Introductory Simulation of BRAT Research Group Robotics:

- Optimizing Solidworks Projects for Export
- Guide to Beginning ROS & Gazebo Simulation on Windows 7/Virtual Ubuntu 16 (Part One)
- Guide to the Solidworks->URDF->Gazebo Workflow (Part Two)
- Guide to Control of Robotic Simulation (Part Three) (*future work)*

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FORWARD: Optimizing Solidworks Projects for Export

- Before beginning, become familiar with all 3 tutorials at the bottom of this page and download the installer: http://wiki.ros.org/sw_urdf_exporter. For simulation purposes, **organize sub-assemblies by INERTIAL ROBOTIC LINKAGEs in your main Solidworks Assembly.** This makes the placement of coordinate systems and exporter procedure much more fluid.

PART ONE: Setting up ROS Kinetic on a Virtual Machine (VM)

- *The VM is almost always fast enough for quickly verifying/debugging your model in gazebo, but is still severely stunted as it can only access virtual computer resources (no graphics cards, CUDA, etc.). Many robots shared as ROS packages (such as the PISA Hand and Dense Clutter Grasper) require ROS library extensions that need access to such hardware. There are workarounds for VMs, however I have a machine with Linux installed to the hard disc if you want to experiment with any robotic packages that need graphics card or other hardware access.*

1) Download the latest version of the VM we will use, VirtualBox: http://download.virtualbox.org/virtualbox/5.1.24/VirtualBox-5.1.24-117012-Win.exe

2) Download the VirtualBox Extension Pack: http://download.virtualbox.org/virtualbox/5.1.24/Oracle_VM_VirtualBox_Extension_Pack-5.1.24-117012.vbox-extpack

3) Download Ubuntu 16.04 LTS: https://www.ubuntu.com/download/desktop (an .iso disc image)

4) Install VirtualBox 5.1 following the prompts and allow it to start upon completion. Install VirtualBox Extension Pack (which enables USB 2.0 & 3.0 support)

5) Click “New” and follow prompts, you are creating your specific Ubuntu VM (VirtualBox can have many VMs inside it). Choose Name, select Type: Linux, select Version: Ubuntu (##-Bit). Next I recommend setting your RAM to ½ your system’s actual RAM so you can still use both systems simultaneously, but you can change this later if you need to in the Ubuntu VM’s settings by right-clicking it in VirtualBox. I’ve set both my VM’s to 8192.

6) Create a Virtual Hard Disk. Choose VDI. Choose Fixed Size. I chose 25GB which is the default. You can choose any disk/drive for the location, such as a USB if convenient. *If you don’t create this there is nowhere for Ubuntu to install and it will use RAM to load the desktop and user shell, meaning each time you close the virtual machine it is erased back to the factory .iso and has to be reinstalled when the VM boots.*

7) Right-Click your VM once finished and enter ‘settings’. You can adjust the previous settings as well as new ones. Go to ‘System’ then into ‘Processor’ and enable as many CPU cores as you physically have. Go to ‘Display’ and MAX OUT the Video Memory. Go to ‘USB’ and select 3.0. There are more settings tabs to tweak if you need your performance to improve.

8) 'Start' your VM and it will open a new window, navigate to and select your downloaded Ubuntu .iso file as the start-up disc.

9) Ubuntu should have booted and is running out of the allocated virtual RAM. Follow the 'Install Ubuntu' Prompts with all default choices (note: if you were installing linux as Dual-boot alongside windows, this is the point where you risk damaging/deleting your windows OS, but the partitions you see here are virtual/unimportant).

10) Once you must enter personal information you *should* choose your password to be "1" or some others single character. This is because you will need to enter it frequently when giving ROS, Gazebo and other linux commands. The purpose of this password isn't security; it is best to not think of it as a security feature but identification of the Superuser in the Command Terminal over that of the default user (if you choose not to set a password at all, the terminal will still hang and prompt you for one when you use the common 'Sudo' command, but since one doesn't exist you'll be stuck). Allow the Virtual Machine to restart, and then verify that access to your sized virtual hard drive using Nautilus (the Linux equivalent of File Explorer)

11) Upon restart it may ask you to remove installation media. The way I do this is by exiting the VM all together (selecting power off when prompted) and restarting it manually from here, the .iso should now be unloaded. Verify your system is properly installed by going to ubuntu's 'Details' page and look at Memory (should be ~0.2GiB less than your RAM (so mine was 7.8)) and Disk (should be ~2.5 GB less than your virtual hard drive (" 22.5)). Click "Install Updates" to get most recent updates (assuming your Windows OS has internet access, VirtualBox will automatically create an access point for your system so you should already have internet). You may need to restart again.

12) We will now install ROS, which comes with Gazebo. Go here in the VM's browser to begin using the Terminal to install ROS: http://wiki.ros.org/kinetic/Installation/Ubuntu

13) **Press Ctrl+Alt+T** to open Terminal. The format of this website's guide is similar to all Linux guides: text in grey boxes is intended to be copied (ctrl+c as usual in most of Ubuntu, including the browser) and then pasted **(ctrl+SHIFT+v (or +c) for pasting (or copying).** Copy one command line into the terminal at a time and press Enter, and watch as the command is executed. **You should not disregard output to the terminal during this process.** For example, steps that ping online keyservers (such as step 1.3) may fail randomly. Pay attention and rerun steps or seek assistance if any error messages output, this will save you a lot of grief later! That being said, all commands in this guide should only throw errors at the end of their outputs, so you don't have to have your eyes on everything the terminal is outputting.

    When you finish step 1.4 (choosing "Desktop-full install") which **may take a long time**, copy this text into the terminal to install from pre-built debian packages:

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

    It may say you already had 1 of these 2 installed, which is fine.

14) Test gazebo by executing it in terminal: `gazebo` **You must open a new terminal window as this one is now dedicated to your instance of gazebo. Any Gazebo errors or system output is displayed here. Ctrl+C in a terminal window will kill that terminal and its processes.**

PART TWO: Guide to the Solidworks->URDF->Gazebo Workflow

0. *Minimize VM and Return to Windows*
1. Download and briefly read through "URDFGuide.pdf" I highlighted (in TUHandShare/Robotic Simulation folder, the original source (no highlights) is here: http://blogs.solidworks.com/teacher/wp-content/uploads/sites/3/WPI-Robotics-SolidWorks-to-Gazebo.pdf Read through pages 1-7, and create a coordinate system and axis for **each joint**. You will understand this best by looking at the "before and after" comparison of the Finger I exported to see what an export-ready model looks like. These are available in TUHandShare/Robotic Simulation/ExporterPrep folder. *Overall, you should understand the 3 major qualifications for export-ready: 1) Coordinate Systems for each link 2)Axis for each Joint 3)Two models for collision and visual elements that share these axis and Coord. Systems.*

2. After page 7 URDFguide branches. Skip to page 15, which begins going over the way the exporter builds on export-ready model you've created. Use the instructions and sample export procedure on pages 15-22. For inertial purposes, the material of the models in Solidworks must be specified.

3. Page 23 of URDFGuide requires you return to Ubuntu inside your VM, follow the steps and you should end up with a loadable model in gazebo. As mentioned in URDFGuide, this is an iterative process to get all the meshes right!

4. Once you are satisfied with how your model looks and acts in gazebo, you are finished! The URDF export directory you created can be shared like any other folder (e.g. can be made into a .zip for email, etc.) and placed in any compatible system's .gazebo/models folder.

PART THREE: Guide to Control of Robotic Simulation

(Future Work)