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Wind Speed / Direction Estimation of Quadrotor UAV Based on BP Neural Network

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Abstract: ***In view of the problem that the rotor UAV only uses theIMU to estimate the ambient wind speed / direction, the existing literature generally solves the problem through the UAV's dynamic model or aerodynamic model [1], but the models used are more simplified and complex. In this study, by establishing the function fitting relationship between the ambient wind speed / wind direction and the conventional airborne IMU and other relevant flight parameters of the rotorcraft, the estimation of the ambient wind speed / direction in the flight process of the rotorcraft can be completed.***

Keywords: BP Neural Network, Quadrotor, Wind speed / direction estimation, Ambient air flow

1. Introduction

In chemical plants, industrial production bases and other places, as well as in the process of dangerous goods transportation, due to equipment aging, system failure or human error, it may cause the leakage of hazardous materials such as toxic and harmful gases. This kind of emergency is more common at home and abroad, and has become the focus of attention of governments. In order to avoid such incidents and ensure the safety of people's lives and property, it is necessary to study the location of toxic and harmful gas leakage sources, which has very practical significance and practical application value.

Following the 1990s, researchers began to use mobile robot active olfactory technology to detect odor sources [2]. In outdoor environment, wind will affect the diffusion of odor plumes leaked from odor sources, and odor molecules fluctuate with the wind. They believed that the process of odor plume transmission is mainly affected by the diffusion of molecules. As a result, the concentration gradient distribution of odor plumes becomes stable, and the olfactory robot can search for odor sources through the concentration gradient. At the beginning of the experiment, the spread degree of odor plumes in outdoor three-dimensional real environment was generally simplified, using simulated environment or manufactured wind tunnels, wind fields, etc. [3], the olfactory robot can judge the flow direction of odor plumes according to the wind speed / direction, so the wind speed / direction becomes an important reference information for the olfactory robot to locate odor sources.

In the outdoor environment, due to the complex terrain, the wind speed / wind direction will change locally around 10 m above the ground,and the air flow pattern is irregular and unpredictable, which has strong time-varying and randomness. Therefore, the efficiency of searching for odor source is generally low when only relying on the ground two-dimensional olfactory robot and wind direction indicator to detect and locate the odor source.

In recent years, with the development of computer technology, sensor technology, robot technology and artificial intelligence, the research on active olfactory is also constantly improving and improving, and gradually innovating in search algorithm. Using flying robot to replace the traditional two-dimensional ground mobile robot for odor source search, the search range is increased from two-dimensional plane to three-dimensional space. The ability of olfactory robot to search complex 3D scene is improved.

Russell and Kennedy [4] proposed that the olfactory robot airborne anemometer can obtain the environmental wind speed / wind direction information, but for the rotor UAV, the anemometer is too heavy to be airborne; moreover, the rotation of the UAV rotor will produce downwash airflow, which will cause strong disturbance to the local wind field measured under it, so it is difficult to extract the output of anemometer from the complex mixed signal of UAV In order to increase the difficulty of accurate measurement of environmental wind speed / direction, it is necessary to obtain useful information.

According to the relevant literature, when the rotor UAV hovers, the fitting relationship between the relevant flight attitude data and the current ambient wind speed / wind direction can be obtained through its conventional airborne inertial measurement unit IMU [5], and the current wind speed / wind direction can be estimated. However, this method has some defects such as incoherent motion of the rotor UAV.

The wind speed / wind direction estimation based on BP neural network needs to collect the wind speed / direction information in the environment through the flight of the rotor UAV. That is to say, in the process of estimating the current environmental wind speed / wind direction by detecting the odor plume in the actual movement of the rotor UAV, it needs to integrate the relevant flight data such as the dynamic model of the rotor UAV, the effect of wind on its own attitude, motor speed, and air resistance parameters.

In this paper, the current wind speed / direction estimation method is optimized to make the olfactory robot overcome the disadvantages of only relying on the wind direction meter to measure the wind speed / direction, improve the detection range of the olfactory robot, and reduce the limitations brought by the wind speed meter. During the experiment, a large number of flight parameters and wind speed / direction data measured by the anemometer are obtained, which together constitute the training set, verification set and test set. After repeated training by BP-ANN, the optimization model is obtained. At this time, the accuracy of wind speed / direction estimation can be guaranteed.

2. Wind speed / direction estimation based on BP-ANN

2.1 Basic principle of BP-ANN

The new artificial neural network technology is a complex function model created by simulating the working principle of human brain. It is an information processing system that can automatically process the nonlinear mapping relationship between variables. Its application scenarios involve many disciplines. BP-ANN is a multi-layer feedforward neural network trained by backward propagation algorithm with reference to error. As the core part of forward network, BP-ANN has been developed more mature. In the extensive application of artificial neural network, the other 80% neural network is improved by BP-ANN.

BP-ANN (see **Error! Reference source not found.**) is a multilayer feedforward neural network which is trained by the back-propagation algorithm with reference to the error. In this paper, the wind speed / direction estimation of rotor UAV mainly uses the function approximation of BP-ANN, which trains the input vector and the corresponding output vector are trained into a model to approximate a certain function.

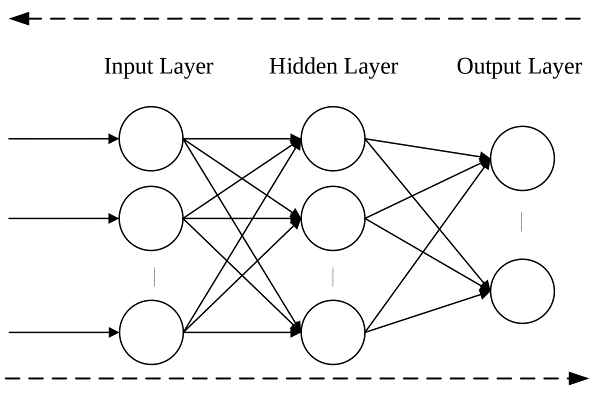

Figure 1: Structure of BP-ANN network model

2.2 Establishment of BP-ANN model

2.2.1. Model parameter selection

In the research of wind speed / direction estimation in the environment, the real wind speed / direction data in anemometer test environment is used as the training sample set of BP-ANN network model. The flight data of three attitude angular velocities (pitch angle, roll angle, yaw angle), acceleration of UAV in X / Y / Z direction, and rotation speed of four rotors are selected to eliminate the data after normalization. After the influence of the inter dimension, it can be used as the input parameters of the neural network model, and then the neural network model for the estimation of the environmental wind speed / direction is established. After the neural network training, the output parameters are the environmental wind speed / direction information.

2.2.2. Activate function selection

In this paper, according to the real-time wind speed / direction in the environment of rotor UAV flight parameter estimation, the BP-ANN network model adopts the classic three-layer network structure, which includes an input layer, a hidden layer and an output layer. After adjusting the three-layer structure of the output layer neurons, the error signal of each layer neuron node is calculated, the back-propagation error is adjusted, and the weights and thresholds of each layer are gradually corrected. Among them, the mapping function of hidden layer neuron adopts nonlinear transformation and continuous function -- Sigmoid function (also called s function):

$$\sigma(z) = \frac{1}{1+e^{-z}} \text{(Error! Bookmark not defined.)}$$

2.2.3Network model training

In the process of calculating the wind speed / wind direction in the current environment from the flight parameters of the rotor UAV, there are 4860 flight parameters and airspeed data samples of the rotor UAV. 4000 groups of data samples are selected as the model training samples, and a variety of artificial neural network topology structures are used for repeated tests to balance the training effect and detection effect of BP-ANN network model and ensure the environmental protection The moderate wind speed / wind direction estimation can ensure a certain accuracy, while still has the corresponding generalization performance.

According to the analysis of the training model, the neural network topology structure with 16 hidden layer nodes is finally determined. The number of nodes in the input layer, hidden layer and output layer is 10, 16 and 3 respectively, the learning rate of the network model is 0.05, and the training target error parameter is set to 0.001. BP-ANN improves the gradient descent method in training, and uses the error back-propagation principle between the predicted value and the actual value, and gradually adjusts the weights and thresholds between the network layers, so that the error decreases along the gradient direction. After 58 iterations, it can converge to 0.000994, that is, the airspeed information estimation model is obtained and saved.

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3. Experiment and Result Analysis

3.1 Experimental system

The rotor UAV usually carries Pixhawk[6]open source flight control for autonomous flight. Pixhawk is suitable for any mobile robot platform, such as fixed wing, multi rotor, helicopter, automobile, ship, etc. it is composed of PX4FMU and PX4IO, which are mainly responsible for attitude estimation, solution and other control operations, as well as remote control input and output I/O operations. Pixhawk flight control hardware module can run two sets of firmware codes, namely Px4 native firmware and APM for Px4 firmware. The flight control flow chart of rotor UAV (see Fig.2).

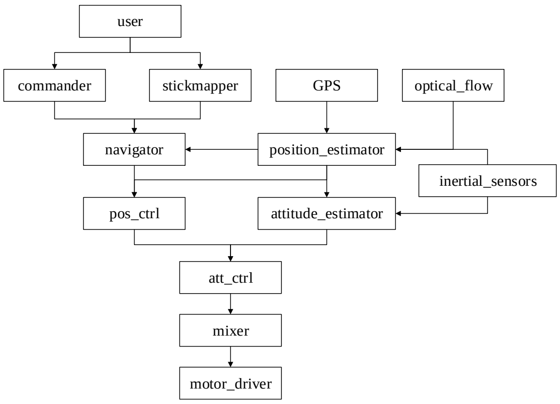


Figure 2: UAV flight control process

In this study, Linux version of Ubuntu 16.04 is selected as the development environment of Px4 code, and Pixhawk flight control source program is modified and compiled. Then, serial communication is used to communicate with raspberry pie in the rotorcraft, and the flight data package of the rotorcraft is transmitted back to the ground terminal. Finally, the wind speed / direction in the environment is estimated by the above BP-ANN model.

3.2 Experimental results and analysis

BP-ANN shows strong applicability and fault tolerance in the training process of environmental wind speed / direction estimation. The training model is established by using the training set, and the error is guaranteed to be within the appropriate range under the verification of the verification set. At this time, more accurate prediction results can be obtained by introducing the prediction set to the above model. Figure 3 shows the simulation prediction output of function approximation by BP-ANN neural network. To sum up, as shown in Figure 3, the estimated flight / air vector of the rotor UAV is in good agreement with the airspeed [7]measured by the airspeed meter. Most of the sample errors are kept in a reasonable range, but a few data fitting errors exist, which may be due to the accuracy of GPS positioning in the rotor UAV, as well as the measurement deviation of flight parameters such as rotor speed and attitude angle, or packet loss of flight parameters of rotor UAV during transmission as a result.

In order to verify the accuracy of the wind speed / direction prediction model, MSE (Mean Square Error) is used to quantify the error, which makes the comparison between the estimated value and the actual value intuitive.In this experiment, 4000 sets of data are selected as the training set of neural networks, and 860 groups of data are selected as the test set to estimate the airspeed value of rotor UAV. MSE after BP-ANN training is shown in Fig. 4.

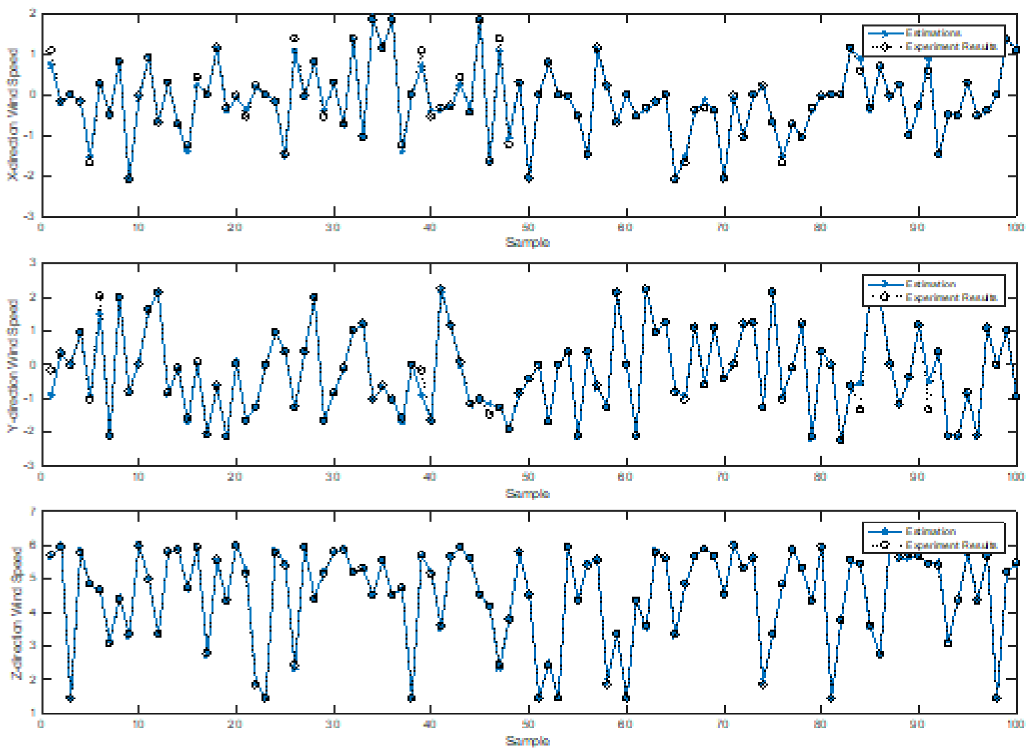


Figure 3: Wind speed / direction estimation output of BP-ANN network

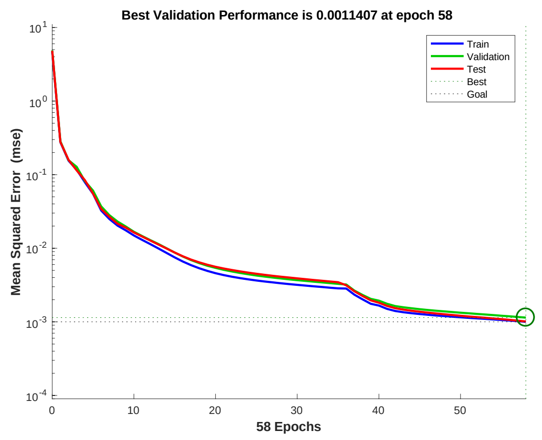


Figure 4: Prediction error MSE of BP-ANN network

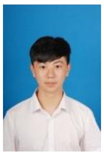
4. Conclusion

In view of the strong time-varying and randomness of the wind speed / direction in the environment, this study uses the rotor UAV to estimate the wind speed / direction in the environment in real time during the flight process. In this paper, the real-time calculation ability based on BP-ANN model is proposed. Compared with the traditional wind speed / direction calculation method, it makes up for the disadvantage of complex and variable wind speed / direction, effectively improves the estimation efficiency of environmental wind speed / direction, has strong robustness, and provides a new and efficient feasible way for the calculation of wind speed / direction in the environment.

References

[1] Patrick P. Neumann, et al. Gas Source Localization with a Micro Drone using Bio-Inspired and Particle Filter-based Algorithms. Advanced Robotics 27.9(2013):725-738.
[2] Meng Qinghao, Li Fei, Zhang Minglu, Zeng Ming, Wei Xiaobo. Research on the realization method of multi robot active olfaction in turbulent plume environment [J]. Journal of automation, 2008 (10): 1281-1290.
[3] Schiano, Fabrizio. Towards Estimation and Correction of Wind Effects on a Quadrotor UAV. Imav 2014.
[4] Russell, R Andrew, Kennedy, Stephen "a new air" ow sensor for minimal mobile robots. "Mechatronics s (2000) 10:935 – 942.
[5] Neumann, P.P. and M. Bartholmai, Real-time wind estimation on a micro unmanned aerial vehicle using its inertial measurement unit. Sensors & Actuators A Physical, 2015. 235: p. 300-310.
[6] Meier L, Tanskanen P, Fraundorfer F, et al. PIXHAWK: A system for autonomous flight using onboard computer vision[C]// IEEE International Conference on Robotics & Automation. IEEE, 2011.
[7] Cho, Am, Kim, Jihoon, Lee, Sanghyo, Kee, Changdon. Wind Estimation and Airspeed Calibration using a UAV with a Single-Antenna GPS Receiver and Pitot Tube[J]. IEEE Transactions on Aerospace & Electronics Systems, 2011, 47(1):109-117.

Author Profile



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