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INDUSTRIAL PATTERN RECOGNITION EXPERIMENT - A SYNTAX AIDED APPROACH

by

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Introduction

The pattern recognition experiment, of which we give an account here, is a part of a DNC workshop project. The aim of this work has been a feedback loop of a programmable automata /industrial robot/, to make it applicable for various assembly and material handling activities. The workshop is controlled by a minicomputer executing the postprocessor programs of the NC machines. These postprocessors are produced by a more powerful central computer. The recognizer of the robot should work on the same basis; the possibilities of the combined mini-central computer approach was investigated on this stage of our activity. We wanted to apply methods published earlier by other authors such as Fu [1], [2], [4], [5], [6], Grenander [3], Rosenfeld [7], Evans [8], Shaw [9], [10]; some special aspects of this task and its possibilities led to a few new ideas. We should like to give an account of these, outlining the problem as a whole only to explain the context.

1/ Constraints of operation

According to the goal roughly mentioned in the introduction, this pattern recognition experiment converts its interest to industrial /man made, standardized/ objects, which can be found on one working place. The process of recognition initializes the different programs of the robot, corrects the manipulation due to change in workpiece, size, position, etc.

a/ Only a limited class of objects must be recognized in one working period;

b/ These classes can be analysed by a learning-teaching procedure, before starting the working period;

c/ The contours of the objects are well defined /as it is usually the case with industrial objects/ and in most cases they can be described by arcs and lines just as in a regular practice of NC control;

d/ A well defined background and controllable and suitable illumination can be applied.

Keeping practical industrial application in view, the solution must be an economical real time one, using mostly the control mini-computer. The hardware needed must fall within the limits of the price range of a commercial robot.

2/ Hardware

a/ Background and illumination, according to d/ of section Constraints. For general use this needs a special study, but our efforts until now were concentrated on software development, being the kernel of difficulties and the main point of recent interest.

b/ A commercial closed-loop TV camera. This will be supplied for later use with a plumbicon tube and an adjustable stand.

c/ An analog discriminator unit, sharpening the contour lines, giving a 0-1 transition at the bounds and edges. The discrimination level is also adjustable.

d/ An interface between discriminator and computer.

e/ A minicomputer /CII-10010 licence/ with 1 μs cycle time, 12 KB memory sharing work between mini- and central computer; the mini's disc will also be used.

f/ The central computer used until now, is a CDC 3300, with a 112 K, 24 bit word core memory.

3/ Feature extraction

8 x 16 points are windowed from the 256 x 256 points full frame using second line of the TV picture. This has been a compromise between low core requirement combined with fast processing picture primitives and noise sensitivity. The terminal symbols of the grammatical analysis /the atoms of the pictures/, are:

line
arc
node
undefined

About 20 real time routines are constructed to evaluate these primitives with the following characteristics:

a/ We read the pattern points in 8 x 16 quadratic blocks and these are transferred in one block to the computer core. The complete processing of these blocks is less than 40 ms in most cases, within that time the cathode-ray returns to the zone of the processed block.

b/ For faster computation the lines are identified by step differences from the horizontal or vertical axis depending on which direction is more convenient. In this way we avoid the lengthy divisions needed by the evaluation of slopes.

c/ The filtering omits every isolated error in one line; by computing the step differences we allow a variable deviation which grows with the length of the atom up to a limit defined by the program.

d/ The arcs are retrieved from line-segments, the centre of the arc is checked by chords.

e/ The attributes /coordinates of end points, centres of arcs, etc./ are calculated and assigned to the listing of the primitives by the subroutines.

4/ Strategy of recognition

The number of classes, to be recognized, is limited, but the description is general and within the classes given a very great number of different objects can be identified. That is the reason why the direct method has been amended by a heuristic one. The process of recognition is divided into two steps. In the second one, which is the actual recognition and analysis, every object has its fixed grammatical description and this is analysed by a top-down, syntax directed algorithm. Such a top-down analysis accomplished one by one for every object, would be very time consuming, not flexible and unfitted for a minicomputer. A heuristic method is included into the first stage of the process, partly executed by a central computer. This yields a suggestion for the trials with the syntax directed analysis, combining syntactic methods with stochastic ones.

5/ Some characteristics of the grammatical analysis

The algorithm as it was stated before, is a top-down one in the recognition stage and a bottom up analysis by the commonly used way in the heuristic phase. By the latter information can obtained simultaneously for several objects with the same logical steps.

The construction of the grammatical rules was based on the method of Evans [8]. The main advantage of this approach against those which are more widely used /such as Shaw [9], Ledley [11], Narashimhan [12], [13], etc./ is, that the geometrical and topological relations are not apriori fixed, but can arbitrarily be defined and included in the systems in forms of subroutines. The quantitative and qualitative attributes are not previously defined either. The fixed grammatical analysis developed e.g. by Shaw for bubble-chamber patterns, is less redundant for a given purpose, but can be applied only to a more limited class of objects. In order to give a picture in a full context, the method applied, will be briefly discussed here. The form of the rules is as follows:

Left nonterminal	right terminals and/or non-terminals/relations/ attributes of the left nonterminal
terminals	l, a, n, u /see section 3

relations	relations between the quantitative attributes of the right symbols. The number of relations is free, those used in our experiments, are summed up in table 1.
attributes	end points, slopes, centres, lenght, curvatures, relative proportions, etc.

Using the hierarchical possibilities of the grammatical method, we apply for levels of picture completeness:

primitives /atoms/

generalized picture primitives /GPP/, a simple combination of primitives /see example in section 7/

lobes x/

/complete picture elements, essential and characteristic within the object class. Having identified these lobes, we can make a probabilistic guess for the object to be recognized/

object

/the picture to be recognized, the starting symbol of the grammar/.

Recognition and listing of the primitives have been briefly described in section 3. The next phase comes below:

The objects are classified by a PROBLOB /Preliminary Recognition of Objects by Lobes/ algorithm according to certain characteristics before the proper recognition and syntactic analysis. A probability distribution is given for the identity of the actual object and that of the known ones.

The set of GPP-s is assembled for a certain scene of observation during the learning period. This can be done either automatically, or with human interaction. In the experiment detailed in the example, the number of GPP-s is 20. The lobes are composed of these GPP-s as lists in a fixed sequence. The lobes are not defined previously, but are constructed by the learning algorithm.

The learning phase is distributed between the mini and central computer, the recognition is based on the mini.

---

x/ lobe, after the philosophical fun of Hegel. He argues that men have ear-lobes, animals not, so the characteristic difference between men and animals may be the lobe.

Let us denote the GPP-s by ℓ_1, ℓ_2, ... ℓ_n and the lobes composed by them with $L_1 \ldots L_N$.

Consequently:

$$L_i = \ell_{i1}, \quad \ell_{i2}, \ldots \ell_{iJ}, \quad \text{where} \qquad /1/$$

$$J \leq n$$

We have m different objects: O_1, O_2, ... O_m.

The kth object has been optically processed and the picture analysed during the learning period $\underline{N}$ (O_k) times. The probability of occurrence of the O_k object among the whole set during the learning.

$$p(O_k) \sim \frac{N(O_k)}{\sum_{\ell=1}^{m} N(O_\ell)} \qquad /k = 1, \ldots m/ \qquad /2/$$

The conditional probability of the case, that the $\underline{O}_k$ object contains the L_i lobe:

$$p\left(L_i | O_k\right) \sim \frac{N\left(L_i | O_k\right)}{N\left(O_k\right)} \qquad /3/$$

$N\left(L_i | O_k\right)$ is the number of observations, where the lobe $\underline{L}_i$ belongs to the object $\underline{O}_k$. For these cases it is valid that:

$$\sum_{i=1}^{N} p\left(L_i | O_k\right) \sim \frac{\sum_{i=1}^{N} N\left(L_i | O_k\right)}{N\left(O_k\right)} = 1 \qquad /4/$$

The conditional probability of the case, that a recognized $\underline{L}_i$ lobe identifies the $\underline{O}_k$ object, can be obtained from the Bayes-formula:

$$p\left(O_k | L_i\right) = \frac{p\left(O_k\right) p\left(L_i | O_k\right)}{\sum_{j=1}^{m} p\left(O_j\right) p\left(L_i | O_j\right)} \qquad /5/$$

This conditional distribution is the result of the learning phase. On the basis of the table of conditional distribution for lobes and objects in the recognition phase, we can find only the most probable lobes and have a short cut through their identification.

The recognition phase collects the GPP-s of the viewed object on the basis of the extracted primitives and the grammatical analysis using the GPP-s defined in the problem. This algorithm is the same both during the learning and the recognition. The result is a list of GPP-s found in the given picture. This list is the measured lobe $\underline{L}_M$. The $\underline{L}_M$ is to be matched to the list possible $\underline{L}_i$-s obtained during the learning. A practical measure of distance is defined by the difference $\underline{d}(L_M, L_i)$ in the lobe lists. In our experiment $\underline{d}(L_M, L_i) \leq 3$, e.g. only those lobes are taken into consideration which differ maximum by three GPP-s from the measured $\underline{L}_M$. By the limitation of the distance the comparison algorithm will be very fast.

For every lobe a grade of recognition can be defined by means of the distances.

$$q(L_i, L_M) = \begin{cases} \dfrac{\left[1+d(L_M, L_i)\right]^{-1}}{\sum_{j=1}^{r}\left[1+d(L_M, L_j)\right]^{-1}} & \text{if } \underline{d}(L_M, L_j) \leq 3 \\ 0 & \text{if } \underline{d}(L_M, L_j) > 3 \end{cases} \qquad /6/$$

$\underline{r}$ is the number of lobes having a distance ≤ 3.

This definition is an arbitrary one. It is easy to compute, it has no singularities and divides fairly sharply the probability values. The distribution is obviously regular.

By these $q(L_i, L_m)$-s and $p(O_k | L_i)$-s

calculated in the learning phase, the grade of the object being $\underline{O}_k$ is:

$$Q(O_k, L_M) = \sum_{\ell=1}^{N} q(L_\ell, L_M)\, p(O_k | L_\ell) \qquad /7/$$

$$\sum_{k=1}^{m} Q(O_k, L_M) = 1 \qquad /8/$$

The $Q(O_k, L_M)$ values are ordered by magnitude, this list is applied at the top-down analysis.

6/ Listing

A special list processing system LIDI-72 developed by Uzsoky and Fidrich [14] for computer aided design of digital equipment is used. The system is FORTRAN based. LISP 1,5, SLIP, SNOBOL and other list processing languages also available on our CDC-3300, have shown a memory requirement of minimum twice as much as this one for our application. The list structure of LIDI directly represents the information structure described by an arbitrary graph. Each element of the list has a heading corresponding to the node, an optional number of pointers corresponding to the branches and a sequential list of integer type attributes /Fig. 1./. The input information /i.e. the list of the extracted primitives, grammar, etc./ is written in tree form. The system contains subroutines for the creation of arbitrary list structures, modification, deletion and retrieval. Other subroutines offer a possibility for the user to define and program deliberate operations on the data structure-segment concerned.

The system LIDI has the following advantages against other list processing systems generally used:

1/ The flexible dynamic storage distribution is combined with a memory saving sequential one.

2/ The information structure should not be transformed into a binary tree.

A simplified structure of the grammarlist is sketched on Fig. 2.

7/ Example

The picture to be recognized, is a machine part on Fig. 3. /distance screw/. For the given class of machine parts, the GPP-s of Fig. 4. are constructed. The measured lobe contains the following list:

$$L_M = \{1,2,3,8,9,10,13,15\}$$

Table 2. contains the rules of grammar used in the example in the course of identifying the GPP-s of L_M.

During the learning period the following lobes and corresponding $p\left(L_i \mid \text{distance screw}\right)$ conditional probabilities were found.

$L_1 = \{1,2,3,8,9,10,13,15\}$

$p(L_1 \mid \text{distance screw}) = 0{,}80$

$L_2 = \{1,2,3,8,9,10,15\}$

$p(L_2 \mid \text{distance screw}) = 0{,}15$

$L_3 = \{1,2,3,10,13,15,20\}$

$p(L_3 \mid \text{distance screw}) = 0{,}05$

On objects <u>distance bar</u> and <u>finished nut</u>:

$L_4 = \{1,2,10,13,15\}$

$p(L_4 \mid \text{distance bar}) = 0{,}70$

$L_5 = \{1,2,3,10,13,15\}$

$p(L_5 \mid \text{distance bar}) = 0{,}20$

$L_5 = \{1,2,10,15\}$

$p(L_6 \mid \text{distance bar}) = 0{,}10$

$L_2 = \{1,2,3,8,9,10,15\}$

$p(L_2 \mid \text{finished nut}) = 0{,}75$

$L_7 = \{1,2,3,8,9,10\}$

$p(L_7 \mid \text{finished nut}) = 0{,}25$

The distances of $\underline{L}_M$ from $\underline{L}_1$-$\underline{L}_7$ are:

$d(L_1,L_M) = 0$, $d(L_2L_M) = 1$, $d(L_3,L_M) = 3$,

$d(L_4,L_M) = 3$, $d(L_5L_M) = 2$, $d(L_6,L_M) = 4$,

$d(L_7,L_M) = 2$.

In the course of learning we handle a number of other machine parts, but the lobes found on them, are very different from $\underline{L}_M$. The grades assigned to each lobe, are calculated on the basis of the distances /Eg./6/ in section 5./.

$q(L_1L_M) = 3/8$, $q(L_2L_M) = 3/16$,

$q(L_3L_M) = 3/32$, $q(L_4L_M) = 3/32$,

$q(L_5L_M) = 1/8$, $q(L_6L_M) = 0$,

$q(L_7L_M) = 1/8$.

The distribution of conditional probabilities by lobes $\underline{L}_1 \ldots \underline{L}_7$ for the analysed objects, are summed up in table 3. For the sake of simplicity, the occurrence of the objects during the learning period was supposed to be uniform. On the basis of the data for the given L_M, the three objects give the following grades:

$Q\left(\text{distance screw}, L_M\right) = 0{,}43$

$Q\left(\text{distance bar}, L_M\right) = 0{,}12$

$Q\left(\text{finished nut}, L_M\right) = 0{,}22$

$Q\left(\text{all other objects}, L_M\right) = 0{,}23$

Conclusion

The work reported here is not a completed one. All the algorithms, programs are running, but the electro-optical device must be improved, and the software system as a whole is only in experimental stage. Nevertheless the results achieved until now, have unambigously proven the correctness of the basic aim, that is the possibility of a recognition of standardized industrial objects driven by a minicomputer, supposing a short access of a central tral computer is available. Some new ideas are added to the grammatical picture processing methods, especially regarding the list organization, and a heuristic method with probabilistic elements.

Acknowledgement

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References

[1] P.H. Swain and K.S. Fu: Nonparametric and linguistic approaches to pattern recognition. School of Elec. Engrg., Purdue Univ., Lafayette, Ind. Tech. Rept. TR-EE 70-20 /June 1970/

[2] K.S. Fu - P.H. Swain: On syntactic pattern recognition. Software Engineering, Vol. 2., pp. 155-182 /1971/

[3] U.Grenander: Doundations of pattern analysis. Div. of Applied Math., Brown Univ., Providence, R.I., Tech. Rept. 2 /Project Graphics/ /1967/

[4] P.H.Swain and K.S.Fu: Stochastic Programmed Grammars for Syntactic Pattern Recognition. School of Elec. Engrg., Purdue Univ., Lafayette, Ind. /1970/

[5] T.Huang - K.S.Fu: On Stochastic Context-Free Languages. Information Sciences, Vol. 3 /1971/ pp. 201-224.

[6] K.S.Fu: An introduction to pattern recognition. Lecture of the Seminar on the Problem of Artificial Intelligence, held in Budapest, 1971.

[7] A.Rosenfeld: Picture Processing by Computer. Computing Surveys, Vol.1, No. 3., September 1969.

[8] T.G.Evans: A Grammar-Controlled Pattern Analyser. IFIP Congress 68, Appl. 3., North-Holland Publ. Comp., Amsterdam, 1968.

[9] A.C.Shaw: A Formal Description and Parsing of Pictures. Stanford Univ. SLAC Report No. 84, 1968.

[10] A.C.Shaw: A formal picture description scheme as a basis for picture processing systems. Information and Control Vol. 14, 9-52 /1969/

[11] R.Ledley et al.: FIDAC: Film input to Digital Automatic Computer and associated syntax-directed pattern recognition programming system. Optical and Electro-optical Inf. Proc., M.I.T.Press, 1965.

[12] R.Narasimhan and V.S.N.Reddy: Some experiments in scene generation using COMPAX. Technical Rep., No. 103, IFIP Working Conf. on Graphic Language, Vancouver, 1972

[13] R.Narasimhan: Syntax directed interpretation of classes of pictures. CACM Vol.9, 166-173 /1966/

[14] M.Uzsoky - I.Fidrich: LIDI-72- a LIst processing system of Digital Techniques Department, Computer and Automation Institute of the Hung.Academie of Scs., intern report.

[15] T.Vámos - Z.Vassy: A Restricted Goal Syntax Aided Pattern Recognition Experiment. Acta Technica, Hungarian Academy of Scs., Tom. 75 /1973/.

$A = B$	Equality of coordinates
$A \neq B$	Inequality of coordinates
$\phi = \psi$	Equality of slopes
$\lvert\phi-\psi\rvert = \text{const.}$	Fixed difference of slopes
$\lvert\text{distance}(A,B) - \text{distance}(C,D)\rvert = \text{const.}$	Fixed difference of distances
$\text{distance}(A,B) \lesseqgtr \text{distance}(C,D)$	Relation between distances
$\lvert\text{distance}(A,B) - \text{distance}(C,D)\rvert \lesseqgtr \text{const} \cdot \text{distance}(A,B) + \text{distance}(C,D)$	Relative relation of distances
$A \cong B(\overline{CD})$	Points A and B lie on the same side of line CD
$A \ncong B(\overline{CD})$	Points A and B lie on different sides of line CD

Table 1. Relation

$\text{ARC1} \rightarrow \langle \text{Arc} \mid \; \mid A=A_1;\ B=B_1;\ C=C_1;\ K=K_1;\ \phi=\text{ATAN}(\overline{A_1B_1})\rangle$

$\text{ARC1} \rightarrow \langle \text{ARC1};\ \text{Indef} \mid A_1=A_2 \mid A=B_1;\ B=B_2;\ C=C_1;\ K=K_1;\ \phi=\phi_1\rangle$

$\text{ARC1} \rightarrow \langle \text{ARC1};\ \text{ARC1} \mid A_1=A_2;\ C_1=C_2; \mid A=B_1;\ B=B_2;\ C=C_1;\ K=K_1;\ \phi=\text{ATAN}(\overline{B_1B_2})\rangle$

$\text{GPP1} \rightarrow \langle \text{ARC1} \mid A_1=B_1 \mid K=K_1;\ R=\text{distance}(K_1,C_1)\rangle$

$\text{GPP2} \rightarrow \langle \text{ARC1} \mid K_1 \cong C_1(\overline{A_1B_1}) \mid K=K_1;\ R=\text{distance}(K_1,C_1)\rangle$

$\text{GPP3} \rightarrow \langle \text{ARC1} \mid K_1 \ncong C_1(\overline{A_1B_1}) \mid K=K_1;\ A=A_1;\ B=B_1;\ R=\text{distance}(K_1,C_1);\ \phi=\phi_1\rangle$

$\text{LIN1} \rightarrow \langle \text{Line} \mid \mid A=A_1;\ B=B_1;\ \phi=\text{ATAN}(\overline{A_1B_1})\rangle$

$\text{LIN1} \rightarrow \langle \text{LIN1};\ \text{Indef} \mid A_1=A_2 \mid A=B_1;\ B=B_2;\ \phi=\phi_1\rangle$

$\text{LIN1} \rightarrow \langle \text{LIN1};\ \text{LIN1} \mid A_1=A_2;\ \phi_1=\phi_2 \mid A=B_1;\ B=B_2;\ \phi=\phi_1\rangle$

$\text{ARC2} \rightarrow \langle \text{ARC1};\ \text{ARC1} \mid A_1=A_2;\ K_1 \neq K_2 \mid A=B_1;\ B=B_2;\ K=K_1;\ L=K_2\rangle$

$\text{GPP8} \rightarrow \langle \text{ARC2};\ \text{LIN1} \mid A_1=A_2;\ B_1=B_2 \mid$

$\text{GPP9} \rightarrow \langle \text{ARC1};\ \text{LIN1};\ \text{LIN1} \mid A_1=A_2;\ B_1=A_3;\ B_2=B_3;\ C_1 \cong B_2(\overline{A_1A_2})\rangle$

$\text{PLIN} \rightarrow \langle \text{LIN1};\ \text{LIN1} \mid A_1 \neq A_2;\ A_1 \neq B_2;\ \phi_1=\phi_2 \mid A=A_1;\ B=A_2;\ C=B_1;\ D=B_2;\ \phi=\phi_1\rangle$

$\text{ARCH} \rightarrow \langle \text{PLIN};\ \text{ARC1} \mid A_1=A_2;\ C_1=B_2;\ \ \lvert\phi_1-\phi_2\rvert=90^\circ\ A=B_1;\ B=D_1;\ C=C_2;\ D=A_1;$
$E=C_1;\ \phi=\phi_1\rangle$

$\text{GPP10} \rightarrow \langle \text{ARCH} \mid C_1 \ncong A_1(\overline{D_1E_1}) \mid A=A_1;\ B=B_1;\ \phi=\phi_1\rangle$

$\text{GPP13} \rightarrow \langle \text{LINE1};\ \text{LINE1};\ \text{LINE1} \mid A_1=A_2;\ B_2=A_3;\ \lvert\phi_1-\phi_2\rvert=90^\circ;\ \text{distance}(A_2B_2) <$
$< 0{,}3\ \text{distance}(A_1,B_1);\ \text{distance}(A_2,B_2) < 0{,}3\ \text{distance}(A_3,B_3)\rangle$

$\text{GPP15} \rightarrow \langle \text{LINE1};\ \text{LINE1};\ \text{LINE1} \mid A_1=A_2;\ B_2=A_3;\ B_1 \cong B_3\ \overline{A_1,B_2} \mid \text{distance}(A_1B_1) -$
$-\text{distance}(A_2,B_2) \mid < 0{,}5\ \text{distance}\ (A_1,B_1) + \text{distance}\ (A_2,B_2);$
$\text{distance}(B_1,B_3) > \text{distance}(A_2,B_2) \mid \rangle$

$\text{GPP20} \rightarrow \langle \text{LINE1};\ \text{LINE1};\ \text{LINE1} \mid A_1+A_2;\ B_2=A_3;\ B_3=B_1 \mid \rangle$

Comments: 1/ The attributes of the terminals: A,B coordinates of the end points
C coordinates of the centre of curvature
K an arbitrary point of an arc

2/ $A \simeq B(\overline{CD})$ denotes, that A and B are on the same side of line $\overline{CD}$

3/ Terminal symbols are written with lower case letters

4/ In relations of equality a certain relative difference is permitted.

Table 2.

	Distance screw	Distance bar	Finished nut	Other objects ...	...	...
L_1	1,0	0	0	0	0	0 ...
L_2	0,17	0	0,83	0	0	0 ...
L_3	0,30	0	0	0,30	0,40	0 ...
L_4	0	0,8	0	0	0	0,20 ...
L_5	0	0,40	0	0,50	0,10	0 ...
L_6	0	1,0	0	0	0	0 ...
L_7	0	0	0,50	0	0	0 ...(0,50)

Table 3.

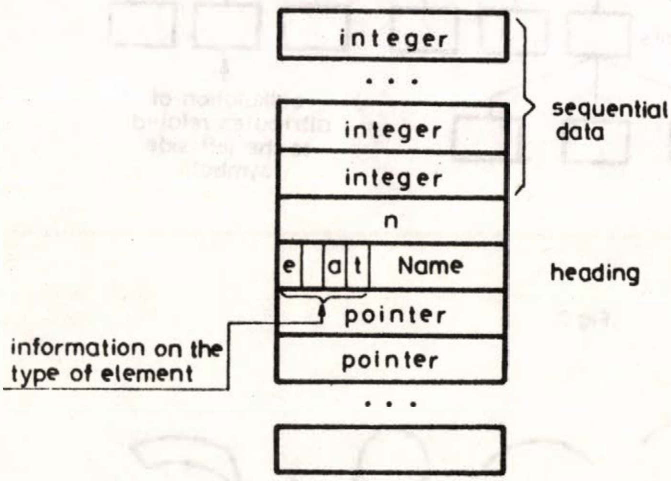

integer
. . .
integer
integer
n
e
a
t
Name
pointer
pointer
. . .
sequential data
heading
information on the type of element

Fig. 1.

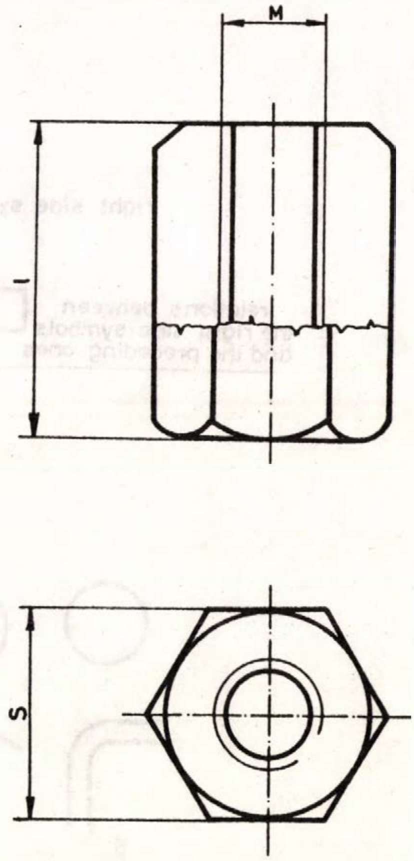

M
l
S

Fig.3.

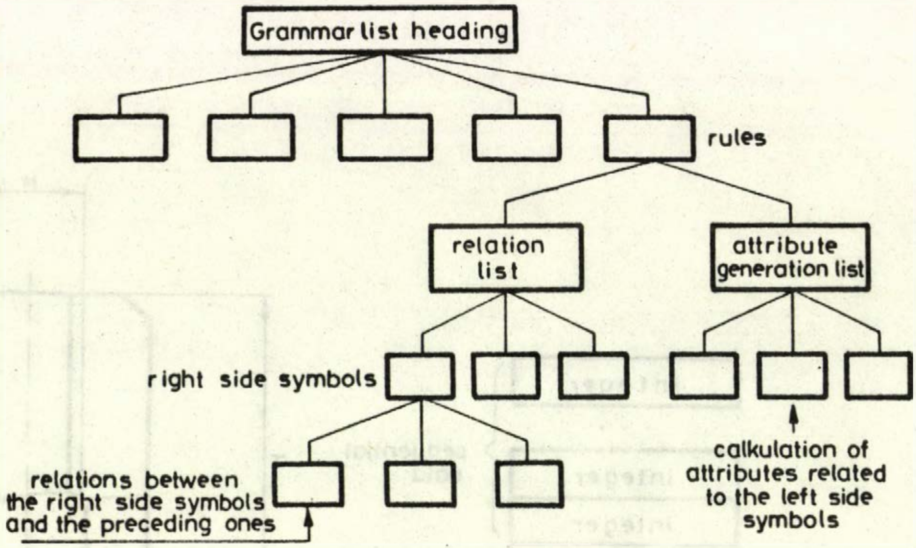
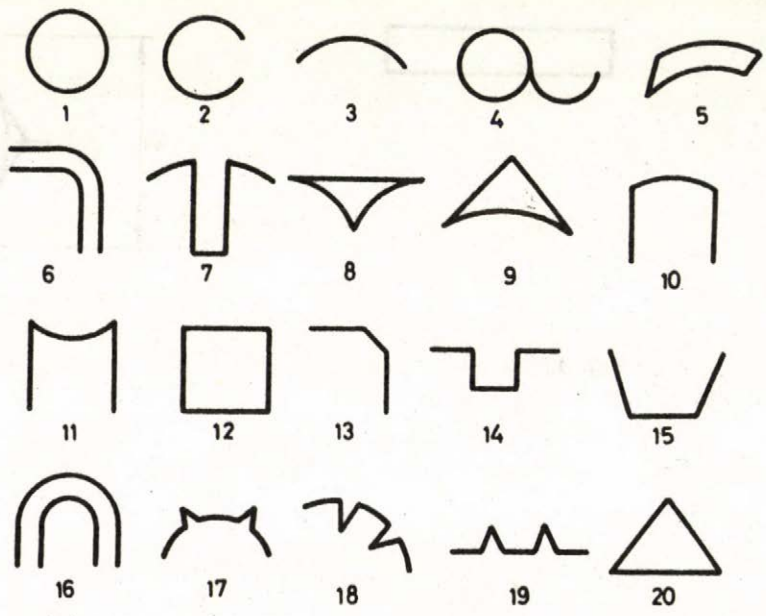

Grammar list heading
rules
relation list
attribute generation list
right side symbols
relations between the right side symbols and the preceding ones
calkulation of attributes related to the left side symbols

Fig. 2.


1
2
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20

Fig. 4.

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