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RECOGNITION SYSTEM OF RADIOCONTROLLED CARRIAGE FROM STATIC IMAGE

The paper contains mathematical model and recognition algorithm of radio-controlled carriage. On the base of the suggested algorithm the program of carriage recognition is elaborated. The results of testing on carriage images of different quality, brightness and with different degree of noise prove satisfactory operation of the program.

Key words: *radio-controlled carriage, structural-invariant algorithm, recognition system, neural network, Lagrange polynomial.*

Introduction

Nowadays rapid technological development takes place in the spheres of robotics, considerable progress is achieved in the sphere of artificial intelligent systems. Research, carried out in the sphere of robotics, computer-based recognition of various mechanical objects, in particular, radio-controlled carriage, are very actual. Problems, discussed, in the paper are actual for various branches of human activity. For instance, similar systems are being developed in military sphere, since the usage of radio-controlled devices is much safer, than human interference (e.g. field engineering). This branch of research is developed in industries, where the environment is very harmful for human health (e. g. chemical and radiation survey), or in the spheres where human interference is impossible (space and deep-water environments with extreme values of pressure/temperature). Solution of recognition problem provides processing of large arrays of data, contained in the image, that is why, for the solution of the problem it is expedient to apply the system of artificial intelligence [1].

The object of research is radio-controlled carriage, that must be recognized on static picture. The subject of research is the system, capable to recognize the object in the process of normal recognition procedure (when the carriage is available on the picture completely and the quality of the picture is sufficient) for solution of recognition problem and in case of problems emerging while recognition (for instance, when the carriage is available on the picture partially or when the picture is very small or contains much noise). The aim of the research is to develop the system, that efficiently solves the problems of complex object recognition, namely: radio- controlled carriage on condition of various quality of input image.

Analysis of state-of-art of the problem

In recent years research in the sphere of development and construction of automatic systems of pattern recognition and automatic training attract much attention. There exist numerous examples of such systems. For instance, promising results were obtained while creation of devices and programmes intended for reading printed symbols, these programmes solve the problems of symbols recognition, processing of electrocardiograms, language recognition, fingerprints recognition, interpretation of photos. Other examples include programmes, recognizing symbols of handwritten inputs, classifying seismic activity, programmes, intended for searching of military object, weather forecasting programmes, etc [1]. We will consider the examples of the systems, that can be used for solution of recognition problem by radiocontrolled carriage.

– Automatic classification of data, obtained by means of remote control [2].

Quite recently, the problem of environment control and monitoring of natural resources attracted the attention of scientific community of the USA; as a result, a number of new approaches, regarding pattern recognition , began to develop.

Among them we should mention automatic classification of data, obtained by means of remote

control. Since the volume of data, obtained from multirange spectral portable devices, installed at aircrafts, satellites and space stations is extremely large, there appears a necessity to apply automatic facilities for processing and analysis of this information. Remote data collection is used for solution of various problems. Among branches, particularly interested in this technology, we can list land use, revealing of the diseases of agricultural crops, forestry, control of water and air quality, geological and geographic survey, weather forecast and other problems, connected with the protection of environment [2].

– Development environment of machine vision systems National Instruments Vision. Development Module (NI Vision DM) [3].

Environment Ni Vision DM (Version 8.5) is intended for engineers and scientists, using machine vision technologies in industrial and scientific problems. Module contains interactive shell NI Vision Assistant, intended for development of applications prototypes without programming and powerful library with more than 200 functions of image processing IMAQ Vision [3].

The ability of common usage of NI Vision assistant and IMAQ Vision enables to reduce the time of machine vision systems creation, since NI Vision Assistant can perform automatic regeneration of codes in Lab View, C/C++ and Visual Basic Assistant. We obtain the possibility to integrate the diagram of videocollection in industrial system of measurements and automation, which can include traffic control, measuring devices control or control of devices of signal input/output.

This environment is rather powerful and universal but its interface is not convenient, where it is difficult to adjust the operation of the system and add in it proper recognition algorithms.

– Programming complex Ident Smart Studio for independent recognition of graphic objects [4].

One more powerful programming product for solution of similar problems is the system of complex objects recognition Indent Smart Studio [4], in which programming recognition module Pattern Searcher is developed. The given system is intended for recognition of wide class of objects, including biological objects and animals. It can be adapted and adjusted by the user for recognition of required class of objects, that shows the versatility of this programming product application. But only general information was published about this system and free copy of demoversion of recognition module Pattern Searcher 1.0 Demo [4], realizing only minimum possibilities of its operation on one example of recognition object is available, but this module cannot be used for recognition of wide range of objects.

Short survey of basic methods of image recognition

Modern stage of development of computer engineering is characterized by intensive efforts aimed at searching of new principles of data processing, caused by the requirements of high performance of these systems, as well as, their flexibility and reliability.

Working with images we should solve the following problems, emerging due to three basic problems: description (modeling) of the image; elaboration and selection of mathematical tools needed for image analysis and processing; hardware realization of mathematical method of image processing. That is why, we can distinguish such basic methods of recognition:

– linguistic methods;

– heuristic methods;

– mathematical methods.

Linguistic (syntactic) methods. If the description of patterns is performed by means of subpatterns and their relations, then for construction system linguistic or syntactic approaches are used applying the principle of properties similarity. Patterns, belonging to the same class, have a number of common features or signs, which reflect the similarity of such patterns. These common properties can be partially input in the memory of recognition system. When non-classified pattern is presented in the system, then the set of certain features is selected, then these features are compared with the features, stored in the memory of recognition system. While using this method, the main problem is to allocate common properties of recognized objects for their further classification. The selection of such properties depends on the developer of recognition system, as

well as on the sphere, where the given recognition system will be used.

Mathematical method. The basis of mathematical method forms of classification rules, which are formulated and deduced within the frame of certain mathematical formalization by means of principles of generality of properties and clusterization. When the patterns of certain class are vectors, the components of which are real numbers, then this class can be regarded as a cluster. Construction of recognition system, that is based on realization of the given principle, is defined by special location of separate classes. If the clusters, belonging to different classes, are located far from each other, then simple recognition schemes can be used, for example, classification, based on the principle of minimum distance.

Heuristic analysis. The basis of heuristic analysis are intuition and human experience. Principles enumeration of class member and their general properties are used in this analysis. Systems, constructed on such methods contain the set of specific procedures, elaborated for the given recognition problems. This means that the structure and quality of heuristic system is are determined by the skills and experience of the developers.

Analysis of the methods of problem solution

While developing the recognition system the already known methods and means that can be used for solution of this problem must be analyzed and the most rational method is to be selected. Structural-invariant method and recognition means based on neural network are such rational approaches.

We will consider structural-invariant method for construction of formal description, data processing and complex images recognition where the common property of recognized objects is the colour.

Structural-invariant algorithms are intended for construction of formal description of bound objects, based on the analysis of information regarding mutual location on the contour of points of local extremum curvature and classification of descriptions formed in such a manner [5].

Algorithm constructs the system of signs of investigated objects on the basis of special points findings – poles while contour interpolation. Contour is presented by means of parametric functions $x(t) = x_t$, $y(t) = y_t$, $t = 1, ..., N$, where N – is the number of contour points. For computation of poles values parametric representation of interpolation polynomial of third degree in Lagrange form is used. For functions $x(t)$ and $y(t)$ this polynomial has the form:

$$P_{ttt} = -\frac{(t_2 - t_1)^2}{(t_2 - t_0)(t_1 - t_0)} p_{000} + \frac{(t_2 - t_0)^2}{(t_2 - t_1)(t_1 - t_0)} p_{111} - \frac{(t_1 - t_0)^2}{(t_2 - t_1)(t_2 - t_0)} p_{222}, \quad (1)$$

where P_{ttt} – is pole value; P_{000}, P_{111}, P_{222} – are values in node points of interpolation; t_i – are elements of non-decreasing sequence, formed from the coordinates of node points.

Poles P_{ttt} are located close to geometric object and random linear variation of parameter t does not influence geometric location of the poles.

$$t=aT+b, \quad (2)$$

where $a, b \in R$ (R – is the region of object location), T – is the period of digitization. Such change means composition of carry conversion and transformation of similarity. Hence, values of poles distances to curve $x(t)$ and $y(t)$ can be used as object description.

In order to define the type of each part of the contour tangent equations drawn in points of local extremes are considered. If for drawn tangents the condition is carried out

$$|k_1 - k_2| \le \left| k - \frac{|k_1 + k_2|}{2} \right|, \quad (3)$$

where k, k_1, k_2 – are angular coefficients of the straight line drawn across the points of local extremes and tangents, drawn in these points, then we assume, that corresponding part of the

contour is the section of straight line. If such condition is not carried out, then we find the point of crossing of normals with tangents (r_1), drawn in points of local extreme s, and the distance from this point to points of local (PLE) (r_2). In case, when the condition for the values of these distances is carried out

$$|r_1 - r_2| \le \frac{\max(r_1, r_2)}{|r_1 - r_2|}, \tag{4}$$

where r_1, r_2 – are calculated values, we assume that the part of the contour is an arc, in other case, the part of the contour is the arc of the ellipse

In each case, part of the contour takes the symbol:*l* – if part of the contour is the section of the straight line, *c* – if the part of the contour is the arc of the circle, *e* – if the part of the contour is the arc of the ellipse.

It is proved, that such system of signs has invariant properties while affine transformation of the object [5].

For classification of objects the values of each function of input object are compared with the values of corresponding function of class representative. Minimum of mean-square error is taken as the criterion. If the value of the error takes minimum value comparing with class representative, then we assume that the input object belongs to the same class as the class representative does. Such application of minimum mean-square error criterion is possible due to periodicity property of the functions: function repeats it value in a certain non-zero period, i.e., it does not change its value while adding to argument fixed non-zero number (period).

Let us consider the application of neuronetworking technologies for the solution of recognition problem. Important contribution in the development of neurocybernetics was performed by neurophysiologist Frank Rosenbladt, who suggested the model of recognition device and called it "Perception" (from Latin word "percepto"). In the process of device development the scientist proceeded from some notions regarding the structure of human brain and vision system. Try to reconstruct the functions of human brain, Frank Rosenbladt used simple model of biological neuron and the system of interconnections [6].

Receiving unit of perception is photoelectric model of retina – the field of receptors, comprising several hundreds of photo resistors (*S*-elements). Each element of receptors field can be in two states – excited or non excited, depending if the contour of projected on the field figure falls on corresponding photoresistance or not. At the output of each element signal x_i ($i = 1, 2, \ldots, n$, where n – is the number of elements) appears, that is equal one, if the element is excited, and equals zero-in opposite case (Fig 1). The next stage of the perception is associative, or *A*-elements, each of them has several inputs and one outputs. While preparing the perception for the experiment outputs of receptors are connected to the inputs of *A*-element, connection can be performed either with sign "plus" or "minus". The choice of receptors, which are connected to the given *A*-elements, as well as the choice of connection sign, is performed randomly, *A*-elements perform algebraic summation of signals, arrived at their inputs and obtained sum is compared with the value equal for all *A*-elements [4].

But the usage of neural networks for recognition problems is not always optimal, since the given method has a number of disadvantages. For instance, the combination of weight coefficients, at which the available set of images can be successfully recognized does not always exist; lack of the possibility to define how much time will be required for the neuronetwork training; diposition of the network to faulty reactions to input signal; low-efficiency while retraining,

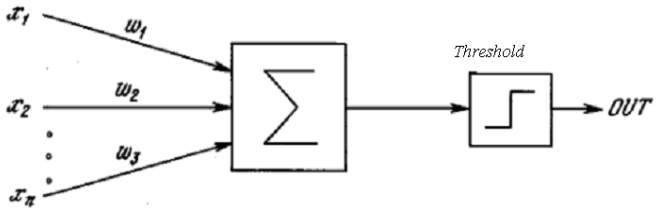

Fig. 1. Perception neuron

when new data are to be introduced, without eliminating the information, stored before. All theses drawbacks are rather important and complicate the process of construction of efficiency recognition system.

Recognition algorithm, based on the method of linguistic recognition, where colour is the common feature of objects recognition, is the simplest and the most rapid method, however it does not provide sufficient accuracy of recognition, since it has a number of disadvantages. One of these disadvantages is that the algorithm can non- efficient if the brightness of the picture changes or if the light gleams appear on the picture. That is why, it is suggested to apply this algorithm in the process of recognition in combination with structural-invariant algorithm. As this can improve the accuracy of recognition.

Hence, while carriage recognition there appears the possibility to use the combined algorithm, consisting of structural invariant algorithm, that will perform recognition of radio-controlled carriage, and algorithm, based on the method of linguistic recognition. This improves the accuracy and operation rate of recognition system as well as its noise immunity.

General algorithm of recognition system operation

We develop general algorithm of recognition system operation. Data array is sent to the input of the algorithm, where all the properties of each point of the image are written. Dato array is processed (pixel-wise: from the first to the last pixel; in the same manner as the electron beam passes across the TV screen), during the test of each point its properties are controlled in accordance with the logic rules of the algorithm. If the point does not correspond, by its properties, to the point, that must be recognized, the corresponding pixel further is not processed, and the algorithm starts to consider not neighboring point, but the point which is located at the certain distance from the given point. Such methods, as the research showed, enable to increase the operation rate of the algorithm up to 40%. If the point, that corresponds by its properties to the point which is to be recognized, is found, then the algorithm starts to consider the neighboring points, and if their properties satisfy the condition of recognition, the given area is considered to be recognized (for instance, the front part of the carriage is recognized), and the algorithm continues its operation until the coordinates of the front and rear parts of the carriage are found and its orientation in the is defined. If the algorithm, based on the method of linguistic recognition, has recognized the carriage non-completely or additional problems have emerged while recognition, (for instance, several carriages are present in the picture) then the algorithm is performed, that operates using structural invariant method. The given algorithm operates slower, but it operates not with the whole picture, but with the data, obtained while operation of linguistic algorithm. As a result of algorithm operation we obtain the coordinates of the carriage and its orientation or the message informing that is not possible to recognize the carriage.

Proceeding from the above-mentioned regarding the basic principles of radio-controlled carriage recognition algorithm operation we obtain the diagram, shown in Fig 2.

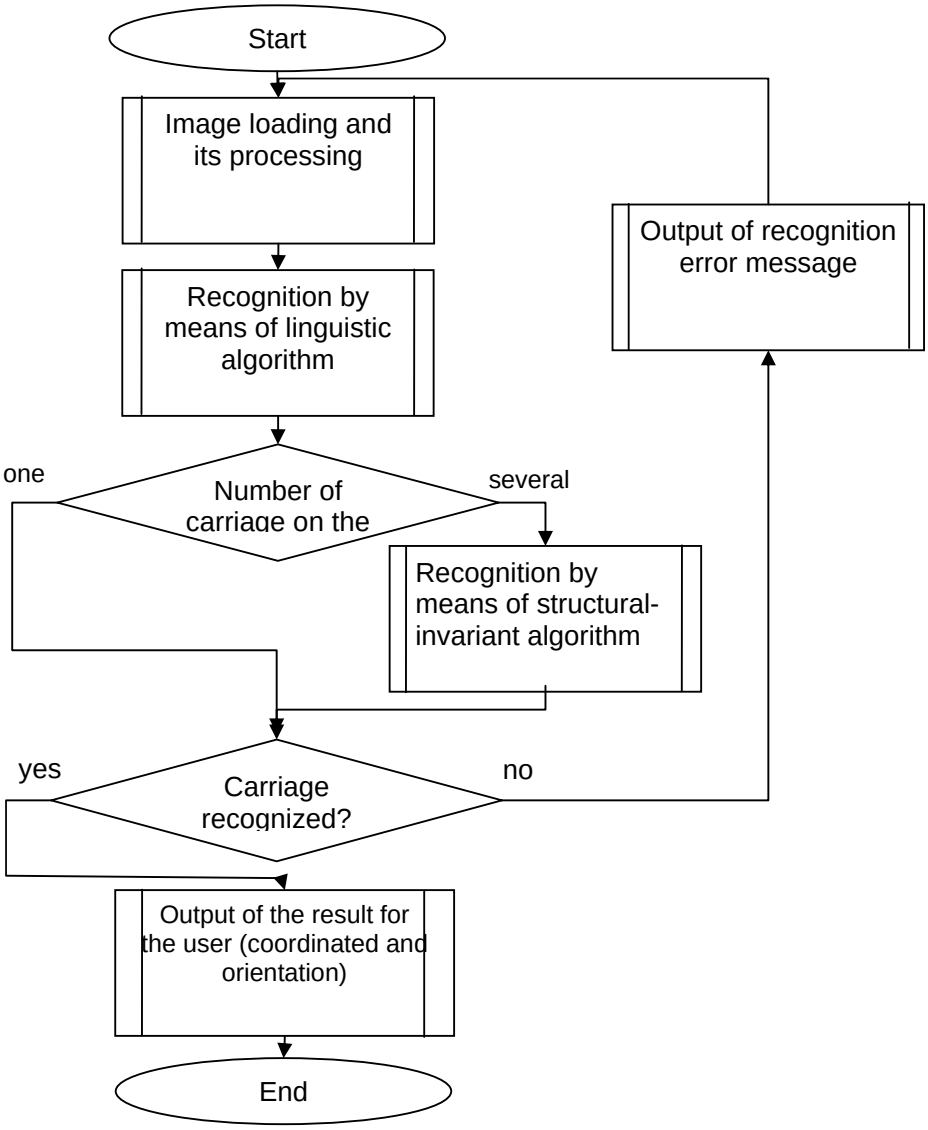

Fig. 2. Operation algorithm of principle programming module of the system

Analysis of the results of programme testing

On the basis of the suggested recognition algorithm, the programme is developed that rather efficiently solves the problem of radio-controlled carriage recognition in static picture. The results of programme operation are presented below.

30 images were tested, among those images only 3 were not recognized. There is no need to mention all of them, since there are many analogous among them, that is why we will give only three examples of images, which are characteristic for such class of images, as qualitative, bright and of bad quality (very dark).

Fig 3 shows that the object of recognition is seen very distinctly that is why it was recognized correctly and rapidly (recognition time was less than 40 μs, coordinates (686; 762); (1124; 1100), orientation – 48^0). In case of excess brightness of the image and great number of blinks, linguistic algorithm recognized wrongly one of the coordinates, that is why in this case we apply structural-invariant algorithm, as a result operation rate of the system decreased and the time of carriage recognition was 150 μs (fig. 4), coordinates: (1156; 413); (1218; 885), orientation 2^0.

In case when the picture is of very low quality and the carriage is hardly seen (Fig 5), the programme analyzed the picture during 100 μs, but having failed to find the object of recognition, stopped operation and reported about the error. To recognize such low quality objects, they must be

processed by means of special programme filters prior to recognition, but in this case the time of recognition considerably increases.

Fig. 3. View of programme window with the results of recognition

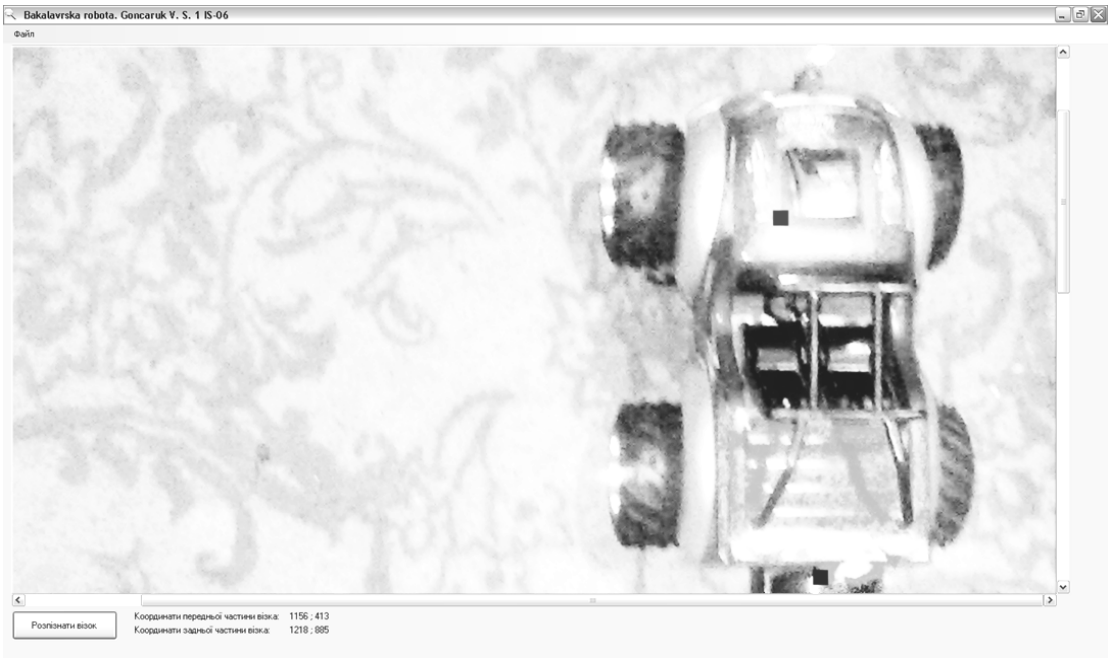

Fig. 4. View of programme window in case of inaccurate recognition

Fig. 5. View of programme window when the carriage can not be recognized

Conclusions

The paper studied main approaches regarding the development of recognition system of radio-controlled carriage on the static image. The comparison of various recognition methods is performed. The comparison showed the expedience of applying the combined recognition algorithm, using linguistic and structural-invarient methods, that enable to increase operation rate and accuracy of recognition.

The scheme of general algorithm of recognition of radio-controlled carriage is suggested. The main drawback of the given system – insufficient universality of recognition, that can be improved by means of application of more universal recognition method. This enables to improve the operation of the system in various branches as well as reduce dependence of the programme on the given object of recognition.

The programming product that can recognize radio-controlled carriage form static image is developed.

By means of the programme thirty images of the carriage were tested, among these images twenty seven images were recognized correctly. Three misrecognized pictures were of bad quality and contained noise, as a result recognition algorithm turned out to be inefficient in given cases. In other cases the programme recognized radio-controlled carriage correctly and rapidly.

The enlargement of the possibility of the developed programming complex is planned in order to recognize moving objects in real-time mode. It will allow to use the given programme as a module to complex system of radio-controlled objects control in real time.

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