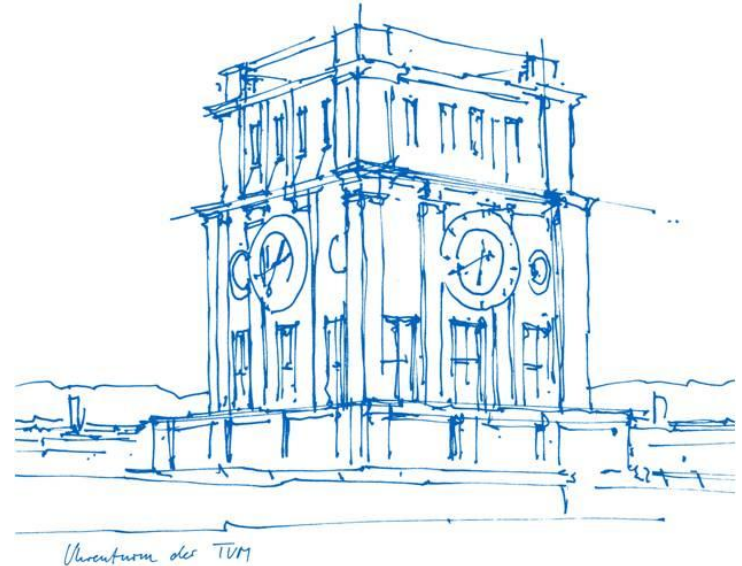


# XR4GeoData: Geovisualization with Immersive Environment

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# Introduction

TU Munich – Chair of Big Geospatial Data management current research:

- science of geometric and spatial data (data science)
- spatial machine learning, big data, and high-performance computing
- time series analysis and trajectory computing,
- social network analysis,
- indoor location-based services.



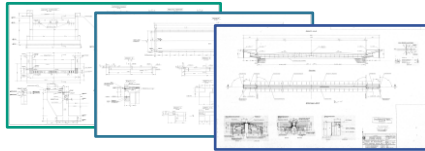
PhD research (Uni Freiburg/ Fraunhofer IPM):

- Multi-data Fusion for 3D reconstruction of Complex Structures (Bridges).

Postdoc research:

- Geospatial multi-sensor data acquisition, Human Computer Interaction  
4D spatial data analysis.

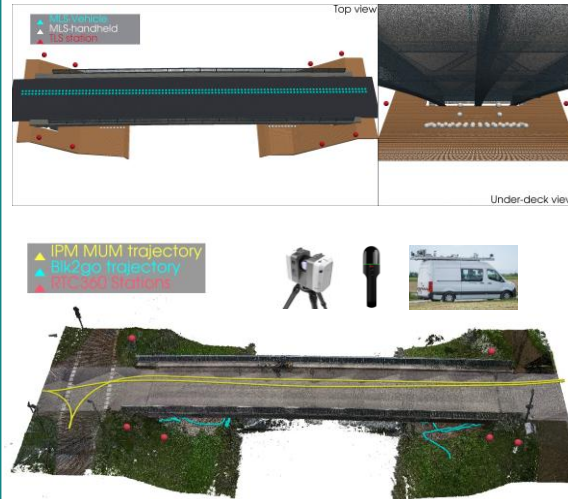
## Plan2Model: Reconstruction Synthetic Spatial Data.



Semi-automated reconstruction of up-to-scale synthetic 3D point cloud with semantic information from structural plans.

Poku-Agyemang, Kwasi Nyarko, and Alexander Reiterer. "3D reconstruction from 2D plans exemplified by bridge structures." *Remote Sensing* 15.3 (2023): 677. DOI: <https://doi.org/10.3390/rs15030677>

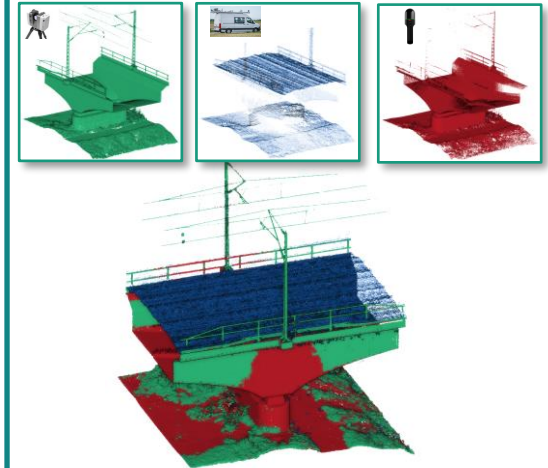
## Plan4Scan: Optimization of Spatial Data Acquisition



Efficient and informed data acquisition to maximise levels of details, accuracy, precision and completion of complex scenes.

Poku-Agyemang, Kwasi Nyarko, and Alexander Reiterer. "Model-based planning of complex 3D laser scanning campaigns for bridge digitisation." *Automation in Construction* 177 (2025): 106289.

## Weighted Point cloud Fusion



Remove duplications, redundancy and noise from spatial data while maintaining details and completion and improve accuracy.

Poku-Agyemang, Kwasi Nyarko, and Alexander Reiterer. "Weighted Multiple Point Cloud Fusion." *PFG-Journal of Photogrammetry, Remote Sensing and Geoinformation Science* (2025): 1-14. DOI:<https://doi.org/10.1007/s41064-024-00310-1>

## Geospatial Data Acquisition.



- Improvement in measurement techniques
- Improvement in precision, accuracy and details
- Increased data volumes from **KB** to **PB**

## Geospatial Data Management.



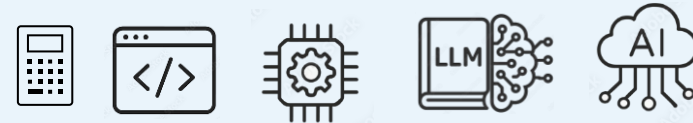
- Improvement in data storage, centralization and distribution
- Expanded data modalities and improve data formats
- Migration to Big Geospatial data management.

## Geospatial Data Communication.



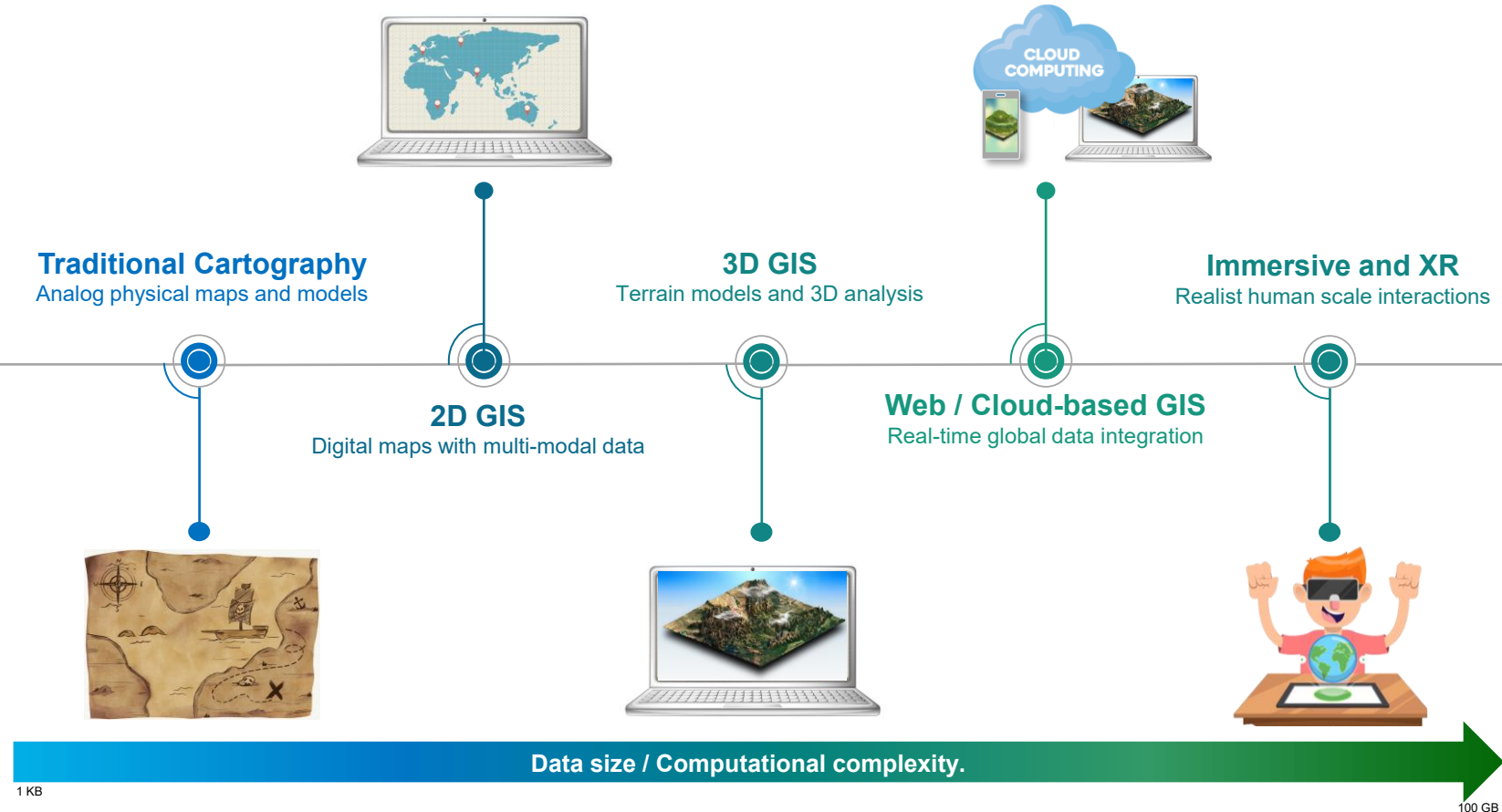
How can the communication of geospatial data be improved through advancing **visualization of geospatial data**?

## Geospatial Data Analysis.

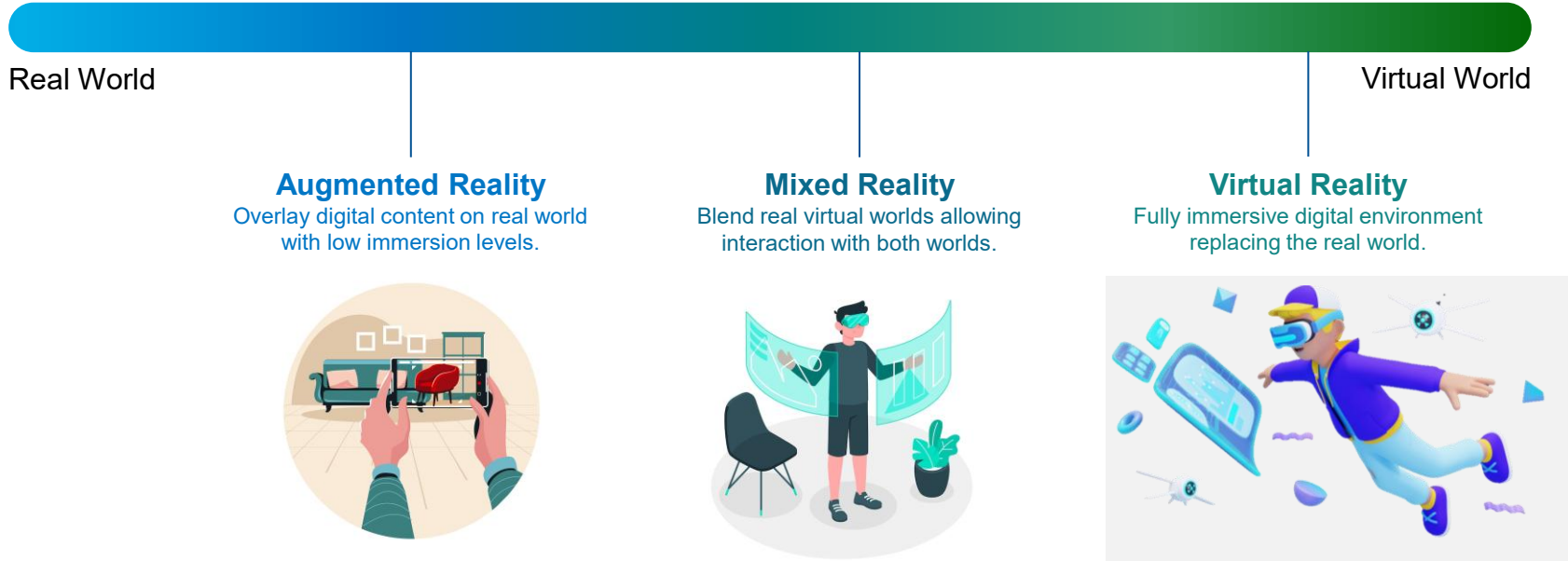


- Improvement in efficiency of data processing.
- Automation and real-time data analysis with advanced ML and DL models for simulation and predictions.
- **HPC** and cloud computing for big data analysis.

# Geospatial Data Visualization



# Extended Reality





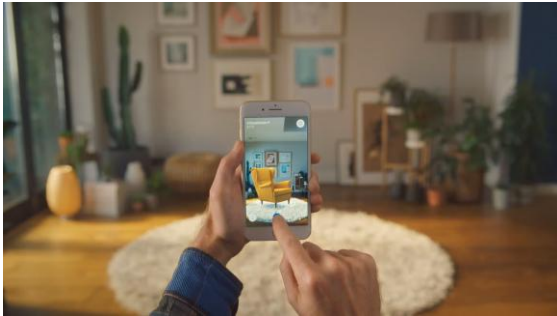
# Geovisualization and Augment Reality

## Application in Geoscience:

- Indoor navigation.
- Underground utilities visualization
- Spatial planning: IKEA

## Open research / application:

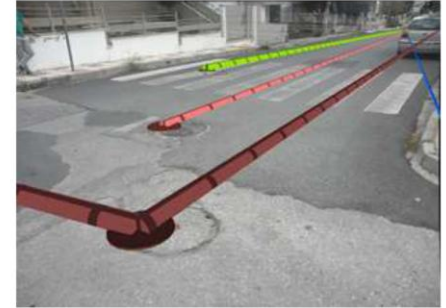
- Data acquisition: position of sensors.
- Engineering and construction: virtual setting out of designs.



IKEA Place app



Dickmann, Frank, Julian Keil, Paula L. Dickmann, and Dennis Edler. "The impact of augmented reality techniques on cartographic visualization." *KN-Journal of Cartography and Geographic Information* 71, no. 4 (2021): 285-295.



(a)



(b)

Stylianidis, E., Valari, E., Pagani, A., Carrillo, I., Kounoudes, A., Michail, K. and Smagas, K., 2020. **Augmented reality geovisualisation for underground utilities.**

# Geovisualization and Mixed Reality

## Application in Geoscience:

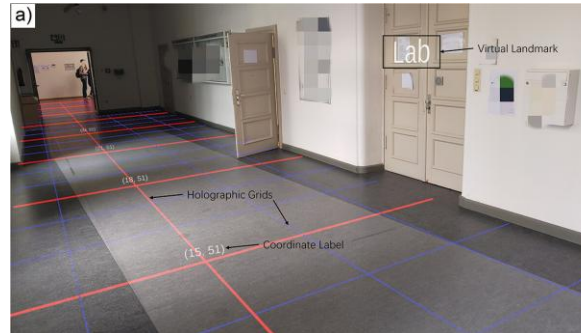
- Dissemination of Complex 3D models.
- Enhance surveying knowledge.
- Bridge monitoring and inspections.

## Open research / application:

- Data acquisition: occlusion analysis.
- Engineering and construction: collaborative analysis of scenes.



Janeras, M., Roca, J., Gili, J.A., Pedraza, O., Magnusson, G., Núñez-Andrés, M.A. and Franklin, K., 2022. Using mixed reality for the visualization and dissemination of complex 3D models in geosciences—application to the Montserrat massif (Spain). *Geosciences*, 12(10), p.370.



Wang, S. *et al.* (2024) 'Mixed reality-based coordinate system for enhancing survey knowledge acquisition: a study on allocentric and egocentric perspectives', *Cartography and Geographic Information Science*, 52(2), pp. 160–180. doi: 10.1080/15230406.2024.2409915.



"Digitale Zwillinge Vorantreiben: Besprechungen in Virtuellen Umgebungen." customQuake. Accessed September 12, 2025. <https://www.customquake.de/case-studies/mdfBIM+.html>.



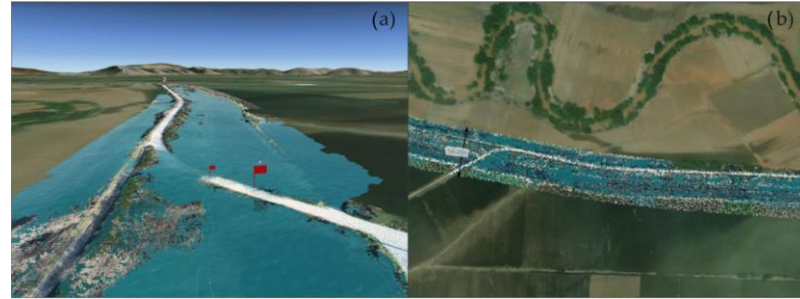
# Geovisualization and Virtual Reality

## Application in Geoscience:

- Simulation of Flooding from LiDAR data.
- Point cloud annotation.
- Multi-temporal geological monument.

## Open research / application:

- Large scale Geodata visualization
- Multi-modal data visualization.



Papadopoulou, E.E. and Papakonstantinou, A., 2024. Combining Drone LiDAR and Virtual Reality Geovisualizations towards a Cartographic Approach to Visualize Flooding Scenarios. *Drones*, 8(8), p.398.



Franzuebbers, A., Li, C., Paterson, A. and Johnsen, K., 2022, December. Virtual reality point cloud annotation. In *Proceedings of the 2022 ACM symposium on spatial user interaction* (pp. 1-11).



Papadopoulou, E.E., Papakonstantinou, A., Kapogianni, N.A., Zouros, N. and Soulaellis, N., 2022. VR multiscale geovisualization based on UAS multitemporal data: The case of geological monuments. *Remote Sensing*, 14(17), p.4259.

## Challenges:

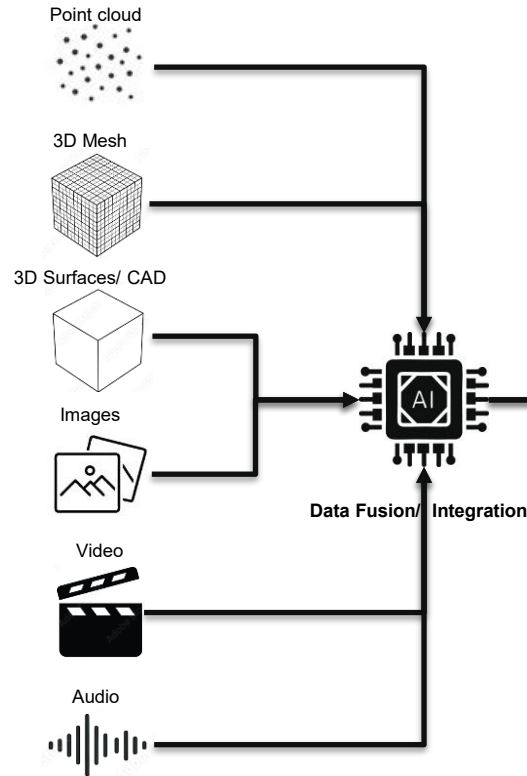
- Restricted to small scale datasets and simplified scenes
- Single data modality (Point cloud, mesh, ...)
- Limited local computational and visualization capabilities
- Limited to single user/player visualization.
- Scalability and continuous implementation.

## Research question:

How can a cloud-based framework be designed to enable scalable, **multi-user immersive** geovisualization of large-scale, multi-modal geospatial data with **efficient interaction support**?

# XR4GeoData: TUM-BGD Pipeline

## Multi-modal Data



## Data Management System



## Data Processing and Modelling

## Data Visualization / Interaction



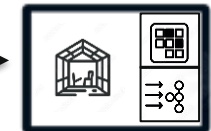
## Desktop/ Web-based



## Extended Reality



## Mobile-based device





# XR4GeoData: TUM-BGD VR Initial Result



- Improve data streaming with smart data retrieval for Big Point cloud data.
- Explore other modalities eg. Meshes, CAD, 2.5D Images and 360 images.
- Develop AR/ MR visualization tool for interactive geospatial data communication.
- Explore HPC + GPU clusters for real-time multi-user/player modelling and geometry update.
- Publish the first version for the Geoscience community.
- Evaluation of immersive technology and geospatial data communication.

Thank you

