CIRP Journal of Manufacturing Science and Technology 13 (2016) 15–23

Contents lists available at ScienceDirect

CIRP Journal of Manufacturing Science and Technology

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

A knowledge database of qualified digitizing systems for the selection of the best system according to the application

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ARTICLE INFO

Article history:
Available online 21 January 2016

Keywords:
Knowledge based system
Reverse engineering
Inspection
Non-contact sensor
Decision process

ABSTRACT

Digitizing systems are widely used in industry for applications such as Reverse Engineering or inspection. Given the diversity of solutions, the selection of the most appropriate systems for an application has become a challenging task. To be efficient, system selection must rely on a knowledge base of the digitizing system performance with regard to the given application. Within this context, this paper aims at presenting how a knowledge database of qualified digitizing systems can be established according to ability and quality criteria. The best system is afterwards obtained by optimizing a cost function built as the weighting sum of the criteria, weighting depending on the considered application.

Introduction

Considering the large diversity of digitizing systems now proposed, the choice of the most appropriate system for a given application can be difficult. This has become a critical issue as applications are more and more diversified – Reverse Engineering, part inspection, rapid copying, dynamical balancing, and so on – and have different requirements. The selection is generally done by an expert in connection with the application requirements.

In the literature some studies address this issue. In [1], the authors proposed to select the most appropriate system for an application of old mechanism redesigning based on a decision tree. The choice relies on various criteria classified into categories: operability factors (whether completeness is required or not, whether palpation is authorized or not ...), and data on the object to be digitized (material, accessibility, accuracy, dimensions ...). To perform the selection, those criteria (or categories) are hierarchized as a decision tree. For applications of part inspection, Savio et al. [2] present a selection guide of the digitizing system type based on the object dimensions and the measuring uncertainty. These authors propose a classification of the types but the approach remains qualitative. Loriot [3] introduces several criteria, such as acquisition time, accuracy, material texture, ergonomics, and so on, to classify digitizing systems for duplication, visualization and analysis applications that belong to the computer graphics field. The aim of his study is to define a hierarchy of the applications for a given system. Barbero et al. [4] perform a comparative study of various digitizing systems based on the evaluation of different criteria: accuracy, density of points, completeness, etc. The study only focuses on system assessment and not on the selection of the most appropriate one in relation with an application. In [5], a measuring system selection is presented for an application of part inspection based on various factors such as sensor uncertainty, geometric attributes, material, surface finish and part flexibility. They propose to select the most suited sensor using a knowledge-based method. But, in practice, the knowledge is simply formalized as basic rules: a tactile probe is not suitable for flexible parts, the sensor uncertainty should satisfy the requirement of the tolerance being measured, etc. If such an approach seems interesting, the list of all the rules used is not clearly detailed. Moreover, the approach is only implemented for a laser scanner and a touch probe. For a specific application of crankshaft balancing, Zuquete et al. [6] propose to select the best-suited system by assessing optical digitizing systems thanks to indicators. Those indicators–noise, trueness, accessibility, and measured area, are obtained through a specific protocol based on the measurement of simple artefacts. Audfray et al. [7] extend this work by defining an assessment protocol applicable to a large range of digitizing systems and suggest storing information in databases. The first database is provided by the manufacturer's information and is used to select admissible systems according to criteria of ability. The second one, which results from the assessment protocol, is referred to as the qualified digitizing system database and gathers performance indicators (digitizing noise, trueness, acquisition time, etc.) that are used to elaborate a cost function. The best system is

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http://dx.doi.org/10.1016/j.cirpj.2015.12.002
1755-5817/

thus selected among the admissible systems as the one that minimizes the cost function built as the weighting sum of the indicators.

Methods proposed in the literature do not answer the general issue of finding the best digitizing system according to an application that could be RE, copying, part inspection, etc. They are most generally only dedicated to a given application, or if they consider various applications, they propose a classification of the systems but not a selection of the most appropriate system. Nevertheless, we can bring out some interesting key points. First, selection methods rely on criteria that can be classified into categories. Then, knowledge-based methods seem relevant to help in finding the most appropriate system, as for instance by criteria hierarchization as a decision tree [1] or by the use of simple rules [5].

The approach developed by Audfray et al. [7], applied first to part inspection, is interesting as the selection is made on the basis of non-subjective and evaluable performance indicators. It could be easily extended to other applications by linking the weightings with the considered application. This would require a change in the database structure so that it would include a database of applications. Within this context, this paper aims at presenting how a knowledge-based system can be used for the selection of the best digitizing system for a given application. As it will be described in the Database of qualified digitizing systems section, a digitizing system is a couple sensor/device. The originality of the approach is that a large diversity of triangular-based sensors (laser-plane, structured light, etc.) can be considered for a wide variety of applications (RE, part inspection, crankshaft balancing, etc.).

Knowledge for the selection of the best digitizing system

The idea is to design and develop a knowledge-based system that can be used systematically for the selection of the best digitizing system in relation with a given application. Therefore, the proposed approach inspired by the method proposed in [8] couples an efficient and systematic knowledge database with a decision system to support the optimal selection satisfying the application and the user constraints. The aim is the use and the communication of knowledge between different users; therefore, we consider knowledge within an objectivist perspective for which formal knowledge is preferred to tacit knowledge [9,10]. In this direction, the proposed knowledge-system consists of two databases. The first one concerns the digitizing systems and gathers qualified information issued from an assessment protocol. The originality is here that this database is built from objective information, as the protocol is the same for all digitizing systems. The second database is designed to embed and structure the expert's knowledge concerning the various applications requiring a digitizing system. The objective is to limit the intervention of the expert to this database construction, and not to the decision process. Then, the selection of the best system for a given application is performed through a decision process based on the assessment of performance functions.

Database of qualified digitizing systems

Database structure

A digitizing system is defined by a sensor/device couple [7]. The sensors, or acquisition systems, are generally classified into two main categories: contact or non-contact sensors. The latter are most often optical sensors based on triangulation techniques, tomography or vision (Fig. 1).

The device, or displacement system, allows the relative sensor/surface positioning throughout the whole digitizing process. The most classical devices include 3D positioning systems: CMM, machine tools, robots or articulated arms. Either sensors or devices possess intrinsic factors corresponding to manufacturer's data such as (without being exhaustive) sensor technology, field of view, resolution, device working space, acquisition speed, accuracy, etc. These characteristics are essential for the digitizing system selection, but the main difficulty is that they are not comparable. For instance, manufacturers give a value of accuracy but they generally do not specify how this value is obtained, and when they specify their protocol, the conditions under which it is obtained vary in function of the manufacturer. The selection of the best digitized system must lead to the choice of a sensor and a device according to non-subjective criteria. It is thus necessary to build objective indicators allowing the comparison between systems.

In the literature, some authors propose to classify the selection criteria according to categories. In [1] for instance, authors separate operability factors from factors related to the part to be measured. Classification according to quality and/or performance criteria is also addressed [5–7]. Within this context, we propose to define 3 main categories of indicators. Some of them are directly built from the intrinsic factors, whereas others result from a specific protocol.

- *Ability indicators*: they account for the aptitude of the system according to the measuring scale, the part properties (rigidity,

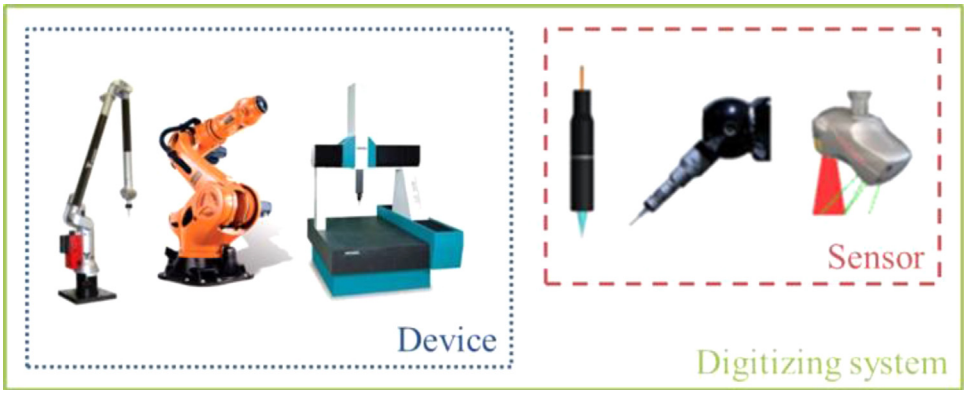

Fig. 1. Digitizing systems.