Computer-Aided Collaborative Subway Track Planning in Multi-Scale 3D City and Building Models

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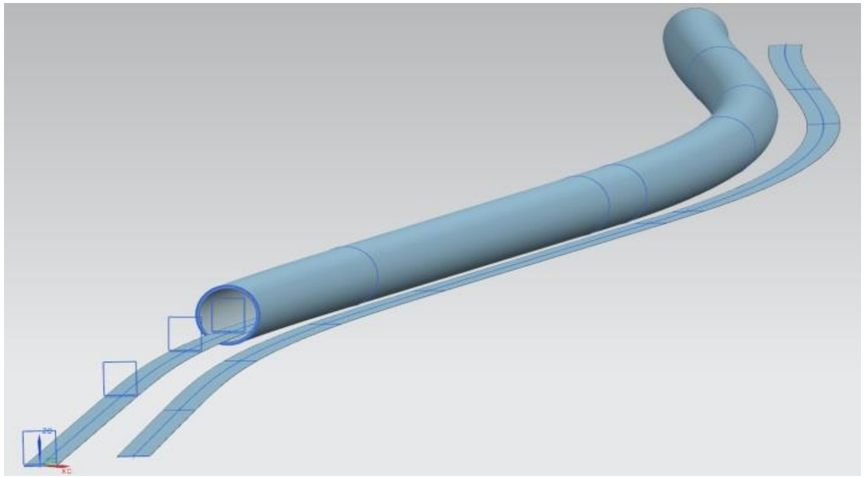
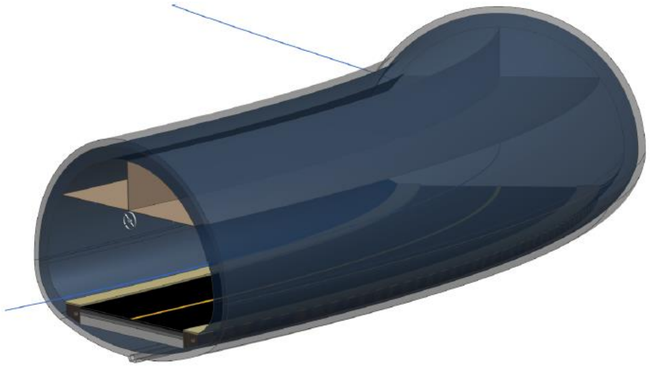


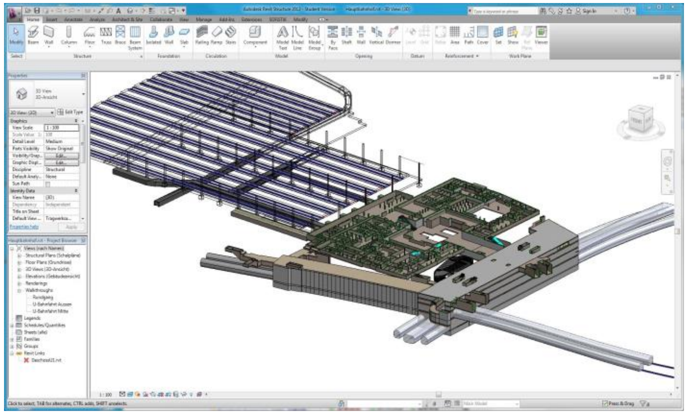
Problem description: planning of inner-city subway track

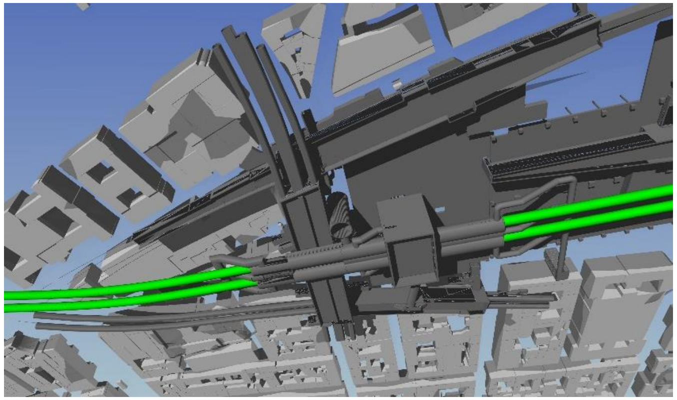
- highly complex planning task
  on different levels of details
- multitude of stake holders
  → demands collaborative planning
  → high risks (time, quality, costs)
- planning mostly 2D-based
  → conflicts are hard to detect
- insufficient incorporation of available
  spatial data sources and building models



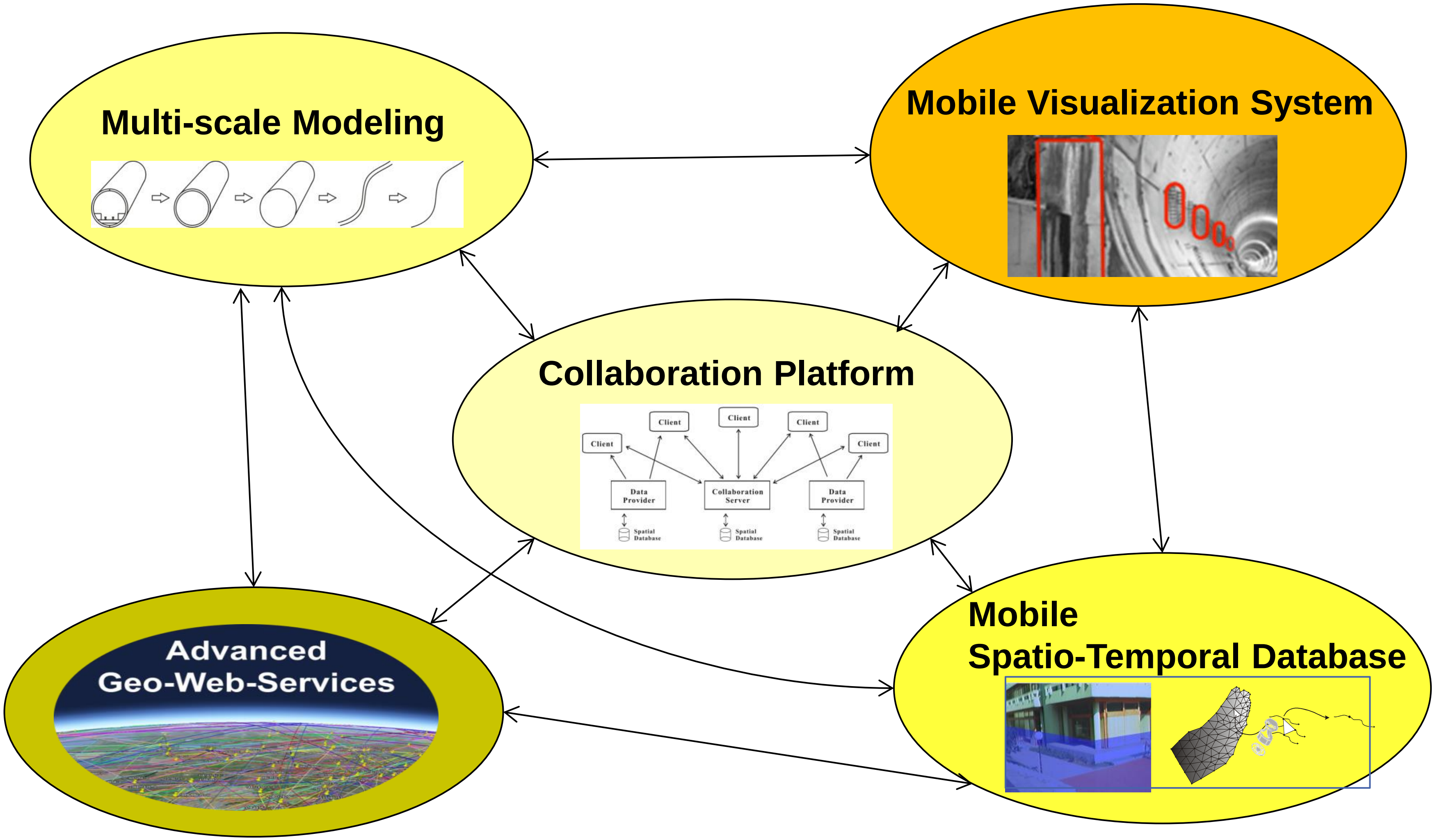
Challenges for 3D Tracks Planning

- **Multi-disciplinary, cooperative work**
  → Methods for synchronous collaboration
- **Different abstraction levels (LoD)**
  → Mechanisms for ensuring consistency between different level of details
- **Persistent storage of complex models**
  → spatio-temporal databases
- **Flexible access to information with geo-reference**
  → Advanced Geo Web Services
- **Evaluation of draft planning on site**
  → Augmented Reality technologies





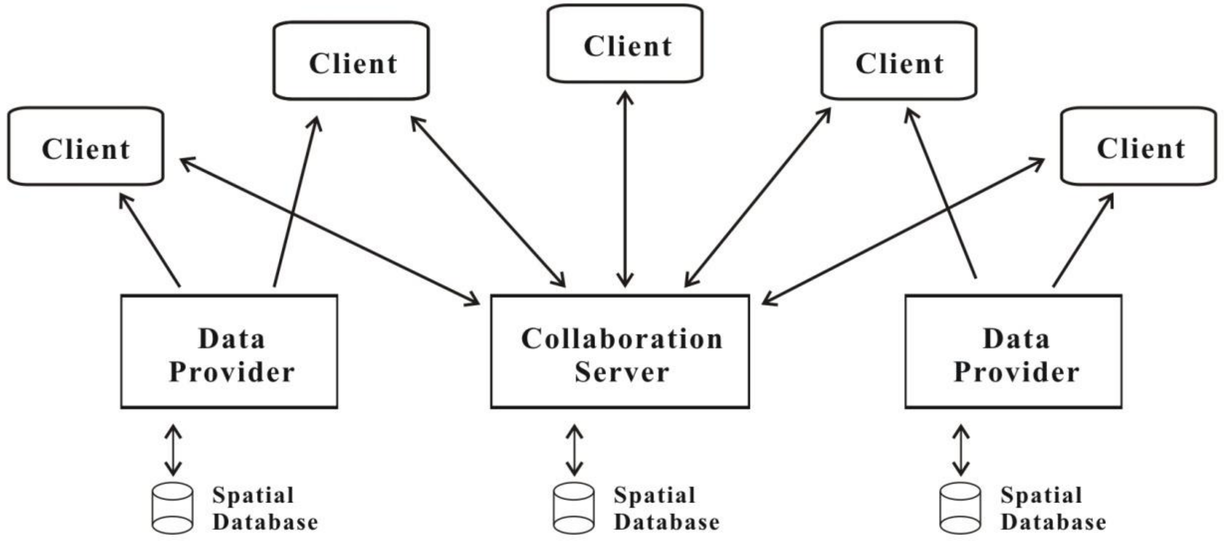
Overview



Multi-scale Modeling
Mobile Visualization System
Collaboration Platform
Client
Client
Client
Client
Client
Data Provider
Collaboration Server
Data Provider
Spatial Database
Spatial Database
Spatial Database
Advanced Geo-Web-Services
Mobile Spatio-Temporal Database

The central component: Collaboration platform

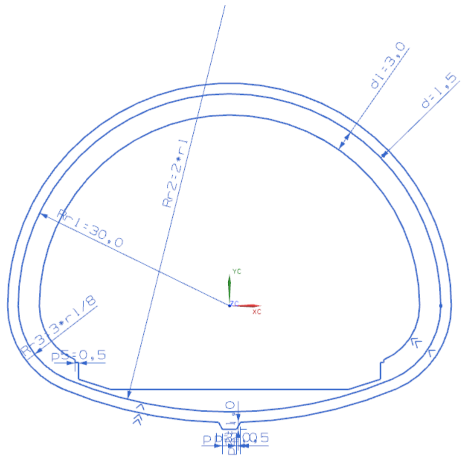
- distributed multi-user system with centralized data management



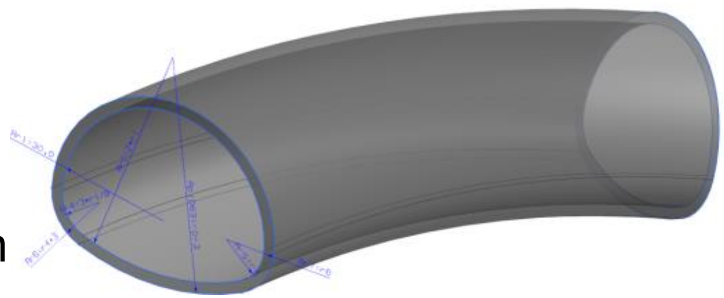
- development of methods for synchronous collaboration
- integration of external (also unknown) data sources during runtime

Geometric modeling during tracks planning process

- **Procedural modeling** supports the process of planning
  - **Paramatric models**
  - Conditions are describing dependencies between entities



- <u>Example</u>:
  - Clothoid describes the course of the tunnel
  - Sketch describes the tunnel cross-section
  - Sweep of the sketch along the clothoid results in tunnel geometry



Construction of multi-scale models

- complex
- time intensive
- error-prone

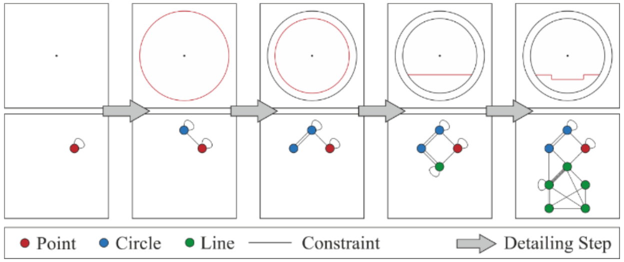
→ automation reasonable and necessary

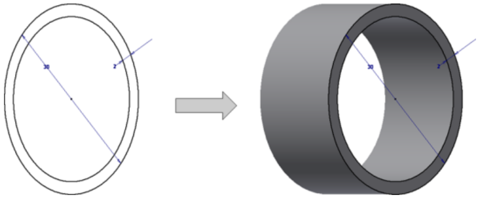
Construction operations have to be formalized with graph replacement rules

Graphs for sketch and procedural model

Sketch graph:

- nodes: geometric elements
- edges: parametric constraints

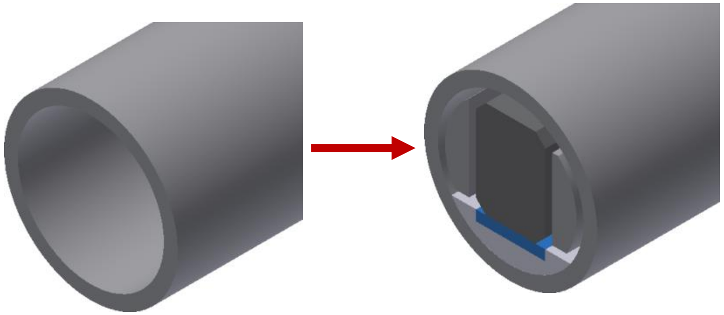


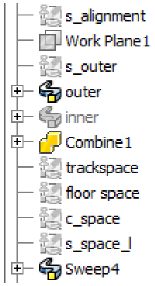


Procedural graph:

- describes construction operations
- Complete process of the construction operations is reproducible

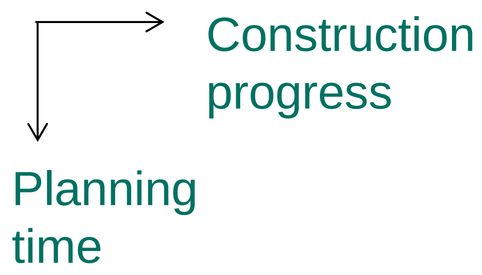
  => construction history





Managing the geometries in space and time:

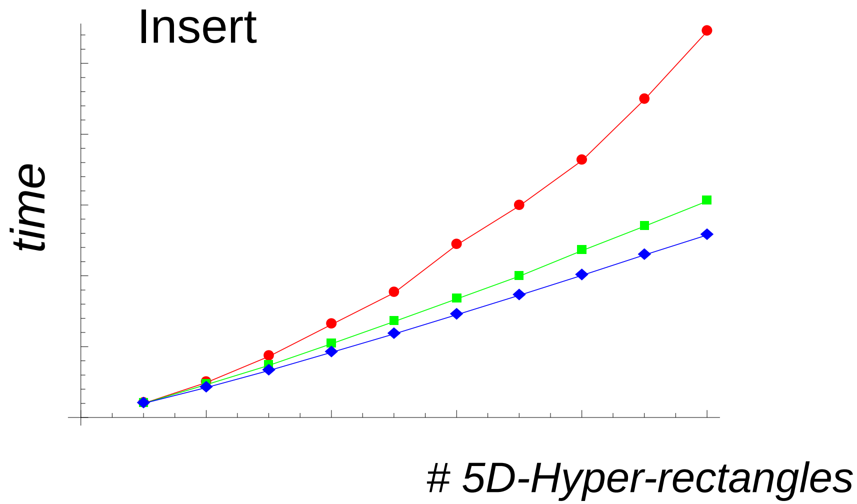
Bi-temporal spatio-temporal index (3D space +2D time)

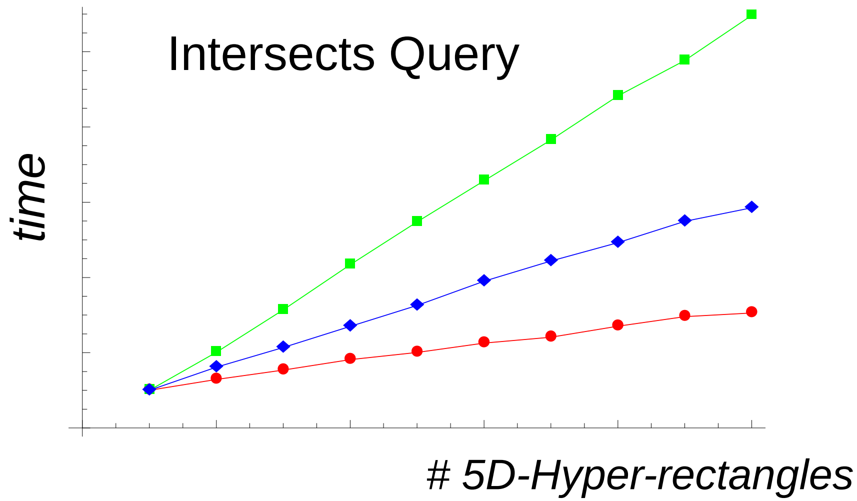


- **Approach:**
  - Divide bounding rectangles into lower and upper boundary points
  - Store both boundary points in parallel working trees
  - Each sub-tree stores n-dimensional points
  - Each point contains pointer to bounding rectangles
  - Both trees return results to the same result set

Performance tests

- Real-world data:
  part of city models from
  Karlsruhe und Munich city
  repeatedly multiplied

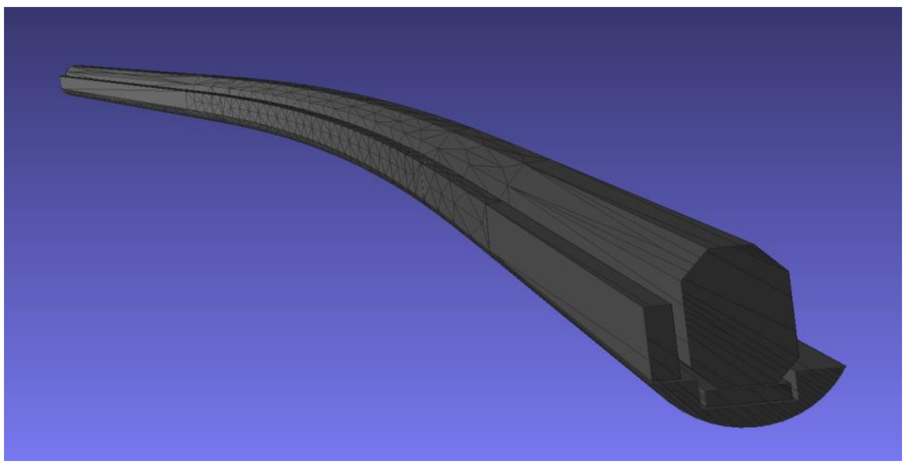




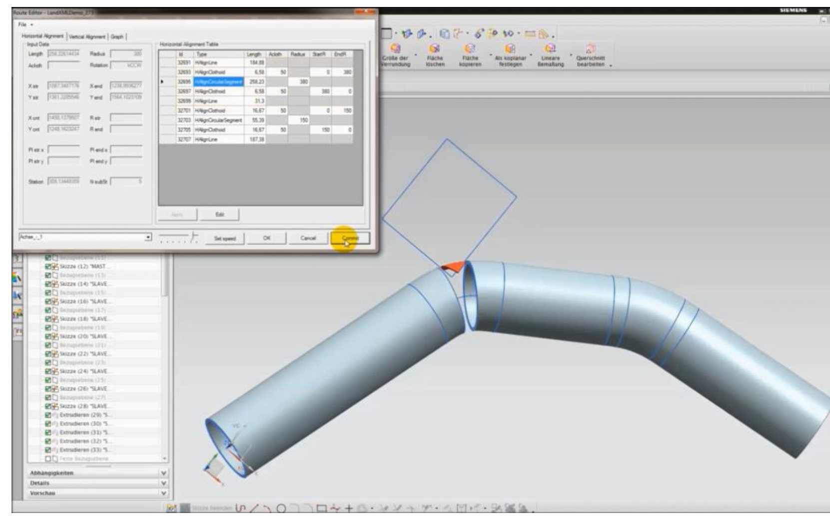
R-Tree
R*-Tree
new structure

Model integration on the basis of Geo-Web-Services

- Web services for model integration (IFC standard => CityGML standard)
  - ➔ Consistency checks (e.g. overlap with existing building stock)



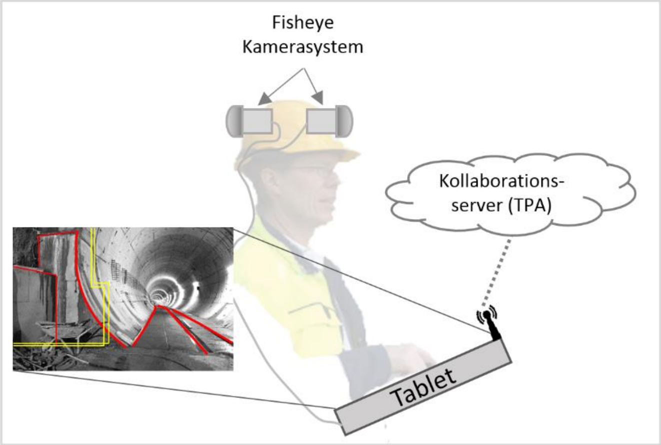
Triangulated tunnel geometry

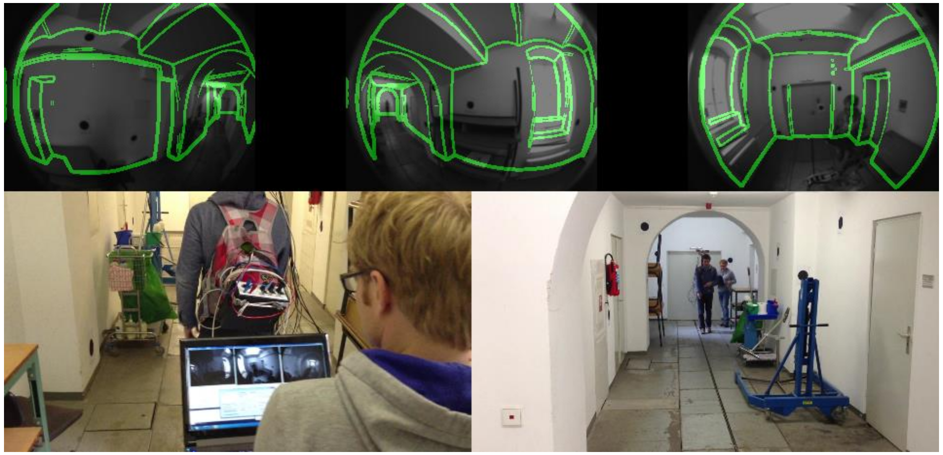


Intersection with underground structures

Augmented Reality methods for in-sito visualization

- Design and implementation of multi-fisheye camera system
- Methods development for
  - Calibration of the camera system
  - Online in-sito visualization of objects
  - (Self-) Initialization / localization of the system without GPS





Outlook: Transfer to the Gulf Region

- **IT methods needed for infrastructure projects**
  - 3D modeling of natural and built environment
  - 3D database to support spatial planning
  - Multi-scale modeling
  - Augmented reality methods