RBOT 250 Labs: Robot Manipulation, Planning, and Control.

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Prerequisites

- A Working Knowlegde of C++: Occasionally, we would dabble into using the C++ 1z standards in our coding styles
- A working knowledge of the python programming language
- A working knowledge of the robot operating system (ROS) middleware.
- To ease setup for labs, a dockerized environment has been provided for you that has all the tools you need to get a jumpstart most of the lab exercises in the notes.

Loading the Docker Environment

- Ensure you have a Ubuntu OS. For now, any distro from 14.04+ would do.
- To download and install the Ubuntu OS, hop over to the Ubuntu download page: https://ubuntu.com/download/desktop and follow the download and installation instructions
- When you are done installing ubuntu, be sure to install the docker environment
- Go to this webpage, choose your Ubuntu version, browse to pool/stable/, choose amd64, armhf, arm64, ppc64el, or s390x, and download the .deb file for the Docker Engine - Community version you want to install.

- Install Docker Engine - Community, changing the path below to the path where you downloaded the Docker package.
  - sudo dpkg -i /path/to/package.deb
- Confirm that your installation runs by testing the hello-world-run image: docker run hello-world
- Further instructions can be found on this webpage.

- When you are done, there is a docker image that is already prepared for your use for most of the simulations we would use in this course.
- It can be pulled like so:
  - "docker pull lakehanne/brandeis:melodic"
- Run the image: "docker run -ti –rm

  lakehanne/brandeis:melodic -v /tmp/.X11-unix:/tmp/.X11-unix:ro -e DISPLAY=$DISPLAY –privileged -v /dev/bus/usb:/dev/bus/usb"
- This would launch the image together with usb access and access to your xorg server. The ros installation is at "/opt/ros/melodic" and the catkin workspace is located at "/home/rbot250/catkin_ws/src". This is the directory from which all tutorials shall be launched.

ROS Introduction

- An easier way to run would be to launch the 'docker-run' executable available here: 'https://github.com/lakehanne/Shells/blob/master/docker-run'.
- Follow the instructions that the bash script gives you
- Note that to compile, I have installed the catkin-build tools globally in the image which you can use as follows:
  - 'catkin build'
  - You can also run catkin build with the alias 'cb'
  - To compile just a single package, say dr_kdl, run 'cb dr_kdl'
- Now that you have the ros environment setup, why don't you start playing around with the tutorials at ROS Tutorials Page.

Three Dimensional Conformal Radiation Therapy

- Intensity Modulation: Control external beam's physical delivery
- *Conform* internally uniform fields with MLCs using a projection of target volumes [**?**]
- Improve tumor's local control

../../../Proposal/figures/cfrt_imrt

L-R: Conventional radiotherapy. Conformal radiotherapy (CFRT) without intensity modulation. CFRT with intensity modulation. Reprinted from **?**.

../../../PhDThesis/figure

A multi-leaf collimator for IMRT/3DCRT. ©Varian Medical Systems.

Conformal RT Treatment Planning Parameters

- Optimal treatment *parameters* ▷ good treatment outcome
  - dose-limiting structures
  - OARs within a target volume
  - doctor's dose prescription
  - dose fractionation
  - **patient positioning**
  - **dose distribution**

Frame-based Radiotherapy Treatment

- Accurately irradiate a *moving target* and a *moving patient* with the aid of robots[**??**]

../../IROS2017/Google/figures/frame1.jpg

../../IROS2017/Google/figures/frame2.jpg

Frameless and Maskless Radiotherapy

figures/igrt.png

HexaPOD

../../../PhDThesis/figures/hexapod.png

Cyberknife/Novalis systems

../../../B00/figures/cyberknife.jpg/B00/figures/cyberk

The Novalis ExacTrac Module

../../../Proposal/figures/novalis.png

The Case for Soft Robots

- Frame-based immobilization
  - LINAC misalignments $\implies$ negative dosimetry effects
  - $\times$ Fractionated treatments
- Frameless RT
  - Incompatible with most conventional LINACs
- Cyberknife/Novalis Systems
  - Reliance on pre-treatment images
  - Rigid motion compensation issues
- Involuntary patient motion requires adaptive positioning

[0] Morphological computation, Cephalopods, Adaptive Controller for changing head dynamics: shape, weight etc

Beam Orientation Optimization

- During treatment planning, a **b**eam **o**rientation **o**ptimization problem (BOO) is separately solved
- Radiation is delivered from $\approx (5 - 15)$ different beam orientations during IMRT
- BOO determines the best beam angle combinations for delivering radiation
- Process of determining beamlets' intensities is termed **fluence map optimization** (FMO)