



RADIO SCIENCE FOR HUMANITY

Two technics of the IRCGN freezing scene group: forensic surveying by GPR and freezing scene by drone

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GPR, survey, drone, modelisation

Abstract

The national forensic institute of the french Gendarmerie (IRCGN) has within its staff a group specialized in the freezing of a scene, whether it's a criminal or an accident one. This group is armed with several equipments, which represent different sensors with their own capabilities and limits, enabling it to fulfill its missions. Two of these sensors are presented here. The first one, which is used by experts of IRCGN since 2005, is a ground penetrating radar (GPR). Real tool to assist investigators in the operationnal survey, the GPR allows to search for some elements such as body remains [1], objects (weapons, ammunitions, narcotics,...) hidden under a floor or inside of walls [2], but also areas of underground pollution or buried toxic waste.

The second presented equipment is more recent : it's based on the use of a drone. This technology makes it possible to take into account a large area in a simple and fast way. The aerial images obtained are used to generate, thanks to the photogrammetry, points clouds or ortho-photographies of the overflown scene.

1 Introduction

The purpose of a criminal investigation is to implement any useful means for the manifestation of truth. There are usually three different ways to bring a person to justice. First, and probably the least probable: via the confession of the author of the facts. Then, there is the flagrant offense, where the facts are noted in the same time of the commission. Finally, the most common, the result of a criminal investigation using scientific and forensic techniques, such as those we are used to seeing on our screens, in the various series of "CSI" disseminated around the world.

The GPR, which is a used mean of this third category, is a relevant tool used by the french Gendarmerie to find useful informations for a judicial inquiry [3]. Indeed, the GPR offers a non-destructive technique for surveying sensitive areas. But the use of such a tool is not simple. And in order to avoid the detection of false positives, it's important to understand not only how the GPR fits into the very strict research protocol; but also the limits of use of this equipment. After a first part, where the theoretical principles will be briefly described, the application of the GPR in the forensic field will be presented, before detailing the encountered limits.

The second part of our contribution also concerns an emerging technology, that finds its place in the modern technological tools used in forensic sciences. It's the drone. Real aerial vector of criminal investigation, this small machine remotely controlled allows to acquire quickly and safely informations of a scene. It will fly over crime or accident scenes and provide investigators with informations in three dimensions.

2 Operating principle of GPR

The GPR operating principle is quite simple; the interpretation of the results is more complex.

Pulsed electromagnetic waves are sent into the material to be probed. The receiving antenna collects a portion of the reflected waves. The reflections come from the rebounds of these waves which intervene at the interface between materials with different dielectric constants and which are encountered as the wave progresses in the probed medium. The reflections are materialized on a radargram, interpreted in live by the expert (see Figure 2)

The propagation of a GPR wave is based on Maxwell's equation. The method consists in sending a small pulse of energy into a material via an antenna and recording the necessary force and time to return the reflected signal as illustrated in FIG. 1. The propagation of the radar signal depends on the electrical properties regarding the composition of the subsoil. The equipment evaluates the difference in term of homogeneity, due to the different electrical conductivity properties (dielectric permittivity) between the structure of the environment and the target. The amplitude of the reflected signal is determined by the contrast between the dielectric constants of two materials.

The velocity of the wave is mainly determined by the dielectric constant of the material. The velocity is proportional to the inverse square root of the dielectric constant of the material.

The table 1 below shows the relative permittivities of common materials.

material	Permittivity ϵ_r	Conductivity σ	Depth of penetration (100 Mhz)
void	1		0
very dry soil	3	0.0001	40
very wet soil	30	0.002	0.2
ice (fresh water - 10°C)	3	0.00008	0.3
Fresh water(20°C)	80	0.005	0.001
Sea water	70	5	

Table 1 : Conduction value [4]

The velocity conditions the reception time of the reflected wave : (1)

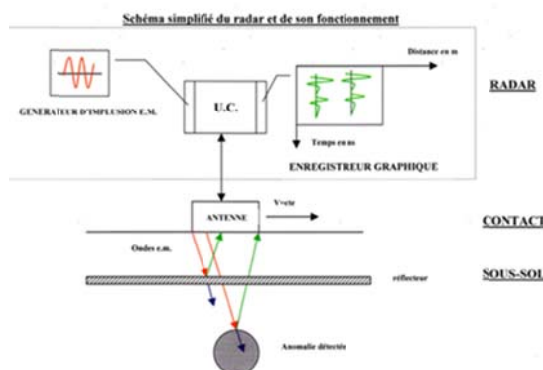


Figure 1- GPR operating principle

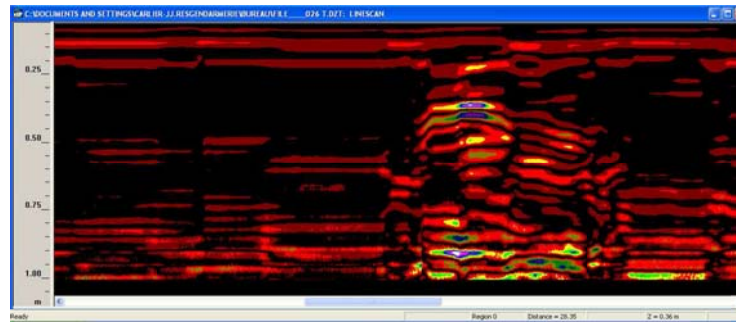


Figure 2- A radargram exemple

The delay (between the emission and the reception) characterizes the depth, but also the size of the target. So velocity (and permittivity) is a factor that determines the location and shape of the target. The resistance to penetration of the wave depends on frequency and conductivity. The penetration depth of the GPR depends on the considered material and the frequency used. Low frequencies generally penetrate more deeply, but there is a loss of resolution and thus loss of detection power for small elements. This is why it is necessary to use an appropriated frequency range to the size of the target and the depth of auscultation.

The radar is towed along a search grid defined on the site. The equipment sends the data to a central processing unit, where it is stored and analyzed. The main difficulty is in the interpretation of the GPR response in a very noisy environment

2.1 The difficult radargrams interpretation

Although the use of GPR is a valuable help for investigators, especially assisting them in case of search, by surveying areas that can not easily be controlled; the fact remains that the generated radargrams represent images that are difficult to interpret. Most of the time, they are not directly related to the real geometry of the objects. On the other hand, the results of the analysis strongly depend on the medium and the dielectric contrast between the matrix and the searched elements. This low discriminating power of the GPR prevents a correct and easy discrimination between the elements relevant to the investigation and those which are not. Proper coordination with investigators is therefore necessary in order to minimize the impact of false positives.

The results are given to investigators directly in the field, without waiting for a return to the laboratory.

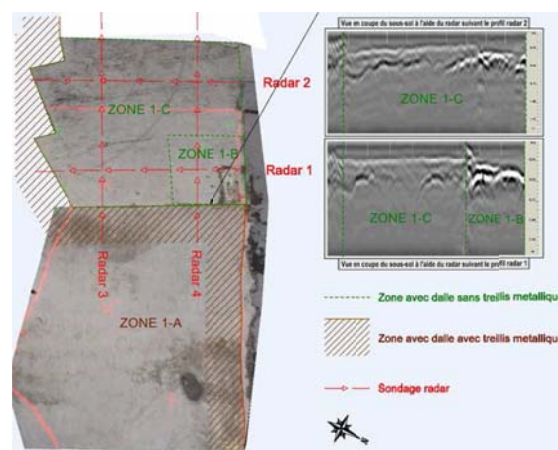


Figure 3- Example of survey for the detection of underground waste

2.2 Limits and constraints

Practical experience shows that there are many cases where site conditions are not favourable to the use of GPR. The performances are mainly dependent on the characteristics of the materials, ie the target to be detected and its environment. For example, waves decrease exponentially and the return signal quickly becomes undetectable in materials such as moist clay which absorb much energy.

The electromagnetic environment directly influences the relevance of the measurements. Soil conditions can vary considerably, and they affect the performance of the GPR. Usually, dry sandy soils with low salt, allow good survey performances, but heavy clay soils are difficult to penetrate with GPR. It is also very difficult to analyze an area, if a telecommunications antenna emits in close proximity with the same frequency range, creating disturbances. Under such conditions, it is very important to adjust the system to accommodate this particular environment.

The topography of the site is also a limiting factor. The GPR can not operate properly on a very rough area, even if the system remains portable. An important factor is the distance between the antenna and the ground surface which should be as low as possible.

3 Using a drone for scene freezing

For some large-scale scenes (aerial crash, cars accident, extended crime scene, etc...), it may be interesting, or even essential, for places difficult to access, to use aerial photography to freeze a scene configuration and the position of its elements. Since the use of a helicopter is not always possible, as it is also a significant cost, the use of a drone makes sense in forensics.

3.1 Interests of the Drone

Using an embedded photographic sensor on this type of aerial vector has several advantages. The first is a low cost of use. Then, and even if the drone telepilots of the french Gendarmerie receive a specific training, the simplicity and the speed of implementation of the tool also constitute an important advantage. Finally, for complex scenes to be taken into account, or scenes that would be polluted with NRBC, the use of this mean of remote acquisition can be the only effective to perform the digitization of the scene.



Figure 4- Drone of the french Gendarmerie

3.2 Use of aerial images

In addition to save the crime or accident scene on image-type media, modern photogrammetry techniques allow for more advanced uses of these aerial images, which go far beyond the simple re-visualization of these images. Thus, it is possible to generate an ortho-photography of the scene overflown [5], which can constitute a true plane map of the places. This image can be scaled, allowing direct distances measurement.

Moreover, aerial images generated by drone can be used to generate three-dimensional point clouds. Then, these 3D models can be given to the investigators who can visualize the scene in the most appropriate point of view.

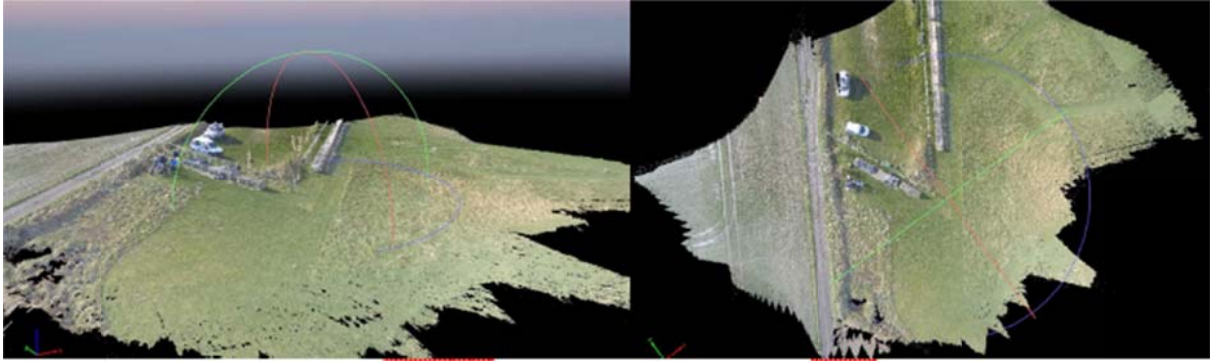


Figure 5- 3D model generated with photogrammetry

The condition for obtaining these results is to fly over the scene in accordance with a very particular flight plan respecting the shooting requirements of photogrammetry.



Figure 6- Ortho-photography

4 Conclusion

The GPR is complex to use because it's impossible to constitute a library of echoes or reference traces. The difficulty is directly related to the couple "environment-elements to detect": some bones in a heterogeneous soil will be more difficult to detect than industrial wastes where the volume of what is sought will be an advantage for a good detection. In favorable cases, the implementation of GPR often saves time in the search for elements useful for a judicial inquiry.

In addition, aerial images generated by Drone can be used to generate three-dimensional point clouds. These 3D models can then be given to the investigators who can visualize the scene in the most appropriate point of view. The condition for achieving these results is to fly over the scene in accordance with a particular flight plan that meets the photogrammetry requirements.

5 References

- [1] B. N. Damiata, J. M. Steinberg, D. J. Bolender, and G. Zoëga, “Imaging skeletal remains with ground-penetrating radar: comparative results over two graves from Viking Age and Medieval churchyards on the Stóra-Seyla farm, northern Iceland”. *Journal of Archaeological Science* 40, 2013, no. 1, pp. 268–278
- [2] A. Ruffell, J.K. Pringle, S. Forbes, “Search protocols for hidden forensic objects beneath floors and within walls”, *Forensic Science International*, 237, 2014, pp. 137-145
- [3] P. Perrot, L. Chartier, J. Carlier, “The role of ground penetrating radar in forensic sciences”, *International Crime Science Conference*, London, UK 2007
- [4] P. Perrot, G. Galou and H. Daudigny, " GPR: Applications in criminal investigation ", presented at the *IEEE Conference on Antenna Measurements & Applications (CAMA)*, Antibes, 2014.
- [5] W.M. Grip, R.W. Grip, R.D. Morrison, “Application of Aerial Photography and Photogrammetry in Environmental Forensic Investigations”, *Environmental Forensics*, 1, 3, 2000, pp. 121-129