System of Autonomous Navigation of the Drone in Difficult Conditions of the Forest Trails

Anton A. Zhilenkov[1], Ignat R. Epifantsev
Faculty of Control Systems and Robotics, Department of Control Systems and Informatics
ITMO University
Saint Petersburg, Russia
[1]zhilenkovanton@gmail.com

***Abstract*— Problems of realization of completely autonomous systems of navigation are considered in a set of spheres of human activity today. The most important task is today the attempt to create on the basis of system of technical sight completely autonomous system of navigation for motor transport, the marine transport and aircraft. In article the problem of creation of such system for the drone which is carrying out research or rescue operations on the difficult area is considered. And it is concrete in the wood. The main objective of system is finding of footpaths among trees on which the drone can follow. The main tool of the solution of this problem offers use of artificial neural networks of deep training or convolution networks. The quantity of layers and dimensions of local networks at their use is proved in problems of autonomous navigation of drones on the basis of systems of technical sight.**

Keywords—Autonomous navigation; deep learning; control system; drone

I. Introduction

To date, the autonomous navigation of robots in the wooded area is an unsolved problem. Its solution is of paramount importance in a variety of applications. Of course, mainly we are talking about self-following on paths, glades and other similar paths, since moving through them is most effective for ground robots at medium and long distances. This is due to the nature of the trails - they do not pass along extremely steep slopes and in impassable terrain (for example, over swampy terrain or in impenetrable thickets). Therefore, most types of robots can walk along forest trails [1-2]. Moreover, small unmanned aerial vehicles capable of moving at low altitude under the tree crowns can follow them. Providing autonomous navigation of robots in the wooded area can significantly increase the speed, efficiency and safety of performing reconnaissance, search and search and rescue operations on it.

In connection with this and many similar problems, today one of the most urgent is the task of increasing the intelligence of robotics objects while ensuring their maximum autonomy [3-4]. This requires the presence of high computing power in the onboard means of robotic facilities while maintaining small dimensions and lower power consumption of the latter.

The methods and tools developed in solving this problem will solve similar problems not only in the wooded area, but also in a variety of other applications [5].

Existing systems that realize recognition, navigation in complex unknown conditions in advance and similar functions require information support of the human operator, remote computer or entire networks of computers and cloud computing [6]. They transmit the information of the onboard vision systems to the remote means of information support via the radio channel and after processing the information they receive instructions for further action. This requires a broad communication channel and its sufficient length, which is not always possible, and in some cases extremely undesirable. For example, when there is a threat that the control can be intercepted, or there may be an unwanted object detection by radio signal, or powerful interference in the communication channel, it can lead to loss of controllability and catastrophe, etc [7-8]. To get rid of these and many other shortcomings of existing systems is possible by increasing the level of intelligence of control systems of robotics objects.

The proposed system can find wide application in robotics of military, dual and special purpose.

II. Formulation of the Problem

The main aim is the development of an intelligent system of autonomous navigation for robotic facilities that provides the ability to perform reconnaissance and search operations on wooded and other terrain with a complex environment with an unknown map.

To achieve this goal, the following main tasks must be accomplished:

1. Develop algorithms and models for processing panoramic video, route recognition, machine learning, decision making, optimized for the characteristics of mobile hardware platforms.

2. Design a mobile hardware platform of the autonomous navigation system using architectures that are maximally adapted to implement on them neural networks and other technologies in demand in the project, including hardware acceleration of artificial intelligence.

3. Create software that implements the developed algorithms and models based on the projected mobile hardware platform.

4. Develop methods and tools for training machine intelligence, focused on the effective preparation of the system

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being developed for use in different terrains with the characteristic features of the environment.

III. The Novelty of Proposed System

The novelty is in:

- complete autonomy in intellectual recognition of pathways of motion that are difficult for machine vision systems, which does not require, in contrast to existing systems, support from the human operator or remote computing resources;

- complete autonomy in decision making when navigating in a complex environment, which does not require, unlike existing systems, support from the human operator or remote computing resources;

- full autonomy for communication, which, unlike existing systems, does not require the presence of a wide radio channel, and is capable of storing a complete radio silence when performing a task;

- a specialized mobile platform with hardware acceleration of artificial intelligence, using deep parallelization of computing, and focused on solving problems that require high intellectualization and autonomy in mobile and embedded applications.

IV. Description of the System

Under the complex environment mentioned in the project name, in the first place are meant such properties of the surrounding space of the robot, which make it difficult to recognize possible routes [10-11]. For example, the paths of the clearing and other paths in the forest (see Fig. 1).

Fig. 1. Demonstration of the complexity of route recognition for autonomous navigation systems

To solve the problems of autonomous navigation in such conditions, it is proposed to use methods of classification and decision making realized with the use of artificial neural networks and fuzzy logic: neural networks of deep learning, impulse neural networks, systems of neuro-fuzzy inference.

Studies show that using the method of deep parallelization of computations is a promising way of solving problems of increasing the intelligence and autonomy of mobile robotic objects in this case, which, in turn, requires the development of specialized hardware platforms that ensure the maximum efficiency of the implementation of these algorithms and methods [9].

The project involves the use of advanced technologies and the results of the latest scientific research in the field of building intelligent systems for identification and management, as well as the development of design documentation and the production of an existing prototype with the declared functions and characteristics.

The structure of the system being developed is shown in Figure 1. The system includes a panoramic panoramic video system (1), a system of parallel image processing units (2), a recognition and classification system (3), and a decision system (4).

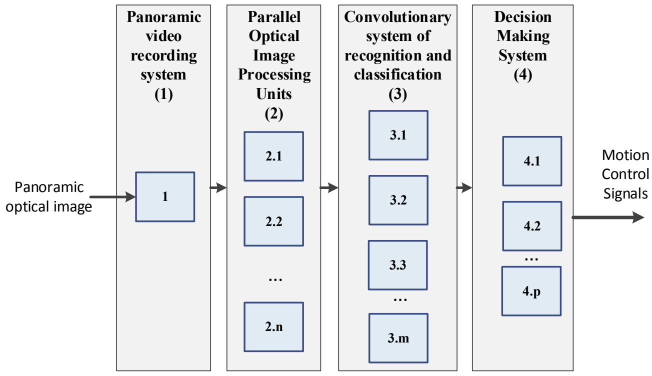

Fig. 2. Simplified structure of intelligent autonomous navigation system

The unit (1) comprises an optical system, a CMOS or CCD matrix that converts the analog image signal into a digital signal. Preliminary studies have shown that for effective navigation of the system being developed, the field of view should be no less than 1200 horizontally. In this connection, the author proposes the use of three video sensors (each including an optical system and a CCD or CMOS sensor): one for providing a central field of view and two side vision sensors positioned at an angle of 300 horizontally with respect to the central one. All with a viewing angle horizontally at least with an angle of 600.

According to the results of modeling, this approach (with three fields of view) is most effective in training the system and its functioning.

V. Functional Description of the Developed System

Each of the units 2.1 - 2.m of the system (2) realizes the digital processing of the signals coming from the system (1), and transfers the processing results to the system input (3). The main function of the system (2) is to extract the information necessary for the recognition and classification efficiency of the system (3) on the optical image obtained by the system (1): filtering, dividing the image into the central and peripheral areas, etc.

The system (3) is a classifier that is a convolution artificial neural net of deep learning of direct propagation with a complex configuration, trained to recognize traversable routes on the video image received by the system (1). Blocks (3.1) - (3.m) map the layers of the network. Thus, the block (3.1) is a convolutional layer comprising 3 neuron arrays of dimension about M x M neurons each, forming in aggregate the input layer of the network. Behind the input layer are hidden layers (3.2) - (3.m-3) with the number of neurons in the layer decreasing in proportion to the movement to the output. The output layer of the network includes three neurons (3.m-2) - (3.m). The input image of each video sensor with color preservation is anisotropically scaled to the MxM size (at the current stage of the M = 110 studies) and enters the corresponding matrix of the neurons of the input layer. The output of the network is three values that reflect the probability that the input belongs to the classes "turn right", "turn left" and "move forward", respectively (see Fig. 3). This approach provides a solution to a variety of problems in the classification of images [12-14].

Block (4) contains a decision system and a path analysis system. The first is responsible for assessing and deciding on the direction of motion, the second is responsible for analyzing the incoming decisions based on information on the previous trajectory of the traffic, the map of the terrain, etc. Their work is interrelated, and the result is a set of motion control commands.

Fig. 3. Demonstration of the input classification result

VI. Decision Making System

Figure 4 is a diagram explaining the general principle of choosing the direction of movement of the object. Having recognized the route, identifying its position relative to the control object and the direction of the motion vector along the route (it is performed based on the identification results and the approximated curve of the trajectory traversed), the system measures the deviation angle of the actual object motion vector from the desired path vector and, if the angle does not exceed 80, then a "forward motion" command is generated. Otherwise, the "turn left" or "turn right" command is activated, depending on the sign of the angle between the vectors.

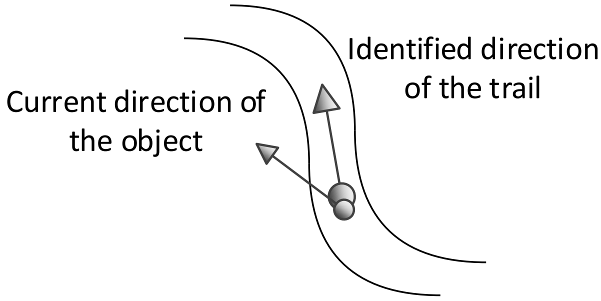

Fig. 4. Simplified demonstration of the principle of decision-making

This description of the operation of the system is simplified. In reality, the system operates on vectors and trajectories in three-dimensional space, rather than on a plane, producing control signals for the vertical movement control channel [15-16].

At this stage of development, the training of the proposed system is carried out on the basis of the inverse propagation method for 100 epochs. The training data represents about 20,000 frames, which include original shots of shooting different wooded terrain, as well as frames, which are their derivatives, which are obtained by offset, rotation and scaling of originals in the ranges ± 20%.

At the current stage of development, the intelligent control system of each agent of the system can be implemented on the basis of a microcontroller with 4 cores of the ARM Cortex A-53 type and a GPU with 128-256 cores.

VII. Conclusions

The results of the project can be used in robotic systems of military, dual and special purpose for autonomous execution of reconnaissance, search and search and rescue operations. In addition, the results obtained during the implementation of the project can be used to create a single-chip artificial intelligence accelerator system that can be used in the widest range of tasks.

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