Automatic Robotic Painting of Parts in Batch Size One

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Abstract

Today industrial automation of spray painting is limited to high part volumes and robot trajectories that are programmed by off-line programming and manual teach-in. This paper presents an approach that uses range image data to obtain the geometry of an unknown part and to automatically generate the robot spray painting trajectories. Laser strip range sensors are installed in front of the paint booth to acquire a range image of the part. Utilizing process knowledge (a geometric library containing descriptions of different geometric features relevant for the painting application) geometric primitives are detected in the range data. From the geometric primitives a normal vector field is generated that enables to extract main faces. The main faces are located in 3D space and the process knowledge related to each geometric primitive is utilized to obtain the trajectory for the paint gun. Results of painting a car mirror and a steering column are given.

1 Introduction

The objective of the European RTD project *FlexPaint* (www.flexpaint.org) is to automate robot programming for painting applications of small lot sizes with a very high number of part variants. The project goal is to provide economic possibilities for usage of robots for industrial painting tasks. As a matter of fact, economic justification hinder the application of the currently used conventional automation technology (off-line programming and/or manual teach-in) used for high volume production.

In this paper an inverse approach is presented to automatically obtain robotic paint paths from range sensor data and to automatically generate a feasible, complete and executable robot program. The approach must cope with a large spectrum of parts as depicted in Fig. 1. For each industrial customer the part families are known. The goal is to be able to paint any order of parts coming along the conveyor. The technical challenge is to detect the geometry of the part on the conveyor, to automatically infer from the geometry the robotic painting trajectory and to automatically generate a collision free robot program.

The automatic generation of a 3D paint path has been attempted in the SmartPainter project. The painting motion was generated by virtually folding out the surfaces to be painted, putting on the painting motion and folding back the surfaces and letting the painting motions following this folding of surfaces [2, 6]. However, this strategy is only applicable when 3D models of the objects are available and the curvature of the objects is relatively small. The patented technology from Advanced Robotics Technologies uses a 2D digital photo as input. The user decides on the screen where to apply paint strokes. The path planning for a robot is then done automatically [7].

The approach presented here uses range images of the part to detect geometric features and select the appropriate painting strategy. No CAD models of the parts are required. The paper progresses by giving an overview of the "inverse approach" to automatically generate the paint path from the sensor data (Section 2). The next

Figure 1: Examples of parts to be painted automatically: various gear boxes with motor, compressor tank, steering column of a truck, small parts on a frame, and rear view mirrors on a frame. The pictures show the parts in correct relative size.

sections describe the extraction of the basic geometries (Section 3 and 5) and the generation of the paint path (Section 4). Section 6 gives the results of the experiments.

2 System Description

The FlexPaint approach is based on the observation that the parts in Fig. 1 comprise a large number of *elementary geometries* with typical characteristics for an entire product family. Examples are rib-sections (cooling ribs), cylindrical surfaces (both shown on the motor, left in Fig. 1), and cavities (shown at the top of the gearbox and at the steering column in Fig. 1). Another type of surface are the surfaces of the rear view mirror. These surfaces are smooth free-form surfaces, which are very difficult to represent by use of simple geometric attributes such as cylinders, spheres and boxes.

The specification of elementary geometry types is based on the constraints of the painting process. The idea is to detect elementary geometries that can be linked to a process model. For example, the geometry ”flat surface” can be painted with a simple pattern of straight paint strokes. More complex geometric shapes, such as cavities or ribs, need specific painting strategies: spraying into the cavity and painting parallel to the rib orientation, respectively.

The elementary geometry types are defined in the *Geometry Library* and related to the process knowledge, which is specified in the *Procedure Library*. Fig. 2shows how the FlexPaint system operates.

The module “detect part geometry” uses the geometric definitions of the geometry library to describe the part given by the range sensor data (for details see Section 3). Additionally a simplified solid model is calculated, which represents a convex hull approximation of the part. It is utilized to model the part when generating collision-free motions (see Section 5).

The geometric part description is used to generate the painting trajectory of the spray gun (see Section 4). The module “establish collision-free robot motions” takes the tool trajectory and calculates the actual arm trajectories for a given robot manipulator and finally generates the program in a specific robot language (see Section 5).

3 Geometry Detection

The objective is to detect the elementary geometries in a range image. This section will present in detail the approach of detecting Process-oriented Features.

4 Paint Path Generation

The generation of paint paths is divided into the following steps: planning of the painting process, planning of collision free spray gun motions, and simulation of the robot trajectory to generate a robot program. Details will

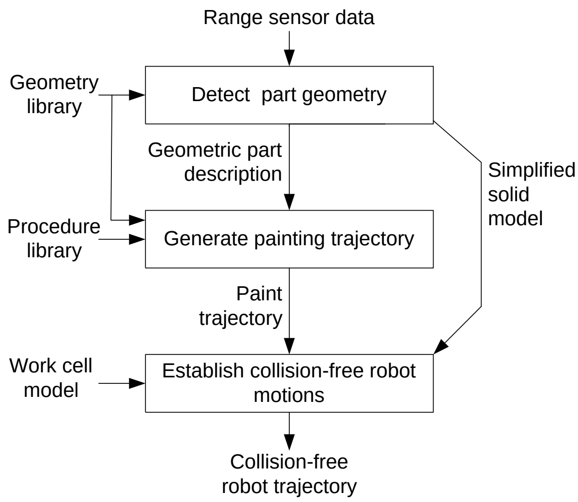

Figure 2: Block diagram of the FlexPaint system.

be given in the full paper.

5 Collision Free Trajectories

The trajectories of the paint gun and a simple convex hull model of the part and the cell are then used to obtain a Collision Free Robot trajectory. This module is already a commercially available product from AMROSE, Ltd., but had to be customized for the FlexPaint project. Finally, the robot programm is generated automatically using RobotStudio, which is a virtual controller for ABB robots.

6 Experiments

The system is already implemented as a prototype and has been tested in ABB's technical center in Eichen, Germany (see Fig. 3). The purpose of these experiments was to prove the basic system concept. It was realised that process quality has to be optimized by establishing validated painting procedures for the individual geometric primitives. The painting procedures used were not established by preceding experiments. The prototype system used only one laser scanner and one robot. Since the surface was only scanned from one direction it was only possible to perform automatic spray painting of the scanned surface. However, it was observed that a relatively good painting quality was achieved on these parts of the surfaces, which were scanned. Some painting errors were caused by switching on and off the spray gun in wrong positions. Fig. 4 shows the robot executing the automatically generated program.

The prototype installation demonstrated to be capable of realising production constraints: (1) any series of parts of the industrial parts shown in Fig. 1 can be scanned. And, (2) the motion of the conveyor requires a processing time of about 30 seconds. Range image processing requires only about five seconds on a PC and path planning can be executed in 30 seconds on a high end PC.

7 Conclusion

Even though the project is primarily aimed towards robotic spray painting, the "inverse approach" proposed can be applied for obtaining process motions for a large range of processes in the field of surface treatment. Examples of processes in which the approach can be applied are: powder painting, washing and cleaning with liquid (including high-pressure cleaning), washing and cleaning with physical contact between tool and part, de-

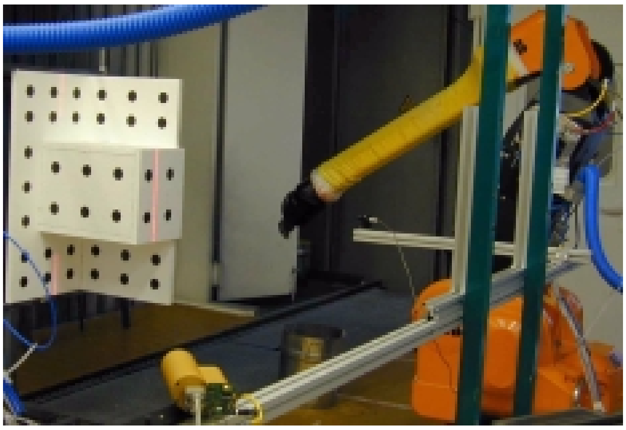

Figure 3: Painting cell with the calibration tool (left) and the camera (bottom front).

Figure 4: The robot painting the steering column with the automatically generated program. The black paint can be seen on the part.

greasing, sandblasting, polishing, sealing (e.g. for corrosion protection), inspection systems, polishing, grinding, deburring and gluing.

Acknowledgements

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