Neural network's usage for images analysis and combustion interferometry.

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Introduction

Results of usage of neural networks for interference investigations of physical processes, in particular, combustion processes represented for the first time. Interference methods have the wide and unique possibilities in combustion research [1,2]. It are unique methods which allow to determine the integral characteristics of a flame, for example, mass of a flame (mass of a gas in the field of a flame), the elevating force of Archimedes operating on a flame, quantity of a heat in a flame etc.

In accordance with the basic interferometric equation the phase difference distribution, S(x, y), in the interferogram plane (x,y) is an integral of the refractive index distribution, n(x, y, z), within the flame:

$$\lambda S(x,y) = \int [n_o - n(x,y,z)]dz \qquad (1)$$

where S(x,y) is measuring in unit 2π, n_o is the refractive index of the undisturbed medium surrounding the flame and x,y,z are the Cartesian co-ordinates, with the Oz axis directed along the light beam passing through the flame. By Eq. (1) and Gladstone-Dale equation:

$$\rho(x,y,z) = [n(x,y,z) - 1]/k*$$

where ρ is density, k^* is an average value of Gladstone-Dale constant, the following formula would be derived:

$$m = [(n_o - 1)V - I]/k$$

where m is mass of gaseous phase of object, V is object volume, $I = \lambda\iint S(x,y)dxdy)$ is an object eikonal, λ is a wave length of interferometer light source, k^* is an average value of the Gladstone-Dale constant. Also the interferometry makes possible determination of the "the elevating force of Archimedes" acting on the heated gas:

$$F_A = (I/k)g$$

Mass is the fundamental characteristic of a thermodynamic system. With the volume, pressure and equation of state known, it allows the following thermodynamic characteristics to be determined:

-temperature corresponding to the equation of gaseous state, T,

-enthalpy (isobaric thermal effect) $H=mc_p(T-T_o)$, where $c_p=a+bT$ is the composition-average specific heat of the gaseous mixture,

-average specific enthalpy, $H_m=H/m$, and enthalpy density, $H_v=H/V$

We use the special program (workstation - WS) "Interferometry" [3] for the automatic calculation of the integral characteristics of a flame. The example of interferograms of a flame formed at an ignition of a polymeric fuel by laser radiation is shown in a fig. 1. At usage WS "Inerferometry", the operator should fulfil approximately ten operations with the help of the computer mouse. These operations are connected to determination of an eikonal. The involvement of the operator is obligatory. The operator should have good knowledge of principles of decoding of interference pictures. Therefore the determination of eikonal can not be completely automized. It does not allow to use WS "Interferometry" and other similar programs in monitoring systems and handles of combustion processes, where the instant response to change of the characteristics of system is required.

The basic problem

The basic problem, which was set in our work, was a problem of learning of possibilities of neural network's using for calculation of the integral characteristics of a flame on basis of incomplete parameters of interference images.

The required integral characteristics of a flame were mass of a flame, the elevating force of Archimedes operating on a flame and quantity of heat in a flame. As incomplete parameters of the interference images, the following geometrical parameters of the interference image of a flame were used: maximal height (h) and width (w) of the image, its square (s) and perimeter (e). Their determination is considerably more simple, than determination of eikonal and can be completely automized.

The Neural Network Wizard 1.7 of BaseGroup Corporation (www.basegroup.ru) was used in our work. This program works on basis of algorithm of back propagation (return allocation of an error). The program was trained with the help of various combinations of the above-stated geometrical parameters of the interference image. They moved on an input of a computer program. Three integral characteristics of a flame (mass, elevating force of Archimedes and quantity of a heat) were installed on an output of the program. It was necessary to find what combinations of entry values yield more exact results and to receive the neural network program, which would allow to determine the integral characteristics of a flame on basis of incomplete (geometrical) parameters of the interference image.

The analysis of the obtained results

The six sets of values of integral characteristics (output parameters) and geometrical characteristics of the interference images (input parameters) represented in the table 1. The five sets were used at training the program. The set N4 was used for testing the program. Twelve various combinations of each set of values of the geometrical characteristics were used as input data at training and testing of the program. Results of testing of the program are shown on the diagrams 1-3 (for each integral characteristic). The horizontal line on the diagrams specifies the value obtained by WS "Interferometry", that is exact value. Vertical columns correspond to the values obtained with the help of the program. The each column corresponds to various input data combinations. For example, the signature (**hse**) shows that the height (**h**), the square (**s**) as well as the perimeter of the image (**e**) were used as the input data.

The results show that the programs can calculate the integral characteristics of a flame enough successfully. But the analysis of results shows also, that the result of the program operation considerably depend from the combination of input data which is used at training. For example, if the combination of values of height and perimeter of the image is used the error is small.

The error is much higher if the combination of values of width and height of the image (**wh**) are used at training. The more detailed analysis shows, that the combinations of values which include width and square of the image give more higher error. On the other hand, smaller error turns out at usage of combinations of values which include height and an perimeter of the image. That is, the values of height and perimeter of the image are more essential parameter to calculate the integral characteristics of a flame, than width and square of the image. The significance of geometrical parameters of the images for calculation of integral characteristics is well visible on the diagram 4. The data for it settled up as follows. The first column matters 8% that corresponds to an average error of calculation when the combinations which included value of width of the image were used at training. The second column shows an average error of calculation when the combinations which included value of height were used. And so on. The diagram 4 shows, that the height and perimeter of the image are in 1,5 time more essential arguments at training, than square of the image and in 2 time - than width of the image. As a whole the results of operation show, that for calculation of the integral characteristics of a flame it is better to use the programs, trained on one of the following combinations of geometrical parameters of images: e, h, he, whe, hs.

Perspectives

We have trained the Nervous Network Wizard 1.7 on the basis of five interferograms (the sixth interferogram and its data were used for check of the trained program). If to increase the number of interferograms, it is possible to receive enough good program for calculation of integral characteristics of the flame formed at ignition of polymeric fuel by laser radiation. The advantage of this program will consist of considerably more simple operation of the operator and the much greater speed of operation of the program. It is of great importance in scientific research of combustion processes, but it is especially important for combustion control systems. Determination of square, perimeter, height and widths of a flame are operations, which can be completely automized. It presumes to use the program in applied researches and at development of automatic control systems of combustion processes.

Direct usage of the interference images in industrial systems is impossible (difficultly). The interference methods can be used, in main, at research of laboratory models of combustion processes. Therefore in control systems it is necessary to use neural networks trained on the usual video images of a flame, but with the help of exact interference methods. That is, input data at training the program will be geometrical and some others the automatically measured characteristics of the video images. And the output data will be the integral characteristics of flame determined by interference methods.

Main problem of our work was the research of neural network opportunities for the analysis and recognition of the complex optical images, and also a problem of usage of neural networks in monitoring and control systems of combustion processes and modern detonation engines. The solution of these problems will allow essentially to expand the opportunities of optical monitoring and control systems of industrial performances.

This direction is connected to usage of neural networks for simulation of quality management of education at the Chuvash State University. We plan to train neural networks for research of nonlinear effects in social and economic systems with the help of mathematical models of various physical and chemical processes. The schedule of usage of neural networks consists in the following. The neural network is trained on the basis of numerical calculations of mathematical models to detection various nonlinear effects (a hysteresis, the critical phenomena etc.). After that, the trained neural network will use the data about various characteristics of an education system for a prediction of nonlinear effects. We hope that application of neural networks will allow to carry out simulation of a quality control system even in conditions of incompleteness of the data on an education system, the big errors of measurement, stochastic character of the data on an education system.

Outputs

1. Possibilities of neural networks in interference investigations of combustion processes are researched for the first time.
2. The neural network permitting to calculate integral characteristics of a flame with the help of incomplete data about interference images of a flame was created.

References

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0.021 **0.024** **0.028**

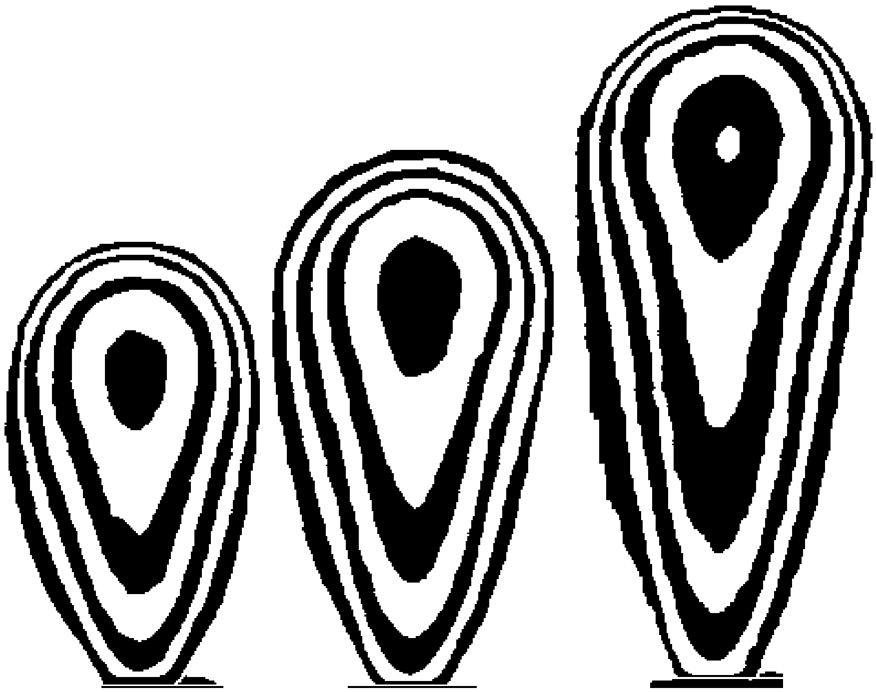

Fig. 1 The interferograms of a flame formed at an ignition of powder by laser radiation. Under interferograms the time (in seconds) from the moment of a beginning of activity of laser radiation is shown.