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Aircrafts Dedicated Guidance System based on improved mathematical model with Modern Visual Presentation

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Abstract. This paper aims to introduce an alternative method of navigating aerial transportation. Its goal is to aid pilot while conducting two most dangerous operations: taking off and landing the plane. Proposed system novelty lies in its separation from all the other systems available on deck. Any fault of hardware or software on the plane will not influence the proposed system. It will offer second set of data for the pilot, precise information about what is visible from the position of the sensor – at the bottom of fuselage. This can greatly increase safety while conducting manoeuvres in bad weather conditions. We also believe that we reached simplicity and cost of implementation of the proposed system at a level good enough to make this idea very popular among industry specialists. From the perspective of mathematical specialist, it offers interesting point of view on methods how algorithm and equation were created.

Keywords: aircraft system, algebraical analyse of approach, approach landing system, intelligent aircraft system, visual aircraft system
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1. Introduction

Public aviation is evolving at unbelievable rate. Millions of passengers trust their lives in hands of sophisticated safety systems integrated into airplanes. Solutions that take part in race to deliver best user experience and reach highest possible landing success rate in history of air transportation are being improved constantly. One of the systems that is still required to be developed should be able to guide aircraft safely onto any airstrip, to offer successful landing results even if ILS systems are nonexistent or malfunctioning at target airport. There is clear need of backup system to observe changes in terrain, detect obstacles and offer the possibility of emergency landing even in most excruciating scenarios. Such system could be used to achieve higher safety levels, minimise amount of passenger lives lost due to numerous accidents and it would be even possible to use it to support military aircrafts in unfriendly environment.

One of the biggest limitations of modern civilisation is the flow of time. Although technologies make life easier, even till this day there are still many things that cannot be done without human presence, which is why everyone travels longer and longer distances. As a result of people travelling longer distances transport is also developing, and referring to the lack of time, people always want to travel as fast as possible. According to the Federal Aviation Administration, aerial transportation is selected by approximately 2,264,000 people each day, which is an average of more than 800,000,000 transferred people per year [1]. Therefore, scientists are forced to emphasise the importance of safety in aviation even more.

As learned from statistics from past years the number of aviation accidents in the world is decreasing [2]. This is taking place due to the use of newer technologies and also due to the newer systems supporting the work of a pilot. Precision landing systems are able to bring the aircraft safely to the ground by themselves without the aid from a pilot, but those are still dependent on installations integrated at the airport and systems installed on board. If even one of these two elements for some reason do not work, it is not possible to use this system. Besides, not all airports are equipped with features to support precision landing, which does not give enough security for example in cases where plane must land at an airport that is being renovated, or one that does not have a precision approach landing system. In this case, the pilot is put into a difficult situation since he or she is forced to land because of system failure or a dangerous incident, which occurred on board of the aircraft, for example: a fire or passenger in critical condition because of an illness or accident. In this case, every minute counts, and it is not always possible to find an airport, where you can land safely without damaging the machine or causing damages among the passengers.

The proposed solution is to support pilot during the approach to land in conditions and situations that do not give the possibility of using precision approach landing systems that are currently used in aircrafts. It is a system that has a broad spectrum of use, which aims to enable safe landing in conditions where the precision approach landing systems fails to guide the plane onto the runway. This solution does not need to interfere neither with the airport nor with any devices at the airport and it is based on hardware that have been already used for many years. It should be used as a support system for the landing process itself but also ultimately can be developed into an independent system to support precision approach landing system and the system that guides the entire process of landing by the computer.

Solution in which artificial neural networks are used is deliberate and it is to help the pilot in making the right decisions and to prompt when those decisions should be reconsidered when dealing with the sudden change of situations, for example: change in weather conditions or failure of any of the devices on board. The system will be more versatile. It will help the pilot, and he will be able to make sure that the decisions made by him are consistent with the decisions proposed by the system, or if the system found a more logical solution to the problem with the landing approach. An airplane equipped with the system will become more economical than fitting more hardware onto the aircraft or airstrip, because by installing it on the plane it will automatically recognise all the lanes and areas of the runway.

2. Analysis of the examined problem

Most aircraft accidents take place during take-off or during landing. The system being tested is supposed to help during the planes approach for landing. Every controlled airport that allows planes to land have specific procedures for landing. „Cleared to land" is said by the air traffic controller in order for the pilot to begin taking steps to bring the aircraft safely to the ground. For this purpose, pilot moves on to begin the procedures associated with the landing, by lowering the altitude of the flight to the first point of contact with the airport runway. The type of approach to landing according to safety procedures depends on the machine parameters which will land, terrain conditions around the airport and aviation obstacles. Two basic procedures are distinguished, precision-based approach and non-precision-based approach [3], [4].

While approaching landing strip, captain interprets navigational aid consisting of segments defined in procedures created by the International Civil Aviation [5], [6]. Intake is lowering the height from cruising position to the position „fixed" in which the initial approach has begun and this point is marked IAF. Three steps are happening one by one:

1. IAF (Initial Approach FIX) is exceeded, aircraft with its landing gear pulled out rises to minimum 300 meters above the air traffic obstacles;
2. IF (Intermediate Fix) – a stage in which the speed parameters and configuration parameters are changed, so they can go to the last segment;
3. FAP (Final Approach Point) in precision approach or FAF (Final Approach Fix) in non-precision approach, for which the machine moves in the axis of the runway and begins to approach for landing.

This phase ends in MAPt position in which the pilot decides whether the conditions are suitable, and if he can land or will attempt to approach the landing again. It is also possible that pilot will decide to fly to an alternate airport. The approach for landing is done with supporting systems whose job is to keep the plane in the axis of the runway at suitable weather conditions.

2.1. Supporting systems for precision approach landing currently in use

Landing the aircraft is one of the most difficult operations associated with this means of transport. Consequently, there are many systems that support this complex operation. The most popular are:

- ILS (Instrumental Landing System) [7] is a system built in order for the aircraft to be precisely taken down to the deciding point on the glide path or, depending on the version of the system, to touchdown on the runway. The system consists of 2 basic beacons which give signals in the vertical and horizontal axis defining the landing path and the angle at which the aircraft ought to lower the flight in order to come in contact with the runway in the right place. Three beacons are determining the distance and height of the vessel to the runway threshold. The radio telemeter is used as a substitute or and additional device to beacon tracers.
- MLS (Microwave Landing System) [8] is the successor of ILS and it is a system to precisely approach for landing by working on the principle of emitting flat beam signals through antennas in the direction of approach and departure (about 13 times a second) and in the direction of the glide path 39 times a second. The system placed in the machine receives and decodes the signal by receiving information about the tilt angle and glide path. This system works in a basic configuration, it consists of the following elements: the elevation station, the azimuth station, devices that load and transfer data, and radio beacons for support. The reception range can reach up to 40 miles.
- GNSS (Global Navigation Satellite System) [9] is a precision landing approach system based on the combined readings of artificial satellites operating within the GPS (Global Positioning System) and the Russian counterpart of this system called GLONAS [10] and data from an International Maritime Satellite, however, this system does not fully work by itself and the approach to landing is dealt with by using additional support systems.

These systems are, however, imperfect in many ways. Even ILS system is showing some grave drawbacks [11], [12]. It is known that is has problems with determining the space for only one straight approach path and doing it in the form of a straight line. It provides only the brief information about which way the deviation from the approach path occurred. Another issue with that system is that it only works on 40 channels that this could be a problem for airports located far away and it can easily disrupt radio signals. Last but not least, restrictions concerning the location to install the system are vast, and in the event of failure, reflections can generate interference. Of course one cannot forget about financial issue — high cost of installation. Installing ILS just for the airport would exceed $ 1,000,000 in costs.

TABLE 1

Category of ILS systems [13]

Function description \ ILS category	CAT I	CAT II	CAT III A	CAT III B	CAT III C
Decision height no less than	60 m	60 m - 30 m	30 m	15 m	No min.
The minimum visibility on the runway	550 m	300 m	150 m	170 m – 50 m	No min.
Visibility in the airport area	800 m	–	–	–	–

2.2. Defining the research problem

Systems currently used in aviation are systems based on radiolocation, where tracking the target point is based on reading the radiation at a certain frequency and comparing it to the readings of the signal. Nowadays, the wireless communication system is so easy to access that even simple watch is able to transmit up to date information to the phone with the help of radio waves. Therefore, it should be possible to utilise it to such actions as improving the safety of the aircraft by using resources that have as little interference as possible. Since the system bringing the plane to the ground can be disrupted by a radio transmitter, then it must be stated that it should not be considered very safe.

Most security systems used nowadays locate obstacles using image processing systems [14]. These systems can locate and predict the possibility of pedestrian walking onto the runway and they can also check if the installation of components in the electronic system is correct. It can also be used to detect and support the approach of precision landing [15]. Until this day, pilot was responsible for locating the airport and for guiding the plane onto the runway. At the moment, the system IVAGS (Intelligent Visual Aircraft Guidance System) is being tested, but it could become the pilot's third eye. The system can recognise the airport on the basis of area photographs and it can lead the aircraft onto the runway by using artificial neural networks to recognise the airport [16].

The research problem in the context of the issue is quite specific. The main goal is to design a system, whose job is to determine the runway by using the image seen through the camera, recognise touchdown zone markings and to determine the aiming point of the runway in order to determine the landing path.

2.3. Analysis of the research problem

The problem applies to, using the system of artificial neural networks to help recognise the image of the runway, on which the aircraft is to be directed. The systems main and hardest task is going to be to detect the runway, even though this element is quite distinctive. When detecting the markings of the runway is not possible, the system has the possibility of determination by the ratio of the lane, the apparent touchdown point on the runway. Therefore, the attempt to recognise marks and signs on the runway will be repeated with suitable frequency. At the moment of character recognition, the system will have the task to define the touchdown zone and to define the point where the aircraft will be guided. Machine could be determined as a point that moves through space at a certain speed and it has a goal to reach a certain target. The use of space to virtualise coordinate system, whose centre will be located at the touchdown point which is the objective, in order to determine planes position.

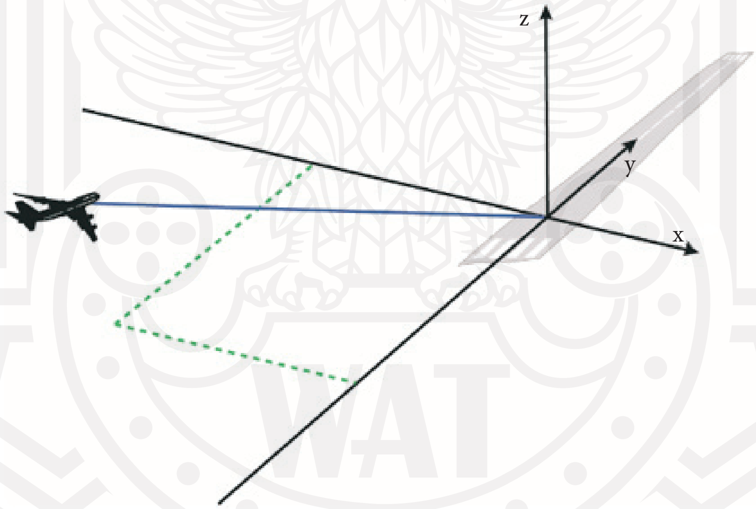

Fig. 1. Determination of the position of the coordinate system with the recognition of the centre of the touchdown zone as the beginning of the coordinate system

2.4. Mathematically algebraic analysis of the problem

A coordinate system will help to determine whether it was possible to land, from the given position of the aircraft, on the detected airport. In this case, selecting the standard approach angle, for example: during the procedure of non-precision approach the angle cannot cross 30 degrees.

Norm of a vector is calculated:

$$\|\underline{x}\| = \sqrt{x^T x} \tag{1}$$

$$\|\underline{x}\| = \sqrt{\sum_{i=1}^{n} x_i^2} \tag{2}$$

The norm of the vector *x* will be equal to the square root of the product of the matrix, representing the vector *x* received and the matrix of the vector *x*, which converted, gives the root of the product of the sum of items from *i* equals *n* to the square elements of the vector *x* [17].

An angle of approach, received from the cosine angle between the vector of a distance from the point of touchdown from aircraft, which is the centre of the coordinate system, and the projection vector point in which the aircraft has an area created by the XY axes. It will be the area of the extension area on the runway. The angle between vectors will determine whether the aircraft while at a given point is able to make approaches to the threshold of the runway, preserving the angle of approach at maximum 30°.

The calculation of the approach angle, based on the example of the mode of coordinates, can be accomplished. In the modes of coordinating XYZ, the exact positions *a* are determined with the coordinates of $x_a\ y_a\ z_a$. This vector begins in the coordinate system XYZ. To define the area determined by the XY axes, the point on the basis will be designated by vector paths. A goal is to find the end point of the vector and the perpendicular to the area of the XY axis. It will be the vector *b* with the coordinates at $x_b\ y_b\ z_b$.

It is possible to use calculation:

$$\begin{gathered}\text{for } a\ [x_a\,;y_a\,;z_a], \text{ the projected vector } b\ [x_b\,;y_b\,;z_b] \\ \text{where: } x_a = x_b \cap y_a = y_b \cap z_b = 0\end{gathered} \tag{3}$$

The angle between the vectors is calculated by:

$$\|\underline{a} - \underline{b}\|, \sqrt{(\underline{a} - \underline{b})^T (\underline{a} - \underline{b})}, \sqrt{\sum_{i=1}^{n} (a_i - b_i)^2} \tag{4}$$

Such an equation can be determined on a simple 3D graph:

To receive *α* cosine angle in the radians can be used:

$$\cos\alpha = \frac{\dfrac{\underline{a}' \cdot \underline{b}}{\|\underline{a}\|}}{\|\underline{b}\|} \tag{5}$$

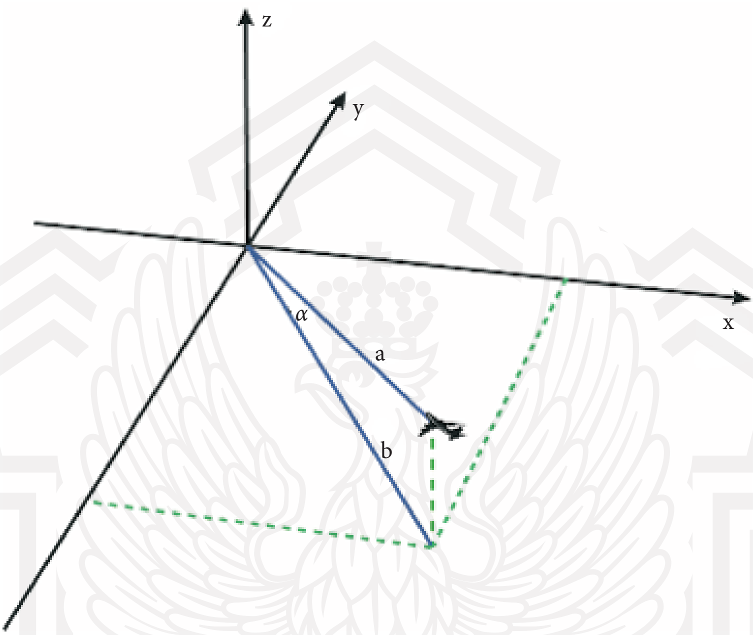

Fig. 2. Determination of the altitude angle for the approach to landing

Then, we must apply the inverse cosine, otherwise value – $\cos^{-1}$, after that it is possible to change the angle in radians to an angle in degrees. Finally, the obtained result is compared with the angle of approach and output is a solution in which it is known whether it is possible to finish the approach under the appropriate angle. If it is not possible, the pilot must make the decision to go-around [18]. Research completed with the assistance of MathLab allowed the possibility of detection of one anomaly at the moment when the aircraft is found above the place of landing and the projected point falls in the middle of the coordinate system.

An algorithm was created to always respond with one of three variables: *Xa*, *Xb* or *Xc*. First one will mean that status of landing was achieved. *Xb* will inform about departure. *Xc* will set message of plane being under point zero. At first, conditional to cover situation when both $na \in R$ and $nb \in R$ are larger than $eps \in R$ is put into equation:

$$status = \frac{(1+\operatorname{sgn}(na-eps))}{2} \operatorname{sgn}^2(na-eps)\frac{(1+\operatorname{sgn}(nb-eps))}{2}\operatorname{sgn}^2(nb-eps) \tag{6}$$

This equation throws a value of *status* = 1 if condition is fulfilled and a value of *status* = 0, when it is not. At next step, vector calculation was added to this equation to throw its value when condition is fulfilled:

$$status = \frac{(1+\operatorname{sgn}(na-eps))}{2}\operatorname{sgn}^2(na-eps)\frac{(1+\operatorname{sgn}(nb-eps))}{2} \operatorname{sgn}^2(nb-eps)\frac{a\cos(\frac{a`b}{na*nb})}{180\pi} \tag{7}$$

Then, another condition was added within already existing condition to divide results between those that are available when *alphadeg* is larger than 30 and those that are generated when it is not larger than 30. *Xa* and *Xb* variables were added, those elements will represent final values that can be reached when certain values are achieved at each of the conditional parts of this equation.

$$status = Xa\left[1-\frac{(1+\operatorname{sgn}(alpha\deg-30))}{2}\operatorname{sgn}^2(alpha\deg-30)\right] \frac{(1+\operatorname{sgn}(na-eps))}{2}\operatorname{sgn}^2(na-eps)\frac{(1+\operatorname{sgn}(nb-eps))}{2} \operatorname{sgn}^2(nb-eps)\frac{a\cos(\frac{a`b}{na*nb})}{180\pi} + Xb\frac{(1+\operatorname{sgn}(alpha\deg-30))}{2} \operatorname{sgn}^2(alpha\deg-30)\frac{(1+\operatorname{sgn}(na-eps))}{2} \operatorname{sgn}^2(na-eps)\frac{(1+\operatorname{sgn}(nb-eps))}{2}\operatorname{sgn}^2(nb-eps)\frac{a\cos(\frac{a`b}{na*nb})}{180\pi} \tag{8}$$

Last part was added to the equation to make sure it throws a value of variable *Xc* whenever it is not possible to fulfil conditionals resulting in calculating status as variables *Xa* or *Xb*.

$$
\begin{aligned}
status = Xa\Bigg[1 - \frac{(1+\operatorname{sgn}(alpha\deg - 30))}{2}\operatorname{sgn}^2(alpha\deg - 30)\Bigg]\\
\frac{(1+\operatorname{sgn}(na-eps))}{2}\operatorname{sgn}^2(na-eps)\frac{(1+\operatorname{sgn}(nb-eps))}{2}\\
\operatorname{sgn}^2(nb-eps)\frac{a\cos(\frac{a`b}{na*nb})}{180\pi} + Xb\frac{(1+\operatorname{sgn}(alpha\deg - 30))}{2}\\
\operatorname{sgn}^2(alpha\deg - 30)\frac{(1+\operatorname{sgn}(na-eps))}{2}\\
\operatorname{sgn}^2(na-eps)\frac{(1+\operatorname{sgn}(nb-eps))}{2}\operatorname{sgn}^2(nb-eps)\frac{a\cos(\frac{a`b}{na*nb})}{180\pi}\\
+Xc(1-\operatorname{sgn}^2(na-eps))(1-\operatorname{sgn}^2(nb-eps)) +\\
+Xc(1-\operatorname{sgn}^2(na-eps))\frac{(1+\operatorname{sgn}(eps-nb))}{2}\operatorname{sgn}^2(nb-eps)\\
+Xc(1-\operatorname{sgn}^2(nb-eps))\frac{(1+\operatorname{sgn}(eps-na))}{2}\operatorname{sgn}^2(na-eps)
\end{aligned}
\tag{9}
$$

This final equation will respond with *Xa* value when *na* and *nb* are larger than *eps* and when *alphadeg* is smaller or equals a value of 30. If *alphadeg* is larger than 30 but *na* and *nb* are still larger than *eps*, it will reach a value of *Xb*. If *na* or/and *nb* are smaller or equals a value of 0, the equation will throw a value of *Xc*.

The script uses the data from a sample point, in which aircraft was found and it is data from vectors based on the centre of the coordinate system and the point *a* [10, 5, 2]. The vector based on the point *B* and the centre of the coordinate system is the vector projected on the area formed by the axes of XY, it will make a point that is located at the same distance from axis X and Y, but the value on axis Z will be equal to 0, so its coordinates will be: *b* [10, 5, 0]. At next step, next norm of the vector is calculated, based on the point *a* and the norm of the based vector projected to the point *B*, then it is checked to see if any of the values do not reach value of zero, because the system would return the specific value *NaN*, which is not a specified value [19]. Therefore, the first conditional instruction program protects against actions, in which point could be found exactly above the touchdown point, or else on the axis Z or theoretically of course, below the point on the axis Z. The value of *NaN* would be possible only in cases where the value of a standard vector or the vector *B* would be equal to 0, in this case the formula for the cosine of the angle α, will help to obtain equation in which division by 0 appears, and therefore, it would be an unmanageable operation.

```
a = [10;5;2]
b = a;
b(3) = 0;
b
na = norm(a);
nb = norm(b)
if (na > eps) & (nb > eps),
        cosalpharad = a'*b/na/nb
        alpharad = acos(cosalpharad)
        alphadeg = alpharad/pi*180
        if (alphadeg <= 30),
                disp('land!');
        else
                disp('departure!');
        end;
else
        disp('you are under point zero');
end;
```

Fig. 3. Code designed for the Mathlab program

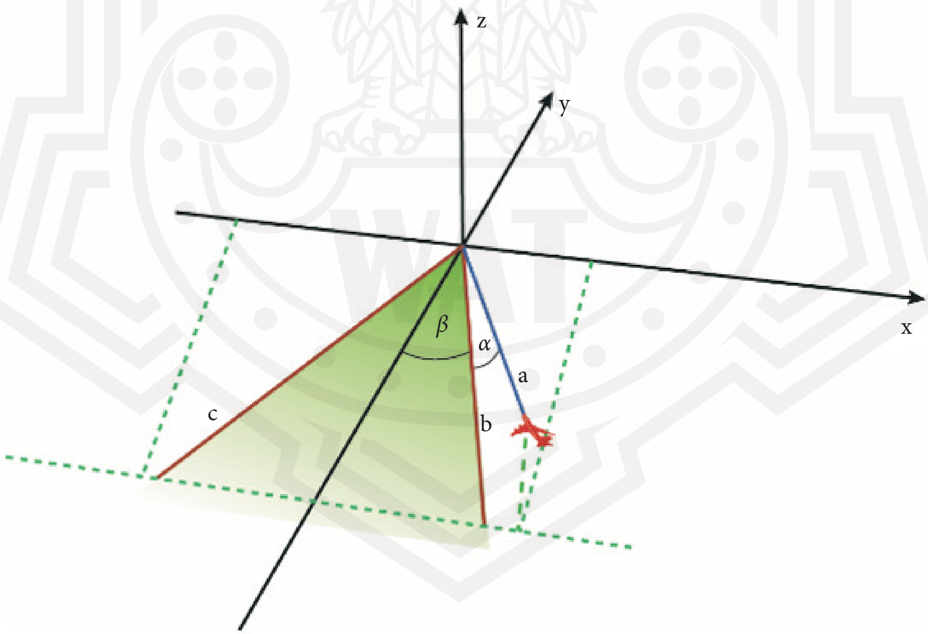

Fig. 4. The definition of the deviation angle of approach from the path in the axis of the zone

In an analogous manner, it was possible to receive a 25-degree angle between axis X and point, which will give a restriction in the width of the approach to the landing path. This time the angle between the vectors, where one of them is determined by the centre of the system *I* point projected by the airplane on the surface of axis XY should be calculated. However, the second one will be located directly on axis Y. The designated angle and *I* beta will constitute a restriction for the machine trying to land. If it is found in the range where there are restrictions, it will have the possibility of landing. Otherwise, the decision will be made to stop the landing procedure.

2.5. Final approach navigation

It was investigated how the presented project could be used to aid pilots in conducting landing maneuver. This was challenging point because there are randomly appearing conditions [20] that can disrupt data while approaching airport. It was known that there will be a camera mounted at the bottom side of fuselage, which will offer live 60 FPS high resolution stream, but it will be too easy to lower precision of gathered data if there will not be any precautions taken for possible problematic situations. A plane could go into unstable flight, vibrate from overload and even deviate from the course by few degrees because of the wind direction. To secure a system from those effects, advanced stabilisers would have to be added to the camera mount. It is also important to take note that landing might happen at night, which means that the project must be versatile and must offer additional sensors to acquire live view even when there is no light available.

It was decided that a solution with two cameras and an infrared sensor will be the most optimal specification of hardware for this task. Two high resolution cameras will offer great possibilities of stabilisation of the image and an infrared sensor will present opportunity to simulate night vision live video stream. Two cameras will make it possible to use software stabilisation algorithm, simple one, which will compare two streams and chose the best frame to be presented to the system. There is also opportunity to use advanced stabilisation equations and to add the possibility of computations made on larger amount data to achieve even more precise results. It will be possible to take into consideration data from previous frames and to activate additional sharpening functionality. Infrared sensor is a must, it will help to recognise edges of shapes visible on the image, like landing strip, aiming spots or traffic pattern indicators [21]. This will expand algorithm efficiency even at daytime.

There is one hardware limitation of devices such as Intel R200 and Microsoft Kinect that needs to be taken into consideration. Those machines are offering low amplification of infrared signal, because of small size of implemented optic system. A distance range for any recognition for those devices is at maximum level of about 50 m.

It will be enough to use recognition algorithm for landing strip spots but it must be noted, that with more advanced sensors, this control could start much higher above the ground.

Procedure of landing must begin with exactly the same task, as pilots are normally conducting onboard of planes not equipped with the presented system. Aiming spot must be located. It consists of two large rectangles painted on tarmac surface, at the beginning of landing site. For this action, all three measuring optic devices are being used: both cameras and one infrared sensor.

2.6. Landing strip aiming spot recognition

This task requires an algorithm that can recognise aiming point on a landing pad [22]. This must use both data streams, camera and infrared. Investigation was made on a small scale landing pad that simulates real object at a smaller scale. Simulation was made for aiming spots, Microsoft Kinect v2 was used for this experiment:

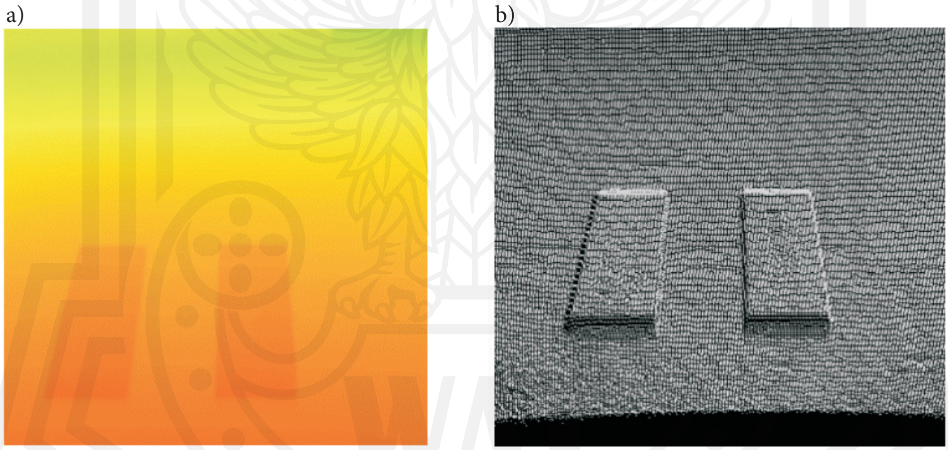

Fig. 5. (a) Infrared signal translated into colour map of a distance; (b) RAW signal from an infrared sensor

Infrared sensor usage makes it possible to observe rectangular stripes at night. Result shown in Fig. (1b) will be the same for every time of day. An angle of descend will not influence results, aiming spots are visible in the range of 15-75 degrees, calculated from a ground surface.

A single shape finding algorithm can find two high opacity rectangles on the live stream frames and use middle of found area as zero point for both X and Y axis. This will work exactly like fiducials system in production machines. This will calibrate starting point for further calculations. Aiming spot will be the point at which an algorithm will start an informing pilot, that there is a landing strip below.

There is also additional information recognised from both figures (1a, 1b). Application not only recognises an aiming spot in vertical and horizontal position, but there is also information about two angles, one concerning deviation between plane ascending course and airstrip surface, second about image rotation, which indicates if plane course is parallel to the landing strip. From those variables, it is possible to calculate a plane altitude above the ground and route correction that must be made to land properly within the landing strip.

Additional advantage of multiple sensors installed at the fuselage is the possibility of calculation of plane speed by using shift of recognised shapes between frames grabbed by a camera and an infrared sensor. Momentarily, such a project will add safety profits, with another measurement device that can confirm if proper results are visible for the pilots at the cockpit if needed [23].

2.7. Implementation of the hardware

One of the most difficult tasks of this project lies in hardware implementation. Standard cameras offer parameters which are too low to be able to properly identify images. One of the best solutions turns out to be a camera with an appropriately sized sensor that offers resolution on par with automatically controlled high-quality lens with a high focal length and a large aperture in relation to the lens. This means, that it will be a lens, which will be able to zoom in an image even from several dozen kilometers, while the object will have appropriate lighting, which means the lens will not suppress the reflected light from the object. After passing through the lens light will settle on the sensor to create an image.

For the implementation of this task, one of the solutions would be an ultra-high sensitive, long-range camera [24]. These types of cameras are presently used to monitor long distances between areas in different field conditions. They are characterised by a high sensitivity matrix which is useful when monitoring at night because it is able to obtain an image even at very low light. Light sensitivity in such cameras can reach up to 0.00003 lux. Cameras use various solutions to improve contrast, so that the object can be extracted from the image even with detection of high intensity light from far distances [25]. One of these solutions is the technology of joining pixels which provide in a monochrome image data up to 150 times more sensitive than in colour cameras, according to manufacturer's specification. Cameras also use modern solutions which provide visibility during bad weather and during the conditions of low visibility. It can ensure an image of complete vision during fog, rain, hail, snow, and dust. Solutions achieved in cameras are due to interpolating the image to curtained neighbouring pixels, whose values are formed by averaging the value of the pixel located nearby.

Camera CHM-100 is a unique camera. It consists of 4 professional cameras working in one housing unit and forming a single unit. The purpose of the first camera is to create wide angle shots, focal lens of 1 mm (the focal length of the human eye is about 1 mm), it records images continuously day and night. From the second camera, it was possible to obtain high contrast ratio between colours, which gives a good quality image over a large distance. The best quality of the third camera is the ability to work with low lighting – 0.00003 lux, which means it is able to obtain images during the night by using the lighting from the stars, although the image obtained will be a monochrome image. Fourth camera is a very high contrast device and gives the ability to work in bad weather conditions like fog, snow, rain, and sand. This device has optical zoom of 100x and two ranges of focal lengths, in which one of them is 6-25x and the second one is 25-100x. The device has a lens and zoom changing system.

Detecting objects the size of container ships is possible from a distance of over 30 km, and the object recognition is possible at a distance of 25 km. Precise identification is possible at a range of 20 kilometers. An object that is the size of a car can be detected from about 18 km, at a distance of 15 km it can be identified and at about 8 kilometers it can be seen like standing next to the observer. Human is an element that can be identified from a distance of 10 km. At about 7 km, humans outfit can be recognised and at 3.5 km a precise identification of the person can be made. Detection of an object happens when the object is within the field of view and the pixels are able to identify the outline of the object. Recognition starts when an object is located, such as a car or a boat, identification is when it is possible to identify the model of the car or in the case of a human observer it is able to recognise their gender.

a) b) c)

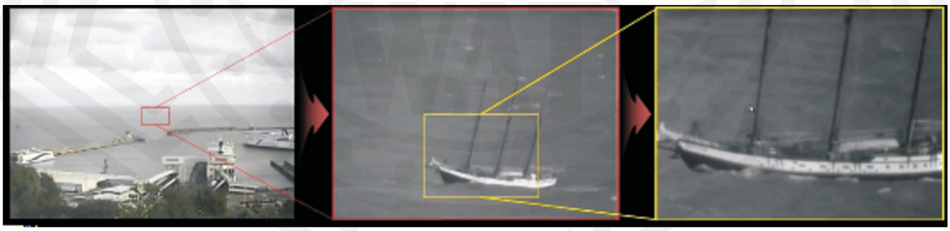

Fig. 6. The camera image CHM-100 (a) wide angle colour image; (b) the zoom lens 6-25x (c) the zoom lens 25-100x Photography contained in the product data sheet. Website http://chimide.pl/wp-content/uploads/2015/03/CHM-100.pdf

3. Summary

The designed system has a lot of potential for development. One of the applications features support and control of the correct location of a centre of a coordinate system towards which our device/craft is headed. If, based on the camera image, that point has not been precisely determined, the system will compare its location with other data, such as GPS, GLONAS, or even the Galileo. In that case, it can correct the location of the point or display information on the detected discrepancy. Each occurrence of this kind is only recorded in the logs as the system continuously reads the camera image and instantaneously identifies the point. This is due to the fact that while the aircraft is approaching the runway, it is moving towards the touchdown point. Owing to that, the system is fed increasingly accurate image out of which it can move the centre of a coordinate system, relative to which the landing proceeds. The system aims at as accurate results as obtainable.

This project produced the solution which was not previously used, which has the ability to make travel and transport a lot safer. The introduction of prototype devices and tests can give more answers, whether the proposed solution will work in real life, although it is very likely due to the work proven in theory. The device is completely safe because it does not interfere with the landing system and it only gives the pilot hints. The project will continue to develop and in the future there will be expanded versions by additional elements, over which there is research being conducted.

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Specjalny system naprowadzania statków powietrznych oparty na ulepszonym modelu matematycznym z nowoczesną reprezentacją wizualną

Streszczenie. Artykuł ma przedstawić alternatywny sposób nawigacji w transporcie lotniczym. Jego celem jest wsparcie pilota w wykonaniu dwóch najniebezpieczniejszych operacji: startu i lądowania samolotem. Oryginalność systemu polega na jego oddzieleniu od wszystkich innych układów dostępnych na pokładzie. Jakakolwiek usterka sprzętu lub oprogramowania w pojeździe nie będzie miała wpływu na działanie proponowanego systemu. Rozwiązanie zapewni pilotowi drugi zestaw danych, dokładną informację o tym, co jest widoczne z położenia czujnika – w dolnej części kadłuba. Znacząco zwiększy to bezpieczeństwo podczas wykonywania manewrów w złych warunkach pogodowych. System osiągnął prostotę i koszt wdrożenia na poziomie na tyle atrakcyjnym, że pomysł ten zyskał duże uznanie wśród specjalistów z branży. Z punktu widzenia specjalisty matematycznego rozwiązanie oferuje ciekawy punkt widzenia na metody tworzenia algorytmu i równań.
Słowa kluczowe: systemy statku powietrznego, algebraiczna analiza podejścia, system wspomagania podejścia, inteligentny system lotniczy, wizualna reprezentacja statku powietrznego
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