

## Robotic Integration for End-Stations at Scientific User Facilities

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### Supplementary Information

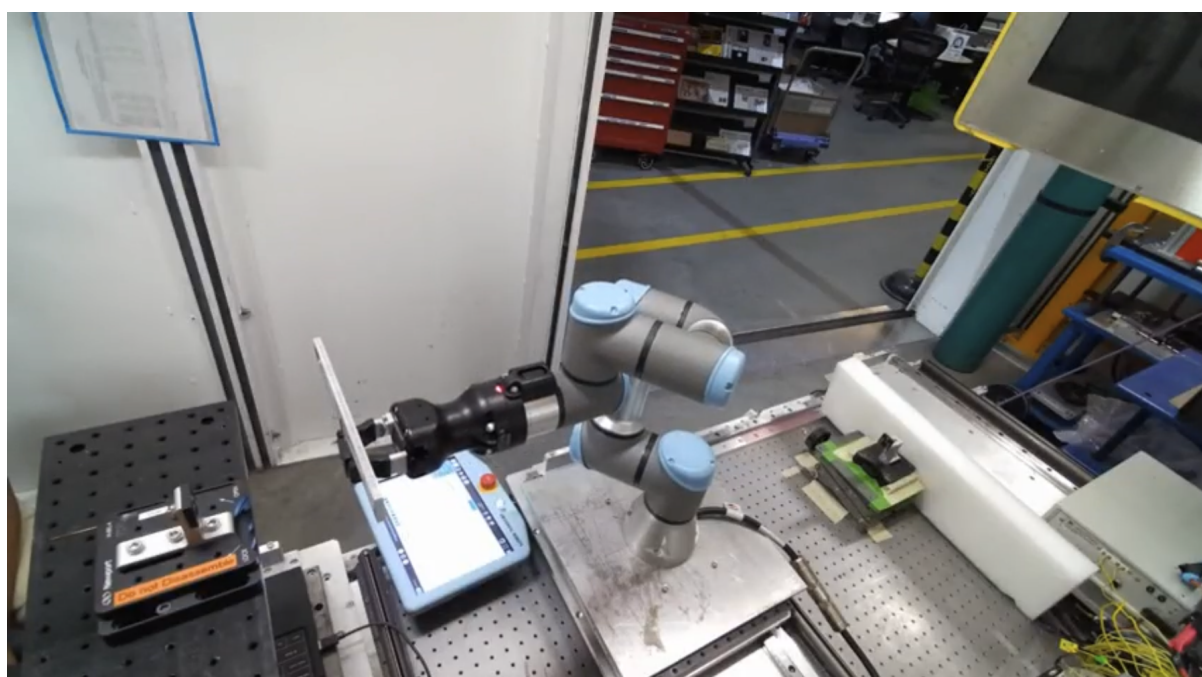


Figure S1: An example deployment of the robot system without computer vision enabled at the Pair Distribution Function (PDF) Beamline. Here the sample library was placed in line with the X-ray beam, well below the beam path. The robot was mounted on a motorized sled to traverse the beamline hutch. The sled was moved using *Bluesky* control, to place the robot in reach of the sample library (right) and destination location (left). Once the sample was placed at the destination, the robot moved to the edge of the beamline hutch to avoid interfering with any radiation. The sample holder carried 30 samples, which could be further aligned against the beam using the diffraction intensity on the detector (upper right).

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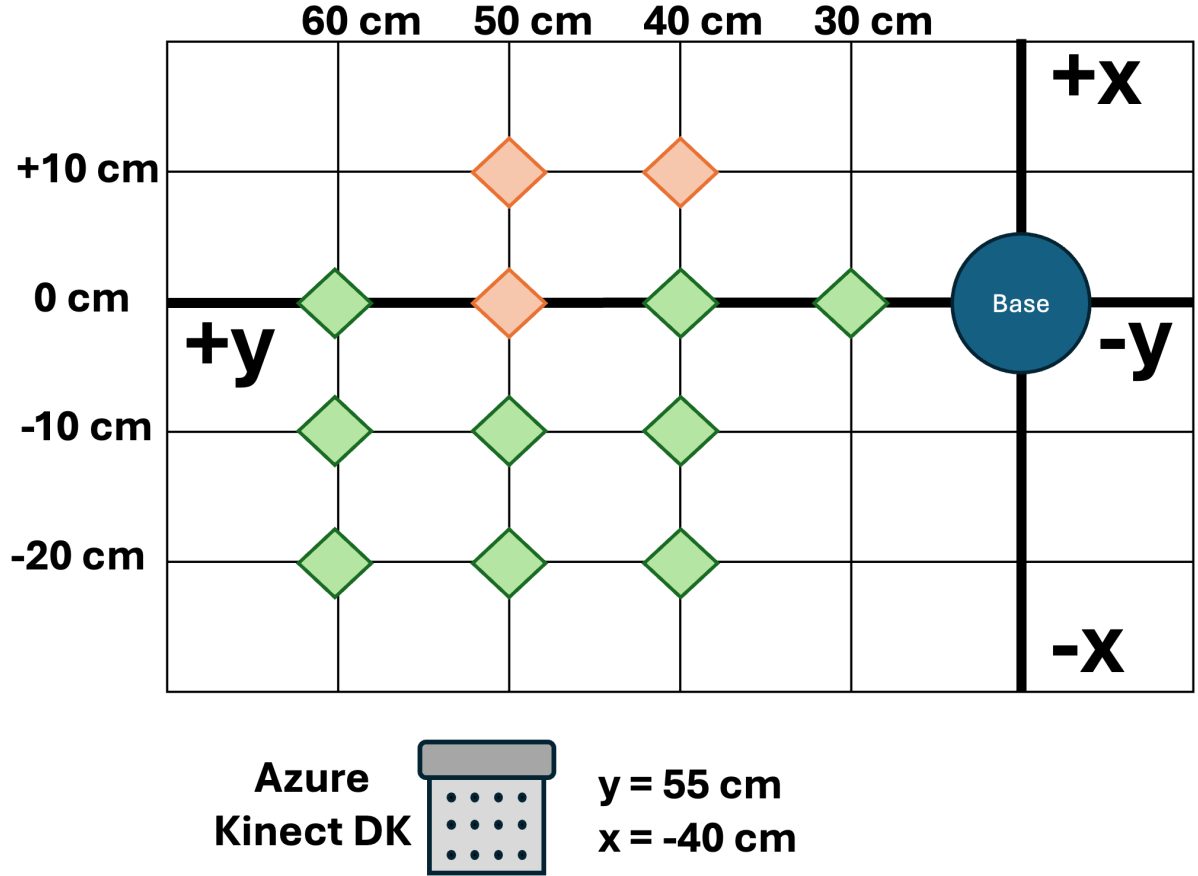


Figure S2: Fiducial markers were placed in a grid pattern with 10cm distances from the robot. Green markers represent positions where the fiducial marker was readily visible to the camera, and had no failed grasping attempts during the experiments. Red markers represent positions where failures were encountered and repeatedly attempted 4 times with a 50% success rate. The positions marked in green were repeated to be robust across the yaw angles outlined in Table. S1

Table S1: At positions within 55cm of the camera lens we manually varied the yaw angel of the sample holder to induce a failed grasp by the robot. These angular limits are tabulated below with respect to Figure S2. A yaw angle of 0 degrees corresponds to the ArUco tag normal orthogonal to the camera lens normal (i.e., facing away), and a yaw angle of 90 degrees corresponds to the ArUco tag normal parallel to the camera lens normal (i.e., face on).

$x$ position (cm)	$y$ position (cm)	Minimum Yaw (deg)	Maximum Yaw (deg)
0	60	25	44
0	50	40	68
0	40	20	68
0	30	25	90
-10	60	15	46
-10	50	15	55
-10	40	35	65
-20	60	7	36
-20	50	16	38
-20	40	36	42

## Video Supplement

The attached video shows a single cycle of sample pick-and-place, sample selection, and sample grasp at 6-times speed. This was taken prior to beginning the overnight campaign that performed 195 continuous measurements without error. At the start of the video, the sample is loaded into the receiving sample

mount, a *psuedo* measurement has been conducted, and the robot proceeds to return the sample to the location where it was initially found in the library. The system then chooses the next sample using *Bluesky Adaptive*, cross references that sample to an ArUco tag, locates the tag, and grasps the sample. The video ends as the robot is executing the trajectory to place the new sample at the receiving mount.