



All-Terrain Autonomous Navigation Robot with GPS-IMU

Jaguar V2

User Guide



Install Fuse; Charge the battery pack
before use



WARNINGS

Do **NOT** power on the robot before reading and fully understanding the operation procedures explained in this manual.

Always charge the battery when battery is running low or before storage.

Always turn your robot off when not in use. Over-draining the battery (such as keeping the robot on without charging) will damage the battery.

Never position your finger(s) in between the track and/or arm's moving parts even when the power is off.

The robot arms must be positioned to the rest position before turning on the robot.

Neither the robot, nor the program is bug free, accident could happen; you have to make sure that the robot always maintains a safe distance from people during operation.

Failure to follow these warnings could cause serious injury or death and/or damage to the robot.

Copyright Statement

This manual or any portion of it may not be copied or duplicated without the expressed written consent of Dr Robot.

All the software, firmware, hardware and product design accompanying with Dr Robot's product are solely owned and copyrighted by Dr Robot. End users are authorized to use for personal research and educational use only. Duplication, distribution, reverse-engineering, or commercial application of the Dr Robot or licensed software and hardware without the expressed written consent of Dr Robot is explicitly forbidden.

www.DrRobot.com

Contact

General: info@DrRobot.com

Technical Support: support@DrRobot.com

Tel: (905) 943-9572

Fax: (905) 943-9197

Table of Contents

I.	Specifications	5
	Key Features	5
	Jaguar Core Components	7
	Main Upgrade Options	7
II.	Knowing Your Robot	8
	Overlook	8
	Operation Scenario	9
	Software Installation	9
III.	Operation of Jaguar Robot	10
	Turn on/off the Platform	10
	Using Dr Robot Jaguar Control Program	10
	Recharging	14
IV.	Hardware and Electronics	16
	Network Settings	16
	Wireless Router Setting	16
	Device Default Network Settings	16
	Advanced Network Settings	16
	Hardware Architecture	16
	Motor Driver Board	18
	Motion and Sensing Controller	18
	Camera	18
	GPS	18
	9 DOF IMU (Gyro, Accelerometer & Digital Compass)	19
	Laser Scanner	19
	Batteries	19
	Charger	19
	Powertrain (motor, speed-reducer and encoder)	19
	The Jaguar Control program	20
	Laser Scanner	20
	GPS	20
	Advanced Development	21

I. Specifications

Jaguar Mobile Robotic Platform is designed for indoor and outdoor applications requiring robust maneuverability. It comes with two articulated arms and is fully wirelessly (802.11G) connected. It integrates outdoor GPS and 9 DOF IMU (Gyro/Accelerometer/Compass) for autonomous navigation. Jaguar platform is rugged, light weight (< 25Kg), compact, weather and water resistant. It is designed for extreme terrains and capable of climbing up stairs (up to 200mm 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 robust maneuverability
- With two synchronized (or optional independently controlled) articulated arms
- Indoor and outdoor operation for extreme terrains
- Weather and water resistant enclosure
- Climbing up > 45° slope or stairs (max 200mm or 8")
- Light weight (< 25Kg) and compact design with large payload capacity
- Autonomous navigation with outdoor GPS and 9 DOF IMU (Gyro/Accelerometer/Compass)
- Managing max 200mm (8") vertical step (obstacle)
- Surviving max 1500mm (5ft) 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: 200mm (8")
Stair climbing: Max stair step height 200mm (8")
Traverse: > 260mm (10")
Two articulated arms (Standard: synchronized motion; Optional: independent controlled)
Speed: 0 – 5Km/hr
Turning radius: 0, min 850mm (33.5") 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: 1500mm (5ft) Rated: 900mm (3ft)
Self-correction from flip-over with articulated arms

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

WiFi802.11G (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: 2 hours (Optional 4 hours)

Motor

Track Motors (24V): 2 units
Max output (after gear down) (x2): Max 80W, 100Kg.cm/track
Rated current: 2.75A, Max current: 16A

Arm Motor (24V): 1 unit
Max output (after gear down): Max 80W, 450Kg.cm
Rated current: 2.75A, Max current: 16A

Dimensions

Height: 176mm (7")
Width: 700mm (27.6")
Length: 820mm (32.3") (extended arms) / 640mm (25.2") (folded arms)
Weight: 25Kg (Standard Configuration)

Payload

Carrying Payload (on flat surface): max 15Kg
Dragging Payload (on flat surface): max 50Kg

Application Development

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

Microsoft **ROBOTICS STUDIO**



Visual Studio

LabVIEW

MATLAB



ROS



Jaguar Core Components

JAGUARV2-ME	Jaguar V2 Chassis (including motors and encoders)	1
PMS5006	Motion Controller (Jaguar V2 Version)	1
WF5802G	WiFi 802.11b/g Wireless Module	1
PMCHR12	DC-DC Power Board	1
AXCAM-A	640x480 Networked Color Camera (max. 30fps) with Two-Way Audio	1
OGPS501	Outdoor GPS Receiver with 5Hz Update Rate and WAAS	1
IMU9002	9 DOF IMU (Gyro/Accelerometer/Compass)	1
WRT802N	802.11N wireless AP/router	1
BPN-LP-20	22.2 V 10 AH LiPo Battery Pack	1
LPBC5000	2A LiPo Battery Charger	1
GPC0010	Gamepad Controller	1
SDC2130	2X20A Motor Controller	2

Main Upgrade Options

Jaguar Manipulator Arm	JAGUARARM
Laser Scanner (Range 4m) for Indoor Application	LAS04M
Laser Scanner (Range 5.6m) for Indoor Application	LAS56M
Laser Scanner (Range 30m) for Outdoor Application	LAS30M
Upgrade to 22.2V 20AH Li-Polymer Battery Pack	BPN-LP-U20
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 robot.



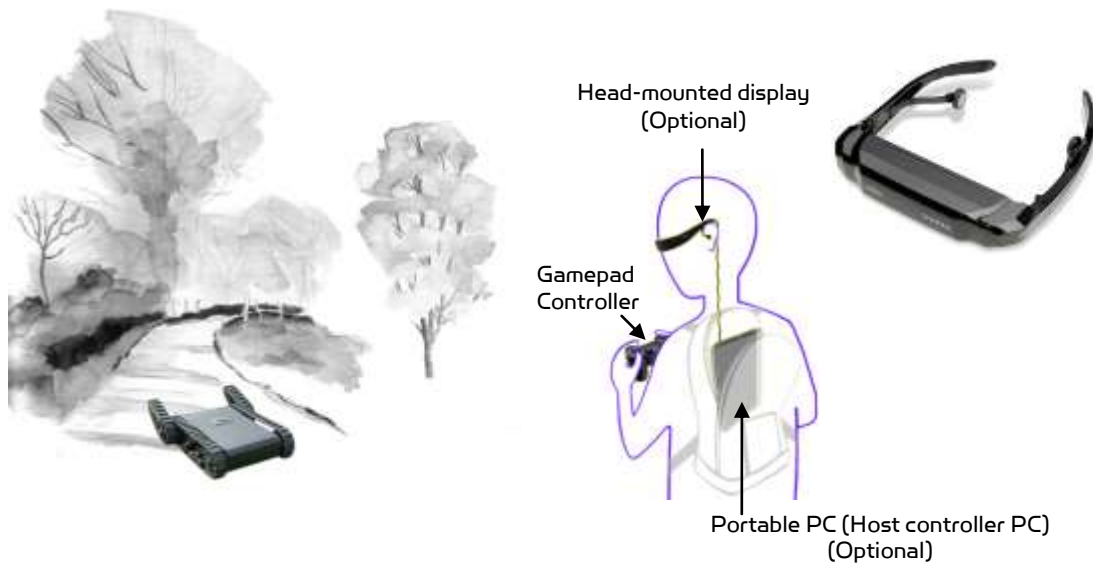
Jaguar Platform

Operation Scenario

Diagram below illustrates the typical operation scenario. The Jaguar 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 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).

Turn on/off the Platform

Please follow the below steps to turn on the robot.

1. Turn the main switch to "ON" position.
2. Press the start button for a while (around 1 second) then release.
If you see the green LED on the start button is on, the system is powered up.
If not, please check the battery to make sure it is fully charged.

Turn the main switch to "OFF" position, the system will shut down.



Using Dr Robot Jaguar Control Program

After turn on the robot, please make sure your PC could find the WiFi network with SSID "DriJaguar", and connect with this network with key "drrobotdrrobot". After successful connection, please fix your PC IP address as "192.168.0.104" at this wireless interface. You could try to ping the main control module by command "ping 192.168.0.60" to make sure the connection work well.

This program will demonstrate how to control and navigate the Jaguar, move the arm-tracks 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_v2.xml" under c:\DrRobotAppFile\.

When "Connect Robot" is clicked, it 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 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_v2.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 Controller

Initializing or resetting arm-track position:


After powering up the robot, or when the actual arm position is different from the arm position window (shown on the below), you should reset the arm-track position as following:

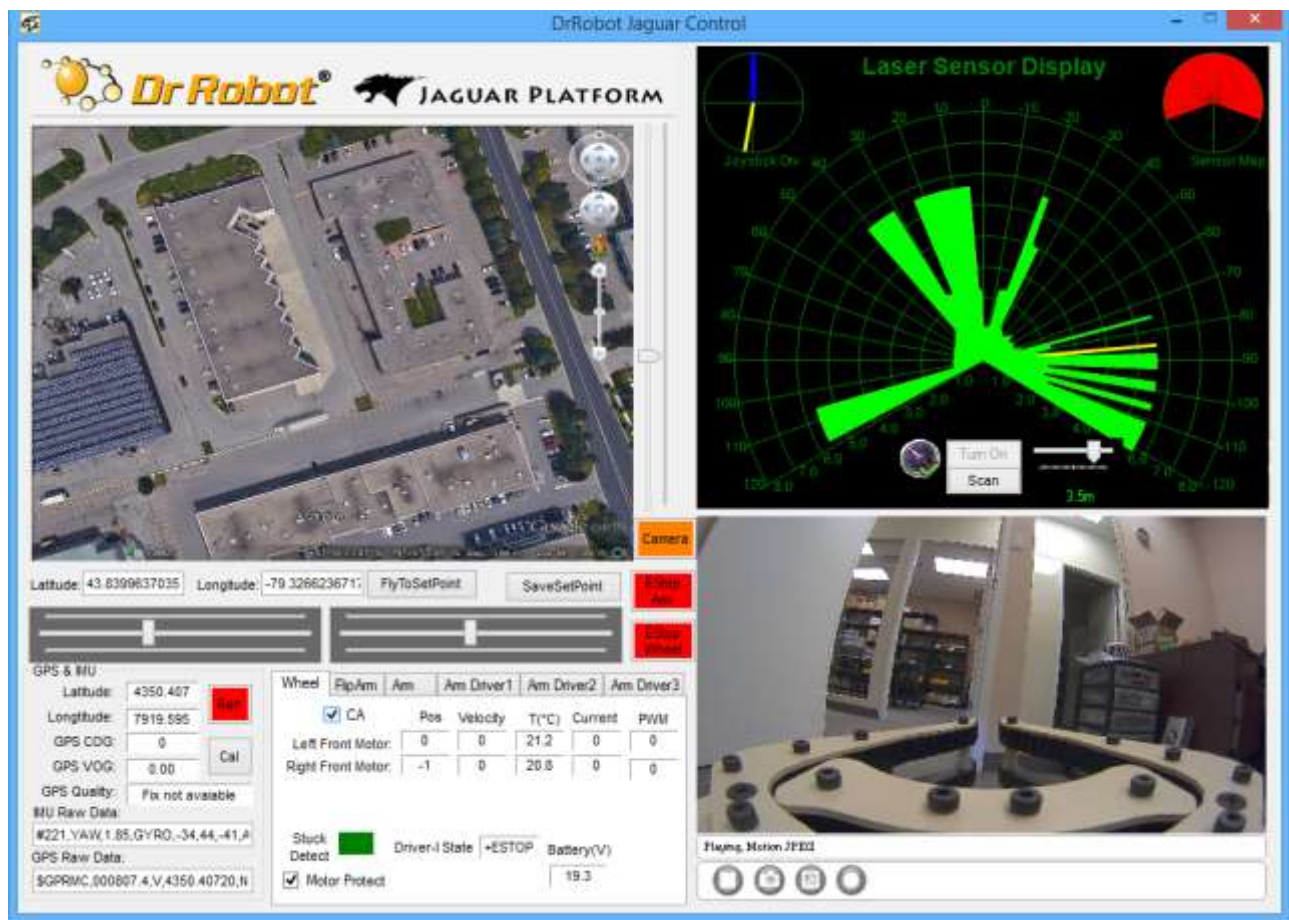
- drive the arm forward and being flat on the ground (as shown below), we call this initial or "0" position (extend forward)



- then, click the "Set arm's initial position" button to save this value and reset arm position display.

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

Click "Turn on" and then "Scan" button. You could use trackbar to adjust the data cut-off distance (i.e. any obstacle with distance larger than this value will be ignored). By checking , you will enable the collision avoidance function. The blue line in the "joystick Drv" polar display means the joystick drive direction, and the yellow line means the robot will go to direction due to the collision avoidance algorithm.



Wheel	FlipArm	Arm	Arm Driver1	Arm Driver2	Arm Driver3
<input checked="" type="checkbox"/> CA					
Left Front Motor:	0	0	21.2	0	0
Right Front Motor:	-1	0	20.8	0	0


Stuck Detect	<input checked="" type="checkbox"/>	Driver-I State	+ESTOP	Battery(V)	19.3
<input checked="" type="checkbox"/> Motor Protect					19.3

Battery information and motor information is displayed here. If the robot uses the included LiPo 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.

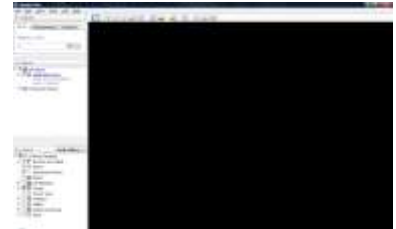
Motor Protect When selected, the motors will be disabled when measured motor temperature is higher than the safety threshold (we recommend this feature is enabled for normal operation); When de-selected, this motor over-heat protection feature is disabled.

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 to "c:\DrRoboAppFile" 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.




is to disable arm action.

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) Turn off the robot

2) Loose the screws of Battery Box, disconnect the 2-Pin Tamiya connector and take the Battery Box out.

3) Power on the Charge Station. Use  to make sure "LiPo BALANCE" is displayed on the LCD screen. If not, use "Type/Stop" button to change

battery type to "LiPo Battery" and press  to set charging mode to "LiPo BALANCE".




4) You can use  +  /  +  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 robot.

5) Connect the charging 7-Pin & 4-pin connectors to charger






6) Press  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  button again to start charging.



8) Press  to switch the display to show the battery status. The display should show each battery reading as below image.



*** Note:** If any battery reading is missing, please turn off the charging station and turn the Power switch to "OFF", and check the 7-pin connector, make sure it is connect well.

9) Keep the charger away from children and pet at all time! Never leave the charger unsupervised when it is connected to its power supply. For more detail about charger station operation, warning and error message, maintenance and safety message, please refer to "Intelligent Digital Balance Charger Operating Manual".

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	drrobot
KEY	drrobotdrrobot	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

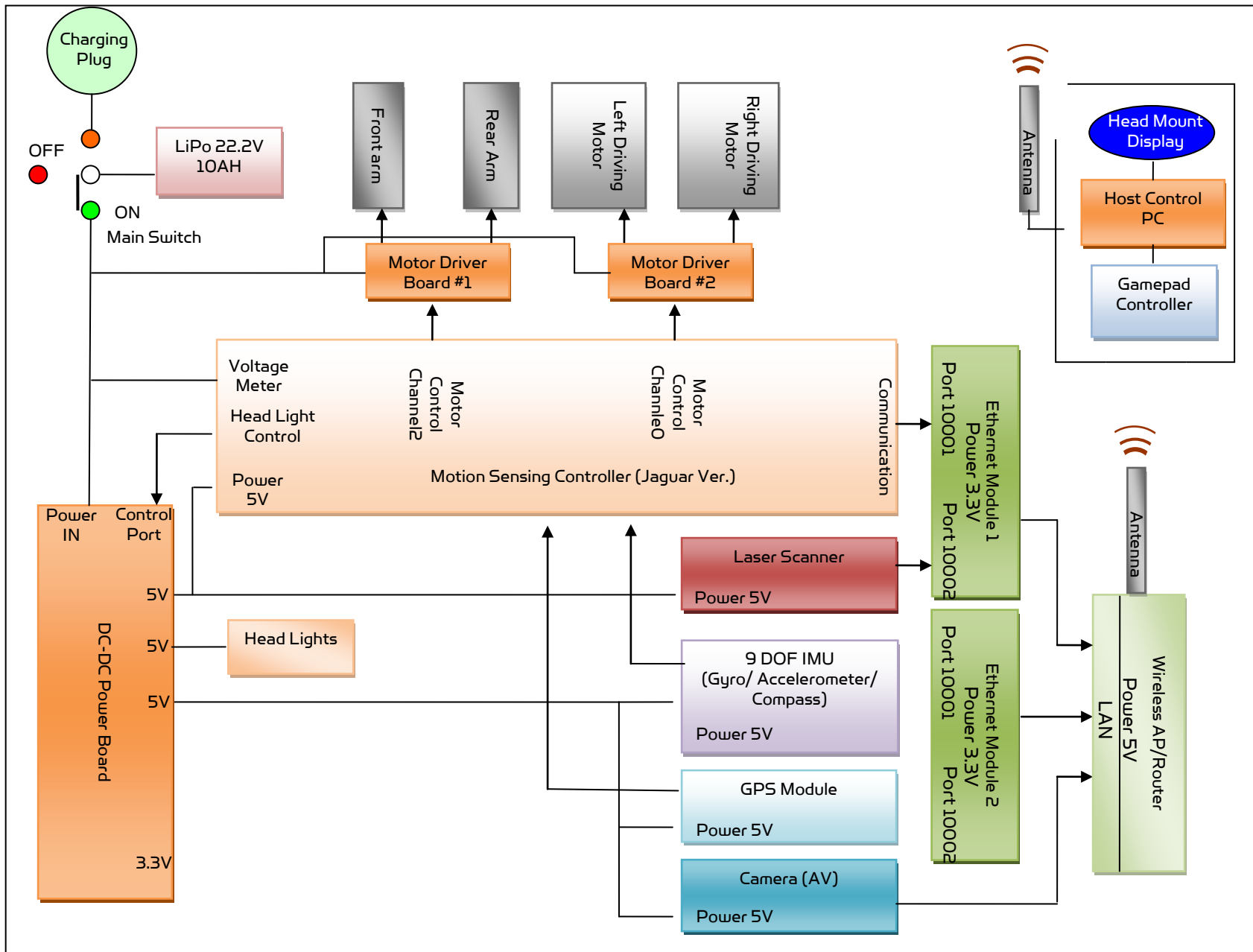
Advanced Network Settings

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).



Motor Driver Board

Two motor driver boards are used, one for the left and right track/wheel motors while the other one is for the arm motor.

Input power	H-Bridge 2 channels
Max current	up to 10A continuous power per channel, peak up to 20A per channel for a few seconds
Input voltage	12~30V, 30V absolute max
Motor control	Open loop PWM control; Velocity control; Position control
Sensor sampling	Encoders, motor current, motor temperature

Motion and Sensing Controller

PMS5006 board is based on ARM Cortex-M4 controller. It will work as a main control center. Receive remote PC control command and send back all the sensor data, including IMU sensor, GPS module data and all the motor sensors, such as motor encoder, motor temperature, and motor driver board state.

Input power	5V
Motor Control Channel - 0	Channel 0 will control front left motor and channel 1 will control front right motor.
Motor Control Channel - 1	reserved
Motor Control Channel - 2	Channel 0 will control front flipper arm motor and channel 1 will control rear flipper motor.
Motor Control Channel - 3	Reserved
IMU/GPS Reading	Read GPS and IMU readings
Input power	5V
Motor Control Channel - 0	Channel 0 will control front left motor and channel 1 will control front right motor.

Camera

Input power	5V
Lens	4.4mm: 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

9 DOF 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	12V
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, including the gearbox and /or pulley system.

Flipper Arm shaft

Track-arm motor (1 unit)	DC motor with steel gearbox
Motor rated voltage	24V
Motor rated current	2.75A
Motor max current	16A
Shaft rated speed	19RPM
Shaft rated torque	92Kg.cm
Shaft encoder resolution	1083 counts per revolution

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	170RPM
Shaft rated torque	14.5Kg.cm
Shaft encoder resolution	1227.4 counts per revolution *

*Before pulley-belt speed reduction (34:20), the motor shaft encoder resolution is 722 counts per revolution.

The Jaguar Control program

The Jaguar Control program is written with Visual Studio 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:

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.

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 for Hokuyo URG-04LX.

For URG-04LX-UG01(5.6m) or UTM-30LX(30m) setting is: 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. 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.

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 ROS, LabVIEW and MATLAB. Please contact support@drrobot.com for further information.