flowcharts, pseudo-codes in python programming for freshmore students with the aid of finch," in *Proc. 23rd International Conference on Computer in Education*, Nov. 30-Dec. 4, 2015.

[7] C. H. Yoong, "Benefits and introduction to python programming for freshmore students using inexpensive robots," in *Proc. IEEE International Conference on Teaching, Assessment and Learning for Engineering*, 2014.

[8] Raspberry Pi Foundation. (2016). Raspberry Pi 3rd generation. [Online]. Available: https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

[9] Trek. (2010). Ai-ball. [Online]. Available: http://www.thumbdrive.com/aiball/intro.html

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