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SIMULATION MODELING OF NEURONETWORKING RECOGNITION SYSTEM OF MULTICOLOUR SPOTTED IMAGES OF LASER BEAM PROFILE

As a result of the research, carried out, the technique of preprocessing of multicoloured images of laser team profile is suggested, simulation modeling of recognition system based on radial-basis neural networks is performed.

***Key words**: intelligent systems, systems of laser beams profiling, pattern recognition, neural networks, image processing in real time.*

Introduction

Wide range of problems in world industry and science is solved by means of laser technologies. In particular, while manufacturing the components of electronic equipment, in holography, medicine, especially in ophtalmology, surgery, oncology, in science for investigation of substances properties by means of non-linear optics, in methods of processing, transfer and storage of information, in military sphere, in construction, etc.

Laser-based technologies are of high scientific and technological complexity, their application requires considerable computational resources, needed for research, regulation and operation. In spite of this, specific laser properties, such as high monochromasity, coherence, are very useful, enabling their application for the solution of various applied problems. To perform the task, put forward, laser must be highly accurate, since even minor malfunction can lead to unpredictable consequences and even fatal outcome. However, propagating in the atmosphere or in specific environment, the light beam can undergo distortions, which are evaluated by means of specialized methods based on corresponding statistic arrays of quantitative data with further compensation by means of specialized hardware[1]. The problem of qualitative and quantitative evaluation of laser beam fluctuation for their further compensation aimed at accurate calibration of laser system is very actual.

Problem set up

The profile of laser beam in 2D space is usually presented in the form of spotted image with spectral distribution of columns according to radiation intensity. Then, one of the problems of laser profiling (according to spotted image of its profile) can be reduced to recognition of dynamic sequence of multicolour spotted image by certain signs.

Aim of research

The aim of the given research is to develop intelligent system of compression and recognition of spotted images of laser beam profile for further diagnostics of laser technical state in read time. At this stage of research the problem of simulation modeling of neuronetworking system of recognition of spotted images of laser beam profile is put forward.

Description of the technique spotted images compression and recognition

The initial stage of neuronetworking recognition is formalization of the task and construction of minimum initial vector, containing necessary information regarding the object of recognition. Initial data for the given task is the sequence of frames of dynamic long video-route of the laser beam, presented in the form of 8-bit “BMP”-files in colour model RGB or Greyscale of 128x128 dots dimensionality, for instance, as shown in Fig1.

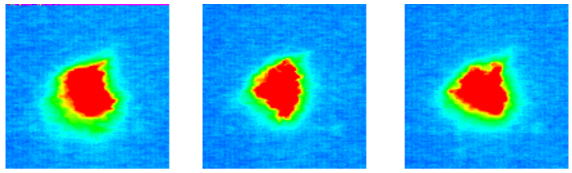


Fig.1. Examples of initial spotted images

Before the system starts recognizing the spotted image, it is necessary to perform its preprocessing to make the recognition easier. Preprocessing of the image for further recognition includes the following procedures: allocation of informative part of the image (“smart crop”), topological analysis of the obtained working area (segmentation) averaging of the light in each area of segmentation [2].

Having analyzed a great number of spotted images of single-mode laser routes (14 routes, 2044 images each), areas on the image were classified according to the influence on the locations of energy centre and general evaluation of the “correctness” of the spot.

The image is divided into 5 intensity rings and correspondingly, into 30 areas (Fig 2). Relatively the radius of allocated informative part of the image the radii of internal rings are distributed in the following way:

$$R_0 < 0.4R;\ \ 0.4R \le R_1 < 0.6R;\ \ 0.6R \le R_2 < 0.7R;\ \ 0.4R \le R_3 < 0.9R;\ \ 0.9R \le R_4 \le R.$$

The central area is the most important and must include part of the image with maximum brightness. Peripheral points in real images are subjected to fluctuations (it is also true regarding peripheral points of level and digital cuts of the image), that influences the form of spectral lines [3]. That is why colour intensity in boundary region will be average all along the total length of the ring.

Fig. 2. Segmentation diagram of laser beam spotted image

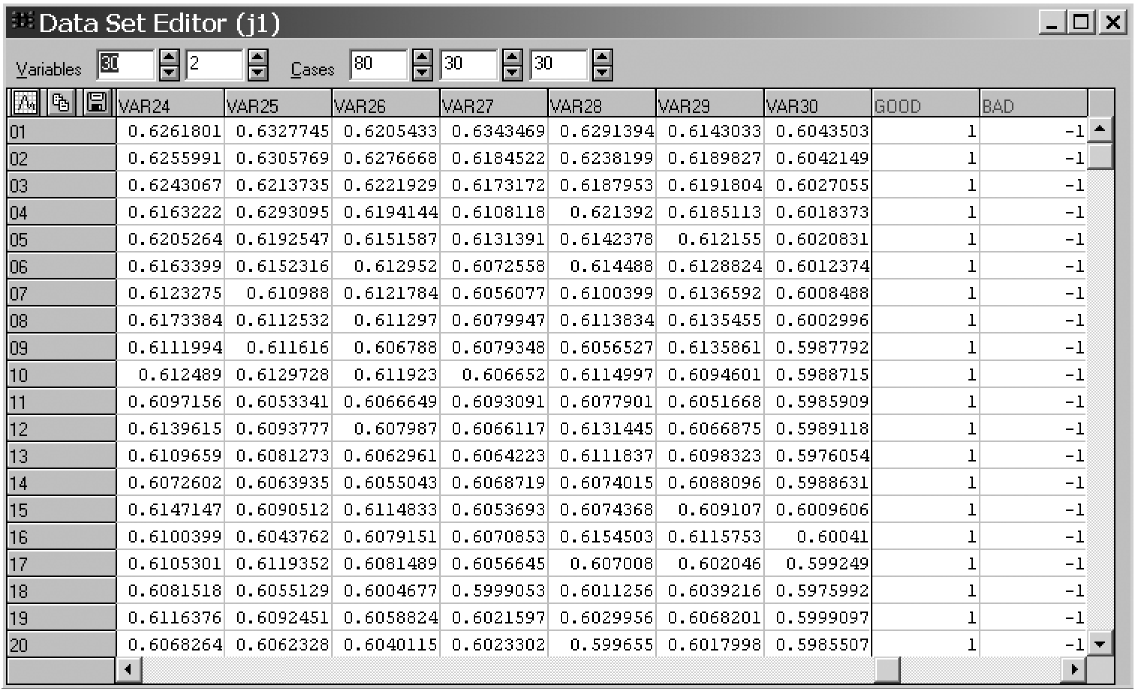
Colour intensity is averaged in each area, as a result of realization of preprocessing we obtain the image in “compact” form, suitable for transfer at the inputs of neuronetworking structure. For description of spotted image, in the given case, we need 30 bytes, as it is defined by 1-byte real value of average intensity of each of 30 areas.

Simulation modeling of neuronetworking system designed for for recognition of spotted images of laser beam profile

Simulation modeling was carried out in Statistica Neural Networks 4.0 (SNN) package of StatSoft company, that provides rapid and efficient methods of neuronetworking modeling and analysis [4].

As initial data for neuronetworking model averaged values of colour intensity in 30 areas, obtained as a result of preprocessing of spotted images, were taken.

Initial variables are fraction positive numbers with accuracy up to seven signs after the point, which may take the values from 0 to 1. The fragment of file data with initial data (net_10.sta) in shown in Fig 4. In this fragment VAR1-VAR30 are initial variables, GOOD and BAD are reference outputs HM. From one long laser video-route (2044 images) by the results of identification of characteristic forms of spots 140 images (70 “good” and 70 “bad”) depending on distortion level were selected for training of neural network. First of all it is necessary to define the criterion of network optimum complexity – i.e., empirical method of generalization error evaluation.



	VAR24	VAR25	VAR26	VAR27	VAR28	VAR29	VAR30	GOOD	BAD
01	0.6261801	0.6327745	0.6205433	0.6343469	0.6291394	0.6143033	0.6043503	1	-1
02	0.6255991	0.6305769	0.6276668	0.6184522	0.6238199	0.6189827	0.6042149	1	-1
03	0.6243067	0.6213735	0.6221929	0.6173172	0.6187953	0.6191804	0.6027055	1	-1
04	0.6163222	0.6293095	0.6194144	0.6108118	0.621392	0.6185113	0.6018373	1	-1
05	0.6205264	0.6192547	0.6151587	0.6131391	0.6142378	0.612155	0.6020831	1	-1
06	0.6163399	0.6152316	0.612952	0.6072558	0.614488	0.6128824	0.6012374	1	-1
07	0.6123275	0.610988	0.6121784	0.6056077	0.6100399	0.6136592	0.6008488	1	-1
08	0.6173384	0.6112532	0.611297	0.6079947	0.6113834	0.6135455	0.6002996	1	-1
09	0.6111994	0.611616	0.606788	0.6079348	0.6056527	0.6135861	0.5987792	1	-1
10	0.612489	0.6129728	0.611923	0.606652	0.6114997	0.6094601	0.5988715	1	-1
11	0.6097156	0.6053341	0.6066649	0.6093091	0.6077901	0.6051668	0.5985909	1	-1
12	0.6139615	0.6093777	0.607987	0.6066117	0.6131445	0.6066875	0.5989118	1	-1
13	0.6109659	0.6081273	0.6062961	0.6064223	0.6111837	0.6098323	0.5976054	1	-1
14	0.6072602	0.6063935	0.6055043	0.6068719	0.6074015	0.6088096	0.5988631	1	-1
15	0.6147147	0.6090512	0.6114833	0.6053693	0.6074368	0.609107	0.6009606	1	-1
16	0.6100399	0.6043762	0.6079151	0.6070853	0.6154503	0.6115753	0.60041	1	-1
17	0.6105301	0.6119352	0.6081489	0.6056645	0.607008	0.602046	0.599249	1	-1
18	0.6081518	0.6055129	0.6004677	0.5999053	0.6011256	0.6039216	0.5975992	1	-1
19	0.6116376	0.6092451	0.6058824	0.6021597	0.6029956	0.6068201	0.5999097	1	-1
20	0.6068264	0.6062328	0.6040115	0.6023302	0.599655	0.6017998	0.5985507	1	-1

Fig. 3. Fragment of initial data array

Since generalization error is defined only for data, that do not belong to training set, the obvious solution up the problem is division of the data into 3 sets [5]:

1) training sample (80 sets of variables) which provides the adjusting of weights in training process;

2) control sample (30 sets of variables) which provides the control over the process of training and helps to prevent network retraining [11];

3) test sample (30 sets of variables) which is intended for evaluation classification properties of already trained network.

In the process of research 30 neural networks (NN) were constructed and selected on the basis of error minimization criterion in training and control samples. In previous research only multilayered perceptrons were considered as basic and simple for further realization, type of NN. Another paradigm of NN, that is efficient for image recognition, is NN, radial-basis functions (RBF).

In the given research 10 best RBF NN were chosen (Fig. 5). In these networks neurons of the hidden layer realize functions, which radially change around the chosen centre and take zero values only in the vicinity of this centre. Schematic diagram of neuron RBF-network model is shown in Fig. 4 [6].

Neuron of such network has n-D input $\overline{x}$ and n-D weight vector $\overline{\vartheta}$. That is, the output of the neuron is the value of the radial function from the argument equal to the distance between initial vector of weight vector. In the context of neural networks under the function of radial form simple Gaussian is meant. The output of neuron is defined by the formula $\varphi(\|\overline{x}\overline{\vartheta}\|)$, where $\varphi(p) = \exp-(b \cdot p^2)$ and $0 < \varphi(p) \le 1, \forall x \in R$. Values at the output of neuron are greater when initial vector is closer to weights vector. If the distance is zero, then the output of neuron acquires maximum value (one) [6].

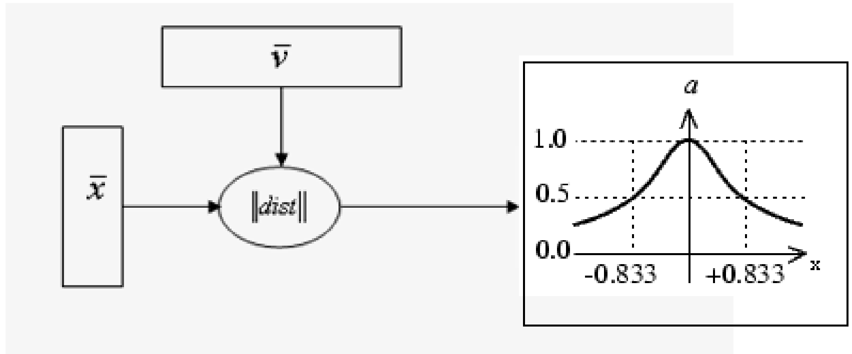
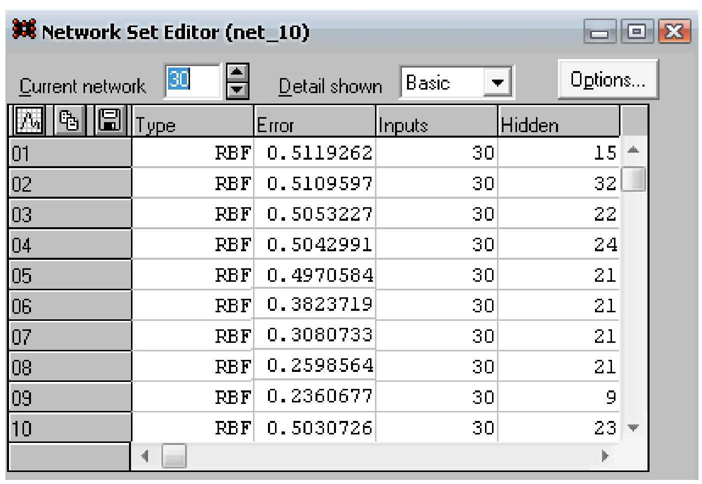


Fig. 4. Model of RBF-neuron

Among the properties of RBF-networks we should underline the following ones [7]:

1. Simplicity of the structure and ability to interpret the values of weight coefficient.
2. Training ability (creation of new clusters, modification of weight values of associative bonds).
3. Two-directivity (multi-directivity for the case, when the number of bases is great than two).
4. Scalability of network structure allows to match correctly different information regarding the object (process) of investigation.
5. The number of references and heuristics for selection if the function of hidden layer activation must be known beforehand.

The results of training of the best modeled network (№8 in the list on the Fig. 5) has the error value of 0.2360677 and 21 neuron in the hidden layer. Its structure is shown on the Fig.6. Generalized results of images recognition by the RBF NN are shown in table 1.



	Type	Error	Inputs	Hidden
01	RBF	0.5119262	30	15
02	RBF	0.5109597	30	32
03	RBF	0.5053227	30	22
04	RBF	0.5042991	30	24
05	RBF	0.4970584	30	21
06	RBF	0.3823719	30	21
07	RBF	0.3080733	30	21
08	RBF	0.2598564	30	21
09	RBF	0.2360677	30	9
10	RBF	0.5030726	30	23

Fig. 5. List of the best variants of structural organization of RBF-based NN

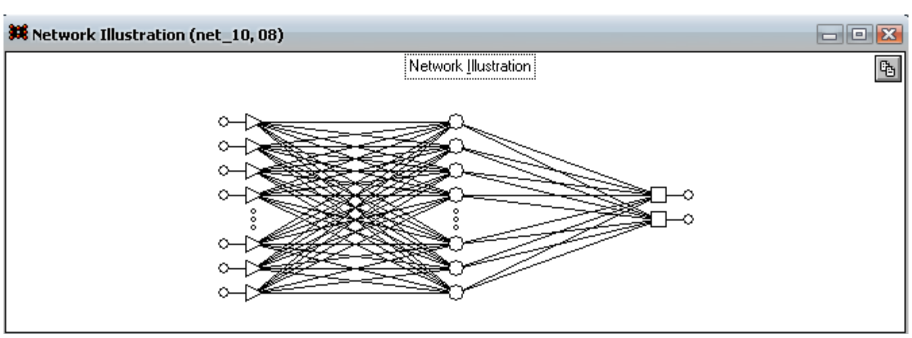


Fig 6. Structural organization of NN chosen for modeling

Table 1

Generalized table of recognition results of modeled RBF NN

Type of the set	Correct recognition	Correct recognition %	Incorrect recognition
Training	80	100	0
Control	23	92	2
Testing	24	96	1

The obtained result of modeling of MLP-based neuronetworking recognition system is shown in Fig 7.

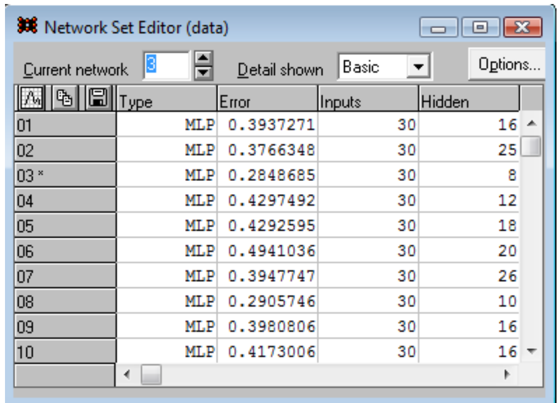


Fig. 7. List of the best variants of MLP-bused neural network structure

Error value of the best RBF-network 0,2360667 and correspondingly 0,2848685x MLP. The hidden layer of RBF system consists of 24 neurons and MLP consists of 8 neurons. Quantitative results of spotted images sample, performed by MLP and RBF networks are presented in table 2.

Table 2

Comparative table of recognition results obtained by modeled neural networks

Type of the set	MLP, Correct recognition %	RBF, Correct recognition %
Training	96,7	100
Control	90	92
Testing	94,7	96

While performing the research, it was defined, that unlike multilayer perceptron, RBF-network have higher operation rate and better recognition results, although they comprise greater number of neurons. Within the frame of the task put forward, of dynamic processing of spotted images of laser beam profile, operation rate of neuronetworking system is one of the basic requirements, that is why greater number of neurons in the hidden layer, namely 21, is normal while using the resources of modern computers.

Conclusions

Actuality of development of spotted images recognition method in problems of laser beams profiling is substantiated, method of problem solution is proposed. Simulation modeling of RBF-paradigm laser neuronetworking system is carried out.

In the process of recognition of the sample containing 140 spotted images, performed by neural network, modeled in SNN, the following results are obtained : in 100% - correctly recognizing images from training sample, 92% - from control sample 96% - from testing sample, that is why further program realization of intelligent system of spotted images recognition, based on RBF-network is expedient [8].

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