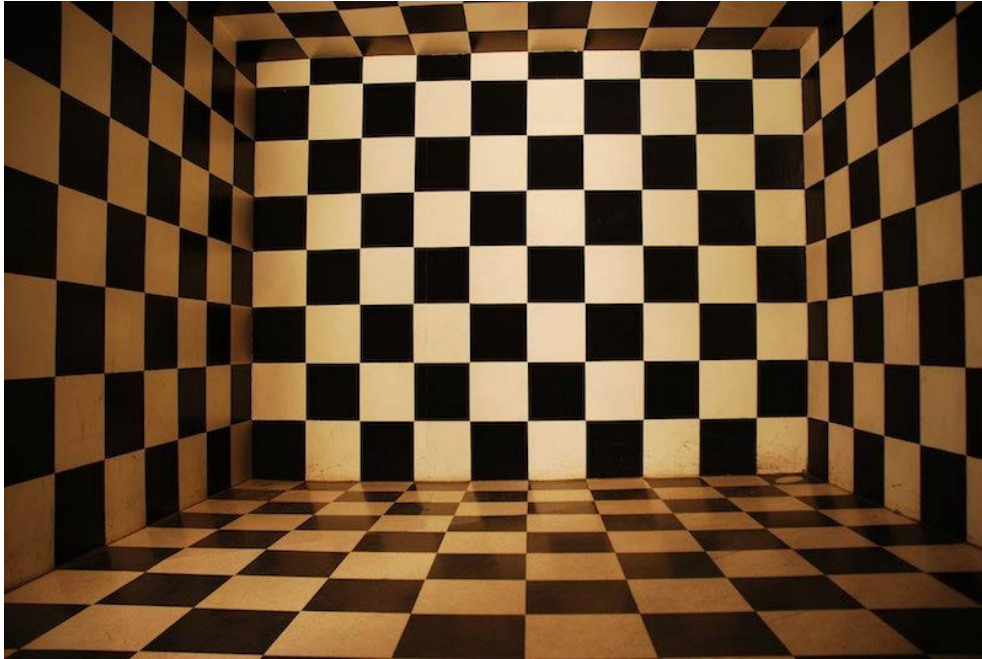


Lecture 5.3

Scene geometry from a single view

Thomas Opsahl

Introduction



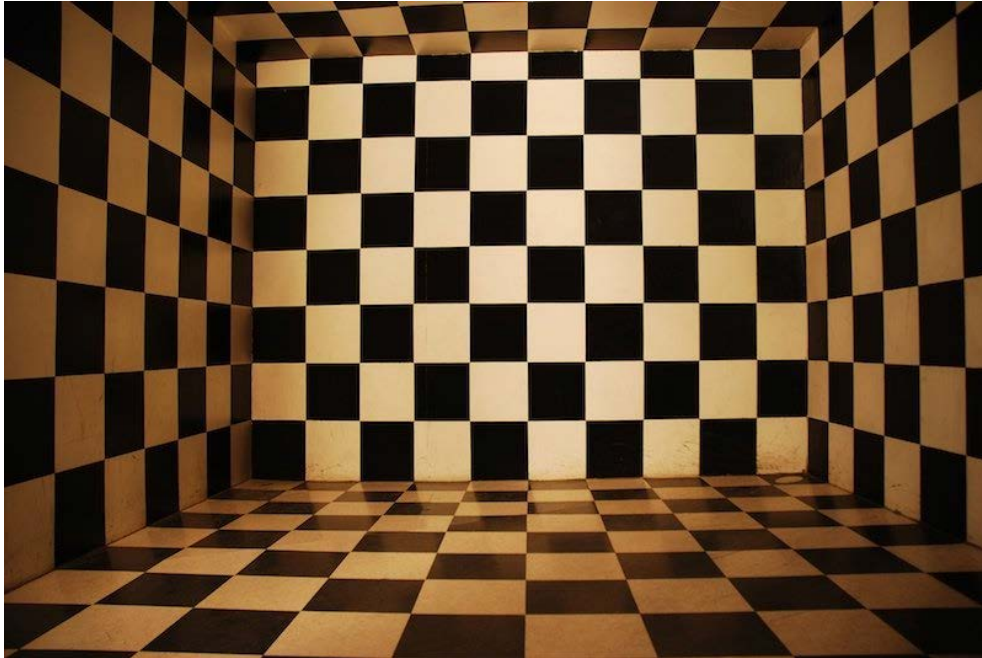
<https://www.freeimages.com>



<https://flicker.com> (Melita)

- Can we extract information about the 3D scene from an image?

Introduction



<https://www.freeimages.com>



<https://flicker.com> (Melita)

- Can we extract information about the 3D scene from an image?
- Only if we can recognize objects/regions with known 3D shape/orientation
 - Planar regions, parallel lines, horizontal surfaces, vertical structures

Introduction



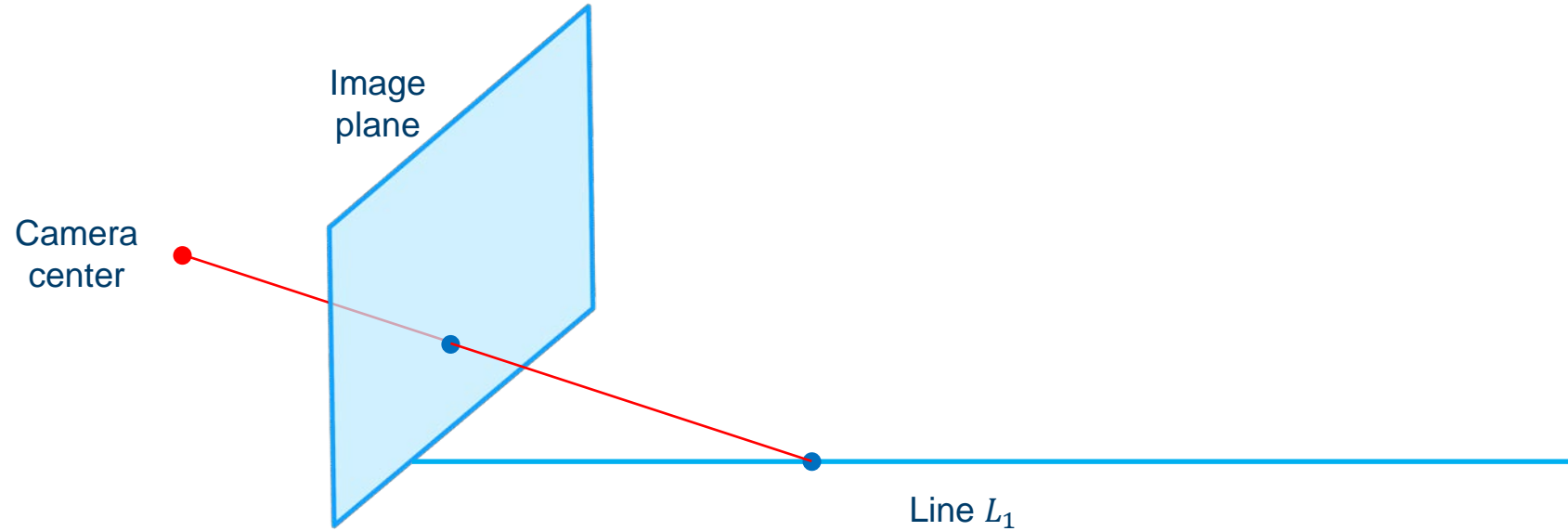
<https://www.freeimages.com>



<http://www.thisisinsider.com/optical-illusion-floor-viral-reddit-2017-10>

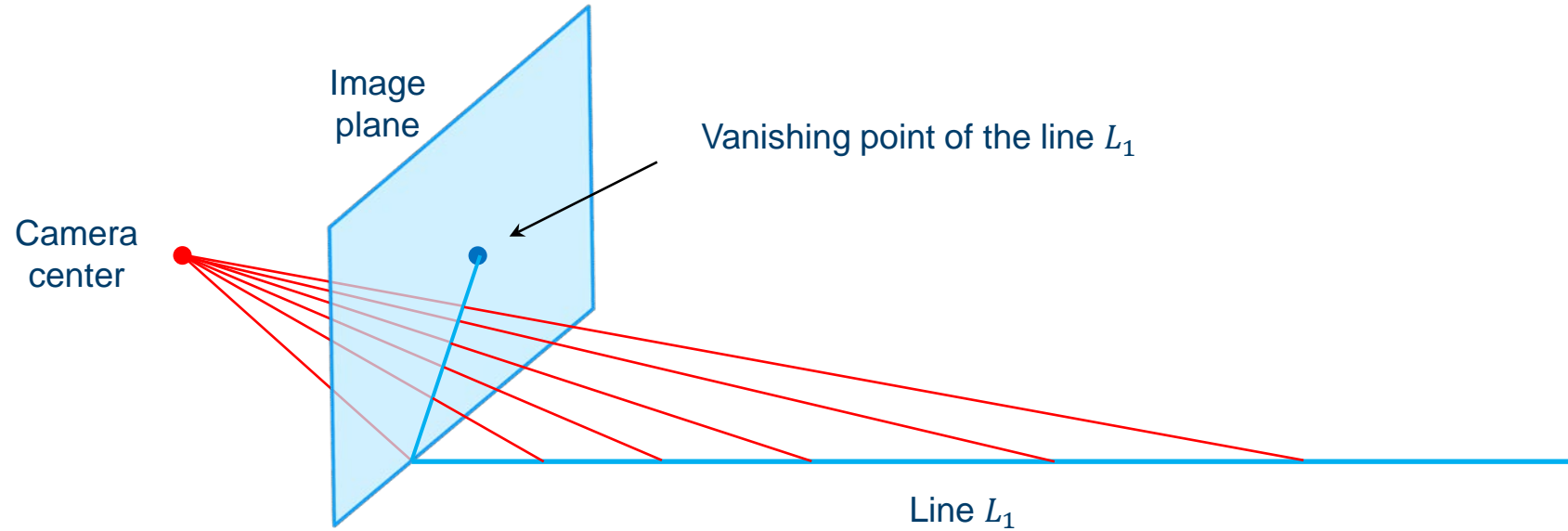
- Can we extract information about the 3D scene from an image?
- Only if we can recognize objects/regions with **known** 3D shape/orientation
 - Planar regions, parallel lines, horizontal surfaces, vertical structures

Perspective projection of lines



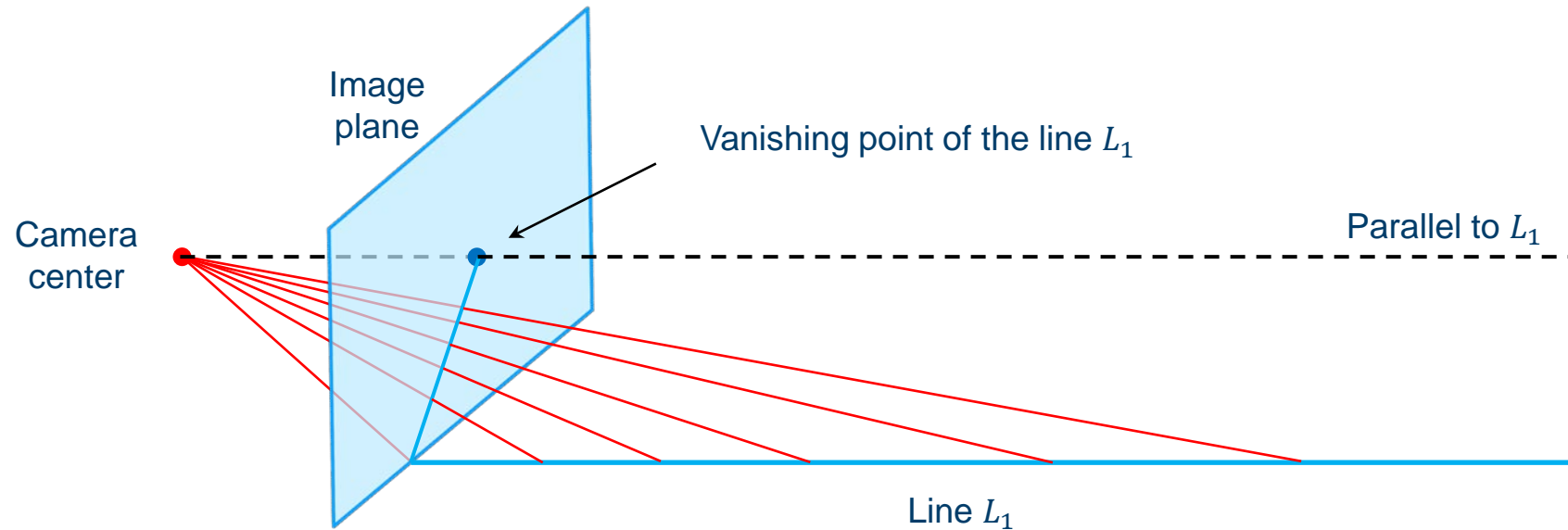
- Infinite lines in the world project to line segments of finite length in the image plane
 - Unless the line is orthogonal to the camera's optical axis

Perspective projection of lines



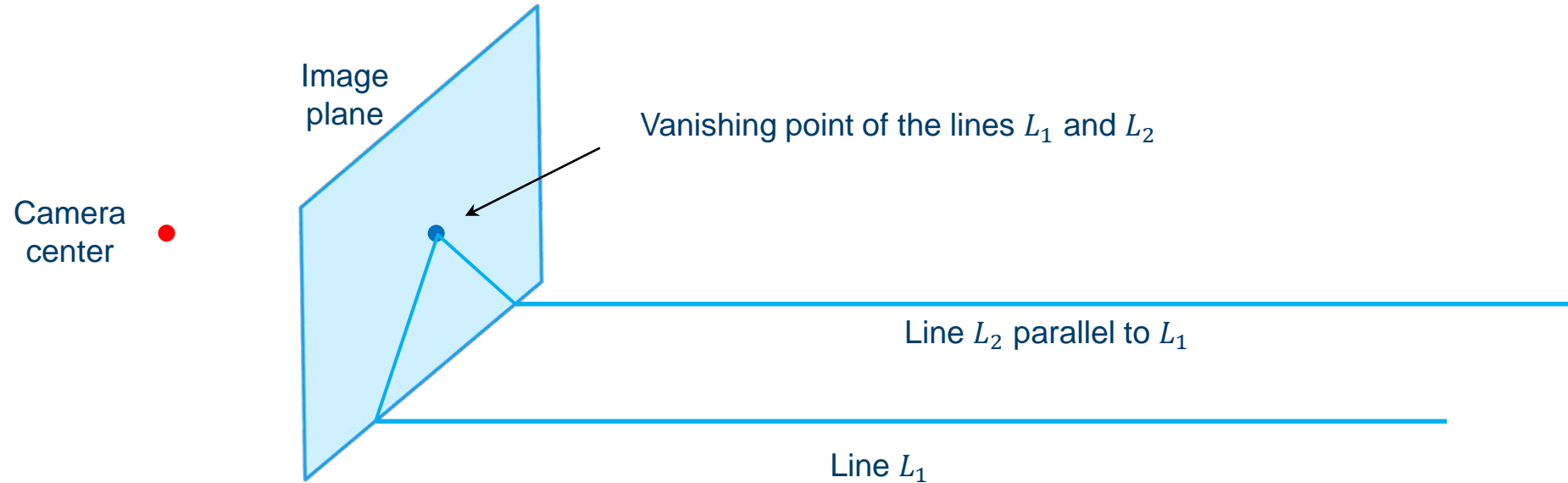
- Infinite lines in the world project to line segments of finite length in the image plane
 - Unless the line is orthogonal to the camera's optical axis
- The convergence point of the projected line we refer to as the lines vanishing point

Perspective projection of lines



- Infinite lines in the world project to line segments of finite length in the image plane
 - Unless the line is orthogonal to the camera's optical axis
- The convergence point of the projected line we refer to as the lines vanishing point
 - The line through the camera center and the vanishing point is parallel to the original line

Perspective projection of lines



- Infinite lines in the world project to line segments of finite length in the image plane
 - Unless the line is orthogonal to the camera's optical axis
- The convergence point of the projected line we refer to as the lines vanishing point
 - The line through the camera center and the vanishing point is parallel to the original line
- Parallel lines in the world have the same vanishing point in the image!
 - Rotating the lines or the camera changes the vanishing point

Example



Image: Flickr.com (Melita)

Example

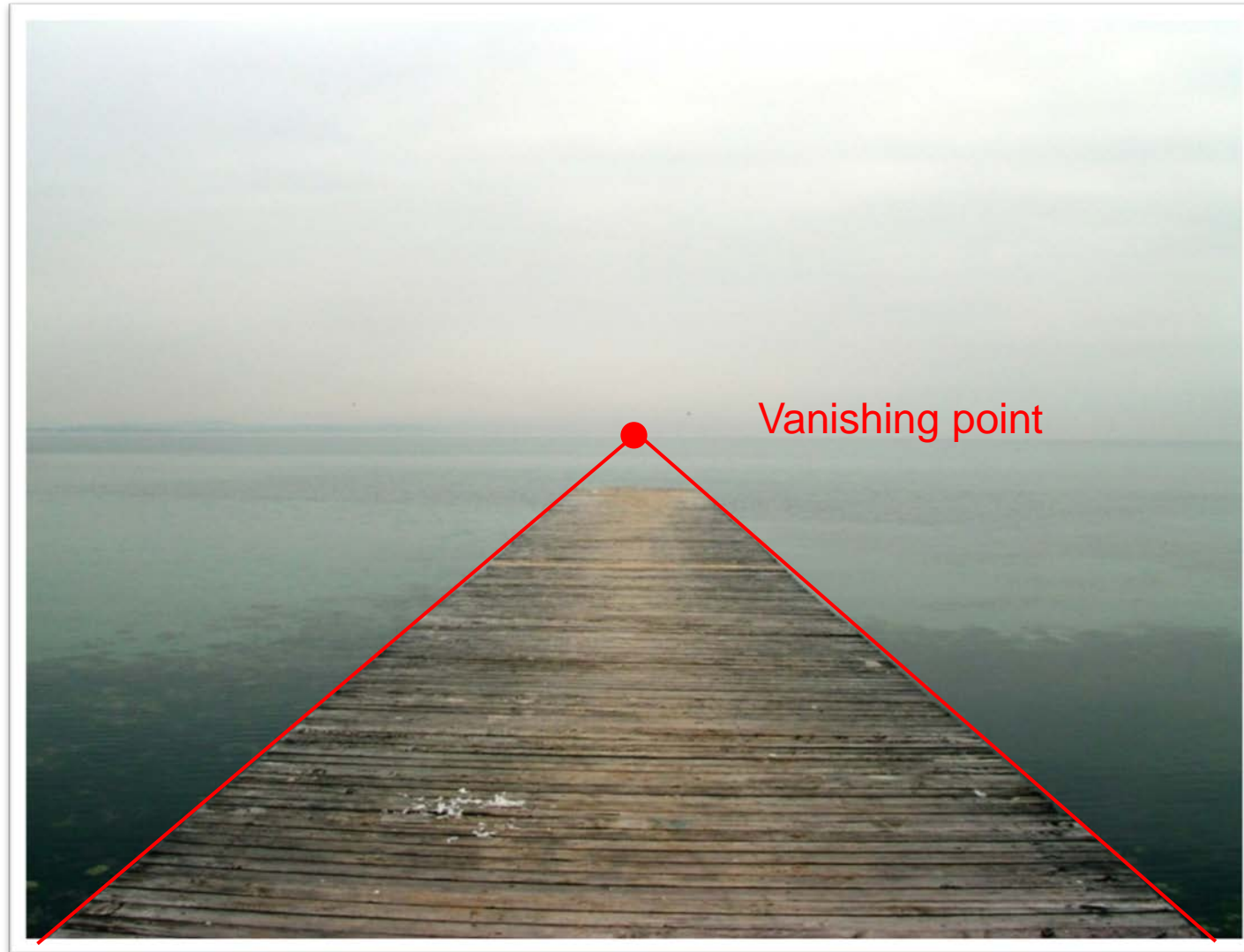
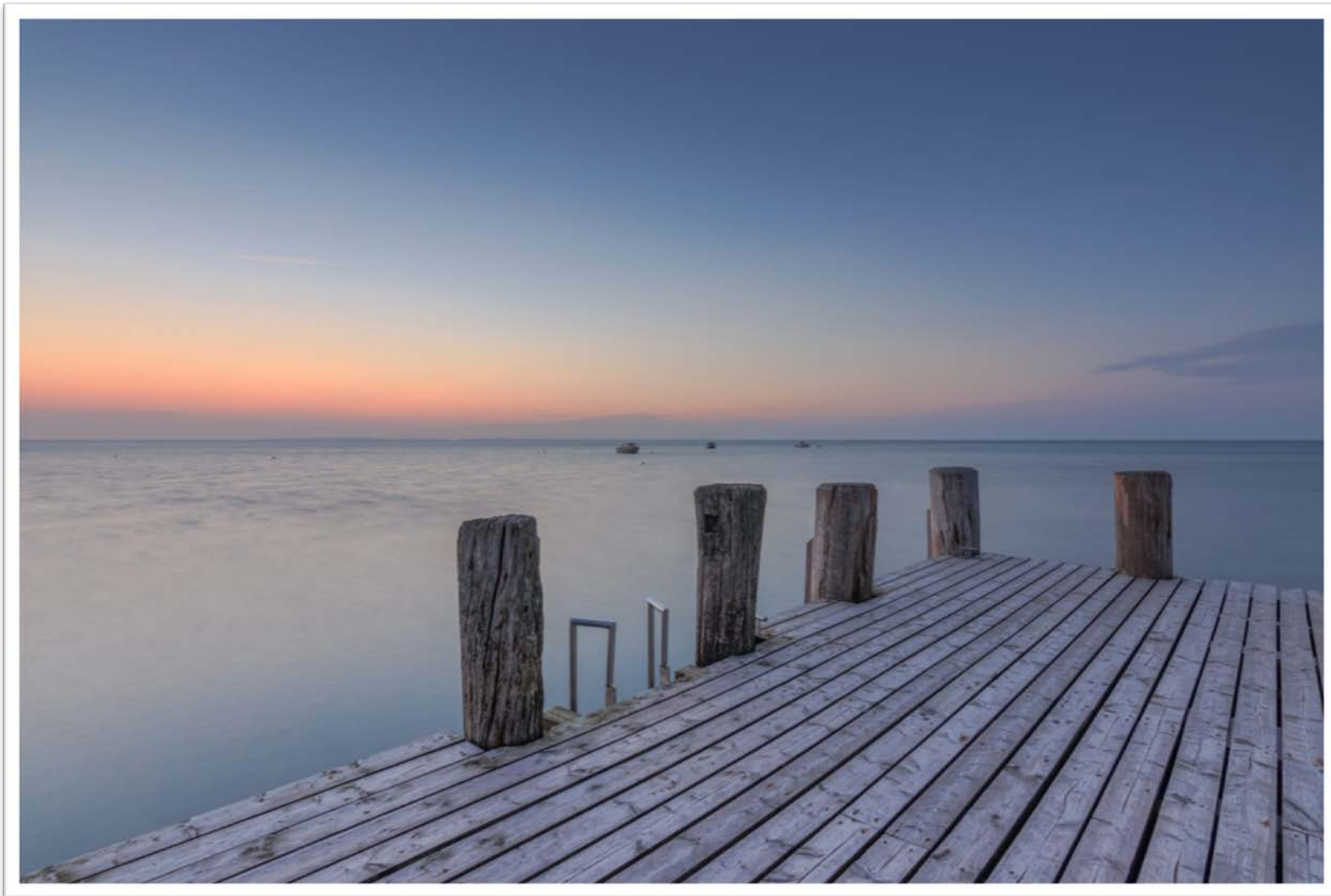


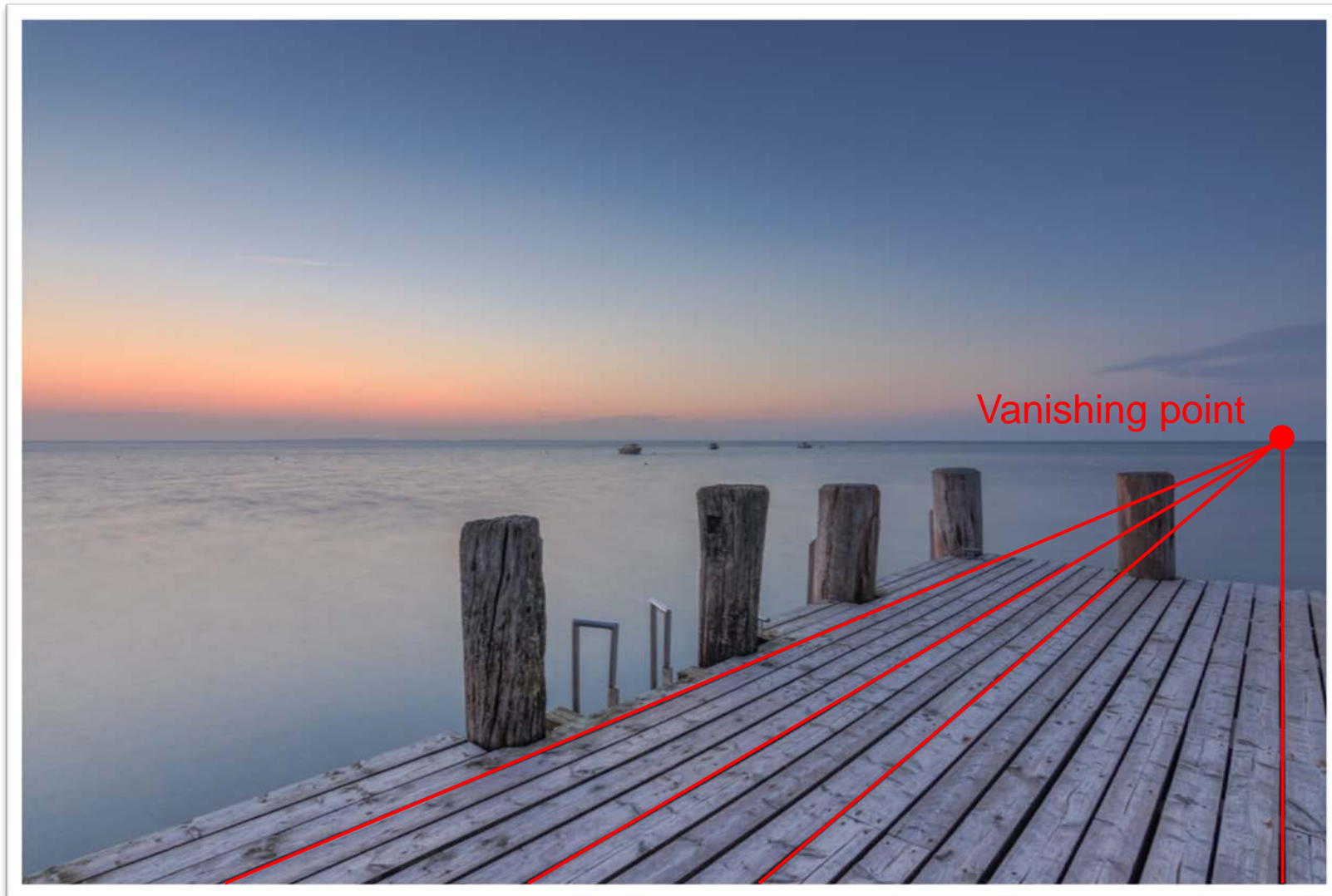
Image: Flickr.com (Melita)

Example



<https://www.pexels.com/photo/pier-on-sea-against-sky-330205>

Example



<https://www.pexels.com/photo/pier-on-sea-against-sky-330205>

Perspective projection of planes

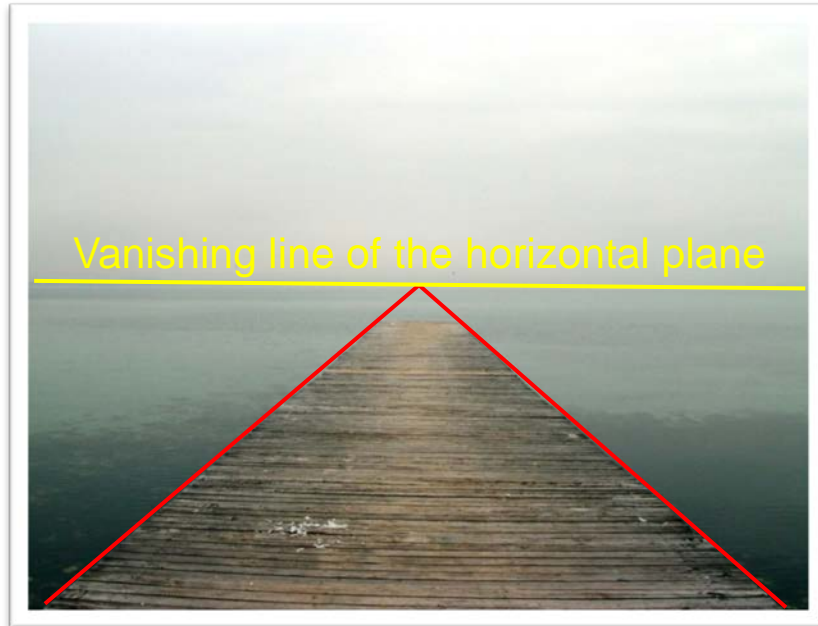
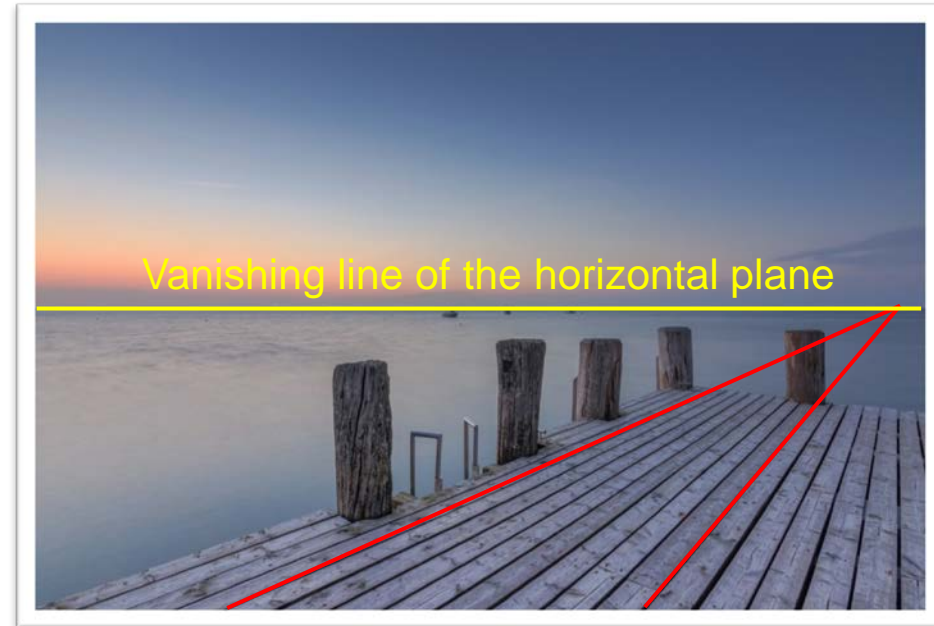


Image: Flickr.com (Melita)

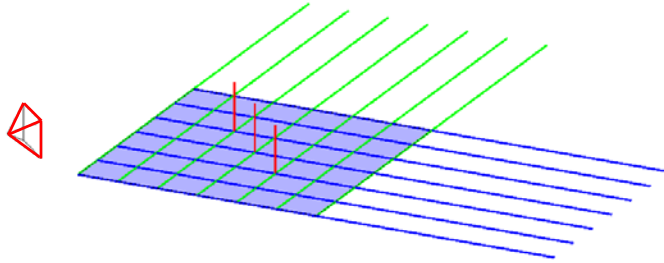


<https://www.pexels.com/photo/pier-on-sea-against-sky-330205>

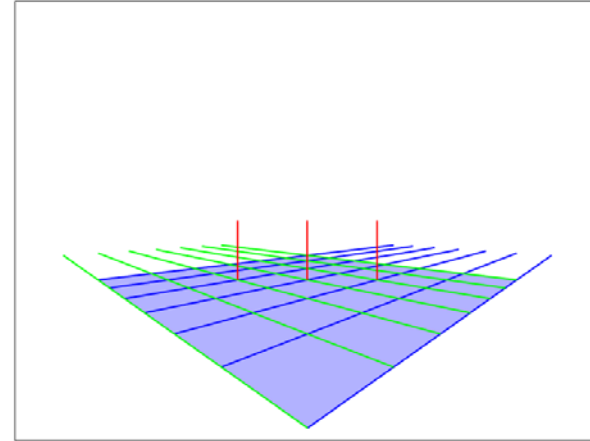
- Infinite planes in the world project to finite regions in the image
 - Unless the plane is parallel to the image plane
- In the image, the plane converges towards the so called vanishing line
 - Parallel planes will have the same vanishing line
 - Any pair of parallel lines in the plane (or in a parallel plane) will intersect at the vanishing line

Vertical structures on a horizontal plane

Straight and
level camera



3D geometry

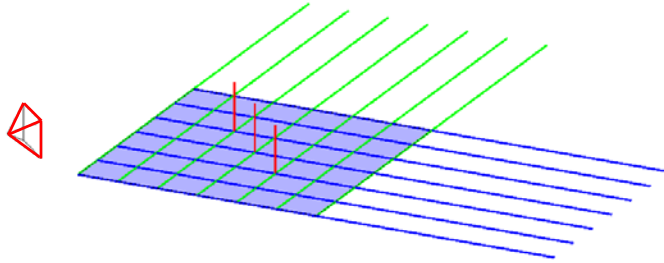


Captured image

- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- No vanishing point for the vertical direction
 - The vertical structures in the scene projects to vertical lines in the image
 - The vertical direction is parallel to the image plane

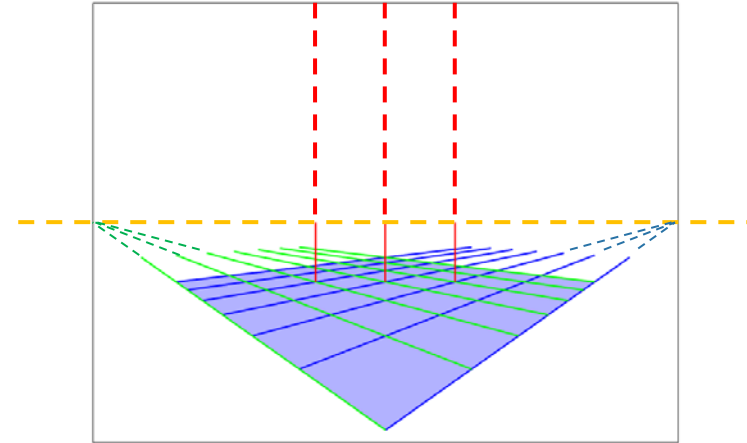
Vertical structures on a horizontal plane

Straight and level camera



3D geometry

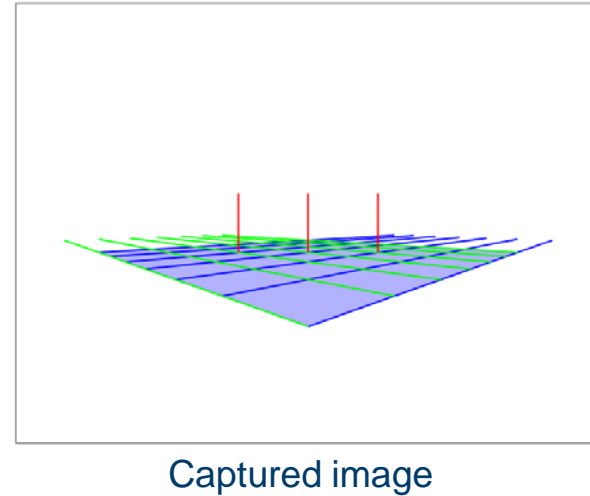
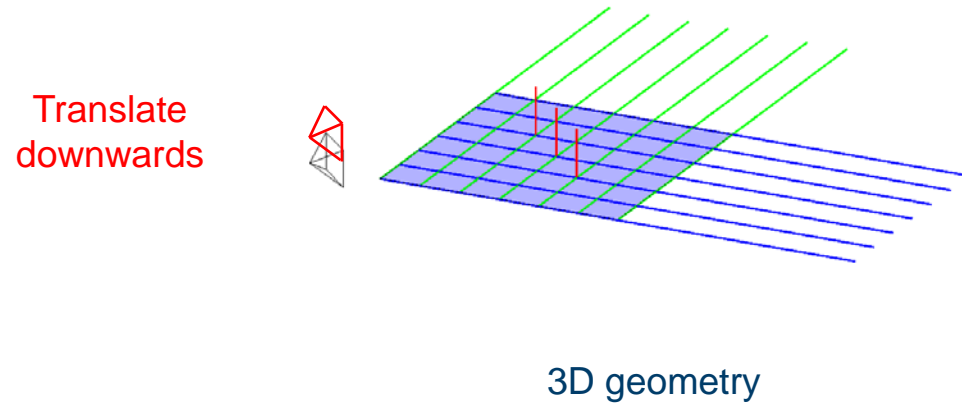
The top of the vertical structures are at the same height as the camera



Captured image

- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- No vanishing point for the vertical direction
 - The vertical structures in the scene projects to vertical lines in the image
 - The vertical direction is parallel to the image plane

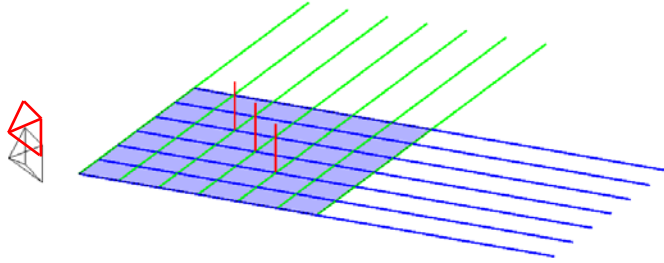
Vertical structures on a horizontal plane



- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- No vanishing point for the vertical direction
 - The vertical structures in the scene projects to vertical lines in the image
 - The vertical direction is parallel to the image plane

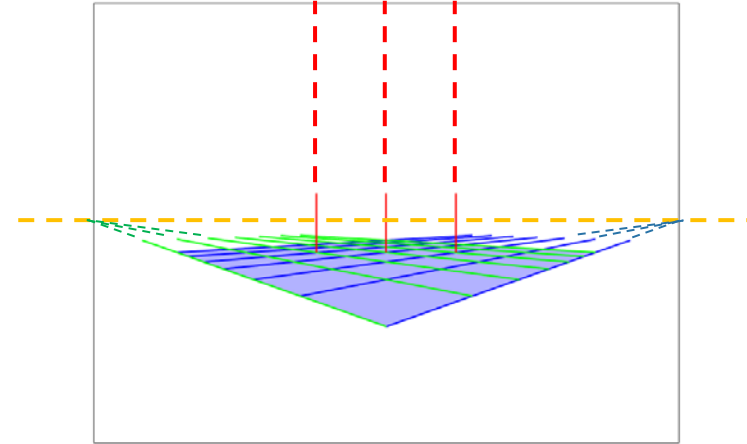
Vertical structures on a horizontal plane

Translate
downwards



3D geometry

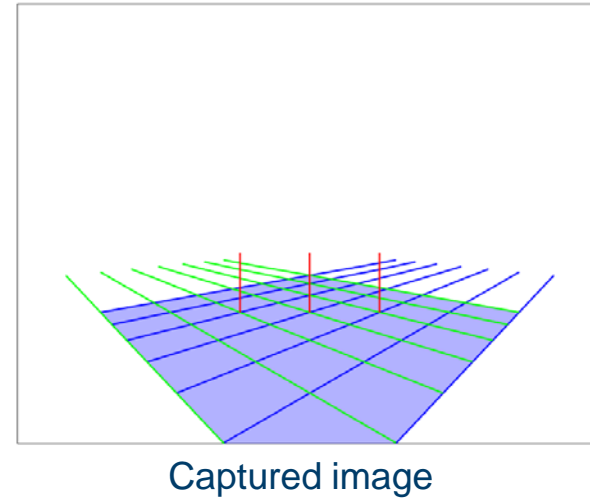
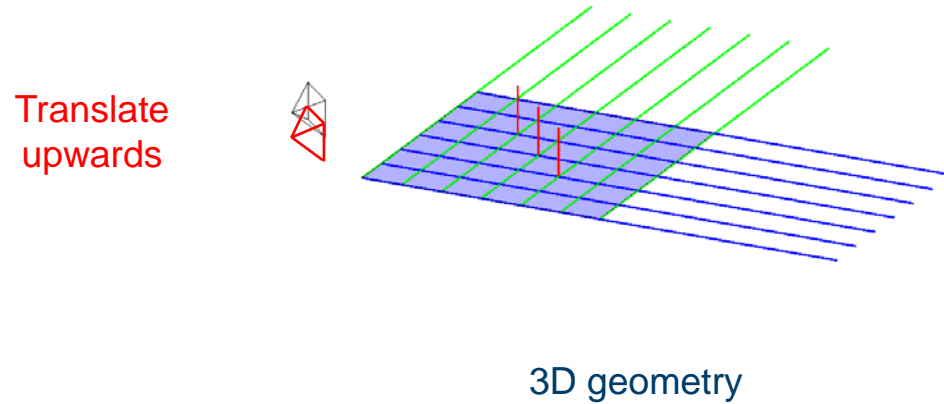
The top of the vertical structures are
higher than the camera



Captured image

- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- No vanishing point for the vertical direction
 - The vertical structures in the scene projects to vertical lines in the image
 - The vertical direction is parallel to the image plane

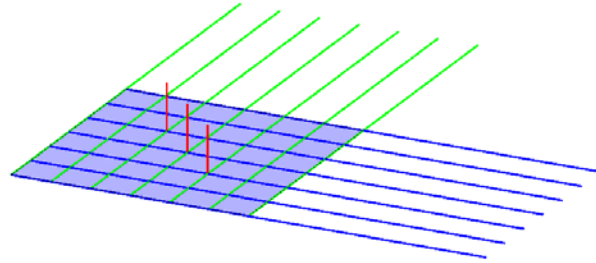
Vertical structures on a horizontal plane



- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- No vanishing point for the vertical direction
 - The vertical structures in the scene projects to vertical lines in the image
 - The vertical direction is parallel to the image plane

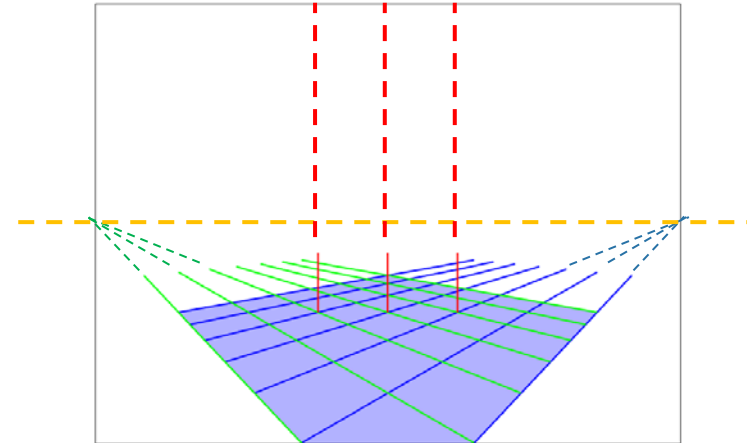
Vertical structures on a horizontal plane

Translate upwards



3D geometry

The top of the vertical structures are lower than the camera

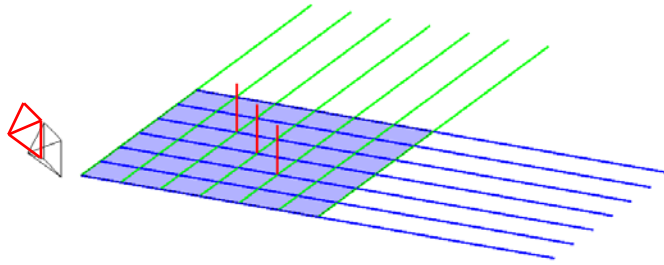


Captured image

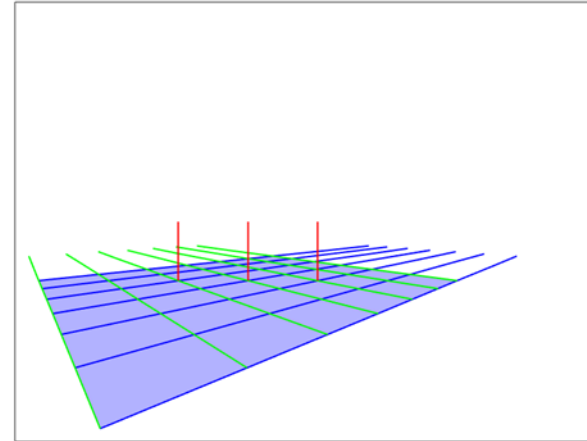
- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- No vanishing point for the vertical direction
 - The vertical structures in the scene projects to vertical lines in the image
 - The vertical direction is parallel to the image plane

Vertical structures on a horizontal plane

Translate
rightwards



3D geometry

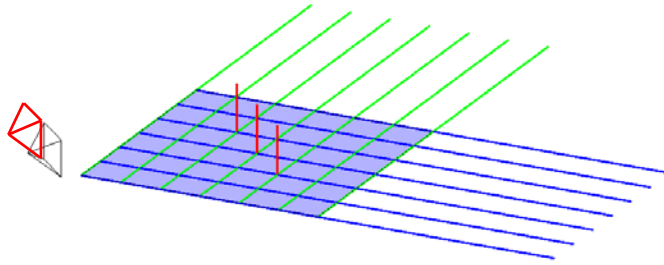


Captured image

- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- No vanishing point for the vertical direction
 - The vertical structures in the scene projects to vertical lines in the image
 - The vertical direction is parallel to the image plane

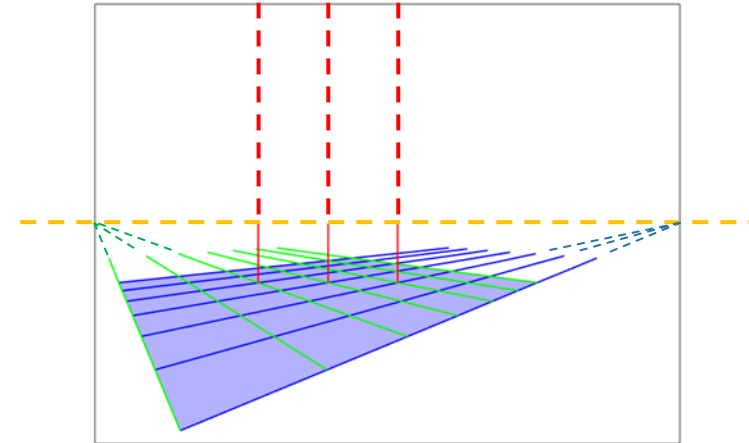
Vertical structures on a horizontal plane

Translate
rightwards



3D geometry

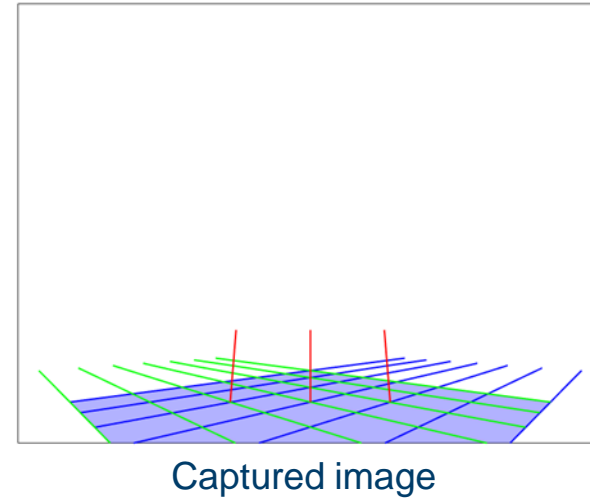
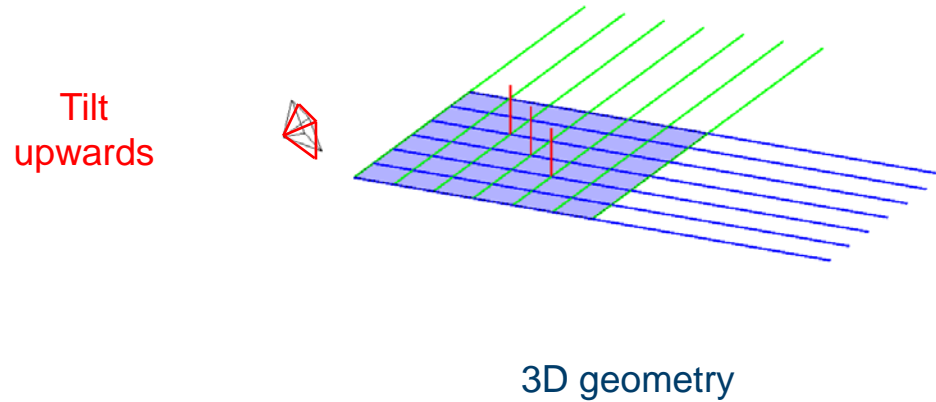
The top of the vertical structures are
at the same height as the camera



Captured image

- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- No vanishing point for the vertical direction
 - The vertical structures in the scene projects to vertical lines in the image
 - The vertical direction is parallel to the image plane

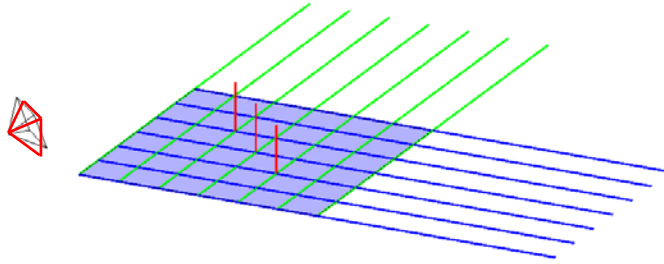
Vertical structures on a horizontal plane



- The vanishing line of the horizontal plane is horizontal in the image and it runs through the center point
 - The optical axis of the camera (the center pixel) is parallel to the horizontal plane
- The vertical direction has a vanishing point
 - The vertical structures in the scene do not project to vertical lines in the image
 - The vertical direction is not parallel to the image plane

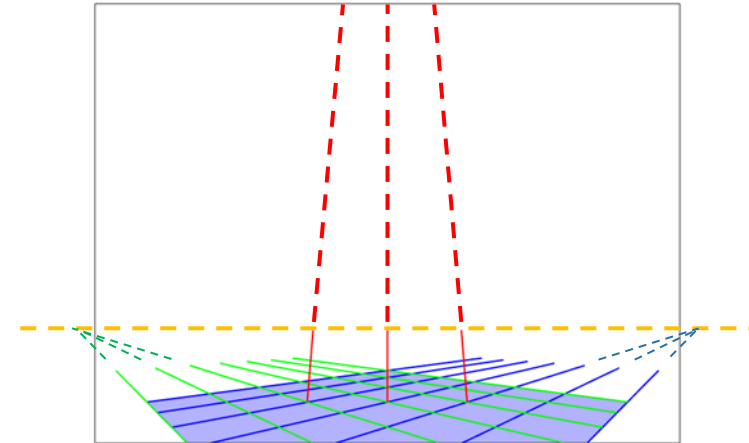
Vertical structures on a horizontal plane

Tilt
upwards



3D geometry

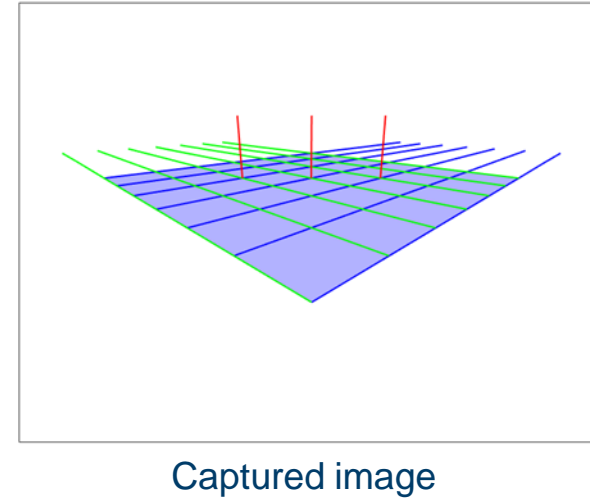
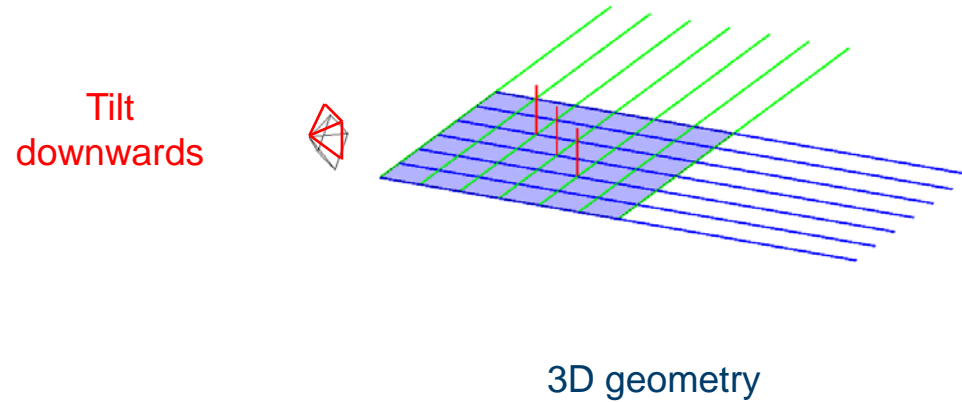
The top of the vertical structures are
at the same height as the camera



Captured image

- The vanishing line of the horizontal plane is horizontal in the image but it does not run through the center point
 - The optical axis of the camera (the center pixel) is not parallel to the horizontal plane
- The vertical direction has a vanishing point
 - The vertical structures in the scene do not project to vertical lines in the image
 - The vertical direction is not parallel to the image plane

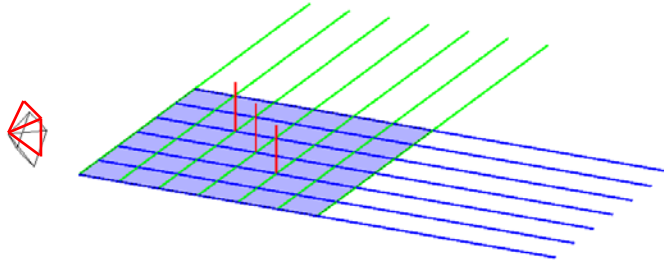
Vertical structures on a horizontal plane



- The vanishing line of the horizontal plane is horizontal in the image but it does not run through the center point
 - The optical axis of the camera (the center pixel) is not parallel to the horizontal plane
- The vertical direction has a vanishing point
 - The vertical structures in the scene do not project to vertical lines in the image
 - The vertical direction is not parallel to the image plane

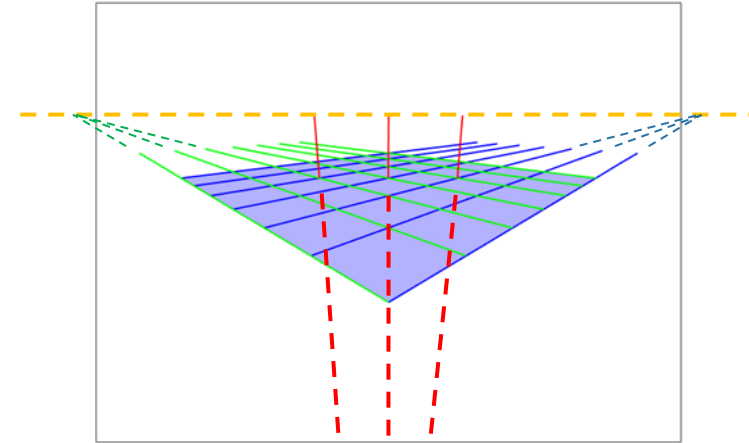
Vertical structures on a horizontal plane

Tilt
downwards



3D geometry

The top of the vertical structures are
at the same height as the camera



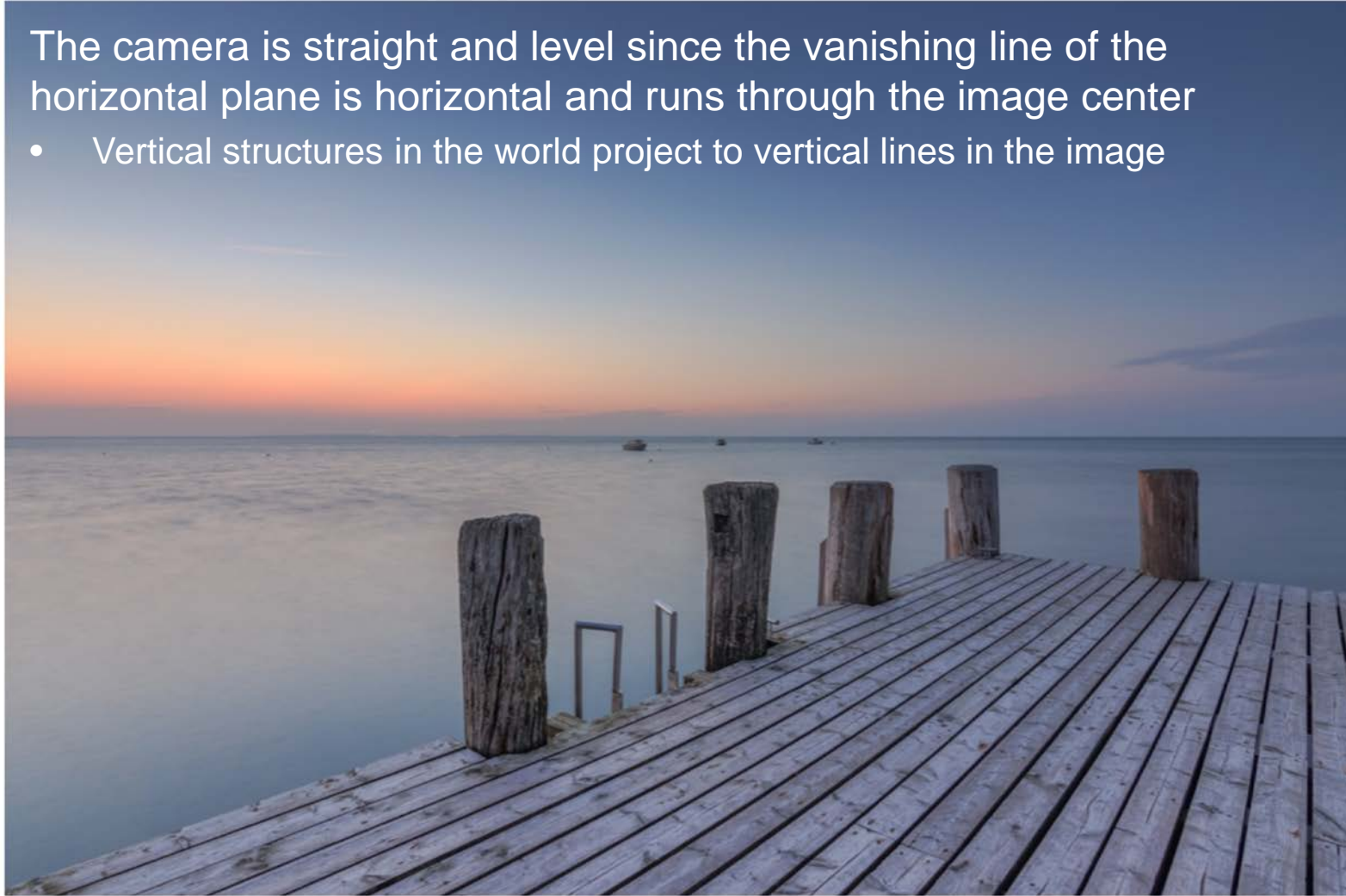
Captured image

- The vanishing line of the horizontal plane is horizontal in the image but it does not run through the center point
 - The optical axis of the camera (the center pixel) is not parallel to the horizontal plane
- The vertical direction has a vanishing point
 - The vertical structures in the scene do not project to vertical lines in the image
 - The vertical direction is not parallel to the image plane

Example

The camera is straight and level since the vanishing line of the horizontal plane is horizontal and runs through the image center

- Vertical structures in the world project to vertical lines in the image



<https://www.pexels.com/photo/pier-on-sea-against-sky-330205>

Example

The camera is straight and level since the vanishing line of the horizontal plane is horizontal and runs through the image center

- Vertical structures in the world project to vertical lines in the image

The line connecting the bottom of vertical objects has a vanishing point on the vanishing line of the horizontal plane



<https://www.pexels.com/photo/pier-on-sea-against-sky-330205>

Example

The camera is straight and level since the vanishing line of the horizontal plane is horizontal and runs through the image center

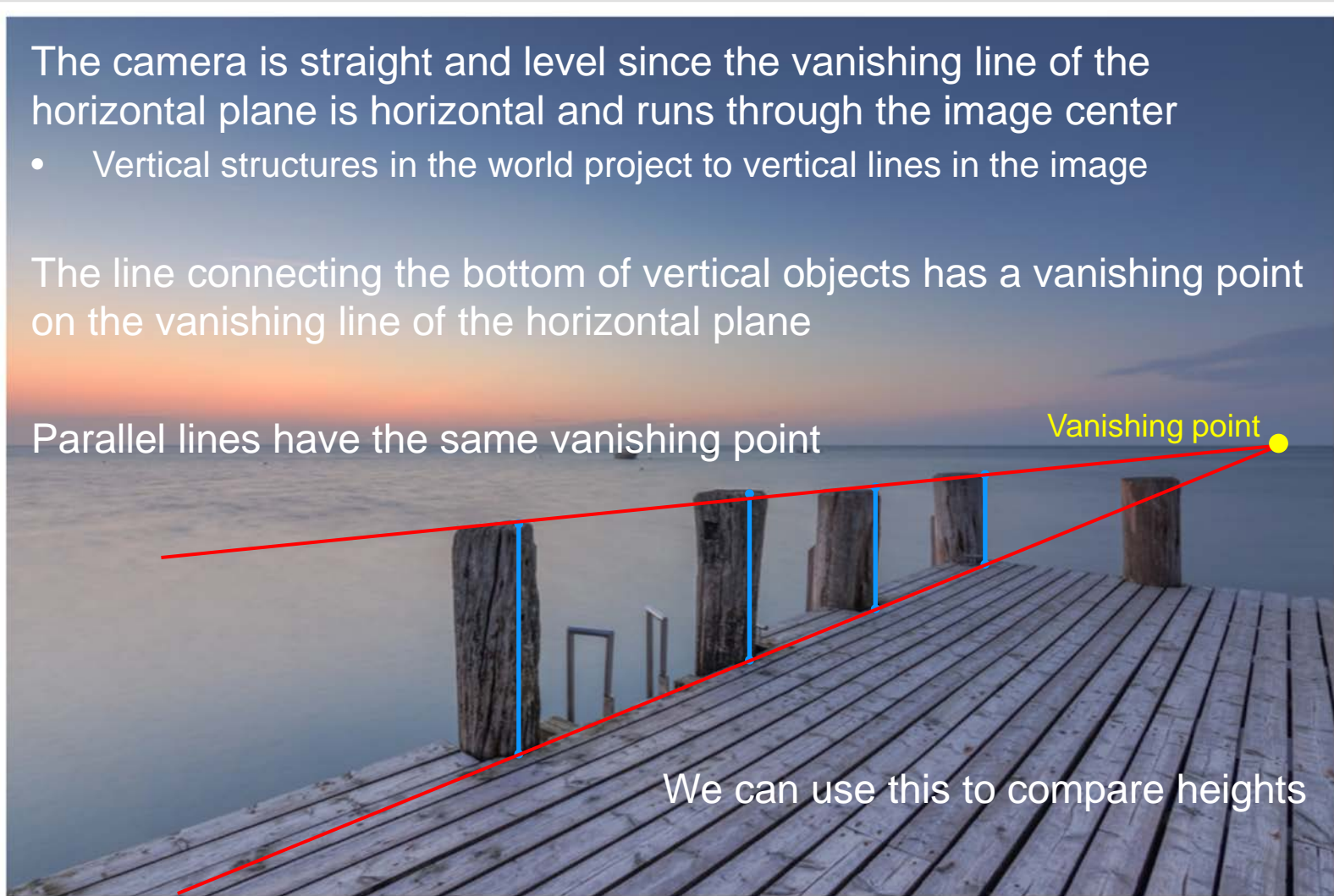
- Vertical structures in the world project to vertical lines in the image

The line connecting the bottom of vertical objects has a vanishing point on the vanishing line of the horizontal plane

Parallel lines have the same vanishing point

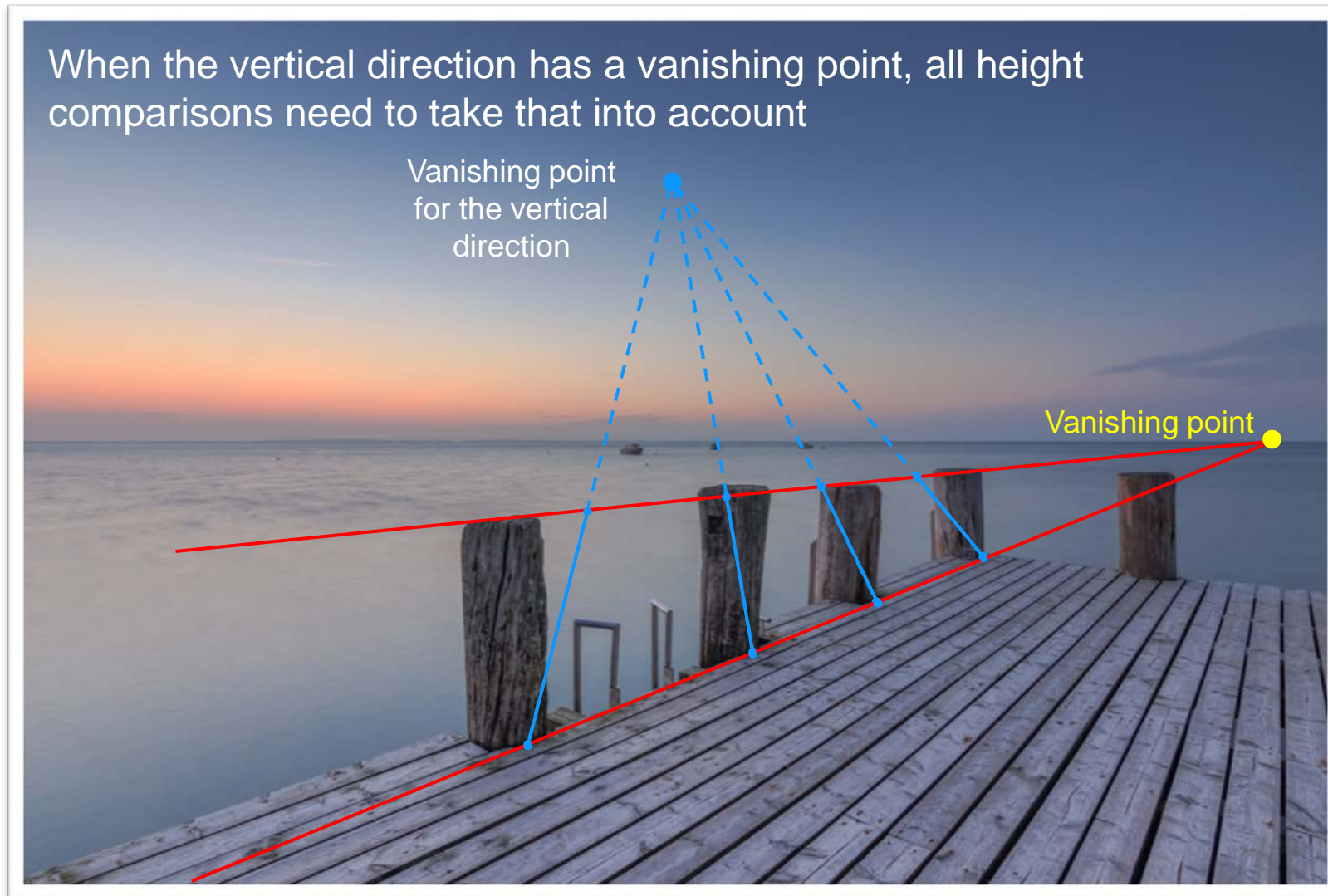
Vanishing point

We can use this to compare heights



<https://www.pexels.com/photo/pier-on-sea-against-sky-330205>

Example



<https://www.pexels.com/photo/pier-on-sea-against-sky-330205>

Example

- Given an image



<http://www.robots.ox.ac.uk/~vgg/hzbook/>

Example

- Given an image
 - Undistort



<http://www.robots.ox.ac.uk/~vgg/hzbook/>

Example

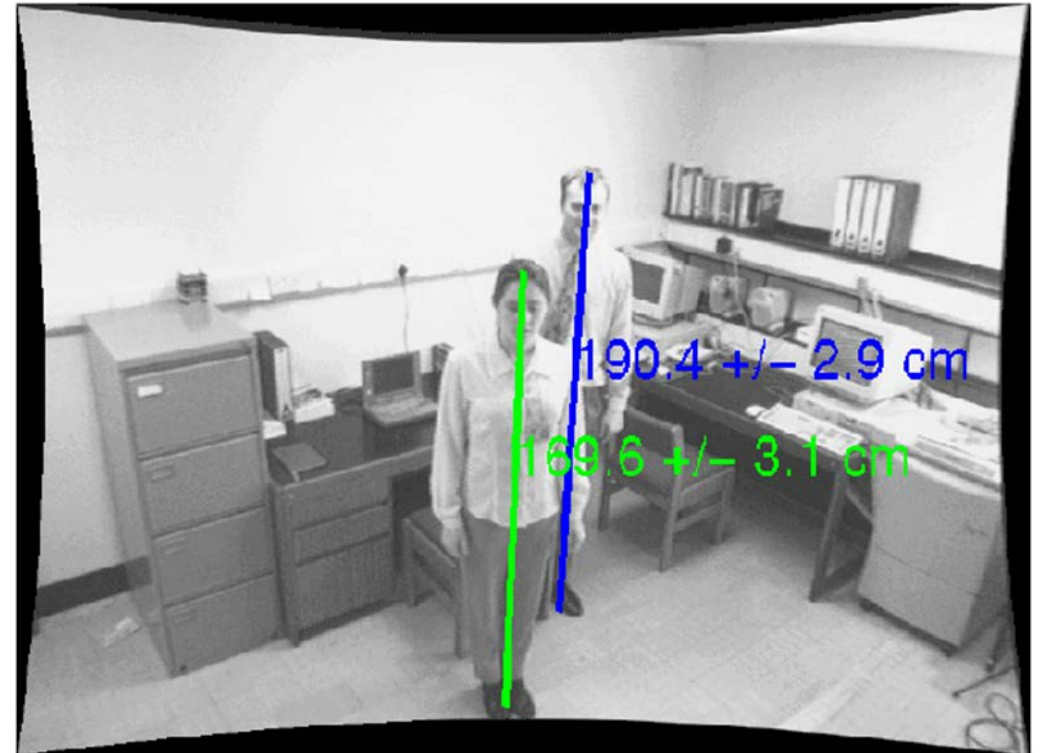
- Given an image
 - Undistort
 - Estimate the vanishing line of the horizontal plane from lines in the scene that we know are parallel and horizontal
 - Estimate the vanishing point of the vertical direction from lines in the scene that we know are vertical



<http://www.robots.ox.ac.uk/~vgg/hzbook/>

Example

- Given an image
 - Undistort
 - Estimate the vanishing line of the horizontal plane from lines in the scene that we know are parallel and horizontal
 - Estimate the vanishing point of the vertical direction from lines in the scene that we know are vertical
 - Measure heights of objects by comparing with a known height in the scene



<http://www.robots.ox.ac.uk/~vgg/hzbook/>

Summary



- Vanishing points
 - Perspective projection of infinitely long lines (non-parallel to the image plane)
 - Parallel lines have the same vanishing point
- Vanishing lines
 - Perspective projection of planes (non-parallel to the image plane)
 - Parallel planes have the same vanishing line
- Optional reading
 - *Single View Metrology* by A. Criminisi, I. Reid and A. Zisserman