Software Management of 3D Printer

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Abstract – **This current report „Software management of 3D printer"– a working model is a continuation of another report which reviews a hardware platform for making a 3D printer. The aim of this report is to present the software realization, configuration and programming of a firmware for the realized working model of a RepRap 3D printer.**

Keywords – **Firmware, model of a RepRap 3D printer**

I. Introduction

The main conceptual aspect considered in this report, is a modern 3D printing technology which turns a 3D computer model (CAD) into a real physical object depending on the size of the used model. Open Source technology called FDM (Fused Deposition Modeling) consists of series of thin layers of molten thread of the used material to achieve the shape of the desired object. This makes the three – dimensional (3D) print entirely different from the traditional technology, in which the shaping form of the desired object usually takes material.

The type of technology for printing a 3D model includes materials such as ABS and PLA.

ABS (acrylonitrile butadiene styrene) – this kind of plastic is used in monitors, coffee machines, TVs, mobile phones production.

PLA (polylactide) – this kind of plastic is made by bio - degradable products, such as cornstarch and potato starch, sugar beet and other raw starch containing materials [1].

II. Firmware of a RepRap 3D printer

The main software management of a REPRAP 3D printer, this report features consists of three parts:

- firmware;
- software for communication and control of RepRap 3D printer;
- Bench software Slicer and CAT.

Fig.1 represents a scheme of a printer software management from the creation of a 3D CAD model to its sending to the printer for printing.

Firmware is a specialized software micro – programme, which programs and is stored in a printer`s microprocessor. In the memory it is stored as ROM, EPROM and flash - memory.

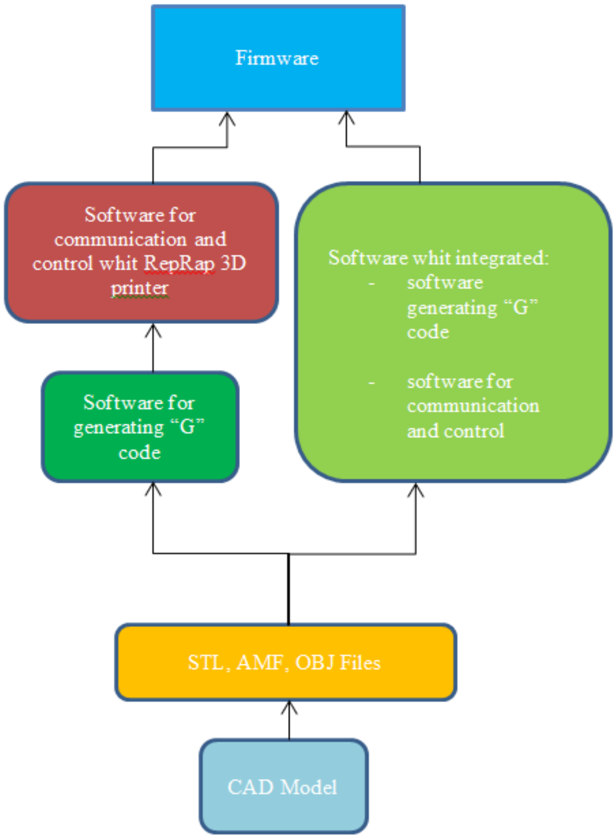

Fig. 1. Scheme presenting software management of a printer

These programs have all embedded systems, such as the RepRap in the 3D printer. In this way it affects all components of the device and synchronizes their functions in the best possible way. A program used for shaping a detail is made by the "G" and "M" languages. Commands /codes/ with address "G" are called preparatory and are responsible for the setting of the machine to perform a certain task. Codes with address "M" are called auxiliary.

The "G" and "M" languages are a popular name of a programming language, developed for the management of machines with digital – programme management.

A. Commands for linear movement

Commands for linear movements are the most widely used G-codes. They define most of the movements of the RepRap 3D printer, which could be linear with ultimate speed or circular with defined submission. These commands include all the instructions for interruption or

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modification of submission. All the functions in a firmware read or generate "G" and "M" commands.

Fig.2 shows a block scheme for the management of firmware of a 3D printer. Apart from the G-codes in a working model of a RepRap 3D printer, auxiliary "M" commands are also used [1, 2, 3].

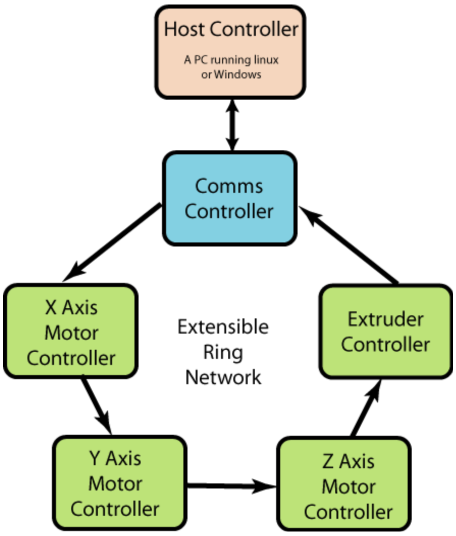

Fig. 2. Management of a firmware

The Programming of the controller, which manages the printer, is carried out by PC and by USB interface in connection.

In recent years, with the development of microcontroller's extension and the enlargement of their scope of options, that enables pre-programming of systems and the increase in the random access memory and program memory capacity, interfaces, and their number of digits, lead to a fast advancement of high level preprogrammed systems. These systems have disposal of standard interfaces such as:

- RS 232;
- USB;
- Ethernet,

And they are elaborated by new companies as open code projects in which the final product does not require an expensive programming hardware from every programmer or an amateur [1].

Preprogrammed systems are factory preloaded with a miniature microprogram named bootloader, whose aim is to allow the user to preprogram the system without the modification of a standard company programmer. These systems were further developed thanks to their mass production as an open code software and free software, which makes them attractive, easy to use and most important-cheap enough for the mass user to use effectively. The programming of such controller, for example for RepRap 3D printer, requires a computer and development environment Arduino.

The development environment Arduino is written in Java and is based on Processing. It uses an AVR-GCC compiler and the programming language is accomplished by is Wiring, which resembles the programming language C++.

B. Setting of a firmware for RepRap 3D printer

- Hardware setting

Before compiling and "sending" the firmware to the device memory, it is necessary to configure the RepRap 3D printer to ensure its proper working .The settings for the configuration file are very important "Configuration.h" [4, 5].

One of the main steps is the configuration of the serial port, which is located on the printed circuit board (PCB). On the basis of the values of the resistor, the temperatures of the extruder and the heated bed, which is responsible for the RepRap 3D printer that prints work, are calculated. This resistor is shown in fig. 3.

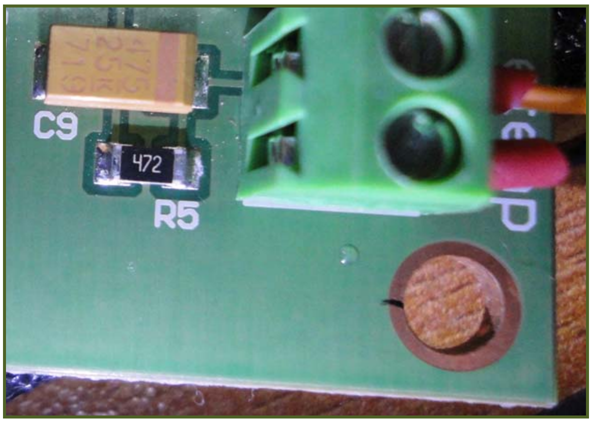

Fig. 3. Serial resistor

It can be seen that its notation 472 which means that the resistor is 4700 Ω. Preset the configuration constant SERIAL_R to 4700

```
#define SERIAL_R 4700
```

Next step is to choose a value for speed of communication. This is the speed used for communication between software which manages the printer interface of Marlin firmware.

```
#define BAUDRATE 115200
```

The third step is to choose the number of sensors to use. It is achieved through configuration of constants. We have to bear in mind, that the developed 3D printer has a sensor of the extruder part and sensor of the bed, units are given only to „TEMP_SENSOR_0" and TEMP_SENSOR_BED.

```
#define TEMP_SENSOR_0      1
#define TEMP_SENSOR_1      0
#define TEMP_SENSOR_2      0
#define TEMP_SENSOR_BED  1
```

The type of the used sensor (thermistor) is EPCOS NTC G560 B57560G107F 100K - 100000 Ω. The value of the configuration constant is E_NTC 100000.0.

```
#define E_NTC 100000.0
```

The type of plastic which is used by default is ABS.

To set the starting temperature 0 °C, the following relation is used [3]:

$$C = K - 273{,}15. \quad (1)$$

The value of the configuration constant is ABS_ZERO -273.15

#define ABS_ZERO -273.15

These values of the configuration file are very important because the proper temperature of printing depends on them.

It is known that analog – digital converter is 10 bit (by the previous article) and it has a range of 2^{10}, which means that it is between 0 and 1023, so in this case the resistance of the thermistor will be R = V.RS/(1023 - V). The temperature resistance is calculated by the following formula:

$$r_e = R.e^{-\frac{BETA}{T}} , \quad (2)$$

Where:
BETA is coefficient with size [K] and its value is from 2000K to 5000K and T is calculated by this formula (3)

$$T = \frac{B}{\ln\left(\frac{R}{r_\infty}\right)} , \quad (3)$$

where:
R is the resistance of the thermistor,
B is coefficient with size [K] – from 2000K to 5000K,
r_∞ is temperature resistance.

```
#define E_BETA 3974.0
#define E_RS SERIAL_R
#define E_NTC 100000.0
#define E_R_INF ( E_NTC*exp(-E_BETA/298.15) )
```

Here the minimal temperature is calculated when the heater turns off. What follows is to check whether the thermistor is connected properly or whether it is damaged. In case it is, it will not switch off. Here the constants are HEATER_0_MINTEMP 1 for heater of the extruder and BED_MINTEMP 1 for the heated bed

```
#define HEATER_0_MINTEMP 1
#define BED_MINTEMP 1
```

The heater will switch off when it reaches the maximum preset temperature in order to avoid overheating. This function is used to protect the heater and inputs of the plate.

MINTEMP is used to protect the thermistors , where constants are HEATER_0_MAXTEMP 275 for the heater of extruder and BED_MAXTEMP 150 for the bed heater.

```
#define HEATER_0_MAXTEMP 275
#define BED_MAXTEMP 150
```

Manual setting of a firmware

These settings are:
- configuration of final stop blocks;
- stepper motor;
- base area where the printing is made;
- steps for certain unit, in this case per millimeter.

The setting in which one of the axis reaches the final switch for the starting point of the coordinate for either axis. Permitted values are: true and false.

#define min_software_endstops true

A setting in which the axis does not exceed the limits preset - permitted values are: true and false

#define max_software_endstops true

Maximum range from 0 to the final switch, which an axis could go is introduced by constants X, Y, Z in millimeter:

#define AXES_MAX_LENGTHS {190, 190, 200}

Normal velocity mm/min

#define HOMING_FEEDRATE {10*60, 10*60, 1*60, 0}
Rapid speed mm/min

define FAST_HOME_FEEDRATE {50*60, 50*60, 3*60, 0}

After all settings have been adjusted, maybe the most important is to tune the settings of the RepRap 3D printer and the number of steps per millimeter the stepper engine can make.

It is known that there are 4 axis, so the steps must be set for axes X, Y, Z and feed motion of the material of the extruder E.

#define DEFAULT_AXIS_STEPS_PER_UNIT {80.0000, 80.0000, 4000, 561}

It is particularly important while doing these settings to know the specifications of stepper engine – degree of step, model of strap, number of teeth of the gear - wheel, the distance between carvings of a sprig and micro steps of the driver.

The chosen model strap is GT2 with interdental distance of 2 mm, the gear-wheel used has 20 teeth with distance between the carvings of the sprig 0,8 mm and micro steps of the driver 16;
The Formula for the steps per millimeter for axes X and Y is:

$$\text{Steps per millimeter} = \frac{\left(\frac{360^o}{1{,}8^o}\right).16}{2.20} = 1454{,}55 \quad (4)$$

Where:
dbts - the distance between the teeth of the strap;
msd – micro steps of the driver.
There is no strap, so for axis Z, the formula is transformed and reduced to:

$$\text{Steps per millimeter} = \text{steps per millimeter on axis Z} \quad (5)$$

The formula for the extruder E for steps per millimeter is the following:

(6)

If:
The number of detents of the big gear = 45;
The number of detents of the small gear = 11;
The diameter of the working part of the feed = 7mm;
The result is:

$$\frac{(200.16).\left(\frac{45}{11}\right)}{7.3,14159} = \frac{13088}{21,99}.\frac{100}{105,7} = 561 \text{ steps/mm.}$$

In this way the already adjusted firmware is ready to be compiled and transferred to the memory of the controller.

III. CONCLUSION

The technology used in the 3D printer production leads to some basic conclusions, formulated as follows:

Technology enables making a lot of unique products and articles made to order;

It enables the production of more complicated forms, which is impossible through the means of traditional methods. It is hard to enumerate all the examples, of the utility of 3D printing. One thing is certain – this technology is yet to enter in our everyday life, medicine, manufacture, and art and security services;

3D printing will certainly develop in next years, as one of the fifth leading trends, which will change the technologies and the world in 2015.

The best thing is that the 3D print “opens the door” for creativity and innovation.

ACKNOWLEDGEMENT

The authors would like to acknowledge the support of the "Research & Development" division of Plovdiv University in the project: НИ15-КС-016/24.04.2015.

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