Semantic Segmentation for Flexible and Autonomous Manufacturing

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***Abstract*—Customized mass production of boats and other vehicles requires highly complex manufacturing processes that involve a high amount of automation. Key elements to enhance the efficiency of such systems are represented by vision and sensing, which provide robots with detailed information about the working environment. In this paper, we focus on the sanding process of boat molding tools by means of a robot, proposing the use of semantic segmentation to detect the key elements involved in production and increase the automation of the production process. We demonstrate the potential of semantic segmentation in an industrial environment which differs from the domestic scenes typically considered in the literature: it features a lower degree of variability with respect to domestic scenarios, but higher performances are required in the production environment to address challenging manufacturing operations successfully. Our segmentation algorithm has been thoroughly validated on a industrial dataset that was created on purpose, whose acquisition and annotation were speeded up thanks to our optimized pipeline.**

***Index Terms*—scene understanding, semantic segmentation, machine learning**

Fig. 1: Example of the industrial scenario considered in the COROMA project, including a boat hull and the sanding robot.

I. Introduction

The manufacturing process of boats, as well as aircrafts and automobiles, requires the production and assembly of several components, with extensive use of light and strong materials like Glass Fiber Reinforced Polymers (GFRPs). Such composite materials are common choices being the perfect trade-off considering all these aspects and given that they can also be easily molded into complex shapes. The mass production of GFRP components comprehends the design and manufacturing of a molding tool for each component. The surfaces of the molding tools must be perfect, since every imperfection in the molding tools affects the final component. The whole process to smooth and polish the surface include many sanding operations which represent more than half of the total manufacturing time and despite being heavy tasks, they are generally performed by human workers.

Under this perspective, one of the aims of the EU project COROMA[1] (COgnitively enhanced Robot for flexible MAnufacturing of metal and composites) is the robotic automation of the sanding procedure in the production of boats to improve the quality of work and achieve better efficiency and performance in the production phase. One of the key contributions of the project is to use vision to make the robot fully autonomous and capable of navigating across the production environment: once a boat to be sanded is recognized, the robot moves towards the boat and begin the sanding procedure as depicted in Figure 1. To achieve this goal, the robot needs to analyze and understand the environment, decomposing the scene into its most meaningful parts, like the boat components or structural elements (e.g. floor and walls), producing a point-wise labeling of the scene [1].

In the robotics community such problem is known as semantic segmentation: given an input image, the objective is to assign to each pixel in the image a label representing the class of interest which the pixel belong. Semantic segmentation is often tackled using supervised machine learning, where an algorithm learns to map an input to an output based on example input-output pairs. This requires huge datasets of pixel-wise annotated frames where each pixel is associated to a class label. Unfortunately, popular datasets for semantic segmentation are collected in indoor scenario like office and apartments [2] and do not contain the classes of interest for the particular industrial application (e.g. the boat components). This highlights the need to acquire a dataset specific for the industrial application, which is usually a time-consuming task especially regarding the annotation phase that is generally done manually for each single image in the dataset. To address this problem we proposed an optimized pipeline to quickly collect a dataset in an industrial setting.

[1] https://www.coroma-project.eu