A Design and Application for 3D printer based on Virtual instrument

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Abstract: In recent years, the application and design of 3D printer has received extensive attention. In this paper, a virtual instrument based 3D printer is designed. Firstly, a printer platform with a box structure is built, then virtual instrument technology is used to construct the control center, after that data acquisition card is applied to combine them together to form a complete 3D printing system. The experiments show that the designed 3D printer is effective in printing 3D products.

1. Introduction
With the rapid development of science and technology, mechanical machining methods have made great progress, with which many new applications and products come into people’s lives. These new things brought great convenience to people’s life. During the time that people enjoy their conveniences, its shortcomings are increasingly exposed. The most prominent one is the basis of traditional mechanical machining technology, which is subtractive manufacturing process. These methods, on the one hand, can hardly process complex products(workpiece) due to its complex structure, process demand and precision tools needs, on the other hand, it has a large loss. Subtractive manufacturing processes, such as machining, can result in up to 90% of the original block of material being wasted, which greatly limits its development. For these reasons, 3D printing technology has been developed.

In contrast, 3D printing is a process for creating objects directly by adding material layer by layer in a variety of ways. As a kind of advanced multidisciplinary manufacture technology, 3D printing technology combines machinery, material, software and numerical control together to complete 3D print\(^1\).

The earliest 3D printing technologies first became visible in the late 1980’s, at which time they were called Rapid Prototyping (RP) technologies. It is a rapid prototyping device using light curing and paper stacking technology\(^2,3\). This technology has become increasingly mature through constant updates and corrections. Usually, materials (powder, metal, photosensitive resin and etc.) are manufactured layer by layer, with scanning in X–Y plane, cross section of the digital model forms, and through discontinuous shift of 3D printers in the Z coordinate direction, the 3D model can form\(^4,5\).

Although 3D-printer technology has made significant progress not only on print rates but print cost in rapid prototyping procedures. There are still many drawbacks remain, one of which is its rigid model. A 3D printer, usually, is composed by mechanical structure, control circuit and the host computer software. As the core part, the software of the system need more flexible to achieve rapid development and easy expansion, but traditional 3D model usually use text programming tools to
accomplish printing task. This may lead simplicity, portability and ease of operation, but the disadvantage is also obvious, which is its debugging and updating is relative hardly to executive, and the most important one is its development cycle is longer. Virtual instrumentation is a technology that uses software and modular measurement hardware to create user-defined measurement and control systems. The merit of using virtual instrument is that it has the properties of increased flexibility, saves time and money, faster development, better investment, easier solutions, numerous add-on software products and so on. Especially, at the point of programming, debugging and rapid development, virtual instrument is more suitable for 3D printer design and applications. For these reasons, we designed a virtual instrument based 3D printer.

2. The establishment of the 3D printing system
The proposed 3D printing system is composed of 3 main parts: machine construction based on box structure, data acquisition board and software in host computer. The box structure based machine construction includes aluminum alloy profiles, stepper motors, extruder, heating panel and some accessories. The data acquisition card in this system is Elvis II and software in this system is LabVIEW. The diagram is shown in Figure 1.

![Figure 1 System diagram of 3D printer](image)

In the system, the programming processes in host computer is core, with which motors of machine construction are controlled to achieve the goal of 3D printing.

The data acquisition card: NI ELVIS II is applied, which is a hands-on design and prototyping system that integrates 12 of the most commonly used instruments – including the oscilloscope, DMM, function generator, and Bode analyzer – into a compact form factor ideal for the hardware lab or classroom. Based on NI LabVIEW graphical system design software.

2.1. Software designing of 3D printing system
In the software design section, we divide the system into various functional modules: log in module, parameter settings module, manual function module, auto printing (3D printing) module and two dimension printing module. In order to integrate the individual modules together, a main interface is needed to recall each module, the overall software design of 3D printing system is shown in Figure 2.

![Figure 2 Main program flow chart](image)

In the system, initialization part is used to prepare the basic environment for system to work. For security use, a process for user to log in is designed, after that the main interface is designed

Parameter setting module: The parameter setting function is used to complete the temperature and related motion parameter settings to achieve accurate and rapid printing.

Manual function module: There are two reasons to set manual function: 1. This function facilitates the developer to debug default values; 2. The printing system needs to be preprocessed before printing, like preheating the system and initialize the coordinates of nozzle. The schematic diagram of manual
function is shown as follows:

![Flow chart of manual function](image)

**Flow chart of temperature detect:**

![Temperature detect](image)

2.2 **Auto printing (3D printing) module**

Auto printing is the core part of software, which is used to perform 3D printing task. In this part, “STL” file processing is the very first step, “STL” is one of the most common file types that 3D printers can read, from the processing procedure, certain information is obtained.

The main steps of processing of STL file are divided into three parts: 1. fixed layer topological slice algorithm; 2. contour optimization; 3. slice data processing. With these three main procedures, coordinate information of specified layer could be gained. According to the same method, layer thickness is determined and multi-layer coordinate information is gotten, with which layer by layer printing could be achieved.

![STL file slicing processing](image)

The procedure of fixed layer topological slice algorithm is described as follows.

The simplest way to acquire the relevant information is the usage of triangular topology information for slicing, this method divided into four steps:

- **Step 1:** Extracting vertex coordinates of triangular patches;
- **Step 2:** Remove irrelevant triangles, i.e. keep the intersecting triangle of current layer;
Step 3: Calculate the crossover points with indexing and sorting process;
Step 4: Rough contour obtained.

In order to get vertex coordinates of triangular patches, first open the “STL” file, from strings inside file vertex coordinates could be got, for better use, save the data in array form.

For the purpose of removing irrelevant triangles, three steps should be executed. First initialize the number of patches, second compare the current patch with the height of layer to determine if it belongs to this layer, finally keep the patches that belong current layer. The flow chart shows the details of these steps:

![Flow Chart](image)

Figure 6 Removing irrelevant triangles

Packing every vertex coordinates that belong to a triangle to a cluster and then sort all clusters in sequence, with this process vertex coordinates of triangles that belong to current layer could be got. The last step is to get crossover point.

After sorting triangles that belong to same layer, what should be done is to find out crossover points. Suppose that the crossover points of the tangent plane \( z = h \) and the triangle are \( V(x, y, z) \), Where the vertexes of a triangle are \( A(x_1, y_1, z_1) \), \( B(x_2, y_2, z_2) \), and \( C(x_3, y_3, z_3) \) in turn. Find the coordinates of the intersection according to Equation 1[6].

\[
\begin{align*}
x &= \frac{z - z_1}{z_2 - z_1} (y_2 - y_1) + x_1 \\
y &= \frac{z - z_1}{z_2 - z_1} (y_2 - y_1) + y_1 \\
z &= h
\end{align*}
\]

(1)

From these process, a series of end-to-end lines could be got, from which a rough contour data of the slice can be achieved.

The procedure of contour optimization is described as follows.

With the process of connecting all the point, a contour could be obtained, however this outline is a rough profile. A farther step should be done for better contour, which is removing the relationship of collinearity, micro-line segment and small curvature. The collinear relationship refers to get the contour of the connection point in a straight line; micro line relationship refers to the minimum distance between the contour points; the relationship between the curvatures is the middle point of connection and the ends of the connecting points of line contour in an approximation in a straight line.

The steps are shown as follow:
1. Calculates the slope of adjacent connection points, find the lines with the same slope, and eliminate the collinear points;

2. Calculate the distance between adjacent points, when the distance between lines is smaller than the threshold, the two points corresponding to the line segment are small segments, and delete any one of them;

3. Calculate the curvature formed by connected points, When the curvature is less than the threshold, the corresponding point of curvature is deleted.

The diagram are shown below:

![Figure 7 Slice contour optimization](image)

At present, what we got is the contour of the cutting plane that could print only contour of an object. In order to get the whole 3D products, the contours of each layer should be filled. This layer is obtained by filling the minimum circumscribed rectangle. And then fill the minimum circumscribed rectangle at a certain interval.

After grid filled process, the layer filling graph is obtained by collecting points lie in and inside the polygon, also excluding the points outside the polygon. Thus, the slicing work is done, with each slicing work the whole 3D product could be printed.

From the steps above, we would get 3D products.

Two dimension printing: Taking into account the ability of 3D printers, in order to make better use of its abilities, two-dimensional printing is designed. This module is conducive to the choice of printing methods, picture processing, and related hardware control, and improves the system's multi-function printing function.

3. Experimental results and discussion
From what we designed above, we got the 3D printer mechanical structure, data acquisition card and logic circuit like this:
In order to verify the effectiveness of the system, the designed function implementation is listed step by step as follows:

Log in part and main operation interface are shown as below:

The manual function and automatic interface are shown below:

Process of a sample printing is shown in figure 11(a)–(d).
Two dimensional printing:

From what listed above we could get the conclusion that our designed 3D printer is effective.

4. Conclusion
In this work, we designed a VI based 3D printer. In this 3D printing system, the mechanical structure of the box structure is used to form the mechanical body, combined with LabVIEW, which is the core element of the system. With the proper use of LabVIEW we get 3D printing procedure, from which we could print 3D product step by step. The experiment shows that our designed system could work well and effective.

References
[1] Do A V, Khorsand B, Geary S M, et al. 3D Printing of Scaffolds for Tissue Regeneration Applications.[J]. Advanced Healthcare Materials, 2015, 4(12):1742-1762.
[2] Zhang J, Yu Z. Overview of 3D printing technologies for reverse engineering product design[J]. Automatic Control & Computer Sciences, 2016, 50(2):91-97.
[3] Stopp S, Wolff T, Irlinger F, et al. A new method for printer calibration and contour accuracy manufacturing with 3D-print technology[J]. Rapid Prototyping Journal, 2008, 14(3):167-172.
[4] Ali M H, Mir-Nasiri N, Ko W L. Multi-nozzle extrusion system for 3D printer and its control mechanism[J]. International Journal of Advanced Manufacturing Technology, 2016, 86(1-4):999-1010.
[5] Ghadamli F, Linke B. Development of a Desktop Hybrid Multipurpose Grinding and 3D Printing Machine for Educational Purposes ☆[J]. Procedia Manufacturing, 2016, 5:1143-1153.
[6] LUOWY. Analysis of data conversion and slice post-processing technology based on 3D printing models [D]. Nanjing: Nanjing Normal University, 2015