



All-Terrain Autonomous Navigation Robot with GPS-IMU

Jaguar-4x4-Wheel

User Guide



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I. Specifications

Jaguar-4x4-wheel Mobile Robotic Platform is designed for indoor and outdoor operation requiring higher ground clearance and faster maneuverability. Jaguar-4x4-wheel platform is a wheeled version of the Jaguar-Lite platform. Jaguar-4x4-wheel is driven by four powerful (80W) motors, one for each wheel. Jaguar-4x4-wheel platform is rugged, light weight (< 20Kg), fast (max 15km/hr), with high ground clearance (88mm), compact, weather and water resistant. It is designed for tough terrains and capable of running over vertical step up to 155mm and climbing up low rise stairs (up to 110mm step). Jaguar-4x4-wheel is fully wirelessly (802.11G) connected. It integrates outdoor GPS and 9 DOF IMU (Gyro/Accelerometer/Compass) for autonomous navigation. The integrated high resolution video/audio and laser scanner (optional) provide remote operator detail information of the surrounding. Besides the ready to use control and navigation software, a full development kit including SDK, data protocol and sample codes, is also available.

Key Features

- Rugged and reliable mobile platform for indoor and outdoor applications with faster maneuverability (max 15Km/hr)
- Indoor and outdoor operation requiring higher ground clearance and on tough terrains
- Weather and water resistant enclosure
- Climbing up > 45° slope and stairs (max 110mm or 4.5")
- Light weight (< 20Kg) and compact design with large payload capacity
- Autonomous navigation with outdoor GPS and 9 DOF IMU (Gyro/Accelerometer/Compass)
- Managing max 155mm (6") vertical step (obstacle)
- Integrated Laser scanner (Optional)
- Integrated high resolution video camera with audio
- All 802.11G (optional 802.11N) wirelessly connected
- Head mounted display (optional) and Gamepad controller providing outdoor operation with large and clear view even under direct sunlight
- Ready to use control and navigation software
- Full development kit including SDK, data protocol and sample codes, supporting Microsoft® Robotics Studio, Microsoft® Visual Studio, NI LabVIEW®, MATLAB®, Java®

Mobility

Terrain: Sand, rock, concrete, gravel, grass, soil and others wet and dry

Slope: > 45°

Maximum vertical step: 155mm (6")

Stair climbing: Max stair step height 110mm (4.5")

Traverse: > 200mm (8")

Speed: 0 – 15Km/hr

Turning radius: 0, min 750mm (29.5") diameter of turning space

Ground clearance: 88mm (3.5")

Operator remote control

Autonomous navigation with GPS and 9 DOF IMU (Gyro/Accelerometer/Compass)

Indoor vision landmark GPS (Optional)

Survivability

Sealed weather resistant enclosure

Temperature: -30° to +50°

Shock resistant chassis

Electronics

Motion and sensing controller (PWM, Position and Speed Control)
5Hz GPS and 9 DOF IMU (Gyro/Accelerometer/Compass)
Laser scanner (4m or 30m) (Optional)
Temperature sensing & Voltage monitoring
Headlights

Video / Audio

Color Camera (640x480, 30fps) with audio

Communication

WiFi 802.11G (Optional WiFi 802.11N)
Ethernet
Serial (RS232)

External Auxiliary Ports

Ethernet (Optional)
General purpose communication and power port (Optional)

Operator Control Unit

Gamepad controller
Head mounted display (dual 640 x 480), equivalent to 60" display viewed in 2.7m (9 feet) (Optional)
Portable computer (Optional)

Power

Rechargeable battery: LiPo 22.2V 10AH
LiPo battery charger with balancer
Nominal operation time: 2 hours (Optional 4 hours)

Motor

Wheel Motors (24V): 4 units
Max output (after gear down) (x4): Max 80W, 65Kg.cm/wheel
Rated current: 2.75A, Max current: 16A

Dimensions

Height: 255mm (10")
Width: 530mm (21")
Length: 570mm (22.5")
Weight: 19.5Kg (Standard Configuration)

Payload

Carrying Payload: max 30Kg
Dragging Payload: max 50Kg

Application Development

Full development kit including SDK, data protocol and sample codes, supporting Microsoft® Robotics Studio, Microsoft® Visual Studio, NI LabVIEW®, MATLAB®, Java®



Jaguar Core Components

JAGUAR4x4W-ME	Jaguar 4x4 Wheel Chassis (including motors and encoders)	1
PM55005-J	Motion and Sensing Controller (Jaguar Version)	1
WF5802G	WiFi 802.11b/g Wireless Module	2
DMD2500	25A (peak 50A) Dual-channel DC Motor Driver Module	2
PMCHR12	DC-DC Power Board	1
AXCAM-A	640x480 Networked Color Camera (max. 30fps) with Two-Way Audio	1
OGP5501	Outdoor GPS Receiver with 5Hz Update Rate and WAAS	1
IMU9000	9 DOF IMU (Gyro/Accelerometer/Compass)	1
WRT802G	802.11b/g wireless AP/router	1
MCR3210	RS232 Interface Module	1
BPN-LP-10	22.2 V 10 AH LiPo Battery Pack	1
LPBC5000	5A LiPo Battery Charger	1
GPC0010	Gamepad Controller	1

Main Upgrade Options

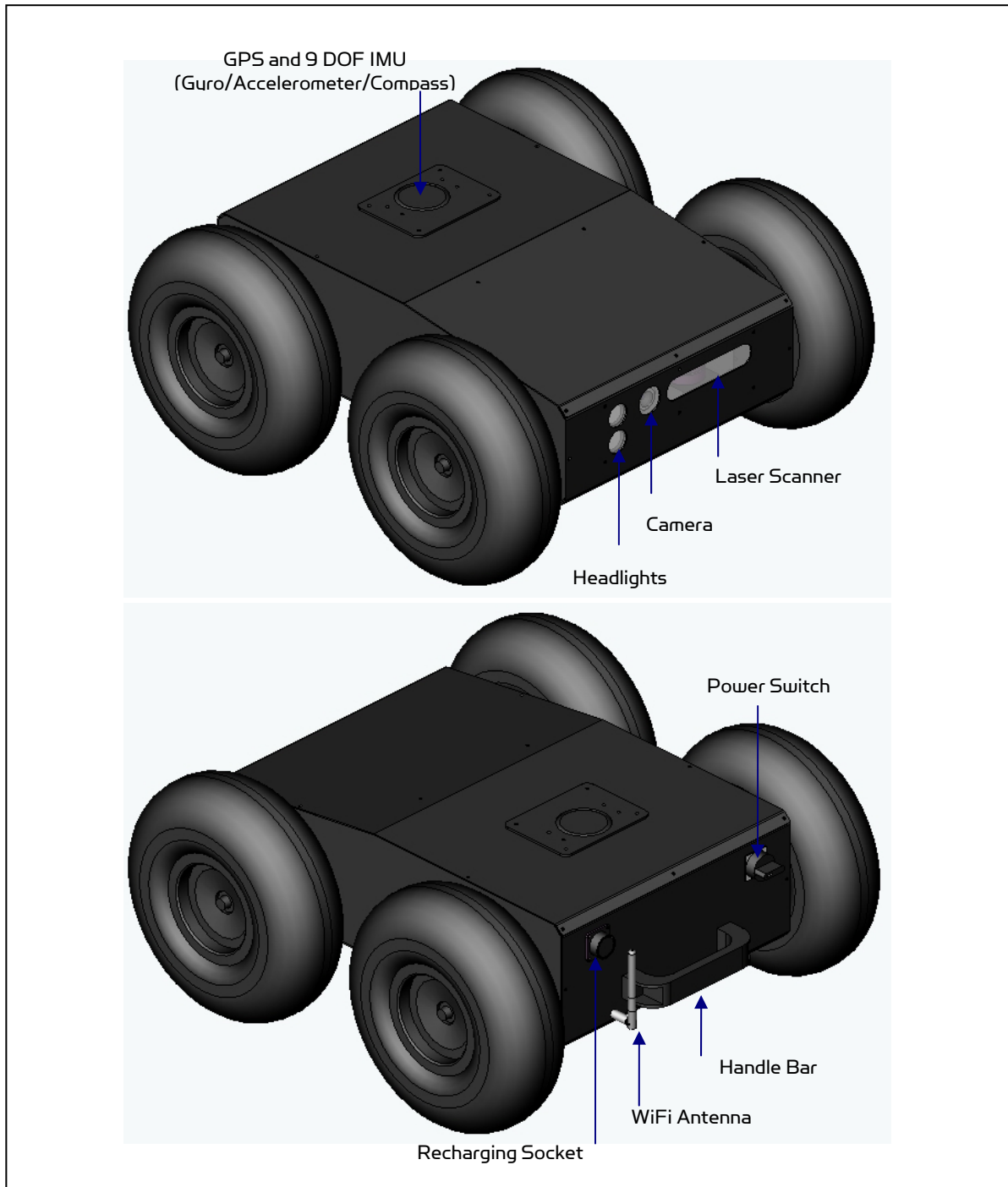
Laser Scanner (Range 4m)	LAS04M
Laser Scanner (Range 30m)	LAS30M
22.2V 20 AH Li-Polymer Battery Pack	BPN-LP-10
Head Mounted Display (800x600)	HMD8H6H
802.11N Wireless AP/Router	WRT802N
Host Controller PC	HCPC1008

Please contact support@drrobot.com for custom design and integration inquiry.

II. Knowing Your Robot

Overlook

The figure below illustrates the key components that you will identify on the Jaguar-4x4-Wheel robot.



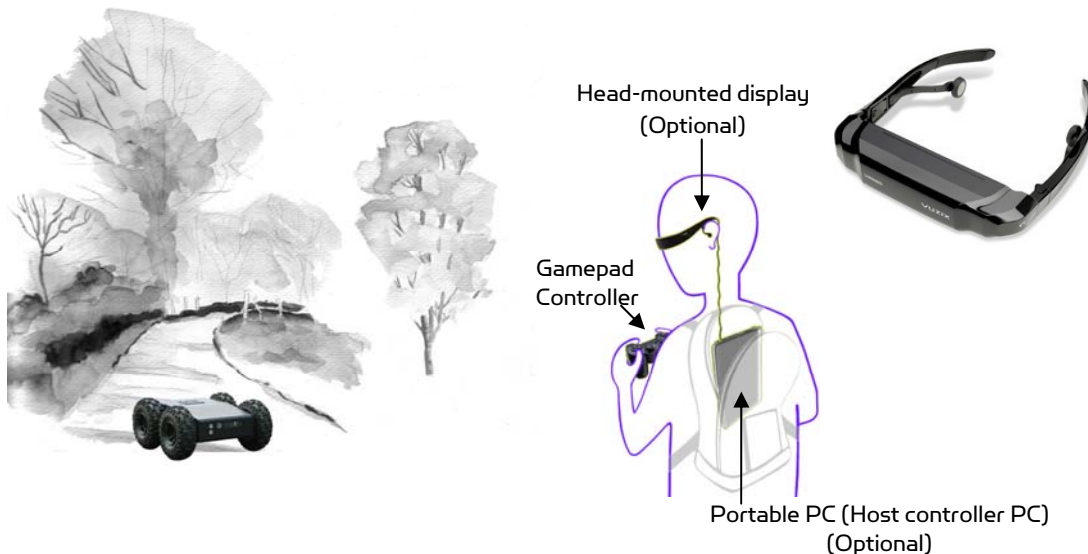
Jaguar-4x4-Wheel Platform

Operation Scenario

Diagram below illustrates the typical operation scenario. The Jaguar-4x4-wheel is a wireless networked outdoor mobile robot. It comes with a wireless 802.11 AP/router. The remote host controller PC running the "Jaguar Control" program connects to the Jaguar-4x4-wheel robot via:

- Network cable – Connect the robot on-board AP/router. (DO NOT connect to the WAN port), or
- Wireless – To connect the host controller PC to the on-robot wireless AP/router, configure the host PC's wireless settings using the default wireless configuration settings found in the Network Connection session of this manual.

Human operator carrying the host controller PC could use the head-mounted display (accessory option) and the included game-pad controller in outdoor environment to monitor and control the operator under any outdoor lighting environment, even under direct sunshine. The included "Jaguar Control" program will therefore be projected on the head-mounted display, where you could see all the sensor information from the robot, and the video streamed from the camera on robot (Please refer to "Jaguar Control program" session for detail).



Typical Operation Scenario

Note: The host controller PC running the "Jaguar Control" program could be mounted on the robot instead off the robot if your application requires so.

Software Installation

Jaguar Control programs, application development library and supporting documents could be found from the Jaguar software CD.

On the host controller computer, you should install the following programs from the installation CD:

- **"Jaguar Control" program** - installed by the Setup.exe from CD
- **Google Earth program** - could be downloaded from <http://earth.google.com/download-earth.html>. Please follow its installation instruction.

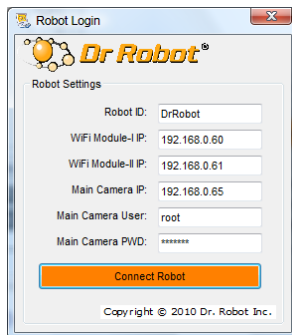
III. Operation of Jaguar Robot

End user could develop his own Jaguar control program using the supplied development API and tools. Here, we will show you how to control the robot using the included “Jaguar Control Program” (You need to install Google Earth program first).

Using Dr Robot Jaguar Control Program

This program will demonstrate how to control and navigate the Jaguar-4x4-wheel, and how to interpret, process, display and log multi-sensor information. This program is provided with source code (c#).

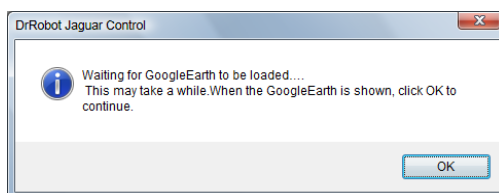
- updates motor encoder reading, motor temperature, board voltage and battery voltage measured at 10Hz;
- reads and displays IMU and Laser Range sensor data;
- displays GPS readings on the Google Earth;
- displays and controls Axis camera.



Once you start this program, you will see a “Login Window”

It will read all the configuration information from “outdoorrobotconfig.xml” under c:\DrRobotAppFile\.

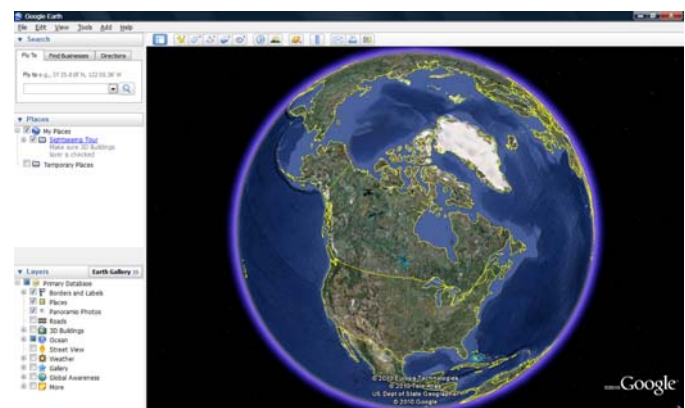
When “Connect Robot” is clicked, it will start the WiRobotGateway program (also under c:\DrRobotAppFile\.) and will try connecting to the Robot.

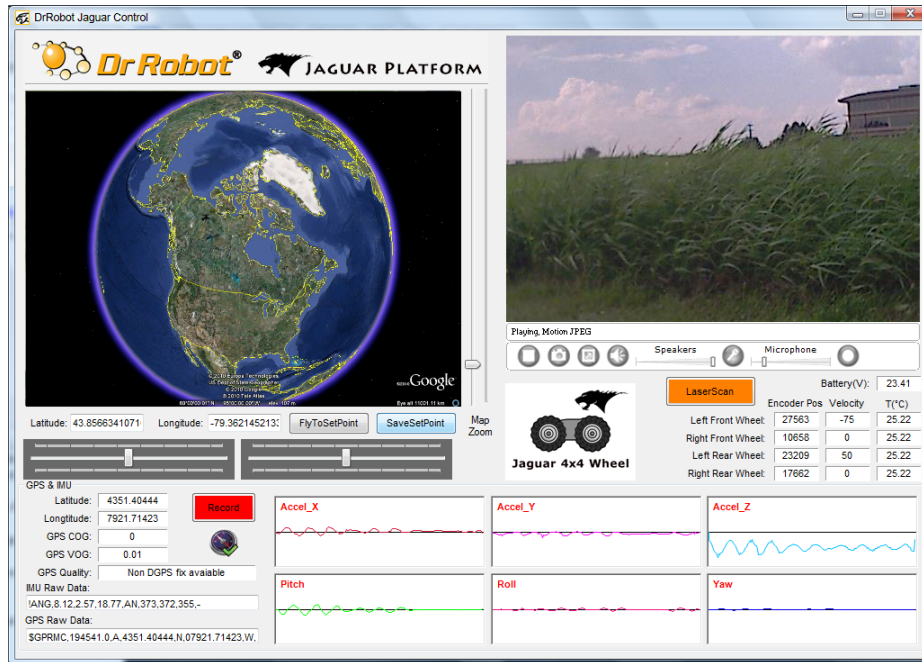


Google Earth is then loaded (this may take a while).

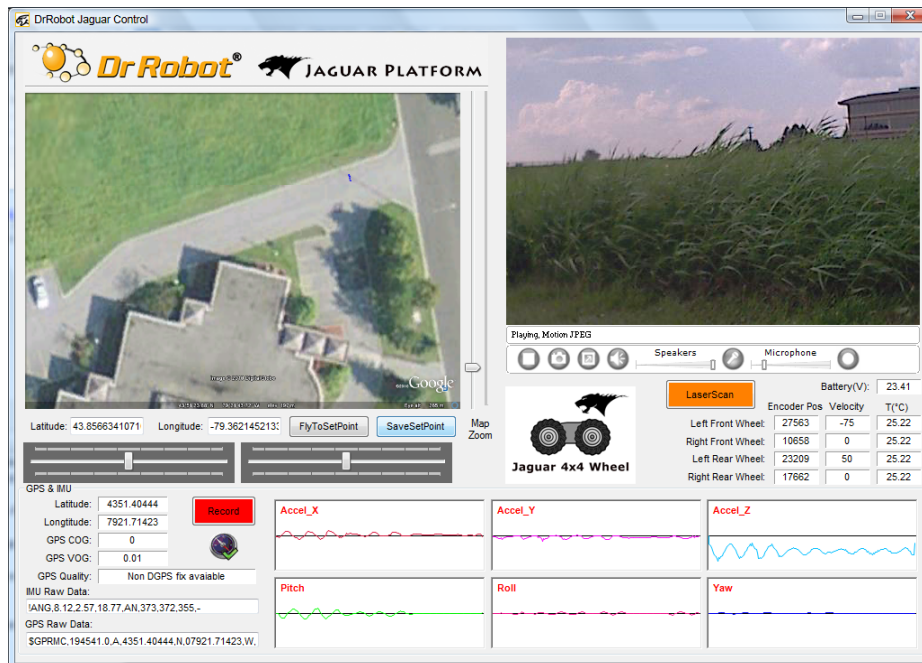
Google Earth supports offline use (without Internet), but you have to obtain the map online ahead of use.

When Internet is not presented, this loading process will take a longer time when trying to connect with Google Earth website. You will not get the correct Latitude and Longitude position by clicking on map before the map loading is finished. When loaded, click “OK” button.





"FlyToSetPoint" button will bring you to the location (latitude/longitude) specified in "outdoorrobotconfig.xml". This is the location you would like the map to center and show around. You should modify this location according to your location. This could be done by inputting the value in this xml file or navigating on Google Earth map to your interested point, then clicking "SaveSetPoint" button. The location value of the map center will then be saved to the "outdoorrobotconfig.xml" when program is closed.



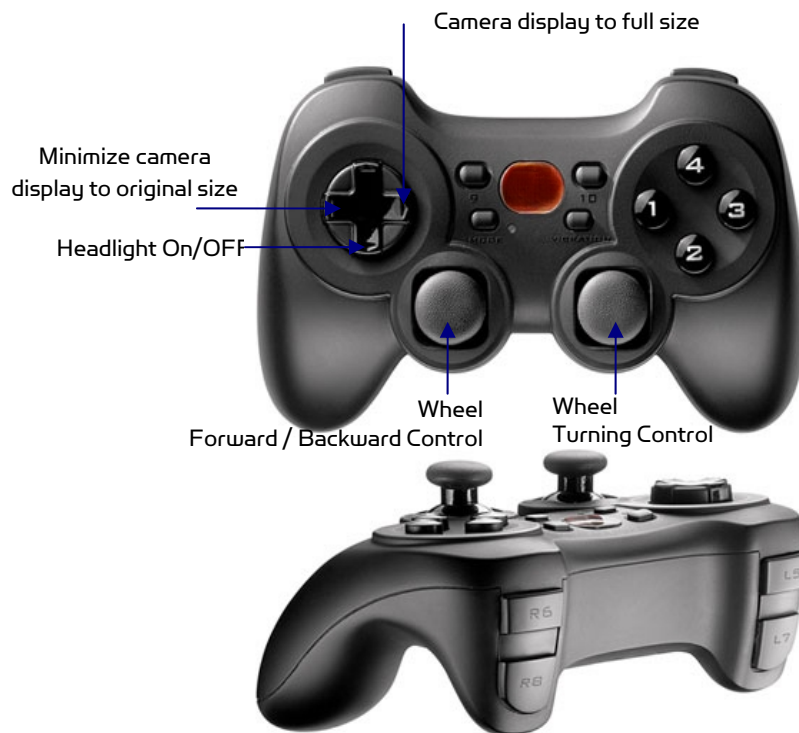


You could use the vertical track bar to zoom in or out.

When the GPS-IMU module is presented, this program will connect and display the GPS information on Google Earth and IMU raw data on the 6 chart boxes.

When camera is presented, the video and AV control buttons will be shown in the video window.

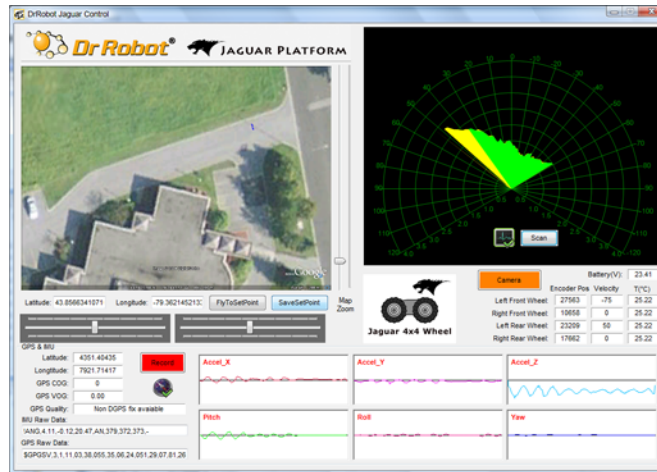
You could use the included Gamepad controller to navigate the robot. When used outdoor, especially under direct sun lights, head-mounted display (optional accessory) will provide clear and large display with excellent outdoor experience.



Gamepad Control

Note: when using Gamepad control, you need to make sure the program window is in "focus".

When  is clicked, it will display laser scanner data in polar view as shown below.




	Battery(V):	23.55	
	Encoder Pos	Velocity	T(°C)
Left Track Motor:	18800	50	25.43
Right Track Motor:	23265	0	25.43

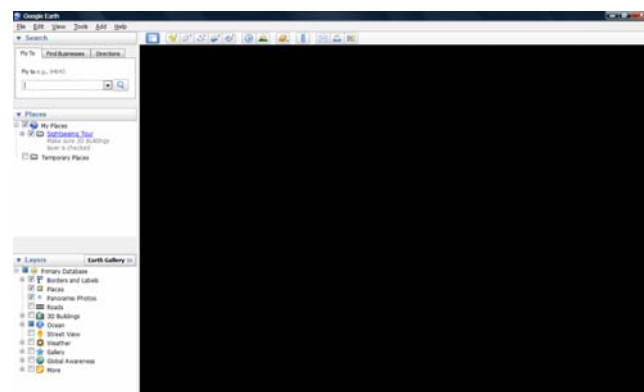
Battery information and motor information is displayed here. If the robot uses the included Li-Po battery, you need to stop the robot when voltage is below marked voltage (22.2V) in order to prevent battery damage. Motor temperatures are also displayed here. "Encoder Pos" boxes show the encoder position values received in motor driver board from motion control board.

The two horizontal track bars show the Gamepad controller's left and right stick control value.



You could record raw GPS-IMU/Encoder sensor data using  button. The raw sensor data file will be saved under current execution folder with file name GPSIMURec*.txt.

All traces are displayed on Google Earth by KML data. Since the current version of Google Earth does not provide programming method to clear these KML data, there is risk of memory leak. You could manually clear these KML data by right-clicking on "Temporary Places", then choosing "Delete Contents". (That is why we did not hide Google Earth program)



On normal program exit, Google Earth will be closed. However, you should double check using "Windows Task Manager"; otherwise, you may not be able to display Google Earth when you start Jaguar control program again.

Recharging

Jaguar robot uses high performance LiPo batteries. Extreme caution is needed when dealing with this type of battery, explosion and damage could occur. Please read the Charge Station manual first and follow all the safety rules before proceeding further.

- 1) Power on the Charge Station. Make sure "LiPo Charge" is displayed on the LCD screen. If not, use "Type/Stop" button to change it to "LiPo Battery".
- 2) Use "INC" button to choose how to charge battery. You can choose "LiPo Charge", "LiPo Balance" or "LiPo Fast Chg". We recommend using "LiPo Balance" charge to extend battery life and reduce risk.
- 3) You can use "Enter/Start" + "INC" + "DEC" buttons to change the charge current, DO NOT exceed the 5A charging current and do not modify the battery voltage. It should be "22.2V (6S)" for Jaguar-4x4-Wheel robot.
- 4) Connect the charging cable to Jaguar-4x4-Wheel charging socket and make sure it is fastened well.
- 5) Turn the Power switch (CCW) to charge position.
- 6) Keep pressing "Enter/Start" button for few seconds, the charge station will check the battery and display what the reading is. It should be same as your settings above.
- 7) If everything is right, you can press "Enter/Start" button again to start charging.

IV. Hardware and Electronics

Network Settings

Wireless Router Setting

The included pre-configured wireless 802.11 B/G router has the following pre-set settings:

SSID	DriJaguar	Router LAN	192.168.0.245
WEP	128bits	Login ID	admin
KEY	112233445566778899AABBCCDD	Password	drrobot
Key Type	Open Key		

Device Default Network Settings

Note: The WiFi modules are configured to serial-to-Ethernet mode in Jaguar platform.

WiFi Module 1	192.168.0.60
Port 1	Port Number 10001, UDP 115200. 8, N, 1, no flow control
Port 2	Port Number 10002, TCP 115200. 8, N, 1, no flow control

WiFi Module 2	192.168.0.61
Port 1	Port Number 10001, TCP 115200. 8, N, 1, no flow control
Port 2	Port Number 10002, TCP 115200. 8, N, 1, no flow control

Camera	192.168.0.65 Port 8081
User ID	Root
Password	Drrobot

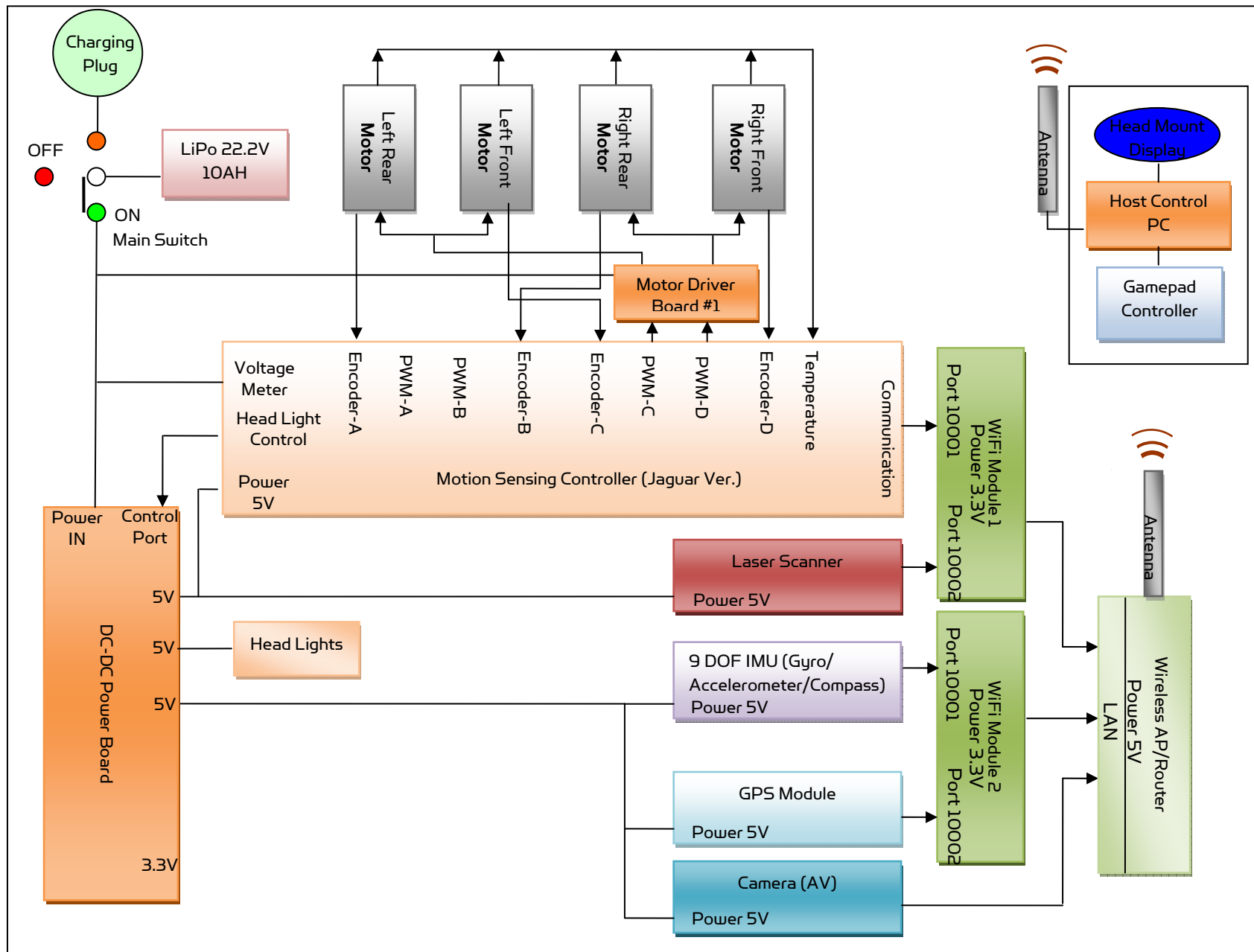
Advanced Network Settings

You could also change the WiFi AP/router settings such as IP and SSID etc., If you need to do so, you are required to change the network settings on the WiFi modules on the robot by following the guidelines as illustrated on the WiFi Module manual.

Please contact support@DrRobot.com if you need further support.

Hardware Architecture

The diagram below illustrates the inter-connection between the core electronic circuits and modules (some are optional accessories).



Motor Driver Board

The left front and left rear motors are connected to the 1st channel on the motor driver board while the right front and right rear motors are connected to the 2nd channel.

Input power	H-Bridge 2 channels
Max current	up to 25A continuous power per channel, peak up to 50A per channel for a few seconds
Input voltage	6~24V, 30V absolute max

Motion and Sensing Controller

This is a special version of PM55005 board.

Input power	5V
6 PWM output	Channel 3, 4 for left and right wheels
Motor control mode	PWM control; Velocity control; Position control
Sensor sampling	Encoders: Channel 1,2 for left and right rear wheel Channel 3,4 for left and right front wheel
	Board voltage measuring
	Battery voltage measuring
	Motor temperature measuring (4 units)
	Other extended A/D channels (please contact Dr Robot).

Camera

Input power	5V
Lens	4.4 mm: 47° horizontal view, F2.0, fixed iris, fixed focus
Light sensitivity	1-10000 lux, F2.0 0 lux with headlights LED on
Resolutions	640x480 to 160x120
Frame rate	H.264: 30 fps in all resolutions Motion JPEG: 30 fps in all resolutions MPEG-4 Part 2: 30 fps in all resolutions
Video compression	H.264 (MPEG-4 Part 10/AVC), Motion JPEG MPEG-4 Part 2 (ISO/IEC 14496-2)
Audio streaming	Two-way
Other features	PIR motion sensor with configurable sensitivity. Max range: 6 m

GPS

Input power	5V
Update rate	5Hz
Sensitivity	- 185dBW minimum
Accuracy	Standard GPS service: Position: <= 15m 95% typical Velocity: 0.1knot RMS steady state WAAS service: Position: <= 3m 95% typical
Output Interface	NMEA 0183, default GPRMC/GPGGA/GPGSA/GPVTG Binary Output

9DOF IMU (Gyro, Accelerometer & Digital Compass)

Input power	5V
Gyro Sensors	LY530ALH - 300°/s single-axis gyro LPR530ALH - 300°/s dual-axis gyro
Accelerometers	3 Axis ADXL345 13bit resolution Max +/-16G
Magnetic Compass	3 Axis HMC5843 magnetometer
Output Frequency	50Hz Output all sensor raw data and processed data by on-board MCU through serial port

Laser Scanner

Two laser scanner options are available, one with measurement range of 0.02-4m, and other one is 0.1-30m.

Input power	5V
Detectable range	0.02-4m
Accuracy	0.02 to 1m: +/- 10mm 1 to 4m: 1%
Measurement Resolution	1mm
Angular Resolution	approx 0.36° (360°/1024 partition)
Scanning angle	240°

Input power	12 V
Detectable range	0.1-30m
Accuracy	0.1 to 10m: +/- 30mm
Measurement Resolution	1mm
Angular Resolution	approx 0.25° (360°/1440 steps)
Scanning angle	270°

Batteries

Battery type	Li-Po
Rated Voltage	22.2V (6 cells, 3.7V/cell)
Capacity	10Ah
Discharge rate	Max 50A continuous, Max 100A peak
Max charge rate	10A
Cycle life	500-1000 times

Charger

Charger type	Balance Charger
Maximum charge current	5A
Maximum discharge current	5A
Power Input	100-240V

Powertrain (motor, speed-reducer and encoder)

The following specifications are defined at the output shaft after speed-reduction.

Drive wheel shaft

Track-wheel motors (4 units)	DC motors with steel gearbox
Motor rated voltage	24V
Motor rated current	2.75A
Motor max current	16A
Shaft rated speed	290RPM
Shaft rated torque	8.5Kg.cm
Shaft encoder resolution	722 counts per revolution

V. Further Development & Programming

The Jaguar Control program

The Jaguar Control program is written with Visual Studio 2008 express (in C#) under .Net 3.5 framework. You could download the development tools (Visual Studio 2008 express under .Net 3.5 framework) free from Microsoft. Please refer to the "Dr Robot Application Development Notes on C# Programming for Robot Control" for further information.

The control program uses the supporting components and libraries that should have been installed when you install the control program from the installation CD:

1. **DRROBOTSentinelCONTROL.OCX:** Please refer to "WiRobot SDK API Reference Manual.pdf" for detail.
2. **WiRobotGateway.exe**
3. **AXIS Media Control Library Set** These are the camera control component for the AXIS Mini Camera (P/N: AXCAM) used for Jaguar robot. Please refer to "AXIS Media Control SDK Help" for detail.

Motion Control/Sensing System:

Jaguar-4x4-Wheel comes with a special version of PMS5005 as its motion control and sensing board. It follows the Dr Robot WiRobotSDK protocol. User could control and access Jaguar by Dr Robot ActiveX control (DrRobotSentinelActivexControl.ocx) and WiRobot gateway program.

Based on the protocol, you could develop your own program for any operation system. You could request protocol sample code from Dr Robot using C++/Java. You should also contact Dr Robot with any questions regarding SDK API and protocol.

The communication port is connected at WiFi module-I port 1.

Gateway program will connect to this board at 192.168.0.60, port 10001.

Here is C# sample code to control Jaguar-4x4-Wheel System with ActiveX control,

myJaguar is DrRobotSentinelActiveXControl.

Wheel Motor control:

```
private void myJaguar_MotorSensorEvent(object sender, EventArgs e)
{
    leftRearWheelMotor.encoderDir = myJaguar.GetEncoderDir1();
    leftRearWheelMotor.encoderPos = myJaguar.GetEncoderPulse1();
    leftRearWheelMotor.encodeSpeed = myJaguar.GetEncoderSpeed1();

    rightRearWheelMotor.encoderDir = myJaguar.GetEncoderDir2();
    rightRearWheelMotor.encoderPos = myJaguar.GetEncoderPulse2();
    rightRearWheelMotor.encodeSpeed = myJaguar.GetEncoderSpeed2();

    forwardPower = myJaguar.GetMotorPWMValue4();
    turnPower = myJaguar.GetMotorPWMValue5();
}
```

You could read board voltage(5V) and battery voltage in standard sensor Event.

```
private void myJaguar_StandardSensorEvent(object sender, EventArgs e)
```

```

{
    boardVol  = ((double) myJaguar.GetSensorBatteryAD1() / 4095 * 9);
    motVol = ((double) myJaguar.GetSensorBatteryAD2() / 4095 *
33.749);
}

```

You could read motor temperature sensor in custom sensor event, function Trans2Temperature() is based on the sensor specification to translate AD value to temperature (in celcius degree).

Also you could read left/right wheel motor encoder in this event.

```

private void myJaguar_CustomSensorEvent(object sender, EventArgs e)
{
    // front left track motor
    double tempM =
Trans2Temperature((double)myJaguar.GetCustomAD5());
    tempM = double.Parse(tempM.ToString("0.00"));
    lblTemp1.Text = tempM.ToString("0.00");
    // front right track motor
    tempM = Trans2Temperature((double)myJaguar.GetCustomAD6());
    tempM = double.Parse(tempM.ToString("0.00"));
    lblTemp2.Text = tempM.ToString("0.00");
    // rear left track motor
    tempM = Trans2Temperature((double)myJaguar.GetCustomAD7());
    tempM = double.Parse(tempM.ToString("0.00"));
    lblTemp3.Text = tempM.ToString("0.00");
    // rear right track motor
    tempM = Trans2Temperature((double)myJaguar.GetCustomAD8());
    tempM = double.Parse(tempM.ToString("0.00"));
    lblTemp4.Text = tempM.ToString("0.00");

    leftFrontWheelMotor.encoderPos = myJaguar.GetEncoderPulse4();
    leftFrontWheelMotor.encodeSpeed = myJaguar.GetEncoderSpeed4();
    leftFrontWheelMotor.encoderDir = myJaguar.GetEncoderDir4();

    rightFrontWheelMotor.encoderPos = myJaguar.GetEncoderPulse5();
    rightFrontWheelMotor.encodeSpeed = myJaguar.GetEncoderSpeed5();
    rightFrontWheelMotor.encoderDir = myJaguar.GetEncoderDir5();
}

```

To stop all motor, you could use:

```

myJaguar.DcMotorPwmNonTimeCtrAll(16384, 16384, 16384, 16384, 16384,
16384);

```

For track/wheel motor control, we use differential-drive mode. Under this mode, PWM channel 3 is forward power and PWM 4 is turning power.

To move forward with full power

```

myJaguar.DcMotorPwmNonTimeCtr(3,0);

```

To move backward with full power

```

myJaguar.DcMotorPwmNonTimeCtr(3,32767);

```

To turn left with full power

```

myJaguar.DcMotorPwmNonTimeCtr(4,0);

```

To turn right with full power

```
myJaguar.DcMotorPwmNonTimeCtr(4,32767);
```

To control head lights, using expanded IO port bit7.

```
Turn off light: myJaguar.SetCustomDOUT(expandedIO & 0x7f);
```

```
Turn on light: myJaguar.SetCustomDOUT(expandedIO | 0x80);
```

Software watchdog: The system will automatically, stop all the motors if it does not received any data package in 5 seconds.

Laser Scanner

Laser Ranger sensor (4m version, URG-04LX) is connected to WiFi module-1 port 2 after voltage level conversion. You could access the sensor data via TCP socket at port 10002 with IP 192.168.0.60.

Default settings for the serial port are: 115200, 8, N, 1, no flow control, TCP, port number 10002

Date and communication protocol could be found in "URG-04LX commspec_eg.pdf".

GPS

GPS sensor output interface is RS232 serial port, and connected to WiFi module-2 port 2 after voltage level conversion. You could access the sensor data via TCP socket at port 10002 with IP 192.168.0.61.

Default settings for the serial port are: 115200, 8, N, 1, no flow control, TCP, port number 10002

NMEA 0183 sentence is described in file "GPS18x_TechnicalSpecifications.pdf". GPS configuration tool is SNSRXCFG_200.exe

9 DOF IMU (Gyro/Accelerometer/Compass)

The output interface for this IMU sensor module is serial port. It is connected to WiFi module-2 port 1. You could read from this sensor via TCP port 10001 at IP 192.168.0.61. Serial Port Settings: 57600, 8, N, 1, no flow control, TCP, port number 10001. The sensor output rate is 50Hz (20ms) with output format of ASCII.

It's easier to read with a terminal program since the sensors' measurements are reported in ASCII. DCM estimation and all measurements are delimited with "," characters as well as a carriage return and line feed at the end of the data frame.

Format:

"ANG,roll,pitch,yaw,AN,gyroY,gyroZ,gyroX,accelX,accleY,accelZ,magnetomX, magnetomY, magnetomZ"

After "ANG", roll, pitch, yaw are estimated angle value by on board DCM algorithm. The unit is degree.

After "AN", the data are raw AD value for each sensor. Please note that the accelX, Y, Z value have been adjusted by subtracting the offsets by on board firmware.

Sample data string:

"ANG,0,0,10,AN,379,378,379,1,-2,243,4096,-1558,256"

Camera with Two Way Audio

You need to install the camera ActiveX control on your system by running the "AXISMediaControlSDK.exe". You could find some sample codes (C++, C#, VB) in C:\Program Files\Axis Communications\AXIS Media Control SDK\samples and the corresponding SDK documents in C:\Program Files\Axis Communications\AXIS Media Control SDK\doc.

By using the Microsoft's "Windows Media Encoder 9" and Axis video capture driver, you could also access this camera in Intel's OpenCV as same as accessing a USB camera.

Advanced Development

Please refer to document “GPS-IMU Sensor Module and Outdoor Autonomous Navigation Program” for detail on autonomous navigation programming using the Jaguar GPS and IMU system module.

Support and sample codes are available for using OpenCV, LabVIEW and MATLAB. Please contact support@drrobot.com for further information.