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INTEGRATED APPLICATION OF MODERN REMOTE SENSING TECHNOLOGIES FOR CHARACTERIZATION OF HEATING SYSTEM INFRASTRUCTURE

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ABSTRACT: *Ground penetrating radar technology is a modern method of remote sensing which is applied in various engineering fields. Its main application in geodesy and geomatcis is in detection of underground utilities. Integration of GPR technology with thermal camera mounted on an unmanned aerial vehicle results with a fast, reliable and comprehensive system for detecting the heating system pipeline. After detail analysis of thermal images and results from GPR scanning it is possible to esablish the current state and geometry of the pipeline and determine future steps in correct maintenance of the system.*

Keywords: *Remote sensing, ground penetrating radar, thermal camera, district heating network, unmanned aerial vehicle*

INTRODUCTION

Detection of the underground utilities is one of the problems that geodesy deals with and it consists of two parts. First part is the process of detection and registration, and the other one is inputting the data into the database. It's a recommendation that the acquired data should be stored in a standard way that is defined by the INSPIRE directive. [5]

When it comes to registration of the underground utilities, current state can be described as having a high percentage of unregistered or false registered utilities. It is well known that a significant number of villages in Serbia don't have adequate records of the underground utilities. Main reason is that the contractors place the utilities without inviting a surveyor to map its location and depth or they change the existing utilities without updating the cadaster. This creates a huge issue when it comes to building new roads

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or buildings because no one can know for sure, if the ground below is clear of any utilities that can cause a catastrophe if they are cut or broken in the process.

It is necessary to determine the exact location of the utility of interest, as well as to estimate risky places that need to be additionally checked for replacement or improvement.

HEATING SYSTEM INFRASTRUCTURE

Heating system pipeline is a part of remote heating system and it represents hierarchical system of pipelines, measuring and regulating devices that connect the manufacturing source to the end user. Whole system consists of three elements: heat source, distribution network and end users. Distribution network consists of a pair of pipes, one to send and one to return the medium. There are examples of 3 part pipeline, where 3rd pipe transports hot sanitary water. The most often used medium is hot pressurized water.

Heating system is only one of many utilities that we use every day without paying much attention to, but the importance of it cannot be stressed enough. First classification of the pipeline can go in two categories: set above ground, and set below ground. The focus in this work is on the pipeline that goes underground, as it is the one that can create problems in detecting and determining the position and depth.

Knowing the nature of the medium that is distributed in this pipeline, it is important to prevent any loss of the energy and heat as it is expensive. That is why these pipes have an insulation. Two ways have shown right in doing this. First way (Figure 1) is to set a pipeline in a concrete channel. These concrete channels have standard dimensions with corresponding pipe dimensions. Respecting these standards plays a huge role in later detection of the pipeline. The other one (Figure 2) is by using preinsulated pipes that can be laid directly into the ground. Third option is to replace the concrete channel pipes with the preinsulated ones. [2].

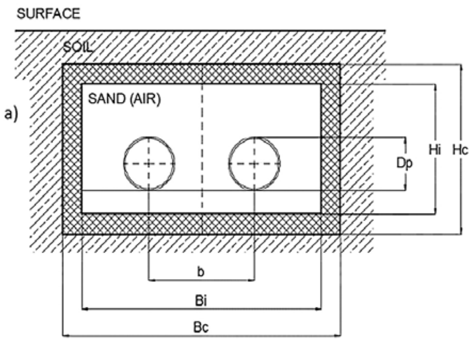


Figure 1.

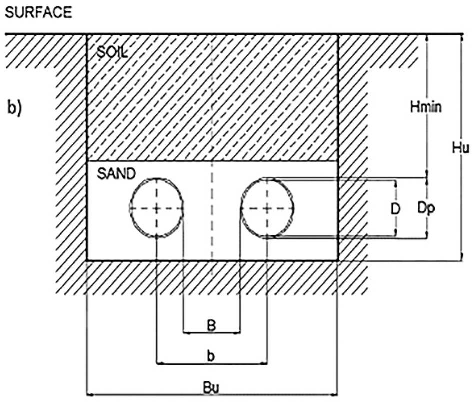


Figure 2.

GROUND PENETRATING RADAR

Ground penetrating radar is meant for detection, precise display of location and shape of underground objects. It is considered as a new method of measurement with constant technical improvements. Most important application of this technology is on detecting utilities made from different types of materials.

Hardware of GPR consists of several components:

- Antenna that sends and receives signals
- Computer unit with an operating system
- Battery
- Storage for the data
- Carrying vehicle (with encoder – used to position the vehicle)
- Additional parts (for example a GPS unit)

The most important characteristics is antenna's central frequency. Antennas used for detection of the utilities have frequency from 200MHZ to 2000MHZ, with the antennas of 200, 400 and 900MHZ being the ones used the most. [4] The scanning depth and detectability are corelated with the frequency.

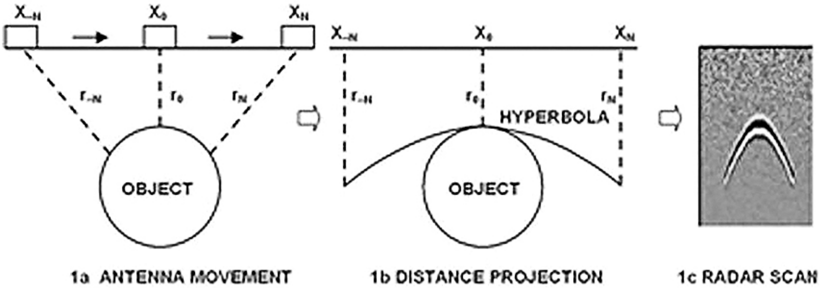
As the vehicle moves above the ground, antenna sends high-frequency, polarized electromagnetic waves into the ground. Due to inhomogeneity of the ground caused by the presence of different soil type, underground utilities and objects, rocks and similar, part of the waves reflects back and part of it goes through. This process repeats itself as long as the wave has enough power to pass through. Reflection of the wave happens be-

Figure 3.

cause of the differences in electrical and magnetic attributes of the material and soil. One of the most important attribute is dielectric constant. It represents how difficult it is for the field (in this case – electromagnetic wave) to porpagate inside a medium due to the response of the medium to the field.

There are several ways to determine this attribute (table with predetermined values, instrument recalibration based on the known depth, interractive analysis). Another attributes are magnetic permability, which only has influence at specific locations nearby active volcanos, and medium permability that depends on humidity.

Antenna recieves reflected signals that are continuous. Since we use computer in data processing, those signals need to be converted into discreete signals. As a result, we get a discreete signal represented with a certain number of points – usually 512. Every reflected signal gets its representation trough these 512 values. When we allign all recieved signals one after another, the result is graphic representation of scaned area called a radargram. The waves that antenna sends are spreading into a cone and that creates another phenomena. The utility or object underground is getting detected before the antenna is right above it. This produces a hyperbolic reflection on the radargram when it comes to cylindric objects, when the scanning line is perpendicular to the utility. (Figure 4) [4]



1a ANTENNA MOVEMENT 1b DISTANCE PROJECTION 1c RADAR SCAN

Figure 4.

Three main modes of GPR are

- *Distance mode* – uses encoder, data is collected at equal distances
- *Time mode* – without encoder, radargram is formed based on scans taken in same time intervals
- *Point mode* – used for large and uneven area, a single scan is recorded

RESULTS AND DISCUSSION

The goal is to detect the pipeline with minimum work and cost. While GPR can be great in this alone, one technology can help this process. If you integrate GPR with a mobile system capable of very fast, reliable and relatively inexpensive detection of heating pipelines using thermal imaging aerial inspection, you get a full system for simple identification of the characteristics of heating pipelines, prevention and registration of damage and later automated data extraction. [3] The idea is to mount a thermal camera on an unmanned aerial vehicle and swipe the area of interest. Since the object of scanning is heating system pipeline, thermal camera will catch the changes in the temperature that appear due to higher temperature nearby the pipeline. These thermal images can then help in determining the locations to be scanned with a GPR for a detailed picture of the current state.

Following hardware has been used to achieve the goal:

- Thermal camera PI 400 LW, spectral range 7.5 - 13 µm, temperature range -20 – 100 °C , shown in figure 5
- Unmanned aerial vehicle Aibot X6, max speed of 50 km/h, climb rate up to 8m/s, flight time up to 30’, shown in figure 6

Figure 5.

Figure 6.

Before the field work, it is possible to create synthetic radargrams that are simulating real situation and give the insight to expected results. The software that can provide those radargrams is GPRMax. [1]. Two radargrams that simulate both types of heating system pipeline installation were created using this software, and the results are shown on figures 7 and 8.

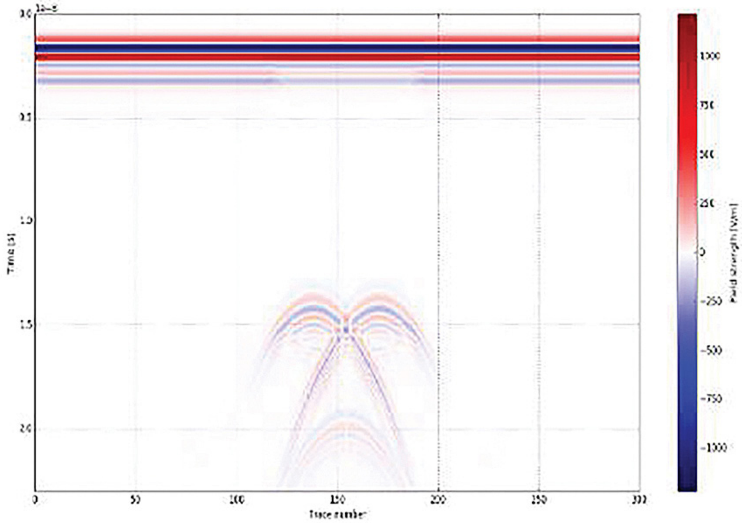


Figure 7.

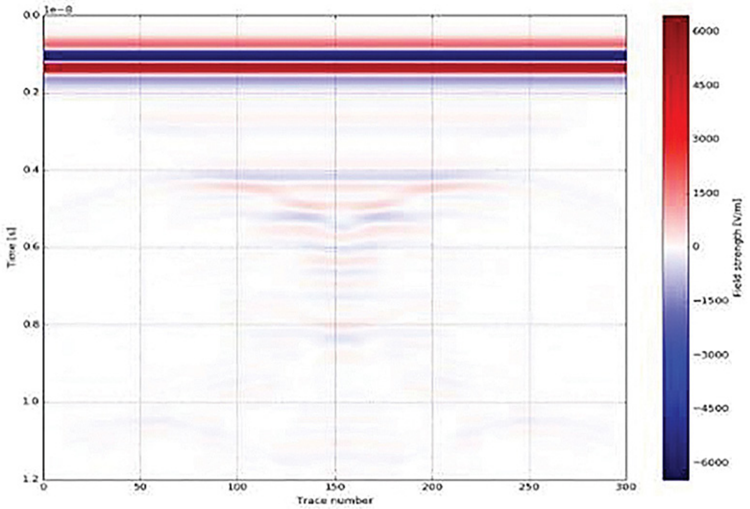


Figure 8.

Figure 9 shows a thermal image at location 1. Dark stripe on location is from a car parked above the pipe. Temperature difference is approximately 3 - 4 °C. Comparison between the records and real situtation shows the missing pipe.

Figure 10 shows a radargram that represents a pipeline set in a concrete channel. Based on the estimated cover width of 140 cm it's conculded that it's pair of pipes of 250mm in diameter.

Figure 11 represents the thermal images at locations 3 and 4. Repeated situation where the current records do not match real state. Thermal image implies intensive radiation.

Temperature differences are about 8 - 9 °C which suggests the pipes might be damaged. Figure 12 shows the radargram of the concrete channel, width of 140 cm suggests a pair of pipes of 250 mm in diameter. Figure 13 represents the radargram at location 4. Cover width of 80 cm indicates a pair of pipes of 65 mm in diameter.

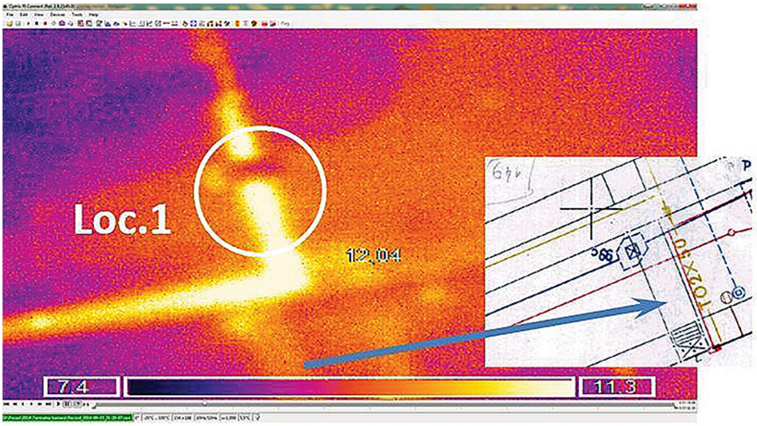


Figure 9.

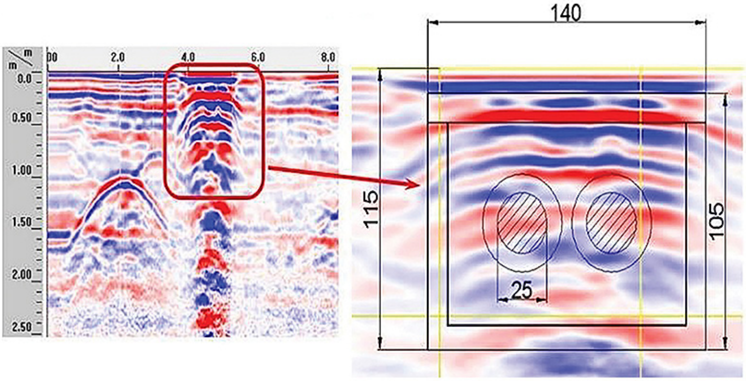


Figure 10.

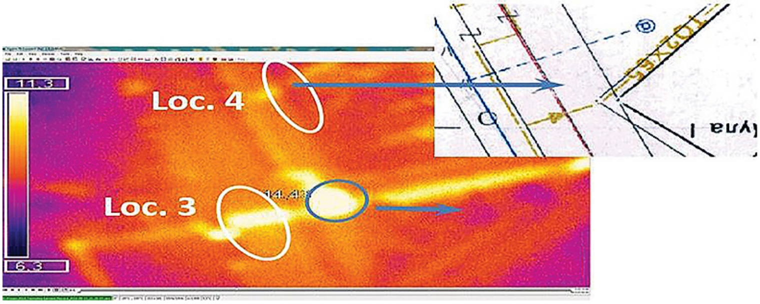


Figure 11.

Figures 14 and 15 show the thermal image and corresponding radargram for location 5. Estimated cover width of 140cm indicates a set of pipes of 250 mm in diameter.

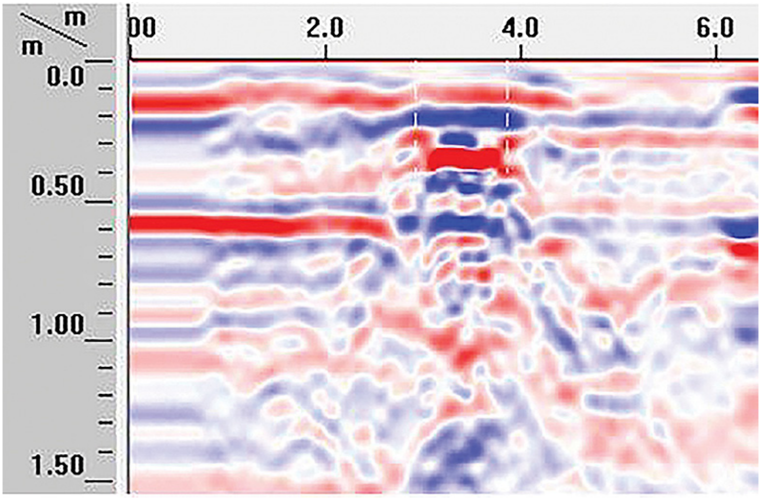


Figure 12.

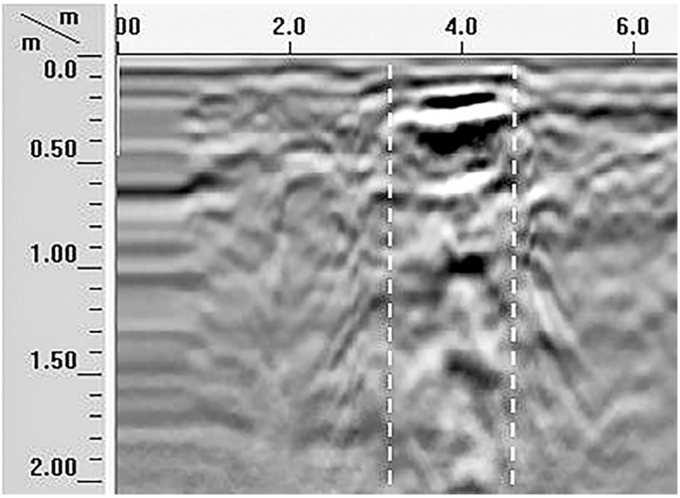


Figure 13.

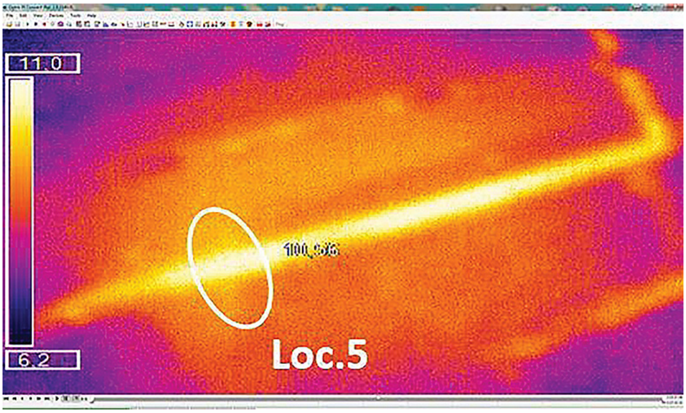


Figure 14.

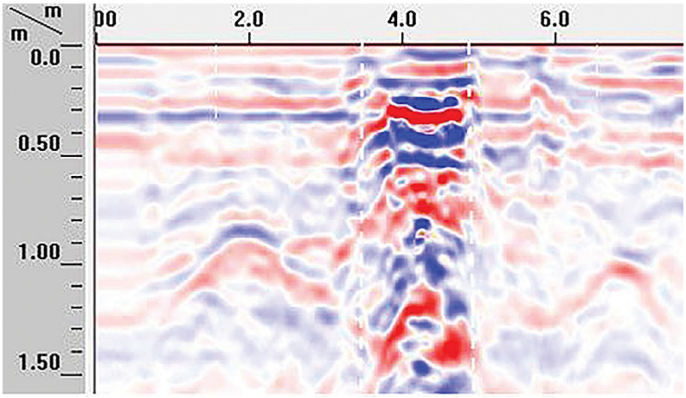


Figure 15.

CONCLUSION

Thermal imaging on UAV provided fast and efficient acquisition of heating pipeline traces and enabled comparison between real and cadastral data, as well as heat dissipation detection. This data narrowed the area of GPR scanning. Presented radargrams provided details about heating pipeline structure, using information on concrete channel width and its standard dimensions.

Exact position of the utility, its depth, diameter can be determined using additional software analysis of acquired radargrams. Technology of GPR can help in creating comprehensive 3D models that provide higher insight into the situation and has the advantage in applications that require spatial positioning of the objects.

Integration of these two systems turned out to be a good choice in dealing with the tasks of detection of the underground utilities. This approach requires much less time in comparison to the conventional methods. It should be a solution that everyone involved in creating and maintaining an underground utility records converge to.

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