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W-CAPS –
An Absolute Positioning System for 100 Euros

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Contents

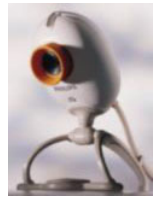
1) Introduction

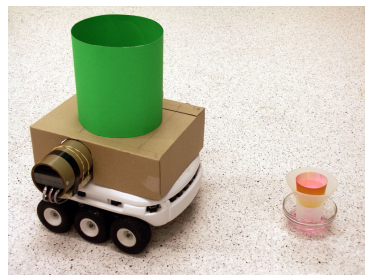
- **W**eb-**C**amera-Based **A**bsolute **P**ositioning **S**ystem
  - tracking a colour blob with ***N*** web-cameras
  - determine position by triangulation

- Why W-CAPS ?
  - cheap system
  - standard components
  - easy to set-up
  - centimeter-level accuracy
  - not restricted to robots

2) Set-Up of W-CAPS

- *N* web-cameras
  - Philips PCVC 740K
  - resolution: 320×240 pixel

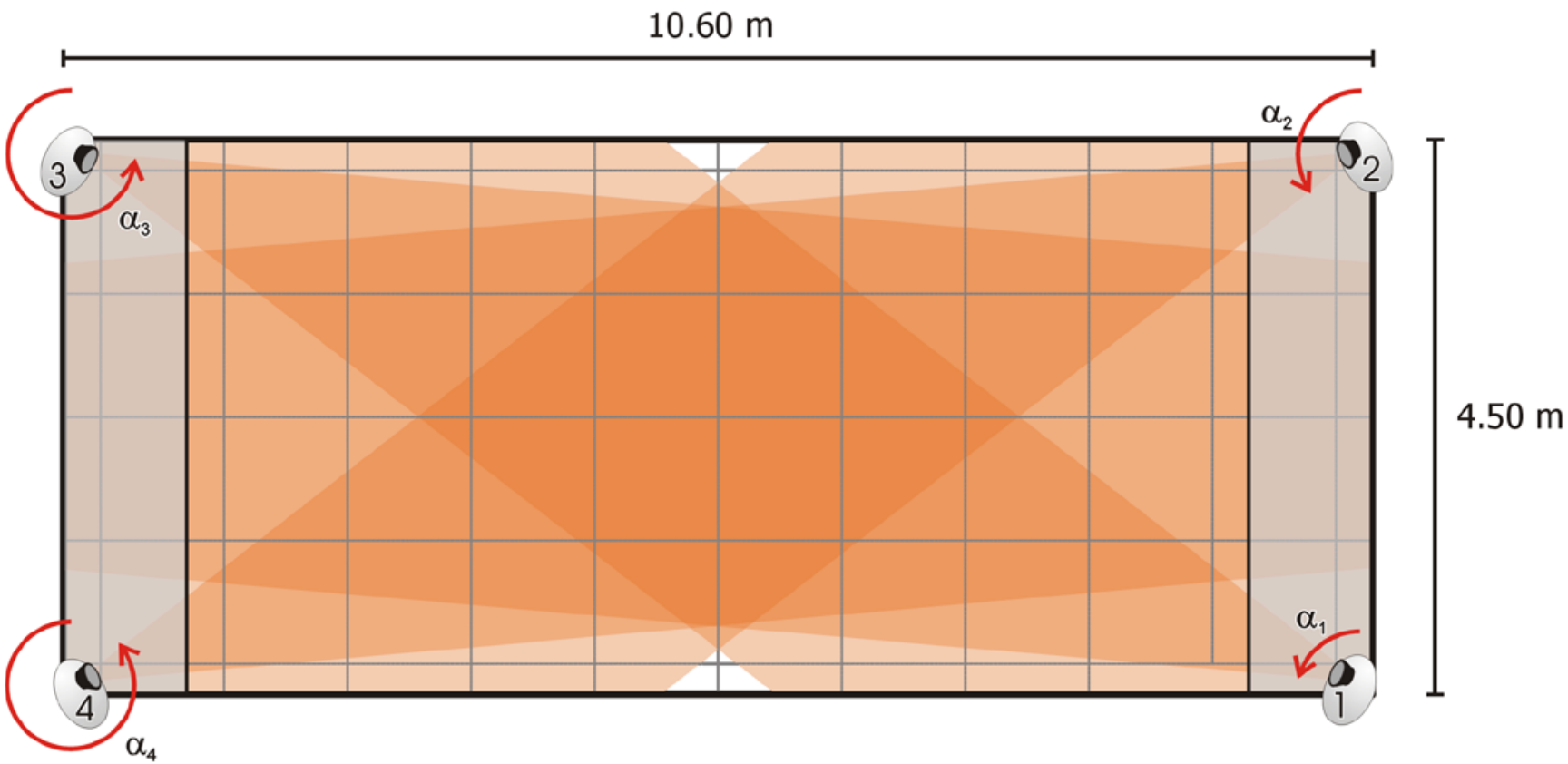
$N \times$ 



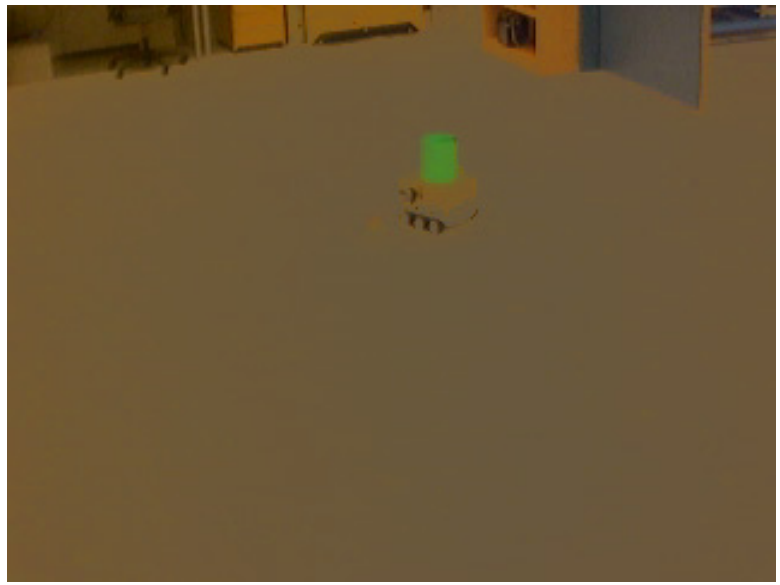
- the coloured object
  - green/blue hat made of cardboard
- standard PC
- USB connectors
- stable support

3) Determining 2D Positions

- *N* = 4 web-cameras



3.1) Luminance Adjustment

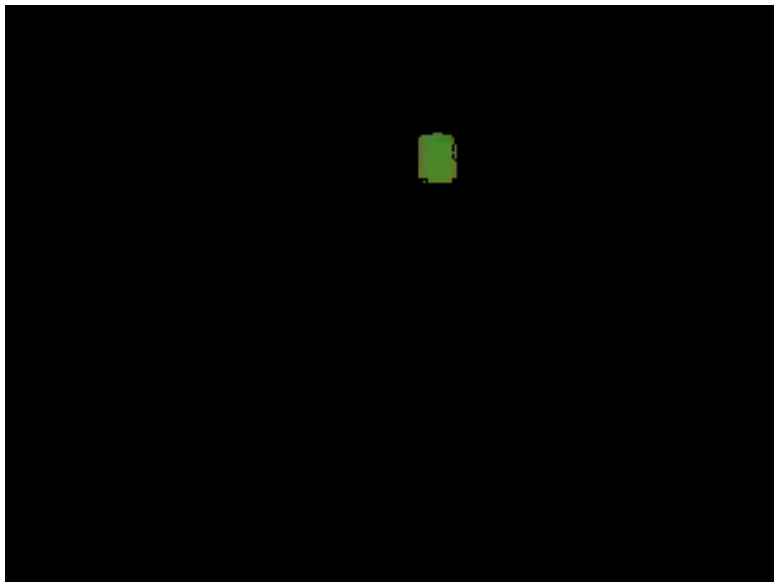


- normalise (r,g,b) value

$$(r', g', b') = 255 \times \frac{(r, g, b)}{r + g + b} \quad \text{if } r+g+b \geq B_{norm}$$

$$(r', g', b') = (r, g, b) \quad \text{otherwise}$$

3.2) Use Contiguous rgb-Colour-Range



- consider pixels within contiguous colour range

$$(r', g', b') \in [(r_{min}, g_{min}, b_{min}), (r_{max}, g_{max}, b_{max})]$$

3.3) Calculate Centre of Colour Blob

- use median
- ensure centre's validity

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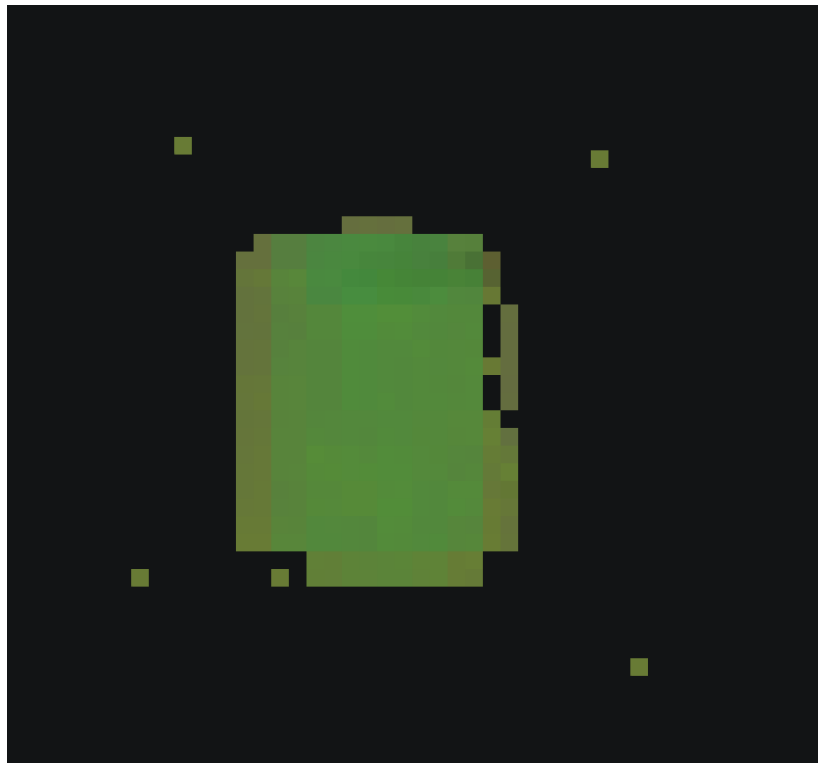
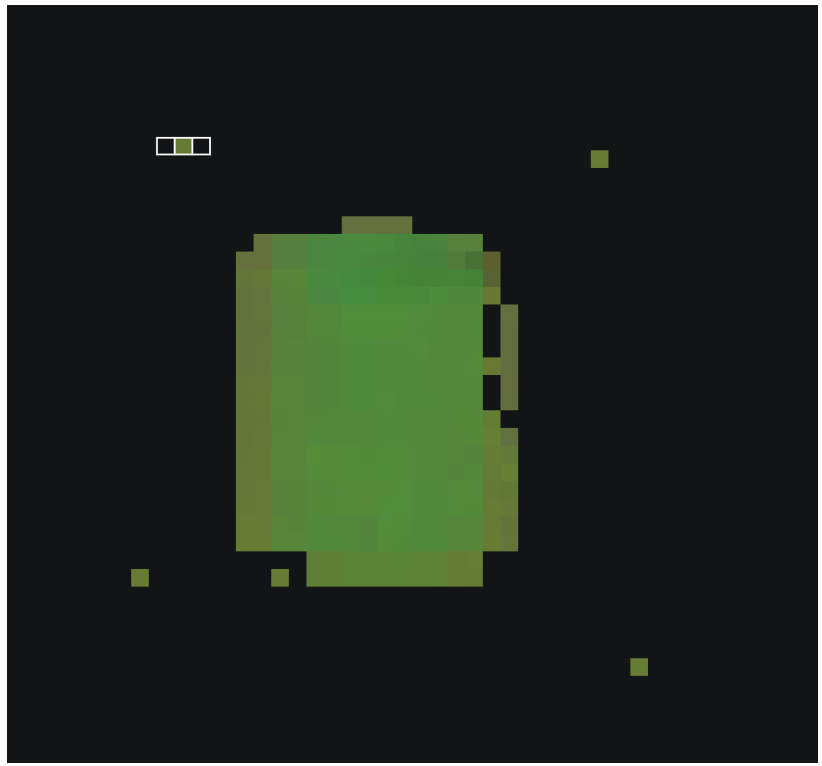
- ensure centre's validity

3.3) Calculate Centre of Colour Blob



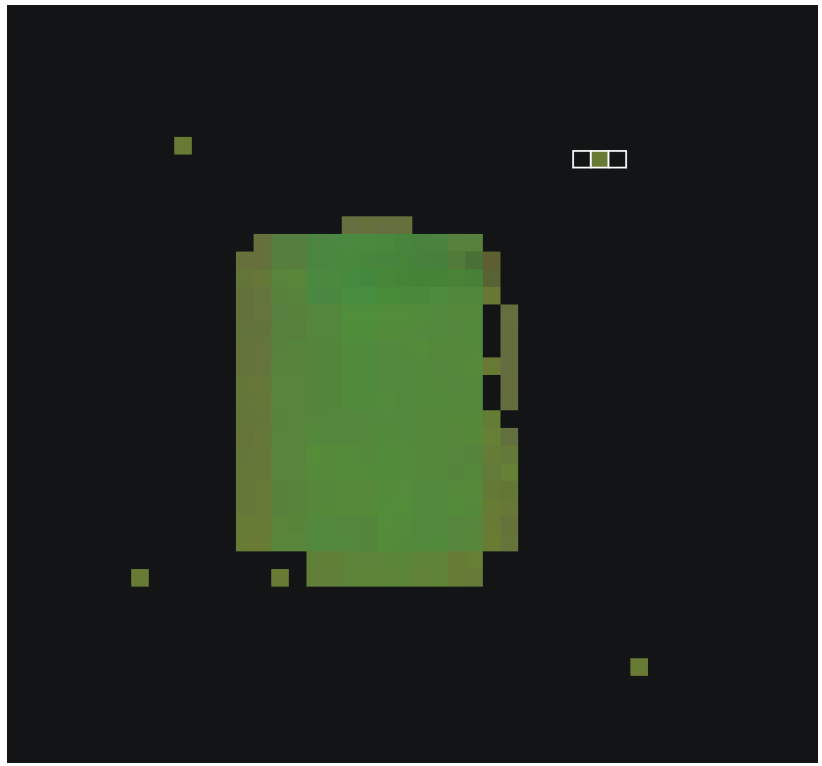
- ensure centre's validity

3.3) Calculate Centre of Colour Blob



- verify blob quality:
  - more than N_{arr} rows with N_{row} succesive pixels

3.3) Calculate Centre of Colour Blob



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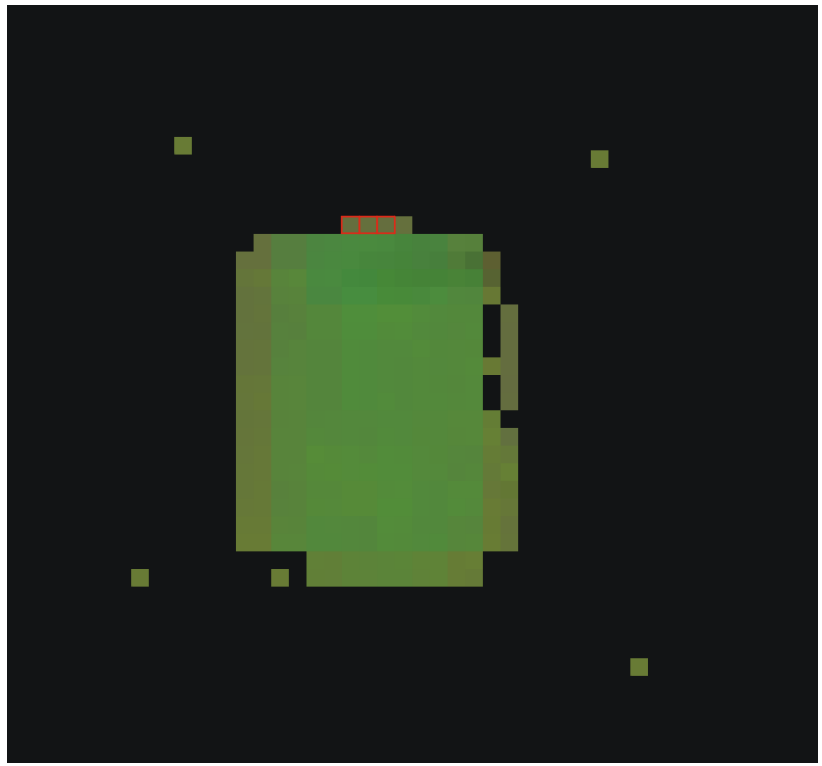
  - more than N_{arr} rows with N_{row} succesive pixels

3.3) Calculate Centre of Colour Blob



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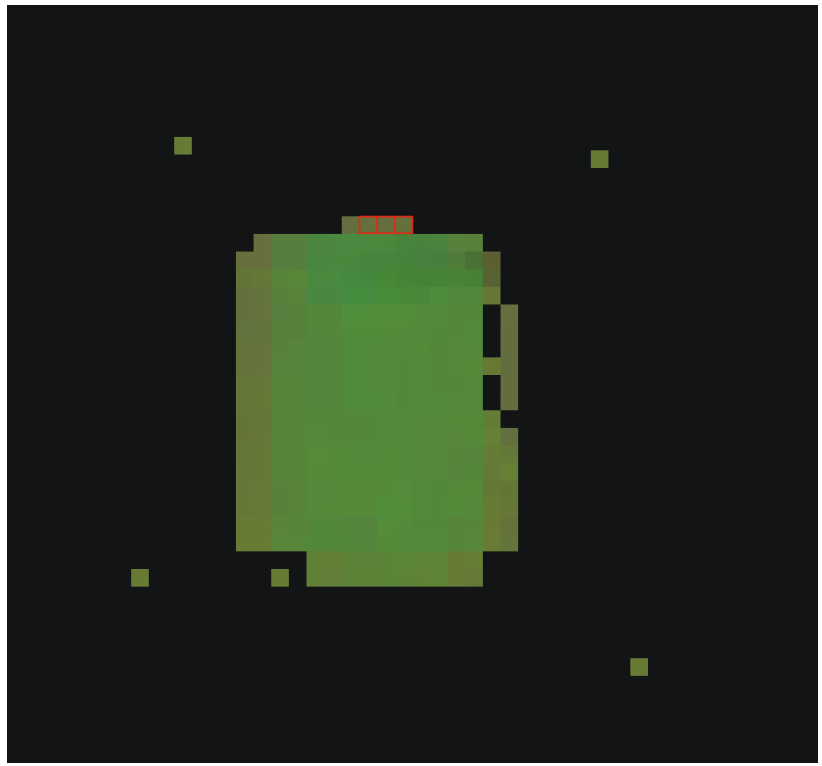

- verify blob quality:
  - more than N_{arr} rows with N_{row} succesive pixels

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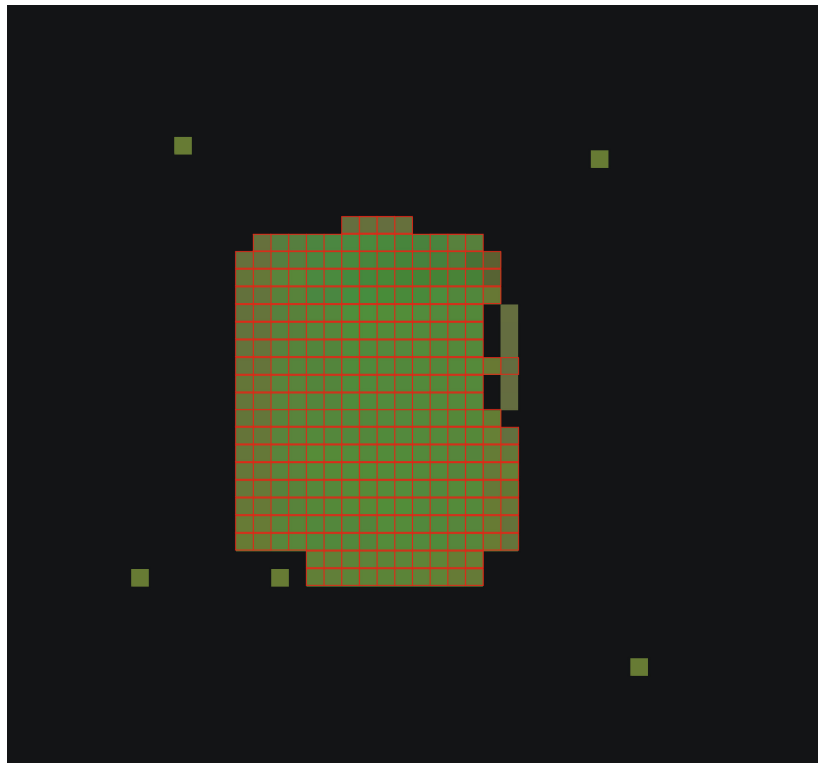
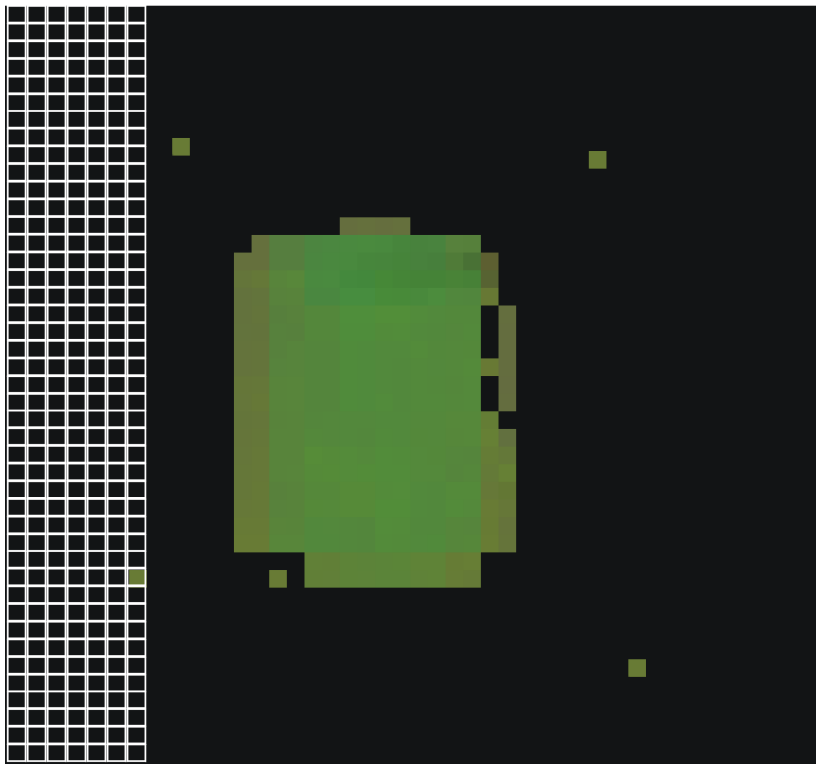


$n_{arr} = 269$

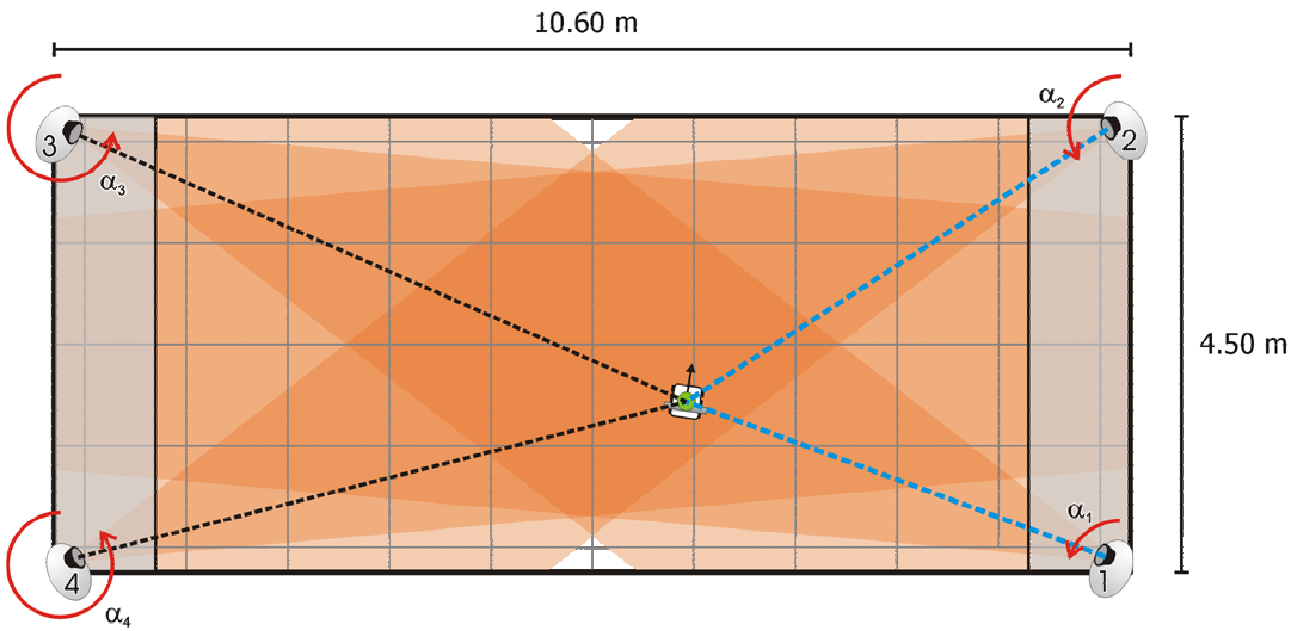
- verify blob quality:
  - more than N_{arr} rows with N_{row} succesive pixels

3.3) Calculate Centre of Colour Blob



- verify blob quality:
  - more than N_{void} empty columns (less than N_{col} pixels)

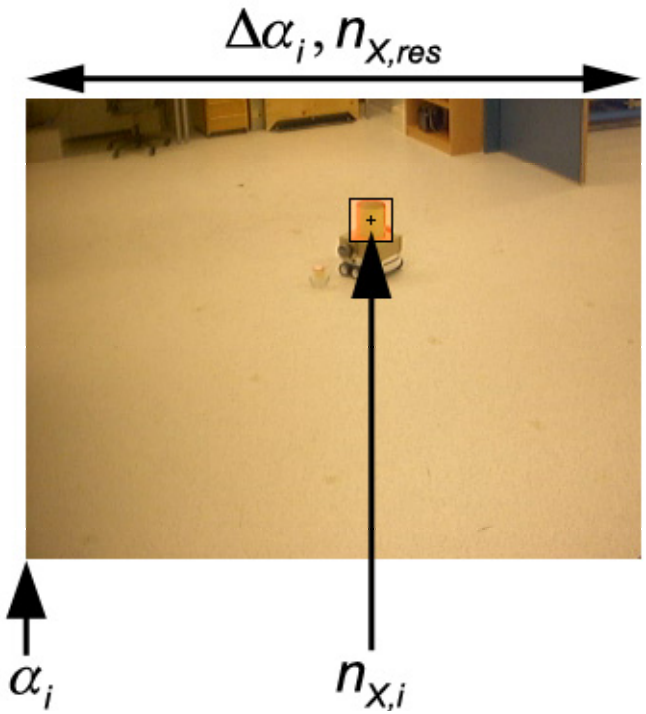
3.4) Calculating List of Position Estimates

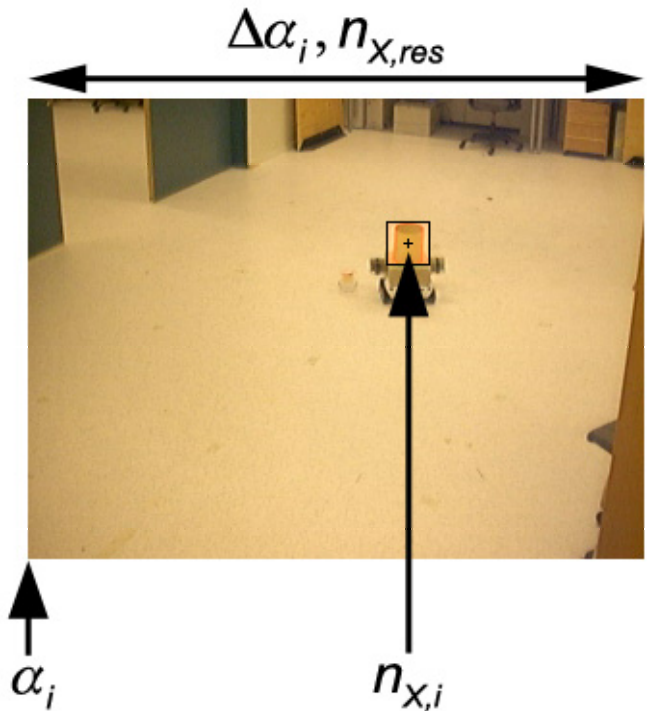


- calculate angles from centre pixels

$$\varphi_i = \alpha_i - n_{x,i} \frac{\Delta\alpha_i}{n_{x,res}}$$

3.4) Calculating List of Position Estimates





$$\varphi_i = \alpha_i - n_{X,i} \frac{\Delta\alpha_i}{n_{X,res}}$$

3.4) Calculating List of Position Estimates

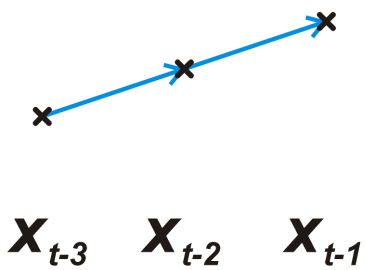
$$\text{if } \delta_{dir}(\varphi_i, \varphi_j) \geq \varphi_{min}$$

$$\vec{x}_{ij} = \frac{(C_i B_j - C_j B_i, A_i C_j - A_j C_i)}{A_i B_j - A_j B_i}$$

$$A_i = \sin(\varphi_i) \qquad B_i = -\cos(\varphi_i) \qquad C_i = A_i X_i + B_i Y_i$$

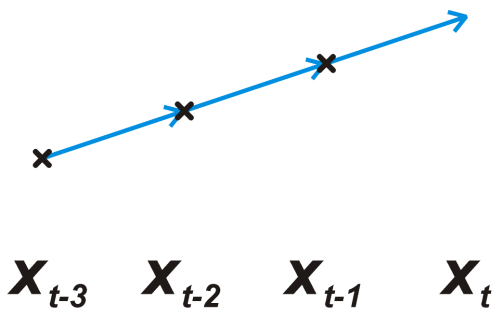
- calculate by triangulation
  - if angles differ sufficiently

3.5) Calculating the Overall Estimate



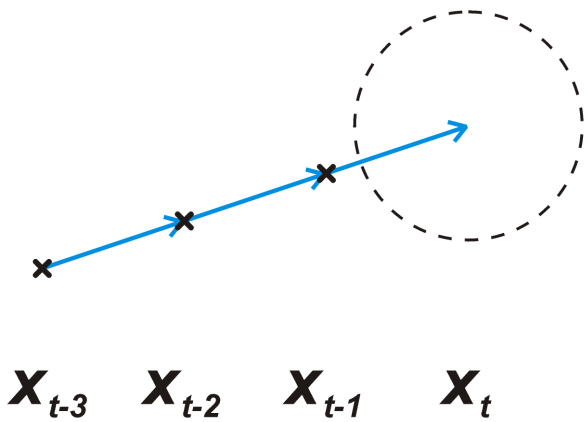
- use last valid estimates to propagate position

3.5) Calculating the Overall Estimate



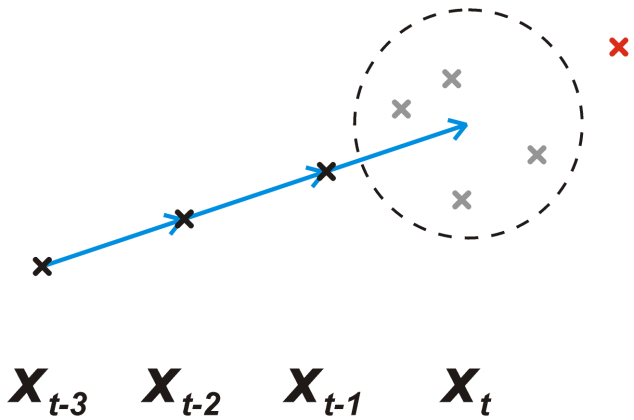
- circle around estimated new position

3.5) Calculating the Overall Estimate



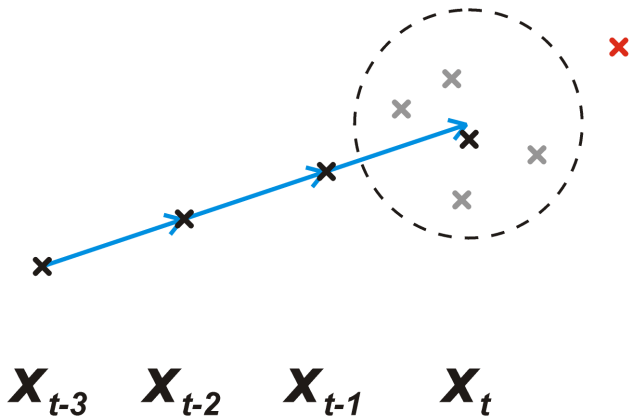
- grow circle with $v_{max}\,(t - t_{last})$

3.5) Calculating the Overall Estimate



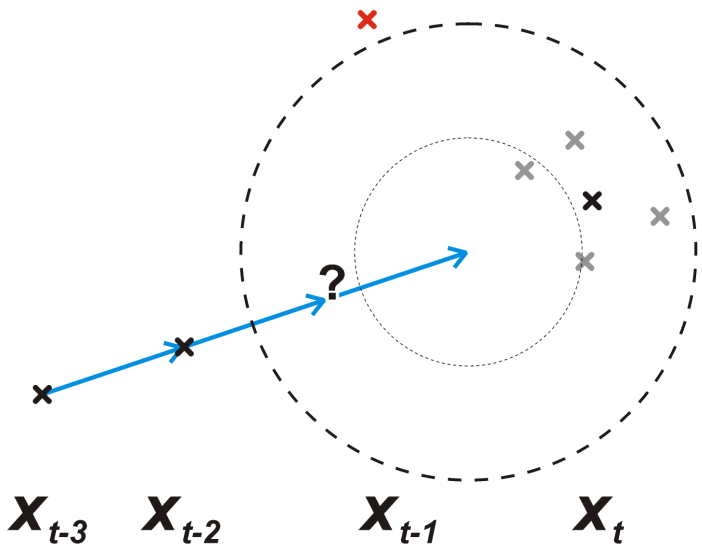
- use only triangulation estimates inside

3.5) Calculating the Overall Estimate



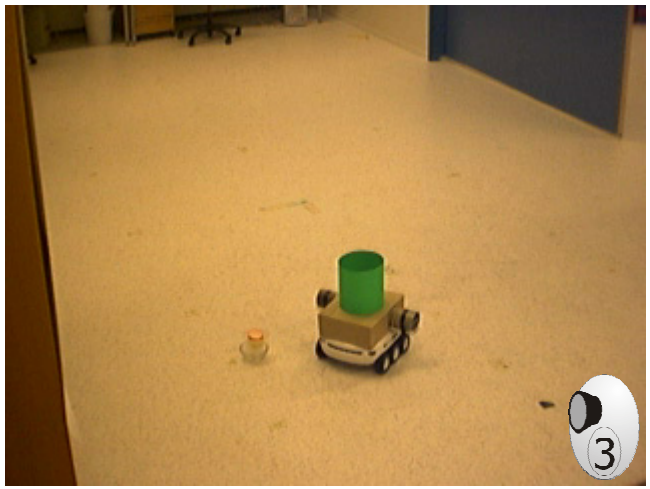
- average over all estimates

3.5) Calculating the Overall Estimate

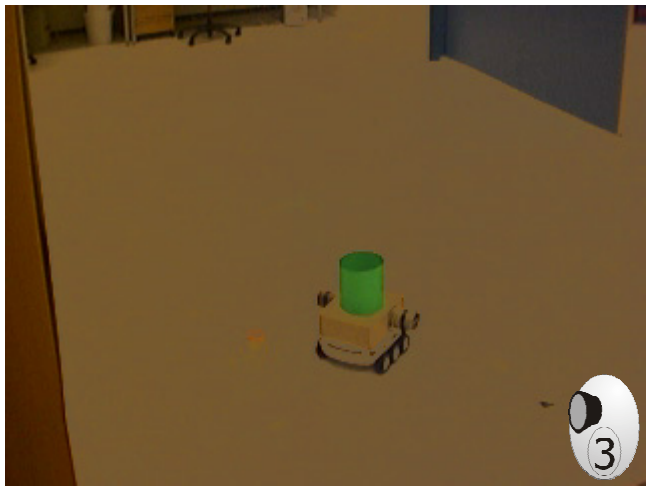


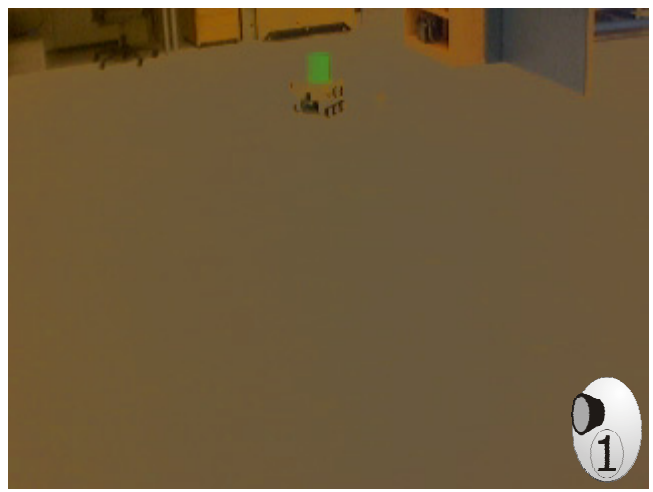
- use time since last valid estimate

3.6) Example

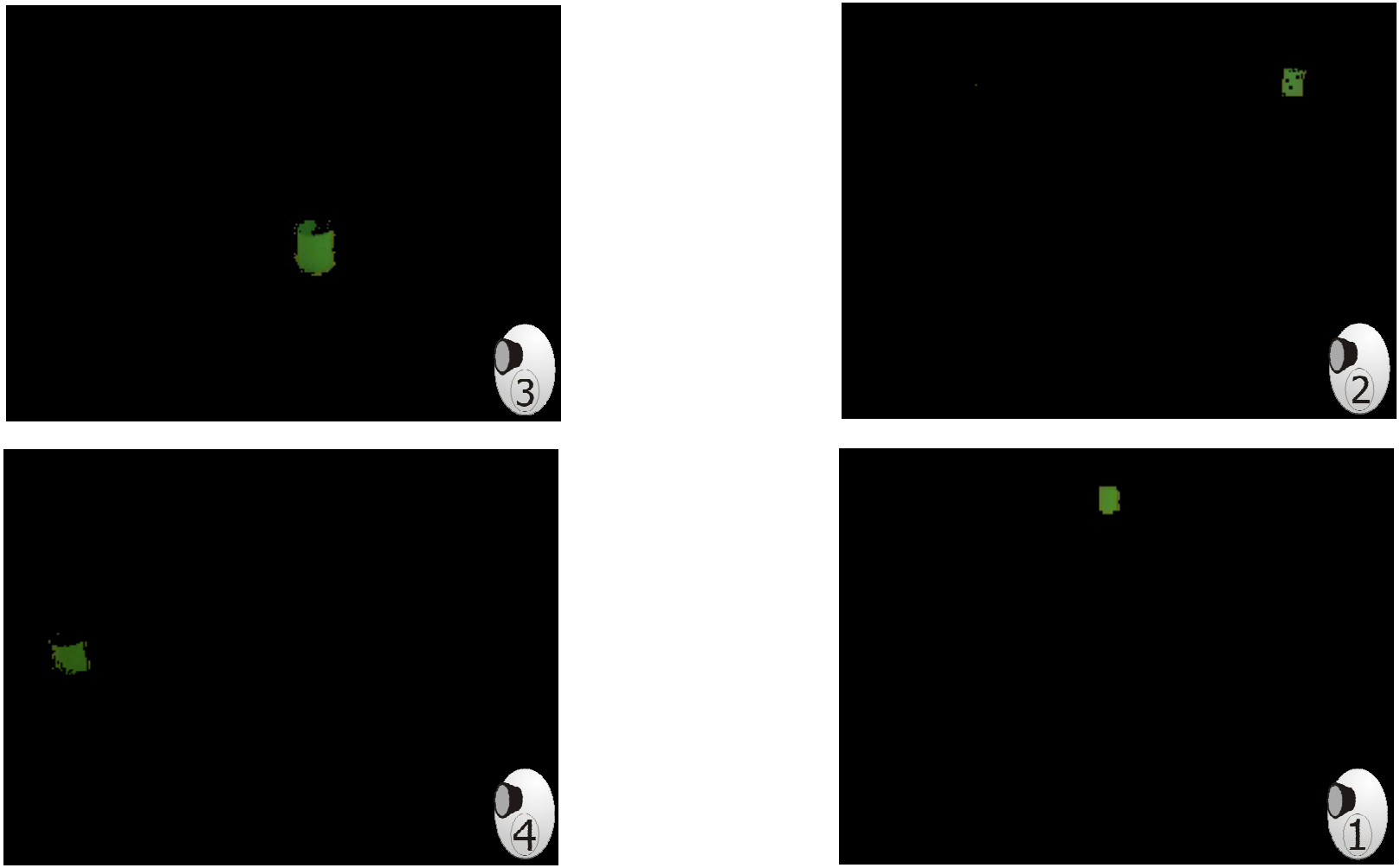


3.6) Example

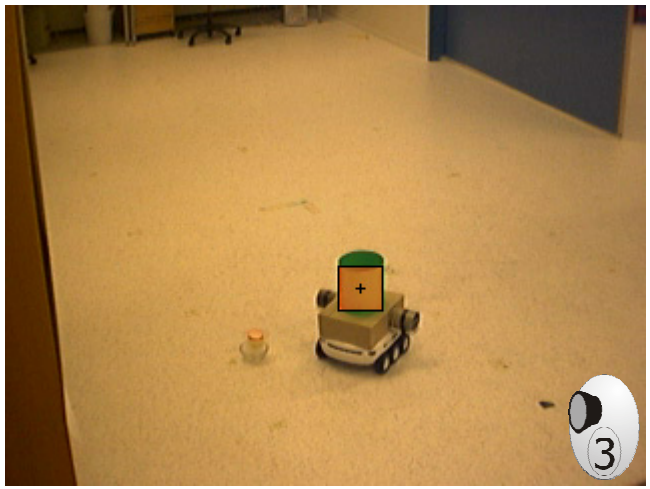


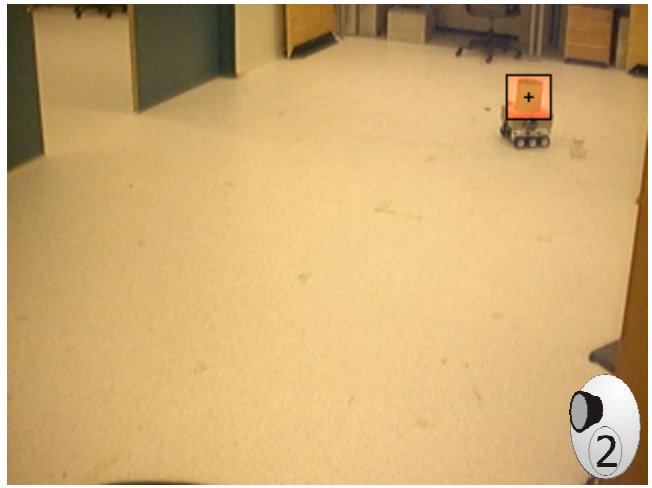


3.6) Example

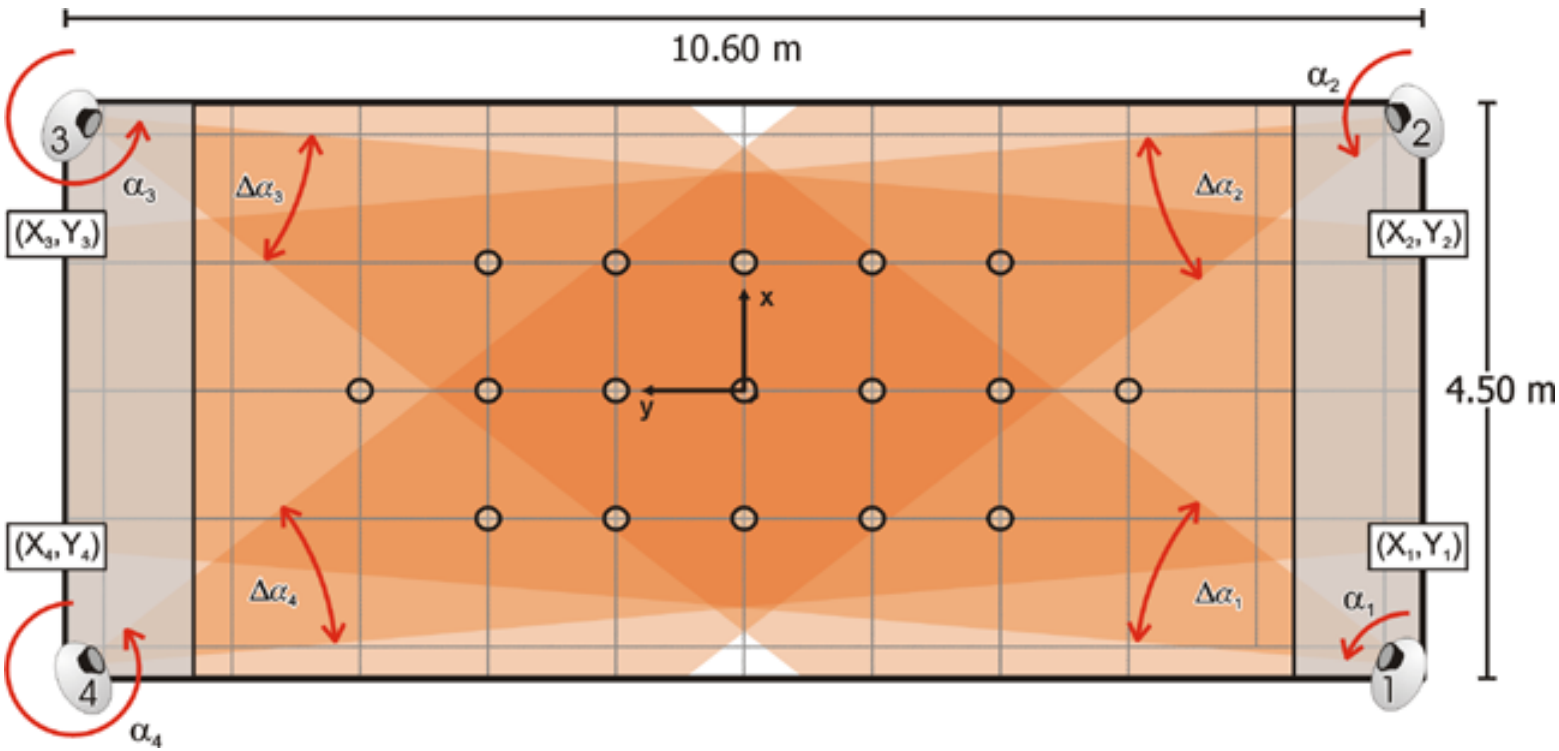


3.6) Example



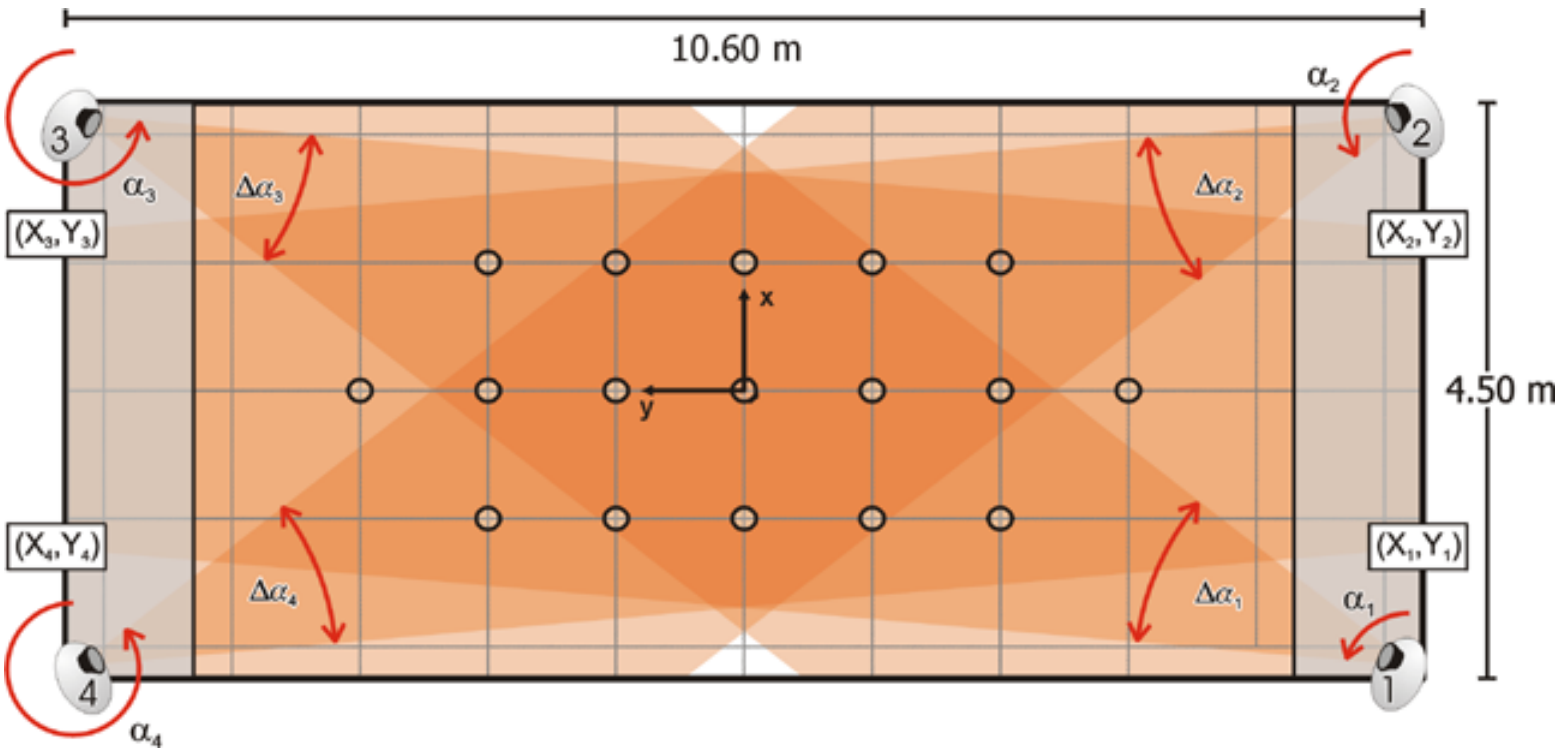


4) Calibration



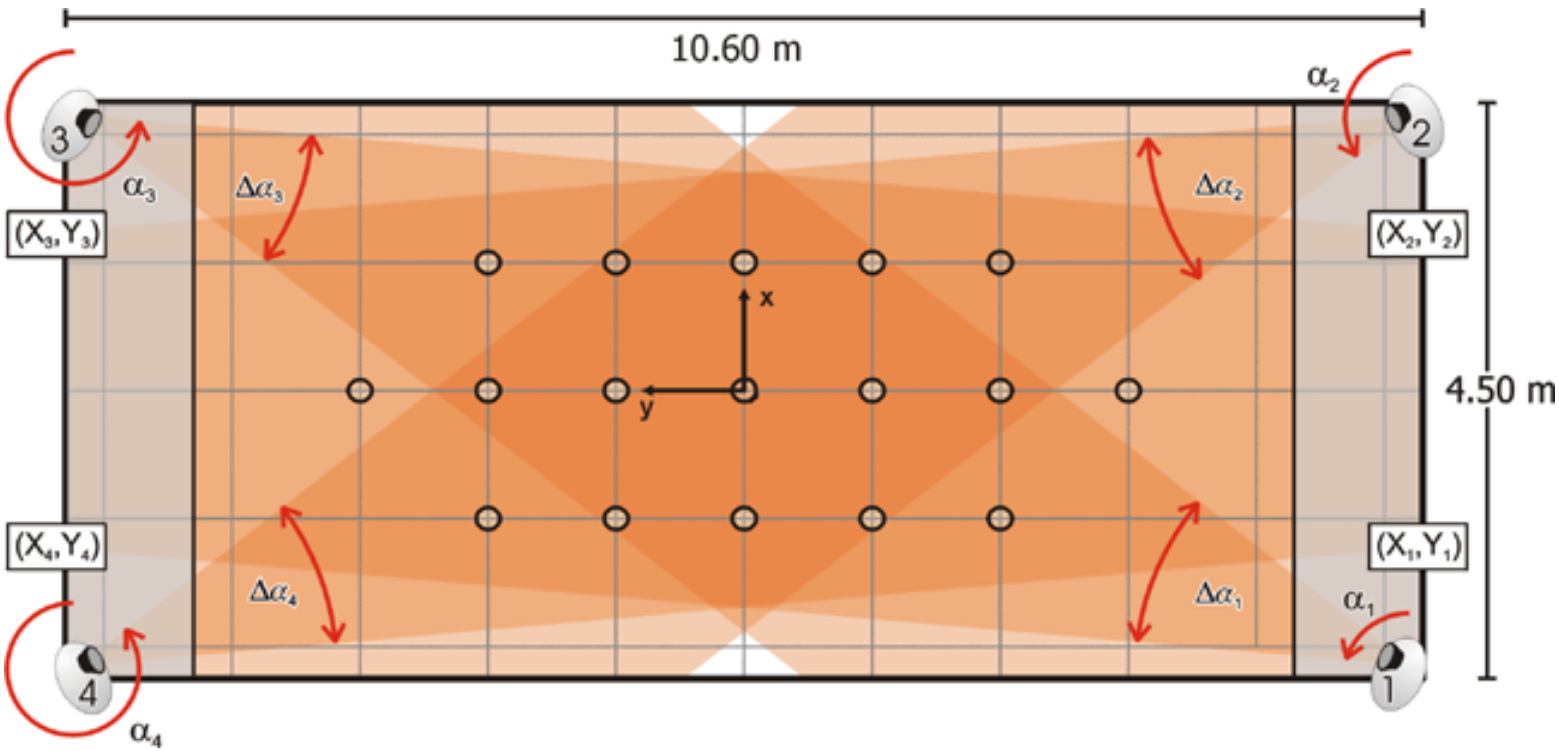
- minimise average distance to calibration points

4) Calibration



- consider also the angular range of the cameras!

4) Calibration

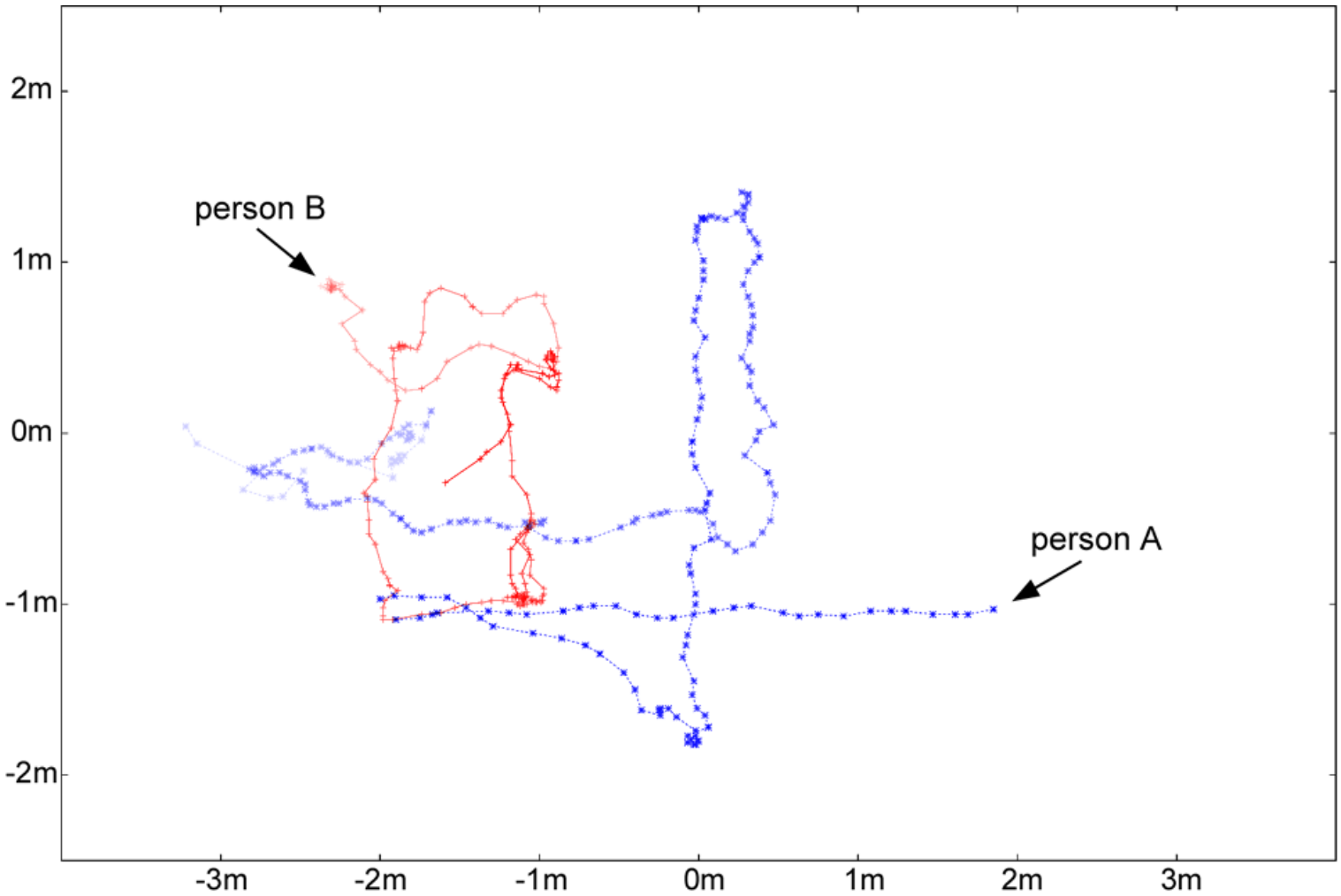


- average distance < 1cm

5) Example Applications - Person Tracking

- person tracking (inauguration)
  - tracking 2 hats
  - high v_{max}

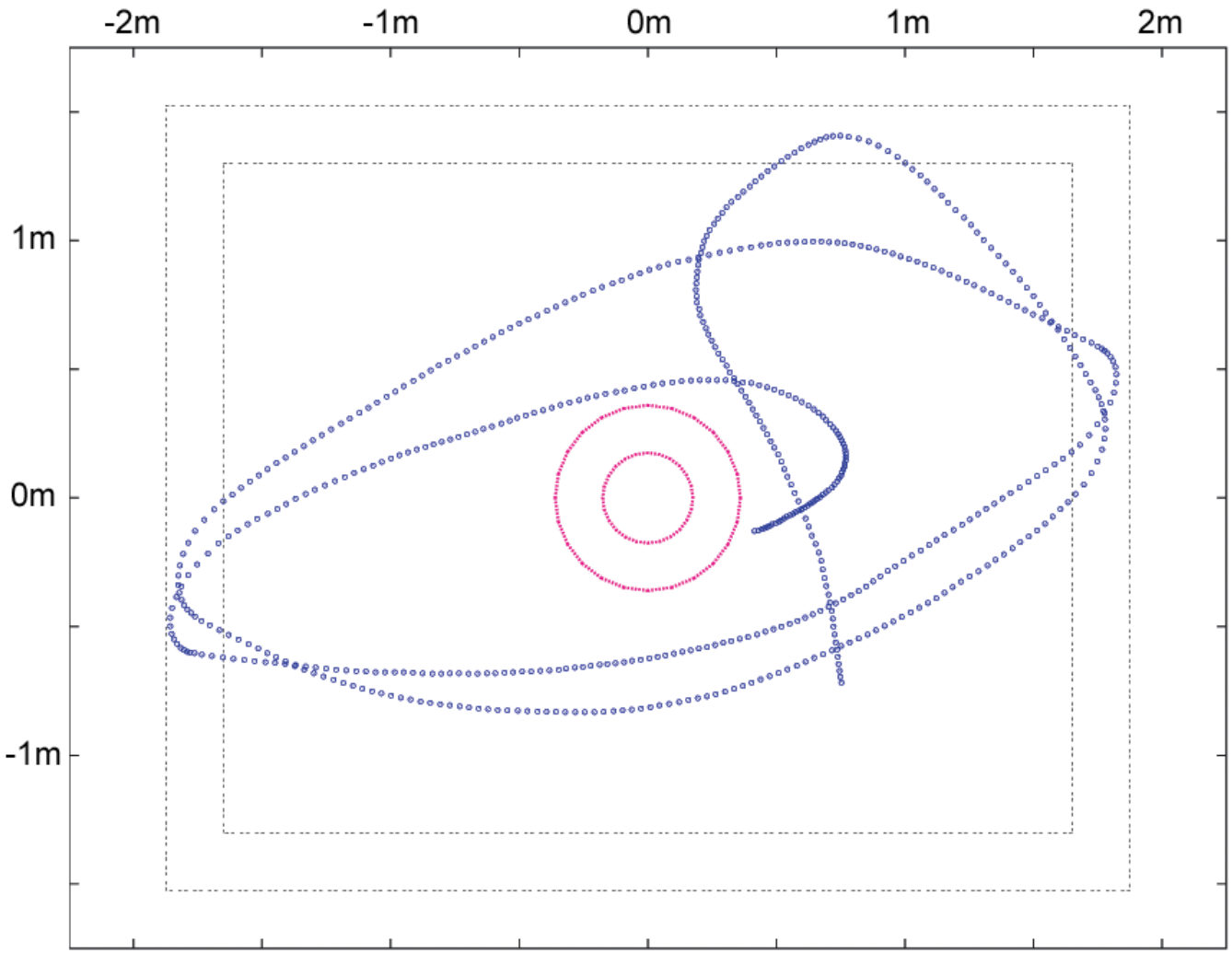
5) Example Applications - Person Tracking



5) Example Applications - Robot Tracking

- robot tracking
  - limited v_{max}
  - fusing odometry information
  - estimation of heading possible

5) Example Applications - Robot Tracking



6) Conclusions

- W-CAPS was used in several experiments
  - providing training data for person tracking [CieDuc03]
  - gas source localisation [LilDuc03]
  - gas concentration mapping [LilDuc03]
  - adaption for the TeamSweden
- Future Work ?
  - introduce weighted average of triangulation estimates
  - add heading determination

Thank you!

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