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Introducing DAGSI Whegs™: The Latest Generation of Whegs™ Robots, Featuring a Passive-Compliant Body Joint.

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DAGSI Whegs™ is the latest generation of full size Whegs™ robots (Fig 1). The robot is designed for collaborative work with the Air Force Institute of Technology (AFIT) in SLAM with active feature recognition. Whegs™ vehicles use abstracted biological principles to navigate over irregular and varied terrain with little or no low level control [1,4,5]. Torsionally compliant devices in the drive train of each wheel-leg allow its gait to passively adapt when climbing large obstacles or steep inclines. Whegs™ is similar to the RHex line of robots [2] that preceded Whegs™ in that the foot motion of all 6 legs is circular, but it differs in many aspects: 3 leg-spokes versus 1, 1 drive motor vs. 6, leg rotation for steering instead of skid steering, passive gait adaptation vs. active gait control, and Whegs™ has a body joint.

DAGSI Whegs has a sealed body that allows it to move in mud, rocks, snow as well as indoors without contaminating its fragile components. The body joint has a sealed pass-through for wiring. These adaptations will also allow us to explore amphibious concepts of the Whegs™ design [3]. Its current foot design has a rigid high-traction surface for outdoors, with a soft boot that can easily be installed for indoor use. It has the power to climb steep inclines and full-height stairs. A single 150 Watt drive motor can deliver all of its torque to any of the six wheel-legs. The weight of the robot is 14 kg, and it can climb stairs with 5 kg of payload. Its small turning radius allows it to navigate stairwells and buildings, as well as rugged outdoor terrain. Two four bar mechanisms cause all four turning wheel-legs share the same center of rotation, as in Ackerman steering. This provides optimal turning, and reduces impact loading on the steering servos. DAGSI Whegs has two large flexible payload bays, each measuring 7” by 13” for sensors, power and control electronics.

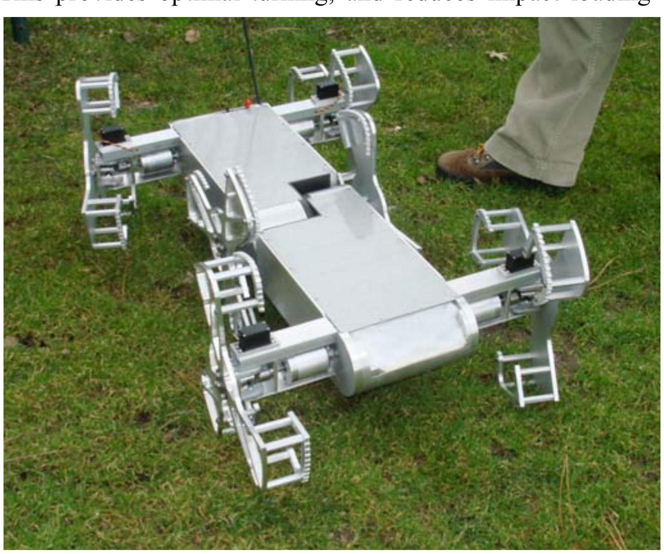

Figure 1: DAGSI Whegs™ with outdoor feet.

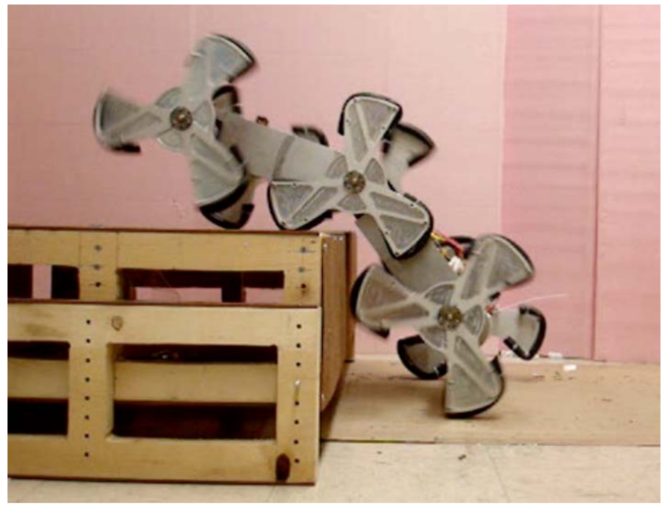

Figure 2: DAGSI Whegs™ successfully climbing a 34 cm obstacle.

Unlike previous Whegs™ designs, DAGSI Whegs™ has a body joint that is passively compliant but actively controlled. This provides many benefits, including allowing the robot to climb over much larger obstacles and reducing the chances of getting stuck in rough terrain. The passive compliance also acts as a suspension, sharing the loads among the wheel-legs and isolating the body from damaging impacts. The coaxial body joint design is watertight and allows for wires to pass between the body segments. When the body joint motor drives the joint actively, a worm and driven gear function in a normal fashion. However, when the front of the body experiences a load, the worm is not backdriven. Instead, the worm slides axially but not radially on its shaft, and is cushioned on both sides by Belleville springs (Fig 3). This reverse action is effectively a rack and pinion, where the front body segment is the pinion, and the worm is a spring-loaded rack. Such a design could also be controlled in a manner similar to series elastic actuators [6].

With a locked body joint and a wheel-leg radius of 7” (18 cm), the maximum height rectangular step the robot can overcome is 10.5." (or 27 cm) On larger obstacles, the vehicle high-centers and falls backwards. The middle wheel-legs can get on to the obstacle, but the resultant force pushes the robot’s center of gravity behind its ground-reaction forces. With an active body joint, an obstacle height of 13.4” (or 34 cm) was overcome (Fig 2). Initially, the robot flexes its front end up to help the foot land flat on top of the obstacle. Once the front wheel legs are situated on top of the obstacle, the front body segment flexes down, lifting the middle wheel-legs up, allowing them to get a foothold on top of the obstacle. The robot then moves forward and once the center of gravity of the robot is on top of the obstacle, it slowly flexes its front segment up again to allow the rear legs to climb up.

Figure 3: The inner workings of the passive compliant body joint. The worm is cushioned on the axle by Bellville springs. The wiring pass through can be seen above the driven worm gear.

On higher obstacles than this, the rear wheel-legs leave the ground before the robot's center of gravity is positioned safely on top of the obstacle. Future work will look at the importance the location of the center of mass plays in obstacle climbing, as well as the size and shape of the wheel leg.

In summary, Dagsi Whegs™ incorporates many new design features that make it the most robust and versatile full-size whegs to date, and we believe it will be exceptionally well suited for autonomous robotic missions. Furthermore, the innovative body joint design may have many applications in robotics where a measure of passive compliance is desirable.

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