VejForum
December 08-09, 2021

Anvendelsen af Augmented Reality til visning af underjordisk infrastuktur

Hvem er jeg?
Lasse Hedegaard Hansen

- Veje og trafik civilingeniør fra Byggeri og Anlæg, Aalborg Universitet (færdig i 2018)
- Ph.d.-studerende på AAU
  - Augmented Reality for Subsurface Utility Engineering
  - Min Ph.d.-afhandling er indsendt!

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Motivation

- Graveskader påført nedgravet ledninger er dyrt problem! Årlige estimerede omkostninger for samfundet:
  - DKK 280 millioner i Danmark
  - GBP 270 millioner i UK
  - USD 30 millarder i USA
- Anvend AR til at forbedre arbejdsprocesser i marken ifbm. ledningsarbejde
  - Forsøge at løse kendte visualiseringsproblemer ifbm. med at viser underjordiske ledninger i AR

Hvad er hovedårsagerne til graveskader?

- Eksisterende ledningsoplysninger er dårlige, unøjagtige og manglende

Undersøgelse fra Norge

Feil påvisning/feil på kart/feil antall kabler

Undersøgelse fra USA

Lack of depth.

Marks too far from the utilities.
Temporary nature of marking.

Kilde: Rapport fra arbeidsgruppe graveskader, 2. nov. 2015, Norge.

Table 4. Homogeneous groups of root causes based on respondents' experience

Group number	Deficiency	*M*	*SD*
1	Lack of depth.	6.38	3.3
2	Marks too far from the utilities.	5.8	3.0
	Temporary nature of marking.	5.7	3.2
3	Excavators relied on the general contractors to notify one call center.	5.18	3.3
	Excavators relied on the landowner's advice it was safe to dig.	4.96	3.5
4	Excavators do not wait for three working days.	4.28	3.1
	Schedule tight and cannot afford to hand-dig within 2 ft of the marks.	4.15	3.2
	Penalties are too low.	3.85	3.1
5	It is less expensive for excavators to damage utilities than to excavate safely.	2.98	2.89

Ahmed Jalil Al-Bayati and Louis Panzer. Reducing Damage to Underground Utilities: Lessons Learned from Damage Data and Excavators in North Car- olina. Journal of Construction Engineering and Management, 145(12):1–8, 2019. ISSN 07339364. doi:10.1061/(ASCE)CO.1943-7862.0001724.

Eksisterende AR løsninger

Trimble SiteVision

vGIS

Klassisk anvendelse af AR: 3D as-designed vejmodeller

- Forskningsprojekt fra 2017
- Case: Herning-Holstebro motorvejen

COWI

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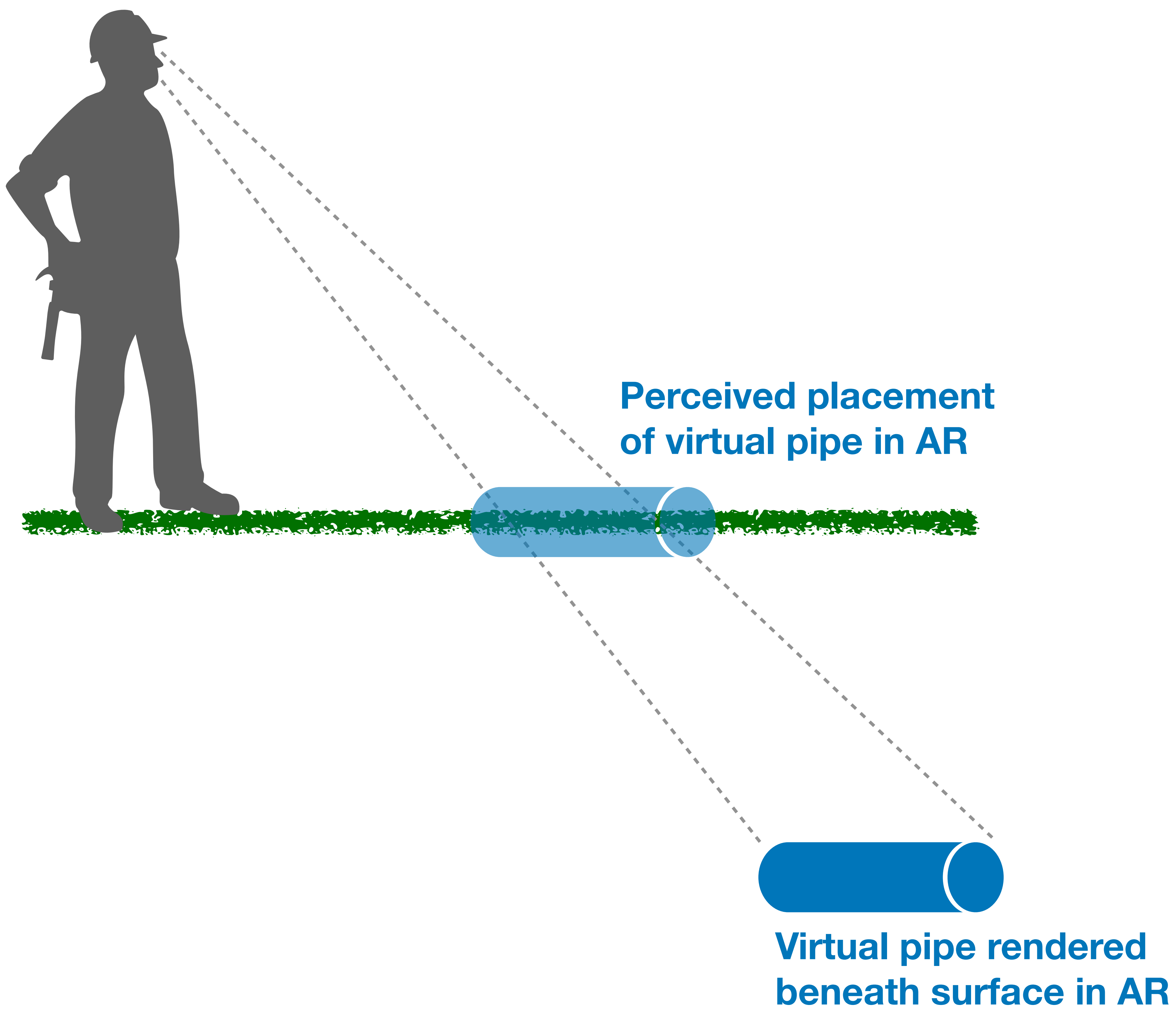
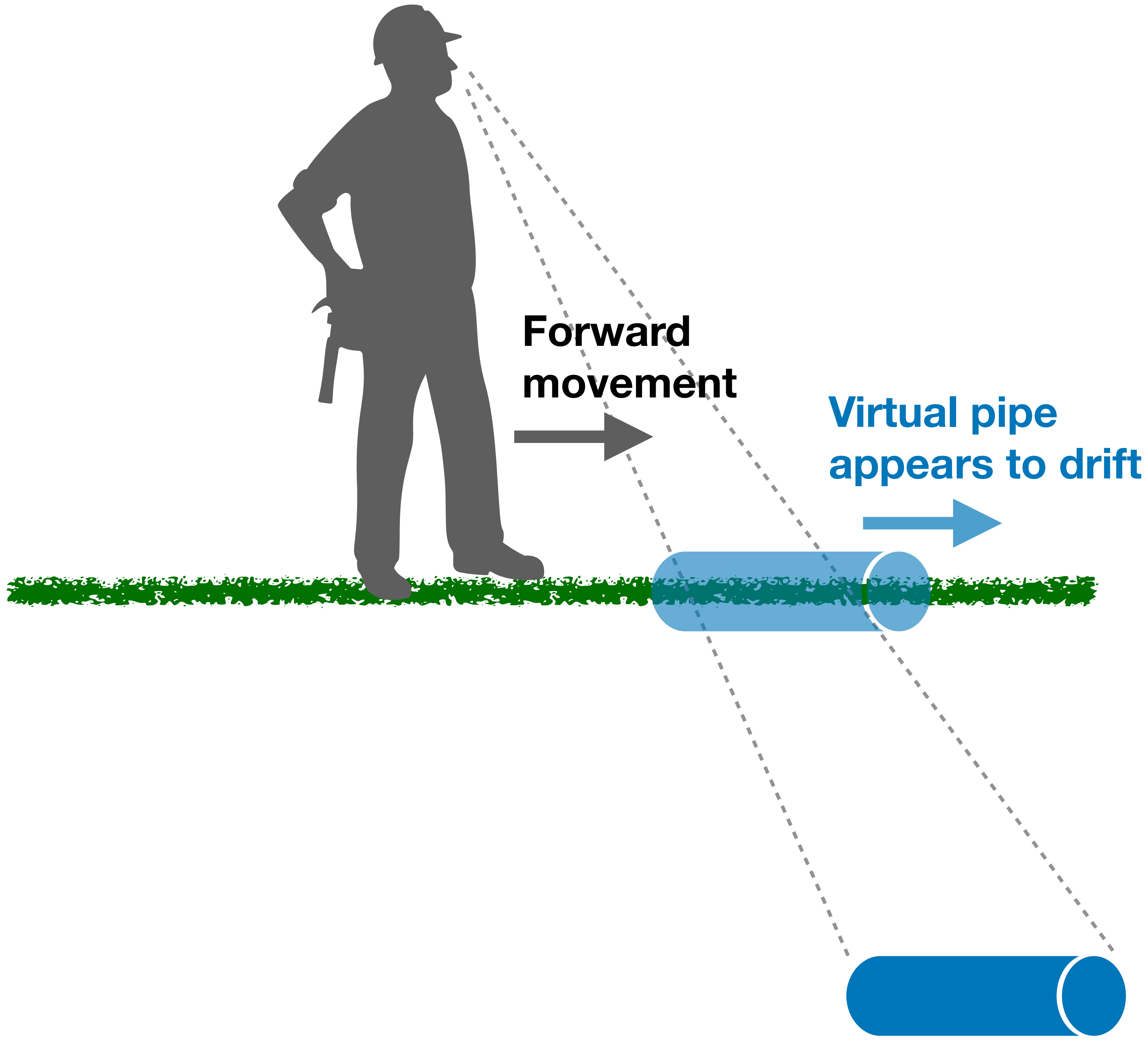
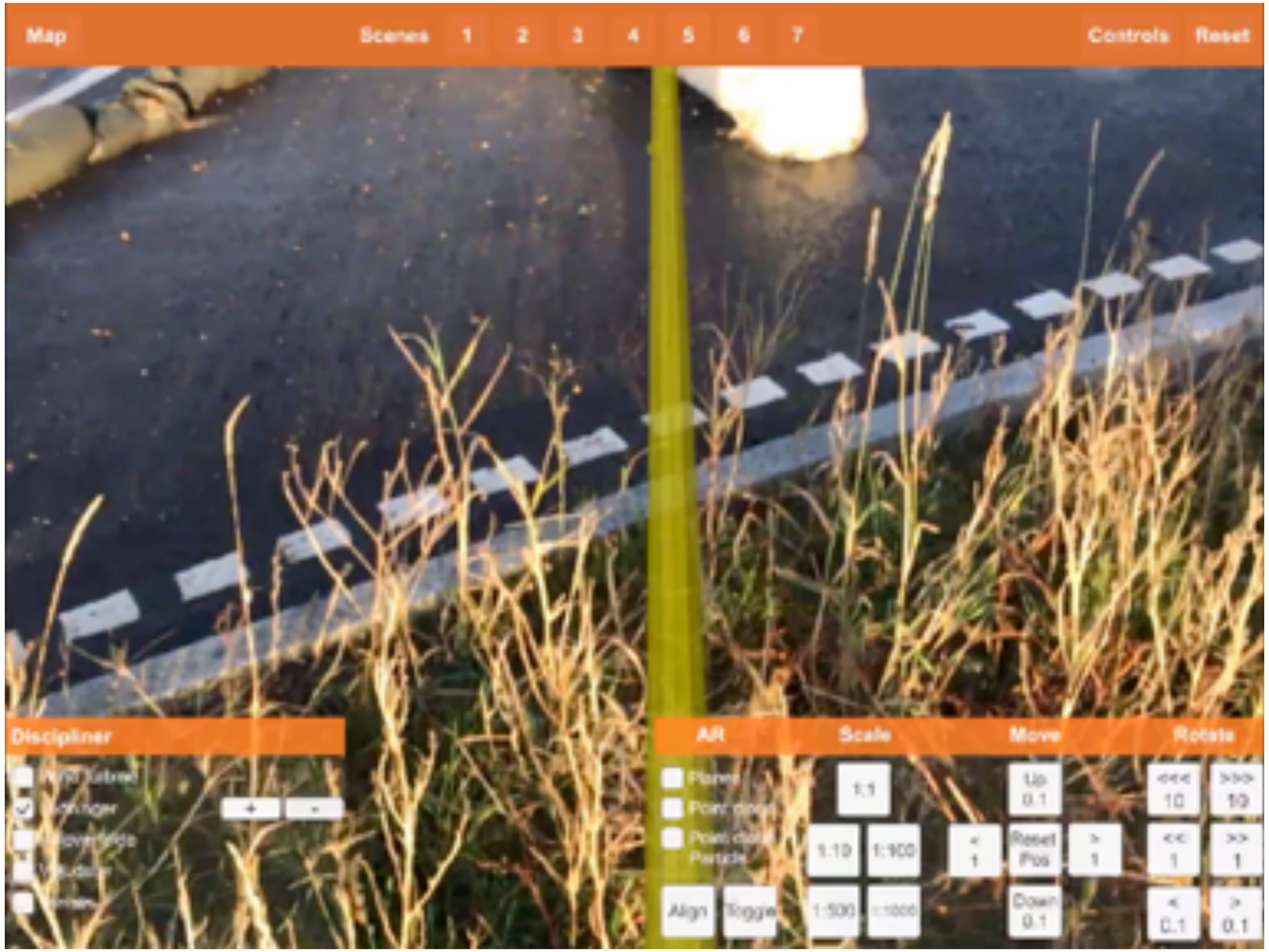
Udfordringer med under-jorden visualisering



Udfordringer med under-jorden visualisering

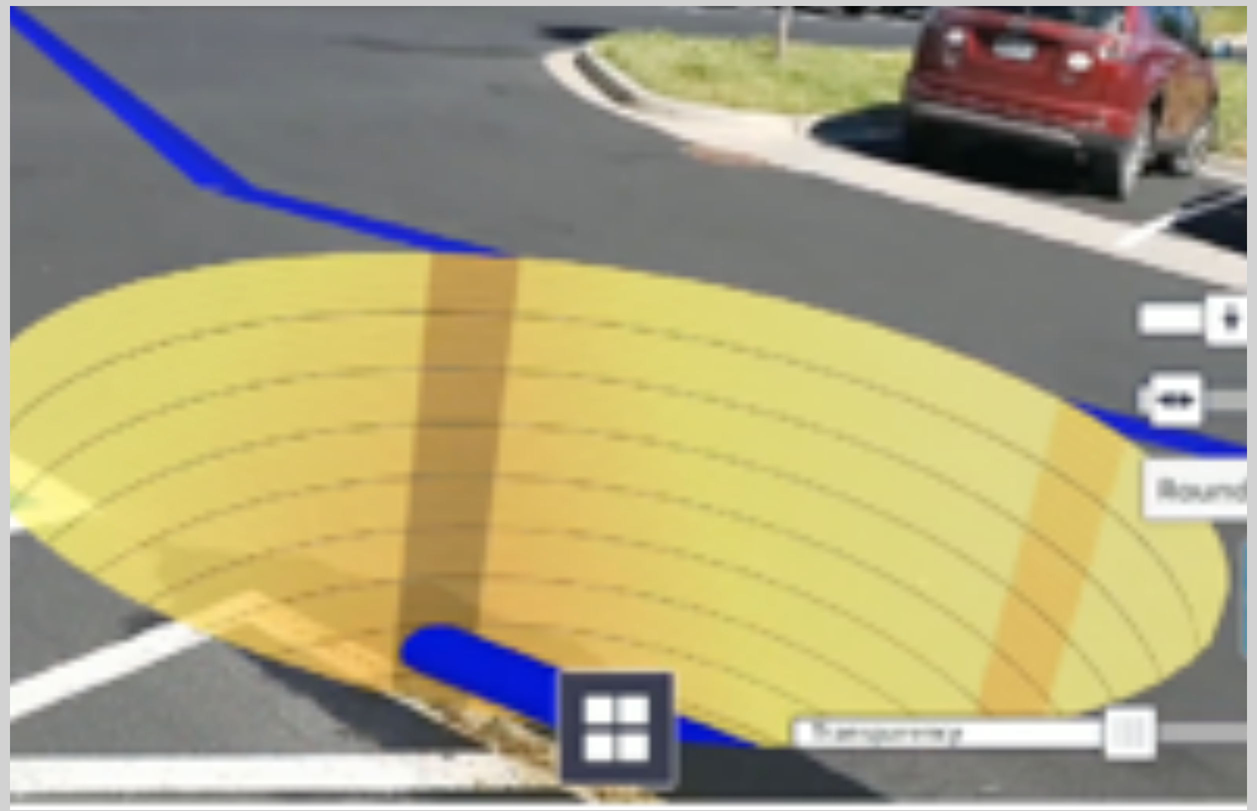
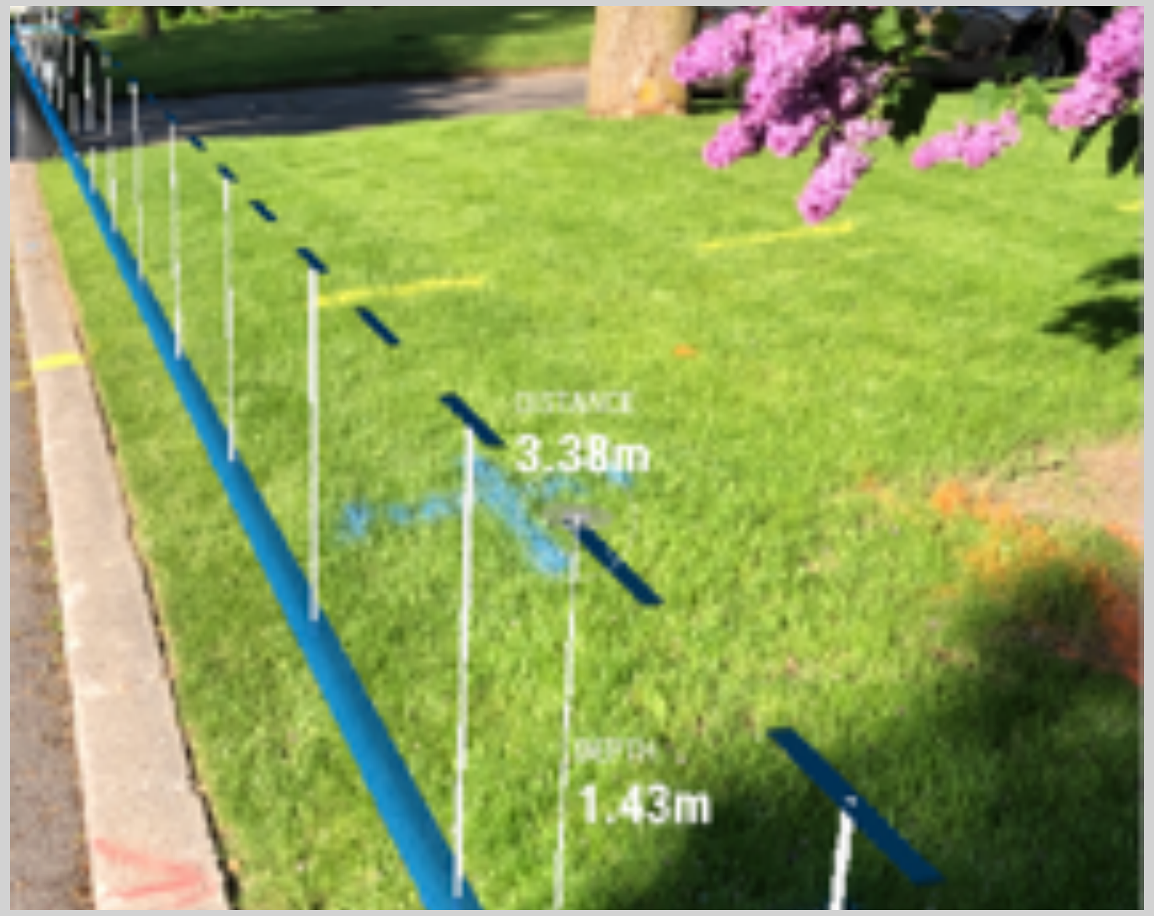




AR for Infrastructure Visualisation

Status for nuværende AR løsninger:

- Ledningsdata i 3D
- Ingen nye metoder siden 2009

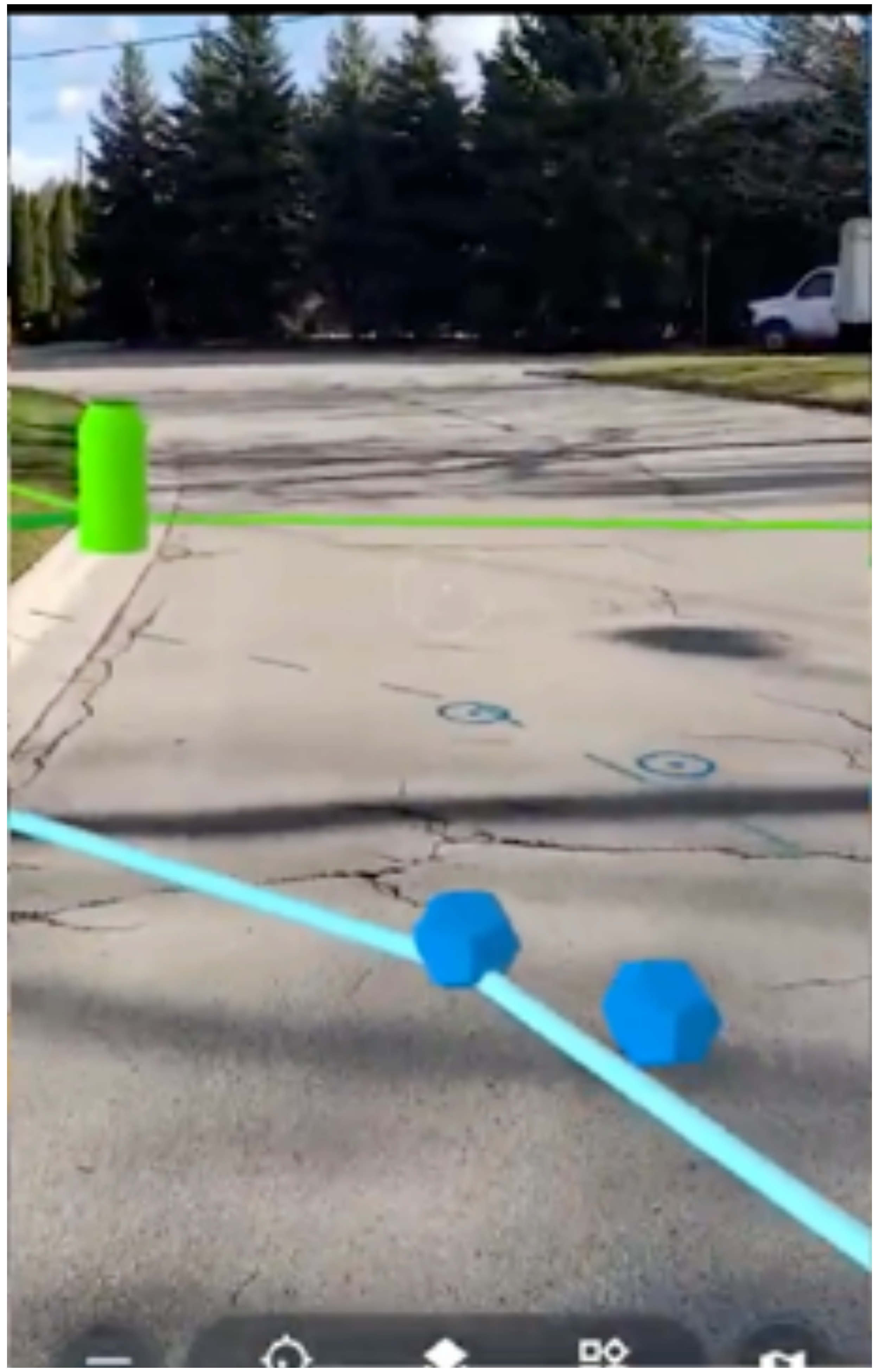
	Cut-away	Shadow projection
Current commercial Visualization methods	SiteVision 	vGIS 
Visualization methods from pervious research [1]		

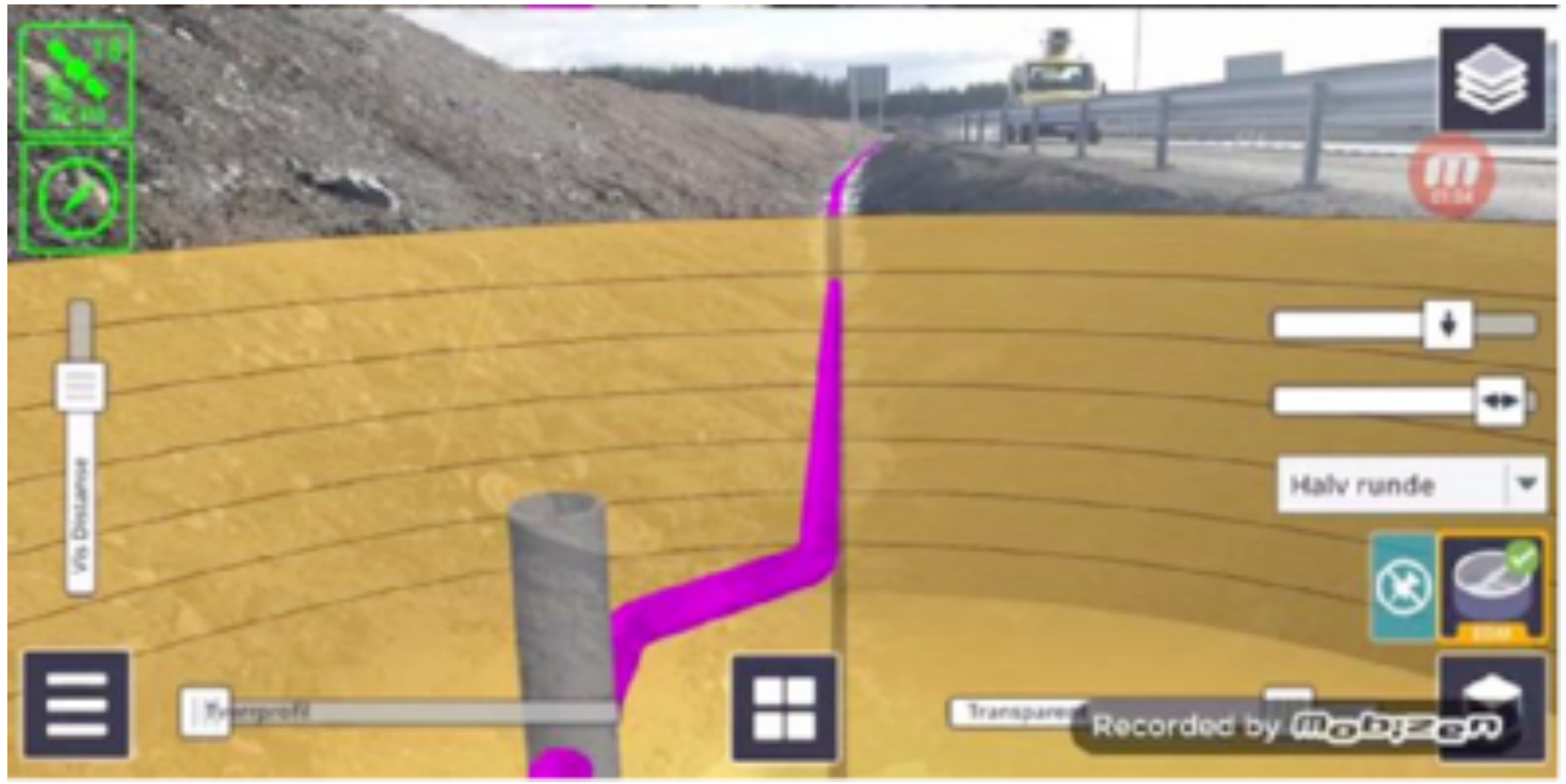
[1] G.Schall, E.Mendez, E. Kruijff, E.E. Veas, S. Junghanns, B. Reitinger, and D. Schmalstieg. Handheld augmented reality for underground infrastructure visualization. Personal and Ubiquitous Computing, 13(4):281– 291, 2009. doi: 10.1007/s00779-008-0204-5

AR for Infrastructure Visualisation

Status for nuværende AR løsninger:

- Ledningsdata i 3D
- Ingen nye metoder siden 2009
- Planar ground surface estimation





Augmented Reality for Subsurface Utility Engineering

Vizario.CapsLoc:

A compact sensor box for centimeter-accurate outdoor positioning developed by AR4.io

https://www.ar4.io/vizario-capsloc/

Virtual Utility Marking

Reads conventional GIS utility data and outputs plausible looking *virtual utility markings* in AR that are relatable for utility workers.

Virtual Utility Daylighting

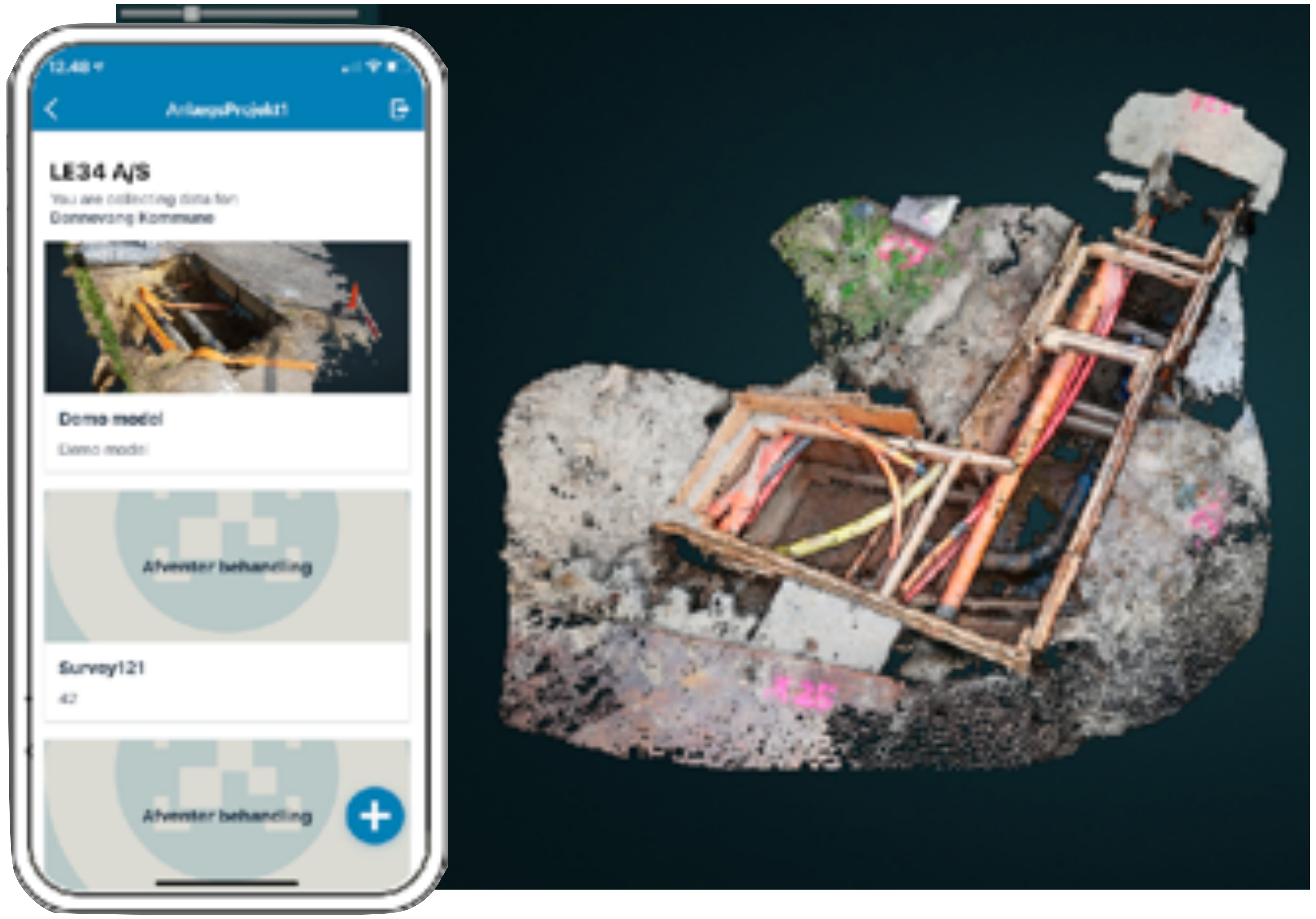
Visualisation of 3D reconstructions of real utility excavations holes by fusing seamlessly with the real environment to uncover the underground utilities

Hansen, L. H., Fleck, P., Stranner, M., Schmalstieg, D., & Arth, C. (2021). Augmented reality for subsurface utility engineering, revisited. *IEEE Transactions on Visualization and Computer Graphics*, *27*(11), 4119-4128. doi: 10.1109/TVCG.2021.3106479

Reality Capture and Augmented Reality

SmartSurvey©

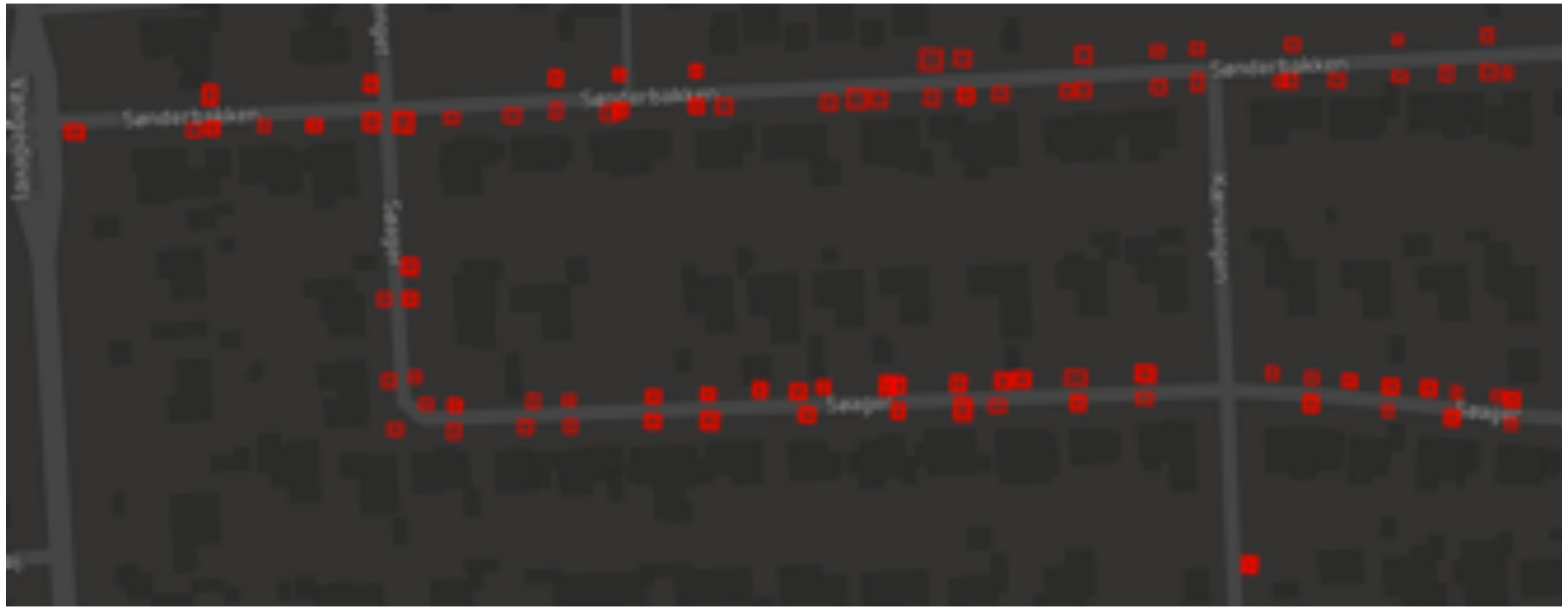
Reality Capture
LE34 SmartSurvey



Augmented Reality
Trimble SiteVision

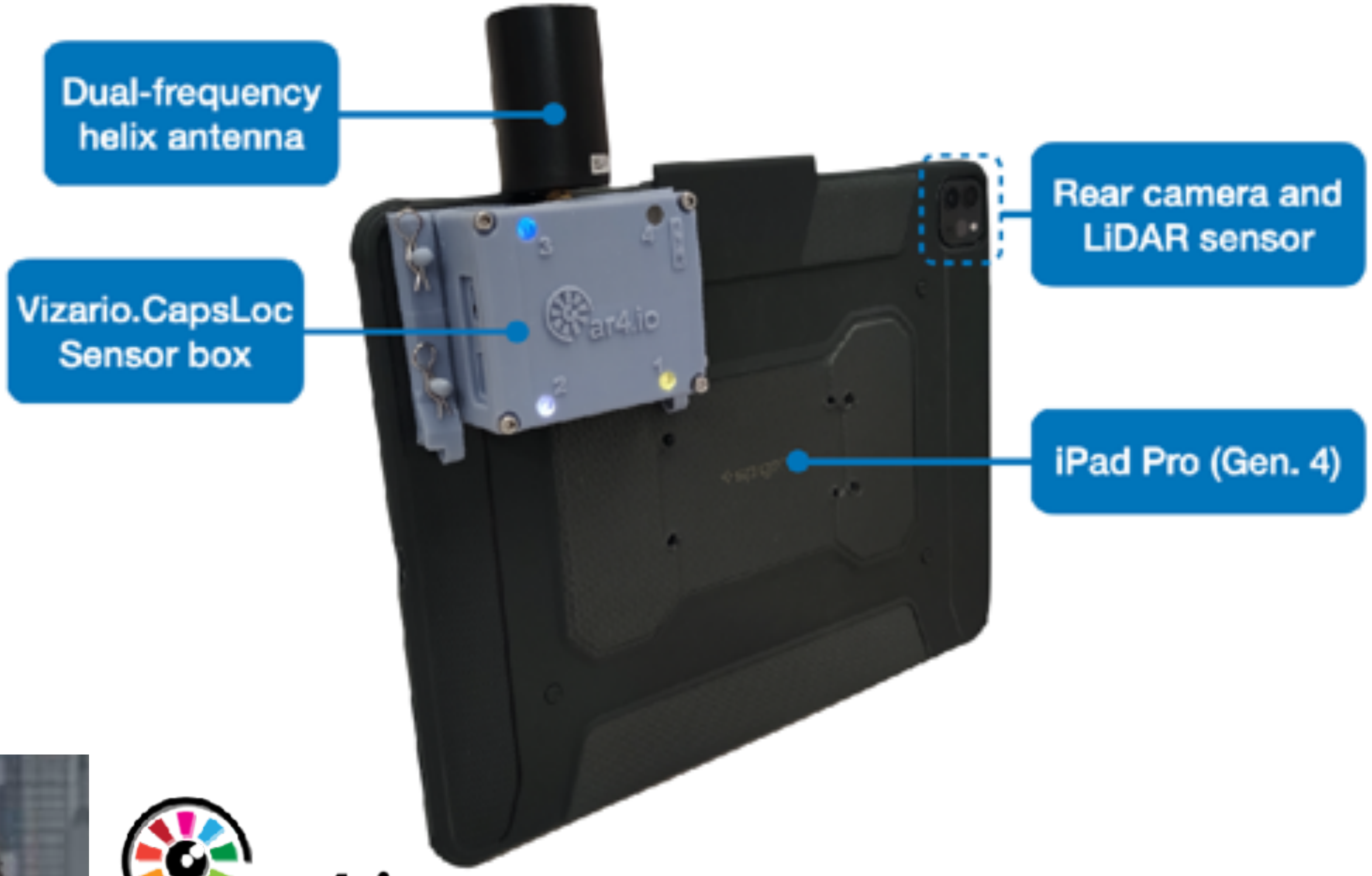
Punktskyer af ledningshuller

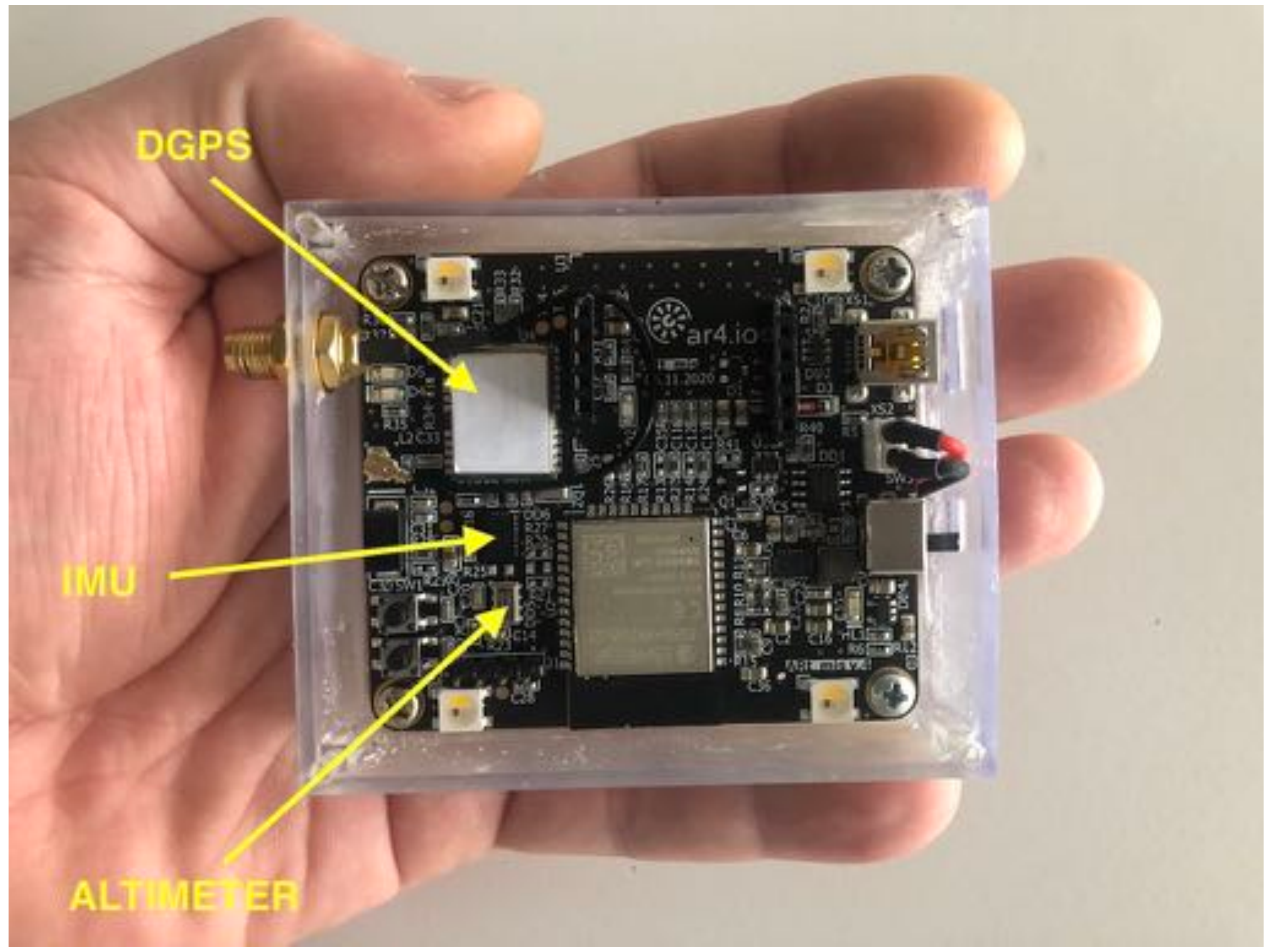
- +3500 ledningshuller af Novafos og Aarhus Vand
- Ønske om at anvende punktsky data ifbm. planlægning af nye ledningsprojekter
- Kan vi anvende det som visualiseringsdata i AR?



AR system setup

- iPad Pro (4th gen) with LiDAR sensor
- CapsLoc sensor-box by AR4 using low-cost components [4]
- Compact helix-based, dual-frequency antenna
  ~ 200 Euro





Clemens Arth
Founder
clemens@ar4.io

[4] M. Stranner, P. Fleck, D. Schmalstieg, and C. Arth. A high-precision localization device for outdoor augmented reality. In *ISMAR-adj.*, 2019.

Accuracy evaluation

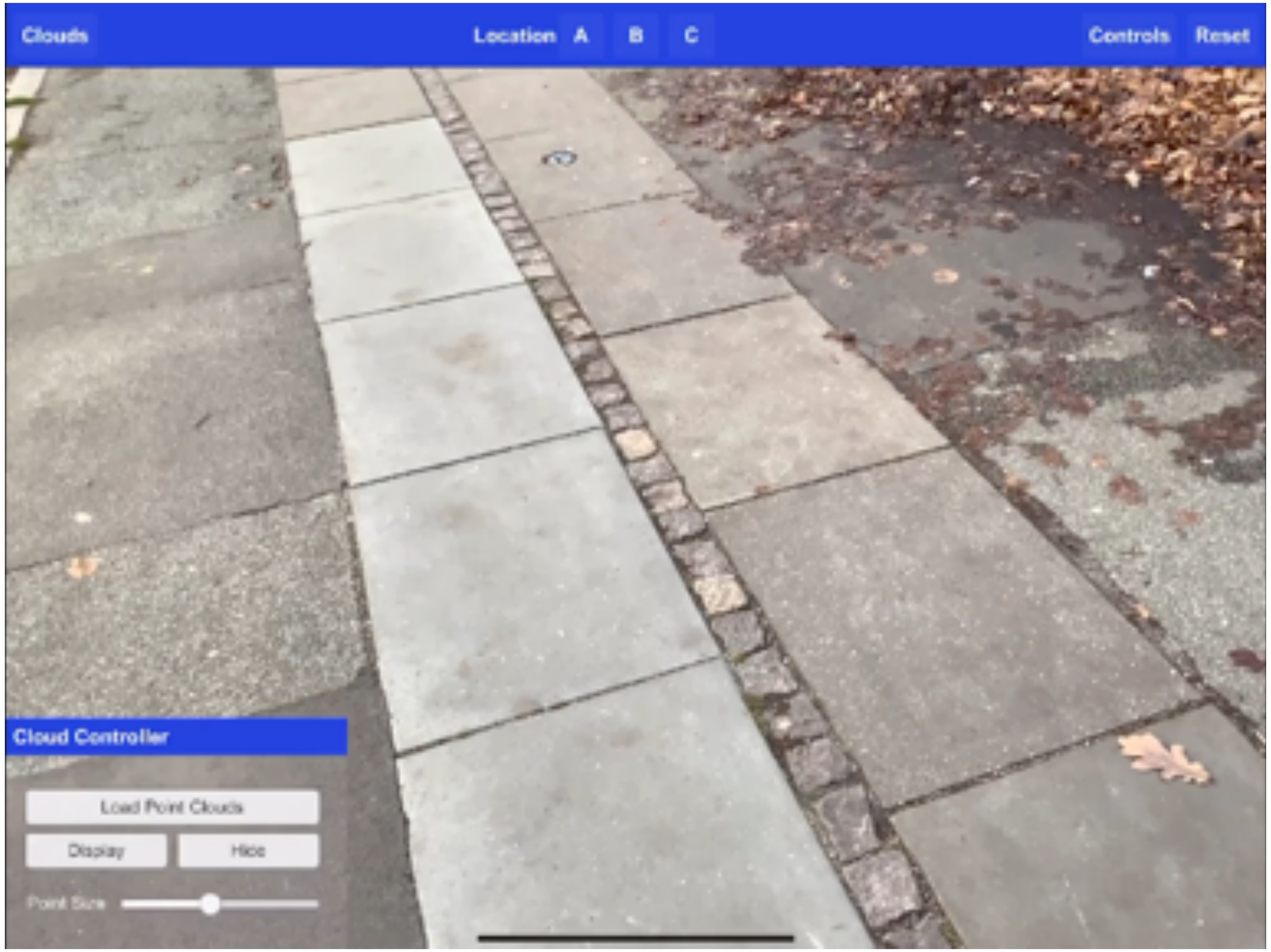
- The challenge is to keep a robust **fixed** RTK connection
- Helix antenna great for 6DoF movement = our use case

Date	RTK	Δ	ε	ε_{1m}	ε_{2m}	ε_{3m}
31/5/21, 12:35	float	47	12	3	1	1
31/5/21, 12:50	fixed	85	10	11	8	10
31/5/21, 12:45	fixed	287	2	8	10	11
31/5/21, 12:38	fixed	291	1	1	3	9
31/5/21, 12:53	fixed	207	1	1	4	5
1/6/21, 15:54	float	91	30	23	21	19
1/6/21, 15:27	float	365	25	13	16	20
1/6/21, 15:34	fixed	199	9	6	10	12
2/6/21, 11:28	float	122	17	20	27	35
2/6/21, 11:24	float	264	15	21	30	33
2/6/21, 11:31	float	157	15	10	5	2
2/6/21, 11:34	fixed	59	10	11	9	7
2/6/21, 11:18	fixed	66	10	2	2	2
2/6/21, 11:14	fixed	281	6	2	2	4
2/6/21, 11:07	fixed	165	1	3	3	4

Mean (μ) fixed only	**5.56**	**5.00**	**5.67**	**7.11**
StdDev (*std*) fixed only	**4.28**	**4.12**	**3.50**	**3.55**
Mean (μ) float only	19.0	15.0	16.67	18.33
StdDev (*std*) float only	6.96	7.72	11.71	14.58
Mean (μ) fixed and float combined	10.93	9.0	10.07	11.6
StdDev (*std*) fixed and float combined	8.61	7.53	9.33	10.75

Virtual Utility Daylighting in action

Virtual Utility Daylighting in action



Virtual Utility Daylighting med Trimble SiteVision

- Udført af mine bachelor studerende (veje og trafik, AAU)
  - Shout-out: Anders, Caroline, Elias og Johan


13
5cm
Transparency

Interview resultater

- Fordele
  - Giver et klart 3D billede af hvad der er nede i jorden.
  - Mulighed for at se dybder, udbredelse, materialetyper, osv.
  - Åbner for drømmen om at “se nede under jorden ” inden man graver.
- Ulemper
  - Kun punktsky data for steder som er 3D registreret.
  - Bekymringer om det giver en falsk tryghed
  - LER data er lovgivende data og vil derfor dominere

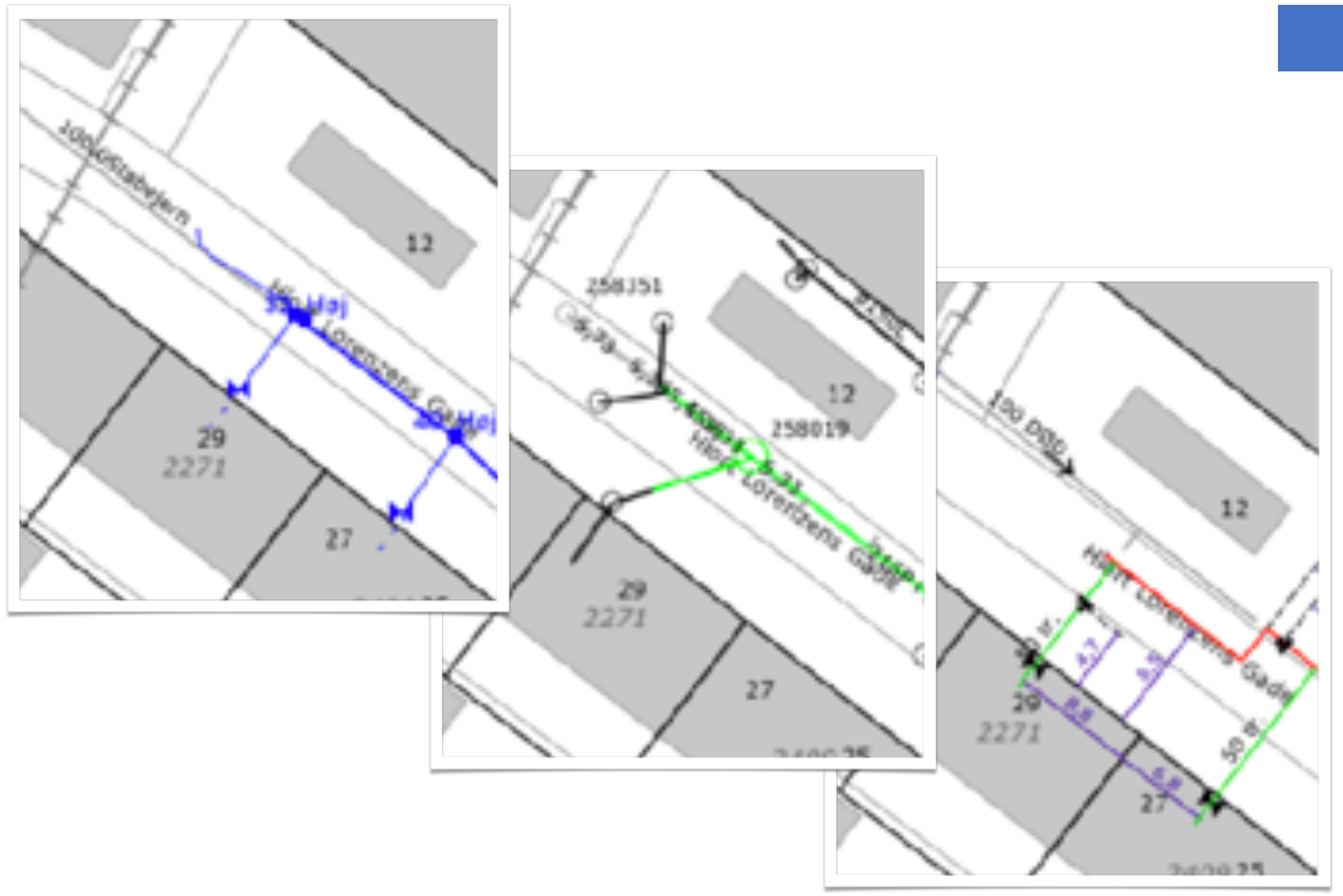
”… det vil være rigtig fedt det her, det vil være en kanon hjælp, fordi med traditionelle ledningsoplysninger ser man ikke alle de kabelkrydsninger, som vi ser nu [med AR prototypen]…”

AARSLEFF

Virtual Utility Marking

Vi tager udgangspunkt LER data

- **2D-vector data** af ledninger gemt i GIS
- Selvom i mange tilfælde kun pdf-tegninger



Virtual Utility Marking

*Could we make an AR visualisation method that was **relatable** for SUE workers by resembling the **visual appearance** of real utility markings?*

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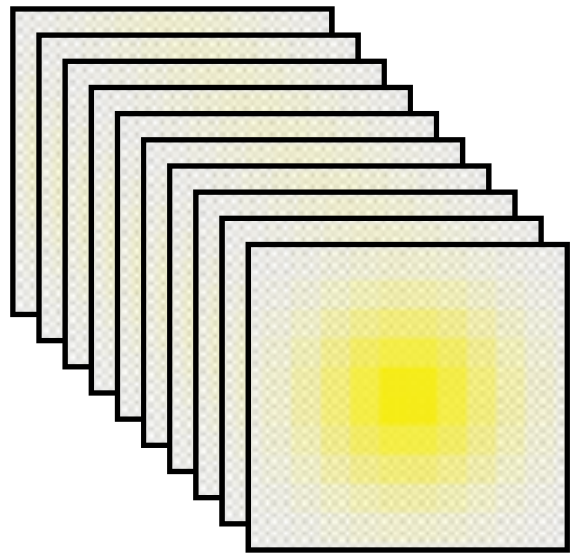
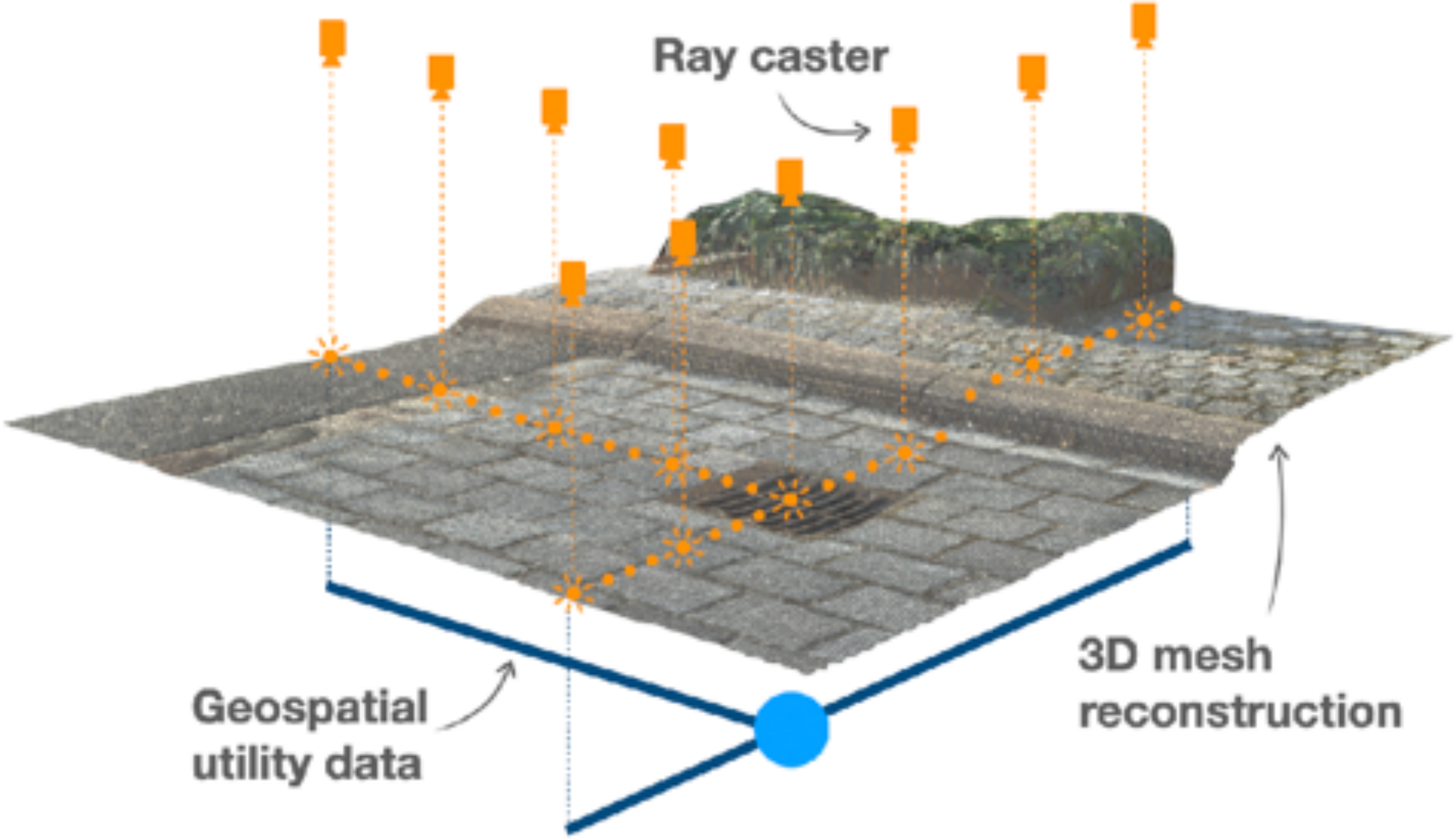
1. the placement of markings follows the ground surface;



16x16 pixel sprites

Resolution: 30 per meter



Virtual Utility Marking

*Could we make an AR visualisation method that was **relatable** for SUE workers by resembling the **visual appearance** of real utility markings?*

1. the placement of markings follows the ground surface;
2. the markings blend into the ground surface;

-

Blending per-pixels luminance values of the ground layer, denoted by $g \in [0,1]$, and the top layer, denoted by $t \in [0,1]$, using the formula

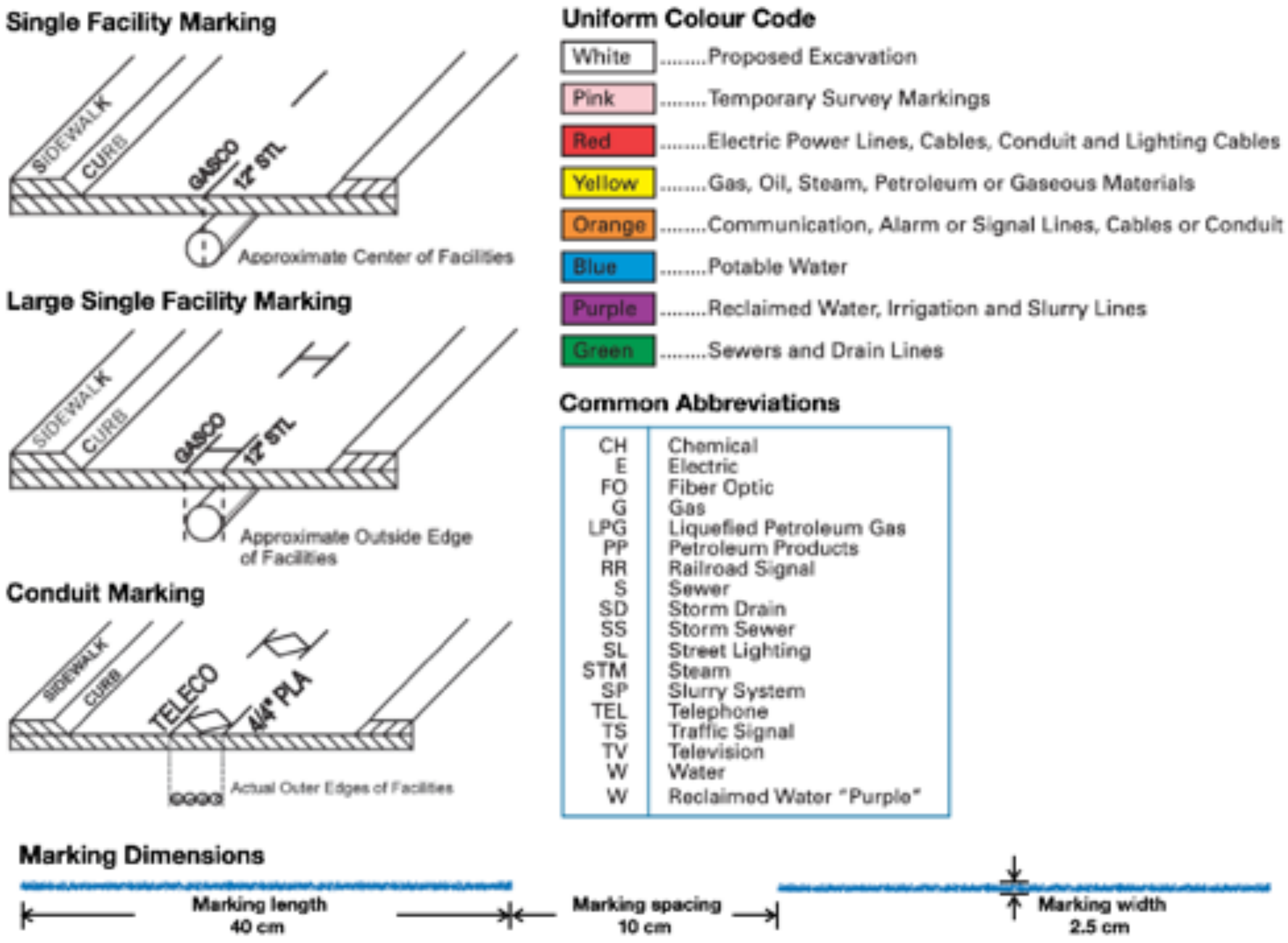
$$f(g,t) = \begin{cases} 2gt, & \text{if } t < 0.5 \\ 1 - 2(1-g)(1-t), & \text{otherwise,} \end{cases}$$

A.k.a: Overlay Blend mode effect in photoeditor software

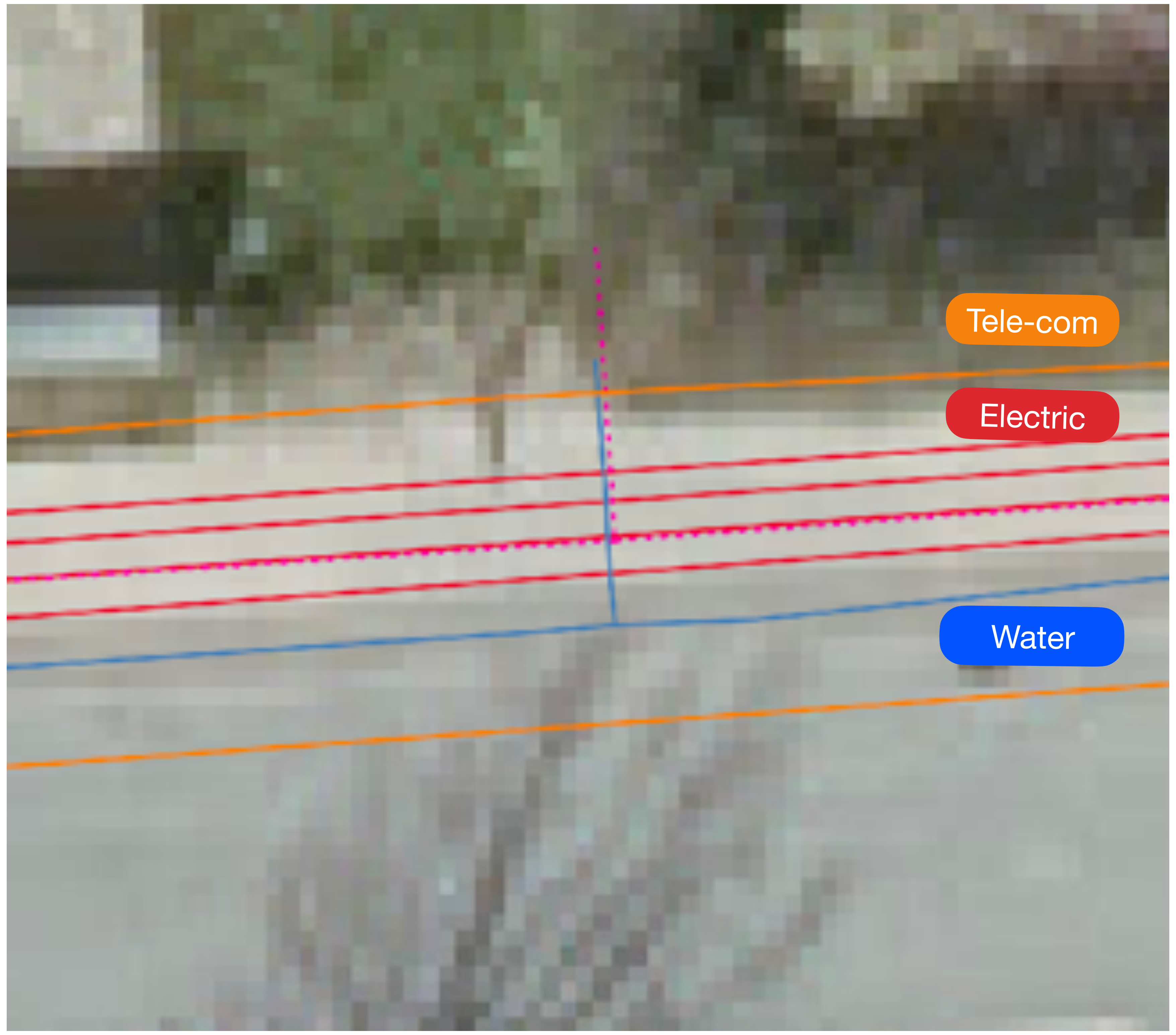
Virtual Utility Marking

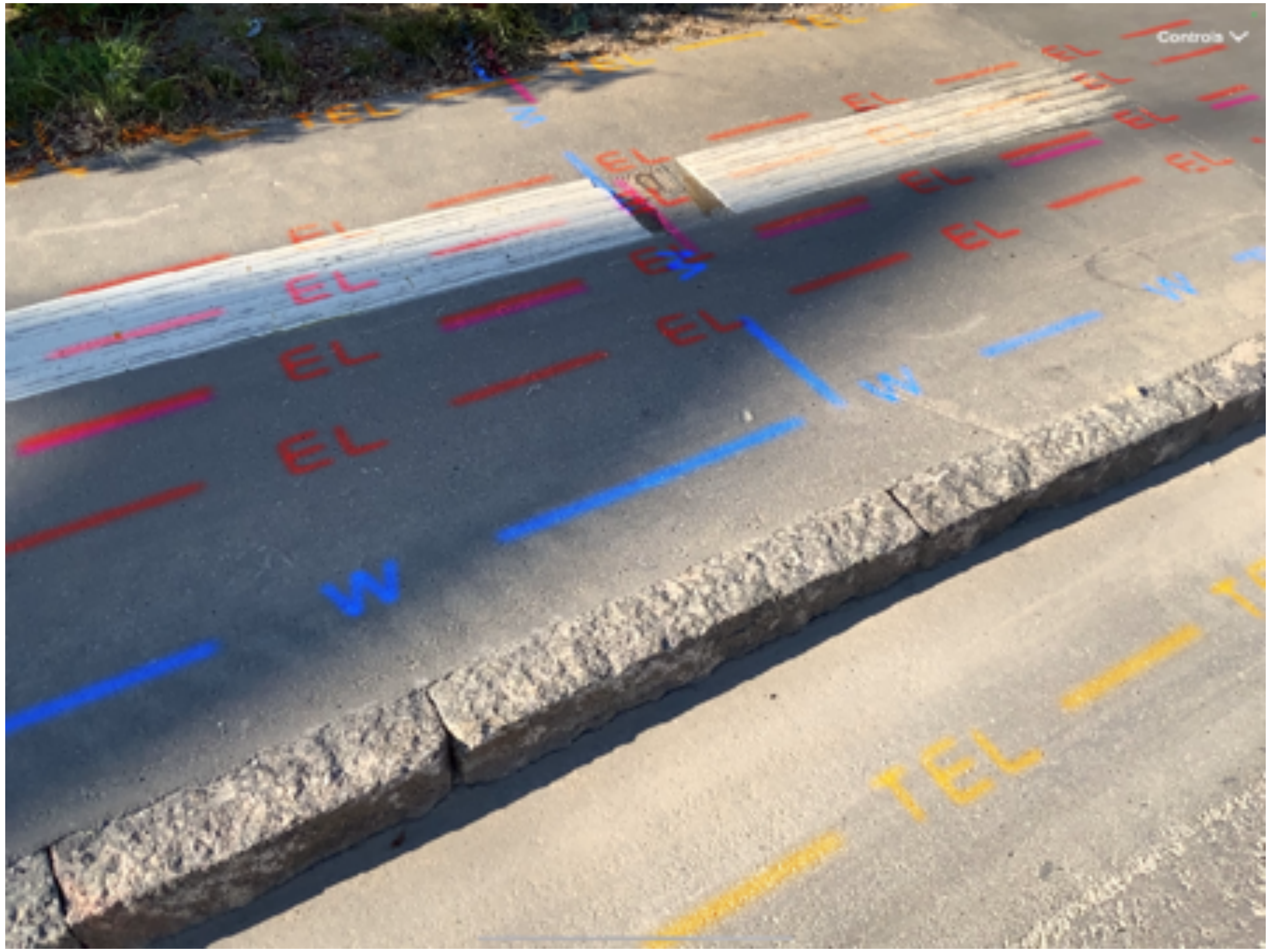
Could we make an AR visualisation method that was ***relatable*** *for SUE workers by resembling the* ***visual appearance*** *of real utility markings?*

1. the placement of markings follows the ground surface;
2. the markings blend into the ground surface;
3. the design of the markings follows the styles, symbols and colours set forth in industry guidelines.



Virtual Utility Marking in action





Virtual Utility Marking in action

- On-surface placement by using real-time 3D reconstruction mesh from LiDAR sensor

Virtual Utility Marking in action

- On-surface placement by using real-time 3D reconstruction mesh from LiDAR sensor
- Clearly useful when surface elevation change
  - Constructed environments

Virtual Utility Marking in action

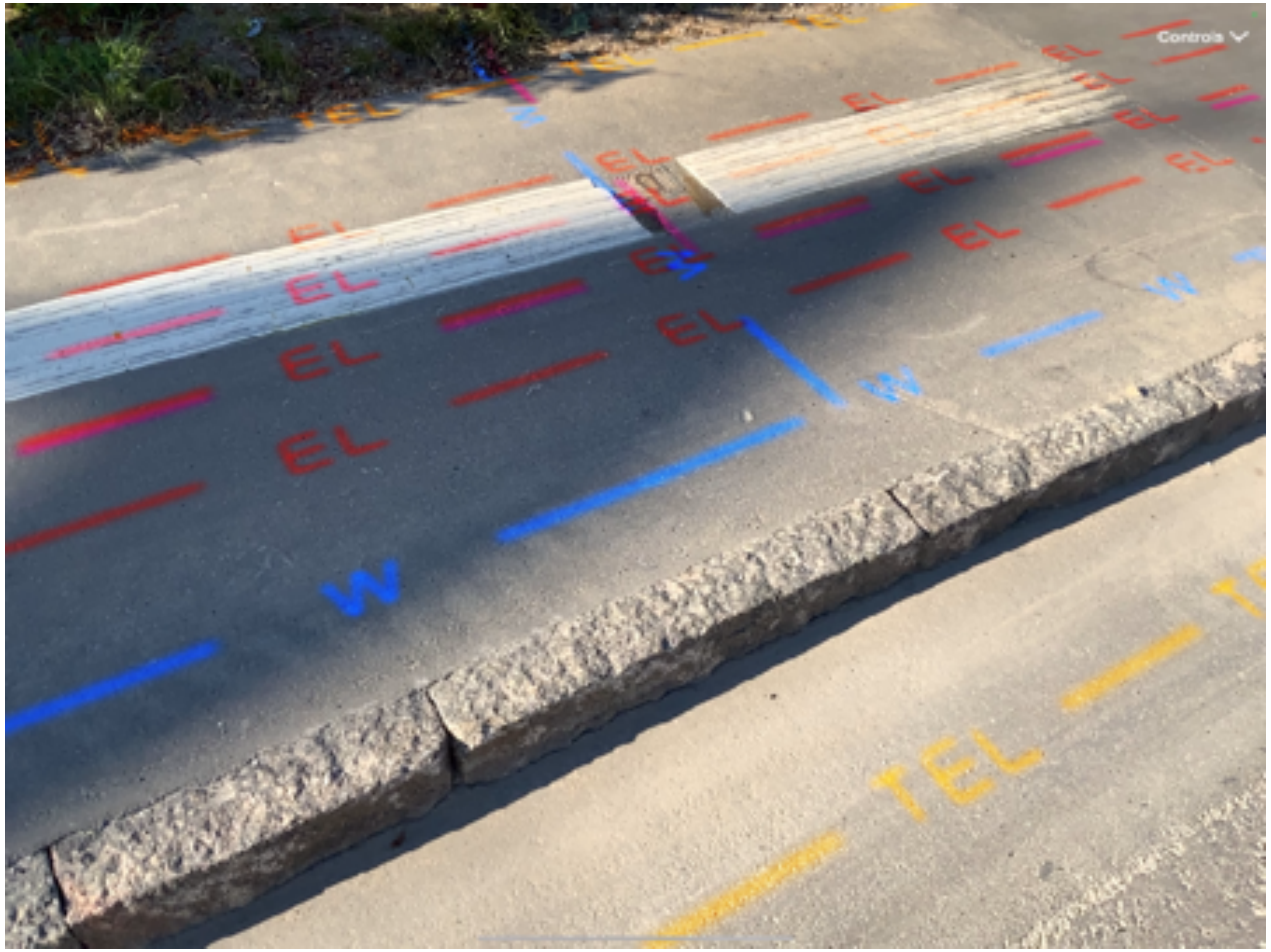
- On-surface placement by using real-time 3D reconstruction mesh from LiDAR sensor
- Clearly useful when surface elevation change
  - Constructed environments
  - During excavation

Virtual Utility Marking in action

- Realistic looking texture blending between **virtual** spray marking and **real** ground surface
  - Wet surface

Virtual Utility Marking in action

- Realistic looking texture blending between **virtual** spray marking and **real** ground surface
  - Wet surface
  - Shadows



Virtual Utility Marking in action

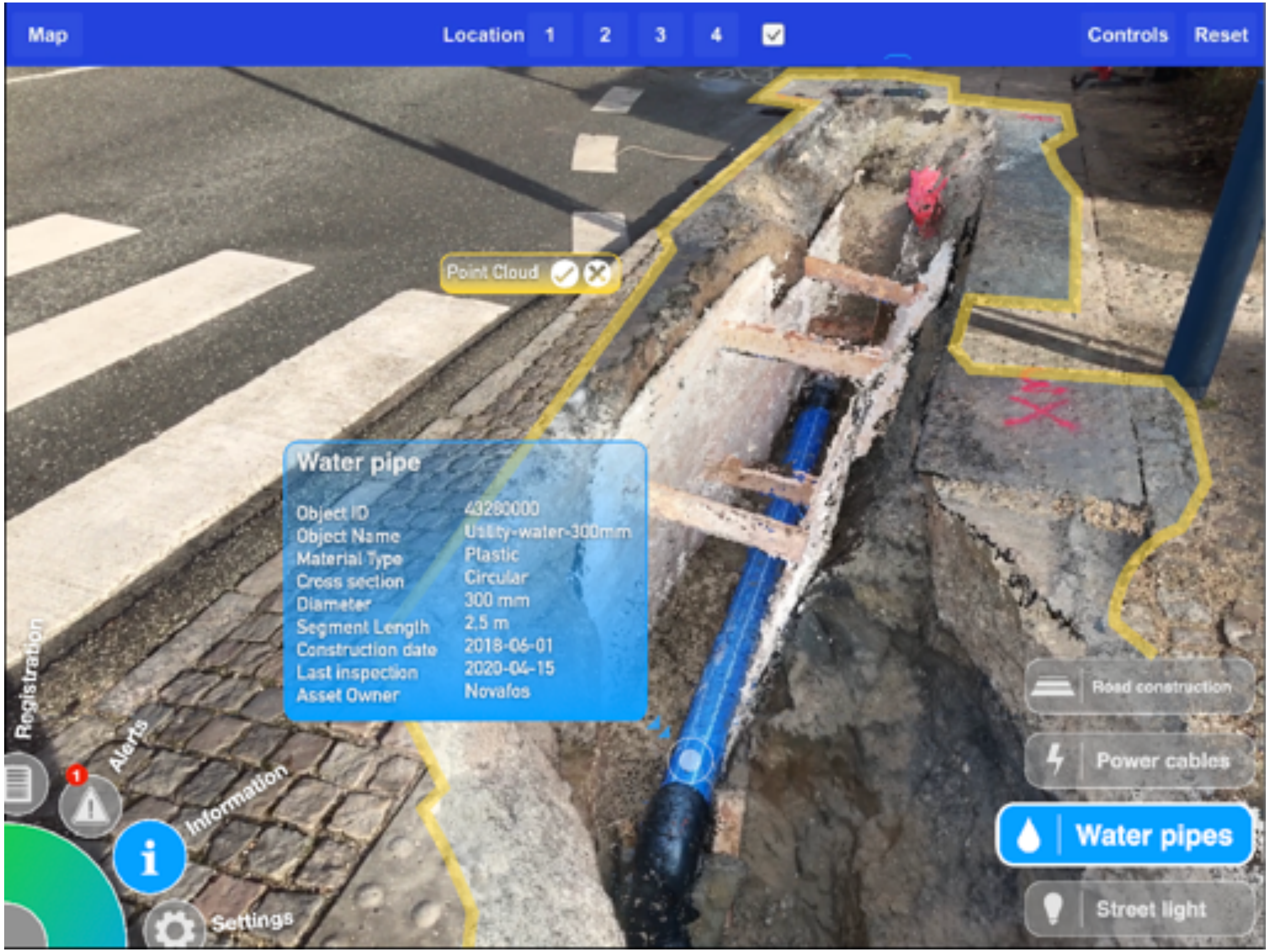
- Realistic looking texture blending between **virtual** spray marking and **real** ground surface
  - Wet surface
  - Shadows
  - Dark > light surfaces

Virtual Utility Marking in action

- The design of the markings follows the **styles**, **symbols** and **colours** set forth in industry guidelines.

Interview

- Fordele
  - Meget forståligt
  - Direkte til vores anvendelse
  - visualisering svæver ikke over jorden
- Bemærkninger
  - Ønske om at visualisere nøjagtighedsklasse (fra LER 2.0) af ledningsdata.
  - Ønske om koble LER ledningsdata med punktsky data



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