

# Rollo - Localization of a humanoid robot

## 1.0

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# Chapter 1

## Hierarchical Index

### 1.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

runtime_error	
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## Chapter 2

# Class Index

### 2.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

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## Chapter 3

# File Index

### 3.1 File List

Here is a list of all documented files with brief descriptions:

<a href="#">rollo.hpp</a>	Header file holding Rollo specific parameters and global references for the ROS nodes . . . .	13
<a href="#">rollo_comm.cpp</a>	Communication between ROS and Rollo . . . . .	15
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## Chapter 4

# Class Documentation

### 4.1 udp\_client\_server::udp\_client Class Reference

#### Public Member Functions

- `udp_client` (const std::string &addr, int port)  
*Initialize a UDP client object.*
- `~udp_client` ()  
*Clean up the UDP client object.*
- int `get_socket` () const  
*Retrieve a copy of the socket identifier.*
- int `get_port` () const  
*Retrieve the port used by this UDP client.*
- std::string `get_addr` () const  
*Retrieve a copy of the address.*
- int `send` (const char \*msg, size\_t size)  
*Send a message through this UDP client.*

#### 4.1.1 Constructor & Destructor Documentation

##### 4.1.1.1 udp\_client\_server::udp\_client::udp\_client ( const std::string & addr, int port )

Initialize a UDP client object.

This function initializes the UDP client object using the address and the port as specified.

The port is expected to be a host side port number (i.e. 59200).

The `addr` parameter is a textual address. It may be an IPv4 or IPv6 address and it can represent a host name or an address defined with just numbers. If the address cannot be resolved then an error occurs and constructor throws.

#### Note

The socket is open in this process. If you `fork()` or `exec()` then the socket will be closed by the operating system.

#### Warning

We only make use of the first address found by `getaddrinfo()`. All the other addresses are ignored.

**Exceptions**

<a href="#"><i>udp_client_server_↔ runtime_error</i></a>	The server could not be initialized properly. Either the address cannot be resolved, the port is incompatible or not available, or the socket could not be created.
--	---

**Parameters**

in	<i>addr</i>	The address to convert to a numeric IP.
in	<i>port</i>	The port number.

**4.1.1.2 udp\_client\_server::udp\_client::~~udp\_client ( )**

Clean up the UDP client object.

This function frees the address information structure and close the socket before returning.

**4.1.2 Member Function Documentation****4.1.2.1 std::string udp\_client\_server::udp\_client::get\_addr ( ) const**

Retrieve a copy of the address.

This function returns a copy of the address as it was specified in the constructor. This does not return a canonicalized version of the address.

The address cannot be modified. If you need to send data on a different address, create a new UDP client.

**Returns**

A string with a copy of the constructor input address.

**4.1.2.2 int udp\_client\_server::udp\_client::get\_port ( ) const**

Retrieve the port used by this UDP client.

This function returns the port used by this UDP client. The port is defined as an integer, host side.

**Returns**

The port as expected in a host integer.

**4.1.2.3 int udp\_client\_server::udp\_client::get\_socket ( ) const**

Retrieve a copy of the socket identifier.

This function return the socket identifier as returned by the socket() function. This can be used to change some flags.

**Returns**

The socket used by this UDP client.

**4.1.2.4 int udp\_client\_server::udp\_client::send ( const char \* msg, size\_t size )**

Send a message through this UDP client.

This function sends `msg` through the UDP client socket. The function cannot be used to change the destination as it was defined when creating the `udp_client` object.

The size must be small enough for the message to fit. In most cases we use these in Snap! to send very small signals (i.e. 4 bytes commands.) Any data we would want to share remains in the Cassandra database so that way we can avoid losing it because of a UDP message.

#### Parameters

in	<i>msg</i>	The message to send.
in	<i>size</i>	The number of bytes representing this message.

#### Returns

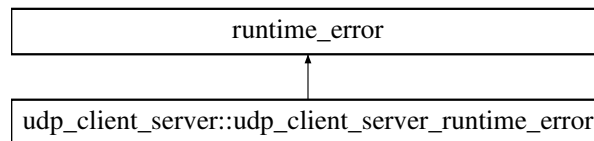
-1 if an error occurs, otherwise the number of bytes sent. `errno` is set accordingly on error.

The documentation for this class was generated from the following files:

- `udp.h`
- `udp.cpp`

## 4.2 udp\_client\_server::udp\_client\_server\_runtime\_error Class Reference

Inheritance diagram for `udp_client_server::udp_client_server_runtime_error`:



#### Public Member Functions

- **`udp_client_server_runtime_error`** (const char \*w)

The documentation for this class was generated from the following file:

- `udp.h`

## 4.3 udp\_client\_server::udp\_server Class Reference

#### Public Member Functions

- `udp_server` (const std::string &addr, int port)  
*Initialize a UDP server object.*
- `~udp_server` ()  
*Clean up the UDP server.*
- int `get_socket` () const  
*The socket used by this UDP server.*
- int `get_port` () const  
*The port used by this UDP server.*
- std::string `get_addr` () const

*Return the address of this UDP server.*

- int [recv](#) (char \*msg, size\_t max\_size)

*Wait on a message.*

- int [timed\\_recv](#) (char \*msg, size\_t max\_size, int max\_wait\_ms)

*Wait for data to come in.*

### 4.3.1 Constructor & Destructor Documentation

#### 4.3.1.1 `udp_client_server::udp_server::udp_server ( const std::string & addr, int port )`

Initialize a UDP server object.

This function initializes a UDP server object making it ready to receive messages.

The server address and port are specified in the constructor so if you need to receive messages from several different addresses and/or port, you'll have to create a server for each.

The address is a string and it can represent an IPv4 or IPv6 address.

Note that this function calls `connect()` to connect the socket to the specified address. To accept data on different UDP addresses and ports, multiple UDP servers must be created.

#### Note

The socket is open in this process. If you `fork()` or `exec()` then the socket will be closed by the operating system.

#### Warning

We only make use of the first address found by `getaddrinfo()`. All the other addresses are ignored.

#### Exceptions

<a href="#">udp_client_server</a> ↔ <a href="#">runtime_error</a>	The <a href="#">udp_client_server_runtime_error</a> exception is raised when the address and port combination cannot be resolved or if the socket cannot be opened.
--	---

#### Parameters

in	<i>addr</i>	The address we receive on.
in	<i>port</i>	The port we receive from.

#### 4.3.1.2 `udp_client_server::udp_server::~~udp_server ( )`

Clean up the UDP server.

This function frees the address info structures and close the socket.

### 4.3.2 Member Function Documentation

#### 4.3.2.1 `std::string udp_client_server::udp_server::get_addr ( ) const`

Return the address of this UDP server.

This function returns a verbatim copy of the address as passed to the constructor of the UDP server (i.e. it does not return the canonicalized version of the address.)

#### Returns

The address as passed to the constructor.



## 4.3.2.2 int udp\_client\_server::udp\_server::get\_port ( ) const

The port used by this UDP server.

This function returns the port attached to the UDP server. It is a copy of the port specified in the constructor.

## Returns

The port of the UDP server.

## 4.3.2.3 int udp\_client\_server::udp\_server::get\_socket ( ) const

The socket used by this UDP server.

This function returns the socket identifier. It can be useful if you are doing a select() on many sockets.

## Returns

The socket of this UDP server.

## 4.3.2.4 int udp\_client\_server::udp\_server::recv ( char \* msg, size\_t max\_size )

Wait on a message.

This function waits until a message is received on this UDP server. There are no means to return from this function except by receiving a message. Remember that UDP does not have a connect state so whether another process quits does not change the status of this UDP server and thus it continues to wait forever.

Note that you may change the type of socket by making it non-blocking (use the [get\\_socket\(\)](#) to retrieve the socket identifier) in which case this function will not block if no message is available. Instead it returns immediately.

## Parameters

in	<i>msg</i>	The buffer where the message is saved.
in	<i>max_size</i>	The maximum size the message (i.e. size of the <code>msg</code> buffer.)

## Returns

The number of bytes read or -1 if an error occurs.

## 4.3.2.5 int udp\_client\_server::udp\_server::timed\_recv ( char \* msg, size\_t max\_size, int max\_wait\_ms )

Wait for data to come in.

This function waits for a given amount of time for data to come in. If no data comes in after `max_wait_ms`, the function returns with -1 and `errno` set to `EAGAIN`.

The socket is expected to be a blocking socket (the default,) although it is possible to setup the socket as non-blocking if necessary for some other reason.

This function blocks for a maximum amount of time as defined by `max_wait_ms`. It may return sooner with an error or a message.

## Parameters

in	<i>msg</i>	The buffer where the message will be saved.
----	------------	---

in	<i>max_size</i>	The size of the <code>msg</code> buffer in bytes.
in	<i>max_wait_ms</i>	The maximum number of milliseconds to wait for a message.

**Returns**

-1 if an error occurs or the function timed out, the number of bytes received otherwise.

The documentation for this class was generated from the following files:

- `udp.h`
- `udp.cpp`

## Chapter 5

# File Documentation

### 5.1 rollo.hpp File Reference

Header file holding Rollo specific parameters and global references for the ROS nodes.

#### Macros

- #define `ROLLO_AXLE_L` 0.0205
- *Rollo*
- #define `ROLLO_WHEEL_RADIUS_L` 0.020
- #define `ROLLO_WHEEL_RADIUS_R` 0.020
- #define `ROLLO_WHEEL_N` 4
- *Number of wheels.*
- #define `ROLLO_SPEED_MAX` 56
- *Maximum speed [%].*
- #define `ROLLO_SPEED_MIN` 6
- *Minimum speed [%].*
- #define `PI` 3.1415926535
- *Mathematical constants.*
- #define `CM` "COMM"
- *Node names.*
- #define `CT` "CTRL"
- *Control.*
- #define `LC` "LOC "
- *Localization.*
- #define `OD` "ODOM"
- *Odometry.*
- #define `PP` "PREP"
- *Preprocessor.*
- #define `KF` "EKF "
- *Extended Kalman filter.*
- #define `VS` "VIS "
- *Visualization.*
- #define `PACKAGE` "Rollo"
- *ROS.*
- #define `TOPIC_COMM_WS` "/Rollo/wheelspeed"

- ROS topics.*
- #define **TOPIC\_CTRL\_CMD\_VEL** "/Rollo/cmd\_vel"  
*Topic for commands generated by control node expressed in linear and angular velocity.*
- #define **TOPIC\_EKF** "/Rollo/ekf"  
*Topic for extended Kalman filter results with all three estimated states and covariance matrix, stamped.*
- #define **TOPIC\_PREP\_MC** "/Optitrack\_Rollo/ground\_pose"  
*Topic for motion capture data.*
- #define **TOPIC\_PREP\_P2DT** "/Rollo/pose2dstamped"  
*Topic for position and orientation, stamped.*
- #define **CR** "\033[0m"  
*GNU/Linux terminal color codes.*
- #define **C1** "\033[38;5;63m"  
*Color 1.*
- #define **C2** "\033[38;5;220m"  
*Color 2.*
- #define **C3** "\033[38;5;87m"  
*Color 3.*
- #define **C4** "\033[38;5;84m"  
*Color 4.*
- #define **C5** "\033[38;5;160m"  
*Color 5.*
- #define **C6** "\033[38;5;161m"  
*Color 6.*
- #define **C7** "\033[38;5;162m"  
*Color 7.*
- #define **C8** "\033[38;5;22m"  
*Color 8.*
- #define **CEE** "\033[38;5;124m" /\* Error \*/  
*Error.*
- #define **CSS** "\033[38;5;154m" /\* Success \*/  
*Success.*
- #define **CWW** "\033[38;5;202m" /\* Warning \*/  
*Warning.*

### 5.1.1 Detailed Description

Header file holding Rollo specific parameters and global references for the ROS nodes.

#### Author

Rabbia Asghar  
Ernest Skrzypczyk

#### Date

20/2/16

### 5.1.2 Macro Definition Documentation

#### 5.1.2.1 #define CM "COMM"

Node names.

Communication

5.1.2.2 `#define CR "\033[0m"`

GNU/Linux terminal color codes.

Reset

5.1.2.3 `#define PACKAGE "Rollo"`

ROS.

ROS package name

5.1.2.4 `#define PI 3.1415926535`

Mathematical constants.

Pi

5.1.2.5 `#define ROLLO_AXLE_L 0.0205`

Rollo

Axle length

5.1.2.6 `#define ROLLO_WHEEL_RADIUS_L 0.020`

Wheel radius:

- Left

5.1.2.7 `#define ROLLO_WHEEL_RADIUS_R 0.020`

- Right

5.1.2.8 `#define TOPIC_COMM_WS "/Rollo/wheelspeed"`

ROS topics.

Topic for wheel speed containing the actual speed of wheel, preferably extracted from encoders or if not available by using a lookup table

## 5.2 rollo\_comm.cpp File Reference

Communication between ROS and Rollo.

```
#include "ros/ros.h"
#include <sstream>
#include <iostream>
#include "string.h"
#include "rollo.hpp"
#include "geometry_msgs/Twist.h"
#include "rollo/WheelSpeed.h"
#include "udp.h"
```

## Functions

- int `decodeVelocities` (double `x`, double `z`, char `*Message`, int &`VelocityL`, int &`VelocityR`)  
*Range of speed of the Rollo.*
- void `subscriberCallback` (const geometry\_msgs::Twist::ConstPtr &`msg`)  
*Subscriber callback.*
- int `udpSend` (char `ip`[16], int `port`, char `*Message`)  
*Send UDP packets.*
- int `main` (int `argc`, char `**argv`)  
*Node main.*

## Variables

- char `nodeName` [20] = `C3 CM CR`  
*Global variables updated in the `subscriberCallback()` function, processed and used to send commands to the specified `ip` address at the UDP `port`.*
- char `TopicWheelSpeed` [64] = `TOPIC_COMM_WS`  
*Topic for wheel speed containing the actual speed of wheel, preferably extracted from encoders or if not available by using a lookup table.*
- char `TopicCmdVel` [64] = `TOPIC_CTRL_CMD_VEL`  
*Topic for commands generated by control node expressed in linear and angular velocity.*
- char `ip` [16] = `"192.168.0.120"`  
*Rollo default IP: 192.168.0.120.*
- int `port` = 900  
*UDP port.*
- double `tol` = 0.01  
*Tolerance for determining linear and angular velocities from the control node.*
- int `v_l`
- int `v_r`  
*Velocities for both wheels.*
- unsigned const int `nb` = 3  
*Number of bytes in the message.*
- char `Message` [`nb`] = {0x7b, 0x50, 0x10}  
*Message combined, complete stop default.*
- char `MessageEmergencyStop` [`nb`] = {0x7b, 0x50, 0x10}  
*Emergency variables.*
- double `lastMessageTime` = 0  
*Last message from control node.*
- double `currentTime` = 0  
*Current time holder.*
- int `EmergencyTime` = 3  
*Emergency time [s].*
- bool `FlagEmergency` = 0  
*Emergency flag.*
- char `Mode` [1]  
*Message mode description.*
- int `VelocityL`
- int `VelocityR`  
*Message velocities description.*
- unsigned int `loopcounter` = 1  
*Loop counter for debugging purpose.*

- double `RolloMax` = `ROLLO_SPEED_MAX`  
*Maximum speed of the Rollo.*
- double `RolloMin` = `ROLLO_SPEED_MIN`  
*Minimum speed of the Rollo.*
- double `RolloRange` = `RolloMax` - `RolloMin`

### 5.2.1 Detailed Description

Communication between ROS and Rollo.

#### Author

Rabbia Asghar  
Ernest Skrzypczyk

#### Date

18/2/16

Command prototype: `roslaunch rollo rollo_comm _rate:=10 _ip:=192.168.0.120 _port:=900 _em:=3 _square:=0 _forwardtime:=25 _turntime:=6 _squarespeed:=0.4`

#### Parameters

<i>rate</i>	Command sending frequency of the node <!10 [Hz]>
<i>ip</i>	Internet protocol address of target robot <!192.168.0.120 [1]>
<i>port</i>	User datagram protocol target connection port <!900 [1]>
<i>em</i>	Emergency time <!3 [s]>
<i>square</i>	Square test switch <!0 [1]>: <ul style="list-style-type: none"> <li>• 0 – Off</li> <li>• 1 – Simple square test</li> <li>• 2 – Double square test</li> <li>• n – N-th order square test</li> </ul>
<i>forwardtime</i>	Time for forward motion of robot <!25 [s]>
<i>turntime</i>	Time for turning the robot <!6 [s]>
<i>squarespeed</i>	Square test forward motion speed <!0.4 [1]>:

Provides basic communication structure between ROS holding nodes used for localization and Rollo.  
Main aspects include:

- decoding linear and angular velocities provided by control node
- translate and send message to Rollo
- publish decoded velocities
- square test or n-th order
- emergency procedure

#### See also

<https://github.com/em-er-es/rollo/>

## 5.2.2 Function Documentation

### 5.2.2.1 int decodeVelocities ( double x, double z, char \* Message, int & VelocityL, int & VelocityR )

Range of speed of the Rollo.

Decode linear and angular velocities

Velocities are decoded and stored as partial bytes of the UDP packet

#### Parameters

x	Linear velocity
z	Angular velocity
&Message	UDP message to be send to target robot
VelocityL	Decoded velocity [%]
VelocityR	Decoded velocity [%]

#### Returns

0

Determine corresponding operation mode based on velocities

Since control node can provide abstract control values, an ideal case could be used for decoding velocities. This is discouraged, since using alternative control methods would probably have a realistic value set.

Linear velocity is approximately 0:

- Complete stop
- Right rotation
- Left rotation
- Lowest speeds for previous modes

Linear velocity is above tolerance threshold

Determine speeds based on the position of the "dial" z:

-a-   - - - * -b- - - -
-1      z              0                      1

Temporary velocity holder declaration

Eliminate problems with dividing through zero by adding a small number to variables

Calculate velocities according to relation expressed in linear and angular velocities ratio

Translate velocities for Rollo:

- Left wheel velocity - Second byte
- Right wheel velocity - Third byte
- Temporary fix for errartic behaviour of Rollo

Determine forward or backward movement based on linear velocity



### 5.2.2.2 `int main ( int argc, char ** argv )`

Node main.

Depending on specified parameters processes data from control node and Rollo and transmits them to appropriate targets or runs a square test of n-th order

**Parameters**

<i>rate</i>	Command sending frequency of the node <!10 [Hz]>
<i>ip</i>	Internet protocol address of target robot <!192.168.0.120 [1]>
<i>port</i>	User datagram protocol target connection port <!900 [1]>
<i>em</i>	Emergency time <!3 [s]>
<i>square</i>	Square test switch <!0 [1]>: <ul style="list-style-type: none"> <li>• 0 – Off</li> <li>• 1 – Simple square test</li> <li>• 2 – Double square test</li> <li>• n – N-th order square test</li> </ul>
<i>forwardtime</i>	Time for forward motion of robot <!25 [s]>
<i>turntime</i>	Time for turning the robot <!6 [s]>
<i>squarespeed</i>	Square test forward motion speed <!0.4 [1]>:

**Returns**

0

**Initialization**

Initialize node

Initialize nodehandle

Initialize subscriber and define topic and message queue size

Publish velocities as [rpm]

Initialize node arguments using command line

Initialize node parameters from launch file or command line. Use a private node handle so that multiple instances of the node can be run simultaneously while using different parameters.

Node main parameters

Emergency parameters

Square test parameters Default values

Node frequency rate [Hz]

Initialize subscriber message type

Initialize publisher message type

Initialize variables for computing linear and angular velocity of the robot

Client initialization

**Square test**

Alternatively this square test could be in control node, however communication node is "closer" to Rollo

- Print information on current run
- Compose turn command
- Check square run variable and determine turning direction

For multiple runs the robot would go back and forth providing more reliable data on the actual error In ideal case even a high order square run would result in the robot being at the initial position with initial orientation

- Compose forward command
- Set initial time
- Initialize bytes sent variable for debugging
- Print square test parameters

#### Main square loop

Moving forward

Send command 3 times

Wait for the specified time to move forward

Turning

Send command 3 times

Wait for the specified time to turn

#### Main square loop end

Update run finish time

Print duration time

Turn around

Send command 3 times

Wait for twice the specified time to turn around

Update square run counter and check for exit condition

Stop

Send stop command 10 times

Update square run counter and check for exit condition

#### Square test end

#### Main loop

- Send control command to Rollo
- Check if emergency condition has been met:
- Print emergency message
- Conduct emergency stop

Send emergency message 10 times

- Hard condition emergency procedure  
Exit with an error code if hard condition is set by using negative values for emergency time
- Soft condition emergency procedure

Set emergency flag

Empty procedure sequence if emergency flag is raised

- ROS spinOnce

- Sleep before running loop again

Callback function for subscriber

- Compose message
- Publish message
- Print published message

ROS spinOnce

Sleep before running loop again

Increase loopcounter

Main loop end

#### 5.2.2.3 void subscriberCallback ( const geometry\_msgs::Twist::ConstPtr & msg )

Subscriber callback.

Read newest velocities from control node and translate them into UDP message. Update latest message time.

Parameters

<i>msg</i>	Message from control node containing linear and angular velocities
------------	--

Returns

0

Update the UDP message

Update last message time

Reset emergency flag

#### 5.2.2.4 int udpSend ( char ip[16], int port, char \* Message )

Send UDP packets.

Send provided message using included UDP library command `udp_client_server::udp_client.send()`

Parameters

<i>&amp;ip</i>	IP address of the target robot
<i>&amp;port</i>	UDP port of the target robot
<i>&amp;message</i>	UDP message sent to robot

Returns

Bytes sent

Client initialization

Send UDP message

Check if number of bytes sent is equal to bytes of composed message

Error handling

Return bytes sent or error code

### 5.2.3 Variable Documentation

#### 5.2.3.1 char ip[16] = "192.168.0.120"

Rollo default IP: 192.168.0.120.

Ip address hardcoded

#### 5.2.3.2 char MessageEmergencyStop[nb] = {0x7b, 0x50, 0x10}

Emergency variables.

Emergency message - complete stop

#### 5.2.3.3 char NodeName[20] = C3 CM CR

Global variables updated in the `subscriberCallback()` function, processed and used to send commands to the specified ip address at the UDP port.

Node name using console codes

## 5.3 rollo\_control.cpp File Reference

Convert input from keyboard and publish control commands for Rollo.

```
#include "ros/ros.h"
#include "geometry_msgs/Twist.h"
#include "geometry_msgs/Vector3.h"
#include <stdio.h>
#include <termios.h>
#include <unistd.h>
#include <fcntl.h>
#include <sstream>
#include <iostream>
#include "rollo.hpp"
```

### Functions

- int `kbhit` (void)  
*Keyboard keystroke.*
- void `decodeKey` (char character, double &Speed, double &Turn)  
*Decode key.*
- int `main` (int argc, char \*\*argv)  
*Node main.*

### Variables

- char `NodeName` [20] = C2 CT CR  
*Global variables.*
- char `TopicCmdVel` [64] = TOPIC\_CTRL\_CMD\_VEL  
*Topic for commands generated expressed in linear and angular velocity.*
- double `LimitVelocityF` = 1  
*Limit velocity forward.*

- double `LimitVelocityR` = -1  
*Limit velocity reverse.*
- double `LKeysSteps` = 0.1  
*Left key set velocity step.*
- double `RKeysLinearV` = 0.4  
*Right key set linear velocity step.*
- double `RKeysAngularV` = 1  
*Right key set angular velocity step.*

### 5.3.1 Detailed Description

Convert input from keyboard and publish control commands for Rollo.

#### Author

Rabbia Asghar  
Ernest Skrzypczyk

#### Date

18/2/16

Command prototype: **roslaunch rollo rollo\_control \_rate:=10**

#### Parameters

<i>rate</i>	Running frequency of the node <!10 [Hz]>
-------------	--

Robot control using following key sets

q	w	e		u	i	o
a	s	d	f/F	j	k	l
z	x	c		m	,	.

Left key set:

- q/e : increase/decrease speeds 0.1 and -0.1
- w/s : increase/decrease only linear speed by 0.1
- a/d : increase/decrease only angular speed by 0.1
- z/c : increase/decrease speeds 0.1 and -0.1
- x : reset angular speed

Independent key set:

- f/F : full speed forwards/backwards

Right key set:

- u/o : increase/decrease set speeds for diagonal movement forwards
- i/, : increase/decrease set speeds for forward/backward movement
- j/l : increase/decrease set speeds for rotations
- m/. : increase/decrease set speeds for diagonal movement backwards

- k : stop

Global key set:

- \* : stop
- <CTRL>-C : quit

Python script available online used as reference.

See also

[https://github.com/ros-teleop/teleop\\_twist\\_keyboard/blob/master/teleop\\_twist\\_keyboard.py](https://github.com/ros-teleop/teleop_twist_keyboard/blob/master/teleop_twist_keyboard.py)  
<https://github.com/em-er-es/rollo/>

Author

Rabbia Asghar  
 Ernest Skrzypczyk

Date

18/2/16

Command prototype: **roslaunch rollo rollo\_control \_rate:=10**

Parameters

<i>rate</i>	Running frequency of the node <!10 [Hz]>
-------------	--

Robot control using following key sets

q	w	e		u	i	o
a	s	d	f/F	j	k	l
z	x	c		m	,	.

Left key set:

- q/e : increase/decrease speeds 0.1 and -0.1
- w/s : increase/decrease only linear speed by 0.1
- a/d : increase/decrease only angular speed by 0.1
- z/c : increase/decrease speeds 0.1 and -0.1
- x : reset angular speed

Independent key set:

- f/F : full speed forwards/backwards

Right key set:

- u/o : increase/decrease set speeds for diagonal movement forwards
- i/, : increase/decrease set speeds for forward/backward movement
- j/l : increase/decrease set speeds for rotations
- m/. : increase/decrease set speeds for diagonal movement backwards

- k : stop

Global key set:

- \* : stop
- <CTRL>-C : quit

Python script available online used as reference.

See also

[https://github.com/ros-teleop/teleop\\_twist\\_keyboard/blob/master/teleop\\_twist\\_keyboard.py](https://github.com/ros-teleop/teleop_twist_keyboard/blob/master/teleop_twist_keyboard.py)

## 5.3.2 Function Documentation

### 5.3.2.1 void decodeKey ( char *character*, double & *Speed*, double & *Turn* )

Decode key.

Compute linear and angular command velocities based on keyboard input. Key pressed character <key> as input argument.

Parameters

<i>character</i>	Character to be decoded
<i>&amp;Speed</i>	Linear velocity
<i>&amp;Turn</i>	Angular velocity

Returns

NULL

See also

[https://github.com/ros-teleop/teleop\\_twist\\_keyboard/blob/master/teleop\\_twist\\_keyboard.py](https://github.com/ros-teleop/teleop_twist_keyboard/blob/master/teleop_twist_keyboard.py)

Left key set control

Full speed forward/backward

Right key set control

Default value

Velocity limits

Linear velocity limits

Angular velocity limits

Print decoded velocities

### 5.3.2.2 int kbhit ( void )

Keyboard keystroke.

Check if a key is pressed on keyboard and return it.



## Parameters

<i>NONE</i>	
-------------	--

## Returns

1 if a key is pressed on keyboard, otherwise 0.

## See also

[https://github.com/sdipendra/ros-projects/blob/master/src/keyboard\\_non\\_blocking\\_input/src/keyboard\\_non\\_blocking\\_input\\_node.cpp](https://github.com/sdipendra/ros-projects/blob/master/src/keyboard_non_blocking_input/src/keyboard_non_blocking_input_node.cpp)

## 5.3.2.3 int main ( int argc, char \*\* argv )

Node main.

Initialize variables and nodehandle, read and translate input information into command messages.

## Parameters

<i>rate</i>	Running frequency of the node <!10 [Hz]>
-------------	--

Publish to command velocity topic as specified in configuration header file according to format `geometry_msgs::Twist`

## Returns

0

## Algorithm structure

## Initialization

- Initialize nodehandle for publisher
- Publisher initialization with topic, message format and queue size definition
- Node arguments using command line
- Initialize node parameters from launch file or command line. Use a private node handle so that multiple instances of the node can be run simultaneously while using different parameters.
- Publishing rate [Hz]
- Publisher variables for conventional messages
- Initialize variables for computing linear and angular velocity of the robot
- Initialize character holder

## Main loop

- Check if a key is pressed
- Read character
- Decode key pressed
- Prepare message to publish linear and angular velocities

- Print message with velocities
- Publish message in Twist format
- ROS spinOnce
- Sleep to conform node frequency rate

Main loop end

### 5.3.3 Variable Documentation

#### 5.3.3.1 char nodeName[20] = C2 CT CR

Global variables.

Node name using console codes

## 5.4 rollo\_ekf.cpp File Reference

EKF implementation for localisation of the robot.

```
#include "ros/ros.h"
#include "std_msgs/String.h"
#include "std_msgs/Header.h"
#include "geometry_msgs/Pose.h"
#include "geometry_msgs/Pose2D.h"
#include "tf/tf.h"
#include "rollo/Pose2DStamped.h"
#include "rollo/WheelSpeed.h"
#include "rollo/EKF.h"
#include <sstream>
#include <iostream>
#include <eigen3/Eigen/Dense>
#include "rollo.hpp"
```

### Functions

- void [subscriberCallbackMeasurement](#) (const rollo::Pose2DStamped msg)  
*SubscriberCallbackMeasurement.*
- void [subscriberCallbackControlInput](#) (const rollo::WheelSpeed msg)
- rollo::WheelSpeed [interpolateOdometry](#) (rollo::WheelSpeed Odometryold, rollo::WheelSpeed Odometrynew, double EKFilterTimeSecs)  
*Linear interpolation of values from odometry.*
- rollo::Pose2DStamped [interpolateMeasurement](#) (rollo::Pose2DStamped zOld, rollo::Pose2DStamped zNew, double EKFilterTimeSecs)  
*Linear interpolation of values from measurement (motion capture)*
- Eigen::Vector3d [FSTATE](#) (Eigen::Vector3d x\_pp, Eigen::Vector2d u)  
*FSTATE nonlinear state equations,  $f(x_{k-1}, u_{k-1})$*
- Eigen::Matrix3d [JacobianFSTATE](#) (Eigen::Vector3d x\_pp, Eigen::Vector2d u)  
*JacobianFSTATE.*
- Eigen::Vector3d [HMEAS](#) (Eigen::Vector3d x\_cp)  
*HMEAS measurement equation,  $h(x_k)$*
- int [main](#) (int argc, char \*\*argv)  
*Node main.*

## Variables

- rollo::Pose2DStamped [zPose2DStamped](#)  
*Global variables updated in the SubscriberCallback functions.*
- double **zTimeSecs** = 0
- rollo::WheelSpeed **Odometry**
- double **OdometryTimeSecs** = 0
- char [NodeName](#) [20] = C1 KF CR  
*Node name using console codes.*
- char [TopicEKF](#) [64] = [TOPIC\\_EKF](#)  
*Topic for extended Kalman filter results with all three estimated states and covariance matrix, stamped.*
- char [TopicWheelSpeed](#) [64] = [TOPIC\\_COMM\\_WS](#)  
*Topic for wheel speed containing the actual speed of wheel, preferably extracted from encoders or if not available by using a lookup table.*
- char [TopicPose2DStamped](#) [64] = [TOPIC\\_PREP\\_P2DT](#)  
*Topic for position and orientation stamped from preprocessor node.*

### 5.4.1 Detailed Description

EKF implementation for localisation of the robot.

#### Author

Rabbia Asghar  
Ernest Skrzypczyk

#### Date

20/2/16

Command prototype: **roslaunch rollo\_ekf \_rate:=1:**

#### Parameters

<i>rate</i>	Sampling frequency of the node <!1 [Hz]>
-------------	--

Based on input from communication node in form of control commands and measurement from preprocessor node, extended Kalman filter implementation estimates of states for localization and publishes estimated states with covariance.

Localization of the robot consists of 3 states:

- Position (x, y)
- Orientation (Theta)

Timing for EKF update is inspired from Robot Pose EKF (robot/pose/ekf) package available for ROS:

Timings and data at those specific time instants are synchronized in such a manner, that the latest measurements with newer timestamps are interpolated to one and the same timestamp, when all necessary data is available. This allows for a relative comparison of available data, even though an additional error is introduced through interpolating.

#### See also

[http://wiki.ros.org/robot\\_pose\\_ekf](http://wiki.ros.org/robot_pose_ekf)

Kalman filter equations were first simulated in MATLAB, then translated into C++, compared and verified with previous results.

#### See also

<https://github.com/em-er-es/rollo/>

## 5.4.2 Function Documentation

### 5.4.2.1 Eigen::Vector3d FSTATE ( Eigen::Vector3d *x\_pp*, Eigen::Vector2d *u* )

FSTATE nonlinear state equations,  $f(x_{k-1}, u_{k-1})$

This is part of time update(or prediction update) of EKF. Given "a priori" state estimate,  $x_{k-1|k-1}$  and  $u_{k-1}$ , it computes predicted value for state,  $x_{k|k-1}$ .

#### Parameters

<i>x_pp</i>	contains "a priori" state estimate, $x_{k-1 k-1}$ .
<i>u</i>	is control input vector, calculated from odometry. It consists of 2 elements, delta S and delta theta.

#### Returns

Eigen::Vector3d, state prediction  $x_{k|k-1}$ .

### 5.4.2.2 Eigen::Vector3d HMEAS ( Eigen::Vector3d *x\_cp* )

HMEAS measurement equation,  $h(x_k)$

This computes estimated measurement vector based on the latest state estimate.

#### Parameters

<i>x_cp</i>	contains state prediction $x_{k k-1}$ computed in time update of EKF
-------------	--

#### Returns

Eigen::Vector3d, contains estimated measurement vector.

### 5.4.2.3 rollo::Pose2DStamped interpolateMeasurement ( rollo::Pose2DStamped *zOld*, rollo::Pose2DStamped *zNew*, double *EKFfilterTimeSecs* )

Linear interpolation of values from measurement (motion capture)

This function performs linear interpolation of robot pose2D for a given time instant. The time for which the robot pose2D are computed is defined by *EKFfilterTimeSecs*.

#### Parameters

<i>zOld</i>	contains robot pose2D and timestamp read at previous instant when EKF was updated.
<i>zNew</i>	contains robot pose2D and timestamp read currently.
<i>EKFfilterTimeSecs</i>	is the time instant for which the EKF update need to be performed and robot pose2D need to be computed.

#### Returns

rollo::Pose2DStamped, contains robot pose2D computed for time instant given by *EKFfilterTimeSecs* using linear interpolation.

### 5.4.2.4 rollo::WheelSpeed interpolateOdometry ( rollo::WheelSpeed *Odometryold*, rollo::WheelSpeed *Odometrynew*, double *EKFfilterTimeSecs* )

Linear interpolation of values from odometry.

This function performs linear interpolation of right and left wheel speed for a given time instant. The time for which the odometry values are computed is defined by *EKFfilterTimeSecs*.

## Parameters

<i>Odometryold</i>	contains left and right wheel speed and timestamp read at previous instant when EKF was updated.
<i>Odometrynew</i>	contains left and right wheel speed and timestamp read currently.
<i>EKFfilterTimeSecs</i>	is the time instant for which the EKF update need to be performed and odometry values need to be computed.

## Returns

rollo::WheelSpeed, contains left and right wheel speed [rad/s] computed for time instant given by *EKFfilterTimeSecs* using linear interpolation.

5.4.2.5 Eigen::Matrix3d JacobianFSTATE ( Eigen::Vector3d *x\_pp*, Eigen::Vector2d *u* )

JacobianFSTATE.

This computes Jacobian matrix by taking the partial derivatives of  $f(x_{k-1}, u_{k-1})$  with respect to  $x$ .

## Parameters

<i>x_pp</i>	contains "a priori" state estimate, $x_{k-1 k-1}$ .
<i>u</i>	is control input vector, calculated from odometry. It consists of 2 elements, delta S and delta theta.

## Returns

Eigen::Matrix3d is the Jacobian matrix

5.4.2.6 int main ( int *argc*, char \*\* *argv* )

Node main.

Initialize node, nodehandle, subscribe to messages from preprocessor and communication nodes and publish estimated state of the robot.

## Parameters

<i>rate</i>	Sampling frequency of the node <!1 [Hz]>
-------------	--

Initializes Extended Kalman Filter relevant variables. As a part of initializing, function waits for one message from each subscriber and save timestamps for the first iteration of EKF. State estimate,  $x_{(0|-1)}$  is initialized as the first measurement read from the preprocessor node. Covariance of state estimate,  $E(0, -1)$  is initialized as identity matrix.

Run EKF in loop, update estimates. Await new sensor data, determine time step for EKF update and perform necessary interpolation.

Publishes newest estimates of state variables, covariance matrix and timestamp.

## Returns

0

Initialize node

Initialize nodehandle for subscribers and publisher

Initialize subscribers

Initialize publisher and define topic and message queue size for the publisher

Initialize node arguments using command line

Initialize node parameters from launch file or command line. Use a private node handle so that multiple instances of the node can be run simultaneously while using different parameters.

Publishing rate [Hz]

Initialize variables involved in computation of EKF Define number of states

Initialize noise covariances and matrices

Initialize vector for control input  $u$  and variables involved in its computation

Initialize state estimate vector "a priori" and measurement vector

Initialize Jacobian matrix with the partial derivatives of  $h(x_k)$  with respect to  $x$ , identity for provided system

Initialize  $E_{pp}$ : "a priori" estimated state covariance,  $E_{k-1|k-1}$  ( $p$  refers to  $k-1$ )

Initialize variables involved in the prediction update of EKF

Initialize variables involved in the innovation update of EKF

Initialize state estimate vector and state covariance matrix a posteriori

Variables for time

Initialize measurement vector with timestamp and odometry data with timestamp from subscriber messages Initialize state estimate using measurement vector reading

**Initialization loop**

**Initialization loop end**

**Main loop**

Check if new data is available from measurement (motion capture) and odometry (control input)

Determine time step for EKF update and perform interpolation for the sensor data not available at respective time step

Update timestamp

Interpolate measurements

Update state

Update timestamp

Interpolate for measurement

Update variables involved in EKF update

Update `prevOdometry` and `prevzPose2DStamped` for next loop

Perform EKF update if all sensor data is available

Determine  $dt$

Update `PreviousEKFilterTimeSecs` for the next loop

Determine control input  $u$  from  $nL$  and  $nR$

Prediction update Nonlinear update and linearization at current state

Partial covariance update

Innovation update Nonlinear measurement and linearization

Update  $E_{pp}$  and  $x_{pp}$  for next loop for next loop

Prepare data for publishing

Pose2D

Covariance

Publish

Synchronize to rate

Main loop end

5.4.2.7 void subscriberCallbackControlInput ( const rollo::WheelSpeed *msg* )

Read new message

5.4.2.8 void subscriberCallbackMeasurement ( const rollo::Pose2DStamped *msg* )

SubscriberCallbackMeasurement.

Subscribe to the topic '/Rollo/preprocessor/pose2dstamped' of the preprocessor node. Read filtered position and orientation of the robot and timestamp. Update global variables `zPose2DStamped` and `zTimeSecs` for use in EKF update.

Parameters

<i>msg</i>	- custom defined message (preprocessor node).
------------	---

Returns

NULL

Read new message

### 5.4.3 Variable Documentation

5.4.3.1 rollo::Pose2DStamped `zPose2DStamped`

Global variables updated in the SubscriberCallback functions.

Initialize custom defined messages for measurement and odometry. Measurement message includes Pose2D along with timestamp. Odometry message includes timestamp and angular velocities for left and right wheel. Initialize variables that save timestamps from both measurement and odometry subscribers in double (float64 in message format).

## 5.5 rollo\_preprocessor.cpp File Reference

Preprocessor for Rollo measurement using Mocap OptiTrack motion capture data.

```
#include "ros/ros.h"
#include "std_msgs/String.h"
#include "geometry_msgs/Pose.h"
#include "geometry_msgs/Pose2D.h"
#include "rollo/Pose2DStamped.h"
#include "tf/tf.h"
#include <sstream>
#include <iostream>
#include "rollo.hpp"
```

### Functions

- void [subscriberCallback](#) (const geometry\_msgs::Pose2D::ConstPtr &msg)

*Subscriber callback.*

- int **main** (int argc, char \*\*argv)

*Node main.*

## Variables

- char **nodeName** [20] = C1 PP CR

*Global variables updated in the SubscriberCallback function, processed and published.*

- double **x**

*Absolute coordinates.*

- double **y**

- double **theta**

- double **x\_mm**

*Absolute coordinates in various units.*

- double **y\_mm**

- double **theta\_deg**

- char **TopicMotionCapture** [64] = TOPIC\_PREP\_MC

- char **TopicPose2DStamped** [64] = TOPIC\_PREP\_P2DT

*Topic for position and orientation, stamped.*

### 5.5.1 Detailed Description

Preprocessor for Rollo measurement using Mocap OptiTrack motion capture data.

#### Author

Rabbia Asghar  
Ernest Skrzypczyk

#### Date

16/2/16

Command prototype: **roslaunch rollo rollo\_preprocessor \_rate:=25 \_samplesize:=4 \_sampling:=0**

#### Parameters

<i>rate</i>	Sampling frequency of the node <!25 [Hz]>
<i>samplesize</i>	Number of elements that are averaged/subsampled <!4 [1]>
<i>sampling</i>	Selects if the raw data should be subsampled after a certain delay or averaged over a certain period <!0 [1]> <ul style="list-style-type: none"> <li>• sampling 0 sets subsampling</li> <li>• sampling !0 sets averaging</li> </ul>

Filter the raw data from optitrack motion capture system and publish it along with time stamp for modeling of odometry and the measurement in Kalman filter

#### See also

<https://github.com/em-er-es/rollo/>



## 5.5.2 Function Documentation

### 5.5.2.1 `int main ( int argc, char ** argv )`

Node main.

Initialize variables, nodehandle, subscribe to motion capture data from mocap\_optitrack node and publish position and orientation after processing with time stamp. The position and orientation are published along with timestamp to topic /Rollo/preprocessor/pose2dstamped in format custom defined message, rollo::Pose2DStamped.

Parameters

<i>rate</i>	Sampling frequency of the node <!25 [Hz]>
<i>samplesize</i>	Number of elements that are averaged/subsampled <!4 [1]>
<i>sampling</i>	Selects if the raw data should be subsampled after a certain delay or averaged over a certain period <!0 [1]> <ul style="list-style-type: none"> <li>• sampling 0 sets subsampling</li> <li>• sampling !0 sets averaging</li> </ul>

Returns

0

Initialization

Name of the preprocessor node

- Nodehandle for subscriber and publisher
- Subscriber
- Publisher initialization with topic, message format and queue size definition
- Node arguments using command line

Sampling is either done using subsampling (0) or simple averaging (1)

- Initialize node parameters from launch file or command line. Use a private node handle so that multiple instances of the node can be run simultaneously while using different parameters.
- Publishing rate [Hz]
- Publisher variables for conventional messages
- Message type
- Publisher variables for processing
- Initialize variable to publish message
- Loop counter holder
- Loop condition variable

**Main loop**

- Prepare data for publishing
- Publish
- Reset variables
- For subsampling sleep for time defined by rate and then read the states from the `subscriberCallback()` without `usleep()` delay

For averaging sleep for time defined by rate before reading states from the `subscriberCallback()`

- Increase loop counter

**Main loop end****5.5.2.2 void subscriberCallback ( const geometry\_msgs::Pose2D::ConstPtr & msg )**

Subscriber callback.

Subscribe to motion capture data from mocap\_optitrack node and read position and orientation from Optitrack node.

**Parameters**

<i>msg</i>	<p>Message generated by mocap_optitrack node in format:</p> <ul style="list-style-type: none"> <li>• Position x [m]</li> <li>• Position y [m]</li> <li>• Orientation [rad]</li> </ul>
------------	---

**See also**

[https://github.com/ros-drivers/mocap\\_optitrack](https://github.com/ros-drivers/mocap_optitrack)

**Returns**

NULL

**Acquisition:**

- Raw x coordinate [m]
- Raw y coordinate [m]
- Raw theta [rad]

Conversion into degrees in the range 0 to 360 degrees

Print message with acquired data

**5.5.3 Variable Documentation****5.5.3.1 char NodeName[20] = C1 PP CR**

Global variables updated in the SubscriberCallback function, processed and published.

Node name using console codes

## 5.5.3.2 char TopicMotionCapture[64] = TOPIC\_PREP\_MC

Topics Topic for motion capture data

## 5.6 rollo\_visualization.cpp File Reference

Visualize motion capture data and EKF estimates.

```
#include "ros/ros.h"
#include "geometry_msgs/Twist.h"
#include "geometry_msgs/Vector3.h"
#include <stdio.h>
#include <termios.h>
#include <unistd.h>
#include <fcntl.h>
#include <sstream>
#include <iostream>
#include "rollo.hpp"
```

### Functions

- int [kbhit](#) (void)  
*Keyboard keystroke.*
- void [decodeKey](#) (char character, double &Speed, double &Turn)  
*Decode key.*
- int [main](#) (int argc, char \*\*argv)  
*Node main.*

### Variables

- char [NodeName](#) [20] = C2 CT CR  
*Global variables.*
- char [TopicCmdVel](#) [64] = TOPIC\_CTRL\_CMD\_VEL  
*Topic for commands generated expressed in linear and angular velocity.*
- double [LimitVelocityF](#) = 1  
*Limit velocity forward.*
- double [LimitVelocityR](#) = -1  
*Limit velocity reverse.*
- double [LKeysSteps](#) = 0.1  
*Left key set velocity step.*
- double [RKeysLinearV](#) = 0.4  
*Right key set linear velocity step.*
- double [RKeysAngularV](#) = 1  
*Right key set angular velocity step.*

### 5.6.1 Detailed Description

Visualize motion capture data and EKF estimates.

**Author**

Rabbia Asghar  
Ernest Skrzypczyk

**Date**

25/2/16

Command prototype: **roslaunch rollo rollo\_\_rate:=10**

**Parameters**

<i>rate</i>	Running frequency of the node <!10 [Hz]>
-------------	--

Robot control using following key sets

q	w	e		u	i	o
a	s	d	f/F	j	k	l
z	x	c		m	,	.

**Left key set:**

- q/e : increase/decrease speeds 0.1 and -0.1
- w/s : increase/decrease only linear speed by 0.1
- a/d : increase/decrease only angular speed by 0.1
- z/c : increase/decrease speeds 0.1 and -0.1
- x : reset angular speed

**Independent key set:**

- f/F : full speed forwards/backwards

**Right key set:**

- u/o : increase/decrease set speeds for diagonal movement forwards
- i/, : increase/decrease set speeds for forward/backward movement
- j/l : increase/decrease set speeds for rotations
- m/. : increase/decrease set speeds for diagonal movement backwards
- k : stop

**Global key set:**

- \* : stop
- <CTRL>-C : quit

Python script available online used as reference.

**See also**

[https://github.com/ros-teleop/teleop\\_twist\\_keyboard/blob/master/teleop\\_twist\\_keyboard.py](https://github.com/ros-teleop/teleop_twist_keyboard/blob/master/teleop_twist_keyboard.py)  
<https://github.com/em-er-es/rollo/>

## 5.6.2 Function Documentation

### 5.6.2.1 void decodeKey ( char *character*, double & *Speed*, double & *Turn* )

Decode key.

Compute linear and angular command velocities based on keyboard input. Key pressed character <key> as input argument.

Parameters

<i>character</i>	Character to be decoded
<i>&amp;Speed</i>	Linear velocity
<i>&amp;Turn</i>	Angular velocity

Returns

NULL

See also

[https://github.com/ros-teleop/teleop\\_twist\\_keyboard/blob/master/teleop\\_twist\\_keyboard.py](https://github.com/ros-teleop/teleop_twist_keyboard/blob/master/teleop_twist_keyboard.py)

Left key set control

Full speed forward/backward

Right key set control

Default value

Velocity limits

Linear velocity limits

Angular velocity limits

Print decoded velocities

### 5.6.2.2 int kbhit ( void )

Keyboard keystroke.

Check if a key is pressed on keyboard and return it.

Parameters

<i>NONE</i>
-------------

Returns

1 if a key is pressed on keyboard, otherwise 0.

See also

[https://github.com/sdipendra/ros-projects/blob/master/src/keyboard\\_non\\_blocking\\_input/src/keyboard\\_non\\_blocking\\_input\\_node.cpp](https://github.com/sdipendra/ros-projects/blob/master/src/keyboard_non_blocking_input/src/keyboard_non_blocking_input_node.cpp)

### 5.6.2.3 int main ( int *argc*, char \*\* *argv* )

Node main.

Initialize variables and nodehandle, read and translate input information into command messages.

**Parameters**

<i>rate</i>	Running frequency of the node <!10 [Hz]>
-------------	--

Publish to command velocity topic as specified in configuration header file according to format `geometry_msgs::Twist`

**Returns**

0

**Algorithm structure****Initialization**

- Initialize nodehandle for publisher
- Publisher initialization with topic, message format and queue size definition
- Node arguments using command line
- Initialize node parameters from launch file or command line. Use a private node handle so that multiple instances of the node can be run simultaneously while using different parameters.
- Publishing rate [Hz]
- Publisher variables for conventional messages
- Initialize variables for computing linear and angular velocity of the robot
- Initialize character holder

**Main loop**

- Check if a key is pressed
- Read character
- Decode key pressed
- Prepare message to publish linear and angular velocities
- Print message with velocities
- Publish message in Twist format
- ROS spinOnce
- Sleep to conform node frequency rate

**Main loop end****5.6.3 Variable Documentation****5.6.3.1 char NodeName[20] = C2 CT CR**

Global variables.

Node name using console codes

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