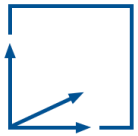
Augmented Reality and Industry

Prof. Gudrun Klinker, Ph.D.

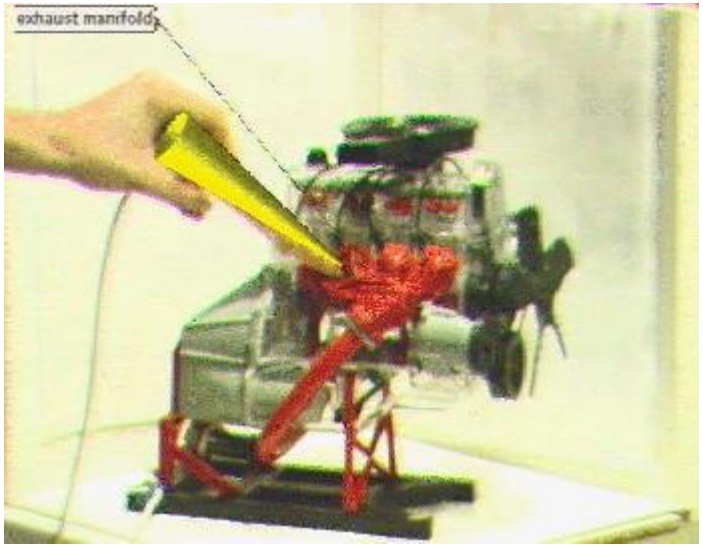


Sep 30, 2015

ISMAR 2015, Fukuoka, Japan

ECRC (European Computer-Industry Research Centre)

- ECRC: 1995
  - Siemens, Bull, ICL



G. Klinker, K. Ahlers, D. Breen, P.-Y. Chevalier, C. Crampton, D. Greer, A. Kramer, E. Rose, M. Tuceryan, R. Whitaker: **Confluence of Computer Vision and Interactive Graphics for Augmented Reality**. *PRESENCE - Teleoperators and Virtual Environments, Special Issue on Augmented Reality 6(4), 1997, pp. 433-451.*

ECRC

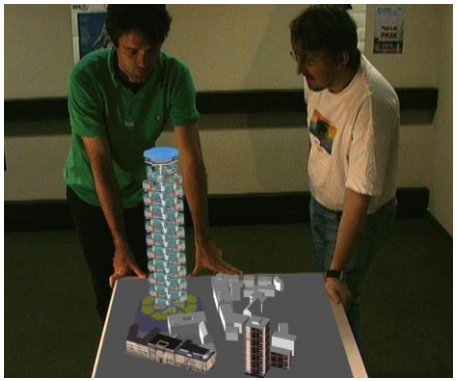
- Mostly magnetic tracking
- Starting work on optical tracking

D. Koller, G. Klinker, E. Rose, D. Breen, R. Whitaker, M. Tuceryan: **Real-time vision-based camera tracking for augmented reality applications.** *Proc. ACM Symp on Virtual Reality, Software and Technology (VRST'97), 1997, pp. 87-94*

CICC

Collaborative Integrated Communication in Construction)

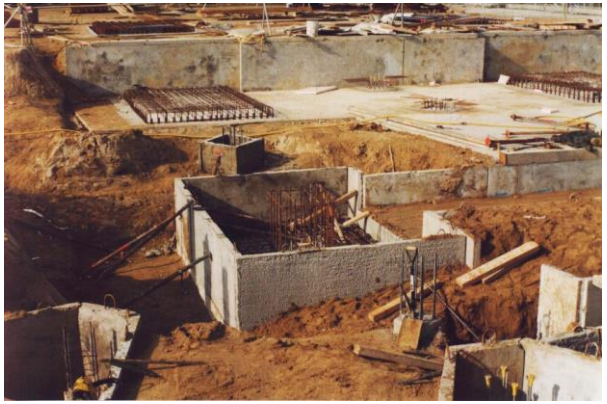
- EC-project, 1995-1998
- ECRC, FhG-IGD
  British and Spanish partners such as Ove Arup



G. Klinker, D. Stricker, D. Reiners: **Augmented Reality for Exterior Construction Applications.** *Augmented Reality and Wearable Computers, W..Barfield und T. Caudell, eds. Lawrence Erlbaum Press, 2001.*

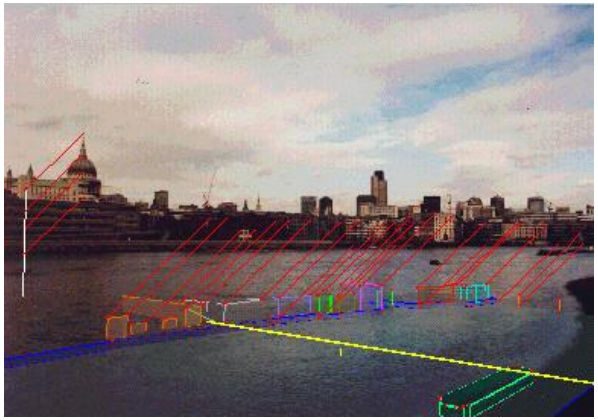
Theory meets reality

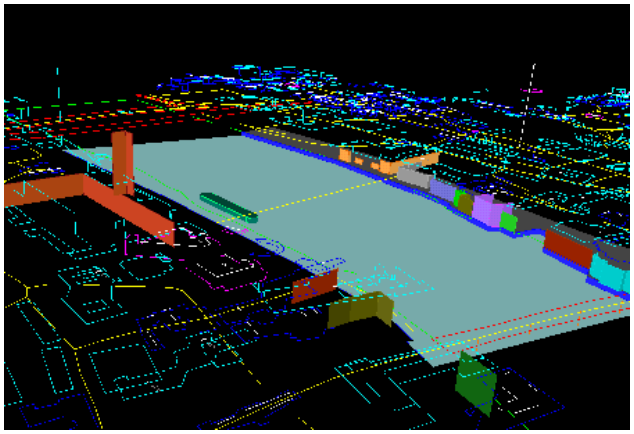
So: how you want to do AR here?



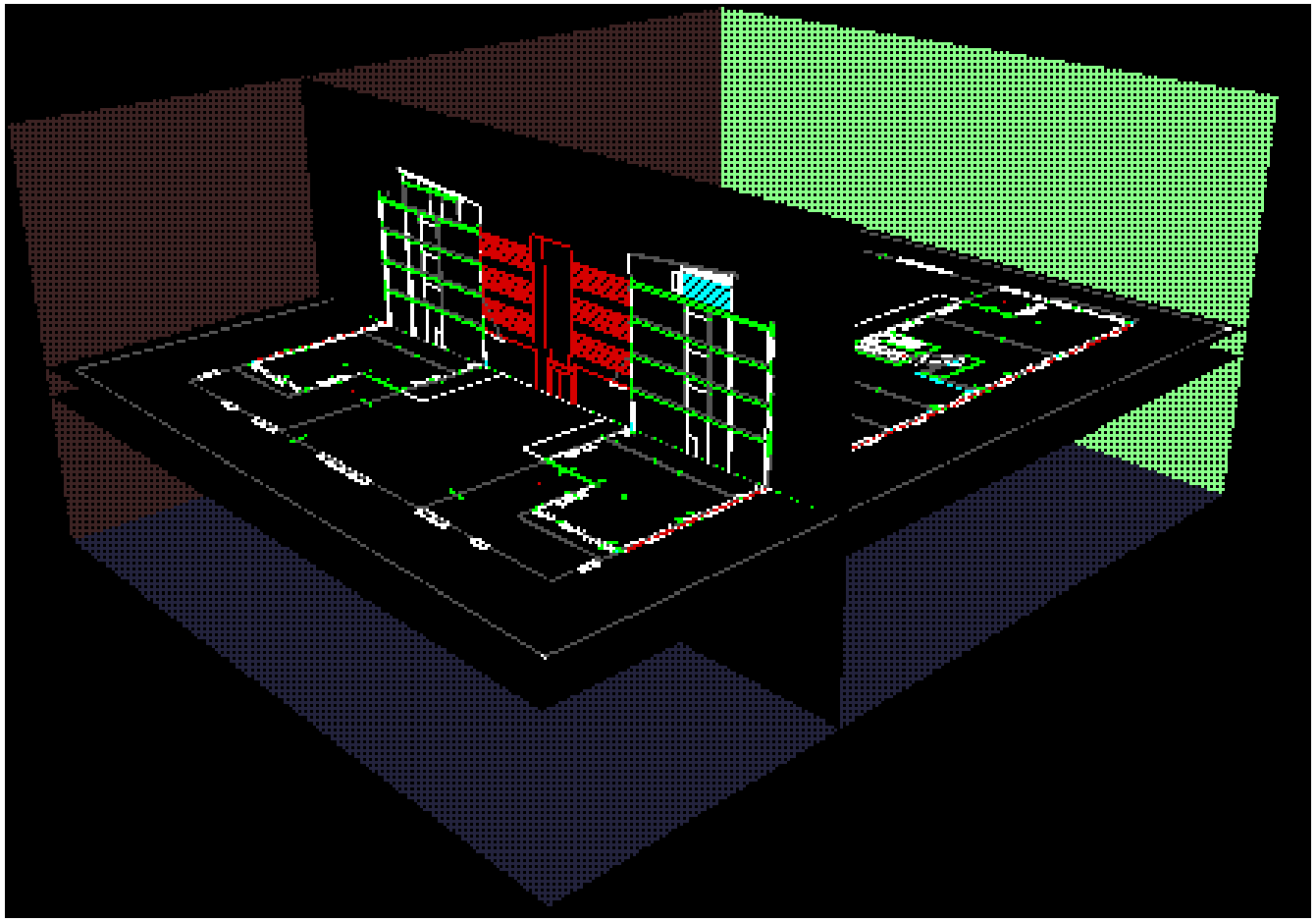
Reality Models and Diminished Reality





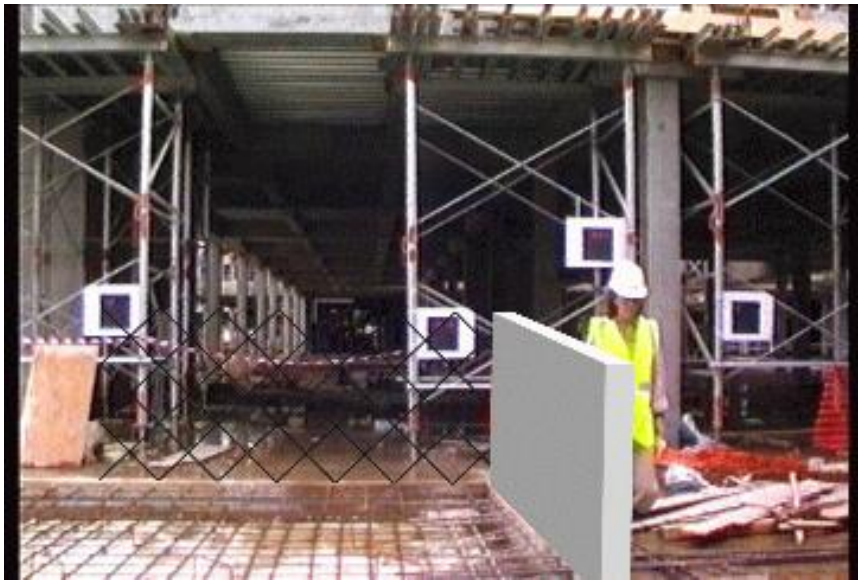



Virtual Models



CICC

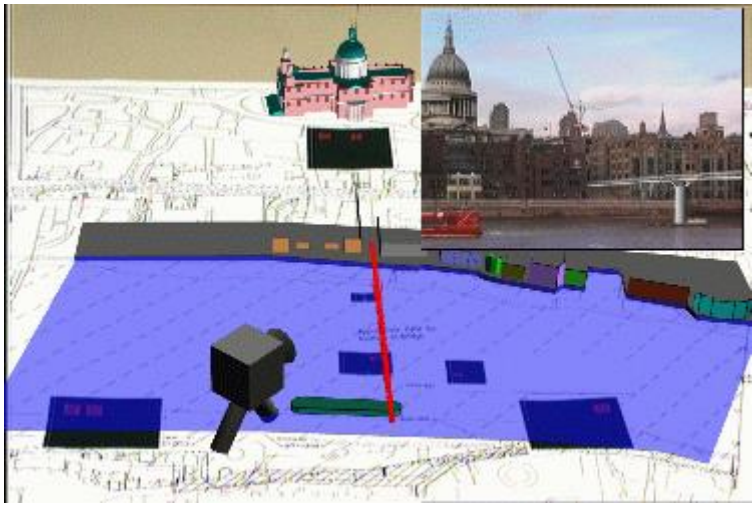
Marker-based tracking

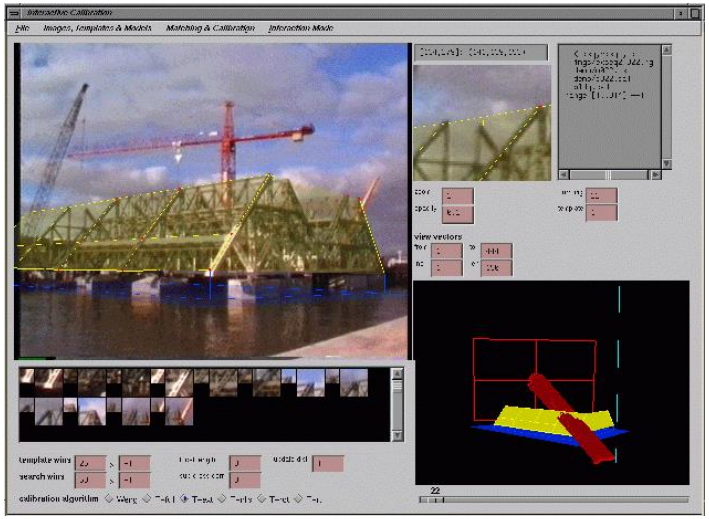


D. Stricker, G. Klinker, D. Reiners: **A Fast and Robust Line-based Optical Tracker for Augmented Reality Applications**. *Proc. 1rst International Workshop on Augmented Reality (IWAR'98), San Francisco, Nov. 1998, pp. 31-46.*
G. Klinker: **Augmented Reality: A problem in need of many computer vision-based solutions.** *NATO Advanced Research Workshop at the 8. International Conference on the Computer Analysis of Images and Patterns (CAIP-99), org. by A. Leonardis and R. Bajcsy. Ljubljana Slowenia, Aug. 29-31, 1999.*

CICC

Markerless tracking by interactive tools





CICC

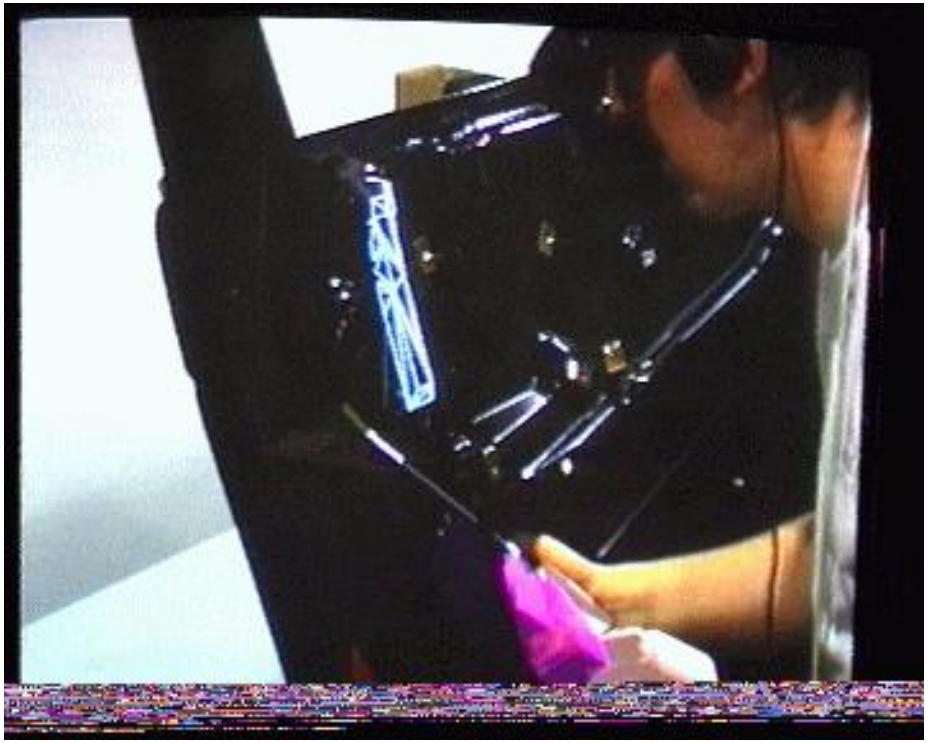
Lessons learned:

- Don‘t tell people responsible for real construction sites that you will equip all workers with an HMD!
- Real construction sites begin without any infrastructure: everything changes all the time
  - How many markers? Where?
- Not a unified work culture
- You need extremely robust, extensible markerless tracking!

- Ideally, you would work at a construction site before telling people how to apply AR

Doorlock Assembly

- FhG-IGD / ZGDV, 1997



D. Reiners, D. Stricker, G. Klinker, S. Mueller: **Augmented Reality for Construction Tasks: Doorlock Assembly**. *Proc. 1rst International Workshop on Augmented Reality (IWAR'98), San Francisco, Nov. 1998, pp. 31-46.*

Doorlock Assembly

- CAD-models for rendering and occlusion handling
- Real car door

- Marker-based tracking
- Calibrated OST-HMD

Doorlock Assembly

- Presented at the Hanover Fair 1997.
- Starting point of the German „AR-Industriekreis“

- BMBF Flagship projects:
  - ARVIKA (1999-2003)
    spinoffs: metaio, ART
  - ARTESAS (2004-2006)
  - AVILUS, AVILUS PLUS (2008-2011)
  - ARVIDA (2013-2016)

http://www.amazon.de/ARVIKA-Augmented-Reality-Entwicklung-Produktion/dp/3895782394

https://books.google.co.jp/books?isbn=3540765506

http://www.springer.com/gp/book/9783642206351

www.arvida.de

ARVIKA

Target-actual comparison

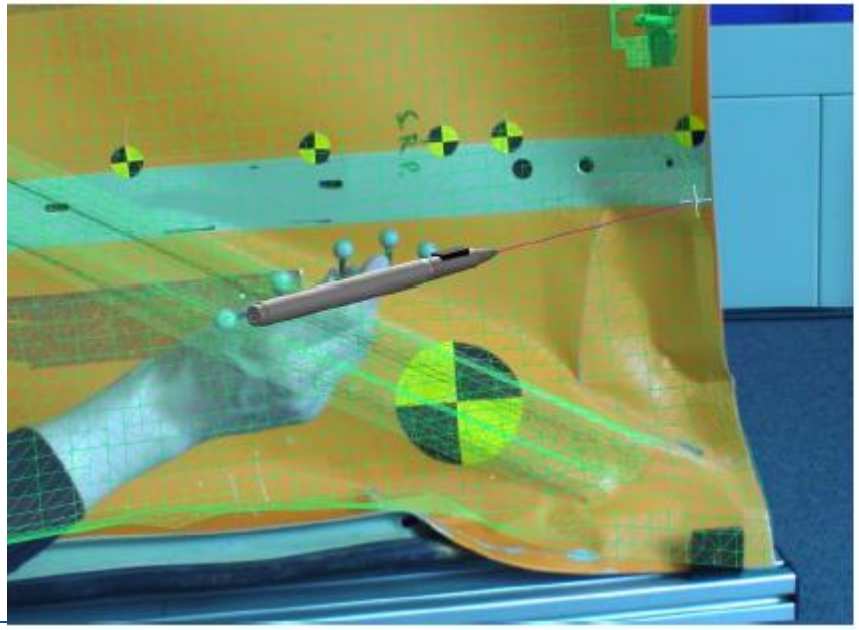
- Precision
- Crash tests

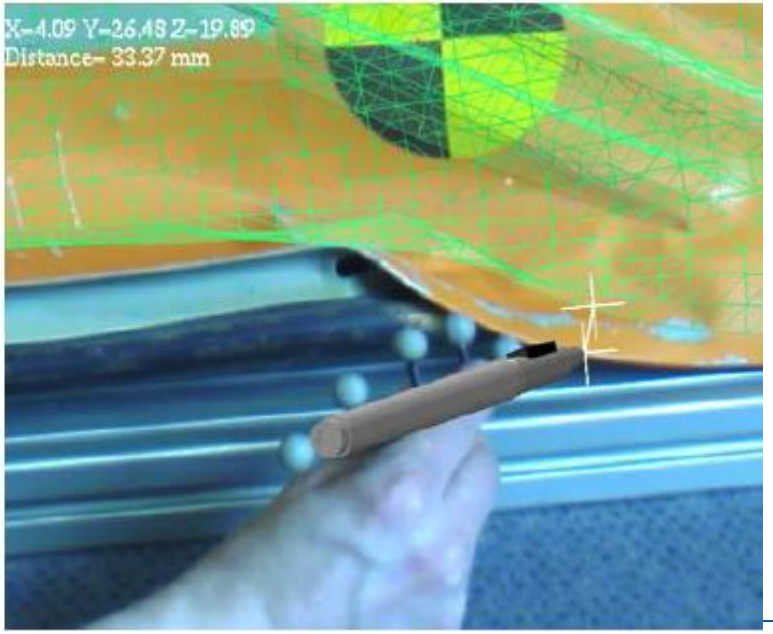
S. Nölle: *Augmented Reality als Vergleichswerkzeug am Beispiel der Automobilindustrie*. Dissertation, Technische Universität München, 2007.

ARVIKA

Measurements:

- Real vs. virtual





Doorlock Assembly / ARVIKA

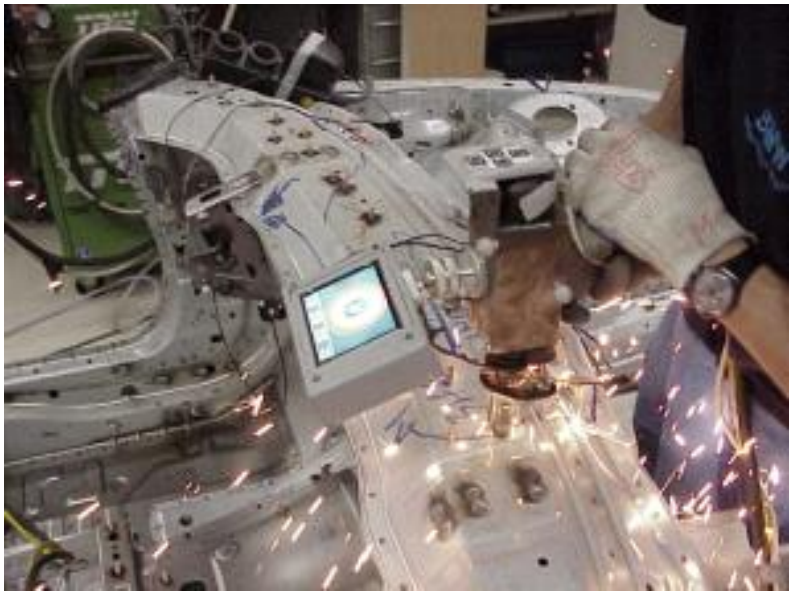
Issues learned:

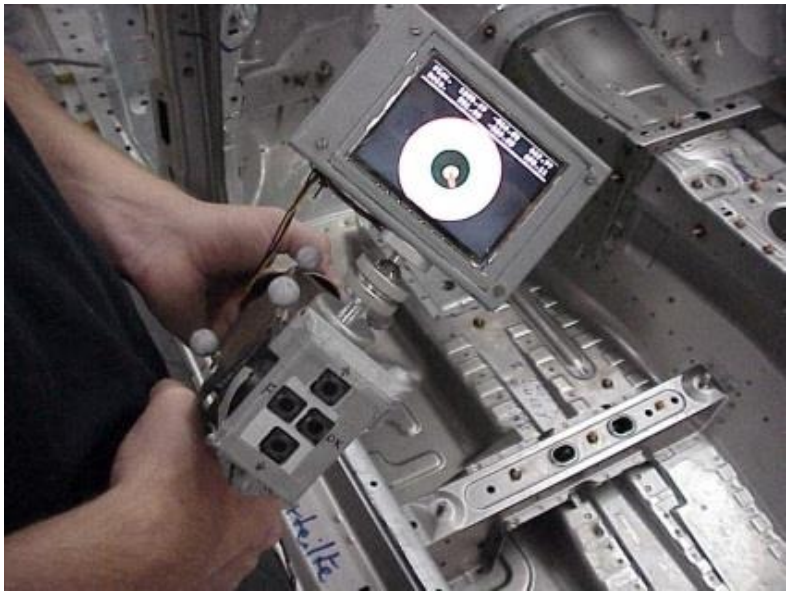
- How to introduce customers to new technology
  - have a convincing demo, on „customers‘ terms“
- How not to disappoint customers
  - Danger of overpromising / wishful thinking

- Proceed in small steps, iteratively

PAARTI: Intelligent Welding Gun

- BMW project, ARVIKA, 2001-2003
- TU Munich





Echtler, Sturm, Kindermann, Klinker, Stilla, Trilk and Najafi: *The Intelligent Welding Gun: Augmented Reality for Experimental Vehicle Construction*. In: Virtual and Augmented Reality Applications in Manufacturing (Ong and Nee, eds.), Springer Verlag, 2003.

PAARTI: Intelligent Welding Gun

Task

- Weld 300-500 studs to the car frame
- Max. 1mm error (position)
- 4 minutes/stud

Idea

- Use AR to help users see the stud positions on the frame

PAARTI: Intelligent Welding Gun

A problem in search of a solution

System design options

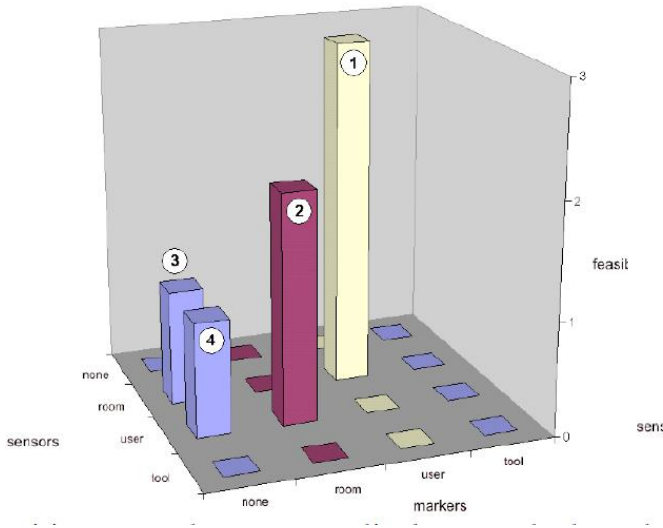
Involved devices/resources	Positions
• Display	• on the user (HMD)
• Sensors (cameras)	• on the tool (IWG)
• Markers	• on the object (Projector)
	• nowhere (marker-less)

In principle, $4^3 = 64$ potential solutions

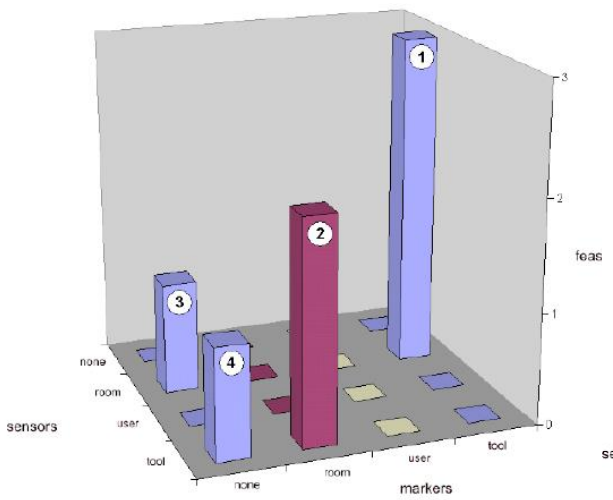
PAARTI: Intelligent Welding Gun

Solution space (focus on displays)

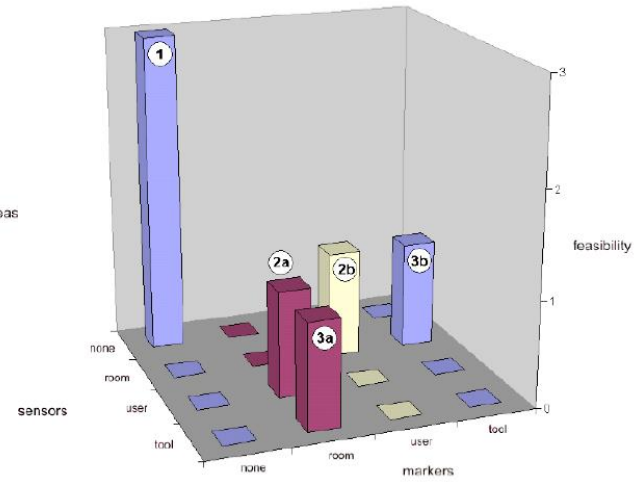
HMD



IWG

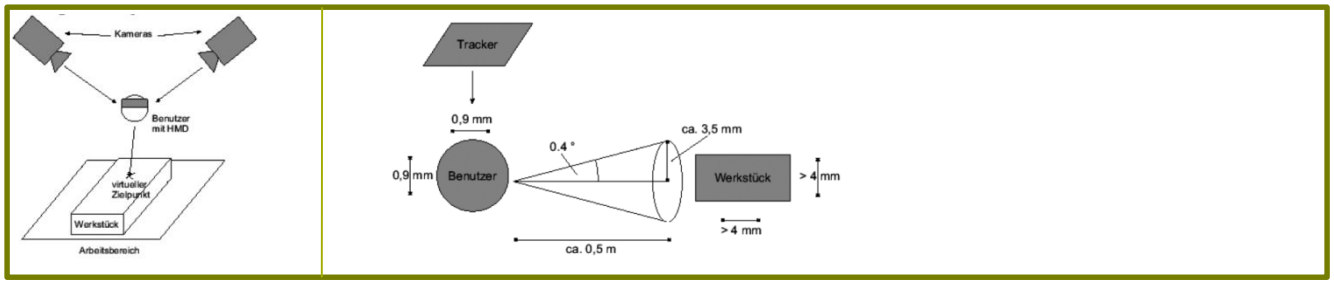


Projector

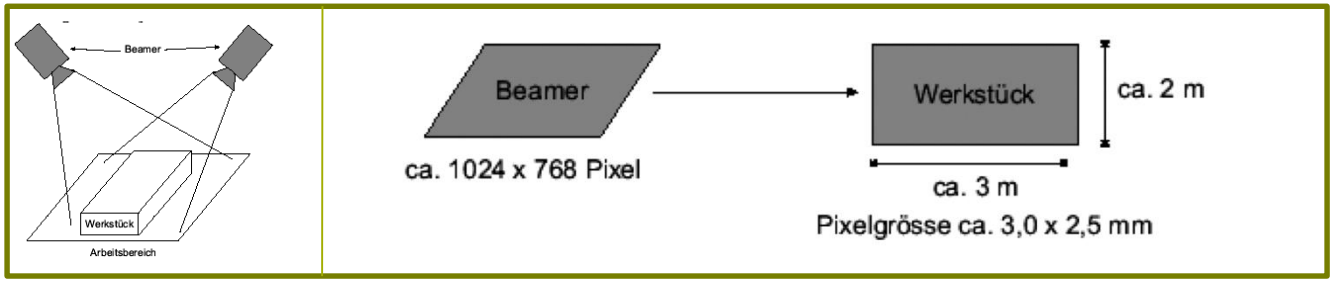


PAARTI: Intelligent Welding Gun

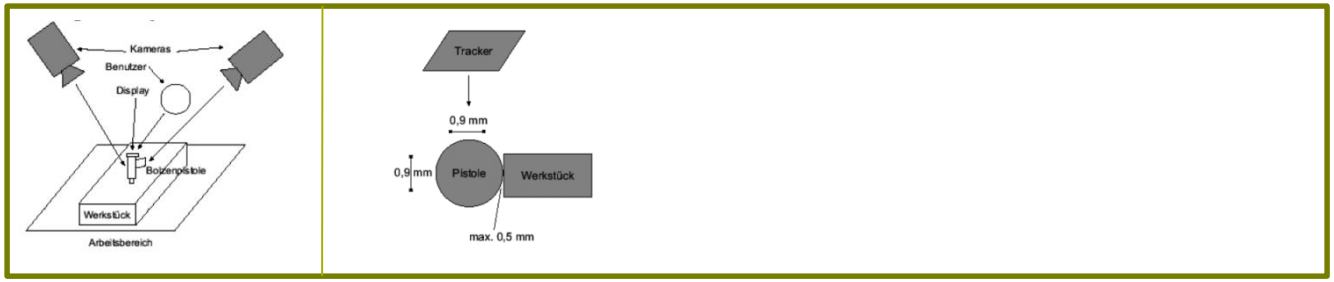
Setup, expected precision



HMD



Projector

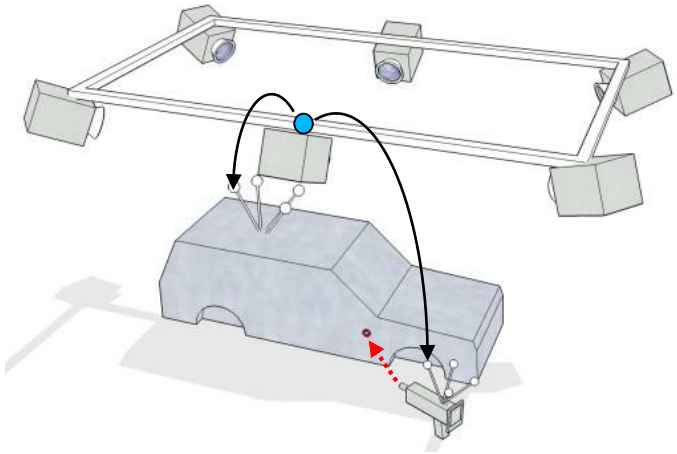


IWG

PAARTI: Intelligent Welding Gun

Solution: Intelligent Welding Gun (IWG)

- Apparatus
  - Outside-in tracking (6 cameras)
  - Stationary computer
  - (Tethered) mobile intelligent gun with display
- Process
  - Computer: Select welding point
  - Computer: 3D-presentation on the gun (notch and bead metaphor)
  - Human: Search and weld
  - Human: Press button on the gun to get the next welding point



4 minutes / stud → < 1 minute / stud

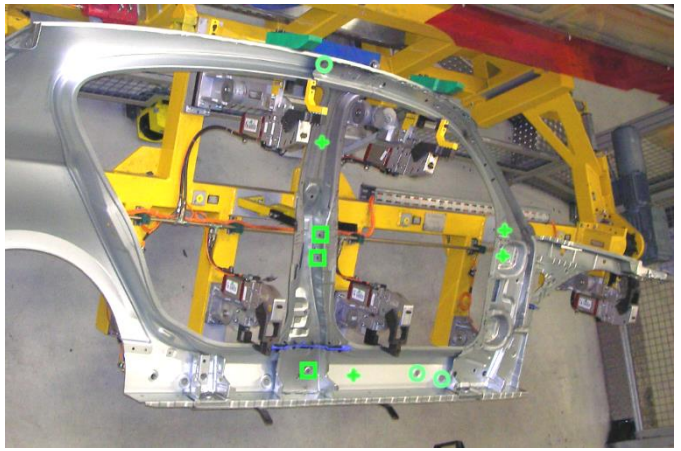
PAARTI: Intelligent Welding Gun

PAARTI: Intelligent Welding Gun

Further steps:

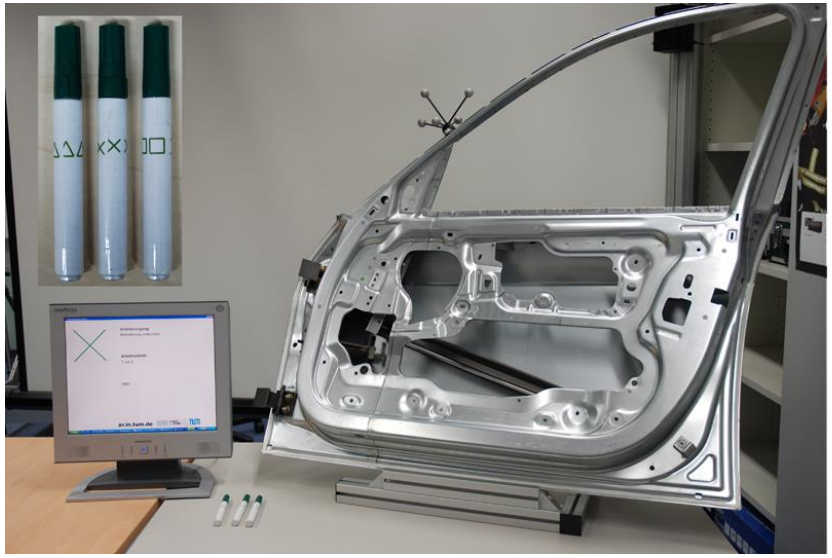
- Productization by
  BMW, ART, Tucker and viception
- Similar concepts installed at
  Volkswagen (by metaio)
  - Replace optical tracking with mechanical tracking
    (higher precision at the cost of reduced mobility)
  - Present information on a nearby display

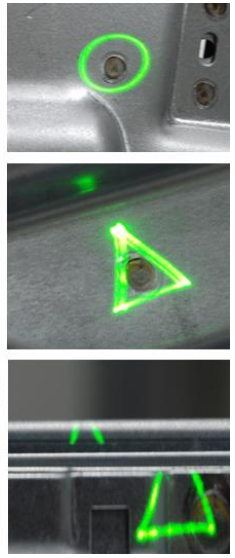
AR-Laser



Quality assurance

- BMW, 2006
- „What to do“ vs. „Where to do it“





B. Schwerdtfeger, D. Pustka, A. Hofhauser, G. Klinker: **Using Laser Projectors for Augmented Reality.** *15th ACM Symposium on Virtual Reality Software and Technology (VRST), Bordeaux, France, October 27-29, 2008, pp. 134-137*

PAARTI and AR-Laser

Lessons learned:

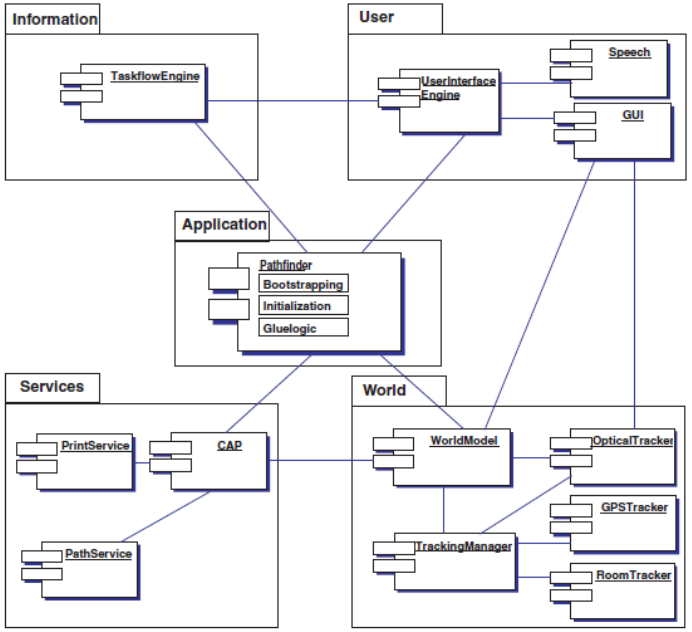
- A problem in search of a solution vs.
  A solution in search of a problem

- What is AR?
  Inclusive vs. Exclusive definition

DWARF

Distributed Wearable Augmented Reality Framework

- TUM, 2001 – 2005
- Flexible, reconfigurable framework
- Services declaring needs and abilities
- Automatic connection across computer network
- Ubiquitous AR



M. Bauer, B. Bruegge, G. Klinker, A. MacWilliams, T. Reicher, S. Riß, C. Sandor, M. Wagner: **Design of a Component-Based Augmented Reality Framework**. *Proceedings of The Second IEEE and ACM International Symposium on Augmented Reality (ISAR 2001), pp. 45-54*

DWARF

Sad lessons learned

- Industry is not always ready for radically innovative ideas
- Hang in there!

Steerable Simulation Environments

Sheep

- TUM, 2002
- Based on DWARF
  - ISMAR-Demo to illustrate the power of DWARF
- Ubiquitous Manipulation

MacWilliams, Sandor, Wagner, Bauer, Klinker, Brügge: *Herding Sheep: Live System Development for Distributed Augmented Reality*. ISMAR 2003.
Sandor, MacWilliams, Wagner, Bauer and Klinker: *SHEEP: The Shared Environment Entertainment Pasture.*. Demo at ISMAR 2002, Darmstadt.

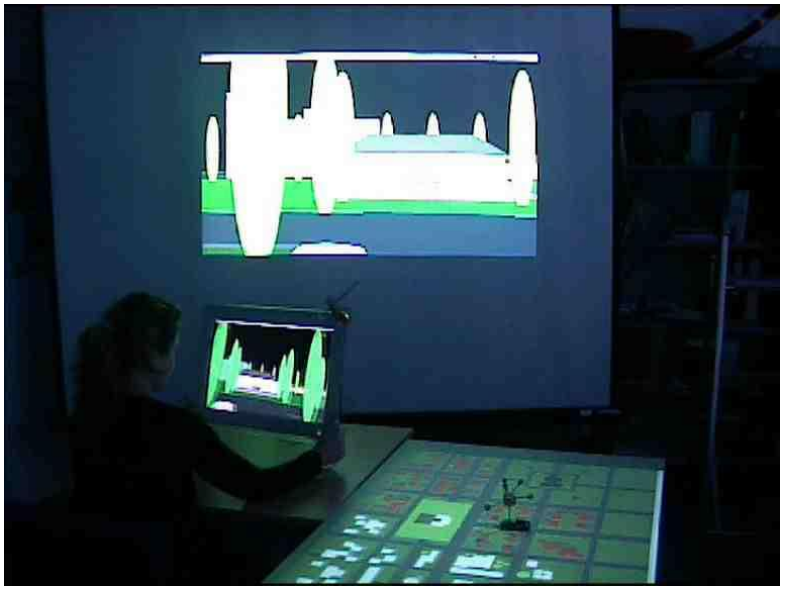
Steerable Simulation Environments

Sheep

Steerable Simulation Environments

Driving Simulators

- CAR
  - TUMMIC (BMW), 2005
  - A steerable alternative to
    - Real test drives
    - Standard driving simulators



Sandor and Klinker*: Lessons Learned in Designing Ubiquitous Augmented Reality User Interfaces.* In: Emerging Technologies of Augmented Reality. Interfaces & Design, (Haller, Billinghurst, Thomas, eds.), Idea Group Inc Publishers., 2006.

Steerable Simulation Environments

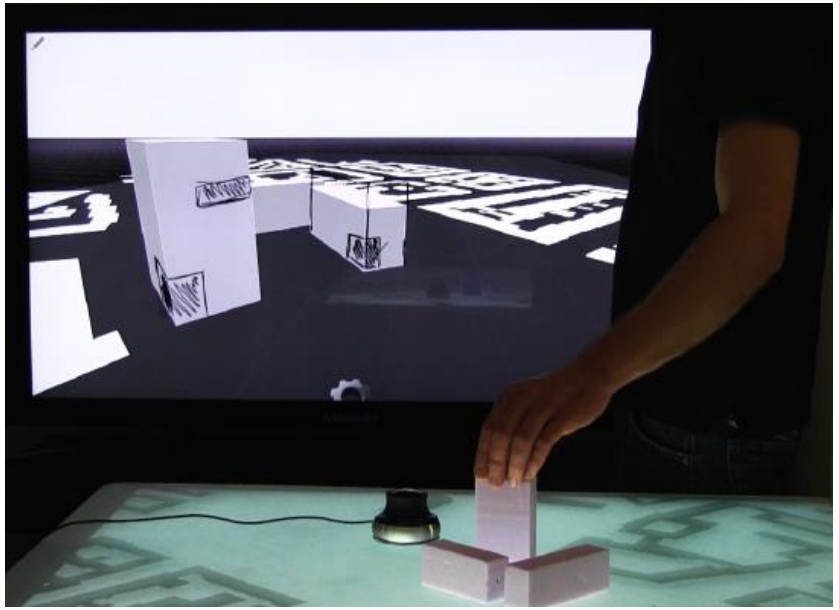
Driving Simulators

- Parent
  - TUMMIC (BMW), 2007

M. Tönnis: ***The Tangible Car - Rapid Intuitive Traffic Scenario Generation in a Hybrid Table-top and Virtual Environment***. The Fourth International Workshop on the Tangible Space Initiative in conjunction with the Sixth IEEE and ACM International Symposium on Mixed and Augmented Reality, Nara, Japan, Nov. 13 - 16, 2007.

Steerable Simulation Environments

- Architectural Workbench, since 2011



G. Schubert, M. Tönnis, V. Yanev, G. Klinker, F. Petzold: **Dynamic 3D-Sketching - A design tool for urban and architectural design.** *Proc. 19th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA), May 2014.*.

Steerable Simulation Environments

Lessons learned

- Mixed multi-display environments (2D-3D) with tangible or touch capabilities are becoming attractive to industry (some 10 years after SHEEP)
- Tedious to set up – without an underlying framework.

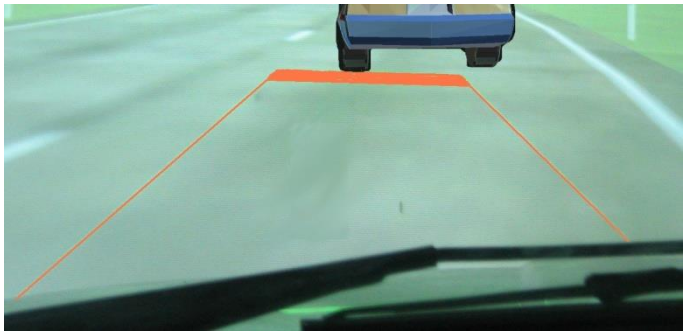
Driver Assistance

- BMW-projects
  - „TUMMIC“ (2003-2007),
  - „ISPA (2007-2010)

Driver Assistance

Danger Ahead

- Goal: Avoid rear-end accidents (e.g.: using ACC)
- Approach: Visualization of the breaking path in the HUD
  - Bar [Bubb 76]
  - Drive path



Tönnis, Lange and Klinker: *Visual Longitudinal and Lateral Driving Assistance in the Head-Up Display of Cars*, ISMAR 07, Nov 2007.

Tönnis, Lange, Klinker , Bubb: *Transfer von Flugschlauchanzeigen in das Head-Up Display von Kraftfahrzeugen.* VDI/VW Tagung “Integri.Sicherheit und Fahrerassistenzsysteme, Wolfsburg, Okt.’06.

Driver Assistance

Danger Ahead

Evaluations in a Fixed-Base Driving Simulator

- Test participants drive faster with a drive-path assistant.
- The drive-path assistant generates higher speed oscillations.
- Steering is improved.
- Test participants preferred the bar.
- Drive path reduced concentration on the driving task.

Driver Assistance

Danger Ahead

Important issues

- Information overload
  Too much information, too rapid changes
- Perceptual tunneling
  Focusing on a single stimulus
- Cognitive capture
  Absentmindedness, reduced situational awareness
- Occlusion of real objects

Driver Assistance

Lessons learned

- Complex user-centered evaluations regarding the usability of systems
  - In-depth focussing on critical aspects
  - In-breadth assertation that the evaluation environment is robust
- Burning issue for mobile AR:
  To what extent can humans act „normally“ within their „real“ physical environment while they interact simultaneously with a virtual world?

Navigation Support

Bavarian project FORLOG, 2005-2007

- Order picking (logistics)

Setup

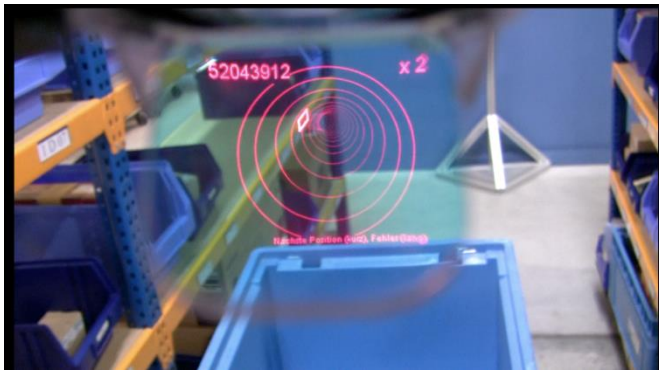
- Collection of large assortments in series production
- Several phases of navigation
- Existing systems
  - Mobile data terminal with scanner
  - Pick-by-light
  - Pick-by-voice

Schwerdtfeger, Reif, Günthner, Klinker: *Pick-by-Vision – There is Something to Pick at the End of the Augmented Tunnel.* Submitted to: Special Issue on "Autmented Reality" of the Springer Journal on Virtual Reality (M. Billinghurst and D. Schmalstieg, eds.), Springer Verlag, 2010.

Navigation Support

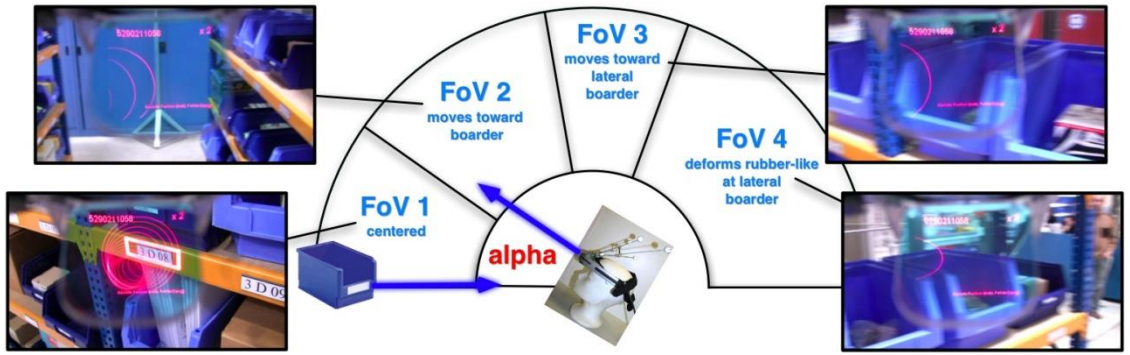
Pick by Vision

- Tracked HMD



Issues

- Clear visualization (3D depth)
- Imprecise tracking
- Minimal occlusions
- User support in any situation



Navigation Support

Lessons learned

- Usability testing in complex environment very tricky
  - Many confounding factors
    - Less is more
  - Comparing apples and oranges
- Start with very small test groups
  - „On the job learning“
- Very incremental: hard to publish

- Industry is very interested

Tracking Framework

German Project (DFG) DySenNetz (2004 - 2007)

Bavarian Project (BFS) TrackFrame (2006 - 2009)

EU Project Presenccia (2006 - 2009)

German Project (BMBF) AVILUS (2008 - 2011)

German Project (BMBF) Asyntra (2009 - 2011)

German Project (BMBF) ARVIDA (2013 - 2016)

- UbiTrack

Tracking Framework

Literature

Pustka, Huber, Bauer and Klinker: *Spatial Relationship Patterns: Elements of Reusable Tracking and Calibration Systems*, ISMAR 06, Oct. 2006. AWARD.

Huber, Pustka, Keitler, Echtler and Klinker: *A System Architecture for Ubiquitous Tracking Environments*, ISMAR 07, Nov. 2007.

Pustka: Construction of Data Flow Networks for Tracking in Augmented Reality Applications. 3rd Workshop Virtuelle und Erweiterte Realit-t der GI-Fachgruppe VR/AR, Koblenz. Sept. 2006.

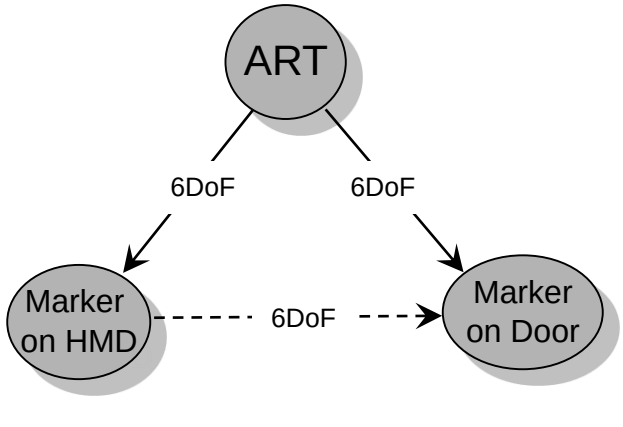
D. Pustka, M. Huber, G. Klinker: **Integrating Gyroscopes into Ubiquitous Tracking Environments.** *IEEE Virtual Reality, Reno, Nevada, Mar. 8-12, 2008, pp. 283-284*.

D.Pustka, M. Huber, C. Waechter, F. Echtler, P. Keitler, J. Newman, D. Schmalstieg, G. Klinker; **Automatic Configuration of Pervasive Sensor Networks for Augmented Reality.** *IEEE Pervasive Computing, Volume 10, Number 3, July-Sept. 2011, pp. 68-79*.

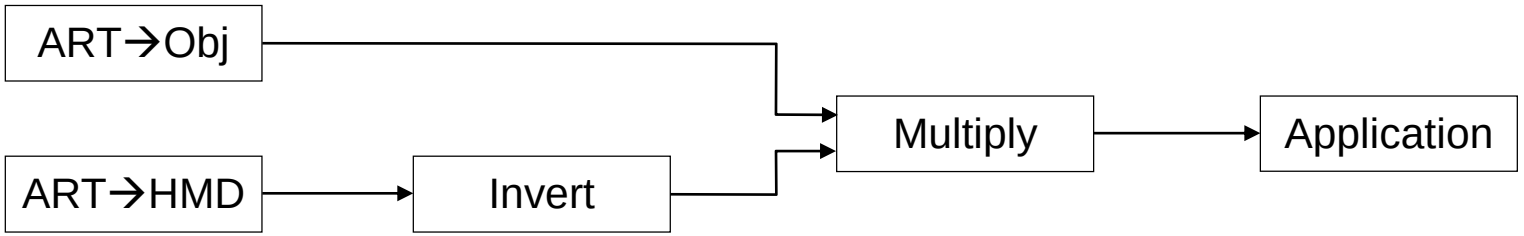
M.. Huber, M. Schlegel, G. Klinker: **Temporal Calibration in Multisensor Tracking Setups.** *9. Workshop der GI-Fachgruppe Virtuelle und Erweiterte Realität (VR-AR 2012), Düsseldorf, Germany, Sept. 2012, pp. 201-212.*

Tracking Framework

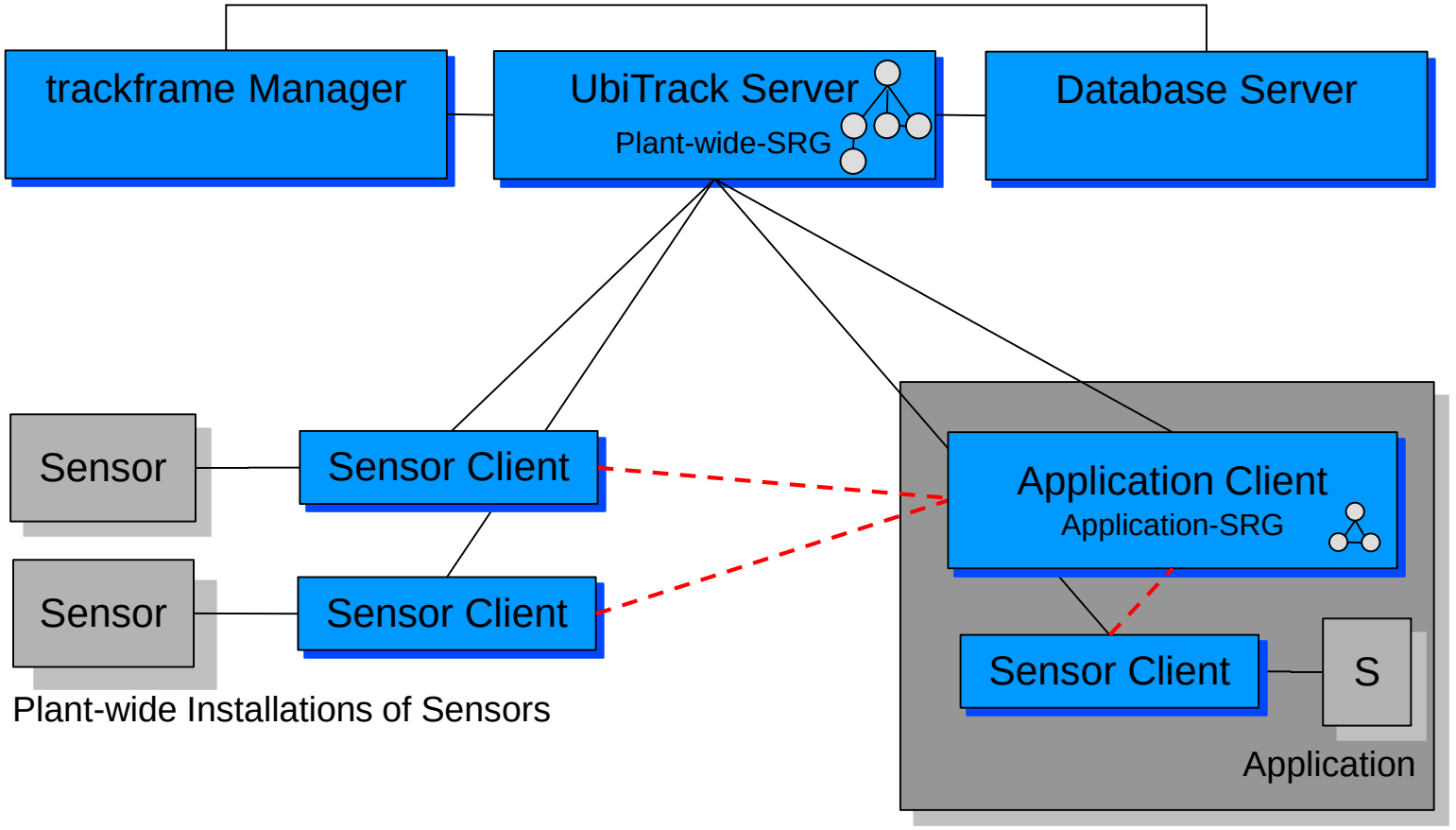
- Spatial relationship graph



- Data flow network



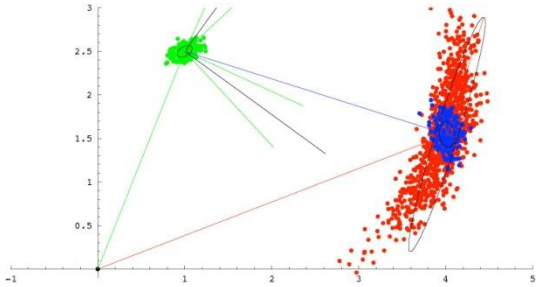
Tracking Framework

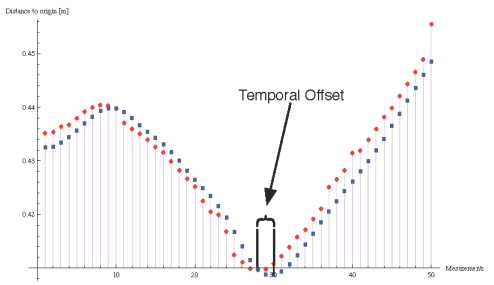


Tracking Framework

Research issues

- Automatic compilation of data flow networks from SRGs
  - SR patterns
- Error propagation
- Patterns for Registration, Calibration, Tracking
- Activity control: push vs. Pull
- Temporal calibration (analog time delays)

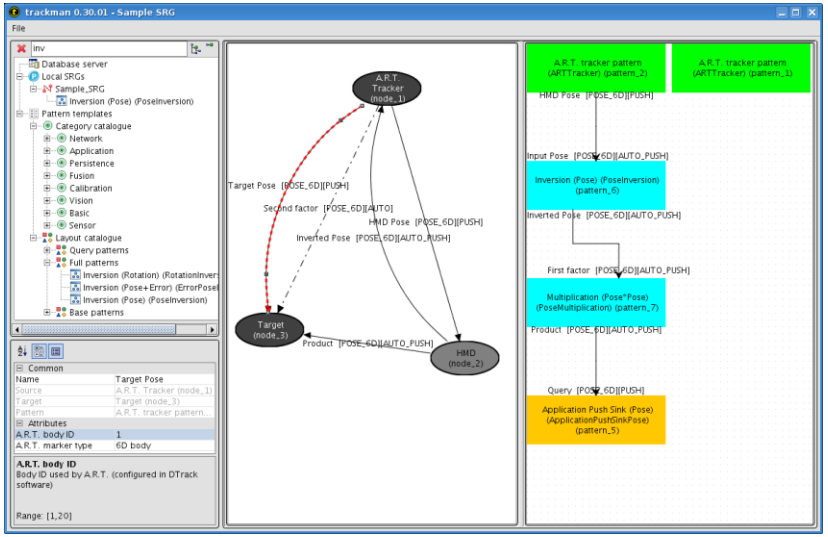


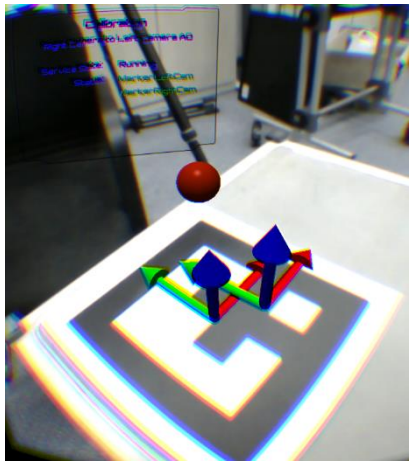


Tracking Framework

Utilites

- Interactive Tracking Manager
  - Online configuration
  - Online validation
- AR 4 AR

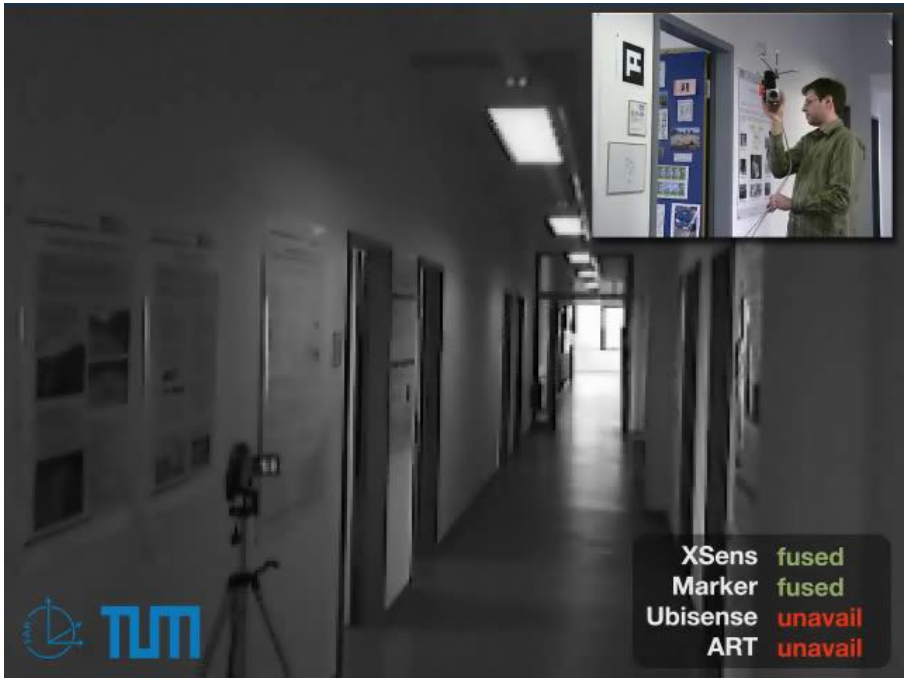


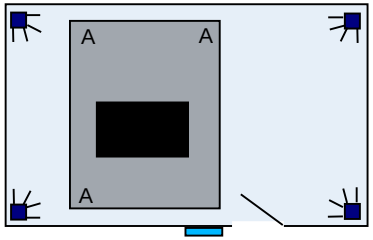


Tracking Framework

Inspectors

- Dynamic reconfiguration
- Dynamic initialization
- Dynamic occlusion





Tracking Frameworks

The good part

- Ubitrack is now a central part of the ARVIDA reference architecture
  - Restful architecture
  - Used and tested by all industry partners across a large number of applications
  - Critical when metaio was bought by <a>.
- Slow and steady wins the race

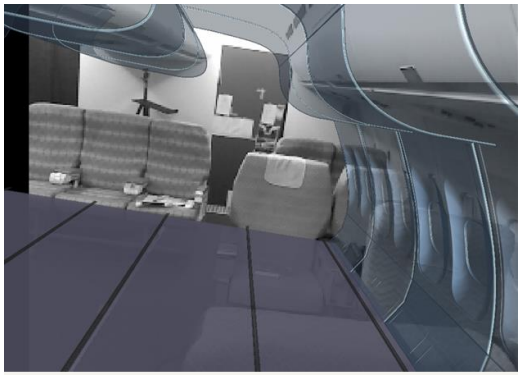
Tracking Contests

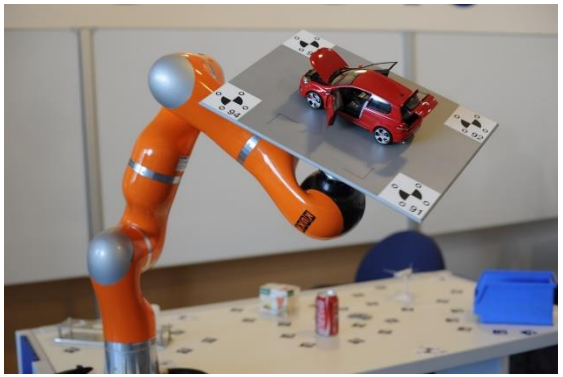
2008, Cambridge

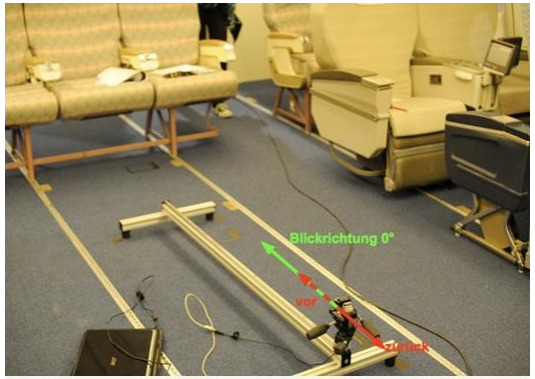


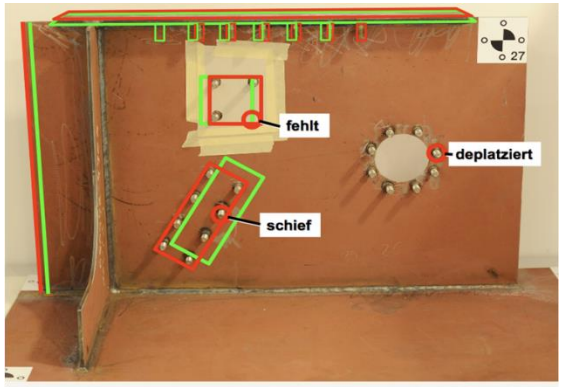

Tracking Contests

2010, AVILUS, Munich









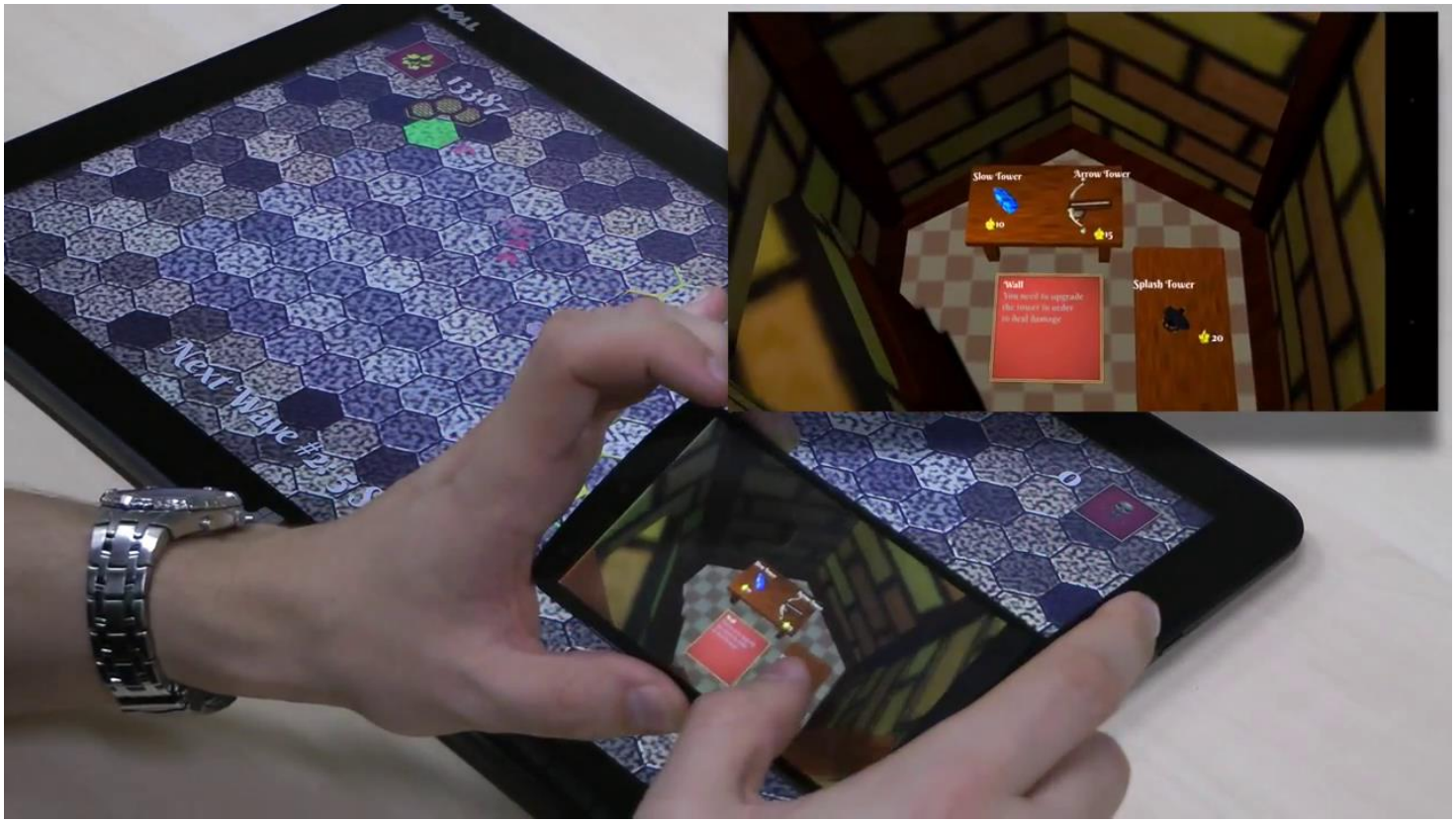
Tracking Contests

Take-home message

- Extremely critical to industry
  - Valuable
  - Potentially damaging
- Should become a global effort
  (combine with City of Sights and with Trakmark)

AR Games (TUM-Games Engineering)

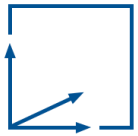
Towering Defense: Information between displays



Future AR

- Information is everywhere:
  - Confluence of AR, VR, Ubiquitous Computing, Tangible Interaction
  - Combination of mobile and stationary services
    → Frameworks for AR-ready environments
- Technology will outpace the human w.r.t. sensing and displays
  - Technology > Human Sensing
    → Magical User Experiences
- Humans need to stay in control
  - Holy grail: „intuitive“ affordances
  - Danger: „mixed physics“

Thank you!



Videos can be found on our YouTube Channel: www.youtube.com/AugmentedRealityTUM

Papers can be at: http://campar.in.tum.de/Chair/PublicationsFar