User Manual for PrecisionEnhancer software (LINUX version)

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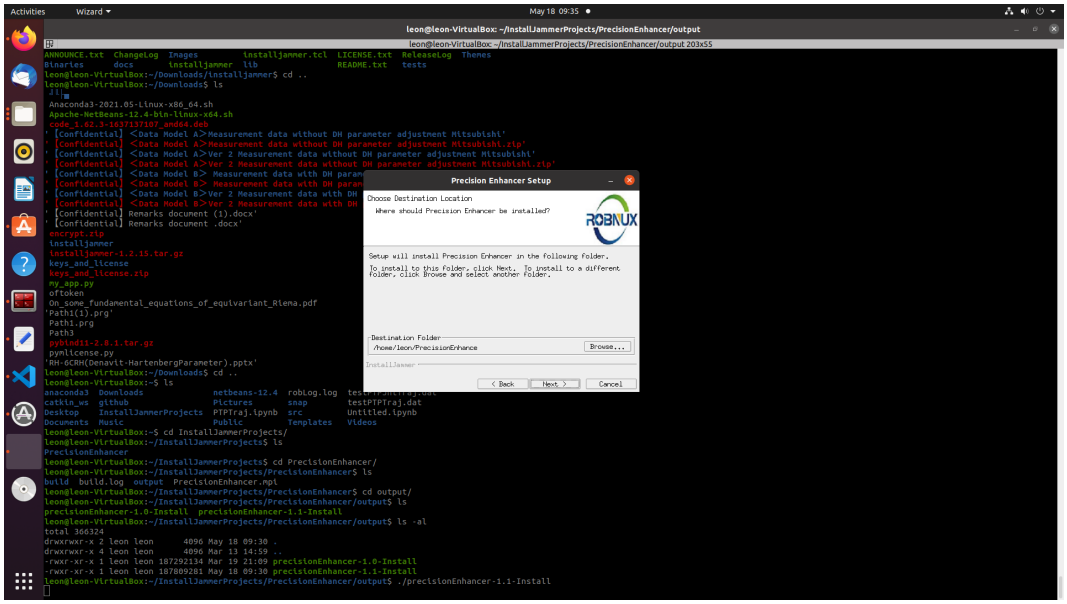
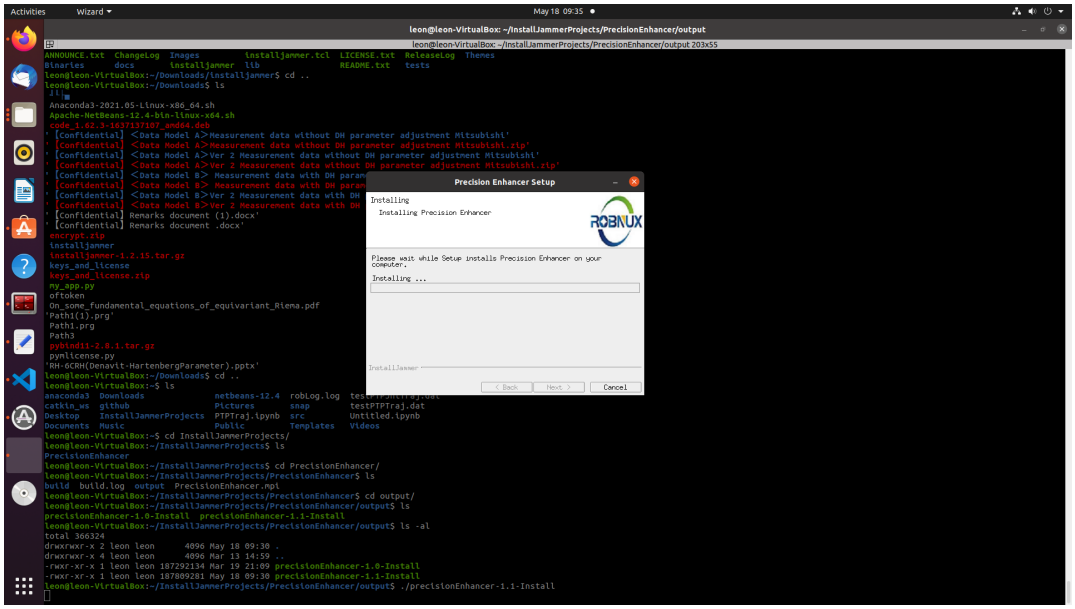
Chapter 1: Software Installation

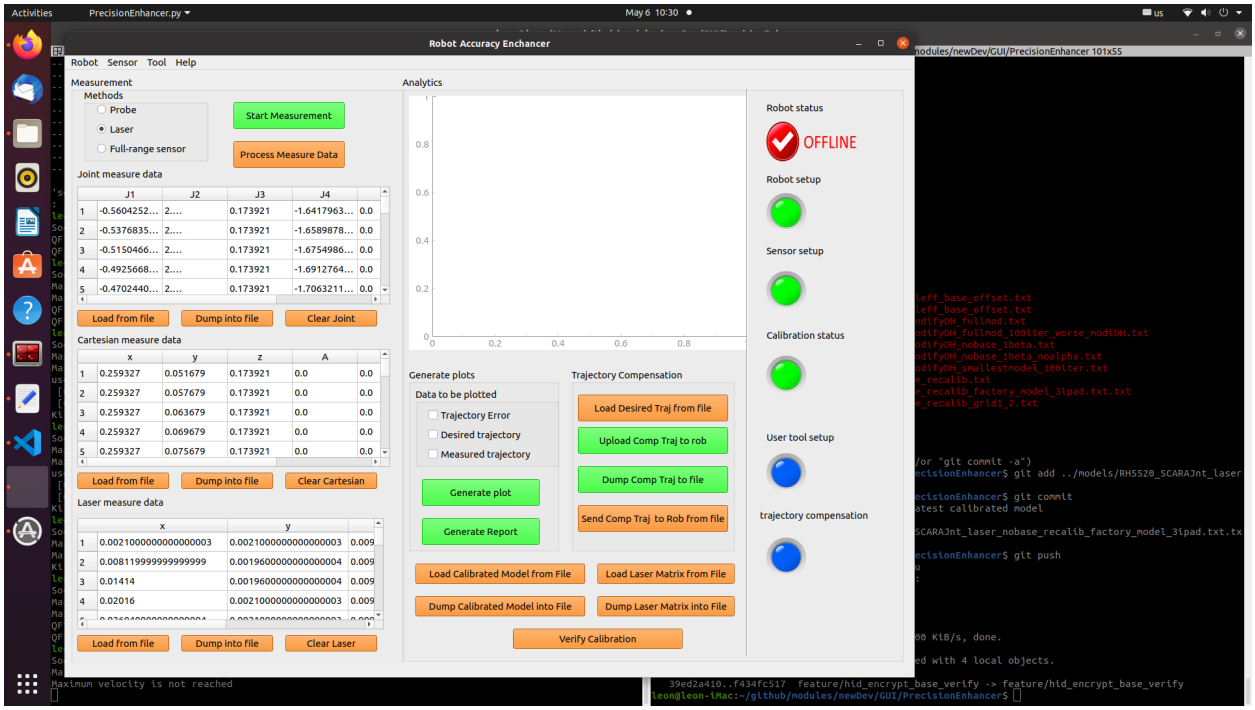
To install PrecisionEnhancer software, download or get a copy of the software PrecsionEnhancer-Ver-Install (where Ver denotes the version). Then open up a terminal through CTRL+ALT+T and type the command:
$: ./PrecisionEnhancer-Ver-Install.
The installation wizard will guide you through the entire installation process including the place (folder) to install.





Chapter 2: Quick Start of the Software

To start and run the software, go to the installation folder of the software, e.g.,
$: cd my_install/PrecisionEnhancer
$: ./PrecisionEnhancer
You will see the following application GUI.



Chapter 3: Overview of GUI controls

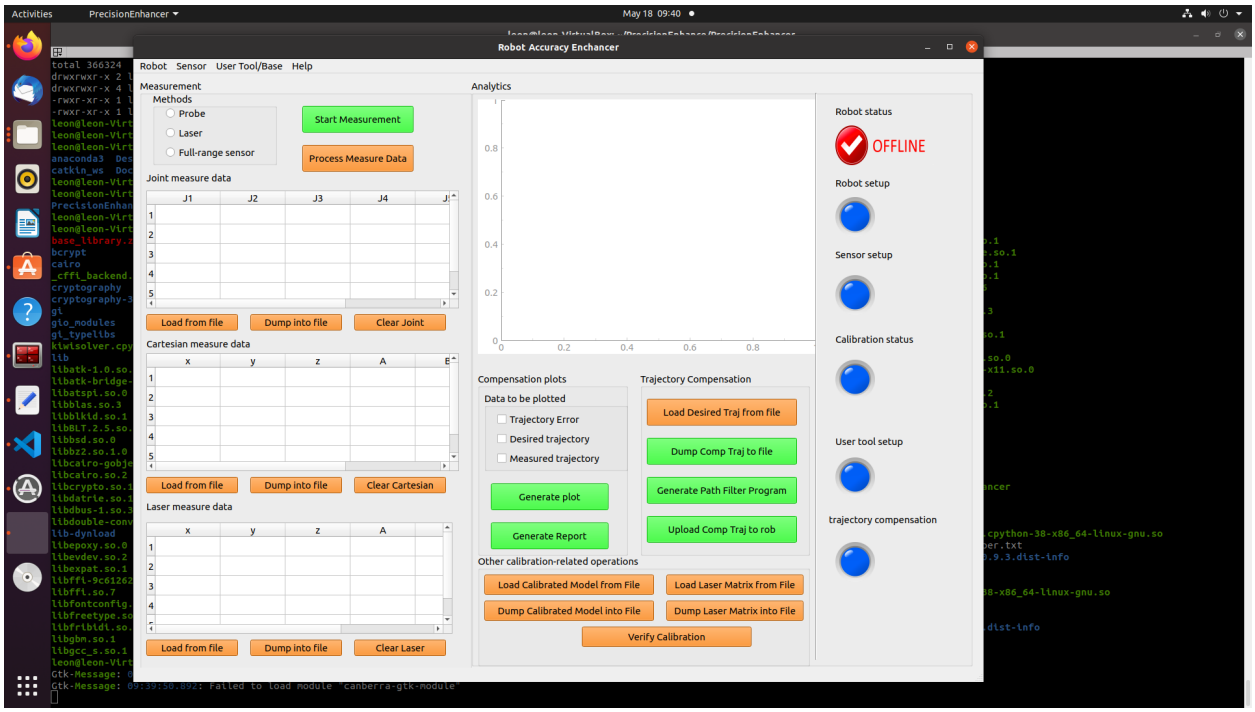
Precision Enhancer GUI consists of control menus, main window, and status flag bar.

3.1 Control menus

Control menus are located on top of the application GUI, including “Robot”, “Sensor”, “User Tool/Base”, “About”.

3.2 Main window

The main GUI window is divided into “Measurement”, “Compensation”, “Analysis”, “Other calibration related operation”, and “status lights” sections.



3.2.1 Measurement section

In the measurement section, users pick a measuring method: “Probe”, “Laser” or “Full range sensor”. If robot and sensors are all set up (see Chapter 3), users can click “start measurement menu”, then this application will initiate the measuring robot program running on robot controller. Afterwards, robot will go through every grid point, stop there for a given amount of time, and then report back the joint/cart back to application, and at the meantime, application will record the sensor readings, and put them into the joint/cart/laser tables in the Measurement section of main GUI. After measurement is done, users can click “Process Measure Data” to start the calibration algorithm, and when calibration is done, it will prompt the users to save the calibrated robot model file” into user chosen folders.

Users can postpone running the calibration algorithm by first dumping joint/cart/laser data into files first, and at any later time to load them back in (through the “local from file” button below joint/cartesian/laser tabel), and then click the “process measure data” button afterwards.

3.2.2 Compensation section (or path filtering section)

Users click the “load desired traj from file” button to load the data file that contains the desired path. This app. Will run a path filtering algorithm to filter the path and produce the compensated path.

Note 1: Before we run path filtering, we need to make sure the robot has been calibrated through measurement and "process measurement data" or by clicking "load calibrated robot model" in the "Other calibration related operation" section.

Note 2: After path filtering is done, users can click "dump comp traj to file" to save the filtered path into files (csv files).

3.2.3 Analysis section
This section is for plotting the desired and compensated path, and their difference. Note this needs to be done after doing path filtering

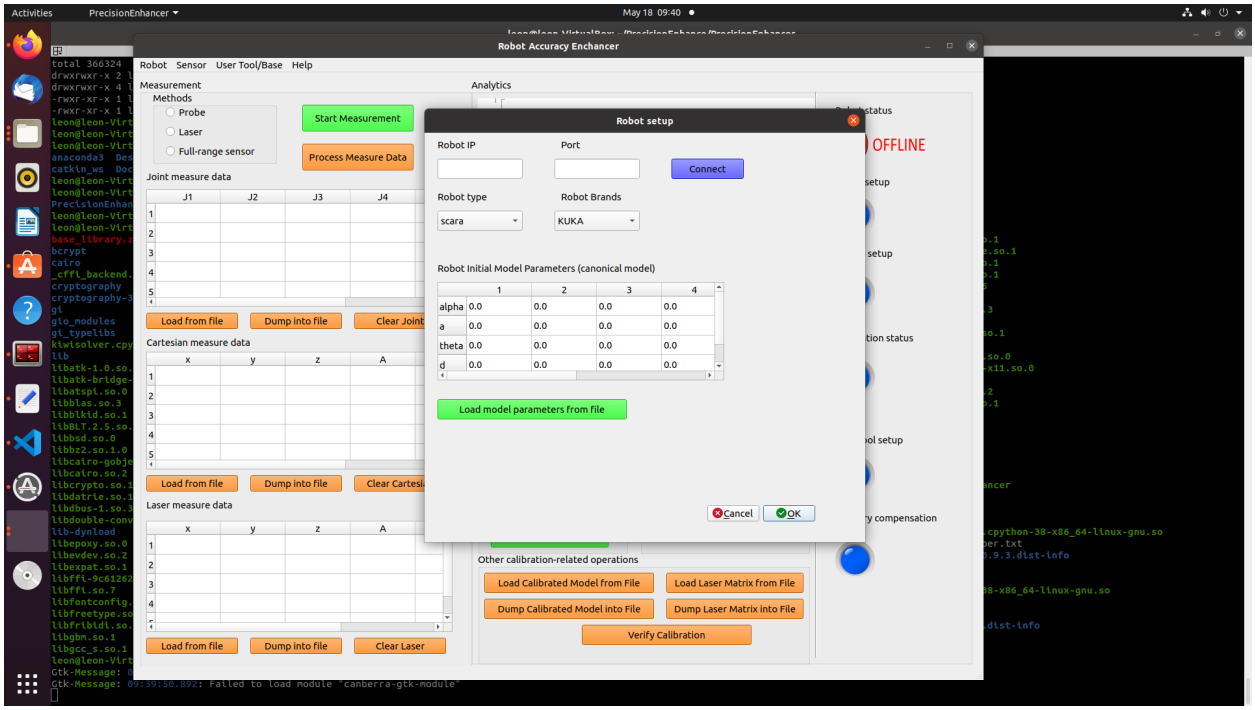
3.2.4 Other calibration related operation
This section contains buttons to load previously calibrated robot models, or save previous calibrated models into files. It has also a "Verify Calibration" button, which is only applicable when robot calibration model has been loaded or measured and user too/base (see chapter 6) has been set up. Note: if a calibrated robot model is loaded, users can load joint/cartesian/laser data in "measurement" section, and then click "Verify Calibration" button. Then this app. Will run algorithms to verify if calibrated model will improve the tracking error w.r.t. Laser measuring data.

3.2.5 Status lights
There are status lights corresponding to robot communication, robot setup, sensor setup, calibration, compensation status. Each light will turn green if the corresponding setup has been done.

Chapter 4: Robot Setup (menu)

This menu is used for setting up robot models. Users can pick robot model types, such as "scara" or "6axis". Users shall also choose the vendors based upon their robot bands, because later on during path filtering, the software will generate "correct" filtered path files according to different robot brands.

During grid measurement for robot calibration, this software will communicate with the robot controller to collect joint/cartesian/sensor readings at each grid point. This communication relies on the setting of ip address (e.g. entering 192.168.0.30) and port number (e.g. 5000). Making sure to correctly set up the communication parameters on the robot controller side before running the calibration function of this software. After entering ip address and port number, click the "connect" button. If communication is successfully established, the button will turn into a green color.

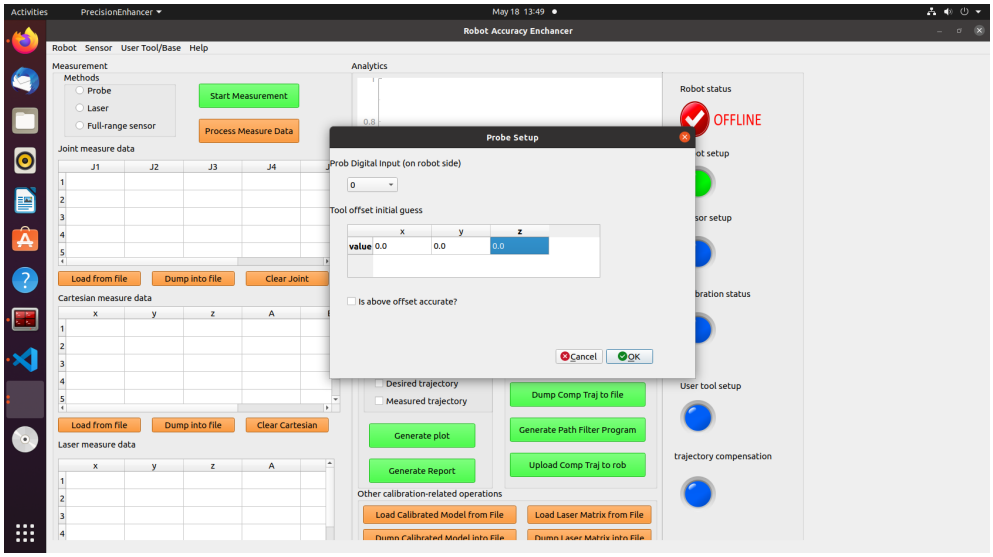


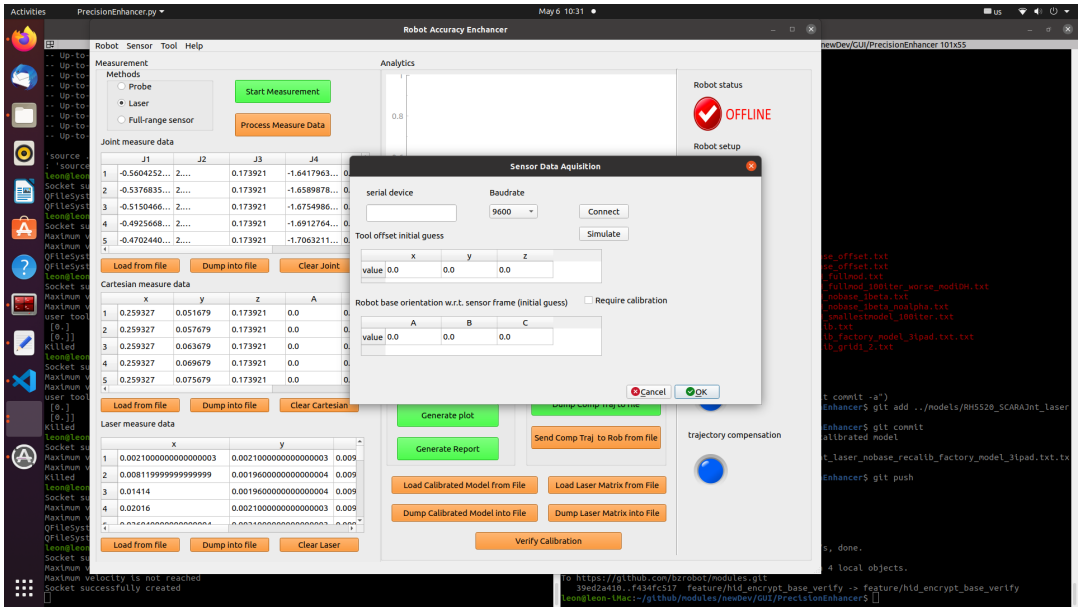
Users can choose to manually enter the DH parameters within the table of a robot canonical model, or click “Load model parameters from file” to load the canonical model from a data file. A typical model file contains a column of data in the form of:

alpha_1
alpha_2
….
alpha_k
a_1
a_2
…
a_k
theta_1
theta_2
…
theta_k
d_1
d_2
…
d_k

Chapter 5: Sensor Setup (menu)

After setting up the robot model, users need to set up the used sensors for calibration. Currently this software supports 3 different types of sensors: probe, laser, and Fullrange sensor (under developing). Before clicking this sensor menu, make sure sensors have been installed onto the robot end-effector, cables have been hooked up to the PC that runs this software, and also make sure sensor drivers have been installed (linux provides default drivers for serial-com based sensors). When clicking the senor menu, choose either probe (for probing based calibration) or laser/full-range sensor (for coordinate-measuring based calibration).





Clicking the sensor menu will pop up a new GUI window. On the top of GUI, users need to enter the serial device name (e.g. “/dev/ttyACM0”) , choose the correct Baud Rate, and then click “connect”. If communication is okay, the “connect” button will turn green.

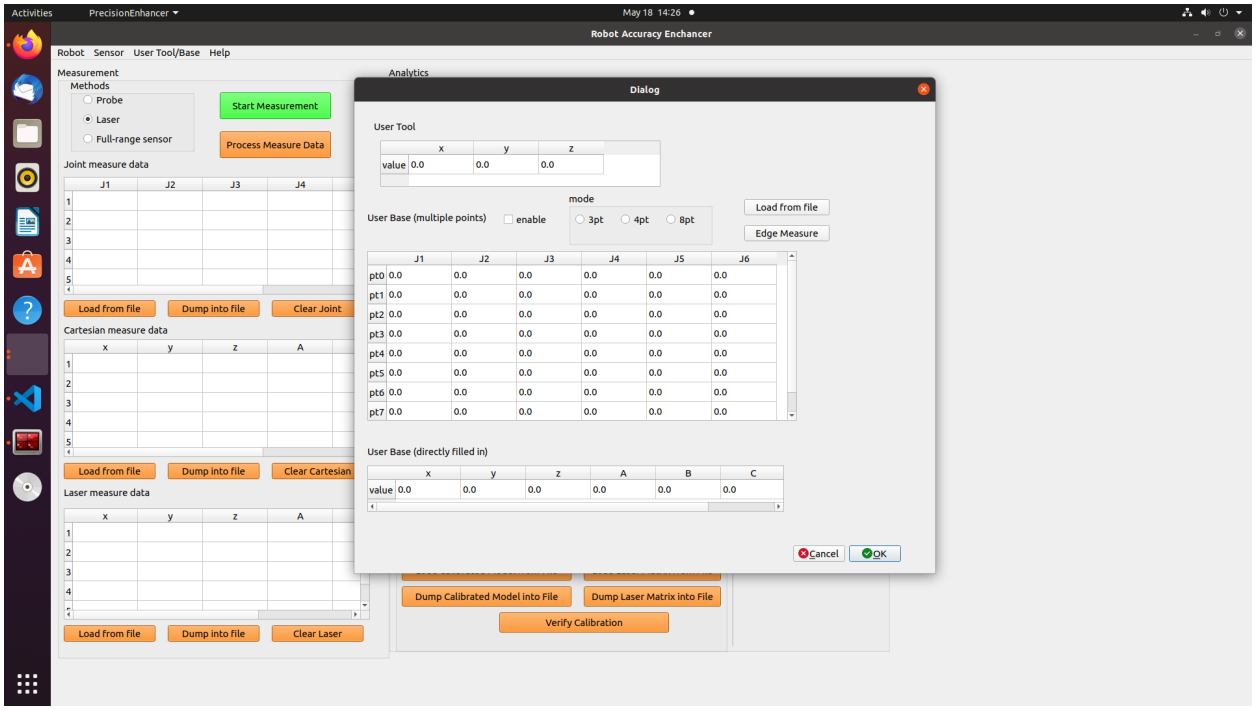
Note 1: It is necessary to set up the tool offset (x, y, z) of the used sensors. This offset denotes the installation offset from robot flange to the tip of the sensor. For probe sensors, this offset is the (x,y,z) of the probe tip w.r.t. the flange. It could be roughly measured using standard method provided by each robot vendor. For laser sensors, we simply set this offset as 0.

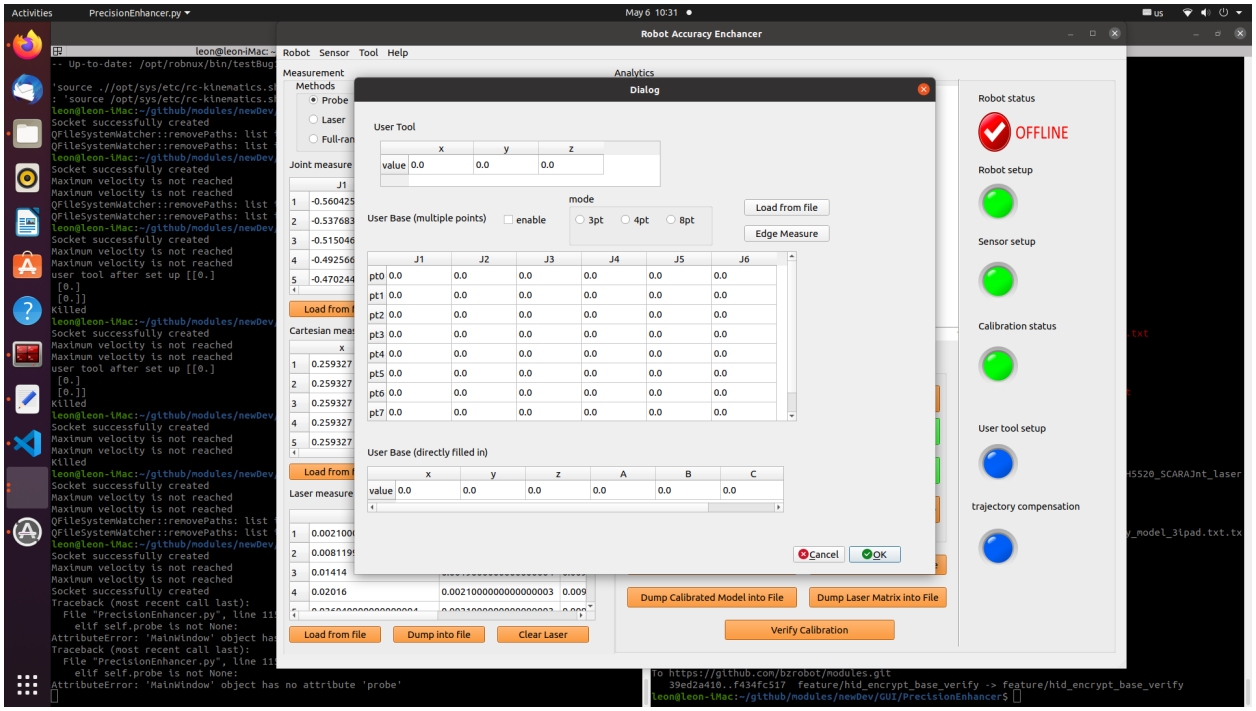
Note 2: In some applications, the measuring coordinate frame might have different orientation from the default robot base reference frame. Users can enter the rough number in degrees of the roll, pitch, yaw of the default robot base frame w.r.t sensor measuring coordinate frame. By checking “require calibration”, this rough base offset will be optimized during calibration through iterative algorithm.

Chapter 6: User tool/base Setup (menu)

Recall in the actual mass production, robots will use different end-effectors (called user tool) from the one using for calibration. Moreover, many applications might use work obj frame (called user base) and desired robot paths given w.r.t. the work obj frame. This application allow to do path filtering w.r.t. different user tools and base frames.

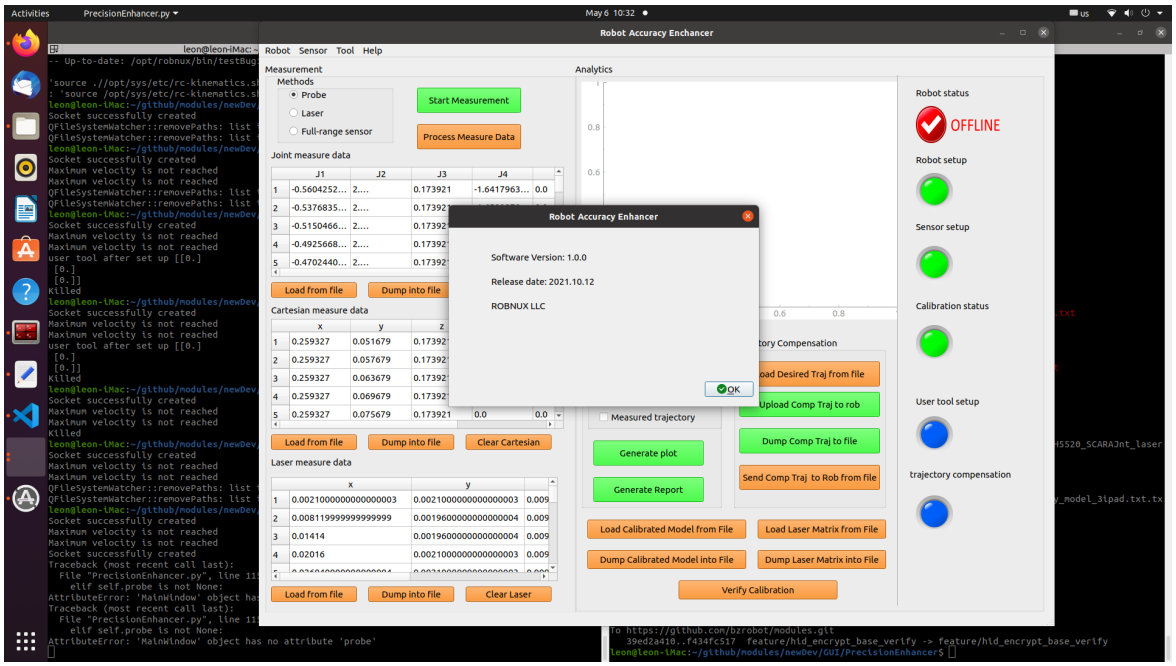
Clicking this menu will pop up a dialog which allows users to enter the user tool and user base frame. For accurately user base measuring, this dialog provide 8pt method that employ laser sensor to automatically scan work obj edges to figure out an accurate work obj. Frame. For 3pt, 4pt method, users have to enter measuring data manually.


Activities
PrecisionEnhancer
May 18 14:26
Robot Accuracy Enchancer
Robot Sensor User Tool/Base Help
Measurement
Methods
Probe
Laser
Full-range sensor
Start Measurement
Process Measure Data
Joint measure data
J1 J2 J3 J4
Load from file
Dump into file
Clear Joint
Cartesian measure data
x y z A
Load from file
Dump into file
Clear Cartesian
Laser measure data
x y z A
Load from file
Dump into file
Clear Laser
Analytics
Dump Calibrated Model into File
Dump Laser Matrix into File
Verify Calibration
Dialog
User Tool
x y z
value 0.0 0.0 0.0
mode
User Base (multiple points)
enable
3pt
4pt
8pt
Load from file
Edge Measure
J1 J2 J3 J4 J5 J6
pt0 0.0 0.0 0.0 0.0 0.0 0.0
pt1 0.0 0.0 0.0 0.0 0.0 0.0
pt2 0.0 0.0 0.0 0.0 0.0 0.0
pt3 0.0 0.0 0.0 0.0 0.0 0.0
pt4 0.0 0.0 0.0 0.0 0.0 0.0
pt5 0.0 0.0 0.0 0.0 0.0 0.0
pt6 0.0 0.0 0.0 0.0 0.0 0.0
pt7 0.0 0.0 0.0 0.0 0.0 0.0
User Base (directly filled in)
x y z A B C
value 0.0 0.0 0.0 0.0 0.0 0.0
Cancel
OK

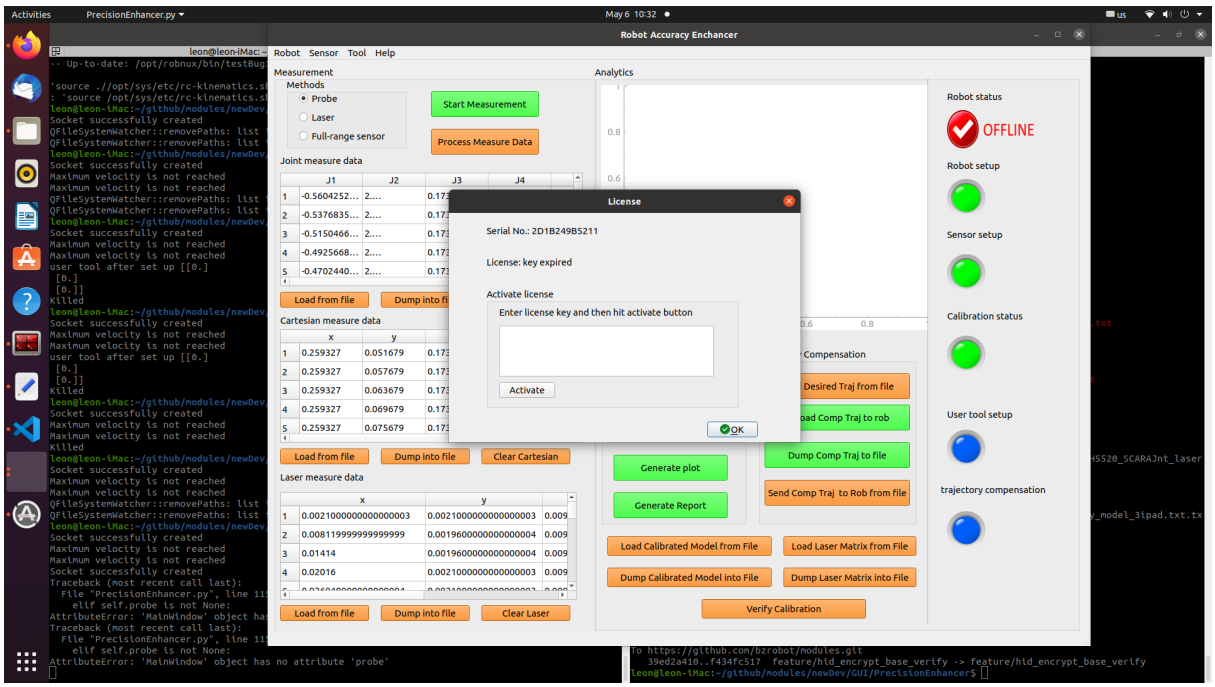

Activities
PrecisionEnhancer.py
May 6 10:31
Robot Accuracy Enchancer
Robot Sensor Tool Help
Measurement
Methods
Probe
Laser
Analytics
Dialog
User Tool
x y z
value 0.0 0.0 0.0
mode
User Base (multiple points)
enable
3pt
4pt
8pt
Load from file
Edge Measure
J1 J2 J3 J4 J5 J6
pt0 0.0 0.0 0.0 0.0 0.0 0.0
pt1 0.0 0.0 0.0 0.0 0.0 0.0
pt2 0.0 0.0 0.0 0.0 0.0 0.0
pt3 0.0 0.0 0.0 0.0 0.0 0.0
pt4 0.0 0.0 0.0 0.0 0.0 0.0
pt5 0.0 0.0 0.0 0.0 0.0 0.0
pt6 0.0 0.0 0.0 0.0 0.0 0.0
pt7 0.0 0.0 0.0 0.0 0.0 0.0
User Base (directly filled in)
x y z A B C
value 0.0 0.0 0.0 0.0 0.0 0.0
Cancel
OK
Robot status
OFFLINE
Robot setup
Sensor setup
Calibration status
User tool setup
trajectory compensation
Dump Calibrated Model into File
Dump Laser Matrix into File
Verify Calibration
Load from file
Dump into file
Clear Laser

Chapter 7: License (menu)

By clicking “help” -> “about”, users can check the info of this application. By clicking “help”->”license” to check whether the software has been activated.



Users can record the serial number, and use that for purchasing the license. The license will be a string, and users enter this string to the text box in the License dialog. The license will be activated.



Chapter 8: Calibration procedure

Robot calibration follows the following steps:

(1) Robot setup by clicking robot setup menu: choose robot type, entering canonical robot model parameters, set up robot communication (or just skip robot communication if using a set of previously measured data)
(2) Sensor setup by clicking sensor setup menu: choose sensor type, sensor communication (or just skip sensor communication by clicking “simulation” button if using a set of previously measured data)
(3) Measuring robot joint /cartesian and laser data by clicking “start measurement” or by clicking load joint /cart/ laser data from files.
(4) Clicking “processing measurement” and save calibrated model
(5) Done

Chapter 9: Path filtering procedure

Path filtering follows the following steps:

(1) Finish the above calibration procedure, or directly clicking the “load calibrated model from file” from mainwindow if using a previously calibrated robot model
(2) Click “user tool/base” menu to set up user tool and base (or called work obj frame)
(3) Click “load desired Traj from file” button to load the desired path file
(4) Click “dump comp traj to file” to save filtered path into compensated path file
(5) In analysis section, choose the data to be plotted, and click “Generate plot” to verify if path filtering is okay

Chapter 10: Future work

(1) Automatically generate user application program based upon user tool and work obj frame and filtered path
(2) Support more robot brands