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Autonomous locomotion of Leg-Wheel Transformation robot

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ABSTRACT

The Leg-wheel method has gained method over the last decade in the number of robotic laboratories around the world. When applied to different platforms, it has independent mechanism and actuator for legs and wheels. This robot will perform with unique transformation mechanism which switches directly as driving mechanism on the wheels (full circle) and two degrees of freedom as leg (joining two divided circle as a leg). Then the actuating power is used in legged and wheeled modes. The robot performance will consider in various scenarios, including driving and turning in wheeled mode and walking on irregular terrain passing in legged mode.

KEY WORDS: Leg, locomotion, mobile robot, transformation, wheel.

1. INTRODUCTION

The Legs and wheels are two widely adopted methodologies utilized on ground locomotion platforms. After a long evolution process, the most ground animals are developed with agile and robust legs which are able of driving their body to move on the uneven terrains smoothly and rapidly. Wheels are the smart human inventions specialized in rolling on the flat ground whose excellent performance of power efficiency and traveling speed sets a high standard which can hardly be attempted by the legs. Therefore, a leg-wheel hybrid platform with high mobility on both flat grounds (via wheel mode) and rough terrains (via legged mode) seems to be on the track of 'future' mobile platforms suitable for general indoor & outdoor environments. The leg-wheel hybrid robots can be classified according to their morphology. One of the popular categories is "articulated-wheeled" robots, where the robots usually combine active or passive wheels on the feet of articulated legs. Roller Walker also has a passive wheel on the leg of each 3 degree-of-freedom (DOF) leg so that locomotion can switched from quadrupedal walking into roller skating on flat ground. Bipedal Walker has wheel driving mode when the wheeled foot module was mounted. Stair-climbing robot has four active and four caster wheels on the feet of its eight unified prismatic joint legs, which improves mobility on the flat ground. Likewise, robot PAW adds four active wheels on the distal ends of its compliant legs of the original quadruped. Robot Walk'n Roll also adopt a similar approach. Hylos uses active 2 degree-of-freedom suspension mechanisms on its four wheels to increase its mobility on the uneven terrain. The other popular method is "leg-wheel separated" robots, where the robots have both legs and wheels mounted on the body, and the motion of the robot is generated by collaboration of these two mechanisms. Chariot III has two wheels and four 3 degree-of-freedom legs. Wheeleg has pneumatically actuated 3-DOF front foot and two independently driven back wheels. A standard wheelchair with two front legs improves its mobility on step crossing. Octal Wheel has a unique wheel-arm mechanisms which are held by an arm with two wheels positioned on each side, and the robot is capable of climbing over obstacles such as stairs. Whegs driven by four 3-spoke wheels without "rims" has excellent mobility on both flat and rough terrains, which alters the morphology of wheels (full circle) into legs (joining two divided circle as a leg). The actuators are ideally positioned so the robot can actuate in both wheel mode (moves in 1-DOF rotational motion) and leg mode (moves in 2-DOF planar motion) correctly.

Leg-Wheel Transformation: Switching between wheel & leg modes of this transformation mobile robot is achieved by the transformation mechanism that includes a 2-Degree-Of-Freedom driving mechanism and a leg–wheel switching mechanism. The door hinges are attached to each wheel is free to move about its diametric axis. While driving mechanism on the leg-wheel component, rotation of the spoke and translational adjustment of 'active spoke' is defined by the distance between the hip joint and the rim. The 2-DOF mechanism is indeed driving the rotation 'θ' and the translation 'r' in polar coordinate. When the robot at the wheel mode, the rim must rotate about the hip joint with a uniform distance equal to the radius of the rim, and this set point position control needs the rotational movement of both motors with equal speed during locomotion. The rotational of the spoke, equivalent to θ, is driven by the rotational motion of the square sleeve, driven by motor 1 by belt transmission system composed of two pulleys and a timing belt. A rack installed on the spoke is driven by a pinion which connects to motor 2 directly. Then the kinematic equation of input (motor speed) & output (leg motion) can be calculated as,

$$\dot{\theta} = \begin{bmatrix} \dot{r} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} a & -a \\ 1 & 0 \end{bmatrix} = \begin{bmatrix} \dot{\varphi}_1 \\ \dot{\varphi}_2 \end{bmatrix} = J\dot{\varphi}$$

Where, a is the radius of the pinion, $\dot{\varphi}_1$ & $\dot{\varphi}_2$ are the rotational speed of the motor 1 and 2, Input (motor speed, $\dot{\varphi}_T = [\dot{\varphi}_1 - \dot{\varphi}_2]^T$), Output (leg motion, $\dot{\varphi}_T = [\dot{r}\ \dot{\theta}]^T$).

The switching between circle rims (at wheel mode) to two half-circle rims (at leg mode) is driven by a micro radio controlled servo motor installed on the one-half of the wheel. One half circle rim is mounted in the spoke directly, and the other one is mounted on the top of the radio controlled servo. The 180◦ rotational motion of the radio controlled servo turns the half circle rim next to the other half circle rim (leg mode) or away from the wheel mode. All the four micro servos mounted on the wheel will not get directly powered by wires as if we connect the servo directly to wire, all wires will be wrapped around the wheels during motion leading to the failure of the project. So power will be supplied with the help of the copper brush. And the important factor is, before switching wheel into leg all the spoke must be in a vertical position to move the center of the wheel to the diametric opposite end of the leg.

2. MATERIALS

Robot Frame: The robot's frame design is made of aluminum. Partially Annealed Al. grade-H2 type is used to make a 15*300*120mm. rectangular shaped body. The leg distance from each other is increased so that the movement of the robot is reduced and also the limitation posed by the leg movement is addressed. The construction of the robot frame as per its dimensions finalized using Solid works.

Table.1. Properties of Aluminium

Properties	Value	Unit
Elastic Modulus	6. 9e+010	N/m^2
Poisson Ratio	0.33	N/A
Shear Modulus	2-7e+010	N/m^2
Density	2700	Kg/m^3
Tensile Strength	68935600	N/m^2
Yield Strength	27574200	N/m^2
Thermal expansion coefficient	2.4e-005	K^{-1}
Thermal conductivity	200	W/(m K)
Specific Heat	900	J/(Kg K)

Arduino Mega: The Arduino is the open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It is dedicated to artists, designers and to create the interactive objects to the environment. It consists of an open hardware design on the Arduino board with Atmel AVR processor to support input and output. And the software contains standard program compiler boot loader runs on the board. The board which uses the Arduino programming language by wiring method and to develop the environment by processing method. Arduino used for controlling the motors like, DC Motors & Servo Motors. The robot needs the specific angle rotation of servo motors which is done by Arduino.

Motor Selection: A servo motor is a rotary actuator it allows for precise control of the angular position. It consists of a motor to the sensor for feedback position through a reduction gearbox. And also, it requires a relatively complicated controller, to module designed specifically for the use of servomotors. Then the motor is paired with some encoder for providing position and speed feedback. In the simple, the position is measured and considered as output. Then it is related to the command position, to the controller. Then the output position get differs from the required, then error signal formed which causes the motor to rotate in each direction. Then the position approaches, the error signal will reduce to zero and the motor stops. The Servos mounted on the wheel is used for transforming wheel to leg. The servos are not directly gets powered through wires since wires would roll in the main shaft and will stop the entire motion of the robot. So we are using brushes of copper to power the servo. Use for shifting the clutch requires one motor.

Power source: The Lithium polymer battery used in this project. This battery size is, and it helps to reduce the weight of the robot and provides 5.5 amp current and a voltage of 12.5 volts which is sufficient for DC motor and servo motor use further.

Project Objective: The project objective was broken into several key goals. The first was to evaluate literature encompassing the leg wheel transformation robot. This provides the basis for an information design approach based on the previous experiment and procedures by others. The other goal was associated with the development of a micro-controller based control system capable of maintaining the stability of the robot. The resultant physical circuitry will be finalized in a micro-controller unit design as part of another goal.

a) The research will be conducted into the theory of a wheel transforming and the various considerations that may be necessary during the construction of a leg wheel transformation robot. This will present an indication of the potential problems. This will provide overall direction of the project.

b) The prototype of the robot must traverse rough terrain comfortably by switching mode (leg or wheel) according to environment demands. The prototype must able to climb stairs makes as a multi-utility vehicle. The prototype must be controlled wirelessly via X_BEE with the range around 30 m.

c) Micro-controller unit is used for capable of achieving the control system will be completed including the necessary circuitry, sensor and circuit board. Additional the unit will be Configured with an interface for future incorporation.

d) The robot design will be finalized with the resultant resource requirements sourced.

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e) A completed final dissertation consisting of the design, simulation manufacture and testing processes used to derive the robot will be submitted.

Design Consideration: The modeling software was used to design the concept of this leg-wheel hybrid platform is to include a 'transformation mechanism' which is capable of deforming a specific portion of the body to act as a wheel or leg.

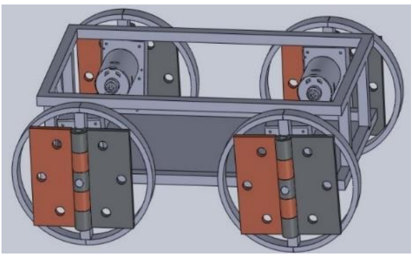

Fig.1. Design of wheeled Robot.

From a geometrical point, a wheel normally has a circular rim and a rotational axis placed at the center of the rim. The rim touches the ground, and the rotational axis connects to the moving platform at a point referred as a "hip joint" shown in Figure 2. On the flat ground, the contact point is direct below the hip joint with a fixed distance (radius of the circular rim), thereby fixing the height of the hip related to the ground. Shifting hip point out of the center of rim indicates the locomotion is switching from wheeled mode to the legged Mode. It motivates us to do a design mechanism which can directly constrain the relative position of the hip about rim. Although the circle is a 2D object, the straight forward method is to leave the hip point along radial direction of the circle (rim).

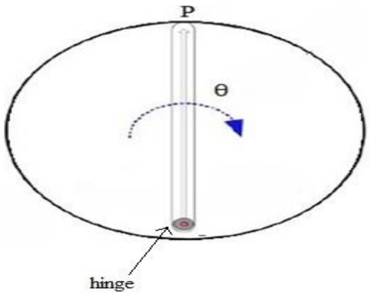

Fig.2. Hinge joint at wheeled mode.

The inertia of leg and space is taken by the leg strongly change the function and agility of leg motion. To decrease the inertia of moving rim, it is supported by a single spoke, which also acts as the housing of moving hip point. To reduce the space taken by the rim, in the leg mode the rim is folded in the half-circle leg with active actuation on hip rotation and on radial motion of the hip, and the leg itself is identical to have 2 engaged (active) DOF along with two principal axes in the polar coordinate. In leg mode, the rim is folded in half, and the hip point is moved near to the rim, and then the platform is transformed into a quadruped robot shown in Figure 4. A change of leg length adjusted by changing the position of the hip joint in the spoke and movement of the leg is driven by rotational joint at the hip. The leg mode is designed for the platform to have the capability to cross uneven terrains also.

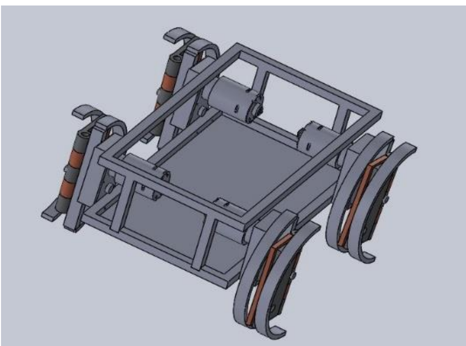

Fig.3. Design of Legged Robot

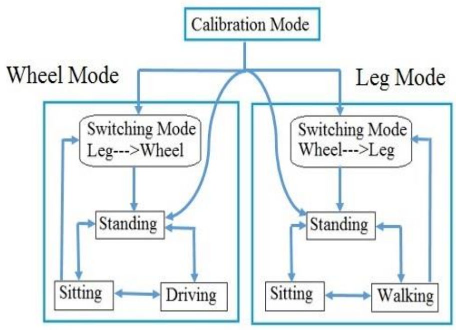

Fig.4. Behavior of the robot

3. CONCLUSION

The robot operated with a transformation mechanism is capable of changing the property of its wheels into 2 degree-of-freedom legs, where the similar set of actuators can use in both modes. It follows that the robot can act as either a wheeled mode or as the legged mode. And the transformation mechanism is also described in detailed. Through the design of a 2 degree-of-freedom differential driving module, motor power can be effectively utilized in both modes. By performing several experimental trials, the validity of the design of the transformation mechanism is tested and estimate the driving and walking behavior of the robot is evaluated.

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