Case Report

ELECTROMAGNETIC SENSOR ONBOARD DRONES FOR THE DETECTIN OF LAND MINES

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Abstract: The objective of this paper is to present an electromagnetic sensor that generates pulse inductance [1], integrated on an Unmanned Aerial Vehicle (UAV) which complements the current technology in this area, adding equipment to the detection of landmines. The electromagnetic sensor developed, locates landmines deployed during armed conflicts, which daily kill innocent people, block economic and social development, hinder the displacement of people, causing serious social and economic problems for many years. Flights can be made over mined areas allowing the identification of the exact location of each land mine.

Keywords: Landmines, Electromagnetic sensor, UAV tracker

1. Introduction

The aircraft used in this project is classified as VTOL (Vertical Take-Off and Landing), and it can maintain the exact location and the accuracy of the data collected. This project is entirely open source, working in conjunction with a team of demining experts to protect the population from the affected areas.

More than 5,000 people are landmine victims every year in the world, and those who do not die are mutilated. Approximately 65 countries have landmines implanted in their territories [3].

Landmines are hidden a few centimeters below the ground surface, with a weight of 3 to 5 kilos to be fired [6]. This low-cost artifact (approx. US$ 5.00) consists of a trigger that detonates the internal explosive charge. However, its withdrawal can cost 500 times more. There are more than 360 types of land mines.

In a full day's work, a landmine specialist can examine and clear 20 m^2 of land from these explosive artifacts [9].

Since the Ottawa Convention in December 1997, a ban on the use, stockpiling, production and transfer of mines against persons has been established [8]. This convention was based on international rules of the Universal Declaration of Human Rights, prohibiting the use of weapons that do not distinguish between civilian and military, causing unnecessary injury and suffering [5].

Currently 162 countries have signed The Ottawa Treaty, an international agreement banning antipersonnel land mines, one of the worst and most cowardly weapons humans ever invented to kill and maim. These countries decided not to use, store, produce and transfer this weapon. In the last revision, those countries participating in this agreement established until 2025 to de-mine their territories and provide full assistance to the victims. Thus an international response was announced to the widespread suffering caused by land mines [3].

There is a global network seeking for a world free of landmines, including the Brazilian Action for Humanitarian Disarmament [3], the International Campaign to Eradicate Landmines (ICBL), the International Committee of the Red Cross (ICRC) and the Landmine Monitoring and Cluster Munition Monitor, which established the "International Day for Anti-Personnel Mine Awareness" held on April 4th [3].

There are several techniques for the detection of landmines [7]. The most frequently ones used:

- Detection by cameras with an infrared sensor. They are used to detect the thermal capacitance difference between the soil and the mine.
- Detection with dogs, bees and rats (Figure 1) which are trained to sniff out explosives with great accuracy.

Figure 1. Rat sniffing terrestrial mine Source: http://www.hypeness.com.br

- Detection by surface inspection (Figure 2). Bayonets or metal probes at a size of approximately 25 cm are used to search for mines, centimeter per centimeter.

Figure 2. Detection of a mine by surface inspection Source: http://www.diepresse.com

- Manual detection (Figure 3). Instruments are used that generate a variable magnetic field, inducing a current in metallic objects and accusing the mine presence.

For this purpose, three classic types of technology are used:

- Very low frequency (VLF)
- Pulse Induction (PI)
- Beat Rate Oscillation (BRO)

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Figure 3. Manual detection of mines. Source: http://www.defesaaereanaval.com.br

The theoretical background of this Project is the work from [10].

According to these authors, the measurements for the detection of the land mines are executed by passive sensors embarked on an aircraft flying at ten to hundred meters altitude. However, the spatial resolution of the images is quite low, where one can barely see the pixel of a landmine. Thus different detection techniques must be adopted and used for comparison with high resolution images, obtained from sensors at an altitude ranging from 1 to 3 meters from the ground.

Based on the aforementioned reference, the authors of this work constructed an aircraft, integrating the electromagnetic sensor to sweep the ground at a height of 1 meter from the soil.

2. Materials and Methods

2.1. Materials used

The following materials were used: universal board, integrated circuits, diodes, transistors, capacitors, resistors, potentiometers, trim-pots, sockets, loudspeaker, solder, led, soldering iron, tin, enameled copper wire, various wires and battery.

Following the specifications of the aircraft used (Figure 4) and (Table 1):

Figure 4. Aircraft used. Source: The authors.

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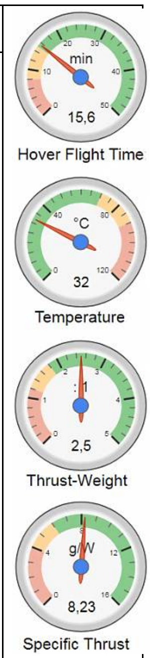
Table 1. Aircraft specifications. Source: The authors.

Description	Value
Frame model	F550
Number of motors	6
Motor model	920 Kv
Controller (ESC)	30 mAh
Propeller	10" x 45"
All-up Weight	1862 g
Add. Payload	2093 g
Maximum Tilt	25 °
Maximum Speed	5.5 m/s
Rate of climb	7.7 m/s
Throttle (linear)	51 %
Battery capacity (12V)	6000 mAh
Used capacity (batt)	85 %
Mixed Flight Time	11.1 min
Hover Flight Time	15.6 min
Motor Temperature	32 °C
Thrust-Weight:	2.5 : 1
Specific Thrust:	8.23 g/W



Humanitarian demining processes

The detection of landmines depends on the following factors:

- Depth of object
- Metal type of object
- Object size
- Soil composition
- Object form
- Interference with other objects
- Type of metal detector
- Coil size.

The Project elaboration consisted on the assembly of an integrated circuit plate of a Polish PI, according to the flow diagram (Figure. 5), created by [1].

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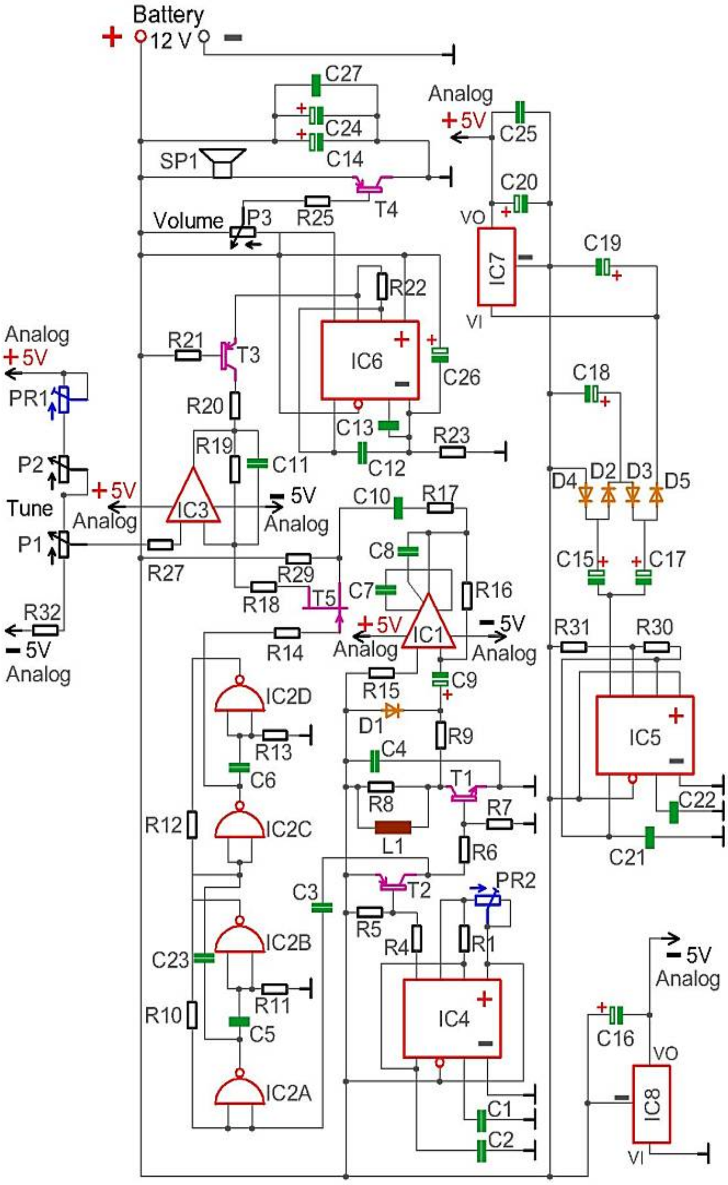

Figure 5. Flow diagram of the Polish PI. Source: http://www.ep.com.pl

Capacitors, resistors, transistors, potentiometers, trim-pots, sockets, integrated systems and other electronic components were assembled on a board. (Figure 6).

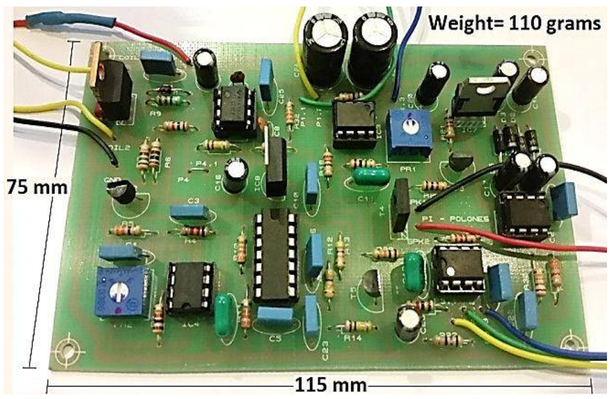

Figure 6. Board Source: The authors

A coil (Figure 7) was wrapped with an enameled copper wire with 25 turns and a diameter of 25 centimeters, to generate a magnetic field. Subsequently, the electromagnetic sensor was coupled to a

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plastic rod to avoid interference with the coil, which was a few centimeters from the ground, and integrated with the controller board. The sonar on the bottom of the aircraft allows maintain the desired flight height.

Figure 7. Coil Source: The authors

The electromagnetic sensor generates a magnetic field (Figure. 8) and can detect interferences up to 1 meter away.

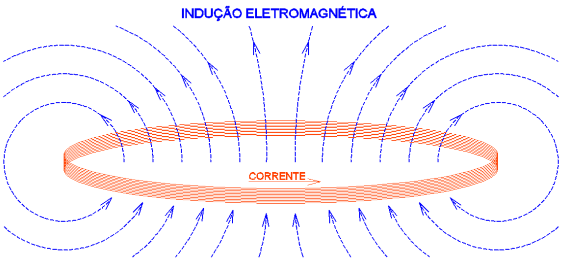
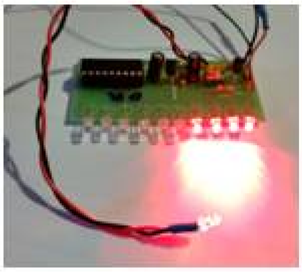


Figure 8. Electromagnetic induction of Electric current. Source: The authors

When the aircraft is close to a buried metallic object there is an oscillation in the magnetic flux generated by the coil, both an audible (Figure 9) and a visual alarm (Figure 10) are triggered, indicating the existence of the object.

(**a**)

Figure 9. Audible Alarm. Sources: The authors.



(**b**)

Figure 10. Visual alarm Sources: The authors

The coordinates of the geographic position and intensity of the detected signal of the flight site are stored on the memory card and can be used to compile a landmine map and to analyze the reliability of the detection.

In order to increase its stability, the aircraft has a gyroscope, a compass and a barometer. All flight information is transmitted by the First Person View FPV (First Person View) through the communication protocol for small aircraft MAVLink (Micro Air Vehicle Communication Protocol).

After the identification of landmines, removal teams start to deactivate them.

Flights are performed in longitudinal or transverse lines (Figure 11).

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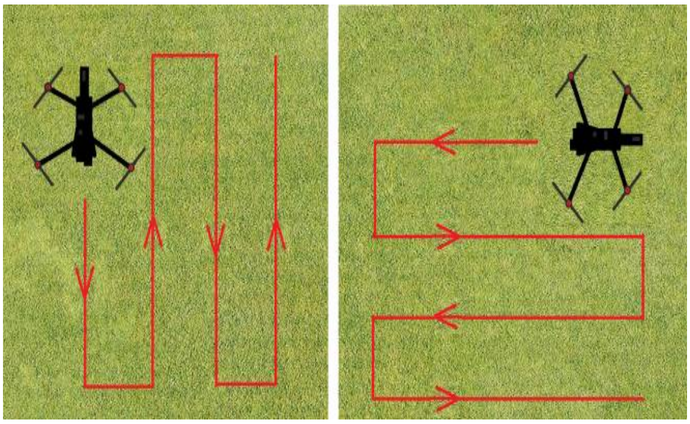

Longitudinal flight Transverse flight

Figure 11. Flight configuration Source: The authors

3. Results and Discussion

Flight planning was performed with Mission Planner software on an area with 3 small buried metal objects, simulating a minefield. The aircraft departed from Home and proceeded to the first Waypoint of the route, maintaining a constant altitude of 1 meter above the ground, waiting 10 seconds as stipulated in the planning and following in a longitudinal flight to the observer for the next points A constant speed of 1 meter per second was kept, in parallel lines with spacing of 25 centimeters between them. The aircraft was stable on the flight to the last point of the route and returned to the takeoff point (Home) and landed accurately. The GNSS data receiver coupled to the aircraft allowed for autonomous navigation on the established route and the reception of the data with the geographical position of the buried objects.

When the aircraft passed over the metal object buried between 5 and 20 centimeters in the ground, the emission of a variable sound was recorded in the electromagnetic sensor and the indicator lights were activated according to the signal level. The three buried objects were found, proving the efficiency of the electromagnetic sensor. According to the depth of the object, a weaker signal was obtained.

The identification of the metallic object type and its composition were not possible. Each object found must be treated like a mine, even if it is not.

The intensity and geographic position were stored on the memory card attached to the aircraft.

With the data obtained it was possible to compose a geo-referenced map of the localized metallic objects.

The data can also be used within a GIS software such as Qgis, Google Earth and SPRING.

4. Conclusions

The project proved effective in locating land mines buried in the ground.

It contributes directly to the evolution of techniques and equipment for the detection of landmines, being complementary to the procedures currently used.

The use of the aircraft with the integration of an electromagnetic sensor provided the identification of the landmine site without the need of the de-miner to walk on the minefield, proving to be an efficient ally with respect to the safety of the involved persons.

Finally, the generated geo-referenced maps can be used for the analysis of minefields and to plan its elimination.

Author Contributions: Conceptualization was derived by F.N. and W.M.; methodology was derived and implemented by F.N. and W.M.; survey and validation by F.N. and W.M; formal analysis was conducted by F.N and W.M; investigation was performed by F.N. and W.M.; resources to support the research were provided by F.N., H.K. and E.S.; writing—original draft preparation was done by F.N., H.K. and W.M; writing—review & editing, was done by H.K. and E.S.;

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visualization (data, tables, & figures) was done by W.M.; supervision was from H.K.; project administration was from H.K.; funding acquisition to support the research were sought by E.S., F.N. and H.K.

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References

1. Bajda, L. Wykrywacz metali o dużym zasięgu. Czyli coś dla poszukiwaczy zaginionych pamiątek Przeszłości. Elektronika Praktyczna, Poland, 2009. Available at: < http://ep.com.pl/Archiwum/2009/Lipiec.html> Access June 4th 2016.].
2. Diepresse. Kroatien: Vom Minenopfer zum Minenräumer. Available at: <http://www.diepresse.com/home/wirtschaft/international/631695/Kroatien_Vom-Minenopfer-zum-Minenraeumer> Access Mai 12th 2017.
3. Dhesarme. Dia Internacional de Conscientização sobre o Perigo das Minas Terrestres: secretário-geral das nações unidas emite declaração em apoio. Available at: < http://www.dhesarme.org/2017/04/07/dia-internacional-de-conscientizacao-sobre-o-perigo-das-minas-terrestres-secretario-geral-das-nacoes-unidas-emite-declaracao-em-apoio/> Access Mai 5th 2017.
4. ICRC. Convención de 1997 sobre la prohibición de las minas antipersonal y sobre su destrucción. Available at: < http://www.icrc.org/spa/assets/files/other/1997_minas.pdf> Access July 6th 2016.
5. ICRC. Métodos e os meios de guerra. Disponível em: <https://www.icrc.org/por/war-and-law/conduct-hostilities/methods-means-warfare/overview-methods-and-means-of-warfare.htm> Access Mai 11th 2017.
6. Ministério da Defesa. Manual de campanha, Minas e armadilhas. Available at: <http://bdex.eb.mil.br/jspui/bitstream/123456789/367/1/C-5-37%20.pdf> Access Sept. 23rd 2016.
7. Nunes, V.W. Detecção de Minas Terrestres por Radiação Penetrante. Available at <http://antigo.nuclear.ufrj.br/DScTeses/Wallace/WallaceValloryNunes.pdf> Access Mai 11th 2017.
8. ONU. Treated de Ottawa. Available at <http://www.un.org/es/disarmament/instruments/convention_landmines.shtml> Access April 5th 2017.
9. Ratier, R. Por que as minas terrestres são tão perigosas? Super Interessante, n. 181, out. 2002. Available at: <http://super.abril.com.br/historia/por--que-as-minas-terrestres-sao-tao-perigosas> Access April 5th 2017.
10. Tjahjadi, T.; Gu, I. Y.; Popham, T. J. Landmine Field Detection using Joint Temporal and Spatial-scale Detectors. Available at: <http://www.dcs.warwick.ac.uk/~tpopham/EUDEM.pdf> Access June 12th 2016.