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A review on GPR drone integrated system.

Una revision de un sistema integrado GPR dron.

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ABSTRACT

Ground Penetrating Radar (GPR) is a widely used technology in many kinds of geological survey. It's a geological method that uses radar pulse to image the surface. It is a non-intrusive method of surveying the subsurface to investigate underground utilities such as concrete, asphalt, metals, pipes, cable etc. To add onto these properties of GPR, here a drone and several sensors, which will make GPR surveys more efficient and accurate. The GPR is mounted over a drone (DJIM600 Pro) which will give more precision in work and exploring difficult areas. A GPR mounted on a drone enables to see the underground surface of ground without compromising safety and providing more efficient surveying. Also, it can be used for surveying in unreachable areas and make our job easier. In order to increase the application level of GPR drone integrated system several sensors such as pressure, thermal, humidity, snowfall, rain, gas, infrared sensors are also mounted. In short, GPR drone integrated system with sensors is the easiest and safe solution for geological surveys, archaeological surveys, weather forecasting etc.

Keywords: GPR; geology, drone.

RESUMEN

El radar de penetración terrestre (GPR) es una tecnología ampliamente utilizada en muchos tipos de estudios geológicos. Es un método geológico que utiliza pulsos de radar para obtener imágenes de la superficie. Es un método no intrusivo de levantamiento del subsuelo para investigar servicios públicos subterráneos como concreto, asfalto, metales, tuberías, cables, etc. Para agregar a estas propiedades de GPR, aquí hay un dron y varios sensores, que harán que los levantamientos de GPR sean más eficientes y precisa. El GPR está montado sobre un dron (DJIM600 Pro) que dará más precisión en el trabajo y la exploración de áreas difíciles. Un GPR montado en un dron permite ver la superficie subterránea del suelo sin comprometer la seguridad y brinda una topografía más eficiente. Además, se puede utilizar para realizar levantamientos topográficos en áreas inalcanzables y facilitar nuestro trabajo. Para aumentar el nivel de aplicación del sistema integrado de drones GPR, también se montan varios sensores como presión, térmica, humedad, nevadas, lluvia, gas, sensores infrarrojos. En resumen, el sistema integrado de drones GPR con sensores es la solución más fácil y segura para estudios geológicos, estudios arqueológicos, predicciones meteorológicas, etc.

Palabras llave: GPR; geología, dron.

INTRODUCTION

Ground Penetrating Radar (GPR) has been extensively applied to investigate subsurface or buried objects in geology, civil engineering, environment and soil science. In most cases GPR surveys are hard work and can be very dangerous for field personnel due to harsh topographic environment and weather conditions. This is where drones come into play. GPR fixed on drone (DJIM600 Pro) can be used for any kind of surveys. In many ways sensors of a drone can considered as its eyes and ears. By using sensors along with GPR drones can be used for various purposes like measurement of pressure, altitude, temperature, humidity and gas detection.

GROUND PENETRATING RADAR

Ground Penetrating Radar (GPR) has been extensively applied to investigate subsurface or buried objects in geology, civil engineering, environment and soil science. GPR is a technique of obtaining subsurface imaging using electromagnetic radiation. The main component of GPR system is the antenna. The antenna comprises a transmitter and receiver and it is moved over the surface. The energy radiated by the antenna penetrates the surface, and is either absorbed or reflected back at any discontinuities (D.S. Prakash Rao, V.S.S. Kumar, Ravande Kishore and V. Bhikshma, 2007). The signal transmitted by the antenna is reflected at the interfaces of different materials and it is sensed by the receiver to create the images of reflections as the antenna is moved over the surface. The noninvasive and versatile nature of GPR allows the operator to collect high quality data in a timely manner (http://www.UtilityLocatingand Mapping with GPR Systems).

Distance of penetration is estimated from the measurement of time taken by the transmitted and reflected signal to travel and the velocity of signal. GPR is valuable in locating defects and voids in concrete structure, determine embedded reinforcement and other subsurface details. Masonry and earth structures can also be scanned to evaluate the condition of inner layers (D.S. Prakash Rao, V.S.S. Kumar, Ravande Kishore and V. Bhikshma, 2007). GPR is also efficient for detecting previously installed utilities in the subsoil, such as concrete tubes, water and gas pipelines, electric and telephone cables etc (Grandjean et al. 2000).

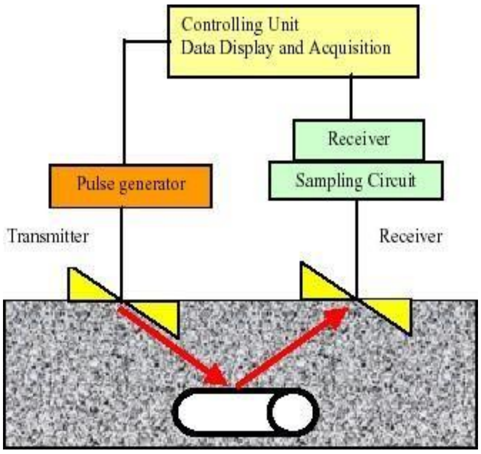

Fig 1. GPR System

ANTENNA

The most important element of the GPR system is antenna. The main significant factor of antenna is the depth of penetration, which depend upon the conductivity of material. The characteristics of antenna depend upon the quality of data, range resolution, and the depth of penetration. In higher frequency antenna, the depth of penetration is less and has small size and pulse duration. 1500 MHz frequency penetrate about 0.5 metre while 15 MHz antenna can penetrate up to 200 metre, with the increase in frequency the dimension and weight of antenna decreases.

PRINCIPLE OF GPR

Electromagnetic wave propagation in subsurface material: The electromagnetic wave behaviour in subsurface material is strongly depend on its electrical conductivity and the electrical conductivity is normally controlled by water. Electromagnetic diffusive field, when the penetration depth is large. However, the interpretation is not easy in these methods. GPR use the electromagnetic wave and its interpretation is rather easy. The material characteristics vary from diffusive to dielectric, When the frequency is changed. Generally, there is a direct relationship between the transmitter frequency and the resolution that can be obtained; conversely there is an inverse relationship between frequency and depth of penetration (Lara et al. 2013).

Reflection of electromagnetic wave: GPR transmit a pulsed electromagnetic wave from a transmitter located on the ground surface and signals are received by a receiving antenna on the ground surface. The transmitted signals propagate through the subsurface material and is reflected by the objects. The received signal is recorded by personnel computer (PC). Knowing electromagnetic wave velocity (v) and measuring travel time(t), the depth of reflecting object (d) in metres can be estimated by the equation:

$$d=(v*t)/2 \qquad (1)$$

Dielectric constant of rock and geological material: The dielectric constant is the ratio of permittivity of a substance to permittivity of free space. Water contained in the material is most significant in the dielectric constant. Detection of geological boundary by GPR normally very effective, when geological materials has very small water content. The dielectric constant of the material governs the velocity of the energy propagation which is inversely proportional to the square root of dielectric constant.

LIMITATIONS OF GPR

- Strength loss - Although the maximum depth of analysis is about 3 m in favourable conditions the pulses lose strength very quickly in conductive materials, thereby affecting the depth of penetration and in some cases making the use of GPR totally unsuitable.

- Not identify specific utilities - GPR does not identify specific utilities such as water, gas, electrical, telephone etc. hence verification using other methods is necessary.

- Highly skilled operators needed - Highly skilled operators are needed because GPR output is difficult to interpret.

- Cost of equipment is high – Digging holes in wrong place is more expensive.
- Large batteries – High energy consumption can necessitate large batteries for extensive surveys. Current equipment last for 8 to 15 hrs.
- Performance limited by signal scattering - In heterogeneous conditions like rocky soil its performance is limited.

GPR DRONE INTEGRATED SYSTEM

A ground penetrating radar mounted on a drone enables to see through the surface of ground, ice, rock, freshwater, and buildings or through structures at unsafe and hazardous environments. In most cases, GPR surveys are hard work and can be very dangerous for field personnel due to harsh topographic environments and weather conditions. Some areas are still strictly out of bounds to human. This is where drone comes into play. It allows technician to investigate hazardous places from a safe distance (DJIM600 pro,2019).Drones are light weight, easily transportable and capable of flying autonomously at low altitudes with high precision.

DJIM 600 Pro

The Matrice 600 pro inherits everything from Matrice 600 along with improved flight performance and better loading capacity. This is the latest drone platform supported by phase one industrial, as itcontinously innovates inspection tools uniquely capable of addressing diverse aerial imaging applications (DJI M600 & M600 pro2017).This system is a modular design so, it's easy to mount additional modules. The airframe is equipped with the latest DJI technologies, including the A3 pro flight controller, Light bridge 2HD transmission system, Intelligent Batteries and Battery Management system (James Trew, 2016). It's ideal for professional aerial photography and industrial applications.

Fig 2. GPR drone (DJIM 600 pro) integrated system

Antenna: DJIM 600 pro drone and Radar Cobra Plugin – In GPR, but the antenna is different in each setup:

- SUBECHO – 70 (SE - 70) Antenna
- SUBECHO – 150 (SE – 150) Antenna

SE – 70 has a frequency range of 80 MHz and a penetrating depth of 80 m. SE – 150 has a frequency range of 124 MHz and a penetrating depth of 40 m.

Table 1. Specifications of antenna

SUBECHO MODELS	SE – 70	SE - 150
Frequency range, MHz	20 - 140	20 - 280
Bandwidth, MHz	120	260
Centre frequency, MHz	80	124
Size (L*W*H), cm	139*15*21	92*22*22
Weight, kg	3,7	3,5

Drone Technology Enhancing Ground Penetrating Radar: Drones combined with GPR can make many things possible which were previously impossible. While fieldwork on challenging terrain can be dangerous for surveyors, drone technology can make the job more safer and efficient.

Aerial Surveying Work with Drone: When drone take off, integrated software on board the drone automatically starts recording results from GPR. While it's flying technicians can view the radar status and monitor survey information via a remote screen. Once the drone is landed, the information can be transferred to ground control system.

ADVANTAGES OF USING DRONES FOR GPR

- Accuracy – Advanced drones fly at low altitudes, close to the ground surface, and with targeted precision. For airborne surveying and inspections, this translates to better data resolution for surveying and photography. The measurements collected from GPR equipment is extremely accurate, and the documentation is high-quality

- Efficiency - Technicians can complete surveys and project faster and using less invasive methods. The equipment can cover even large areas and difficult topography, collecting the data required in a fraction of the time. Completing projects faster and using less invasive methods means cutting costs in the process as well.

- Safety – Technicians can work remotely when dealing with tough conditions. Survey technicians can now work remotely when dealing with tough conditions and difficult terrain. Working from a distance, they can send the drone into environments that would be unsafe and hazardous for manned vehicles or humans to traverse.

- Versatility – Land surveying with drone technology vastly increases the range of land access. Today, surveying crews can access areas that would have previously been impossible to cover without large, specialized equipment.

APPLICATIONS

GPR drone can be used in areas where deep ground penetration is required. Some applications are,

- Bathymetry of fresh water - The GPR-drone integrated system enables to measure the depth of water or profiling the bottom of freshwater, rivers, lakes, ponds up to 15 meters in depth. It can be used even when the water is frozen.

- Geological survey for soil layer profiling - Soil layer profiling is a standard task that needs to be done before any serious area development or construction works. The standard technique is drilling dozens of holes or conducting a GPR survey on carts. GPR- drone integrated system delivers higher work productivity and enables safer work conditions for the personnel in cases of rough terrain.

- Mapping of underground infrastructure - Mapping of underground infrastructure is an important task before starting any construction works on previously developed territories or in cases when actual documentation and maps for underground infrastructure is missing [Nexet al.2014].

DRONE WITH SENSORS

Drones can now be used for aerial inspection and surveillance. Drones are better able to predict storm formations than traditional methods, and that ability can be saviour when severe weather conditions are predicted. Drones are capable of playing an integral role in forecasting and relaying the most accurate information to scientists and the public. Hence drones are the best and the most efficient alternatives to traditional methodologies when it comes to weather forecasts [Colombia and P. Molina, 2014]. For this we fix some of the sensors over the drone. For example, gas sensors are used for detection and monitoring of harmful substances within the environment such as carbon monoxide, carbon dioxide and methane are elements of environmental risk assessment.

Digital Barometric Pressure Sensor: Digital barometric pressure sensor measures air pressure then converts it into altitude. Drones utilize air pressure sensors to stabilize altitude, allowing hover capabilities needed for videography or photography. Barometer consists of aneroid cell inside. The aneroid cell expands or contracts when there are small changes to atmospheric pressure and resulting in display.

Fig 3. Barometric pressure sensor

High Resolution Altimeter Sensor: This is used for measuring altitudes from a fixed level. The sensor module includes a high linearity pressure sensor. The communication protocol is simple, without the need of programming internal registers in the device. The gel protection and anti- magnetic stainless-steel cap allows the use in water resistant.

Fig 4. Altimeter sensor

Humidity sensing in tough weather conditions: A humidity sensor measures and reports both moisture and air temperature. Relative humidity becomes an important factor when looking for comfort. There are three types of humidity sensors.

Capacitive – Measures relative humidity by placing a thin strip of metal oxide between two electrodes.

Resistive – Utilize ions in salts to measure the electrical impedance of atoms. As humidity changes, the resistance of the electrodes on either side of the salt medium also changes.

Thermal – Two thermal sensors conduct electricity based upon the humidity of the surrounding air. The difference between the two measures the humidity.

Snowfall Sensor: It is a powerful and cost effective 2D multipoint, laser-based snowfall sensor. It is a scanning snow gage which scans its laser in a circular path on the snow surface and measures the distance from each point on the path. Once it completes a set of measurements, it takes an intelligent average of the depths to provide a representative average snow depth of the target area.

Rain Sensor Module: The rain sensor module is an easy tool for rain detection and measuring rainfall intensity. The module features a rain board, control board, power indicator LED and sensitivity potentiometer.

Gas Sensing System: It is proposed to aim at gas concentration analysis and the measurements of volatiles diffused in large area. Metal oxide sensor detect concentration of various types of gases by measuring the resistance change of the metal oxide due to adsorption of gases. Atmospheric oxygen residing on the metal oxide surface is reduced by the target gases, allowing more electrons in the conduction band. This will lead a band bending and an electron depleted region (Binions et al.2013).

Fig 5. Metal oxide sensor

Thermal Sensor: Thermal sensor measures the relative surface temperature of objects. When long wave radiation emitted from objects strikes the thermal sensor, its heats up micro-bolometer and this changes electrical resistance. These changes are converted to electrical signals and stored as raw data or processed into thermal imagery.

Infrared Sensor: It consists of an IR source, a sample chamber, a light filter and an IR detector.IR light is directed through the atmospheric sampling chamber to the detector. The methane gas in the sampling chamber absorbs light at specific wavelengths. The detector measures the attenuation at the specified wavelength only which is used to determine the concentration of methane present [Triki et al. 2015].

Fig 6. Infrared sensor

CONCLUSION

Extensive researches and new technologies have led to the inventions of GPR. It is most widely used method for investigating subsurface structures or buried objects, geological and archaeological surveys. In most cases, GPR surveys are hard work and can be very dangerous for field personnel. This is where drones come into play. Here, GPR is mounted over DJIM 600 pro drone which is more efficient and safer when compared to normal drones. Such approaches assure delivery of accurate survey results safely and efficiently. To add on to its applications sensors are also fixed on drones in addition to GPR. The sensors of a drone can be considered as its eyes and ears. Meanwhile, the steady improvement of drones will increase the amount of weather forecasters of the future (Georgia Institute of Technology, 2013).

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