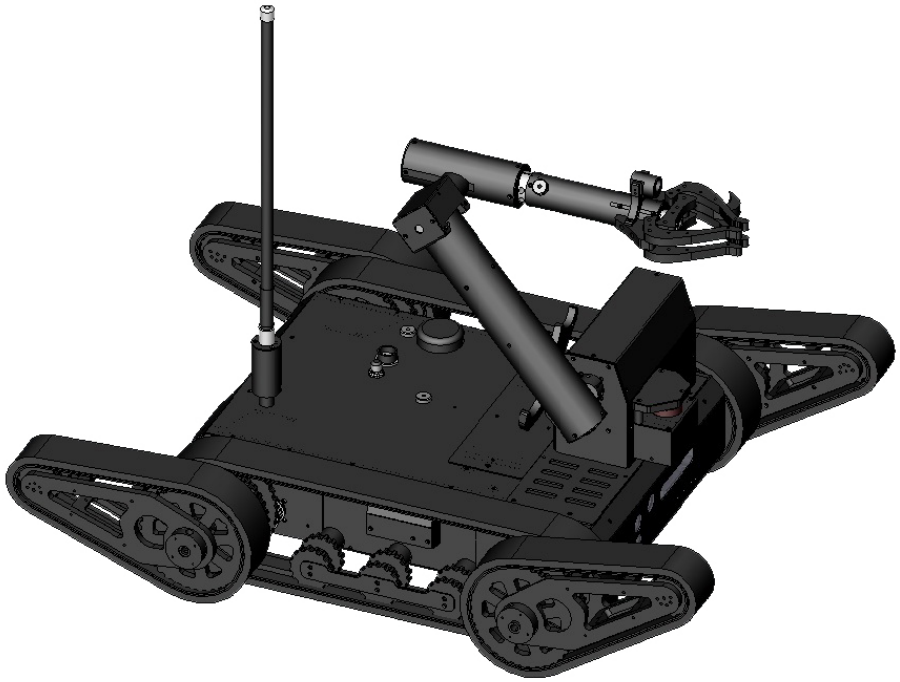
All-Terrain Autonomous Navigation Robot with GPS-IMU

Jaguar V4

with Manipulator Arm

User Guide



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

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I. Specifications

Jaguar V4 Mobile Robotic Platform with manipulator arm is designed for indoor and outdoor applications requiring robust maneuverability, terrain maneuverability and object manipulation. It comes with four articulated arms and is fully wirelessly 802.11N connected. It integrates outdoor GPS and 9 DOF IMU (Gyro/Accelerometer/ Compass) for autonomous navigation. Jaguar V4 platform is rugged, light weight (< 30Kg), compact, weather and water resistant. It is designed for extreme terrains and capable of stair or vertical climbing up to 300mm with ease. The 4 articulated arms could convert the robot into various optimal navigation configurations to overcome different terrain challenges. The integrated high resolution video/audio and optional laser scanner 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.

The integrated rugged 3+1DOF robotic manipulator (Jaguar Arm) is designed for compact mobile robots. It is light on weight, low on power consumption and compact on size. It has 3 DOF + 1 DOF gripper, with maximum reach of over 707mm (28 in), max payload capacity of 4Kg at max reach, while weights under 10Kg. Wrist mounted color video camera provides high resolution (720 x 480) close-up view. Jaguar Arm is ideal for object inspection and handling. It could also work as an articulated sensor platform. Integrated software features independent joint space control as well as gripper Cartesian space control. While it only has 3 rotation joints (excluding gripper), when working together with the Jaguar mobile robot, Jaguar Arm could achieve full 6DOF, and reach virtually any position and at any orientation within its allowed working space.

Key Features

- Rugged and reliable mobile platform for indoor and outdoor applications with robust maneuverability
- With Four articulated arms that could convert the robot into various navigation configurations to overcome different terrain challenges
- Indoor and outdoor operation requiring higher ground clearance and on tough terrains
- Weather and water resistant enclosure
- Climbing up > 55° slope or stairs (max 300mm or 12")
- Light weight (< 41Kg) and compact design with large payload capacity
- Autonomous navigation with outdoor GPS and 9 DOF IMU (Gyro/Accelerometer/Compass)
- Managing max 300mm (12") vertical step (obstacle)
- Integrated Laser scanner (Optional)
- Integrated high resolution video camera with audio
- All 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
- Rugged robotic arm (3DOF + 1DOF gripper) for compact mobile robots
- 707mm (28 in) reach with max 4Kg payload
- Wide gripper opening (150mm/ 6 in)
- Integrated joint-space and gripper Cartesian space arm control
- Wrist mounted camera providing high resolution (720x480) close-up view
- Full development kit including SDK, data protocol and sample codes, supporting Microsoft® Robotics Studio, Microsoft® Visual Studio, ROS, NI LabVIEW®, MATLAB®, Java®

Mobility

Terrain: Sand, rock, concrete, gravel, grass, soil and others wet and dry
Slope: > 55°
Maximum vertical step: 300mm (12")
Stair climbing: Max stair step height 300mm (12")
Traverse: > 360mm (14")
Four articulated arms
Speed: 0 – 4.5Km/hr
Turning radius: 0, min 850mm (33.5") diameter of turning space
Ground clearance: 38mm (1.5"); Max 150mm (6") with Stand-Up Arms
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 (5.6m, 4m or 30m) (Optional)
Temperature sensing & Voltage monitoring
Headlights

Video / Audio

Color Camera (640x480, 30fps) with audio on base
Color Camera (720x480, 30fps) on manipulator

Communication

WiFi802.11N
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 20AH
LiPo battery charger
Nominal operation time: 3 hours

Motor

Track Motors (24V): 4 units
    Max output (after gear down) (x2): Max 80W, 100Kg.cm/track
    Rated current: 2.75A, Max current: 16A

Flipper Motor (24V): 2 units
    Max output (after gear down): Max 80W, 450Kg.cm
    Rated current: 2.75A, Max current: 16A

Dimensions

Height: 400mm (15.7") (manipulator at rest)
Width: 700mm (27.6")
Length: 980mm (38.5") (extended arms) / 640mm (25.2") (folded arms)
Weight: 41Kg (Standard Configuration)

Payload

Carrying Payload (on flat surface): max 10Kg
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, ROS, NI LabVIEW®, MATLAB®, Java®

Jaguar Core Components

JAGUARV4-ME	Jaguar V4 Chassis (including motors and encoders)	1
JAGUARARM	Jaguar Manipulator Arm	1
PMS5005-JV4	Motion and Sensing Controller (Jaguar V4 Version)	1
WFS802G	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
OGPS501	Outdoor GPS Receiver with 5Hz Update Rate and WAAS	1
IMU9000	9 DOF IMU (Gyro/Accelerometer/Compass)	1
WRT802N	802.11N wireless AP/router	1
BPN-LP-20	22.2 V 20 AH LiPo Battery Pack	1
LPBC5000	2A LiPo Battery Charger	2
GPC0010	Gamepad Controller	1
SDC2130	2X20A Motor Controller	2

Main Upgrade Options

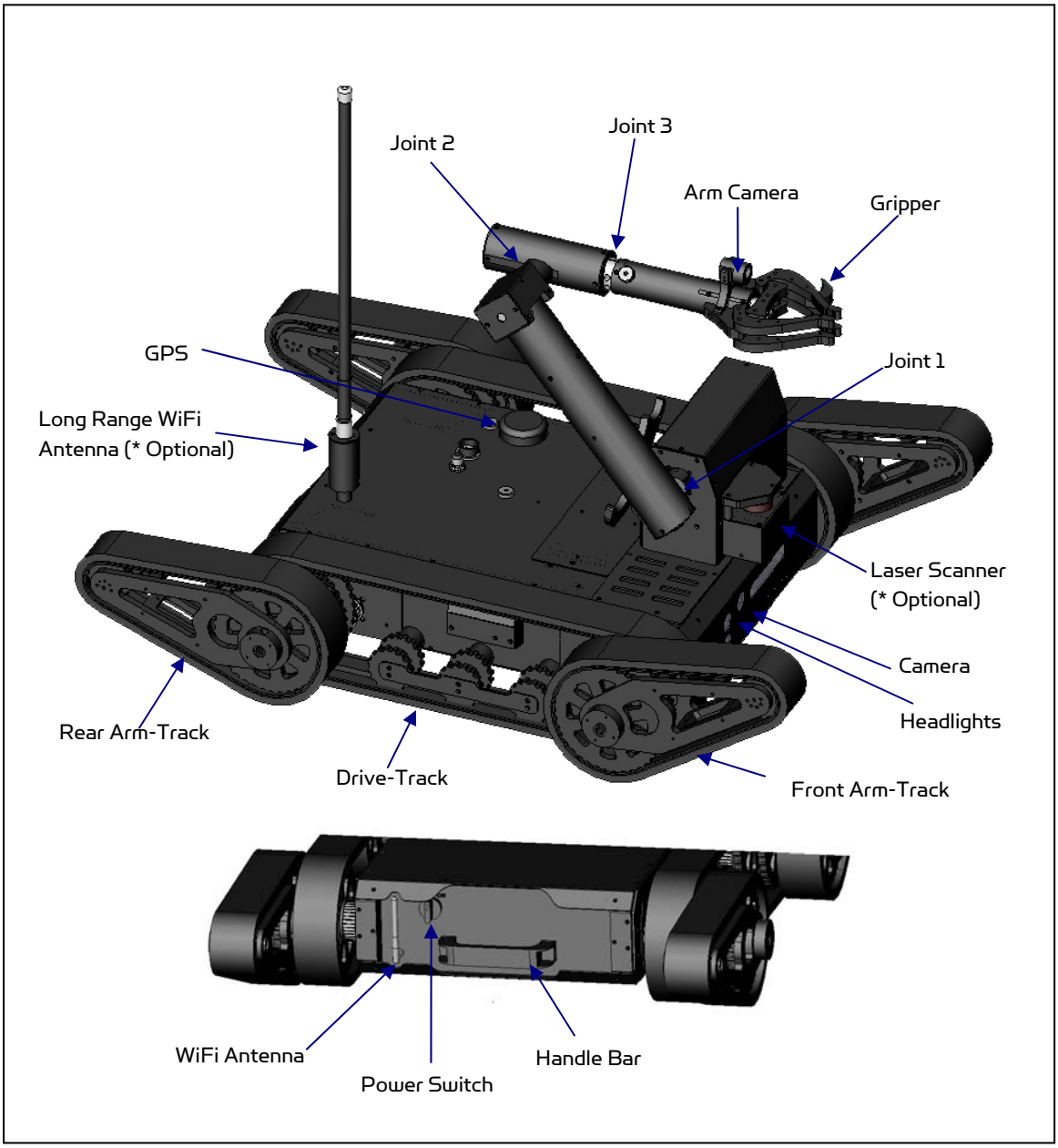
Laser Scanner (Range 4m) for Indoor Application	LAS04M
Laser Scanner(Range 5.6m) for Indoor Application	LAS56M
Laser Scanner (Range 30m) for Outdoor Application	LAS30M
22.2V 20 AH Li-Polymer Battery Pack	BPN-LP-20
Head Mounted Display (800x600)	HMD8H6H
802.11N Wireless AP/Router	WRT802N
Host Controller PC	HCPC1008

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

II. Knowing Your Robot

Overlook

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



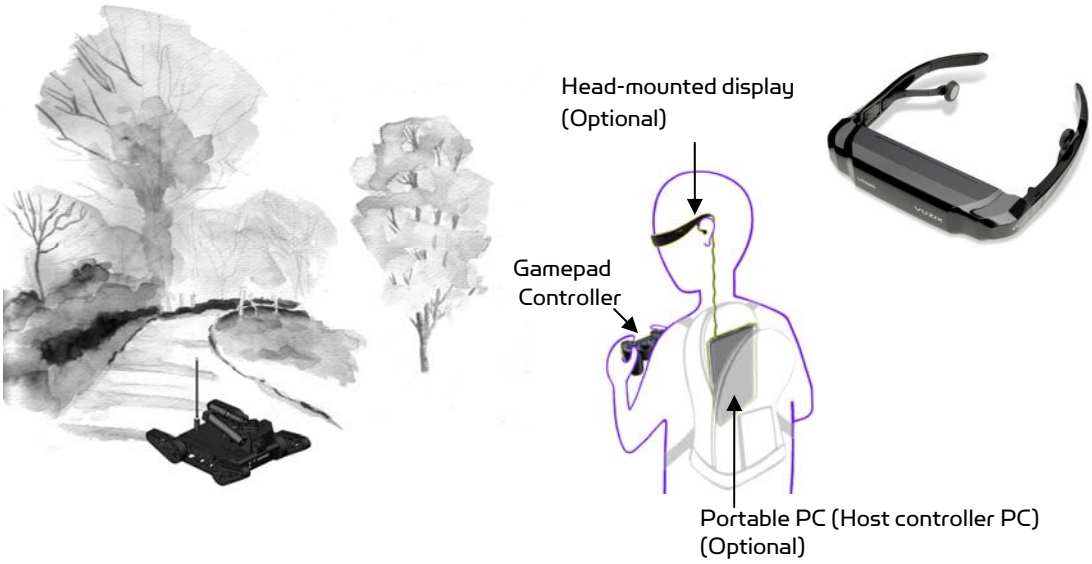
Jaguar V4 with Manipulator Arm Platform

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.

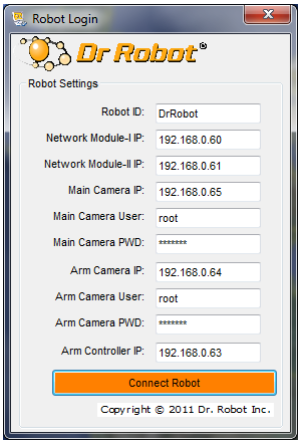
   If not, please check the battery to make sure it is fully charged.

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

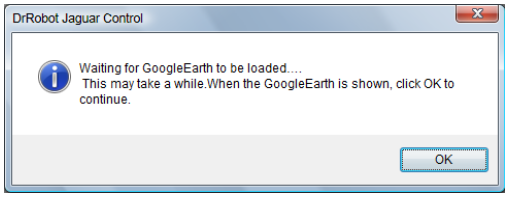
Using Dr Robot Jaguar Control Program

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#).

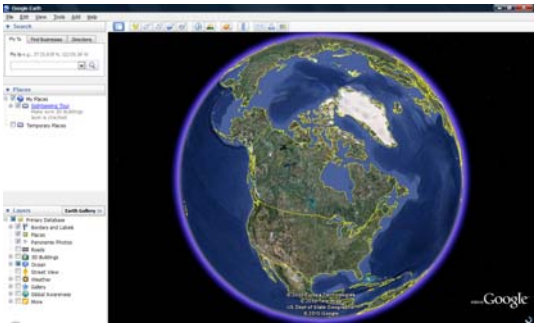
- updates motor encoder reading, motor temperature, board voltage and battery voltage measured at 10Hz;
- reads and displays IMU and Laser Range sensor data;
- displays GPS readings on the Google Earth;
- displays and controls Axis camera.



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



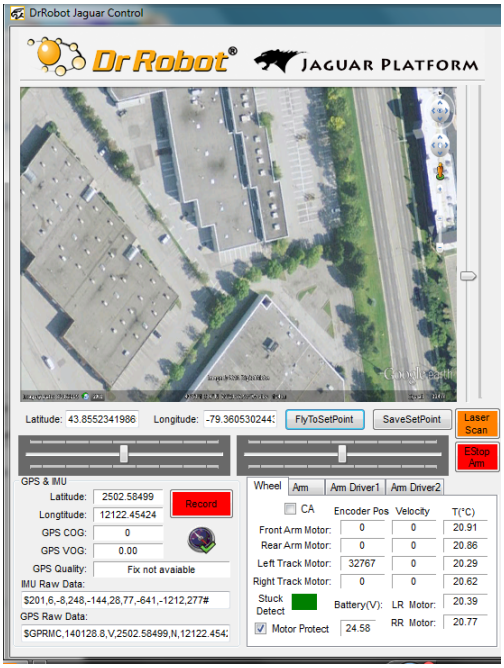
When "Connect Robot" is clicked, it will start the WiRobotGateway program (also under c:\DrRobotAppFile\) and will try to connect to the Robot.



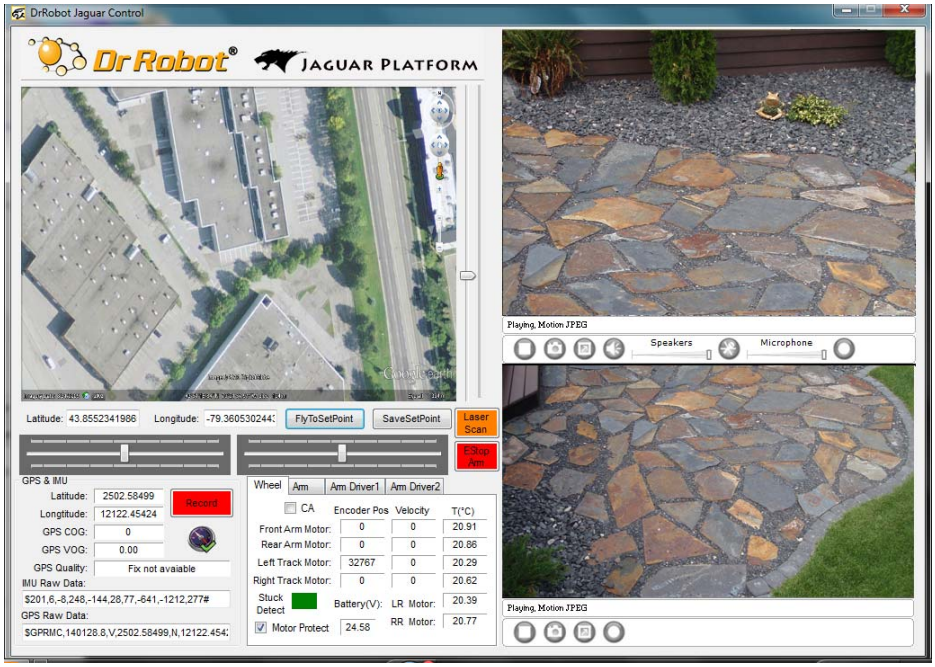
Google Earth is then loaded (this may take a while).

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.xml" when program is closed.



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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

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

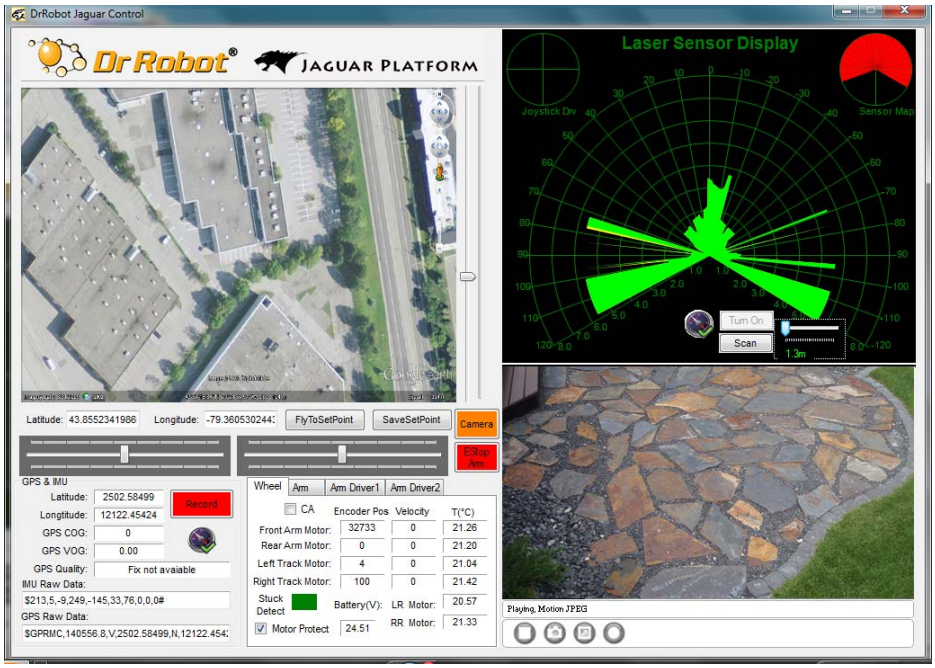
Initializing or resetting arm-track position:

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

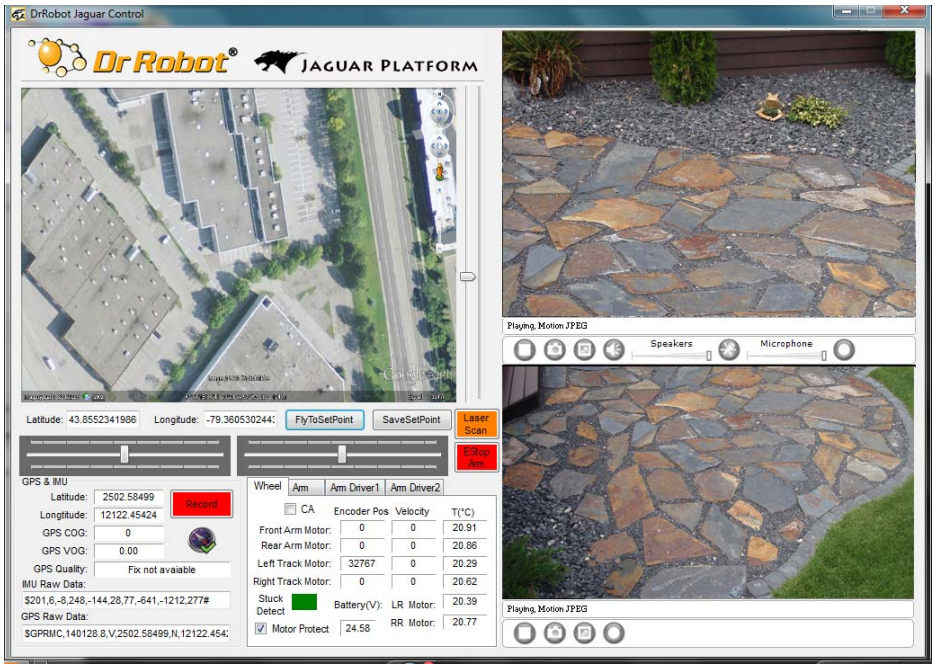
- drive the arm forward and being flat on the ground (as shown below), we call this initial or "0" position (extend forward)

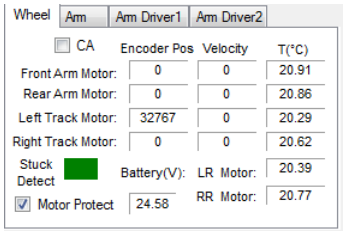
- then, click the "X" button on Gamepad to save this value and to set initial position.

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

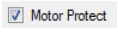


Click "Turn on" and then "Scan" button. You could use trackbar to adjust the data cut-off distance (i.e. any obstacle with distance larger than this value will be ignored). By checking ☐ CA , you will enable the collision avoidance function.

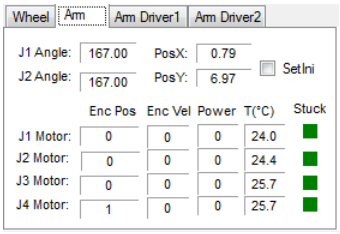




Battery information and motor information is displayed here. If the robot uses the included LiPo battery, you need to stop the robot when voltage is below marked voltage (22.2V) in order to prevent battery damage. Motor temperatures are also displayed here. "Encoder Pos" boxes show the encoder position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



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

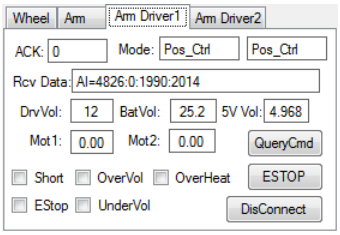


Shows Joints Angle Information and Control Value
* Arm J4 is Gripper

If you press the "Start" button on gamepad to set manipulator initial position, it will "check" 

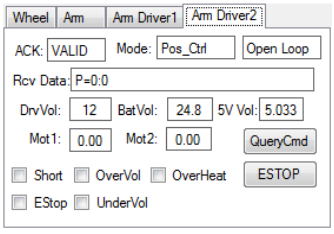
.
After that, you could press "B" button on gamepad to reset manipulator arm to initial position.

When you operate the manipulator arm, please pay attention to the temperature sensor readings to avoid overheating the motors



"Arm Driver1" tab will display motor driver controller 1 states (for Joint 1 and 2). If you did not get the sensor reading back, you could click "QueryCmd" button to send query command. Please make sure the channel 1 and 2 are working in position control mode (Mode:3).

will display channel1, 2 motor's current.



"Arm Driver2" tab will display motor driver 2 states (for Joint3 and Gripper). If you did not get the sensor reading back, you could click "QueryCmd" button to send query command. Please make sure the channel 1 is working in position control mode (Mode:3) and channel 2 is working in open loop mode.

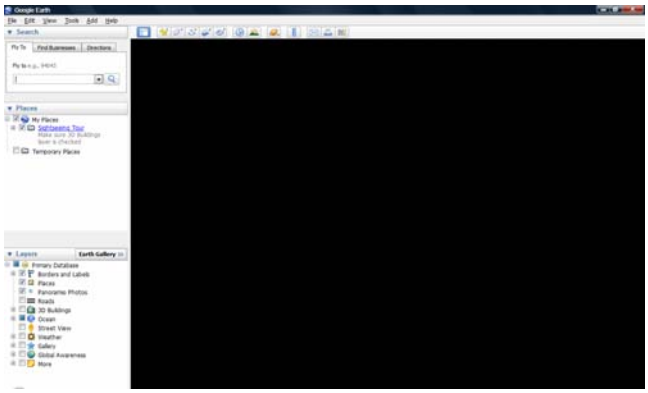
will display channel 1 and 2 motor's current.

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 by using "Windows Task Manager"; otherwise, you may not be able to display Google Earth when you start Jaguar control program again.

is Emergency Stop for manipulator arm (disable) action.

You could click the 

button to resume the manipulator arm controller.

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.

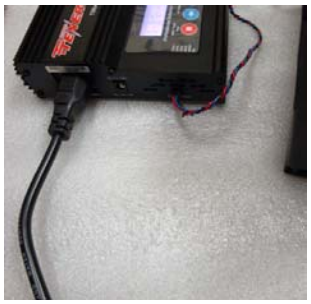
1) Turn off the robot

2) Loose the locking screws of the 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 shown.

* 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 connects 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 Operation Manual".

IV. Hardware and Electronics

Network Settings

Wireless Router Setting

The on-robot pre-configured wireless AP has the following pre-set settings:

SSID	DriJaguar	**AP LAN**	192.168.0.245
WEP	128bits	**Login ID**	admin
KEY	drrobotdrrobot	**Password**	drrobot
Key Type	Open Key		

Note: for robot with long range wireless upgrade, the AP IP could be 192.168.0.20 instead of 192.168.0.245.

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 10001 to base controller board	UDP 115200. 8, N, 1, no flow control
Port 2	Port 10002 to Laser Scanner(option)	TCP 19200/115200. 8, N, 1, no flow control

Ethernet Module 2	192.168.0.61	
Port 1	Port 10001 to IMU sensor	TCP 57600. 8, N, 1, no flow control
Port 2	Port 10002 to GPS sensor	TCP 115200. 8, N, 1, no flow control

Ethernet Module 3	192.168.0.63	
Port 1	Port 10001 to manipulator motor controller 1	TCP 115200. 8, N, 1, no flow control
Port 2	Port 10002 to manipulator motor controller 2	TCP 115200. 8, N, 1, no flow control

Camera	192.168.0.65 Port 8081
User ID	root
Password	drrobot

Manipulator Arm Camera	192.168.0.64 Port 8082
User ID	root
Password	drrobot

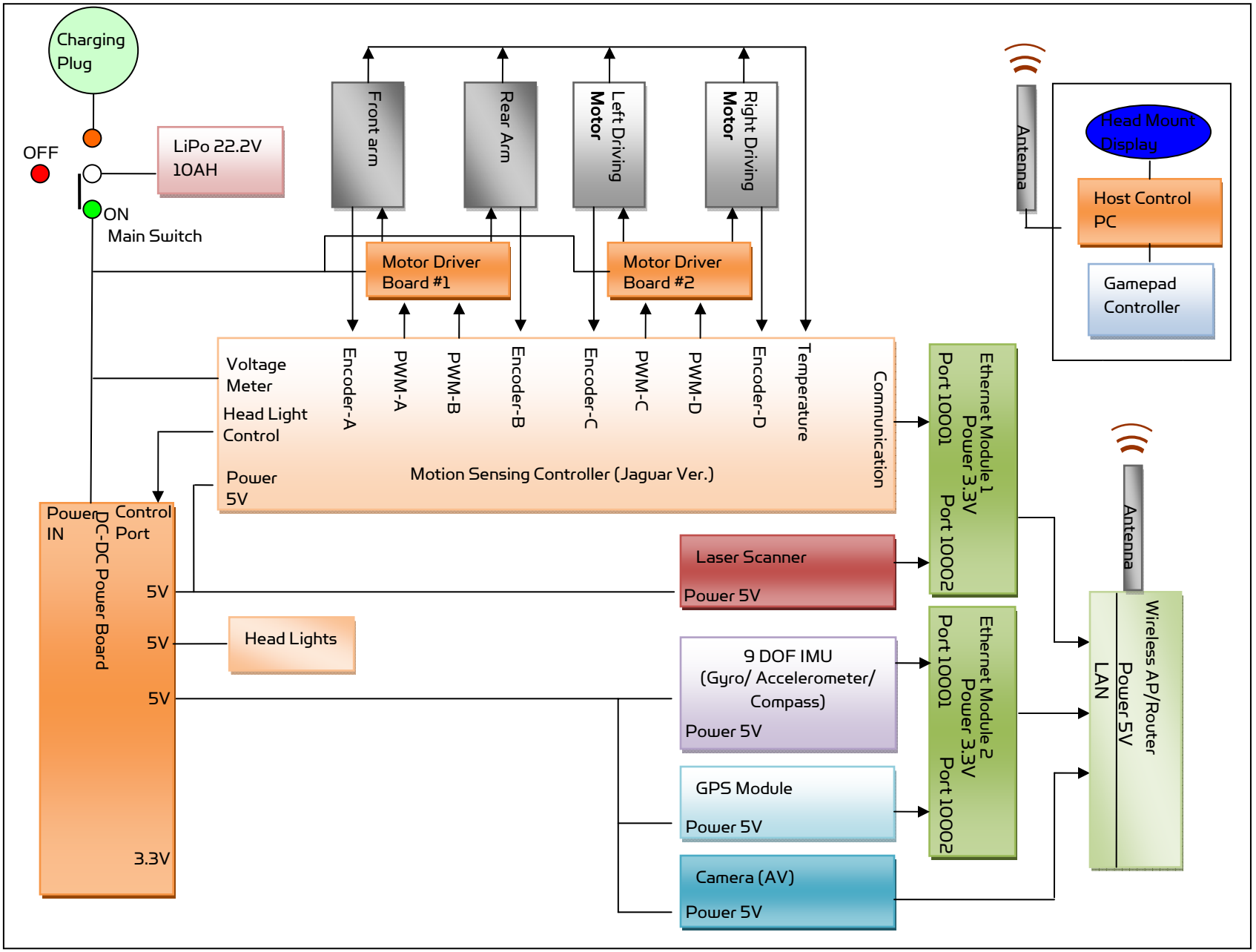
Advanced Network Settings

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).



Jaguar V4 Base System

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 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 PMS5005 board.

Input power	5V
6 PWM output	Arm motor: Channel 0 Left and right track/wheel motors: Channel 3 – Drive Power; Channel 4 – Turn Power
Motor control mode	PWM control; Velocity control; Position control
Sensor sampling	Encoders: Channel 0,for left and right arm-track Channel 3,4 for left and right track/wheel
	Board voltage measuring
	Battery voltage measuring
	Motor temperature measuring (3 units)
	Other extended A/D channels (please contact Dr Robot).

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	ITG-3200 triple-axis gyro
Accelerometers	3 Axis ADXL345 13bit resolution Max +/-16G
Magnetic Compass	3 Axis HMC5883L 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

Jaguar Manipulator Arm System

Motor Driver Board

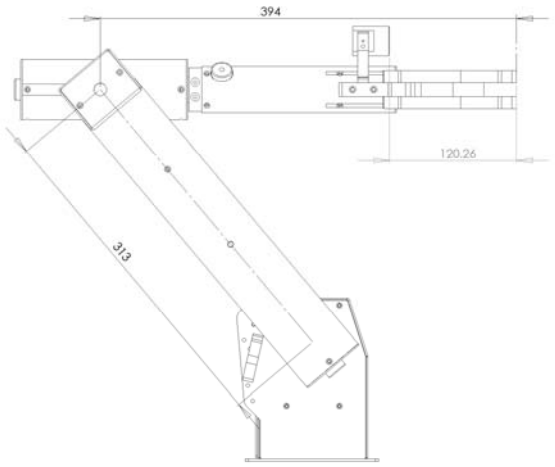
Two motor driver boards are used,

Input power	H-Bridge 2 channels
Max current	up to 10A continuous power per channel, peak up to 20A per channel for a minute
Input voltage	7~30V

Camera

Input power	48V
Resolutions	720x480 to 176x120
Horizontal Field of View	51°
Frame rate	H.264: 30 fps in all resolutions Motion JPEG: 30 fps in all resolution
Video compression	H.264 (MPEG-4 Part 10/AVC), Motion JPEG

Dimension



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 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.

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 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 System with ActiveX control,

`myJaguar` is DrRobotSentinelActiveXControl.

Arm and drive motor control:

```
private void myJaguar_MotorSensorEvent(object sender, EventArgs e)
{
      //here is front arm ouput pwm value
      armMotor[0].pwmOutput = myJaguar.GetMotorPWMValue1();

      //here is front left arm encoder reading
      armMotor[0].encoderDir = myJaguar.GetEncoderDir1();
      armMotor[0].encoderPos = myJaguar.GetEncoderPulse1();
      armMotor[0].encodeSpeed = myJaguar.GetEncoderSpeed1();

      //here is front right arm encoder reading
      armMotor[1].encoderDir = myJaguar.GetEncoderDir2();
      armMotor[1].encoderPos = myJaguar.GetEncoderPulse2();
      armMotor[1].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 *
      34.498);
}
```

You could read motor temperature 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)
 {
      // front arm motor temperature
      double tempM =
      Trans2Temperature((double)myJaguar.GetCustomAD5());
      tempM = double.Parse(tempM.ToString("0.00"));
      lblTemp1.Text = tempM.ToString("0.00");
```

```
            // left track motor
            tempM = Trans2Temperature((double)myJaguar.GetCustomAD7());
            tempM = double.Parse(tempM.ToString("0.00"));
            lblTemp3.Text = tempM.ToString("0.00");

            // 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);
```

To control arm motor using PWM control with value 32767 (full PWM) you could use:

```
myJaguar.DcMotorPwmNonTimeCtrAll(32767,NOCONTROL, NOCONTROL, NOCONTROL,
NOCONTROL, NOCONTROL);
```

or

```
myJaguar.DcMotorPwmNonTimeCtr(0,32767);
```

Using position control, move motor to encoder position 2000 in 2000 ms, you could use:

```
myJaguar.DcMotorPositionTimeCtrAll(2000,NOCONTROl,NOCONTROL,NOCONTROL,N
OCONTROL, NOCONTROL, 2000);
```

or

```
myJaguar.DcMotorPositionTimeCtr(0, 2000, 2000);
```

Using velocity control, move motor at encoder speed 200, you could use:

```
myJaguar.DcMotorVelocityNonTimeCtrAll(200,NOCONTROL,NOCONTROL,NOCONTROL
,NOCONTROL,NOCONTROL);
```

or

```
myJaguar.DcMotorVelocityNonTimeCtr(0,200);
```

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 receive 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 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, 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 ASICII.

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

Format:

"$seq,accelX,accleY,accelZ,gyroY,gyroZ,gyroX,magnetomX,magnetomY,magnetomZ#"

After "seq", the data are raw AD value for each sensor.

Sample data string:

"$2,0,9,255,20,40,3,235,400,20#"

Please note the magnetic sensor will be measured every 220ms, so if the output value is 0, means no magnetic sensor in this data package.

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.

Manipulator Arm

The manipulator arm is controlled by 2 RoboteQ SDC2130 control boards.
The program will communicate with it via 192.168.0.63, port 10001/10002 using TCP protocol.
You could find the manual from RoboteQ web site. You need to make sure that none of the motors gets stuck when driving the arm, since this may over-heat and burn the motors and/or motor driver board.
The emergency stop command is "!EX\r" and resume command is "!MG\r".

Joint Number	
Joint1 (Motor Driver board 1 channel 1)	Encoder : One circle count is 5700 Angle Resolution: 5700/ (2*PI) This joint is working in position control mode(mode 3): For example: Command: "!PR 1 -200\r" It will drive this joint up. Command: "!PR 1 200\r" It will drive this joint down. Command: "!P 1 -250\r" It will drive this motor to encoder position -250.(make sure you know where it is and not in stuck state) On control board, we set current limitation for this joint. It will enter emergency stop state when current is over 12A or current over 7A for over 1000ms. You could read temperature sensor via analog channel 3(AI 3). The temperature sensor is B57164K103J, you could find how to conver the readings to temperature from the sample codes.
Joint2(Motor Driver board 1 channel 2)	Encoder : One circle count is 5700 Angle Resolution: 5700/ (2*PI) This joint is working in position control mode(mode 3): For example: Command: "!PR 2 -200\r" It will drive this joint up. Command: "!PR 2 200\r" It will drive this joint down. Command: "!P 2 -250\r" It will drive this motor to encoder position -250.(make sure you know where it is and not in stuck state) On control board, we set current limitation for this joint. It will enter emergency stop state when current is over 8A or current over 6A for over 1000ms. You could read temperature sensor via analog channel 4(AI 4). The temperature sensor is B57164K103J, you could find how to conver the readings to temperature from the sample codes.
Joint3(Motor Driver board 2 channel 1)	Encoder : One circle count is 3724 Angle Resolution: 3724/ (2*PI)

	This joint is working in position control mode(mode 3): For example: Command: "!PR 1 -200\r" It will drive this joint to right. Command: "!PR 1 200\r" It will drive this joint left. Command: "!P 1 -250\r" It will drive this motor to encoder position -250.(make sure you know where it is and not in stuck state) On control board, we set current limitation for this joint. It will enter emergency stop state when current is over 8A or current over 5A for over 1000ms. You could read temperature sensor via analog channel 3(AI 3). The temperature sensor is B57164K103J, you could find how to conver the readings to temperature from the sample codes.
Gripper(Motor Driver board 2 channel 2)	Encoder : One circle count is 756 Angle Resolution: 756/ (2*PI) This joint is working in open loop control mode(mode 0): For example: Command: "!G 2 -200\r" It will drive Gripper close. Command: "!G 2 200\r" It will drive Gripper open. Command: "!G 2 0\r" It will stop this motor.(make sure you send this command to stop the Gripper before it reaches mechanical limitation) On control board, we set current limitation for this joint. It will enter emergency stop state when current is over 2A or current over 1A for over 1000ms. You could read temperature sensor via analog channel 4(AI 4). The temperature sensor is B57164K103J, you could find how to conver the readings to temperature from the sample codes.

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.