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Experimental Validation of a Leg-wheel Hybrid Mobile Robot *Quattroped*

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***Abstract*—This video submission presents the experimental validation and testing of a leg-wheel hybrid mobile robot *Quattroped*. By combining the smooth and efficient motion of wheels on the flat ground with the great mobility of legs on rough terrains, the design of the robot aims for agile and versatile yet efficient locomotion in both natural and artificial environments. Compared to most hybrid platforms, which have separate mechanisms of wheels and legs, this robot is implemented with a transformation mechanism that directly changes the morphology of wheels (i.e., a full circle) into half-circle legs, each with 2 active degrees-of-freedom (i.e., combining two half circles as a leg). The experimental testing includes flat terrain driving and turning in the wheeled mode, leg-wheel mode switching, and step crossing, bar crossing, natural rough terrain walking, and stair climbing in the legged mode.**

I. Introduction

Legs and wheels are two widely adopted methodologies utilized on the ground locomotion platforms. After a long evolution process, most ground animals are evolved with agile and robust legs, which are capable of driving their bodies to move on the uneven natural terrains smoothly and rapidly. Wheels, in contrast, are smart human inventions specialized in rolling on the flat ground, whose excellent performance of power efficiency and traveling speed sets a high standard where the leg can hardly compete. However, even in the human environment, which has been altered mostly with flat ground, there are still certain environmental settings with height variations; stairs is the one widely seen. Thus, a leg-wheel hybrid platform with great mobility on both flat ground (by wheels) and rough terrain (by legs) seems to be an attractive combination suitable for general indoor-outdoor environments.

Various leg-wheel hybrid mobile robots have been reported: Shrimp rover [1], Loper [2], IMPASS[3], Paw[4], Whegs[5], and others. In addition, the hexapod robot RHex [6] uses alternating "tri" half-circles to simulate wheeled locomotion. Previously, the authors of this paper have reported on the design of a novel 4-leg/4-wheel hybrid mobile platform *Quattroped* [7] shown in Fig.1. Compared to most hybrid platforms, which have separate mechanisms of wheels and legs, this robot is implemented with a transformation mechanism that directly changes the morphology of wheels (i.e., a full circle) into half-circle legs, each with 2 active degrees-of-freedom (DOFs). This paper reports the experimental evaluation of the robot.

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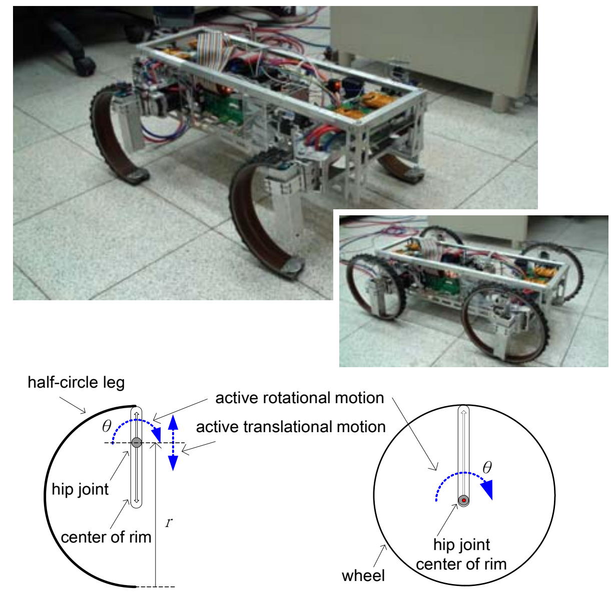

Fig. 1. Picture of the *Quattroped*, a leg-wheel hybrid mobile platform (top). Illustrative sketches of the leg-wheel motions (bottom).

II. Leg-wheel Mechanism

As shown in Fig.1, the 2-DOF driving mechanism provides two active driving motions: rotation of the spoke and translational adjustment of the "active spoke" defined by the distance between the hip joint and the rim. Equivalently, if the hip joint is defined as the origin, the 2-DOF mechanism drives the leg-wheel components along with two principal axes of the polar coordinate. At each hip, two DC motors are installed on the body side and they provide the desired rotational and translational movements by differential driving strategies. Thus, leg-wheels are free of complicated mechanical and mechatronic constructions, and their light weight improves the dynamic response of the motions.

The switching between one full-circle rim (wheeled mode) and two half-circle rims (legged mode) is driven by a DC motor installed inside the spoke, shown in Fig. 2. One half-circle rim is mounted on the spoke directly, and the other one is mounted on the rotating horn, on top of the motor, with 180° rotatable range. That motor is installed inside the spoke and its power and control signal are passed through a connector pair, which is controlled by a mini RC servo as shown in Fig. 2.

III. Characteristics of the Wheeled Mode

While the robot operates in the wheeled mode, the behavior is similar to that of general four-wheel-drive vehicles. Like most vehicles, the front wheels have the tuning capability, which is achieved by using two high-torque RC servo motors

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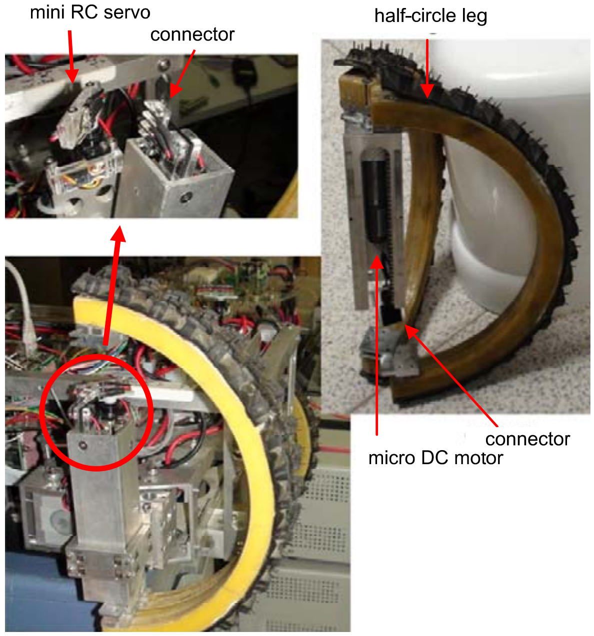

Fig. 2. Pictures of the transformation mechanism of the robot.

installed on the body. The turning control is programmed according to standard Ackermann steering[8].

As shown in the video, experimental evaluation shows that the robot in this mode can be driven and turned on flat ground stably and smoothly. In addition, since the DC motors are installed on the main body, the torque generated by the motors is mainly used to drive the robot forward smoothly, not on the change of body dynamics, which manages the power consumption efficiently.

IV. Characteristics of the Legged Mode

The advantage of the leg lies in its multi-DOF nature, so the leg can present adequate configuration, bridging the body and the terrain for locomotion. The design of the 2-DOF leg provides the required adjustability in the sagittal plane, and the rolling shape of the leg matches the idea of "distributed foot contact" to increase the mobility of the robot [9].

Two types of patterns can be generated in the typical leg motion: one is swing reposition (like animals do), and the other is full-rotation reposition. Experimental evaluation shows that the latter case provides better mobility on obstacle passing, owing to the large ground clearance. In addition, energy efficiency of the latter case in the current development is better as well.

As shown in Fig. 3 and in the video, experimental evaluation confirms that the robot in this mode can perform step crossing, bar crossing, natural rough terrain walking, and stair climbing [10, 11].

V. Conclusion

The video demonstrates various experimental evaluations of the robot. The differential drive and transformation mechanism are functional. The robot, in the wheeled mode, can drive and turn, just like an ordinary wheeled vehicle. The developed stable walking gait and preliminary cross-over trotting gaits are confirmed functional. Negotiation of several uneven terrains is also demonstrated.

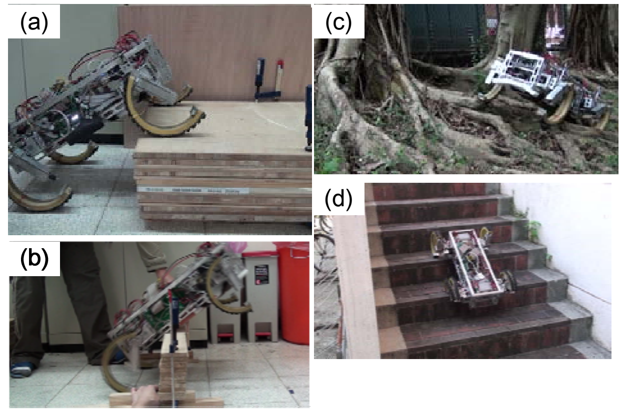

Fig. 3. The robot driven in various scenarios: (a) step crossing; (b) bar crossing; (c) natural rough terrain walking; (d) stair climbing

The authors are currently in the process of developing different legged gaits to enlarge the mobility of the robot, so it can be operated on wider variations of rough terrain. In addition, they are investigating the dynamic legged locomotion on the flat ground, to mimic animal locomotion.

VI. Acknowledgment

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