Contributions of Information and communication technologies to industrialization of additive manufacturing

Abdelhak Kaci[1*]*, Samir* Hamaci[2]*, Ikram* Elabassi[2] and *Rachid* Chelouah[3]

[1] CY Cergy Paris Université, L2MGC, Neuville-sur-Oise, 95031 Cergy-Pontoise, France
[2] ECAM-EPMI, Quartz, 13 Bd de l'Hautil, 95000 Cergy, France
[3] CY Cergy Paris Université, ETIS, Neuville-sur-Oise, 95031 Cergy-Pontoise, France

Abstract. Additive manufacturing is in clear progress in the field of civil engineering construction, essentially boosting by the development of new information and communication technologies. For better industrialization of the use of this technique, in-situ control of products manufactured along the production line is a major issue. In this work we were able to supervise the quality of printed object along the process by comparing the target values and those measured by image processing obtained by a camera installed in the printing device. We have developed a program that allows us to measure the deformations of the different layers and thus to assess the difference between the values of the target ratings and those achieved. This deviation is defined as a criterion for validating piece conformity and can also be used to adapt the process parameters.

1 Introduction

In the last years, the use of additive manufacturing or 3D printing technique keeps increasing. According to study of Sculpteo [1], after prototyping and proof of concepts, production with 3D printing continues also to rise. We observe also that an increase in the use of 3D printing for research and education which corresponds to increased demand for new materials and technologies in the market. However mass production and industrialization are less important (about 13%) and need to be improved.

The global additive manufacturing market is doing very well, having exceeded the $ 10 billion mark in 2019 (According to the latest report by the American firm SmarTech Analysis) and this for the four main segments of 3D printing: equipment, materials, software and services. The forecast for 2029 can reach 53 billion dollars!

Moreover, additive manufacturing is present in all sectors of industrial activity: services, automotive, aeronautics, health, mechanics and recently in civil engineering in the two sectors of Building and Public Works [2]. The market is estimated at around 3.2% and several projects are being carried out and others are under development thanks to start-ups and the new information and communication technologies (NICT).

During the printing process, the settings of the process parameters must be made according to the rheological parameters of the material which varies during the process [3].

---

* Corresponding author: abdelhak.kaci@cyu.fr

For better industrialization of the use of this technique, in-situ control of products manufactured along the production line is a major issue. We propose in this work to supervise the quality of printed object along the process by comparing the target values and those measured by image processing obtained by a camera installed in the printing device. Using developed program, we that allows us to measure the deformations of the different layers and thus to assess the difference between the values of the target ratings and those achieved. This deviation is defined as a criterion for validating piece conformity and can also be used to adapt the process parameters.

2 Materials and equipment

2.1 Tested materials

The used mixture is essentially based on clay. The water content was determined according to rheological criteria target taking account printing process requirement:

1. the quality of outlet flow and;

2. the yield stress value able to deposit different layers without collapsing.

The best mix is obtained for the water dosage of 35% where material was extruded with a constant and continuous flow rate. The slump test is used to estimate a yield stress value. The estimated critical height corresponds to 7 layers which was confirmed by the tests carried out and showing in present video. So, we could print 6 superposed layers and we noted that from the 7th one the element collapses. Which is similar for study of Chems et al. [4].

2.2 Used equipment

For printing we have used a homemade printer "BK3D" (figure 1) where different instructions are introduced in "g-code" file format (including trajectories, displacement and extrusion speeds, ...). A digital camera was installed with adapted lighting system.
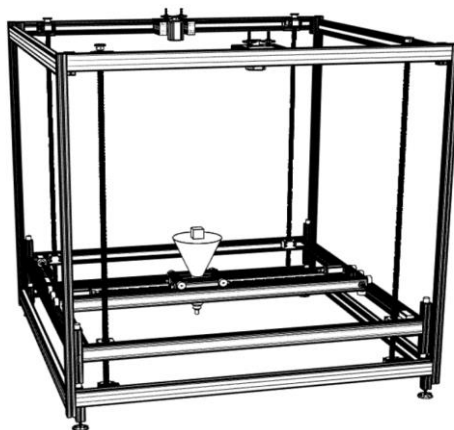

Fig. 1. Schematic of the used 3D Printing device (BK3D)

3 Artificial vision control

In this part, we present our approach to control the quality of the produced part, using artificial vision. The principle consists in using a camera which will captured the image of the printed part, which will be analyzed by an image processing algorithm developed for this goal.

3.1 Region of interest

The first step of the analysis consists in extracting the part of the image to be analyzed which is called region of interest (ROI).
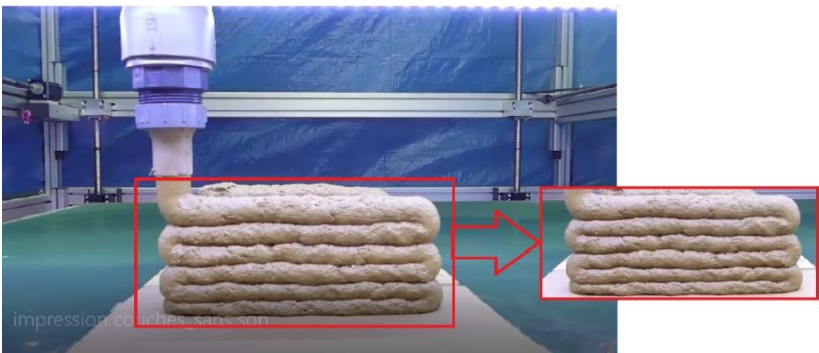

Fig. 2. Extraction of region of interest (ROI)

3.2 Image processing

In this second step we do some transformation of image thanks to functions included in the OpenCV software.

3.2.1 Gray function

We use the gray function to eliminate the colors and have the image in shades of gray. The class named Imgproc from the OpenCV software package provides methods to convert an image from one color to another.

Fig. 3. Applied Gray function on ROI.

To be able to be more precise for the function which will follow, we will pass the gray image with a blur. During the Gaussian blur operation, the image is convolved with a Gaussian filter instead of the filter in box. The Gaussian filter is a low pass filter that removes high frequency components are reduced.

3.2.2 Canny function

This function is used to detect the edges of an image (figure 4.a).

(a)   (b)

Fig. 4. Edge detection with Canny function: (a) without threshold values (b) with threshold values.

To detect only the edges of the layers and not what is between the layers, we have defined a minimum (150) and maximum (255) threshold so that only the contours of the layers remain (figure 4.b).

3.2.3 Hough Lines

With Canny image result we can use Hough transformation to detect lines (figure 5.a). To have more precision we must readjust the min_line_length values (minimum number of pixels making up a line) and max_line_gap (maximum gap in pixels between line segments connectable). In our case they values are : min_line_length = 30 and max_line_gap = 25.
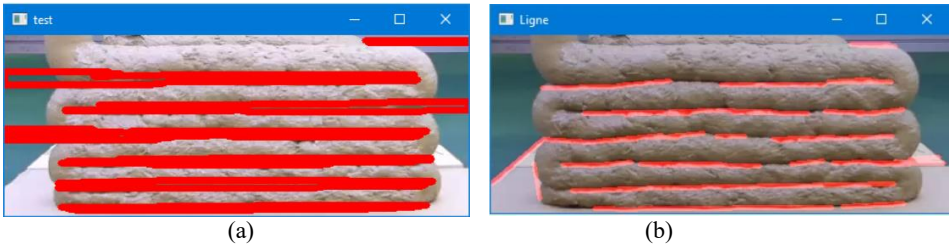

(a)   (b)

Fig. 5. Hough lines : (a) without threshold values (b) with threshold values.

To have more precision we must readjust the min_line_length values (minimum number of pixels making up a line) and max_line_gap (maximum gap in pixels between line segments connectable). In our case they value are: min_line_length = 30 and max_line_gap = 25.
So that lines are not separated and that the lines which are not horizontal disappear, we have defined a condition to draw the lines which are on the same plane in y.

We had 41 lines and the goal is to merge them to have only 9. The objective would be to have a maximum of 7 lines. For this, the min_line_length and max_line_gap parameters must be improved.

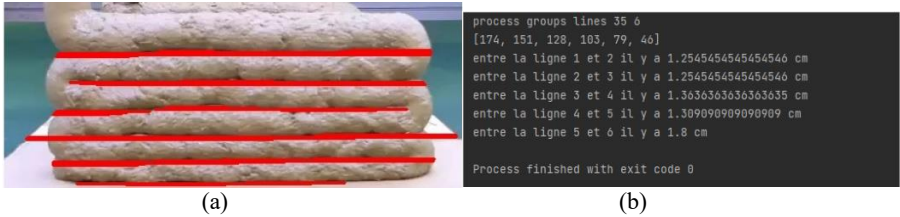(a)   (b)

Fig. 6. (a) Hough lines (b) estimated distances between lines.

Then the hough lines are refined to make them more readable.
The coordinates of the lines and their base number plus the number that remains after processing can be obtained with writing program. Thanks to the coordinate, we determine the distance (in pixels) between each line and with the size of the nozzle we can determine the size (in cm) and then a condition is added to stop the printer process. The distances between the lines are displayed in cm (Figure 6.b).

3.3 Acceptability criteria

To validate the quality of the printed product, we have defined an acceptability criterion related to the thickness of the layers, which amounts to calculating the distance between two lines. The principle consists in calculating the absolute error and the relative error to see if the latter are acceptable. For that, we note :

- ΔX= Absolute error, which corresponds to the absolute value of the difference between the actual desired distance between two layers, which is denoted X and the measured distance, which is denoted X0.

$$\Delta X = |X0 - X| \tag{1}$$

This error must tend towards a value denoted by β, otherwise the printed product is of poor quality, the printing must be redone.

A second comparison parameter is analyzed, to be able to verify the quality of the printed part, it is the height of the part. For that, we calculate the relative error of the height of the printed part.

- $\Delta\xi$= Relative Error, which corresponds to the ratio between the absolute error and the real distance. It is expressed as a percentage.

$$\Delta\xi = (|h0 - h\,I|)\,/\,h \tag{2}$$

An error threshold, noted δ, is set to validate the quality of the printed part.

4 Conclusion

The control of quality of printed element is crucial for the industrialization of 3D printing technique. The uses of computer vision can contribute of this.

In this study we have shown a methodology to evaluate a quality of printed object thanks to computer vision. The evaluation of distances can be used to assess a quality using and admissibility creteria.

This preliminary work will serve to build a data base to more understand relationship between materials properties and process. Machine learning technique will be used for this aim in order to improve quality of printed object on acting on mix design formulation or in the process parameters (velocity of extrusion, displacement, ….).

Acknowledgment

References

1. The State of 3D Printing, e-book, by Sculpteo (2020)
2. Mechtcherine, V., Bos, F.P., Perrot, A., da Silva, W.R.L., Nerella, V.N., Fataei, S., Wolfs, R.J.M., Sonebi, M., Roussel, N. : Extrusion-based additive manufacturing with cementbased materials – Production steps, processes, and their underlying physics: A review. Cement and Concrete Research **132**, (2020)
3. Ngo TD, Kashani A, Imbalzano G, et al, Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. Composites Part B: Engineering **143**:172–196,(2018)
4. Anwar, C., Benamara, A., Kaci, A.," Flax Fibers Composite Made up by 3D Printing ", Construction Technologies and Architecture, **1,** 842-846 (2022)