The Design and Development of a Handheld Modular Laser Scanner

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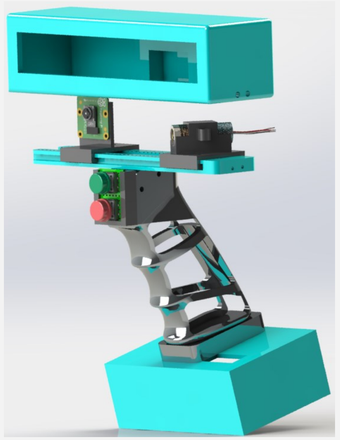
Major Goals

- Development of a modular prototype.
- Capable of producing high quality point clouds of subject.
- Ability to track pose in 3D space.
- Variable scan range.

Prototype



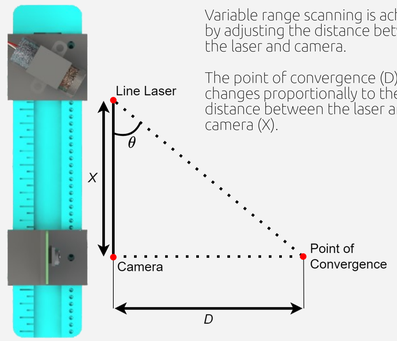
The Prototype is composed of various modular components:

- Raspberry Pi Housing
- Handle
- Slider Base
- Top Casing
- Fixed Holder Slide
- Angled Holder Slide
- Camera and Laser Slider Modules
- Green and Red Pushbuttons

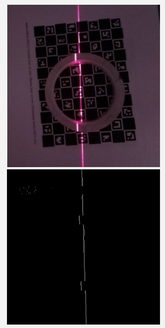
Variable Range Scanning:

Variable range scanning is achieved by adjusting the distance between the laser and camera.

The point of convergence (D) changes proportionally to the distance between the laser and camera (X).

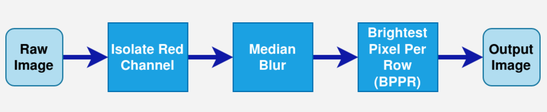


Laser Isolation



Laser Isolation:

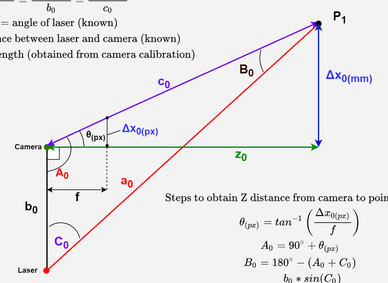
- Laser wavelength of 650 nm corresponds to the colour red.
- Discard G and B layers in RGB image, the laser should have high intensity.
- Median blur reduces 'salt and pepper' noise.
- Set the brightest pixel per line to 255 (white) and the rest to 0 (black).



Laser Triangulation

$$\frac{sin(A_0)}{a_0} = \frac{sin(B_0)}{b_0} = \frac{sin(C_0)}{c_0}$$

C_0 = angle of laser (known)
b_0 = distance between laser and camera (known)
f = focal length (obtained from camera calibration)



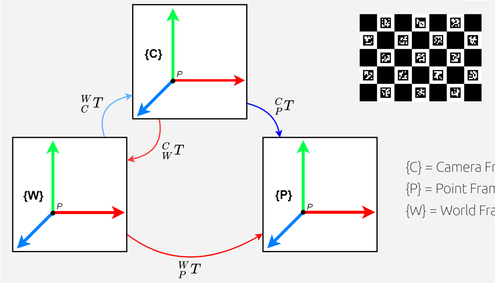
Steps to obtain Z distance from camera to point in space

$$\theta_{(px)} = tan^{-1}\left(\frac{\Delta x_{0(px)}}{f}\right)$$
$$A_0 = 90^\circ + \theta_{(px)}$$
$$B_0 = 180^\circ - (A_0 + C_0)$$
$$c_0 = \frac{b_0 * sin(C_0)}{sin(B_0)}$$
$$z_0 = c_0 * cos(\theta_{(px)})$$

Laser Triangulation:

Given focal length, distance between the camera and laser b_0, and angle of the laser module C_0, trigonometry is used to calculate distance z_0 from the camera to point P_1 .

Pose Estimation

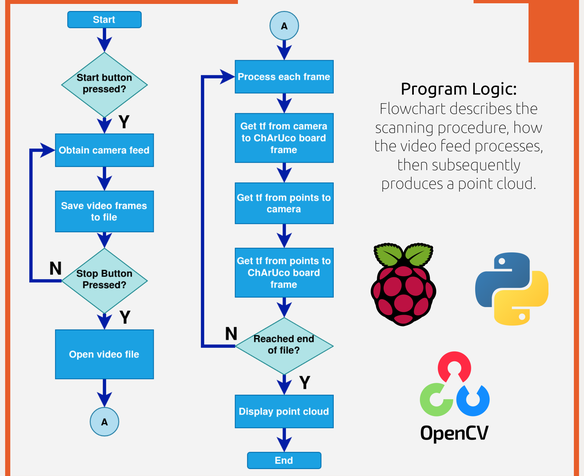


{C} = Camera Frame
{P} = Point Frame
{W} = World Frame

Pose Estimation:

- The triangulated laser points are mapped from {C} to {P}.
- ChArUco board gives pose transform from {W} to {C}.
- Inverse transform gives {C} to {W}.
- Applying inverse transform to points yields point cloud with respect to {W}.

Program Logic

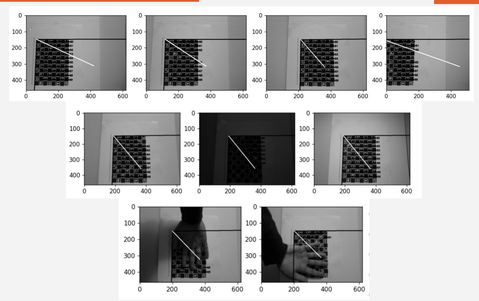


Program Logic:

Flowchart describes the scanning procedure, how the video feed processes, then subsequently produces a point cloud.

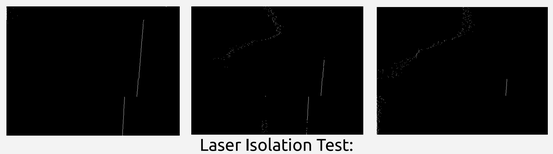
OpenCV

Results & Tests



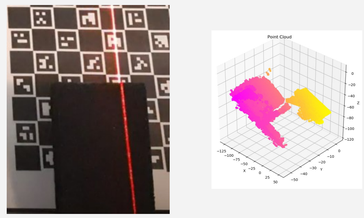
Pose Estimation Tests:

Pose Sweep, Brightness and Interference tests conducted to determine robustness given distance from subject, ambient lighting conditions, and interference from external sources, respectively.



Laser Isolation Test:

Laser Isolation Brightness test conducted to determine accuracy loss due to ambient lighting conditions.



Results:

The resulting point cloud successfully maps the points to the world coordinate frame.

The scanner is able to function at various distances.

The generated point clouds include plenty of noise which must be improved moving forward.