Deep Mapping: A Digital Twin Approach to Real-Time Modeling, Monitoring and Assessment of Subsurface Infrastructure

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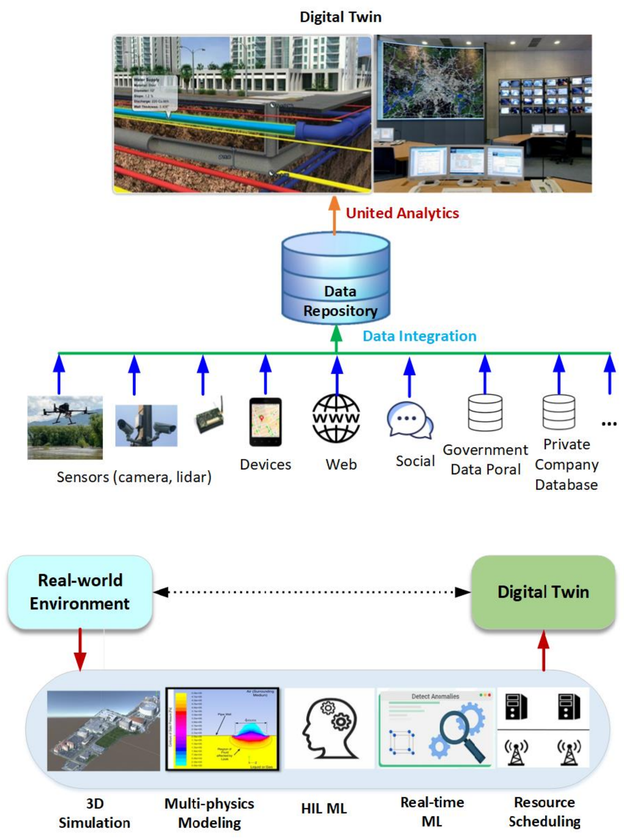
Challenge:

- Unknown/aging conditions and unknown locations of subsurface infrastructure raise profound concerns related to safety, health, and economic implications across multiple domains.
- Precise and real-time mapping, monitoring, visualization and assessment of subsurface infrastructure pose formidable technical obstacles
- A digital twin of subsurface infrastructure and environment has modeling, simulation, mapping, and predictive capabilities to help overcome those challenges.

Solution:

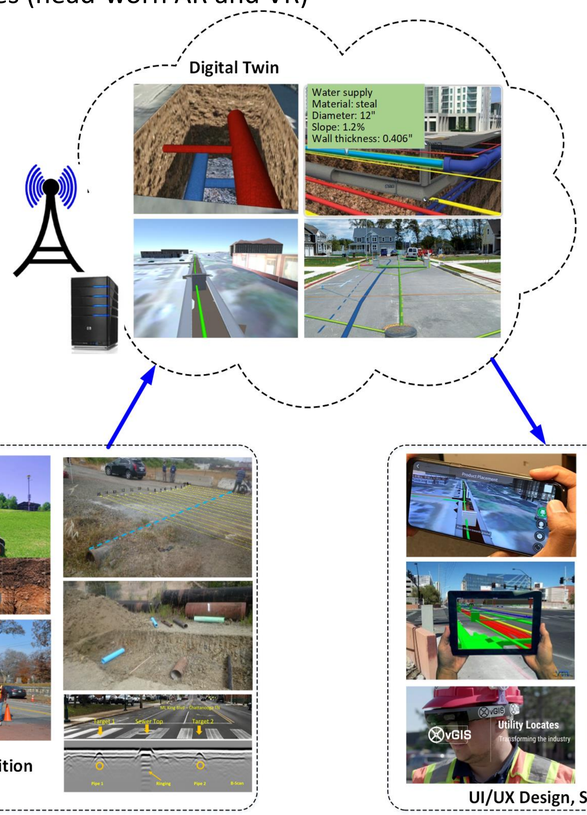
- Aggregating data in silos and from various sources (sensors, databases, social media); developing advanced extract, transform, and load (ETL) methods/tools and knowledge graphs to handle and link data across silos using semantic relationships
- Automating the construction and maintenance of the digital twin
  - Generative AI-powered multi-physics modeling and simulation to automatically and accurately replicate the dynamic conditions and behaviors of subsurface infrastructure and environment
  - Machine learning (ML) enabled real-time detection of the changes of the physical process
  - Robust synchronization between physical processes and the digital twin
  - Significant computational resources needed to perform detailed simulations, rendering, analysis in real time (edge-cloud computing, quantum computing)



- Bidirectional interaction: users send data to the digital twin while the digital twin pushes actionable intelligence to users
  - Generating context-aware insights and actionable intelligence: developing real-time human-in-the-loop (HIL) ML models (reinforcement learning) to forecast future events and suggest actions
  - Developing intuitive user interaction and interfaces by combining cognitive psychology, and human augmentation technologies (head-worn AR and VR)

Performance Metrics:

- Autonomy
- Accuracy
- Adaptivity
- Interactivity
- Latency
- Reliability (false alarm rate)
- Resilience
- Sensitivity



Broader Impact:

- Facilitating management and maintenance of underground utilities; improving their service, sustainability and resilience; reducing costs and waste
- Utility and construction industries, municipal utility officials are particularly interested in applying digital twins of surface infrastructure and environment
- Partnerships with community for testing, result dissemination, and potential commercialization
- Incorporating research findings into teaching and curriculum, new courses on digital twins, outreach to K-12 schools
- Contributing to establishing industry standards, guidelines, and performance requirements