Appendix : Protocol Specification

Overview

The **kobuki driver** communicates with the robot by using predefined protocol. In general, the driver sends the commands to the robot and the robot sends some feedback data or sensor readings. These commands and feedback data are converted into bytestreams for communication via serial interface. The protocol specifies that rules and forms of bytestreams.

Structure of Bytestream

A bytestream can be divided into 4 fields; Headers, Length, Payload and Checksum.

Name	Header 0	Header 1	Length	Payload	Checksum
Size	1 Byte	1 Byte	1 Byte	N Bytes	1 Byte
Description	0xAA (Fixed)	0x55 (Fixed)	Size of payload in bytes	Described below	XOR'ed value of every bytes of bytesream except headers

Header

Two bytes of headers, header 0 and hader 1, are fixed value for both bytestreams, commands and feedback data. This headers are used to detect the starting point of bytestream.

Length

Length indicates the length of following bytes that single bytestream hold. Default size of this field is 1 byte. Length can be used to distinguish each bytestreams. Minimum value of this field is 3.

Payload

Payload contains actual data of bytestream.

Structure Of Payload

Payload is a consist of several sub-payloads.

Payload				
Sub-Payload 0	Sub-Payload 1	Sub-Payload 2	...	Sub-Payload N-1

Structure Of Sub-Payloads

Sub-payload can be divided into three parts; Header, Length and Data.

Name	Header	Length	Data
Size	1 Byte	1 Byte	N Byte(s)
Description	Predefined Identifier	Size of data in byte(s)	Described below

Checksum

Checksum is XOR'ed value of entire bytestream except headers. Checksum process ensure the integrity of bytestreams.

Here is simple code snippet for it.

```
unsigned int packet_size(buffer.size());
unsigned char cs(0);
for (unsigned int i = 2; i < packet_size; i++)
{
  cs ^= buffer[i];
}
return cs ? false : true;
```

Entire Bytestream

Headers		Length	Payload					Checksum
Header 0	Header 1		Sub-Payload 0	Sub-Payload 1	Sub-Payload 2	...	Sub-Payload N-1	

Above table shows the structure of entire bytestream.

Minimum length of payload is 3; Payload with a sub-payload, that has only 1 byte data.

Theoretical minimum length of entire packet(bytestream) is 7.

Data Types

Data field in Sub-payload is a mixture of below three data types; byte, short and int.

Name	Description	Byte Length	Bit Length	Data Range	C/C++ Identifier	
Unsigned Byte	8-bit unsigned integer	1	8	0~255	unsigned char	uint8_t
Unsigned Short	16-bit unsigned integer	2	16	0~65,535	unsigned short	uint16_t
Unsigned Int	32-bit unsigned integer	4	32	0~4,294,967,295	unsigned int	uint32_t

Serialization-Deserialization

Serialization is the process of converting a data structure into a bytestream. Deserialization is reversal process. Each data types are serialized and deserialized by `LSB-First Order`. It means Least Significant Bytes will comes first on the bytestream. For example, The integer number 2,864,434,397(0xAABBCCDD) can be serialized into:

0xDD	0xCC	0xBB	0xAA

So, 0xDD will arrive first in bytestream.

Here are template functions to handle it on kobuki_deriver, **buildVariable()** and **buildBytes()**.

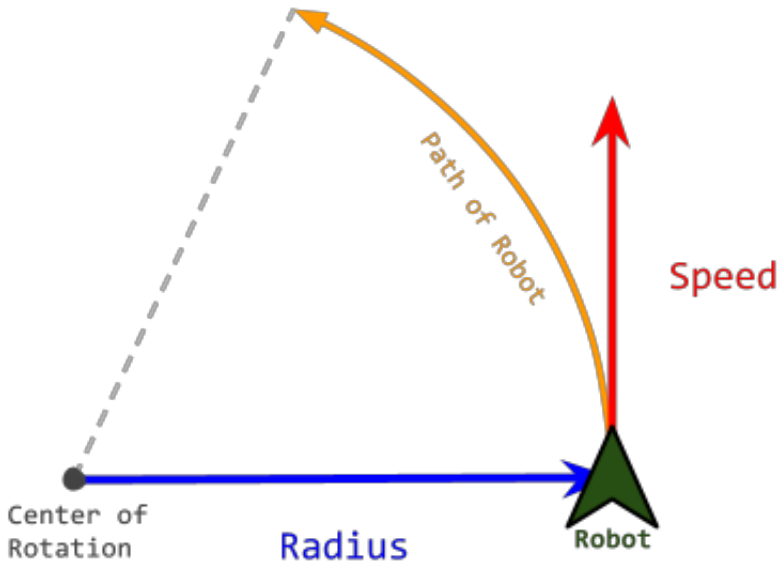
Command Packets

Command Identifier

ID	Name	Description
1	Base Control	Control wheel motors
2	*Reserved*	
3	Sound	Play custom sounds
4	Sound Sequence	Play predefined sounds
5	*Reserved*	
6	*Reserved*	
7	*Reserved*	
8	*Reserved*	
9	Request Extra	Request extra informations
10	*Reserved*	
11	*Reserved*	
12	General Purpose Output	Control general purpose outputs
13	Set Controller Gain	Set PID gain of wheel velocity controller
14	Get Controller Gain	Request current PID gain of wheel velocity controller

Base Control

Control wheel motors to moving robot. Robot will follow the arc line, which radius is **<Radius>** mm, with **<Speed>** mm/s. Positive Radius indicates center of arc line that robot follows is located at the left side of the robot. Negative is opposite.



Velocity Representation

But actual value of Speed field is little bit different. Here is conversion table.

Motion	Speed(mm/s)	Radius(mm)
Pure Translation	Speed	0
Pure Rotation	$w^{i)} * b^{ii)} / 2$	1
Translation + Rotation	Speed * (Radius + $b^{ii)}$ / 2) / Radius, if Radius > 1 Speed * (Radius - $b^{ii)}$ / 2) / Radius, if Radius < -1	Radius

i) w is rotation speed of the robot, in [rad/s].
ii) b is *bias* or *wheelbase*, that indicates the length between the center of the wheels. Fixed at 230 mm.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	1	0x01	Fixed
Length	Size of data field	1	4	0x04	Fixed
Data	Speed	2			in mm/s
	Radius	2			in mm

Sound

Play custom sounds with note and duration.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	3	0x03	Fixed
Length	Size of data field	1	3	0x03	Fixed

Data	Note	2			$1/(f \cdot a)$, where f is frequency of sound in Hz, and a is 0.00000275
	Duration	1			Duration of playing note in milli-seconds

Warning:
This command is implemented on the kobuki with firmware, but not implemented yet on driver software(kobuki_driver).

Sound Sequence

Play predefined sounds by its index.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	4	0x04	Fixed
Length	Size of data field	1	1	0x01	Fixed
Data	Sequence number	1			0 for ON sound 1 for OFF sound 2 for RECHARGE sound 3 for BUTTON sound 4 for ERROR sound 5 for CLEANINGSTART sound 6 for CLEANINGEND sound

Request Extra

Request extra data from robot. Especially version info of kobuki; Hardware Version, Firmware Version and Unique Device IDentifier(UDID)

UDID is unique to device. so can be used to identify on multiple robots.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	9	0x09	Fixed
Length	Size of data field	1	2	0x02	Fixed
Data	Request flags	2			Set the flags to request extra data 0x01 for Hardware Version 0x02 for Firmware Version 0x08 for Unique Device ID

See also:
Hardware Version Firmware Version, **Unique Device IDentifier(UDID)**

General Purpose Output

This command has multiple roles. It controls LEDs, digital outputs and external powers.

				Value in	

	Name	Size	Value	Hex	Description
Header	Identifier	1	12	0x0C	Fixed
Length	Size of data field	1	2	0x02	Fixed
Data	Digital output flags	2			Set the flags to set high on output pins of expansion port 0x0001 for digital output ch. 0 0x0002 for digital output ch. 1 0x0004 for digital output ch. 2 0x0008 for digital output ch. 3 Set the flags to turn on external powers 0x0010 for external power 3.3V ch. 0x0020 for external power 5V ch. 0x0040 for external power 12V/5A ch. 0x0080 for external power 12V/1.5A ch. Set the flags to turn on LEDs 0x0100 for red colour of LED1 0x0200 for green colour of LED1 0x0400 for red colour of LED2 0x0800 for green colour of LED2

Set Controller Gain

Set PID gain of wheel velocity controller of robot.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	1	0x01	Fixed
Length	Size of data field	1	13	0x0D	Fixed
Data	Type	1			0 for factory-default PID gain 1 for user-configured PID gain
	P gain	4			Kp * 1000 (default: 100*1000)
	I gain	4			Ki * 1000 (default: 0.1*1000)
	D gain	4			Kd * 1000 (default: 2*1000)

Get Controller Gain

Request PID gain of wheel velocity controller of robot.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	1	0x01	Fixed
Length	Size of data field	1	14	0x0E	Fixed
Data	unused	1			

Feedback Packets

Feedback Identifier

Kobuki sends below default feedbacks periodically in 50 Hz, when it powered on.

ID	Name	Description	Availability
1	Basic Sensor Data	Basic core sensor data	By default
2	*Reserved*		
3	Docking IR	Signals from docking station	By default
4	Inertial Sensor	Gyro data both angle and angular velocity	By default
5	Cliff	PSD data facing floor	By default
6	Current	Current of wheel motors	By default
7	*Reserved*		
8	*Reserved*		
9	*Reserved*		
10	Hardware Version	Version number of kobuki hardware	On request
11	Firmware Version	Version number of kobuki firmware	On request
12	*Reserved*		
13	Raw data of 3-axis gyro	Raw ADC data of digital 3-axis gyro	By default
14	*Reserved*		
15	Reserved		
16	General Purpose Input	Inputs from 25-pin expansion port	By default
17	*Reserved*		
18	*Reserved*		
19	Unique Device IDentifier(UDID)	Unique number to identify robot	On request
20	*Reserved*		
21	Controller Info	PID gain values of wheel velocity controller.	On request

Basic Sensor Data

Basic core sensor data.

	Name	Size	Value	Value in Hex	Description
Header	Feedback Identifier	1	1	0x01	Fixed
Length	Size of data field	1	15	0x0F	Fixed
	Timestamp	2			Timestamp generated internally in milliseconds It circulates from 0 to 65535
					Flag will be setted when bumper is pressed

Data	Bumper	1			0x01 for right bumper 0x02 for central bumper 0x04 for left bumper
	Wheel drop	1			Flag will be setted when wheel is dropped 0x01 for right wheel 0x02 for left wheel
	Cliff	1			Flag will be setted when cliff is detected 0x01 for right cliff sensor 0x02 for central cliff sensor 0x04 for left cliff sensor
	Left encoder	2			Accumulated encoder data of left and right wheels in ticks Increments of this value means forward direction It circulates from 0 to 65535
	Right encoder	2			
	Left PWM	1			PWM value that applied to left and right wheel motor This data should be converted signed type to represent correctly Negative sign indicates backward direction
	Right PWM	1			
	Button	1			Flag will be setted when button is pressed 0x01 for Button 0 0x02 for Button 1 0x04 for Button 2
	Charger	1			0 for DISCHARGING state 2 for DOCKING_CHARGED state 6 for DOCKING_CHARGING state 18 for ADAPTER_CHARGED state 22 for ADAPTER_CHARGING state
	Battery	1			Voltage of battery in 0.1 V Typically 16.7 V when fully charged
	Overcurrent flags	1			Flag will be setted when overcurrent is detected 0x01 for left wheel 0x02 for right wheel

Note:
This sub-payload will be sent by default.

See also:
Appendix : Kobuki Parameters - necessary parameters for conversion of encoder ticks to robot pose.

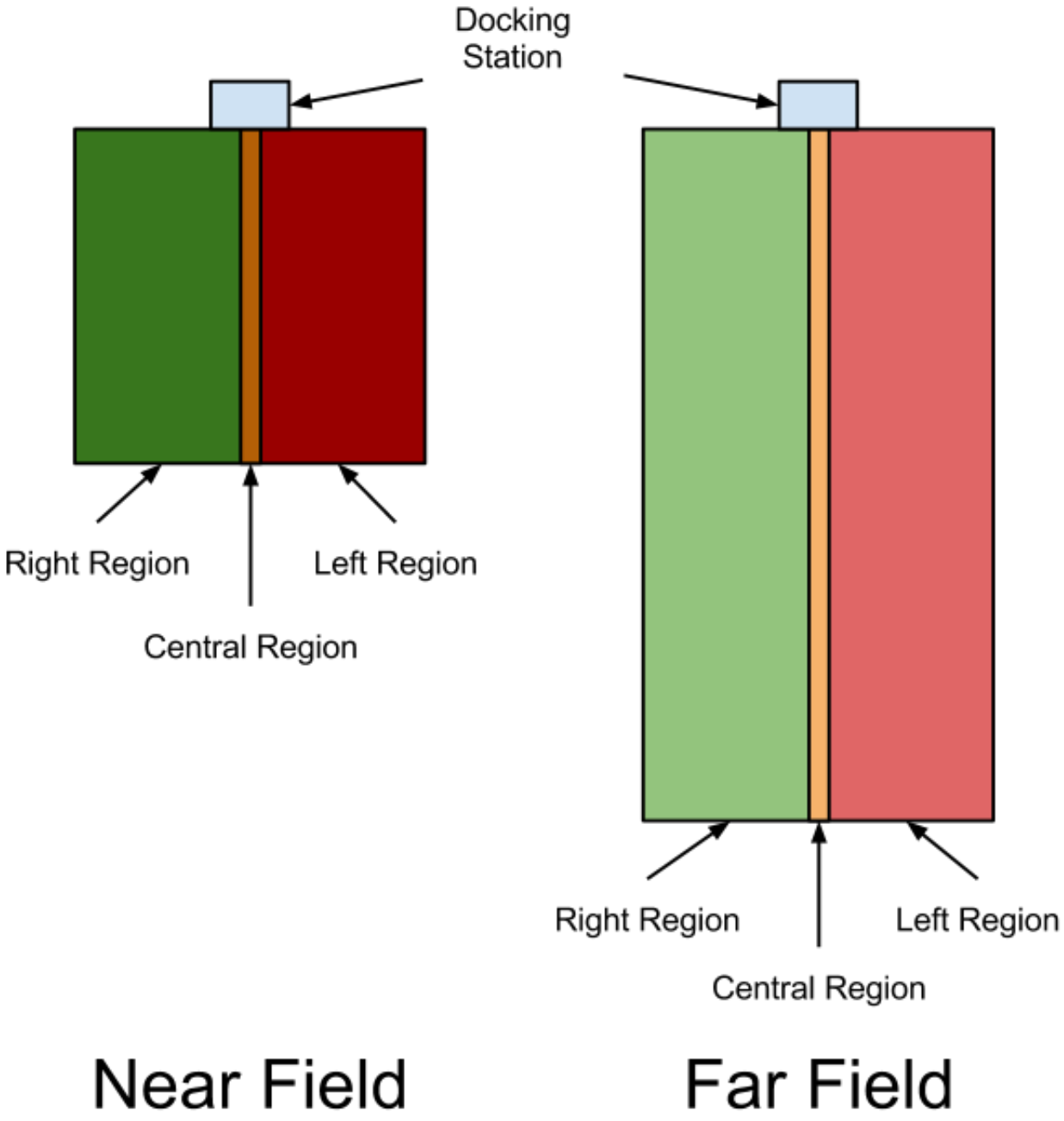
Docking IR

Signals from the docking station.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	3	0x03	Fixed
Length	Size of data	1	3	0x03	Fixed

	field				
Data	Right signal	1			Flag will be setted when signal is detected 0x01 for NEAR_LEFT state 0x02 for NEAR_CENTER state 0x04 for NEAR_RIGHT state 0x08 for FAR_CENTER state ox10 for FAR_LEFT state 0x20 for FAR_RIGHT state
	Central signal	1			
	Left signal	1			

Kobuki's docking station has 3 IR emitters. The emitted IR lights cover three regions in front of the docking station: left, central and right, each divided in two sub-fields: near and far. Each beam encodes this information, so the robot knows at any moment in which region and sub-field he is. Also, as regions and fields are independently identified, they can be overlap on its borders.



Docking IR Fields

Inertial Sensor Data

Inertial sensor data. Only 1 axis gyro data only available.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	4	0x04	Fixed
Length	Size of data field	1	7	0x07	Fixed
Data	Angle	2			Factory calibrated
	Angle rate	2			Factory calibrated
	Unused	1			
	Unused	1			
	Unused	1			

Note:
This sub-payload will be sent by default.

Cliff Sensor Data

This sub-payload provides ADC data of PSD sensor, which is facing the floor.

This value is related with distance between sensor and floor surface. See the datasheet for more detailed information.

This data also available in the Cliff field of **Basic Sensor Data** , as a boolean type, processed on the kobuki.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	5	0x05	Fixed
Length	Size of data field	1	6	0x06	Fixed
Data	Right cliff sensor	2			ADC output of each PSD Data range: 0 ~ 4095 (0 ~ 3.3V) Distance range: 2 ~ 15 cm Distance is not linear w.r.t. ADC output. See the datasheet for more detail.
	Central cliff sensor	2			
	Left cliff sensor	2			

Note:
This sub-payload will be sent by default.

See also:
Basic Sensor Data

Current

Current sensor readings of wheel motors.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	6	0x06	Fixed
Length	Size of data field	1	2	0x02	Fixed
Data	Left motor	2			in 10mA
	Right motor	2			in 10mA

Note:
This sub-payload will be sent by default.

Hardware Version

Hardware version info in triplet form; <major>.<minor>.<patch>

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	10	0x0A	Fixed
Length	Size of data field	1	4	0x04	Fixed
Data	Patch	1			
	Minor	1			
	Major	1			
	Unused	1	0	0x00	Fixed

Note:
This sub-payload will be sent on request.

See also:
Request Extra

Firmware Version

Firmware version info in triplet form; <major>.<minor>.<patch>

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	11	0x0B	Fixed
Length	Size of data field	1	4	0x04	Fixed
Data	Patch	1			
	Minor	1			
	Major	1			
	Unused	1	0	0x00	Fixed

Note:
This sub-payload will be sent on request.

See also:
Request Extra

Raw Data Of 3D Gyro

Raw ADC data of digital 3D gyro; L3G4200D

Due to difference of acquisition rate and update rate, 2-3 data will be arrived at once.

Digit to deg/s ratio is 0.00875, it comes from datasheet of 3d gyro.

	Name		Size	Value	Value in Hex	Description
Header	Identifier		1	13	0x0D	Fixed
Length	Size of data field		1	2+6N		
Data	Frame id		1			Frame id of 'Raw gyro data 0' Every sensor readings can identified by frame id , It circulate from 0 to 255
	Followed data length		1	3N		
	Raw gyro data 0	x-axis	2			ADC output of each-axis in 0.00875 deg/s
		y-axis	2			
		z-axis	2			
	:					
	Raw gyro data N-1	x-axis	2			
		y-axis	2			
		z-axis	2			

Note:
This sub-payload will be sent by default.

Warning:
Sensing axis of 3d gyro is not match with robot. It is rotated 90 degree counterclockwise about z-axis. So, below conversion will needed.

```
const double digit_to_dps = 0.00875;
angular_velocity.x =  -digit_to_dps * (short)raw_gyro_data.y;
angular_velocity.y =   digit_to_dps * (short)raw_gyro_data.x;
angular_velocity.z =   digit_to_dps * (short)raw_gyro_data.z;
```

General Purpose Input

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	16	0x10	Fixed
Length	Size of data field	1	16	0x10	Fixed
Data	Digital input	2			Flag will be setted, when high voltage is applied 0x01 for digital input ch. 0 0x02 for digital input ch. 1 0x04 for digital input ch. 2 0x08 for input output ch. 3
	Analog input ch.0	2			12-bit ADC output of each channel Data range: 0 ~ 4095(2^12-1) Voltage range: 0 ~ 3.3 V
	Analog input ch.1	2			
	Analog input ch.2	2			
	Analog input ch.3	2			
	Unused	2			
	Unused	2			
	Unused	2			

Note:
This sub-payload will be sent by default.

Unique Device IDentifier(UDID)

Contains Unique Device IDentifier of robot. This value is unique for all robot in the world. It can be represented by triplet form: <UDID0>-<UDID1>-<UDID2>

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	19	0x13	Fixed
Length	Size of data field	1	12	0x0C	Fixed
Data	UDID0	4			
	UDID1	4			
	UDID2	4			

Note:
This sub-payload will be sent on request.

See also:
Request Extra

Controller Info

Contains PID gain of wheel velocity controller of robot.

	Name	Size	Value	Value in Hex	Description
Header	Identifier	1	1	0x01	Fixed
Length	Size of data field	1	21	0x15	Fixed
Data	Type	1			Current controller setup 0 for factory-default PID gain 1 for user-configured PID gain
	P gain	4			Kp * 1000 (default: 100*1000)
	I gain	4			Ki * 1000 (default: 0.1*1000)
	D gain	4			Kd * 1000 (default: 2*1000)