Autonomous Vehicle Control Documentation

Release 0.0.1-rc1

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Contents

My PhD project involves using model predictive control to avoid moving obstacles.

Contents:

CHAPTER 1

Software

1.1 ROS

1.1.1 Installing ROS

From Pre-Built Debians

For ROS kinetic:

```
sudo apt-get install ros-kinetic-desktop-full
```

From source

Additional steps/notes to the link above.

1. Remove any sourced files from the `bash.bashrc` files.
2. `2.1`: after making the `catkin_ws`

   Run:

   ```
   catkin init
   ```

   Note: make sure that there are no other external workspaces that you are building on

3. Resolve Dependencies

Before you build the `catkin_ws` make sure that you have the required dependencies!

```
rosdep install --from-paths src --ignore-src --rosdistro kinetic -y
```

Potential Issues:

Using the second option (`Desktop Install`) for `kinetic`, the following issues may occur:

Note: potential error:

```
/home/febbo/ros_catkin_ws/src/opencv3/opencv_contrib/rgbd/src/odometry.cpp:41:45:␣
↪fatal error: unsupported/Eigen/MatrixFunctions: No such file or directory␣
↪compilation terminated.
```

The fix is to changed line 41 in `odometry.cpp` to (or where `eigen3` is):

```
#include <eigen3/unsupported/Eigen/MatrixFunctions>
```

Note:

potential error:

```
c++: error: /home/febbo/ros_catkin_ws/build_isolated/qt_gui_cpp/src/qt_gui_
↪cpp_shiboken/libqt_gui_cpp_shiboken/qt_gui_cpp_recursivepluginprovider_
↪wrapper.cpp: No such file or directory
c++: fatal error: no input files
compilation terminated.

<== Failed to process package 'qt_gui_cpp':
```

After posting an issue here. The fix was identified to be removing `shiboken` with:

```
sudo apt-get remove libshiboken*
```

An issue with the above fix is that if you try updating your ros dependencies and it installs `shiboken`. So, installing Qt 5 with:

```
sudo apt-get install qt5-default
```

Note: *potential error <https://github.com/ros-planning/navigation/issues/579>*:

```
-- Found Bullet: /usr/lib/x86_64-linux-gnu/libBulletDynamics.so
CMake Error at /usr/share/cmake-3.5/Modules/FindPackageHandleStandardArgs.cmake:148␣
↪(message):
  Could NOT find SDL (missing: SDL_LIBRARY SDL_INCLUDE_DIR)
Call Stack (most recent call first):
```

Note: potential error

```
CMake Error at /usr/local/lib/cmake/gazebo/gazebo-config.cmake:172 (find_package):
By not providing "Findignition-math3.cmake" in CMAKE_MODULE_PATH this
```

Installing missing Dependencies

Note: This is a truly magical command that works well (even when doing a source build)!!

Go to the `catkin_workspace` and type:

```
rosdep install --from-paths src --ignore-src -r -y
```

Uninstalling ROS

From Pre-Built Debians:

If you're running Ubuntu, and installed ROS with `apt-get`, the first step would be:

```
sudo apt-get remove ros-*
```

Remove configuration files:

```
sudo apt-get purge ros-*
```

Remove packages that are no longer required:

```
sudo apt autoremove
```

From Source

TODO

1.1.2 Resources and Tutorials

Tutorials and Resources

- Node Tutorial Python
- Writing a Publisher Subscriber
- Publishing the State Info
- Navigation Tutorials
- Turn your package into a python module
- MIT stuff
- basic ROS concepts
- best practices
- Installing Packages
- Navigating the File System

Other packages:

```
sudo apt-get install libfcl-dev
```

Great Commands

To check for any missing dependencies:

```
rosdep check --from-paths . --ignore-src --rosdistro kinetic
```

To automatically install missing dependencies:

```
rosdep install --from-paths . --ignore-src --rosdistro kinetic -y
```

Potential Issues

permission denied: .gvfs

Fix unmount Gnome virtual file system and delete the mounting point:

```
sudo umount /home/febbo/.gvfs
sudo rm -rf .gvfs/
```

Useful Questions

- good path following code
- https://github.com/osrf/homebrew-simulation/issues/167

1.1.3 Useful ROS Packages

tf2

This package uses geometry_msgs for some of the messages.

Useful functions

Warning: use tf2 not tf

Commands

Check tf tree:

```
roswtf
rosrun tf tf_monitor
rosrun tf view_frames
```

to print a particular transformation:

```
rosrun tf tf_echo /map /odom
```

Joint States

Terminology

1) Quaternions: a way to describe rotations that does not have singularities. It has four numbers, the first three describe an axis and the third is the amount of rotation about that axis.

The first three components are imaginary:

```
q=xi+yj+zk+w
```

The magnitude of a quaternion is:

```
magnitude=sqrt(x^2+y*2+z^2+w^2)
```

where:

```
x = x / magnitude
y = y / magnitude
z = z / magnitude
w = w / magnitude
```

http://www.euclideanspace.com/maths/geometry/rotations/conversions/quaternionToEuler/

- Almost never have to set these manually in ROS!
- Programming Quaternions
- ‘ a calculator <http://quat.zachbennett.com/>‘_
- ‘ a Gazebo example <http://gazebosim.org/tutorials?tut=drcsim_atlas_siminterface&cat=>‘_

Tutorials and Resources

- tutorials
- FAQ
- docs
- setting up the frames: for SLAM
- setting up your robot using tf

Example Resources

- python omniaxbot

Issues

- quaternions
- using tf

- joint states

Potential Errors

Note: potential error:

```
fatal error: tf/transform_broadcaster.h: No such file or directory
compilation terminated.
```

Use tf2! The new version of tf.

RViz

Official visualization tool for ROS

http://wiki.ros.org/rviz/Troubleshooting

obstacle_detector

To use this package you must install Armadillo C++.

Installing Armadillo C++

Put these programs in the `/opt` folder

First you need OpenBlas

To get it type:

```
sudo git clone https://github.com/xianyi/OpenBLAS.git
```

Then go into the `OpenBlas` folder and type:

```
sudo make
```

Get devel files from Debian repos as per:

```
sudo apt update
apt search openblas
sudo apt install libopenblas-dev
sudo update-alternatives --config libblas.so.3
sudo apt install cmake liblapack-dev
apt search arpack
sudo apt install libarpack2-dev
```

Then you need LAPACK

To get it type:

```
sudo git clone https://github.com/Reference-LAPACK/lapack-release.git
```

Then go into the `lapack-release` folder and type:

```
sudo mv make.inc.example make.inc
sudo make
```

Warning: Then you may run into this issue:

```
./liblapack.a ../../librefblas.a
make[2]: Leaving directory '/opt/lapack-release/TESTING/LIN'
Testing COMPLEX16 LAPACK linear equation routines
./LIN/xlintstz < ztest.in > ztest.out 2>&1
SEP: Testing Symmetric Eigenvalue Problem routines
./EIG/xeigtstz < sep.in > zsep.out 2>&1
Makefile:467: recipe for target 'zsep.out' failed
make[1]: *** [zsep.out] Error 139
make[1]: Leaving directory '/opt/lapack-release/TESTING'
Makefile:42: recipe for target 'lapack_testing' failed
make: *** [lapack_testing] Error 2
```

As per this site the stack size can be increased with:

```
ulimit -s 100000
```

Then run:

```
sudo make
```

And it should compile fine!

Note: can also install SuperLU and ARPACK etc. **'as per<https://github.com/conradsnicta/armadillo-code/tree/8.300.x>'_**

Now we can get Armadillo C++

To get it type:

```
sudo git clone https://github.com/conradsnicta/armadillo-code.git
```

Then go into the `armadillo-code` folder and type:

```
sudo cmake .
sudo make
```

Eigen

a C++ library that I use for quaternion transformations, to get started

Note: when going to use it with ROS there is no FindEigen.cmake on Ubuntu, so you need to include it in your package by default.

http://wiki.ros.org/jade/Migration#Eigen_CMake_Module_in_cmake_modules

roscpp

A C++ implementation of ROS that allows users to quickly interact with ROS.

rospy

Common Messages

a meta package for common messages

message_filters

Make the decision to use data based off of the time stamp. Basically sequence the data

PCL

Point cloud library

Ackermann Group

Group that supports Ackermann steering geometry.

navigation

install with:

```
sudo apt-get install ros-kinetic-navigation
```

hector_localization

install with:

```
sudo apt-get install ros-kinetic-hector-localization
```

ros_control

install with:

```
sudo apt-get install ros-kinetic-ros-control ros-kinetic-ros-controllers
```

pointcloud_to_laserscan

install with:

```
sudo apt-get install ros-kinetic-pointcloud-to-laserscan
```

teleop_twist_keyboard

Cartographer

A Google map builder

laser_pipeline

Meta-package for laser data processing

robot_localization

Provide state estimates given sensor data

robot_state_publisher

- turorial
- load new parameters on the server
- Troubleshooting
- messages being blocked
- use_sim_time = `false`

Requires:

- joint_state_publisher

clock

For a ROS node to use the `/clock` topic set the `/use_sim_time` parameter before node is started

ControlIt!

MoveIT

Install

ROS Kinetic on Ubuntu:

```
sudo apt-get install ros-kinetic-moveit
```

Using With Kinetic

Go to this link and download the PDF for instructions.

URDF

Unified Robot Description Format (URDF), an Extensible Markup Language (XML) format (a markup language (can document revisions) that is both machine and human readable)

catkin-tools

Lots of useful info on setting up workspaces.

1.1.4 Useful Examples

ADAS

Great example for controlling autonomous vehicles.

ROS tutorial for Autonomous Cars

http://www.robotigniteacademy.com/en/

IPA320

Very useful resource for using ROS with Gazebo

- https://github.com/ipa320
- https://github.com/ipa320/srs_public/blob/master/srs_user_tests/ros/scripts/move_robot_sim.py

Potential Vehicle Models

- robots.ros.org
- http://wiki.ros.org/Robots/Husky
- http://wiki.ros.org/Robots/Grizzly
- http://wiki.ros.org/Robots/Jackal

NVIDIA's Driveworks

https://developer.nvidia.com/driveworks

1.1.5 My Personal Build

Packages required for MAVS

as of 8/22/2017 on top of ros-kinetic-full:

```
sudo apt-get install ros-kinetic-controller-manager
sudo apt-get install ros-kinetic-joint-state-controller
sudo apt-get install ros-kinetic-effort-controllers
sudo apt-get install ros-kinetic-teleop-twist-keyboard
sudo apt-get install ros-kinetic-pointcloud-to-laserscan
sudo apt-get install ros-kinetic-velodyne-description
```

Packages used in my catkin_ws

as of 8/22/2017 on top of ros-kinetic-full:

```
sudo apt-get install ros-kinetic-move-base
sudo apt-get install ros-kinetic-gmapping
sudo apt-get install ros-kinetic-amcl
sudo apt-get install ros-kinetic-ackermann-msgs
sudo apt-get install ros-kinetic-transmission-interface
sudo apt-get install ros-kinetic-moveit-ros-move-group
sudo apt-get install ros-kinetic-robotnik-sensors
sudo apt-get install ros-kinetic-robot-pose-ekf
sudo apt-get install ros-kinetic-moveit-kinematics
sudo apt-get install ros-kinetic-moveit-ros-visualization
sudo apt-get install ros-kinetic-moveit-planners-ompl
sudo apt-get install ros-kinetic-teb-local-planner
sudo apt-get install ros-kinetic-joint-limits-interface
sudo apt-get install ros-kinetic-map-server
sudo apt-get install ros-kinetic-robot-state-publisher
sudo apt install ros-kinetic-rqt
```

To use Autoware

added:

```
sudo apt-get install ros-kinetic-nmea-msgs ros-kinetic-nmea-navsat-driver ros-kinetic-
↪sound-play ros-kinetic-jsk-visualization ros-kinetic-grid-map ros-kinetic-gps-common
sudo apt-get install ros-kinetic-controller-manager ros-kinetic-ros-control ros-
↪kinetic-ros-controllers ros-kinetic-gazebo-ros-control ros-kinetic-joystick-drivers
sudo apt-get install libnlopt-dev freeglut3-dev qtbase5-dev libqt5opengl5-dev libssh2-
↪1-dev libarmadillo-dev libpcap-dev gksu libgl1-mesa-dev libglew-dev python-wxgtk3.0


sudo apt install ros-kinetic-roslint
sudo apt-get install ros-kinetic-joint-state-publisher
sudo apt-get install ros-kinetic-controller-manager
```

my .bashrc

sourced:

```
source /opt/ros/kinetic/setup.bash
source /home/febbo/Documents/workspace/tutorials/catographer_ws/install_isolated/
↪setup.bash
source /home/febbo/Documents/workspace/tutorials/velodyne_simulator/devel/setup.bash
source /home/febbo/Documents/workspace/tutorials/kobuki_desktop/devel/setup.bash
source /home/febbo/.julia/v0.6/MAVs/catkin_ws/devel/setup.bash
source /home/febbo/Documents/workspace/tutorials/mastering_ros/chapter_3_codes/devel/
↪setup.bash
source /home/febbo/catkin_ws/devel/setup.bash
alias tf='cd /var/tmp && rosrun tf view_frames && evince frames.pdf &'
. ~/.bash_profile
source /home/febbo/ros_catkin_ws/install_isolated/setup.bash
```

1.1.6 Potential Errors

Warning: Potential Error:

```
fatal error: tf2/LinearMath/Quaternion.h: No such file or directory compilation␣
↪terminated.
```

It is trying to find some file and it cannot. The problem may be that the header files where not specified! To fix:

```
include_directories(
  ${catkin_INCLUDE_DIRS}
)
```

1.2 Gazebo

1.2.1 Installation

Automatically installed after following the ROS installation instructions.

Make sure after you install it you source the setup.sh file in the `.bashrc` script:

```
source /usr/share/gazebo-7/setup.sh
```

Also source any setup.bash scripts that are in your projects:

```
source /home/febbo/.julia/v0.6/MAVs/workspace/devel/setup.bash
```

Also in the `setup.sh` file in the `usr/share/gazebo-7/` directory, add to the resource path if you need to as:

```
export GAZEBO_RESOURCE_PATH=/usr/share/gazebo-7:/usr/share/gazebo_models:/usr/share/
↪gazebo-7/worlds${GAZEBO_RESOURCE_PATH}
```

In the above example we also added the `/worlds` folder.

Note: Using the gui to create models is limited because the default full version of ros kinetic does not let you edit the models after you save them. So, then I started to learn how to make the models directly using XML. The only way to get around this is to build from source but then you won;t be able to use any ROS Ubuntu package related to Gazebo from the ROS deb repo.

From source (option A)

Follow these instructions

Additional notes:

- Step 1:

  To get the `Gazebo-8` stable branch:

```
/opt$ sudo hg clone https://bitbucket.org/osrf/gazebo /opt/gazebo -b gazebo8
```

  To get the `Gazebo-7` stable branch:

```
/opt$ sudo hg clone https://bitbucket.org/osrf/gazebo /opt/gazebo -b gazebo7
```

sudo hg clone https://bitbucket.org/osrf/gazebo /tmp/gazebo -b gazebo7

- Step 3:

  Configure Gazebo:

```
sudo mkdir build
cd build
sudo cmake ../
```

  Build Gazebo:

```
/opt/gazebo/build$ sudo make -j4
```

  Install Gazebo:

```
sudo make install
```

- Step 4:

  Set up environmental variables and

From source (option B) -preferred for `Gazebo-7`

http://gazebosim.org/tutorials?tut=install_dependencies_from_source

Potential Issue

Note: If not sourced properly:

```
febbo@febbo-HP-ZBook-17-G2:~$ gazebo
gazebo: error while loading shared libraries: libgazebo_common.so.7: cannot open␣
↪shared object file: No such file or directory
```

Then try:

```
febbo@febbo-HP-ZBook-17-G2:~$ find / -name 'libgazebo_common.so.7' 2>/dev/null
/usr/local/lib/libgazebo_common.so.7
/tmp/gazebo/build/gazebo/common/libgazebo_common.so.7
```

And updated the `/etc/bash.bashrc` file appropriately:

```
gksu gedit /etc/bash.bashrc
```

By adding (in this case):

```
export LD_LIBRARY_PATH=/usr/local/lib:$LD_LIBRARY_PATH
```

Note: when trying to start Gazebo from the command line:

gazebo: error while loading shared libraries: libsdformat.so.5: cannot open shared object file: No such file or directory

1.2.2 Terminology

1) Xacro:

   (Xaxro) (XML macros) an XML macro language useful for shorter robot descriptions.

   - xacro:include: import content from another file
   - property: define constants *${property_name}*
   - xacro:macro: include the file where the macro is and call it using the macro's name and filling in the required values

2) SDFormat

   An XML format that describes environments for robot simulators visualizations and controls. Originally part of Gazebo but now is stable enough that it stands alone.

1.2.3 Basics

Model Structure

Make sure that the model is structured correctly. An issue that was ran into is described here where I tried to put a model in a lower level directory. Models need to go just below `catkin/src/`, then `setup.sh` must be modifed as:

```
export GAZEBO_MODEL_PATH=/usr/share/gazebo-7/models:/home/febbo/catkin_ws/src/:$
↪{GAZEBO_MODEL_PATH}
```

Model State Info

Using `rospy` to get the model states.

World Files

Note: When saving a world file, put it into the folder with the other world files!

1.2.4 Tutorials:

- Add Sensor to A Robot
- Gazebo Plugins
- Getting SDF information for a model
- Control Plugin
- 3D models

1.2.5 Resources:

- 3D Warehouse: a place to grab CAD models
- Possible Model for HMMWV
- simplify a .dae file
- 3Delicious
- Free 3D

1.2.6 Useful Software

- Blender

1.2.7 Issues

- importing Collada files

1.3 ROS and Gazebo

1.3.1 Installation of gazebo_ros_pkgs

From Pre-Built Debians:

For ROS Kinetic

```
sudo apt-get install ros-kinetic-gazebo-ros-pkgs ros-kinetic-gazebo-ros-control
```

Gazebo 8 and ROS kinetic (preferred)

remove all Gazebo and ros binaries:

```
sudo apt-get remove --purge '.*gazebo.*' '.*sdformat.*' '.*ignition-math.*' '.
↪*ignition-msgs.*' '.*ignition-transport.*'
sudo apt-get remove ros-*
sudo apt-get purge ros-*
sudo apt autoremove
```

install dependencies:

```
sudo apt-get update
sudo apt-get install python-rosinstall python-rosinstall-generator python-wstool␣
↪build-essential
sudo apt-get install -y wget
sudo apt-get install -y lsb-release
sudo apt-get install -y sudo
sudo apt-get install -y mesa-utils
sudo apt-get clean
```

Get gazebo and ROS binaries:

```
sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu $(lsb_release -sc) main" > /
↪etc/apt/sources.list.d/ros-latest.list'
sudo apt-key adv --keyserver hkp://ha.pool.sks-keyservers.net:80 --recv-key␣
↪421C365BD9FF1F717815A3895523BAEEB01FA116
sudo sh -c 'echo "deb http://packages.osrfoundation.org/gazebo/ubuntu-stable `lsb_
↪release -cs` main" > /etc/apt/sources.list.d/gazebo-stable.list'
wget http://packages.osrfoundation.org/gazebo.key -O - | sudo apt-key add -
sudo apt-get update
sudo apt-get install ros-kinetic-ros-base
sudo apt-get install -y gazebo8
sudo apt-get install -y ros-kinetic-gazebo8-ros-pkgs
sudo apt-get install -y ros-kinetic-fake-localization
sudo apt-get install -y ros-kinetic-joy
sudo apt-get install -y ros-kinetic-robot-state-publisher
sudo apt-get install -y ros-kinetic-rviz
sudo apt-get clean
sudo apt autoremove
```

Other packages (I am currently using. . . updated):

```
sudo apt install rosbash
sudo apt-get install ros-kinetic-ros-core
sudo apt-get install ros-kinetic-turtlesim
sudo apt-get install ros-kinetic-xacro
sudo apt install ros-kinetic-teleop-twist-keyboard
sudo apt install ros-kinetic-velodyne-description
sudo apt install ros-kinetic-controller-manager
sudo apt install ros-kinetic-joint-state-controller
sudo apt install ros-kinetic-rqt-gui
sudo apt install ros-kinetic-effort-controllers
sudo apt install ros-kinetic-pcl-ros
sudo apt install ros-kinetic-pointcloud-to-laserscan
```

http://wiki.ros.org/velo2cam_gazebo

Initialize rosdep:

```
sudo rosdep init
rosdep update
```

From Source

After installing `ROS` from source with the `Desktop Install` you will also need to put the following packages into the `/ros_catkin_ws/src` folder:

```
git clone https://github.com/ros-simulation/gazebo_ros_pkgs -b kinetic-devel
git clone https://github.com/ros-perception/image_common -b hydro-devel
git clone https://github.com/ros-controls/control_toolbox -b kinetic-devel
git clone https://github.com/ros-controls/ros_control -b kinetic-devel
git clone https://github.com/ros-controls/realtime_tools -b kinetic-devel
```

Then rebuild the workspace:

```
./src/catkin/bin/catkin_make_isolated --install
```

To test installation, run:

```
roscore &
rosrun gazebo_ros gazebo
```

1.3.2 Resources

Examples of using ROS and Gazebo

Get the position of a model:

```
gazebo::math::Pose pose = this->model->gazebo::physics::ModelState::GetPose();
```

Pose to initialize the model to:

```
msgs::Set(msg.mutable_pose(),
math::Pose(math::Vector3(1, -2, 0), math::Quaternion(0, 0, 0)));
```

Writing Publisher Subscriber

Messages

Example Resources

- gazebo_and_ros_control: with a tutorial
- srs: a very useful example of using python for control

Tutorials

- ROS and Gazebo: using `roslaunch`
- a blog post to help get started
- A helpful resource lots of questions answered
- Gazebo ROS API for C-Turtle
- ROS Plugins
- a blog post
- another blog post
- JointTrajectory: good for controlling a robot when you don't care about the physics

Tools

- gazebo_ros_pkgs or the look at the source code
- pygazebo: a python interface to Gazebo
- gazebo_ros_p3d : Ground Truth Pose and Rates Interface

Potential Packages to Fork for Closing the Loop

- ADAS
- Georgia Tech
- https://github.com/CPFL/Autoware

car_demo

A recent package by Tully Foote with a Gazebo model of Mcity using ROS Kinetic and Gazebo 8.

Additional Install Notes

Required Packaged (on top of Desktop Install)

(for a source build) clone into the `src` directory:

```
git clone https://github.com/ros-planning/navigation.git
git clone https://github.com/ros-drivers/joystick_drivers.git
```

Joystick

Usually when you plug in the Joysick it automatically sends that can be viewed with either:

```
cat /dev/input/js0
```

Or:

```
cat /dev/input/js1
```

Note: potential error: `libusb` is not installed on the machine. I ran into this issue, where the `ps3joy` package failed with this error:

```
CMake Error at /usr/share/cmake-3.5/Modules/FindPkgConfig.cmake:578 (message):
  None of the required 'libusb' found
Call Stack (most recent call first):
  CMakeLists.txt:6 (pkg_search_module)
```

The fix is to install `libusb`:

```
sudo apt-get install libusb-dev
```

Additional Info (not needed)

install a program to test and calibrate:

```
sudo apt-get install joystick
```

to test:

```
jscal /dev/input/js0
jstest /dev/input/js0
```

NVIDIA-DOCKER

To show the current architecture, type:

```
dpkg --print-architecture
```

type:

```
wget -P /tmp https://github.com/NVIDIA/nvidia-docker/releases/download/v1.0.1/nvidia-
↪docker_1.0.1-1_amd64.deb
sudo dpkg -i /tmp/nvidia-docker*.deb && rm /tmp/nvidia-docker*.deb
```

install nvidia-modprobe:

```
sudo apt install nvidia-modprobe
```

Note: potential error:

```
Error response from daemon: create nvidia_driver_375.66: error looking up volume␣
↪plugin nvidia-docker: plugin "nvidia-docker" not found.
See 'docker run --help'.
```

the fix is:

```
journalctl -n -u nvidia-docker
```

Warning: Restart computer after installing GPU software

1.3.3 Issues

Helpful Questions

- Using python to set ModelState in Gazebo
- publisher and subscriber in C code
- set position in gazebo
- Using python as a node

My Questions

- *Increasing Model Fidelity <http://answers.gazebosim.org/question/17599/increasing-model-fidelity-ex-modeling-surface-forces-pacejka-tire-model/>*

1.4 Project Chrono

1.4.1 Background

Physics simulator organized as a set of modules that has a high-fidelity HMWWV model validated using Adams.

1.4.2 Install

Get the IRRlicht engine

Make sure that you have the required files:

```
sudo apt-get install cmake-extras cmake-qt-gui build-essential xorg-dev freeglut3-dev
```

After **'downloading <http://irrlicht.sourceforge.net/?page_id=10'_** unzip:

```
sudo unzip /home/febbo/Downloads/irrlicht-1.8.4.zip -d /opt/irrlicht
```

Compile the `Irrlicht Engine 1.8.4` as a shared lib:

```
/opt/irrlicht/irrlicht-1.8.4/source/Irrlicht$ sudo make sharedlib
/opt/irrlicht/irrlicht-1.8.4/source/Irrlicht$ sudo make install
```

Chrono

Install instructions

Go into `/opt` folder:

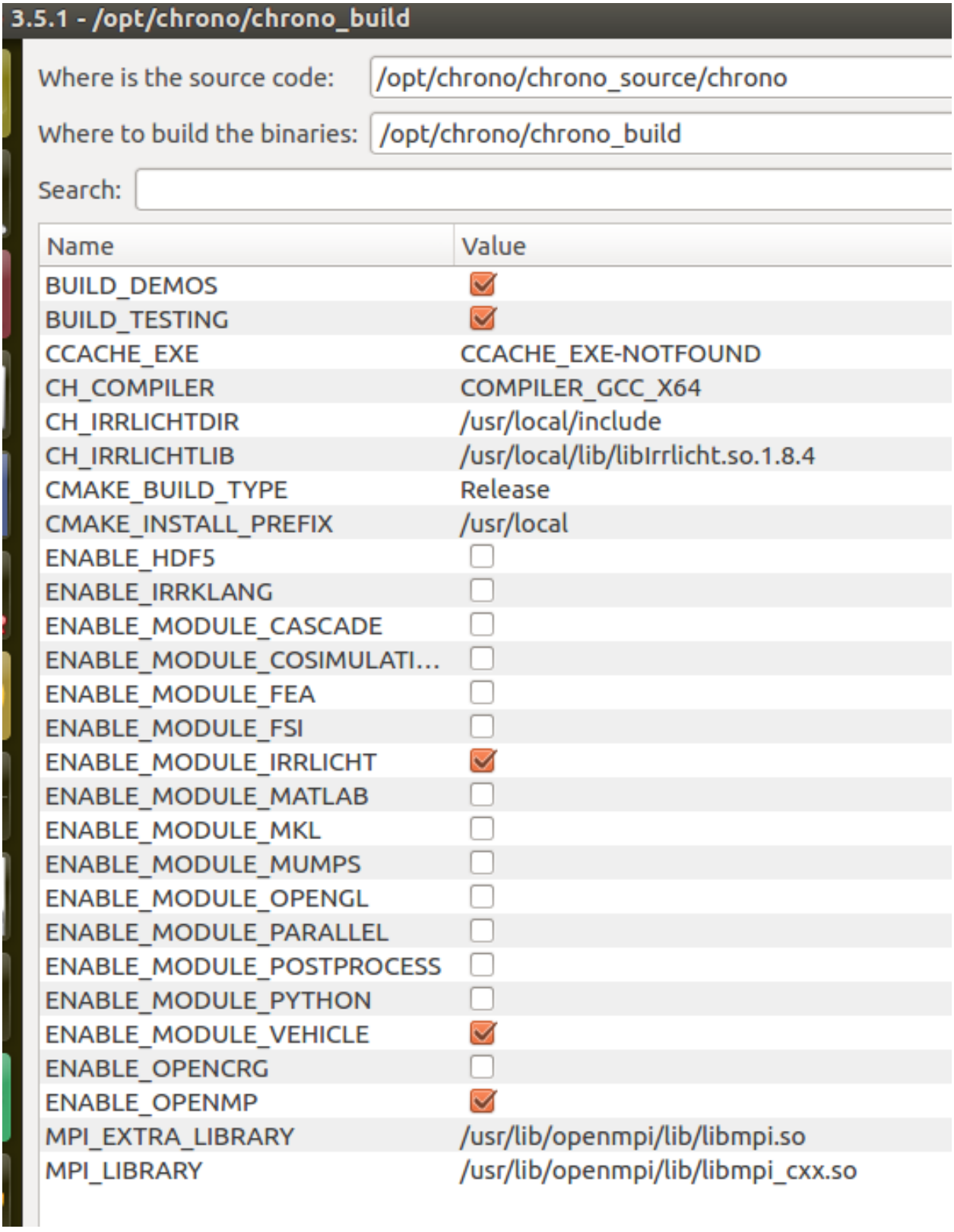
```
sudo mkdir chrono
cd chrono
sudo mkdir chrono_source
sudo mkdir chrono_build
cd chrono_source
```

Clone the develop branch into the `/opt/chrono/chrono_source` directory:

```
sudo git clone -b develop https://github.com/projectchrono/chrono.git
cd chrono
```

To configure:

```
sudo cmake-gui
```



Then to build (assuming ninja was used) go into the `build` directory and type:

```
chrono/chrono_build$ sudo ninja
```

Then you can modify permissions if desired:

```
sudo chmod -R 777 chrono_build/
```

The rest is old....

VEHICLE Module

Connecting to Gazebo

A repo was developed to connect Gazebo to Chrono.

Install

1) Install Gazebo 7 from source

2) run:

```
sudo apt-get install libogre-1.9-dev
```

1.4.3 Potential Fixes

Try updating `glib` with:

```
sudo apt-get update && sudo apt-get upgrade
```

1.4.4 Issues:

- https://groups.google.com/forum/#!topic/projectchrono/ETBnyS18MNM
- https://groups.google.com/forum/#!topic/projectchrono/1GI3RiZI-2A
- https://stackoverflow.com/questions/13978692/strcpy-sse2-unaligned-s-not-found
- https://sourceforge.net/p/irrlicht/bugs/375/

Issue might look something like:

```
/build$ ninja
[1/2] Building CXX object demo_Steerin....dir/demo_VEH_SteeringController.cpp.o
FAILED: /usr/bin/c++      -MMD -MT demo_SteeringController/CMakeFiles/demo_
↪SteeringController.dir/demo_VEH_SteeringController.cpp.o -MF demo_
↪SteeringController/CMakeFiles/demo_SteeringController.dir/demo_VEH_
↪SteeringController.cpp.o.d -o demo_SteeringController/CMakeFiles/demo_
↪SteeringController.dir/demo_VEH_SteeringController.cpp.o -c /home/febbo/Documents/
↪workspace/tutorials/chrono_tutorials/source/demo_SteeringController/demo_VEH_
↪SteeringController.cpp
/home/febbo/Documents/workspace/tutorials/chrono_tutorials/source/demo_
↪SteeringController/demo_VEH_SteeringController.cpp:22:37: fatal error: chrono/core/
↪ChFileutils.h: No such file or directory
```

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```
compilation terminated.
ninja: build stopped: subcommand failed.
```

https://github.com/projectchrono/chrono/issues/79

In this case, copy the Resources ==========

- https://vimeo.com/uwsbel
- http://sbel.wisc.edu/Animations/

1.4.5 OLD

NOT NEEDED:

make a build directory:

```
src/Chrono_Gazebo/gazonoVehicle$ sudo mkdir build
```

set up build environment:

```
src/Chrono_Gazebo/gazonoVehicle$ sudo cmake CMakeLists.txt
```

make:

git clone git://git.code.sf.net/p/libosmscout/code libosmscout-code

1.4.6 Shared Pointers

http://api.projectchrono.org/shared_pointers.html

1.4.7 TEMP

gazonoVehicle.cc

//gazebo_ros includes NOTE because ros is not in usr/include/ there are sourcing issues #include <ros/callback_queue.h> #include <ros/subscribe_options.h> #include <ros/ros.h> #include “boost/thread/mutex.hpp” #include <std_msgs/Float64.h>

Issue:

/usr/bin/ld: cannot find -lpthreads

https://stackoverflow.com/questions/30600978/cpp-usr-bin-ld-cannot-find-lnameofthelibrary

1.5 Polysync

Polysync does play with ROS

http://docs.polysync.io/flows/getting-started/

It talks to MATLAB http://docs.polysync.io/articles/development/ecosystem-tools/matlab-and-simulink-toolbox/

Also, it looks like it supports the Puck (along with many other sensors)

http://docs.polysync.io/sensors/velodyne-vlp-16-puck/

All in all it looks like the documentation was well made and it is yet another very useful tool and they claim if we follow their tutorial we can build a self-driving Kia Soul for under $10,000 (I think this excludes LiDAR and gps etc.) ! Looking through the wiki a bit it looks like the vehicle needs to only slightly be modified.

1.6 julia

1.6.1 Getting Started with julia

Extensive julia documentation is available here.

Building julia release 0.5 - current

Recently a new version of julia was released and it will be tested. The following directions also assume that julia was previously installed on the machine. If it was not, skip to step 3.

Remove current version of julia

1. get a graphical file manager with **ROOT ACCESS**:

```
gksu nautilus
```

Also, may need to:

```
sudo apt install gksu
```

- NOTE: be **very** careful in here!!

2. Type `ctrl+l` to type into location bar

- now navigate to where julia is and delete the binaries (or bin), ie. it might be in /usr/local/begin

Add new version current version of julia

3. unzip the .gz into the `\opt` folder (the place where by convention you'd put "optional" packages)

for instance:

```
sudo tar -xvf /home/febbo/Downloads/julia-0.5.0-linux-x86_64.tar.gz -C /opt
```

4. Check it:

```
febbo@febbo-HP-ZBook-17-G2:/opt/julia-3c9d75391c/bin$ ./julia
OR
febbo@febbo-HP-ZBook-17-G2:/opt/julia-3c9d75391c/bin$ /opt/julia-3c9d75391c/bin/julia
               _
   _       _ _(_)_     |  A fresh approach to technical computing
  (_)     | (_) (_)    |  Documentation: http://docs.julialang.org
   _ _   _| |_  __ _   |  Type "?help" for help.
  | | | | | | |/ _` |  |
  | | |_| | | | (_| |  |  Version 0.5.0 (2016-09-19 18:14 UTC)
 _/ |\__'_|_|_|\__'_|  |  Official http://julialang.org/ release
|__/                   |  x86_64-pc-linux-gnu

julia>
```

5. Now we need to create a symbolic link so that we can just type `julia` in the command line. There are three ways to do this (**just do the third option; it is permanent**):

1. create an "alias"

- create an alias using the following command..

  type:

```
alias julia='/opt/julia-3c9d75391c/bin/julia'
```

2. add `/opt/julia-3c9d75391c/bin` to your PATH

   - all directories contained in the PATH are accessible from **ANYWHERE**
   - you can see the current PATH variable by typing in your terminal..

   type:

```
echo $PATH
```

   - you can redefine a variable in bash e.g. by doing..

   type:

```
PATH=new definition here

  * (no spaces----> this is important)
```

   - add your julia path to the existing path, you can do that by saying...

   type:

```
PATH=/opt/julia-3c9d75391c/bin:$PATH

  * the $PATH contains the old value, so you're basically adding␣
↪your folder and a colon and then all the rest, into a new PATH␣
↪variable
```

   The Problem with The Above Two Options is that:

   With both adding to the path or creating an alias, is that these changes are **TEMPORARY** the minute you close your terminal and open it again, you'll see that these changes have disappeared try it and see!

   - so to make it permanent, you actually have to do option 3

3. change a file called bashrc which is run every time a terminal starts

   - the file you need to edit should be /etc/bash.bashrc

     so type:

```
gksu gedit /etc/bash.bashrc
```

   If it exists and it's the right file, you should see its contents inside gedit

   - go to the very end of that file
     - add the alias line...

     type:

```
alias julia='/opt/julia-3c9d75391c/bin/julia'
```

     and press enter!!

- The enter is important; all commands should always end with a newline

6. Now close the terminal and type:

```
febbo@febbo-HP-ZBook-17-G2:~$ julia
               _
   _       _ _(_)_     |  A fresh approach to technical computing
  (_)     | (_) (_)    |  Documentation: http://docs.julialang.org
   _ _   _| |_  __ _   |  Type "?help" for help.
  | | | | | | |/ _` |  |
  | | |_| | | | (_| |  |  Version 0.5.0 (2016-09-19 18:14 UTC)
 _/ |\__'_|_|_|\__'_|  |  Official http://julialang.org/ release
|__/                   |  x86_64-pc-linux-gnu

julia>
```

So, it should be running!

7. If you are using Atom, make sure that you change the path in the config folder in settings:

```
juliaPath: "/opt/julia-3c9d75391c/bin/julia"
```

8. next time you download a new version of julia:

- simply extract it under /opt in the same way and either replace the old one

OR

- if you want to keep both, you can just update your alias in /etc/bash.bashrc to point to the new one

Building julia release 0.5 - old

1. Type:

```
sudo apt -rm julia
```

2. Also, julia can be completely removed by deleting the `~/.julia` folder.

Note: Can also remove PPA (according to this):

```
sudo apt install ppa-purge
```

- although this does not seem to be useful.

Fresh install instructions for UBUNTU:

A. Follow these instructions.

Or

B. Type this terminal:

```
sudo add-apt-repository ppa:staticfloat/juliareleases
sudo add-apt-repository ppa:staticfloat/julia-deps
sudo apt-get update
sudo apt-get install julia
```

Bleeding Edge Version - previously used

I found that julia is constantly being developed and that most of the developers do not make sure that every version is maintained, this can create issues when using particular packages. So, if you want to use the latest and greatest features, you might consider the bleeding edge version of julia.

Fresh install instructions for UBUNTU:

A. Follow these instructions.

Or

B. Type this terminal:

```
sudo apt-add-repository ppa:staticfloat/julianightlies
sudo apt-add-repository ppa:staticfloat/julia-deps
sudo apt-get update
sudo apt-get install julia
```

Warnings

If you are getting warnings like this:

```
WARNING: Deserialization checks failed while attempting to load cache from /home/
↪febbo/.julia/lib/v0.6/JuMP.ji.
WARNING: Module Lazy uuid did not match cache file.
INFO: Recompiling stale cache file /home/febbo/.julia/lib/v0.6/JuMP.ji for module␣
↪JuMP.
WARNING: Deserialization checks failed while attempting to load cache from /home/
↪febbo/.julia/lib/v0.6/ReverseDiffSparse.ji.
WARNING: Module Lazy uuid did not match cache file.
INFO: Recompiling stale cache file /home/febbo/.julia/lib/v0.6/PyPlot.ji for module␣
↪PyPlot.
WARNING: Deserialization checks failed while attempting to load cache from /home/
↪febbo/.julia/lib/v0.6/PyCall.ji.
WARNING: Module Conda uuid did not match cache file.
```

It is a precompilation failure; restart Julia

1.6.2 Useful Packages and Programs

This page includes details of the packages and programs that I am using in OCP.

Adding and Removing Packages in julia

A useful description of the syntax for adding and remove packages in julia can be found here.

All packages that I have on julia

I have many packages and to configure them all can be tricky, so I include a list of commands that you can copy and past into julia to get started. Make sure that you are restarting the both julia and the terminal after things are installed.

Basics

```
Pkg.add("DataFrames")
Pkg.add("IJulia")
Pkg.add("Parameters")
Pkg.add("PkgDev")
Pkg.add("AmplNLWriter")
#Pkg.clone("https://github.com/JunoLab/Juno.jl")
Pkg.add("HDF5")
Pkg.build("HDF5")
Pkg.add("SymPy")
Pkg.add("Jacobi")
```

Math

I use:

```
Pkg.add("DiffBase")
Pkg.clone("https://github.com/Keno/Polynomials.jl")
Pkg.add("DifferentialEquations")
Pkg.add("Dierckx")
Pkg.add("ImplicitEquations")
Pkg.add("Interpolations")
```

Optimization

I use:

```
Pkg.add("JuMP") # adds MathProgBase automatically
Pkg.add("Ipopt")
Pkg.add("CoinOptServices")
Pkg.add("NLopt")
Pkg.build("NLopt")
```

Plotting

Basically I use Plots.jl to interface with some of these:

```
Pkg.add("Conda")
ENV["PYTHON"]=""
Pkg.add("PyPlot")
Pkg.add("Plots")
Pkg.build("PyPlot")
Pkg.add("ImageMagick")
Pkg.add("GR")
Pkg.add("Plotly")
Pkg.add("StatPlots")
Pkg.add("PlotRecipes")
Pkg.add("UnicodePlots")
Pkg.add("Gadfly")
Pkg.add("RDatasets")
Pkg.add("Winston")
Pkg.add("PGFPlots")
```

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```
Pkg.build("PGFPlots")
Blink.AtomShell.install()
import Conda # to fix pyplot!!!
Conda.add("qt=4.8.5")
```

My Packages

I started these:

```
Pkg.clone("https://github.com/huckl3b3rry87/VehicleModels.jl")
Pkg.clone("https://github.com/huckl3b3rry87/NLOptControl.jl")
```

Miscellaneous

probably do not need:

```
Pkg.clone("https://github.com/pwl/MovcolN.jl")
Pkg.add("Devectorize")
Pkg.add("FactCheck")
```

Useful Command After Installing Packages

Type:

```
Pkg.update()
```

Customizing Keybindings and Tab Completion

Info here

type:

```
import Base: LineEdit, REPL

const mykeys = Dict{Any,Any}(
  # Up Arrow
  "\e[A" => (s,o...)->(LineEdit.edit_move_up(s) || LineEdit.history_prev(s, LineEdit.
↪mode(s).hist)),
  # Down Arrow
  "\e[B" => (s,o...)->(LineEdit.edit_move_up(s) || LineEdit.history_next(s, LineEdit.
↪mode(s).hist))
)

function customize_keys(repl)
  repl.interface = REPL.setup_interface(repl; extra_repl_keymap = mykeys)
end
```

atreplinit(customize_keys)

1.6.3 Basic Pkg. Usage Notes

Optimization

Currently the only optimization tool that is being tested it IPOPT.

1. IPOPT

It is very easy to get going using IPOPT in julia using IPOPT.jl.

Derivatives

JuMP.jl is one of the most useful packages for solving the OCP because it takes **very** fast automatic derivatives and it allows the user to easily set up optimization problems. So, with this tool there is no need to write out the complicated Jacobian and Hessian functions.

The documentation for this package can be found JuMP docs.

Some useful Methods are found by clicking.

Some useful commands Query upper and lower bounds of all constraints in the model:

```
JuMP.constraintbound(m::Model)
```

MathProgBase.jl

MathProgBase.jl.

Polynomial Division

There was an issue when JuMP was sent a term with polynomial division. This section deals with the attempt to use the Polynomials.jl to take care of the polynomial division on the front end, before the expressions are sent to JuMP.

Basic Functionality:

```
using Ploynomials
Poly([1,0,3,4])
Poly(1 + 3x^2 + 4x^3)
```

Division Functionality:

```
P1 = Poly([1,2,3,5,7])
P2 = Poly([1,0,3])
P3 = div(P1,P2)
Poly(0.22222222222222218 + 1.6666666666666667x + 2.3333333333333335x^2)
```

Plots.jl

A very powerful plotting tool is Plots.jl. It took some time to get everything working because I was not using the same versions of the packages as the developers, but in the end it was work the time. It you run the code that I have listed below you should not have to deal with the setup issues that I had.

With PGFPlots:

```
sudo apt-get install pdf2svg
```

http://nbviewer.jupyter.org/github/sisl/PGFPlots.jl/blob/master/doc/PGFPlots.ipynb

Problem 1

I wasted a bunch if my time, could not recreate in a simpler example, but basically, when `plot()` should have worked it failed and when I changed the order of the terms in `plot()` it works.

Solution 1

EX:

```
for i in 1:k
#             plot!(dfs[i][:t],dfs[i][:SA]*180/pi,w=w2,label=label_string[i])
              plot!(dfs[i][:t],dfs[i][:SA]*180/pi,label=label_string[i],w=w2)
end
```

Problem 2

Segfault when attempting to plot after Conda update to Segfault with qt >=4.8.6 on ubuntu

I was running into an issue with Plots.jl after doing a `Pkg.update()`:

```
   _       _ _(_)_     |  A fresh approach to technical computing
  (_)     | (_) (_)    |  Documentation: http://docs.julialang.org
   _ _   _| |_  __ _   |  Type "?help" for help.
  | | | | | | |/ _` |  |
  | | |_| | | | (_| |  |  Version 0.6.0-dev.508 (2016-09-06 20:36 UTC)
 _/ |\__'_|_|_|\__'_|  |  Commit b1f1525 (26 days old master)
|__/                   |  x86_64-linux-gnu

julia> using Plots
julia> plot(rand(4,100))
signal (11): Segmentation fault
while loading no file, in expression starting on line 0
unknown function (ip: 0x32735)
Allocations: 14606607 (Pool: 14605017; Big: 1590); GC: 25
Segmentation fault (core dumped)
```

Solution 2

Change back to old Conda:

```
import Conda
Conda.add("qt=4.8.5")
using PyPlot
plot(rand(10))
```

Check out this link.

DifferentialEquations.jl

Useful Commands

all of the timepoints:

```
sol[:]
```

Many times you might want to use a good interpolation. For example, the plots use something like:

```
[sol(t) for t in linspace(t0,tend,100)]
```

To get 100 points from time t0 to tend for the first component:

```
[sol(t)[1] for t in linspace(t0,tend,100)]
```

The array of timepoints for component j:

```
[sol[i][j] for i in 1:length(sol)]
```

Parameters.jl

Great package for working with parameters. More info can be found at this link.

1.6.4 Making Your Own Packages

To create packages and modules click this to get started.

Or type:

```
using PkgDev
PkgDev.generate("VehicleModles","MIT")
```

Possible Next Steps:

- Make a github repository with this name (plus a `.jl` at the end of the name) github.com
  - Don't add a `README.MD` automatically using github, there will be a conflict if you will make one from the using `sphinx-quickstart`
    - Or just pick one, don't do both!
- Make some documentation getting_started_with_docs
  - Or, if everything is setup, type:

    ```
    sphinx-quickstart
    ```

  - Then:

    ```
    git remote add origin git@github.com:huckl3b3rry87/new_repo.jl
    ```

To tag:

```
using PkgDev
PkgDev.tag("VehicleModles")
```

To view the package:

```
$ cd ~/.julia/v0.6/VehicleModles && git show --stat
```

To recompile a package:

```
Pkg.test()
```

To go into the package directory:

```
cd(Pkg.dir("LiDAR"))
```

In Juno, the workflow for building a package, you can do a `Ctrl+J Ctrl+k` to quit the current process and then use `using PKG` again.

it'll be in your lib folder and all setup to be used with using:

```
Pkg.test
Pkg.dir
etc
```

Then in order to run `Pkg.update()` without getting this error:

```
ERROR: Update finished with errors.
=> Package NLOptControl cannot be updated.
GitError(Code:ERROR, Class:Merge, There is no tracking information for the current␣
↪branch.)
etc....
```

Which is talked about here, you have to:

```
julia> Pkg.checkout("NLOptControl")
INFO: Checking out NLOptControl master...
INFO: Pulling NLOptControl latest master...
INFO: No packages to install, update or remove
```

Making Modules

look here

Directories

Try:

```
@__FILE__
```

link

1.6.5 Macros

Detailed information on macros in julia is found here.

@def

Given some parameters:

```
using Parameters

@with_kw immutable Vpara @deftype Float64
    m  = 2.6887e+03
end
pa = Vpara(); # initialize parameter set
```

Instead of unpackaging the same parameters each time in a nested function like this:

```
function outer_f(pa::Vpara)
  num = zeros(Float64, (10,1))
  for i in 1:10
   num[i] = inner_f(pa::Vpara,i)
  end
  return num
end
```

with:

```
function inner_f(pa::Vpara,i)
  @unpack_Vpara pa
   m + i + 0.1
end
```

We define a macro as:

```
macro def(name, definition)
  return quote
    macro $name()
      esc($(Expr(:quote, definition)))
    end
  end
end
```

then redefine `inner_f1()` as:

```
@def inner_f2 begin
  m + i + 0.1
end
```

We also need to modify the `outer_f()` as:

```
function outer_f(pa::Vpara)
  @unpack_Vpara pa
  num = zeros(Float64, (10,1))
  for i in 1:10
    num[i] = @inner_f2
  end
  return num
end
```

The `@def` macro is functionally equivalent to copying and pasting the contents of inner_f() into outer_f().

Parallel Computing

http://docs.julialang.org/en/stable/stdlib/parallel/#Base.addprocs https://www.youtube.com/watch?v=JoRn4ryMclc
container:

```
rr=RemoteChannel()
# stores a value -> like a container that you can put something in and take something␣
↪out
```

adding something to the container:

```
put(rr,0)
```

to add some processors:

```
addprocs()
```

calling a processor:

```
remotecall(function, proc,data)
# don't use this all of the time -> sort of low level
```

Example:

```
addprocs(1)
rc=remotecall(rand,2,100,100)
# then later...
f=fetch(rc)
```

An easier way to do this example is using `@span`:

```
r=@spawn rand(100,100)
# it picks a processor and sets this up for us
```

When you are typing you are typing to processor #1.

Number of processors:

```
nprocs()
```

Be able to run something everywhere:

```
@everywhere println(myid())
```

Also try:

```
fetch(@spawn myid())
```

Another useful macro:

```
@parallel
# works with ``for`` loops
#a=zeros(20) # wrong --> returns all 0's
a = SharedArray(Float64,20)
@parallel for i=1:20
  a[i]=i;
end
```

1.6.6 JuliaBox and Jupyter Notebooks

A way to run julia online without installing anything is to use JuliaBox with Jupyter notebooks.

The examples will be demonstrated using this tool.

Jupyter Notebooks

If you have IJulia installed you can run the examples using the following commands in julia:

```
using IJulia

# a few examples of changing the path
notebook(dir = Pkg.dir("VehicleModels")*"/examples")
notebook(dir="/home/febbo/Documents/workspace/OCP/examples")
```

More information can be found ‘ here <https://github.com/JuliaLang/IJulia.jl>‘_.

1.6.7 julia notes

Using kwargs...

function:

```
function test(A; kwargs...)

    kw = Dict(kwargs)

    # if there was nothing passed -> set default
    if !haskey(kw,:mode); kw = Dict(:mode => :default) end
    mode = get(kw, :mode, 0);

    if mode == :default
      B = 10
    elseif mode == :LGRM
      B = A
    else
      print("pick a mode","\n")
    end
    return B
end

B=test(2)
B=test(2;(:mode=>:LGRM))
```

Making Variables Programatically

https://docs.julialang.org/en/latest/manual/metaprogramming.html

code:

```
ex=Array(Expr,4,1);
for i in 1:4
  ex[i]=Expr(:(=),Symbol("x",i),i)
  eval(ex[i])
end
```

vector case:

```
A=[1 2 3 4]
ex=Array(Expr,4,1);
for i in 1:4
  ex[i]=Expr(:(=),Symbol("x",i),A)
  eval(ex[i])
```

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```
end
x1
```

Using JuMP to make a @NLexpression

making nlexps:

```
function test(n,exp,x)
  @eval begin
    x1=$x[1,1]
    x1=eval(x1);
    eq=@NLexpression($n,$exp)
  end
  return eq
end
```

to test:

```
using JuMP, Ipopt
n = Model(solver=IpoptSolver(print_level=0))
@variable(n,x[1:4,1:4])
exp=test(n,:(sin(x1)),x)
@NLconstraint(n,exp==0)
@NLobjective(n,Min,x[1,2])
solve(n)
```

making nlexps withough @eval to work with exp_arrs:

```
function test(n,exp_arr,x)
  code=quote
    x1=$x[1,1:4]
    x1=eval(x1);
    @NLexpression($n,$exp_arr[1])
    end
  return eval(code)
end
```

to test:

```
using JuMP, Ipopt
n = Model(solver=IpoptSolver(print_level=0))
@variable(n,x[1,1])
exp_arr=[:(sin(x1)),:(sin(x1))]
exp=test(n,exp_arr,x)
@NLconstraint(n,exp==0)
@NLobjective(n,Min,x[1,2])
solve(n)
```

example in REPL

```
function EX(A)
  code=quote
    temp=$A[1]
    solution=$temp
  end
```

(continues on next page)

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```
  return eval(code)
end

A=[:(2+4);:(9-8)]
EX(A)
```

1.6.8 Problems and Solutions

python ENV with PyCall

Fix:

```
_       _ _(_)_     |  A fresh approach to technical computing
(_)     | (_) (_)    |  Documentation: https://docs.julialang.org
_ _   _| |_  __ _   |  Type "?help" for help.
| | | | | | |/ _` |  |
| | |_| | | | (_| |  |  Version 0.6.0 (2017-06-19 13:05 UTC)
_/ |\__'_|_|_|\__'_|  |  Official http://julialang.org/ release
|__/                   |  x86_64-pc-linux-gnu

julia> ENV["PYTHON"]="/usr/bin/python"
"/usr/bin/python"

julia> Pkg.build("PyCall")
INFO: Building Conda
INFO: Building PyCall
INFO: PyCall is using /usr/bin/python (Python 2.7.12) at /usr/bin/python, libpython =␣
↪libpython2.7
INFO: /home/febbo/.julia/v0.6/PyCall/deps/deps.jl has been updated
INFO: /home/febbo/.julia/v0.6/PyCall/deps/PYTHON has been updated

julia> using PyCall
INFO: Recompiling stale cache file /home/febbo/.julia/lib/v0.6/PyCall.ji for module␣
↪PyCall.

julia> @PyCall.pyimport yaml

julia>
```

1.7 git

1.7.1 Website links

- https://github.com/
- The Pro Git book is available here!

1.7.2 Useful Commands

add everything to the commit (including new file and files that were deleted):

```
git add -A
```

commit all of the changes:

```
git commit -m "some message about what you did"
```

push to remote account:

```
git push origin master
```

view current tags:

```
git tag
```

making a new tag:

```
git tag -a V0.0.1 -m " new version 0.0.1"
```

committing a tag:

```
git push origin master --tags
```

checkout a tag:

```
git checkout -b [branchname] [tagname]
```

see which branch you are on:

```
git branch
```

to make a new branch:

```
git checkout -b [name_of_your_new_branch]
```

to change the working branch:

```
git checkout [name_of_your_new_branch]
```

to push the branch to github:

```
git push origin [name_of_your_new_branch]
```

delete a local branch:

```
git branch -d the_local_branch
```

delete a remote branch:

```
git push origin --delete the_remote_branch
```

remove a large file from a commit that has not been pushed to master yet:

```
git filter-branch --index-filter 'git rm -r --cached --ignore-unmatch papers/MO3/
↪results/laptop/demoZ/D/videos/Final.mp4' HEAD
```

or remove a large folder from a commit that has not been pushed to master yet:

```
git filter-branch --index-filter 'git rm -r --cached --ignore-unmatch papers/MO3/
↪results/laptop/demoZ/D/videos/*' -f HEAD
```

connecting to github:

```
git remote add origin git@github.com:username/new_repo
```

- making a branch look here

Then make a new repository using the interweb

- Check out this link for more info.

Caching your github password:

```
git config --global credential.helper 'cache --timeout=3600'
# Set the cache to timeout after 1 hour (setting is in seconds)
```

Working with Remote Repositories

To clone a repo:

```
git clone https://github.com/CPFL/Autoware
```

To view the remote:

```
febbo@febbo-HP-ZBook-17-G2:~/Documents/workspace/Autoware$ git remote -v
origin        https://github.com/huckl3b3rry87/Autoware (fetch)
origin        https://github.com/huckl3b3rry87/Autoware (push)
upstream      https://github.com/CPFL/Autoware.git (fetch)
upstream      https://github.com/CPFL/Autoware.git (push)
```

Removing a remote origin:

```
git remote rm origin
```

Setting an origin:

```
git remote set-url origin "https://..."
```

- Source is this

Revert to an old commit:

```
git push -f origin $old_commit_id:master
```

Make sure that you commit changes before moving from one branch to another the changes that you make do not belong to any particular branch!

remove files that where previously cached that are now in `.gitignore`:

```
git rm -r --cached .
git add .
git commit -am "Removed ignored files"
```

Update your fork from the from the upstrean remo:

```
git fetch [name _of_remote]
git fetch https://github.com/CPFL/Autoware
```

More info here

To automatically fetch and merge from a remote:

```
git pull upstream master
```

Remove submodule:

```
git rm --cached the_submodule_path
```

<<<<<<< HEAD Merging development branch with master ———————————————— Merge `master` into `develpment` to see if there are any conflicts, so `master` remains clean:

Merge `master` into `development` to see if there are any conflicts, so `master` remains clean:

```
(on branch development)$ git merge master
(resolve any merge conflicts if there are any)
git checkout master
git merge development (there won't be any conflicts now)
```

<https://stackoverflow.com/questions/27828404/why-does-git-status-show-branch-is-up-to-date-when-changes-exist-upstream>‘_ Resolving mere conflicts ———————————————- ======= Basics of Collaborating on git == This is a beginners guide to collaborating on git. Several examples will be provided assuming `TulgaErsal` is collaborating with `huckl3b3rry87` on the `PhD` repo.

Getting started

This tutorial assumes that you are using a command line interface to git, for Windows consider using cmder and make sure that you download the full version that has git for Windows. Additionally, Atom is a useful tool for resolving merge issues visually.

Fork a Repository

1) Go to github.com and login. If it is a private repo that you will be collaborating on, then accept any invitations to collaborate.

2) Navigate to the repo that you will be collaberating on i.e.:

```
https://github.com/huckl3b3rry87/PhD
```

3) In the top right conner of the page click `Fork`

4) open terminal and navigate to a folder where you will be working i.e.

```
cd Documents\workspace\
```

5) in the terminal, clone the forked repo that you will be collaborating on:

```
git clone https://github.com/TulgaErsal/PhD
```

6) To see the current remote repo, type:

```
git remote -v
```

This should say:

```
origin  https://github.com/TulgaErsal/PhD.git (fetch)
origin  https://github.com/TulgaErsal/PhD.git (push)
```

7) To add the original repo as the upstream type:

```
git remote add upstream https://github.com/huckl3b3rry87/PhD.git
```

8) make sure that the upstream was added:

```
git remote -v
```

Which should say:

```
origin    https://github.com/TulgaErsal/PhD.git (fetch)
origin    https://github.com/TulgaErsal/PhD.git (push)
upstream  https://github.com/huckl3b3rry87/PhD.git (fetch)
upstream  https://github.com/huckl3b3rry87/PhD.git (push)
```

Example 1

To make sure that you are using the most recent version of the upstream (or original repo) you need to get the latest code and merge it into your repo. Use the terminal to navigate to the git folder with the repo that you are working on. Then type:

```
git merge upstream/master
```

Note: The above command attempts to automatically merge, and if there are merge issues they can easily be resolved using the Atom text editor.

Note: If you run this example just after setting everything up there should be no differences in the upstream repo.

Example 2

Each day that you make changes you can push them to your local repository.

Option 1 (using Atom)

If you are using the Atom text editor, this is very easy to do.

1) open the `Packages` tab and scroll down to `Github` and click `Toggle Git Tab`.
2) Click `Stage All` to stage the changes
3) Write a commit message and click `Commit`
4) Under the `Commit` button push the `up` arrow then click `Push`
5) Put in your git user info

Option 2 (using terminal)

1) add changes:

```
git add -A
```

2) commit changes

```
git commit -m "updated docs"
```

3) push changes

```
git push origin master
```

Example 3

This example is for when you are ready to commit to the upstream repo, this example shows you how to make a `pull request`.

Assuming that, your local changes have all been committed to the local repo you can easily make a pull request at::

```
https://github.com/TulgaErsal/PhD.git
```

Just click the `New Pull Request` button.

This will then alert the original repo owner and they can then merge your changes.

>>>>>>> 583ccf8843b87e3b5ba41467af531075812f8d41

1.7.3 Create a disconnected git branch

1) start with a fresh copy of the repo

2) Create a new disconnected branch:

```
git checkout --orphan gh-pages
```

3) hop onto that branch:

```
git checkout -b gh-pages
```

4) At this point there are no commits but lots of files from whatever branch you were on. Have git remove those files:

```
git rm -rf .
```

then follow the rest here:

https://coderwall.com/p/0n3soa/create-a-disconnected-git-branch

```
julia> Pkg.clone("https://github.com/JuliaMPC/MPCDocs.jl")
INFO: Cloning MPCDocs from https://github.com/JuliaMPC/MPCDocs.jl
INFO: Computing changes...
INFO: No packages to install, update or remove

julia>
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git checkout --orphan gh-
↪pagesSwitched to a new branch 'gh-pages'
```

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```
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ branch
The program 'branch' is currently not installed. You can install it by typing:
sudo apt install rheolef
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git branch
  master
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git checkout gh-pages
error: pathspec 'gh-pages' did not match any file(s) known to git.
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git checkout -b gh-pages
Switched to a new branch 'gh-pages'
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git rm -rf .
fatal: pathspec '.' did not match any files
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ ls
MPCDocs  MPCDocs.jl
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ cd MPCDocs
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/.trash/MPCDocs/MPCDocs$ ls
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/.trash/MPCDocs/MPCDocs$ cd ..
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/.trash/MPCDocs$ cd MPCDocs.jl/
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/.trash/MPCDocs/MPCDocs.jl$ ls
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/.trash/MPCDocs/MPCDocs.jl$ cd ..
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/.trash/MPCDocs$ git branch
  master
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/.trash/MPCDocs$ cd ..
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/.trash$ cd ..
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5$ cd MPCDocs/
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git branch
* master
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ ls
appveyor.yml  LICENSE.md  README.md  REQUIRE  src  test
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git checkout -b gh-pages
Switched to a new branch 'gh-pages'
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git branch
* gh-pages
  master
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ ls
appveyor.yml  LICENSE.md  README.md  REQUIRE  src  test
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git diff
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git branch
* gh-pages
  master
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git rm -rf .
rm '.codecov.yml'
rm '.gitignore'
rm '.travis.yml'
rm 'LICENSE.md'
rm 'README.md'
rm 'REQUIRE'
rm 'appveyor.yml'
rm 'src/MPCDocs.jl'
rm 'test/runtests.jl'
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git branch
* gh-pages
  master
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ ls
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git clean -fdx
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git branch
* gh-pages
  master
```

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```
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git push origin master
Everything up-to-date
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git push origin gh-pages
Total 0 (delta 0), reused 0 (delta 0)
To git@github.com:JuliaMPC/MPCDocs.jl.git
 * [new branch]      gh-pages -> gh-pages
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$ git branch
* gh-pages
  master
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/MPCDocs$
```

1.7.4 Forking a Repository

Follow what this page talks about

also if you are doing this in julia see Another way to connect to github it using ssh

do a:

```
git branch
```

Initially the error was:

```
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/VehicleModels$ git push origin master
Permission denied (publickey).
fatal: Could not read from remote repository.

Please make sure you have the correct access rights
and the repository exists.
```

- This was obtained when initially setting up the git repositories in julia after cloning a package and trying to push modifications back up to the remote repository.
- Information on this can be founds at , or by following the two steps a fix may be obtained:

FOLLOW:

https://help.github.com/articles/generating-a-new-ssh-key-and-adding-it-to-the-ssh-agent/

NOTE: just hit enter, don't change the default location!!! THEN:

https://help.github.com/articles/adding-a-new-ssh-key-to-your-github-account/

1. Make an ssh key and add it to github, following.
2. Check out this, or use the following commands:

- A program to hold private keys for public authentication.

  type:

  ```
  ssh-agent
  ```

- Initially the agent does not hold any private keys.

  So run:

  ```
  ssh-add
  ```

1.7.5 Mistakes I Made

- Make sure that you are working on the master branch!
  - Do not check out a tag and start making changes only to realize that you are not on the master branch!
- Trying to connect to github using ssh

  1) Create a github repository, with the name (for example: huckl3b3rry87/LiDAR.jl)

  2) Then

  Type this in the terminal:

```
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/LiDAR$ git remote add origin git@github.
↪com:huckl3b3rry87/LiDAR.jl
```

  3) Then

  Try this:

```
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/LiDAR$ git pull master
```

  4) Next

  Get this:

```
fatal: 'master' does not appear to be a git repository
fatal: Could not read from remote repository.

Please make sure you have the correct access rights
and the repository exists.
```

  Next we are going to test the ssh connection

  5) Attempt to ssh to GitHub By typing:

```
febbo@febbo-HP-ZBook-17-G2:~/.julia/v0.5/LiDAR$ ssh -T git@github.com
Hi huckl3b3rry87! You've successfully authenticated, but GitHub does not provide␣
↪shell access.
```

  6) realize that you messed up by typing:

```
git pull master
```

  and not:

```
git pull origin master
```

1.8 Documentation

1.8.1 Creating Documentation

Sphinx

Installation

In the terminal run:

```
pip install sphinx


* `Uninstall <https://pip.pypa.io/en/stable/reference/pip_uninstall/>`_
```

Useful Resources

- an awesome video introduction
- toctree
- basic commands and syntax
- useful resource
- making sections

Common Commands

To start documenting:

```
sphinx-quickstart
```

To manually build documentation:

```
make html
```

To clean out an old build folder when things have changed significantly:

```
make clean
```

Images:

```
.. image:: gnu.png
```

To make a comment:

```
.. Comment here
```

Something

To make a warning

Type:

```
.. warning:: this is a warning
```

Which looks like this:

> **Warning:** this is a warning

To make a note

Type:

```
.. note:: please be careful with spacing!
```

Which looks like this:

Note: please be careful with spacing!

To make a todo box

Type:

```
.. todo:: testing
```

Which looks like this:

Todo: testing

changing the themes

- In `conf.py` change:

```
html_theme = 'haiku'
```

- Or a main one:

```
import sphinx_rtd_theme
html_theme = "sphinx_rtd_theme"
html_theme_path = [sphinx_rtd_theme.get_html_theme_path()]
```

- An awesome theme

Manging References

Properly managing references is a critical habit and these are some of the useful software tool that I use to manage my references.

Using Sphinx BibTex extension

Sphinx BibTex extension

- To install

  Do this:

```
pip install sphinxcontrib-bibtex
```

In `conf.py` add:

```
extensions = ['sphinxcontrib.bibtex']
```

Warning: that it is *added* to the rest of extensions!! Not just at the top, or it will be removed!!!

Like this:

```
extensions = [
    'sphinx.ext.autodoc',
    'sphinx.ext.doctest',
    'sphinx.ext.intersphinx',
    'sphinx.ext.todo',
    'sphinx.ext.coverage',
    'sphinx.ext.mathjax',
    'sphinx.ext.ifconfig',
    'sphinxcontrib.bibtex',
    ]
```

Also, you can avoid these errors on readthedocs.com:

```
python /home/docs/checkouts/readthedocs.org/user_builds/nloptcontroljl/envs/latest/
↪bin/pip install --exists-action=w --cache-dir /home/docs/checkouts/readthedocs.org/
↪user_builds/nloptcontroljl/.cache/pip -rpip install sphinxcontrib-bibtex
Could not open requirements file: [Errno 2] No such file or directory: 'pip install␣
↪sphinxcontrib-bibtex'
You are using pip version 8.1.2, however version 9.0.1 is available.
You should consider upgrading via the 'pip install --upgrade pip' command.
Command time: 0s Return: 1
```

By typing:

```
requirements.txt
```

Into the Advanced Settings Page and making a requirements.txt file with:

```
pip install --upgrade pip
pip install sphinxcontrib-bibtex
```

More on this is here

Example: To cite:

```
according to :cite:`someone` yada yada..
```

Then, at the end of the document include:

```
.. bibliography:: references.bib
```

Useful Work-flow Technique

Setting up a server to build the documentation when a change is detected.

Installation:

```
pip install sphinx-autobuild
```

Then go into your main directory and type:

```
sphinx-autobuild docs docs/_build/html
```

Or the directory that contains `conf.py` and type:

```
sphinx-autobuild . _build_html
```

Then visit the website: http://127.0.0.1:8000/

- This will show you the live changes (after each save!!)

More information can be found using this resource.

Useful Software

Read The Docs

To get it:

```
pip install sphinx_rtd_theme
```

Read the Docs is useful resource to host the webpage.

Some Issues:

- The git repository for OCP is private and this website only hosts public repositories.
- Had to remove the last line here in `conf.py` for the code to work with ReadtheDocs.

like this:

```
extensions = [
    'sphinx.ext.autodoc',
    'sphinx.ext.doctest',
    'sphinx.ext.intersphinx',
    'sphinx.ext.todo',
    'sphinx.ext.coverage',
    'sphinx.ext.mathjax',
    'sphinx.ext.ifconfig',
    'sphinx.ext.viewcode',
    'sphinxcontrib.bibtex',
]
#    'sphinx.ext.githubpages',
```

- Had to make sure that the name of the project was correct
- Had to make sure that the webhook was activated on github

MkDocs

Potential Issues

1. Make sure that the "toctree" is indented by 3 space characters. I listed the .rst files by 4 space characters and this created an issue. To resolve the issue, you need to have the same indentation level.
2. When cross referencing things in the document make sure you skip a space when you define the ref.

- like this

  works:

```
.. _ploy_div:

Polynomial Division
-------------------
```

- not like this

  fails:

```
.. _ploy_div:
Polynomial Division
-------------------
```

3. Trying to uninstall sphinx so that I could get a newer version without bugs:

```
febbo@febbo-HP-ZBook-17-G2:~/Desktop/useful downloads$ pip uninstall sphinx
Cannot remove entries from nonexistent file /home/febbo/anaconda3/lib/python3.5/site-
↪packages/easy-install.pth
```

The problem: This probably won't work:

```
conda update setuptools
```

The fix, was to download `ez_setup.py` from this link and run it in the terminal:

```
febbo@febbo-HP-ZBook-17-G2:~$ python ez_setup.py
```

Then I could uninstall Sphinx-1.4.1:

```
febbo@febbo-HP-ZBook-17-G2:~$ pip uninstall sphinx
Uninstalling Sphinx-1.4.1:
/home/febbo/anaconda3/bin/sphinx-apidoc
/home/febbo/anaconda3/bin/sphinx-autogen
/home/febbo/anaconda3/bin/sphinx-build
/home/febbo/anaconda3/bin/sphinx-quickstart
/home/febbo/anaconda3/lib/python3.5/site-packages/Sphinx-1.4.1-py3.5.egg
Proceed (y/n)? y
Successfully uninstalled Sphinx-1.4.1
```

There was reason I needed to uninstall this version of Sphinx was because the citations where not working.

Finally I installed Sphinx-1.5.2:

```
#Install from newest dev version in stable branch::
pip install git+https://github.com/sphinx-doc/sphinx@stable
```

Markdown

Tools

- Documentor.jl.
- plugin for Atom
- GitBook Toolchain Documentation

1.8.2 Miscellaneous

Pandoc

Software used to convert documentation from one format to another.

1.9 LaTeX

1.9.1 Install

Use Texmaker and when you change the build directory, make sure that you add build/ before the % to all the commands in configure.

Install on Ubuntu:

```
sudo apt-get install texlive-full
```

Other packages:

```
sudo apt-get install texlive-latex-extra
sudo apt-get install texlive-bibtex-extra biber
sudo apt-get install texlive-fonts-recommended
sudo apt-get install texlive-publishers
```

misc:

```
sudo apt-get install pdflatex
```

1.9.2 Beemer

Adobe Reader

http://www.ubuntugeek.com/install-adobe-reader-in-ubuntu-16-04.html

Convert to Individual Files

https://tex.stackexchange.com/questions/240243/getting-gif-and-or-moving-images-into-a-latex-presentation

type:

```
convert -coalesce something.gif something.png
```

Syntax Highlighting: listings

http://users.ecs.soton.ac.uk/srg/softwaretools/document/start/listings.pdf

Syntax Highlighting: minted

usepackage{minted}

which needs:

```
sudo apt-get install python-pygments
```

OLD

http://heather.cs.ucdavis.edu/~matloff/beamer.html

FFmpeg

https://trac.ffmpeg.org/wiki/CompilationGuide/Ubuntu

https://stackoverflow.com/questions/10225403/how-can-i-extract-a-good-quality-jpeg-image-from-an-h264-video-file-with-ffmpeg

Change quality:

```
ffmpeg -i input.mp4 -qscale:v 2 output_%03d.jpg
```

Embedding movies1:

https://tex.stackexchange.com/questions/252348/how-to-embed-a-video-in-beamer-and-reproduce-it-by-using-okular

code:

```
\usepackage[loop,controls,buttonsize=0.24cm,buttonbg=0.8,autoplay]{animate}
%% normal frame
\begin{frame}{Why julia?}
  \begin{figure}
        \centering
          \animategraphics[loop,width=\textwidth,every=1]{100}{videos/v1/out_}{1}
↪{1199}
        \caption{Our Algorithms where not Solving in Real-Time!}
  \end{figure}
\end{frame}
```

Embedding movies2:

https://tex.stackexchange.com/questions/240243/getting-gif-and-or-moving-images-into-a-latex-presentation

Embedding movies3:

https://tex.stackexchange.com/questions/429/animation-in-pdf-presentations-without-adobe-reader

animate package

http://mirror.hmc.edu/ctan/macros/latex/contrib/animate/animate.pdf

Viewing slides

Okular:

```
sudo apt-get install okular
```

xPDF

install:

```
sudo apt-get update
sudo apt-get install xpdf
```

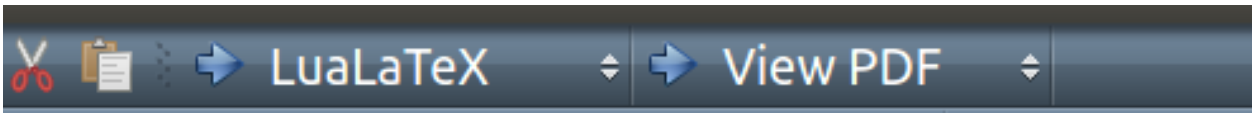
1.9.3 Software Tools

Texmaker

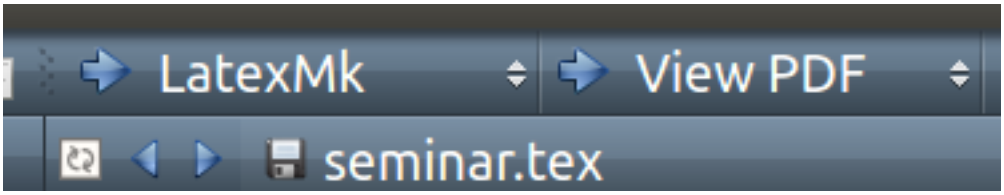
A useful program to use LaTeX on Ubuntu.

> **Warning:** make sure that you play with the build option if it is saying that the references where not found.

For instance, after a while this worked:



Then, the above option did not work and this worked:



To insert `.svg` files automatically

Useful links:

- svg package

- shell-escape command

Convert SVG to PDF

sudo apt-get install inkscape

https://tex.stackexchange.com/questions/194148/how-to-make-latex-automatically-call-inkscape-to-export-figure-to-pdf-tex

https://tex.stackexchange.com/questions/99475/how-to-invoke-latex-with-the-shell-escape-flag-in-texmakerx/99476#99476

Making Figures With LaTeX

http://www.texample.net/tikz/examples/tag/diagrams/

1.9.4 Plotting

PGFPlots

Documented here

TikZ and PGF

Documentation is here

With julia

- a recent package is PGFPlotsX
- the original package is PGFPlots

Miscellaneous

How to include a '.svg' into LaTex <http://anorien.csc.warwick.ac.uk/mirrors/CTAN/info/svg-inkscape/InkscapePDFLaTeX.pdf>'_

MWE:

```
\documentclass[]{memoir}
\usepackage{svg}
\setsvg{inkscape=inkscape -z -D,svgpath=figs/}

\begin{document}

\begin{figure}[!ht]
 \centering
 \includesvg[width=0.5\columnwidth, svgpath = ./relativePATHtoSVG/]{filename}
\end{figure}

\end{document}
```

1.10 C

1.10.1 Including files

There are 2 kinds of include directives:

- double quoted ones (#include “xyz.h”)
  - the working directory
- angle bracket ones (#include <xyz.h>)
  - usually /usr/include/.

Other Notes

- Place the header file in the same directory as your .c file and use -I. when compiling
- You shouldn’t place your header files in /usr/include that is meant for the system headers.

Useful resources

- https://stackoverflow.com/questions/27660713/including-header-file-from-static-library

1.11 Operating Systems

1.11.1 Linux

Useful Programs

In the terminal:

```
sudo dpkg --install atom-amd64.deb
sudo apt install ffmpeg
sudo apt-get install cmake bar time binutils make libssl-dev gfortran libunwind8-dev␣
↪gcc g++ #clang curl perl wget m4 patch pkg-config
sudo apt-get install gsfonts-x11
sudo apt-get install notepadqq
sudo apt-get update
sudo apt-get install gfortran
sudo apt-get install libnlopt0
sudo apt-get install openssh-server
sudo apt install ipmiutil
sudo apt-get install hdf5-tools
apm install latex # Atom package manager for latex!
sudo apt-get install pdf2svg # for PGFPlots
pip install sphinxcontrib-bibtex
sudo apt-get install texlive-luatex
sudo apt install aptitude
sudo apt-get install freecad
sudo apt install blender
sudo apt install rpm
apm install latex
sudo apt autoremove
```

Basic Linux Commands

Never run an executable in root!

Some more info can be found on ‘ this page <https://www.cyberciti.biz/faq/tar-extract-linux/>‘.

To move a folder an all of its contents:

```
mv /path/sourcefolder/* /path/destinationfolder/
```

To unpack a tar file:

```
tar -xvf file.tar
```

To extract a .tar.gz:

```
tar -xzvf file.tar.gz
```

Note: Modern `tar` can recognize the format automatically:

```
sudo tar xf armadillo-8.300.3.tar.xz -C /opt
```

Unzip:

```
unzip stuff.zip -d /destination/folder
```

directory comment:

```
$HOME = /home/febbo
```

Run a jar file: java -jar lad

Useful Tools

- Synaptic Package Manager

/etc/bash.bashrc vs. $HOME/.bashrc

Be careful there are two files that configure the terminal!

http://unix.stackexchange.com/questions/140207/messed-up-bash-bashrc-file-commands-not-working-anymore

in my `$HOME/.bashrc`:

```
alias blender='/opt/blender/blender'
alias julia='/opt/julia-6445c82d00/bin/julia'
alias docs='sphinx-autobuild . _build_html'
export DYLD_LIBRARY_PATH="$HOME/knitro/lib:$DYLD_LIBRARY_PATH"
export LD_LIBRARY_PATH="$HOME/knitro/lib:$LD_LIBRARY_PATH"
export PYTHONPATH=$PYTHONPATH:/usr/lib/python2.7/dist-packages
export GAZEBO_PLUGIN_PATH=/home/febbo/.julia/v0.5/OCP/MAVs/workspace/src/velodyne_
↪plugin/build/:${GAZEBO_PLUGIN_PATH}
source /opt/ros/kinetic/setup.bash
export ROS_PACKAGE_PATH=/home/febbo/.julia/v0.5/OCP/MAVs/workspace:$ROS_PACKAGE_PATH
```

Ubuntu package manager

https://launchpad.net/ubuntu/+source/matplotlib

Video Stuff

to converte to MP4

Type:

```
ffmpeg -f gif -i mainSimPath.gif RESULT.mp4
```

Quickly convert to `.gif` files:

Following this link

Add this to your `~/bash_profile` file:

```
# Convert video to gif file.
# Usage: video2gif video_file (scale) (fps)
video2gif() {
  ffmpeg -y -i "${1}" -vf fps=${3:-30},scale=${2:-320}:-1:flags=lanczos,palettegen "$
↪{1}.png"
  ffmpeg -i "${1}" -i "${1}.png" -filter_complex "fps=${3:-10},scale=${2:-320}:-
↪1:flags=lanczos[x];[x][1:v]paletteuse" "${1}".gif
  rm "${1}.png"
}
```

Then load it in the `.bashrc` file:

```
. ~/.bash_profile
```

1.11.2 Setting up a machine for Dual Boot

Todo: transcribe notes from black book on this

1.12 misc

1.12.1 MPT3

- MPT3 is a MATLAB based optimization tool that comes out of The Automatic Controls Laboratory at ETH.
- Lots of other useful software that come out out ETH in Zurich, Switzerland and can be found aqui
- Additionally, I worked with Michal Kvasnica (a former memeber of The Automatic Controls Laboratory at ETH) developing Moving Obstacle avoidance code using MPT3.
  - The result of this work is a tool named OptiPlan and the code can be found here.

1.12.2 BARC

http://www.barc-project.com/

1.12.3 AUTORALLY

http://autorally.github.io/

Georgia tech

https://collab.cc.gatech.edu/borg/home?destination=home

GTSAM

Visual-Inertial-Aided Navigation for High-Dynamic Motion in Built Environments Without Initial Conditions

https://bitbucket.org/gtborg/gtsam/src/8b0c2ecaf4060965eca355bdd907d239b5124de6/GTSAM-Concepts.md?fileviewer=file-view-default

https://www.youtube.com/watch?v=CsJkci5lfco&feature=youtu.be

1.12.4 Different Text Editors

I tried a few different text editors, but this one I really like and it is very similar to coding in MATLAB. It is a tool called JUNO that basically links a nice text editor called Atom to julia, so that you can run julia interactively.

Atom

Atom Flight Manual

Useful things:

spell check <https://github.com/atom/spell-check>:

```
ctrl+shift+;
```

Markdown Preview Package:

```
ctr+shift+m
```

https://github.com/atom/markdown-preview

Subscripts:

```
variable\_1+tab
```

Using /LaTeX with Atom. It was suggested to use *Tex Live <https://www.tug.org/texlive/acquire-netinstall.html>* Where the *quick install instructions are here<https://www.tug.org/texlive/quickinstall.html>* https://atom.io/packages/latex

TeX Live

I use this with Atom.

https://www.tug.org/texlive/ https://atom.io/packages/latex

After installing TeX Live: * Add /usr/local/texlive/2016/texmf-dist/doc/info to INFOPATH. * Add /usr/local/texlive/2016/texmf-dist/doc/man to MANPATH (if not dynamically found). * Most importantly, add /usr/local/texlive/2016/bin/x86_64-linux to your PATH for current and future sessions.

To do this change the bashrc file:

```
gksu gedit /etc/bash.bashrc
```

Paste this at the end:

```
PATH=/usr/local/texlive/2016/bin/x86_64-linux:$PATH; export PATH # make sure that␣
↪there are NO spaces
MANPATH=/usr/local/texlive/2016/texmf-dist/doc/man:$MANPATH; export MANPATH
INFOPATH=/usr/local/texlive/2016/texmf-dist/doc/info:$INFOPATH; export INFOPATH
```

Then in Atom, go to settings and add the path to the texlive:

```
/usr/local/texlive/2016/bin/x86_64-linux
```

Potential Issues

- If the julia binary is not where it belongs (for instance I put it in my /opt/... folder)
  - Change the julia `.config` file (in Atom) to the proper folder (where julia binaries are)
- **Otherwise**
  - leave it as : juliaPath: "julia"

I had to:

```
Pkg.clone("https://github.com/JunoLab/Juno.jl")
Pkg.update()
```

Make sure you close both atom and julia after installation. Now you should be able to run julia from Atom!

1.12.5 Transferring Files To A Website

http://www.umich.edu/~umweb/how-to/homepage.html

https://docs.oracle.com/cd/E26502_01/html/E29001/remotehowtoaccess-14.html

type:

```
sftp sftp.itd.umich.edu
```

Or just do:

```
scp -r /home/febbo/Documents/workspace/PhD/docs/_build/html sftp.itd.umich.edu:/afs/
↪umich.edu/user/f/e/febbo/Private/html
```

Setting Permissions:

https://mfile.umich.edu/?path=/afs/umich.edu/user/f/e/febbo/Private/html

1.12.6 Community Help

There is a tremendous community of people online that will help you with your projects. I have helped when I can, but largely other more experienced people usually help me. Below I have listed a few of the communities that I have been involved with.

Stackoverflow

A more general venue for asking questions to the online community of experts in various feilds.

GitHub

If you have issues with peoples software, you can submit an issue.

Gitter

Basicaly an instant message service for developers. I have used it for julia, plots.jl, and juno.jl.

1.12.7 Making A Thesis

https://github.com/jterrace/sphinxtr

1.12.8 Miscellaneous

Making the Screen Brighter with an Apple Monitor on Ubuntu

Ubuntu Freezing and not Booting with Monitors Plugged in

Blender

3D modeling tool

chmod

changes permissions. For instance:

```
chmod + x filename
```

Allows the file to be executed.

1.12.9 MATLAB

I used MATLAB to develop the work in my 2016 ASME paper. Great software, but julia is faster, free and just plain better:)

1.12.10 Build Tools

catkin

This is the official build system of ROS, it uses the CMake macros and Python to add functionality to Cmake.

Installation Instructions

catkin-tools

These tools are used to facilitate a merged build process. That is several inter-dependent but separately developed CMake projects

Installation:

```
sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu `lsb_release -sc` main" > /
↪etc/apt/sources.list.d/ros-latest.list'
wget http://packages.ros.org/ros.key -O - | sudo apt-key add -
sudo apt-get update
sudo apt-get install python-catkin-tools
```

Warning: If you this was built on an old machine or paths got updated (e.g. a new version of julia) then it may be necessary to clean out the build:

to clean out an old build:

```
rm -rf build
```

If you move a package, delete the `build` and the `devel` folders then do a `catkin_make`

CMake

Ninja

a small build system:

```
sudo apt-get install ninja-build
```

Linuxbrew

For working with Linux and Mac install:

```
sudo apt install linuxbrew-wrapper
```

then:

```
brew install libyaml
```

1.12.11 Reference Management

JabRef

BibTex files can be managed with a free software called JabRef

First I tried a few things including:

```
sudo apt-get install default-jre
sudo apt-get update
```

And:

```
sudo add-apt-repository ppa:openjdk-r/ppa
sudo apt-get update
sudo apt-get install openjdk-7-jre
```

This messed stuff up and then I deleted all of my old java versions using:

```
sudo natilus
```

Ended up needing to follow *this advice <http://askubuntu.com/questions/251213/unable-to-install-default-jdk >*:

```
sudo add-apt-repository ppa:webupd8team/java
sudo apt-get update
sudo apt-get install oracle-java8-installer
java -version
sudo apt-get install oracle-java8-set-default
```

This finally worked and I was able to run JabRef with no problem using:

```
java -jar JabRef-3.8.jar
```

If something is broken:

```
sudo apt-get -f install
```

Using JabRef with LibreOffice

http://help.jabref.org/en/OpenOfficeIntegration http://homepage.usys.ethz.ch/eugsterw/knowhow/jabref-libreoffice/ ls $(which soffice) ls $(which soffice) -l locate libreoffice https://onetransistor.blogspot.com/2015/04/libreoffice-bibliography-jabref.html

http://homepage.usys.ethz.ch/eugsterw/knowhow/jabref-libreoffice/

cd /usr/lib/openoffice/program/soffice

febbo@febbo-HP-ZBook-17-G2:/usr/lib/libreoffice/program$ locate unoil.jar /usr/lib/libreoffice/program/classes/unoil.jar /usr/share/java/unoil.jar /usr/share/libreoffice/program/classes/unoil.jar

febbo@febbo-HP-ZBook-17-G2:/usr/lib/libreoffice/program$ locate jurt.jar /usr/lib/libreoffice/program/classes/jurt.jar /usr/share/java/jurt.jar

Need to make symbolic links to the following java files:

febbo@febbo-HP-ZBook-17-G2:/usr/share/libreoffice/ure-link/share/java$ sudo ln -s /usr/lib/libreoffice/program/classes/jurt.jar febbo@febbo-HP-ZBook-17-G2:/usr/share/libreoffice/ure-link/share/java$

sudo ln -s /usr/lib/libreoffice/program/classes/juh.jar febbo@febbo-HP-ZBook-17-G2:/usr/share/libreoffice/ure-link/share/java$ sudo ln -s /usr/lib/libreoffice/program/classes/ridl.jar

EndNote

I still use this tool, but it costs money and I do not have it on Ubuntu.

CHAPTER 2

Hardware

2.1 LiDAR Devices

2.1.1 Velodyne Puck 16

VPL-16 Setup (for Ubuntu 16.04)

Getting on the LiDAR on the Network

The basic tutorial is here, but you may run into issues like I did. In which case, the following notes may be useful.

First figure out what the devise name is. To show all devices found:

```
ifconfig -a
```

Which gives something like (desktop):

```
febbo@febbo-HP-Z220-SFF-Workstation:~/Documents/workspace/Docs$ ifconfig -a
eno1      Link encap:Ethernet  HWaddr b4:b5:2f:a9:52:61
          inet addr:192.168.1.200  Bcast:0.0.0.0  Mask:255.255.255.255
          inet6 addr: fe80::b6b5:2fff:fea9:5261/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:1604067 errors:0 dropped:0 overruns:0 frame:0
          TX packets:22232 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:1722487876 (1.7 GB)  TX bytes:2422647 (2.4 MB)
          Interrupt:20 Memory:f7100000-f7120000

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:89494 errors:0 dropped:0 overruns:0 frame:0
```

(continues on next page)

(continued from previous page)

```
          TX packets:89494 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1
          RX bytes:145501992 (145.5 MB)  TX bytes:145501992 (145.5 MB)
```

Warning: Note that the device is `eno1`, not `eth0`. Also, on my laptop the device name is `enp0s25`, so it is different depending on the machine.

Then do (desktop):

```
sudo ifconfig eno1 up
sudo ip addr add 192.168.1.200 dev eno1
sudo route add -net 192.168.1.0 netmask 255.255.255.0 dev eno1
```

Then do (laptop):

```
sudo ifconfig enp0s25 up
sudo ip addr add 192.168.1.200 dev enp0s25
sudo route add -net 192.168.1.0 netmask 255.255.255.0 dev enp0s25
```

Next got to: `Network` -> `Options...` and click `Ethernet Settings`

Ethernet Settings

Type the LiDAR's cloned MAC address in the box.

Note: To find the cloned MAC address for the LiDAR; look at the bottom of the device. For me it is:

```
60:76:88:10:47:F9
```

Note:

- Now you can change the name of the network to something, perhaps `LiDAR` in `Edit Connections...`
- To see information about the connection check out `Connection Information`.

Testing the LiDAR

First clone the Velodyne LiDAR ros package into a `catkin_ws`:

```
git clone http://wiki.ros.org/velodyne
```

To run it:

```
roslaunch velodyne_pointcloud VLP16_points.launch
```

To view data run:

```
rosrun rviz rviz -f velodyne
```

Then add try adding `LaserScan` and `PointCloud2` and their topics `/velodyne_points` and `/scan`, respectively.

If you have trouble these instructions will help you display the data in rviz.

Getting on the Computer back on the Internet

Note: If you accidentally deleted the Internet connection or messed it up somehow

On the top right of your screen highlight the `Network` icon and click `Edit Connections`. Then click `Add` add back the Internet with the following steps.

Warning: Make sure that you name the `LiDAR` connection and the `Internet` connection.

First go to: `Network` -> `Options...`

Ethernet Settings

Note: If you are trying to get the Internet back delete the MAC address in the box.

IPv4 Settings

Note: If you are trying to get the Internet back, select the `Method` to be:

```
Automatic (DHCP)
```

Network Commands

random commands:

```
route -n
```

2.1.2 SLAMTEC

360 degree 2D LiDAR for $500 well documented and comes with plenty of ROS support

CHAPTER 3

Huck's notes

These are some notes that I took for classes etc.

Contents:

3.1 Navigation and Guidance of Aerospace Vehicles (AERO 584)

Contents:

3.1.1 Cheat Sheet

not well formated. . . ..look at source!

$$(a^2 - b^2) = (a - b)(a + b)$$
$$(a^3 - b^3) = (a - b)(a^2 + ab + b^2)$$
$$(a^4 - b^4) = (a - b)(a + b)(a^2 + b^2)$$
$$e^a e^b = e^{a+b}$$
$$(e^x)^n = e^{2x}$$
$$(A + B)^T = A^T + B^T$$
$$(AB)^T = B^T A^T$$
$$AB^T = BA^T$$
$$(A^T)^{-1} = (A^{-1})^T$$
$$det(A^T) = det(A)$$

Also, if A is square, then its eigenvalues are equal to the eigenvalues of its transpose. Additionally, if the matrix is also differentiable and nonsingular

$$\frac{d}{dt}(P^{-1}(t) = -P^{-1}(t)\dot{P}(t)P^{-1}(t)$$
$$which can be found with;$$

d$\frac{}{dt(P(t)P^{-1}(t))=\frac{d}{dt}(I)=0}$

$$A^T = -A$$

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

$A^{-1} = \frac{1}{|A|}[r]a_{22} - a_{12}$

$-a_{21}a_{11}$

a_{11}

.

$$|B| = det(B) = \begin{vmatrix} a & b & c \\ d & e & f \\ g & h & i \end{vmatrix}$$
$$= a\begin{vmatrix} e & f \\ h & i \end{vmatrix} - b\begin{vmatrix} d & f \\ g & i \end{vmatrix} + c\begin{vmatrix} d & e \\ g & h \end{vmatrix}$$
$$sin(2a) = 2cos(a)sin(a)$$
$$cos(2a) = 1 - 2sin^2(a) = 2cos^2(a) - 1$$

States that the derivative of the integral is (for constant limits of integration):

$$\frac{d}{dt}(\int_a^b f(x,t)\,dt) = \int_a^b \frac{\partial}{\partial x} f(x,t)\,dt$$
$$States that the derivative of the integral is (for limits of$$

integration that are not constant)

$$\frac{d}{dt}(\int_{f(a)}^{f(b)} f(x,t)\,dt) =$$
$$= f(x,b(x))\frac{d}{dx}b(x) - f(x,a(x))\frac{d}{dx}a(x) + \int_{f(a)}^{f(b)} \frac{\partial}{\partial x} f(x,t)\,dt$$
$$Note :: math : `t` is a variable in the integration limit, so the above$$

formula must be used to derive (t).

$$\int x^n \, dx = \frac{1}{n+1} x^{n+1}$$

$$\int \frac{1}{x} \, dx = \ln |x|$$

$$\int u\dot{v} \, dx = uv - \int v du$$

$$\int e^x \, dx = e^x$$

$$\int a^x \, dx = \frac{1}{\ln a} a^x$$

$$\int \ln x \, dx = x \ln x - x$$

$$\int \sin x \, dx = -\cos x$$

$$\int \cos x \, dx = \sin x$$

$$\int \tan x \, dx = \ln |\sec x|$$

$$\int \sec x \, dx = \ln |\sec x + \tan x|$$

$$\int \sec^2 x \, dx = \tan x$$

$$\int \sec(x) \tan(x) \, dx = \sec x$$

$$dxdy = rdrd\theta$$

don't forget to change the limits of integration!

$$\frac{d}{dt}(tan^-1(x)) = \frac{1}{1+x^2}$$

$$
\begin{aligned}
f(t) &= \mathcal{L}[f(t)] = F(s) \\
1 &= \frac{1}{s} \\
\delta(t) &= 1 \\
\delta(t - t_0) &= e^{-st_0} \\
f'(t) &= sF(s) - f(0) \\
f^n(t) &= s^n F(s) - s^{(n-1)} f(0) - \cdots - f^{(n-1)}(0) \\
t^n (n = 0, 1, 2, \dots) &= \frac{n!}{s^{n+1}} \\
\sin kt &= \frac{k}{s^2 + k^2} \\
\cos kt &= \frac{s}{s^2 + k^2} \\
e^{at} &= \frac{1}{s - a} \\
t^n e^{at} &= \frac{n!}{(s - a)^{n+1}} \\
e^{at} \sin kt &= \frac{k}{(s - a)^2 + k^2} \\
e^{at} \cos kt &= \frac{s - a}{(s - a)^2 + k^2} \\
t \sin kt &= \frac{2ks}{(s^2 + k^2)^2} \\
t \cos kt &= \frac{s^2 - k^2}{(s^2 + k^2)^2}
\end{aligned}
$$

First translation theorom:

$$
\begin{aligned}
\mathcal{L}\left[e^{at} f(t)\right] &= F(s - a) \\
\int_{-\infty}^{\infty} f(x)\delta(x - a)\, dx &= f(a) \\
\int_{-\infty+\epsilon}^{\infty+\epsilon} f(x)\delta(x - a)\, dx &= f(a), \epsilon > 0 \\
\delta(x - a) &= 0
\end{aligned}
$$

Given some nonlinear system of the form:

$$
\begin{aligned}
\dot{x}(t) &= f(x(t), u(t), t) \\
y(t) &= g(x(t), t)
\end{aligned}
$$

$$A linearization can be performed about nominal trajectories$$

$\mathrm{x}^0(t), u^0(t), and u^0(t) (shorthand is 0) by defining the jacobian of w.r.t. the states evaluated at the nominal trajectories (0) as : trajectories (0) as :$

Finally, the output equation may need to be linearized about 0 as well

$$
C(t) = \frac{\partial g}{\partial x}\Big|_0 = \begin{bmatrix} \frac{\partial g_1}{\partial x_1} & \frac{\partial g_1}{\partial x_2} & \cdots & \frac{\partial g_1}{\partial x_n} \\ \frac{\partial g_2}{\partial x_1} & \frac{\partial g_2}{\partial x_2} & \cdots & \frac{\partial g_2}{\partial x_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial f_n}{\partial x_1} & \frac{\partial g_n}{\partial x_2} & \cdots & \frac{\partial g_n}{\partial x_n} \end{bmatrix}\Big|_0
$$

Then the perterbation variables are defined as:

$$\delta x(t) = x(t) - x^0(t)$$
$$\delta u(t) = u(t) - u^0(t)$$
$$\delta y(t) = y(t) - y^0(t)$$

The final linearized system is:

$$\delta \dot{x}(t) = A(t)\delta x(t) + B(t)\delta u(t)$$
$$\delta y(t) = C(t)\delta x(t)$$

$$\dot{x}(t) = A(t)x(t)$$
$$x(t) = \Phi(t, t_0)x_0$$
$$\Phi(t, t_0) = x(t)x(t_0)^-1$$

The system is

$$\dot{x}(t) = A(t)x(t) + B(t)u(t)$$
$$y(t) = C(t)x(t)$$
$$x(t_0) = x_0$$
$$where the solution is,$$

$$x(t) = \Phi(t, t_0)x_0 + \int_{t_0}^{t} \Phi(t, \tau)B(\tau)u(\tau)\, d\tau$$
$$y(t) = C(t)\Phi(t, t_0)x_0 + \int_{t_0}^{t} \underbrace{C(t)\Phi(t, \tau)B(\tau)}_{(G(t,\tau))} u(\tau)\, d\tau$$

The above two equations are called the **variation of constants formulas**. They contain two terms, the first term is the **free response** which is due to $x_0 and the second term is the$**forced resonse**$due to the input u(t). Additionally, the$**impulse response is**$defined as$

The basic equation is:

$$\Phi(t, \tau) = e^{A(t-\tau)}$$
$$Which can be calculated using :$$

$$\mathcal{L}^{-1}\left[(sI - A)^{-1}\right] = e^{At}$$
$$After this, : math : `\tau` must be added in, which can be done with by$$

taking the inverse of $\Phi(\tau, 0) to get \Phi(0, \tau) and then multiplying by \Phi(t, 0) as :$

The STM is the unique solution to

$$\frac{\partial}{\partial t}(\Phi(t, t_0)) = A(t)\Phi(t, t_0)$$
$$with initial conditions : math : `\Phi(t_0, t_0) = I`.$$

To solve:

- multiply the above matrices out
- take the Laplace Transform of each element in the matrix
- solve the algebreic equation for each $\Phi_{i,i}(s)$

- take the inverse Laplace transfrom to find $\Phi_{i,i}(t)$

$$\Phi(t_0, t_0) = I$$
$$\Phi(t, t_0)^-1 = \Phi(t_0, t)$$
$$\Phi(t, t_0) = \Phi(t, t_1)\Phi(t_1, t_0)$$

The system Eqn. [eq:sys1] is stable if, given x(t_0) = $x_0, x(t)(Eqn.[eq : sol1])isboundedisbounded\forall t \geq t_0.Inthiscase,$

may not go to zero. Stability can also be determined by looking at each (i,j) component of the STM as:

$$|\Phi_{ij}(t, t_0)| \leq k < \infty, \forall t_0 \leq t$$

The system Eqn. [eq:sys1] is asymtotically stable if, given x(t_0) = $x_0x(t), x(t)(Eqn.[eq : sol1])decaystozero, thatis$:

The system, Eqn. [eq:sys1], is BIBO stable if when $x_0 = 0, theforcedoutputresponsey(y)toeveryboundedinputu(t)isbounded.This$
$theaboveequationrequiresthatG(t, \tau)isıabsolutelyintegrable.$]

Can we estimate a unique x(t_0) = $x_0, givenu(t)andy(t)overthetimeinterval[t_0, t_1]?Ifwehavex_0wecansolve$

The observability matrix for a LTI system is:

$$\mathcal{O} = \begin{bmatrix} C \\ CA \\ \vdots \\ CA^{n-1} \end{bmatrix}$$

$$ifthe : math : `rank(\mathcal{O}) = n`thenthesystemisobservable.The$$

unobservable states are in the null space of the observability matrix, i.e. $Ox_0 = 0$

Observability Gramian

$$M(t_0, t_1) = \int_{t_0}^{t_1} \Phi^T(t, t_0)C^T(t)C(t)\Phi^T(t_0, t)dt$$

$$astate : math : `x_0 = x(t_0)`unobservableattime : math : `t_0`iff$$

$$M(t_0, t_1)x_0 = 0, \forall t_1 > t_0$$
$$so, theunobservablestatesareinthenull - spaceoftheObservability$$

Gramian. If the only solution that lives in the null-space is the zero vector x(t_0) = $0, thenthesystemiscompletelyobservable.Also, notethattherisnoneedtocarryoutthecompleteintegraltoseethattheObservabili$

A system is controllable if we can find a u(t) that drives the state x(t) from $x_0 infinitetime t_f$.

The observability matrix for a LTI system is:

$$\mathcal{C} = \begin{bmatrix} B & BA & \dots & BA^{n-1} \end{bmatrix}$$
$$if the : math : `rank(\mathcal{C}) = n` then the system is controllable.$$

Recall that the rank of a matrix is the number of linearly independent columns.

Controllability Gramian

$$W(t_0, t_1) = \int_{t_0}^{t_1} \Phi^T(t, t_0) B(t) B^T(t) \Phi^T(t_0, t) dt$$
$$this matrix is always symmetric and positive definite. The system is$$

completly controllable if there exists $t_1 > t_0 : W(t_0, t_1) > 0. If the system is controllable at t_0, then one control that drives the state to t$

Given a LTV system as

$$\dot{x}(t) = A(t)x(t) + B(t)u(t)$$
$$y(t) = C(t)x(t)$$
$$its dual system is$$

$$\dot{x}(t) = -A^T(t)x(t) + C^T(t)u(t)$$
$$y(t) = B^T(t)x(t)$$
$$The controllable (or uncontrollable) states of one system are the$$

observable (or unobservable) states of the other system.

If x is a random vector with a PDF f(x) and g:$\mathrm{R}_n \to \mathbb{R}_m is a function of x$

$$\bar{x} = E[x] = \int_{\mathbb{R}_n} x f(x)\, dx \in \mathbb{R}_n$$
$$P_{xx} = E[(x - \bar{x})(x - \bar{x})^T]$$
$$= \int_{\mathbb{R}_n} (x - \bar{x})(x - \bar{x})^T f(x)\, dx \in \mathbb{R}_{nxn}$$

Note: the covariance matrix is symmetric as well as positive semidefinite, so

$$\forall v \in \mathbb{R}_n, v^T P_x v \geq 0$$
$$Thus,$$

$$v^T P_x v = \int_{R_n} v^T (x - \bar{x})(x - \bar{x})^T v f(x)\, dx$$
$$= \int_{R_n} (x - \bar{x})^2 f(x)\, dx \geq 0$$

If x1 and x2 are subvectors of x

$$P_{x_1 x_2} = E[(x_1 - \bar{x_1})(x_2 - \bar{x_2})^T]$$
$$= \int_{\mathbb{R}_n} (x_1 - \bar{x_1})(x_2 - \bar{x_2})^T f(x)\, dx \in \mathbb{R}_{n_1 x n_2}$$

$$P^+ = ((P^-)^{-1} + C^T R^{-1} C)^{-1}$$

The relative likelyhood that a random variable x will take on vaules on a given interval.

$$Area = P(a \leq x \leq b) = \int_a^b f_x(x)dx$$

If you integrate over the PDF over the entire range then it must equal 1 and the PDF must always be greater than 0.

$$\int_{\mathbb{R}} f_x dx = 1 \forall x, f_x(x) \geq 0$$

For a PDF uniformly distributed over [a,b], f(x)=constant=c. c can then be determined by $\int_a^b c dx = 1 which results in f(x) = \frac{1}{b-a}$.

Given the joint PDF $f_x(x) = f_x(x_1, x_2), the marginal PDF of x_1 is$:

$\phi_x(s) is useful to compute the PDF for x and the Gaussian distribution. The expected value can be used to calculate the characteristi$
n

The statistal properties of x are equivalently specified by PDF f(x) or by the characteristic function $\phi_x(s)$.

Similar to a Fourier Transform $\phi_x(s) can be put back into the time domain with$:

If the following equations are true, then the PDF's are independent.

$$f(x, y) = f_x(x) f_y(y)$$
$$\phi_{xy}(s, r) = \phi_x(s)\phi_y(r)$$

If x and y are independent, the conditional density function and conditional mean satisfy:

$$f(x|y) = \frac{f(x,y)}{f_y(y)} = \frac{f_x(x)f_y(y)}{f_y(y)} = f_x(x)$$
$$E[x|y] = \int_{\mathbb{R}_n} x f_x(x)\, dx = E[x] = \bar{x}$$

If x and y are independent, then they are uncorrelated. But, if they are uncorrelated, they may not be independent!
If x and y are uncorrelated, then they satisfy:

$$E[xy^T] = E[x]E[y^T]$$

If x and y are uncorrelated, the cross-covariances must be zero:

$$\begin{aligned} P_{xy} &= E[(x - \bar{x})(y - \bar{y})^t] \\ &= E[xy^T - x\bar{y}^T - \bar{x}y + \bar{x}\bar{y}^T] \\ &= E[xy^T] - E[x]\bar{y}^T - \bar{x}E[y^T] + \bar{x}\bar{y}^T \\ &= E[xy^T] - \bar{x}\bar{y}^T - \bar{x}\bar{y}^T + \bar{x}\bar{y}^T \\ &= E[xy^T] - \bar{x}\bar{y}^T = 0 \end{aligned}$$

Why model the probablity densit function as a Gaussian (or normal) distribution:

- provides a good statistical model for many natural phenomina
- computationally tractable because the statistical properties are described completely by first (mean,) and second (variance, P) moments
- normality is preserved through linear transforms (both static and dynamic)

A random vector x $\in \mathbb{R}_n is Gaussian distributed or normal if the characteristic function has the form : P = [(x - \bar{x})(x - \bar{x})^T]$.

For such a random vector, we use the notation x=N(,P).

Two vectors x and y are jointly Gaussian distributed if $(x^T, y^T) is Gaussian.$

When a random vector x is Gaussian and it's covariance matrix $P_x is nonsingular, it's PDF can be evaluated with :$

If $P_x is singular, then the above equation will not work, but the characteristic function can define the Gaussian distribution in direc$

In a random process, we are looking at a family of random vectors (x(t),t$\in I) indexed by time.$

$$P(t,\tau) = E[(x(t) - \bar{x}(t))(x(t) - \bar{x}(t))^T], t \in I$$

For two random processes x(t) and y(t)

$$P_{xy}(t,\tau) = E[(x(t) - \bar{x}(t))(y(t) - \bar{y}(t))^T], t \in I$$

Which satisfies:

$$P(t) = E[x(t)x^T(t)] - \bar{x}(t)\bar{x}^T(t)$$

Which satisfies:

$$P_{xy}(t) = E[x(t)y^T(t)] - \bar{x}(t)\bar{y}^T(t)$$

todo..

todo..

This section combines the ideas of **Gaussian distribution** and **random process**

- a random process is x(t) is **Gaussian** if all of the vectors $x_1(t), \ldots x_n(t) are jointly Gaussian$
- a Gaussian random process is **white** if the vectors $x(t_1), \ldots x(t_m) are independent, otherwise it is$ **colored**
- for a **Gaussian** and **white** process, the **covariance kernal** satisfies

$$P(t,\tau) = 0, t \neq \tau$$
$$P(t,\tau) = Q(t)\delta(t - \tau)$$

- a random process is **Markov** if

$$f(x(t_m)|x(t_{m-1}), ..., x(t_1)) = f(x(t_m)|x(t_{m-1}))$$

- a random process is **Gauss-Markov** if it is both **Gauss** and **Markov**

The standard model is:

$$\dot{x}(t) = A(t)x(t) + B(t)u(t) + w(t), t \geq t_0$$
$$y(t) = C(t)x(t) + v(t)$$

1. the intial condition x(t_0)$isGaussian$

the disturbance w(t) is a zero-mean, Gaussian, white process that is independent of x(t_0)$covariance\sigma_w given for the second state variable then$

the measurment noinse v(t) is a zero-mean, Gaussian, white process that is independent of x(t_0)

the processes v(t) and w(t) are uncorrelated

$$E[w(t)v^T(t)] = 0$$

With the standard model and assumptions, the process x(t) is **Markov**.

Recall the variation of consants formula:

$$x(t) = \Phi(t, t_0)x(t_0) + \int_{t_0}^{t} \Phi(t, \tau)B(\tau)u(\tau)d\tau + ...$$
$$+ \int_{t_0}^{t} \Phi(t, \tau)w(\tau)d\tau$$
$$Then,$$

$$x(t_m) = \Phi(t_m, t_{m-1})x(t_{m-1}) + ...$$
$$+ \int_{t_{m-1}}^{t_m} \Phi(t_m, \tau)(B(\tau)u(\tau) + w(\tau))d\tau$$
$$Noticethattheresultsdoesnotdependon : math : `x(\tau)`,$$

$\tau < t_{m-1}$.

Also refered to as the expected value.

$$\bar{x}(t) = \Phi(t, t_0)\bar{x}(t_0) + \int_{t_0}^{t} \Phi(t, \tau)B(\tau)u(\tau)d\tau$$

$$\bar{y}(t) = E[C(t)x(t) + v(t)] = C(t)\bar{x}(t)$$

Using x(t)-(t) we can define:

$$P(t) = \Phi(t, t_0)P(t_0)\Phi^T(t, t_0) + \int_{t_0}^{t} \Phi(t, \tau)R_w(\tau)\Phi^T(t, \tau)d\tau$$
$$Theaboveequationalsosatisfies the Lyapunov Equation.$$

For the output y(t):

$$P_y(t) = C(t)P(t)C^T(t) + R_v(t)$$

with the standard model and assumptions, the covariance matrix satisfies:

$$\dot{P}(t) = A(t)P(t) + P(t)A^T(t) + R_w(t)$$
$$Whichcanbederivedusingthe**LeibnizIntegralRule**.$$

To find the steady state covariance matrix:

- set (t)=0
- then solve for P_{ss}
  - this will require a computer!

For the state x(t):

$$P_x(t,\tau) = \Phi(t,t_0)P(t_0)\Phi^T(t,t_0) + \int_{t_0}^{t} \Phi(t,\sigma)R_w(\sigma)\Phi^T(t,\sigma)d\sigma$$

For the output y(t):

$$P_y(t,\tau) = C(t)\Phi(t,t_0)P(t_0)\Phi^T(t,t_0)C^T(\tau) +$$
$$\int_{t_0}^{t} C(t)\Phi(t,\sigma)R_w(\sigma)\Phi^T(t,\sigma)C^T(\tau)d\sigma + R_v(t)\delta(t-\tau)$$

After evaluating f(x,y)$\frac{}{f_y(y),theresultisPDFofaGuassianvectordefinedas:}$

$$P_{x|y} = P_x + P_{xy}P_y^{-1}P_{yx}$$

Basic estimation procedure is:

1. determine $^- = \bar{x}whichisanestimateofthestate$
   2. based off of state equations
   3. affected by state uncertainty, w(t)

collect measurments from output equation y(t)

update estimate of state $(^-)basedoffofnewinfofromy(t)$

based off of output equation

affected by sensor uncertainty, v(t)

Measurments are incorporated simultaneously.

$$\hat{x}^+ = \hat{x}^- + k(z - C\hat{x}^-)$$
$$P^+ = P^-C^T(CP^-C^T + R)^{-1}$$
$$where,:math:`k = P^-C^T(CP^-C^T + R)^{-1}`orinanalgebraically$$

equivalent form,

$$\hat{x}^+ = (P^+(P^-)^{-1})\hat{x}^- + (P^+C^TR^{-1})z$$
$$P^+ = ((P^-)^{-1} + C^TR^{-1}C)^{-1}$$
$$where:math:`R`isthecovarianceofthesensormeasurmentfrom$$

y(t)

also note: z=y

Measurments are incorporated recursively.