A Review on Service Robots: Mechanical Design and Localization System

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Abstract. Service robot is becoming more popular in recent study. It has opened up various opportunity to solve problems as well as the challenges need to be studied. While there are many successfully developed service robot out there, the general design principle with respect to the application need a description with solid justification. This review paper seeks and compare the design principle, specification, and hardware selection of several successfully developed service robot such as Sacarino and Blackbot. Based on the study, the most important design principles include simple mobile platform, modular structure, and aesthetic design.

1. Introduction
Service robot can be defined as the robot that perform predefined tasks originally done by human in a specific area or field. However, less expectation were to be set on these robot to accomplish the tasks as perfect as human did, at least it can achieve some degrees of acceptable results [1]. One cannot doubt that service robot is getting popular nowadays either to the researcher, industry, or commercial. The emergence of Industrial Revolution 4.0 (IR4.0) has deem the importance of service robots particularly in automation process, medical services, and many other fields. Furthermore, the affordability of high processing computer nowadays enable these robots to be brought to the consumer as part of their living [2].

Researcher and developer are mostly interested in designing the service robot for daily life assistance such as elderly care. This is because studies showed that aging population has become the common problem nowadays due to higher aging population and declining birth rate in recent years. It is expected that robot technology have an important role for the sustainable health of the society and overcome the manpower shortage in the medical industry. These kind of task require the robot at least to be able to know the surrounding conditions, recognize objects, and avoid obstacles [3]. Researcher in [4] carried out a study from a focus-group about the system requirement of a service robot for elderly care which shows that the focus-group prefer a robot with simple user interface, require no prior knowledge to be operated, and easy to be understood.

Apart from that, a robotic company Savioke has created the first hotel receptionist robot Botlr that has been introduced in Aloft Hotel in Cupertino, California. The robot can do the hotel management tasks such as greeting people and deliver items to the specific hotel room. The robot has a storage compartment that can store items like toiletries, newspapers, and water bottles to be delivered to the guest room. According to the survey, 56% of respondent prefer to have a service robotic in the hotel [5].

The rest of the article is organized as follows: Section 2 described the service robot design layout, hardware selection, and service robot comparison. Section 3 introduces the important design components of service robot, and section 4 describe the technological aspect related to service robot which currently gain the interest among researchers.
2. Design Layout and Consideration

When it comes to design, there are several layout and consideration that has been proposed to design a service robot. This aspect is important as the general reference for the early development phase of a service robot so that it gives the idea of the starting point.

The works in [6] developed a restaurant service mobile robot and described the five layers structure of the robot. The first layer consists of drive and castor wheels, rechargeable power supply, and infrared navigation sensor. The second layer has the electronic driver and I/O board as well as the emergency stop mechanism. The third layer is where the PC based controller is placed. It is connected to the electronic driver and I/O board via RS232. The fourth layer is the storage compartment. This is where the dishes are placed for transportation within the restaurant. The fifth layer is for user interface utilities such as touch screen panel, speaker, and microphone for voice command. Other than that, the robot also have wireless network module and laser positioning system.

A receptionist robot codenamed Xinxin is well explained in [7]. The robot is designed to be modular and the author described the hardware design of the robot into six module which are mobile module, laser scanning module, somatosensory module, arm module, display module, and voice module. The mobile module is based on the commercial robot named Kobuki. The battery has been customized with 12-cell 18650 Lithium ion which enable the robot to work for 6 hours on a single charge. Rplidar A1 is used as the laser scanning module. In the other hand, Microsoft Kinect camera is used as the somatosensory module which detect the human gesture and movement. The arm module consists of several motors that provide extra degree of freedom instead of the mobile platform. 7-inch touch-screen device is used as the display module for this robot. Lastly, the voice module developed based on iFlyTek Speech Lab System that provide many features related to voice command and synthesis.

Other than that, researcher in [8] developed ‘BlackBot’ a receptionist robot. In general, this robot consist of two modules joined by a pan-tilt mechanism. The modules are the body module with mobile platform and the head module with LCD display for user interface. The mobile platform has three-wheeled mobile with differential drive mechanism powered by two DC motors. In the other hand, the control system architecture of the robot consists of 4 layers which are the hardware, software framework, application program interface, and service application. To be more specific, the author described the design specification of BlackBot such as the height is 1600mm, weight is 30kg, maximum travel speed is 0.25m/s, material used is aluminum frame, DC motors rated power is 35W each, and the processor used is Core i5 with 4GB RAM.

The works in [9] describe the design structure of ‘Sacarino’ the hotel receptionist service robot into three levels. The first level includes the hardware, mechanical structure, sensors, and actuators. The second level is the robot’s control architecture which include the control algorithm, software, modelling, and programming. The third level is the application in which the robot is given the specific services or tasks. According to the author, development of a service robot should consider the application level in the first place. This to ensure the robot able to provide the service successfully with minimal failure. In the hardware level, there are two main parts which are the mobile base for robot to maneuver and the anthropomorphic upper body for user interface and interaction with human. The mobile base has synchro-drive mechanism which comprises of two motors, one for turns and the other for traction.

In addition, researcher in [10] described the design philosophy of service robot and identified the requirements for future robots such as friendly and cooperative interface, simple structure, function that are easy for humans to understand, and gentle appearance in harmony with surroundings.

A service robot that is designed for household tasks should have enough workspace area for it to get access to the objects and furniture just like human do [4]. However, in terms of the robot size, the limitation is the typical door sizes because the robot is needed to move from one point to another inside the house. The robot weight is hard to compromise because it often depends on battery capacity, platform stability, payload, and manipulators. In most cases, the robot operates autonomously alongside human, thus safety is the main criteria for service robot. Furthermore, according to interviews with market player it was found that a service robot should be kept low cost and affordable in order to be accepted by the consumers [4]. Due to this limitation factor, a design architecture of minimal cost such as selecting the differential drive platform with an arm manipulator as the basic design has been introduced. The dimension factor makes the robot to be designed so that it can pass through smallest door in the house/building and even maneuver across the corridors. The stability of the robot is kept to
the maximum by placing the lead batteries on the lowest point possible to lower the center of gravity, thus making the robot safer to work alongside human.

According to researcher in [5], the design process of a service robot begins with selecting the material. The chosen material depends on its weight and motor torque. The motor torque in the other hand must follow the design principle of minimizing the cost, thus cheaper motor need to be selected. This in turns determine the size, weight, and travel speed of the robot.

Last but not least, researcher in [11] developed MILO a personal service robot for general application such as housekeeping, mobile tele-conferencing, and tele-presence at home. The author pointed out five considered criterions in the development of MILO. The first one is safety since MILO is intended to work and interact closely to people. This include sensors redundancy and intelligent algorithm control algorithm. The second criterion is low cost hardware and component. This can be achieved by simplifying the mechanical structure and materials for fabrication. Next, the third criterion is form factor of the design. Since MILO is intended to work alongside human, the shape should not be threatening. The fourth consideration criterion is expandability, easy for maintenance, and flexibility. The mechanical design is made modular while the electronics design allows extension with other module. The fifth criterion is simple and efficient user interface. Table 1 summarizes the important aspect in service robot by comparing the service robot in [6], Xinxin, Blackbot, and Sacarino.

### Table 1. Summary of service robot design layout.

| Name            | Unnamed [6] | Xinxin [7] | Blackbot [8] | Sacarino [9] |
|-----------------|-------------|------------|--------------|--------------|
| Application     | Restaurant waiter | Hotel receptionist | Hotel receptionist | Hotel receptionist |
| mobile platform | Differential drive | Differential drive | Differential drive | Synchro drive |
| Design layout   | Five layer structure | Six modular | Two modular | Three level architecture |
| User interface  | LCD screen | LCD screen on chest | LCD screen head and facial expression | LCD screen on chest |

3. Design Components

3.1 Mobile Platform Mechanism

There are a few options of mobile platform mechanism that are typically used in service robot. The three most popular used mechanism are differential drive, omni-directional with mecanum wheel, and synchro-drive. Each mechanism has its own advantages and disadvantages.

Differential drive is the most widely used mobile platform mechanism. This is due to low cost, simplicity, and easy to implement with minimal complexity in control system [12]. This mechanism is powered by at least two independent motor which drive the wheels. Fuzzy PID can be used as the controller for differential drive wheel which able to produce sophisticated trajectories even though non-
identical motors were used [13]. Other than that, a steering wheel can also be added to the differential drive platform to provide extra degree of freedom and extend the ability to manoeuvre making this mechanism expandable [14].

For the omni-directional with mecanum wheel mechanism, at least two wheels are needed to move the platform. It is quite efficient mechanism to move a robot platform since no need for a stopping for making a turn or curvature [15]. The most important component is the wheel itself. It is a specially designed wheel which comprises of small roller along the main wheel oriented co-axial with the main wheel shaft. The small roller enable the wheel to skid sideways [16]. With tangential superimposition, the platform with mecanum wheel can move in any direction without changing the orientation with respect to the global frame [17] [18]. Other than that, this wheel provide more advantage in narrow space maneuvering [19]. Reseracher in [19] choose the omni-directional with four mecanum wheel mechanism in the design of state-of-the-art wheel chair. This new configuration gives extra ability to maneuver for the wheel chair user. Low cost microcontroller also used to control the whole system which proves that this mechanism can be controlled with lower processing system. Reseracher in [15] enhanced the mecanum wheel by using odometry sensors to measure the wheel speed more accurately. It consist of two dummy wheel with encoder placed at the center of the mobile platform that are perpendicular to each other.

Synchro-drive mechanism is also a type of omni-directional but there is no need for a specially designed wheel like mecanum wheel. It uses the normal wheel, but there is a specially designed steering mechanism for each wheel. In synchro-drive, all wheels are steered simultaneously so that they all facing the same orientation and direction. In common configuration, the synchro-drive consist of one motor for steering and the motors on each wheel for driving. All of the wheel have vertical steering shaft and are connected either via the gears or chain drive for a synchronize rotation in the vertical axis. This mechanism has two degree of freedom and the platform will always stay on the same orientation at all time. In the other hand, this mechanism is holonomic and can move in any direction. However, the wheel need to stop before changing the direction of travel [20] [21].

Table 2. Summary of mobile mechanism

| Mobile Mechanism          | Advantage                   | Disadvantage                  |
|---------------------------|-----------------------------|-------------------------------|
| Differential drive        | – Simple                    | – Cannot maneuver in sideways |
|                           | – Low cost                  |                               |
| Mecanum wheel drive       | – High maneuver ability     | – High cost mecanum wheel     |
|                           | – 3 DOF                     |                               |
| Synchro drive             | – Can maneuver in tight space | – Complex steering mechanism |

3.2 Upper Body

On the upper body of service robot, there are several components need to be selected and decided with respect to the robot application. This include manipulator, storage compartment, and user interface screen.

Reseracher in [22] developed the 6 degree-of-freedom (DOF) arm on both side of the service robot. Besides that, the robot is also equipped with a human like head. Both the arm and the head are designed so that the service robot appear to be human like which is one of the attraction factor. Other than that, a touch screen is mounted on the chest of the robot to provide information as well as the user interface.

A robot explained in [23] is known as Care-O-bot and it has 28-DOF. This service robot has single arm manipulator and tray compartment for storage. The manipulator itself is a 7-DOF lightweight arm. The workspace of the manipulator is designed so that it can reach the floor space. The tray compartment is used to place the items such as food and medicine for the patient. Due to it focused application, this
robot has no anthropomorphic head and upper body. The overall structure is designed to be able to support human thus making the stability is an important criteria instead of appearance.

In the other hand, researcher in [24] stated that service robot with dual arm is more practical than the single arm, albeit its subjectivity to pre-determined tasks. For a subjective task application such as to grasp object, it is better that the service robot has dual arm. Hence, dual arm manipulator which has different structure and functionality between each other has been developed to cover different operation tasks for elderly care. The whole upper body structure of the robot is kept simple without anthropomorphic appearance.

4. Positioning of a Service Robot

As it opens various application opportunity, service robot also require technological improvements in many aspects especially the software and control algorithm such as collision avoidance, path-planning, localization, positioning, and Human-Robot Interaction behaviour. Recent studies show high focus and interest in these aspect.

A positioning system for service robot which is based on dual vision sensor is presented in [25]. The proposed system consist of two vision sensor which is placed on the robot and on the room to construct the mapping of the room. This system automatically making the service robot smart in terms of positioning, navigation, obstacle avoidance, and human-robot interaction. The system use V-SLAM technique to run the algorithm. It compares the predictive information from its depth visual information to form navigation and avoidance. The robot is no longer depends on guide line to manoeuvre instead it navigate through the dual vision system and able to avoid obstacle. These enhancement makes the robot more efficient and improve the speed in completing the tasks.

The works in [26] in the other hand developed a positioning system by using wireless fingerprinting technique. This technique involve two stages which are offline and online. During offline stage, the RSS information is collected and recorded. Next, during online stage, the unknown RSS information acquired is compared with the recorded information in the database by using specific matching algorithm. Hence, the closest value is selected as the positioning results. This method have several advantage compared to SLAM because it utilizes the existing wireless infrastructure in the room or building without the need to implement a new system, therefore cost facilitative.

5. Conclusion

As a conclusion, service robot is a promising technology because it offer many possibilities in terms of application, research, and enhancement. Since the development process and parameter of service robot is very subjective with respect to its application, the design consideration and principle from the previous researcher is summarized in this paper. The design parameters and factors has been justified with further comparing the design of successfully developed service robot. Next, the critical components of service robot discussed with details along with several option available to be selected. The selection of the design component is important to determine the functionalty of the robot and ensure the efficiency. Last but not least, the enhancement aspect of service robot is highlighted by summarizing the previous work from researchers including service robot navigation, positioning, obstacle avoidance, and Human-Robot interaction.

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