Autonomous Robotic Systems 2022/2023
Master in Electrical and Computer Engineering
Software Installation Guidelines

Software requirements, for this course:

- MatLab (2021b or later) [~7GB of disk space].
- Virtual Machine Player software (VMware Player/Fusion).
- ROS - Robot Operating System (ROS 1 Melodic) [image file w/ ~25GB of disk space]
- Gazebo 9 - Robot simulation software [included in the image file].
- 'TurtleBot3 v0x.zip' package [ROS interface between MatLab and the TurtleBot robot], available at: https://home.isr.uc.pt/~pedromartins/software/turtlebot3

Note: The installation of ROS + Gazebo is not a trivial task, specially for inexperienced linux users. It is recommended to use a pre-installed virtual machine (w/ Ubuntu 18 Bionic) image, which the download link, is available bellow.

1. MatLab Installation (2021b or later)

Go to the Mathworks website, login with your student account, download and install the latest version.
https://www.mathworks.com/products/get-matlab.html?s_tid=gn_getml

The following toolboxes are required:
- Image Processing Toolbox.
- Robotics System Toolbox.
- ROS ToolBox.

2. Virtual Machine (VM) image

2.1. Download VM image

Download the virtual machine image with ROS and Gazebo already installed (on a guest OS: Ubuntu 18 Bionic).

VMware compressed image (7.8GB):
https://web.deec.uc.pt/software/ros_melodic_dashing_gazebov9_linux_win_v4.zip

This file needs to be uncompressed, which results in a folder with 25GB.

2.2. Virtual Machine player (software to run the VM image)

- Windows and Linux users could use VMware Player software (free).
- MacOS users have the equivalent VMware Fusion Player (free for students).
- Alternative: VirtualBox for all systems (free and open source), however, users must download a specific virtual image file (see reference links at the end of document).

Download and install VMware Player software
https://www.vmware.com/go/getplayer-win (windows 64-bits)
https://www.vmware.com/go/getplayer-linux (linux 64-bits)

Download and install VMware Fusion Player (mac 64-bits)
(requires creating an account)
https://customerconnect.vmware.com/web/vmware/evalcenter?p=fusion-player-personal
(press licence & download option)

- Decompress the archive to a location on your hard drive.
- Start VMware Player.
- In VMware Player, press Open a Virtual Machine.
- Browse to the location of the Ubuntu image, select the ros_melodic_dashing_gazebov9.vmx file.
- Start the virtual machine.
- (Press “I copied it”, if a window opens that asks if you copied or moved the virtual machine)

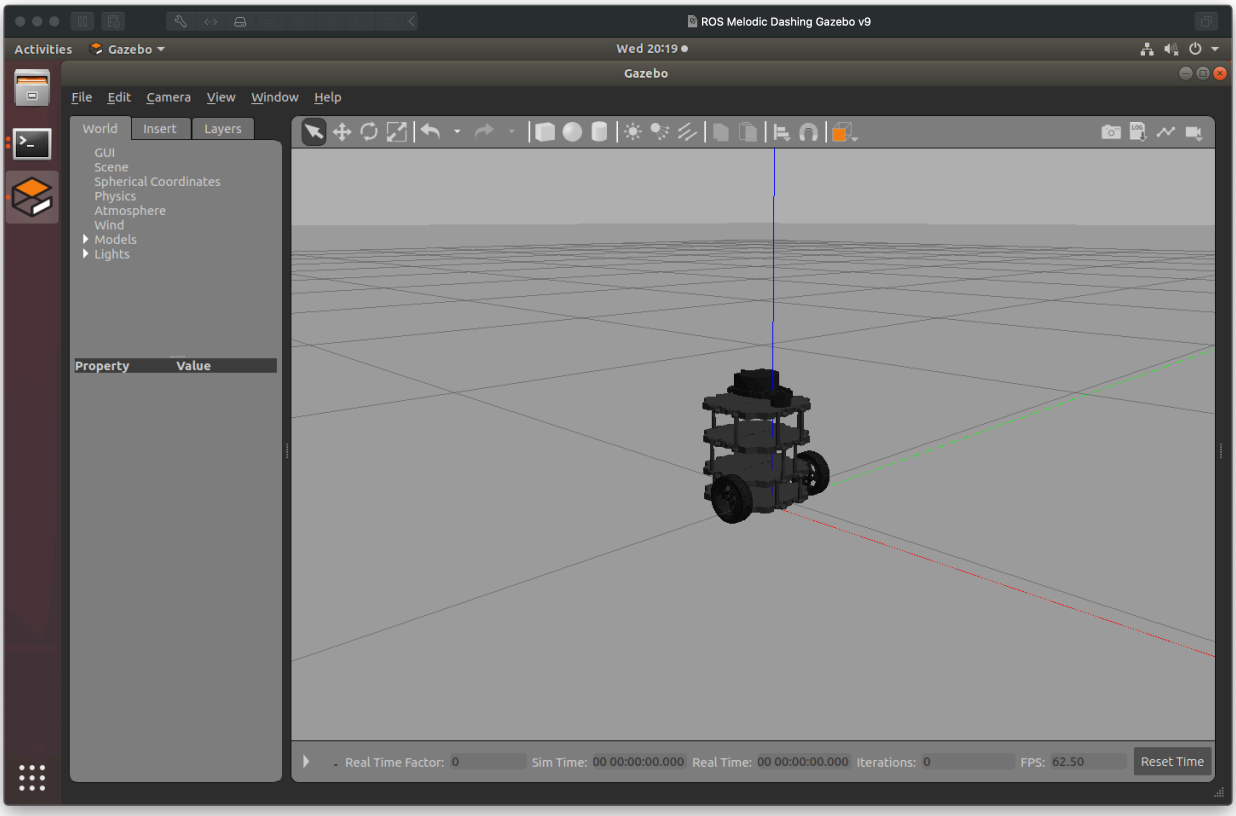
2.3. Run Virtual Machine (VM)

Check VM settings before running the first time.
- 2 processors w/ 4GB RAM is enough (in older machines select just 1 CPU and 2GB RAM).
- [Optional] Choose Bridged Network (autodetect) in the network adapter section.
  Bridged network allows the VM IP address to be in the same range that the host machine.

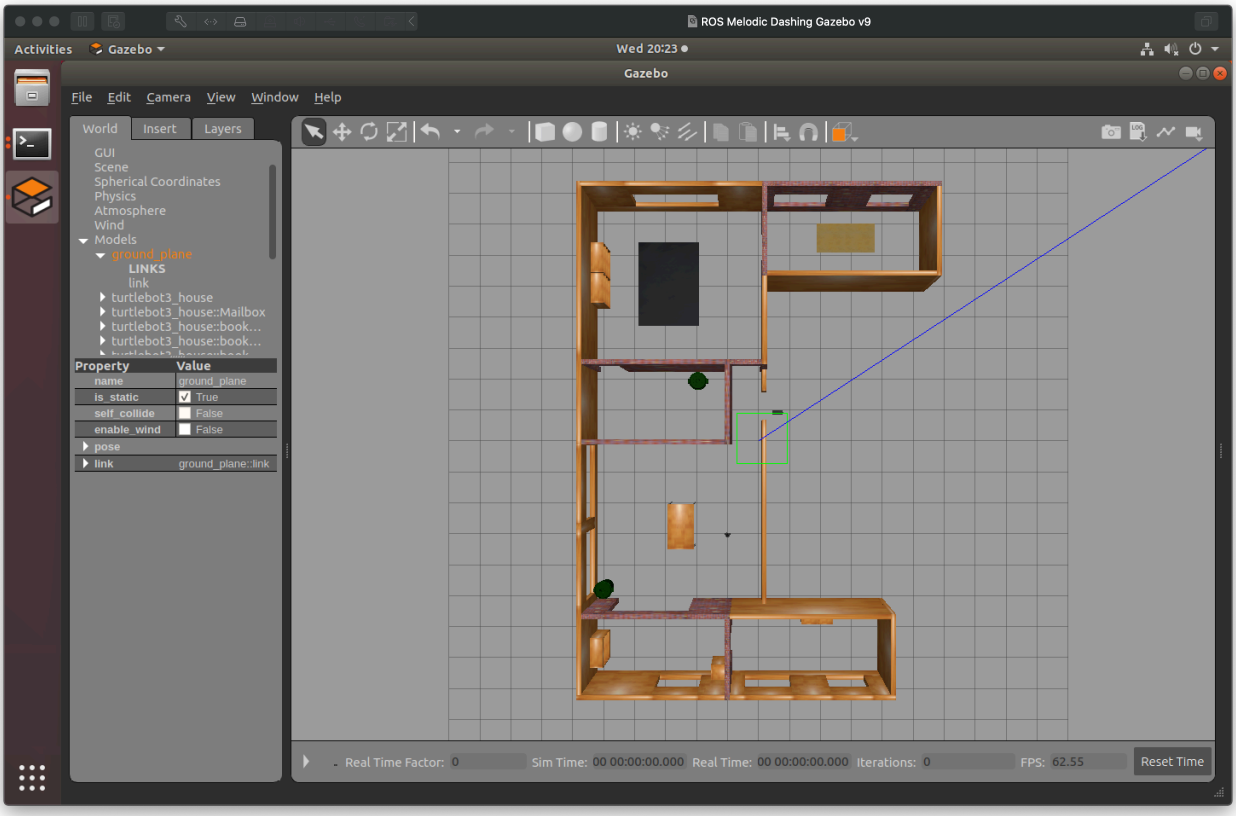
- Launch the virtual machine.
- Check the username, password and IP address (shown at the wallpaper’s top right)
- Update, if required, the keyboard layout, in Settings App (language and region - input sources).
- The display resolution could be adjusted in the Settings App > Devices > Screen Display.

- Open terminal, and run the start-up (empty) Gazebo world:
  `user@ubuntu:~$ ./start-gazebo-empty.sh`

- For TurtleBot3 examples, use the previous Gazebo Empty or Gazebo House scripts (`start-gazebo-house.sh`)



Gazebo simulation, in an empty world, with the Turtlebot3 robot.



House world simulation with Turtlebot3.

3. Download ‘TurtleBot3 v0x.zip’ MatLab package

The ‘TurtleBot3 v0x.zip’ includes:
- MatLab class (`TurtleBot3.m`) file. Main class that allows to interface between MatLab and the TurtleBot robot (real/simulated).
- Multiple 2D & 3D maps (maps folder).
- Tools folder (utility functions).
- Code demo examples.

3.1 Download package

The ‘TurtleBot3 v0x.zip’ is available at course repository webpage (https://ucteacher.uc.pt/).
Download it, uncompress all files and copy them to the MatLab working folder.

3.2 Install 3D maps (required for lab #2 and later)

3.2.1. Copy the entire "maps" folder to the virtual machine (to any location):

- Some virtual machines also support simple drag-and-drop functionality.
- Windows users can use WinSCP (https://winscp.net/) to copy data between you computer and the virtual machine (use a sftp connection).
- MacOs users can use the free Cyberduck App.
- Linux users just need to write in the location path: sftp://user@192.168.1.xxx (replace with the IP of virtual machine).
- Some virtual machines also support simple drag-and-drop functionality.

3.2.2. Open terminal, navigate to the directory location of the maps folder, and run the install script as:
>> user@ubuntu:~$ sh install_maps.sh
The message "---done---" should appear upon a successful installation.
The home folder (/home/user) should hold eight new scripts (start-gazebo-"map".sh).

[3.2.2. Uninstall 3D maps]
Similarly, all maps and respective configuration files can be removed by running the uninstall script.
>> user@ubuntu:~$ sh uninstall_maps.sh

3.3 [Extra] Compile (*) Auxiliary ROS Message (access to encoders data w/ real TurtleBot)

* Only supported in linux64 and mac64 systems. Requires python** and cmake.
(** Matlab 2021b requires python 2.7. Matlab 2022b requires python 3.9).

3.3.1. Check which python and cmake versions are installed (and detected by MatLab):
`TurtleBot3('check-versions');`
If all packages are installed but not detected, go to the `setupPath()` function (in `TurtleBot3.m`) and modify the PATH settings according to your system.
After that run: `TurtleBot3('setup-path');`

3.3.2. Compile auxiliar sensors-state ROS message:
`TurtleBot3('setup-sensors-msg');`

3.3.3. Check if new ROS message is available:
`TurtleBot3('check-sensors-msg');`

4. Run MatLab demos:

In the provided demos, the TurtleBot is initially controlled under a MatLab environment, that issues commands (thought ROS) to the Gazebo simulator. Later on, this procedure is extended to the real robot.

- Edit each `demoXXX.m` file and update the local host and virtual machine IP addresses (i.e. modify the `IP_OF_TURTLEBOT` and `IP_OF_HOST_COMPUTER` string variables).
- The IP address of you machine can be found using the `ifconfig` terminal command (linux and Mac) or `ipconfig` (Windows).
- **Note** (Windows users): Accept firewall rules for `libmwros1server` service in both private and public network profiles, when asked for the first time.

4.1. Read robot location (pose)

- Launch the virtual machine.
- Open terminal, and start the empty Gazebo world (`./start-gazebo-empty.sh`).

- Launch MatLab (host machine)
- Run the `demoPose.m`

4.2. Read lidar data

- Launch the virtual machine.
- Open terminal, and start the house Gazebo world (`./start-gazebo-house.sh`).

- Launch MatLab (host machine)
- Run the `demoLidar.m`

4.3. Teleoperation with keyboard

- Launch the virtual machine.
- Open terminal, and start the house Gazebo world (`./start-gazebo-empty.sh`).

- Launch MatLab (host machine)
- Run the `demoKeyboardOperation.m`

4.4. Add 3D virtual obstacles

- Launch the virtual machine.
- Open terminal, and start the empty Gazebo world (`./start-gazebo-empty.sh`).

- Launch MatLab (host machine)
- Run the `demoGazeboObjects.m`

5. Operate with real TurtleBot robot

There are 2 TurtleBot robots available, which are configured to connect via the `TurtleNet` WIFI network. They have the following (static) IP address:

```
tbot1: 192.168.1.200
tbot2: 192.168.1.201
```

5.1. Connect to TurtleNet WIFI network

Use the following network information:

```
SSID: TurtleNet
password: turtleSRA
```

Upon connection, your machine should have an IP in range of 192.168.1.xxx.
This is you `IP_HOST_COMPUTER` value.

5.2. Connect to a robot via secure-shell protocol (ssh)

In Windows, an external ssh client is required. Use Putty (https://www.putty.org/).
Fill the Host name / IP Address text box with `192.168.1.200` when using TurtleBot1 (or `192.168.1.201` for TurtleBot2) and then click Open.
The username is `pi` and the password is `qwerty`

In Linux and MacOs, simply open a terminal session and write:

```
>> ssh pi@192.168.1.200     # [tbot1]. Use 192.168.1.201 for tbot2
>> password = qwerty
```

5.2.1. Startup ROS server

Upon connection by ssh, start the ROS server by typing in the following command:

```
>> roslaunch turtlebot3_bringup turtlebot3_robot.launch
```

Wait for startup, while a set of log messages are being shown. Proceed after receiving `'[INFO] [xxx]: Calibration End'` status. The ROS server is now running.
The shell session should remain open during the entire operation with the robot.

For terminate ROS server, press: **`[ctrl + c]`**

5.3. Connect using MatLab

Update your code with updated connection settings:

```
IP_TURTLEBOT = "192.168.1.200";                    % TurtleBot IP
IP_HOST_COMPUTER = "192.168.1.xxx";                % local machine IP
tbot = TurtleBot3(IP_TURTLEBOT, IP_HOST_COMPUTER); % init connection
```

Run as standard.

5.4 Shutdown TurtleBot

Termine the ROS server (by pressing **`[ctrl + c]`** in the previous shell session).

Shutdown robot Operation System:

```
>> sudo shutdown now
```

Power down OpenCR (robot's controller):

```
Turn off power switch.
```

6. References (and useful links):

TurtleBot3 resources:

https://emanual.robotis.com/docs/en/platform/turtlebot3/features/#features
https://emanual.robotis.com/docs/en/platform/turtlebot3/simulation/

MathWorks:

https://www.mathworks.com/help/ros/ug/get-started-with-gazebo-and-a-simulated-turtlebot.html
https://www.mathworks.com/help/ros/ug/communicate-with-the-turtlebot.html

VMware compressed original Ubuntu18+ROS+Gazebo image file (7.8GB) [MathWorks server]:

https://ssd.mathworks.com/supportfiles/ros/virtual_machines/v2/ros_melodic_dashing_gazebov9_linux_win_v4.zip

VMware Fusion (download archive):

https://customerconnect.vmware.com/downloads/info/slug/desktop_end_user_computing/vmware_fusion/12_0

VirtualBox Ubuntu+ROS+Gazebo image file:

https://web.deec.uc.pt/software/ros_melodic_dashing_gazebov9_mac_v4.ova

- Start VirtualBox.
- In VirtualBox, select the Import Appliance entry in the File menu.
- Verify the virtual machine settings and press Import (might take a few minutes).
- Start the virtual machine.

VirtualBox for macOS users (download and install dmg file):

https://download.virtualbox.org/virtualbox/6.1.18/VirtualBox-6.1.18-142142-OSX.dmg

Alternative links (with vm images and vm player software):

https://mega.nz/folder/DVEmXZgR#CTO0cXiQRVT3PKujQYtDsw

Disable IPv6 on Ubuntu:

https://itsfoss.com/disable-ipv6-ubuntu-linux/

Manually Install ROS (Melodic) + TurtleBot3 Simulation Package (in Ubuntu 18 LTS):

http://wiki.ros.org/melodic/Installation/Ubuntu
https://emanual.robotis.com/docs/en/platform/turtlebot3/quick-start/
https://emanual.robotis.com/docs/en/platform/turtlebot3/simulation/#gazebo-simulation