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# Robot body language telepresence PROJECT CHARTER

| | |
|---|---|
| Version: | v 1.0 |
| Date: | 20 Mar 2019 |
| Sponsor: | Virtual Experience Laboratory |
| Group Number: | V10 |
| Authors: | Minh Doan Quang, Lachlan Clulow, Jesse Buhagiar, Sreeja Manikyam |

## Document Control

| | |
|---|---|
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### Distribution

| Version | Issued | Recipient | Entity / Position |
|---|---|---|---|
| V 1. | 24 Mar 2019 | Vic Ciesielski | Supervisor |
| | | | |

### Amendment History

| Section | Page | Version | Comment |
|---|---|---|---|
| 1 - 8 | 2- 12 | 1.0 | Initial Project Charter draft write up |
| | | | |

### Staff or Entities Consulted

| Name | Position / Organization |
|---|---|
| Ian Peake | Virtual Experience Laboratory |

Add rows as needed. If not relevant, enter N/A.

### Related Documents

| Name | Author | Description |
|---|---|---|
| | | |
| | | |

***Preface***

The purpose of this document is to outline the Charter for Robot Body Language Telepresence Project. It serves as an agreement between the project team, the sponsor and the supervisor. It outlines the project's purpose and how the project will be approached, resourced, managed and delivered.  Any amendments after this document has been signed off will be via addenda.

## Table of Contents

## 1 Project Summary

Our Project’s mission is to research and develop a telepresence application for the robot ‘Rosie’ at Virtual Experience Laboratory. The intent of the project is to allow Rosie to mimic human body movement using data from a Microsoft Kinect device. Rosie is a Baxter robot manufactured by Rethink Robotics that is longer available on the market. Therefore, Rosie is considered one of the legacy robots that RMIT has at the moment. This project will allow RMIT to extend the useful lifetime of Rosie, as the RMIT Vietnam Campus also have another Baxter robot. This project will allow the Baxter robots from both campuses to behave as human avatars. They will help convey the body language of the speakers from one side of the telepresence call to the other. Rosie will be able to retrieve data from a human skeleton sensor; in this case it will be the Microsoft Kinect. Rosie will be able to recreate the movement of a human by using the data retrieved from the sensor.

Objectives:

- Tracking human skeleton using kinect SDK provide by Microsoft
- Communicating between Sensor and Rosie, sending data and retrieve data
- Handing retrieved data and turn it into actual robot movement
- Improve the legacy code from previous project group

## 2 Project Sponsor

The project sponsor is Professor Heinz Schmidt of Virtual Experience Lab. Virtual Experiences Laboratory is a sub part of RMIT in which create a space for students and industry to have experiences on advanced technology. Providing a range of industry application including manufacturing, electronic engineering, information technology, analytics, games and medical imaging. Also, VXLab act as the middleman to connect industry and student together. Allow students to have access to real industrial project and also allow industry to found potential candidate.

Focus Technology:

- Virtual Reality
- Cloud Computing
- Robotics

Office located at: RMIT building 91 Victoria, Carlton VIC 305

## 3 Stakeholders and End Users

| NAME & ORGANIZATION | PROJECT ROLE | PROJECT RESPONSIBILITIES |
|---|---|---|
| Professor Heinz Schmidt Virtual Experience Laboratory, Executive | N/A | Project Sponsor |
| Ian Peake Virtual Experience Laboratory | Product Owner / Lab Manager | Mentoring and supervising development team |
| Vic Ciesielski, RMIT | Supervisor | Supervising and monitoring the project |

## 4 Appointment of Project Leader

The project leader is Lachlan Clulow. We all as team decided that Lachlan would be leading us during the second meeting with the supervisor. He is proficient in C, Java and python programming skills. He is very familiar with Linux command line and has very good software engineering project management skills

## 5 Project Team Members

The project team members and their respective roles are:

| | |
|---|---|
| Print Name: | Mr. Minh Doan Quang |
| Student Number: | S3608452 |
| Role: | Developer / Scrum Member |
| | |
| Print Name: | Mr. Lachlan Clulow |
| Student Number: | S3682356 |
| Role: | Developer / Scrum Master |
| | |
| Print Name: | Mr. Jesse Buhagiar |
| Student Number: | S3600244 |
| Role: | Developer / Maintainer / Scrum Member |
| | |
| Print Name: | Mr. Sreeja Manikyam |
| Student Number: | S3705865 |
| Role: | Documentation / Tester |

## 6 Project Methodology and Approach

The approach that our project team has selected for delivering the project is “Scrum”. It is an Agile approach planning and prioritising backload which involves in higher tasks selection for development. Scrum is highly sensitive to customer needs with excellent communication and transparency. It is highly flexible to change. Acceptance criteria defines the exact behaviour of the product. The key concepts we are following in this approach are:

- The product backlog
- Sprint
- Sprint review
- Sprint retrospective

## 7 Project Governance

The Governance model is as follows:

The project governance hierarchy is flat, with all members getting an equal say on input with regards to project direction and code. Any indecision and conflict of ideas will be settled via team vote (though with how large the scope of the project is already; this shouldn't be too much of an issue). We aim to meet up at minimum weekly to discuss and test any new features that have been implemented via the virtual ROS session available on Linux, as well as to get some time in with the actual robot hardware.  Everyone in the group will contribute to the ongoing programming efforts of getting the system up and running (i.e, role of "Developer" in Section 5 above), however there are individual roles. Minh is in charge of solutions for robot arms movement and human skeleton drawing algorithm , Lachlan's main responsibility is project leader and providing development assistance, Sreeja's primary role is handling documentation and application testing, and Jesse is in charge of maintaining the git repository, as well as the docker file.

Scope creep will mainly be settled by discussing with Ian. As there is a fair amount of different modules and subsystems to play with, it's very possible to go crazy with implementing features, however, by discussing what is actually required with Ian, we'll be able to keep the project nice and on track with what's required with regards to "deliverables". Any milestones achieved will be signed off and demonstrated to him before continuing with development on the project.

## 8 Project Scope & Deliverables

- Scope
    - Determine and establish version control, resources, required packages, and materials
    - Determine project roles
    - Source project resources
    - Research ROS environment
    - Research Kinect integration in ROS environment
    - Research Rosie (Baxter + Mobility Base) integration in ROS environment
    - Research Docker containers
    - Research cob body tracker project integration
    - Integrate Kinect sensors and cob body tracking in ROS environment
    - 
- Deliverables
    - Sign off on safety briefings with Lab Manager (end of week 3)
    - Sign off first project charter with project supervisor (start of week 4)
    - Set up ROS environment and apply motion commands to Rosie (end of week 4)
    - Apply correct calibration of Kinect Sensors for use in ROS (end of week 4)
    - Submit to Lab Manager a Docker container to support ROS environment (end of week 5)
    - Lab manager approval of basic motion commands to Rosie (end of week 5)
    - Lab manager approval of Kinect Sensor data collection (end of week 5)
    - Lab manager approval of human to robot joint motion conversion algorithm/software integration (end of week 6)
    - 
    - 
    - Submit Project for Supervisor Approval (end of week 12)

1. Converting Human joint movement to robot joint movement
    a. Research methods to make this conversion
        i. Inverse Kinematics
2. Kinect calibration
    a. Research and apply correct calibration of kinect devices to properly apply kinect skeletal tracking
3. ROS development environment
    a. Research ROS development environment
    b. Analyse previous group project's implementation of ROS and expand upon this
    c. Develop and test skeletal tracking
    d. Apply human joint movement to robot joint movement
    e. Apply movements to rosie
4. Docker file
    a. Research docker file development
    b. Test and develop docker file to set up Telepresence project environment
5. Cob body tracker project
    a. Research cob body tracker project
    b. test and apply cob body tracker in rvis

# ISSUES REGISTER

**Project :** **Robot Body Language Telepresence**
**Project No:** **<Enter Project Number>**
**As At:** **<Enter Date Updated>**

| No | Description | Impact | Date Raised | Phase Raised | Allocated to | Resolution Strategies / Actions | Date Closed |
|---|---|---|---|---|---|---|---|
| *0* | *Sample – Delete this row after Register has been created* | *C – ritical*<br>*H – igh*<br>*M – edium*<br>*L - ow* | | *Planning*<br>*Analysis*<br>*Development*<br>*Testing*<br>*Implementation*<br>*Post Imp.* | *Name/s of person/s resolving the issue* | *Describe the strategies or actions that will be required to close / resolve the issue.*<br><br>*UPDATE: as actions progress and are closed..* | |
| 1 | Virtual Machine was too slow to run Simulation - Baxter SDK | Medium | 16/03/2019 | Planning | Minh Doan Quang | Install Dual Boot Ubuntu instead of Virtual Machine | |
| 2 | Gazebo Simulation fail to run on Ubuntu 18.0.0 | Medium | 19/03/2019 | Planning | Minh Doan Quang | Reinstall Ubuntu 16.0.0 | |
| 3 | Kinect disable by itself some time | Critical | 01/04/2019 | Development | Minh Doan Quang | Rerun kinrosie docker container with people_detection package in rosie/vxlab | |
| 4 | Code after Refactor with new library unable to run | Medium | 15/04/2019 | Development | Minh Doan Quang | Debug | |
| 5 | Unable to implement ROSBridge | High | 29/04/2019 | Development | Lachlan Clulow | Help Minh's to implement ROSBridge | |
| 6 | Unable to connect to WiFi/download ros packages on Ubuntu 14.04 | Medium | 17/03/2019 | Planning | Sreeja Manikyam | Reinstall Ubuntu by dual boot but with 16.0.0 version | |
| 7 | Trouble in installing on to | Medium | 21/03/2 | Development | Sreeja Manikyam | Memory extension | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | docker containers to run Gazebo simulation | | 019 | | | from windows and merging it with Ubuntu | |
| 8 | Kinect sensor calibration too difficult to achieve | Medium | 18/4/20 19 | Development | Lachlan Clulow | Use default freenect2 driver calibration settings | |
| 9 | | | | | | | |
| 10 | ROS Kinetic packages fail to launch on Arch Linux due to missing drivers | Critical | 03/4/20 19 | Planning | Jesse Buhagiar | Reformat Disk and install a compatible Operating System (Ubuntu 16.04) | |
| 11 | ROSLink fails to map custom topic/subscriber | High | 15/5/20 19 | Development | Lachlan Clulow & Jesse Buhagiar | Use existing topic/subscriber to circumvent. | |
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Impact = Impact on the Business or project in the event the issue is not resolved within the required time.

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# RISK REGISTER

**Project :** **VXLab Robot Body Language/Telepresence**
**Project No:** **V10**
**As At:** **2/6/2019**

| No | Description | Impact | L'hood | Mitigation Strategies | Contingency Plan |
|---|---|---|---|---|---|
| *0* | *Sample – Delete this row after Register has been created* | *H – igh*<br>*M – edium*<br>*L - ow* | *H – igh*<br>*M – edium*<br>*L - ow* | *Describe the strategies to mitigate the risk, ie, preventative measures and monitoring mechanism* | *Describe the contingency plan in place, to be implemented in the event that the risk is realized.* |
| 1 | Unable to implement port forwarding for network solution to connect two baxters with kinect as port forwarding is dependent on dynamic ip address | H | M | Developing shell script to update dynamic IP addresses of all components from time to tim. | Use rosbridge websocket server as a proof of concept instead of a scalable and reliable system |
| 2 | Unable to correctly calibrate the Kinect sensor | M | H | | Use default calibration settings |
| 3 | Unacceptable Latency incurred by introduction of ROSLink Relays | H | M | Ensure the networking solution, servers are optimally resourced and located for fast transfer of data over the roslink protocol | Look at alternative server hosting options, different server locations and hardware/software configurations |
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|---|---|
| Impact | = Impact on the Business or project in the event the risk is realized |
| L’hood | = Likelihood of risk being realized |

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# Project Robot Body Language Telepresence
# Development Guide

| | |
|---|---|
| Version: | V1.0 |
| Date: | 22-5-2019 |
| Sponsor: | Virtual Experience Laboratory |
| Author: | Jesse Buhagiar |

## Document Control

| | |
|---|---|
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### Distribution

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| V 1.0 | 2/6/2019 | Vic Ciesielski | Supervisor |
| | | | |

### Amendment History

| Section | Page | Version | Comment |
|---|---|---|---|
| 1 - 6 | 6 - 11 | 1.0 | Development guide write up |
| | | | |

Add a row for each section update or consolidate if changes are minimal. NOTE: Changes should be tracked within the document if the document is to be re-distributed, so that the audience can quickly see the changes.

### Staff or Entities Consulted

| Name | Position / Organization |
|---|---|
| Ian Peake | Virtual Experience Laboratory |

Add rows as needed. If not relevant, enter N/A.

### Related Documents

| Name | Author | Description |
|---|---|---|
| <Enter Document Name> | <Enter Author> | <Enter Document Description |
| | | |

Add rows as needed. If not relevant enter N/A.

## *Preface*

The purpose of this document is to outline a technical guide line for new developers or anyone who is going to join the team and start development.

## *Table* of Contents

## 1 Project Summary

The *Robot Body Language Telepresence* is an attempt at using an existing humanoid, anthropomorphic robotics platform called Baxter, by the now defunct "Rethink Robotics". The sponsor of this project, Ian Peake of the RMIT VXLAB, is aiming to get better use out of the Baxter platform by allowing the two that RMIT own (one in Melbourne, Australia and the other in Saigon, Vietnam) to "communicate" with each other by having the movements captured from a Kinect camera in Melbourne to be transmitted and translated to real movement by the robot in Vietnam. It is also something cool the University can show off at Open Day.
It is our objective to:

1. Turn skeletal information send to the robot (in (x, y, z) format) into robot movement
2. To allow networking of two robots and to send information between them over the internet.

## 2 Setup client/developer machine

The system is somewhat complex to set up, with a lot of software dependencies and specific versions required for a developer to get up and running. Currently, the software required is as follows:

1. Ubuntu Wily or Xenial, either i386 or amd64. Debian Jessie amd64 is also supported.
2. ROS Kinetic
3. Software repositories found at: https://github.com/rmit-s3608452-Doan-QuangMinh/Robot-body-language-telepresence---VXLAB
   https://github.com/imchockers/baxter-sim-demo
   https://github.com/imchockers/kinect_based_arm_tracking

For the purpose of this guide, we'll be using Ubuntu. To install ROS Kinetic on Ubuntu, follow the tutorials on the following page: http://wiki.ros.org/kinetic/Installation/Ubuntu

A Docker image can be used for the client's machine, however this is currently unsupported.

## 3 Code/Comment Standard

To keep the code clean, there has been strict adherence to the *Python Coding Convention* (aka *PEP 8*), which is the format created for the Python Programming language. It is important that a developer follow this style. Python, being an interpreted rather than compiled language, will throw an interpreter fault if there is a discrepancy with formatting (mostly related to indentation). The key rules of this standard are as follows:

1. There are 4 *spaces* per indentation. Tabs are not allowed.
2. An indent should be inserted at the beginning of each new line where there is a block of code, e.g a function or an if/else block
3. Line lengths should not exceed 79 characters

The full style guide can be found here: https://www.python.org/dev/peps/pep-0008

The commenting style follows the Doxygen commenting standard, which includes macros and keywords to generate our own documentation in HTML form that can be uploaded to a web server. A reference to this is found here:
http://www.doxygen.nl/manual/docblocks.html#pythonblocks

An example of both the commenting style and coding style is shown below

```
'''
    Vector Length
```

```
	Returns the length of a given vector, <x, y, z>

	@param  v The vector we want to get the length of

	@return The Length of the vector, @ref v
'''
def vec3_length(v):
	return math.sqrt((v[0] * v[0]) + (v[1] * v[1]) + (v[2] * v[2]))
```

## 4 Version Control Policy

Version control follows a custom version *Gitflow* style of commiting. Regular *Gitflow* dictates that the master branch is only for version releases and that a separate development branch should be set up. However, as we have a relatively small team, we have circumvented this, and all commits are pushed to master. All work MUST be done on a separate fork; pushing directly to the source repository is highly frowned upon. An example of someone adding a feature is described below:

1. The developer types *git pull -u upstream master* (assuming upstream is the name of the remote of the upstream repository) to update their master
2. The developer then types *git checkout -b my_branch* to create a new branch called *my_branch* and then check it out.
3. Features are then developed on this branch
4. When the developer is ready, the branch is pushed back to their *local* forked repository on GitHub, and a pull-request is opened.

Once features have been reviewed (using GitHub's pull request review section), the feature is pulled into the upstream (master) repository's  master branch, and the cycle may begin again.

## 5 Deployment

- Download ROS as described in section 1.
- For real time Kinect 2.0 tracking, install freenect2 drivers via the steps detailed: https://github.com/code-iai/iai_kinect2#install
- Install rosbridge: http://wiki.ros.org/rosbridge_suite
- Install this project packages: https://github.com/imchockers/kinect_based_arm_tracking.git
- If you would like to connect two Baxter Robots via ROSBridge, then run the HTML client/server file. This will open a ROSBridge websocket that will allow a full-duplex Client/Server interaction. This is detailed in the readme files within the git project.

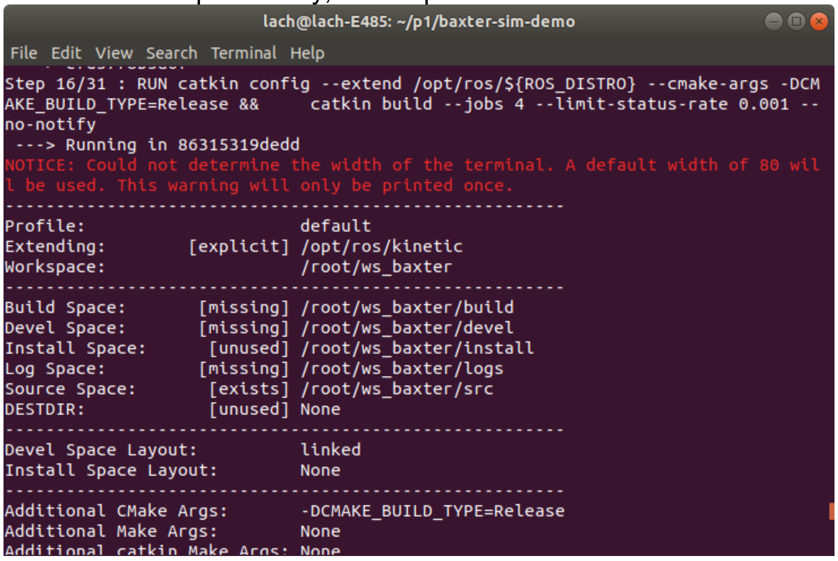
- For project simulation, install Docker : https://www.docker.com/
- Install Simulation environment and build using Docker: https://github.com/imchockers/baxter-sim-demo

## 6 Getting Started

<Illustrate and explain one function, how to start, coding on front end, back end, setting and deployment, screen shot on running example>

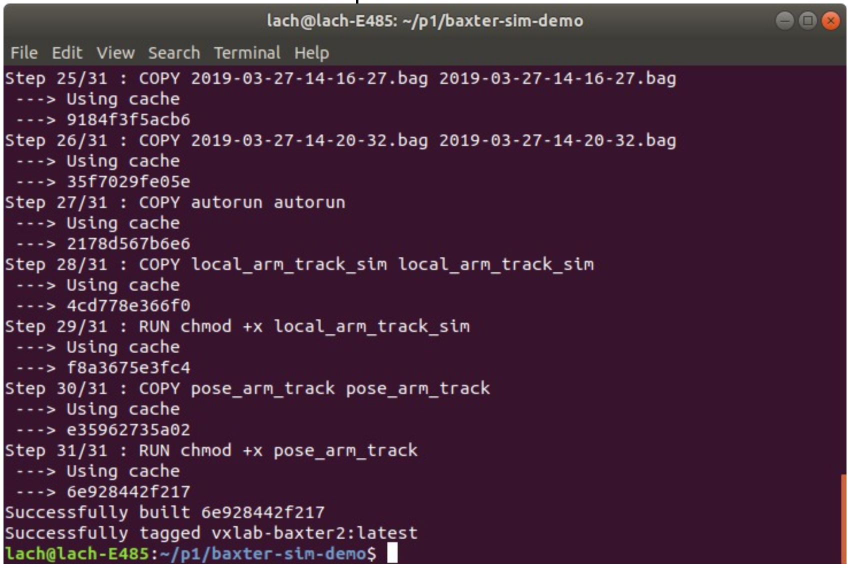
For simulated baxter environment docker container:

1. Clone the baxter sim git repo:
   a. git clone https://github.com/imchockers/baxter-sim-demo.git
   b. cd baxter-sim-demo
2. Build the docker container:
   a. ./build
   b. This may take some time depending on your machines configuration, particularly, this step:


lach@lach-E485: ~/p1/baxter-sim-demo
File Edit View Search Terminal Help

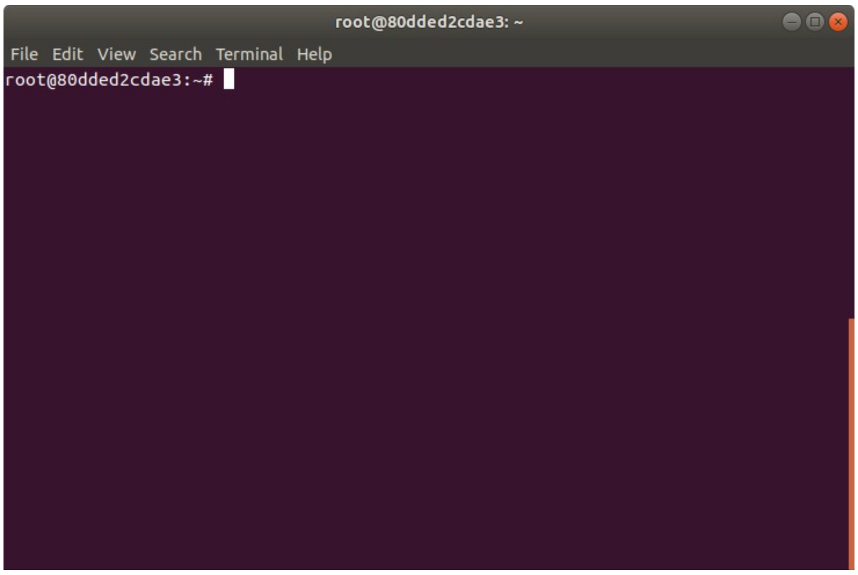
```
Step 16/31 : RUN catkin config --extend /opt/ros/${ROS_DISTRO} --cmake-args -DCM
AKE_BUILD_TYPE=Release &&     catkin build --jobs 4 --limit-status-rate 0.001 --
no-notify
 ---> Running in 86315319dedd
NOTICE: Could not determine the width of the terminal. A default width of 80 wil
l be used. This warning will only be printed once.
-------------------------------------------------------
Profile:                     default
Extending:         [explicit] /opt/ros/kinetic
Workspace:                   /root/ws_baxter
-------------------------------------------------------
Build Space:        [missing] /root/ws_baxter/build
Devel Space:        [missing] /root/ws_baxter/devel
Install Space:       [unused] /root/ws_baxter/install
Log Space:          [missing] /root/ws_baxter/logs
Source Space:        [exists] /root/ws_baxter/src
DESTDIR:             [unused] None
-------------------------------------------------------
Devel Space Layout:           linked
Install Space Layout:         None
-------------------------------------------------------
Additional CMake Args:        -DCMAKE_BUILD_TYPE=Release
Additional Make Args:         None
Additional catkin Make Args:  None
```

3. You should see this upon build:


lach@lach-E485: ~/p1/baxter-sim-demo
File Edit View Search Terminal Help

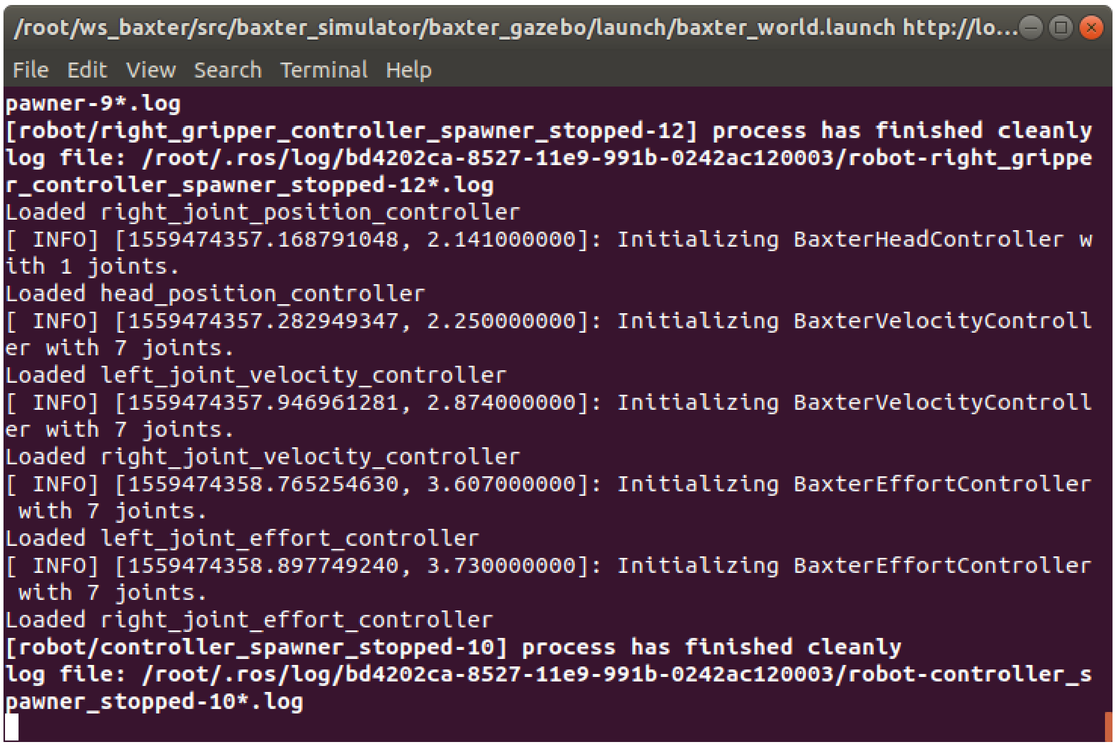
```
Step 25/31 : COPY 2019-03-27-14-16-27.bag 2019-03-27-14-16-27.bag
 ---> Using cache
 ---> 9184f3f5acb6
Step 26/31 : COPY 2019-03-27-14-20-32.bag 2019-03-27-14-20-32.bag
 ---> Using cache
 ---> 35f7029fe05e
Step 27/31 : COPY autorun autorun
 ---> Using cache
 ---> 2178d567b6e6
Step 28/31 : COPY local_arm_track_sim local_arm_track_sim
 ---> Using cache
 ---> 4cd778e366f0
Step 29/31 : RUN chmod +x local_arm_track_sim
 ---> Using cache
 ---> f8a3675e3fc4
Step 30/31 : COPY pose_arm_track pose_arm_track
 ---> Using cache
 ---> e35962735a02
Step 31/31 : RUN chmod +x pose_arm_track
 ---> Using cache
 ---> 6e928442f217
Successfully built 6e928442f217
Successfully tagged vxlab-baxter2:latest
lach@lach-E485:~/p1/baxter-sim-demo$
```

4. Run the docker containers using provided run file:
   a. ./run
   b. May need sudo permissions
5. To enter docker container bash shell do:
   a. docker exec -it vxlab-baxter2 bash
   b. Should be presented with shell like:

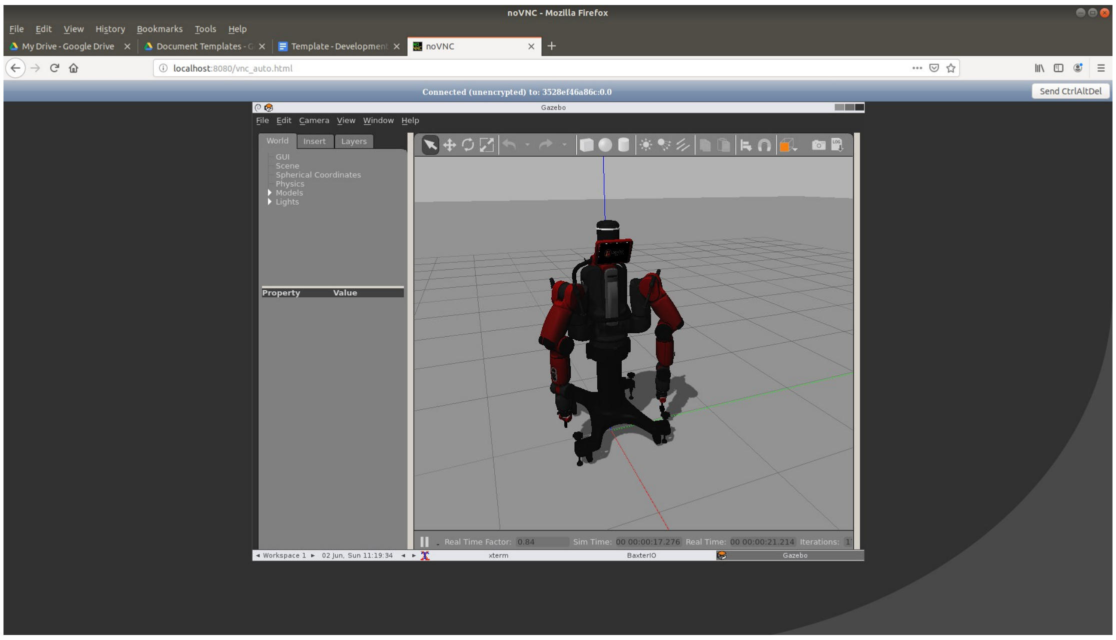


```
root@80dded2cdae3:~#
```

6. To begin Baxter simulator do:
   a. ./simstart
   b. open a browser and go to:
      b.i. http://localhost:8080/vnc_auto.html
   c. Wait for baxter to appear in the simulator and the following log message to appear in the simulator terminal:

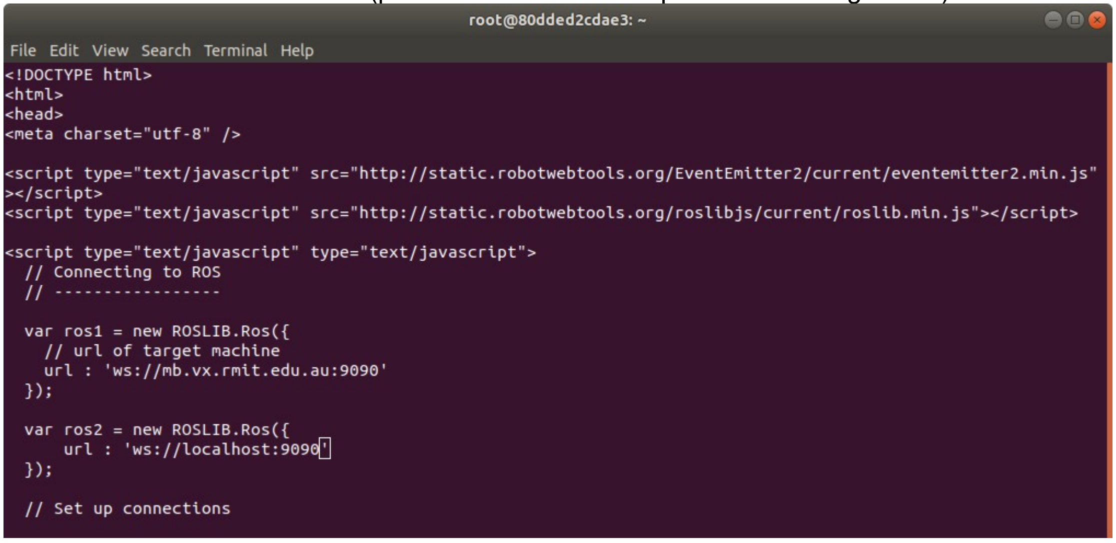

/root/ws_baxter/src/baxter_simulator/baxter_gazebo/launch/baxter_world.launch http://lo...
File Edit View Search Terminal Help

```
pawner-9*.log
[robot/right_gripper_controller_spawner_stopped-12] process has finished cleanly
log file: /root/.ros/log/bd4202ca-8527-11e9-991b-0242ac120003/robot-right_grippe
r_controller_spawner_stopped-12*.log
Loaded right_joint_position_controller
[ INFO] [1559474357.168791048, 2.141000000]: Initializing BaxterHeadController w
ith 1 joints.
Loaded head_position_controller
[ INFO] [1559474357.282949347, 2.250000000]: Initializing BaxterVelocityControll
er with 7 joints.
Loaded left_joint_velocity_controller
[ INFO] [1559474357.946961281, 2.874000000]: Initializing BaxterVelocityControll
er with 7 joints.
Loaded right_joint_velocity_controller
[ INFO] [1559474358.765254630, 3.607000000]: Initializing BaxterEffortController
 with 7 joints.
Loaded left_joint_effort_controller
[ INFO] [1559474358.897749240, 3.730000000]: Initializing BaxterEffortController
 with 7 joints.
Loaded right_joint_effort_controller
[robot/controller_spawner_stopped-10] process has finished cleanly
log file: /root/.ros/log/bd4202ca-8527-11e9-991b-0242ac120003/robot-controller_s
pawner_stopped-10*.log
```


noVNC - Mozilla Firefox
localhost:8080/vnc_auto.html
Connected (unencrypted) to: 3528ef46a86c:0.0
Send CtrlAltDel
Gazebo
World Insert Layers
GUI
Scene
Spherical Coordinates
Physics
Models
Lights
Property Value
Real Time Factor: 0.84 Sim Time: 00 00:00:17.276 Real Time: 00 00:00:21.214 Iterations: 1
xterm
BaxterIO
Gazebo

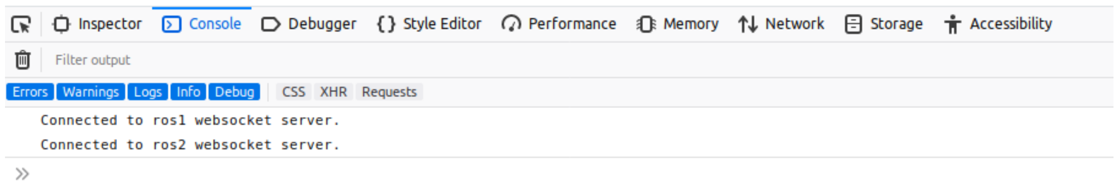
7. (Optional) For local testing, do:
    a. ./local_arm_track_sim
    b. Wait for baxter to raise his arms into a T-pose in the simulator window
    c. Play a /tf bagfile such as the following (should cause baxter to do something resembling a wave):
        c.i. source rosenv.sh
        c.ii. rosbag play 2019-03-27-14-20-32.bag /tf:=/tf_old

8. For networked operation do:
    a. ./pose_arm_track
    Get ottserver.html from:
    https://github.com/imchockers/kinect_based_arm_tracking.git
    b. Edit and save ottserver.html as follows:
        b.i. where var ros1 and ros2 are defined, change the url field the hostnames or ip addresses of the two machines to be connected as below (post 9090 is the default port that rosbridge uses):



```
root@80dded2cdae3: ~
File Edit View Search Terminal Help
<!DOCTYPE html>
<html>
<head>
<meta charset="utf-8" />

<script type="text/javascript" src="http://static.robotwebtools.org/EventEmitter2/current/eventemitter2.min.js"
></script>
<script type="text/javascript" src="http://static.robotwebtools.org/roslibjs/current/roslib.min.js"></script>

<script type="text/javascript" type="text/javascript">
  // Connecting to ROS
  // -----------------

  var ros1 = new ROSLIB.Ros({
    // url of target machine
    url : 'ws://mb.vx.rmit.edu.au:9090'
  });

  var ros2 = new ROSLIB.Ros({
      url : 'ws://localhost:9090'
  });

  // Set up connections
```

    c. Open ottserver.html in a browser and check the web console to ensure connection has occurred



```
Connected to ros1 websocket server.
Connected to ros2 websocket server.
```

d. If playing back rosbag files do:
   - d.i. rosrun time_jump time_jump.py
   - d.ii. rosbag play 2019-03-27-14-20-32.bag /tf:=/tf_old
   - d.iii. See Rosie or baxter simulator on another machine move in response to the bagfile being played.

# Test Management Document for Robot Body Language Telepresence

| | |
|---|---|
| Version: | V1.1 |
| Date: | 1 June 2019 |
| Sponsor: | Virtual Experience Laboratory |
| Author: | Sreeja Manikyam, Lachlan Clulow |

# Document Control

## Distribution

| Version | Issued | Recipient | Position |
|---|---|---|---|
| V <Enter No.> | <Enter Date> | <Enter Full Name> | <Enter Position> |
| V 1.1 | 3/6/19 | Ian Peake | Lab Manager/Supervisor |

## Amendment History

| Section | Page | Version | Comment |
|---|---|---|---|
| 1 - 8 | 4-7 | 1.1 | Test Schedule final write up compilation |
| | | | |

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## Staff or Entities Consulted

| NAME | Position / Organization |
|---|---|
| Ian Peake | Virtual Experiences Laboratory |

## Related Documents

| Name | Author | Description |
|---|---|---|
| <Enter Document Name> | <Enter Author> | <Enter Document Description> |
| | | |

## Table of Contents

## 1 Introduction

<The purpose of this document is to list out the main objectives, assumptions, requirements, schedules and brief explanation of tests that the team has conducted. The tests were basically part of implementation process.>

This is the test management document for the Robot Body Language/Telepresence Project. The outcome of the project is to develop a system whereby a user or users can control a robot (Rosie/Baxter) using their body movements. The body language/motion is captured by a depth sensor (Microsoft Kinect 2.0) and applied to the robot to mimic the actions of the user. This user and robot should be able to be networked such that the user and robot can be in two separate networked locations and the robot behaves as the user's avatar.

## 2 Objectives and Tasks

### 2.1 OBJECTIVES

Unit testing of each of the components in the project to ensure that each component functions:

- Kinect sensor data output
- cob_people_perception ingest and publishing body tracking data
- Conversion of cob* data to joint angles
- Publishing joint angle data
- Network transfer of joint angle data
- Client subscription to networked joint angle data
- Application of joint data to Rosie

Integration testing of each component to ensure the flow of data from kinect sensor to robot movement.

## 3 Approach Overview

- Client side publishing:
  - Kinect sensor data output
    - Ensure kinect sensor is running,
    - Visual inspection, is it powered on?
    - Data flow inspection are /kinect2/* topics being published?
      - e.g. rostopic list | grep kinect2
      - e.g. rostopic echo /kinect2/sd/image_ir/compressed
  - cob_people_perception ingest and publishing body tracking data
    - Ensure cob_people_perception package is running
      - rostopic list | grep body_tracking
    - Test user tracking data output
      - rostopic echo /tf | grep cob
      - Have a user stand in front of the kinect camera and see if there is output
  - Conversion of cob* data to joint angles
    - rostopic list | grep socket
  - Publishing joint angle data
    - rostopic echo /right_e0_socket
- Server:
  - Ensure server connects to clients
    - Open ottserver.html in browser and check console log
  - Network transfer of joint angle data
    - On subscribing client side:

            - rostopic list | grep /right_e0
- Client side subscribing:
    - Client subscription to networked joint angle data
        - rostopic echo /right_e0
    - Application of joint data to Rosie
        - Visual inspection of Rosie, or baxter simulator responding to data input

## 4 Scope

Testing mainly applies to the flow of data within the ROS system and the successful network traversal of this data, all modules in the flow of data will be tested to ensure that the data reliably passes from one module to the next as specified in the architecture document.

## 5 Assumptions

All modules are validated to run in an Ubuntu 14.04 environment running a compatible version of ROS (kinetic or indigo).

All testing should be consistent whether running with Baxter robot units or simulated baxter units.

## 6 Functional Requirements

- System must capture image data and output point cloud data
- System must input point cloud data and convert it to a stream of user joint data
- System must be able to track one specific user at a given time
- System must be able to convert joint data to angles between specific joints for a specified user
- System must be able to transfer joint angle data between ros environments over a network
- System must be able to apply joint angle data to a robot avatar

## 7 Non Functional Requirements

- System shall not incur significant latency due to processing and network transfer of data
- System shall be reliable such that it must remain running for long periods of time without the need to reset the system
- System shall work in a variety of configurations, baxter-to-baxter, baxter-to-simulator, simulator-to-simulator etc.

## 8 Test Schedule

Refer to Test Schedule document

## Test Schedule

| ***Task Name*** | ***Date*** | ***Related Scripts*** | ***Comments*** | ***Expected Result*** | ***Test result*** |
|---|---|---|---|---|---|
| Kinect Sensor Testing | 15/3/19 | rostopic echo /kinect2/image_ir/compressed | Kinect configured, data is output successfully | A stream of ir image data appearing in the console | Success |
| cob_people_perception | 15/3/19 | rostopic echo /tf \| grep cob | Cob body tracking data is output, cob contained in the child frame id of relevant /tf transform frames | A stream of user joint locations in 3d space | Success |
| User tracking | 27/3/19 | rostopic echo /user_tracking Kinect_based_arm_tracking tf_user_tracker.py | | Should output a specific user id when there is at least one user in the frame, after 10 second of not being able to track a user it should either switch to another user or state tracking None | Success |
| User joint data conversion | 4/4/19 | rostopic echo /right_e0_socket Kinect_based_arm_tracking tf_listen_socket_pub.py | | Should output 64 bit float values on a topic for each robot arm joint | Success |
| Apply joint angles data to rosie | 17/4/19 | Kinect_based_arm_tracking tf_listen_v8_controller.py | | Rosie should respond to joint angles data with motion of arms | Success |
| Networking | 29/5/19 | Kinect_based_arm_tracking ottserver.html | Open ottserver.html in a browser and edit the ros1 and ros2 host addresses to the addresses of the | Joint angle data publishing on /*_socket topics in one client should be republished in the destination client node | Success |

| | | | | | |
|---|---|---|---|---|---|
| | | | rosbridge websocket servers | | |

RMIT UNIVERSITY

# Technical Solution Design for Robot Body Language Telepresence

| | |
|---|---|
| Version: | V1.0 |
| Date: | 1 May 2019 |
| Sponsor: | Virtual Experience Laboratory |
| Author: | Sreeja Manikyam, |

## Document Control

### Distribution

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|---|---|---|---|
| V 1.0 | 2/6/2019 | Vic Ciesielski | Supervisor |
| | | | |

### Amendment History

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|---|---|---|---|
| <Enter Doc. Section No.> | <Enter Page No.> | <Enter Version No.> | <Enter Comments to explain the reason for the document text or other changes, e.g., Updated text after walkthrough with the stakeholders, or e.g., Updated section after technical consultation> |
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### Related Documents

| Name | Author | Description |
|---|---|---|
| <Enter Document Name> | <Enter Author> | <Enter Document Description> |
| | | |

***Preface***

The purpose of this document is to < Detail the purpose of this document>

# Table of Contents

# 1 Introduction

<Paragraph summary of the technical solution that was completed including:

- Brief project description
- Brief description of technical environment
- Estimated level of complexity
- Estimated benefits/Problems it solved (quantitative & qualitative).>

### 1.1 Brief Project Description

The idea of the project is to research and develop a functionality for Robot Rosie of Virtual Experience Laboratory so that Rosie can mimic human body movement. Rosie will be able to retrieve data from a human skeleton sensor; in this case it will be the Microsoft Kinect SDK. Then Rosie will be able to recreate the movement of human by using the data retrieved from the sensor.This project will allow the Baxter robots from both campuses to behave as human avatars. They will help convey the body language of the speakers from one side of the telepresence call to the other.

### 1.1 Brief Description of Technical Environment

The technical environment involved in this project are as follows:

- *Baxter Unit:* Baxter robot was manufactured by Rethink Robotics for industrial purposes.

- *Microsoft Kinect:* It is an advanced sensor designed to capture 3D images with high performance along with voice and face recognition.

- *ROS :* Robot Operating System (ROS) is a meta operating system which is open source that can provide functionalities implementation, package management, hardware abstraction, device control and message passing. It also gives the advantage of providing tools and libraries to write, build and run code.

### 1.3 Estimated Level of Complexity

The estimated level of complexity of the project is very high, due to the amount of knowledge required in regards to the size of the Operating System (ROS) as well as the mathematical principles related to Inverse Kinematics (getting the robot arms to move from camera input). However, there is base code that can be built on, supplied by the previous group that attempted the project.

### 1.4 Estimated benefits/Problems it solved

- Test the idea of avatar
- Allow Rosie to imitate human body movement (Microsoft kinect based arm movement)
- Implementation of docker containers **--portability**
- to run the Gazebo simulator **--testing**
- Enable communication between sensors and Rosiesti
- Send and retrieve data
- Handing retrieved data and turn it into actual robot movement

# 2 Technical Environment

<Detail the technical environment/technologies used to complete this project and reason for the choice of the specific technology that is used. For instance, if PHP is used, why it is chosen and if GITHUB etc is used for source control please specify those details as well..>

## 2.1 Baxter Unit

Baxter unit contains distinctive sets of sensors on it to sense objects as well as people nearby which gives it the ability to attune to its surroundings. Baxter provides edge over traditional robots as it is not required to be restrictive during usage and students can work in a classroom environment. Baxter is equipped with sensors in its hands and around its arms to detect and adapt to the environment which enables it to sense any possible collision events beforehand.

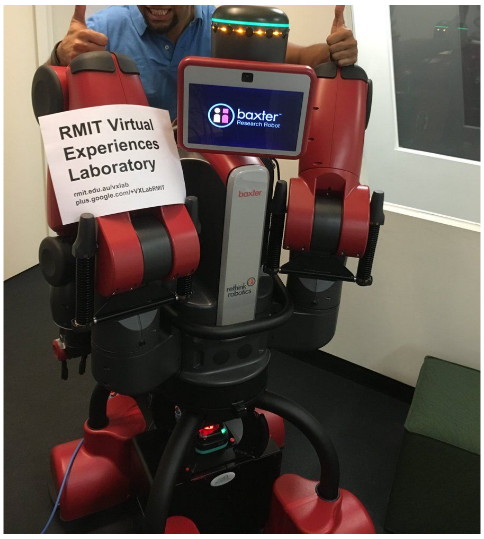

RMIT Virtual Experiences Laboratory
rmit.edu.au/vxlab
plus.google.com/+VXLabRMIT
baxter Research Robot
baxter
rethink robotics

Figure 2.1.1: Baxter robot

## 2.2 Microsoft Kinect

Microsoft Kinect is highly sought in robotics due to its unconventional human-robot interaction. Its components include depth sensor, microphone, set of advanced software to capture motion and gestures, motorized pivot, RGB color camera. Microsoft offers a SDK to program the Kinect sensor and integrate the sensor on the robot. Using the Microsoft Kinect SDK, various operations such as skeletal tracking, audio / image recognition, depth data etc can be performed on the robot.

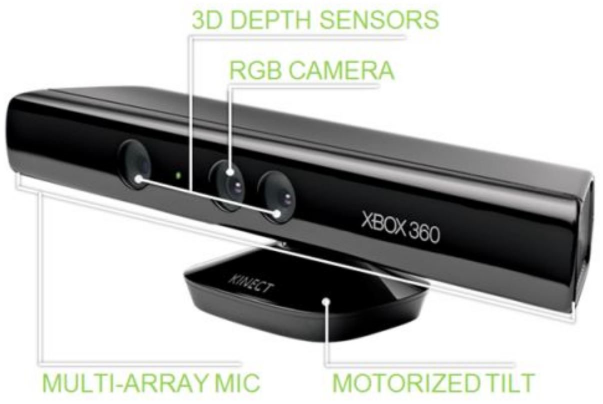


Figure 2.2.1: Microsoft Kinect

**2.3 Robot Operating System (ROS)**

ROS is developed with peer-to-peer network topology being the basis. The processes in ROS are called as nodes which can run on different machines performing the computations of the system. In contrast to other robot systems which provide set only of libraries for communication and protocol, ROS provides an inbuilt system where the nodes are developed with an intention of being able to run a system on ROS with many independent modules.

The communication between these nodes happens in the form of message passing. Within the ROS build system, nodes are been developed. In the ROS framework, to send messages the nodes can utilise two different types of communication. This ROS build system is built on top of a CMake file which performs builds that are modular of both nodes and the messages that are passed between those nodes.

In addition, to provide the basis for robot control ROS incorporates many algorithms, systems and tools in the form of suite which comprises features such as:

- Mapping
- Cloud Interpretation
- Simultaneous localisation
- Vision processing algorithms

***2.3.1* Two types of communications in ROS**

Services is synchronous type of communication implemented in ROS. These are similar to function calls that are implemented in traditional programming languages. The definition of the services include the name of the string and a pair of messages which includes a request and a response.

Topics is asynchronous type of communication implemented in ROS. They are object streams published by a node. The other nodes also known as listeners has the ability to register a handler function that is called every time a new topic becomes available by subscribing. In contrast to the services, Listener nodes do not have the ability to use their subscription to the topic to communicate to the publisher. Publishing and/or subscribing to same topic can be done my multiple nodes and multiple topics can published and/or subscribed by single node.

### 2.4 Python for Coding

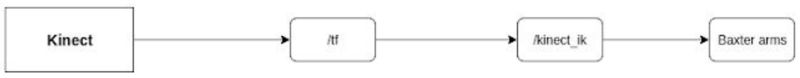
Python is chosen and more preferable to code and build on ROS over C++ because it enabled speed in to building a prototype and is a powerful language with numerous libraries. It helps in creating working demo of node faster by taking care of a lot of things and final code of node would be simple to read and understand its working/functionality. ROS Python APIs handles complex functionalities and can be accessed with effortless calls. It is uncomplicated and less time consuming to catch bugs. Python allows user to work on complex functionalities with just few lines of code.

The build system for Python modules in ROS is also much simpler than it's C++ counterpart. This backs up the idea of how the project is run (agile; with features been created, tested and implemented quickly).

### 2.5 Git for Source Control

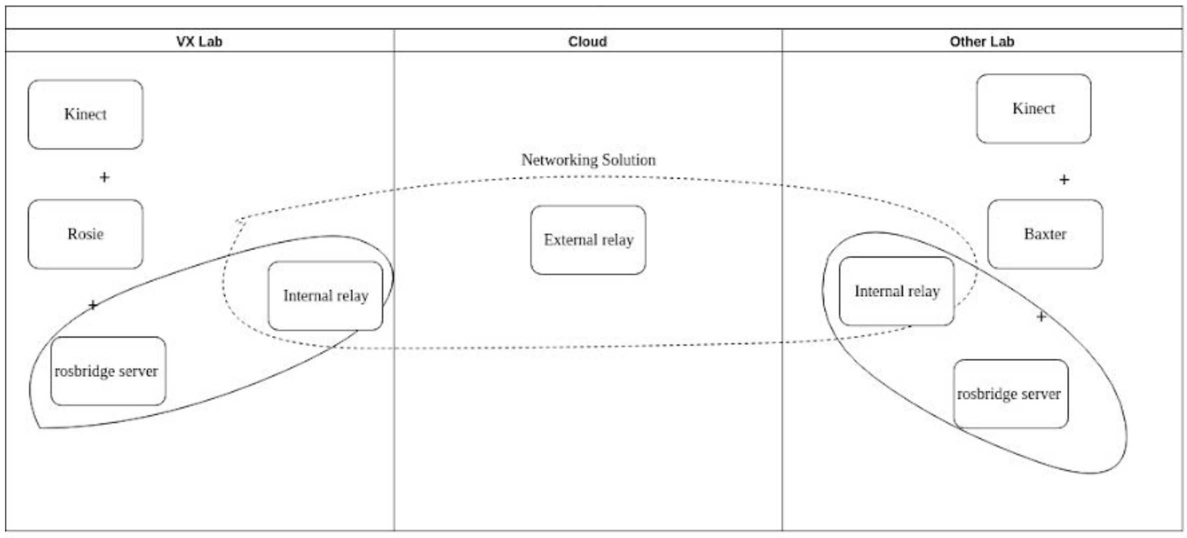
Git was the preferred *Version Control System* for the project, with Github being used as the remote server where the repository was stored. Git is a distributed *Version Control System*, meaning the entire codebase is shared across everyone's machine, including the branches and history. This means that anyone anywhere can work on any part of the codebase without having to necessarily be in the VxLAB. This being the case works well for our group, as we are mostly off site except for once or twice a week.

## 3 System Architecture

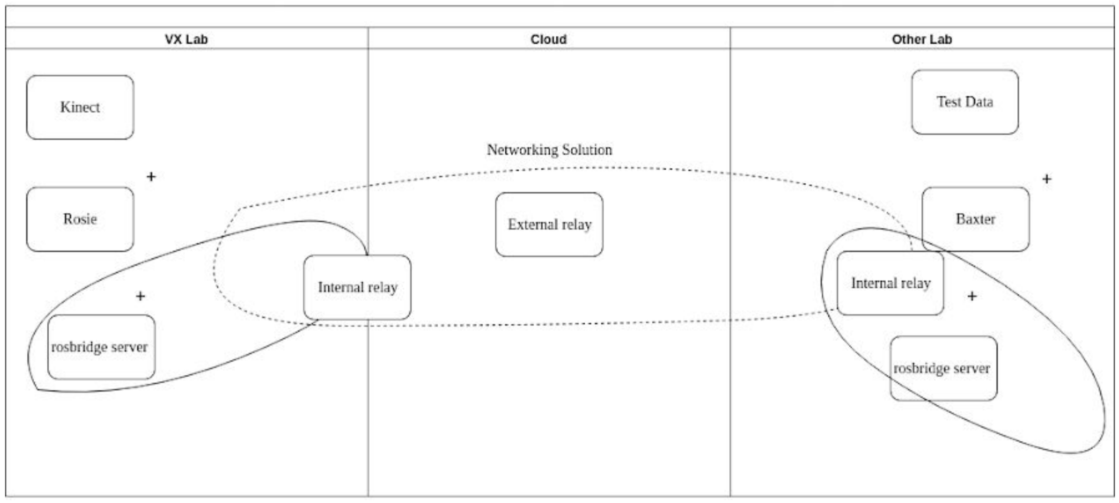


### 4.1 AVATAR Architecture

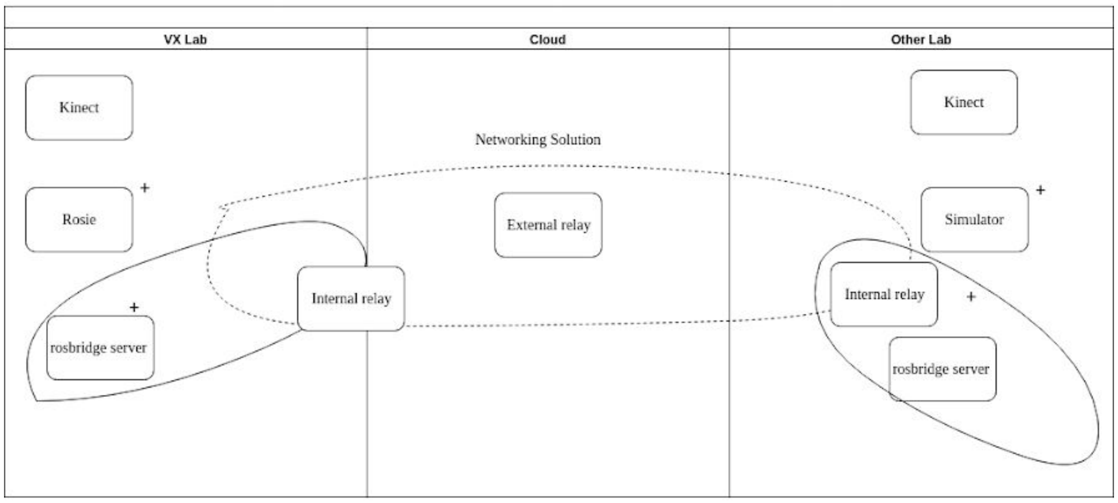
The ideal architecture is two-way architecture which is symmetric in structure and can establish a remote connection between two different baxters and two kinects through a networking solution.



The AVATAR architecture can be tested in two ways using one-way architecture which is asymmetric in structure. The first test use case is where kinect does not exist and instead of kinect we use test data along with baxter to perform operations.



In the second use case is where baxter does not exist and instead of baxter we use simulator along with the kinect to perform operations.



### 4.2 ROS Architecture for tele-operation

ROS allows the robot control through messages which is done with the help of abstraction of capabilities from individual robots. Furthermore, individual ROS nodes which provide these capabilities can also be controlled(start/stop). ROSBridge presents integrated view to the user of the robot and its environment by encapsulating these two features of ROS.

ROSBridge primarily utilizes web sockets, both inside the robot (server) and the application (client) such as a web server for the users to interact with using JSON API. It also furnishes the user control over environment parameters and execution of ROs nodes. ROSBridge has two parts:

(1) ROSBridge Protocol to specify and send commands to ROS based on JSON.
(2) ROSBridge Implementation using rosbridge_suite which contains a collection of packages such as rosbridge_library, rosapi, rosbridge_server which provides transport layer for web socket and to implement the ROSBridge Protocol.

The drawback is that the robot server might a public IP address where the client accesses it via Internet or Port Forwarding, which is not really efficient as latter one is network dependent.

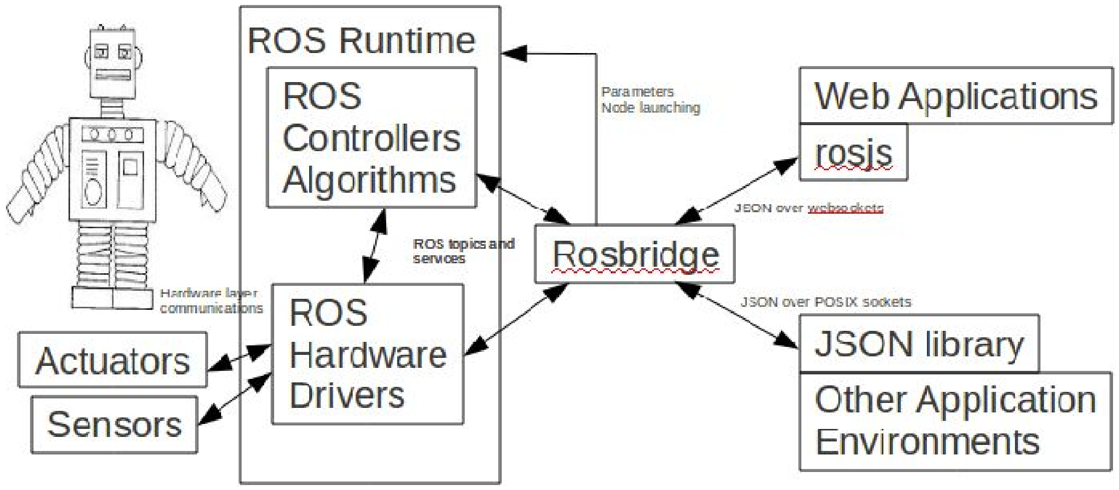


Figure 4.2.1: ROS bridge architecture

ROSLink protocol is initially developed to integrate the ROS enabled-robots with the IoT (Internet of Things). ROSLink protocol is inspired by MAVlink protocol which is a light-weight messaging protocol used for communication between drones. MAVlink protocol follows publish-subscribe to topics is data is sent as streams along with point-to-point transmission. ROSLink considers two clients, one installed in the robot and the other in the user machine. ROSLink messaging protocol is used for communication through a public server.

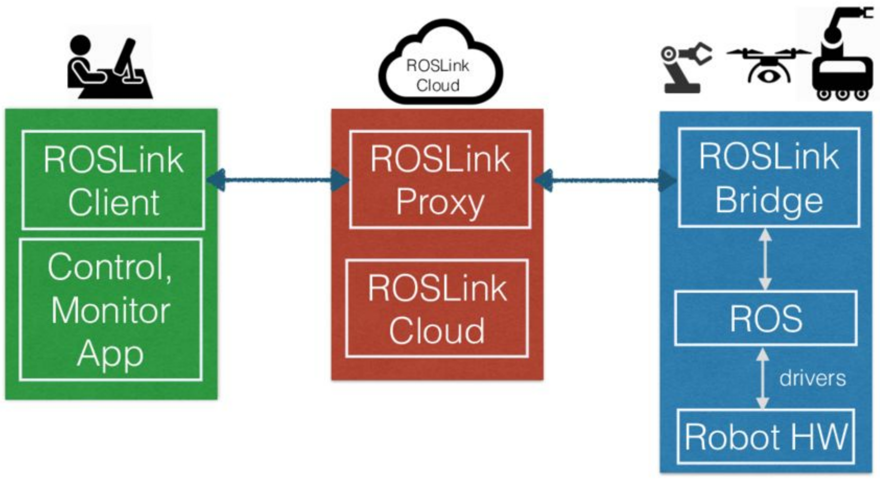


Fig 4.2.1: ROSLink System Architecture

### 4.2.1 Components of ROSLink

1. *ROSLink Bridge:* It acts as an interface between ROS and ROSLink protocol. The primary functionalities are:
    (1) Reading ROS topics and services messages, data serialisation in JSON format, forwarding it to client application
    (2) Receiving serialised JSON data from client application, deserialize it command parsing and execution through ROS.

2. *ROSLink Proxy and Cloud:* It plays the role of a proxy server between the user client application and ROSLink Bridge which is embedded in the robot. It connects by forwarding messages from ROS enabled robot to a user client application using ROSLink Bridge. It also forwards control commands given by user to the robot and updates the user with current status of the robot.

3. *ROSLink Client Application:* It takes care of robot application control and monitoring. Through the ROSLink messages it receives from the robot via the ROSLink Proxy, it monitors the status of the robot. Further, to control the activities of the robot it can also send command by utilising the ROSLink messages.

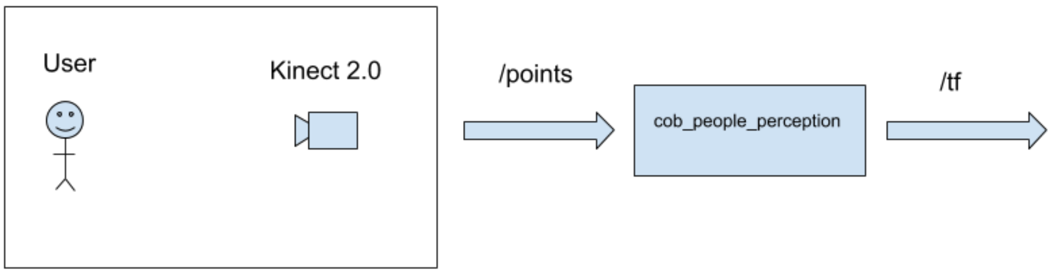
<Detail the system that was built/completed. Explain each component thoroughly. A architecture diagram is essential. >

### 4.3 FUNCTIONALITIES/FEATURES

<Detail the individual/specific functionalities that comprise the system.>

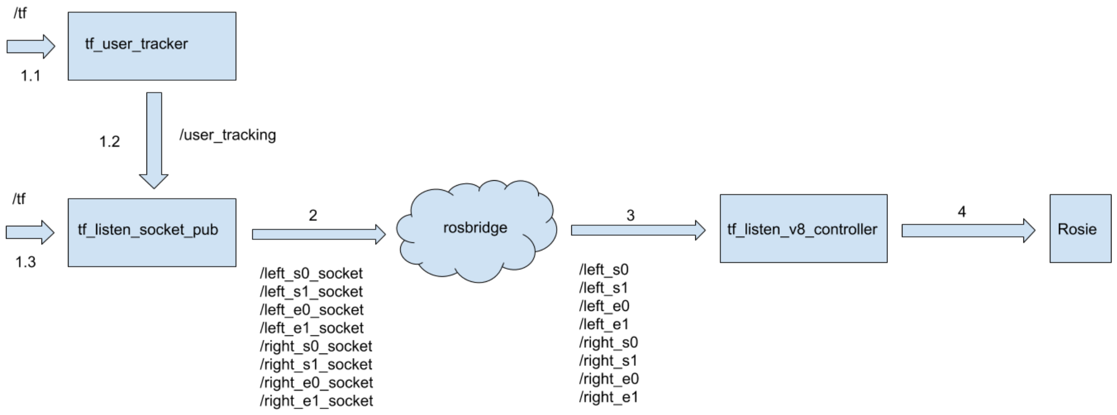
motion capture, mimic, relay, simulation

#### *4.3.1 Motion Capture*



- Microsoft Kinect 2.0 generates image data in the form of point cloud that is published on /points topic in ROS
- The body_tracker module of the cob_people_perception package converts the point cloud data into body tracking data (coordinates of user joints in 3d space relative to the sensor) that is published on the /tf topic.

#### *4.3.2 Mimic*



1. User Tracking
    1. tf_user_tracker tracks a single user by user id from the cob body tracking data captured from /tf
    2. tf_user_tracker publishes the user id on the /user_tracking topic, tf_listen_socket_pub filters the cob data from /tf using this id
    3. tf_listen_socket_pub captures cob body tracking data captured from /tf converts it into joint angle data corresponding with each of a baxter units arm joints.
2. tf_listen_socket_pub publishes this data on a *socket topic corresponding to each arm joint. The rosbridge server subscribes to each of these topics and receives data from each of them
3. rosbridge server republishes the data to another client ros instance on topics corresponding to each baxter unit arm joint. tf_listen_v8_controller subscribes to each of these topics
4. tf_listen_v8_controller captures data from these joint data topics and applies these directly to rosie's arm joints.

#### *4.3.3 Simulation*

- Docker simulation container can be used to simulate a real baxter unit and/or the motion capture portions of the project.
- Baxter unit is simulated in the gazebo simulator software for ROS
- A ROS utility called rosbag can be used to record and play back the /tf topics containing cob body tracking data to be reused later in a testing scenario.
- A ROS package called time_jump can timestamp old recorded /tf data and republish it so it is not ignored by the ROS master node.

## 4 Database Architecture

There wasn't any requirement of a database as there was not much of data that is managed

## 5 Implementation Instructions

Refer to Development Guide

## 6 Non-functional specifications

- Low Latency - the robot should be able to mimic the body movement without much time delay
- System shall work in a variety of configurations, baxter-to-baxter, baxter-to-simulator, simulator-to-simulator etc.

## 7 Summary of test results

Refer to Test Management Document

## 8 Known Issues & Risks

Refer to Issues & Risk Register

## 9 Other Considerations

Extending the scope of this project by implementing the ideal architecture, thereby deploying the project at vietnam campus to connect the baxter to rosie remotely.