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Low-cost 3D food printing

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Abstract

In a close future, it will be possible to print any kind of food through a nozzle, with the desired nutritive quantity, originating richer, healthier and more controlled meals. The exponential growth of this new market led to intensive research worldwide; however, dealing with a low cost printer is not an easy task for the general consumer. This paper presents the difficulties that a common user might face using a 3D food printer, and explains the assembly, configuration and modification of a RepRap Prusa I3 3D printer. An extrusion equipment capable of extruding materials in paste form, focused in the cake industry with sugar pastes, was developed. This extruder allowed the deposition of new materials that couldn't previously be used since they have a solid consistency at low temperatures. The new extruder was tested with two different types of pastes: Nutella® chocolate and sugar pastes. The sugar paste prototypes already produced opened different opportunities to improve the surface quality, use of pastes with different colours, more than one extruder and others that in the limit contribute to the possibility of a small business in the cake design area.

Keywords: 3D printing; RepRap; Prusa I3; sugar paste; extrusion; food printing.

1. Introduction

The evolution and quick growth of the low cost three-dimensional (3D) printers' sales makes this an interesting and updated topic of study. Three-dimensional printing applied to the food industry will be the focus of this work. As this topic takes first steps, this study reveals to be a major opportunity, considering that it will become an important part of the daily routine of the general consumer in a not so far away future, being also an enormous change on people habits. For example, NASA has been studying ways to implement 3D food printing in space [1].

1.1. Structure

The bibliographic review of this study was organized in a way that allows the user to understand the sequence of processes involved in 3D printing, as well as the equipment and software available that are suitable to each kind of user. The non-subtle growth watched in the last decade and how far this technology has evolved will be discussed in this topic. The types of printers and its specific use, the importance of such machines for industry and the way they can revolutionize mass production lines are also addressed. Throughout this chapter, special attention is given to the food industry, but also to the advances that could be associated with this kind of development [2].

The experimental component deals with the configuration development and settings modifications so that handling during the printing process is suitable.

An explanation of the assembly and programming a low cost 3D printing equipment will be given. In the user point of view, this chapter will be very important because it will allow understanding the biggest faults and difficulties in using an equipment of this kind. This work reviews the state-of-art of food printing and

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a 3D commercial printer will be adapted to be able to print sugar paste. This equipment will also open the opportunity to use other types of food, unlocking a new barrier in 3D printing [2].

2. Low Cost Three-dimensional Printing

Low Cost 3D printing is based on a simplification of the FDM process; the principle is the deposition of a melted material by a dedicated extruder. The concept might seems simple, in comparison to industrial processes [3]. Nowadays, low cost 3D printing can be separated in two branches: Open source and Closed source. Having an Open source printer, there is no mandatory software. In other hand, using Closed Source, the choice is limited to what the manufacturer defines for each brand. Companies that produce their own machines mostly use closed systems, while the open systems are more appropriate to the common user; however, as it will be explained, these equipments demand a set of knowledge that are not available to the common users.

In 2013, 3D printers registered a sales increase of 34.9%, the highest value registered until that date. This value corresponds to 2.42 billion euros worldwide [4]. Over the past decade, the average growth was 27%, and in the last three years was 32.2%, according to the *Wohlers Report* from 2014 [5]. This growth was boosted by the appearance of equipments of less than 4,000 €. The personal 3D printers are the roots of a technologic advance that was not seen in over twenty years. The reason for this sudden change is related to the appearing of new low cost technologies, especially with the easy-use that makes them available for every type of users, creating a new market. This change is happening now due to the breaking of patents of FDM in 2004, liberating this process to all users [6].

2.1. Its importance

In what way can a 3D printer be profitable in industry? The basic principle in this sector is manufacture cheap and in large quantities in order to obtain profit. How can be rentable to print a model while in the same period of time an injection machine is able to produce two or three? Three-dimensional printing offers a different perspective of selling, the concept of personalization to companies. The large-scale producers are able to sell small series of a product without falling in great expenses [7]. For example, a toy company decides to fabricate a new car model. For its production several injection moulds are necessary, and each one will cost approximately 100,000 €. As the main goal is to obtain profit, the company will have to produce millions of units to get positive balance. What if the company gets a production order of 3,000 units for a special edition of that model which is slightly different from the original? There are several ways to solve this problem: the company buys new moulds and faces a significant loss, the company buys a new mould and increases the price of the car, or the company 3D prints the special edition car [7]. Additive manufacturing allows a model x to be different from the model y, exactly with the same production cost. The difference between the two models will only be the CAD file, while with other production techniques the components have to be produced separately. With 3D printing, all parts of the model can be produced at once and with several different materials (obviously depending on the 3D printer employed). Summing up, 3D printing offers the advantage of customization and cheap production for a single part, and capability to produce parts that cannot be created with other methods. However, some disadvantages can be identified: not rentable for large series (at least for the majority of products), worst dimensional tolerances, weaker materials properties, and not the best surface finishing [6].

3. Experimental Procedure

3.1. RepRap Prusa I3 construction

In order to accomplish this project, a Reprap Prusa I3 equipment was acquired, which had to be disassembled and posteriorly reconstructed. This model was chosen due to its metallic structural components. Besides being an Open source equipment that allows all kinds of changes, it is a model that presents a stiffer structure, and presents a higher relation quality-price for this study.

3.1.1. Structure assembly

To properly assemble Prusa I3, it should be set up by axis (Fig. 1). The order of the axis is not important because none requires full operation of the others. The assembly of the axis together, and the vertical structure is the subsequent step. Since each one of the axis has several guides, it is necessary to constantly measure the parallelism and distances. After each assembly, a calibration is demanded. Posteriorly it is added the heated bed, the filament extruder and the end stop sensors.

3.1.2. Hardware assembly

The equipment's hardware consists of the coupling among an Arduino 2506, a RAMPS 1.4 (Reprap