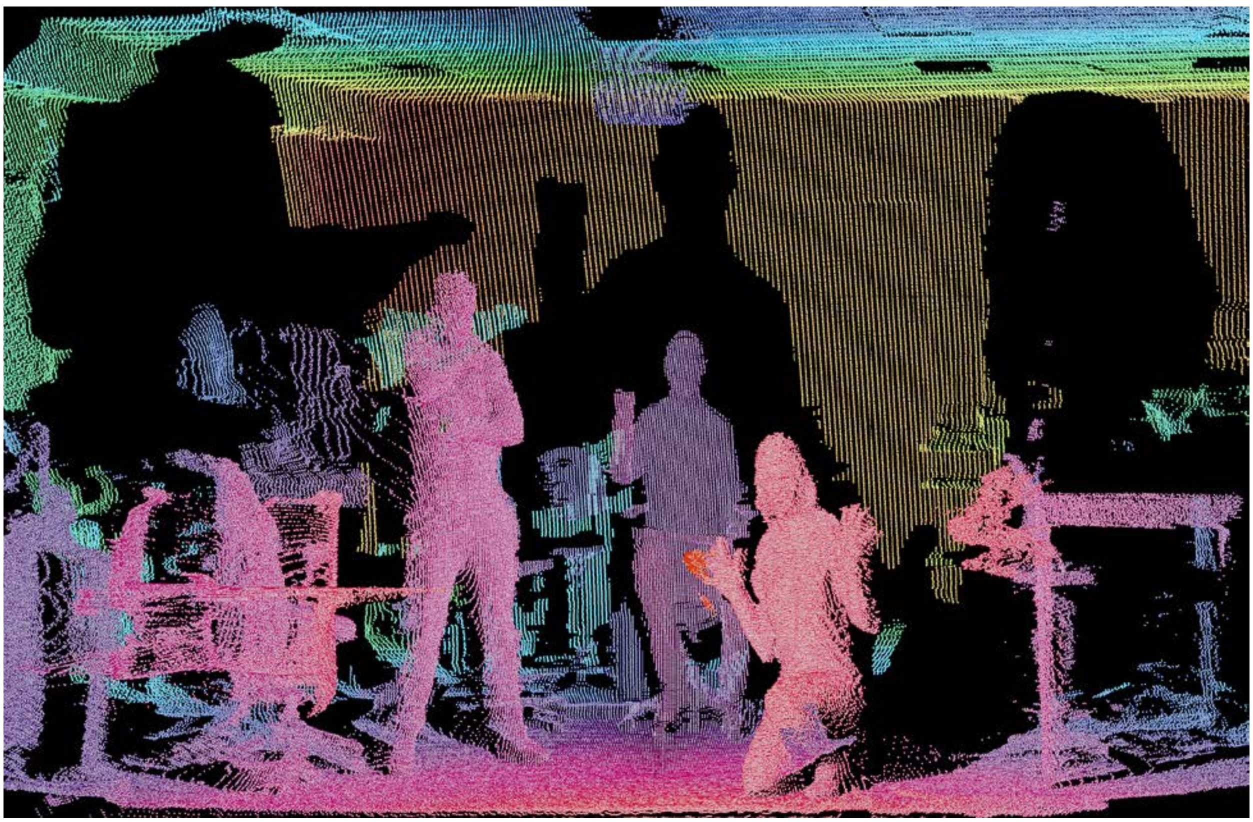
Glendale Community College - ENGR-299 CAPSTONE - June 2016

FINAL REPORT
Team Vision: 3D Scanning Assembly



View the fly through animation here.

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Vision Team Members: Biayna Bogosian + Narek Gharakhanian

INTRODUCTION

Keywords: Computer Vision, Laser Range Finder (Lidar), Remote Sensing, Robot Operating System (ROS), Processing, Python, Point Cloud, 3D Scanning, 3D data visualization.

This project is a 3D Scanning Assembly which couples a Laser Range Finder (Lidar) with an articulation platform in order to 3D scan indoor and outdoor environments within 30m range.

For this phase of the project, we are only focusing on 3D scanning individuals within 1 meter to 1.4 meter range. We are also collecting scanned individuals' personal and contact information for the following reasons:

1. Create an archive of 3D scanned individuals for visualization and analysis.
2. Compose and email a custom 3D scanned image to each scanned volunteer.

PROJECT REQUIREMENTS

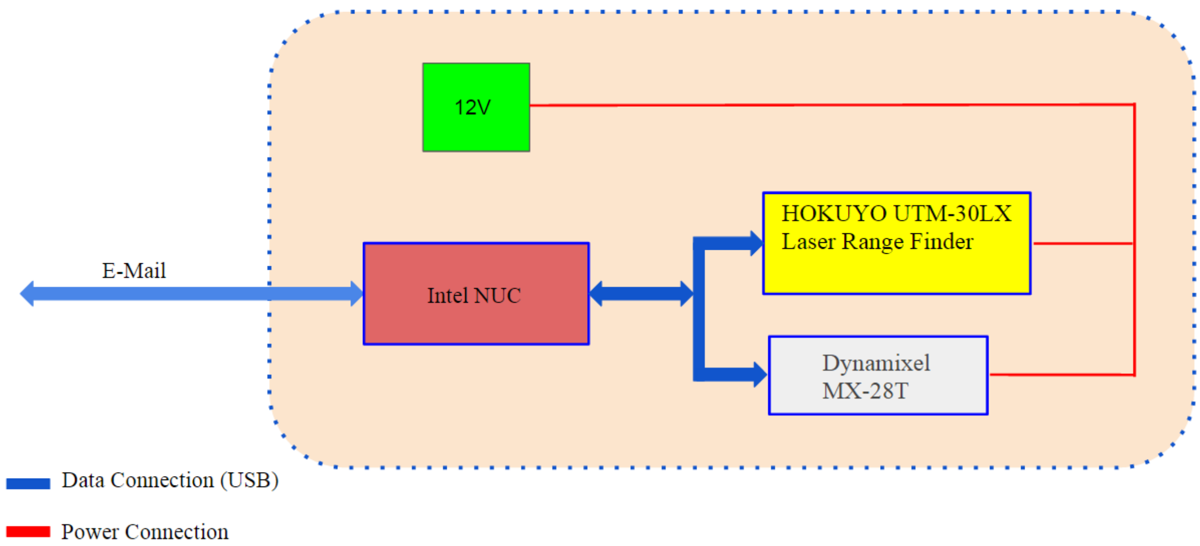
1. 3D Scan static targets and output the scanned data as tabular text file (.csv).
2. Visualize and analyze the scanned data as 3D point cloud in a 3D visualization software.
3. Output multiple views of the scanned 3D point cloud.
4. Stitch images of each 3D scan sequence.
5. Collect data from each 3D scan target.
6. Utilize each target's collected data to e-mail its corresponding stitched image.

CAPABILITIES AND LIMITATIONS

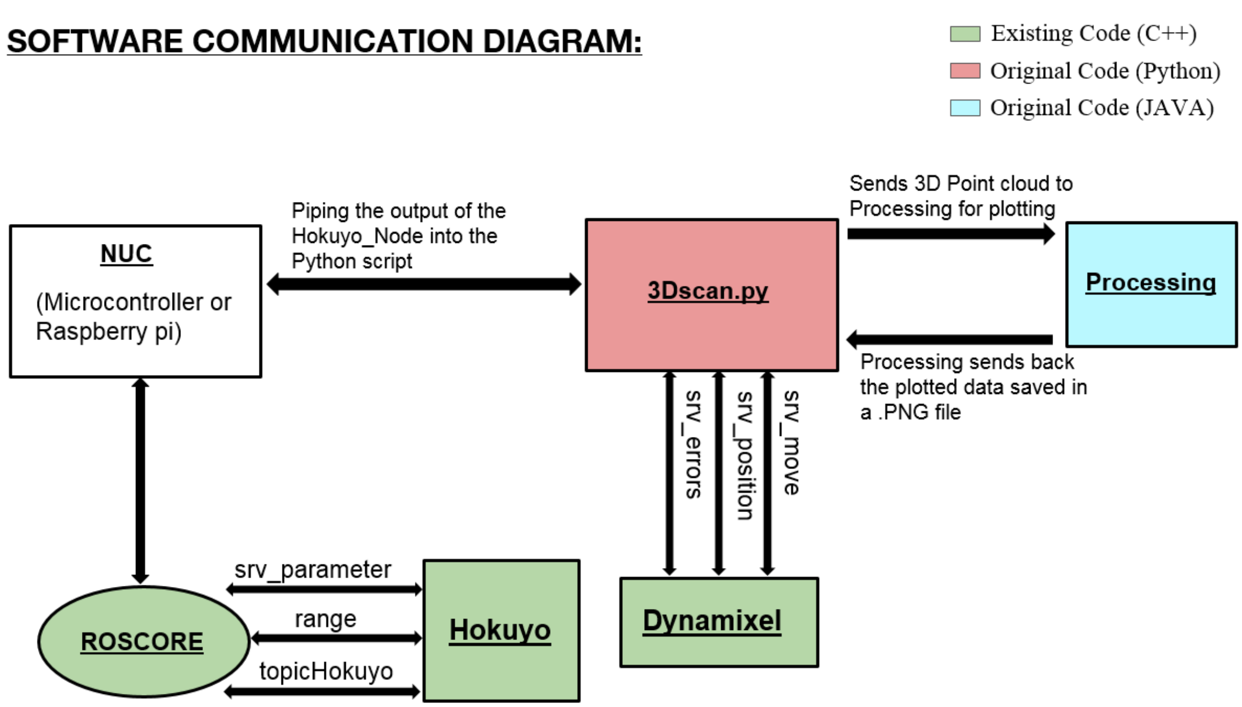
1. The 3D Scanning Assembly's range of influence is between 6cm to 30m.
2. The 3D Scanning Assembly's area of influence is between 0° to 270° per each 2D scan.
3. The 3D Scanning Assembly's scanning target should remain static for the entire duration of scanning. This duration ranges from 5 to 14 seconds depending on the desired scanning resolution.
4. The 3D Scanning Assembly is not able to detect reflective surfaces.

DESIGN DETAILS

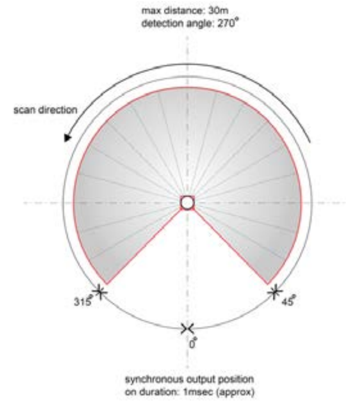
SYSTEM DIAGRAM



SOFTWARE COMMUNICATION DIAGRAM:



LIDAR SPECIFICATIONS

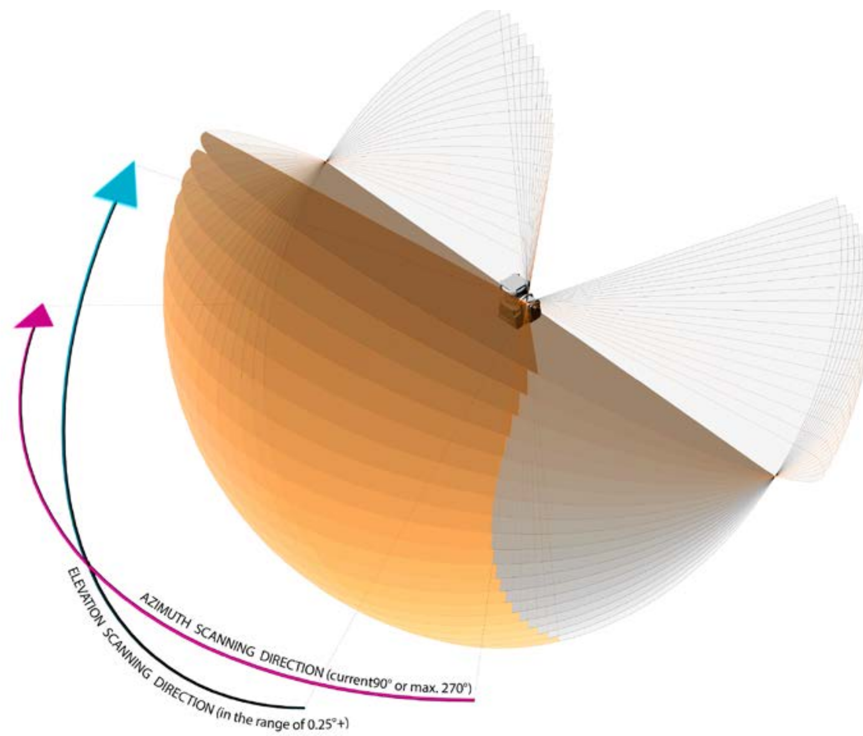


Hokuyo UTM-30LX Scanning Laser Rangefinder

Hokuyo UTM-30LX Scanning Range

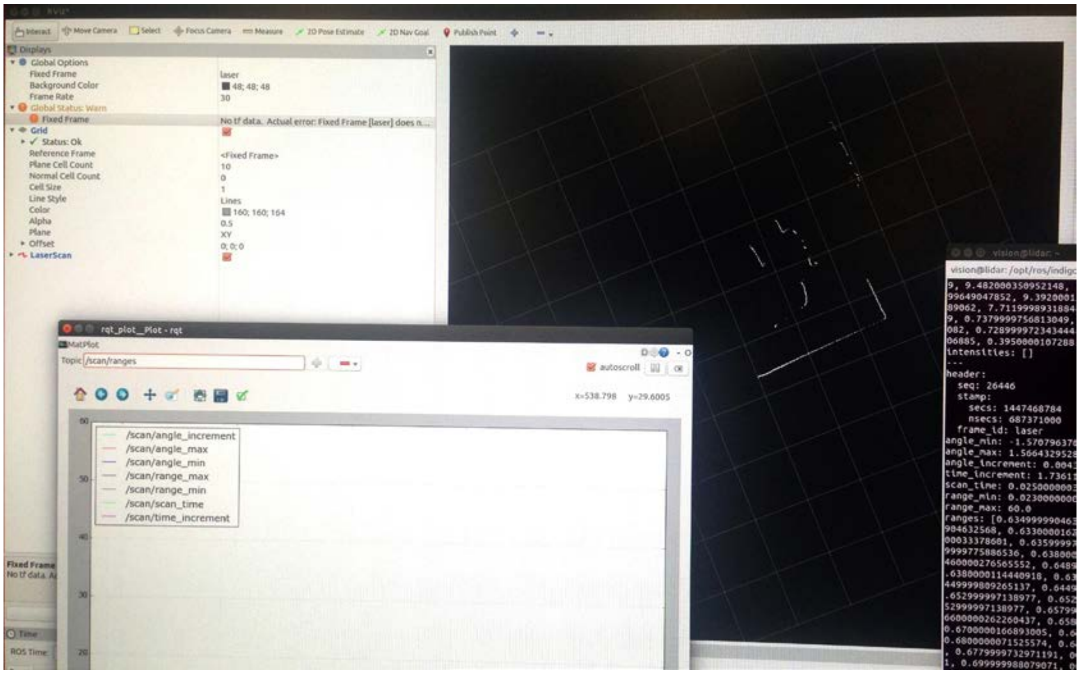
SCANNING RANGE

Proposed scanning method by coupling Hokuyo UTM-30LX lidar with a rotating gimbal to achieve 3D scanning.



PROTOTYPES AND RESULTS

TEST 1: READING 2D LIDAR DATA



Hokuyo UTM-30LX Data Reading. Visualization in RViz.


```
# Single scan from a planar laser range-finder

header:
  seq: 26445
  stamp:                              # the acquisition time of the first ray in the scan.
    secs: 1447468784                  # seconds (stamp_secs) since epoch
    nsecs: 662396000                  # nanoseconds since stamp_secs
  frame_id: laser                     # the laser is assumed to spin around the positive Z axis
angle_min: -1.57079637051             # start angle of the scan [rad]
angle_max: 1.56643295288              # end angle of the scan [rad]
angle_increment: 0.00436332309619     # angular distance between measurements [rad]
time_increment: 1.73611115315e-05     # time between measurements [seconds] - if the scanner is moving, this will be used in interpolating position of 3d points
scan_time: 0.0250000003725            # time between scans [seconds]
range_min: 0.0230000000447            # minimum range value [m]
range_max: 60.0                       # maximum range value [m]

ranges: [0.6439999938011169, 0.6460000276565552, 0.6460000276565552, 0.6399999856948853, 0.6380000114440918, 0.6359999775886536, 0.6340000033378601,
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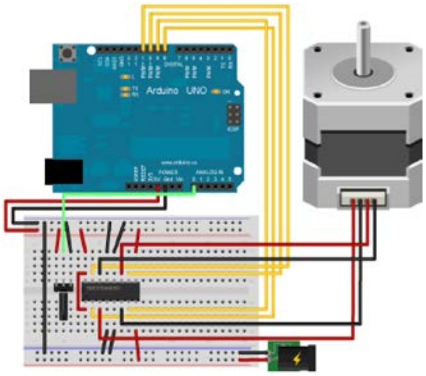
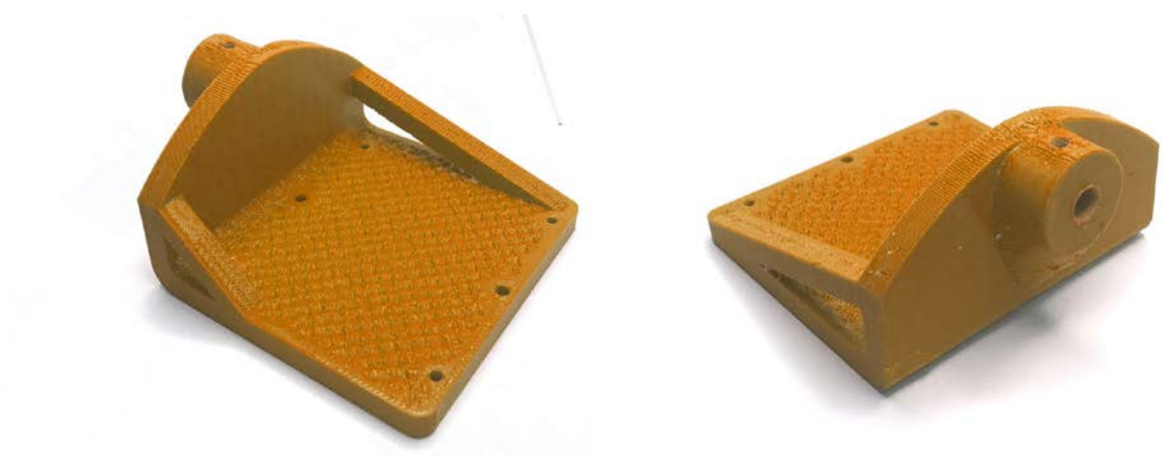
A typical instance of scanned data.

TEST 2: ROTATING LIDAR WITH AN ARTICULATED PLATFORM + A STEPPER MOTOR



Wiring Diagram for controlling a stepper motor with a knob (Arduino code here).

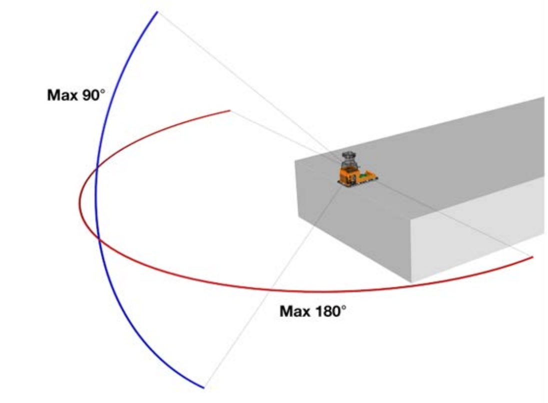
CAD model of the gimbal for connecting a Hokuyo UTM-30LX lidar to a stepper motor. (Gimbal model can be downloaded from GrabCAD).



3D printed gimbal for connecting a Hokuyo UTM-30LX lidar to a stepper motor.

Video of the prototype can be watched on YouTube.

TEST 3: ROTATING LIDAR WITH AN ARTICULATED PLATFORM + SERVO



This proposal utilizes a high precision servo (Dynamixel servo) to control the rotation of the lidar assembly.

Dynamixel Servo Specification	
Power	12 V, 1.4A
Weight	72g
Size	35.6 x 50.6 x 35.5 mm
Resolution	0.088°, 360° in a sec
Operating Angle	0° ~ 360° or Continuous Turn

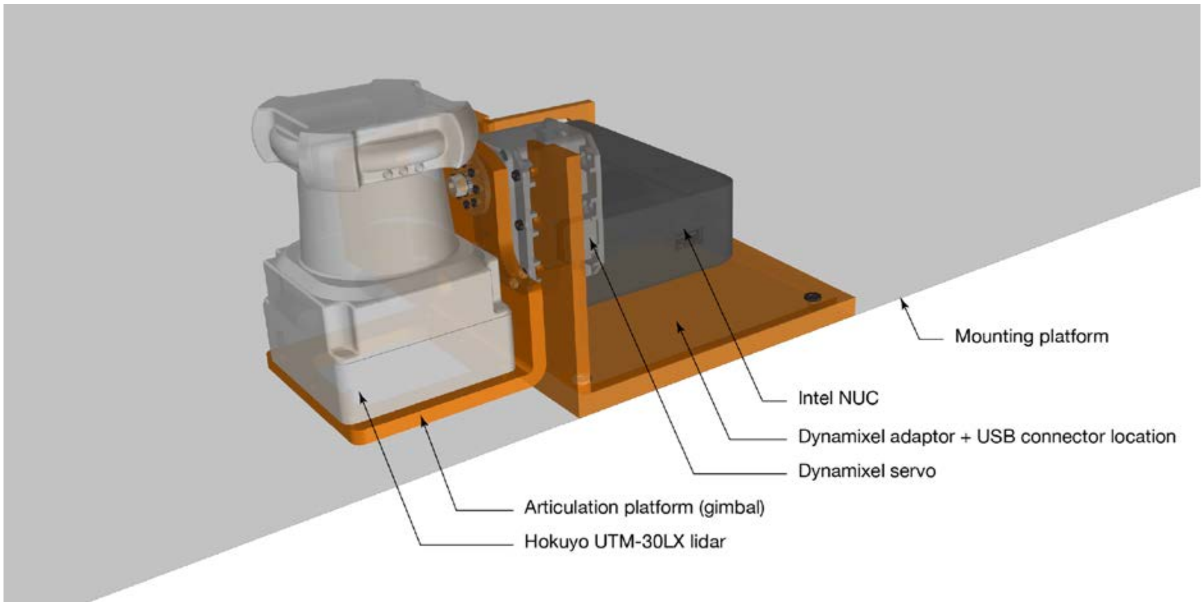

Dynamixel servo, Dynamixel Adaptor, USB to Servo Adaptor

3D printed gimbal for connecting a Hokuyo UTM-30LX lidar to a Dynamixel servo. (Gimbal model can be downloaded from GrabCAD).

3D printed gimbal for connecting a Hokuyo UTM-30LX lidar to a Dynamixel servo. This model has two opening to accommodate the cooling fan and run wires through the side. (Gimbal model can be downloaded from GrabCAD).

FINAL CONFIGURATION AND CAPABILITIES

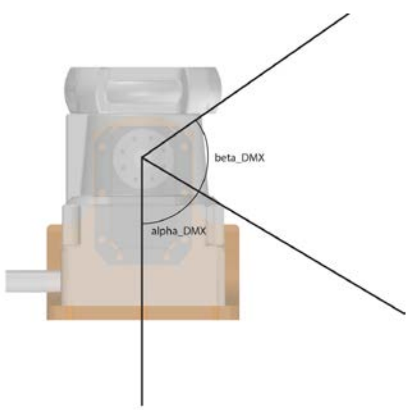
OVERALL ASSEMBLY:



For this prototype, we aligned the front edge of the articulation platform to a mounting surface in order to be able to scan ground information close to the assembly.

CENTER OF ROTATION:

For this prototype we aligned the center of rotation of the Dynamixel servo with the laser line.



TRANSLATION MATH:

This 3D scanning assembly requires to translate the point data from Polar-Coordinate to Cartesian-Coordinate system.

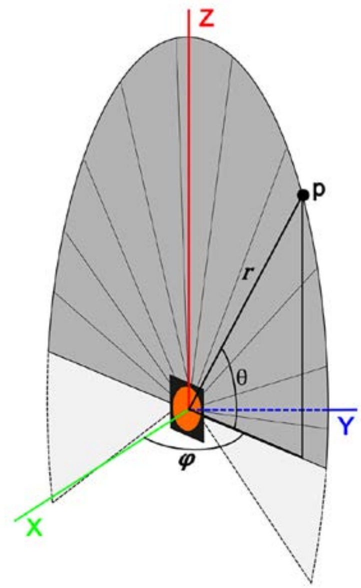
Data points are represented by polar coordinates (ϕ, ρ).
θ Resolution of the laser at 0.25 degree
φ Servo turning angle

We used the formula below to achieve the data translation.

$X = r * \sin(\theta) * \cos(\phi)$

$Y = r * \sin(\theta) * \sin(\phi)$

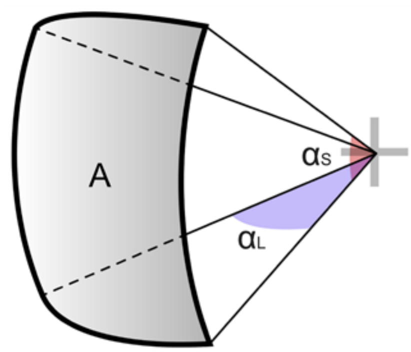
$Z = r * \cos(\theta)$



FIELD OF VIEW OF THE PROPOSED SYSTEM:

α_S = Servo Rotation
α_L = Lidar Area

$A = r\ (2\pi\alpha_S/360)(2\pi\alpha_L/360)$



MASS + POWER BUDGET

Item	Mass (g)	Dimensions (mm)	Power
Lidar: Hokuyo UTM-30LX Scanning Laser Rangefinder	370 g	60 x 60 x 87 mm	12V, 1.0A
PC: Intel NUC	1089 g	68 x 80 x 32 mm	12V, 1.2A
Servo: Dynamixel MX-28T Robot Actuator	72 g	35.6 x 50.6 x 35.5 mm	12 V, 1.4A
USB to Servo Adaptor	55 g	88.9 x 35.6 x 20.3 mm	N/A
Dynamixel Adaptor	49 g	27.9 x 53.3 x 15.2 mm	12 V, 1.4A
Articulation Platform	180 g	70 x 70 x 50 mm	N/A
Mini Cooling Fan	42 g	25 x 25 x 10 mm	5 V, 0.12A

BILL OF MATERIALS

Below are the items needed to reproduce the 3D Lidar Assembly.

Item	Quantity	Price	Resource
Lidar: Hokuyo UTM-30LX Scanning Laser Rangefinder	1	$4,974.00	Acroname.com
PC: Intel NUC	1	$319.00	Fry'sElectronics.com
Servo: Dynamixel MX-28T Robot Actuator	1	$219.90	TrossenRobotics.com
USB to Servo Adaptor	1	$49.90	TrossenRobotics.com
Dynamixel Adaptor	1	$4.90	TrossenRobotics.com
3 pin Bioloid Servo/Sensor Cables	25	$34.90	TrossenRobotics.com
Articulation Platform	1	$100 +/-	GrabCad (needs to be uploaded and linked)
Articulation Platform to Servo machine screws (Phillips pan head, stainless steel, ¼” length, #2-56)	8	$.40	boltdepot.com
Articulation Platform to Lidar screws (Phillips pan head, stainless steel, 7/16” length, #4-40)	4	$.20	boltdepot.com
Mini Cooling Fan	1	$1.04	ebay.com
Thermal Glue	1	$8.99	Fry'sElectronics.com
Triple Channel DC Power Supply	1	$670	Tequipment.net

USER'S GUIDE

To view a complete User's Guide, please watch this video.

KNOWN ISSUES AND LIMITATIONS

1. This 3D scanning assembly should recalculate its transformation matrices by taking into account a lever arm, even when assuming the translation is 0.
2. Current workflow must be further analyzed to achieve faster 3D scanning results. Currently scanning ranges from (4 to 10 seconds) depending on the scanning resolution. By accelerating this process, we can attempt at scanning dynamic targets.
3. Currently we are not creating custom ROS subscribers and publishers. We would like reconstruct the whole project in ROS to take advantage of its full capabilities.

PROJECT SUCCESSES, UNEXPECTED RESULTS, AND LESSONS LEARNED

Successes: This 3D scanning assembly is able to 3D scan any static indoor and outdoor target. It is capable of high resolution point cloud visualization. It is able to take user information, and email multiple views instantly.

Unexpected Results: This 3D scanning assembly required number of calibration tests for successful scanning of various targets.

Lessons learned: It is often difficult to analyze large point cloud data. In this context, one requires additional reference parameters, such as color and texture, to evaluate scanning resolution and translation metrics. Our initial solution is to apply a color gradient to the point cloud which reflects the X,Y,Z coordinates of each point. Therefore, our next step is to couple a camera to the 3D scanning assembly, in order to sample the appropriate color value that corresponds to each point.

RESOURCES AND REFERENCES

3D Scanning Assembly CAD files: 3D Scanning Assembly's GrabCAD page

3D Scanning Assembly video documentations: 3D Scanning Assembly's YouTube Channel

Source code is located at: https://github.com/gcc-robotics/3d_scanner_2016

BIOS

Biayna Bogosian is an architect and media artist designing interactive urban interfaces that respond to environmental data patterns. Biayna is pursuing a PhD in Media Arts & Practice in the School of Cinematic Arts at the University of Southern California. She holds a Master of Science in Advanced Architectural Design from Columbia University and a Bachelor of Architecture from Woodbury University.

Narek Gharakhanian is an undergraduate student majoring in electrical engineering and minoring in math, who soon will be attending Cal Poly Pomona to pursue his Bachelor's degree. Narek attended the FH-Bochum (University of Applied Sciences Bochum) from 2006-2009 in Germany. He is currently working at the City of Glendale. Some of his tasks are software development and application admin.

ACKNOWLEDGEMENTS

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