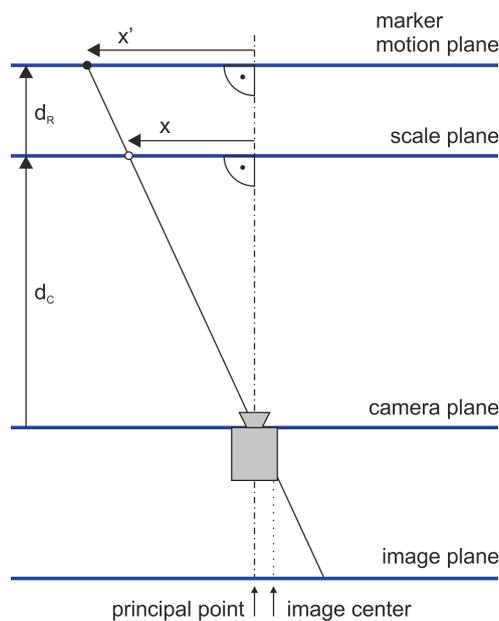


## FalCon MovXact – 2D Image Analysis FAQ

- *Which requirements need to be considered for a later 2D analysis?*

### Principle of monocular imaging:



### Requirements:

1. Direction of view is orthogonal to scale and motion plane, i. e. image plane is coplanar to object planes.
2. A scale exists, typically given by two markers in a plane.
3. Distances to camera (depth values) are known.
4. Recommendable: the camera is calibrated, i. e. also the principal point is known.
5. Note: free, spatial movements cannot be measured correctly!

### Calibration steps from image to world coordinates:

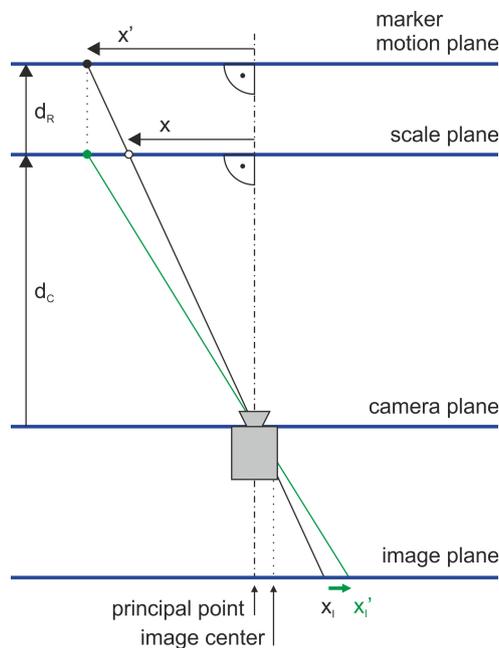
- Rectification of distortion (camera calibration)
- Scaling
- Correction of parallax errors
- free coordinate system (origin and orientation)

- *How are parallax errors of markers with different distance to the camera compensated during a 2D analysis?*

**Principle of the 2½D calibration with known depth values:**

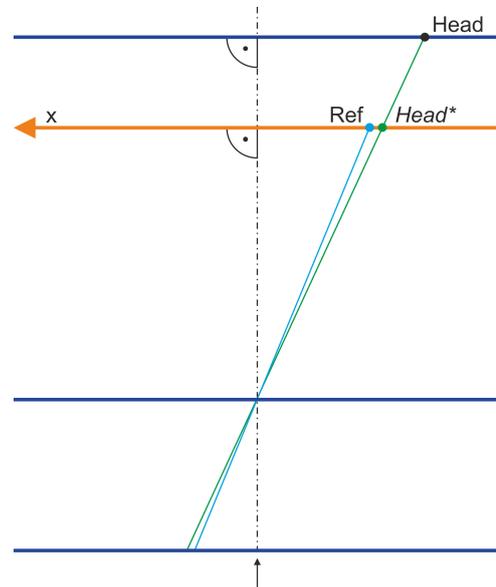
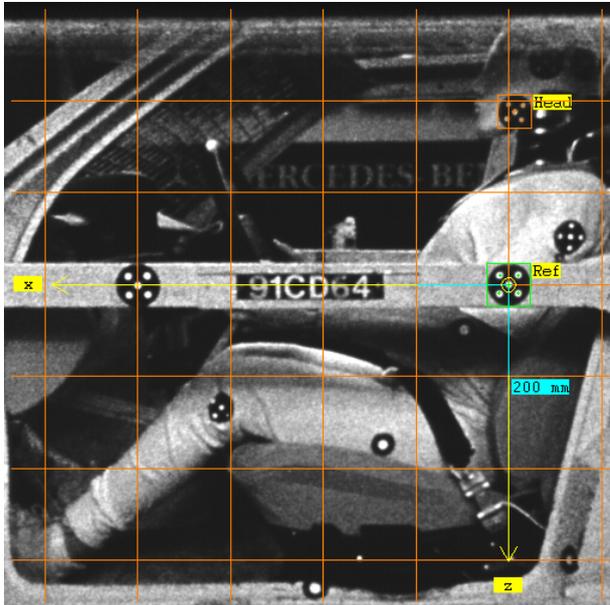
Correction of the image coordinates  
corresponding to back projection from image to marker plane:

Meas. value in image	$x_{Image}$	[pixel]
Absolute depth	$d_c$	camera to scale plane
Relative depth	$d_r$	object to scale plane
By similarity of triangles	$x' / x$	$= (d_r + d_c) / d_c$
Correction factor	$F$	$= (d_r + d_c) / d_c$
Image center	$x_{Center}$	
Principal point <small>relative to center</small>	$\Delta x_{PP}$	
Principal point <small>absolute</small>	$x_{PP}$	$= x_{Center} + \Delta x_{PP}$
<b>Parallax correction:</b>	$x'_{Image}$	$= F * (x_{Image} - x_{PP}) + x_{PP}$

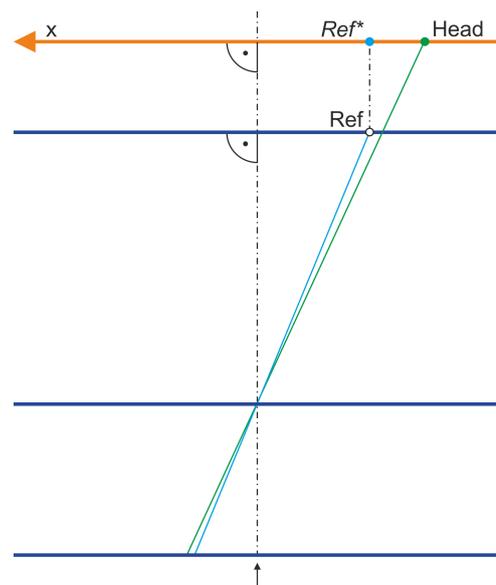


<b>Scaling:</b>	[pixel] $\Leftrightarrow$ [m]
Measured value	$x'_{Object} = scale * x'_{Image}$
with scale	$scale = \Delta s_{Plane} / \Delta s_{Image}$

### Effect of parallaxes during visual assessment:



- Origin of coordinate system = marker *Ref* at a camera distance of 1,000 mm.
- Scale grid and coordinate system are valid in the plane of the marker *Ref*.
- Marker *Head* has a distance of 1,300 mm to the camera, therefore a relative distance to plane *Ref* of 300 mm.
- Marker *Head* seems (**without** consideration of parallaxes!) to be at  $x = -20$  mm.



- Now scale grid and coordinate system (incl. seemingly shifted origin) are shown with respect to the depth at marker plane *Head*.
- Marker *Head* is now located "correctly" (**with** consideration of parallaxes!) at  $x = -150$  mm.

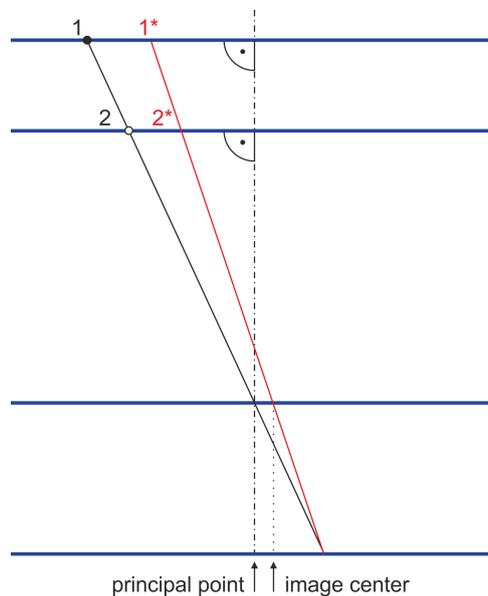
- *What means the term 'principal point' of a camera and which influences does it have to the back projection?*

The **principal point** is the real center of the optical axis in the image plane.

It is determined by mechanical and optical properties of the lens as well as by not centered mounting of the camera sensor.

Generally it differs from the numerical image center.

The camera calibration process determines not only the distortion parameters but also the principal point.

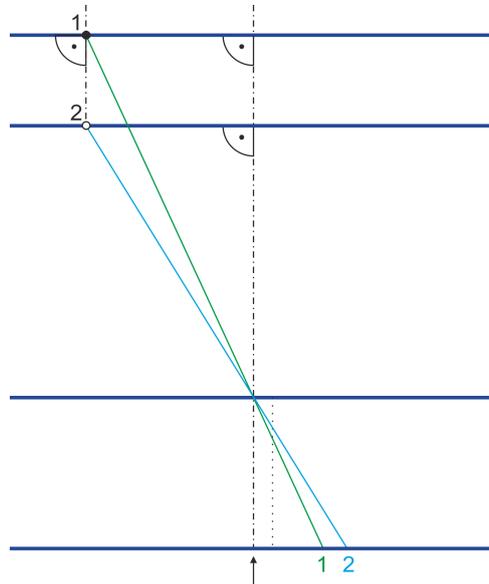


Object point 1 und 2 have different (world) x-coordinates.

They lay on the same viewing ray and thus they are imaged on the same image point.

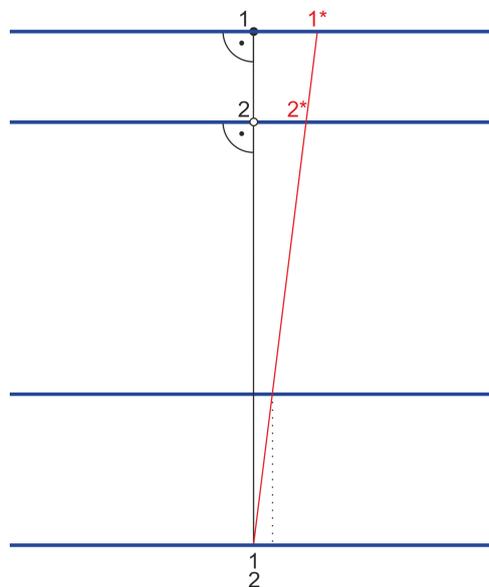
If the real principal point is ignored during **back projection**, i. e. if the image center is taken as center of projection, errors can be caused. These errors are most notable in the area close to the image center.

- **How are object points with same x-coordinate but different depth values imaged?**



Generally they are imaged to different image points.

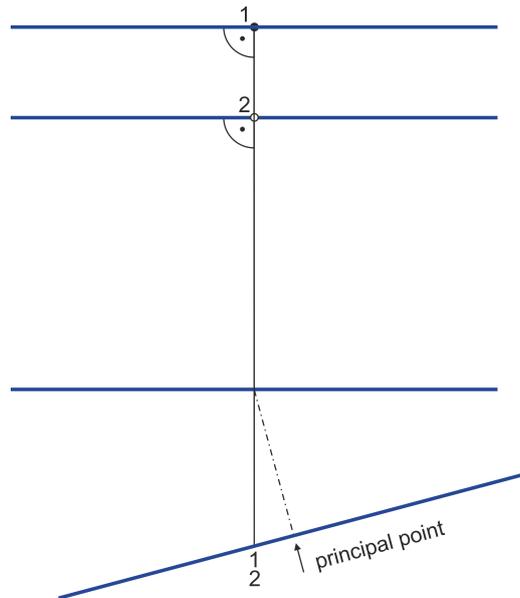
Their distance in the image gets smaller with decreasing x-coordinate, thus...



two points on the viewing ray (= "aligned points") are imaged to the same image point, namely to the principal point.

In this case the error during **back projection** with the assumption image center = projection center is apparent. The measured x-coordinates in the object plane are also different.

- *The projection of two "aligned points" differs from the calibrated principal point or the back projection of image points results in inaccurate coordinates even if principal point and depth values are given precisely:  
 Why?*



The reason can be a deviation from the orthogonal camera view.

Even a small pitch or yaw angle causes a shift of the projected image point (1&2).

**Corrective in case of small angle errors:**

- Use the projected image point (1&2) as corrected principal point.
- Use a calibrated camera position  
 = calculate the exterior orientation from known control points.  
*(option to 2D MovXact license!)*