Design and Implementation of Wheeled Curling Robots

KYUNGHWAN KIM †1 CHANGYONG SONG †2
WOOKBIN JIN †3

Abstract: Curly, the wheeled curling robots for skip, thrower and sweeper are proposed in this paper. The skip robot is in combination with the thrower robot equipped with a gripper for a curling stone as well as a robotic arm with dual cameras. The skip-thrower robot can control its velocity of driving and its angular velocity of curling. The sweeper robot must consider various factors such as sensing of a moving stone and environments, motion planning and control of driving and sweeping motion. Demonstration games were played between human players and Curly in combination with CurlBrain, a remote AI server.

Keywords: Curling Robot, Wheeled Robot, Skip, Thrower, Sweeper

1. Introduction

Curling has been called "chess on ice" in which players must read opponent's intentions and perform complex strategies. In curling, players must take into account infinite number of choices for placing stones, collision of stones and temporal change of ice, whereas chess uses limited number of grids.

The curling robot system consists of software such as on-time recognition of game situation and planning of optimal strategies as well as hardware such as design of wheeled curling robots and autonomous control of driving, curling and sweeping. In this paper, we focus on design and implementation of new wheeled curling robots, Curly.

2. Design of the Curling Robots

2.1 Design of the skip-thrower robot

Curly is a robot system consisting of two types of robot. The skip-thrower robot performs skip and driving/throwing by switching its two operational modes. The skip-thrower robot has 86 kg in weight and 220cm in height.

Fig. 1 shows a schematic design of the skip-thrower robot. In skip mode, the robot stretches or folds its arm in which dual cameras are attached at the end to observe placement of stones and trajectory of a thrown stone. The robot shares image data from the camera with the remote AI game server. The robot uses the third camera in its front for measuring distance between the driving robot and a hog line in driving/throwing mode.

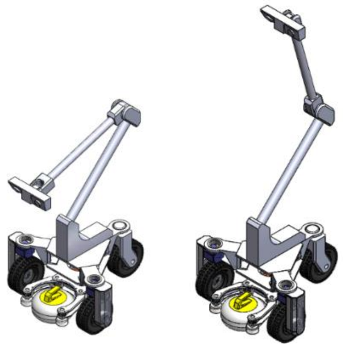


Figure 1. A schematic design of the skip-thrower robot

In driving/throwing mode, the robot uses a gripper for grasping and throwing a stone. The robot can control its velocity of driving and its angular velocity of curling. In Fig. 2, the gripper grasps the sides of the stone and rotates the stone until it releases the stone before the robot reaches to a hog line. The gripper is installed in lower front of the robot.

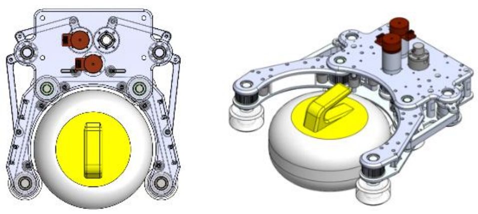


Figure 2. A schematic design of the gripper

2.2 Design of the sweeper robot

The sweeper robot is designed separately with the skip-thrower robot considering many factors such as compact size, sensing of a stone, motion planning and control of sweeping motion.

To make the sweeper robot more compact, the in-wheel electric motor is proposed in Fig. 3. The in-wheel electric motor consists of an electric motor, a gear reducer and a rotary encoder in a wheel. The structure is useful to make the sweeper robot more compact and lighter without using additional power transmission mechanism. Three in-wheel motor with three steering motors are used for a sweeper robot as depicted in Fig. 4. This figure shows direction of driving and sweeping respectively. The yellow and green colors illustrate area of laser sensors for sweeping motion and forward driving motion.

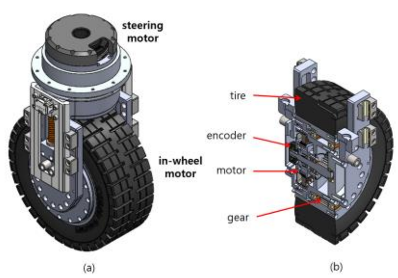


Figure 3. A cross section of the in-wheel electric motor.

†1 NT Robot, Co. †2 NT Robot, Co. †3 NT Robot, Co.

.

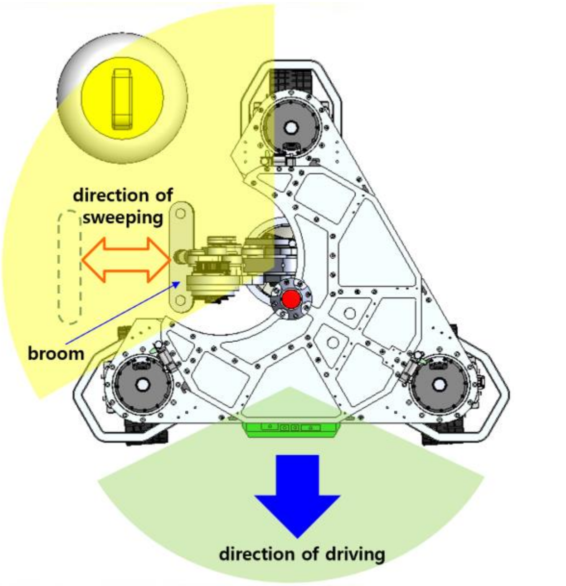


Figure 4. The sweeper robot having three in-wheel motors and three steering motors.

By using two sweeper robots, coordinated driving/sweeping can be done as depicted in Fig. 5. In the coordinated motion, the brooms must avoid collision with each other and a curling stone. Fig. 6 shows the inner structure of the sweeper robot. The user can press the EMG switch at the center of the robot in emergency.

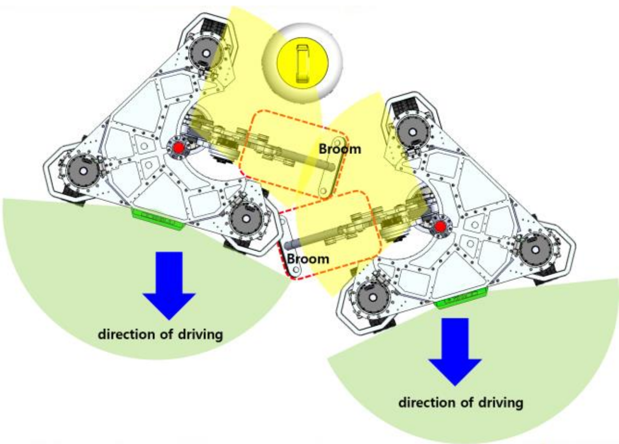


Figure 5. Coordinated driving/sweeping using two robots

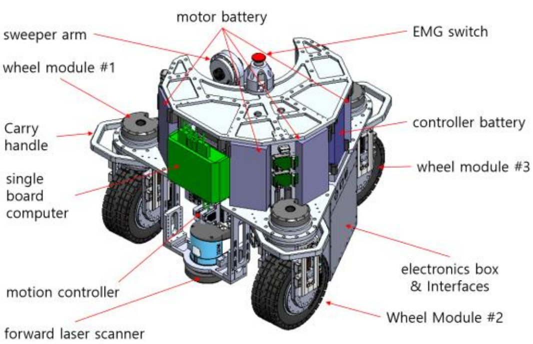


Figure 6. Inner structure of the sweeper robot

2.3 Design of the sweeping arm

In Fig. 7, the sweeper robot holds a delivery stick and broom with a sweeping arm. To satisfy sweeping speed of 5 Hz, the folding/unfolding link mechanism is used in which rotation by a motor is converted into reciprocating motion on ice in Fig. 8(a). Another motor is used for lifting and and lowering the arm in Fig. 8(b).

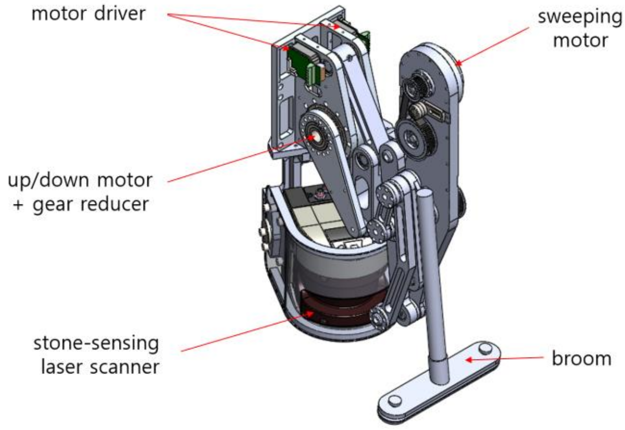
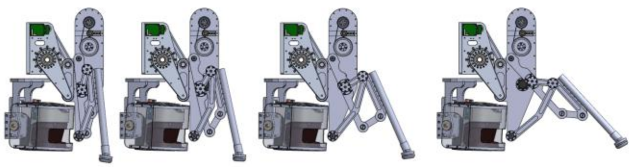
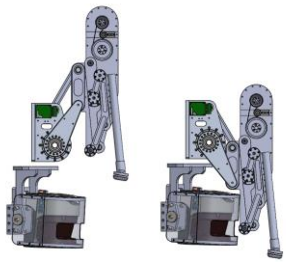


Figure 7. Sweeping arm holding a delivery stick and broom.



(a)



(b)

Figure 8. Motion of a sweeping arm. (a) sweeping (b) lifting

2.4 Design of the scanning sensors

Two laser scanners are used in the sweeper robot to observe a driving stone and forward environments. Fig. 9 shows a laser scanner and its operating range diagram. The operating range of the sensor is from 0 to 10 meters. The aperture angle is 190 degree and the response time is more than 10 msec.

Fig. 10 illustrates how the laser sensor observes a curling stone in robot driving. In Fig. 11, sensing areas by two laser scanners are illustrated by yellow and green colors. To be noted, some portion of area in sensing a stone is hidden by sweeping motion. The stick and broom is distinguished from the stone by image processing.

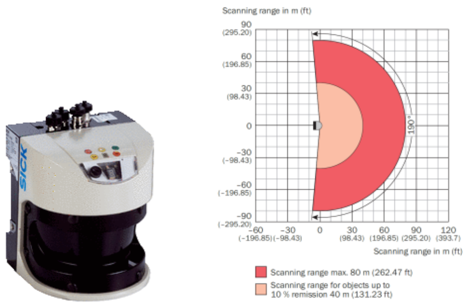


Figure 9. A laser scanner and its operating range diagram

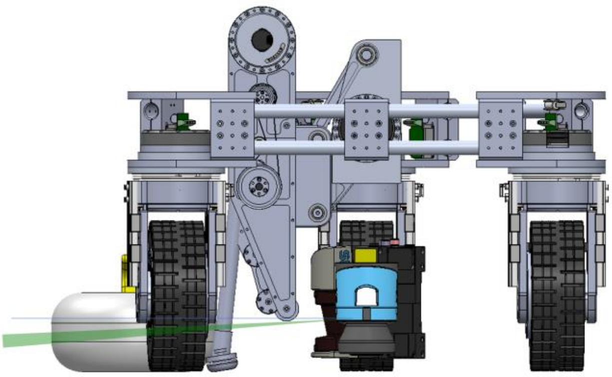


Figure 10. Laser scanner to observe a stone

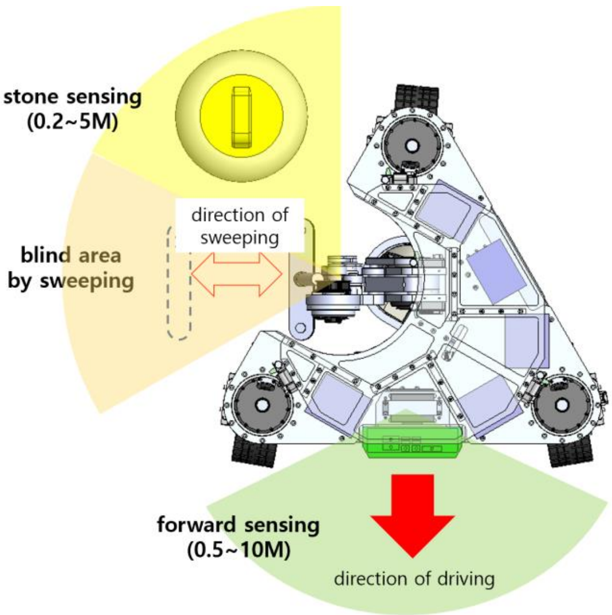


Figure 11. Sensing area of two laser scanners

3. Control of the Curling Robots

3.1 Design of the controller

Fig. 12 is a block diagram of the integrated controller for the curling robots. The laser scanners are used in the sweeper robot. One SBC(Single Board Computer) is used for data acquisition from sensors and controlling a robotic arm and a gripper. Another SBC is used to control six driving and steering motors, which are controlled by analog voltage control for fast response time of motion control.

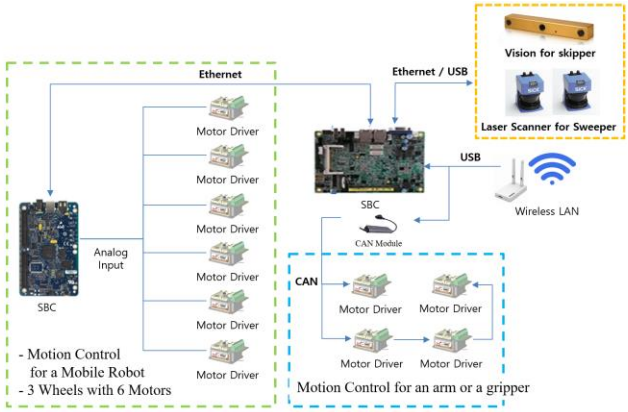


Figure 12. A block diagram of the integrated controller

3.2 Motion control of the curling robots

The skip-thrower robot slides on a sheet of ice toward a target area. The robot must control its sliding or driving velocity so that it can pass a hog line at desired time. The robot can drive with the velocity of 3.5 m/sec. The resolution of velocity control is 0.01 m/sec. To accomplish precision of velocity control on ice, traction control is done to prevent the robot from unintended slide. Precise orientation control of the robot is also important and the robot can control 0.05 degree of orientation in resolution. The property of tires on ice has been tested carefully and the tires with 240mm in diameter and 80 mm in width are selected finally.

4. Implementation of the Curling Robots

Fig. 13 shows a skip-thrower robot with covered cases. This robot can switch modes between skip and driving/throwing. One robot is operated in driving/throwing mode in one side. The other robot is ready for skip mode in the opposite side. Two sweeper robot catches up with the thrower robot and a curling stone after the stone is released near a hog line. CurlBrain decides starting/finishing time and duration of sweeping.

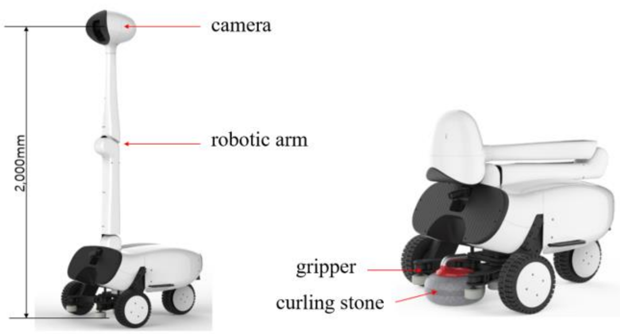


Figure 13. The skip-thrower robot. Skip mode(left) and driving/throwing mode(right)

Fig. 14 shows a demonstration game between Curly and a human player team held in March 2018. Two skip-thrower robots played the game without sweeping motion.

Although our robot team was defeated by a human team with score of 1:3 in four-end game, feasibility of the whole robot system(Curly) and the AI remote server(CurlBrain) was proven successfully. Fig. 15 shows a turn that human players make. The robot is waiting for its turn at the back of a hack.

Figure 14. Demonstration game of the skip-thrower robot. Skip mode(top), throwing mode of grasping a stone(middle), releasing the stone(bottom)

Figure 15. Demonstration game with human players.

5. Concluding Remarks

In this paper, we propose a new wheeled curling robot system consisting of four mobile robots; two skip-thrower robot and two sweeper robots. The skip-thrower robot can switch modes between skip and driving/throwing. The sweeper robot must be designed carefully, considering fast sensing of a curling stone and dexterous sweeping. The feasibility of the curling robots without sweeping motion was tested in a game with human players.

In the next stage of this research, implementation of the sweeper robots will be finished and games with sweeping motion will be tested.

Reference

[1] Cliff Frohlich, *The Physics of Winter Olympics Sports* Am. J. Phys. 79, 565 (2011).

[2] T. Kawamura, R. Kamimura, S. Suzuuki, K. Iizuka, *A study on the curling robot will match with human result of one end game with one human*, IEEE Conference on Computational Intelligence and Games(CIG), Aug 2015.

Acknowledgments

This work was supported by Institute for Information & Communications Technology Promotion (IITP) grant funded by the Korea government (MSIT) (No. 2017-0-00521, AI curling robot wich can establish game strategies and perform games).