

Digital Twins in Virtual Worlds



JOANNEUM
RESEARCH
DIGITAL 

Werner Bailer

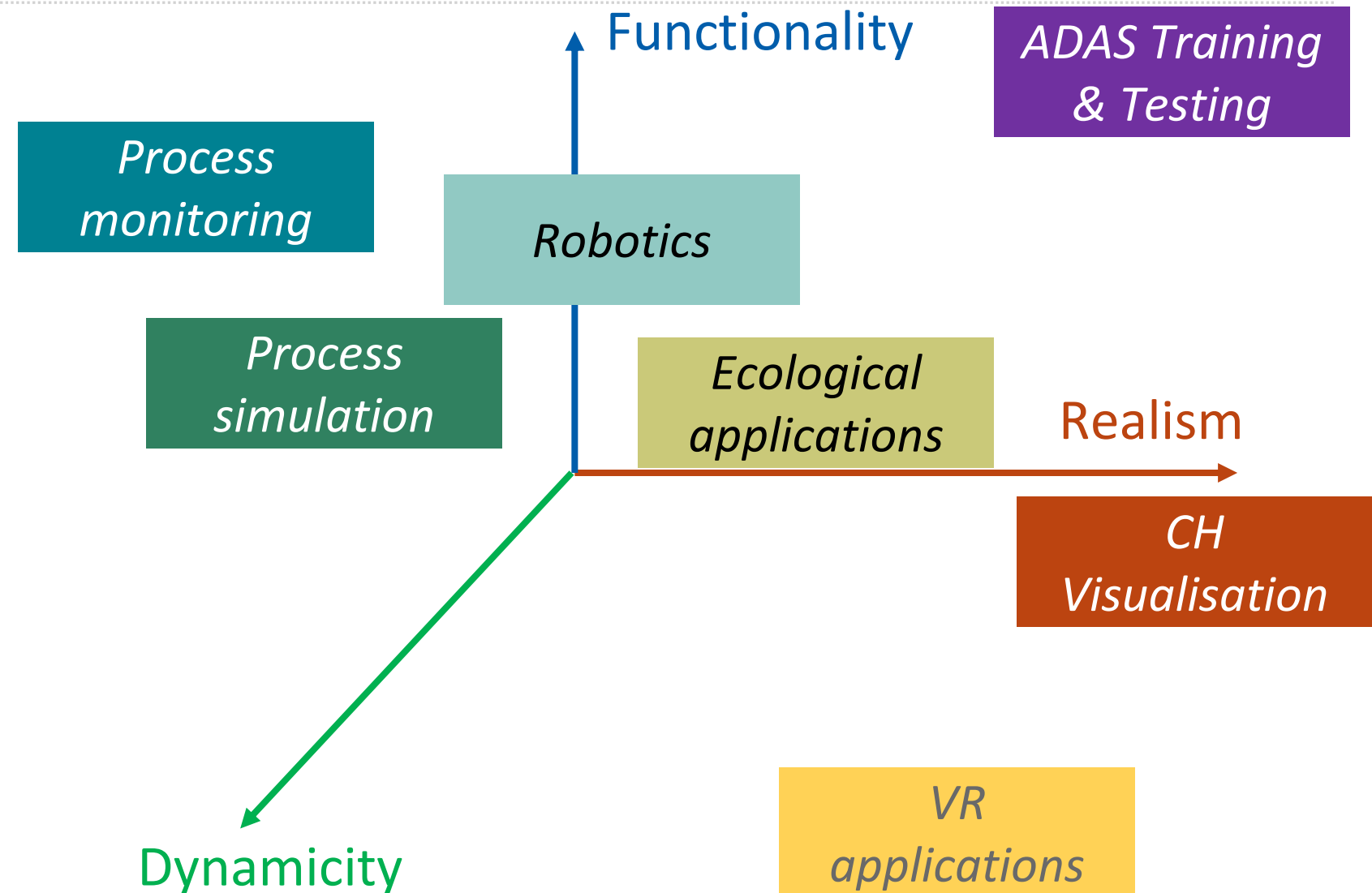
NEM Summit
Brussels, Oct. 2024

DIDYMOS XR
δίδυμος

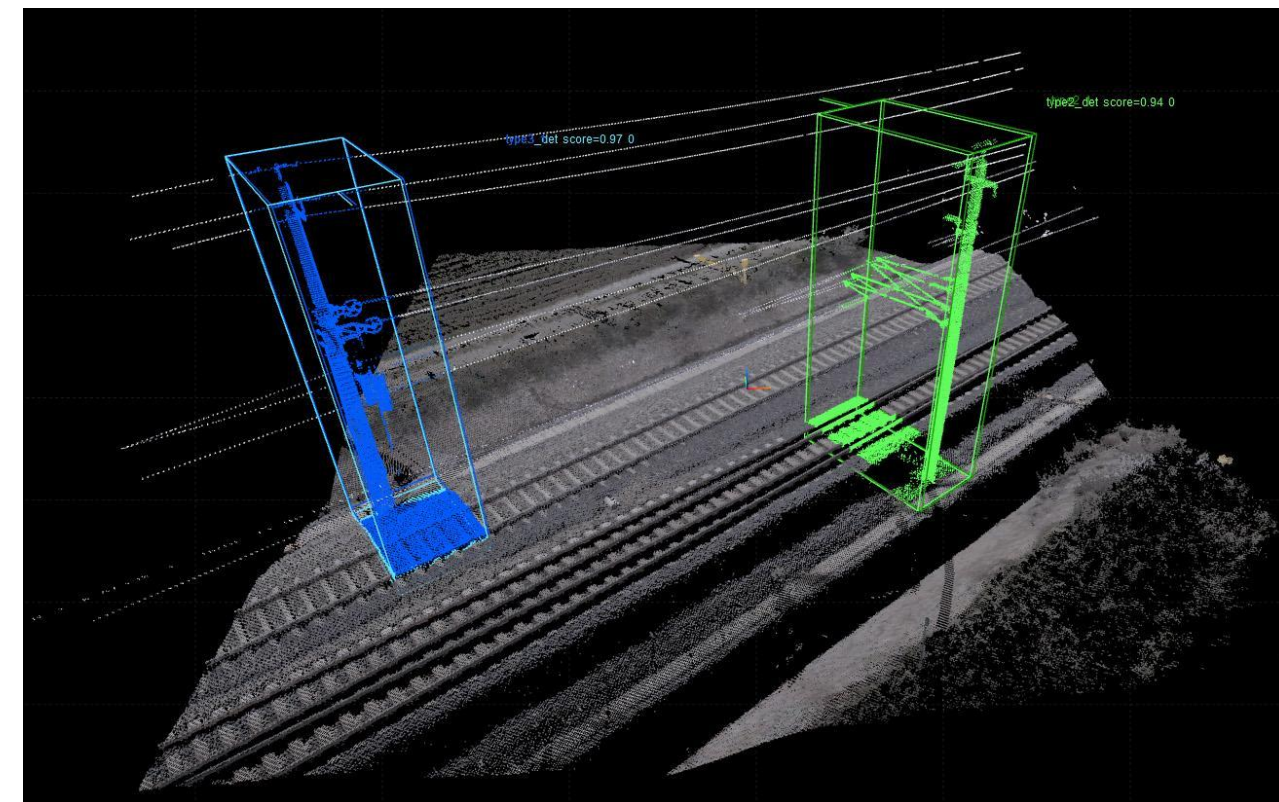
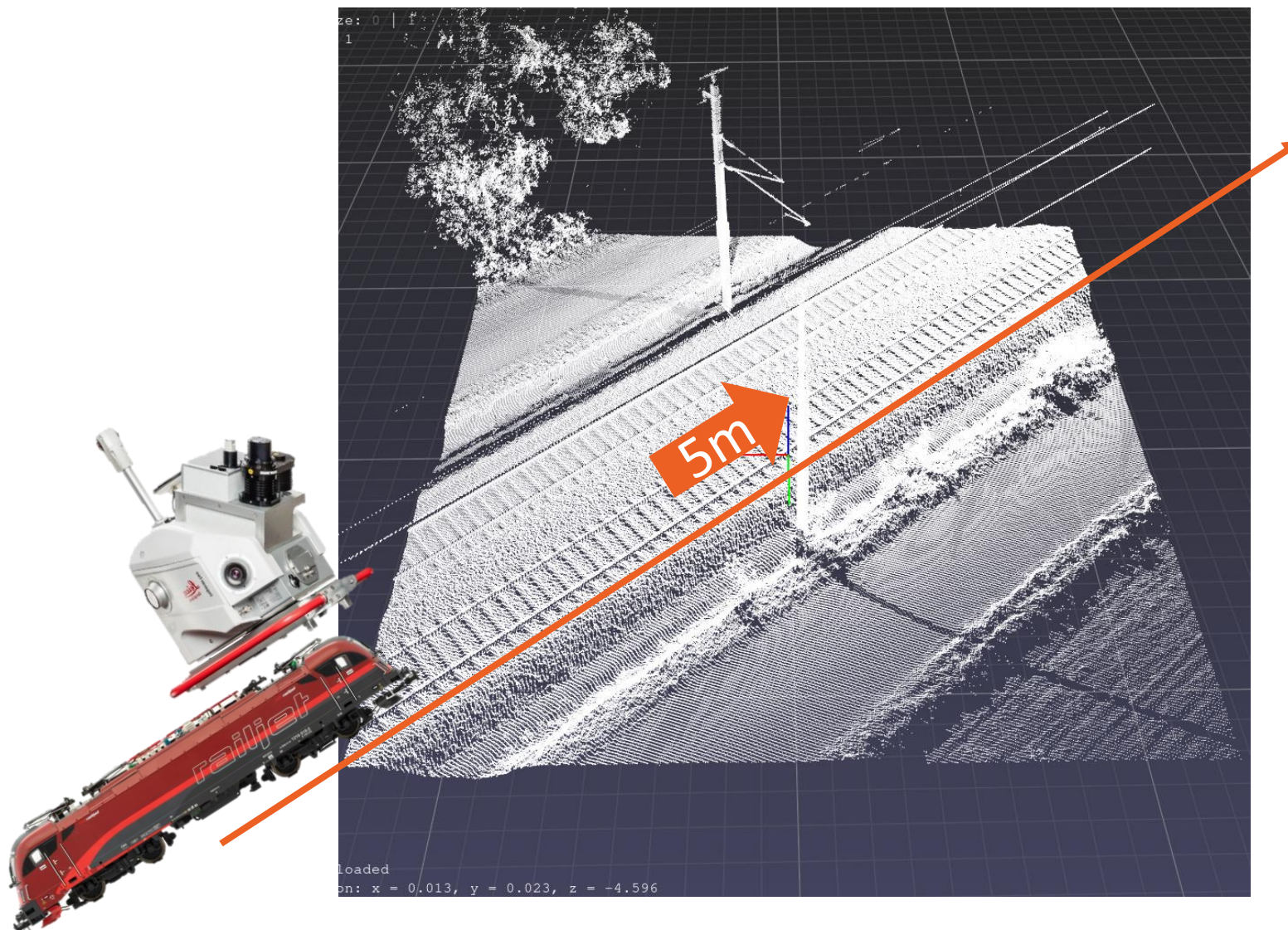
Digital Twins

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- Used in many domains
- Specific focus strongly depends on application

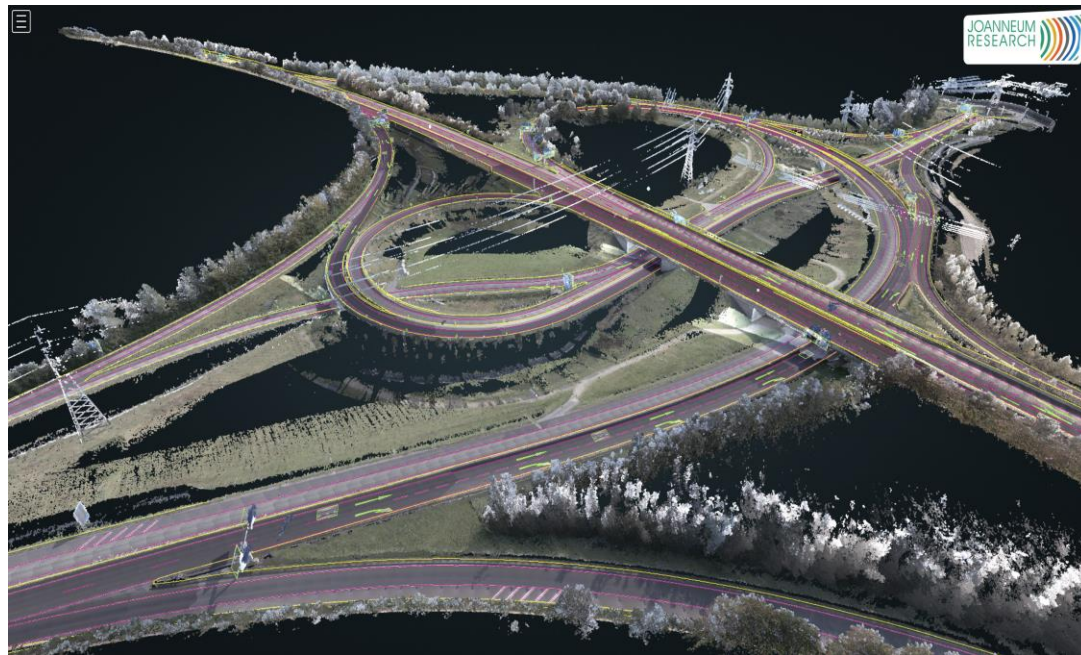


Example: Railway infrastructure

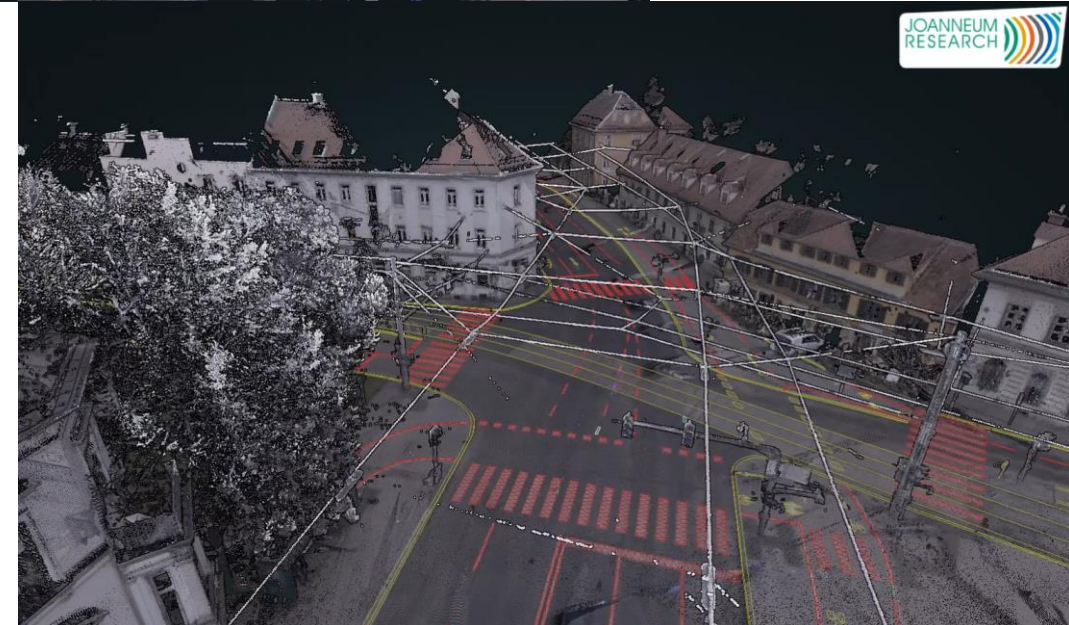
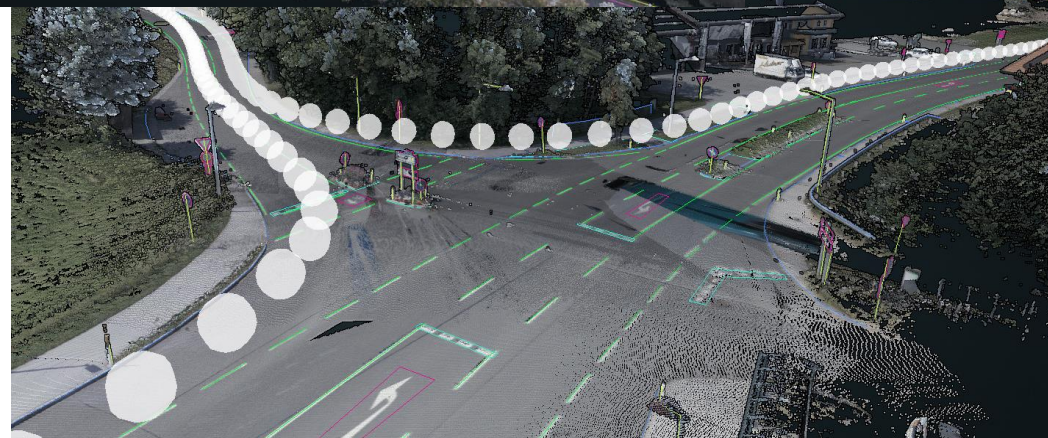




Examples: ADAS/AD testing, Traffic monitoring

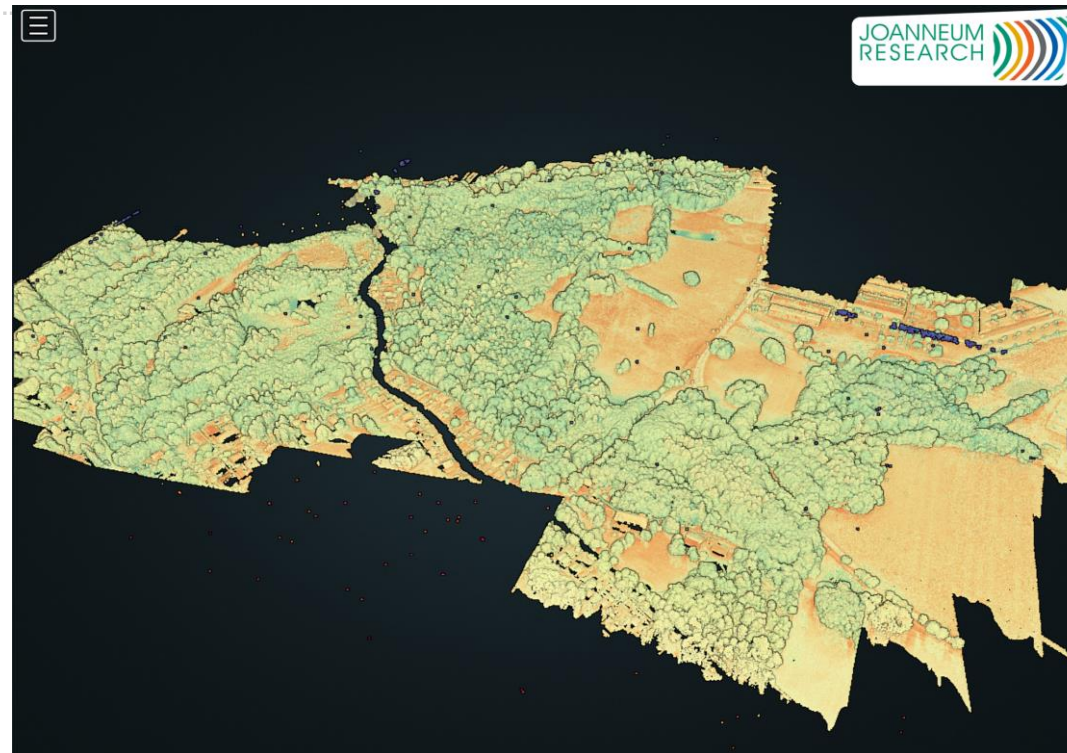


GRAZ



Examples: Ecosystem documentation Spread of neophytical species

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 Federal Ministry
Republic of Austria
Climate Action, Environment,
Energy, Mobility,
Innovation and Technology



A|S|F|i|N|A|G



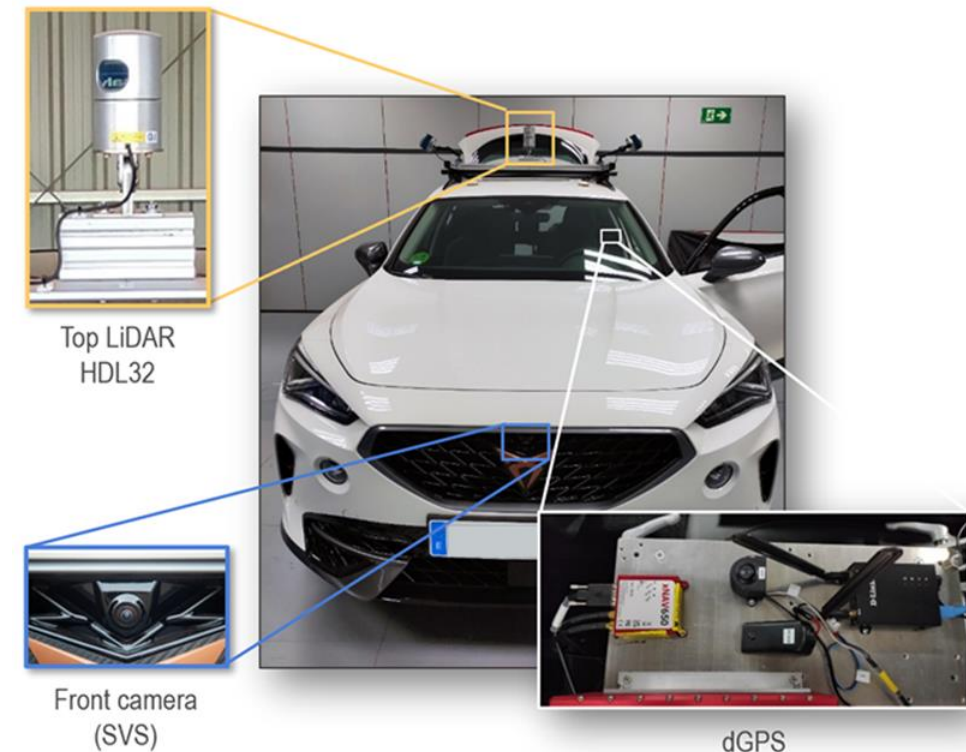
Keeping Digital Twins up to date

- Things in the real world change all the time
- Temporary changes on different scales
 - Time of day, season, specific events, ...
- Changes of objects
 - Degradation/destruction of objects
- Structural changes
 - Elements removed, modified, added



Keeping Digital Twins up to date

- Full new capture in costly and time-intensive
- Make use of sensor data on vehicles moving in the area of interest anyway
 - e.g. trains, city maintenance vehicles, transportation robots, ...
- Only certain viewpoints covered
- Lower quality than dedicated capture
- Needs to detect relevant changes compared to „base“ Digital Twin



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Keeping Digital Twins up to date

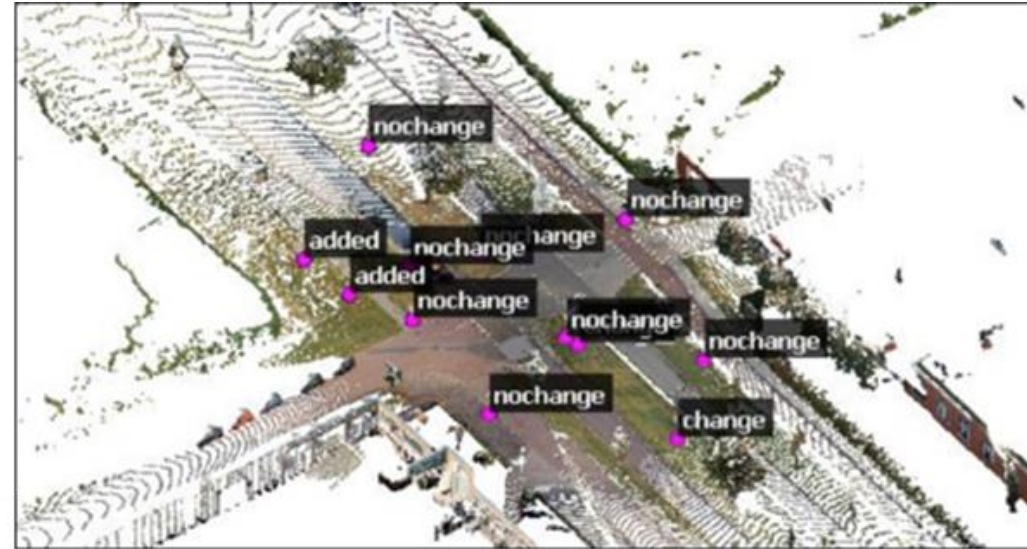
- Relevance of changes depend on application
 - e.g. small objects, vegetation, litter, ...
- Requires understanding scene semantics
 - Vision-language models and synthetic data can be used to train AI models



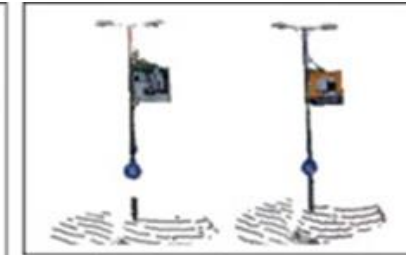
AI-based methods provide new opportunities: Change detection

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- 4-stage siamese KPConv network to detect changes
- Downsample the input point clouds
- Learn features in multiple resolution levels



(a) Single street scene with multiple changed objects.



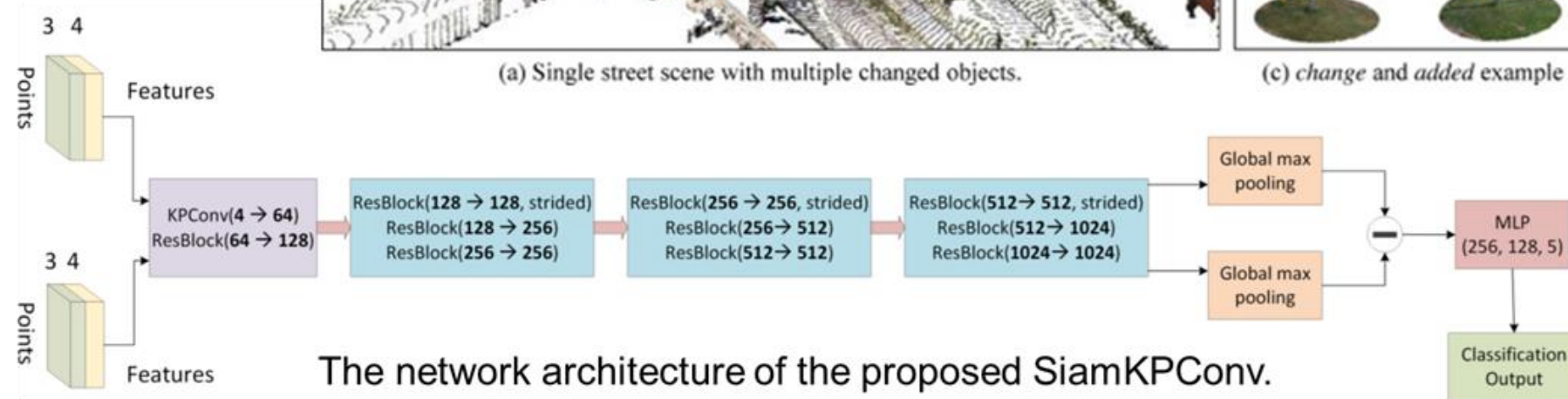
(b) color_change example



(c) change and added example

5 Classes

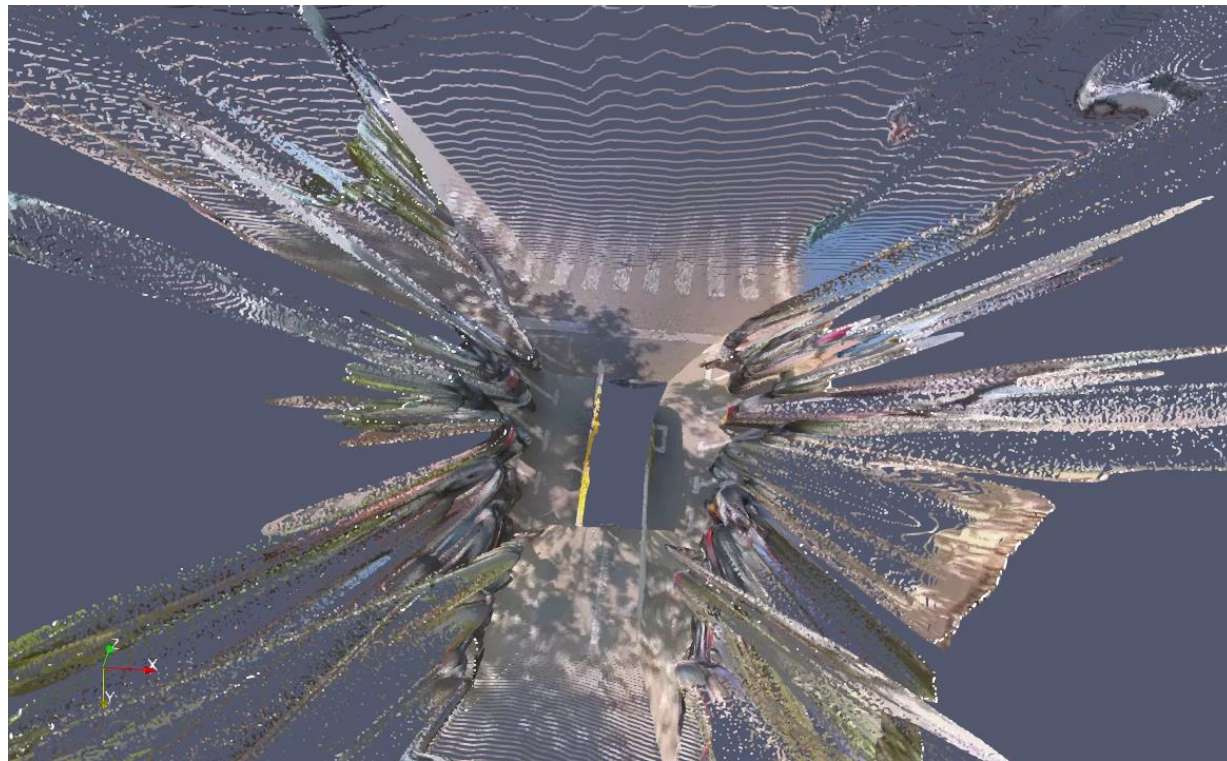
- nochange
- change
- added
- remove
- color_change



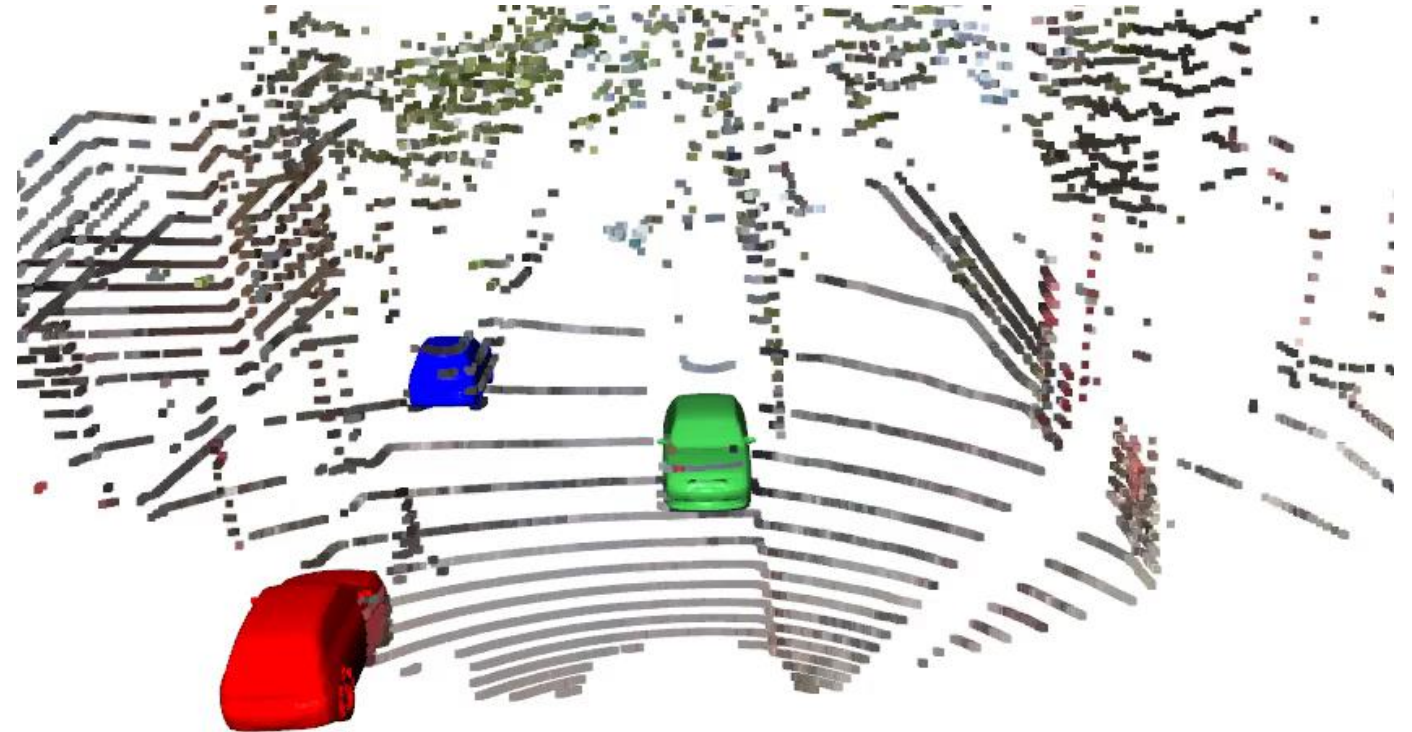
Best Results in SHREC Competition (Accepted in Eurographics 2023 Symposium on 3D Object Retrieval & Computer and Graphics)

AI-based methods: Monoscopic depth and object priming

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Reconstruction from 4 camera views, LiDAR and monoscopic depth estimation



DPSlam and replacing cars with 3D model

AI-based methods: Neural radiance fields (NERFs)



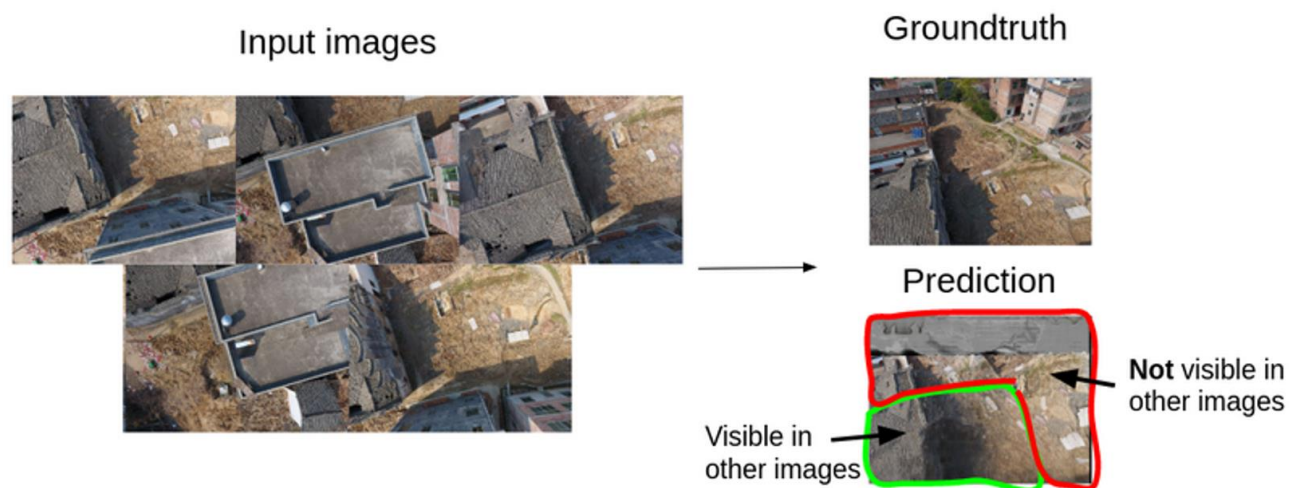
Nerfacto



Real-time Neural Rendering

AI-based methods: GDSNerf and GD Gaussian Splatting

Example of what our model does:

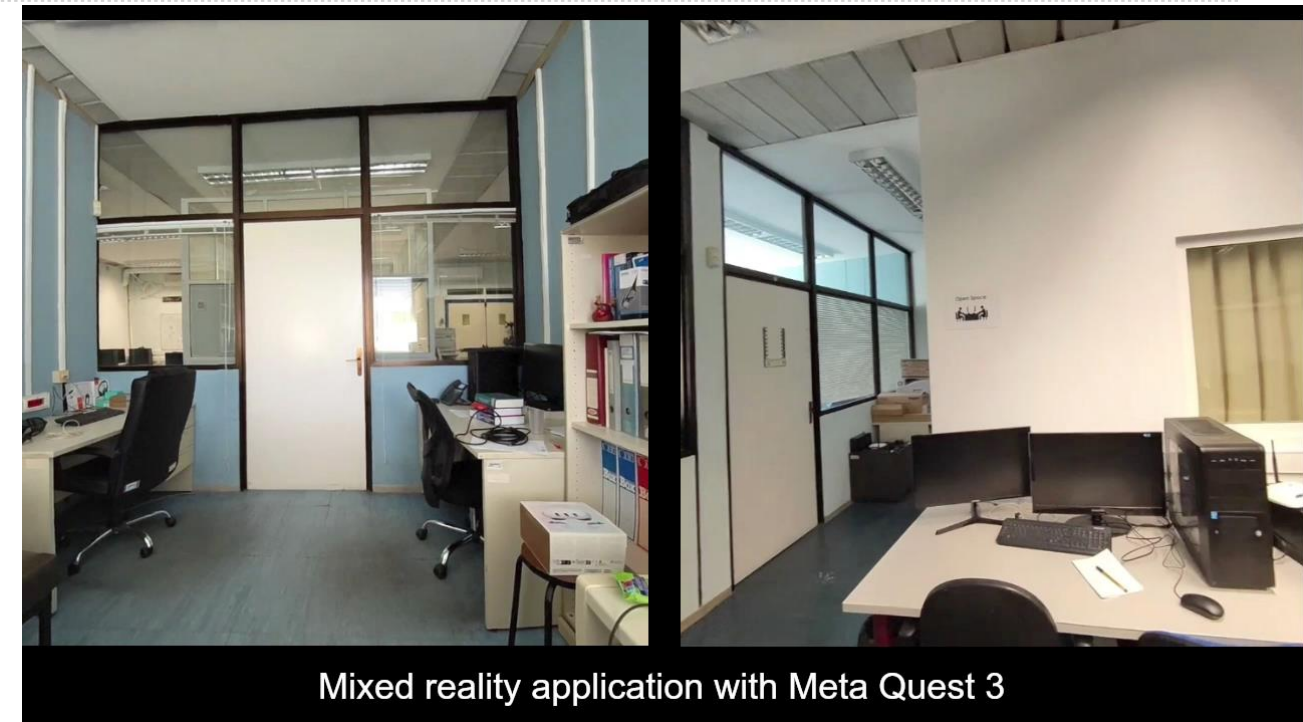
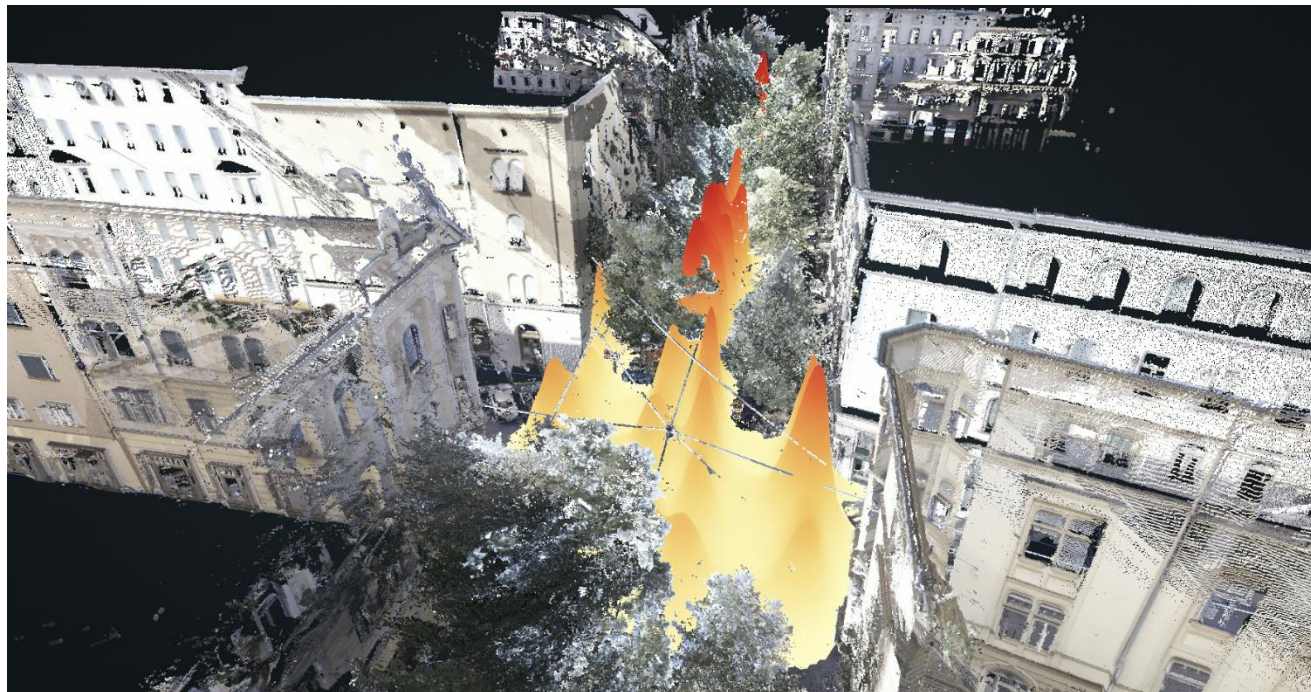


3D Data Enhancement
Gap filling



Using Digital Twins in XR applications

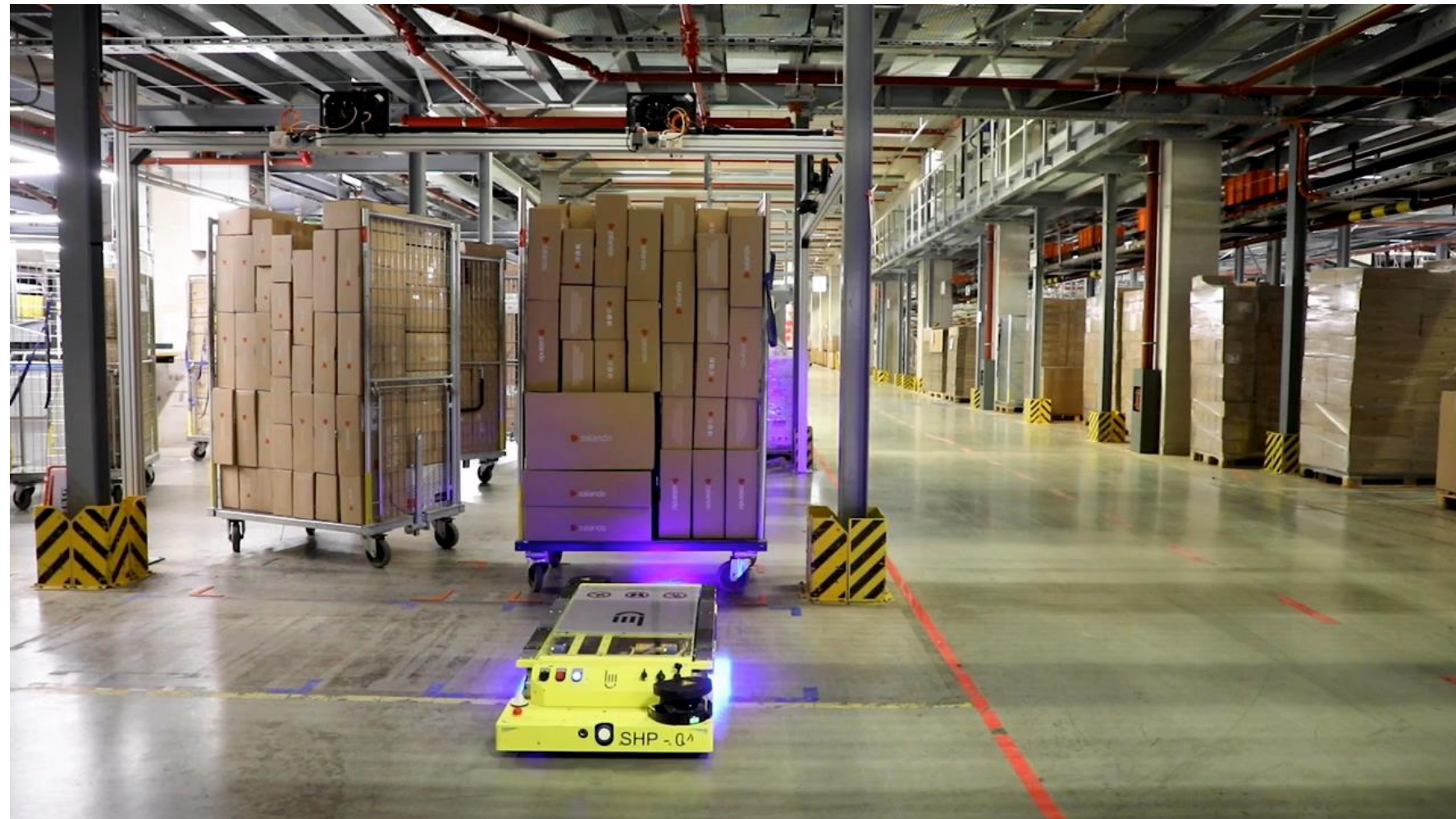
- Making visualisations understandable for non-domain experts



- Present Digital Twins in MR

Using Digital Twins in XR applications

- On-site user interactions using mixed reality



Challenges

- Handling the numerous types of possible changes
 - Moving objects (simplest case)
 - Weather and lighting conditions (different time scales)
 - Season changes of vegetation
 - Specific events taking place
 - Automation has similarities with unusualness detection
 - Learning the patterns when things may change from the data
 - Not all object categories and events known in advance
 - e.g. trash containers might get displaced for emptying and should then come back more or less to the same position
 - e.g. learning which items in an industrial environment may be put somewhere temporarily for stocking/destocking

Challenges

- Digital Twin coverage of the world is patchy
 - Integrating Digital Twins with different granularity, different level of detail, different focus on realism, dynamicity and functionality
 - Captured at different times, handling potentially conflicting information
- Different representations have different strengths and weaknesses
 - Meshes, point clouds, various types of NERFs, 3D Gaussian Splatting
 - Conversion between them may result in quality degradations

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DIDYMOS XR
δίδυμος



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