TERRAPIN

roboTic undERgRound wAterPipe INspector

Domain: Water Supply and Sanitation

Problem

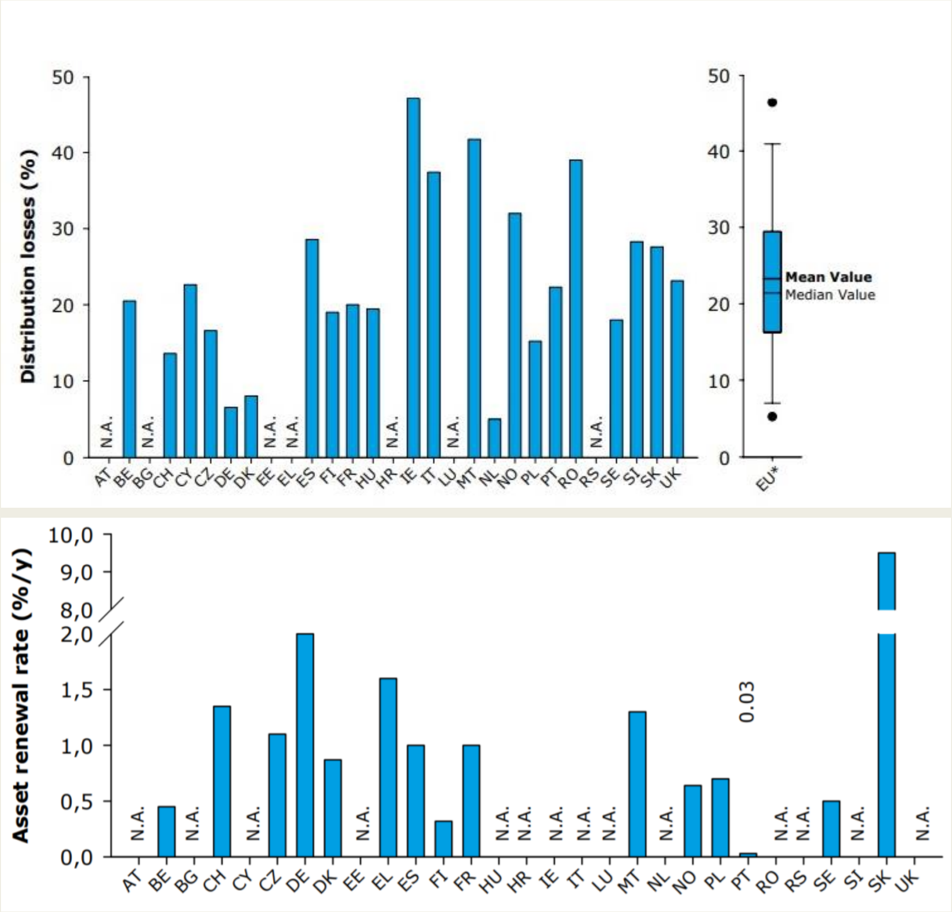
Damages of wastewater networks & water supply networks

- Leaks in wastewater networks inflicts heavy environmental pollution (pollution of the ground as well as groundwater contamination)
- Globally, water loss amounts to 126 billion cubic meters per year
- 20% of water is lost due to leakages
- Water main breaks can cost from $100 to $500.000 [1]
- There are 240,000 water pipe breaks in the US alone every year[2]
- Every year, around 900 billion gallons of untreated sewage escapes aging wastewater systems in the U.S. alone

[1] https://waterfm.com/the-economics-of-water-main-failures/
[2] https://www.jamesdysonaward.org/en-US/2018/project/lighthouse/

Water Leakages in Europe

- Drinking water distribution network losses on average are 23% of water volume for Europe
- Old network with assets renewal only at ~1% rate [3]
- Updating the infrastructure will take decades and cost hundreds of billions of Euros. Other solutions are urgently needed, such as modelling to predict leakage

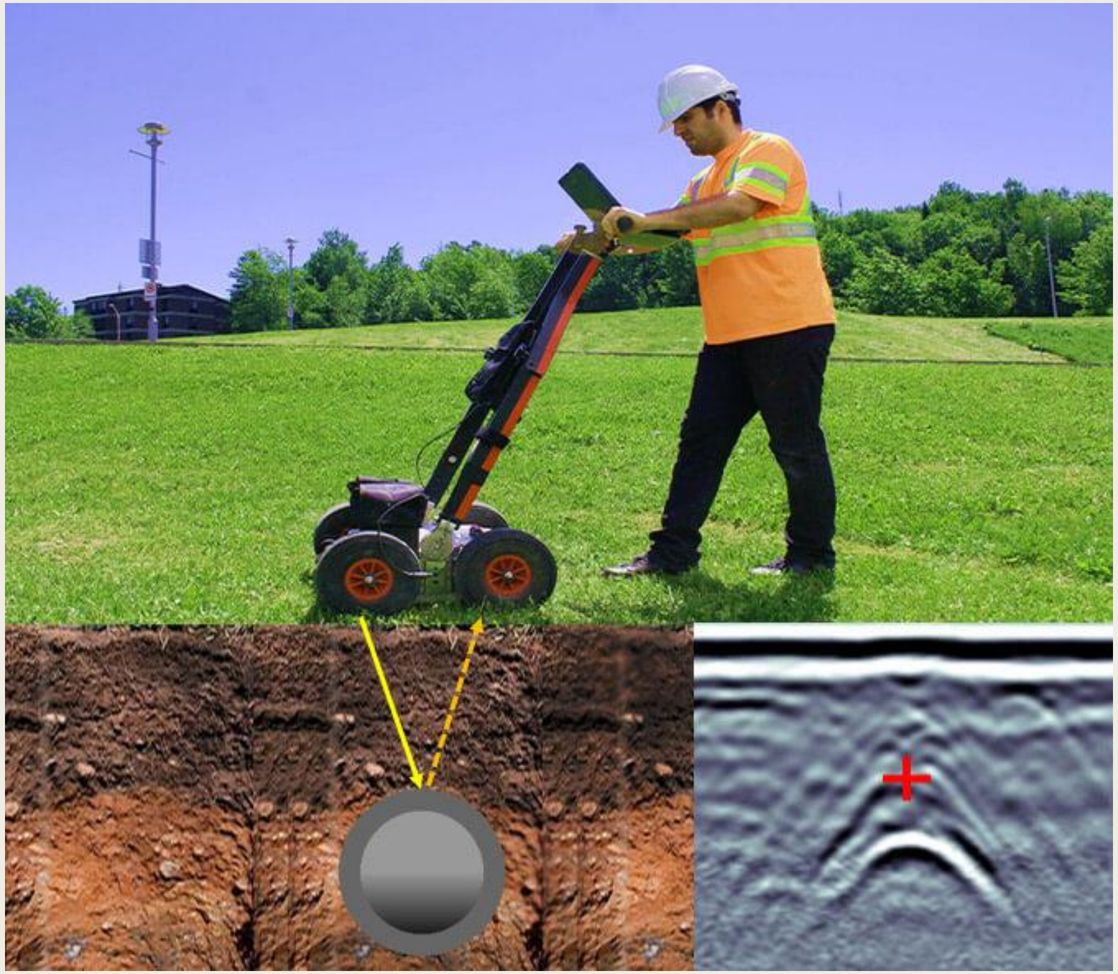


[3] https://www.danva.dk/media/3645/eureau_water_in_figures.pdf

Challenge for underground pipe inspection

Current Practices are expensive and time consuming:

- manual handling/driving of a ground penetrating radar (GPR) sensor above the subsurface inspection area of interest
- manual detection & condition estimation and annotation of detected underground utilities in the collected GPR data
- inability to accurately identify defects and overall water pipe material condition



TERRAPIN Solution

Objective: *Integration of a surface operating rover with a GPR antenna*

☑Rover

☑GPR Antenna

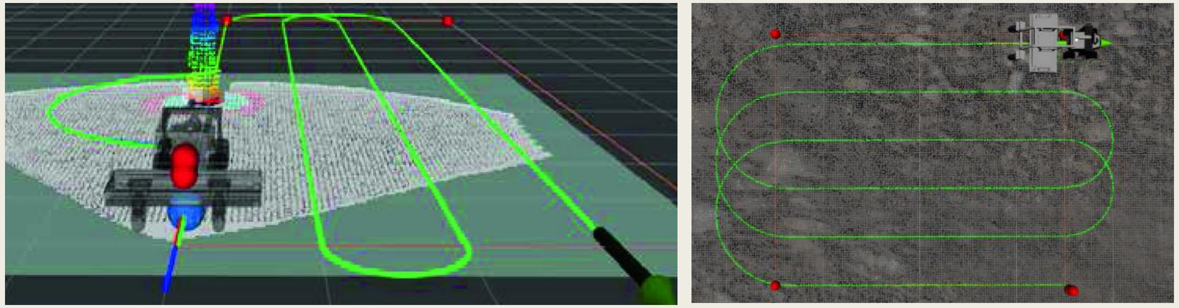
- ☑ HW integration of Rover with GPR antenna
- ☑ Development of a driver for GPR data collection with rover
- ☑ Rover localization fusing stereo-based visual odometry, GPS and IMU measurements
- ☑ Incremental georeferenced metric mapping based on rover localization

Integrated HW approach

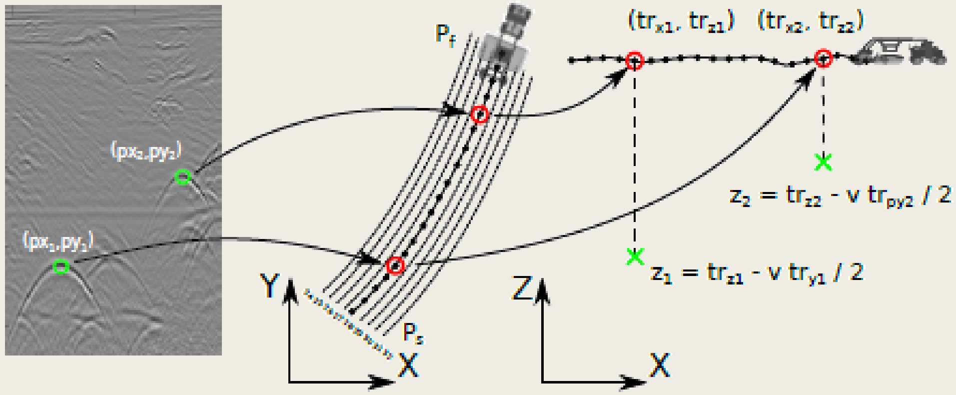
TERRAPIN Solution

Objective: *Subsurface utility and defect mapping with structured rover navigation*

- ☑ GPR data collection
- ☑ Rover structured navigation based on Boustrophedon-like motions (Dubins Paths) for optimal surface coverage with towed GPR antenna
- ☑ Integration of the detected utilities (pipes, leakages etc.) on metric map
- ☑ Utility semantic mapping including georeferenced leakages detection



Calculated Dubins paths in simulation

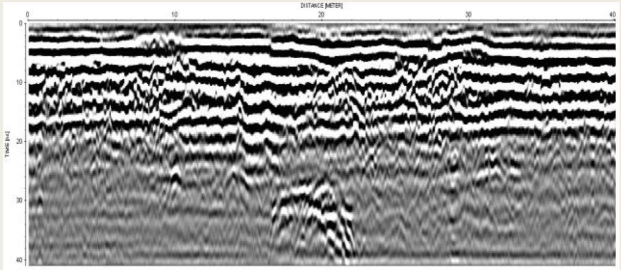


Registration of rover motion with detected utilities

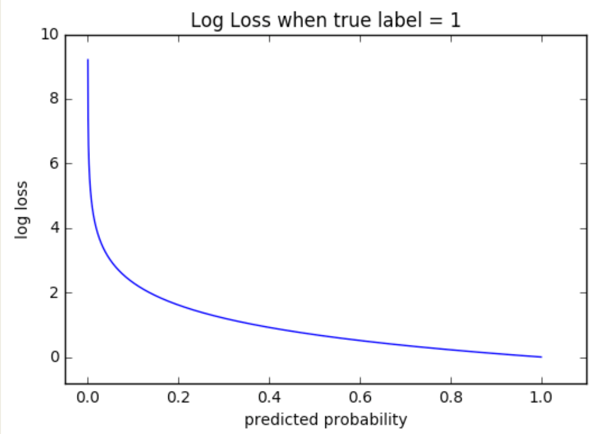
TERRAPIN Solution

Objective: *The automatic detection of water pipes and leakages in the underground space*

- ☑ **Tool of study:** The proposed approach will be based on artificial neural network models, e.g. Convolutional Neural Networks (CNNs), which are appropriate to analyze visual imagery.
- ☑ **Input**: 3D images, from GPR data, that include labels based on whether depict water pipe or not.
- ☑ **Output**: Classification of 3D images for the increase of our model accuracy.
- ☑ **Loss function**: The Cross-entropy loss is used for the classification of 3D images.
- ☑ **Next step**: The parameters, such as the material, the length and the diameter of pipe will be used for the modeling of pipe material degradation.



GPR data



Example of possible loss values through the cross-entropy function

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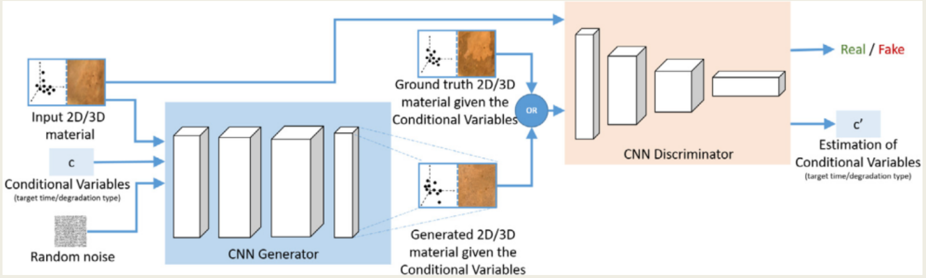
[3] https://www.danva.dk/media/3645/eureau_water_in_figures.pdf

TERRAPIN Solution

Objective: *The modeling of the pipe material degradation*

- ☑ **Tool of study**: The proposed approach will be based on machine learning frameworks, e.g. Generative Adversarial Network (GAN), in which two neural networks contest with each other.
- ☑ **Input**: 3D images from GPR data, random noise and conditional variables such as the material, length and diameter of pipe.
- ☑ **Output**: The degraded image in many snapshots in time.
- ☑ **Loss function**: L1 Loss Function will be used as is not affected by outliers that may arise.
- ☑ **Details**: The simulation of the proposed approach on different materials, lengths and diameters of pipes contributes to the estimation of the pipeline lifespan and urgency of its maintenance.

The proposed Architecture



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TEAM

Hypertech

OZZIE
robotics

pragma.