ALGORITHMS OP THE COMPLEX TACTILE INFORMATION PROCESSING

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1 INTRODUCTION

The tactile information plays an important role for an intelligent robot activity. The main advantage of the tactile information over the optical one lies in its 3-d character. The tactile information can be used both for a finer positioning before gripping the object and for the shape and dimension recognition by a simultaneous handling the object.

Let's solve the latter problem. 3-d objects are gripped by an antropomorphic five-finger hand. The hand consists of a palm to which the object is pressed by multijointed fingers. The artificial hand model has been designed by Chalupa and Marik [1] [5] under the GOALEM project [2]. The complex tactile information is obtained both from the tactile (contact) sensing elements situated on the palm surface and from the position sensing element set (PSES) on the finger joints. The regular rectangular net of the on-off tactile elements is called a tactile sensing unit (TSU). The TSU matrix consists of 16 lines per 32 elements in one line and 7 lines per 21 elements the distance between the centers of neighbouring ones being 3.2 mm and the radius of the elements being 1 mm. For details see [3]

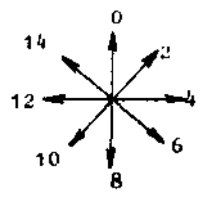
1.1 SHAPE RECOGNITION BY MEANS OF TSU

The TSU "print" of the 3-d object is a 2-d pattern, i.e. a matrix of 0's and 1's. The preprocessing and recognition of this pattern consists of the following steps:

1) The pattern boundary detection.

2) The numerical symbol a_i of the modified Freeman code (Fig.2.) corresponds to the i-th boundary point and the boundary curve is described by a string $A = a_1, \ldots, a_n$ where n is the number of the boundary points.

Fig. 1.



3) The string A is transformed to the string B by a digital filter: For simplicity we have considered the distance between two adjacent boundary points being h (even if it is $\sqrt{2}$ .h for the directions 45° + k.90°). In principle the response of the filter is expressed as a convolution B = f *A modulo 16 where f is the impulse response* Having done a lot of experiments we have arrived at conclusions that for the string lengths n = 20-70 the transfer function

$$f \triangleq F(z) = -\frac{1}{2} + \frac{1}{2} z^{-2}$$

is suitable for the shape recognition* Our experience is in concordance with the theoretical conclusions of [4] .

4) Each number in the string B is considered as a primitive of the structural (linguistic) description. To each primitive the terminal symbol $c_i \in V_T$ is assigned. Each TSU pattern is described by a sentence C = c , ..,c ,

5) For the syntactical analysis of C tree grammars G^1 and G are employed. G^1 and G^2 are the grammars for angular and oval patterns respectively. The shape of the pattern (angular or oval) is roughly determined by the grammar by means of which the parsing is successfully accomplished. The grammars G^1 and G^2 have been derived from the descriptions of the typical patterns.

6) At the semantical analysis stage the right interpretation of the chain A is looked for. For example corner positions, edge lengths and the angle of edges are computed for the angular patterns, centers and symetry axis lengths are evaluated for oval ones. Then we refine the shape classification inside the basic two classes (rectangle, square, triangle, ..., circular line, ellipse,...). The semantical analysis can be expressed in terms of a special grammar for semantical analysis GSA [5].

III THE PROCESSING 0F THE PSES INFORMATION

The position information has obviously the

3-d character. Each finger Is a k-linked plane mechanism. The finger planes are planparallel, equidistant and perpendicular with respect to the palm. The fingers approximate the surface of the object by plecewlse linear curves. The approximation depends on the control principles of the gripping activity which have been similar to those of Okada and Teuchlya [6J : The gripping action is always carried out only for one joint all the joints being successively changed starting from the nearest one. The action of the given joint is finished when the rest of the finger contacts the object or when the joint angle reaches the maximum value*

If the klnematlo-geometrloal analysis for the 3-linked meonanism is employed, the 6 types of approximations can be distinguished £>J • These approximations are taken as the description primitives. Let's label them q , j ■ 1,••••,6, Q *{q_1] • The algorithm for the*' processing of the ^{3} PSES Information (the 4 fingere without the thumb are considered) is expressed in the following way i

1) For x-th finger , x - 1,2,3,4 the description primitive is determined by means of Bayesian adaptive olassifiers.

2) To eaoh primitive q_J € Q the terminal symbol et € V_T is assigned and thus the information provided by PSES Is described as a string of the length m ■ 4.

3) The syntactical analysis of the string Is executed with respect to the grammar which was Inferred from a large set of syntactically correct words. The correction of the description from the syntactical point of view may be carried out if necessary.

4) The semantical analysis by means of the due GSA Is done. In the course of this analysis the contextual verification of the description is carried out and some parameters for the 2^{nd} level are evaluated.

IV IgE j£f PROCESSING LE^EL

The 2^{nd} processing level uses the descriptions and other results of the both 1^{st} level algorithms described above. The processing on the 2™* level consists of three hierarchical stages:
a) the generating of the description,
b) its syntactical analysis,
c) Its semantical analysis.
The 2^{nd} level serves to synthetise the 1^{t} level results and to refine the total recognition results.

v EXfHttMEMT^ JBESiajB. ABB gQNCWSJJQ^

In the case of the first algorithm (Chap.II) the correctness of the classification into 12 shape classes (including convex shapes) was nearly 100%. The numerical errors in the dimension recognition were smaller than the distance between two adjacent tactile elements.

The descriptions produced by the second algorithm (Chap.III) were correct in 96% oases for 5 types of objects.

The shape recognition of prisms, cones, pyramldes, cylinders and spheres in all types of the grips as well as the recognition of their orientation with respect to the hand was successfull in 97% making use of the both levels. The fundamental dimensions and/or the numerical parameters were obtained with numerical errors not exceeding 8%. The processing time on our slow M 6000 computer was always less than 6 seo, but in the most cases even less than 1 sec. The worst results were achieved for prismatic objects.

Using the complex tactile information (TSU and PSES data) and the speoial grammars very good classification results are obtained. The only restriction are the object dimensions which have to be suitable for gripping. The results achieved by the formal grammar approach are much better than those of feature methods [1] W.

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