Augmented Reality

Marker-based Tracking

Seminar Verteilte System

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Tracking Overview

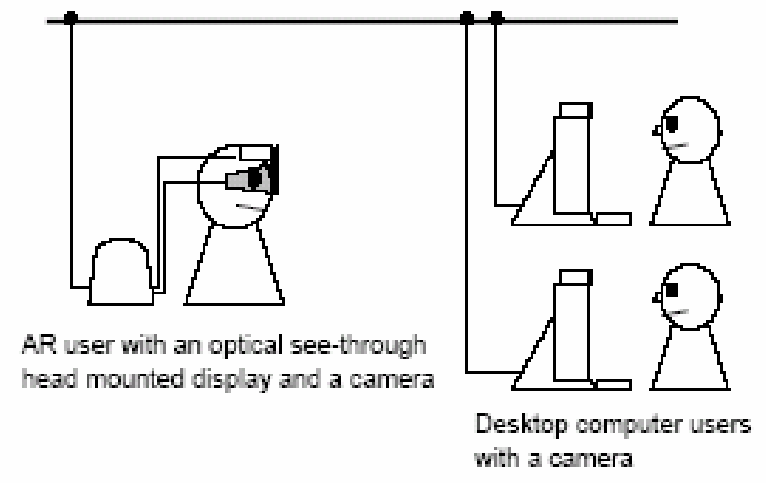
- What ist Tracking in AR?

  Localization of the position and orientation of real physical objects.

Tracking Variations

- acoustic
- magnetic
- optical
- mechanical
- hybrid

Kato / Billinghurst

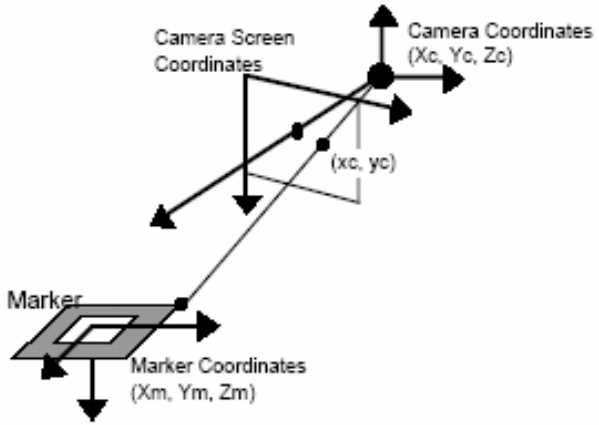


Marker position estimation

- transformation matrix (T_{cm}) estimated by image analysis
- V rotation component
- W translation component
- recalculation of T_{cm} after moving the head

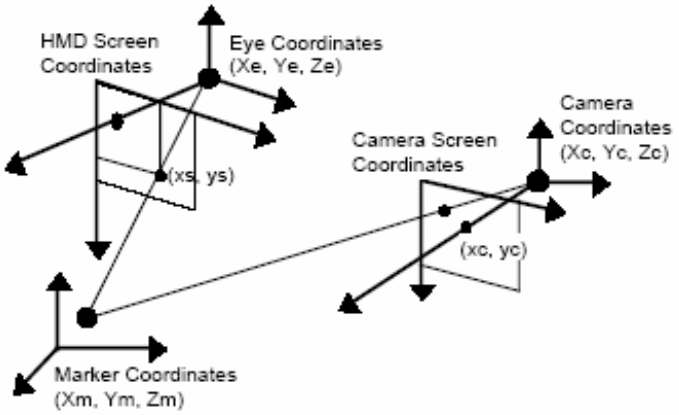
$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} V_{11} & V_{12} & V_{13} & W_x \\ V_{21} & V_{22} & V_{23} & W_y \\ V_{31} & V_{32} & V_{33} & W_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} \mathbf{V}_{3\times3} & \mathbf{W}_{3\times1} \\ 0 \;\; 0 \;\; 0 & 1 \end{bmatrix} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix} = \mathbf{T}_{cm} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix} \qquad \text{(eq. 1)}$$



Calibration

- Calibration of camera and HMD screen
- use of cardbord frame with a ruled grid to obtain pairs of points for camera calibration
- HMD calibration with markers with specific distance to screen.



$$\begin{bmatrix} ix_s \\ iy_s \\ i \\ 1 \end{bmatrix} = Q_{se} \begin{bmatrix} X_e \\ Y_e \\ Z_e \\ 1 \end{bmatrix} = Q_{se}T_{ec} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = Q_{se}T_{ec}T_{cm} \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix}$$

Q_{se}: Perspective Transformation Matrix

T_{ec}: Rotation and translation matrix

Accuracy of Marker Detection

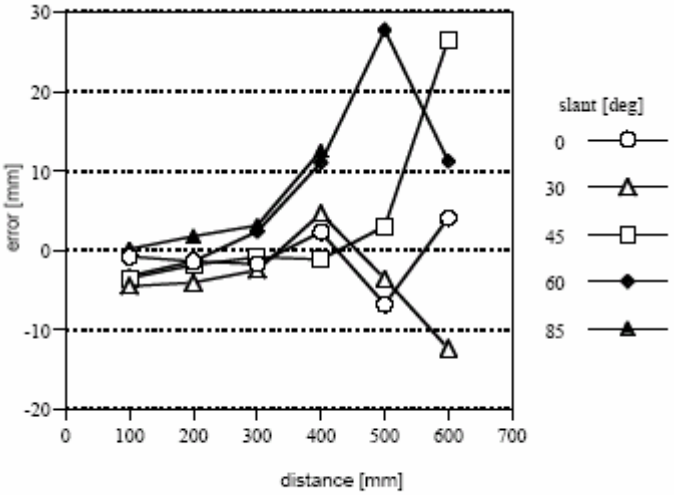


Figure 10. Errors of position.

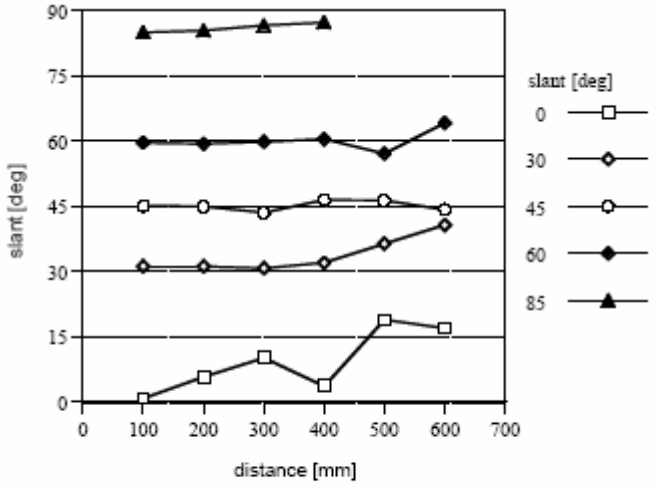


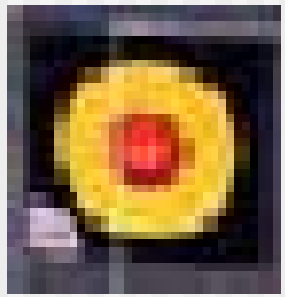
Figure 11. Detected slant.

Overwiev

- Tracking Overview (done)
- Maths of Tracking (done)
- What‘s the best Marker?
- Towards AR with mobile devices

Criteria for a good marker

- Not favor some orientations
- Easy to locate and identify
- must function over wide camera capture range
- must be a member of a set of images that are unlikely to be confused
- Easy to determine position and orientation



Creating a good marker

- What is a good shape?
- What colors should be used?
- How should a specific marker be identified?
- How should a marker be located in an image?

Creating a good marker (2)

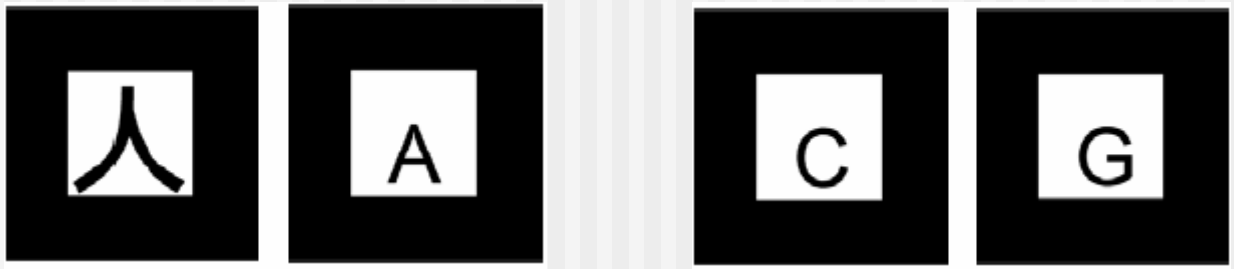
- Shape
  - 4 points for 6 DOF
  - Square
- Color -> monochrochme
  - faster to compute
  - better contrast to surrounding
  - color depends on light
- Locating the marker
  - black border
  - white background

Image identification

- Mathematical comparison between candidate image (I) and pattern (P)

$$\rho = \frac{\sum_x \sum_y (I(x,y) - \mu_I)(P(x,y) - \mu_P)}{\sigma_I \sigma_P}$$

$$\mu_I = \frac{1}{xy} \sum_x \sum_y I(x,y) \qquad \sigma_I = \sqrt{(\sum_x \sum_y (I(x,y) - \mu_I)^2)}$$

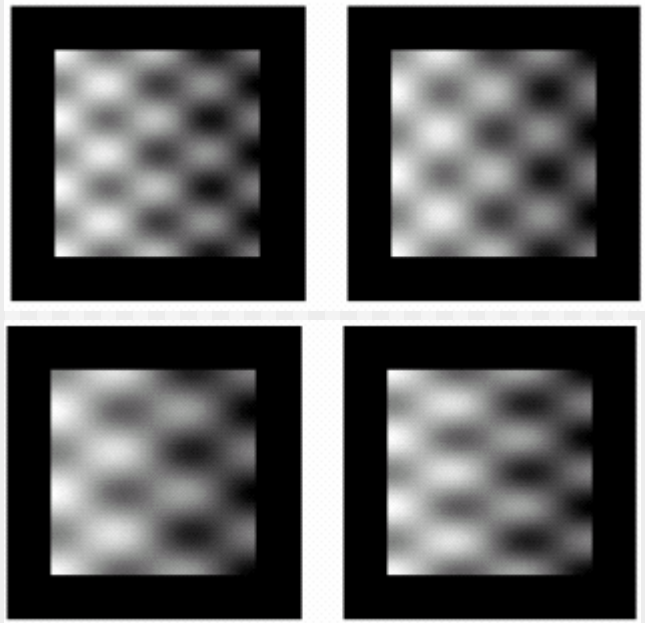


Conclusion

- Square Marker
- Black border / white background
- Border is 15 % of image
- Interior image:

$$I_{u,v}(x,y) = \frac{B_{u,v}(x,y) + B_{1,0}(x,y) + 2}{4}$$

$$B_{u,v}(x,y) = \cos\left(\frac{(2x+1)u\pi}{2N}\right)\cos\left(\frac{(2y+1)v\pi}{2N}\right)$$



Overwiev

- Tracking Overview (done)
- Maths of Tracking (done)
- What‘s the best Marker? (done)
- Towards AR with mobile devices

Traditional vs. PDA

Traditional

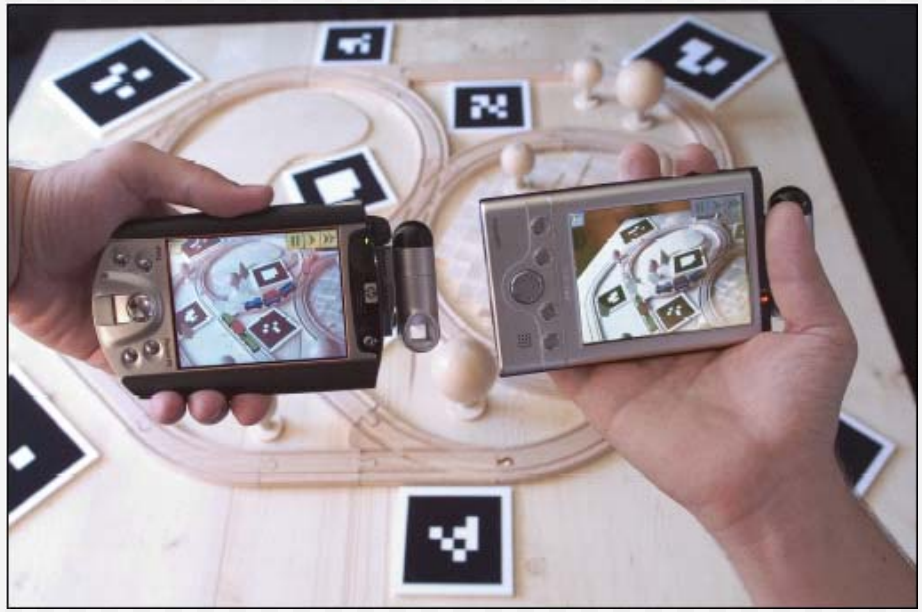
- full view
- hand free

PDA

- less energie consumption
- better portable
- user acceptance

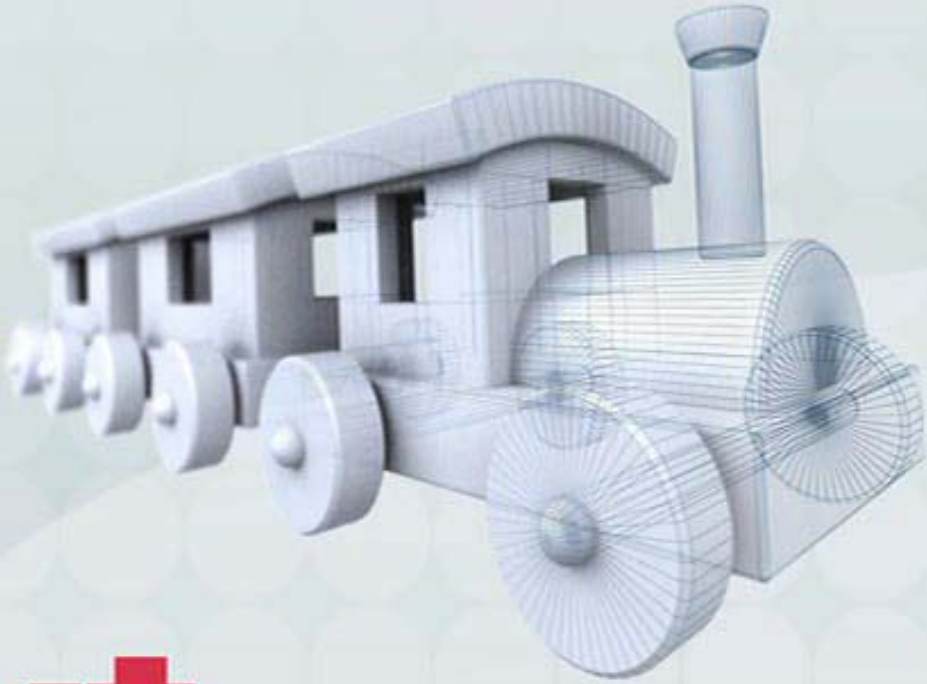
The Invisible Train

- Simple multiplayer game with virtual trains on physical tracks
- user can operate tracking switches and adjust train speed
- actions triggerd
- Tracking based on markers
- game was tested with about 6000 users.



the invisible train

a collaborative handheld augmented reality game



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Results form user tests

- Handheld devices better acceptet than traditional backpack setups.
- only little amount of hardware-failures
- little to no reservations toward the system
- Easy to use, even for people with no AR-experience
- only real problem with battery life time.

Summary

- a lot of application areas
- social acceptance
- some unsolved problems
  - tracking
  - registration
  - sensing

Questions

- Questions?

- Refernces
  - H. Kato, Mark Billinghurst, **Marker Tracking and HMD Calibration for a Video-based Augmented Reality Conferencing System.** Proceedings of the 2nd International Workshop on Augmented Reality (IWAR 99), San Francisco, USA, October 1999
  - Charles B. Owen, Fan Xiao, Paul Middlin, **What is the best fiducial?** The First IEEE International Augmented Reality Toolkit Workshop, pp. 98-105, Darmstadt, Germany, September 2002
  - Daniel Wagner, Thomas Pintaric, Florian Ledermann, Dieter Schmalstieg, **Towards Massively Multi-User Augmented Reality on Handheld Devices.** Third International Conference on Pervasive Computing (Pervasive 2005), Munich, Germany, May 2005