VISUAL PLANNING USING 3D RECONSTRUCTION IN INTELLIGENT ASSEMBLY LINES

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Abstract:

The paper describes a system which is in the designing phase, that has the role to plan the tasks in a automated assembly line. The system is detecting the visual features of the parts (line detection) and then it uses an algorithm to reconstruct the 3D aspect of the object. Using the form features an expert system qualifies the object and then the part is transported to the right assembly post. The paper is structured in four paragraphs starting with an introduction about process planning, the second paragraph discuss about the 3D reconstruction used in the planning process, the third paragraph describe the expert system which qualify the objects and chose the right path that the part must follow in the assembly line.

Keywords:

Visual Planning, 3D Reconstruction, Assembly Line, Intelligent Manufacturing Systems, Expert System

1. INTRODUCTION

Process planning for a mechanical part involves preparation of a plan that outlines the routes, operations, machine tools, fixtures, and tools required to produce the part. It is an important task in production and has been typically done by human experts in the past. However, in the last decade there has been a trend to automate process planning, since it increases production efficiency and parts can be produced more economically. As a result a number of process planning systems have been developed.

There are two basic approaches to automated process planning:

- Variant approach,
- Generative approach.

In the variant approach each part is classified based on a number of attributes and coded using a classification and coding system. The code and the process plan for each part are stored in a database. When it is required to generate a process plan for a new part, the part is coded and a process plan for a part similar to the new part is retrieved from the database. The retrieved process plan is modified if necessary. The variant approach might be useful in a case where there is a great deal of similarity between parts.

In the generative approach, there are no process plans stored in the data base. Instead, the data base contain informations about parts, machines, tooling, and process planning rules. Using the information, a generative process planning system creates the process plan required. Existing generative process planning systems can generate process plans for parts with rather simple geometry. In fact, most existing systems are not truly generative because they require human interaction to describe the part and to obtain information about its features [2].

Using an artificial intelligence (AI) framework, Tsang and Lagoude [6] formulated the process planning problem as a sequence of actions (operations) and resources (machines, tools, etc.) that enable the goal state (producing a finished part) to be reached given the initial state (raw material, also called stock). On the basis of the preceding formulation, a number of intelligent process-planning systems have been developed.

In the following paragraphs is described a process of 3D reconstruction used to generate the necessary 3D object informations in order that the expert system can decide what planning solution will apply.

2. VISUAL 3D RECONSTRUCTION

The 3D reconstruction process is based on seven steps:

1) Image acquisition.
   The acquisition is realized using a 640x480 monochrome camera which is oriented with an known angle from the vertical direction. The camera must have an orientation different from the vertical in order to “see” the faces of the parts as many as possible (Fig1 a)).

2) Binarization.
   In order that all the edges to be detected the binarization process is made with multiple thresholds (in our case were used thresholds (experimentally selected) from 30 or 40 grey levels) the resulting image is obtained by adding the images after each binarization(Fig 1 b)).

3) Thinning
   The resulting image contains lines which have more than one pixel weight, in order to use the line detection algorithm was necessary to thin each line to one pixel tick. The thinning operation is related to the hit-and-miss transform and can be expressed quite simply in terms of it. The thinning of an image *I* by a structuring element *J* is:

   $$thin(I,J) = I - hit - and - miss(I,J) \quad (1)$$

   where the subtraction is a logical subtraction defined by $X - Y = X \cap NOTY$ (Fig 1 c)).

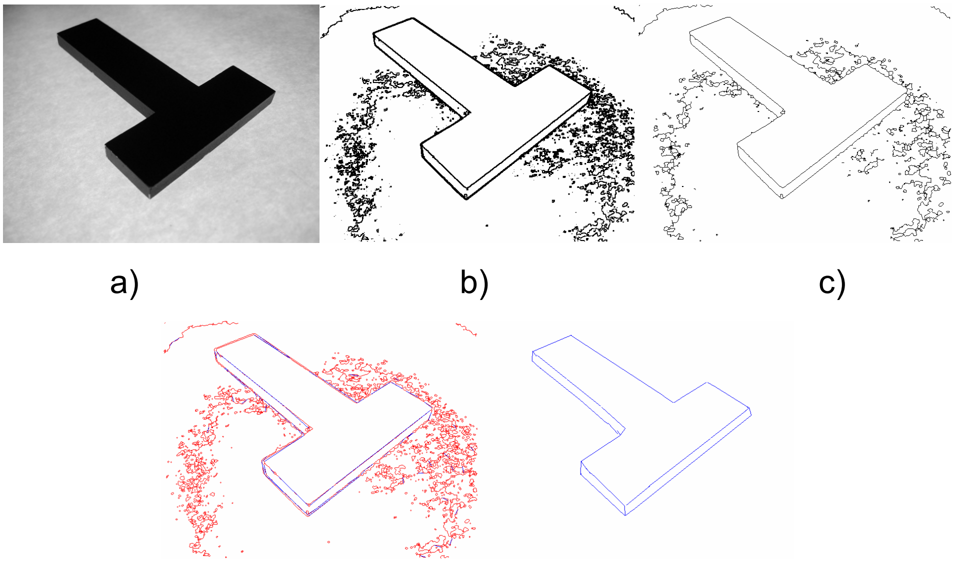
4) Line Detection
   After the step 3 the image contains only one tick curves. The line detection algorithm is based on following each line and detecting the changes in the advance direction. The algorithm scans the image and find a black pixel which has only one or two neighbours, next it chooses one and if $X_i > X_{i+1}$ then X has a decreasing slope, the same is made with Y coordinates. After few pixels (following the line) if the slope of X start to increase then the line is changing the direction and is considered that it starts to be non linear, the same thing happens if the slope of X is chanced from the original value and is constant after few pixels: for example if for the firsts pixels $X_i > X_{i+1}$ and for the last 10 pixels $X_i = X_{i+1}$ then the line describes a corner and is not a straight line. (Fig 1 d))

5) Fragmented Line rebuild
   The result is a set of lines which are fragmented due to the fact that in the image was noise or if the lines where interrupted because they described a corner. The fragmented

lines are reconstructed if the lines have the same orientation and the end points are close enough. (Fig 1 e))

6) Face detection
In our case (we are using objects with parallel edges) the faces are delimited by the detected lines which are parallel two by two and are intersecting, the hidden faces are detected using the property that each face is delimited by 4 edges and the edges are parallel.

7) Building the AAG
After each face was detected the Attributed Adjacency Graph (AAG) is build [2]. In an AAG each node represents a face of the part and each arc represents an edge. In addition, an arc is assigned an attribute value 0 (1) if the angle formed at the edge by the two faces is concave (convex).



a) b) c)

d) e)

Figure 1: The Image processing for 3D Reconstruction
(a) Original Image, b) Threshold, c) Thinning, d) Line Detection, e) Line rebuild)

3. THE EXPERT SYSTEM

Most of the expert process planning systems have been designed based on the premise that each part can be described using a set of predefined features (such as Geometric features)

A geometric feature is a collection of geometric entities such as surfaces, curves, and points having significance in process planning. There is a loose correspondence between geometric features and manufacturing processes. For example, holes may be drilled, reamed, or bored, but normally they are not milled [5]. Some sample geometric features used in development of expert systems for process planning of prismatic parts are illustrated in Table 1.

Determining geometric features of a part might be an easy task for a human, but it is not easy for a computer program. One of the approaches to recognition of geometric features is to use an expert system [1], [3].

Two production rules are given next for recognition of the geometric features in Table 1.

RULE 1 (STEP RECOGNITION)
IF face f1 is adjacent to face f2 IF face f1 is adjacent to face f2
AND the angle between faces f1 and f2 is 90°
THEN the faces f1 and f2 form a step

RULE 2 (SLOT RECOGNITION)
IF face f1 is adjacent to face f2
AND face f2 is adjacent to face f3
AND the angle between faces f1 and f2 is 90°
AND the angle between faces f2 and f3 is 90°
THEN the faces f1, f2 and f3 form a slot

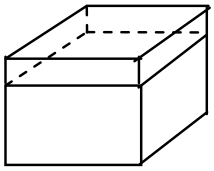
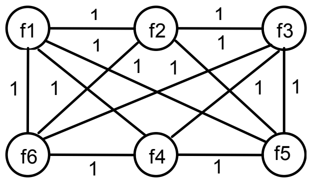
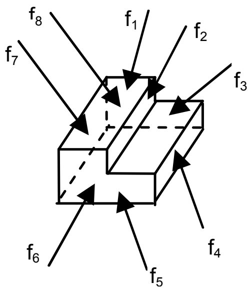
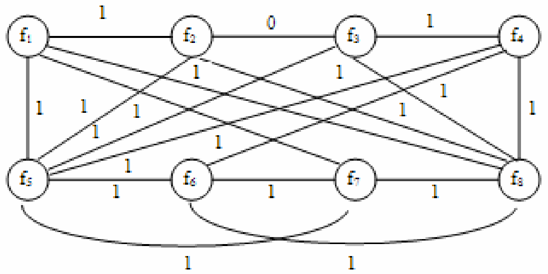
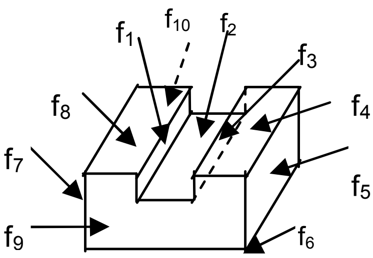
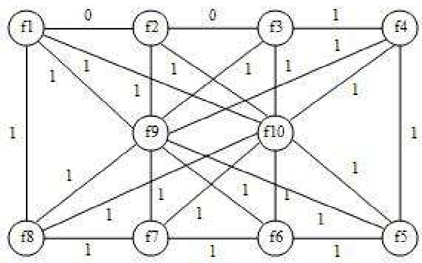
Geometry	Geometric feature of part	AAG
	Plane	
	Step	
	Slot	

Table 1: Sample Geometric Features of Parts

A part and the corresponding attributed adjacency graph are represented in Fig 2. Based on the properties of the AAG part, geometric features can be recognized [4]. Two sample rules for recognition of a step and slot are shown next.

RULE 3(STEP RECOGNITION)
IF an attributed adjacency graph has exactly two nodes linked by an edge with attribute value 0
THEN the feature is a step

RULE 4 (SLOT RECOGNITION)
IF an attributed adjacency graph has exactly three nodes and two edges with attribute value 0
THEN the feature is a slot

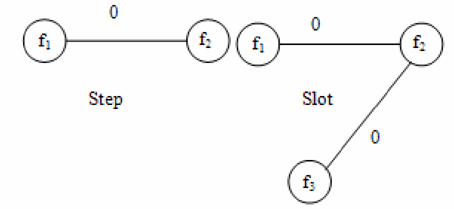


Figure 2: AAG representation of the step and slot in Table 1

4. CONCLUSIONS

The proposed project aims to design, build, experiment and validate a visual planning system, in order to assure an optimized production process with a high availability degree. The project propose an approach using artificial vision to identify the products feeded in the production line, then depending on the geometric features extracted from images and the 3d reconstruction of the object, a production panning expert system will take the decision regarding the optimal path of the object in the flexible manufacturing cell and the tasks that will be executed on the object. In order that the project will obtain significant results the following objectives must be followed:

1) Estimating a set of features of the objects, features extracted from images processed using machine vision. The image acquisition must be dynamic, and the interpretation of the features is done by comparing with a relational CAD database.

2) The 3D reconstruction of the shape of the objects which are feeded on conveyor belts in the manufacturing process, is made using non stereo images. This method will allow object recognition using only the cad information from the designing phase, and also the on-line definition of robot grasping positions in order that the object can be handled in assembly operations in flexible manufacturing cells.

3) Decision system – task planner- based on an expert system which defines using the 3D data obtained from the images processing, the path which an object should follow in the manufacturing process and which operations must be executed.

The 3D reconstruction mechanism in tandem with the knowledge-based production planner expert system is intended to be implemented on the 5-robot assembly cell shown in Fig. 3. The five robotic stations are interconnected by a Bosch Rexroth TS*plus* closed-loop twin-track, pallet-based power-and-free conveyor with four linear bi directional derivations moving subassemblies fixed on pallets in single- or double access AS (Assembly Stations) $AS_{11}, (AS_{12}, AS_{21}), AS_{22}, AS_3, AS_4$. Four Adept robots are used for assembly tasks: two Cobra S600 and two Adept Viper S650 with vision systems. The fifth 3D Cartesian robot retrieves parts from a 3D storage, pacing them on pallets on the belt.

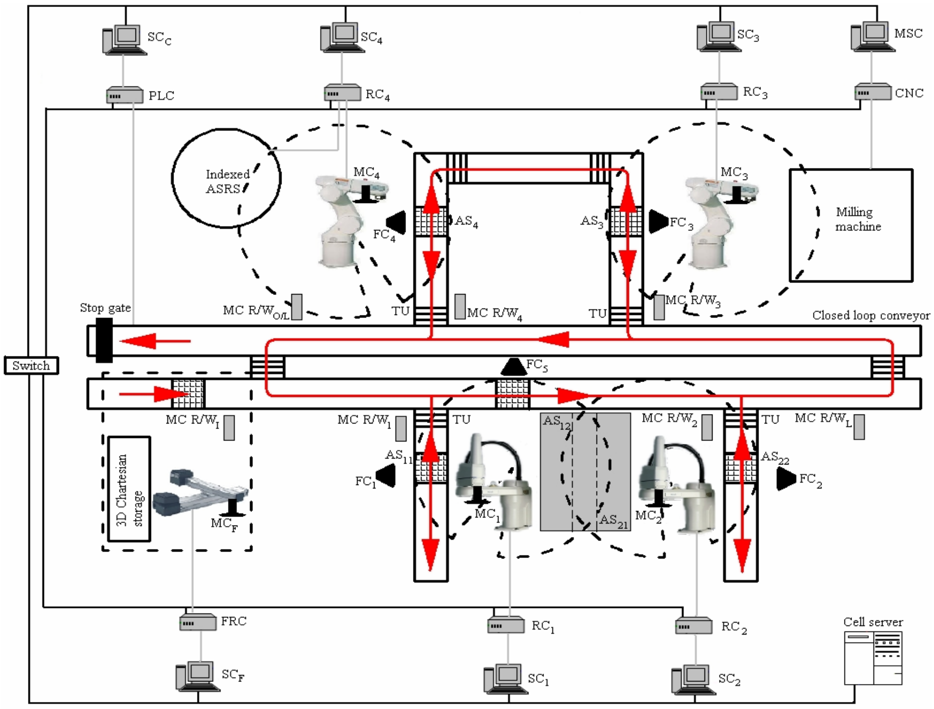


Figure 3: The 3D Visual Planning Infrastructure

All single-access AS are visualized by fixed down-looking cameras; the assembly robots are equipped with arm-mounted cameras taking pictures in a priori defined inspection points. Six magnetic code read / write devices $\mathrm{MC\,R/W}_i, 1 \leq 6$ are placed at the input-workstations-, and loop points to write product codes is on magnetic chips on carrier pallets, respectively to read it at diverting points of the conveyor. The associated assembly data is updated via PLC after completion of any operation. Fault-tolerance is provided to the cell communication system by network redundancy at Station Controller (RC_i) and Station Computer (SC_i) level. The 3D reconstruction algorithm and the production planner will be embedded in an IBM xSeries 3500 Cell Server.

5. REFERENCES

[1] HENDERSON, M. R. AND D. C. ANDERSON (1984). "COMPUTER RECOGNITION AND EXTRACTION OF FORM FEATURES: A CAD/CAM LINK," COMPUTERS IN INDUSTRY, VOL. 5, PP. 329-339

[2] JOSHI, S., N. N. VISSA, AND T. C. CHANG (1988). "EXPERT PROCESS PLANNING SYSTEM WITH SOLID MODEL INTERFACE," INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH, VOL. 26, NO. 5, PP. 863-885.

[3] KUNG, H.-K. (1984). "AN INVESTIGATION INTO THE DEVELOPMENT OF PROCESS PLANS FROM SOLID MODELING REPRESENTATIONS," PH.D. THESIS, OKLAHOMA STATE UNIVERSITY.

[4] KUSIAK ANDREW (1990). "INTELLIGENT MANUFACTURING SYSTEMS," PRENTICE HALL, ENGLEWOOD CLIFFS, NEW JERSEY.

[5] REQUICHA, A. G. AND J. VANDENBRADE (1988). "AUTOMATED SYSTEMS FOR PROCESS PLANNING AND PART PROGRAMMING", IN A. KUSIAK (ED.), ARTIFICIAL INTELLIGENCE: IMPLICATIONS FOR CIM, IFS PUBLICATIONS, KEMPSTON, U.K., AND SPRINGER-VERLAG, NEW YORK, PP. 301-326.

[6] TSANG, J. P. AND Y. LAGOUDE (1986). "PROCESS PLAN REPRESENTATION AND MANIPULATION IN GENERIC EXPERT PLANNING SYSTEMS", 1986 IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION, APRIL 7-10, SAN FRANCISCO, CALIFORNIA