Verti-Wheelers: Wheeled Mobility on Vertically Challenging Terrain

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Project Website: `https://cs.gmu.edu/~xiao/Research/Verti-Wheelers/`

Fig. 1: The Verti-Wheelers: Conventional Wheeled Vehicles Moving through Vertically Challenging Terrain.

Due to their simplicity and efficiency, wheeled robots have been widely used in various applications such as scientific exploration [1], autonomous delivery [2], and search and rescue [3]. Equipped with differential-drive mechanism [4], Ackermann steering [5], or omnidirectional wheels [6], these robots can move through their planar workspaces, avoid obstacles, and reach their goals. However, for any vertical protrusions from the ground, e.g., large boulders or fallen tree trunks, these systems always treat them as non-traversable obstacles due to mobility limitations caused by the wheels.

To overcome the limitations of wheels, researchers have developed robots with alternative actuation: wheels can be replaced by legs when facing extremely rugged terrain [7], [8]; active suspensions are widely used on planetary rovers to achieve better maneuverability, reconfigurability, and therefore mobility by allowing the chassis to actively conform to different underlying terrain [9], [10].

Despite their superior mobility on vertically challenging environments, these costly, specialized hardware require extra engineering effort and may adversely affect vehicles' mobility and efficiency on flat environments. Considering that most ground robots are wheeled with no or passive suspension systems, we present an open-source design of two wheeled robot platforms, the Verti-Wheelers (VW), which are representative of the majority of existing conventional ground mobile robot platforms, and hypothesize that conventional wheeled robots can also navigate many vertically challenging environments (Fig. 1). We identify the following seven desiderata for their hardware: All-Wheel Drive (D1), Independent Suspensions (D2), Differential Lock (D3), Low/High Gear (D4), Wheel Speed / RPM Sensing (D5), Ground Speed Sensing (D6), Actuated Perception (D7).

For the mechanical components in D1 to D4, we base

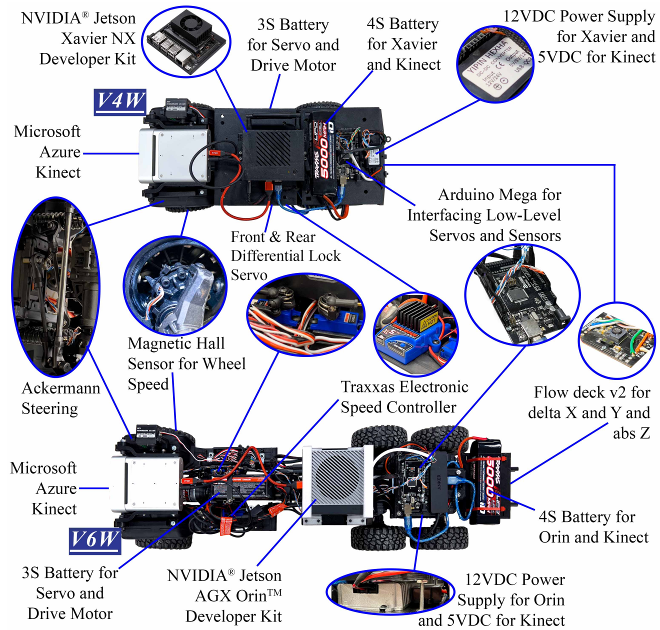

Fig. 2: Components of the Verti-Wheelers.

our platforms on two off-the-shelf, two-axle and four-wheel, three-axle and six-wheel, all-wheel-drive, off-road vehicle chassis from Traxxas. D1 and D2 are therefore achieved. We use an Arduino Mega micro-controller to lock/unlock the front and rear differential (D3) and switch between low and high gear (D4) through three servos. For D5, we install four magnetic sensors on the front and rear axles for our Verti-4-wheeler (V4W) and on the front and middle axles for our Verti-6-Wheeler (V6W), and eight magnets per wheel to sense the wheel rotation. For D6, we install a Crazyflie Flow deck v2 sensor on the chassis facing downward, providing not only 2D ground speed (x and y) but also distance between the sensor and the ground (z). We choose an Azure Kinect RGB-D camera due to its high-resolution depth perception at close range. For D7, we add a tilt joint for the camera actuated by a servo. We use a complementary filter to estimate the camera orientation and a PID controller to regulate the camera pitch angle. We use NVIDIA Jetson AGX Orin and Xavier NX to provide both onboard CPU and GPU computation. To interface all low-level sensors and actuators, we use the Arduino Mega micro-controller. The mechanical and electrical components for both V4W and V6W are shown in Fig. 2

During the demonstration session, we will showcase our VW platforms and demonstrate their autonomous crawling and navigation capability on vertically challenging terrain with a small-scale rock testbed.

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