WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Preventing Experiment the Print of 3D Object from G-Code Files

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ABSTRACT

In this paper, we would like to propose a solution to encrypt 2D slices in 3D printing process to prevent un-authorized users. The 2D slices of 3D printing data is encrypted in the frequency domain or in the spatial domain by the secret key to generate the encrypted data of 3D printing. We implemented the proposed solution in both the frequency domain based on Discrete Cosine Transform and the spatial domain based on geometric transform. The entire 2D slices of 3D printing data is altered and secured after the encryption process.The proposed solution is responsive to the security requirements for the secured storage and transmission. Experimental resultsalso verified that the proposed solution iseffective to 3D printing data and independent on the format of 3D printing models.

Keywords: 3D printing, 3D printing data, 3D printing security, DCT and Geometric Transformation.

1.Introduction

The three-dimensional printing (3D printing) is a method of converting a virtual 3D model into a physical 3D object [1].In order to print a physical 3D object from a 3D printing model by a 3D printer, the 3D printing model must be cut into a set of 2D slices. This set of 2D slices is stored in a file that is the input data of a 3D printer to print physical 3D objects(see Fig. 1). These 2D slices are 3D printing data.Since 3D printing is applied to many areas of life [2], the data of 3D printing is often attacked by pirates. 3D printing models are designed by designer and then stored in a database or transmitted to user via Internet.

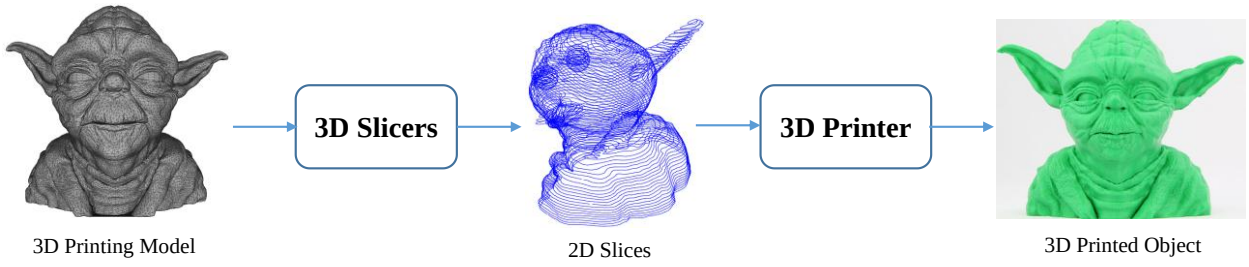


Fig. 1. General 3D Printing Process

To prevent attacks to 3D printing models and the files of 2D slices, encryption solutions for 3D printing model and the file of 2D slice are suitable. The simplest method is to convert 3D printing model or the file of 2D slices into bits-stream and then encrypt them by the data encryption standards as Data Encryption Standard (DES), Advance Encryption Standard (AES) or others. Data encryption is a process of altering the original data to new data that is different with the original data. The conventional work of data encryption is to convert the original data to bits stream and then encrypt it by the encryption standards as DES (Data Encryption Standard), AES (Advanced Encryption Standard), MD5 (Message-Digest Algorithm 5) or Tri-DES as shown in Fig. 2.

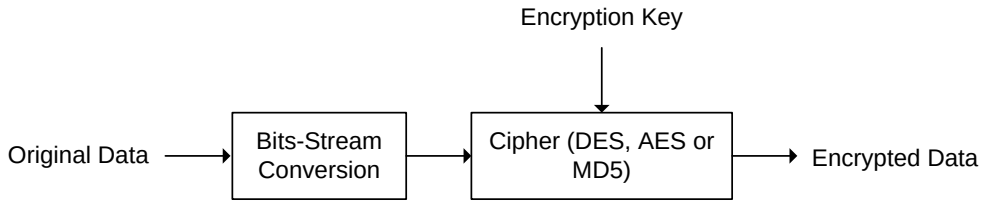


Fig. 2. Conventional Data Encryption

In order to respond toabove issue, we would like to propose an encryption solution for 2D slices in 3D printing. The main idea of the proposed solution is to encrypt the 2D slices of 3D printing in the spatial domain. The 2D slices are extracted from the file of 3D printing and then encrypted by the secret key in the in the spatial domain.

2.The Proposed Solution

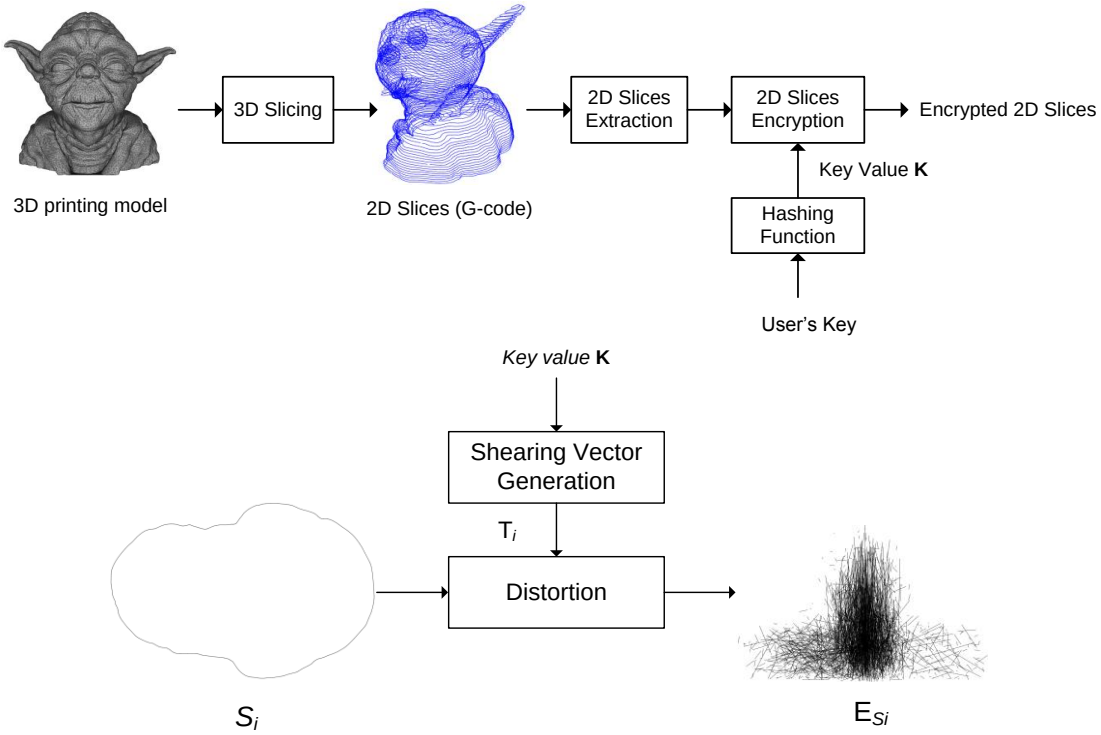


Fig. 3. The encryption process of 2D slices in spatial domain.

In this section, we would like to present an encryption method for 2D slices in the spatial domain as shown in Fig. 3. The function of the encryption method in the spatial domain is also similar the function of the encryption method in the frequency domain. It is applied to alter the shape of 2D slices in 3D printing. Due to the fact that the purpose of the encryption in spatial is to alter the shape of 2D slices, we can use geometric transforms for encryption. But geometric transforms as rotation, translation and scaling (RST) only change the spatial location or size of 2D slice. They did not change the shape of 2D slices. So they are unsuitable for the encryption in the spatial domain.

To respond to the purpose of the encryption in the spatial domain and replace the risks of RST, we apply the distortion that is also a geometric transform for the 2D slices encryption in the spatial domain. Geometric distortion is a transformation used to distort geometric objects [15]. To encrypt the slice$S_i$by the distortion transform, we have to generate the shearing vector$\mathrm{T}_i = \{t_{i,j} | j \in [1, |S_i|\}$ by the secret key value **K**with$t_{i,j}$is computed by Eq. (1):

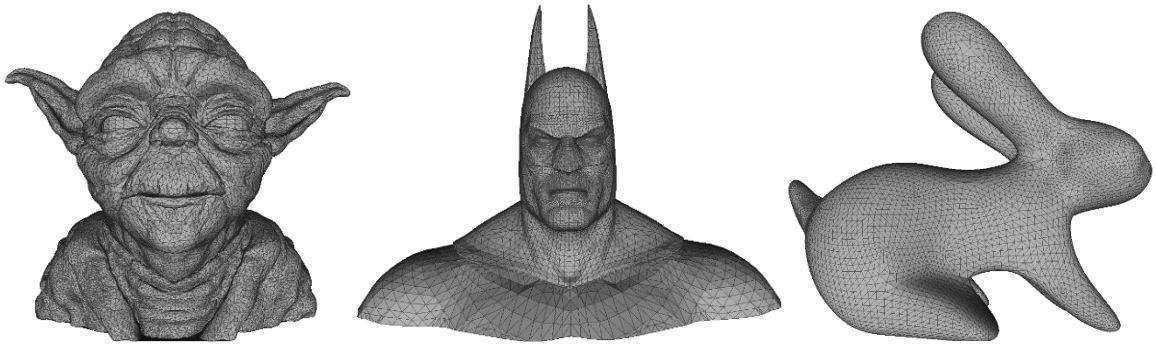
$$t_{i,j} = \frac{\mathbf{K}}{|S_i|} \times (i + j) \tag{1}$$

$$\mathbf{E}_{Si} = Distortion\ (S_i, \mathrm{T}_i)(2)$$
$$= \{e_{i,j}\,|j \in [1, |S_i|] \text{ with} e_{i,j}\,(ex_{i,j}, ey_{i,j}) = (x_{i,j} + t_{i,j}.y_{i,j}, x_{i,j}.t_{i,j} + y_{i,j})$$

The decryption process is an inverse process with the encryption process. The encrypted 2D slices are extracted from the file contained the encrypted 2D slices and then they are decrypted by the secret key value **K**that is used in the encryption process. For the decryption method in the spatial domain, we use the secret key value **K** to compute the shearing vector$\mathrm{T}_i$as described in Eq. (1) and perform geometric re-distortion based on Eq. (2) to get the decrypted 2D slice.

3.Experimental Results and Analysis

We experimented the proposed solution with test models in Fig. 5. The format of 3D printing models is STL files, VRML files [3, 4]. The detailed information of each test model is shown in Tab. 1. Each test models are cut into a set of 2D slices [5]. The number of 2D slices of each 3D printing model is dependent on both the Z-axis height of that model and the thickness of each slice. The thickness of slice is flexible and determined by user. In experiments, we defined the thickness of slice is 1 mm. We tested the encrypted 2D slices with XYZ 3D Printer Pro 3 in 1 [6], 3D printer cannot print the encrypted 2D slices into a physical 3D object (see Fig. 6).



Yoda Batman Bunny

Fig. 5. Test Models

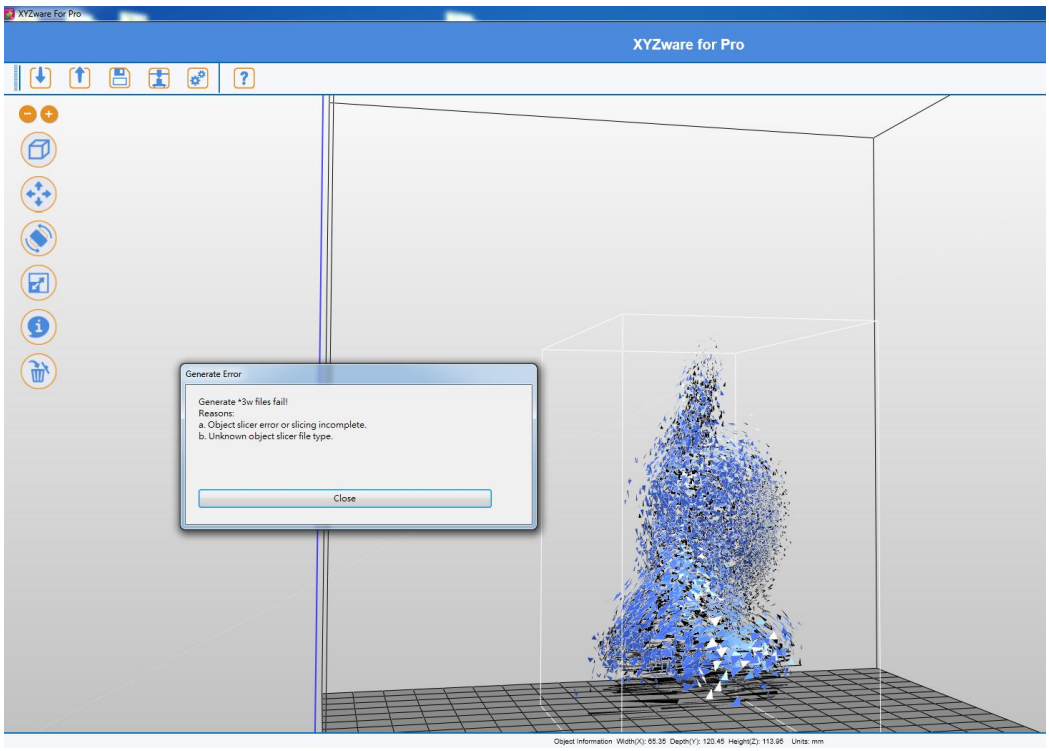


Fig. 6. 3D printer cannot print the encrypted 2D slices.

4.Conclusion

In this paper, we proposed and experimented a security solution for 3D printing based on 2D Slices Encryption. 2D slices in 3D printing file are encrypted before being storage or transmission to prevent attacks from pirates. We experimented the proposed solution by the encryption process in the spatial domain. Experimental results proved that the proposed solution is effective to 2D slices and independent on the format of 2D slices. Dependent on the purpose of each application, developers or researchers can replace the content of 2D slices encryption process by their complex methods. This is an advantage of our solution. In future, we improve the proposed encryption methods and apply them to the secured storage and transmission systems.

Acknowledgement

This work is supported by FPT University, Hanoi, Vietnam;Faculty of Electrical and Electronics Engineering, Vietnam Aviation Academy, Vietnam; and Faculty of Electrical and Electronics Engineering, Ly Tu Trong College of Ho Chi Minh City, Vietnam.

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