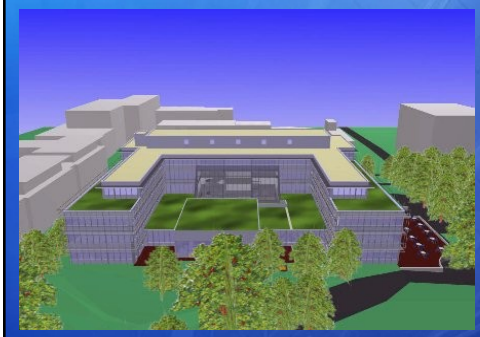
Are we there yet? Current Developments in Making Augmented Reality Practical

Dirk Reiners
University of Louisiana
Lafayette

About Me

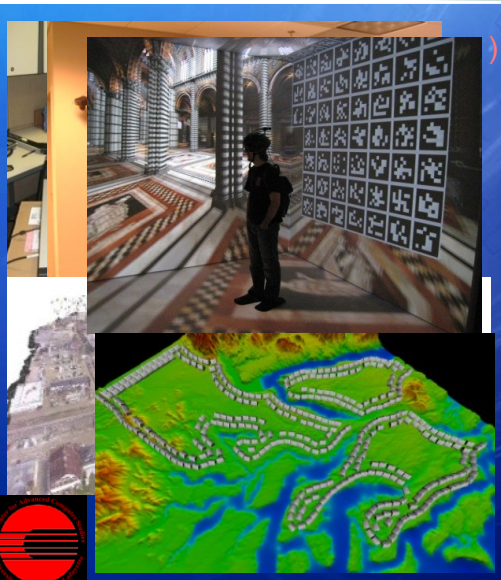
- Since 2006: Assistant Professor at University of Louisiana, Lafayette
- 2003-2006: Assistant Professor at Iowa State University

About Me



- **1998-2003: Senior Researcher at Fraunhofer IGD, Darmstadt, Germany**
- **Research Topics:**
  - Software Systems and Algorithms for Interactive and Immersive 3D Graphics
  - Initiator and Project Lead for OpenSG

Research Projects



- **Wide range of projects:**
  - Virtual welder training
  - Bioinformatics
  - Protein Evolution Analysis
  - Large point cloud display
  - Advanced interaction devices and techniques
  - Urban scene generation

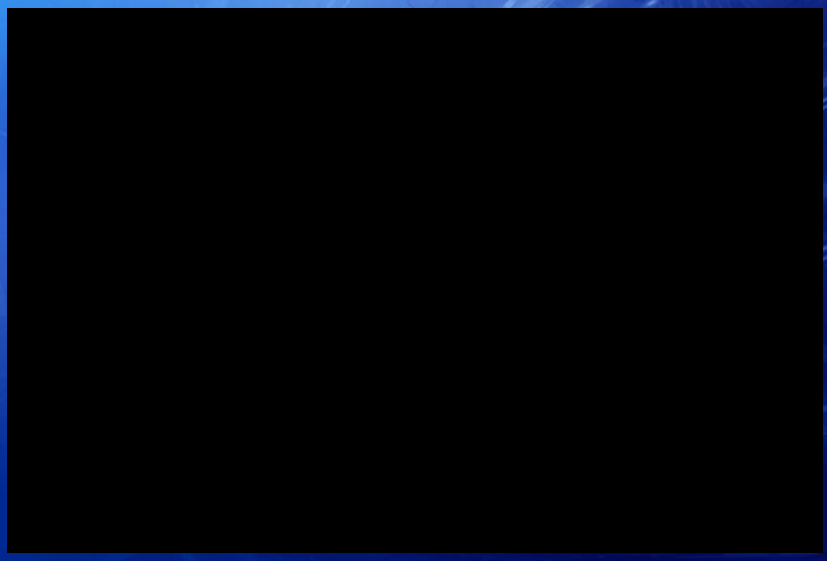
About Me

- 1996-1997: Researcher at European Computer-Industry Research Centre (ECRC)
- Worked on Augmented Reality Display and Applications

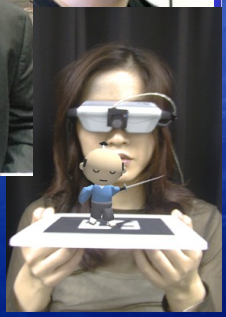
Augmented Reality

- Adding Virtual Objects to Real Scenes
- Offline or Realtime
  - Offline: Movies
- Realtime much more challenging and interesting
  - React to head motions
  - React to scene changes

AR Vision

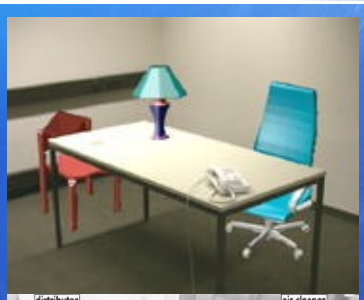


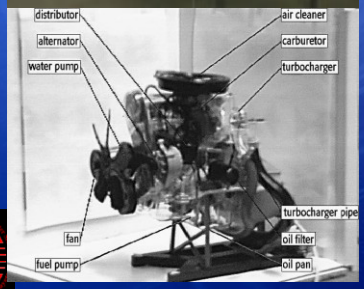
AR Displays



- **Two major kinds:**
  - Video see-through
  - Optical see-through
- **Video**
  - Standard HMD/ Monitor + Camera
- **Optical**
  - Semi-Transparent HMD
- **Video more widely used, easier to do**

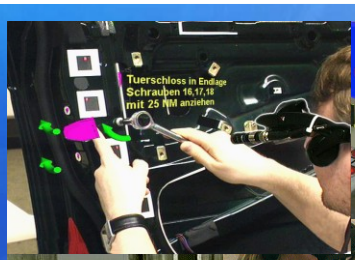
ECRC – UI Group

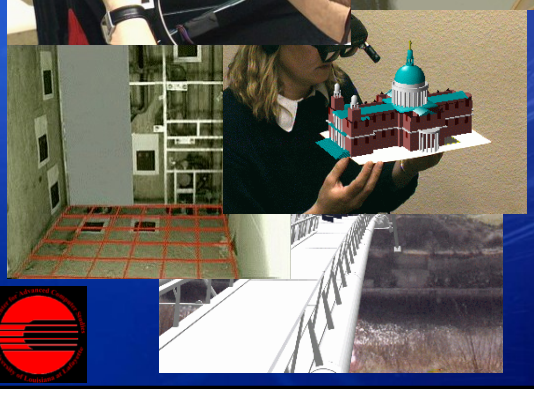




- One of the first Augmented Reality Research Groups
- Mixture of Computer Graphics and Computer Vision Expertise
- Started in early 1990s
- Merged into Fraunhofer IGD in 1996/1997

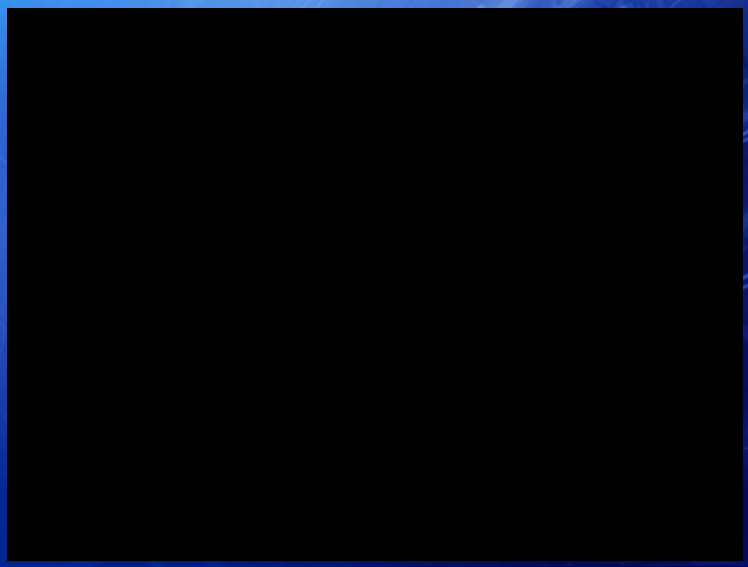
ECRC → Fraunhofer IGD





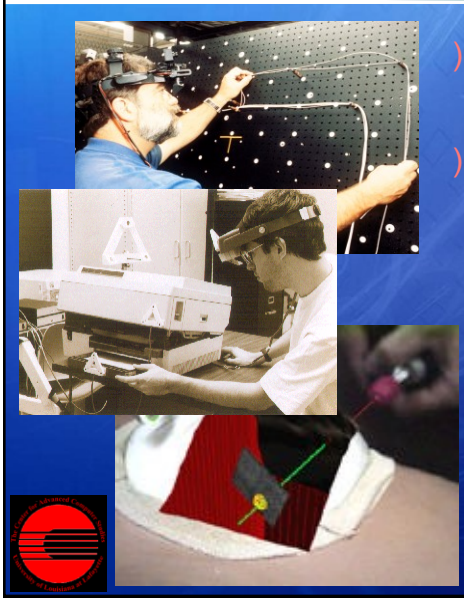
- Group: Gudrun Klinker, Didier Stricker and me
- Research Areas:
  - Tracking, offline + realtime
  - Realistic Display
  - Applications:
    - Architecture
    - Games
    - Assembly Instructions
- Started IWAR
  - Later ISAR/ISMAR

Thames Bridge



Doorlock Assembly

Early AR



- **Coined by Tom Caudell (Boeing) in 1990**
- **Early Applications:**
  - Wire Bundle Assembly (Boeing, ~1992)
  - Copier Repair (Columbia, 1993)
  - Needle Biopsy (UNC, 1992)

VR vs. AR

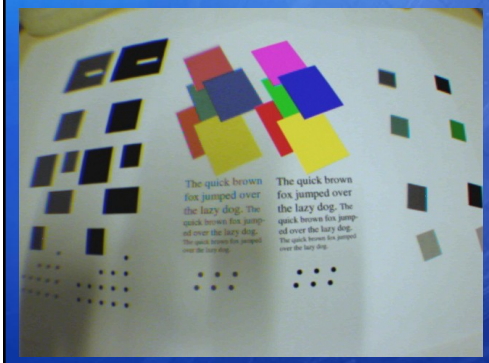
- **VR has established itself pretty well in practical applications**
  - Immersive Visualization
  - Virtual Design Reviews
  - Usability & Human Factors
- **AR is still in the research labs**
  - Enormous Practical Potential…
  - …but lots of challenges, too

VR vs. AR

- **"AR is like VR, only harder"**
  Stefan Mueller, Fraunhofer IGD
- **Target: Mobile, Realtime, Realistic, Accurate**
  - Lower Latency Requirements
  - Larger Tracking Area
  - Lower power devices
  - Lower memory devices
  - Lower graphics power devices

DISPLAY QUALITY

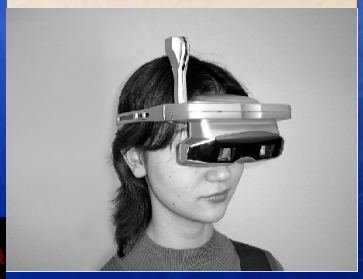
Display Quality



- **Goal: Virtual Indistinguishable from Real Objects**
- **Problem Areas:**
  - Display Geometry
  - Shadows
  - Shading
  - Occlusion
  - Camera Artifacts

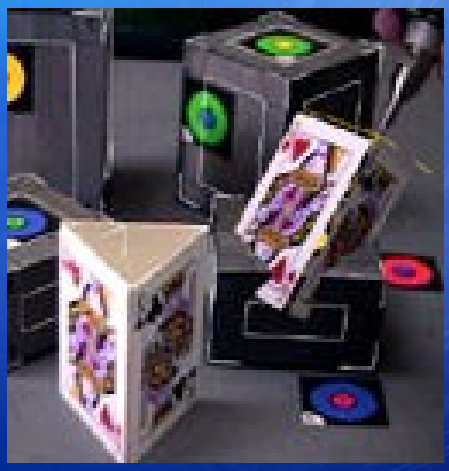
Klein/Murray: Compositing for Small Camera, ISMAR 08

Display Geometry



- **Video See-Through Problems**
  - Camera not at eye point
  - Usually only one camera
- **Result: Image is offset and mono**
- **Solution: Mirrors in front of screens**
  - Mirror into camera pair
- **Canon built it**
  - In 2001…
  - Not commercially viable

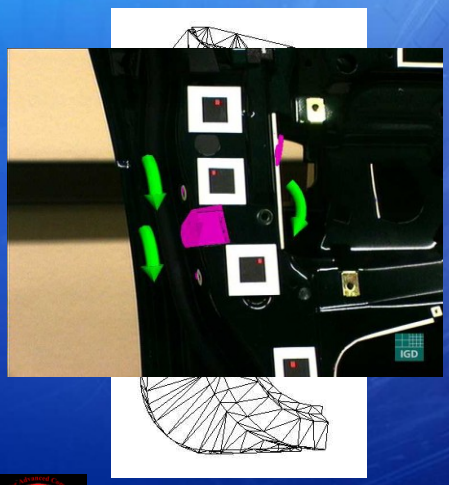
Occlusion



- **Combines a number of different problems**
- **What to occlude?**
  - Real occlude real
  - Virtual occlude virtual
  - Real occlude virtual
  - Virtual occlude real
- **How to display?**
  - Video see-through
  - Optical see-through

Andrei State, UNC

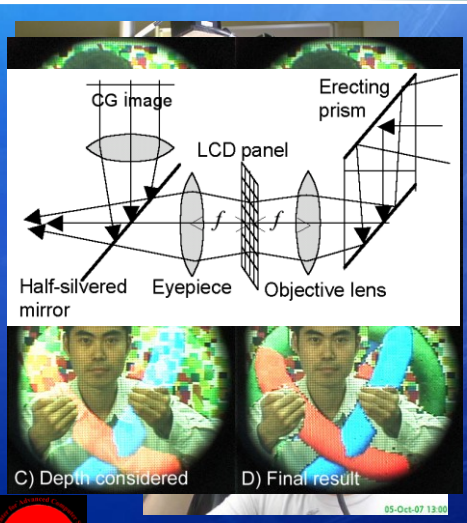
Occlusion: Real-Virtual, Video



- **Basic Idea simple**
  - Render real world into depth buffer only
  - Render augmentation afterwards
- **Problem: Getting Real-World Model**
  - CAD: easy
  - Stereo matching?
    - Hardware Possible
    - Z-Cam

Reiners, e.a.: Augmented Reality for Construction Tasks: Doorlock Assembly, IWAR 98

Occlusion: Virtual-Real, Optical



- **Problem: Need to remove real light**
- **Not possible with standard see-through**
  - Only adds light
- **Need additional blocker LCD panel**
- **Optics non-trivial, but possible**

Kiyokawa, e.a: An Occlusion-Capable Optical See-through Head Mount Display for Supporting Co-located Collaboration, ISMAR 03
Santos, e.a.: Display and Rendering Technologies for Virtual and Mixed Reality Design Review, ICCAVR 07

Shadows

- **Similar to occlusion**
- **Needs reality model**
  - To throw shadows
  - To throw shadows on
- **Can use standard CG algorithms**
  - Many variations in CG literature
- **Shadows are easy, reality model is hard**

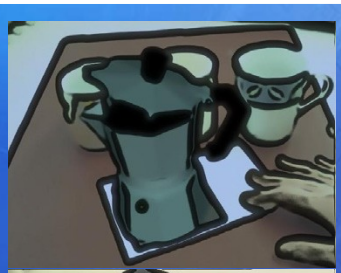
Andrei State, UNC

Shading

- **Long studied problem**
  - First: Fournier ’92 & ’95
- **Basic Idea:**
  - Reconstruct reality, including lighting
  - Add virtual objects, calculate new lighting
  - Apply difference to reality
- **Offline process**
  - Radiosity or Photon Mapping

Grosch: Differential Photon Mapping, EG 05
Drettakis e.a.: Interactive Common Illumination for Computer Augmented Reality, EGWR 97

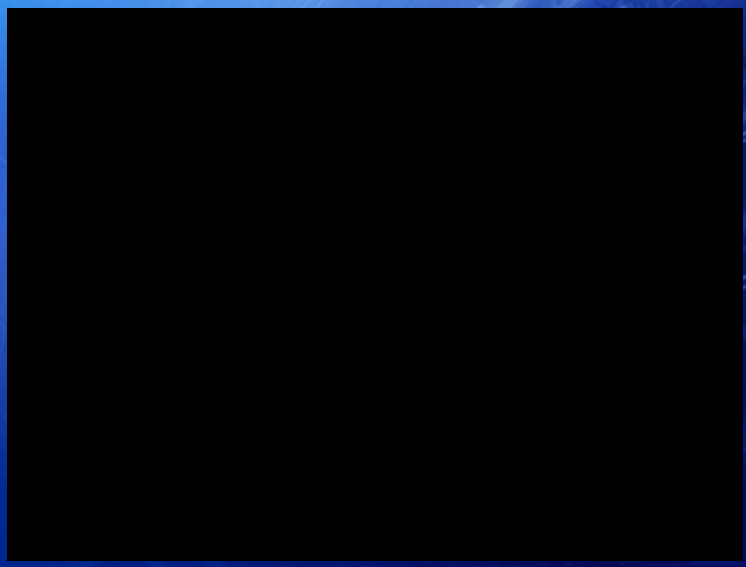
Camera Artifacts - NPR



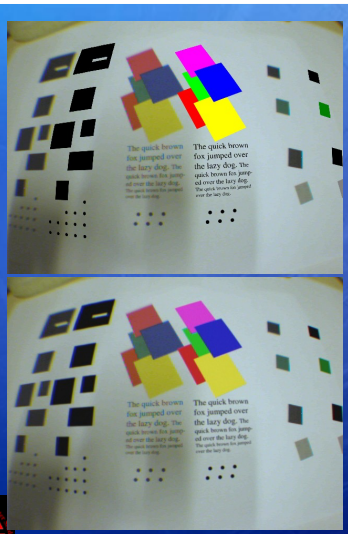
- **Workaround: Make Reality looks less real!**
- **Match Virtual Objects to this Reality**
- **Works well, if artifacts acceptable**

Jan Fischer, WSI-GRIS Uni Tuebingen

Camera Artifacts - NPR



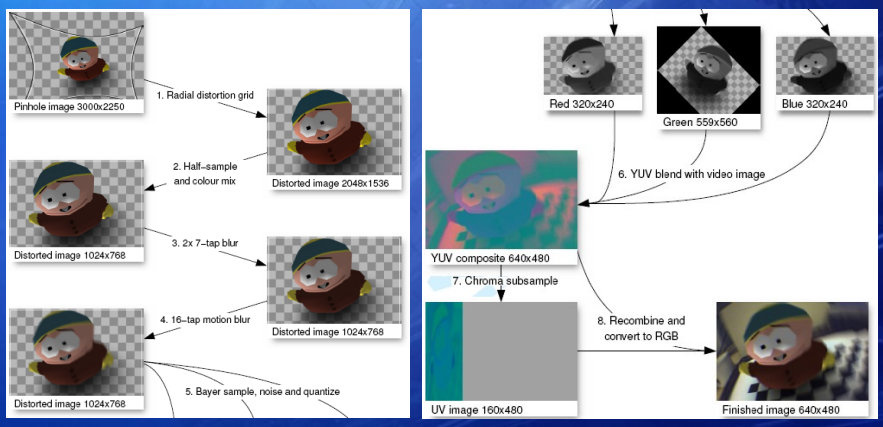
Camera Artifacts



- Typical Cameras for AR: Cheap webcams
- Have many artifacts
- Try to reproduce them for virtual objects
- Many different effects needed for accurate match

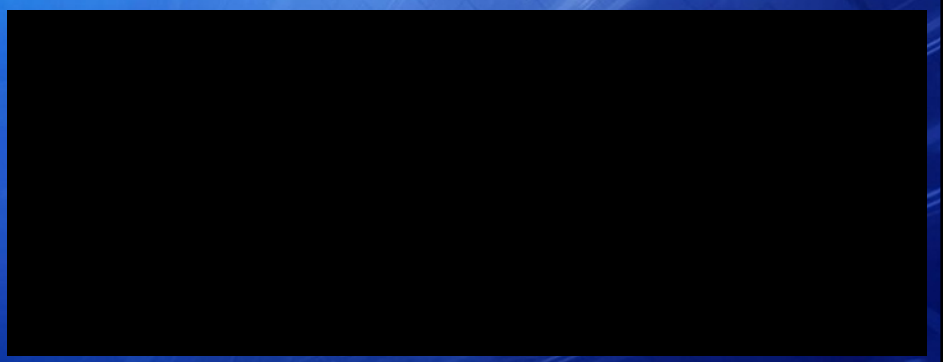
Klein/Murray: Compositing for Small Camera, ISMAR 08

Small Camera Pipeline



Klein/Murray: Compositing for Small Camera, ISMAR 08

Small Camera Comparison



Klein/Murray: Compositing for Small Camera, ISMAR 08

Quality – Are we there yet?

MOBILITY

Mobile Devices

- **Different Levels of Mobility**
  - Desktop
  - Laptop
  - UMPC
  - Handheld
  - Cellphone
- **2-4 years development between levels**
  - Laptops powerful enough for most applications today
  - Others not quite or not easily…

Ultra-Mobile PC

- **Sony Vaio UX-90**
  - Standard Windows XP
  - Intel Core Solo
  - 1.1 GHz
  - 512 MB Ram
  - 0.5 kg
- **Samsung Q1/Q2**
  - Windows Vista
  - Intel Atom A110 800 MHz
  - 1 GB Ram
  - < 1 kg

Handheld / PDA / Pocket PC

- **Example: Dell Axim X51v**
  - Intel XScale PXA270 CPU (624MHz)
  - Intel 2700G 3D chip
  - Windows Mobile
  - 128 MB Ram
- **Others:**
  - Ipaq
  - Dell 650RX
  - Toshiba e-800

Cellphones

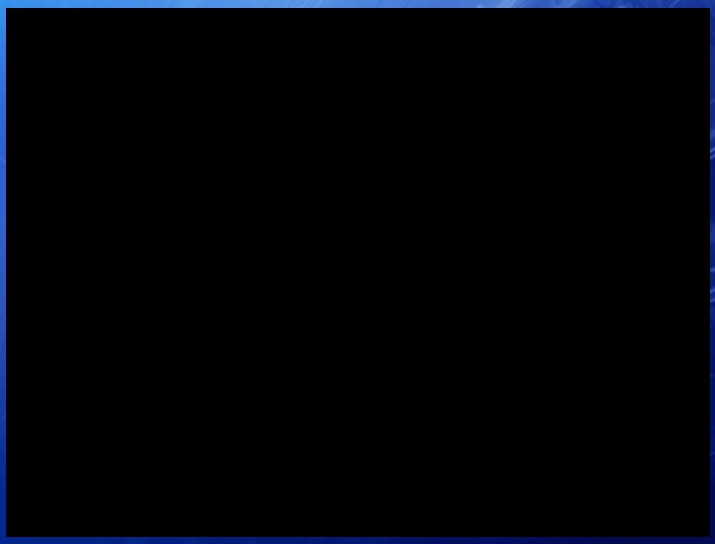
- **i-mate SP5 (HTC Tornado)**
  - Smartphone
  - 200 MHz Texas Instruments OMAP850 CPU
- **HTC MTeoR (HTC Breeze)**
  - Smartphone
  - 300MHz Samsung S3C2442 CPU
- **HTC TyTN (HTC Hermes)**
  - PocketPC phone
  - 400MHz Samsung S3C2442 CPU
- **Gizmondo**
  - Mobile gaming console
  - nVidia GoForce 4500 3D chip
  - 400 MHz Samsung S3C2440 CPU
- **T-Mobile MDA Pro (HTC Universal)**
  - High-end PocketPC phone
  - 520MHz Intel Xscale PXA270 CPU

AR on Cellphones?

- **Possible!**
- **But:**
  - Development non-trivial
  - Very constrained (memory and performance)

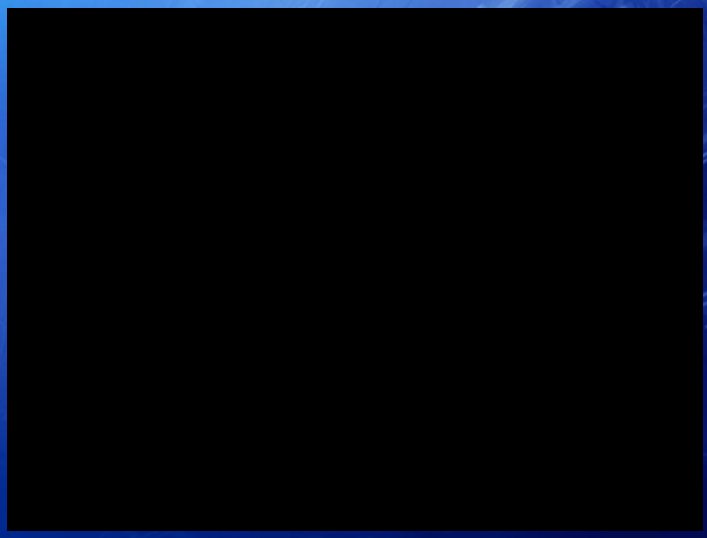
Wagner/Schmalstieg: ARToolKitPlus for Pose Tracking on Mobile Devices, CVWW07

AR on Cellphones



Wagner/Schmalstieg: ARToolKitPlus

AR on Cellphones



Wagner/Schmalstieg: ARToolKitPlus

Mobility – Are we there yet?

TRACKING

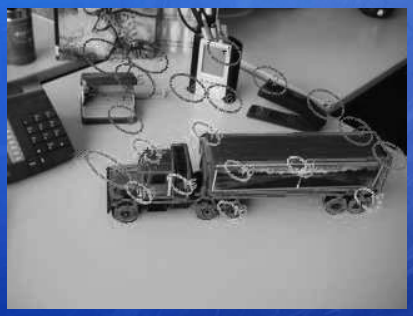
Tracking

- ***The* problem in AR**
  - Since the beginning (e.g. Mizell 92)
  - 20% of all IWAR/ISAR/ISMAR papers cover tracking
- **First Approach: Use VR trackers**
  - Expensive
  - Small Area
  - Low Quality

Optical Tracking

- **Marker-based**
  - Many, many different kinds of markers
- **Problem: Calibration to world space**
- **ARToolkit Idea: marker defines space**
  - Tons and tons of applications
- **Problem: Markers need to be visible**
  - Can get a little intrusive…
- **Still method of choice for low-power devices**

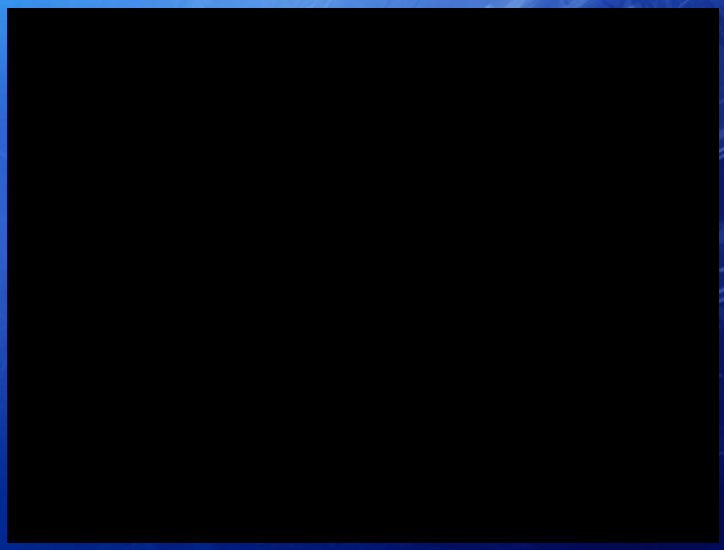
Markerless Tracking



- **Use Scene Features for Tracking**
  - Either based on CAD model (Model-based) or directly from scene (Simultaneous Localization And Mapping, SLAM)
- **SLAM more generic, but harder**
- **Hybrid Possible**
  - Use model for initialization, SLAM for tracking

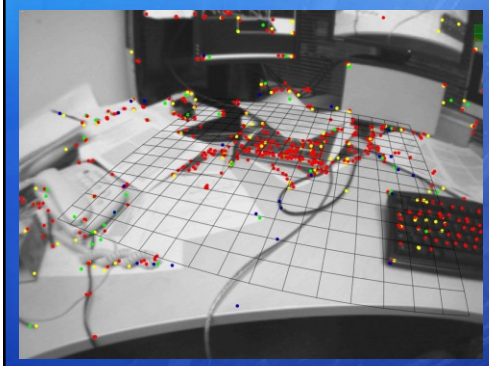
Bleser e.a.: Online camera pose estimation in partially known and dynamic scenes, ISMAR 06

Hybrid Markerless Tracking



Bleser e.a.: Online camera pose estimation in partially known and dynamic scenes, ISMAR 06

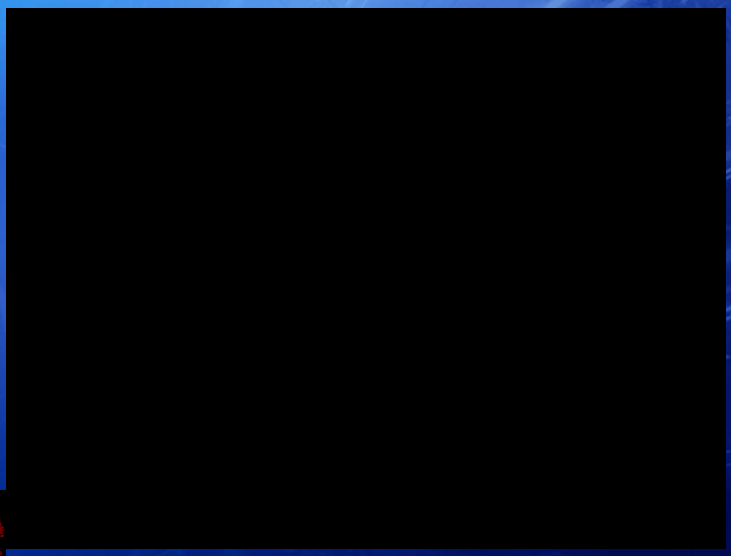
Split Tracking and Mapping



- **Normal: Update Camera Pose and Landmarks**
  - Latter: Expensive
- **Splitting allows**
  - Video-rate pose update
  - Expensive High-quality Mapping (Bundle) based on Keyframes
- **Won ISMAR 2008 Tracking Competition**

Klein/Murray: Parallel Tracking and Mapping for Small AR Workspaces, ISMAR 07

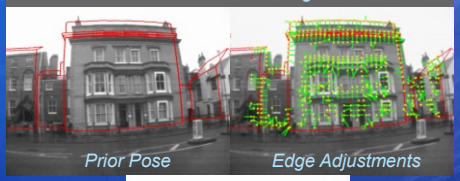
Split Tracking and Mapping



Klein/Murray: Parallel Tracking and Mapping for Small AR Workspaces, ISMAR 07

Outdoor Tracking

Rendered Model | Edge Detection



Prior Pose | Edge Adjustments

New Pose

- **Old problem**
  - GPS ok for position
  - No orientation, slow
- **Model-based/ Feature-based methods help**
  - Indoor and outdoor
- **Outdoor larger areas, larger problems**

Reitmayr/Drummond: Going out: Robust Model-based Tracking for Outdoor Augmented Reality, ISMAR 06

Outdoor Tracking

Reitmayr/Drummond: Going out: Robust Model-based Tracking for Outdoor Augmented Reality, ISMAR 06

Tracking – Are we there yet?

Conclusion

- **Augmented Reality has hard problems**
- **But we have made giant steps in the last 10 years!**
  - Mobile devices almost powerful enough
  - Markerless tracking becoming practical
- **Still a lot of open issues**
  - Tracking Robustness
  - Lighting Integration
  - Display Devices