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Identification of Fish Species using Neural Networks

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Abstract : The number of workers engaged in Japanese fisheries and related industries in Japan has decreased markedly in recent years due to factors such as an aging workforce, issues related to the management of natural resources and the environment, international affairs, and changes in consumer food preferences. There is therefore a need to mechanize and automate aspects related to work usually performed by humans in the fishery industry. In this research, a system for identifying fish species has been developed. The system employs neural networks which learn to differentiate between different fish species using reference points. Reference points are characteristic points that are extracted from images of the body surface of the fish using a method that employs the truss protocol. The ratios of specific truss lengths between reference points relative to total body length are used to compile the dataset used for network inputs. For fish with bodies that have been contorted, only data from the vicinity of the fish head are used for network learning. Given that body color is an important characteristic for species identification, an effective method for capturing color data was investigated and the effectiveness of the proposed method and optimal number of color parameters was determined.

Key words : Fishery engineering, Species identification, Neural network, Truss protocol

Introduction

Various kinds of fishes not distributed in Japan and its adjacent waters have recently made it difficult to differentiate similar native fish species in Japanese fish markets. Although the main cause is said to be a shortage of skilled workers for fish species identification in the markets, the essential problem lies in the depressed Japanese fishery and a decrease in the number of fishery workers in Japan. Therefore, an automated selection of fish species by machinery is vital to the markets. In this report, we develop a quantification method of characteristics in a fish image and an identification method of fish species using the quantified characteristics.

Identification Method

Neural Network

Neural networks are mathematical models of signal processing in human brains. About 14 billion neurons in a human brain connect with each other intricately and perform parallel signal processing. There has not been an increase in the number of human neurons during a lifetime. On the other hand, connections between neurons have increased with growth. One neuron connects with 1000 neurons on average. In the case of neurons having many connections, the figures stand at nearly two hundred thousand. The vast numbers of neurons and their complex connections provide advanced information processing in a human brain.

A dendrite of a neuron receives signals from other neurons through synapses. The signals are multiplied by different weights and then the sum of the weighed signals is produced in a cell body. The output is calculated by using the sum and then transferred to adjoining neurons through axons. A neuron having such a basic structure connects with other neurons. As a result, the connections lead to a network.

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Various network architectures have been proposed. These architectures are classified roughly into two types. In the first type, referred to as a layered neural network model, neurons are organized in the form of layers and connect only with neurons in other layers. Signals are given to an input layer and transferred to an output layer through hidden layers in one direction. In the second type, referred to as a connected neural network model, neurons connect with any neurons. Signals are generally transferred to neurons in both directions. Connected models combining with all neurons are referred to as a fully connected model, and the rest a partially connected model.

Neural networks get intelligence by means of learning. Learning can be characterized as supervised learning or unsupervised learning. For supervised learning, an input signal is paired with a corresponding teacher signal and a set of the pairs is used for learning. Network weights are optimized so that network outputs can approach corresponding teacher signals. This means that the network has a mechanism to output meaningful data. For unsupervised learning, a network develops an ability to classify inputs by using self-organized learning, which gives rise to a network mechanism to output meaningful data. The applications include pattern recognition, image processing, image understanding, time series data processing, character recognition, speech recognition, speech synthesis and automatic control.

Quantification Based on Truss Protocol

When one usually looks at a fish, one focuses on some characteristic parts on the surface and checks the relative positions of the parts. For example, one picks out positions of parts, such as an eye, a mouth, a back fin and a ventral fin, where one can identify each shape easily. The construction of a mechanical system for fish species identification using knowledge and skill of experienced workers probably produces a quality work. In view of this, we have developed a method based on truss protocol[1), 2)] for fish species identification.

As shown in Fig. 1 , landmarks ①－⑫ are located on the surface of a fish and connected in the form of trusses with straight lines. Shape of a fish is characterized by

$$l^*_{qr} = l_{qr} / l_0$$

where l_{qr} is a distance between the landmarks and l_0 is a standard body length. A neural network whose inputs are l^*_{qr} (21 scalars) learns fish species. The network is a layered model shown in Fig. 2 and the back propagation method is used for learning. Eleven species of sample fishes used for learning are *D. macrophthalmus*, *S. notata*, *A. schlegleli*, *A. latus*, *P. trilineatum*, *B. japonicus*, *S. parvisquamis*, *T. japonicus*, *M. c. cephalus*, *A. lacuosus and U. canariensis*. Identification conditions are that one specified fish species is identified from among some fish species and that each of fish species is identified.

Identification Result and Discussion

Identification of specified fish species

In this subsection, we show identification results obtained under the condtion that one specified fish species was identified from among some fish species. The specified species was *D. macrophthalmus* in the identification. For learning, each teacher signal for the specified species was

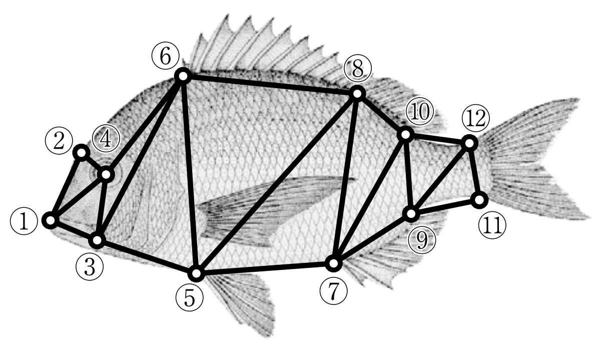


Fig. 1. Landmarks and trusses (original illustration : 4)

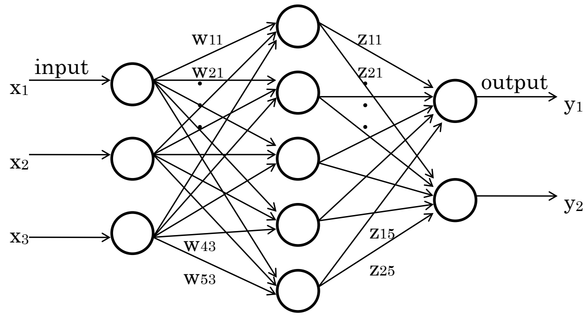


Fig. 2. Neuralnework

1 whereas that for the other species was 0. The network had a three layer strcture with 21 outputs. The number of learning, which was determined as a standard in pretests, was 10000.

Fig. 3 shows a learning result. The figure demonstrates that each output of *D. macrophthalmus*, the specified species, is nearly 1 and that each output of the species having a shape different from that of the specified species is nearly 0. For several species that are located in the central region of Fig. 3, on the other hand, the separation from the specified species is inadequate since these species are more similar in shape to the specified species than the species that are located in the right region of the figure. Fig. 4 shows a learning result with a condition different from that of Fig. 3. It can be seen from the figure that several outputs are about intermediate values due to the

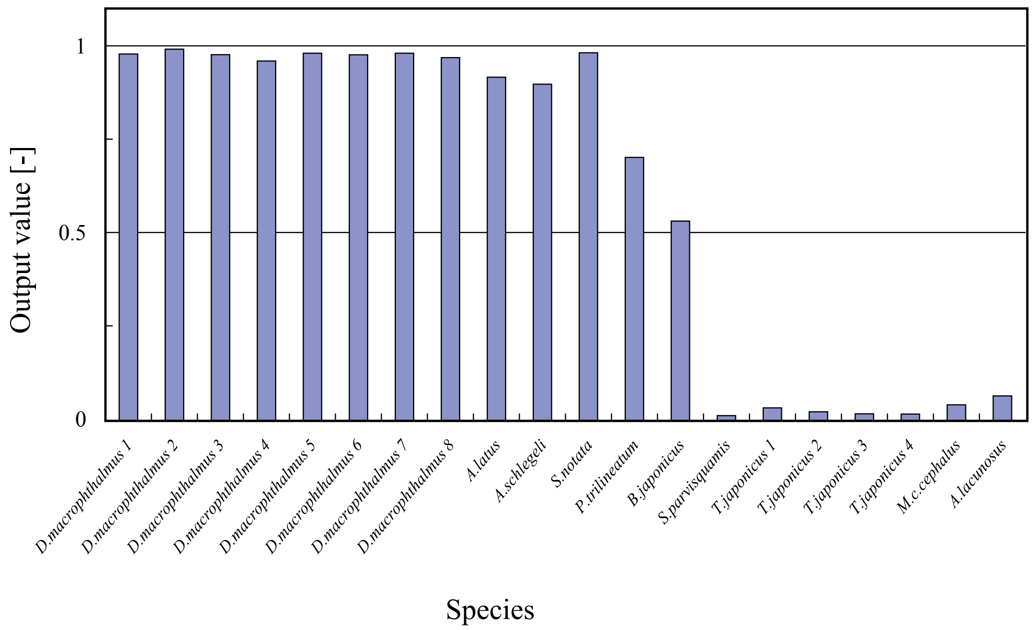


Fig. 3. Learning results

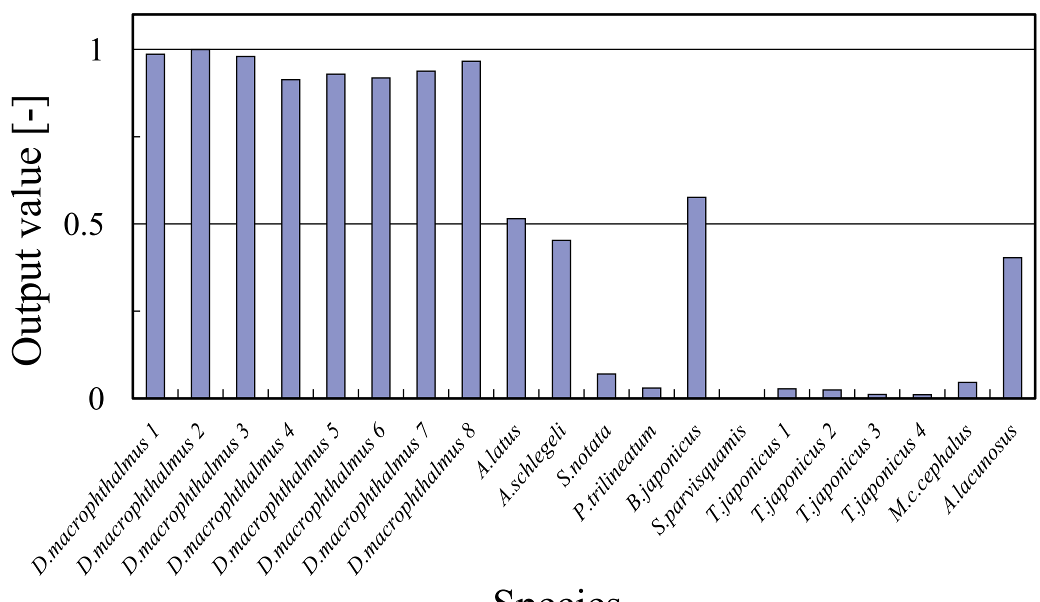
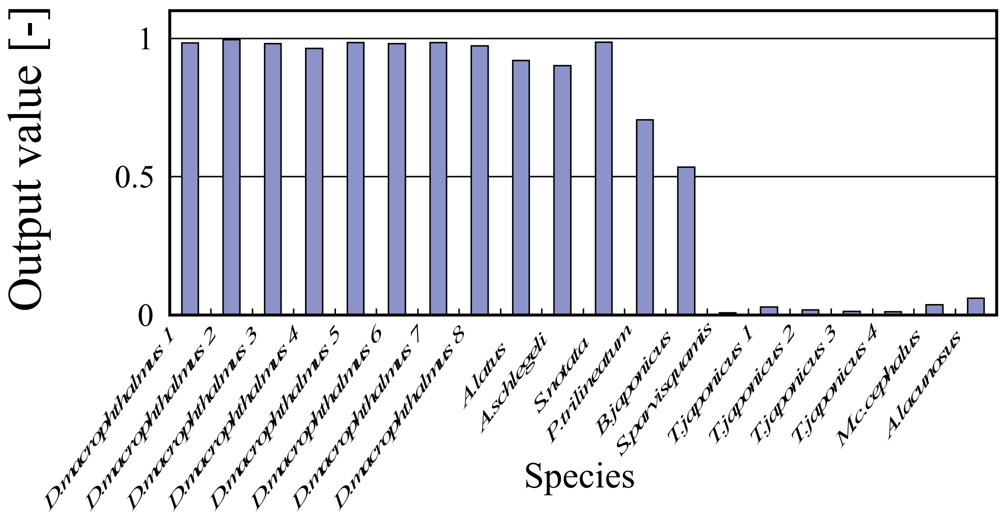


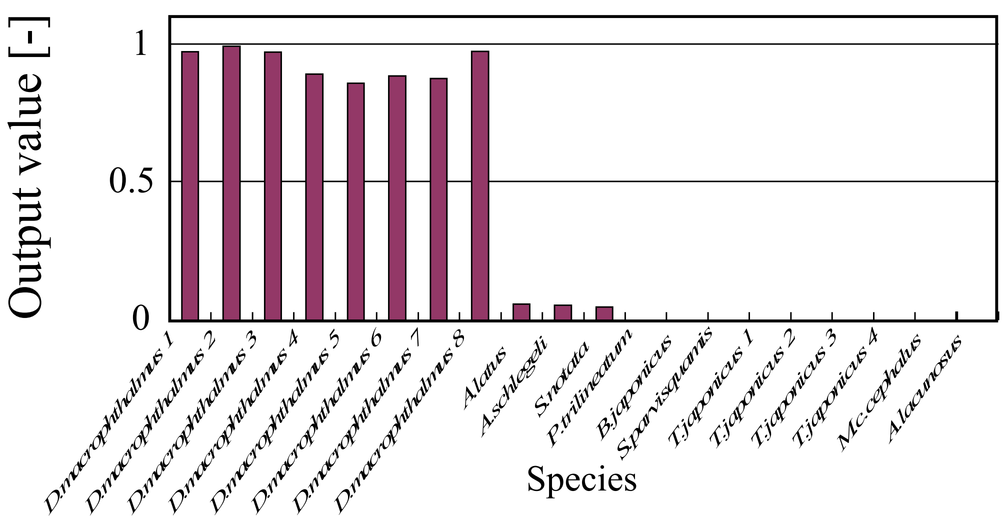
Fig. 4. Learning results

inadequate learning despite the species having a shape different from that of the specified species. In order to improve the learning result, the network had a dual structure. The function of the first part is to discriminate between the specified species and the species having a shape different from that of the specified species. The function of the second part is to differentiate the specified species from the species similar in shape to the specified species. Fig. 5, a result for the dual structure network, demonstrates that the specified species are distinguished from the other species.

It is often difficult to determine landmarks due to factors such as a broken fin. In view of the fact, we developed an estimation method for landmarks. Fig. 6 shows an estimation method for the case where the landmark ⑧ cannot be determined. First, we researched landmarks next to the landmark ⑧ and then drew the base point line connecting the landmarks ① and ⑪. Let θ, P and t be the angle between the base point line and the line connecting the landmarks ⑦ and ⑧, the intersection of this line and



(a) no.1 network output



(b) no.2 network output

Fig. 5. Ldentification by two stage processing

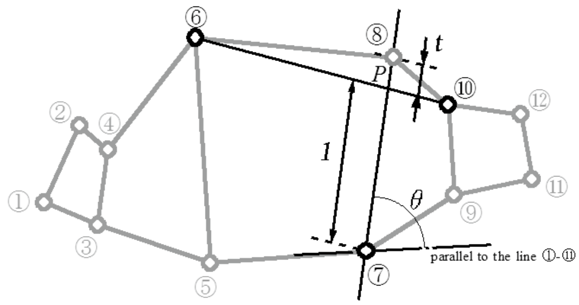


Fig. 6. Extrapolation of uncertain landmark

the line connecting the landmarks ⑥ and ⑩, and the ratio of the distance between the landmark ⑧ and the point P to the distance between the landmark ⑦ and the point P, respectively. We calculated the average of θ and t for sample fishes and then estimated the landmark ⑧. The estimation method produced an excellent result for the case difficult to determine landmarks.

Identification of several fish species

In this subsection, we show identification results obtained under the condtion that each of the three species, *D. macrophthalmus*, *U. canariensis* and *T. japonicus*, was identified. The reason for the selection is that the families of these species are different from each other and a wealth of data for these species were obtained. Two networks, whose outputs were one or three, were used in the identification. For the one output network, learning was carried out under the condition that teacher signals of three species were different from each other. The teacher signals that were specified in this learning are as follows:

D. macrophthalmus = 1, U. *canariensis* = 2,

T. japonicas = 3.

For the three output network, on the other hand, the following teacher signals were used :

D. macrophthalmus = (1,0,0) , *U. canariensis* = (0,10),

T. japonicas = (0,0,1).

Fig. 7 and 8 show results for the one output network and for the three output network, respectively. The figures demonstrate the effectiveness of the proposed methods.

Identification using head area data

When a fish body curves partially, distortion of positional relations between landmarks yields large data errors. Moreover, when a fish image is missing partially, we cannot measure landmark positions. In order to avoid these problems, we focused on a region difficult to change shape and developed a method which locates landmarks in the region.

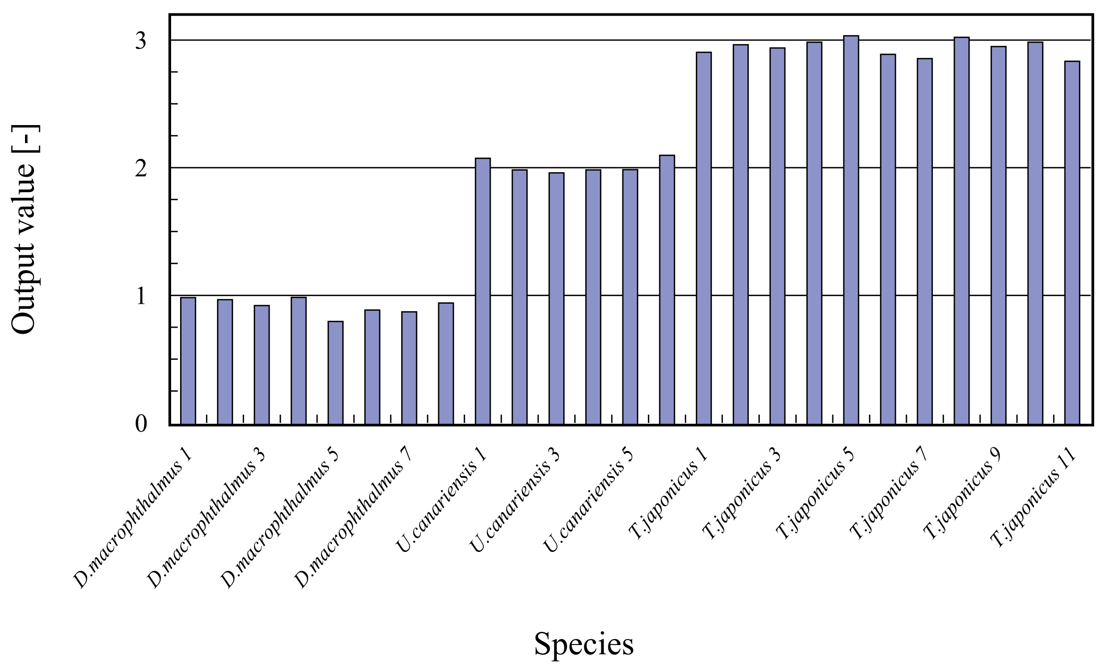


Fig. 7. Identification using one output network

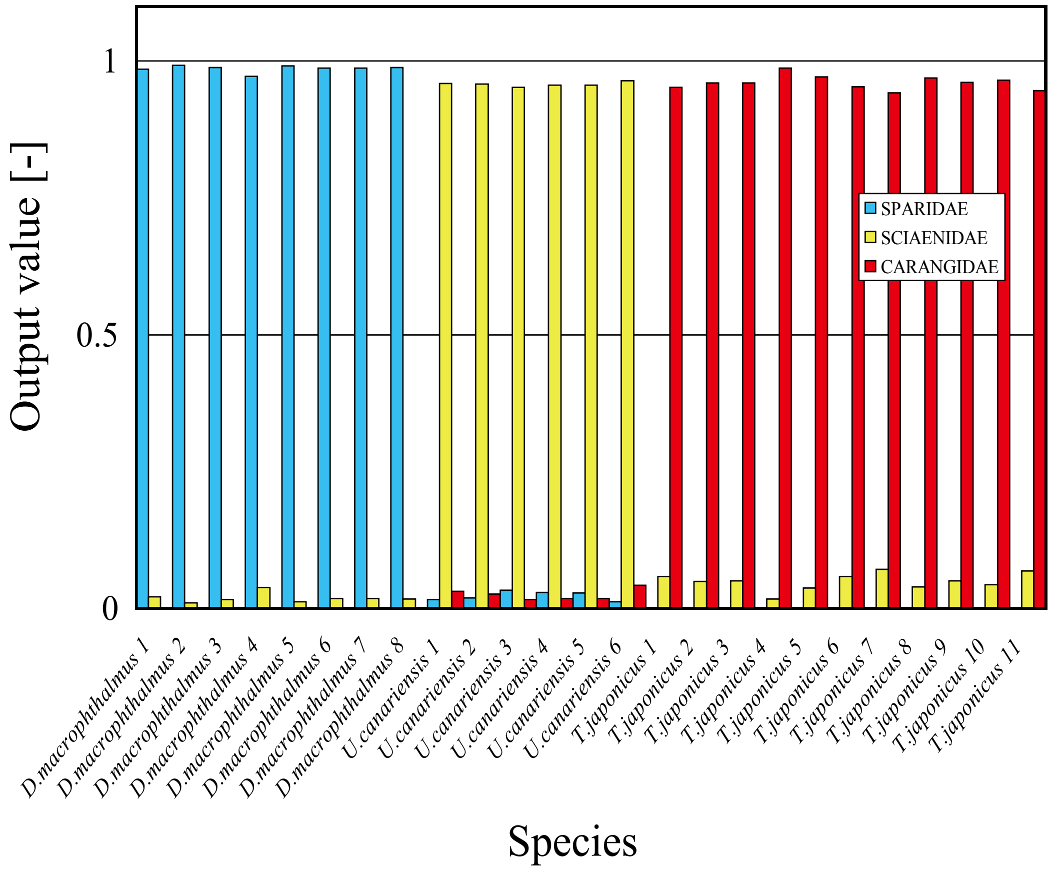


Fig. 8. Identification using three outputs network

As shown in Fig. 9, we drew a circle with a center that was chosen as an eyeball and a radius that was selected as a distance between the eyeball and a root of a pectoral fin. The center and the root were regarded as landmarks ① and ⑥, respectively. The points at which the circle and a fish contour meet were selected as landmarks ② and ⑤. A parietal point and a rostral end were chosen as landmarks ③ and ④, respectively. Learning performed by using a network whose inputs were lengths of line segments connecting landmarks and angles between the segments shown in Fig.10. Fig.11, a typical result, demonstrates the effectiveness of the identification method using head area data.

Identification using body color data

When one usually identifies fish species, one utilizes color data as well as shape data of a fish body. In view of this, we studied an effect of body color data on identification.

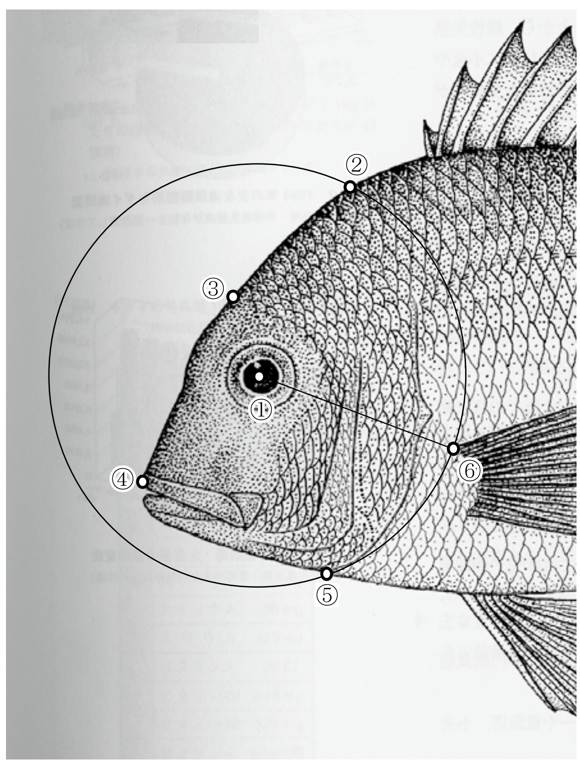


Fig. 9. Landmarks for head area (original illustration : 4)

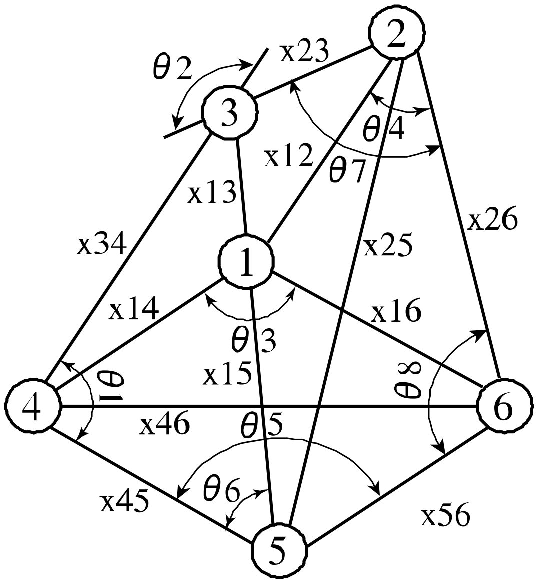


Fig. 10. Landmarks and data for identification

In this report, average RGB values of several points on a fish surface were chosen as color data for identification. The discrimination results showed that the addition of the color data improved the identification performance. The discrimination error, however, decreased slightly. This is mainly because the variance of the color data for each species is large and partly because the sencitivity of the color data is lower than that of the shape data. In view of this result, it is possible that using the color data in early phase of identification is effective.

Conclutions

Conclutions of this report are summarized as follows:

(1) We developed an identification method of fish species with layered neural network learning based on truss protocol.

(2) The proposed method produced the excellent results both in the identification of specified species and in that of several species.

(3) We studied an effect of color data on a fish body surface on identification and verified the effectiveness of the method.

As a future work, we will develop a quantification method of dynamic characteristics in a fish dynamic image and an identification method of fish species using the quantified characteristics.

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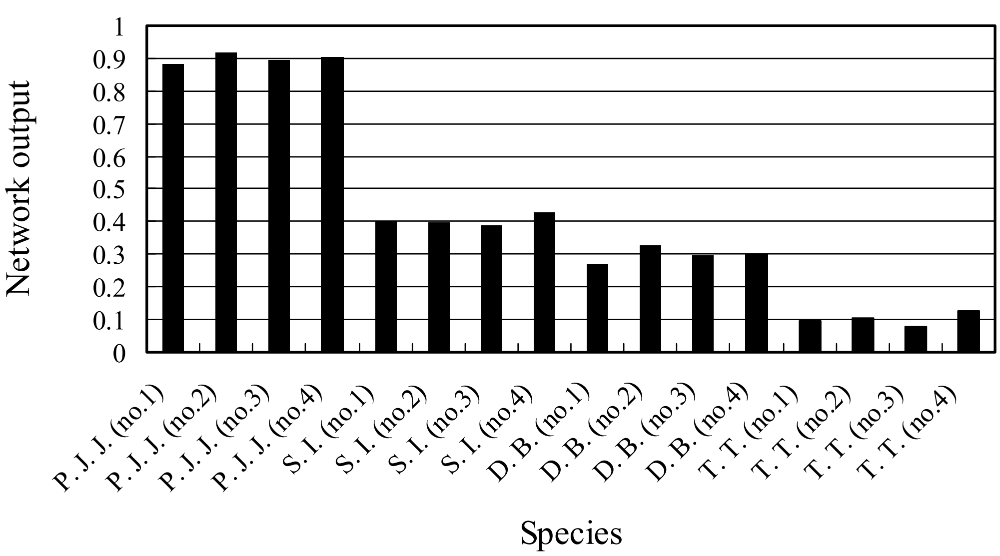

Fig. 11. Identification using head area data