Automation Solutions and Prototypes for the X-Ray Tomography Beamline of Sirius, the New Brazilian Synchrotron Light Source

Gabriel S. R. Costa, Gustavo J. Q. Vasconcelos, , Francis P. O'Dowd, Nathaly L. Archilha
Brazilian Synchrotron Light Laboratory (LNLS)
gabriel.costa@lnls.br

Abstract

Brazil is building Sirius, the new Brazilian Synchrotron Light Source. MOGNO, the future X-ray nano and microtomography beamline is being designed to execute and process experiments in only few seconds. For this reason, prototypes and automated systems have being tested and implemented in the current LNLS imaging beamline (IMX). An industrial robot was installed to allow fast sample exchange and queue measurements creation through an easy-to-use graphical user interface. A flux cell for study dynamics and behaviour of fluids at the rock pore scale in time resolved experiments is being tested.

Automatic Measure System

MOGNO measurements will take only few seconds, what make an automatic system not just interesting but necessary. So, we installed a Mitsubishi RV-2F-D1 robot on IMX (figure 1) as prototype.

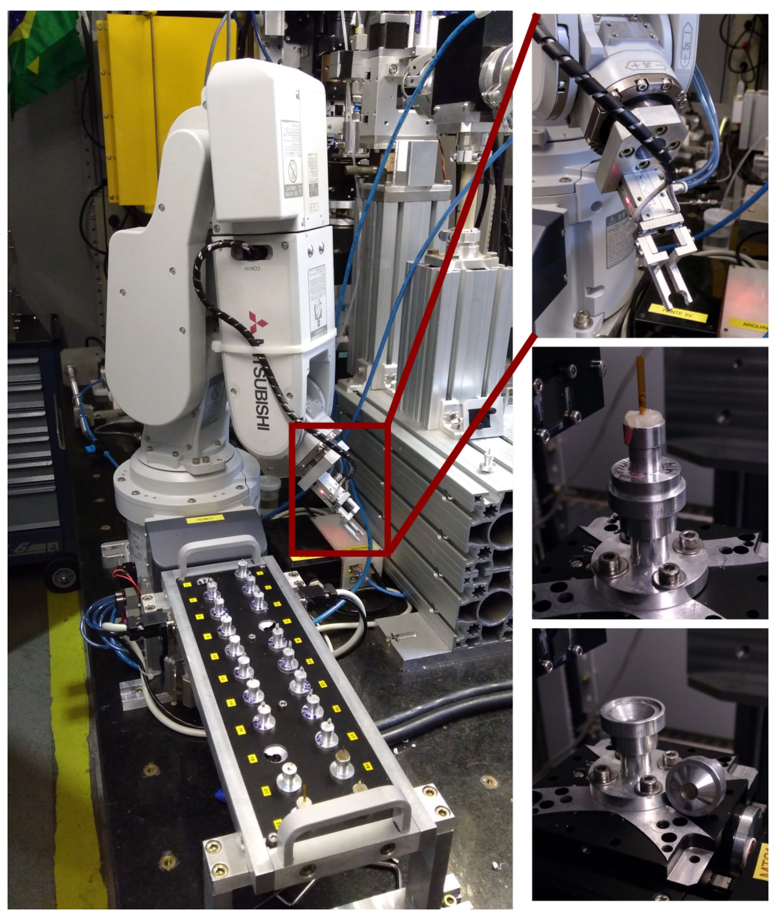

Figure 1: IMX Robot and additional parts

The robot controller has option of remote control using TCP/IP connection with a vast list of commands. We are using Python socket library for to connect and send the commands. Movement programs were saved on robot controller. Like the sample holder moves, ie. for each sample a different positioning is required to place and align it in front of the detector, before moving the robot the script sends the fast-moving motors to a standard position. Vertical sample motor is slower, so the algorithm reads his position using EPICS [1] and updates all Z-coordinate positions of the program that will be run on robot controller. A graphical user interface using Control System Studio (CSS) was developed to allow robot control and measurements queue creation by the users (figure 2).

LNLS is a multi-user facility, so to avoid accidents caused by unfamiliarity with the automated system we added the robot to beamline interlock, and installed some optical-reflexive sensors on rotational stage and sample tray to reduce collision chances. The sensors feedback are able to be seen on figure 2. Sensors are connect to an Arduino microcontroller. An IOC is reading the board output and updating sensors PVs.

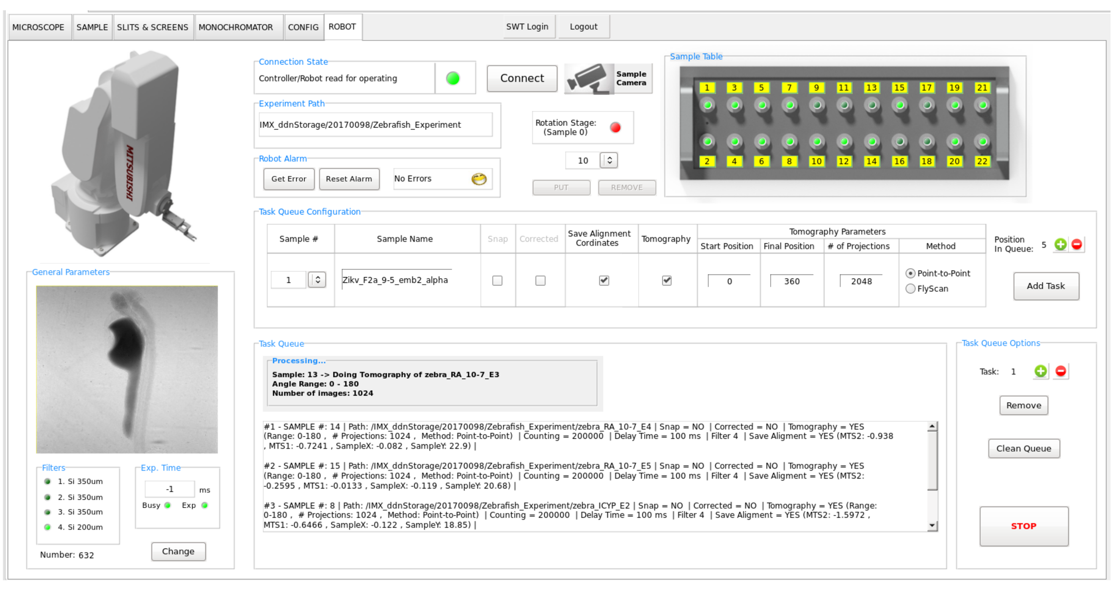

Figure 2: Robot graphical user interface.

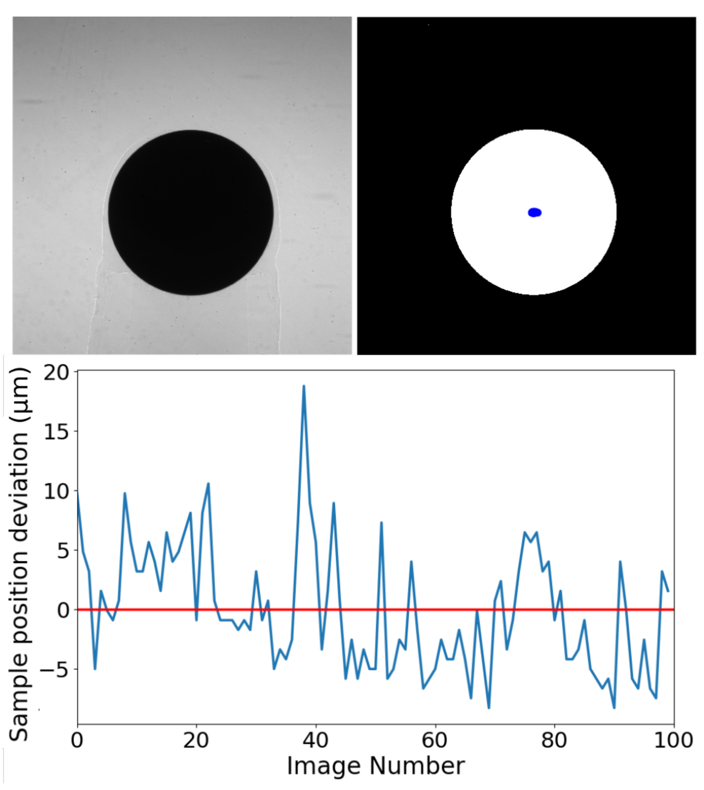

Figure 3: Sample Projection (top, left) and binarized image (top, right) and X-axis position deviation (bottom).

To analyse system repeatability, robot was programmed to place and remove sample from measurement position 100 times and acquire images using a PCO.2000 camera with a 10x objective (pixel size of $0.82\,\mu m$). A sphere with very well defined diameter was used as sample. The obtained images was colour binarized using the OpenCV library on Python (figure 3). The next step was calculate the centre of mass of each image. For X-axis (transverse to the light beam), standard deviation obtained was equal to $5.15\,\mu m$ (figure 3). On Y-axis the standard deviation is even smaller, $0.32\,\mu m$).

To see what robot movement causes on the optical table, a triaxial accelerometer was placed on sample tomography position. The critical results were obtained taking sample from tray odd side with maximum robot velocity (figure 4). The last test was to measure the acceleration caused by the open and close action of robot gripper. Figure 4 shows the results.

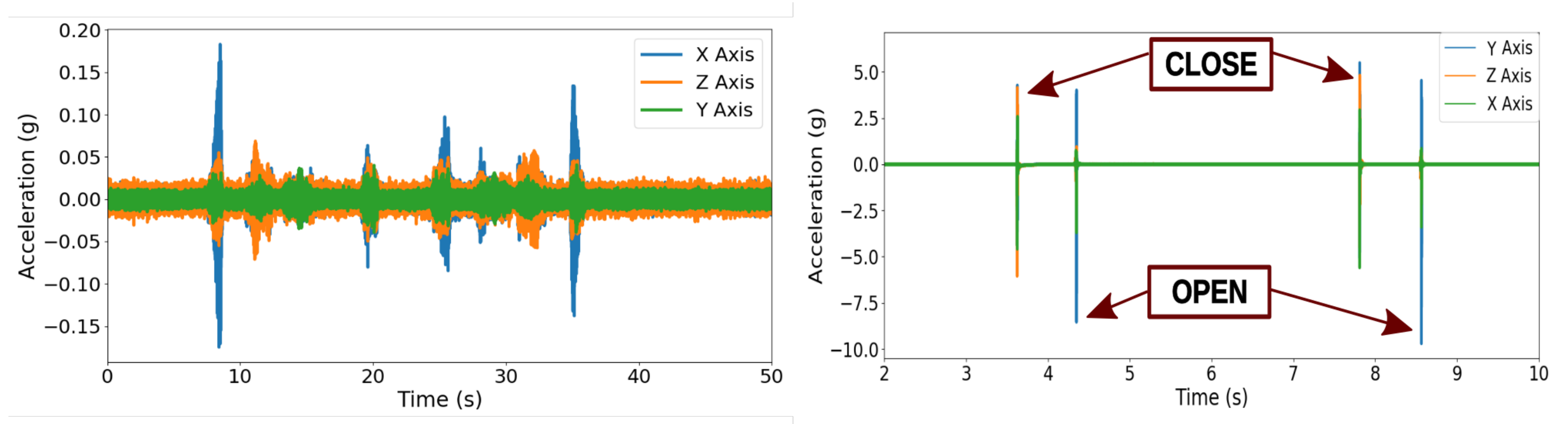

Figure 4: Sample vibration when robot is moving (left) and on gripper open/close (right).

Flux Cell

We are developing a flux cell to inject three fluids on the same time inside the sample during continuous rotation for tomography experiment (figure 5).

It's basically composed by two cylinders: the external, where three hoses come with the fluids (this cylinder is tied on top, forbidding it to rotate with the stage), and the internal, with holes and ducts inside, linking to the top connection where the sample is placed using a fast connection. To separate the three fluids when they are moving from external to internal cylinder and to allow the rotation we are using viton orings. For injection we are developing three syringe pumps.

For first test the Information Technology Centre "Renato Archer" (CTI) from Campinas, Brazil, printed a sample to simulate a rock on their 3D printer using a soft material. We injected water and take some projections using pink beam on IMX Beamline. The rotational stage remained stopped during the injection because the top part which will allow rotation is not done yet. The first results are shown on figure 6.

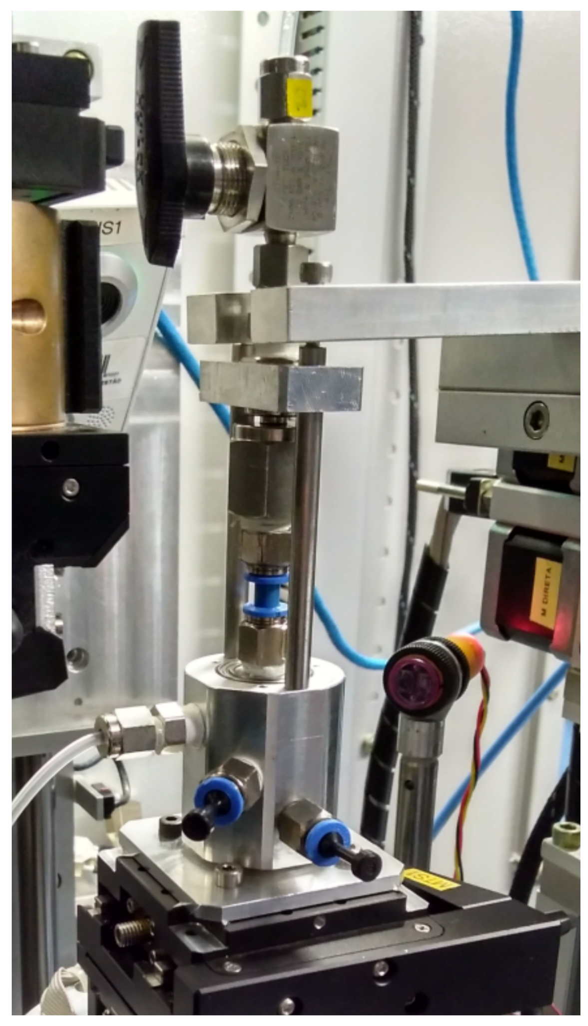

Figure 5: Flux cell mounted under IMX rotational stage.

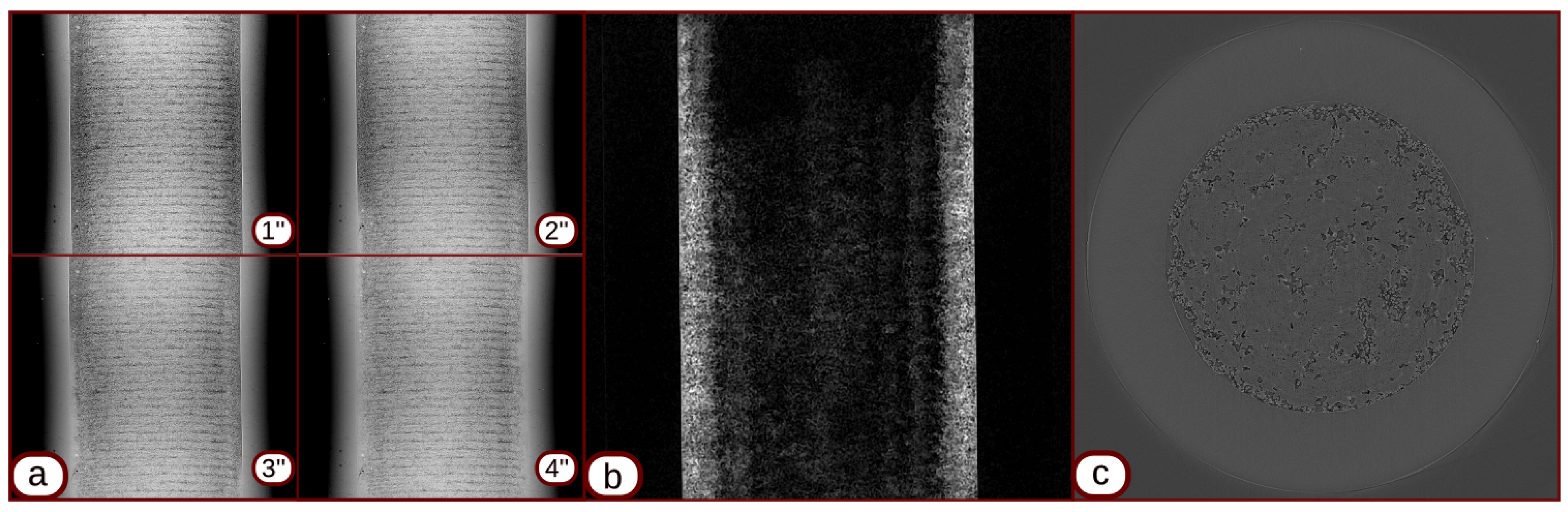

Figure 6: Sample projections during injection (a), first and last projection subtraction (b) and dry sample tomography slice (c).

Conclusion

For automatic system we can highlight two important facts: first is that positioning little deviations shows the good influence of magnet and sample holder on fitting the sample at previous defined position, and second is the high vibration caused by the gripper on open and close movement, that shows the necessity of use another kind of gripper on MOGNO.

It is already able on IMX to use the segmentation software outside the Laboratory using VPN connection. The idea is extent this possibility on the future adding beamline control, so users can send samples by mail and control beamline from their own city.

For flux cell results it is possible to see that preferential water path is on the sample boarder (figure 6a) because porosity is bigger on that part. Printing new samples with homogeneous porosity should be necessary for rotation tests. The next step is finish the system to start testing tomography under continuous rotation.

References

[1] L. R. Dalesio et al. The experimental physics and industrial control system architecture: past, present, and future. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 352(1-2):179–184, 1994.

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