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RECOGNITION ORIENTED MODELING ENVIRONMENT FOR ROBUST 3D OBJECT IDENTIFICATION AND POSITIONING FROM A SINGLE INTENSITY IMAGE

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Abstract: *In this paper we propose a recognition-oriented modeling environment for robust 3-D object identification and positioning from a single 2-D image. Because the sensorial data are not complete and can not be converted into model compatible format, a viewpoint oriented intermediate representation, obtainable also from sensorial data, is defined. This intermediate representation is an attributed relational graph. The proposed recognition-oriented modeling environment builds the complete 3-D geometric model, generates intermediate representations corresponding to a set of uniform distributed directions, groups them into aspects, and computes aspect's average attribute values and the corresponding variances for primitives and relations. These aspects represent data structures suitable for establishing initial correspondences between models and sensorial data.*
Keywords: *3-D object recognition, CAD-based vision, view-based intermediate representation, aspects.*

1. INTRODUCTION

The general problem of automatic object recognition requires object centered 3-D models (Kuno et al., 1991). Because the sensorial data are not complete and can not be converted into model compatible format, a view- point oriented intermediate representation, obtainable also from sensorial data, is necessary. This intermediate representation can take the form of an attributed relational graph (Kak et al., 1988). In this representation nodes are geometrical primitives or association of primitives representing border components with their attributes. The arcs are attributed relations among these primitives. To focus the matching, the projections are joined in aspects (Gigus et al., 1991).
We propose a recognition-oriented modeling environment for robust 3-D object identification and positioning from a single 2-D image. The proposed recognition-oriented modeling environment, builds the complete 3-D geometric model, generates intermediate representations corresponding to a set of uniform distributed directions, groups them into aspects, and computes aspects average attribute values and the corresponding variances for primitives and relations. These aspects represent data structures suitable for establishing initial correspondences between models and sensorial data. The steps of this work are:

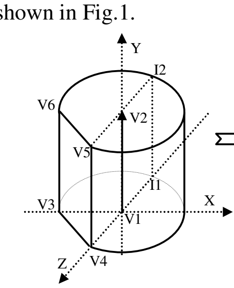
- Geometric modeling system development;
- Adoption of the intermediate representation;
- Projections generation;
- Generation of the intermediate representation;
- Grouping the projections into aspects;
- Aspects representation;
- Range image generation.

2. GEOMETRIC MODELING SYSTEM DEVELOPMENT

In the design of the geometric modeling system the following constraints were taken into account:

- The system is used for industrial objects modeling;
- The allowed surface types are plane, cylindrical, conical and spherical;
- There are complete geometrical descriptions of these objects.

The first problem, which must be solved, is the selection of the model description method. The three accessible methods are: "By showing" with a video camera, an interactive visual language and a specialized description language. The last method was chosen, because usually the descriptions of industrial objects are available.
The considered constraints, the relevance of the shape in the visual recognition and the method used in complete geometrical descriptions, imposed a description language based on surface definition statements. Each type of surface has an associated definition statement. The description of a sectioned cylinder is shown in Fig.1.




```
sec_cyl{
CYL<(V1=0,0,0 V2=0,100,0 V3=-50,0,0
        I1=0,0,-50 V4=0,0,50 V5=0,100,50
        I2=0,100,-50 V6=-50,100,0) ()>
PLN<(V5 V4 V3 V6) ()>
PLN<(V3 I1 V4) ()>
PLN<(V5 I2 V6) ()>
}
```

Fig. 1. Description of a sectioned cylinder

For complete geometric representation of the industrial objects,

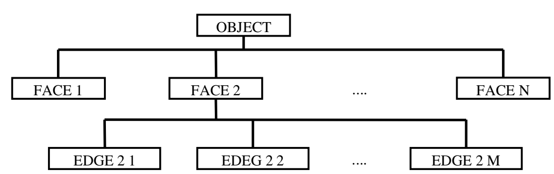


Fig. 2. Boundary representation

the Boundary Representation was chosen (Fig.2), in accordance with the description language.

3. ADOPTION OF THE INTERMEDIATE REPRESENTATION

The specification of the intermediate representation is based on the identification of the boundary geometrical primitives, and of the relations among these primitives. The primitives and relations which can be associated with 3-D shapes and which correspond to some projection invariant properties of the 3-D shapes are preferred. The primitives of this representation are the 2-D line segment, the circular arc and the elliptical arc. The most important relations are angle, parallel, junction and parallelogram (Nedevschi & Goina, 1993). For each primitive and relation a local coordinate system and identification and localization attributes are defined. The intermediate representation has the shape of an attributed relational graph, with attributed primitives in nodes and attributed relations as arcs. The attributes of the line primitive and the angle relation are presented (Nedevschi, 1997):

line(identifier,x_c,y_c,direction,length,avg_gradient,x_b,y_b, x_e,y_e,left_coulor,right_coulor,significance)

angle(identifier,id_line1,end_line1,id_line2, end_line2,x_c,y_c,b_direction,angle,length_line1, length_line2, significance).

4. PROJECTIONS GENERATION

The projection computation algorithm consists of:

- Rotation of the coordinate system so that the Oz axis to become the direction of projection;
- The projection along the Oz axis;

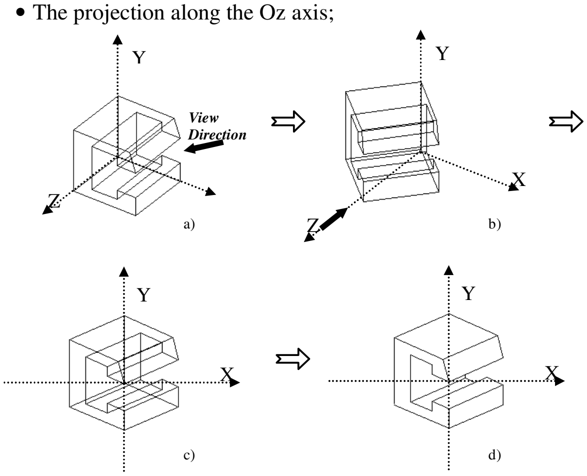


Fig. 3. Projection generation process

As a result, a set of lines is obtained, representing visible edge projections, depicted by the following relations:

Line(ModelId, EdgeId,SegmentId,LineId,(LineAttributes)), where *LineId* specifies the projected line identifier.

This manner of projection representation allows an easy generation of the intermediate representation.

5. GENERATION OF THE INTERMEDIATE REPRESENTATION

By associating the projections corresponding to the segments which belong to the same face, closed contours (C_c) or closed polygonal lines are obtained, where:

$C_c=\{l|\forall l_i, lj\in C_c, l_i\neq l_j, l_i.IdSeg.IdFace=l_j.IdSeg.IdFace\}$ (1)

From the closed contours corresponding to planar faces features as parallelogram, angle, parallel can be extracted and from closed contours corresponding to cylindrical or conical faces features as parallel, angle, arc of ellipse or arc of circle can be extracted. For all extracted features the corresponding attributes are computed.

The intermediate representation of the projection of the sectioned cylinder (Fig. 1) after the direction (0.36, -0.26, 0.89) is presented:

line(1, 210, 151, -90, 96, 0 , 210, 200, 210, 103, 1)
line(2 , 141, 139, -90, 96, 0 , 141, 187, 141, 91, 1)
line(4 , 113, 156, 90, 96, 0 , 113, 108, 113, 204, 1)
line(6 , 127, 196, 31, 32, 0 , 141, 187, 113, 204, 1)
line(8 , 127, 99, -148, 32, 0 , 113, 108, 141, 91, 1)
ellipse(51 , -0, -96, 0, 13, 50, 0, 146, 1)
ellipse(53 , 0, 0, 0, 13, 50, 0, 146, 1)
ellipse(52 , 0, 0, 0, 13, 50, -173, 0, 1)
angle(1, 2, B , 6, B, 141, 187, 150, 121, 96, 32, 1)
angle(2, 2, E , 8, E, 141, 91, -119, -58, 96, 32, 1)
angle(3, 4, E , 6, E, 113, 204, 60, -58, 96, 32, 1)
angle(4, 4, B , 8, B, 113, 108, -29, 121, 96, 32, 1)
parallel(1, 1, B , 2, B, 175, 145, -90, 69, 68, 96, 96, 1)
parallel(2, 1, B , 4, E, 161, 154, -90, 96, 96, 96, 96, 1)
parallel(3, 2, B , 4, E, 127, 148, -90, 32, 27, 96, 96, 1)
parallel(4, 6, B , 8, E, 127, 148, 31, 96, 82, 32, 32, 1)
parallelogram(1, 4, 3, 127, 148, -90)

6. ASPECTS REPRESENTATION

An aspect includes the projections having the same visible edges. The aspect generation is achieved by a grouping technique, which assures the edge space clustering in aspects corresponding classes. For each aspect the average direction is evaluated, and its corresponding solid angle is computed. To enhance the matching process, the aspect representation is introduced. This representation has the same primitives and relations as the intermediate representation, with the following modifications:

- Each attribute has an averaged value on the aspect
- Each attribute gets a domain, corresponding to the attribute variance in the projections included in the aspect

The matching process is achieved in two steps. The first step, corresponding to a course matching between the model aspects and the intermediate representation of the scene, will generate an identification hypothesis, consisting of a model aspect. The second step, corresponding to a fine matching between the projections of the object aspect and the intermediate representation of the scene, will confirm the hypothesis and will determine the position.

7. RANGE IMAGE GENERATION

Range images corresponding to given directions can be generated by a modified z-buffer algorithm. These images can be used for developing range image processing algorithms.

8. RESULTS AND CONCLUSIONS

The modeling environment was completely implemented and tested. The generated representations were used with good results to implement reliable matching systems.

A vision oriented modeling environment was proposed, implemented and tested. The most important contributions are in the field of intermediate and aspect representations definition. More experiments in using these representations are necessary.

9. REFERENCES

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