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1. System Description

a. Mobility

i. The vehicle makes contact with the ground with two standard motorcycle off-road racing tires (Maxx Cross HT). The front tire is slightly thinner than the rear tire. The front tire is also slightly taller than the rear tire. Refer to confidential appendix 1A1-0 and 1A1-1 for illustrations and figures.

ii. Vehicle locomotion is provided by two wheels aligned in a single track. Propulsion is generated by a 4-stroke gas engine and transmitted to the rear wheel via a chain drive. Steering is achieved by turning of the front wheel in opposite direction of the desired heading. This causes the vehicle to lean in towards heading. Braking is achieved using drum brakes on only the front wheel. For more information please see confidential appendix 1A2.

iii. There are 14 components that actuate. They are:

1. The main engine is controlled by clutch, throttle. Power is transmitted to the wheels using a standard chain drive.
2. The clutch is controlled by using Hitec HS-805BB+ RC servo operating at 6V geared 5:1 with modified servo horns to create 2000 oz-in of torque. Pulse Width Control with 1500usec Neutral (PWC) is used to control the position of the servo.
3. The throttle is controlled by using Hitec HS-805BB+ RC servo operating at 6V geared 5:1 with modified servo horns to create 2000 oz-in of torque.
4. Front brake (drum brake) actuated by Hitec HS-805BB+ RC servo operating at 6V (343 oz-in of torque). PWC is used to control the position of the servo.
5. Steering actuator (determines the angle of the front wheel) is controlled via Pulse Width Modulation (PWM) through a 16kHz speed controller. The actuator consists of a permanent magnet 3000 watt 24V DC motor, an optical encoder, potentiometer and an 20:1 worm gear reducer.
6. The sensor gimbal assembly ensures that onboard microcontroller is aware of the attitude of the sensor. Actuation of four Hitec HS-805BB+ RC servo operating at 6V (343 oz-in of torque) (two for roll axis and two for pitch axis) attempt to maximize sensor availability. Sensors need to be properly oriented to be useful, the sensor gimbal assembly provides roll and pitch compensation.
7. Automatic kickstands (left and right) are actuated through 150 watt 24v servo motors.

b. Power

i. Currently we use an internal combustion four stroke 124cc engine for propulsion, a .61ci two stroke engine for CMG angular momentum

maintenance (the CMG must be brought up to speed separately). A 12V lead-acid battery pack is connected to the main engine with a 100 watt alternator for recharging this system powers the electronics on board. A 24V sealed lead acid battery pack is also present for steering and kick stand actuation.

ii. Vehicle propulsion < 30,000 watts

Steering motor < 3,000 watts

Kickstand actuation < 1000 watts

Obstacle Sensing < 300 watts

Processing < 400 watts

Component actuation < 750 watts

Total peak power < 40,000 watts

iii. Currently the vehicle carries .125 Gallons of two-stroke gas, 4 gallons of 92 Octane gas.

c. Processing

i. Hardware components include:

Single Board Computer (SBC) using AMD Athlon 64 bit chip and 512MB RAM. The function of the SBC is to process data from the cameras, read the orientation of the sensor mount, interface with the gps receiver and path planning.

Microcontrollers (MC): One MC based on AMD 186 chips used for Datalogging and interfacing with the speed controllers, PWC output functions to control the RC servos mentioned in 1-a-iii.

One MC based on AMD 586 chips used for interfacing with the Crossbow VG400 MEMS gyro (for attitude information), optical encoders (steering, speedometers [front & back wheels]). Behavior state selection, vehicle balancing,

On-board IC processing includes the following devices:

Optical Encoder interface board (OE), this piece of hardware allows for interfacing of eight absolute encoders using only one RS232 port.

Crossbow Inertial Measurement Unit (IMU) integrated Kalman filter and angular bias elimination to provide direct roll, pitch and heading angles.

d. Internal Databases

i. The only two databases that the vehicle will have pre-stored are the provided waypoint (RDDF) and our augmented waypoint set (ARDDF).

The ARDDF will be generated using a custom application that allows pre-race offline processing of satellite imagery to increase the density of waypoints to provide a tighter route for the vehicle to follow.

The ARDDF will contain no imagery data. The data will be terrain information derived from processing a priori imagery and map data.

The data sets we intend to use are commercial satellite maps 3 feet resolution and 15 feet horizontal accuracy. Processing of the data will

be both manual and automatic.

Automatic data processing will be limited to image stitching and terrain type detection. Terrain type detection is simply categorizing large areas of maps based on the contrast of the pixels in the image. Using manual processing, we intend on viewing individual sections of the map and identify terrain types and set borders between terrain types.

The data processing is intended to provide the vehicle with information to help its terrain type detection. For example, a dry lake bed would be easily identifiable from maps and imagery. Knowing its position, the vehicle can more accurately detect the type of terrain it is over. The imagery will also be used for setting additional speed limits based on contrast. For example, if the dry lake bed is surrounded by small vegetation patches, the imagery will be darker which will indicate that the terrain is more likely to contain obstacles.

e. Environment Sensing

i. Cameras, sensor type is Machine vision and is passive. The sensor horizon is visual, but the ability to focus is limited by the camera (current range is 1 meter to infinity). Custom application was written to interface with PC using a standard USB webcam as a capture device. The application takes the of the pixel motion. This determines which objects are moving fastest and which are slow. This gives us information on objects closing in fast on the vehicle (i.e. rocks, trees and other obstacles). It will also allow us to track a vehicle by identifying it as a fixed object with respect to our own vehicle motion.

Millimeter Wave (MW) sensor Model # ELSC71-1A, manufactured by Epsilon Lambda, (same 77Ghz sensor as all the other teams). This is an active sensor which is based on RF radiation and has a range of 40 meters. The primary purpose is detecting object that represent a danger to the vehicle, like another vehicle or a wire fence. This unit was shipped to us damaged and we have not received the repaired unit back yet.

ii. The cameras are mounted on a gimbaled gyro-stabilized sensor mount directly above the front wheel. No sensor protrude from the vehicle.

f. State Sensing

i. The attitude of the vehicle is determined by two Crossbow MEMS gyro (VG 400, AHRS400). The VG400 provides pitch angle, pitch rate, roll angle, roll rate, yaw angle, xyz accelerations. The AHRS400 provides the same info as the VG 400, but also yaw angle (heading). Steering position is determined by an Absolute Optical Encoder (AOE) and a potentiometer. Wheel rotational positions are determined by

AOEs.

Engine RPM is not computed as this time.

Gear position is not determined at this time.

ii. Vehicle performance is not monitored. The vehicle behaves as follows. First priority is maintaining vehicle stability. Once this is achieved, the vehicle will ask the sensors if there is any required direction (due to obstacles). If there are none, then the vehicle will attempt to proceed along the RDDF trajectory.

g. Localization

i. Geolocation information is obtained by processing two signals. GPS and Omnistar positioning correction signals.

To safely navigate in a 10 feet wide corridor, our vehicle needs a positioning accuracy of 4 feet. We will use Omnistar to provide DGPS correction signal.

ii. In the event of a GPS failure, the vehicle will use its front and rear wheel AOEs to perform dead reckoning to approximate positioning information. The accelerometers and gyros of the Crossbow VG400 will provide supplement information to provide inertial validation of dead reckoning in the event of wheel slippage (in sand for example).

iii. The RDDF will provide the vehicle with maximum speed based on the proximity to a course boundary the closer to the boundary the more stringent the speed limit. If the vehicle exceeds the boundary the vehicle will slow to stop, correct its trajectory and proceed. If the vehicle is unable to correct its trajectory it will stop and shut itself off.

h. Communications

i. No

ii. GPS signal

Omnistar L-band differential correction

i. Autonomous Servicing

i. No

ii. None

j. Non-Autonomous Control

We plan on pushing the vehicle into place both pre and post race, while being pushed the vehicle will steer automatically, but will not propel itself.

2. System Performance

a. Previous tests:

- Created platform to test static stability of motorcycle – we were able to successfully stabilize the vehicle.

- Build small scale CMG – we collected data for full scale CMG manufacturing

- Conducted data collection test of CMG – we noticed that angular momentum is conserved better than we thought (the air drag a spinning disk is very small).

- Tested physics of CMG precession – we noticed that we don't necessarily need to actuate (precess) the gyro to keep the vehicle

standing. We also learned that it might be a good/better idea to use hydraulic jacks to right the vehicle back up. The mass of a CMG sized to right the vehicle up from laying down will be substantial and its angular momentum would need to be precisely oriented to prevent damage to the vehicle.

- Completed test platform for dynamic stabilization – we notice that the vehicle due to its size and weight can take large forces without incurring damages. (We can crash the vehicle into a tree going 25 and it remains intact.) This robustness will allow us to preserve our vehicle in potential collisions with obstacles. The size and weight also reduce the impact the vehicle will have on the environment in the event of a collision.

Created control models for steering and actuation – we noticed that our vehicle is MUCH more stable at high speeds than at low speeds.

Tested 4 different stabilization control algorithms – we noticed that there are no simple control algorithms that will simply solve our stabilization problem.

Created FPGA to create motion gradient from NTSC video – we noticed that this approach is very good at identifying moving object on a static background where as the reverse identifying a static object on a moving background is not perfected yet.

Tested high speed stabilization – we noticed that turning at high speed is extremely complex..

DGPS correction

GPS waypoint navigation

RDDF processing

Gymbal actuation

Steering control

Stability control

b. Next tests will involve testing the:

Improvement of direction and heading control.

3. Safety and Environmental Impact

a. Top vehicle chassis speed 65 mph (no sensing).

Top vehicle speed 25 mph (full sensing).

Effective sensing ranges:

Cameras have a range of 100 meters. This determines which objects are moving fastest and which are slow. It attempts to extrapolate waypoints for possible paths. Paths are determined by matching the pattern of the lower middle section of the video feed up the video feed.

b. Currently 230 miles with the current 4 Gallon fuel tank.

c. Safety equipment

i. Industrial strength racing plastic gas tank with cap

ii. Engine kill switch.

iii. Audible warning device 119bd as per original request, and one amber light mounted on top of the vehicle.

d. E-stop

i. Activating the soft E-Stop will:

Trigger a voltage across one of the DIO lines of the MC which will tell it to run E-stop mode. In this mode the vehicle will:

Engage the clutch to prevent power from being applied from the engine

Engage the vehicle's brakes to bring it to a stop.

All attitude and positioning systems are still running; only forward motion of the vehicle is stopped.

The MC will deactivate the warning devices.

The vehicle will keep itself balanced using the automated kickstands which will remain down until the E-stop is actuated or the vehicles has suffered from an unrecoverable error.

Once the Soft E-stop is deactivated the MC will detect that it is no longer required to be in E-stop mode. The MC will then:

Activate the warning devices

Determine the desired heading

Scan for obstacles

Place the vehicle release the throttle and bring up the kick stands are the vehicle drives off.

Activating the hard E-Stop will:

Cut the power to the SSR (a 3-5V potential must be maintained across the terminals to keep the switch closed) that link the engine propulsion vehicle engine to its electrical system, this will prevent the spark plug from firing and the engine will stall.

The automated kickstands will attempt to deploy, but may not keep the vehicle vertical.

The vehicle cannot recover from a hard E-stop without serious engineering support.

ii. Clearly marked E-Stop switches (See appendix 3D2 for image of EStop switch) are placed on either side of the vehicle, such as to be accessible when the vehicle is laying on its side as well as when standing up. The manual E-Stop has a key which prevents the stop from being removed once activated.

Switches are oil and water tight, meeting NEMA 4, 13, and IP65 when properly installed. Button and body are plastic (emergency stop switch has red buttons). Rated 6 amps @ 250 VAC/24 VDC. UL recognized; CSA certified.

Once activated the E-Stop will:

Cut the power to the SSR (a 3-5V potential must be maintained across

the terminals to keep the switch closed) that link the engine propulsion vehicle engine to its electrical system, this will prevent the spark plug from firing and the engine will stall.

Cut the power to the SSRs that link the electronics to the battery packs, this will cause them to loose power and turn off.

iii. Locate the transmission on the vehicle's port (left) side (is clearly labeled on the outside).

Flip the lever which is labeled "GEAR SHIFTER" Down and then up until the mechanism clicks and the gear is disengaged.

The vehicle cannot be towed, but it can be picked up and moved onto the tow truck easily.

e. Radiator

i. The only device that emits EM on the vehicle is the MW sensor. Its' transmitting power is 10dBm the center frequency is 76.5 ± 0.2 GHz the power emitted is 36 watts.

ii. None, except audible warning device.

iii. Vehicle electronics and engine components are being shielded to prevent EMI. We doubt the vehicle's EM signature will be perceptible.

f. Environmental Impact

i. The vehicle might cause treading under wet conditions, but we expect to do so much less significantly than other race vehicles. The vehicle could potentially damage shrubbery if it collides with one.

ii. Max width 18 Inches, height 5 feet, length 6 feet, weight 250 pounds

iii. Footprint is .25 square foot, maximum pressure is 100 psi. If the vehicle crashes, the roll cage may create a higher pressure because the contact forces would be greater 5000 psi.