KisBot: New Spherical Robot with Arms

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Abstract: - A new type of spherical robot, called KisBot, is presented that includes arms and two types of driving mode: rolling and wheeling. In the rolling mode, the robot uses its arms as pendulums and works like a pendulum-driven robot, while in the wheeling mode, it extends its arms to the ground and works like a one-wheel car. The basic design idea of KisBot is introduced and a prototype is implemented. The robot has a wheel-shaped body between two rotating semi-spheres. Each semi-sphere contains one DC motor for propulsion in the rolling mode and wheeling mode, one RC motor for arm extension, a speed controller for changing the direction of the arm rotation, a battery as the power source, and the mechanical components of the arm. Experiments using the rolling mode and wheeling mode verify the driving efficiency of the proposed spherical robot.

Key-Words: - Spherical robot, Rolling robot, Deformable robot, Locomotion, Motion generation.

1   Introduction

Although wheeled and legged locomotion remain the most typical locomotion methods for robots, the limitations of these locomotion methods in certain environments have led to the investigation of various alternative locomotion methods, including jumping, flying, and rolling, where the last is especially appropriate for spherical robots.

In the case of spherical robots, they have several attractive features. First, the shell protects the inner circuits and mechanisms from dust and external contaminants. Second, since a sphere only has a single contact point with the ground, this minimizes the friction and produces greater energy efficiencies than with wheeled or legged robots. Third, a sphere cannot be overturned, as there is no upside or downside. Fourth, a sphere is omni-directionally symmetrical, meaning a spherical robot can move in any direction. Fifth, spherical robots do not get hooked by obstacles, due to the absence of any edges. Finally, a sphere has a lower ground contact pressure, giving spherical robots a superior locomotion capability on soft ground, such as sand, snow, or vegetation [1].

As a result of these advantages, a variety of spherical robots have already been developed. The first spherical robot, Rollo, was introduced in 1996 [2] and included an IDU(Inside Driving Unit), where an inside wheel is used to roll the outer shell. Rotundus was then developed for surveillance purposes by a Swedish company in 2004 [3]. In this case, a pendulum located at the center of the horizontal axis inside the sphere is used to change the center of mass and generate torque for the outer shell.

Next, Kickbot, a spherical wheeled robot consisting of two independent hemispheres was developed at MIT in 2006 [4]. A spherical toy robot, called Roball, that employs a pendulum-propelling system was then introduced [5], [6], and another pendulum-driven spherical robot developed by Helsinki University of Technology [7].

Notwithstanding, the continuing problems related to conventional spherical robots include unstable movement and stopping difficulties, due to the minimal contact with the ground, and dealing with rough terrain, which is an ongoing challenge for mobile robot research.

Accordingly, to solve these problems, a new spherical robot, KisBot (Kyungpook national university Intelligent Spherical roBOT), is proposed with a spherical body and two extendable arms.

The remainder of this paper includes a description of the design idea for KisBot, its motion generation for different terrains, and the implementation of a prototype. Experimental results confirm the driving efficiency, and some final conclusions are also provided.

2   Design of KisBot

The basic design approach for KisBot is to preserve the advantages of existing spherical robots, while overcoming their disadvantages. Thus, the key feature of KisBot is two extendable arms that are used to enhance its stability, stopping, and locomotion across rough terrains, such as slopes and stairs.

The mechanism of KisBot can be divided into three parts: a wheel-shaped body between two rotating
semi-spheres. Each semi-sphere rotates on a fixed axis at the center of the sphere and includes an arm that can be extended or contracted, where the mass of the arm functions as a pendulum.

Kisbot also incorporates two propulsion methods according to the state of the arms, i.e. contracted or extended.

When the arms are contracted, each semi-sphere acts as a pendulum to propel the robot in the desired direction. In other words, the pendulums change the center of mass of the robot. The two pendulums are also located on a horizontal axis in the lower part of each semi-sphere, which provides additional stability. Furthermore, as the body and semi-spheres are independent of each other, the body can roll, while the semi-spheres remain fixed, which allows the semi-spheres to be equipped with a sensor, such as a camera, for various surveillance applications.

Meanwhile, when the arms are extended, the propulsion method is similar to the locomotion of a wheeled robot. As such, the arms support the ground, while the body works as a wheel based on the repulsive force of the arms. However, since this involves a higher friction than with the pendulum mode, due to the added friction at the contact point between the arms and the ground, an actuator with a high torque is needed to make the body rotate. Nonetheless, the robot is easy to stop and stable due to the arms.

3 Motion Generation
KisBot has four kinds of motion: rolling with the arms contracted, wheeling with the arms extended, lifting by the arms, and stopping.

The rolling motion is suitable for a flat terrain or downhill, and requires minimal energy to move. Plus, the rolling speed of the robot is controlled based on the rotating speed of each semi-sphere. In contrast, the wheeling motion is suitable for uphill or downhill, and since the extended arms increase the friction with the ground, wheeling is easier to control than rolling. Plus, the wheeling torque is higher than the rolling torque.

As shown in Fig. 2, the wheeling motion is simply implemented by rotating the semi-spheres with the arms extended in the opposite direction to the moving direction.

The lifting motion is suitable for overcoming obstacles, as shown in Fig. 3. Conventional spherical robots can encounter difficulties when climbing stairs using a rolling or wheeling motion. However, KisBot is able to deal with this type of situation by using its arms to lift its body. Thus, to overcome an obstacle, the arms are extended forward and then rotated backward, and the robot then proceeds in the wheeling mode.

When the arms are contracted, stopping is achieved by reverse rotation of the semi-spheres and extending the arms. Conversely, when the arms are extended, stopping the body rotation makes the robot stop, which is more stable than the stopping motion with the arms contracted.

4 Implementation
A prototype was implemented using the basic design concept, and the mechanical architecture and electronic architecture are explained in the following sections, respectively.

4.1 Mechanical Architecture
A 3D modeling tool (CATIA) was used to model the mechanical structure of KisBot, including the wheel-shaped body, semi-spheres, and extended arms, as shown in Figure 4.
The wheel-shaped body, as the center part of the robot, consisted of two aluminum disks with cut-outs and a ring-shaped frame made of resin using a Rapid Prototype process. The right and left semi-spheres were also made of resin using a Rapid Prototype process, where each semi-sphere also included an aluminum disk as the base for installing the internal electronic and other mechanical components.

Figure 5 shows the three main parts of the robot: the frame of the wheel-shaped body (Fig.5(a)) and components of the semi-spheres (Fig.(b)). When assembled, the wheel-shaped body and two semi-spheres created a spherical shape.

The size of the robot was almost the same as a soccer ball with a radius of about 10cm. When equipped with all its components, the robot weighed about 2kg.

4.2 Electronic Architecture
Each semi-sphere included several electronic components: a DC motor, RC motor, battery, and speed controller, plus the mechanical components for the arm, as shown in Figure 6.

These components were all placed on an aluminum disk. Two small pipes and a small tip-part formed the arm, and the shoulder of the arm was connected to the RC motor via a mechanical link for the extension or contraction of the arm. The DC motor was used to rotate the semi-sphere and was installed at the horizontal center axis of the sphere. The speed controller was used to change the speed and rotational direction of the DC motor, allowing the robot to move forward or backward. Finally, the battery was the main supply of electric power to the electronic components and motors.

A block diagram of the electronic architecture is shown in Fig. 7.

The robot had two wireless communication channels between the transmitter and receiver. Thus, when the transmitter in the joystick transmitted speed commands, the receiver output the appropriate PWM signals according to the signals received via each channel, where one PWM signal was used to control the RC motor, while the other was communicated to the speed controller of the DC motor.

Figure 8 shows the semi-assembled prototype, where the components were all installed on the aluminum disc in the semi-sphere, and the shell of the semi-sphere attached to the disc. Plus, the battery, which was relatively heavy when compared to the other electronic components, except for the motors, and the speed controller were both placed near the end-tip of the arm in the semi-sphere to lower the robot’s center of mass. The fully-assembled prototype is shown in Fig. 9.
5 Experiments

The prototype was used to test the two driving modes, rolling and wheeling, and the experimental results are shown in Figs. 10 and 11, respectively.

In Fig. 10, the robot uses its two semi-spheres as pendulums and moves like a pendulum-driven robot. In this rolling-mode experiment, although the appropriate signals were transmitted to the robot using the joystick, synchronizing the rotation angles of the two semi-spheres was somewhat difficult. However, when the two semi-spheres had the same rotation angles with respect to the ground, it was possible to move the prototype forward and backward. Meanwhile, in Fig. 11, the robot moves like a one-wheel car with its arms extended in contact with the ground. The robot movement in the wheeling mode was also more stable and faster when compared with that in the rolling mode.

During the experiments, the robot sometimes lost its center of mass, which caused a loss of control. The main reasons for this were a difference in the rotation angle of the two semi-spheres and uneven ground. However, in future studies, these problems will be resolved with the inclusion of a microprocessor and several sensors in the robot control system and a more effective controller design.

6 Conclusion

A novel spherical robot, called KisBot, was introduced to enhance the locomotion capability of conventional rolling robots. Through the use of two arms, KisBot is able to move successfully across different types of terrain. Experiments showed that KisBot is able to move in both a rolling mode and wheeling mode, and can overcome the locomotion limitations of conventional rolling robots. In future work, a microprocessor and several sensors will be added to the robot system for enhanced performance and various surveillance applications.

References:
