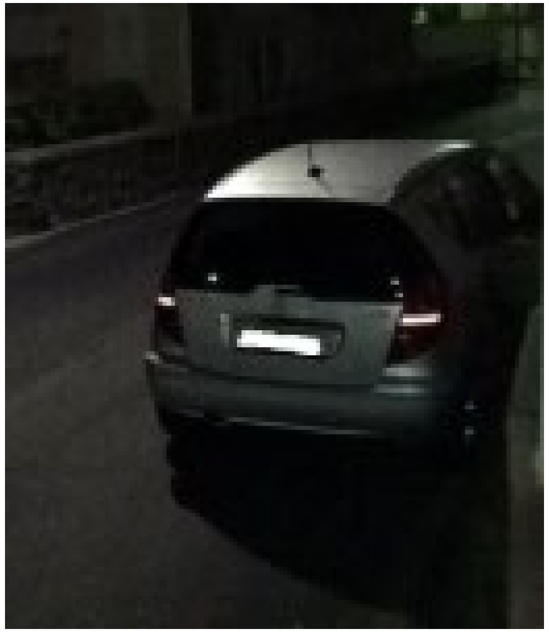
Car motion in the dark



Purpose: develop a system that

- analyzes a video of a moving vehicle taken by a fixed camera

in order to

- determine the occupied space for each frame

knowing

- K MATRIX: the intrinsic calibration parameters of the used camera

and

- MODEL: lenght and width of the car, and distance between car lights

Assumptions

The moving car has a «vertical» symmetry plane.

Two symmetric rear lights are visible:

Suppose that the camera is observing the car from the back,

Between subsequent frames of the video, the car is either translating forwards or steering with constant curvature

The road is locally planar

System operation: offline steps

- Calibrate the camera

- Retrieve the simplified MODEL of the observed car:

 - car width,

 - car lenght,

 - distance between the rear lights, and distance of both from the back of the car (sometimes this could be ≠ 0)

 - height of the rear lights over the ground

System operation online steps basing on two «close» frames

- Extract two symmetric lights in the first frame (or two symmetric features on the lights when the resolution is high enough) that have correspondence in the second frame. Call the «horizontal» segment joining the two symmetric lights THE LIGHT SEGMENT. So the first/second light segment is the one observed in the first/second frame

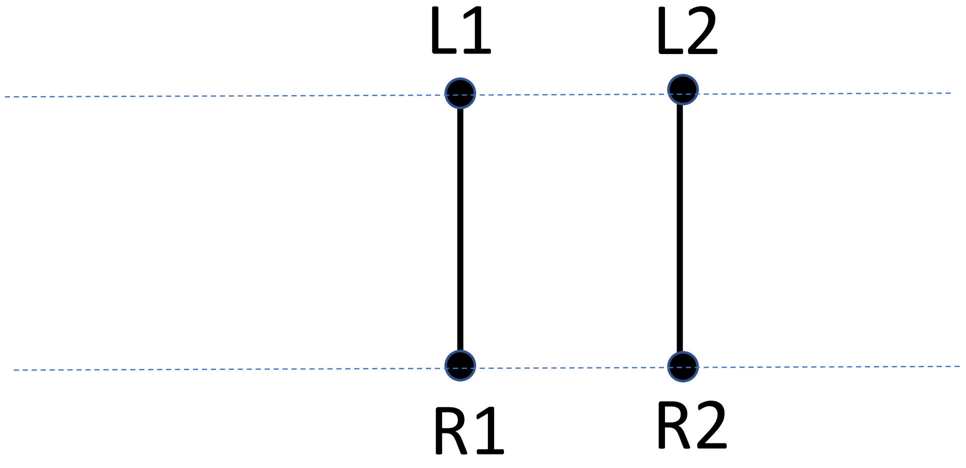
- Apply geometry to find the 3D position of the plane **π** containing the moving light segment, and the position of the lights on **π** (see next slides)

- For each of the two frames, use the simplified car model + the found position of both **π** and the lights in order to determine the space occupied by the vehicle on the road

Geometric facts: within the plane $\boldsymbol{\pi}$

1. **If the car is translating forwards**

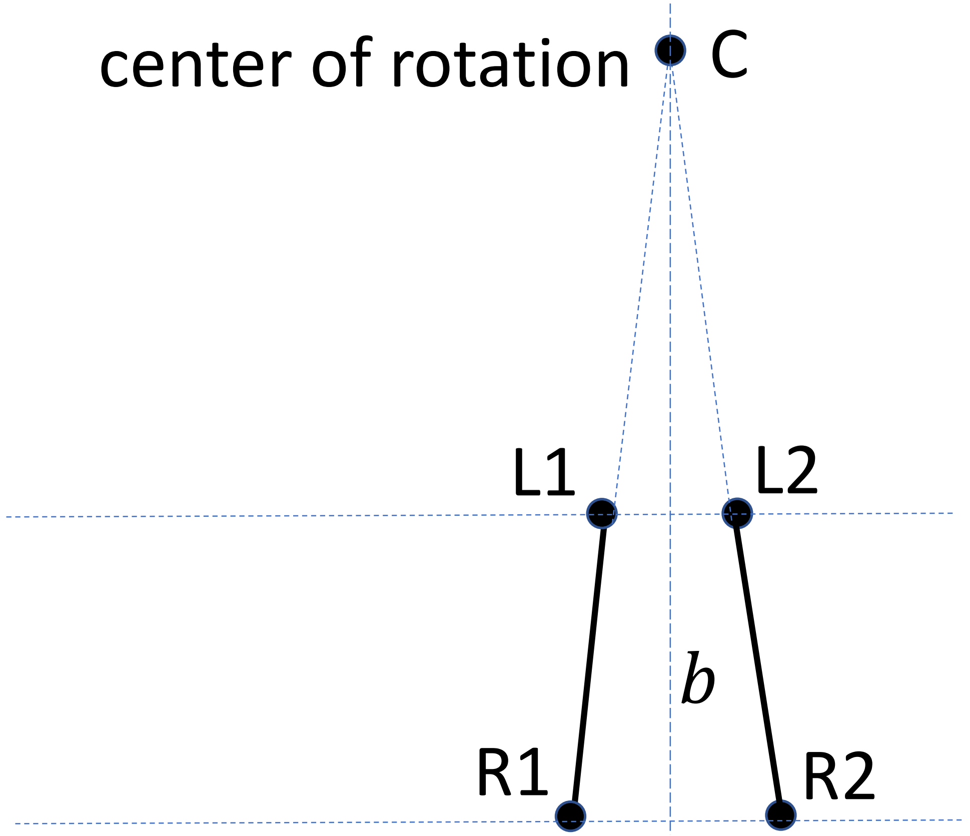
→ the first and the second light segment form a **rectangle**



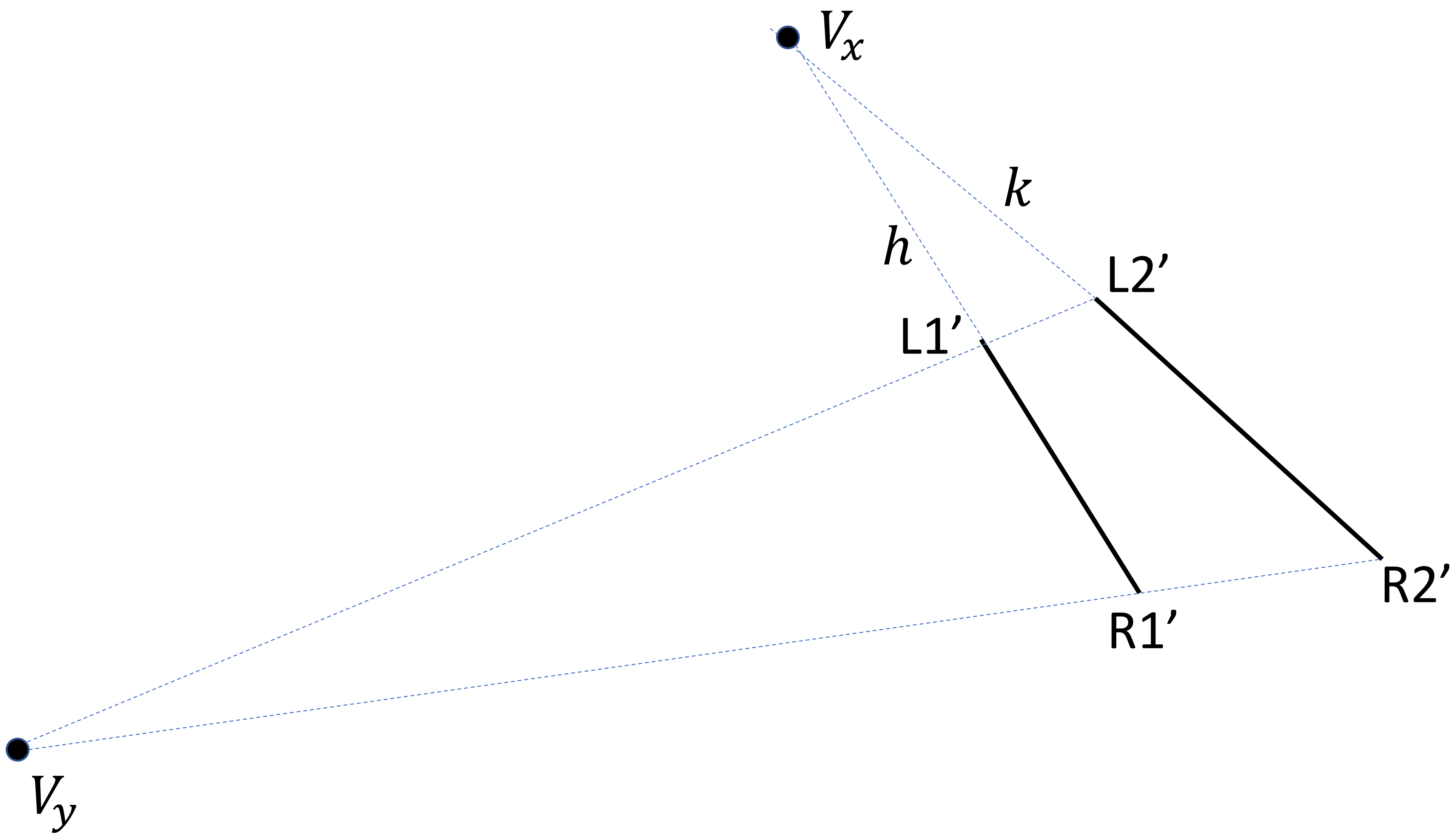
2. If the car is **steering** at constant curvature

→the light segment is rotating about a center of rotation C, that is the intersection between the lines (L1, R1) and (L2, R2) hosting the segments

→ lines (L1, L2) and (R1, R2) are parallel in the real world, and both are perpendicular to the line b bisecting the lines the lines (L1, R1) and (L2, R2)

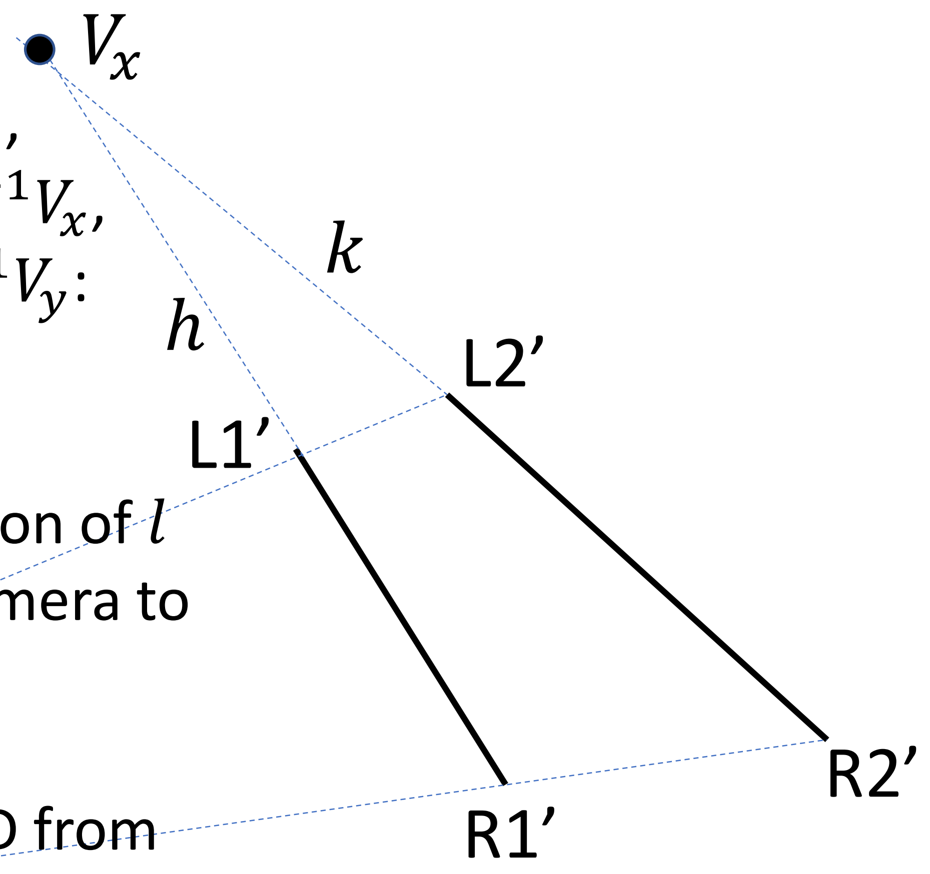


1. car translating forwards: image

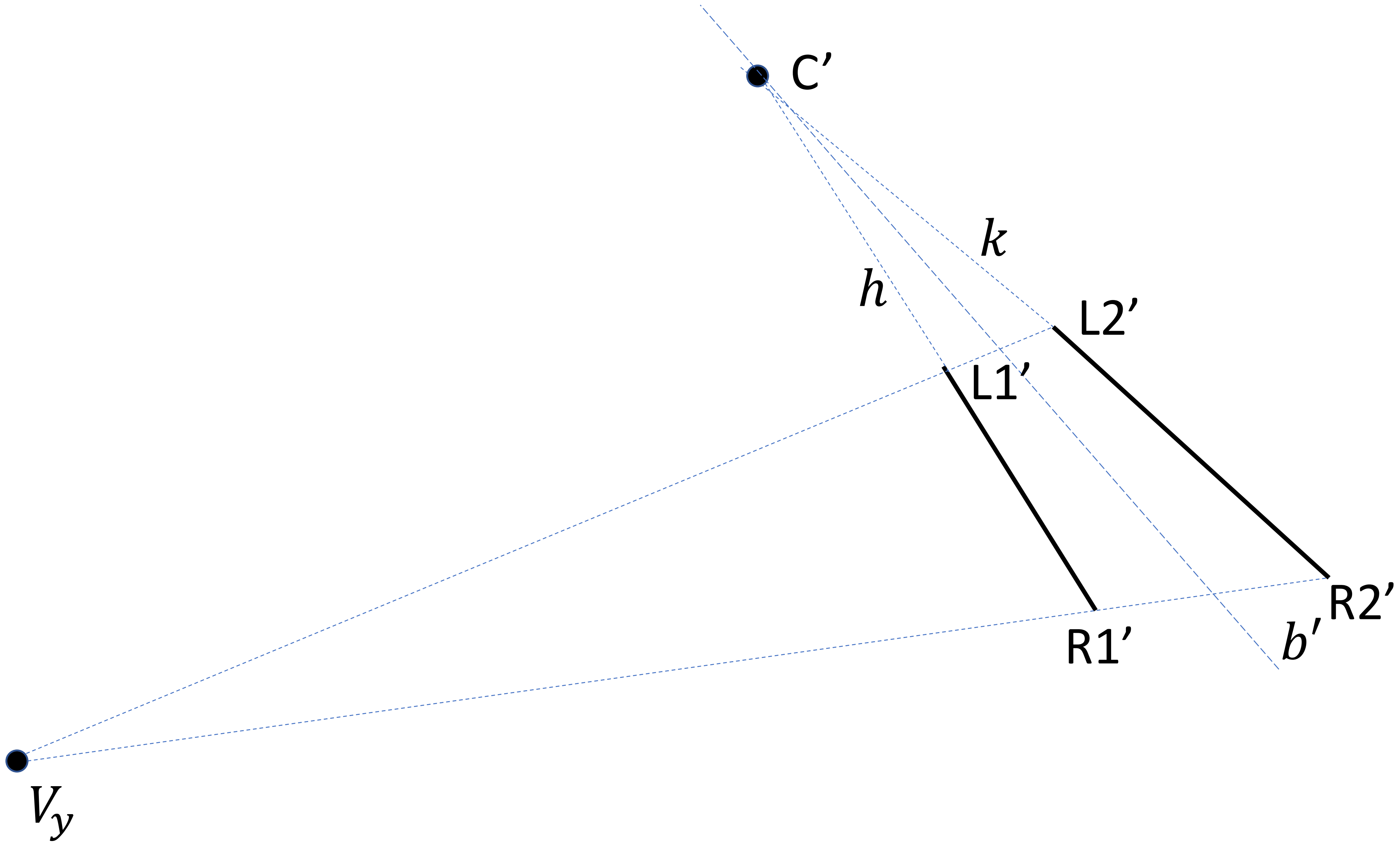


1. car translating forwards: method

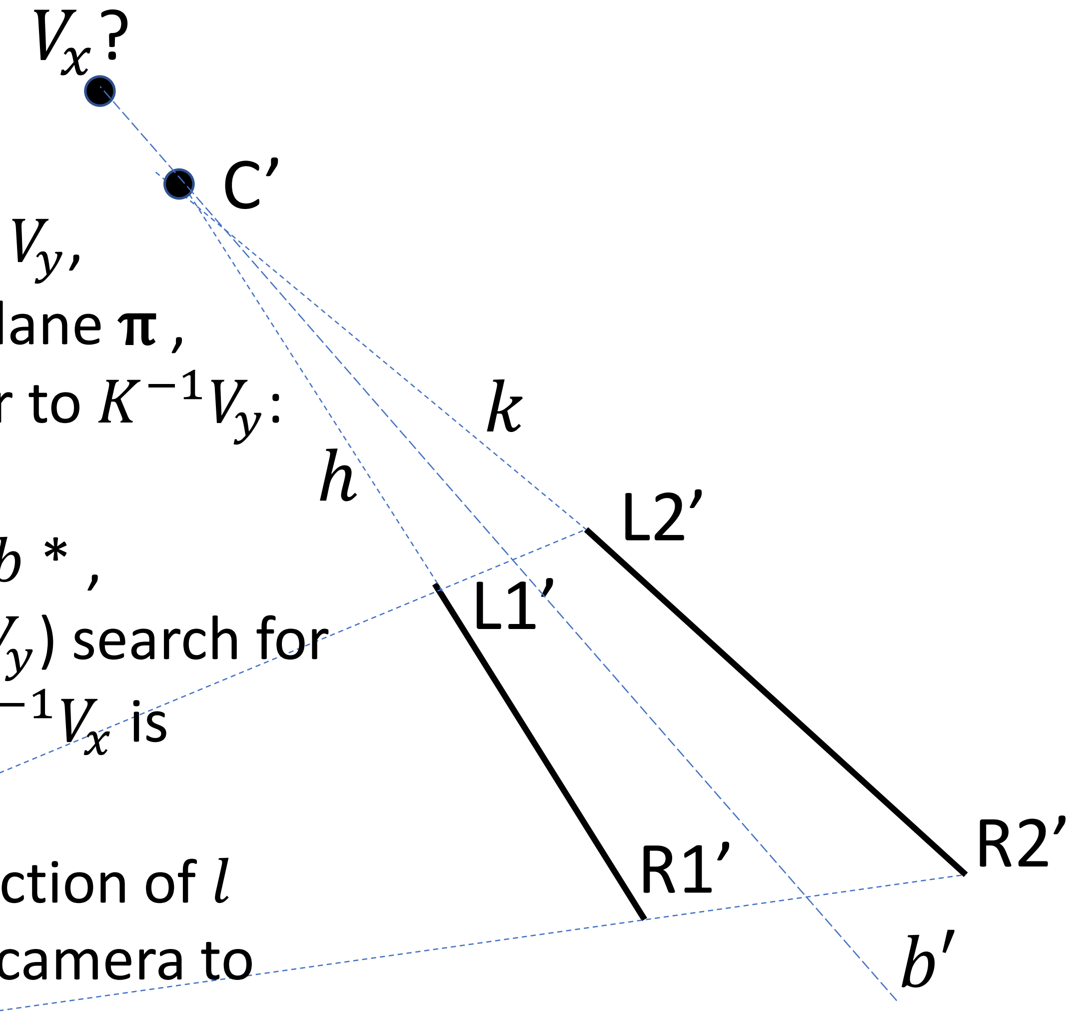
Find intersection points V_x and V_y,
3D direction of light segment: $K^{-1}V_x$,
check if it is perpendicular to $K^{-1}V_y$:
If so, car is **translating** →
Find vanishing line $l = (V_x, V_y)$.
Plane **π** is parallel to backprojection of l
$[K, 0]^T l$, to find distance from camera to
plane **π** use theorem of cosines.
OR
Localize both light segments in 3D from
image knowing direction $K^{-1}V_x$ and size
(use, e.g., theorem of cosines)
OR use time-to-impact



2. car steering with constant curvature: image



2. car steering with constant curvature: method



Find intersection points C' and V_y,
direction $K^{-1}C'$ is parallel to plane **π** ,
check if $K^{-1}C'$ is perpendicular to $K^{-1}V_y$:
If NOT so, car is **steering** →
Find image b' of bisecting line b * ,
To find vanishing line $l = (V_x, V_y)$ search for a point V_x along b' such that $K^{-1}V_x$ is perpendicular to $K^{-1}V_y$.
Plane **π** is parallel to backprojection of l $[K, 0]^T l$, to find distance from camera to plane **π** use theorem of cosines.

* b' : polar of V_y wrt (degenerate) conic $h \cup k$

$$b' = (hk^T + kh^T)V_y$$

Restrictions:

This method, that uses just the images of the car lights, only works if there is enough PERSPECTIVE.

Otherwise, if viewing rays are practically parallel, the above data are not sufficient, and additional information is needed, symmetric elements on another plane

Suggestions:

set up experiment with enough perspective, i.e., place camera with good inclination and allow sufficient motion between used frames (possibly exploiting intermediate frames to help feature tracking)

first focus on case 1 (car translating straightforward); in this case, also front lights can be used

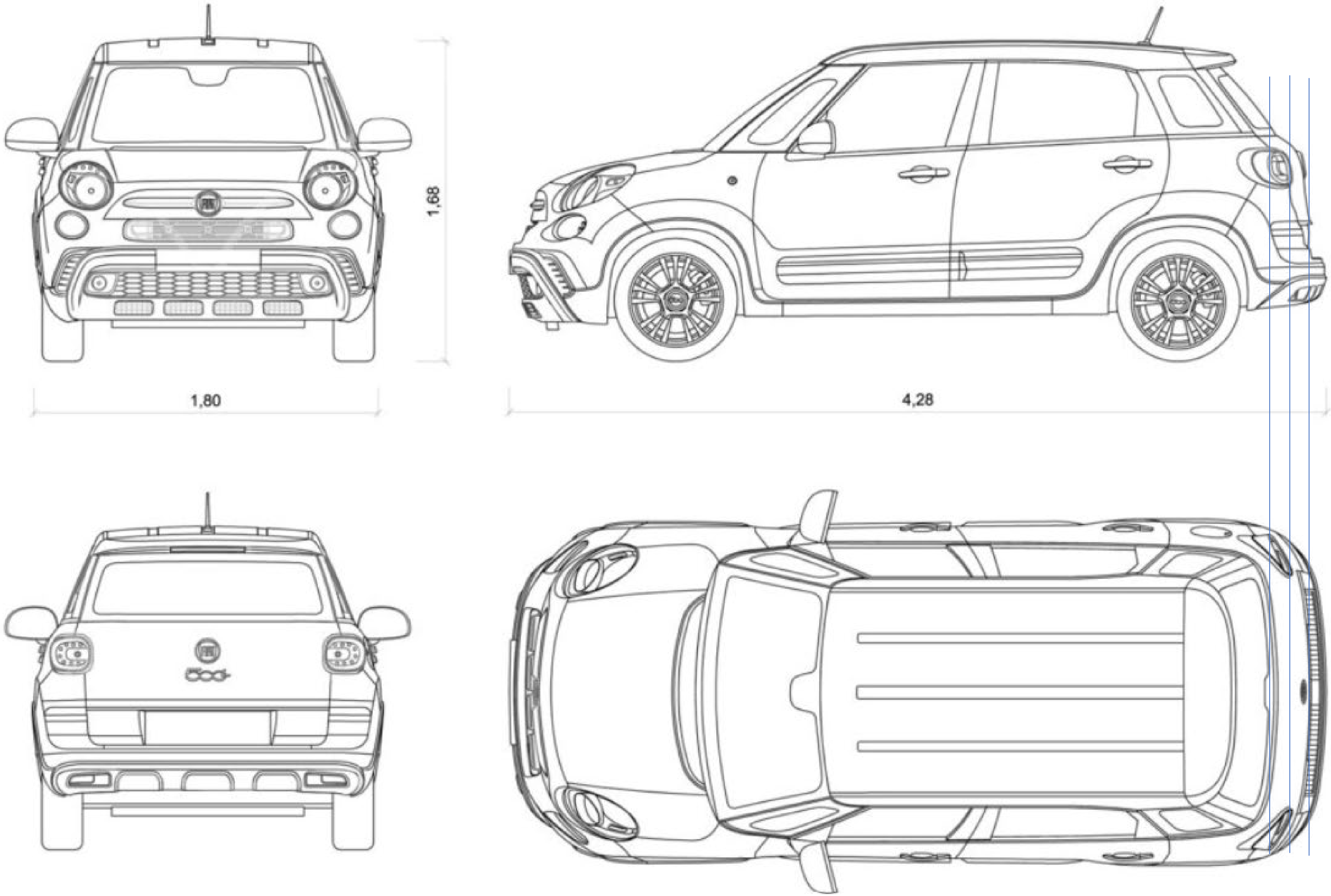
Extract ground truth from independent information (e.g., road plane) not used in the method

Car localization

{'Scion xD Hatchback 2012': '100.00%'}

Use pairs of symmetric features

{'Scion xD Hatchback 2012': '100.00%'}


1,68
1,80
4,28

Proposta operativa: sviluppo e test di 3 tecniche
Ipotesi: camera calibrata → $\mathbf{K}$ nota

1. Localizzazione standard da singola immagine del quadrangolo piano luci posteriori – targa. *potrebbe soffrire mancanza di prospettiva*

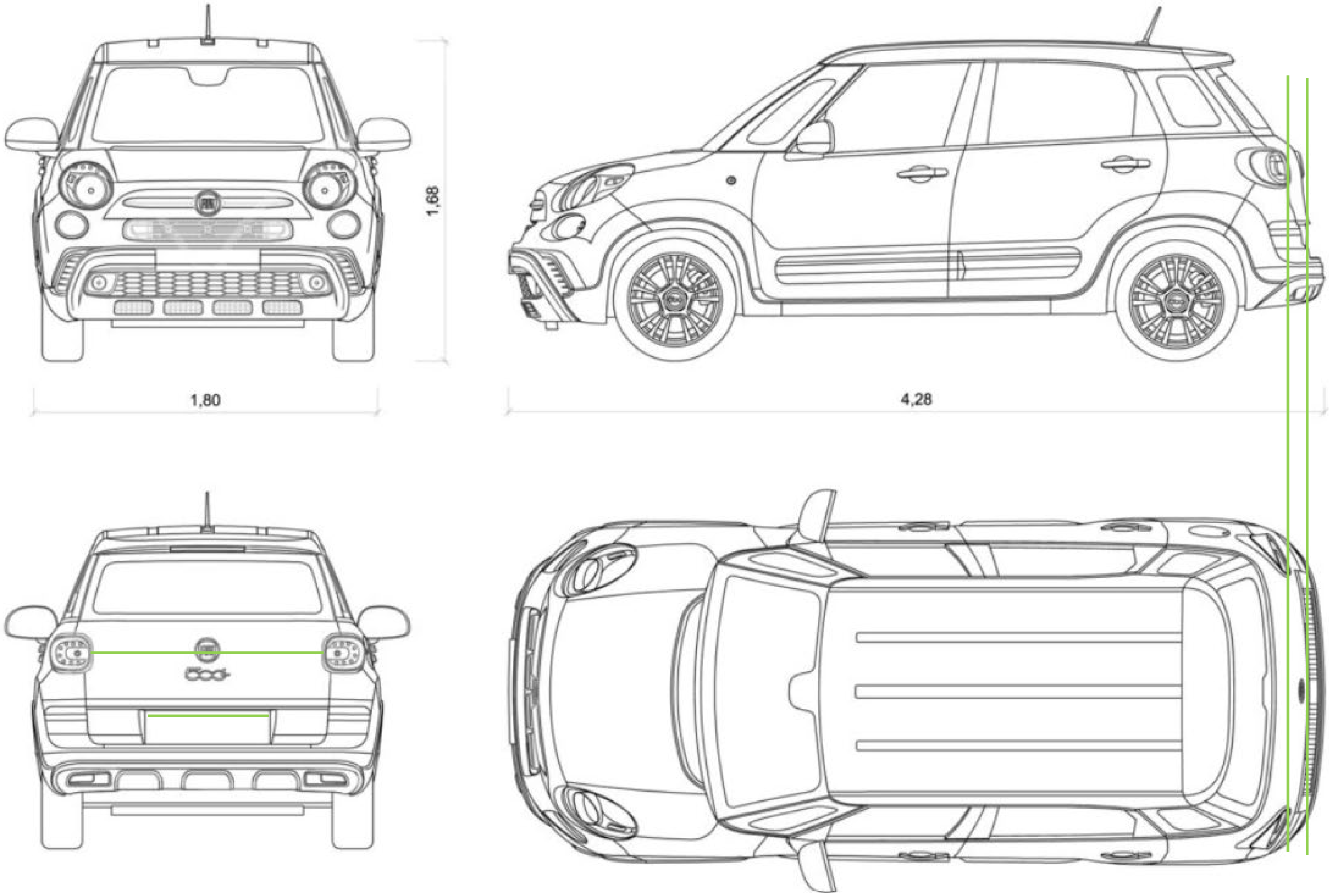
2. Localizzazione «notturna» da coppia di immagini (non consecutive, in modo da aumentare la prospettiva) di un video per il caso **traslatorio**: uso delle luci posteriori

3. Localizzazione con elementi simmetrici non coplanari. Quando a causa della scarsa prospettiva (vanishing point vicini all'∞) la stima dell'inclinazione orizzontale (angolo di rotazione attorno all'asse verticale) è molto incerta, si può usare la differenza con cui appaiono nell'immagine due elementi che nella realtà sono simmetrici

1. Localizzazione standard

Dal modello cad dell'auto determinare le posizioni relative dei due estremi della targa e di due punti simmetrici delle luci posteriori (es quelli più vicini tra loro) e usare metodo di localizzazione da Homography $[\boldsymbol{r}_1 \quad \boldsymbol{r}_2 \quad \mathbf{o}_\pi] = \mathbf{K}^{-1}\mathrm{H}$

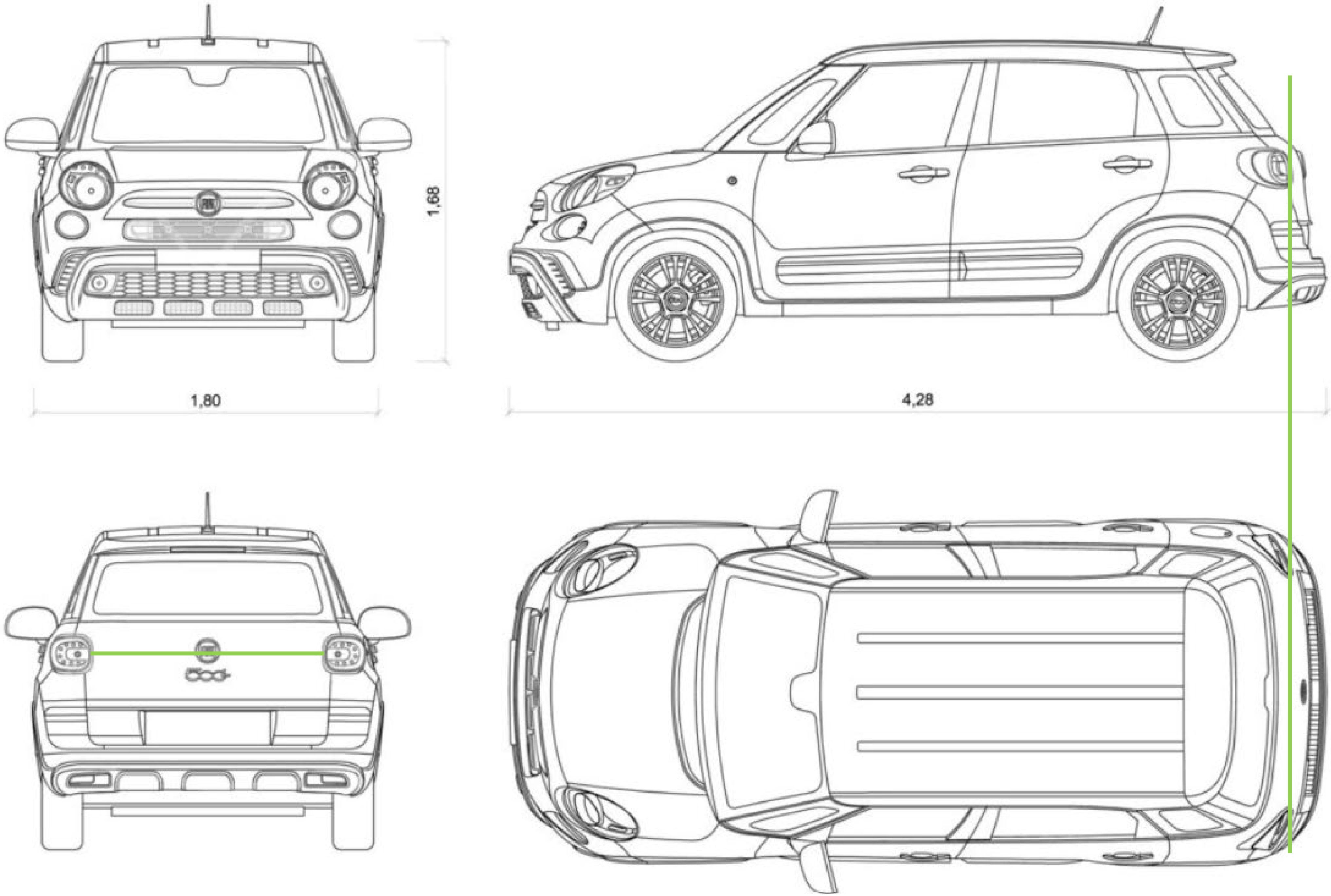
{'Scion xD Hatchback 2012': '100.00%'}


1,68
1,80
4,28

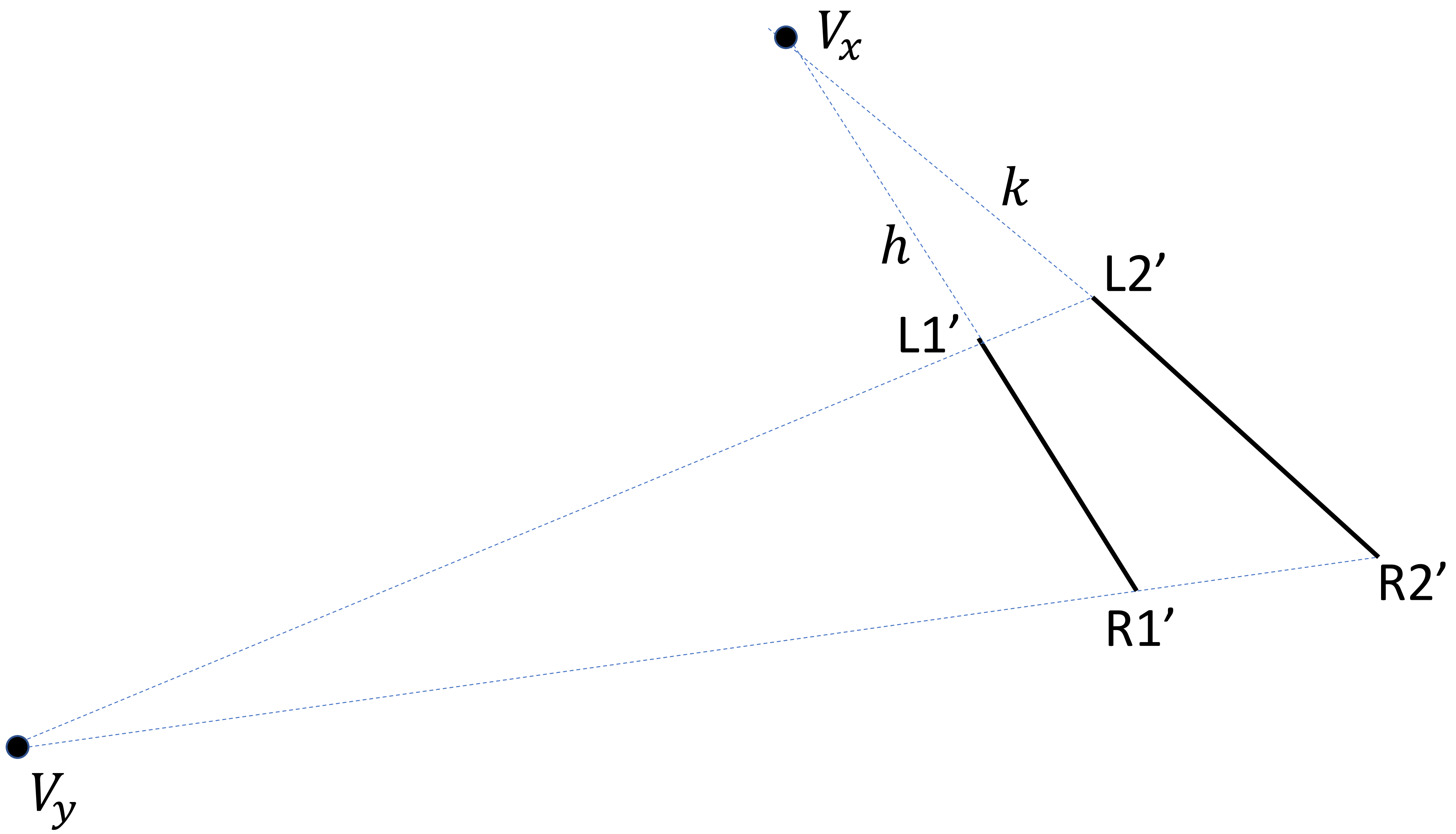
2. Localizzazione «notturna» da coppia di immagini

Dal modello cad dell’auto determinare le posizioni relative di due punti simmetrici delle luci posteriori (es quelli più vicini tra loro) e usare metodo di descritto in nelle due slide seguenti

{'Scion xD Hatchback 2012': '100.00%'}

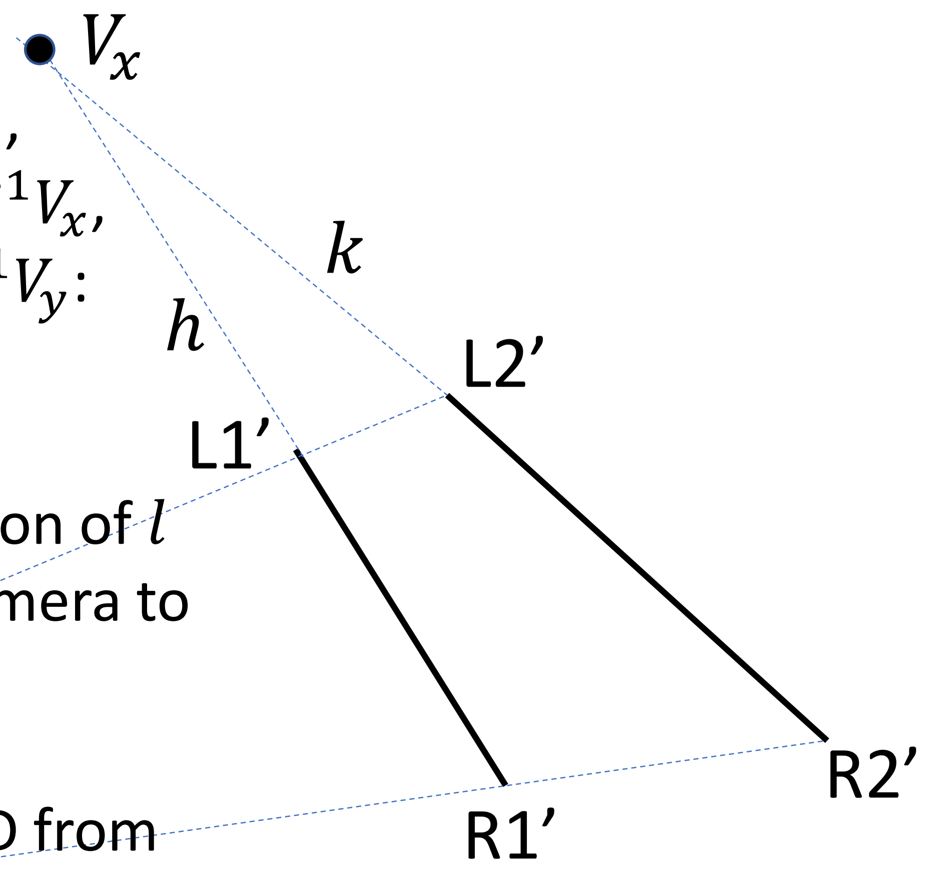

1,68
1,80
4,28

2. car translating forwards: image



2. car translating forwards: method

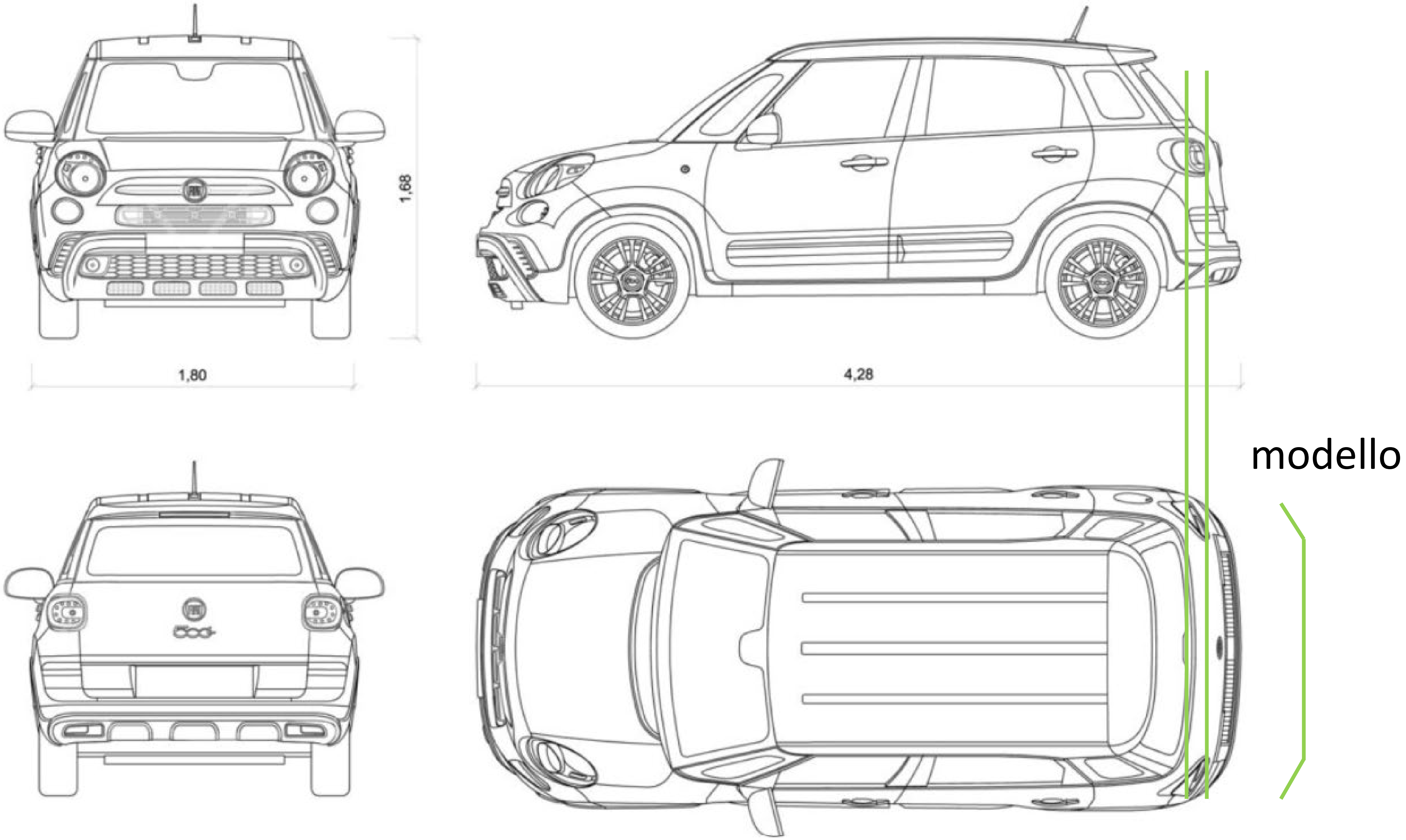
Find intersection points V_x and V_y,
3D direction of light segment: $K^{-1}V_x$,
check if it is perpendicular to $K^{-1}V_y$:
If so, car is **translating** →
Find vanishing line $l = (V_x, V_y)$.
Plane **π** is parallel to backprojection of l
$[K, 0]^T l$, to find distance from camera to
plane **π** use theorem of cosines.
OR
Localize both light segments in 3D from
image knowing direction $K^{-1}V_x$ and size
(use, e.g., theorem of cosines)
OR use time-to-impact



3. Localizzazione «notturna» usando differenze apparenti tra elementi simmetrici

Dal modello cad determinare le posizioni relative di due coppie di punti simmetrici delle luci posteriori (es quelli più vicini tra loro e quelli più lontani) e analizzare la differenza per stimare l’angolo di inclinazione orizzontale

{'Scion xD Hatchback 2012': '100.00%'}


1,68
1,80
4,28
modello

3. Angolo di inclinazione orizzontale

modello

immagine

{'Scion xD Hatchback 2012': '100.00%'}

3. Angolo di inclinazione orizzontale

modello

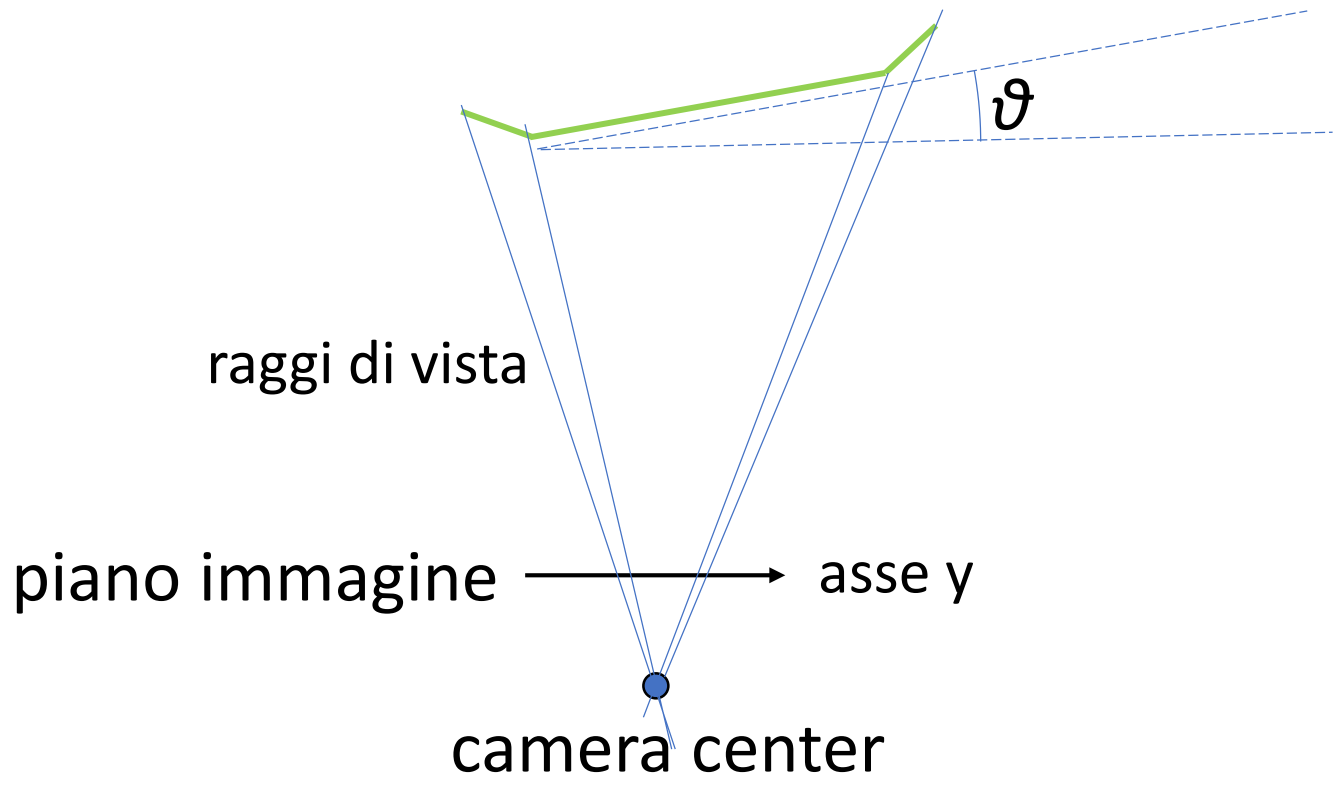
immagine

{'Scion xD Hatchback 2012': '100.00%'}

Asse y che collega una coppia di elementi simmetrici nell'immagine

3. Angolo di inclinazione orizzontale ϑ (rotazione attorno all'asse verticale)

vista dall'alto



Dalle coordinate y dei quattro punti immagine, e dal modello cad, si ricava l'angolo ϑ. Si può così ricavare l'orientamento del segmento che collega i due punti tra loro più vicini delle luci. Da lunghezza del segmento → posizione 3D

…

Nella sperimentazione, il video con immagini diurne –del veicolo con i suoi elementi aggiuntivi- può essere utilizzata come «ground truth».

Una volta trovata la posizione 3D degli elementi dell’auto, si ponga attorno al essi la bounding box del modello dell’auto (parallelepipedo rettangolo con larghezza, lunghezza e altezza) e il risultato l’occupazione di spazio.