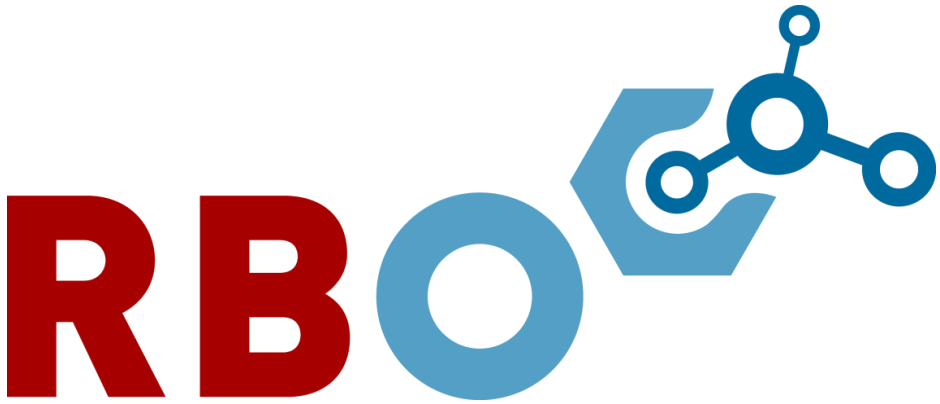
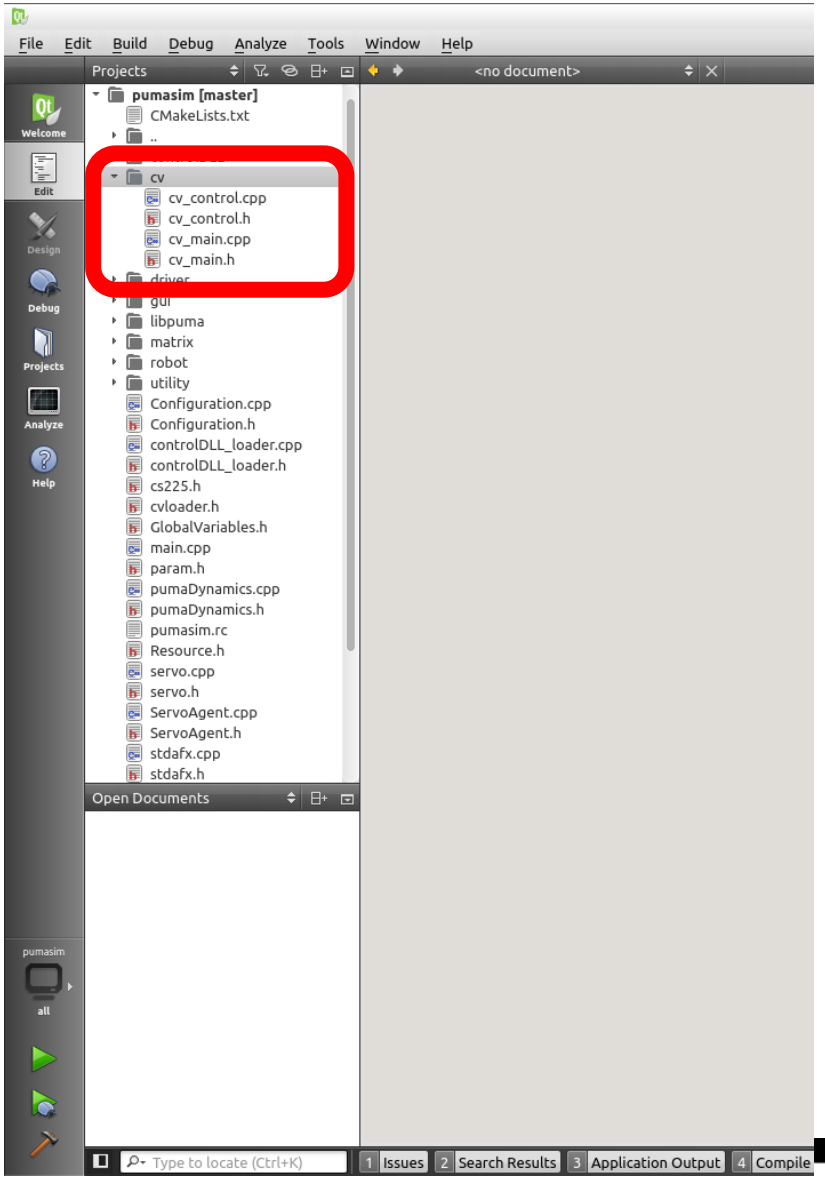


Visual Servoing - Coding

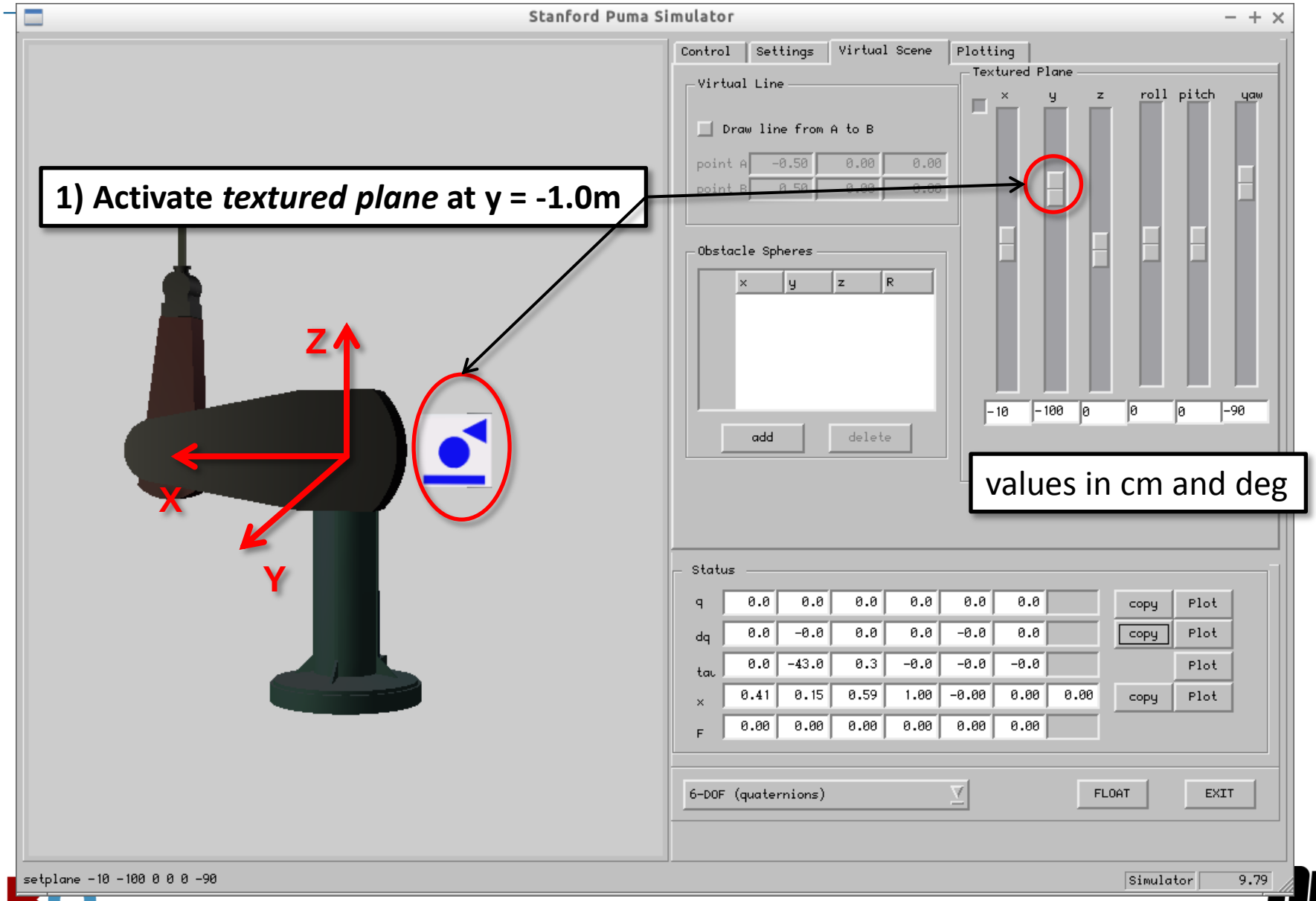
Technische Universität Berlin

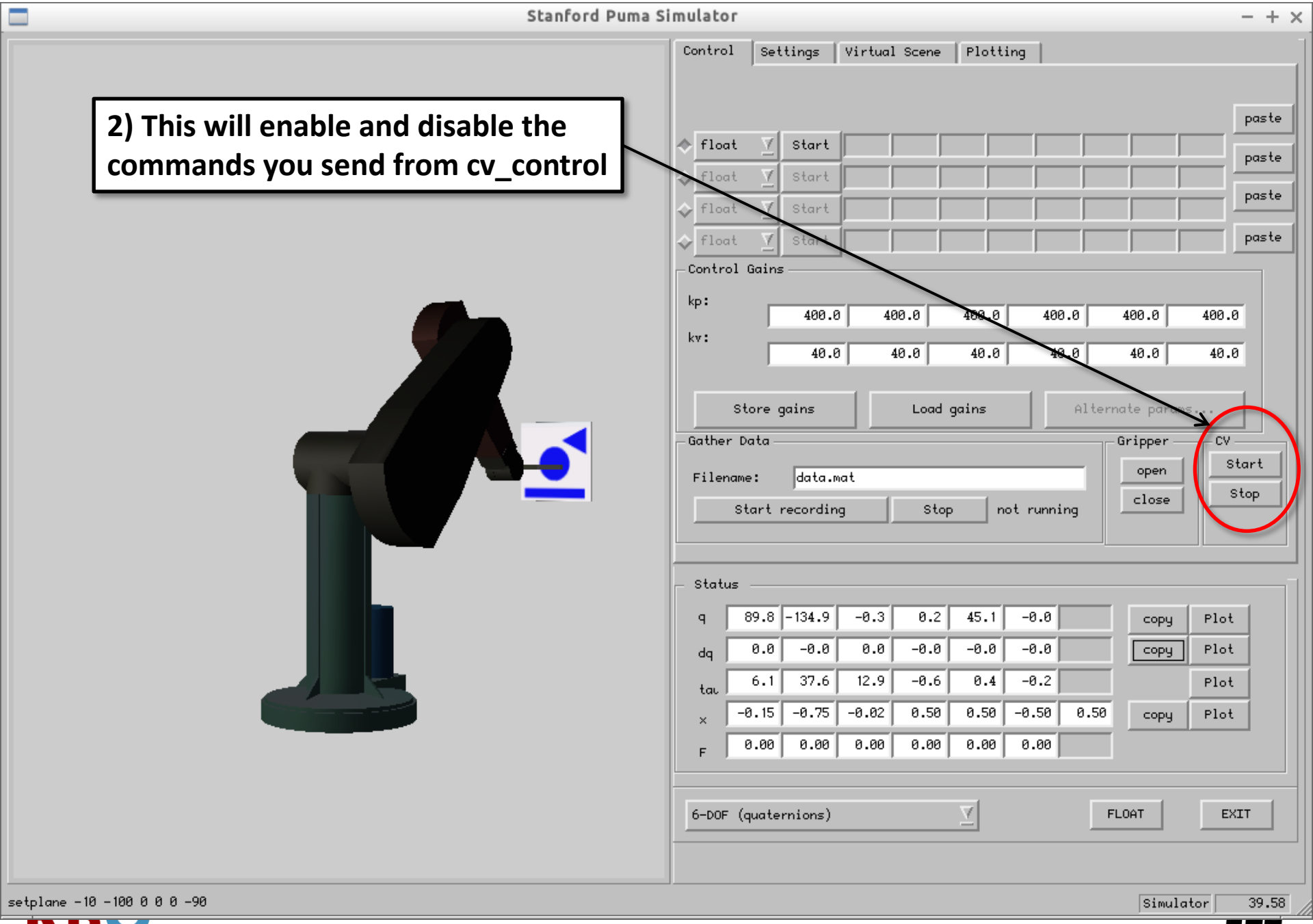
The Extended PUMA Simulator

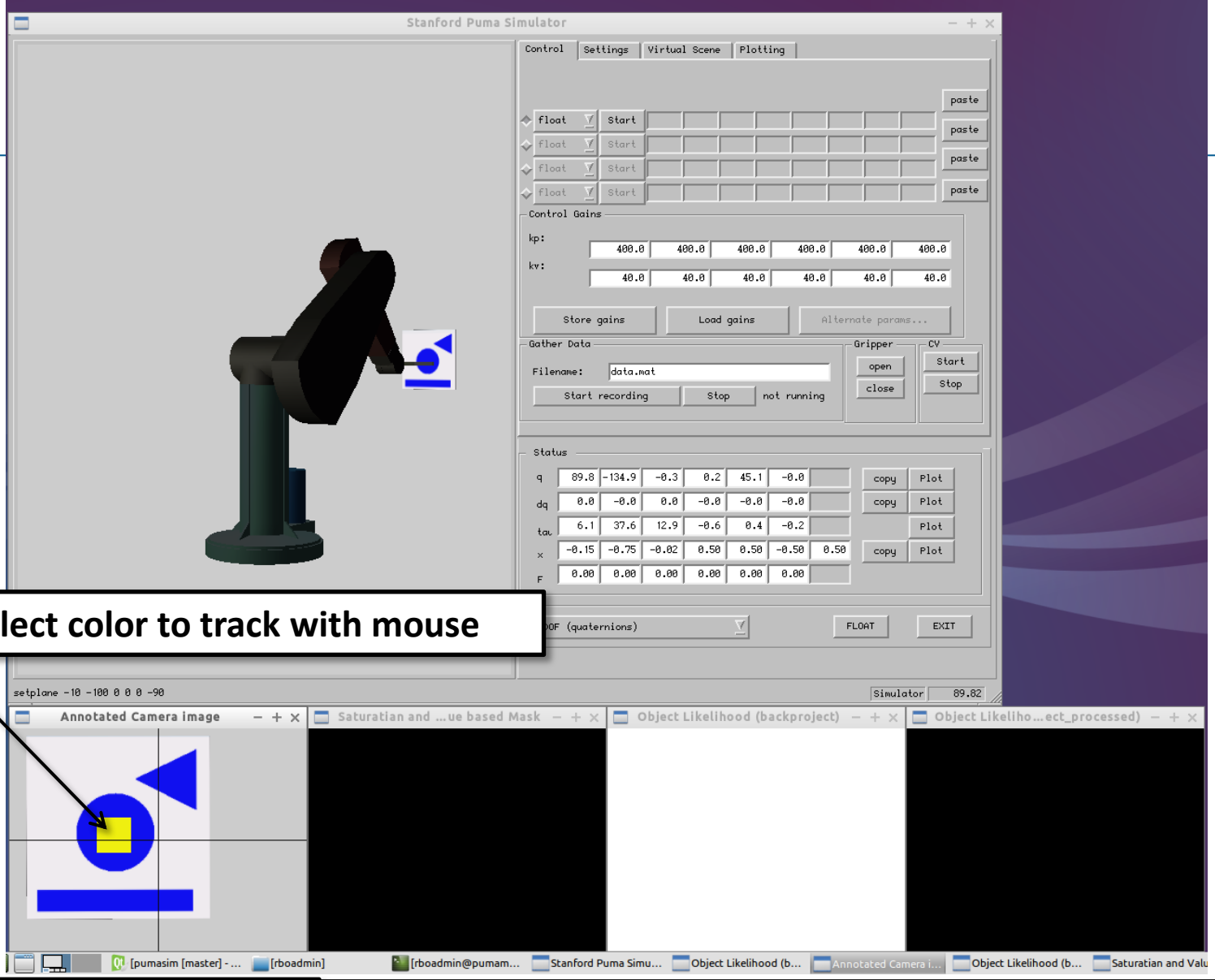
- Folder *cv*
- *cv_control.cpp*: implement stubs for visual feedback loop
  - detect features
  - image jacobian
  - controller commands
- control.cpp
  - process commands from VS



Simulator: Virtual Scene



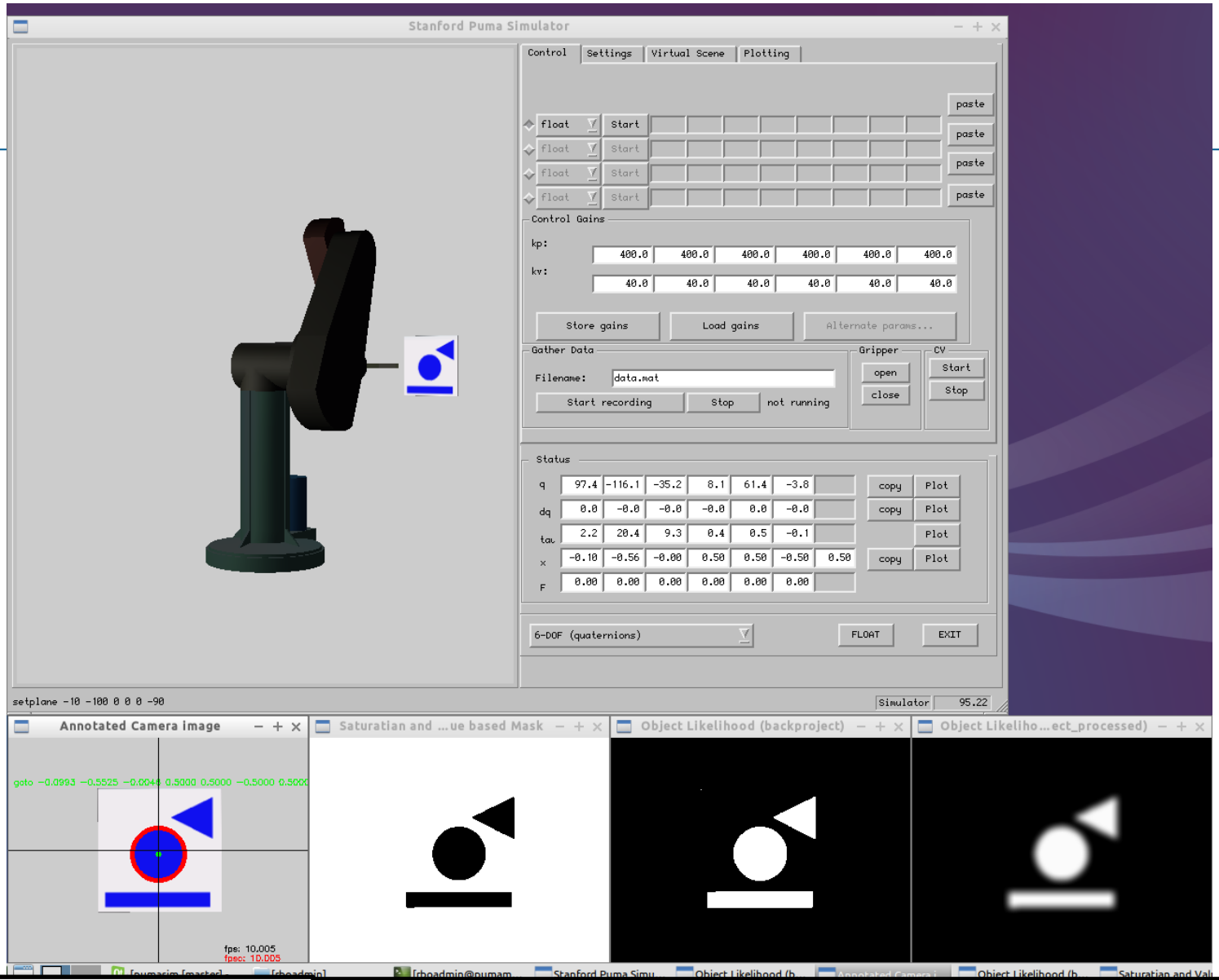

Stanford Puma Simulator
2) This will enable and disable the commands you send from cv_control
Control
Settings
Virtual Scene
Plotting
paste
float
Start
Control Gains
kp:
400.0
kv:
40.0
Store gains
Load gains
Gather Data
Filename:
data.mat
Start recording
Stop
not running
Gripper
open
close
CV
Start
Stop
Status
q
dq
tau
x
F
copy
Plot
6-DOF (quaternions)
FLOAT
EXIT
setplane -10 -100 0 0 0 -90
Simulator
39.58



3) Select color to track with mouse

View of the simulated camera which is mounted on the end-effector

Result of cvCalcBackProject and some image processing



View of the simulated camera which is mounted on the end-effector

Result of cvCalcBackProject and some image processing

Virtual Scene

- The diameter of the circle can be found in the variable length_real
  In the simulation it is 0.107m and in reality 0.15m.
- The position of the plane is relative to the robot base frame

Methods to implement: cv_control.cpp

`bool` **`findCircleFeature`**`(cv::Mat& image, Mat& backproject, Circle &crcl)`

This function detects the circle in backproject and returns true if the circle was found. The circle parameters should be stored in `crcl`. It is only called after you have selected a color in the “Visual Servo” window.

`void` **`getImageJacobian`**`(PrMatrix3 &Jv, float u, float v, float z, float f, float diameter)`

In this function you must assign your image Jacobian to Jv. The parameters `f` and `diameter` are constant and pre-calculated for you.

`float` **`estimateCircleDepth`**`(float f, float diameter, Circle &crcl)`

Here you have to implement the calculation of the depth of the circle.

`void` **`controlRobot`**`(Circle &crcl, PrVector &x, Mat& img, char *cmdbuf)`

You get this from us. Implements the main CV loop. It uses your `getImageJacobian` and `estimateCircleDepth` and the other functions you implement. The function is only called when findCircleFeature returns true. The parameter crcl contains your result of findCircleFeature , cmdbuf is an array of char that should contain the new robot command (this has to switch from command “goto” to “track”).

Methods to implement: cv_control.cpp (2)

void transformFromOpenCVFToFF(PrVector3 vector_opencvf, PrVector3& vector_ff)

Transform a feature vector from openCV frame (origin in upper left corner of the image) to feature frame (origin at the center of the image)

void transformVelocityFromCFToEEF(PrVector3 vector_cf, PrVector3& vector_eef)

Transform the desired velocity vector from camera frame to end-effector frame

You can hard code this transformation according to the fixed transformation between the camera and the end effector (see the sketch in your assignment)

void transformVelocityFromEEFToBF(PrVector x_current_bf, PrVector3 vector_eef, PrVector3& vector_bf)

Transform the desired velocity vector from end-effector frame to base frame

You cannot hard code this transformation because it depends of the current orientation of the end-effector wrt the base

Make use of the current state of the robot x (the pose of the end-effector in base frame coordinates)

Here you have to implement the calculation of the depth of the circle.

control.cpp

- The file contains OperationalSpace control with “track” and “goto”
- add min time for spline t=0.2 in initSpline…
- You are supposed modify “track”

Testing with a real camera

- Change in the CMakeLists.txt the type of build to use the real camera (any webcam should work)

Everybody has to test her/his feature detection algorithm with a real camera **before** the final presentation!

Robot Commands

You have a text based command interface to the robot controller. The syntax is:

```
command param1 param2 …
```

If a new command is received by the controller the corresponding init function is executed once. After that the control function is called with the servo rate of 500Hz.

Example:

```
sprintf(cmdbuf,"goto %.4f %.4f %.4f %.4f %.4f %.4f %.4f",
   0.71,0.15,0.0,0.71,0.0,0.71,0.0);
robotCmd(cmdbuf);
```

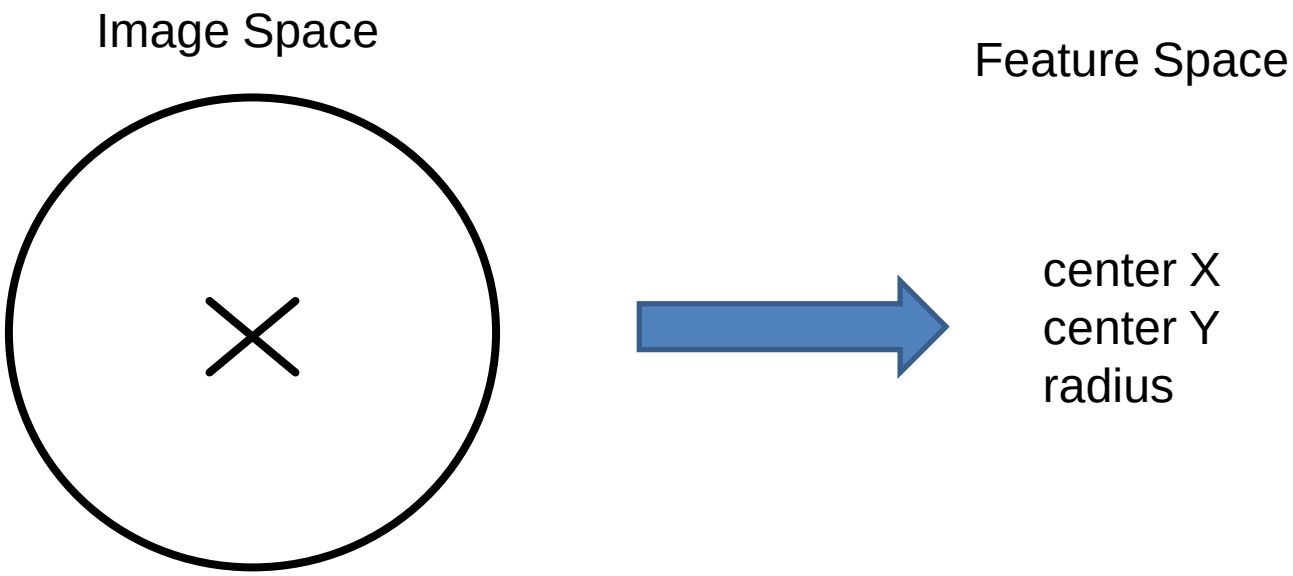
RBO

TU berlin

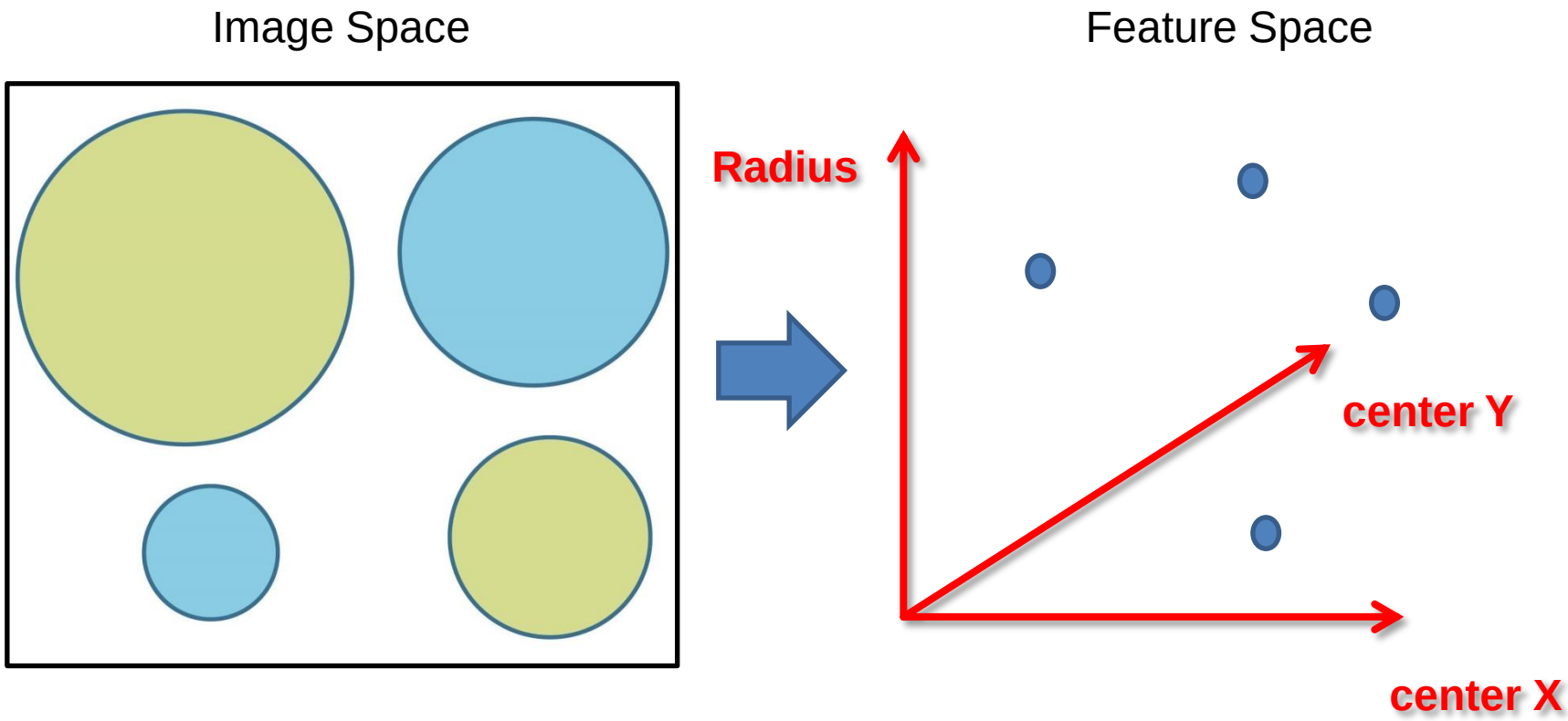
OpenCV

- (**Open** Source **C**omputer **V**ision) is a library of programming functions for real time computer vision
- Documentation: http://docs.opencv.org/

Hough Circle Transform



Hough Circle Transform



Processing Pipeline