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LOCAL POSITIONING SYSTEMS FOR DRONES WITHOUT USAGE OF DIGITAL CAMERAS

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Анотація. У статті аналізуються системи позиціювання дронів, які забезпечують надійний зліт, посадку та доставку вантажів без застосування цифрових камер та їх класифікацію. Ця класифікація включає усі комбінації джерел та приймачів випромінювання, які можуть бути розташовані як на дроні та на посадковому майданчику чи майданчику для доставці вантажу. Наводиться аналіз переваг та недоліків кожної із систем та рекомендації вибору найкращої системи позиціювання дрона.
Ключові слова: система позиціонування дрону, приймачі випромінювання, джерело випромінювання, обчислення координат.
Аннотация. В статье анализируются системы позиционирования дронов, обеспечивающих надежный взлет, посадку и доставку грузов без цифровых камер и их классификацию. Эта классификация включает все комбинации источников и приемников излучения, которые могут быть расположены как на дроне, так и на посадочной площадке или площадке для доставки груза. Приводится анализ преимуществ и недостатков каждой системы и рекомендации выбора наилучшей системы позиционирования дрона.
Ключевые слова: система позиционирования дрона, приемники излучения, источник излучения, вычисление координат.
Abstract. The article describes drone positioning systems that ensure reliable takeoff, landing and delivery of cargo without the use of digital cameras and their classification. This classification includes all combinations of sources and receivers of radiation that may be located both on the drone and on the landing or cargo delivery area. An analysis of the advantages and disadvantages of each system and recommendations for choosing the best drone positioning system.
Key words: drone positioning system, receivers, radiation source, coordinate calculation.
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INTRODUCTION

Nowadays, drones are used in almost all spheres of human activity, whereas delivery remains in the shadows. This is due to the invasion of privacy, difficulty in production, safety during landing, expensive hardware (cameras, stabilization, etc.) and software. All these stop companies to use drones for delivery [1].

However, some companies do it. The main companies which use drones for delivery: Amazon.com, Inc. (US), Deutsche Post DHL Group (Germany), United Parcel Service of America, Inc. (US), Zipline (US), Matternet Inc., (US), Airbus S.A.S. (Netherlands) FedEx (US), EHang (China), and Wing Aviation LLC (US), and Boeing (US). Experts predict 53.8% growth in drone delivery market by 2030 [2-5].

The typical drone Global Positioning System (GPS) units guarantee positioning accuracy of 0,5 - 15 meters [6]. For instance, GPS module Ublox GPS NEO-M8N can provide accuracy 0.6 – 0.9 m [7]. That is why the mentioned operations usually performed under human control. This human control is expensive, and it cannot be stable due to human factor. It moves the companies that manufacture, uses and maintains drones to look for fully automatic system that can guarantee the accurate and reliable measurement of drone coordinates during the most risky TLD.

This work is an attempt to present the classification and analysis of the local positioning systems (LPS) without using cameras that closes the gap between GPS position accuracy and position accuracy necessary for save TLD.

MAIN PART

On Figure 1 showed classification of LPSs without using cameras. Let's take a closer look at each group.

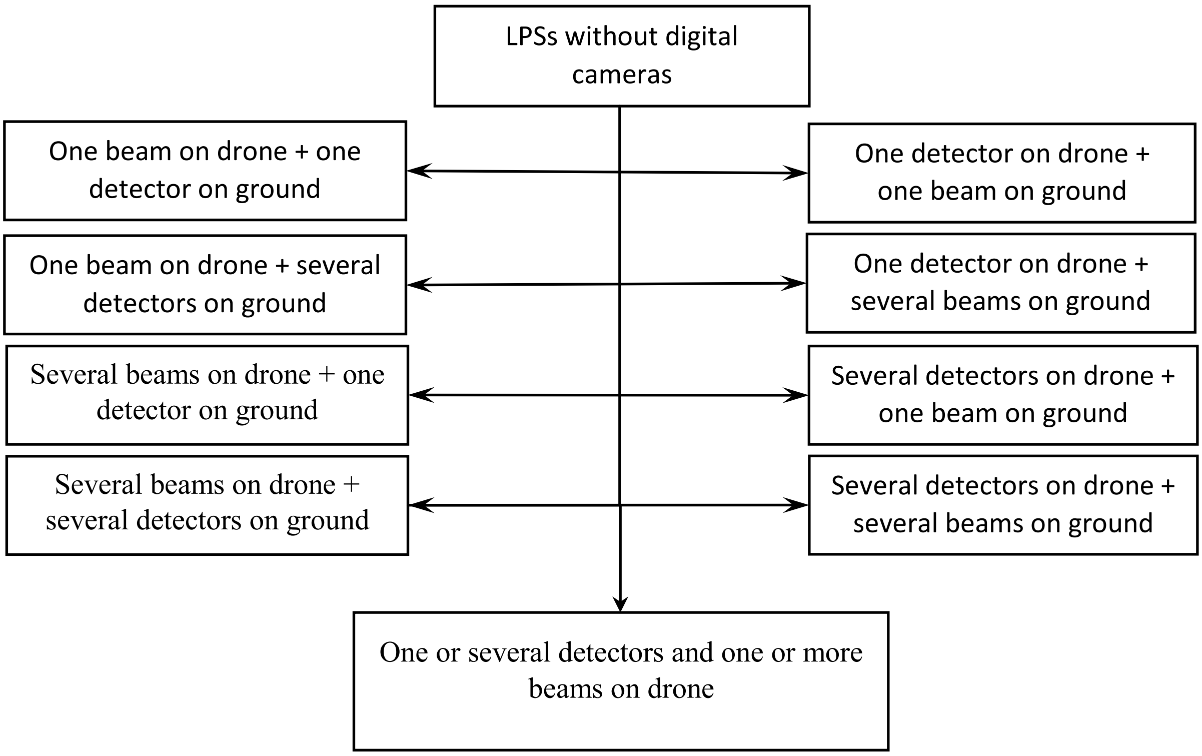

Figure 1 – Classification of LPSs without using cameras

Let's start with systems where one or more detectors are on the ground, and one or more radiation sources are on the drone (Figure 2). An example of such a system would be a radio emitter mounted on a drone and a receiver on the ground. The landing radar in such systems allows with high accuracy to simultaneously determine the azimuth, elevation and range of the aircraft in relation to the runway after it enters the plane of the landing course. When the aircraft deviates from the preset landing course and the preset glide path, the dispatcher sends a radio command to the crew to bring the aircraft to the gliding line. Thus, a direct approach is carried out according to the PRL data, on the screens of which (the heading indicator and the glide path indicator) the location of the aircraft is continuously indicated. The advantages of his system are the possibility of its application for any type of aircraft and the ease of use of the system by the flight crew. The main disadvantages are the impossibility of bringing the aircraft directly to the touchdown point, the difficulty of observing the aircraft movement at close distances, the relatively large complexity of ground-based radar equipment, low bandwidth, the probability of electromagnetic interference is high, since the operators transmit signals to the aircraft, then there is a human factor [7].

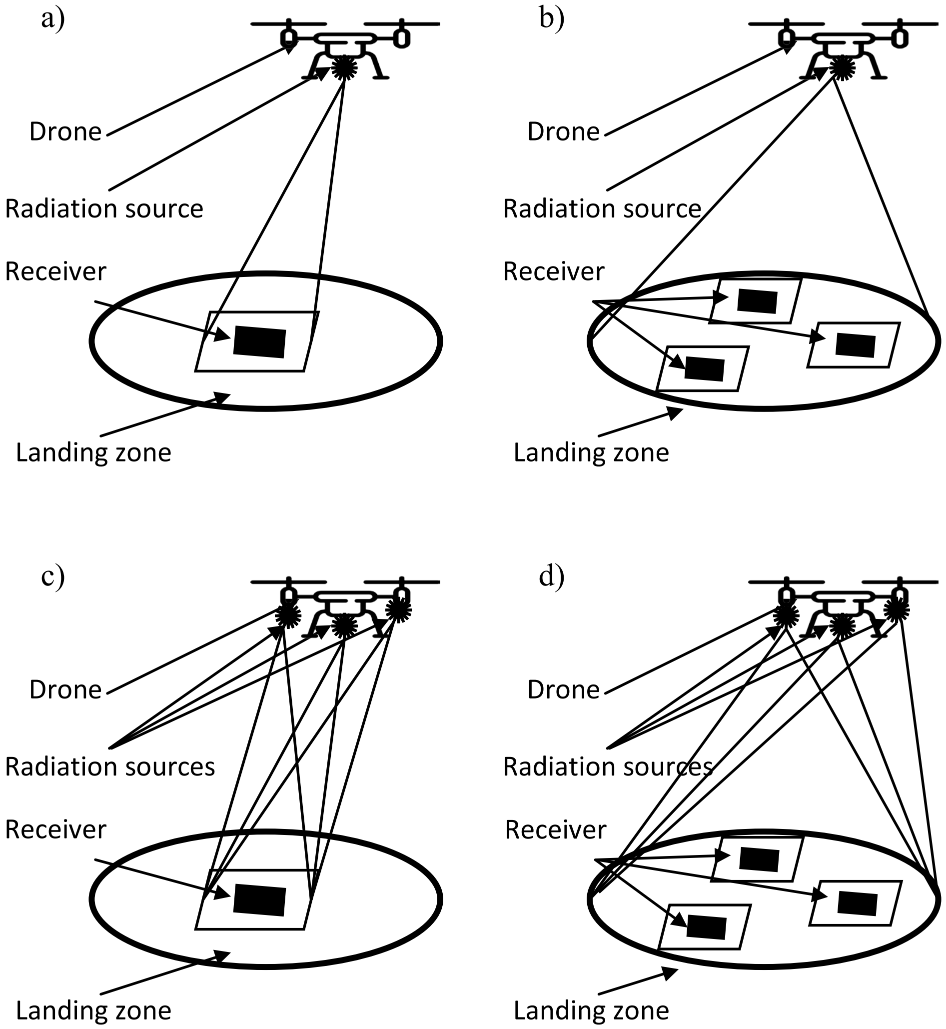

Figure 2 – Radiation source on drone: (a) one receiver on ground, (b) several receivers on ground; Several radiation source on drone: (c) one receiver on ground, (d) several receivers on ground

One more group LPSs which does not use cameras is systems with one or more detectors on drone and one or more beams on ground (Figure 3). For instance, a known method, shown in the patent US4626995A [11], uses LEDs and cameras to control the object. The LED is placed in the place where we want to direct the object, and the camera is placed on the object. The camera receives light from the source within the field of view of the lens, and maneuvers in the direction indicated. The disadvantage of this method, firstly, is that, as a light source, a camera is used which takes up a lot of space and expensive. Secondly, as indicated earlier, in order to maneuver the object, it is necessary to place the LED on our final or intermediate points. This means that we must first place a source of radiation throughout the trajectory, and it is not always possible. (Figure 3, a) The advantages are complete tracking of the trajectory along the beam, high accuracy, low cost. The disadvantages are not the ability to work in conditions of fog, rain, snow, the need to arrange all radiation sources along the trajectory.

The authors of the article [10] describe a device consisting of a ground landing control terminal and a control end of an aircraft, two-way communication, priority of communication, choice of laser communication or radio frequency communication, at the entrance to laser communication as the main means of communication (Figure 3, a). The operational objective is achieved by overcoming the malfunction caused by the malfunction of the airplane compass due to the strong electric field. It is proved that the system is an effective telemetric control system for the navigation data of an unmanned aerial vehicle, which is suitable for many tasks and can provide not only reliable and constant posture maintenance in conditions of complex electromagnetic interference, but also in conditions of complex electromagnetic interference.

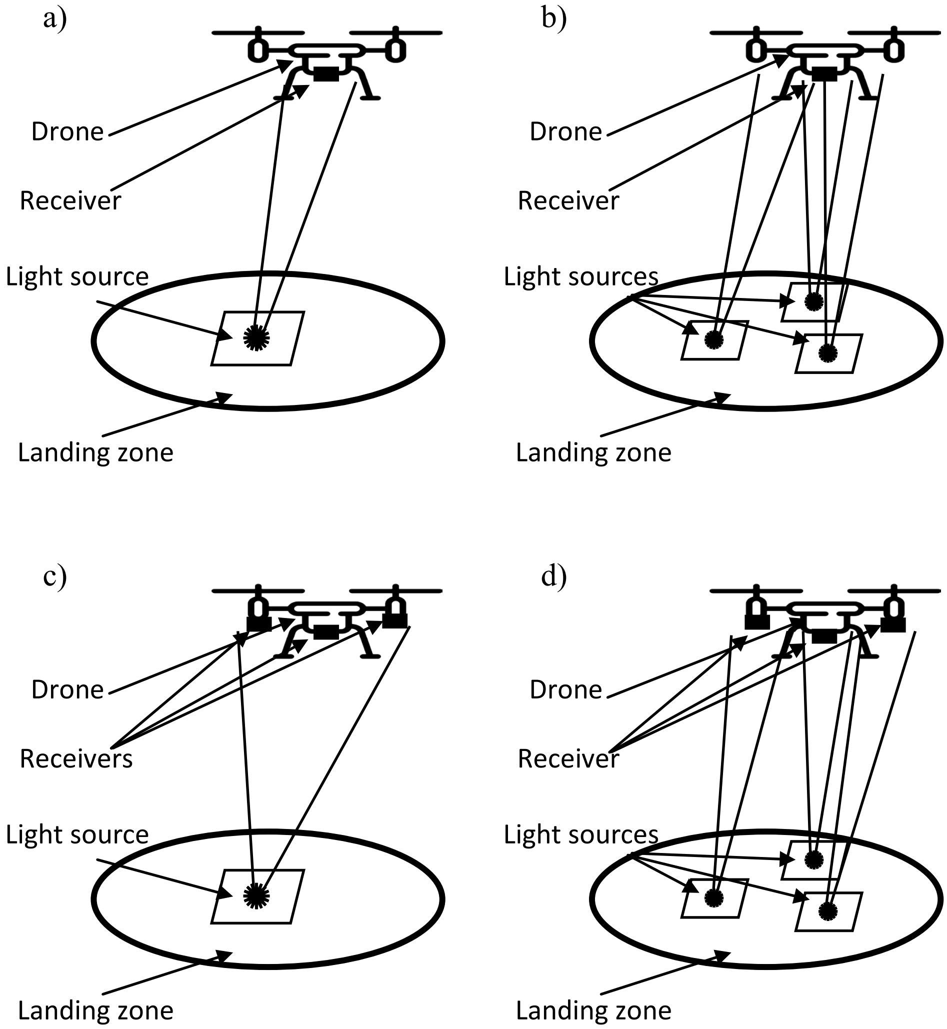

Figure 3 – Receiver on drone: (a) one radiation source on ground, (b) several radiation sources on ground; Several receivers on drone: (c) one radiation source on ground, (d) several radiation sources on ground

An example of such a system is presented in the patent US9435635B1 [8] (Figure 3, b). It describes a method that, by a projection of a grid in space, can detect objects penetration, assist objects when landing, and map objects. The system consists of a grid generator, which displays a relative navigational grid to the three-dimensional space to determine the field; light detection module; the processor is functionally connected to the detector module and is configured to receive the signal, and determines when the signal associated with the detected light indicates the presence of an object's invasion (Figure 2). The advantage of such a system is the accurate tracking of the aircraft during the landing process in three planes. The disadvantages are the complex system for forming the grid, when using an optical grid, the system will not be able to work in bad weather conditions (fog, rain, snowfall), and when using a radio grid, there is a high probability of radio-electronic interference.

Another system is described in the patent US7535380B2 [9] (Figure 3 (b)), by which one can determine the angle of the sliding of aircraft. The device applying this method includes at least one unit for generating a light beam of a certain wavelength, at least one module for transmitting a modulated signal and forming an image, and a device for designing this signal. The task of this system is to assist pilots of aircraft to land and inform them for the correct maneuvers (Figure 3). We can use this system to automatically land drones. In this case, each of the beams will carry certain information about the position of the drone in space (height, deviation from the center of the landing zone, distance to the landing zone). The advantages of this system are high accuracy, there is no influence of electromagnetic interference, the ability to land on moving objects. The disadvantage is not working capacity in conditions of insufficient visibility (fog, smog, rain, snow).

The Ship Relative Instant Multispectral Positioning System which shown in [12] uses one detector on drone and several beams on ground (Figure 3, b). It has two components: blocks – the ship-based multispectral beacon and the airplane-based set of discriminating sensors. The first block is located on the landing platform (in this case, an aircraft carrier) and initializes the signal in the form of the so-called rainbow in the IR range. The second unit is located on an airplane or object that we are landing and consists of a spectrometer and then the signal goes to the control unit.

The resulting system is accurate, can measure range, and it is safe for pilots. This makes it possible to use it both for UAVs and for manned aircraft [12].

The main problem is the use of a multi-spectral transmission channel. This means that the emitter must give a certain frequency with great accuracy, and this is not so easy to achieve. In addition, the spectrometer should give an accurate signal. Therefore, looking at the shortcomings, we can say that this device may have inaccuracies in determining and emitting a specific wavelength [12].

A known method presented in the patent US4856896A [13], by which a device using this method directs the transport operator (for example, planes, ships, trucks, cars, etc.) to their destination (Figure 3, b). The principle of the method is that one or more parallel beam beams are sent in the direction of the operator, which can also form the image for the operator. When the beams of the beam taken at the end will be fixed, it will indicate that the transport reached its destination. The advantages of this system are ease of use and implementation, can be used for any vehicle. The disadvantages are the human factor, not the ability to use in bad weather conditions.

In the closest way, there is a way presented in the patent US2015/0153486 A1 [14]. It uses several detectors on drone and several beams on ground (Figure 3, d). Using this method, you can connect two objects. On both objects, a line with Fresnel lenses is installed (vertically and horizontally). Each Fresnel lens is equipped with a radiation source (LED, incandescent lamp, etc.) on one vertically, on the other horizontally. The receivers are either the transport operator or the line of receivers. Because the rulers of the lenses form a mutually perpendicular straight line, one can find the exact position of the objects to each other. Knowing the position can be controlled by one of the objects to align it. Also, the proposed device provides a system for preventing collisions. The advantages of this system are high accuracy, there is no influence of electromagnetic interference, the ability to land on moving objects. The disadvantage of such a method is the dependence of the results of docking on the transport operator (if the receiver is an operator), or the installation of a line of photocells, which increases the cost, or the use of special equipment for detecting light in the infrared range.

Optical-Electronic positioning system which proposed in [15] [16], uses several detectors on drone and several beams on ground (Figure 3, d). It forms a set of coded beams in three-dimensional space using economical LED light sources. The drones can receive these beams by a very compact photosensor unit (like in TV control) and the codes of these beams directly provide drones with the drone's position relative to the landing zone. This accurate positioning is realized without human control, digital image processing, GPS and processing data from other sensors.

The advantages of this system are system does not invade privacy (does not use cameras), provides safety during takeoff and landing, fully automated (no operators required), high accuracy. The disadvantages are the inability to use in bad weather conditions, it is necessary to install a landing zone at the landing site.

A known method presented in the patent [17] uses several detectors on drone an several beams on drone, which can be used to control a moving object and, in particular, to automatically stop a moving object in a given position and direction. The apparatus using this method contains a pair of photoelectric sensors that contain a light-emitting element and a light-receiving element for a moving object and a pair of reflectors at predetermined positions opposite to photoelectric sensors. The advantages are maneuvering from obstacles during the flight, there is no need to establish a landing zone. The disadvantage of this method is to install a large number of receiving elements, which increases the price of the entire device (Figure 4).

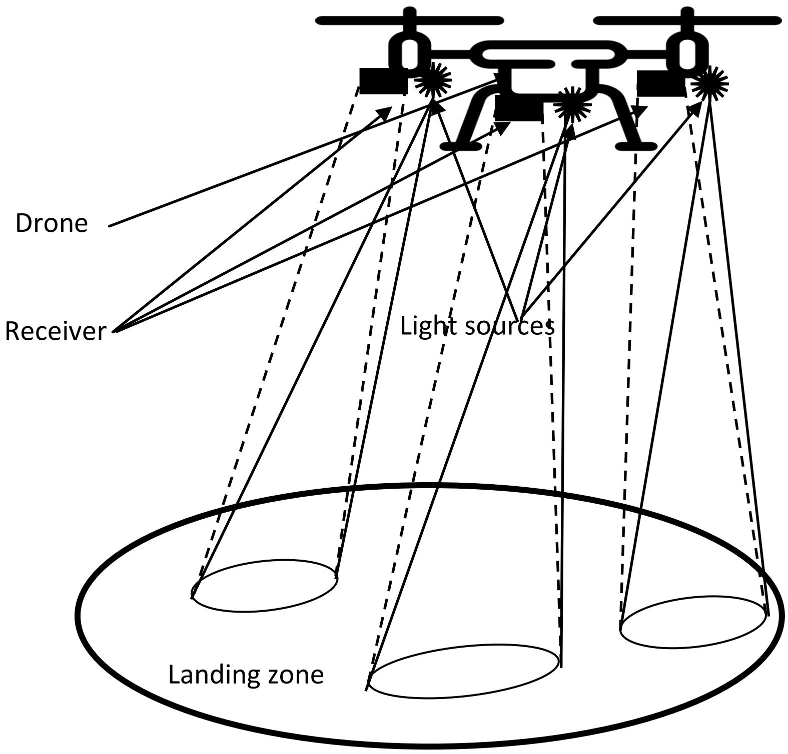

Figure 4 – Principal scheme of US4554498A

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CONCLUSION

The article examined the main types of landing systems that do not use cameras. The principal advantage of these DSP systems is possibility to perform fully automatic take off, landing and goods dropping with expensive stabilized cameras. The comparative analysis has proven that the best DPS systems are ones with several receivers on the drone and several emitters on the ground. They have high accuracy, low cost, simple implementation, easy to use, receivers take up little space on the drone, which will use less energy of the drone and allow you to carry more payload. The main disadvantage of such systems is the inability to use the system during bad weather conditions. This problem can be easily solved, for example, by using terahertz or beams.

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