W-CAPS – An Absolute Positioning System for 100 Euros

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1) Introduction

- **Web-Camera-Based Absolute Positioning System**
  - 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: $320 \times 240$ pixel
- the coloured object
  - green/blue hat made of cardboard
- standard PC
- USB connectors
- stable support

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3) Determining 2D Positions

- $N = 4$ web-cameras
3.1) Luminance Adjustment

normalise \((r, g, b)\) value

\[
(r', g', b') = \begin{cases} 
255 \times \frac{(r, g, b)}{r + g + b} & \text{if } r + g + b \geq B_{\text{norm}} \\
(r, g, b) & \text{otherwise}
\end{cases}
\]
3.2) Use Contiguous rgb-Colour-Range

- consider pixels within contiguous colour range

\[(r', g', b') \in [(r_{\text{min}}, g_{\text{min}}, b_{\text{min}}), (r_{\text{max}}, g_{\text{max}}, b_{\text{max}})]\]
3.3) Calculate Centre of Colour Blob

- use median
- ensure centre's validity
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- verify blob quality:
  - more than $N_{arr}$ rows with $N_{row}$ successive pixels
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$n_{arr} = 269$
3.3) Calculate Centre of Colour Blob

- verify blob quality:
  - more than $N_{\text{void}}$ empty columns (less than $N_{\text{col}}$ pixels)
3.4) Calculating List of Position Estimates

- calculate angles from centre pixels

\[
\varphi_i = \alpha_i - n_{X,i} \frac{\Delta \alpha_i}{n_{X,\text{res}}}
\]
3.4) Calculating List of Position Estimates

\[ \varphi_i = \alpha_i - n_{X,i} \]

\[ \frac{\Delta \alpha_i}{n_{X,\text{res}}} \]
3.4) Calculating List of Position Estimates

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

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

\[ A_i = \sin (\varphi_i) \quad B_i = -\cos (\varphi_i) \quad C_i = A_i X_i + B_i Y_i \]

- 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 $v_{\text{max}} (t - t_{\text{last}})$
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
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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 $v_{\text{max}}$
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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