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A fuzzy sensor for color matching vision system

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ABSTRACT

This article presents the development of a vision system according to a fuzzy sensor concept with the aim to improve the wooden boards color matching. The main difficulty consists in the recognition of gradual color in an industrial context. This problem implies the use of a flexible and robust vision system. It must be focused on the techniques that are able to work with the imprecision of physical measurements and the subjective human definitions of colors. Indeed, the color classes are not often well separated and the different users can have different perceptions of the colors. So, the vision system must be easy to tune. To achieve such a system, the recognition step is done with a fuzzy reasoning classifier that is well-adapted for this application case. The proposed method is quite efficient with small learning data sets because of the generalisation capacity of both feature selection and recognition steps. This technique allows to keep the interpretability of the model. The obtained results are compared with more classical methods and show the efficiency of the proposed fuzzy sensor, especially for merging outputs of several sensors used together in multi-face application case.

1. Introduction

Today, many vision systems appear for the quality control of manufactured products. The wood product industry is particularly placed in a highly competitive market. The furniture suppliers want to improve the quality of wooden products by integrating the notion of color uniformity. In general, the color grading procedure is highly subjective and requires human intervention. Human operator decisions could be subjective and variable due to the fatigue of a work day. One relatively low-cost solution that may be applied to improve the color grading process involves adding a sensor specifically designed to capture the color properties of the wood, to existing industrial wood scanners. One solution is to develop fast and specialized equipment making the color characterization easier. The commonly used systems do not embed the processes in the sensors [1,2]. However, in an industrial context, it is important to design the system by integrating the decision in the sensors. Moreover, the perception function of the sensors must allow to provide the decision module with the useful information; but the precision of these data is not reliable. In this sense, the current sensors must be improved to obtain more "intelligent" tools. Indeed, a human inspector performs measurements, processes and decisions at the same time. An answer to this is to integrate the notion of intelligent sensor, and more precisely, fuzzy sensor concept.

To check the validity of the proposed concept, the experimental results have been obtained through franco-luxembourgian collaboration between the Research Center for Automatic Control of Nancy (CRAN) and a Luxembourgian company. The study framework aims to develop a robust recognition vision system for wooden board color classification. Color is a notion that is not easy to quantify and classical sensors are not sufficient. The proposed colorimetric fuzzy sensor is divided into two main parts.

The first one consists in the measurement part: RGB lines acquisition with CCD linear sensor, physical sensor

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correction and color characterization. This part includes the configuration step of the colorimetric fuzzy sensor.

The second one is the decision part: each wood sample, characterized by a measure is then labeled, using a fuzzy rule classifier.

In this paper, the vision system used and its context of use are presented. Then, the concepts of intelligent, symbolic and fuzzy sensors are detailed. An original approach is presented, using a fuzzy color classification system in relation with the fuzzy sensor concept. Finally, some results are provided to show the efficiency of the proposed approach and the advantage of this method is explained in a multi-face application case, where two sensor outputs are merged together to provide the final decision.

2. Problem statement and background

This study concerns the development of a sorting system for wooden boards according to their colorimetric aspect [3]. It is first necessary to present the production system and the industrial context. Indeed, the industrial constraints and (the industrial) process can add problems which will not be present in laboratory experimentations.

2.1. Presentation of the production system

The recognition of the wooden board color is carried out in real time on the industrial production line. These lines may reach speeds up to 220 m of board length per minute. The industrial process structure with its information flows are schematically represented in Fig. 1. After the color identification step, done by the vision system, color information is sent to an optimization step. Then each board is sent to a sorting line or to a cutting line. The cutting line aims to split the boards into uniformly colored piece of wood. The sorting line aims to group pieces of wood into specific classes, whose number and definition are given by the final customer. The boundary classes are very subjective in both cases. The sorting or cutting decision is taken by the optimization step of the system. This optimization must allow to improve the management of the production in terms of "cost and price" which concerns essentially the production management. To improve their competitiveness, industrialists must increase their production. They must optimize their production according to the needs in the market. Fig. 1 illustrates the connection between the different parts present in a production system. Indeed, the final product needs are saved in the information system of the company and these needs order the optimization of their production. To meet the needs, it is necessary to define the production rules: the quality and the quantity of products.

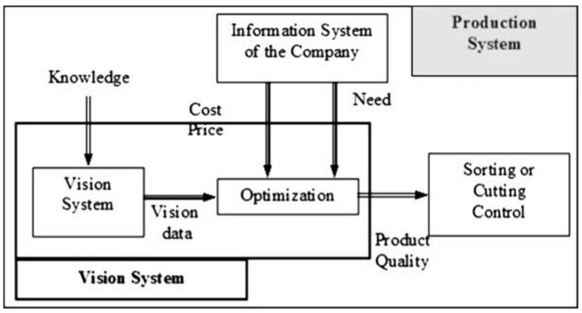

Fig. 1. Schematic representation of the production line. The arrows correspond to the information flows.

2.2. Industrial context

To carry out this study, a concrete industrial problem is considered. The conception of a vision system adapted to the wooden board classification requires the comprehension of the way a human operator works. The originality of the process concerns the color sorting which is realized only on the wooden board edges (board thickness). Indeed, the machining of handrails requires a uniform color in a large thickness (Fig. 2). To obtain this large thickness, three boards are glued by their face. So, the final product makes illusion of a product carved in an uncut wood piece. However, operators use the two wide faces to take their single and global decision (Fig. 2) and it is necessary to make the same classification only by taking into account the edge decisions.

Thus, the used vision system must integrate the a priori knowledge about the sorting, and the industrial constraints (boards only scanned by their edges). Today, the operators have the expertise of this field. In this sense, they are capable of defining a color with linguistic terms by following the human requests. In this case, the right inputs of the system must be defined, and so its comprehensible outputs according to the industrial needs (color classes).

The first part concerns the sensor measurements of the wood color. They are directly tied to the sensor acquisition and the ambient conditions (temperature, humidity, wood dust, etc.) which can make the measurements imprecise. Then, two solutions are conceivable to correct several imprecision:

- modelling the impact of the disruptive parameters to carry out a real-time correction of the data;
- taking into account the physical imprecision (non-perfect sensor) with a specialized process during the classification.

The second part concerns the system outputs. It concerns essentially the wooden experts' requests, i.e. the color range defined by the user. This range is often different according to each application case. Absolute color

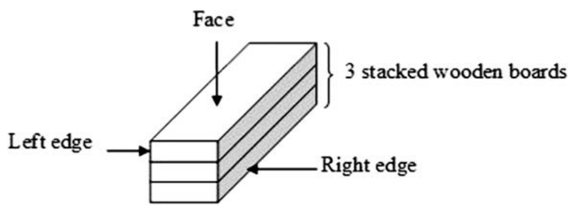

Fig. 2. Schematic representation of the final products considered in the study.