# 3D VISUALIZATION OF SUBSURFACE PIPES BY VOLUME IMAGE PROCESSING OF GROUND PENETRATING RADAR SIGNALS


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## 1. GENERAL INSTRCUTIONS

The maintenance and management of subsurface pipes, which measures more than 1 million km in Japan alone, is an urgent issue in social and security-related terms. As shown in a serious road collapse in Fukuoka, Japan, in 2018, the stability of underground structure affects the social security considerably. Kuwano et al (2015) [1] shows buried pipe breakage leads to the development of underground cavities. In worst case, the cavities grow so large that the road surface above collapses. In this context, it is crucial to analytically estimate the features of underground pipes and subterranean space.

Ground penetrating radar, or GPR, is a geophysical method to survey subsurface using radar pulses. This study employs 3D radar images of subsurface collected by a GPR-equipped vehicle.

Yamaguchi et al (2020) [2] proposes the combination of CNN-based algorithm and Kirchhoff migration to detect underground buried pipes, but its low precision, i.e., plenty of false positives against few true positive, prevents its applicability to real road data. Thus, thus this study aims:

- to demonstrate 3D layouts of subsurface pipes.
- to estimate such parameters as depth and radius of pipes and soil permittivity.
- to clarify the effectiveness of three-dimensional digital signal processing, including 3D spatial frequency filters and edge detection.

## 2. MEDHODOLOGY & RESULTS

Theoretically [3], GPR reflection is hyperbolic because the round-trip time of pulses corresponds to the depth (Z) of target objects at each scan position (X). The spatial depth $Z$ is a function of time $t$, light velocity $c_0$ in vacuum and relative permittivity of soil $\varepsilon$.

$$Z^2 = depth^2 + X^2 \quad where \quad Z = \frac{c_0}{2\sqrt{\varepsilon}}t$$

The equation 1 shows the simplest model of determination of depth of target pipes, but pipe radii, the thickness of air layer, and the inhomogeneity of soil relative permittivity need to be integrated into models for more accurate estimation. Figure 2 illustrates the process of detection of hyperbolic reflection patterns for pipe detection. The original 3d radar images have horizontal stripe noises. Therefore, first, the images are denoised with a certain filter (in this case the mean in scan direction is subtracted from the original). Second, the images are binarized with edge detection. Lastly, theoretically generated hyperbolas are fitted to the binarized image to find the highest correlation point.

Figure 3 showsthe result of 3D extraction of radar reflection as a segment using 3D edge detection.

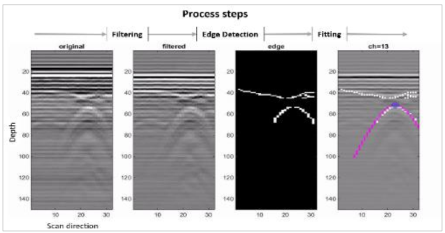


Figure 2: illustrates the process of pipe detection algorithm

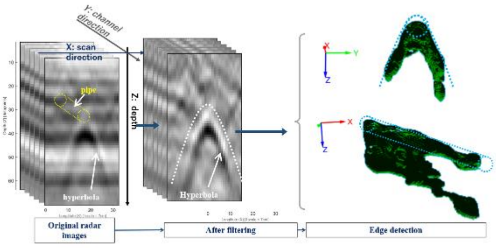


Figure 3 illustrates the process of radar images, composed of frequency filtering, edge detection and fitting.

## 3. CONCLUSIONS

this study addresses the development of automatic pipe detection algorithm. 3D frequency filtering and edge detection is the key for detection of subsurface pipes. Also, by using 3D edge detection, it is possible to comprehend 3D layout of hyperbolic shapes. This finding could help understand the time variation of the reflection of pipes, associated with the status of pipes.

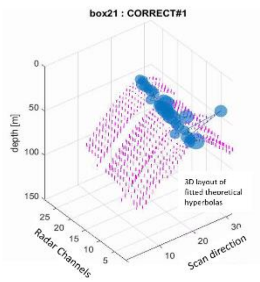


Figure 4. 3D layout of a hyperbolic reflection after processing.

## REFERENCES


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