

USING GEOGRAPHICAL INFORMATION SYSTEMS IN ORDER TO ACHIEVE THE URBAN CADASTRE IN THE SUBCETATE NEIGHBORHOOD OF ARAD WITH THE HELP OF MODERN TECHNOLOGIES

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Abstract: Studies shown in this paper were realised in the west side of Romania, on the administrative territory of Arad city, Subcetate neighborhood, with the purpose of making a situation plan of the underground infrastructure. More specifically, of the natural gas distribution network. This distribution network incorporates pipes and connections with medium pressure, tuning stations, pipeline stations and connections, valves on pipes and connections. The purpose of this study is the acquisition of the GIS data from this underground network. To create such a plan, we used the Leica Ultra Utility Detection and Tracing System pipe locator to find the network, GNSS Leica Viva GS14 and GS16 to determine the points marked on the route with the locator device, Leica FlexLine TS06 total station to determine the points found on the aerial connections and counters found on fences and constructions. Finally, for proper time management, we used Leica Pegasus: Backpack, which it's a mobile mapping system. Concerning the detailed topographic surveys, done in a normal way using GNSS equipment and total stations, the use of Mobile Mapping – LiDAR technology offered a real advantage by reducing work time, investigated area and the complexity of the acquired data because the survey was done with the precision of normal equipment. The pros of using geographic information systems and applying them to all sorts of fields have helped spread this concept. The majority of institutions and companies who work with spatial data have initiated a GIS-type project. The complexity of the underground utility network is constantly growing and obtaining precise information regarding the layout of the underground utilities has never been more important. Once all the data is collected on the field, the next part is using this data to create a plan in AutoCad so the database up-to-date with the postal codes, street names, pipe materials, pipe diameters, burial depth, pressure regime, vertical component, length of the main network and that of the embranchment. Some information was introduced automatically while some needs to be manually put in.

Key words: GIS, gas pipeline, 3d PointCloud, LiDAR, Arad

INTRODUCTION

If at the beginning the implementation of a geographical information system meant buying hardware and software, now the focus shifted towards collecting data and implementing personalized geographical information system (HERBEI ET AL., 2018; HERBEI, 2015; ȘMULEAC ET AL., 2012). These personalized systems were developed for different kinds of use: the inventory of the technical-municipal cadastre, environmental applications, pollution and impact studies, financial strategies analysis, monitoring applications of the technical-municipal networks, applications meant to prevent disasters, tourism, monument protection, urbanistic applications, precision agriculture (HERBEI AND SALA, 2014; HERBEI ET AL., 2016) etc.

The exiting underground infrastructure network can be complicated. The complex pipelines are globally extending at an alarming rate and it has never been more important to

collect information regarding their position. We need precise information in order to protect the existing network and plan ahead for the future one.

If we study the analysis of the geographical space in the recent years we can observe the tendency towards satellite use using certain techniques and method. GIS (SIMON, ET AL., 2017), as well as CAD (SIMON ET AL., 2017) techniques offer a complex analysis with results superior to those used in the past.

In the last years, the number of sensors and collecting systems have developed immensely. Besides total stations and GNSS networks, the most used topographic equipment today offer many more available options for data collecting – not only for land surveying, but for many other things and areas from many different sources (CHATZISTMANIS, ET AL., 2018)

For example, MMS (Mobile Mapping System) equipments collect data as point clouds together with stereographic images by ground scanning. As needed, the range of the laser can be set but it can not pass through solid objects or in another plan for example scanning the roofs of the buildings (TUCCI, ET AL., 2018, POPESCU ET AL., 2016). All the obtained data using equipment are complementary and the final result will be a GIS (HERBEI ET AL., 2011) that displays the natural gas network from the chosen neighborhood.

MATERIAL AND METHODS

The research presented in this paper was done in Arad city, on the limit between historic regions Banat and Crisana. The city is situated between both sides of the Mures river in Crisana and Banat. The case study presented further was done in the Subcetate neighborhood. This neighborhood has an uniform urban fabric unfolded between uneven imits – Infanteriei street, Eugen Popa street and the railway. The street structure is uniform without a main street but with large space meant for green space. The lots have a size of 950-1000 square meters. We can observe variations of the lots close to their limits. The buildings have uneven shapes and different positions. The majority of them are aligned to the road but there are many housings that don't respect that criteria (www.primariaarad.ro).

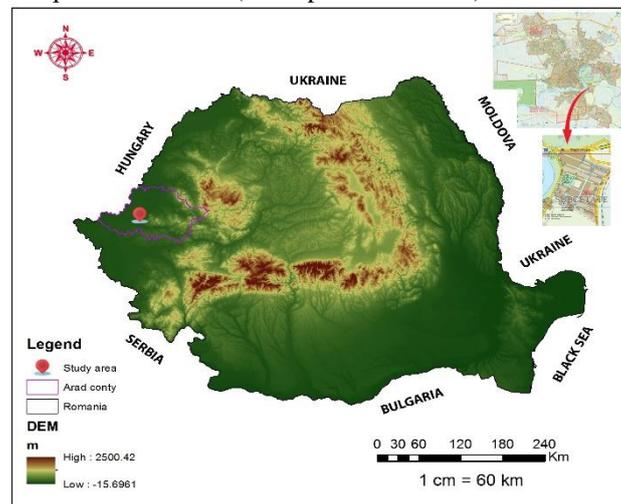


Fig. 1. Location of the study area (SIMON et al., 2018; www.arad-city.map2web.eu)

The working methodology underlying this study has been divided into several stages and is summarized in figure 2.

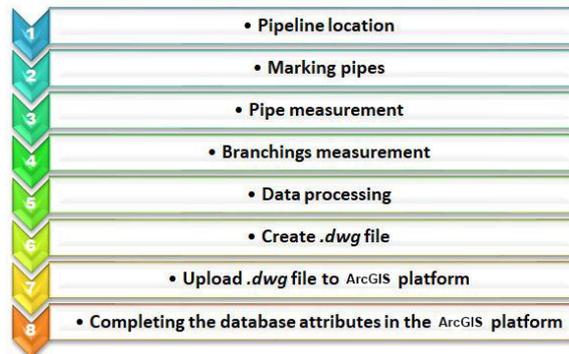


Fig. 2. Workflow

The underground network was found using the Leica ULTRA equipment and the points on the network were marked using topographic sprays. These points were determined afterward using Leica Viva GS14 and GS16 equipment.

The next step was the determination of the aerial connectios, counters and postal codes. This step was firstly done with Leica FlexLine TS06 total station, but due to the large number of streets, the duration of this process was fairly high, right around 1 km a day.

To improve the time management, we decided that we should use the mobile scanning device Leica Pegasus: Backpack. Using this equipment, the time spent on the job went down a lot . For example, a total street length of 6 km was scanned in 1 hour and 17 minutes, activity which was registered with the help of the Garmin Fenix 3HR smartwatch (fig. 3).

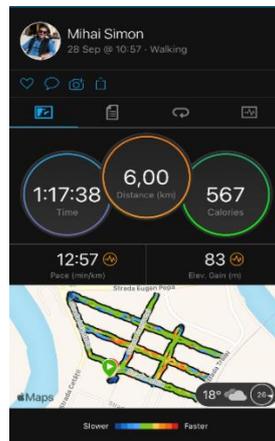


Fig. 3. Registered activity

Equipments used:

➤ *Tools used for data collection (fig. 4)*

Leica Ultra offers the most precise localization. The intelligent processing of the signal was integrated with unique and flexible operation modes to help with time management and to increase confidence in our results (leica-geosystems.com).

The selectable antenna and the personalized frequencies are being optimized for specific applications while the AIM system monitors signal interference levels and recommends in what way to use it so we get the best results (leica-geosystems.com)

To determine the points marked on the network we used the GNSS position technique. The determinations were done using GNSS Leica Viva GS14 and GS16 receiver which allow the determination of the point we want using the RTK method (Real Time Kinematic). The system offers fast positioning with a high precision (up to 2 centimeters), depending of the number of visible satellites. This system is based of GNSS, including GPS-NAVSTAR and GLONASS, providing complementary data needed to improve the signal up to a few milimeters.

To determine points found on aerial connections and counters, we firstly used the TS06 total station with traverses that go from known points on the street network and then return on the other side of the network.

We gave up on using topographic surveys with the total station and instead opted for a newer device: Leica Pegasus Backpack (SIMON ET AL., 2020). This equipment is the best solution for recording data from the environment, regardless if it's inside, outside or underground. It collects and combines image and point cloud type data even in location where the GNSS positioning signal is missing (leica-geosystems.com).

Designed to capture data from the environment with ease, Leica Pegasus: Backpack transforms progressive scanning into a simple procedure. The equipment is a sensor platform and it has an ergonomic design and it combines five cameras that offer a well calibrated 360° degree view with two LIDAR sensors (leica-geosystems.com).

This unique solution of mobile cartography was designed for fast and regular intake of the reality. After the scan is done, millions of points which represent the exact position of all the things in the scanned area are collected, thus the scan process offers a better use of resources because there is no need for another job if there is something missing (leica-geosystems.com).

The GNSS recording will be done using Leica Viva GS08 antenna. This smart antenna is an universal GNSS instrument used to obtain data with high reliability when we require high precision. The antenna will be used as a reference station with its location in areas where there is no obstacles, minimum interference and satellite visibility (far away from buildings, trees, cars, electric lines etc.). The station will collect L1/L2 observations at 1 hz and it will stock RINEX data (.20g, .20o and .20n files). This data will be used to post-process the data obtained from the scan.

All the determinations were done using the European Terrestrial Reference System 1989 (ETRS89), introduced in Europe as a geodetic reference system, but were later automatically transformed into STEREO '70 coordinates using the eTransDat implementation.

➤ *Hardware components:*

For data processing I used a Lenovo Legion laptop that has a powerful processing unit which allowed for data to be easily processed. The main specifications of the laptop are: Intel Core i7-7700HQ 2.80GHz, 8 GB RAM, 1 TB HDD, Nvidia GeForce GTX 1060 6GB.

✚ **Software used:**

The use of modern equipment and the taking of data from the field led, implicitly, to the use of the programs with which it was equipped, but also programs for processing. In this respect, in view of the operations carried out, the following programmes have been used:

- Intertial Explorer for trajectory correction
- Leica Infinity to transform WGS '84 coordinates into STEREO '70

- Pegasus Manager for MMS data processing
- Leica Cyclone for point cloud extraction and processing
- AutoCAD for plan realization
- ArcGIS for database creation



Fig. 4. Tools used for data collection

RESULTS AND DISCUSSIONS

The discovery of the underground utilities require different methods that fit certain situations. There is a variety of technologies that can be used to detect underground networks. Because every technology has its advantages, the best solution is always the most flexible. The best technologies used to detect utilities are: electromagnetic induction (EMI) and the ground penetration radar (GPR) (blog.hexagongeosystems.com). The solution used by us in this study is that of the electromagnetic induction (EMI) because the purpose of this job is to analyze the natural gas network in order to measure it.

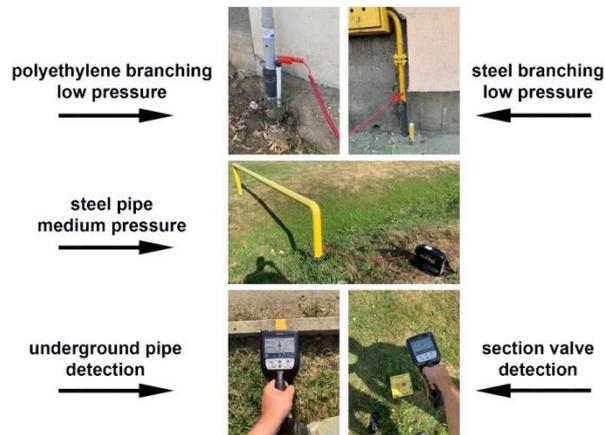


Fig. 5. Localization underground infrastructure

The natural gas network is made out of steel or polyethylene. The localization was done by connecting the inductive of a generator and by finding the route with a receiver. The location device has two cables. The red one must be tied to the gas pipe if its made from steel. If the pipe is made from polyethylene it must be tied to a conductive wire which is located at the base of the connection and follows the whole length of the pipe. The black wire must be tied to a metal which is then put in the ground because it substitutes grounding. After tying up the cable, the generator and receiver must be turned on, the work type and signal selected and then the route can be followed (fig. 5).

The GNSS determination of the marked points was done using the RTK method with the help of GNSS equipment (Şmuleac et al. 2017, 2020). After finishing this process, we have the data needed to create the plan for the natural gas network. In the end we need the data obtained by using the 3D laser scanner on the aerial connections, counters and postal codes.

The mobile 3D laser scan will be done in *two steps*: (fig. 6):

- Placing and configuring the reference station
- The second stage of the mobile scan will be, the stage which in turn is divided into five phases:
 - static initialization for 5 minutes; during this time the equipment will stand still in the position in which it was placed to set up its GNSS Almanac and to establish the position; during this time will set the parameters for cameras as well as distance for pictures.
 - dynamic initialization, for 2-3 minutes, in which the equipment will be continuously moved to activate the GPS/INS system;
 - the actual scan; the area of interest shall be crossed with the equipment mobilised by the operator;
 - completion of the process - after taking the data to complete the whole process in the most correct and accurate manner, initializations will be made again, but this time in reverse order, first the dynamic initialization for 2-3 minutes, then static initialization for 5 minutes



Figure 6. Preparing equipment for scanning

LiDAR data obtained through scanning has been processed in the Pegasus Manager program (ŞMULEAC et al., 2020), which is a reality capture software for mobile mapping, for processing, analyzing and extracting information from point clouds and purchased images. Precise mission planning, data processing, automatic function extraction, integrated quality reporting and online publishing make Pegasus Manager a unique efficient workflow for high-precision deliveries (fig. 7).

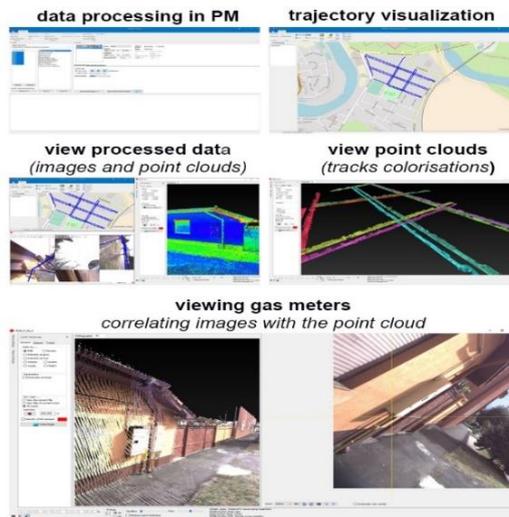


Figure 7. LiDAR Data Processing – Pegasus Manager

We have the possibility to do a quality control and correct the trajectory if we are not satisfied with the result with the help of the program Inertial Explorer (fig. 8).

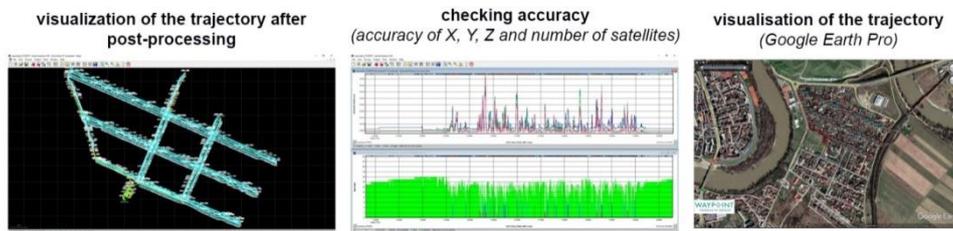


Fig. 8. Quality Control – Inertial Explorer

In the case of this study, it was not necessary to correct the trajectory, the average accuracy being up to 2 cm (fig. 8 – the image in the middle). After processing in PM – Pegasus Manager and obtaining the point cloud, it will be imported into a software for extracting the necessary information, namely Leica Cyclone (fig. 9).

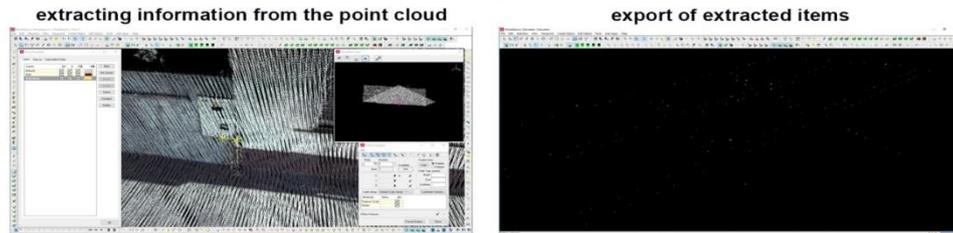


Fig. 9. Extracting information – Leica Cyclone

The required points were extracted using the *Virtual Surveyor* module and were exported as a *dwg* file. This file was copied over the first file in which we had the main network plan, both being in the same coordinate system, thus obtaining a final file with all the information for the respective neighborhood (fig. 10).

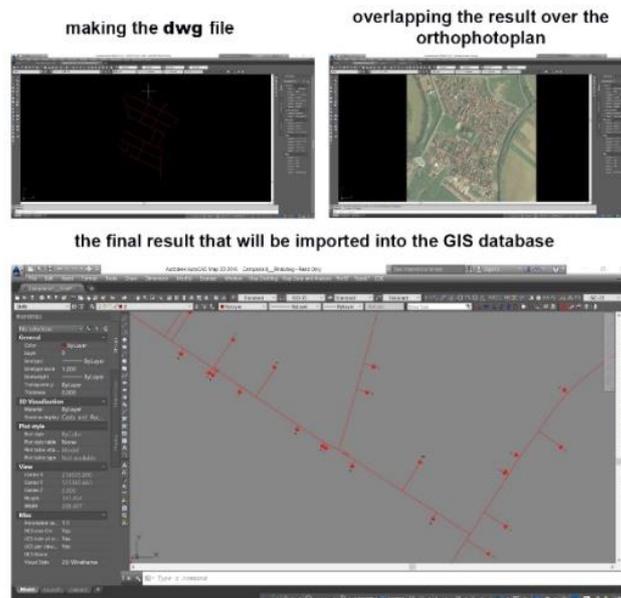


Fig. 10. *dwg* file

The *dwg* file was imported into ArcGIS, where we compiled the database for the natural gas network in the Subcetate district. This database contains information about the main network, as well as about the branches. We have entered information on the material from which the pipes and branches are made, at what depth they are buried, what is their pressure regime, what lengths the main networks as well as the branches have, but also on which streets are and what are the postal numbers to which they are connected (fig. 11).

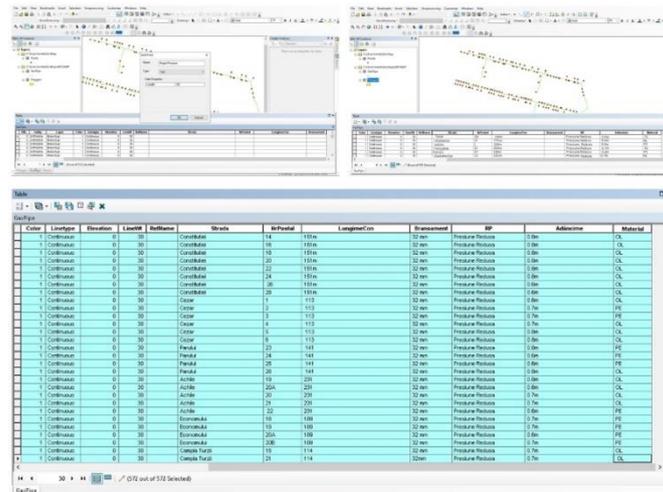


Figure 11. Create the GIS database

CONCLUSIONS

The advantages of using geographical information systems and their applicability in many areas has led to the spread of this concept. Most institutions, companies working with spatial data have initiated a GIS project. The complexity of underground utility networks is constantly increasing, and obtaining accurate information on the location of buried utilities has never been more important.

Other advantages of using MMS technology are:

- ❖ Speed of measurements (for topographical detail or other types of projects);
- ❖ Obtaining the points clouds so a detailed picture, in coordinates of the area of interest;
- ❖ Accuracy and accuracy of the data obtained;
- ❖ The high degree of detail, gives the possibility to use images obtained in projects such as construction, design, road infrastructure, geodesy and general cadastre, architecture, cartography, etc.
- ❖ LiDAR – Mobile Mapping equipment can also be used in locations where the GNSS positioning signal is missing (underground, inside buildings, etc.).
- ❖ Possibility of using data obtained in the GIS environment which allows "combining" with other geospatial data or creating non-graphic databases.

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