Laser Pointer Tracking in Projector-Augmented Architectural Environments

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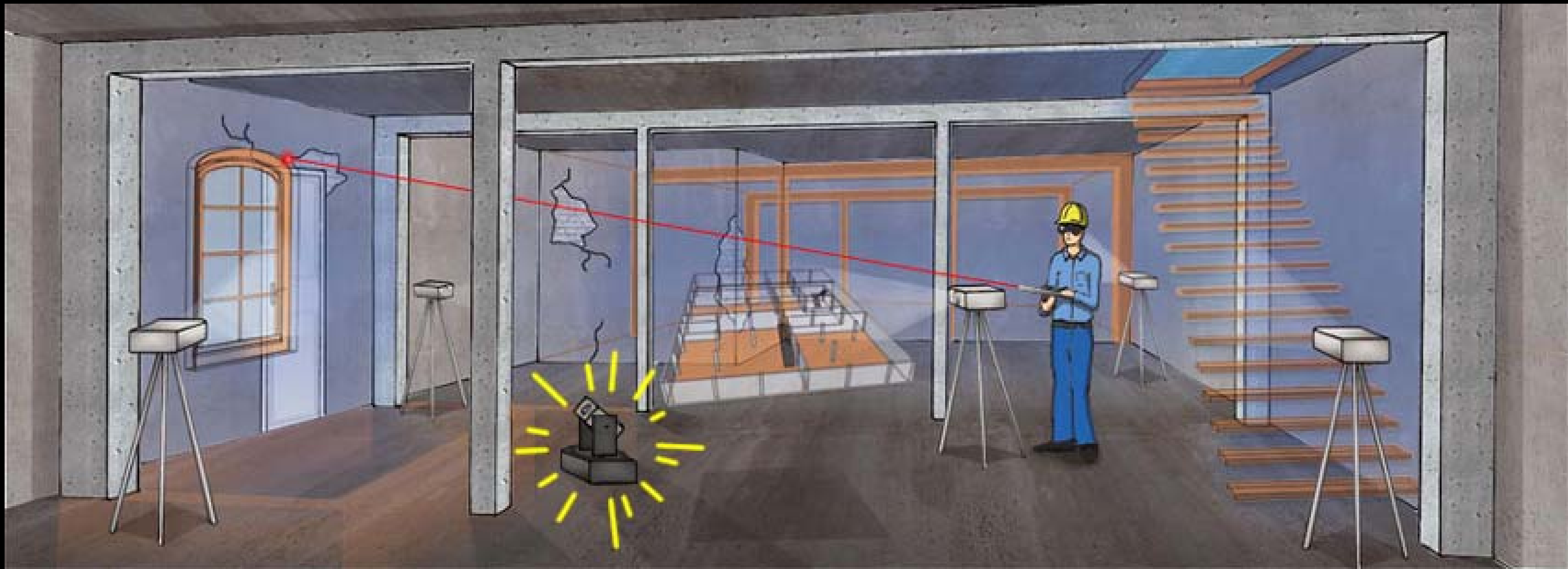
What is this about?

Motivation

- Spatial Augmented Reality for Architecture

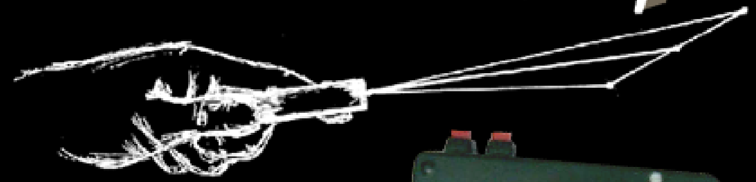


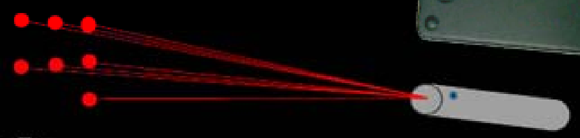
- Visualization
  - Projector-based AR
  - Video see-through AR
- Interaction
  - Laser pointer tracking

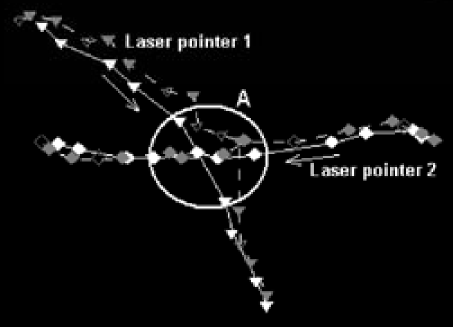
Outline

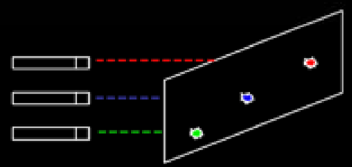
- Related work
- System overview
  - Custom-built PTZ camera
  - Distributed software framework
- System calibration
  - Self-registration
  - Texture capturing
  - Projector calibration
- System while in use
  - Laser pointer tracking
  - Applications
  - Video see-through
  - LED tracking
- Conclusions
  - Summary
  - Results and Discussion
  - Future work

Related Work – Laser Pointer Interaction



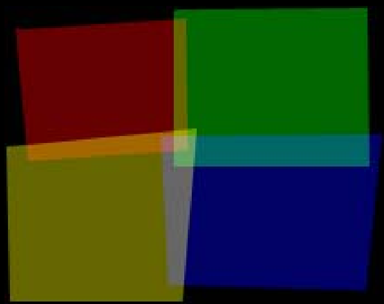


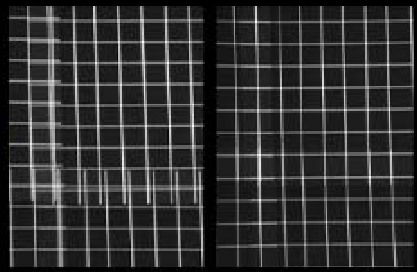


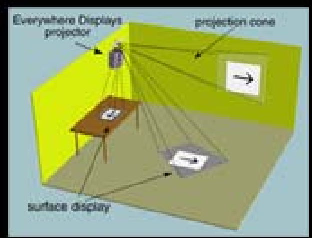


- Interaction techniques
  - Mapping position to mouse movement [Kirstein98]
  - Gesture-controlled events [Olsen01]
- Customized hardware
  - Additional buttons [Oh02] [Bi05]
  - Multiple laser rays [Matveyev03] [Wienss06]
- Infrared laser pointer
  - Avoids visible misregistration and jitter [Cavens02] [Cheng03]
- Large displays/Multi-user
  - Discrimination of lasers [Davis02] [Oh02]
  - Multiple cameras [Ahlborn05]

Related Work – PTZ Camera Systems



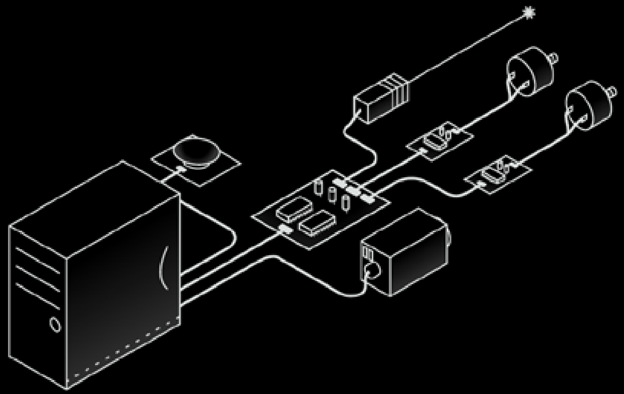




- Calibration of multi-projector systems
  - Un-calibrated camera [Chen00]
- Acqusition of environment geometry and texture
  - Depth enhanced panoramas [Bahmutov04]
  - Large scale acquisition [Bahmutov06]
- PTZ camera and projector [Pinhanez01, Ehnes04]
  - converts optimized everyday surfaces into interactive displays
  - Projector-based display
  - Finger tracking

How does our system work?

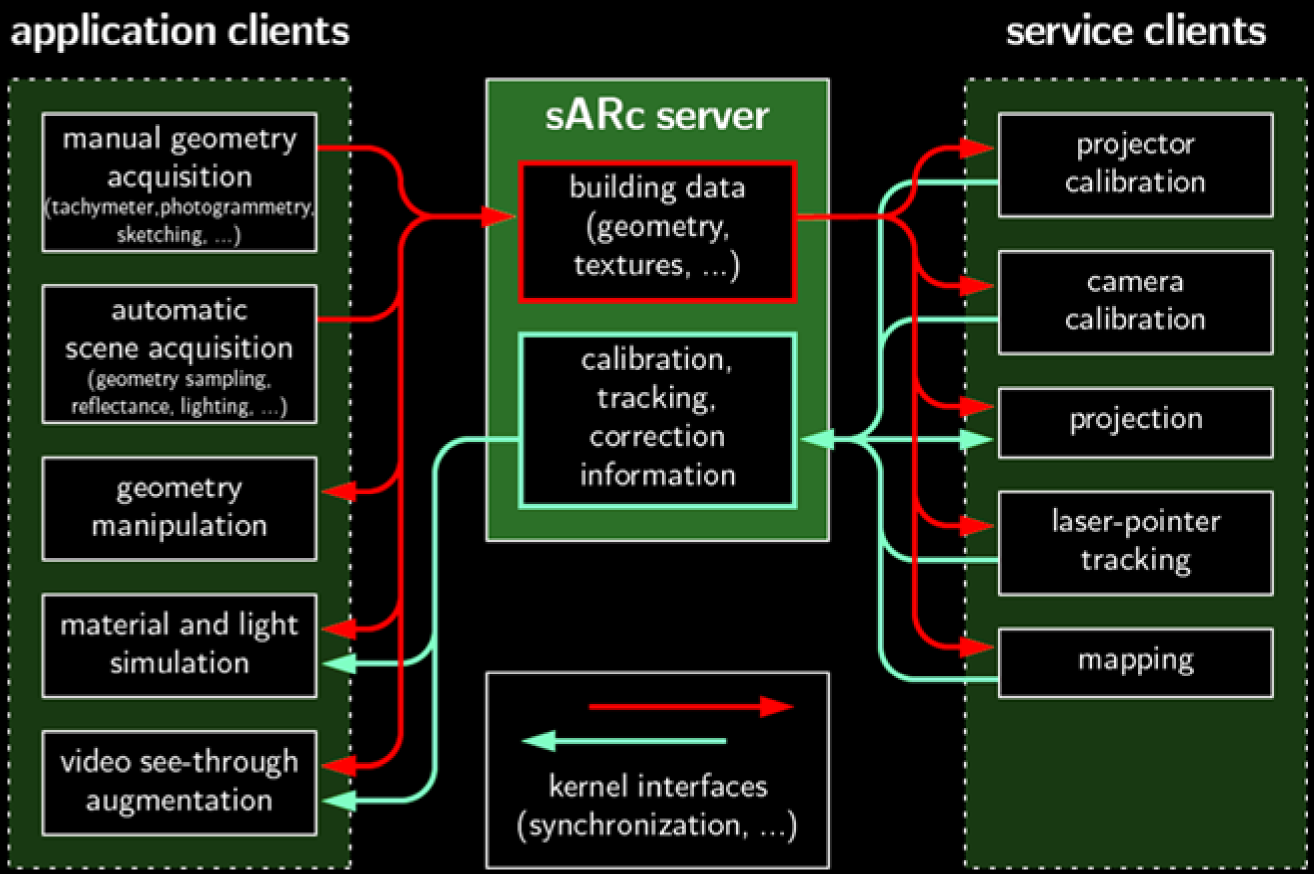
Custom-built PTZ Camera



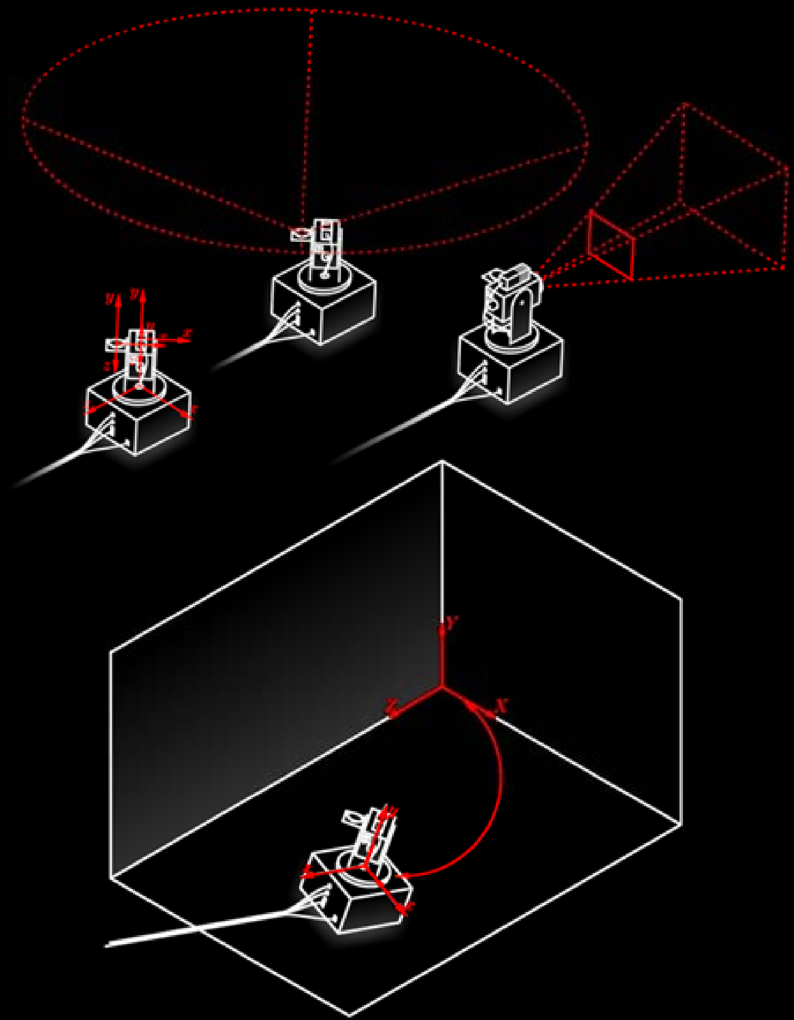
- Two video cameras
  - PTZ detail camera
  - Wide-angle context camera
- Microcontroller
  - Stepper motors
  - Attached laser module
- Connected to a PC
  - Image analysis
  - System control

Distributed Software Framework

- Client/server-based architecture

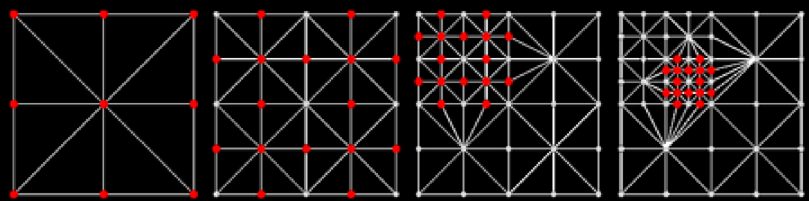


System Calibration



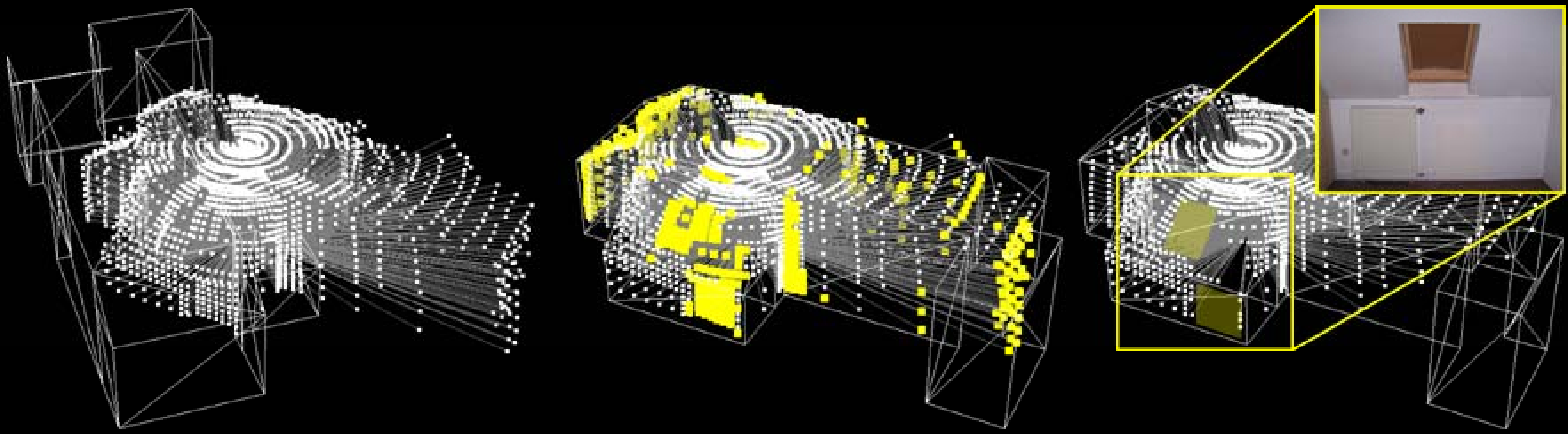
- System's intrinsic parameters
  - Remain constant
  - Pre-calibrated
- System's position and orientation
  - Changes when placed in an environment/room
  - Will be estimated fully automatically

Automatic Self-Registration



- Reference model
  - Taken in advance as part of the architectural surveying process
  - Low resolution
  - Stored on server
  - In world coordinate system
- Sampling the room
  - Adaptive LOD sampling avoids oversampling
  - Results in a point cloud in device coordinate system

Automatic Self-Registration (cont'd)

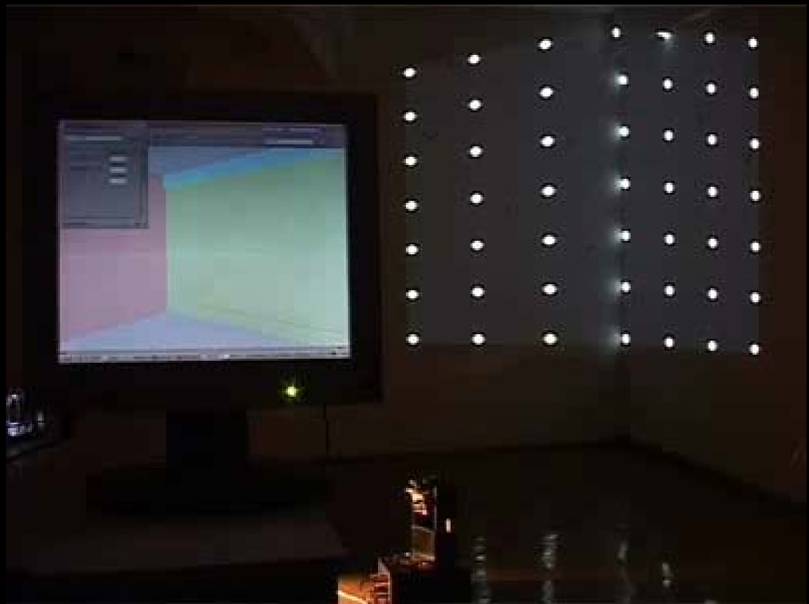


- Match sampled points to reference model
- Outliers (missing details in model) are removed
- Final rigid body transformation matrix (position and orientation) is estimated numerically

Texture Capturing

- Capturing environment's reflectance
- Composed of several photos taken under different orientations
- Short exposure version
  - Everything appears black except bright areas
  - Binarized version is used to mask out such critical regions (later)

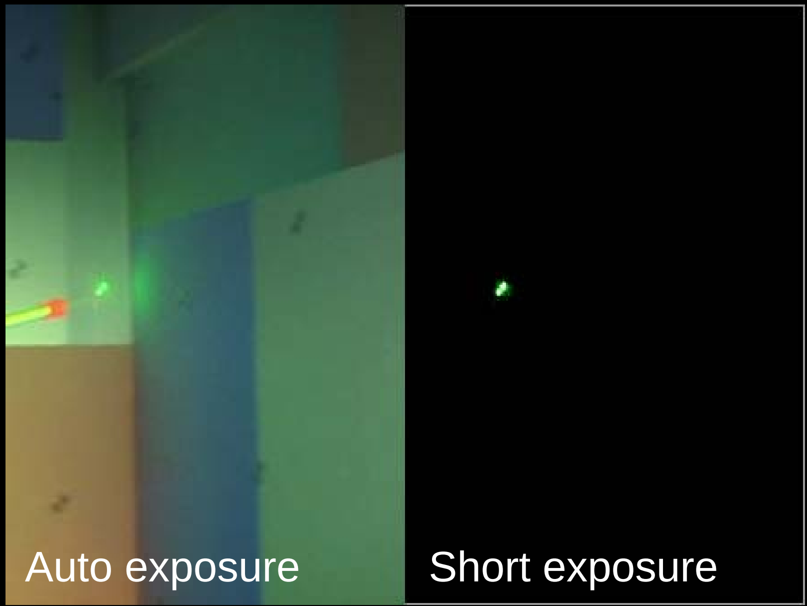
Projector Calibration

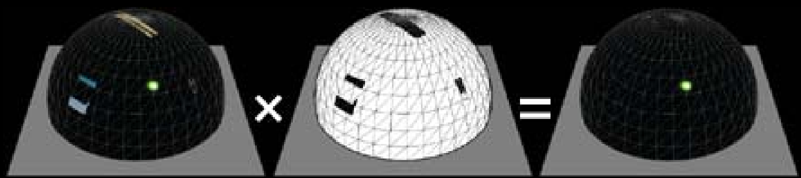


- Unaligned projectors
  - Automatic calibration
  - One after another
- Geometric projector calibration
  - PTZ camera delivers 3D positions of known projected 2D points
- Radiometric compensation
- Blending

How to track a laser pointer in such an environment?

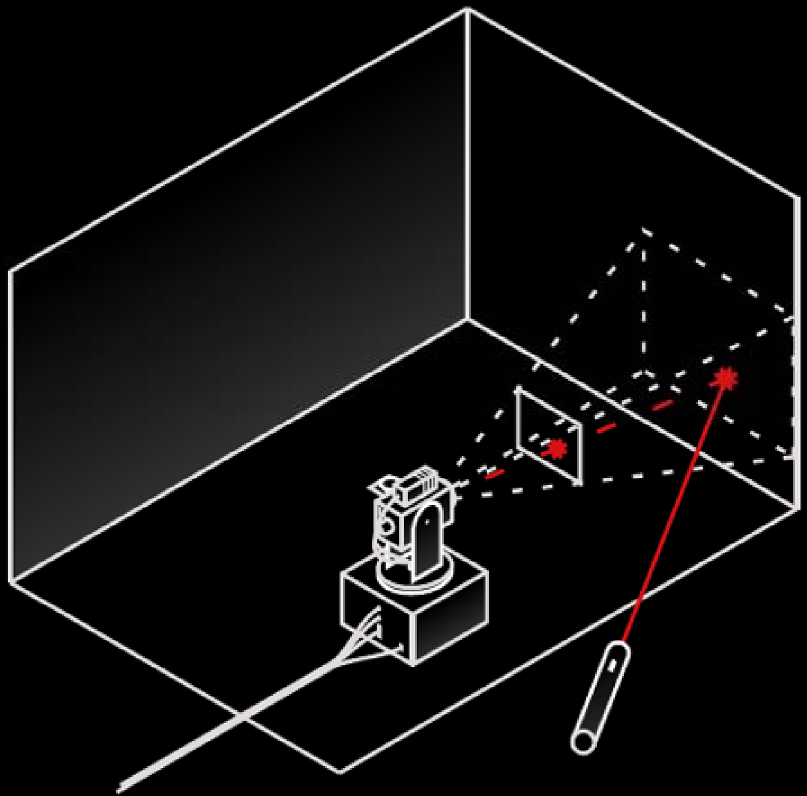
Laser Pointer Tracking





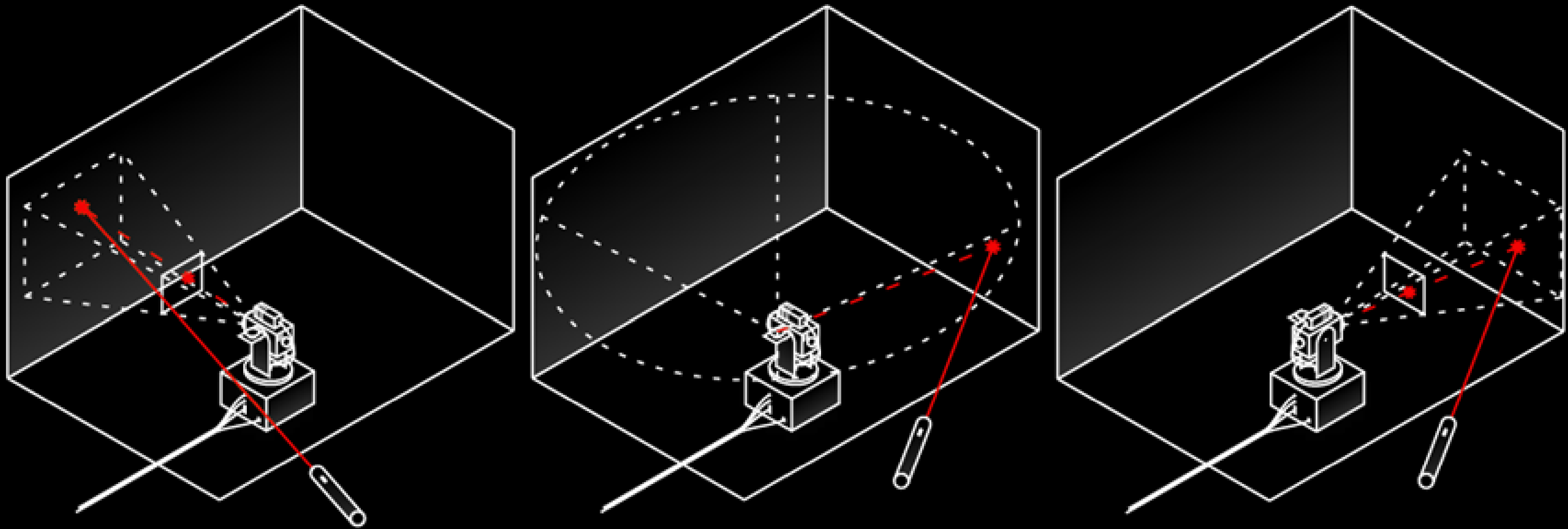
- Laser identification
  - Short exposure to get rid of the background
  - Intensity thresholding
- Critical regions
  - Bright areas (e.g. lights, windows)
  - Masked out by rendering the binary environment map with detail camera settings and multiplying to the current image

Laser Pointer Tracking (cont'd)



- Laser's position on the image plane is known
- Due to known camera parameters, a ray can be defined pointing to that spot
- Intersection of this ray and the environment's geometry serves as the 3D position of the laser

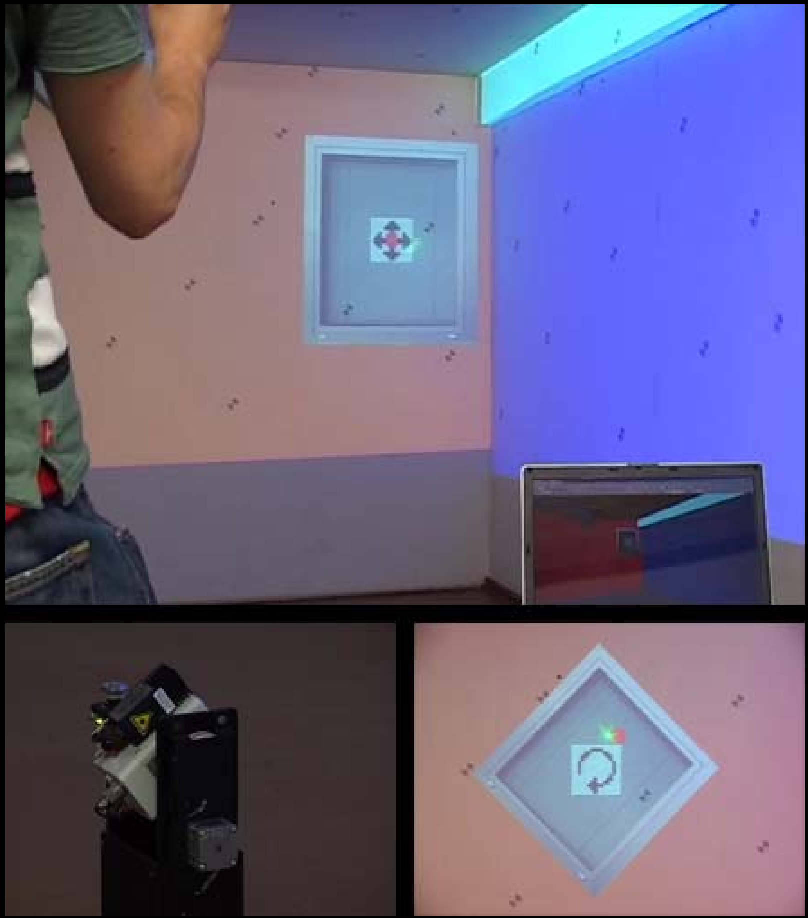
Laser Pointer Tracking (cont'd)



- The detail camera is realigned to center the laser spot when it leaves the central region of the image
- Interplay of detail and context camera
  - If the detail camera loses the spot, the context camera delivers a rough position to realign the detail camera

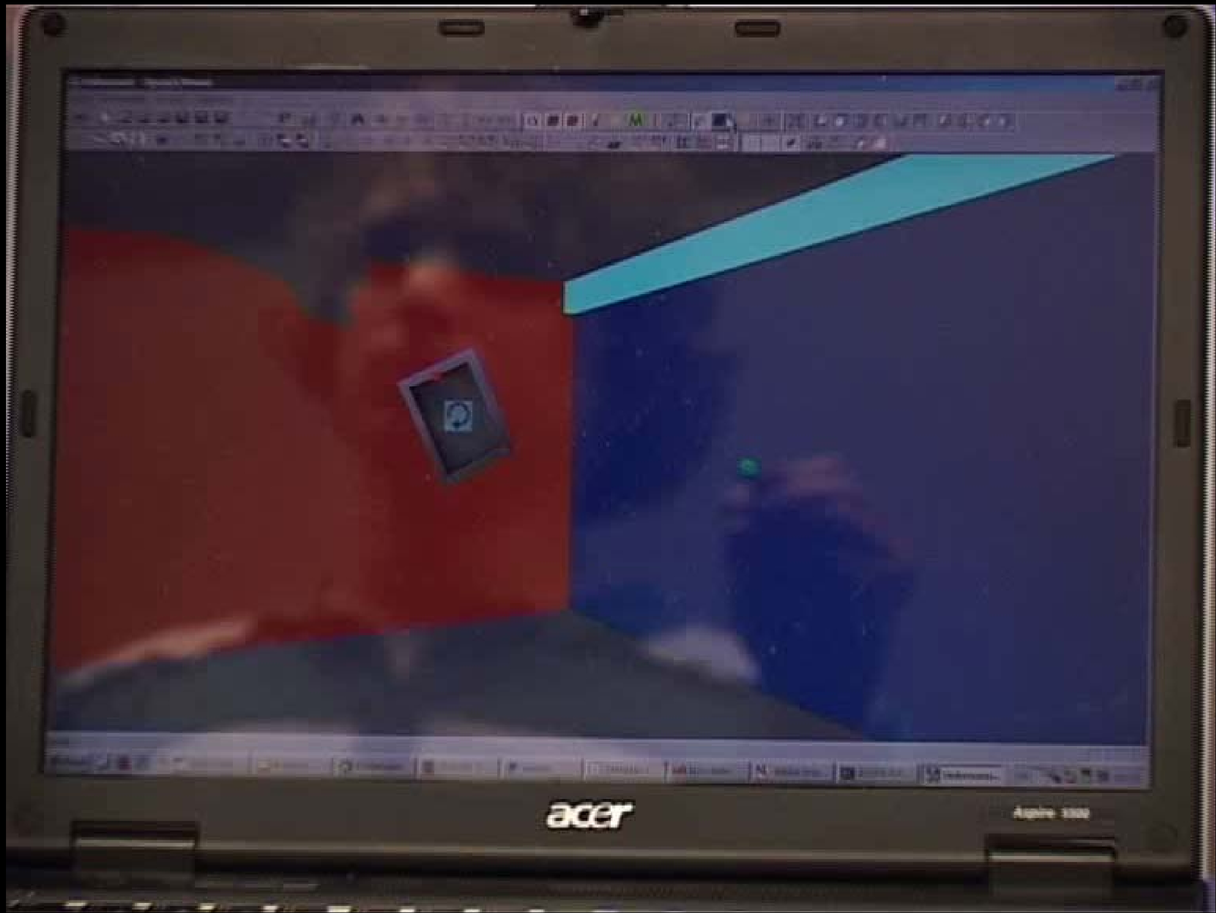
What's all this good for?

Applications

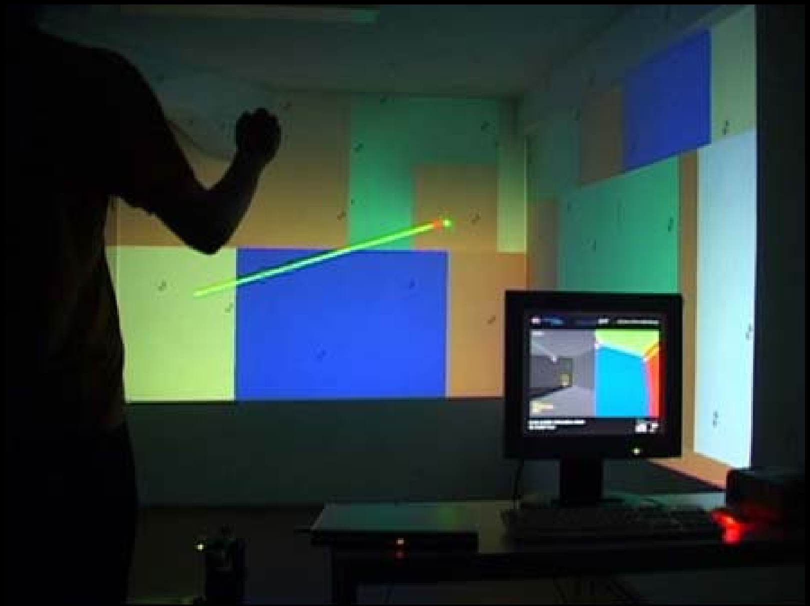


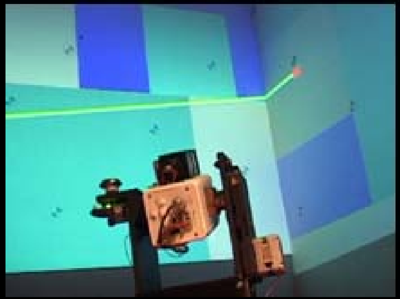
- Demonstrating basic object manipulation
  - Translation
  - Rotation
  - Scaling
- Applies laser pointer tracking and projector-based visualization
- Switching mode using spatial gestures

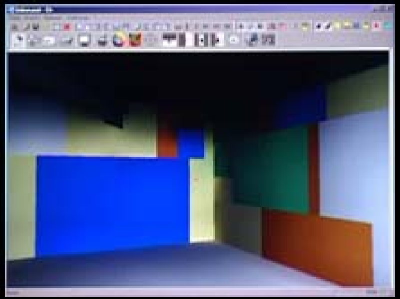
Applications (cont'd)



Applications (cont'd)

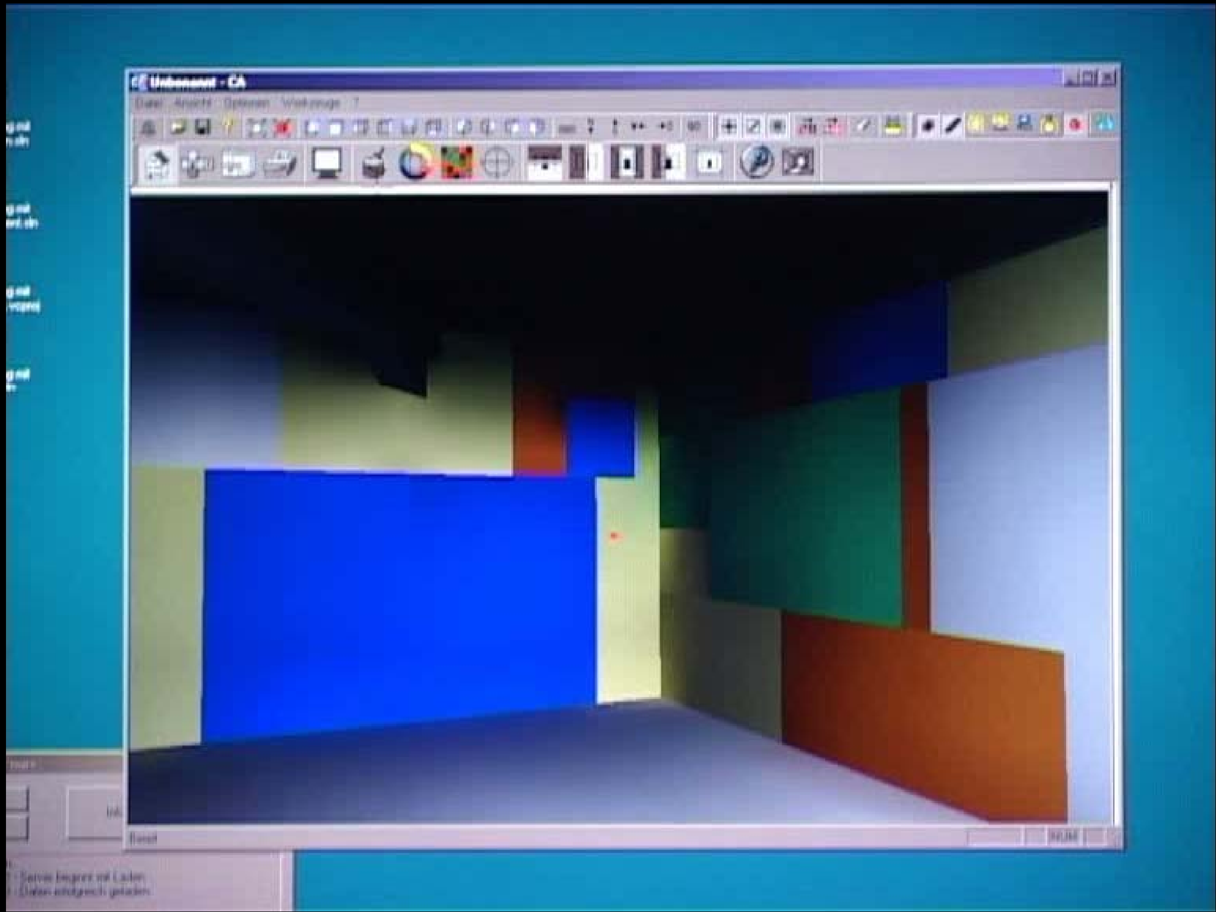






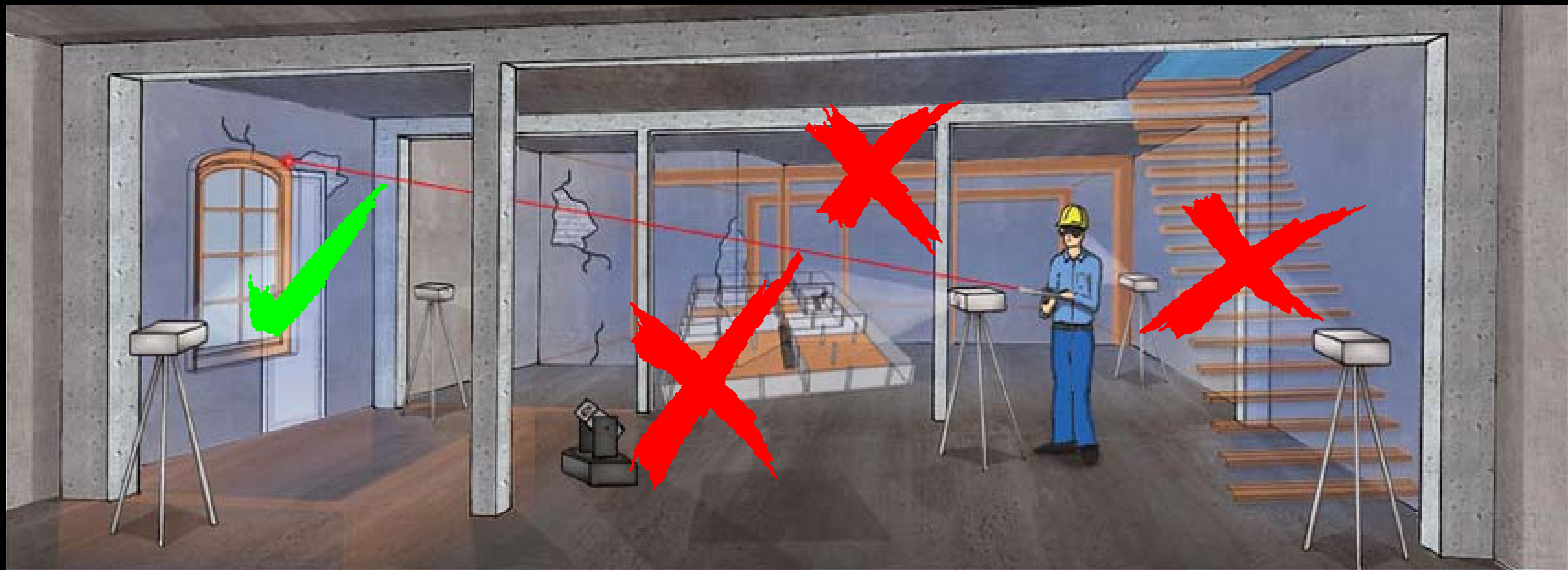
- Colored Architecture[Tonn06]
  - Color and light simulation using real-time radiosity
- On-site planning tool
  - Color drag&drop
  - Replaces time consuming and expensive classical techniques

Applications (cont'd)



Applications in General (so far)

- Interaction directly on the physical surface
- Visualization of structures that lie on the physical surface

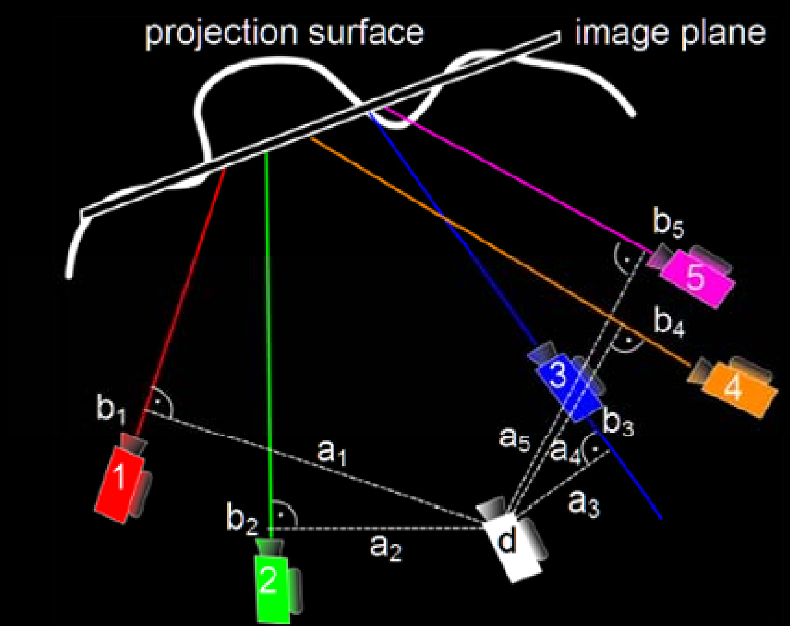


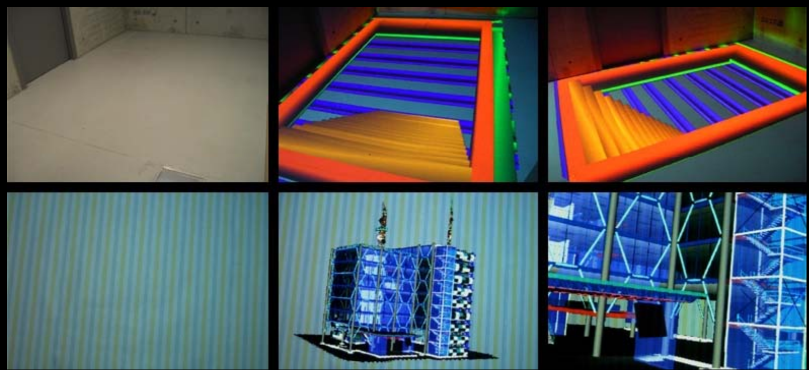
What about floating 3D structures?

Video See-Through

- Augmentation of the whole environment
  - No need for projectors
  - Integrating CG into live video stream
- Required information
  - Camera parameters (intrinsic/extrinsic)
  - Environment's geometry
- Correct occlusions

Stereoscopic Projector-based AR



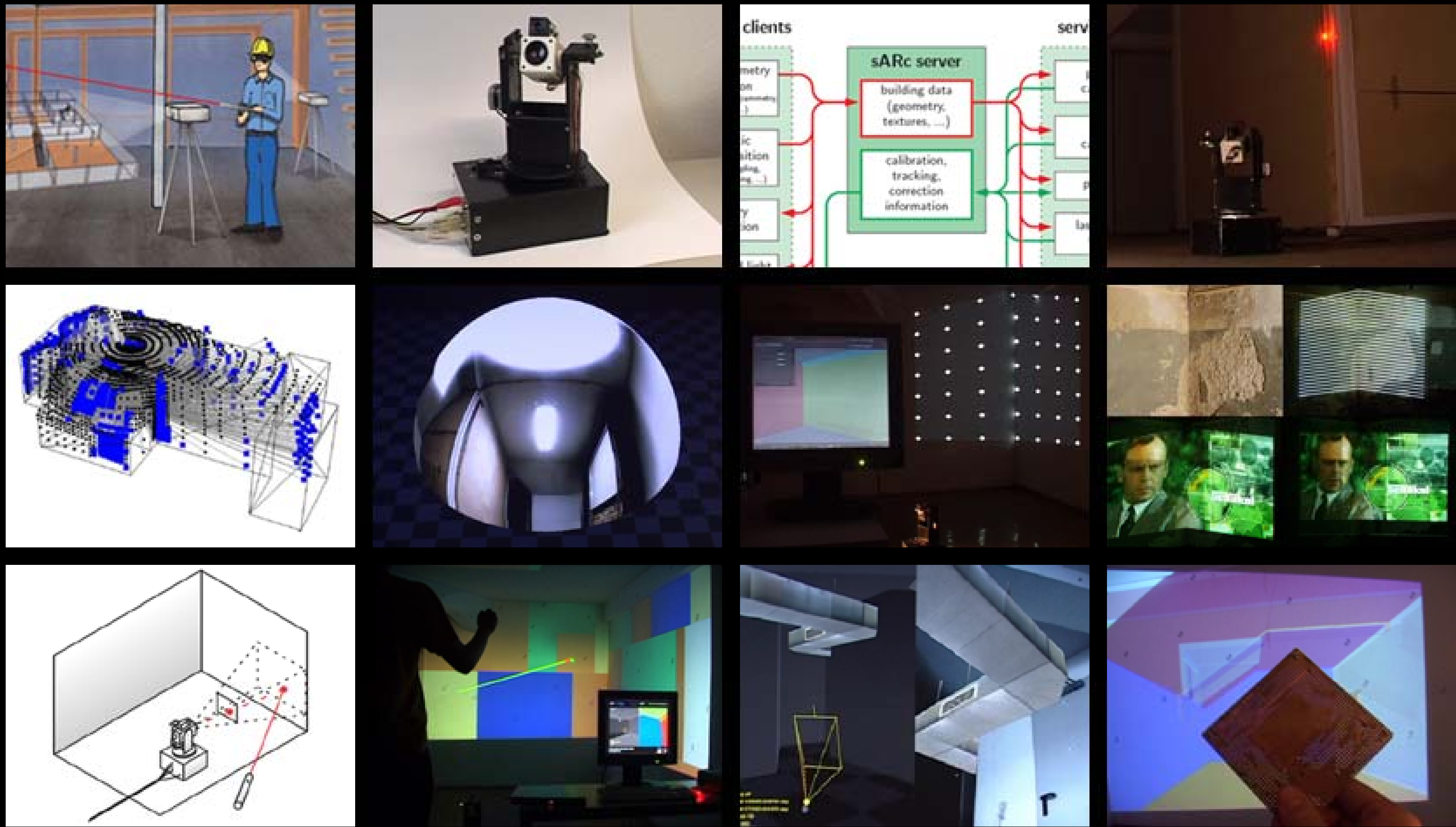


- View-dependent stereoscopic projection in real environments [Bimber05]
  - Geometric warping
  - Radiometric compensation
- Interpolation of pre-calibrated scene parameters
  - Interactive rates
  - On a per-pixel basis
  - Multiple projectors

LED-Marker Head Tracking

- Projector-based approaches require head tracking
- Simple active LED marker is tracked by PTZ camera
- Rough indications of observer's position
- No need for extra tracking hardware!

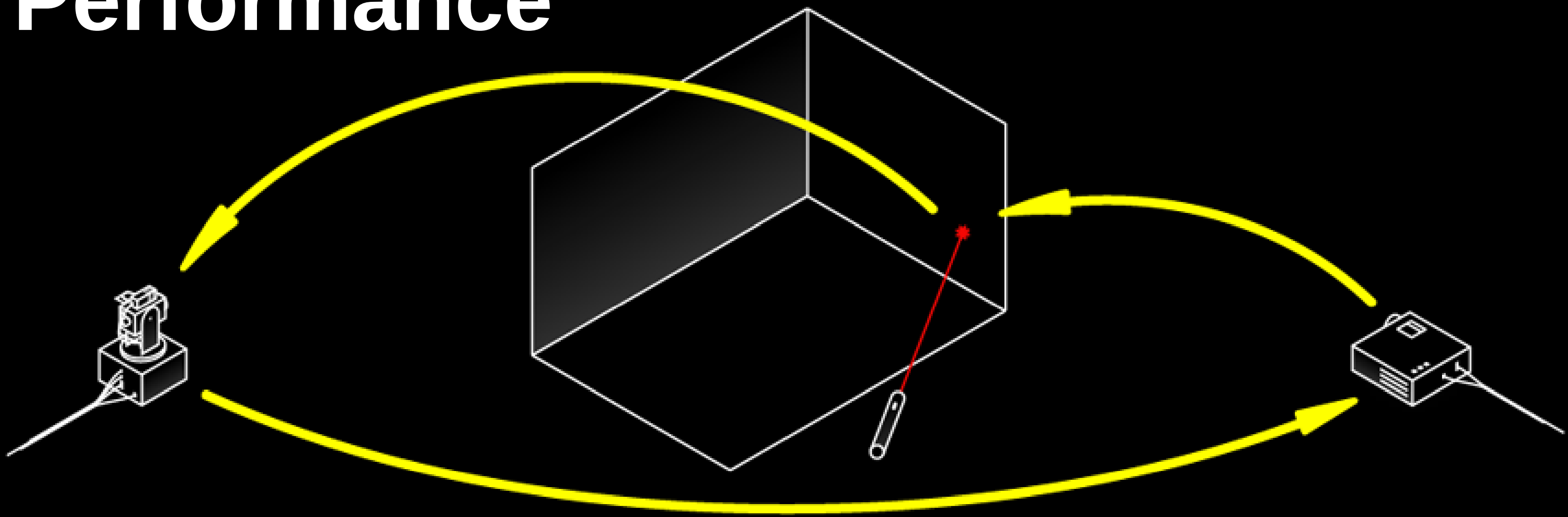
Summary


clients
sARc server
building data (geometry, textures, ...)
calibration, tracking, correction information

Results and Discussion

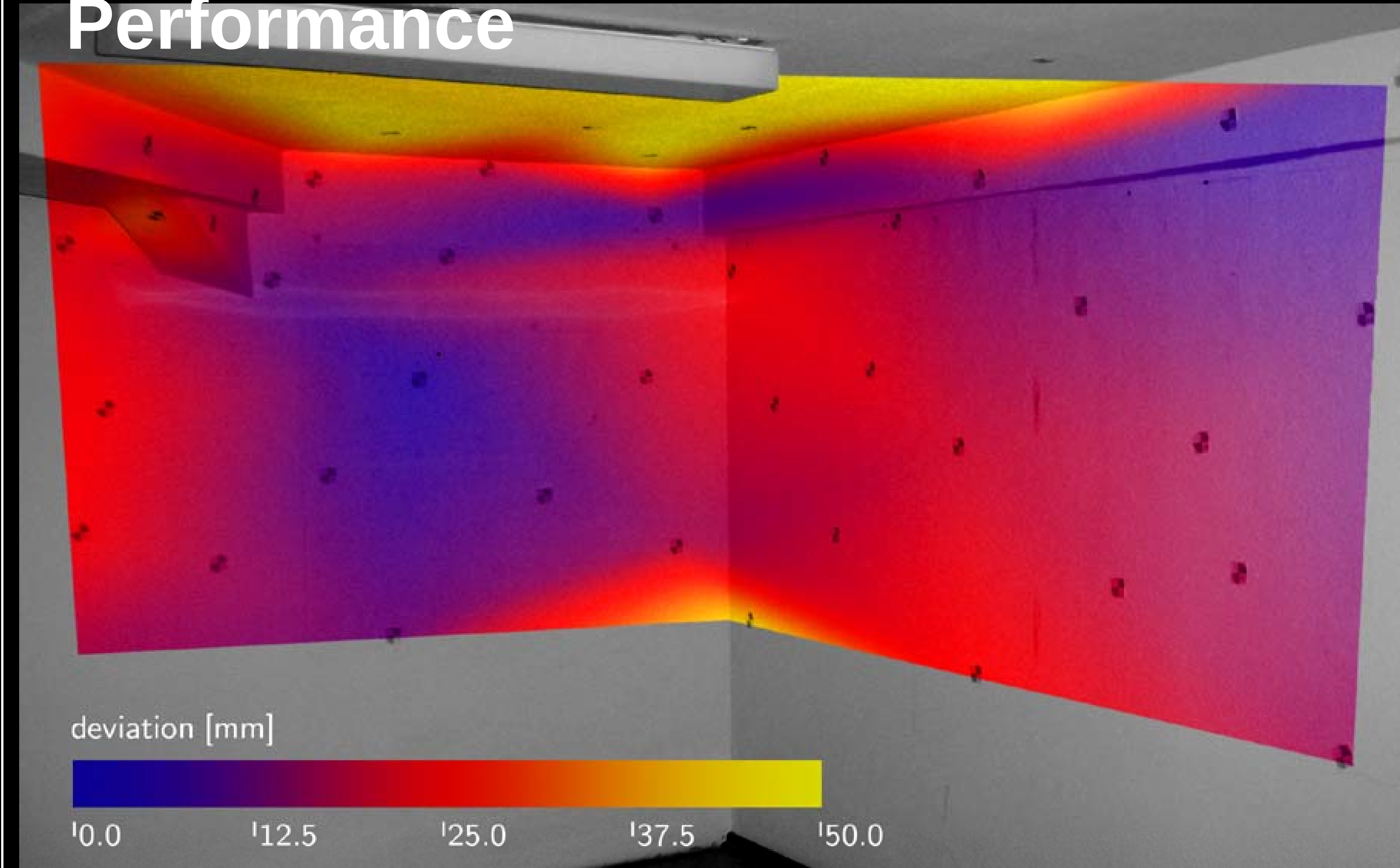
- Results
  - Fully automatic calibration
  - Required for real-world applications
    - Non experts
    - E.g. architects
  - Multi-purpose tool
    - Projector calibration
    - Interaction
    - Video see-through
    - Simple head tracking
- Issues
  - Only one task per time
    - Laser pointer tracking or marker tracking or video see-through
  - Occlusion problems
    - User occluding
    - Occluded surfaces
  - Performance
    - Accuracy
    - Speed and latency

Performance

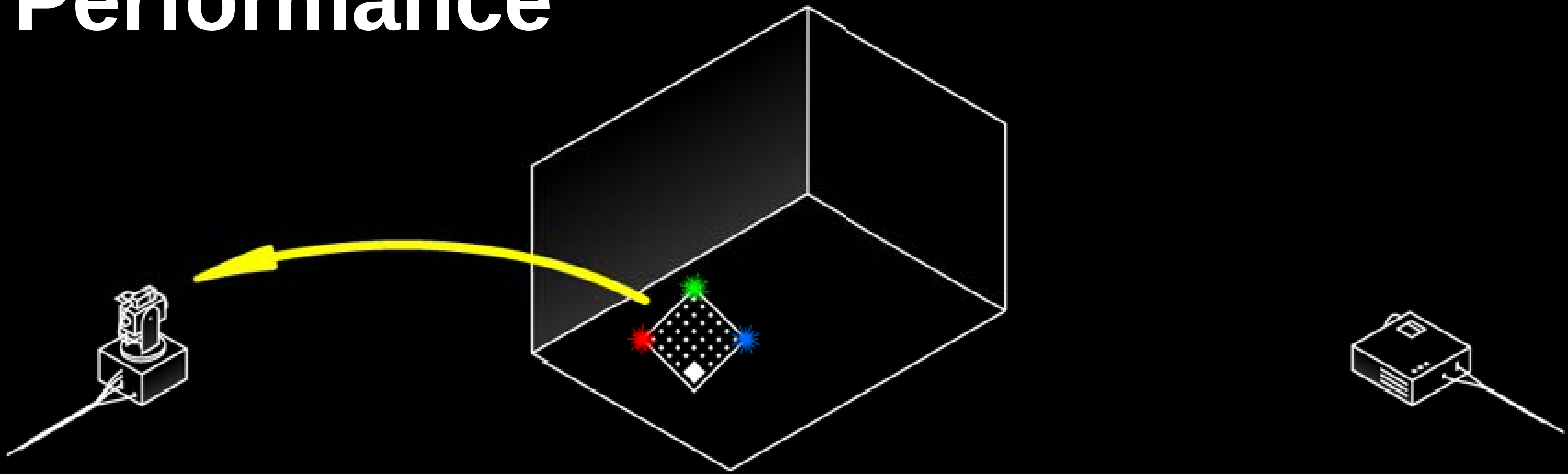


- Camera calibration
  - Takes ~25min
  - Deviation between known 3d points and their tracked position
  - Avg. 0.18deg (8mm @ 2.54m distance)
- Laser pointer tracking
  - Comparing laser dot and cursor
  - Avg. deviation 14mm
  - Latency ~300ms
  - Speed ~30fps
- Projector calibration
  - Takes ~1.5min
  - Deviation between known 3d points and their projection
  - Avg. 0.16deg (10.7mm @ 3.83m distance)

Performance



Performance



- LED marker tracking
  - Avg. deviation 72mm (@2.5m distance)
  - Latency ~300ms
  - Speed ~10fps

Future Work

- Improving the tracking
  - Latency
  - Speed
  - Precision
  - More DOF
- Multiple cameras
  - Cover a larger area
  - Simultaneously track multiple entities
  - Solve occlusion problems
- New prototype
  - PTZ projector-camera system
  - Embedded into tachymeter hardware
  - Single, rotatable system that supports
    - Tracking
    - Scene analysis
    - Projector-based augmentation within the targeted region of interest

Future Work (cont'd)

- Placement techniques for interaction items, considering ...
  - Surface geometry and reflectivity
  - Surface visibility
  - Hand jittering
- New and innovative architectural applications
- New projector-camera enabled interaction tasks e.g. material copy-and-paste
  - Select material samples
  - Scan, analyze, enlarge
  - Re-produced at other surface portions via projector-based AR
- Final user study

Thank you!

▪ References

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[Pinhanez01] C. Pinhanez. *Using a steerable projector and a camera to transform surfaces into interactive displays.*

[Tonn06] C. Tonn and D. Donath. *Color, material and light in the design process -- a software concept.*

[Wienss06] C. Wienss et al. *Sceptre: an infrared laser tracking system for virtual environments.*

Thank you!

- Further information
  - http://www.uni-weimar.de/medien/AR (ARGroup)
  - http://www.sARc.de (Project website)

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