Materials and Design 82 (2015) 290–296

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Computer vision and robotic manipulation for automated feeding of cork drillers

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ARTICLE INFO

Article history:
Received 16 September 2014
Revised 6 April 2015
Accepted 19 May 2015
Available online 20 May 2015

Keywords:
Cork
Computer vision
Machine learning
Forest products

ABSTRACT

The production of cork stoppers is currently a process in rapid evolution. Where in the past hand labor was common, today we observe increasing attempts to introduce technologies that increase the productivity of production lines. One these example are automated cork drillers that produce thousands of cork stoppers per hour. In order to harness this increase in productivity to its full potential, it must the followed by other processes in the production line upstream of the driller, as for example the feeding of the latter.

This article presents the application of computer vision techniques that extract information of cork strips that move on a conveyor belt, to obtain automated feeding of a cork driller using a robotic manipulator. Image Processing extracts information regarding the strip position and orientation, and also which side of the strip is visible. Thus the strip is consistently placed in the driller in order to extract stoppers from the best quality cork. The segmentation of the cork strips is obtained by background subtraction. To estimate the strip visible surface, we apply Machine Learning techniques that enable a robust classification given a set of features extracted from the cork texture.

In the experiences carried out, we were able to obtain 100% classification rate with a test dataset of more than a hundred cork strips.

1. Introduction

Cork plays a key role in the Portuguese economy [1,2]. Portugal produces around 50% of the world cork. Additionally, in order to fulfill its manufacturing sector capacity, it is the fourth largest cork importer. In sum, Portugal is the largest cork exporter in the world, with a share of 67% of all cork exports. Of all these exports, more than 42% are natural cork stoppers. Even with the growing presence of other alternative stoppers, natural cork stoppers are very in demand, and remain one of the main forces of the cork industry. To keep up with this volume of sales, the manufacturing sector must strive for a competitive edge. While some decades ago it was characterized by a traditional family-run business model, the current cork industry has undergone significant changes in the recent decades. Technology, specially in the automation field played a key role. It is estimated that around 40 million cork stoppers are produced daily in Portugal alone. Contributing to this level of productivity are automated drillers can produce several thousand cork stoppers per hour. These advances require other stages of the production line to keep up with the productivity increase while keeping errors at minimum.

We propose to address the problem of feeding the automated drillers, combining machine vision and robotic manipulation to produce a fast, flexible and intelligent system capable of providing the raw material to the machines at the required rate. To solve this problem, a system must be able to detect and identify cork strips, autonomously and robustly. This is a very challenging problem since cork is an heterogeneous material with a broad range of appearances. The cork industry colloquially terms the outer and inner part of the cork bark, the back and the belly, respectively. Additionally, the system must also be able to identify the side of a cork strip. Therefore, the system must recognize three different surfaces.

A promising solution to address the aforementioned issues is the application of Machine Learning [3] approaches. Machine Learning is a sub-field of Artificial Intelligence, that aims to develop and apply techniques that are able to learn directly from provided examples. Machine Learning has been successfully

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http://dx.doi.org/10.1016/j.matdes.2015.05.037
0261-3069/

applied in a variety of fields such as Computer Vision, Natural Language Processing, among others. In the context of this work, Machine Learning provides a powerful alternative in order to develop a system to automate the feeding of the drillers. One can obtain with relative ease, numerous examples of cork strips to train learning algorithms.

Related work pertaining the application of Computer Vision and Machine Learning in the cork industry has mostly focused on quality assessment of either planks [4] or stoppers [5–8]. Most works strive to learn from human interpretable features in order to draw comparisons with human experts. However this requires a domain knowledge that is not always available. In our work we learn from features commonly applied in the literature for surface analysis. To the best of the authors knowledge, this work represents the first development of a system designed to identify which cork surface is visible in an image.

The remaining paper is structured as follows. Section 2.1 presents an overview of the components comprising the vision and manipulation system. This section also provides detailed descriptions regarding the developed work at the software level. The experiments carried out and the results obtained are presented in Sections 3 and 4 concludes the paper.

2. Material and methods

Cork presents many interesting properties that help explain the wide variety of applications, ranging from construction material to fashion accessories [9]. Despite its varied use, one of the cork main applications is the production of wine stoppers. Cork stoppers represent an environmentally friendly alternative to more modern synthetic stoppers made of aluminum or plastic.

Cork wine stoppers can be obtained from single cork blocks or from agglomerated granular particles that usually result from byproducts of other production processes. In the first case, cork planks are cut into long strips with roughly a cork wide. Driller machines punch cylinders of cork that make up a whole stopper. The machines are manually operated and requires great skill. Since cork is an heterogeneous material, operators need to avoid imperfections and look for the best material to extract the stoppers. This slows down the production process and as a skilled worker can produce twenty thousand stoppers a day.

The alternative is to automate this process with robotic punching machines. These machines compromise the ability to avoid the material imperfections with an unparalleled productivity. Each machine can produce several thousand stoppers per hour. In order to minimize waste, the automated production process assumes that cork strips are placed in the same position. This way stoppers can be extracted from inner part of the cork, or the belly. Fig. 1 presents a side view of a cork strip, indicating the belly and the back of the cork.

With the increased productivity of the driller machines, the bottleneck of the production process becomes the feeding process. If manually performed, it is a rather dull task that may carry some risks. This opens the opportunity further automate the production line, by automating the feeding process.

To supply cork strips, a robotic arm is used. In order to maintain a simple conveyor system, computer vision techniques are used to detect a cork strip, estimate the position and orientation and determine the visible side in the image. The following subsections present the developed system, from both the hardware and software perspectives.

2.1. System overview

The following presents the overall system. The goal is to able to automate the feeding of the drillers, speeding up the process while freeing human workers for other tasks. In order to accomplish this goal we designed a system composed of five main components: a conveyor belt, a robotic arm, a gripper tool, a vision system and the processing units.

2.1.1. Conveyor belt

The main purpose of conveyor belt is to transport cork strips to the robotic manipulator. The belt is composed by a single uniform color that contrasts with the cork strips. The color used in our experiments was a dark green, however almost any other color is usable as long as the contrast requirement is met. It moves the strips at an adjustable constant speed and a digital encoder is a coupled to one of the conveyor axles to allow tracking of the moving strips (see Fig. 2).

2.1.2. Robotic arm

The robotic arm is expected to pickup the incoming cork strips and place them inside the driller. The arm is positioned besides the conveyor belt being able to manipulate strips on a portion of the belt length. The manipulator applied is 4 Dof SCARA robotic arm by OMRON presented in Fig. 3.

The SCARA arm can only move along the three main Cartesian directions. In order to rotate the strips we coupled a custom made gripper tool.

2.1.3. Gripper tool

The robotic arm was extended with the addition of a custom made gripper tool to pickup and rotate the strips placing them in the correct feeding orientation. This allows the application of a Cartesian manipulator in this type of tasks. The length of the tool arm was fixed at 20 cm to allow a broad range of incoming strip orientations. The gripper is actuated by pressurized air which allows for a firm grip without damaging the cork [10]. All the development of the gripper tool was made by Azevedos Industria [11] (see Fig. 4).

2.1.4. Vision system

The main focus of our contribution is the development of a vision system capable of detecting and identifying the cork strips that move along the conveyor belt. For initial stages of development a Microsoft Kinect depth sensor was considered. However, the large minimum range coupled with the low resolution of color images restricted the use of the sensor. With a correct placement directly on top of the conveyor belt a PtGrey Chameleon [12] camera proved sufficient. To avoid changes in lighting conditions a lighting a box was built and placed over the conveyor belt creating an area of controlled light.

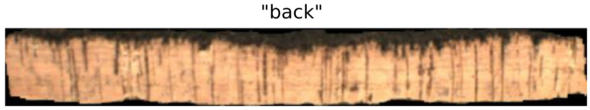

Fig. 1. Side view of a cork strip.