FIG WORKING WEEK 2017

Helsinki Finland

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Creation of LoD1 Buildings Using Volunteered Photographs and OpenStreetMap Vector Data

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Surveying the world of tomorrow –
From digitalisation to augmented reality

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Outline

- Introduction
- Research Goals
- Methodology
- Field Experiments and Results
- Conclusions and Future Work

Introduction - 3D City Models

- 3D city models become increasingly popular among urban planners :

  - Noise and environmental analyses
  - Disaster management
  - Architecture and city planning

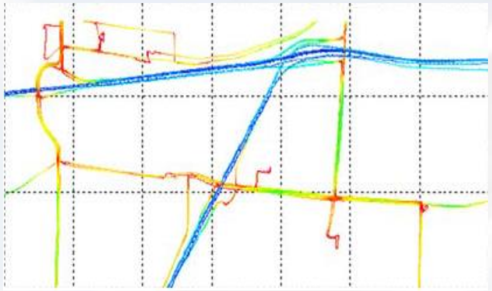
bcgis.com

- Level of Detail – LOD1

Introduction - Volunteered Geographic Information

- VGI: " Thousands of humans acting as remote sensors" (Goodchild, 2007).

- Groups of people can collect geographic data that is either difficult to automate or expensive to implement.



GOODCHILD , California , 2007

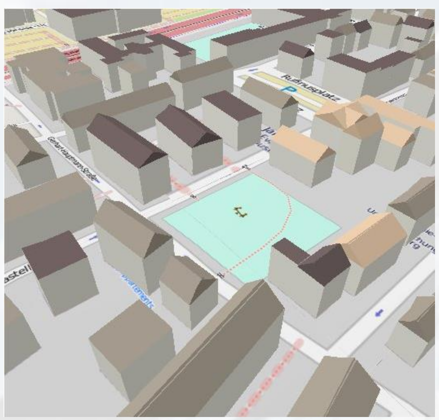
Map creation by walking or driving using smartphones (GPS trajectories)

OSM

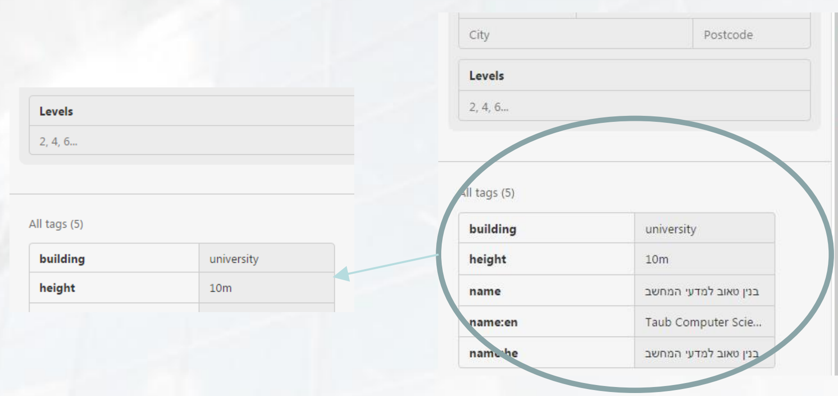
Aerial/satellite imagery digitizing

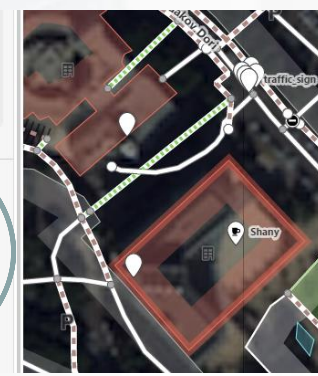
Introduction – OSM

- OpenStreetMap - One of the most famous examples of crowdsourcing VGI maps with more than 3.1 million users.
- More than 6.5 million building 2D footprints, increasing by 1% monthly.
- **Yet**, only 1.4% of OSM buildings have height data.



OSM 3D - Buildings in Heidelberg, Germany

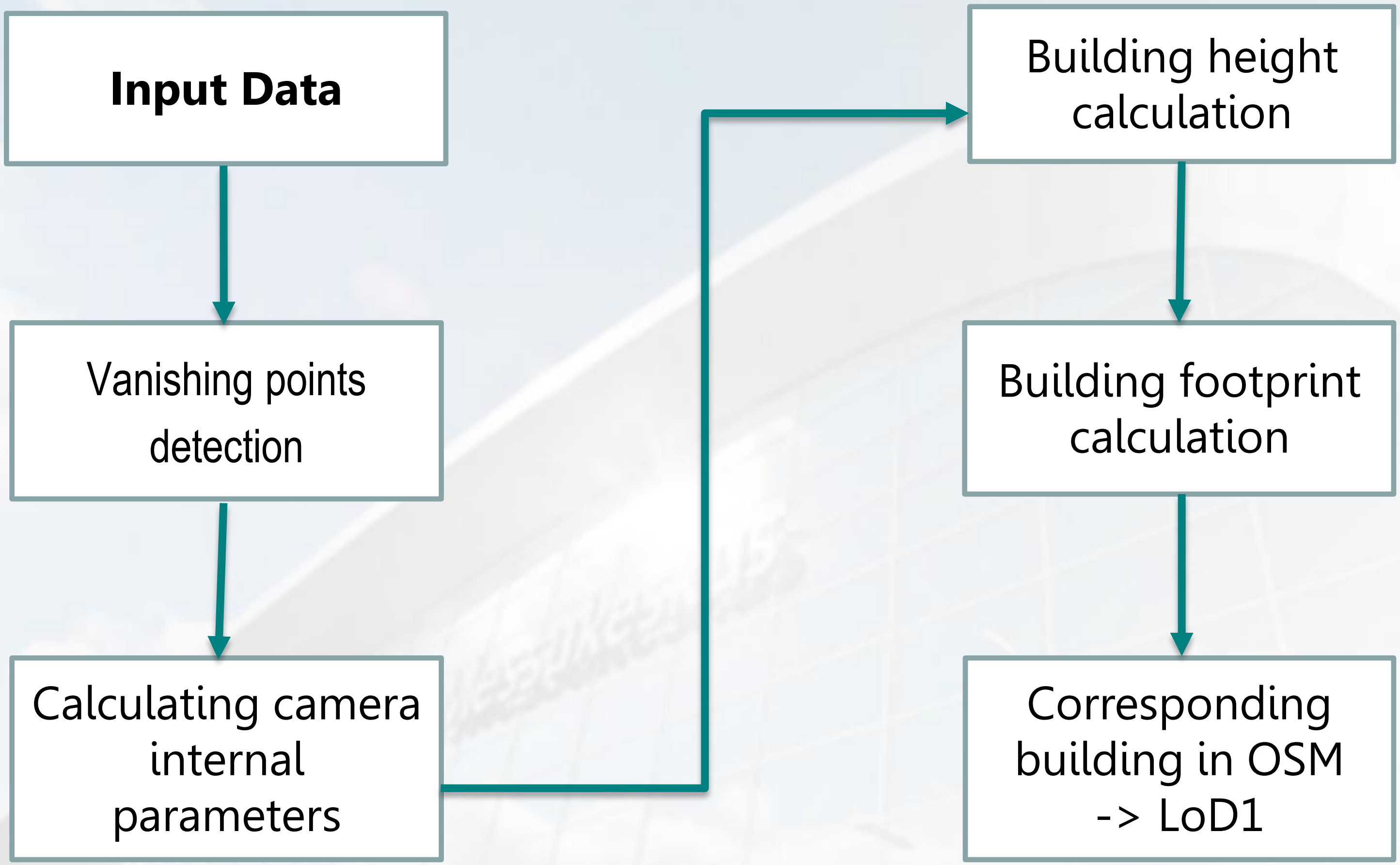




Research Goals

- Investigate whether collective imagery contributed by users (WWW) can be used to produce LoD1 information.
- Extract accurate building heights from single perspective images.
- Produce 3D building models (LoD1) in OSM.

Methodology



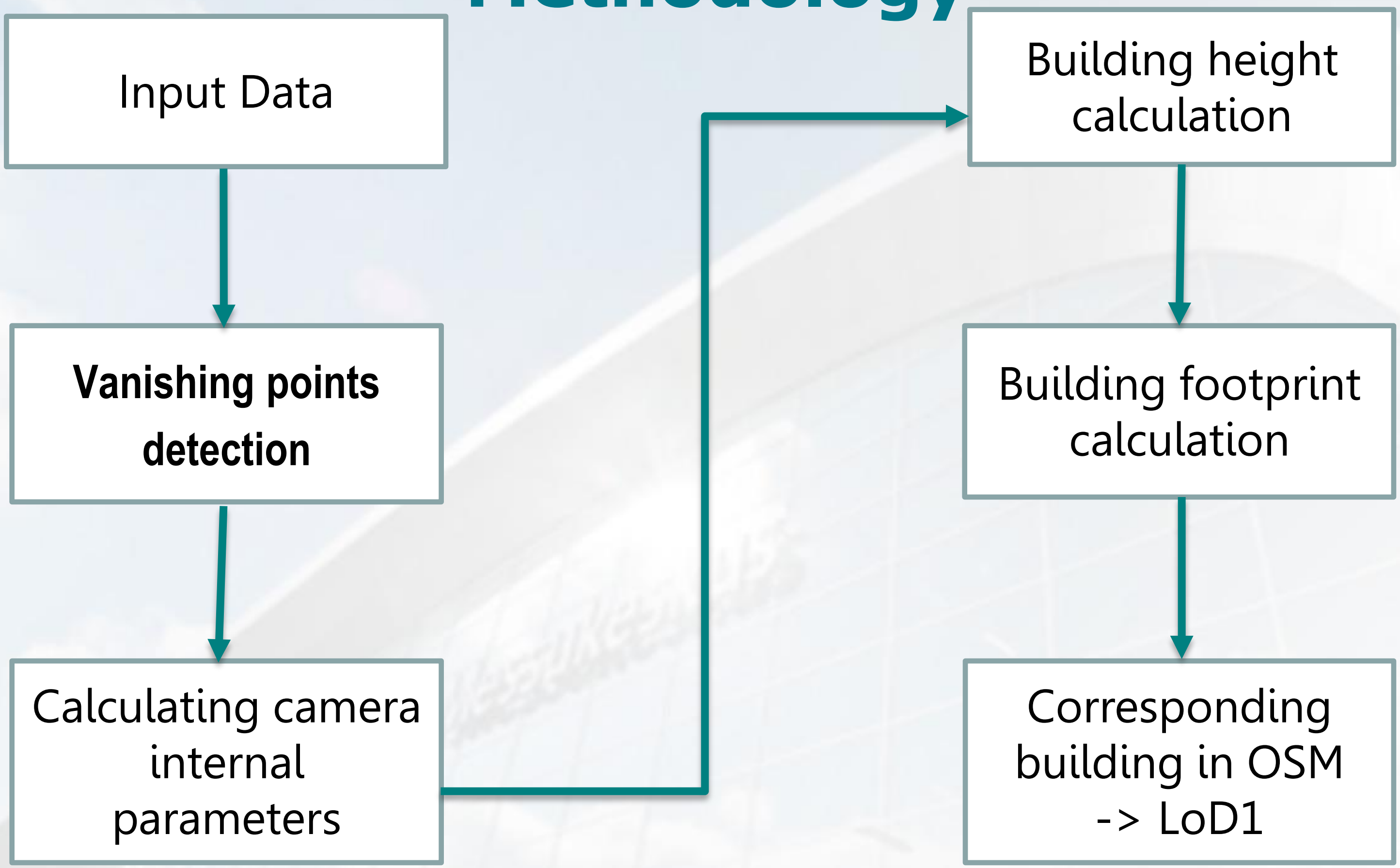
Input Data– Perspective Building Images

Manhattan-world assumption: the imaged scene contains three orthogonal, dominant directions, typically corresponding to the X, Y, and Z axes.

EXIF - Exchangeable Image File format :

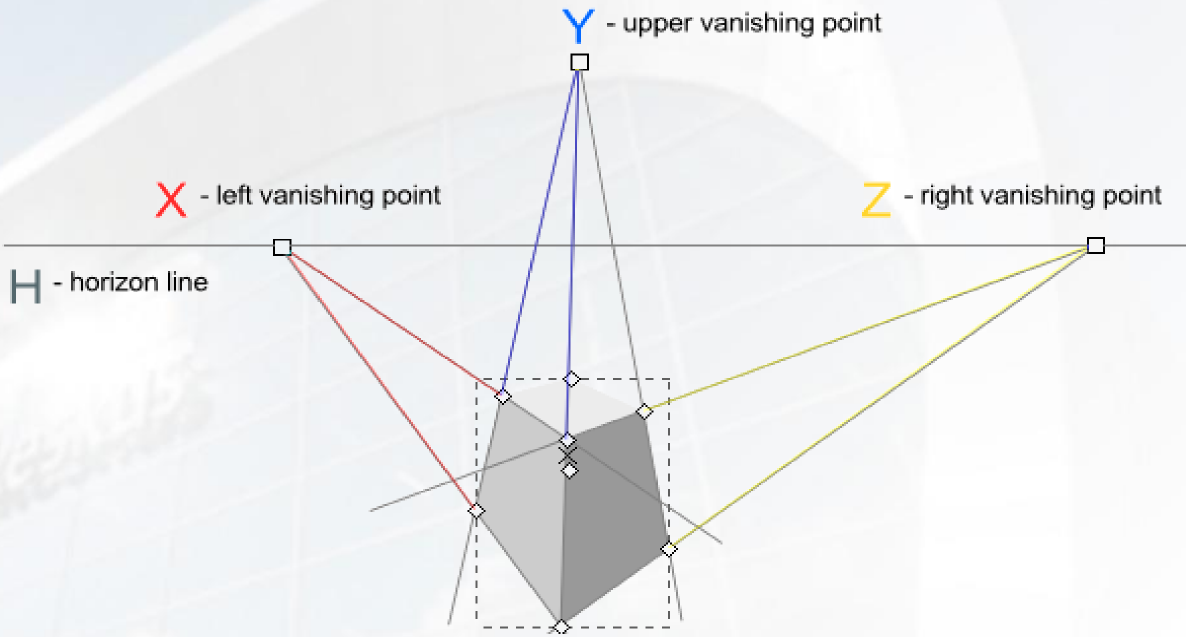
- **Geotagging** – most cameras and smart phones have a built-in GPS receiver that stores location information [lat ,long] → [X,Y]
- **Focal length** – [pixel]
- **Image size** – [pixel]

Methodology



Orthogonal Vanishing Points Detection

- Automatically detect the 3 vanishing points based on the Manhattan-world assumption (orthogonality).



Flickr

derivativesinvesting.net

Orthogonal Vanishing Points Detection

- Several methods for vanishing point detection make use of the line segments detected in images.

Source: Simon, Fond, Berger. Eurographics 2016

Methodology

Input Data

↓

Vanishing points detection

↓

Calculating camera internal parameters

→

Building height calculation

↓

Building footprint calculation

↓

Corresponding building in OSM -> LoD1

Camera Internal Parameters

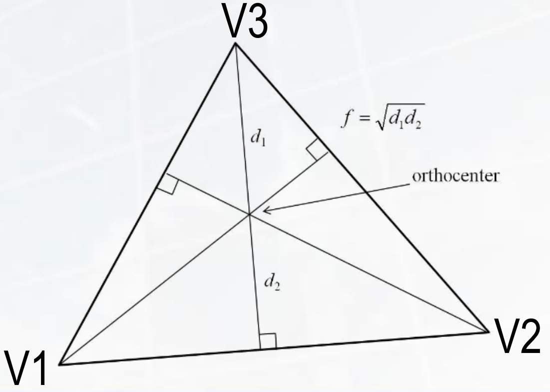
- **EXIF :**
  - Assume principle point is at image center:

$$[u0, v0] = [\frac{Image\ Width}{2}, \frac{Image\ Height}{2}]$$

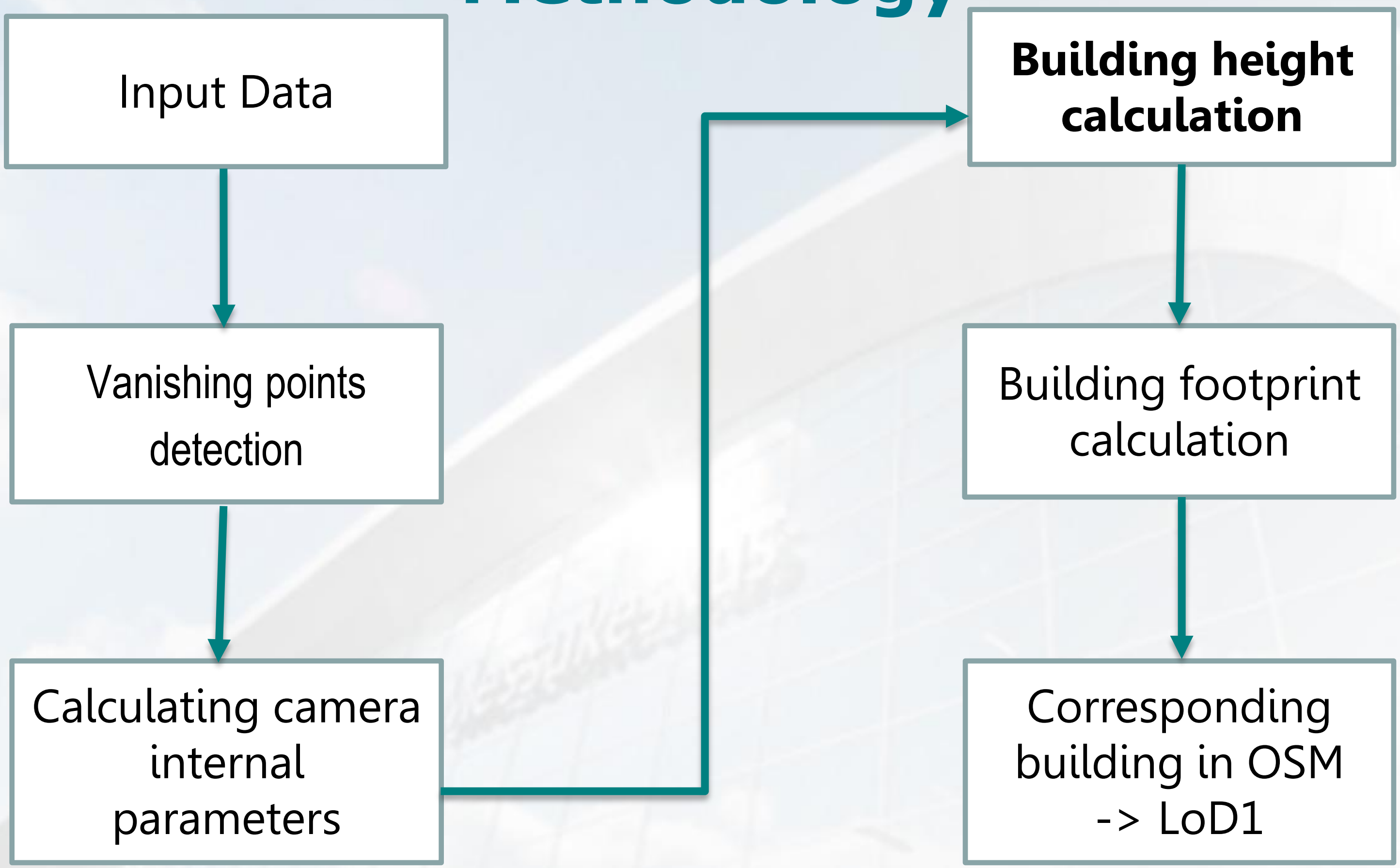
  - Focal length in pixels :

$$new\ f = \frac{original\ f \bullet new\ width}{original\ width}$$

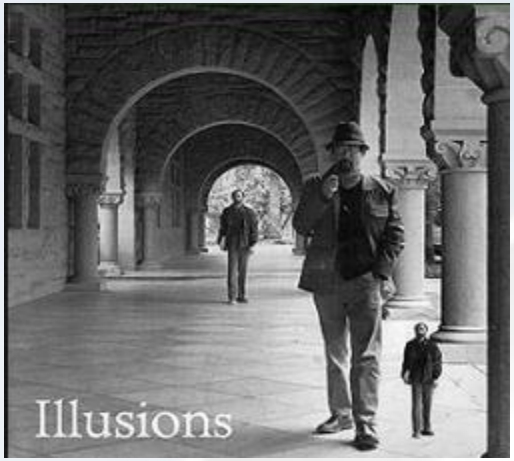
- **Vanishing points :**
  - Camera principal point [u0,v0] is at the orthocenter of the triangle, which has the vanishing points as its vertices.
  - Focal length is estimated using:

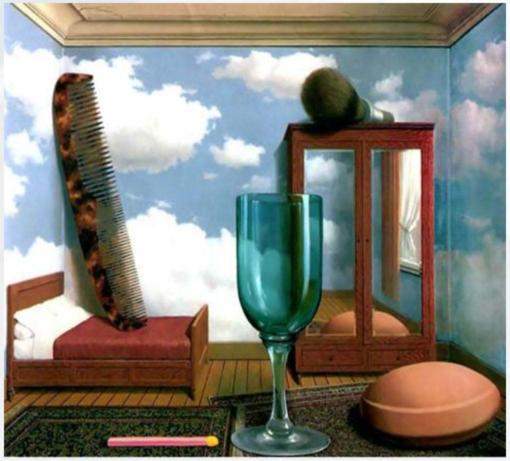


Methodology



Building Height Calculation: Single View Metrology

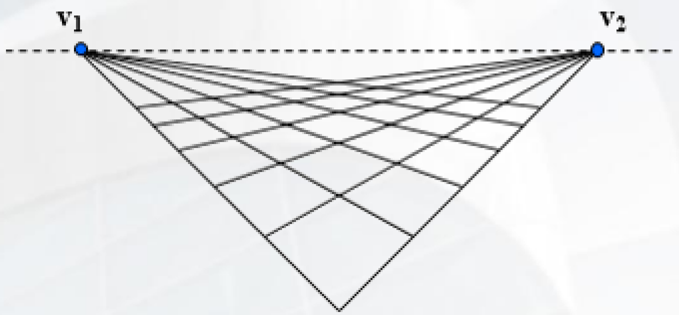




- Single view metrology is used to calculate height in the "real world".
- Cross ratio is preserved by the projective transformation of a projective line.

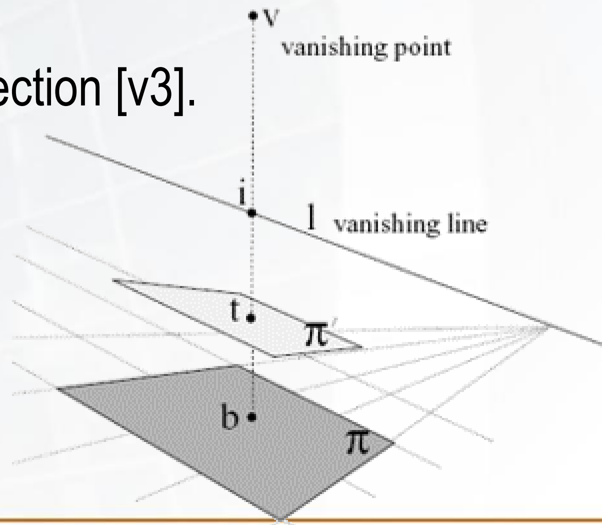
Building Height Calculation: Cross Ratio

- **Horizon line** - Projection of the line at infinity of the reference plane into the image [v1,v2].



- **Vertical point** - A point at infinity in the reference direction [v3].
- **Reference -** height in meter

$$\frac{\|\mathbf{t}-\mathbf{b}\|\|\mathbf{v}_Z-\mathbf{r}\|}{\|\mathbf{r}-\mathbf{b}\|\,\|\mathbf{v}_Z-\mathbf{t}\|} = \frac{H}{R}$$



Building Height Calculation - Example

- Building height is 11.24 m - measured by total station (±2 cm).

	Reference [m]	Calculated Building Height [m]	Error [m]
Stop sign	2.8	11.4	0.16
Pedestrian_a	1.65	11.6	0.36
Pedestrian_b	1.55	11.1	-0.14

Methodology

Input Data

Vanishing points detection

Calculating camera internal parameters

Building height calculation

Building footprint calculation

Corresponding building in OSM -> LoD1

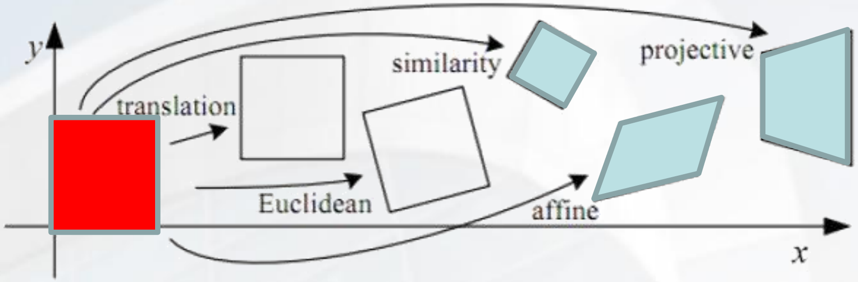
Building footprint - Homography

$$H = M \bullet A \bullet P$$

- Projective

$$P = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ l_1 & l_2 & 1 \end{pmatrix}$$

I1 & I2 are Horizon line parameters



- Affine

$$A = \begin{pmatrix} \frac{1}{\beta} & -\frac{\alpha}{\beta} & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$\alpha \& \beta$ are function of the internal parameters

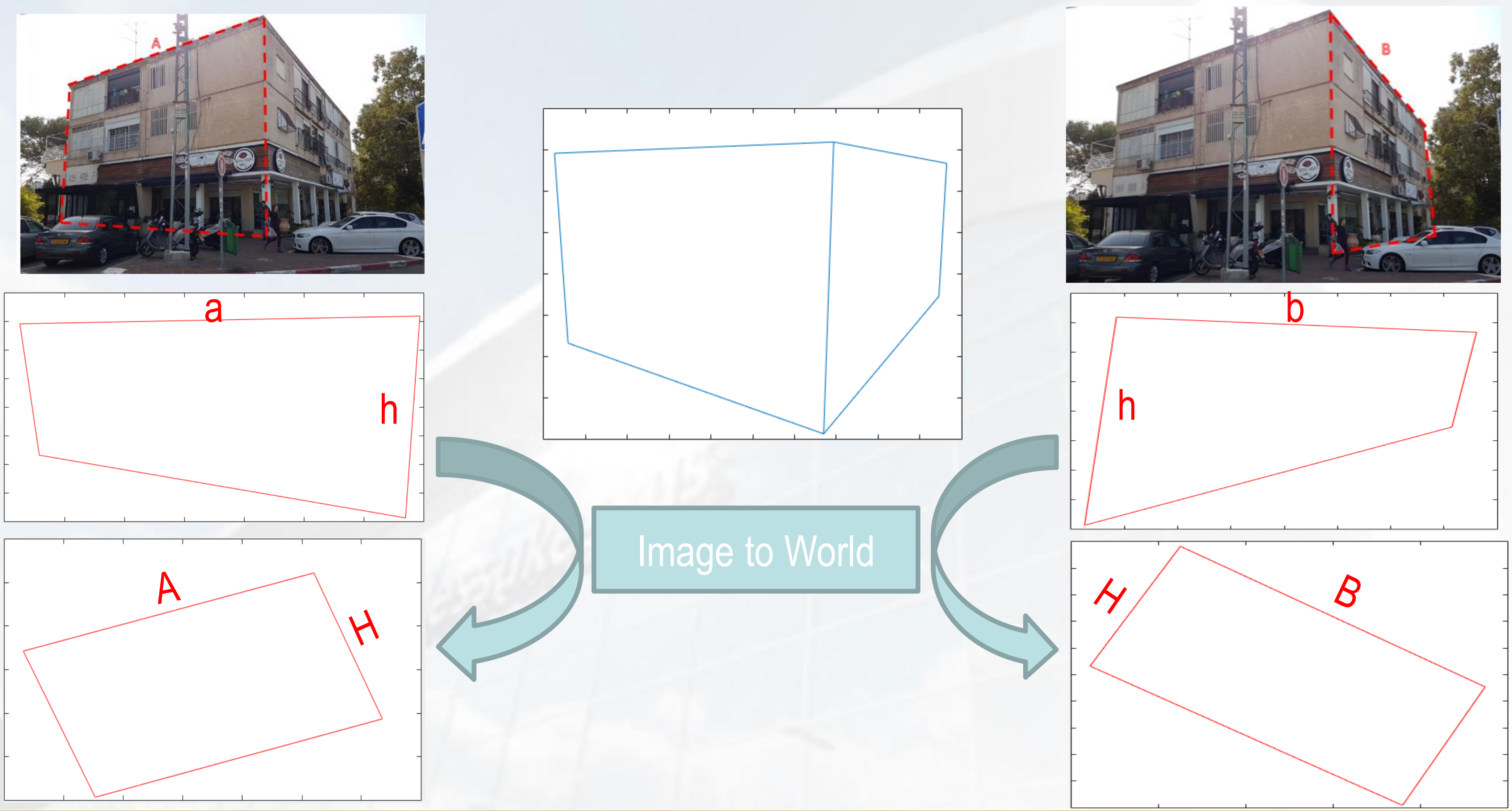
- Similarity

$$M = \begin{pmatrix} sR & t \\ 0^{\top} & 1 \end{pmatrix}$$

$$S = \frac{\text{building height in pixel}}{\text{building height in meter}}$$

Scaling, Rotation & Translation

Building footprint: Homography Results



Field Experiments and Results - Height

Building	Measured	Calculated	Difference
b1	11.24	11.4	0.16
b2	11.63	11.56	-0.07
b3	10.95	11	0.05

b1

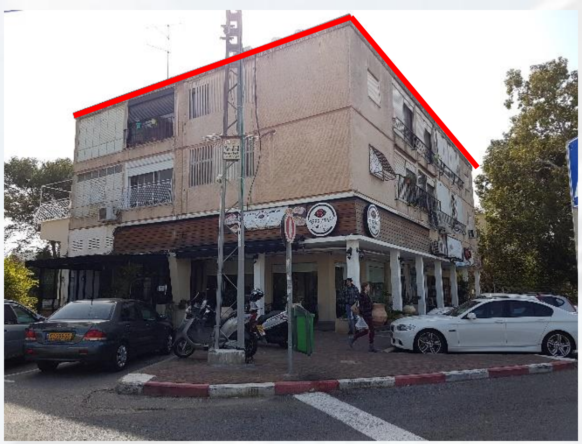
b2

b3

Field Experiments and Results - Footprint

- Building footprints were measured using a tape (±5 cm)

Measured		Calculated via focal length		Calculated via EXIF focal length		Difference			
						Focal		EXIF	
A [m]	B [m]	A [m]	B [m]	A [m]	B [m]	A [m]	B [m]	A [m]	B [m]
16.00	22.60	16.40	23.00	16.20	23.20	0.40	0.40	0.20	0.60
8.80	12.70	8.22	13.50	8.02	13.43	-0.58	0.80	-0.78	0.73
12.20	17.20	12.36	16.71	12.26	15.03	0.16	-0.49	0.06	-2.17



b1

b2

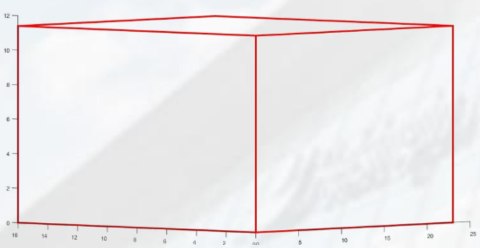
b3

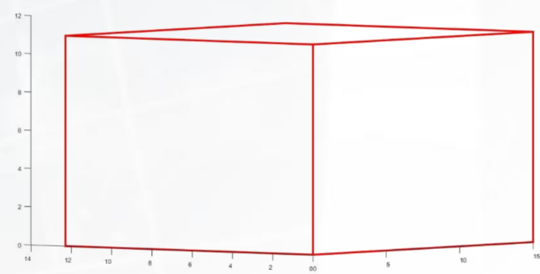
Field Experiments and Results - LoD1

b1

b2

b3





Methodology

Input Data

→ Vanishing points detection

→ Calculating camera internal parameters

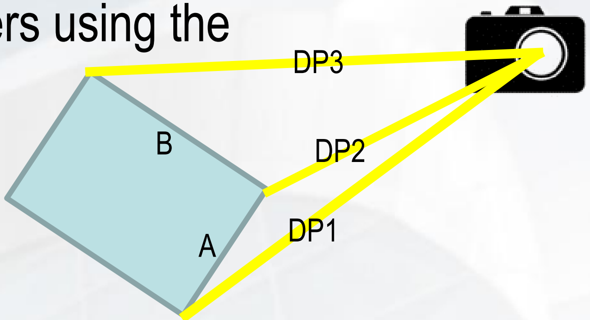
→ Building height calculation

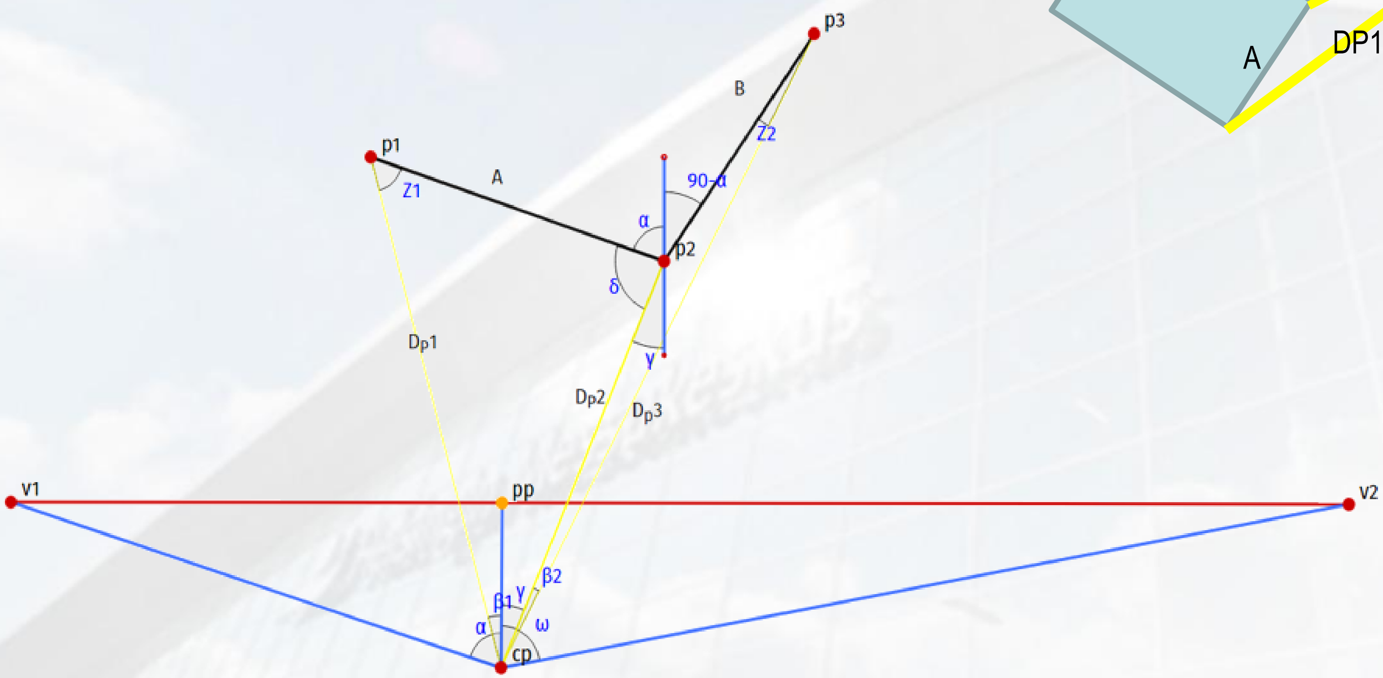
→ Building footprint calculation

→ **Corresponding building in OSM -> LoD1**

Corresponding building in OSM

- Estimate the distances from the building corners using the intersections with the vanishing line





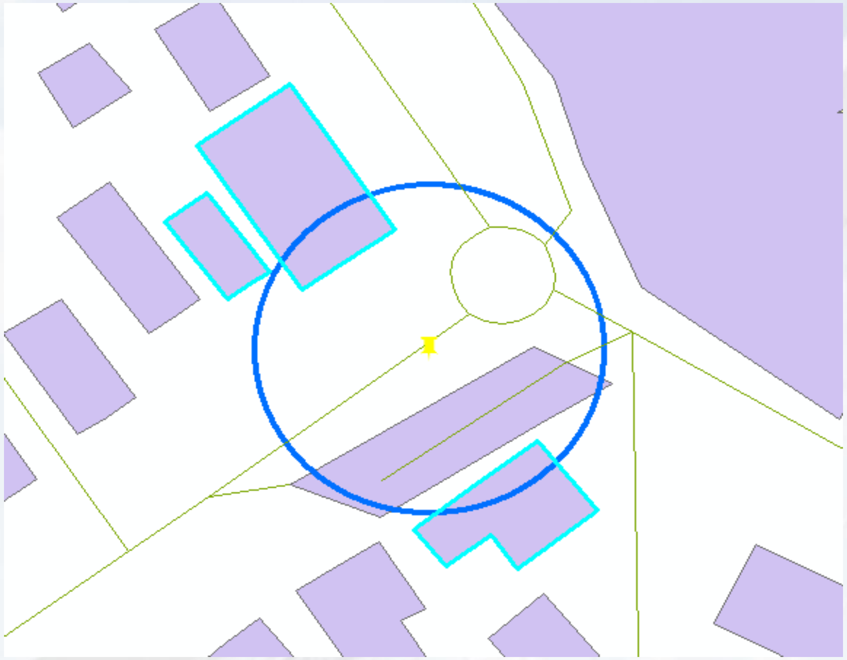
$$Dp1 = \frac{A \bullet \sin(\delta)}{\sin(\beta 1 + \gamma)}$$

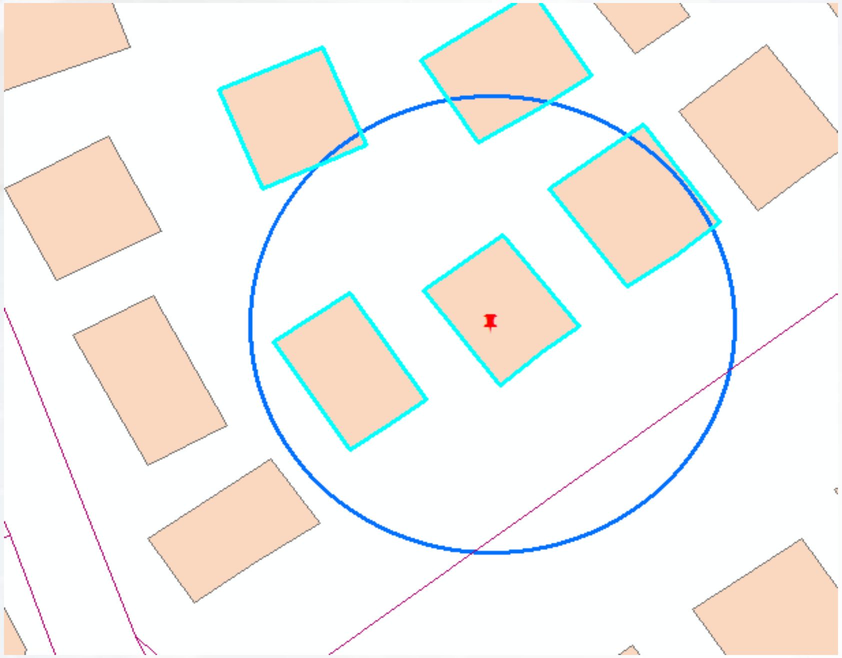
$$Dp2 = \frac{A \bullet \sin(Z1)}{\sin(\beta 1 + \gamma)}$$

$$Dp3 = \frac{B \bullet \sin(270 - \delta)}{\sin(\beta 2 - \gamma)}$$

Corresponding building in OSM – Step 1

- Circular buffer with radius = Dp2 + GPS Accuracy (10 m) + Error (5 m)
- The circle center is the GPS coordinates from the EXIF data





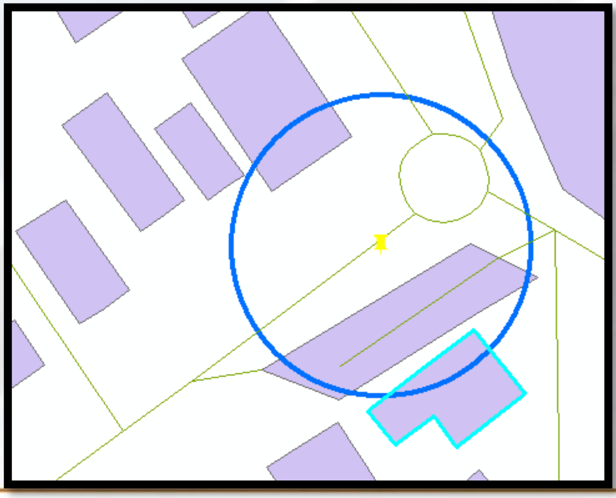
- ❑ If there is only one building inside the buffer - Stop search!

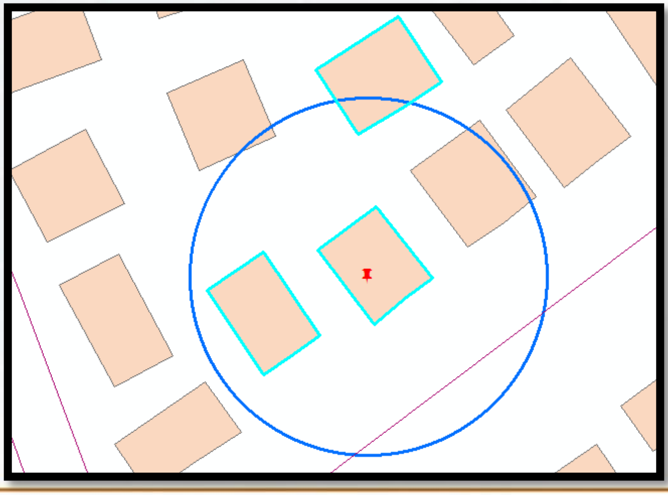
Corresponding building in OSM – Step 2

- Compare between the footprints: keep the building with difference bellow 5 [m] for both A & B

Buildings	Dif_A [m]	Dif_B [m]
1	-1.00	1.00
2	1.87	6.96
3	0.30	-14.80

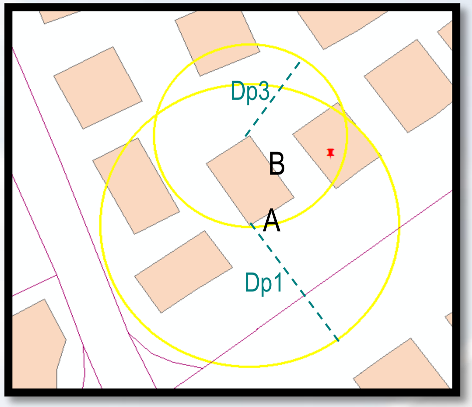
Buildings	Dif_A [m]	Dif_B [m]
1	2.01	4.59
2	3.24	2.95
3	5.54	3.39
4	5.14	0.89
5	3.94	3.89

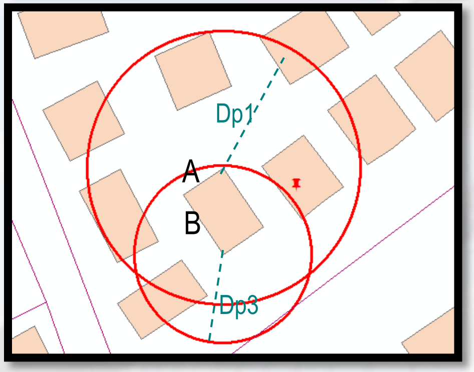


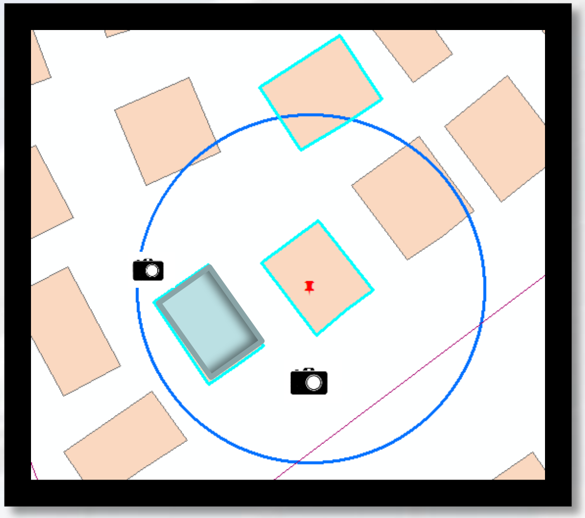


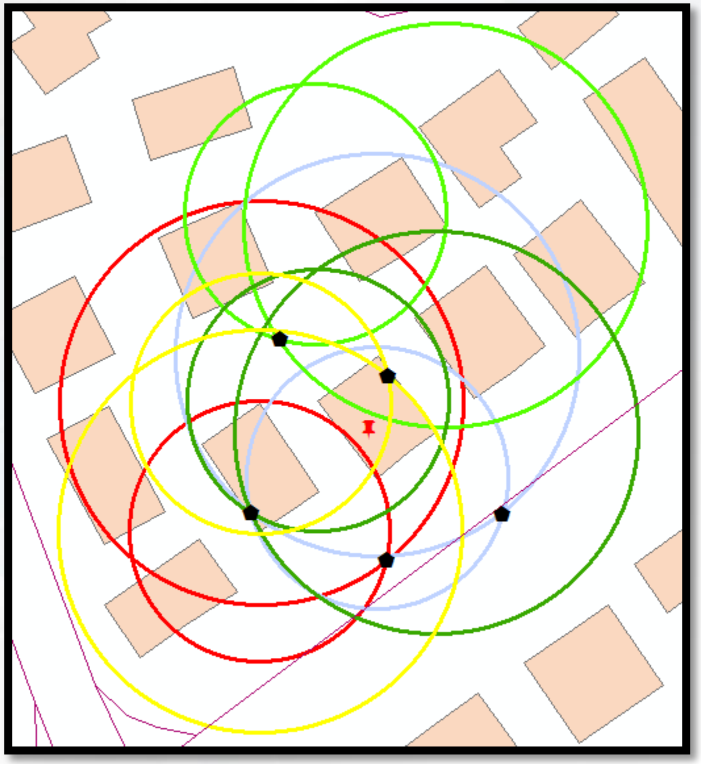
Corresponding building in OSM – Step 3

- Circular buffer with radius of Dp1 & Dp3
- The circles centers are the 2 corners

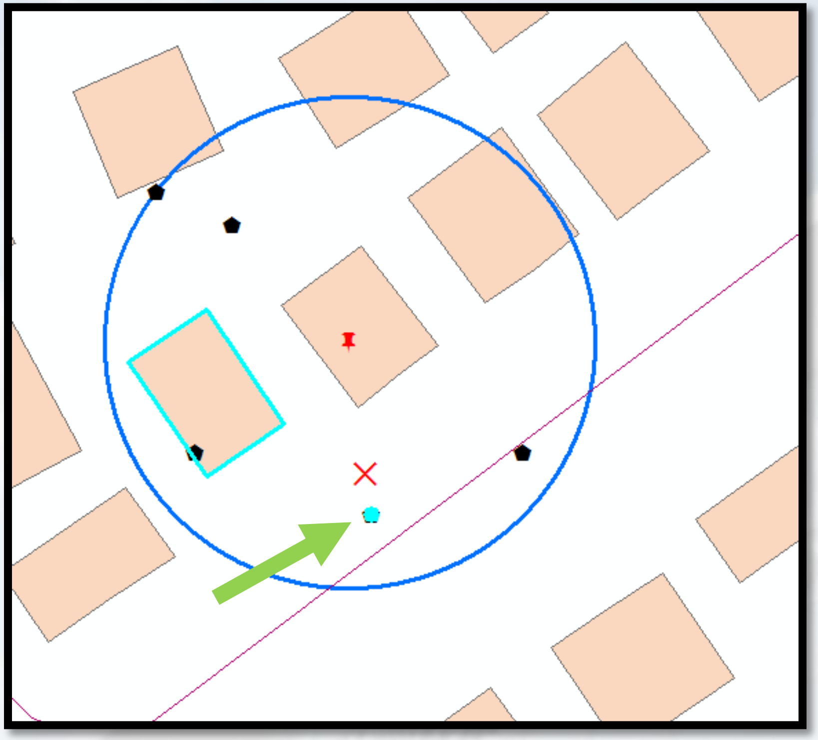


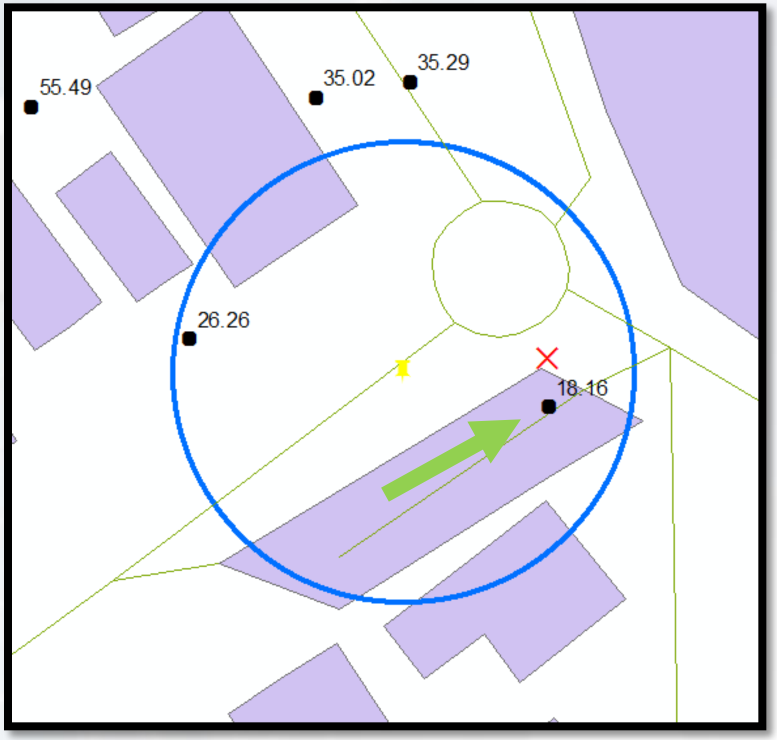






Corresponding building in OSM – Step 3





- X – where the image has been taken in the field
- The difference between X and the nearst intersection point is less than 4 meters

Conclusions

- Using user-generated contributed single image was found valuable to calculate and extract building height and footprint data.
- Algorithms developed are qualitative in calculating LoD1 building values with less than 1.00 m errors (for most cases) to generate 3D city models (reducing cost and work labor).
- Using accurate reference height is important, although errors are still in the range of desired output.
- Automatically Identifying and updating height data in corresponding building feature in OSM.

Future Work

- Analyze methodology and algorithms on more WWW building images.
- Update building footprints in OSM.
- Analyze more complex building shapes and footprints.
- Implement a GUI/app for photographers to automatically update OSM with building height data.

Thank you !

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