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IMPASS: Intelligent Mobility Platform with Active Spoke System

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Abstract— **IMPASS (Intelligent Mobility Platform with Active Spoke System) is a novel mobile robot driven by two rimless spoke wheels. Each of the spokes can be individually actuated with intelligent motion planning to walk over uneven terrain with high mobility. This form of novel locomotion has the potential to combine the efficiency of a wheeled robot and the mobility of a legged robot. A highly mobile robot such as IMPASS could prove very valuable in applications where the terrain is complex and dangerous, such as search and rescue, reconnaissance, or anti-terror response. This video presents an overview of the system concept with examples and demonstrations of its unique mobility. Beginning with an overview of the system concept and hardware, the video then demonstrates the different mobility advantages. These include rough terrain locomotion, dynamic surface locomotion, and large step climbing.**

I. INTRODUCTION

Recently, leg-wheel hybrid robots have been drawing more attention since they have the advantages of both legs and wheels. Legged locomotion is more adaptable to a wide range of unstructured grounds, but the complicated mechanism of the legs is very difficult to implement. On the other hand, wheeled locomotion is fast and efficient, but it tends to be limited to relatively smooth terrain. Therefore, in order to create a walking machine that combines the benefits of both locomotion schemes, the combination of legs with wheels creates a more effective candidate. Previous researchers considered designing a robot that has both wheels and legs, such as RHex [1] and Whegs [2].

Recently, the Robotics and Mechanisms Laboratory (RoMeLa) at Virginia Tech utilized the concept of actuated spokes and proposed a novel hybrid locomotion platform IMPASS, Intelligent Mobility Platform with Active Spoke System, as shown in Figure 1, which incorporates the benefits of wheeled, legged, and spoke systems. The prototype demonstrated in Figure 1 has two spoke wheels and one tail. It is designed to walk on various terrains, cross over obstacles, and climb up steps using its unique ability to intelligently extend and retract its spokes. System design, kinematic modeling, and preliminary analysis on motion profiles, walking, and turning states have been investigated in previous works [3-8].

II. HARDWARE DESIGN

The unique abilities of IMPASS come from the novel hub mechanisms as well as the curved shape of the body. The design has evolved from a hub feasibility concept to a working prototype, including a composite body structure as seen in Figure 1.

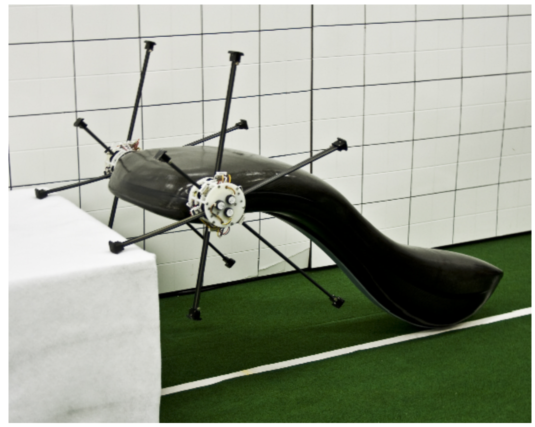

Fig. 1. IMPASS Prototype

A. Hub Design

Each hub on IMPASS consists of three interlocking layers allowing the spokes to pass next to each other without interference. The compliant carbon fiber spokes utilize a tensioned chain and sprocket drive pictured in Figure 2. The chain is driven with a larger central drive sprocket and is routed around two smaller idler sprockets. The combination of the black pulleys and the three-sprocket chain drive ensures that as the spokes flex the chain will not come off of the drive sprocket.

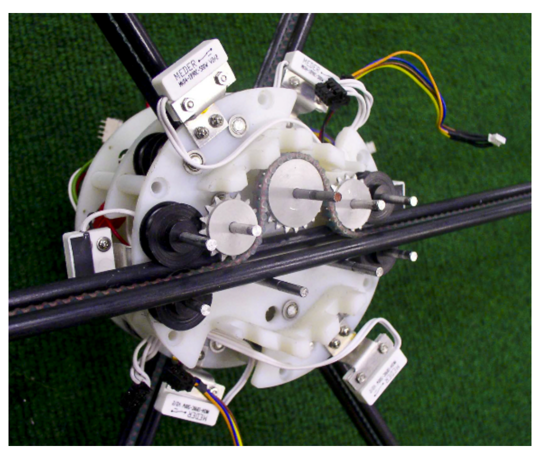

Fig. 2. IMPASS Hub Internals

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B. Body Design

The body of IMPASS is a curved carbon fiber shell. The curved shape is designed to decrease the contact angle between the body and obstacles as IMPASS climbs. This lower contact angle allows IMPASS to climb vertical steps while limiting the force required to pull the tail up the step. The high durability and strength of the carbon fiber shell protects all internal components, including the future computer and batteries.

C. Actuators, Sensors, and Control Hardware

Each hub on IMPASS must contain three separate sets of independent control hardware; one to control each spoke. Each spoke is driven by a Portescap 17N servo motor, and is controlled by an AllMotion EZSV10 motor controller using an optical quadrature encoder, and two magnetic reed limit switches. Each hub is driven by a Maxon RE30 servo motor through a 90 degree worm gearbox. Each hub is independently controlled using an AllMotion EZSV23, with a Maxon HEDL 5540 optical quadrature encoder and a linear cam limit switch.

Terrain information is gathered through the use of a firewire camera, as well as a Hokuyo laser range finder. Future plans for additional sensors include integration of a touch sensor into each foot.

Currently IMPASS is controlled by LabVIEW running on an external laptop through a RS-485 serial connection. Under development is a PC-104 computer setup which will take over all control and allow the removal of the tether. Power is provided by an external power supply, but when the tether is removed nine lithium-ion batteries will take over the task.

III. MOBILITY ADVANTAGES

The unique locomotion concept of IMPASS allows it to travel over obstacles many vehicles cannot. The following are three examples of unique sets of circumstances which lend themselves well to the IMPASS design.

A. Rough Terrain Locomotion

One of the missions of IMPASS is search and rescue. While performing this mission terrain is often unpredictable and rarely level. Small obstacles including debris and holes can cause problems for many wheeled robots. While a tracked robot does better with these types of obstacles, IMPASS is in its own class. By adjusting the spoke length, IMPASS can either step over an obstacle completely, or conform to the terrain. Obstacles such as potholes are overcome by extending a spoke further down than during flat walking and reaching the bottom of the obstacle. If this is impossible, IMPASS can extend its walking stride and step over the obstacle. For the current configuration, the maximum horizontal step is approximately 0.91 meters.

B. Dynamic Surface Locomotion

Many types of terrain found in natural environments are dynamic, including sand, dirt, moss, and small gravel. While many legged robots can traverse these types of terrain, they move relatively slowly in doing so. Wheels travel much faster over harder terrain, but may be completely unable to pass over many of the soft obstacles found in nature. IMPASS can maneuver over a multiplicity of surfaces with little to no reduction in speed, due to the active adjustment of the spokes.

C. Large Step Climbing

The most unique advantage of IMPASS is the ability to climb a step much higher than the robot. By raising the hubs to their maximum extension, and extending the non-adjacent spoke up, the robot can climb a vertical obstacle $\sqrt{3}$ times higher than the nominal spoke length of 0.55 meters. The current configuration of IMPASS allows for a maximum vertical step of about 0.91 meters. The feet of IMPASS are designed with a slight hook on either side to help the foot catch on the obstacle and pull the robot up.

IV. CONCLUSION

IMPASS is a novel spoke-wheel robot developed in the Robotics and Mechanisms Laboratory (RoMeLa) at Virginia Tech. Driven by a rimless spoke wheel, this form of novel locomotion has the potential to combine the efficiency of a wheeled robot and the mobility of a legged robot. Many terrain obstacles lend themselves towards a highly mobile robot such as IMPASS. The mobility advantages of IMPASS could prove very valuable in applications where the terrain is complex and dangerous, such as search and rescue, reconnaissance, or anti-terror response.

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