A method for controlling groups of unmanned aerial vehicles in a virtual environment using haptic gloves

V O Antonov¹, D A Arustamov¹, U V Zavolokina¹, A A Apurin¹

¹Institute of Mathematics and Information Technologies (named after Prof. Nikolay Chervyakov), North Caucasus Federal University, Stavropol, 2 (Edifice 9) Pr. Kulakova, 355000, Russia.

E-mail llllamoroll@gmail.com

Abstract. The development of control of unmanned aerial vehicles (UAVs) is caused by the lack of developments that allow you to perform a fully autonomous flight to the target position with automatic bypass of static and dynamic obstacles. To ensure the correct execution of the flight task, many methods and algorithms have been developed, however, almost all of them are designed only for performing the UAV flight task in manual or semi-automatic mode. However, there are no widely available developments that allow you to perform a fully autonomous flight. Also, existing UAV control systems have low interactivity, due to the fact that the operator uses a two-dimensional map to control the UAV and also most often one joystick to control one UAV. Based on this, the purpose of this work is to increase interactivity and visibility in the management of UAV groups by developing a system for forming a flight task and control in a virtual environment using haptic gloves. The creation of a system for forming a flight task and managing groups of UAVs will allow the use of UAVs in various areas of human activity, including in conditions that are dangerous to human health and life. The description is presented, both mathematical and software. The advantages, disadvantages and limitations of the proposed method are analyzed.

Keywords: haptic glove, virtual reality glasses, a group of unmanned aerial vehicles.

1. Introduction
Scientific and technological progress in recent years has greatly changed the way of life of mankind. The needs of society have also changed, which has led to the need to create technologies that meet new needs and requirements. The development of transport has led to the fact that it has become a multifunctional tool [1]. The advent of flying technology and the development of wireless communications led to the idea of an unmanned aerial vehicle. UAVs have a number of advantages. They can be used in various fields: geodetic companies using UAVs for topographic surveying and support of construction work, agricultural companies for inspecting their lands, security companies for monitoring in hard-to-reach places, rescue services for determining emergency zones and coordinating rescue and search operations, city and dispatch services to monitor the situation in the city, energy companies and regional dispatch services using UAVs to monitor power lines, pipelines and for technical inspection of solar panels, construction companies using UAVs to inspect remote, hard-to-reach and dangerous objects, transport companies for transportation cargo to hard-to-reach places .. They
allow you to save human lives, since in an emergency situation only the UAV itself is lost. Also, the economic costs can be lower, since the training of highly qualified pilots and other crew members is not required [2].

To ensure effective remote control in various tasks, an autonomous UAV operation is required based on data received from sensors in real time, since remote control depends on the quality of communication, which does not always allow effective control. The main task in this area is to obtain new methods of effective control when the UAV moves over rough terrain, including taking into account atmospheric conditions, stationary and dynamic obstacles [3].

2. Informal statement of the problem
The aim of this work is to increase interactivity and visibility when controlling UAV groups by developing a system for generating a flight task and control in a virtual environment using haptic gloves.

The method proposed in this article is aimed at solving the following problems:
1) increasing interactivity;
2) raising the level of the methodological apparatus for managing UAV groups;
3) increasing the level of automation of the control process of UAV groups.

3. A method for controlling groups of unmanned aerial vehicles in a virtual environment using haptic gloves
To control the UAV groups, it is proposed to use the operator's virtual glasses and a haptic glove connected via Wi-Fi to a computer. An operator in virtual reality on a three-dimensional map can select an area to select several UAVs, or one UAV, then he indicates the point at which the UAV needs to arrive, a flight task is built, input data such as flight altitude are set, as well as the data that is needed to collect, this data is transferred to the cloud storage. From the cloud storage, the UAVs receive flight missions and begin to carry them out. After its execution, the data collected by them are transferred to the cloud storage so that the operator can analyze them and make a decision based on them, after which the UAVs return to the home station in automatic mode, where they are recharged or the battery is replaced [4].

The proposed ergatic system generally consists of: an operator, a cloud storage that stores information, a flight controller represented by a haptic glove, one or several UAVs with a flight controller that decrypts and executes commands coming from the cloud storage. The operator processes the measurement results and, on their basis, adjusts the target coordinates of the UAV by generating control commands in the format transmitted via the transmission channel from the haptic glove to the computer and received by the computer. Based on the data received, the PC regulates the rotation speed of the UAV engines. Telemetry and Measurement System (STI) performs measurements and telemetry reception.

A functional diagram of the method for controlling UAV groups in a virtual environment using haptic gloves is shown in figure 1.

The basic functional diagram of a haptic glove with a Wi-Fi module is shown in figure 2.

![Figure 1. Functional diagram of the method for controlling UAV groups in a virtual environment using haptic gloves](image-url)
DJI Googles are supposed to be used as virtual reality glasses.

When constructing a flight task, we will consider the planning problem as a task of finding a path on a graph of a special type - the graph of regular decomposition of the grid. Formally, the grid is a triple:

$$Gr = \langle A, Adj, d \rangle$$

where $A$ is a set of cells, which is a matrix $A_{m \times n} = \{a_{ij}\}$: $a_{ij} = 0 \lor a_{ij} = 1$, $\forall i, j: 0 < i < m, 0 \leq j < n$, $m, n \in \mathbb{N}$; $Adj \subseteq A \times A$ - a relation defining adjacency on a set of cells (a set of adjacent cells); $d$ is a metric on the set $A$ (a function that specifies a method for determining the distance between cells). Hereinafter, we will periodically use the notation $a(i; j)$ or simply $(i; j)$ to denote the cell $a_{ij}$. In those cases when the index coordinates of the cells are not important, we will denote them with letters of the Latin alphabet: $a, b, c$, etc. Two different grid cells $(i_1; j_1)$ and $(i_2; j_2)$ will be considered adjacent if $|i_1 - i_2| \leq 1 \lor |j_1 - j_2| \leq 1$.

In fact, adjacent cells correspond to adjacent elements of the matrix $A_{m \times n}$ [6].

The path as a sequence of cells is shown in figure 3.
A grid cell will be called passable if $a_{ij} = 0$, impassable if $a_{ij} = 1$. The set of cells adjacent to $a_{ij}$ will be denoted as $adj(a_{ij})$ or as $adj(a(i; j))$ [7].

The set of pairwise adjacent impassable cells will be called an obstacle: $Obs = \{a(i_0; j_0), a(i_1; j_1), \ldots, a(i_s; j_s) | a(i_k; j_k) = 1, a(i; j) \in adj(a(i_{k-1}; j_{k-1})), k = 0, 1, ..., s, s \in N\}$.

Constructing a grid of constructing a graph for a given on plane of the region $U$: $x_{min} \leq x \leq x_{max}, y_{min} \leq y \leq y_{max}$, $(U = U_{free} + U_{obs})$ is performed according to the following algorithm:

Step 1. Put $i = 0, j = 0, p_x = x_{min} + l, p_y = y_{max} - l$.
Step 2. If the area $[p_x - l, p_x + l] \times [p_y - l, p_y + l]$ contains at least one impassable point from $U$, then add a cell $a_{ij} = 1$ to $A$, otherwise - a cell $a_{ij} = 0$.
Step 3. Put $j = j + 1, p_x = p_x + 2l$.
Step 4. If point $(p_x, p_y)$ lies in the working area, then go to Step 2.
Step 5. If $p_x > x_{max}$ and $p_y < y_{min}$, then terminate the algorithm.
Step 6. Put $j = 0, i = i + 1; p_y = p_y - 2l; p_x = x_{min} + l$ and go to Step 2.

In fact, the algorithm enumerates the points of the working area that are spaced from each other at a distance of $2l$, “from left to right, from bottom to top.” For each of the points, it is checked whether the square with side $2l$ and centered at the point $(p_x, p_y)$ contains at least one impassable point. If yes, then an impassable cell is added to the grid, otherwise - a passable one [8].

The operation of the algorithm is shown in figure 4.

![Figure 4](image-url)

Figure 4. Work area (a), control object (b) and the corresponding hydraulic engine (c-d)

To visualize the proposed solution, the proposed interface of the software package is presented in figure 5.
Thus, the proposed solution will lead to increased interactivity, methodological apparatus and automation in the control of UAV groups, which will reduce the number of operators required to control the UAV, and will allow for control in automatic and semi-automatic modes [9, 10].

4. Conclusion
A clear advantage of the proposed solution is the high level of interactivity provided by the use of virtual reality glasses and a haptic glove. In addition, the scope of this method of controlling UAV groups can be widely used in various fields of human activity. The proposed method can be applied in the following areas: geodesy, agriculture, security companies, the Ministry of Emergency Situations, city and dispatch services, energy companies, construction companies, transport. However, not every task posed can have a solution given the constraints. In addition, in some special cases, solving a problem may require significant computational resources.

Thus, this article proposes a method to increase interactivity and visibility when controlling UAV groups by developing a method for forming a flight task and control in a virtual environment using haptic gloves. The description of both the design solution and the mathematical component of the method is given.

5. Acknowledgment
The organizing committee thanks RFBR for assistance in holding the conference.

References
[1] Cherif, Nesrine & Jaafar, Wael & Yongacoglu, Abbas 2020 On the Optimal 3D Placement of a UAV Base Station for Maximal Coverage of UAV Users.

[2] Mandal, Murari & Kumar, Lav Kush & Vipparthi, Santosh 2020 MOR-UAV: A Benchmark Dataset and Baselines for Moving Object Recognition in UAV Videos. 2626-2635. 10.1145/3394171.3413934.

[3] Regmi, Yogesh & Manandhar, Gautam 2020 APPLICATIONS OF uavs AND DIGITAL PHOTOGRAFMETRY.
[4] Pathak Nidhi, Misra Sudip, Mukherjee Anandarup, Roy Arijit, Zomaya Albert 2020 UAV Virtualization for Enabling Heterogeneous and Persistent UAV-as-a-Service. IEEE Transactions on Vehicular Technology. PP. 1-1. 10.1109/TVT.2020.2985913.

[5] Petric Jasna, Saska Martin 2020 Mission planning for cooperative construction by UAV teams.

[6] Barbedo Jayme, Koenigkan Luciano, Santos Patricia 2020 Cattle Detection Using Oblique UAV Images. Drones. 4. 10.3390/drones4040075.

[7] Patil Ishwaragowda V 2020 Design And Fabrication Of An Uav.

[8] Pandey Ashish 2020 Introduction to UAV and its purposes.. 10.13140/RG.2.2.24296.70402.

[9] Intellectual algorithm for managing a group of unmanned aircraft // nauchkor.ru URL: https://nauchkor.ru/pubs/intellektualnyy-algoritm-upravleniya-gruppoy-bespilotnyh-appravleniya-gruppoy-bespilotnyh-apps

[10] Development and research of a complex of models and methods for flying sensor networks // URL:https://www.psuti.ru/sites/default/files/field/attachments/2017/12/kirichek_dissertaciya.pdf (date of access: 17.11.2020).