RED RAVEN, THE LINKED-BOGIE PROTOTYPE

Ara Mekhtarian, Joseph Horvath, C.T. Lin

Department of Mechanical Engineering,

California State University, Northridge

California, USA

Abstract

RedRAVEN is a pioneered autonomous robot utilizing the innovative Linked-Bogie dynamic frame, which minimizes platform tilt and movement, and improves traction while maintaining all the vehicle's wheels in contact with uneven surfaces at all times. Its unique platform design makes the robot extremely maneuverable since it allows the vehicle's horizontal center of gravity to line up with the center of its differential-drive axle. Where conventional differential-drive vehicles use one or more caster wheels either in front or in the rear of the driving axle to balance the vehicle's platform, the Linked-Bogie design utilizes caster wheels both in the front and in the rear of the driving axle. Without using any springs or shock absorbers, the dynamic frame allows for compensation of uneven surfaces by allowing each wheel to move independently. The compact and lightweight ground vehicle also features a driving-wheel neutralizing mechanism, a rigid aluminum frame, and a translucent polycarbonate weatherproofing shell.

INTRODUCTION

Red RAVEN, the grand award winner of the 2011 Intelligent Ground Vehicle (IGV) Competition, is mechanically designed to navigate through an autonomous course fast and efficiently. The Cal State Northridge IGV Team designed the vehicle with the innovative Linked-Bogie dynamic frame, which minimizes platform tilt and movement. It also improves traction while maintaining all the vehicle's wheels in contact with uneven surfaces at all times. Its unique platform design makes the robot extremely maneuverable since it allows the vehicle's horizontal center of gravity to line up with the center of its differential-drive axle. Additional key features include a vertically stacked component layout, a light-weight aluminum frame and a polycarbonate shell.

1. Horizontal Center of Gravity (HCG)

Unless a differential drive vehicle can balance the weight of its platform on the two driving wheels similar to a Segway, an additional and floating or caster wheel is required to support the platform weight. One of the design challenges is the positioning of the HCG between the driving axle and the floating wheel to keep the vehicle stable on graded surfaces.

In contrast to most differential drive ground vehicles that use caster wheels either in front or at the rear of the driving axle, the Linked-Bogie design incorporates caster wheels both in front and in the rear of the vehicle to balance the weight of its platform over the driving wheels. Since maneuverability and efficiency are the key aspects of the design, the component layout is designed to center the HCG with the driving axle, resulting in smoother turning.

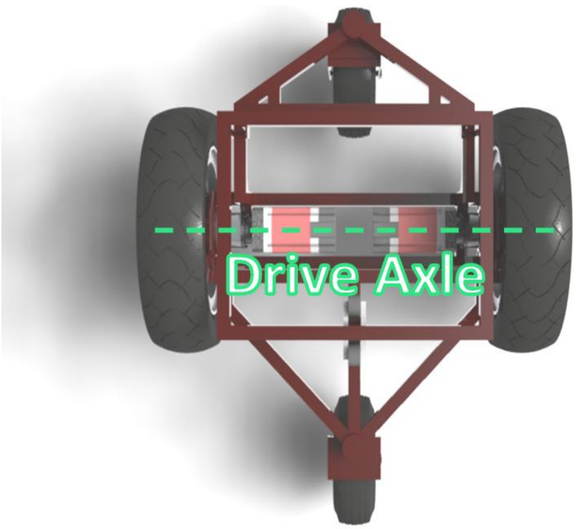

Figure 1– Centered driving axle (Top view).

2. POWER TRAIN

The differential drive system is chosen because it allows a ground vehicle to make zero-radius turns in a tight course, and to simplify motion control and navigation algorithms. The drive train consists of two Quicksilver Controls brushless servo motors, coupled to Apex Dynamics 20:1 gear ratio speed reducers. The power train allows the IGV to quickly accelerate to a top speed of 6.5 MPH, and produces sufficient torque for the vehicle to climb up a 30 degree incline. The inline gearboxes center the weight of the drive train with the driving axle.

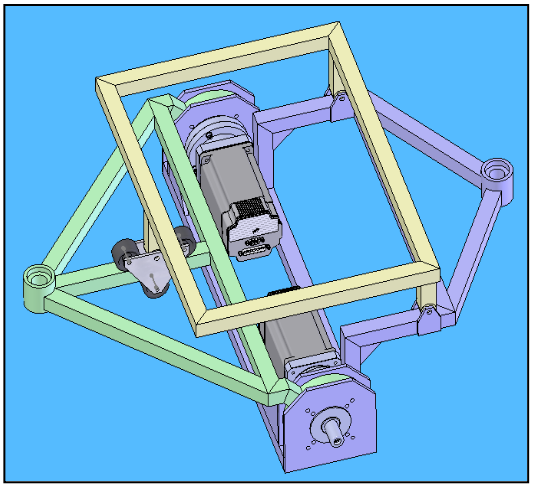

Figure 2– Drive train centered with driving axle.

3. Linked-Bogie Frame

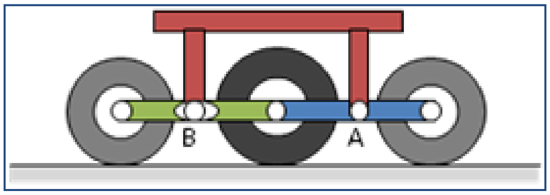

Figure 3 – Basic schematic of Linked-Bogie frame (Side view)

After analyzing multiple design iterations, the Linked-Bogie frame design was found to be ideal for a differential drive vehicle. The Linked-bogie platform (Figure-3) is propelled by two driving wheels (Center), and balances itself with the help of two floating wheels (Front and Rear). The frame mechanism consists of two links (Green and Blue), which connect the center driving wheels to the front and rear floating wheels, and form two bogies linked together at the center of the driving axle. The configuration of the links allows each wheel to move in the vertical direction independently of the other wheels. Since the weight of the main platform (Red) is distributed equally between pivot point “A” at the center of the blue link, and slide “B” at center of the green link, the load on the driving wheels is double the load on the caster wheels, therefore improving traction of the driving wheels, and reducing rocking of the caster-wheels on straight paths at high speed, and constrictions from the caster wheels during sharp turns.

As a result of the dynamic frame, the travel and tilting of Red RAVEN’s main platform, where the sensors are mounted, are both reduced. The vertical movement of the main platform is minimized since points “A” and “B” move half as much as the centers of the wheels. In addition, each wheel can

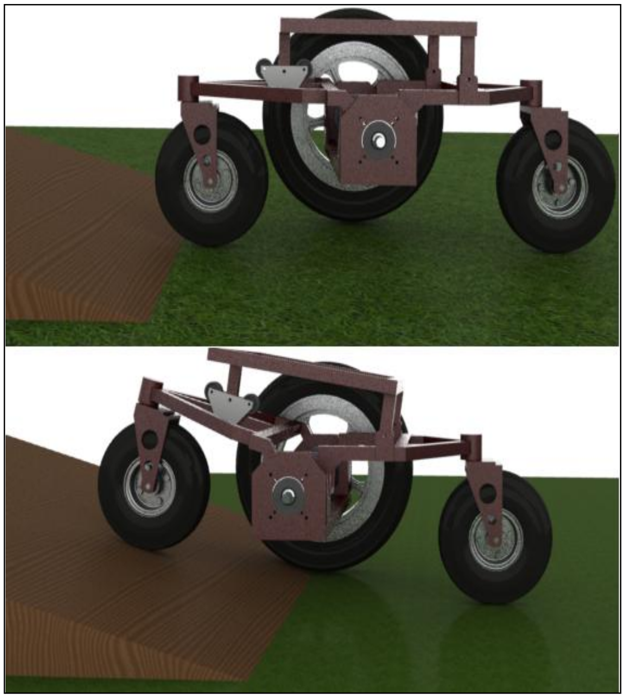

Figure 4 – Dynamic frame adapts to ramp

move independently in the vertical direction, which allows Red RAVEN to maintain all wheels in contact with uneven surfaces at all times (Figure-4).

The chassis is fabricated from 1-inch square 6063 aluminum tubing, chosen for the material's high strength to weight ratio. The aluminum tubing is TIG welded with sealed corners, thereby maximizing the rigidity of the frame and minimizing oxidization of the tubing inner walls.

4. Vertically Stacked Frame

When designing the component layout, three goals needed to be achieved. The first goal was to center the CG with the driving axle, and second, to keep the CG as low as possible. The third goal was to concentrate the mass as close to the center vertical axis as possible, thereby minimizing the robot's rotational inertia during sharp turns.

The ultimate design was found to be Red RAVEN's vertically stacked frame (Figure-5). The design allows for optimal component layout and accessibility, where the heavier components are placed at the bottom and the lighter components are placed at the top. The drive train, batteries, and motor controllers are mounted at the bottom of the robot since they account for most of the robot's weight. The lighter components, such as the Printed Circuit Board (PCB), laptop, GPS receiver, and antenna, are placed higher up on the vehicle. Some exceptions include the location of the Inertial Measurement Unit (IMU) in order to obtain accurate data. Additionally, the PCB is mounted in a central location in order to minimize cable length. Overall, the CG is kept relatively low as shown in Figure-5, and the concentration of mass is kept as close to the central vertical axis of the vehicle as possible. As a result, Red RAVEN can perform fast and efficient turns and remain stable while doing so.

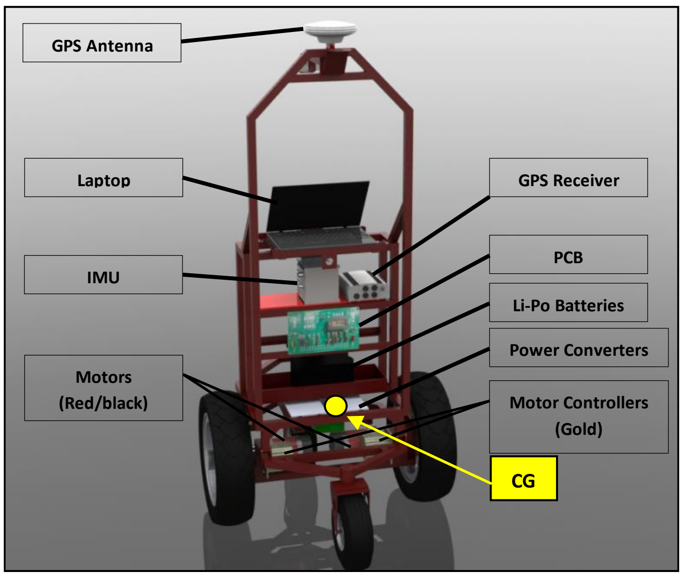

Figure-5 – Component layout, vertically stacked frame

5. Drive Axle De-couplers

Another innovative aspect of Red RAVEN's design is the drive wheel de-couplers. Most robots are designed to have their drive train keyed directly to the driving wheels. The disadvantage of such a design is that, when the robot isn't powered on, it is not possible to roll the robot without risking damage to the drive train. Transporting the robot would require special equipment and handling. To simplify and speed up Red RAVEN's transportation, the vehicle features a mechanical drive wheel de-coupler, to give the user the ability to decouple the drive train from the drive wheels. As shown in Figure-6 below, the drive wheel is mounted to the blue wheel hub. The gearbox output shaft is keyed to the pink inner shaft of the de-coupler.

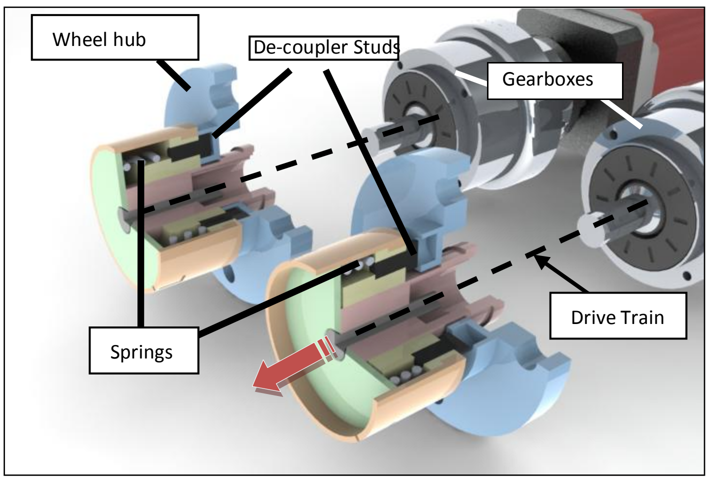

Figure-6 - Driving wheel De-coupler.

The yellow coupler, which is also keyed to the pink inner shaft, has four black studs that insert into the blue wheel hub when the coupler is engaged, thereby coupling the drive train to the diving wheel.

Note that in the left de-coupler, the black studs are inserted in the blue disk, whereas in the right de-coupler the black studs have disengaged from the blue disk. Furthermore, the coupling hub is spring loaded, and locks mechanically when de-coupled. To decouple the motors, the user merely needs to pull out the spring loaded hub and turn it to keep the drive train in a position where it is disengaged from the drive wheels. To engage, the user simply turns the hub in the opposite direction. The feature significantly speeds up relocating the robot during testing and eliminates the need for special handling.

6. Weather-proofing, Serviceability

From a first glance at Red RAVEN, the feature that attracts most attention is the polycarbonate weather-proofing shell. Polycarbonate is used because of its low weight, transparent, durable, and UV resistant properties. Additionally, polycarbonate sheet can be shaped by cold deformation using simple sheet metal tooling. During an inspection, all of the components within the poly enclosure are visible despite being covered from humidity and rain. Red RAVEN not only enjoys protection from unwanted moisture while keeping its components clean, but also looks

Figure- 7- Polycarbonate shell

professionally elegant.

Maintenance and serviceability have been key factors in Red RAVEN's overall design. To facilitate access to the components, the polycarbonate shell opens with the twist of a knob, and stays firmly open with the help of a gas spring mechanism (Figure-8). The side and bottom panels are mounted via thumbscrews, and are easily removable when needed, without the need of any tools.

Figure-8 – Poly shell opens

An additional key feature of the Linked-Bogie frame design is the fact that the main platform can detach from, or pivot on the bogies, allowing full access to the drive train. Servicing the motor compartment below the top platform becomes very convenient once a single bolt is removed from the front slide. Once the bolt is removed, the entire top platform can be pivoted down to allow access to the motors, as shown in Figure-9 below.

Figure-9 – Main platform tilts.