Title:
Augmened Reality for Subsurface Utility Engineering:
Exploring and developing 3D capture and AR visualization methods for subsurface utilities

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Level of study or work: PhD Research Project
(Bachelor thesis, master, research, project, etc.)

Information about you (and your team): I undertook my Civil Engineering and PhD degree at Aalborg University, Dept. of the Built Environment in Denmark. I am currently working as industrial PostDoc researcher at LE34 (Denmarks largest Land Surveying company) and Aalborg University, Department of Planning. I have a passion for underground utilities and how to solve the many challenges related to planning, mapping, and excavation workflows by means of using new technologies within the field of computer vision.

Area of interest
(Identifying the problem, explain why it is important and the current relevance of the topic, up to 250 words)

The problem at hand involves the planning and excavation of underground infrastructure, which is a challenging and high-risk task due to the unseen utilities buried below the surface. The absence of precise and readily accessible information about these subsurface utilities often leads to costly and dangerous mistakes such as utility strikes. These strikes can disrupt essential services, cause financial losses, and potentially result in injuries or fatalities. Therefore, ensuring accuracy in locating these subsurface utilities is an imperative task.

In our current era of rapid urban development and infrastructural expansion, this issue has gained significant relevance. Urban landscapes are becoming denser, with an increasing web of underground utilities such as water pipes, gas lines, and electrical cables. The complexity of these subsurface utilities makes their documentation and visualization essential, yet challenging. Conventional utility map data, which typically provide 2D visualizations, are often inadequate for capturing the intricate 3D network of these utilities.

Emerging technology, such as Augmented Reality (AR) and 3D capturing technology, offers promising solutions. AR allows for the overlay of complex data onto real-world views, providing an enhanced understanding of the subsurface environment. Meanwhile, 3D capturing technology can generate

detailed 3D point clouds of subsurface utilities, offering a comprehensive view of their spatial arrangement. By harnessing these advanced technologies, we can better understand, visualize, and plan around the labyrinth of underground utilities, thereby minimizing the risk of accidental utility strikes, ensuring safety, and enhancing the efficiency of our infrastructural development projects.

Approach to the problem

(Describe your methodology or technology and how it will solve the problem you identified, up to 300 words)

The approach in this PhD research project involved the novel integration of Augmented Reality (AR) and 3D capturing technologies. We developed methodologies to leverage these technologies, aiming to provide a highly informed visualization platform for utility owners, contractors and surveyors. This platform was designed to facilitate better planning and management of underground infrastructure projects.

The research focused on developing an AR visualization method that used 3D capture data from underground infrastructure to aid subsurface utility engineering on-site. We implemented this method in a robust outdoor AR prototype system, capable of accurately displaying the 3D capture data in situ. This resulted in a visualization closely aligned with the actual surroundings. Feedback from professionals who tested this system was overwhelmingly positive. The AR visualization system not only provided a clear spatial understanding of the utilities but also offered sufficient detail to identify the type of utilities and their material properties.

Additionally, we developed another AR visualization method using conventional utility map data as the source. Often, this type of data is the only available source when planning for utility work. This visualization method aimed to represent the utility data as virtual utility markings that seamlessly blended with the ground surface. The design schemes were adapted from real utility marking guidelines prevalent in the industry. This unique visualization provided a clear overview of the map-based utility records, with the virtual utility markings offering an intuitive understanding when viewed directly on the ground surface.

The combined use of these innovative methodologies presents a promising solution to the challenge of accurately identifying and visualizing subsurface utilities. This approach, grounded in AR and 3D capturing technology, is poised to greatly enhance safety and efficiency in managing underground infrastructure projects.

Results, conclusions and next steps

(Present your research results and conclusions of your study, up to 250 words)

In this PhD project, consisting of five focused papers, a combination of Augmented Reality (AR) and Reality Capture (RC) technologies were explored to address challenges in subsurface utility engineering.

Paper I examined the effectiveness of a smartphone-based RC solution, revealing significant benefits such as time savings, enhanced data output, and improved planning for future projects.

Papers II, III, and IV showcased the utility of AR in presenting RC data output. An AR prototype provided accurate in-situ visualization of 3D data, offering a detailed spatial understanding of underground utilities, thereby reducing the risk of excavation damage.

Real industry end-users evaluated the AR visualization methods via hands-on demonstrations and semi-structured interviews. The feedback overwhelmingly suggested that these methods could substantially aid in preventing excavation damage and streamlining on-site planning for underground infrastructure work. This is especially crucial, as the majority of excavation damage is caused by inaccurate and incomplete utility records.

However, regulatory hurdles in Denmark were identified as potential obstacles to adopting 3D capture data, prompting the development of an AR visualization method using conventional utility data.

Finally, **Paper V** addressed the unreliability of legacy records, advocating for enhanced data quality through 3D capture and other sources.

In conclusion, the research underscores the significant potential of integrating AR and RC technologies in managing underground infrastructure. Moving forward, efforts will focus on overcoming regulatory challenges, refining visualization methods, and investigating how 3D capture data as ground truth source for automatically evaluating and upgrading existing legacy utility data.

References

(Additional information, publications, or links, up to 200 words)

The PhD thesis is available for download here:
https://vbn.aau.dk/da/publications/augmented-reality-for-subsurface-utility-engineering-exploring-an

A video presentation of the developed AR methods in action can be seen here:
https://www.linkedin.com/posts/lasse-hansen-dk_phd-research-augmentedreality-activity-6894647801221853184-d0iu

Or downloaded here:
https://upload.le34.dk/f.php?h=1PvY_ri6&d=1

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