Real-time shadow prediction using solar position and camera calibration for ambient video surveillance

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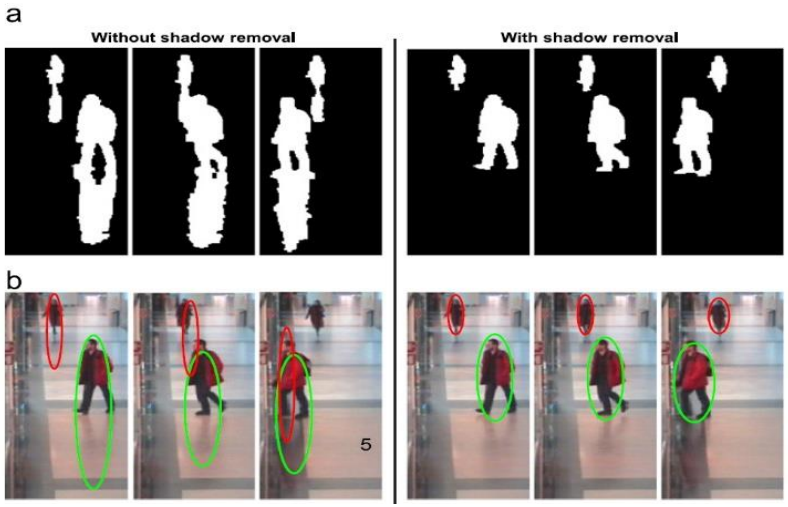
Background

- **Problem**
  - Shadows of the objects usually interfere with an automated recognition system in detecting and tracking them

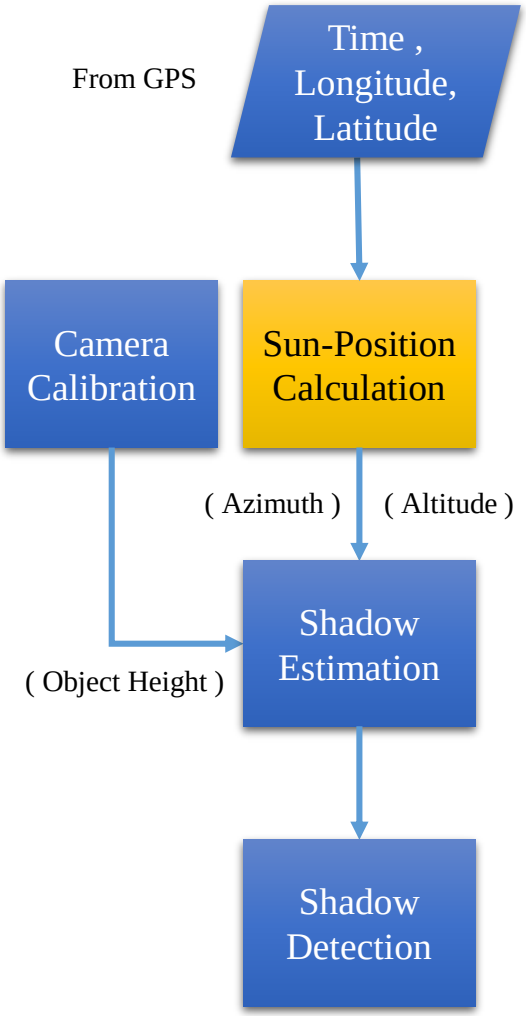


- A case where the correct tracking trajectory can only be obtained when shadows are removed.

- A.Sanin et al. “Shadow detection: A survey and comparative evaluation of recent method” Pattern Recognition (2012)

- **Research Purpose**
  - Predict the orientation and the length of the shadow of an object based on solar position and the weather conditions at the current time

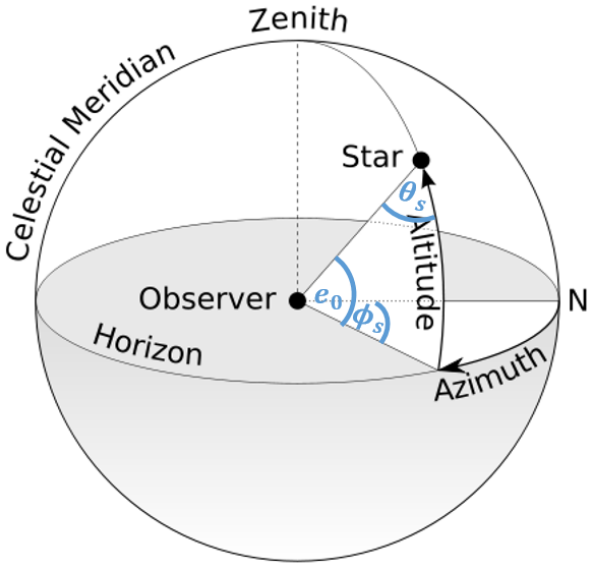
Proposed Method



< Algorithm flow chart >

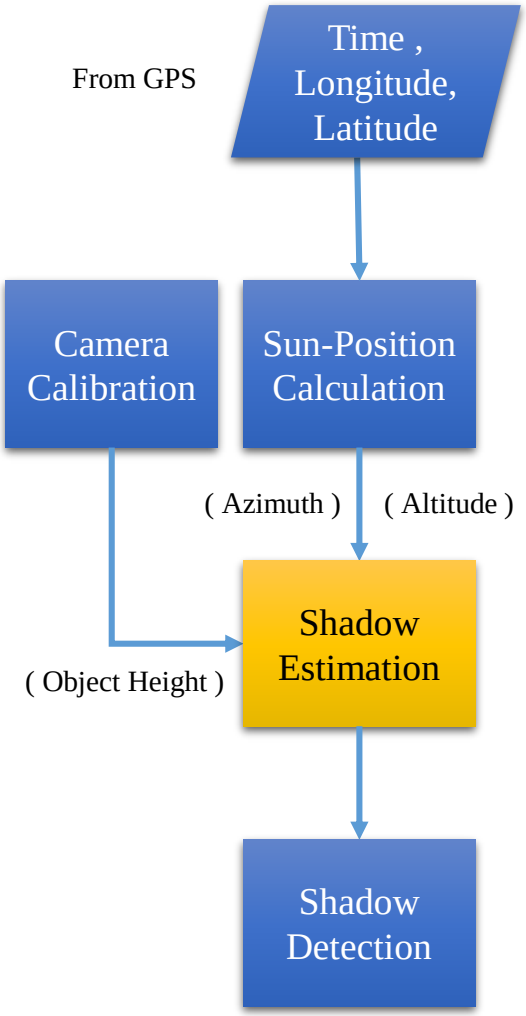
- **Solar position can be described by the azimuth and the altitude**
  - $\theta_s = 90 - e_0 - \frac{P}{1010} \times \frac{283}{273+T} \times \frac{1.02}{60 \tan(e_0 + \frac{10.3}{e_0+5.11})}$
  - $e_0 = arc\sin(\sin\phi_0 \sin\delta' + \cos\phi_0 \cos\delta' \cos H')$
  - $\phi_s = arc\tan\left(\frac{\sin H'}{\cos H' \sin\phi_0 - \tan\delta' \cos\phi_0}\right) + 180$

- θ_s : Sun zenith angle , P is the local pressure , T is time
- **e_0 : Sun's topocentric elevation angle**
- **ϕ_s : Sun's topocentric azimuth angle**
- ϕ_0 : observer geometric latitude calculated using the local latitude
- δ' : the sun declination calculated using the geocentric sun declination from the local longitude and current time
- H' : the topocentric local hour angle from the current time



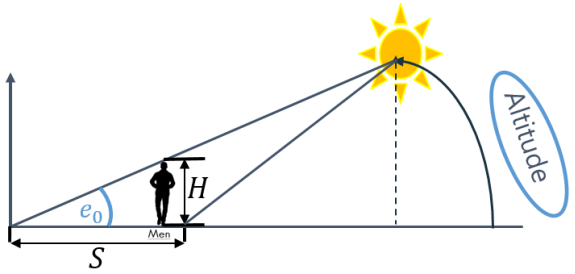
- I.Reda et al. "Solar position algorithmfor solar radiation applications." Technical report NREL/TP-560-34302, National Renewable Energy Laboratory, USA, (2008)
- J.Wang et al. "Shadow extraction and application in pedestrian detection." EURASIP Journal on Image and Video Processing (2014)

Proposed Method



< Algorithm flow chart >

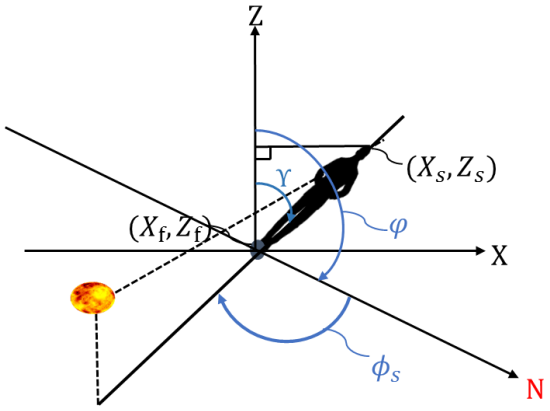
- **Estimation of the shadow's length**

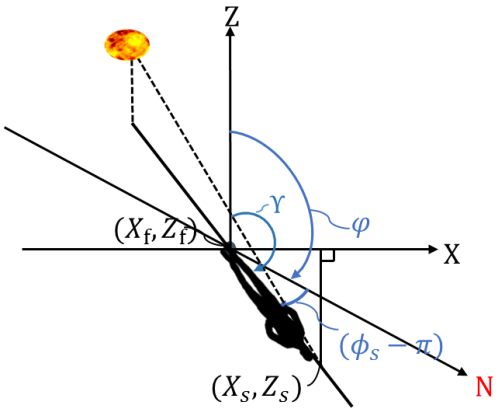


Shadow's Length

$$S = H \cdot \cot e_0$$

- **Relation between shadow's direction and azimuth**



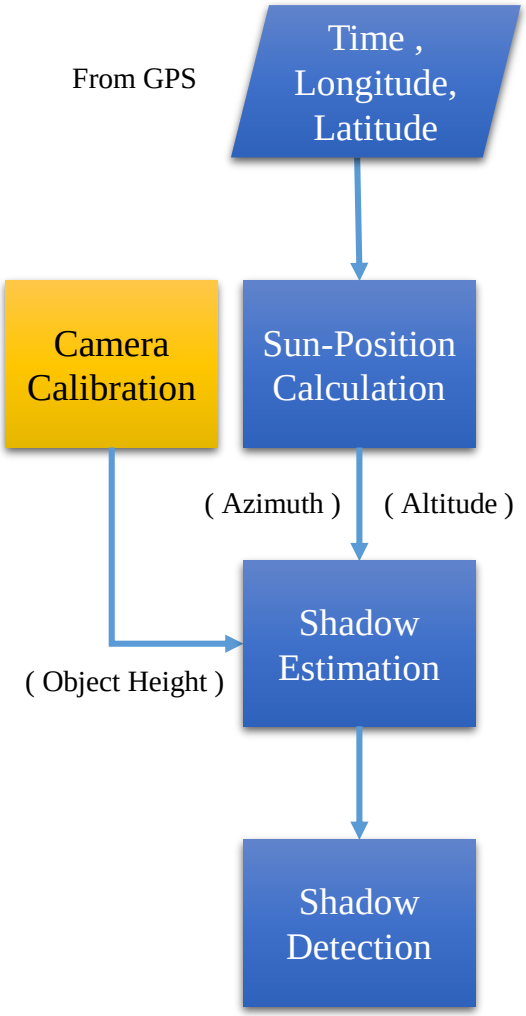


- **N** : True north
- **Z** : forward direction of the camera
- φ : Angle between **N** and **Z**
- ϕ_s : Azimuth angle of the Sun
- γ : Angle between N and shadow
- (X_f, Z_f) : Object orientation
- (X_s, Z_s) : End coordinate of a shadow

Shadow's direction

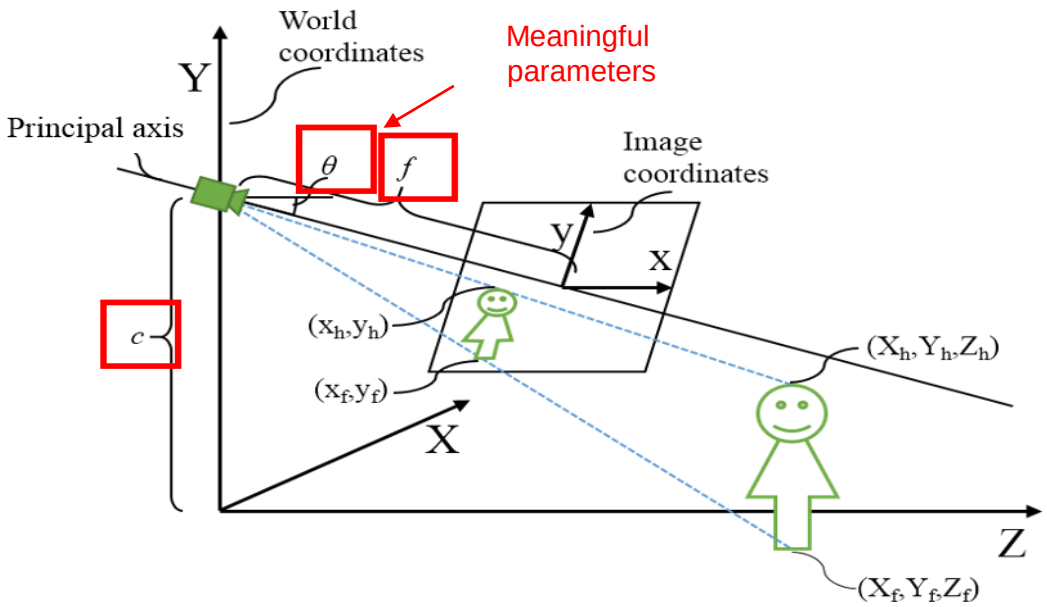
$$\gamma = \phi_s - \pi + \varphi$$

Proposed Method



< Algorithm flow chart >

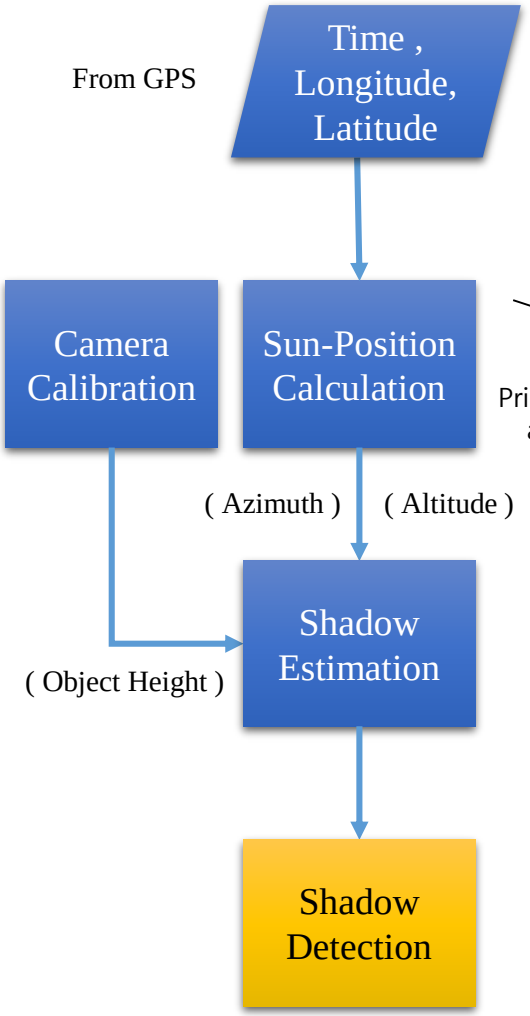
- **Simplified camera calibration method**
  - **Calibration using Head and Foot points of pedestrians**



- **Only consider**
  - f **: focal length**
  - θ **: camera angle**
  - c **: height of camera**

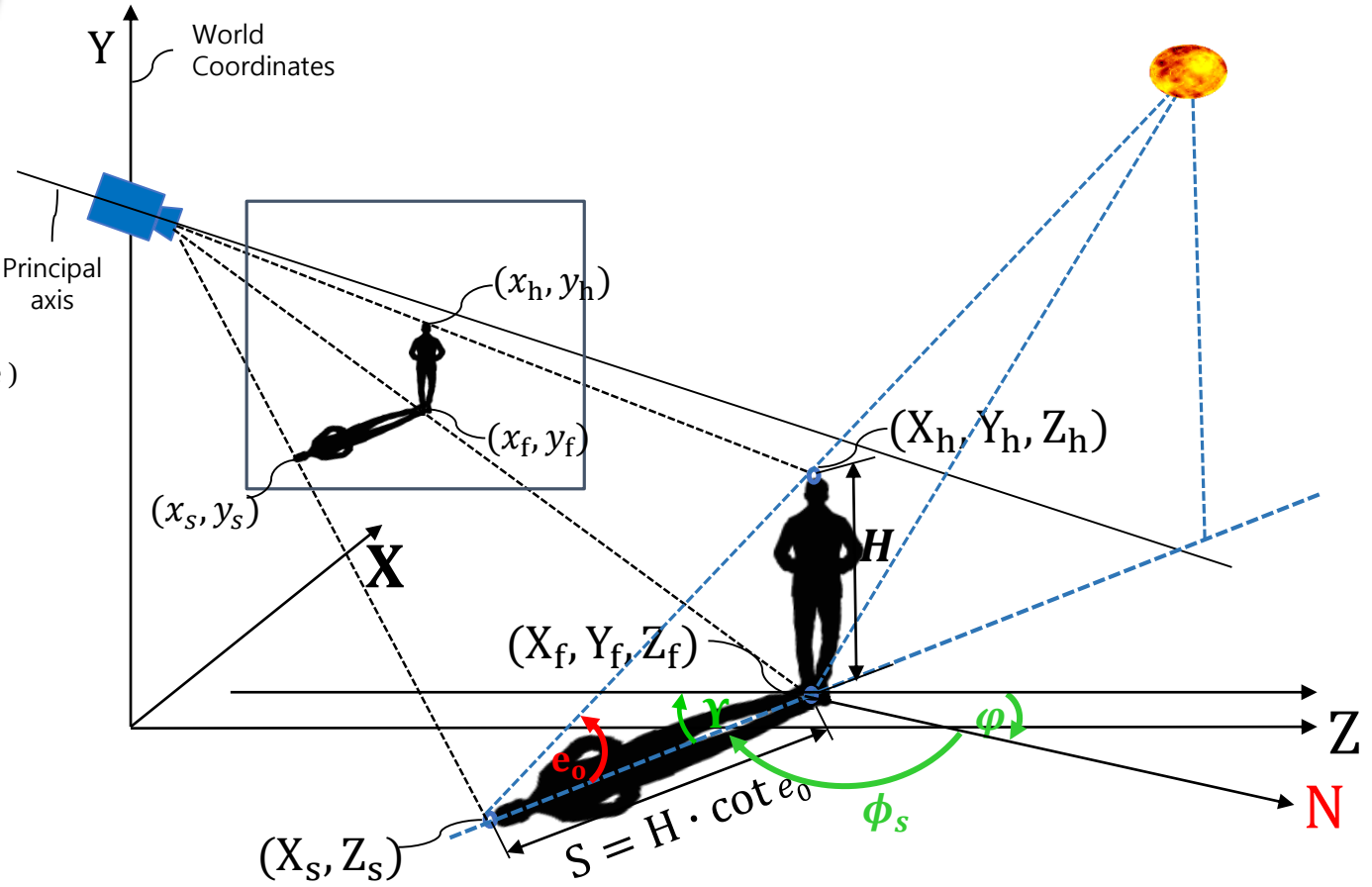
- S. Li et. al., "Simplified Camera Calibration for Human Height Estimation in Video Surveillance", *EURASIP Journal on Image and Video Processing*, under reviewing.

Proposed Method



< Algorithm flow chart >

- **Prediction of the object's height derived from camera calibration and shadow's length**



Experimental Results

- **Static camera and test images for experiments**

- **Comparing real length and predicted length of shadows in various time**
  - Camera : SNC-VB600B
  - Test image's size: 1280x720

- **Results**

Time	Azimuth	Elevation	Meas(cm)	Est(cm)	Error(cm)	Rate
10:00AM	102.7°	54.2°	71.5	73.74	-2.24	3.13%
10:30AM	141.691°	40.82°	113	116.92	-3.92	3.47%
11:00AM	155.1°	38.3°	126	126.62	-0.62	0.49%
11:00AM	150.80°	44.13°	102	104.11	-2.11	2.07%
11:30AM	160.87°	46.56°	95.6	95.64	-0.04	0.04%
11:30AM	164.2°	40.3°	119	117.9	1.1	0.92%
12:00PM	151.4°	73.9°	29	31.03	-2.03	7.00%
12:20PM	177.90°	51.75°	78	79.62	-1.62	2.08%
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01:30PM	204.45°	45.38°	102.5	99.67	2.83	2.76%
02:00PM	238.6°	66.5°	50	45.19	4.81	9.62%
02:00PM	214.02°	42.46°	114	110.38	3.62	3.18%
02:30PM	222.59°	38.76°	131	125.8	5.2	3.97%
03:00PM	255.1°	56.2°	70	68.46	1.54	2.20%
04:00PM	266.5°	44.5°	103	103.23	-0.23	0.22%
04:00PM	243.05°	24.47°	223	221.93	1.07	0.48%
04:10PM	248.44°	27.27°	210	195.94	14.06	6.70%
05:00PM	275.5°	32.6°	159	156.99	2.01	1.26%
06:00PM	283.6°	20.8°	270	265.8	4.2	1.56%

Meas : Measured shadow distance, Est : Estimated shadow distance

$$Error\ Rate = \frac{|Meas - Est|}{Meas} \times 100\%$$

- Max. Error Rate: **9.62%**
- Min. Error Rate: **0.04%**
- Ave. Error Rate: **3.41%**

Conclusions and Future Works

- **Conclusions**
  - **The proposed method is able to predict the direction and the length of object's shadow in an acceptable error rate**
  - **The proposed method can operate in real time**
  - **The relational equation between cameras and the Sun position can be derived from the proposed method**
  - **The proposed method can be easily utilized to outdoor video surveillance systems**
- **Future works**
  - **To develop shadow removal and video quality enhancement method combined with weather conditions**