



All-Terrain Autonomous Navigation Robot with GPS-IMU

Jaguar Lite

User Guide



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I. Specifications

Jaguar-Lite Mobile Robotic Platform is designed for indoor and outdoor operation requiring faster maneuverability. Jaguar-Lite is simply the Jaguar platform without the two articulated arms. Jaguar-Lite is fully wirelessly 802.11G connected. It integrates outdoor GPS and 9 DOF IMU (Gyro/Accelerometer/Compass) for autonomous navigation. Jaguar-Lite platform is rugged, light weight (< 14Kg), compact, weather and water resistant. It is designed for tough terrains and capable of climbing up stairs (up to 180mm step). 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 8.5Km/hr)
- Indoor and outdoor operation on tough terrains
- Weather and water resistant enclosure
- Climbing up > 45° slope and stairs (max 180mm or 7")
- Light weight (< 14Kg) and compact design with large payload capacity
- Autonomous navigation with outdoor GPS and 9 DOF IMU (Gyro/Accelerometer/Compass)
- Managing max 180mm (7") vertical step (obstacle)
- Surviving max 1000mm (3.3ft) drop to concrete
- 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: 180mm (7")

Stair climbing: Max stair step height 180mm (7")

Traverse: > 200mm (8")

Speed: 0 – 8.5Km/hr

Turning radius: 0, min 800mm (31.5") diameter of turning space

Ground clearance: 38mm (1.5")

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

Drop to concrete: Max: 1000mm (3.3ft) Rated: 600mm (2ft)

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 (Optional)

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
Nominal operation time: 3 hours (Optional 6 hours)

Motor

Track Motors (24V): 2 units
Max output (after gear down) (x2): Max 80W, 65Kg.cm/track
Rated current: 2.75A, Max current: 16A

Dimensions

Height: 176mm (7")
Width: 470mm (18.5")
Length: 640mm (25.2")
Weight: 13.5Kg (Standard Configuration)

Payload

Carrying Payload (on flat surface): max 13Kg
Dragging Payload (on flat surface): max 30Kg

Application Development

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

Microsoft **ROBOTICS STUDIO**



Visual Studio



LabVIEW

MATLAB



Jaguar Core Components

JAGUARLite-ME	Jaguar Lite Chassis (including motors and encoders)	1
PMS5005-JL	Motion and Sensing Controller (Jaguar Lite 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
OGP501	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
BPN-LP-10	22.2 V 10 AH LiPo Battery Pack	1
LPBC5000	2A LiPo Battery Charger	1
GPC0010	Gamepad Controller	1

Main Upgrade Options

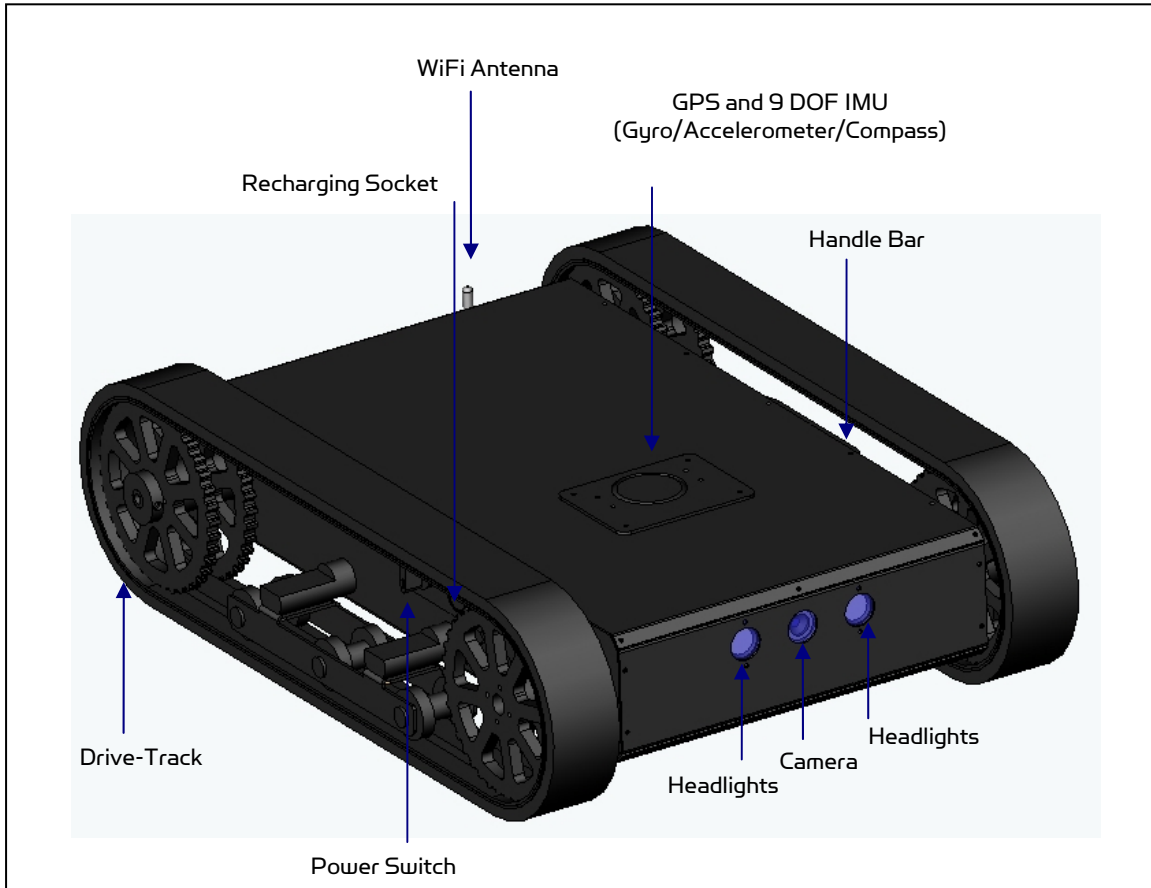
Laser Scanner (Range 4m)	LAS04M
Laser Scanner (Range 30m)	LAS30M
22.2V 20 AH Li-Polymer Battery Pack Upgrade	BPN-LP-20
Head Mounted Display (800x600)	HMD8H6H
802.11N Wireless AP/Router	WRT802N
Host Controller PC	HCPC1008

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

II. Knowing Your Robot

Overview

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



Jaguar-Lite Platform

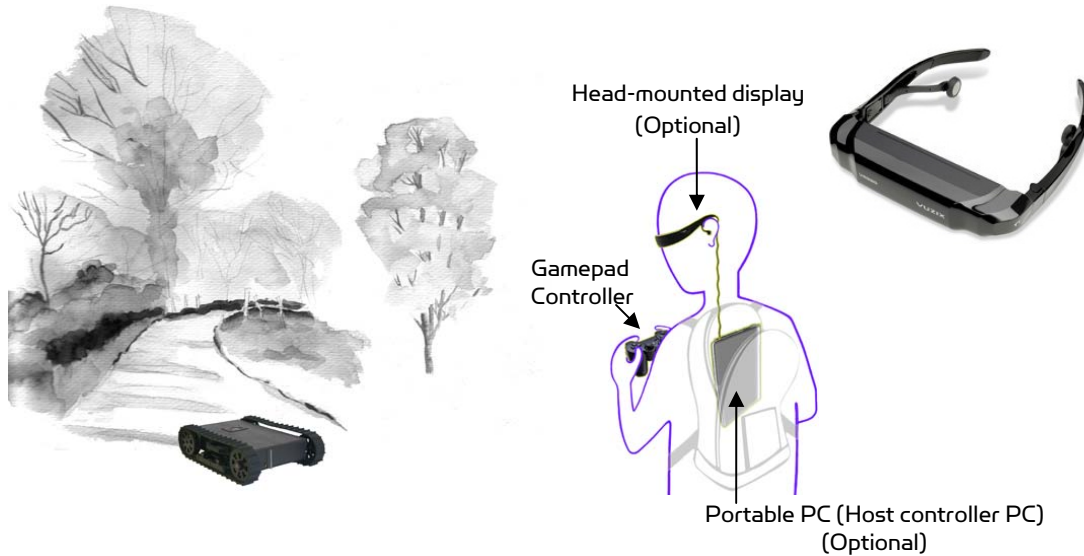
Operation Scenario

Diagram below illustrates the typical operation scenario. The Jaguar-Lite 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-Lite 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.

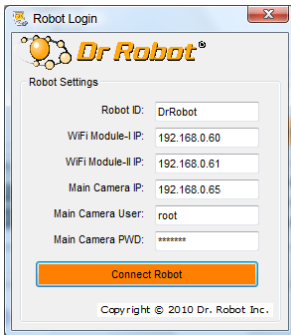
III. Operation of Jaguar-Lite Robot

End user could develop his own Jaguar-Lite 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

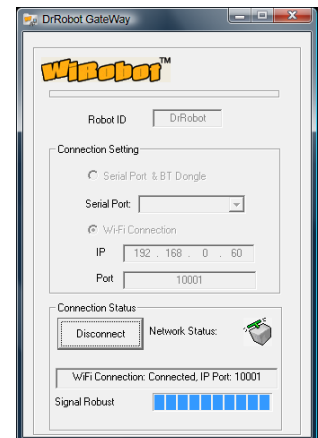
This program will demonstrate how to control and navigate the Jaguar-Lite, and how to interpret, process, display and log multi-sensor information. This program is provided with source code (c#)

- 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.

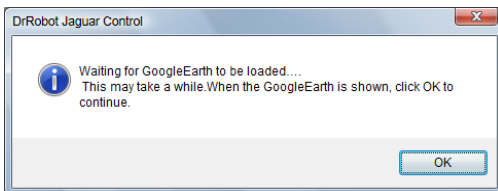


Once you start this program, you will see a "Login Window"

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



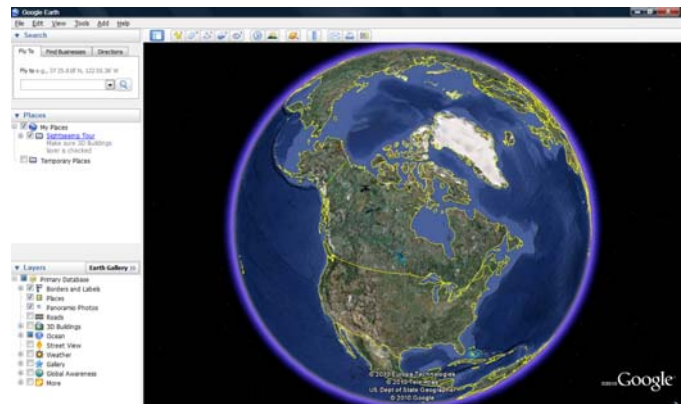
When "Connect Robot" is clicked, it will start the WiRobotGateway program (also under c:\DrRobotAppFile\) and will try connecting to the Robot.

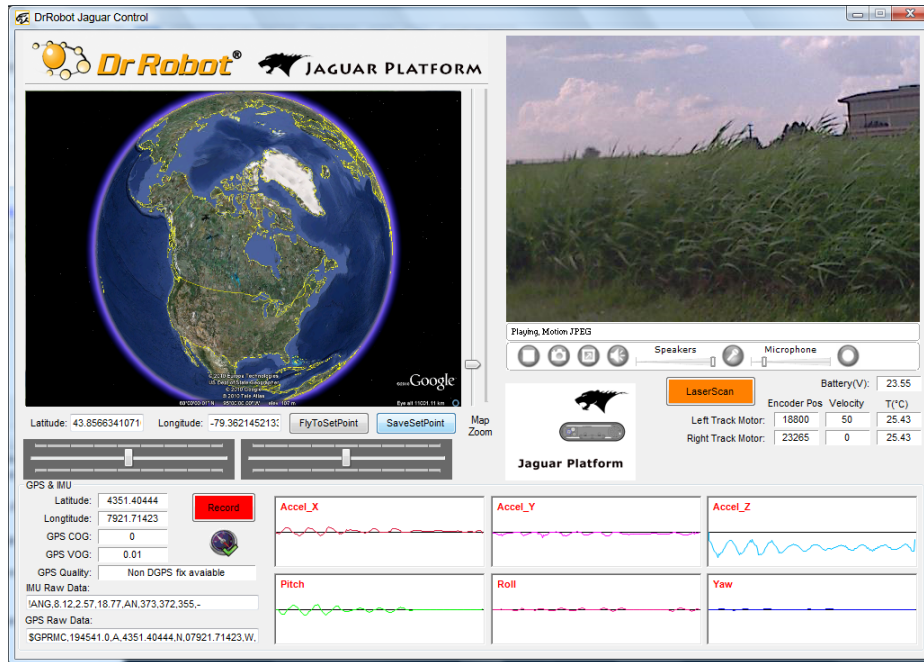


Google Earth is then loaded (this may take a while).

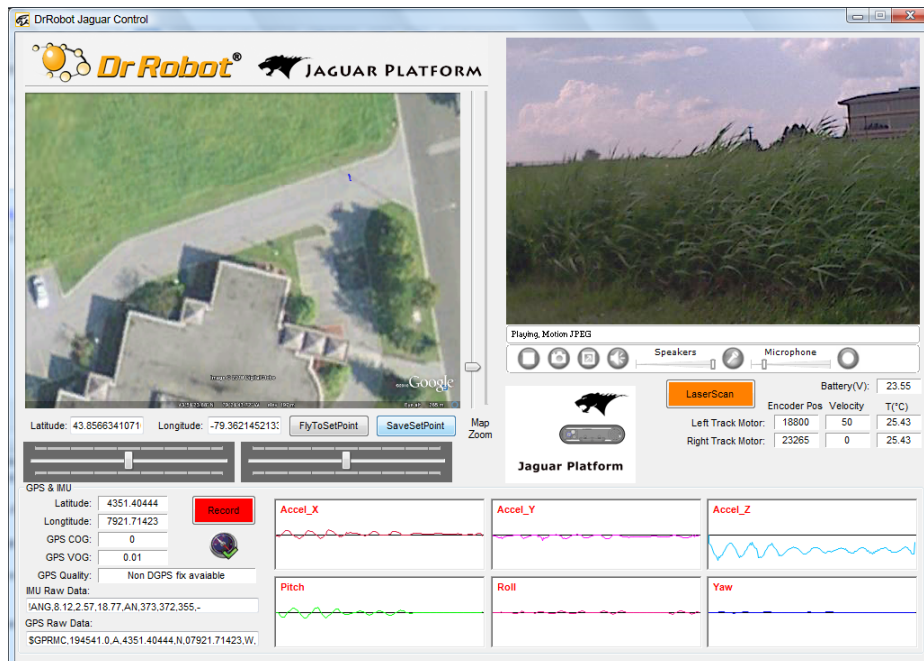
Google Earth supports offline use (without Internet), but you have to obtain the map ahead of use.

When Internet is not presented, this loading process will take 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.



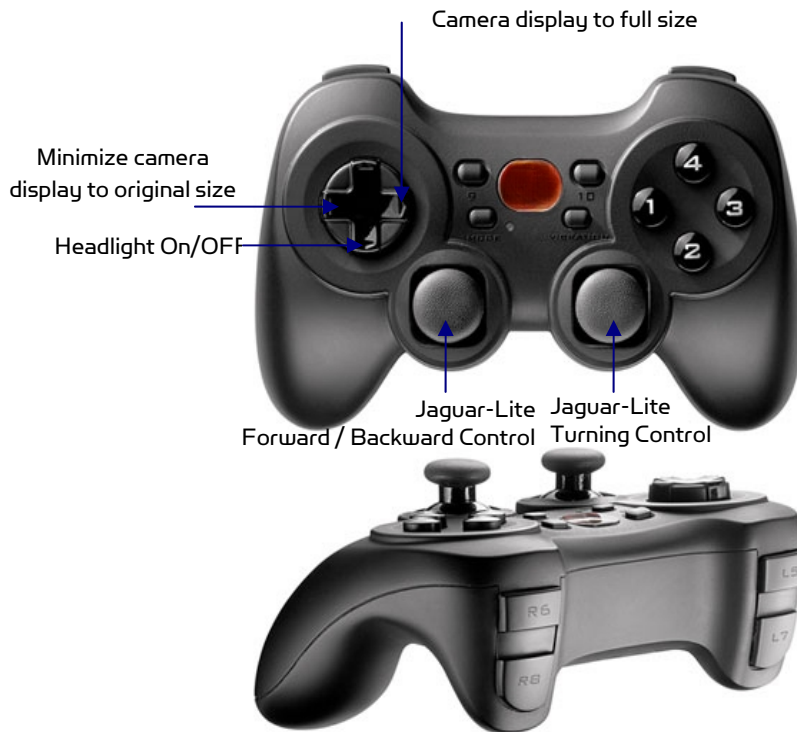


You could use the vertical track bar to zoom in or out.

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.

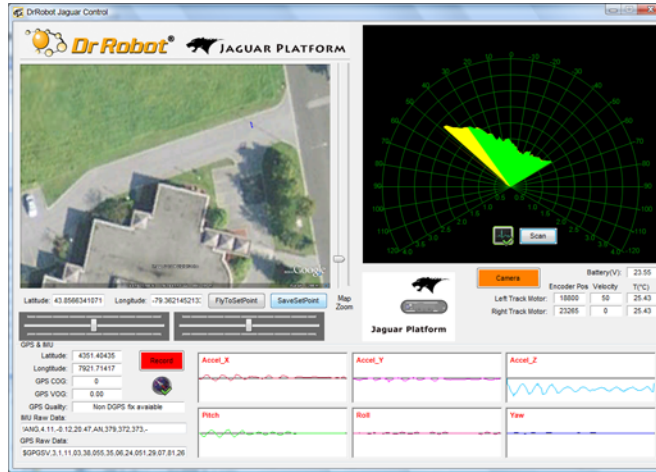
You could use the included Gamepad controller to navigate the robot. When used outdoor, especially under direct sun lights, head-mounted display (optional accessory) will provide clear and large display with excellent outdoor experience.



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

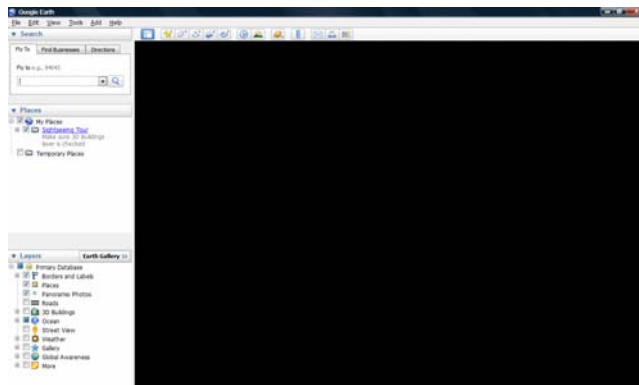
Battery information and motor information is displayed here. If the robot uses the included Li-Po battery, you need to stop the robot when voltage is below marked voltage (22.2V) in order to prevent battery damage. Motor temperatures are also displayed here. "Encoder Pos" boxes show the encoder position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

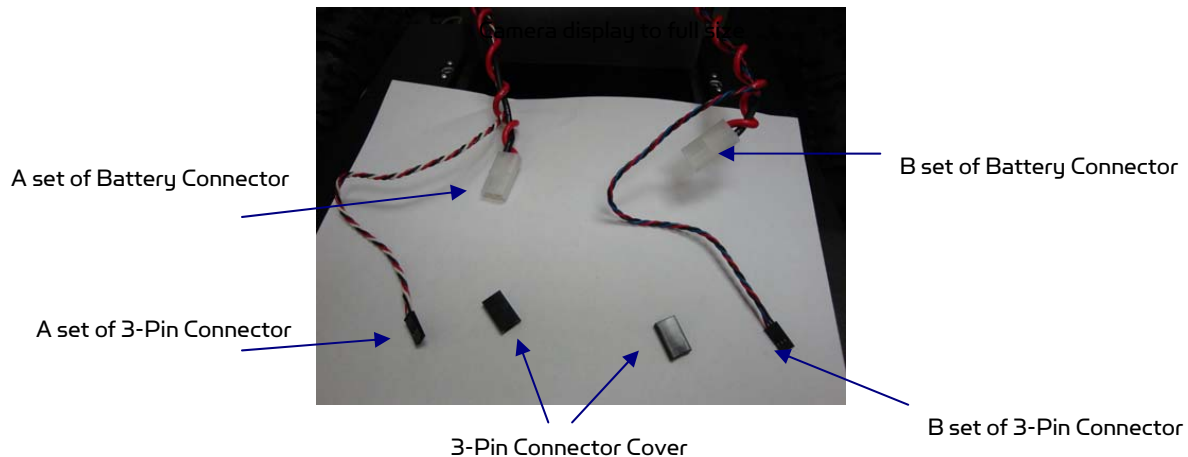
Jaguar robot uses high performance LiPo batteries. Extreme caution is needed when dealing with this type of battery, explosion and damage could occur. Please read the Charge Station manual first and follow all the safety rules before proceeding further.

For Standard Type:

- 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".
- 3) You can use "Enter/Start" + "INC" + "DEC" buttons to change the charge current, DO NOT exceed the 2A charging current and do not modify the battery voltage. It should be "22.2V (6S)" for Jaguar Lite 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.

For Removable Type:

- 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".
- 3) You can use "Enter/Start" + "INC" + "DEC" buttons to change the charge current, DO NOT exceed the 2A charging current and do not modify the battery voltage. It should be "22.2V (6S)" for Jaguar Lite robot.
- 4) Take off the battery package. Unplug the batteries connectors
- 5) Connect with charge cable and plug the temperature sensor cable to temperature 3-Pin port on charger.



- 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.

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 Ethernet modules are configured to serial-to-Ethernet mode in Jaguar platform.

Ethernet 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 19200. 8, N, 1, no flow control

Ethernet Module 2	192.168.0.61
Port 1	Port Number 10001, TCP 57600. 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

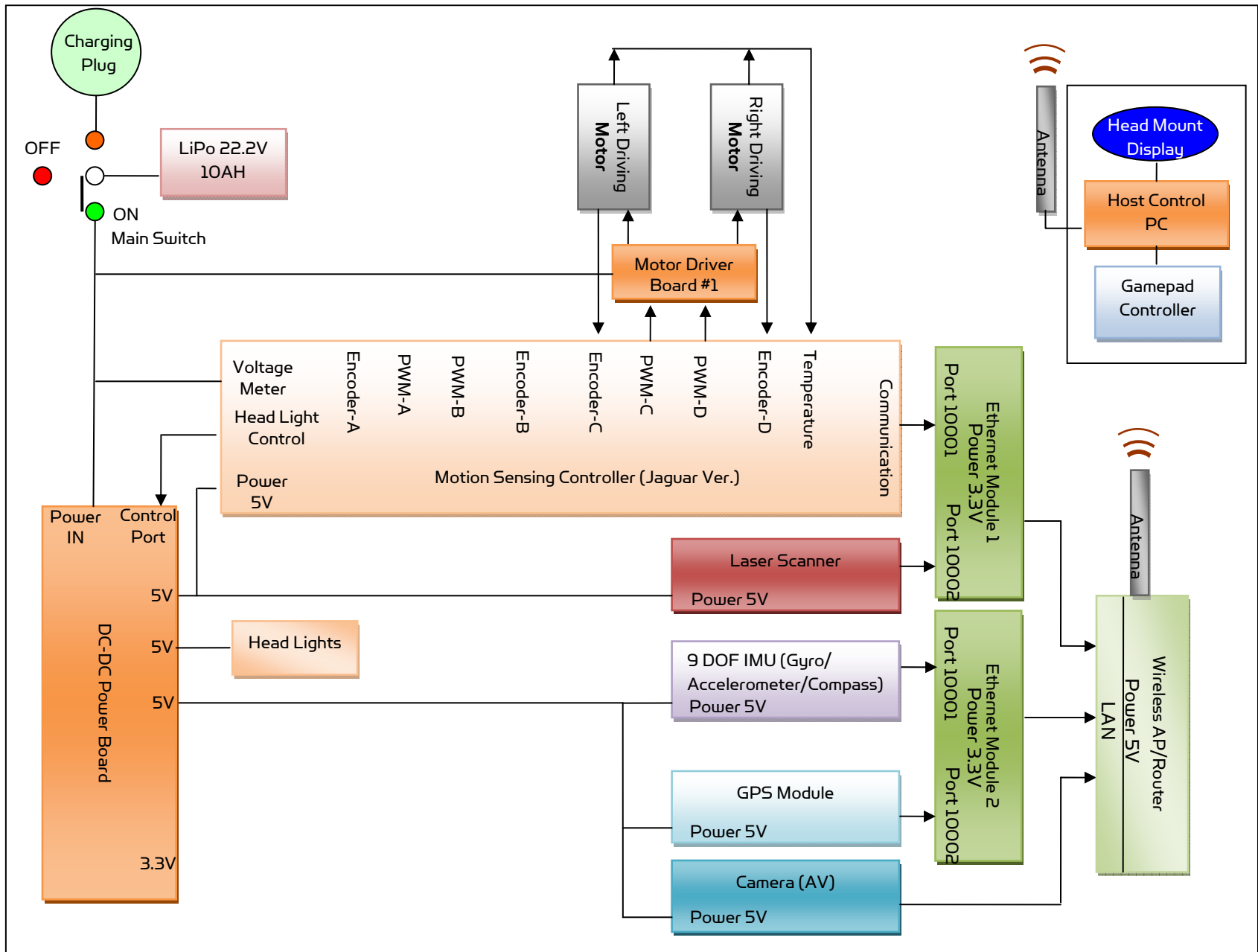
Advanced Network Settings

You could also change the Wireless 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 Ethernet modules on the robot by following the guidelines as illustrated on the Ethernet 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).



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	LiPo Charger
Maximum charge current	2A
Maximum discharge current	2A
Power Input	100-240V

Powertrain (motor, speed-reducer and encoder)

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

Drive track shaft

Track-wheel motors (2 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

IV. 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-A) used for Jaguar robot. Please refer to "AXIS Media Control SDK Help" for detail.

Motion Control/Sensing System

Jaguar-Lite 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 Ethernet 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-Lite System with ActiveX control,

myJaguar is DrRobotSentinelActiveXControl.

Track drive motor control:

```
private void myJaguar_MotorSensorEvent(object sender, EventArgs e)
{
    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 *
    34.498);
}
```

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 and right track/wheel motor encoder in this event.

```
private void myJaguar_CustomSensorEvent(object sender, EventArgs e)
{
    // left track motor
    double tempM =
    Trans2Temperature((double)myJaguar.GetCustomAD5());
    tempM = double.Parse(tempM.ToString("0.00"));
    lblTemp1.Text = tempM.ToString("0.00");
    // right track motor
    tempM = Trans2Temperature((double)myJaguar.GetCustomAD6());
    tempM = double.Parse(tempM.ToString("0.00"));
    lblTemp2.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 Ethernet 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: 19200, 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 Ethernet 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 Ethernet 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,acclY,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.