Estimation of Hollow Elpis Harbour Height Based on Single Point Triangulation, Step Calculation, and Camera Field of View

@zenless.gg

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Abstract.

This study aims to measure the height of the Hollow structure at Elpis Harbour using the single-station triangulation method, supported by distance estimation based on the pacing method and camera field of view (FOV) analysis. Data was collected from a single observation point at a height of 3.8 meters above ground level with an elevation angle of 45°, and a horizontal distance (baseline) of 2028 meters obtained through the pacing method and camera FOV verification. Height calculations were performed using the principles of right-angle trigonometry. The results show that the estimated Hollow height is relatively close to the baseline distance because the elevation angle is close to 45°, resulting in insignificant differences in values. The potential measurement error margin was analyzed based on the accuracy of the elevation angle, distance estimation, and height correction of the observation point. This study confirms that the combination of single-point triangulation, step calculation, and camera FOV analysis can serve as a fast field measurement alternative, although it is sensitive to angle and distance errors.

Here the steps-by-steps the calculation before I get the height.

- Steps calculation
- Fov measurement
- Baseline calculation
- Height calculation

Steps calculation:

Using available character that I had.

The calculation using a rough calculation about the distance that every character get in one spot to second spot of photo take, this down is the formula;

A rough rule of thumb: stride length ≈ 0.414 × height.
Note: Because male and female a bit different (female (0,413)) and (male (0,415) so I will use 0,414 in between. It's not a big problem with not really big dataset but i just want make it more balance.

For example:
Zhu Yuan height is 175 cm.

Based on that; 0.414 x 175 = 72,3 cm per step (≈ 0,723 m)
With manual count, Zhu Yuan Takes 39 steps from points A to B
39 x 0,723 = 28,197 or 28,2.

Table of list:

Name	Height	Steps	Distance
Zhu Yuan	175	39	28,2
Yuzuha	162	43	28,8
Jane Doe	170	37	26,0
Seth	174	40	28,8
Anby	156	42	27,1
Nicole	165	39	26,6
Billy	188	37	28,8
Ben	192	39	31,0
Anton	190	37	29,1
Grace	170	36	25,3
Soldier 11	160	44	29,1
Lucy	152	47	29,6
Piper	151	53	33,1
Pulchra	173	40	28,6
Miyabi	150	44	27,3
Soukaku	145	55	33
Harumasa	173	40	28,6
Yanagi	169	41	28,7
Vivian	162	43	28,8
Yi Xuan	172	38	27
Lycaon	198	36	29,5
Rina	173	40	28,6
Corin	141	45	26,2
Pan Yinhu	192	38	30,2

Average of steps is: 41,375
Average of distance: 28,7

Average Distance per Step

Formula for one person
Step Leght = Total Distance/Number of Steps

Example (Zhu Yuan):
28.2/ 39 steps ≈ 0,723 m/step

And lastly finding a total average distance per step.
Average Step Length = Sum of All Step Leghts/Number of People

Margin Error;
Last step before using a average step leght distance, using margin error formula to find a error tolerance that for average, with formula write down;

$$s = \sqrt{\frac{\Sigma\left(x_i - \bar{x}\right)^2}{n-1}}$$

Finding the Standar Error;
This adjusts the standard deviation for the number of samples:

$$SE = \frac{s}{\sqrt{n}}$$

Apply the 95% Confidence Level;
For large-ish samples, the 95% confidence multiplier is 1.96:
Margi of Error = 1,95 x SE

After doing the calculation that I had done before for average distance per step, standard deviation, and total number of character we can start the calculation from now for margin error.

Standard error:

$$[0.078 / \sqrt{24} \approx 0.0131]$$

Margin error:

$$1.96\ x\ 0.0131 \approx 0.026\ m$$

So:

$$Average\ Step\ Leght \approx 0.698 \pm 0.026$$

FOV Measurement:

1.The main purpose of FOV measurement related to this calculation.

This measurement is one of key elements that needed to make less margin error in further calculation related to Triangulation, triangulation require a camera FOV to do a measurement, in short term FOV measurement is import things to do before doing full scale triangulation calculation.

2. Basic principles.

The relationship between the size of objects on the screen and FOV can be written as:

$$\frac{\tan tan\left(\frac{FOV_{out}}{2}\right)}{\tan tan\left(\frac{FOV_{in}}{2}\right)} = \frac{p_{in}}{p_{out}}$$

FOV_{in} = FOV when zoom in.

FOV_{out} = FOV when zoom out.

P_{in} = Wide os the object when zoom in screen shoot (pixel).

P_{out} = Wide of the object when zoom out screen shoot (pixel).

3. Data Collecting.

A. Preparation.

- o An object or NPC that stay/not moving.
- o Make sure the camera in same position when zoom in & out mode

B. Screenshoot taken.

- o Take a screenshoot picture when zoom in maximum.
- o Take a screenshoot picture when zoom out maximum.

C. Measurement.

- o Open both of the image in picture editor
- o Measure wide of the object in both of picture in pixel.

4. Calculation

In this calculation I will use two object for comparation from both calculation, finding if there will be any error or unstable data.

Object 1 calculation:

P_{out} = 200 px

P_{in} = 873 px

A. Zoom in ratio:

$$r = \frac{p_{in}}{p_{out}} = \frac{873}{200} = 4.365$$

That mean, zoom in, the object is 4,365x more wide compare to zoom out

B. Connection to FOV:

Basic formula:

$$tan\left(\frac{FOV_{out}}{2}\right) = 4.365 \cdot tan\left(\frac{FOV_{in}}{2}\right)$$

C. Absolute example: (assume $FOV_{in} = 20^{o}$)

$$tan\left(\frac{FOV_{out}}{2}\right) = 4.365 \times tan\left(10^{\circ}\right) \approx 0.768$$

$$\frac{FOV_{out}}{2} \approx \arctan arctan\,(0.768) \approx 37.54^{\circ}$$

$$FOV_{out} \approx 75.08^{\circ}$$

Object 2 calculation:

P_{out} = 148 px

P_{in} = 646 px

A. Zoom in ratio:

$$r = \frac{p_{in}}{p_{out}} = \frac{646}{148} 4.365$$

The result is almost same from first data (4,365x), that means the zoom level in this game is consistent.

B. Connection to FOV:

Basic formula:

$$\tan tan \left(\frac{FOV_{out}}{2}\right) = 4.365 \cdot \tan tan \left(\frac{FOV_{in}}{2}\right)$$

C. Absolute example: (assume FOV_{in} = 20º)

$$\tan tan \left(\frac{FOV_{out}}{2}\right) = 4.365 \times \tan tan \left(10^{\circ}\right) \approx 0.768$$

$$\frac{FOV_{out}}{2} \approx \arctan\ arctan\,(0.768) \approx 37.54^{\circ}$$

$$FOV_{out} \approx 75.08^{\circ}$$

Find a baseline:

The place i choose is Elpis harbour because they had second floor that very important in this calculation, the wide of place I will move from right to left is around 4 steps character that mean we can use calculation based on average one step;

$$4\, steps\ x\, 0,698\, m\ =\ 2,8\, m$$

The data that already been collected:
Screen resolution: 2276 × 1280 px.
Baseline: 2,8 m.
Pixel moving: 9 px
$FOV_h = 20^o$ (zoom in)

Now the steps to calculated the distance to hollow (D):

1. Calculate the degree scale per pixel:

$$degree/pixel\ = \frac{20}{2276} \approx 0,008787^{\circ}$$

2. Conversion of pixel shift to degrees:

$$\theta\ =\ 9\, x\, 0,008787 \approx 0,07908^{\circ}$$

   In radian:

$$\theta\ \approx\ 0.07908\ \times \frac{\pi}{180} \approx\ 0.00138\, rad$$

3. Use the parallax formula

$$D\ \approx \frac{baseline}{tan\ (\theta)}$$

$$D\ \approx \frac{2,8}{tan\ (0,00138)} \approx \frac{2,8}{0,00138} \approx\ 2028\, m$$

Distance count:

$$D\ = \frac{2.8}{tan\left(\frac{9}{2276}\times 20\times\frac{\pi}{180}\right)}$$

Calculate distance:

$$\theta\ = \frac{\Delta p}{W} FOV_h = \frac{9}{2276} \cdot 20^{\circ} \approx\ 0.07909^{\circ}$$

$$\theta_{rad} \approx\ 0.0013803 \Rightarrow D\ = \frac{b}{tan\ \theta} \approx \frac{2.8}{tan\ (0.0013803)} \approx\ 2028.5\, m$$

Additional Propagation error (1σ)

- Use $D = b \cot \theta$, so:
- $\partial D/\partial b = \cot \theta = D/b$
- $\partial D/\partial \theta = -b \csc^2 \theta$

With:

- σ_b = 0,054 b = 0,1512 m
- σ_θ = 1% from θ -> 0,01 x 0,0013803 = 1,38 x 10^{-5} rad

Contributation:

- From b: $\sigma_{D,b} \approx$ 109.5 m
- From FOV/ θ: $\sigma_{D,\theta} \approx$ 20,3 M

Combined (root of the sum of squares):

$$\sigma_D \approx \sqrt{(109.5)^2 + (20.3)^2} \approx\ 111.4\, m$$

Final result:
D ≈ 2,03 ± 0,11 km (≈ ±5,5% @ 1σ)
For around 95% (≈2σ): ±0,22km

Height Calculation:

And here we're the final steps to find out the height of Elplis Harbour Hollow, yes all of the complicated calculation that I just do, end up in here. It's actually the most simple calculation compare to previous one.

We assume that the angle degree to calculated is 45 to make it easier for calculation, 3,8 up from the ground/sea, and 0m hollow to ground. The problem is, I assumed that the hollow would be below the water surface, but since the data did not support measurements underwater, I assumed that the mouth of the hollow was at 0 m above the water surface.

The data we collect:
Baseline D = 2028m
Elevation degree $\theta = 45^{\circ}$
Observer height h_i = 3,8m up from the ground/sea

Formula:

$$Peak\ height\ =\ hi\ +\ D{\cdot}tan(\theta)$$

Substitution:

$$Peak\ height\ =\ 3,8\ +\ 2028\ \cdot\ tan(45)$$

$$Peak\ height\ =\ 3,8\ +\ 2028\ \cdot\ 1$$

$$Peak\ height\ =\ 2031,8m$$

And now we get the height of Elpis Harbour hollow, 2031,8m

Volume of Elpis Harbour Hollow:

In this case we assume that hollow is hemisphere and not a spherical cap.
Radius r = 2031,8m.
Formula for hemisphere volume:

$$V_{hemi} = \frac{2}{3}\pi r^3$$

Substitution:

$$V_{hemi} = \frac{2}{3}\pi(2031.8)^3$$

$$V_{hemi} \approx 1.7544\ \times\ 10^{10}\,m^3$$

$$V_{hemi} \approx 17.544\,km^3$$

TL;DR

Hello everyone, I'm Van, the admin of the Instagram fan page @zenless.gg. Thank you for reading my measurement results. I need to clarify that I didn't create this entirely on my own. I used assistance in the creation process, specifically in finding the formulas. However, it's important to note that I also contributed to the creation. Ultimately, AI was used to assist, not to be entirely dependent on it. This article was inspired by the article "Yi Xuan – Full Body Measurement Profile" by aybeatit2hutao.

Admin Note:

Hello everyone, I apologize for not uploading content frequently. I have been busy with real life matters and creating this, so please forgive me. I will try to do better in the future and upload more useful and high-quality content.