ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/01.3001.0010.2386

INCREASING OF THE SAFETY OF THE HELICOPTER'S LANDING THROUGH THE USE OF 3D SCANNING SYSTEM FOR VISUALIZATION THE LANDING AREA

Andrzej Zyluk, Jerzy Łukasiewicz, Joanna Lubieniecka
Jerzy Kusiński, Krzysztof Tchórznicki, Krzysztof Bielecki

Air Force Institute of technology
Ksiecia Boleslawa Street 6, 01-494 Warszawa, Poland
tel.:+48 261 85 13 00, fax: +48 261 85 13 13
e-mail: poczta@itwl.pl.pl

Abstract

Landing of the helicopter is a very complex process, which requires of maximum performance and efficiency of the machine and then the full pilot's and the crew concentration. The main issue is even though that many deck instruments are use on the aircraft, the main role belongs to the pilot's senses. As we know, the senses tends to be unreliable and they have prone to being disrupted (e.g. for pilot's sight area under helicopter, there is illusion that the area is flat − 2D).In many cases, the landing is performed outside the airfield. At the landing area may exists many potentially and invisible from above, dangerous objects – which can damage the tail rotor, or even the main rotor. This article presents one of the methods solving this problem, by using 3D scanning. It discusses the theoretical basis, the concept of the device and developing the prototype. The construction of 3D scanner type is "Time-of-Flight", which is multiplied laser rangefinder. Shown a prototype device with high performance, which has the ability to scan 1 million points per second. It presents results from laboratory test and test field. The device can work with typical MFD (Multi Function Display) mounted in all types of helicopters. Experiments have shown that the easily detected (and displayed) are objects of dimension from range 3-5 mm. The main use of this device is predicted as additional equipment for the helicopter. It can significantly increase flight safety, especially in harsh conditions (night flights, flights during precipitation). The designed device can provide a baseline for the development to other devices, which uses high-resolution 3D scanning modules.

Keywords: *landing, 3D scanning, helicopter, flight safety, landing safety, airfield, air transport*

1. Introduction

Landing is one of the most difficult and dangerous manoeuvre from all of the flight operations performed by a helicopter. It is especially dangerous, when landing is carried outside of the airfield. Factors weather (like fog, rain) could further hinder this manoeuvre. Pilot with based on the terrain view from the window-cockpit (and for him the view will be 2D) must take decision about the landing in 3D-terrain. Objects such as fences, masts, grassed land depression are often not visible from the deck of the machine, but it can be a threat for the main rotor and tail rotor. Night − landing or in poor visibility conditions, without from the ground assistance is even more risky. The solution for these situation would be a system that can display on pilot's MFD the view of the landing area, in the form of the imaging XYZ.

In this way, there is possibility to show the obstacles, which is normally invisible. It proposed to use a 3D laser scanner, operating according to the principle "Time-of-Flight", i.e. FOV that would cover the entire area of the landing. Schematically idea of such system is shown in Fig. 1.

2. The concept of the 3D scanner

System consists the transmitter and receiver systems. Laser with a duration pulse e.g. 4ns flows into the steering beam device (mirror polygon and galvo), where it is directed to required point, leaves the device and stays the way to the target located at a distance of 30 m within 100 ns, then reflects from it and returns to the receiver in the next 100 ns. Therefore, the cycle transmitter-target-receiver return laser pulse stays in 210 ns. Schematic timing of the process shown in Fig. 2.

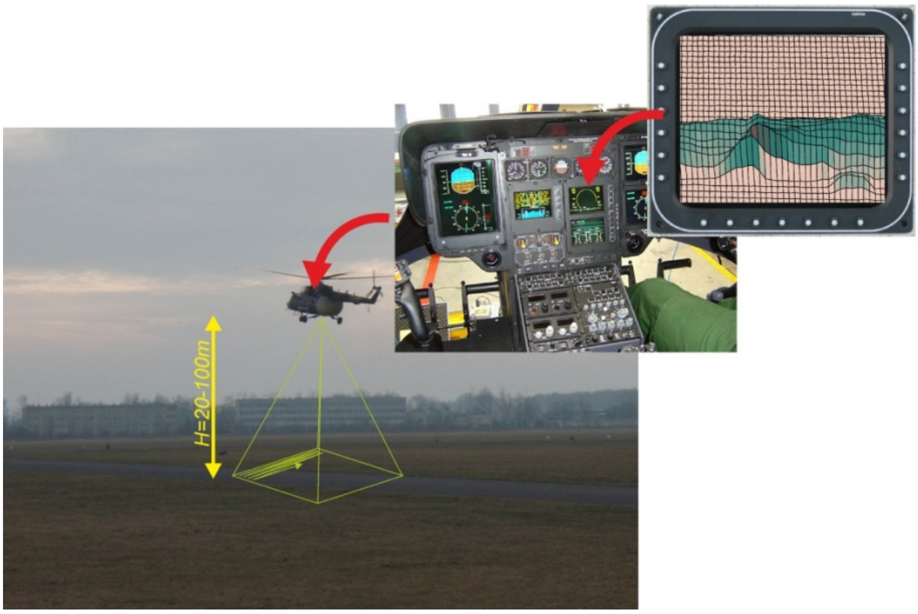

Fig. 1. 3D scanning as a visualisation of the landing area

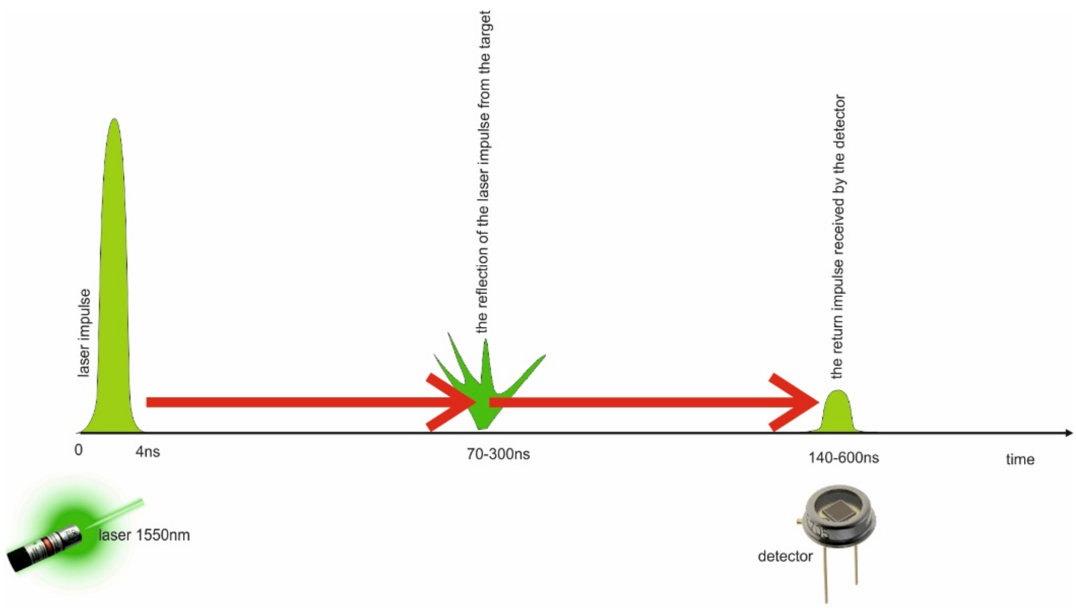

Fig. 2. Timing of the process "generate impulse-reflection-receiving"

The transmitter system consists of (Fig. 3):

- pulsed fibre laser, generating pulses with a duration of 2-4 nanoseconds and frequency of 1 MHz,
- ray steering system directed laser ray to the required point of space, built with the system of the rotating mirror polygon and galvanometer with flat mirror.

The receiver system consists of (Fig. 3):

- optics providing adequate FOV (field of view),
- detector with the maximum efficiency on a band of 1.55 μm,
- Band-pass filter with the desired bandwidth (e.g. 10 nm).

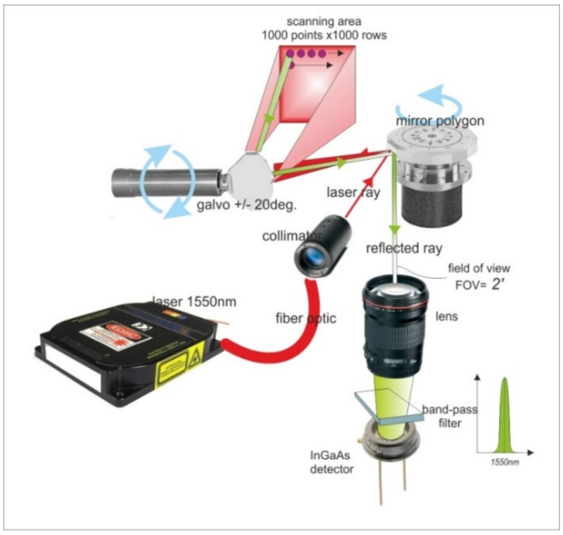

Fig. 3. Schematic structure of 3D scanner

To estimate the power of the echo reflected signal several assumptions were made to allow final answer whether it will be possible to use laser system type "Time-of-Flight" to measure the distance to objects within a certain distance and under certain conditions.

The expression for the power of the echo signal P_{SIG}, assuming that the angle of incidence of the laser beam is close to zero, can be written as follows:

$$P_{SIG} = \frac{P_{TRS}\rho D_{RS}^2 \eta_{OPT}\eta_{FI} e^{-2c_e R}}{4R^2},$$

P_{TRS} – laser radiation power of transmitter [W],
D_{RS} – entrance pupil of receiver [m],
ρ – reflectance coefficient of the target,
η_{opt} – transmission coefficient of the receiver's lens,
η_{fi} – transmission coefficient of the interference filter,
c_e – extinction coefficient of the environment [m^{-1}],
R – distance to the target [m].

In case of the 500 W pulse 1,55 μm laser, distance to the target 30 m, the reflected echo was calculated on level $3*10^{-6}$ W (3 μW), the radiance of background was estimated as $2*10^{-11}$ W (by using 10 nm band-pass filter), which in turn translates to more than 50 dB S/N ratio. This means a strong signal, easy to register using the InGaAs photodiode.

3. Project of the 3D scanner

The 3D spatial imaging will be installed in the helicopter, which at the time of measurement performs hover, and therefore can move in 1 s of length up to 2 meters in the direction of one axis or pitch/roll/yaw, by up to 5º. Since system will send one million of measurement pulses during one second, it is necessary to develop a method for determining changes of the transmitter's position. Proposed for this purpose is to use the AHRS (**A**ttitude and **H**eading **R**eference **S**ystem) system, which contains a three-axis accelerometer and three-axis gyroscope so that it is ensured data (time, distance) of the position data (time, distance, angle), compensating of the impact of the helicopter's movement for the measurement's accuracy. The structure of typical AHRS system shows Fig. 4. It was assumed that is necessary to read the current position at least 100 times per second, so that the movement of the platform (helicopter) between position measurements may be not more than 0.02 m for each axis and the changes of angles: roll/pitch/yaw should be not more than 3' (arcmin).

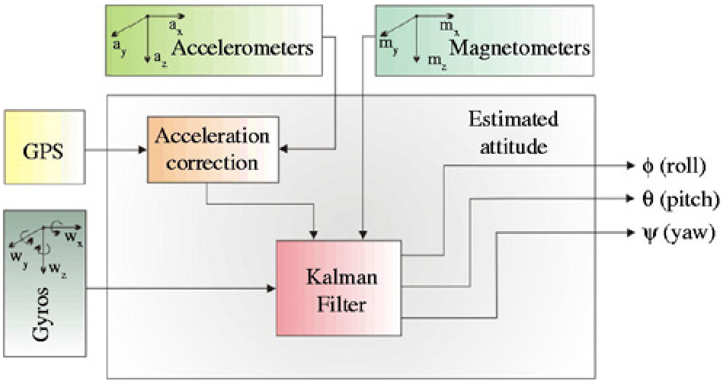

Fig. 4. Schematic structure of the AHRS system

The entire system is controlled by the CPU, which is responsible for controlling the laser transmitter, time synchronization (to an accuracy of 10-11 seconds), processing of the received echo pulse, and distance calculations. CPU, taking into account the data from the AHRS calculates the appropriate corrections (Fig. 5).

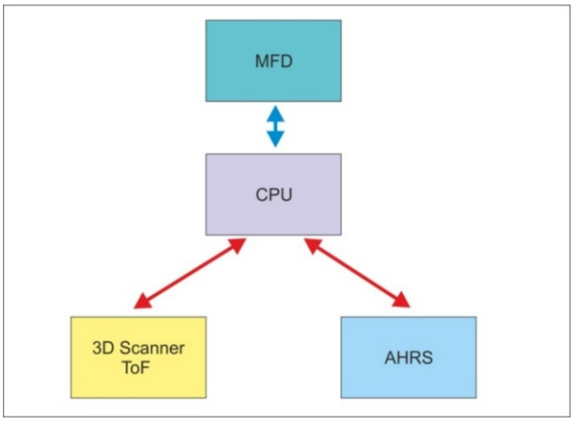

Fig. 5. Schematic structure of the 3D landing system

Calculated output data are transmitted and displayed on a typical multi-function display (MFD), which is shown in Fig. 6.

Fig. 6. Air multi-function display

4. Construction of the prototype and testing

Based on the assumptions and the pervious tests were performed prototype device, which the inside shown in Fig. 7. Red arrows showed main blocks of the device:

- Scanning module (with drivers),
- Input-output optical module,
- AHRS module,
- CPU module,
- Laser module.

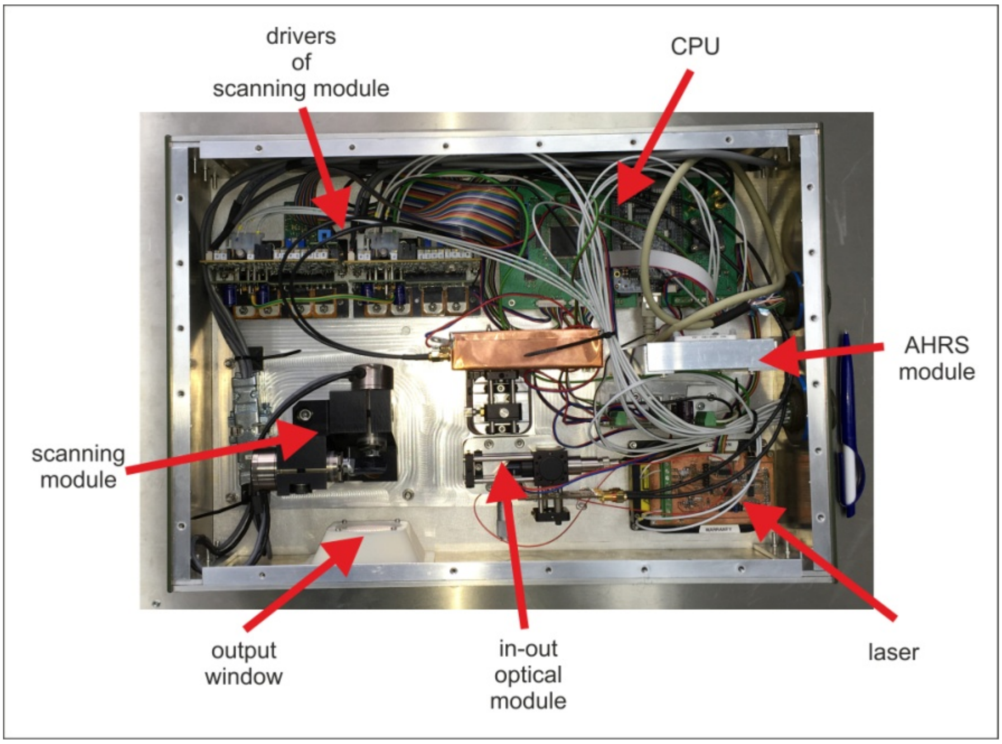

Fig. 7. Prototype of 3D scanning system inside

Figure 8 shows scanning system in housing. Visible raster shows the size of the device. The distance between the holes is 2.5 cm.

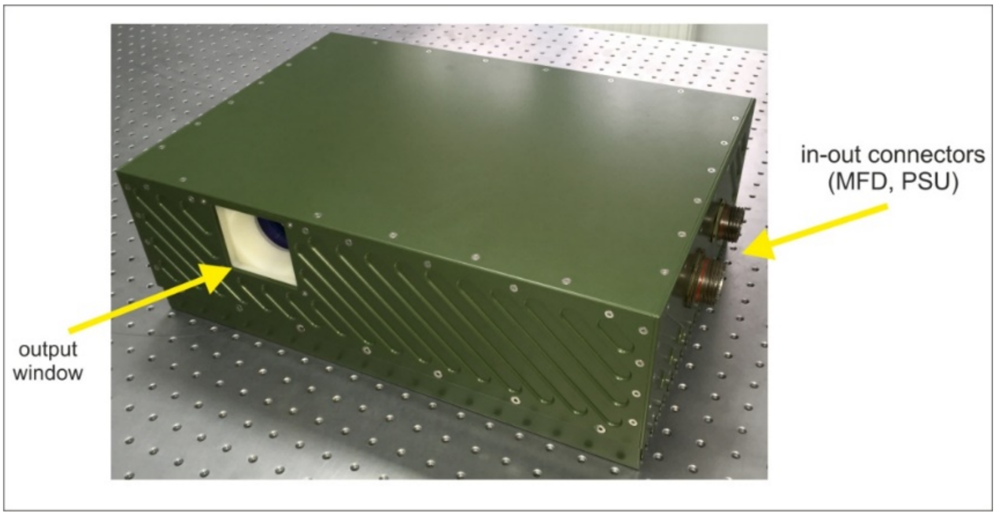

Fig. 8. 3D scanning system. View of prototype in the housing

After making the prototype a carried out a number test. First, laboratory tests, carried out at a distance of 5 m – the scenery and result can see on Fig. 9 and second, field tests, carried out at a distance 30 m.

Fig. 9. Indoor scan, range 5 m. Left – photo, right – 3D scan

Figure 10 shows scenario of the field test with different obstacles:

- the far obstacles: the trees (distance more than 35 m), the wall (distance 30 m), the bushes (distance 20-25 m),
- the near obstacles: the wire (distance 5 m) and the bar (distance 3 m).

We can see on Fig. 9 that all obstacles were detected and displayed.

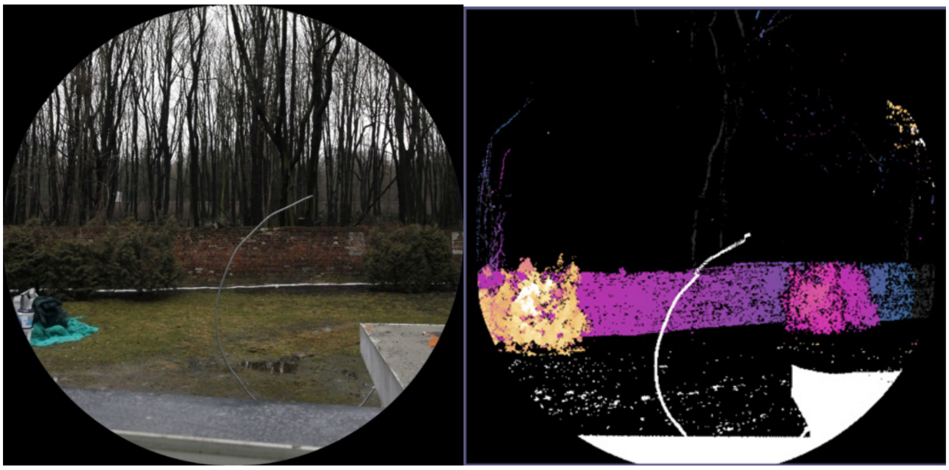

Fig. 10. Outdoor scanning, range – 30 m. Left – photo, right – 3D scan

5. Conclusions

The results of ground tests (laboratory and field) confirm the validity of the adopted concepts. The next step should be mounting prototype on helicopter and testing in flight. In addition, this device can be the basis of other structural high-resolution 3D scanning devices.

References

[1] Vosselman, G., Maas, H. G., *Airborne and Terrestrial Laser Scanning*, CRC Press, Boca Raton USA 2013.

[2] Cywiński, A., *Analiza laserowych źródeł promieniowania do wykonywania pomiarów odległości pod wodą*, Polish Hyperbaric Research, 1(34), 2011.

[3] Marczak, J., *Impulsowy dalmierz laserowy z podszumowym odbiorem sygnału echa*, Problemy Techniki Uzbrojenia i Radiolokacji, R. XXVII, Y. 66, pp. 117-128, Warszawa 1998.

[4] Mierczyk, Z.; Marczak, J.; Zygmunt, M., Ostrowski, R., Gawlikowski, A., *Wojskowe dalmierze laserowe*, Biuletyn WAT, Vol. LI, Nr 6, Warszawa 2002.

[5] Träger, F., *Springer Handbook of Lasers and Optics*, Springer Science +Business Media, LLC New York 2007.

[6] Karłow, N. W., *Wykłady z fizyki laserów*, WNT, Warszawa 1989.

[7] Geary, J. M., *Introduction to Lens Design*, with Practical ZEMAX Examples, Willmann-Bell, Inc., USA 2007.
[8] Kidger, M. J., *Intermediate Optical Design*, The Society of Photo-Optical Instrumentation Engineers, USA 2004.
[9] Paschotta, R., *Field Guide to Laser Pulse Generation*, The Society of Photo-Optical Instrumentation Engineers, USA 2008.
[10] Paschotta, R., *Field Guide to Laser*, The Society of Photo-Optical Instrumentation Engineers, USA 2008.
[11] Midwinter, J. E., Guo, Y. L., *Optoelektronika i technika światłowodowa*, WKiŁ, Warszawa 1995.
[12] Marschall, G. F., *Handbook of Optical and Laser Scanning*, Marcel Dekker, Inc., USA 2004.