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An automated picking workstation for healthcare applications

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A B S T R A C T

The costs associated with the management of healthcare systems have been subject to continuous scrutiny for some time now, with a view to reducing them without affecting the quality as perceived by final users. A number of different solutions have arisen based on centralisation of healthcare services and investments in Information Technology (IT). One such example is centralised management of pharmaceuticals among a group of hospitals which is then incorporated into the different steps of the automation supply chain. This paper focuses on a new picking workstation available for insertion in automated pharmaceutical distribution centres and which is capable of replacing manual workstations and bringing about improvements in working time. The workstation described uses a sophisticated computer vision algorithm to allow picking of very diverse and complex objects randomly available on a belt or in bins. The algorithm exploits state-of-the-art feature descriptors for an approach that is robust against occlusions and distracting objects, and invariant to scale, rotation or illumination changes. Finally, the performance of the designed picking workstation is tested in a large experimentation focused on the management of pharmaceutical items.

1. Introduction

International healthcare systems are under increasing pressure to reduce waste and eliminate unnecessary costs while still improving the quality of patient care. Healthcare logistics and supply chain management are therefore coming under a great deal of scrutiny from both practitioners and academics (Battini, Faccio, Persona, & Sgarbossa, 2009; Bradley, 2000).

For example, Bowman (1997) cites that healthcare supply chain inefficiencies amount to $11 billion (or 48%) of the total annual cost of $23 billion. Among those processes with potential for improvement, pharmaceutical logistics is significant in terms of the resources and costs involved and their effect on the final perceived service level (de Vries, 2011).

Traditional management is therefore currently under scrutiny and innovative models are being implemented on a continuous basis. For example, some contributions have recently appeared which describe methodologies and the effects of the introduction of centralised drugs management on order issue and receipt, centralised warehouse management, distribution to end users or simply regarding centralised logistics management. In this context it is clear that the new emerging figure of central distributor is appreciated for the benefits it brings when introduced into the supply chain, both when managing ward stocks (hence the reference to a Ward Stock Drug Distribution System – WSDDS) and when dispensing unit dose (hence the reference to a Unit Dose Drug Dispensing System – UDDDS) (Summerfield, 1983).

The process of picking items is critical to the performance of distribution centres. This paper therefore focuses on an automated pick-and-place workstation whose operative behaviour is based on innovative computer-vision-driven robotics (as defined in Asadi, 2011) and whose main potentialities are described below:

- *Different object types and a highly variable appearance*: pharmaceuticals are characterised by highly variable appearance in terms of colour, size, primary packages (i.e. regular-shaped boxes, irregular-shaped boxes with transparents, flowpacks, etc.). The workstation manages different types of object of different dimensions and complexity, available for both WSDDS and UDDDS.
- *Randomly available objects*: most of the picking systems consider the scenario of well-separated objects, well-aligned on the belt and with synchronised grasping of the objects. Pharmaceuticals are sometimes characterised by irregular dispositions in a bin or on a conveyor belt, especially when items in flowpacks are handled or UDDDSs are served.
- *Multiple instances and distractors*: while in other image processing and computer vision applications the basic objective is to identify the single best instance of the target/query object, with

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pick-and-place applications the aim is not just to classify the first (or best) instance but to determine the locations, orientations and sizes of all or most of the duplicates/instances. Object duplicates can have different sizes, poses and orientations, and can be seen from different viewpoints and under different illumination. Moreover, in real-life applications the system must also account for the presence of distractors, i.e. other types of objects that differ from the target object and which should not be detected.
- *Heavily occluded objects*: as a consequence of the latter requirements, objects can be severely occluded.
- *High working speed*: when picking workstations are included in fully automated UDCs, the required working speed is very high; a fast detection technique is used to process up to a hundred objects a minute.

The automated picking workstation described in this paper uses state-of-the-art computer vision techniques based on local features, specifically single-point SIFT (Lowe, 2004), which have proven to be robust to scale and translation variations, rotations and, at least partially, illumination changes. When handling complex, reflective, low-textured and heavily occluded objects, humans also rely only on very few visual features. To obtain multiple object identification in such complex scenarios we use a novel clustering method which exploits the Euclidean transformation hypothesis and the definition of a small set of *principal points* of the shape, i.e. points that characterise and delimit the object shape. To improve accuracy with low-textured, reflective or semi-transparent objects, multiple models of the target object can be used.

This paper is structured as follows. Section 2 analyses related publications. Section 3 describes the main components and characteristics of the proposed workstation. In Section 4, a wide experimentation in the field of localisation and picking of pharmaceuticals is conducted and the results reported and commented. Finally, Section 5 outlines some conclusions.

2. Literature review

As anticipated in the introductory section, this paper focuses on the characteristics and effects of the adoption of an automated picking workstation in a pharmaceutical centralised warehouse, using vision-based algorithms for object detection. The literature review is therefore performed by analysing related issues: healthcare supply chains (Section 2.1), picking systems and workstations (Section 2.2), vision-based systems for pick-and-place applications with particular emphasis on the types of object handled and their characteristics (Section 2.3).

2.1. Healthcare supply chains

The healthcare supply chains can be conceptualised as comprising five main actors (Burns et al., 2002): (a) *healthcare producers*: manufacturing and service companies including pharmaceutical and biotechnology manufacturers, medical device makers, medical suppliers and information technology firms; (b) *healthcare product intermediaries*: wholesalers, mail order distributors and group purchasing organisations; (c) *healthcare providers*: hospitals, physicians, integrated delivery networks and pharmacies; (d) *healthcare fiscal intermediaries*: insurers, health maintenance organisations and pharmacy benefit managers; and (e) *purchasers*: government, employers, individuals and employer coalitions.

The portion of the supply chain on which this paper focuses is the relationship between pharmaceutical companies and hospitals and clinics.

Such a relation is also analysed in Battini et al. (2009) where, in the case of companies supplying pharmaceuticals, the authors state that 3 main management models are implemented:

(1) A traditional approach in which there is a central pharmacy store in every hospital that decides what and how to buy. This is the most widespread system (Dongsoo, 2005).
(2) Centralised management of drugs in a district or regional centre (Unique Distributive Centre – UDC), whose insertion in the supply chain is mainly justified by e.g. expected savings due to elimination of stocks duplication along with economies of scale in the purchasing, storing, handling and transportation of items (Nollet & Beaulieu, 2003; Nicholson, Vakharia, & Selcuk Erenguc, 2004; Chandra, 2008).
(3) All physical managing and pharmaceutical movements are carried out by a third party (logistics operator). However, the hospital pharmacy is in charge of deciding what and how to order.

These models are schematised in Fig. 1 using the framework introduced in Caldeira Pedroso and Nakano (2009).

This paper focuses on innovative healthcare supply chains shaped as described in model 2, and in particular on an automated picking solution to improve their performance.

2.2. Picking systems and workstations in distribution centres and warehouses included in healthcare supply chains

Order picking and the process of retrieving products from storage or buffer areas in response to a specific customer request are among the most labour-intensive operations in manual systems and are a very capital-intensive operation in automated systems (Goetschalckx & Ashayery, 1989; Tompkins, White, Bozer, Frazelle, & Tanchoco, 2003; van den Berg & Zijm, 1999).

The focus of this paper is therefore on innovative solutions for improving the behaviour of picking techniques in healthcare supply chains.

Order picking systems can be classified according to whether humans or automated machines are used (de Koster, Le-Duc, & Roodbergen, 2007). The former group includes picker-to-parts, parts-to-picker and put systems. Picker-to-parts systems are characterised by pickers who walk or drive along the aisles to pick items. Parts-to-picker systems include Automated Storage and Retrieval Systems (AS/RS). These use mainly aisle-bound cranes that retrieve one or more unit loads (pallets or bins) and bring them to a pick position from where the picker takes the required number of pieces. Next, the remaining load is stored again. Put systems consist of a retrieval and distribution process where items are initially retrieved, either in a parts-to-picker or in a picker-to-parts manner. Afterwards, a bin with these pre-picked units is usually offered to an order picker who distributes them over customer orders.

Alternatively, automated picking (e.g. see Fig. 2) and picking robot systems use machines for order picking and are preferred for the picking of small, valuable, and delicate items.

Most warehouses typically feature a mixture of such models, examples of which in the field of healthcare supply chains are reported in Figs. 3–5 which illustrate combinations of automated picking with manual picker-to-parts, manual parts-to-picker or robotic picker respectively.

This paper focuses on the robotic picking workstation, which is particularly suitable for applications similar to those depicted in Fig. 5.