Autonomous Flyer Delivery Robot

Tesfaye Wakessa Gussu(✉) and Chyi-Yeu Lin

Department of Mechanical Engineering,
National Taiwan University of Science and Technology,
No. 43, Sec. 4, Keelung Road, Da'an District, Taipei City 106, Taiwan (R.O.C.)
tesfayewakessa@gmail.com, jerrylin@mail.ntust.edu.tw

Abstract. In this study, we developed a socially interactive service robot with an innovative autonomous flyer distribution function. This robot is equipped with innovative flyer storage and delivery system and could store numerous A5 to A7 flyers sizes and tissue packs at a time. Each flyer passes through an internal channel to reach the palm of the robot, which is configured at a commonly reachable height for the majority of people. Every time a flyer or tissue pack is taken from the palm of the robot, the next flyer autonomously arrives at the robot's palm every 8 s. The developed robot was designed to have autonomous cassette and battery swapping mechanisms and could work exclusively within a localized working zone. Furthermore, it is equipped with strategies for localizing and avoiding obstacles. Thus, the robot was observed to perform flyer delivery without human intervention. The developed robot was displayed in various exhibitions held in Taiwan. The robot was seen to perform the expected task of flyer delivery which proves the robots full commercial value and a huge potential of becoming a product in the intelligent service robot market.

Keywords: Social robot · Autonomous robot · Flyer delivery
Swappable battery and cassette · Localized environment

1 Introduction

These days, various types of indoor and outdoor service robots were developed to fully or partially replace the work of humans and to provide various services. Such human-robot interactions may occur once or multiple times and may have single or multiple users, depending on the sociability and intelligence of the robots. A socially interactive courier robot for hospitals [1] was developed to provide service all day long, every day per week. A social robot [2] that allows the user to exercise twice longer in home thereby cutting down their calorie consumption was developed and thus allowed the user to maintain more intimacy with the robot. However, most people including young and elderly are still seen to be more hostile to such robots [3]. This could be due to the fact that humanoid robots servicing in a home environment require a balance between local autonomy and user intervention [4]. The mobile guest companion robot presented in [5] can interact with the residents in various ways such as teleconferencing, verbal query and behaving with integral privacy policy. Services robots are being designed replace people in areas involving hazardous and heavy-duty industry line, remote areas that are rather difficult-to-access, assist, and provide service on busy roads and in

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overcrowded areas. However, social robots serving the purpose of flyer delivery is rarely seen in any kind of environmental settings and we believe that no to less attempt is made to develop such kind of robots resembling human in its appearance and performance flyer delivery intelligently. Thus, this introduces a family of socially interactive service robot with autonomous flyer delivering capability through interaction with the recipient when in operation. To equip this robot with the intended functionality of delivering either flyer or pack of tissues wrapped with flyer, the state-of-art-of-the-art development of this robot is achieved by breaking it down into various modules. The design was modularized because of the intricate nature of the mechanism that ensured the smooth operation of flyer delivery. Moreover, flexibility during mechanism development and the rapid deployment of the customized robotic system design were achieved with ease. Furthermore, Since this robotic system consists of different modules that are functionally independent of each other, modularization allows ease of control of each module. The designed robot comprises a supporting rigid frame, flyer feeding mechanism, and flyer picking and forwarding mechanism. A removable cassette with partitioning is developed to enable autonomous cassette swapping. A conveying mechanism is used to transport the flyer and the tissue- packs from the end of the robot's shoulder to its palm. A display unit with a built-in visually interactive images and audio system is integrated into the head of this robot to enable a coordinated and smooth interaction with the recipient autonomously. Finally, a mobile robotic platform is developed to move the robot within its working area.

2 Design Approach to the Developing of Flyer Delivery Robot

The design approach to the development of socially interactive robots can span from human-centered approach [6–8] to affective-centered approach [5] and related approaches. In this paper, a modular design approach is implemented to the design of the flyer delivery robot shown in Fig. 1(a), moreover, new design metrics is set with respect to the performance, delivery capacity and ergonomics to achieve an efficient delivery mechanism. Thus, the mechanical design of the robot was divided into two main parts: the mobile platform module that provided mobility and the upper body module that provided autonomous flyer delivery.

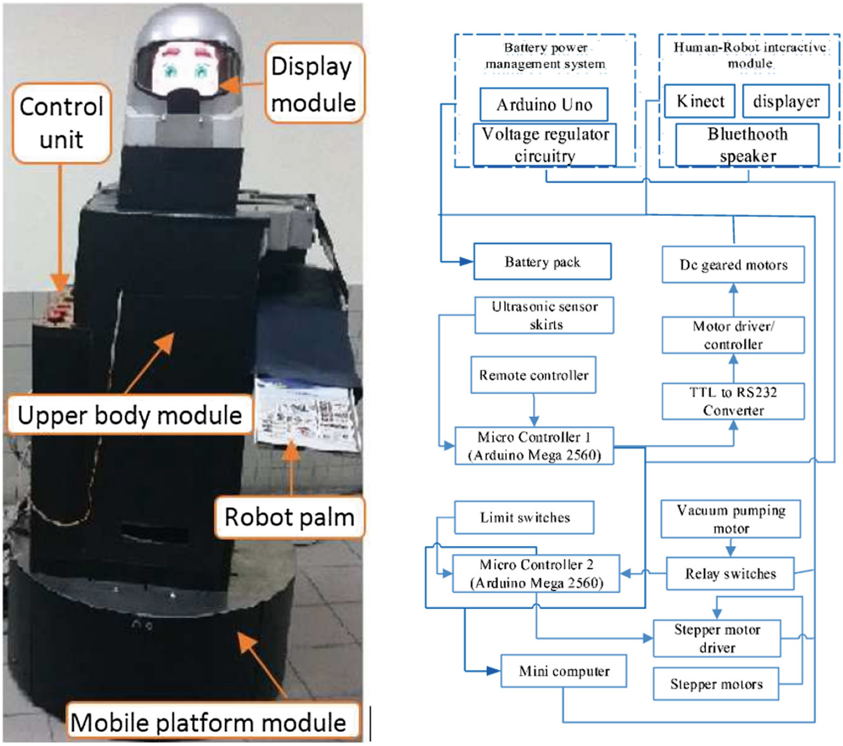
2.1 Performance Specifications of Flyer Delivery Robot

The robot should be able to contain and deliver flyers or packs of tissues wrapped with flyers and to operate autonomously with minimal human intervention.

It should also incorporate an autonomous flyer cassette and battery swapping mechanism.

2.2 Flyer Delivery Capacity Specifications

The robot has a holding capacity of 3000 flyers of A5 to A7 sizes or 600 packs of tissues with 6 mm thicknesses. The average delivery time should not exceed 10 s per flyer or tissue packs.



(a) Flyer delivery robot modules. (b) Control architecture of flyer delivery task

Fig. 1. Flyer deliver robot module and control architecture

2.3 Overall Dimensions of Flyer Delivery Robot

The flyer delivery robot should human-likeness in appearance as it is going to operate among people. Thus, the overall dimensions of the flyer delivery robot were adopted from the anthropometric data and design for ergonomics [9]. These dimensions are summarized in the Table 1. When developing this robot, the minimum height of the robotic palm is designed to provide access to all group of people including kids and disabled persons on wheelchairs. Special consideration is also made to include tall people by setting the robotic height to a minimum value of 0.9 m for ease of comfortable reach when crouching.

Table 1. Overall dimensions of flyer delivery robot

Description	Dimension in meters
Robot maximum height	1.38
Shoulder maximum height	1.09
Robot minimum width	0.551
Robot maximum height	0.612
Maximum height the robotic palm	0.99

2.4 Design of Upper Body Module

The flyer delivery robot shown in Fig. 1(a) consists of upper body module and a mobile platform module. The upper body module comprises a supporting structure for securely positioning the internal mechanisms, a swappable cassette for holding piles of flyers or tissue packs, and a feeding unit having one movable platform. This module also consists of flyer and tissue pack picking, forwarding, and transmission channel as sub-modules. The Tray and the movable platform has a slot for inserting a portioning plate whose usage is dependent on the size of the flyer to be delivered. The feeding, the picking, forwarding and transmission sub-modules are driven by a two-phase hybrid stepper motors. The end-to-end motion of the stepper motors is controlled by the state of the limit switches that are configured at the extreme end of the respective stepper motors. The flyer delivering process is achieved through the coordinated motion of these motors, the limit switches, the reflectance sensor, and the mini-vacuum pumping motor. In This module, the mini vacuum pump is turned on and off during picking and releasing, respectively by using a relay switch. The state of the reflectance sensor configured at the extreme end of the robot palm commands the autonomous feeding, picking, forwarding, and transmission of the top most flyer or tissue pack every time a flyer is taken from the palm. The upper body module has another sub-module integrated in the robot head. This sub-module has a built-in audio and display graphics to facilitate smooth interaction between the robot and receiving people. In general, the flyer delivery process began with the loading of the cassette containing flyers or tissue packs. The system was set to a homing position before feeding took place. At this stage, the feeding distance should be the same as the thickness of the flyer; otherwise, the feeding distance should be adjusted according to Eq. 1

$$\text{feed} = \text{n} * \alpha \tag{1}$$

where n is the number of steps per revolution for the feeding stepper motor, and α is a constant for adjusting the feed. For example, every time the state of the signal received from the reflectance sensor changes from high to low or it shows a change from the set threshold, the value of α must be 7.5 for the feeding motor running with 200 steps per revolution. As a result, the upward advance of the movable platform is limited to the thickness of the flyer chosen for delivery.

2.5 Design of Mobile Robotic Platform Module

The developed flyer delivery robot only delivers the flyers and tissue packs, interact with people through the display module but also has a capability of avoiding obstacles self-localization within the set working environment. In order to develop this mobile platform, a tri-omnidirectional wheel configuration with circular profile proposed and solved with the help of an optimization tool in MATLAB. Thus, the mobile robotic platform is developed using the optimal design values. This robotic platform obstacle both static and dynamic obstacles using a geometry based obstacle avoidance technique presented in [10].

3 Control Architecture of Flyer Delivery Robot

Socially interactive robots could be controlled in various ways, such as a distributed sensor network system that covers an area of a block in a town with many houses, buildings, and roads. This approach is used to manage robot services by monitoring events that occur in the town with the help of an RFID tag is used for tracking moving people within the constructed 3D geometrical models of large-scale environments [11]. However, a combination of inexpensive microcontrollers and sensors was used in this work. The details of the robot control architecture is shown in Fig. 1(b). Due to independent autonomous operation of the upper body and mobile platform module, the two modules are controlled and allowed to operate separately using two Arduino mega 2560 microcontroller boards. A third microcontroller board, Arduino Uno is used as a master controller and to monitor the battery voltage levels. Finally, a graphical user interface was used to manage the three microcontrollers, the Kinect sensor, and the Bluetooth speaker placed within the upper body module of the flyer delivery robot.

4 Conclusion

A flyer delivery robot comprising the following is designed: a mobile platform module for autonomous movement; an upper body module placed on top of the this platform comprising picking, feeding, forwarding, and transmission sub-modules; a swappable cassette and battery pack module for stacking flyers and tissue pack, respectively; a display and audio sub-module for interacting with people; a Kinect camera for detecting an approaching person; and a control system that mainly uses an Arduino microcontroller. The prototype of this robot is developed at a full-scale and displayed in two exhibitions in Taipei (2016). The robot was seen capturing the attention of most visitors. Following visitors interest, reactions, interaction, and their feedback's, it can be concluded that the affective state and affective quality of the developed robot is positive and acceptable during the interaction.

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