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SELECTING EQUIPMENT AND SUPPLIES FOR SELF–REPLICATING 3D PRINTER

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Abstract: A RepRap 3D Printer machine is built in the University of Debrecen, Building Mechatronics Research Centre. The 3D Printer technology will start a second industrial revolution and reforming our everyday life. There are a number of different types of 3D printers, is a Fused Deposition Modelling (FDM) rapid prototyping open–source and low–cost 3D printer machine. All parts of our 3D Printer model are basic materials and available everywhere in the world. The Building Mechatronics Research Centre in the University of Debrecen, as intelligent building provides research infrastructure for building 3D Printers to print out of our 3D model prototypes. The technology guarantee that further robot research projects will be completed. In this context, this paper focuses on the optimization and the construction method of the 3D Printer.
Keywords: 3D printer; building automation; self–replicating; extruder; life cycle

INTRODUCTION

Nowadays, the development of science is very rapid process. Many new technology devices, programs and methods are appeared. One of these new invention is the 3D printing. The 3D printer technology is broad and relatively new scientific field that has been developed in the framework of the Computer Aided Design field. The CAD has revolutionized the engineering design process, and the next step are going to start a new revolution.

The 3D printing is a high level additive manufacturing process of making three dimensional objects from CAD files. The technology has been opened many options to create and test our brand new mechanics or robot tools, this is particularly important nowadays, when unique productions are done industrially. From now on the design and production method can be done by single person.

There is a growing demand for the optimized use of the conventional forms of energy. The main key is building mechatronics which can develop and optimize further the 3D printer technology.

In the University of Debrecen, Faculty of Engineering, Department of Electrical Engineering and Mechatronics, the Building Mechatronics Research Centre as intelligent building provides research infrastructure for researches and becomes a knowledge base.[1] Our department has been established a new laboratory for young mechatronic researchers who have completed the Bachelor of Science degree. [2] The main goal of the activity of the laboratory is the study 3D printer technology and the programming as well.

International researches carried out in the laboratory promote the activity of designers, to use more efficient the 3D printers, and filaments in production aspect.

The aim of the article is to propose the Building Mechatronics Research Centre as Energy Aware Intelligent Space and present recent researches in connection with the additive manufacturing, 3D printer solutions, and building mechatronics systems.

The paper is organized as follows: Section II is about the Building Mechatronics Research Centre as Energy Aware Intelligent Space. Section III presents the self–replicating 3D printer. Section IV describes the right selection of equipment. Section V. includes the summary. Section VI provides giving thanks.

BUILDING MECHATRONICS RESEARCH CENTRE AS INTELLIGENT SPACE

In the University of Debrecen, the Building Mechatronics Research Centre is equipped with surveillance and security system. Two heat pump systems provide energy for the education and living premises. [3] The surveillance and security system retrieves data about the number of residents staying in the rooms.

As Hashimoto [4] writes in his paper: "The Intelligent Space is an area (room, public space, etc.) that has networked distributed sensors, which can be used for observing and gathering information from the space." The camera system within the building is capable of cooperative object tracking.

It allows gathering information not only about the space but also the people staying in it. Morioka [5] states, it is important to track target objects and get the positional information of them in intelligent environments.

In our case, the target objects are residents and 3D printer whose position is of high importance for the security system of the building. 3D printing is a disruptive force in manufacturing, but with the benefits come safety risks. The Building Mechatronics Research Centre has a unique security system with object tracking IP cameras and sensors as well. Previously we used the system to study higher energy consumption awareness through the examination of the consumer's behaviors and stored every data of the Building Automation System (BAS) in data bases. [6] The system focuses now the observation of the 3D printer laboratory during the printing process to avoid accidents. All kind of Fused Deposition Modelling (FDM) printers extrude above 150 Celsius and the heated bed at least 60 Celsius. [7] Beyond these obvious safety hazards, there is growing concern with preventing accidents. Therefore reasons our laboratory is under 24–hour surveillance by TCP/IP cameras. [8]

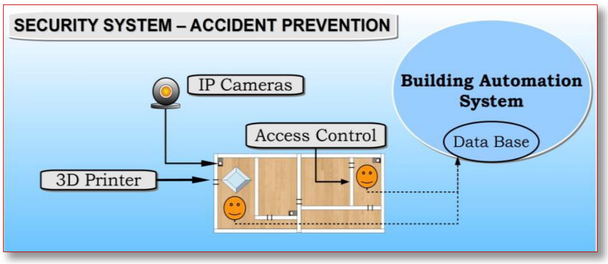

Figure 1. Security system – accident prevention
Source: Compiled by authors

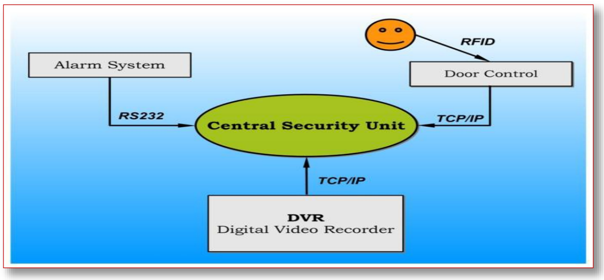

Figure 2. Surveillance system of the building mechatronics research center
Source: Compiled by authors

The primary idea is to focus on system operation with auto– detect mechanism such as alarm system, door control and vision sensors. The building administrator can control the security system and report all suspicious events that appeared. The high resolution TCP/IP cameras can be reached anytime through the internet. Communication is realized with Modbus and M–bus technology. The advanced controls store every data in a data base for surveillance. [9]

THE SELF–REPLICATING 3D PRINTER

The Rapid Prototyping (RP) was the first 3D printing technology in 1980's. It provided more cost effective method for creating prototypes from 3D CAD models. In 1986 Charles Hull [10] was issued the first patent for stereolithography apparatus. From that day many new 3D Printer machines have been invented. One of the first commercial 3D printer machine was the RepRap Darwin project in March 2007. The RepRap and other entry–level machines are Fused Deposition Modelling (FDM) printers. [11]

In the University of Debrecen, Faculty of Engineering, Department of Electrical Engineering and Mechatronics, the Building Mechatronics Research Centre provided research infrastructure to build a low–cost 3D printer. The optimal choice was the Prusa Mendel iteration 2 FDM type of RepRap. This model is an improvement of the Prusa Mendel iteration 1, and it was realized in November 2011. The main reasons why we chose this model of RepRap are as follows:

- Open source philosophy
- Self–replicating
- Cost–effectiveness
- Fused Deposition Modelling (FDM)
- Reliable printing
- Available components

Our self–replicating RepRap Prusa Mendel i2 model was built in October 2014 and from than can be found in the 3D Printer Laboratory of the Building Mechatronics Research Centre.

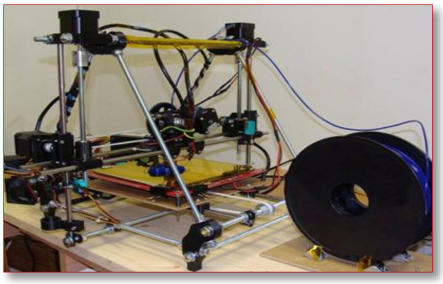

Figure 3. Self–replicating 3D printer – FDM type
Source: Photographed by authors

The external dimensions of the self–replicating 3D printer are 44x47x37 centimetres. We can print precise 3D objects up to 120mm x 100mm x 100mm. [12] Generally we use to print thermoplastic materials like Polylactic acid (PLA) or Acrylonitrile Butadiene Styrene (ABS) plastics.

The printing is a very complicate process and it starts with a 3D CAD file designed in program or scanned. After that we take 3D CAD model, slice it into layers and send that G–code to the 3D printer. [13] The manufacture process works by melting thermoplastic filament that is go through the "Hot End" of the extruder. The extruded material falls onto the heated bed and layer by layer the self–replicating machine creates predetermined 3D object. [14]

The speed of the process depends on size and the complexity of 3D CAD model. In the 3D printer laboratory we printed many 3D components for our further researches in robotics such as KUKA KR5, and Maki Robot. [15] Generally all models represents a high level of quality. One of our printed gears for replacement part of the 3D printer.

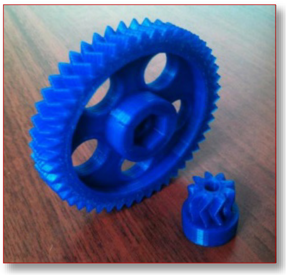

Figure 3. Self–replicating 3D printed gears
Source: Photographed by authors

The self–replicating printer is a unique machine, because most parts of the frame can be downloaded and printable.

SELECTING EQUIPENT AND SUPPLIES FOR SELF–REPLICATING 3D PRINTER

The standard Prusa Mendel iteration 2 printer kit includes stepper motors, Pololu motor controllers, end stops, Arduino Mega2560, Ramps 1.4. etc. [16] The parameters of the parts determines the precision of self–replicating 3D printer. Therefore we tried to choose the parts with the best available parameters. A majority of the components were purchased such as extruder, polylactic acid, stepper motors and motor controllers.

The most important part of the machine is an Arduino based modular RepRap board, which designed to fit the entire electronics. The RepRap Arduino Mega Pololu Shield (RAMPS) [17], interfaces an Arduino MEGA 2560 development platform. The modular design of the RAMPS includes plug in Pololu A4988 stepper motor drivers. The assembled board can control the stepper motors, extruder and the heating system. [18]

The main parts of 3D printer electronic:

- RepRap Arduino Mega Pololu Shield 1.4 (RAMPS)
- Arduino MEGA 2560 Rev.3
- NEMA17 High Torque Hybrid Stepper motors
- Pololu A4988 stepper motor drivers
- Extruder assembly
- MK3 heated bed

The latest version of the RAMPS is 1.4 which contains better capacitors and resistors. Furthermore it has short–circuit protection. The NEMA17 Hybrid Stepper motor the most commonly used parts of the self–replicating 3D printer. This type of stepper motor rated 1.5A to 1.8A and 1.8 or 0.9 degrees per step. [19] After assembly phase we have to upload the current firmware to Arduino MEGA 2560 Rev.3 board and start calibration. Forasmuch as we selected the appropriate devices for the self–replicating 3D printer, than we can achieve the predetermined precision of the printed 3D object. The first printed 3D CAD model was a 20mm cube, the difference was only 0.01 millimetres.

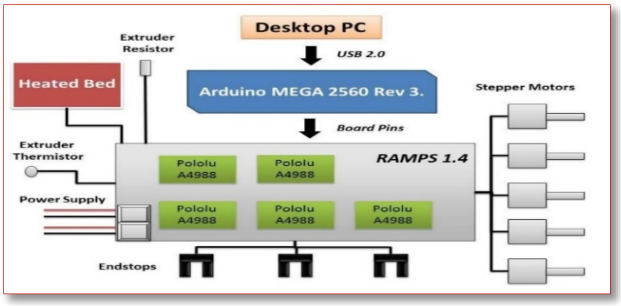

Figure 4. Self–replicating 3D printer – block diagram
Source: Compiled by authors

Figure 5. Self–replicating 3D printed – 20mm cube
Source: Photographed by authors

As mentioned before the self–replicating 3D printer benefits come with safety risks. It extrudes above 180 Celsius and the temperature of the heated bed is 60 Celsius. The Fused Deposition Modelling (FDM) types of printers can cause easily fire during the manufacture process.

In the University of Debrecen, the Building Mechatronics Research Centre is equipped with surveillance and security system [20] that we can reach and control via internet. In the 3D printer laboratory we installed a high resolution IP camera to reduce fire–related accidents.

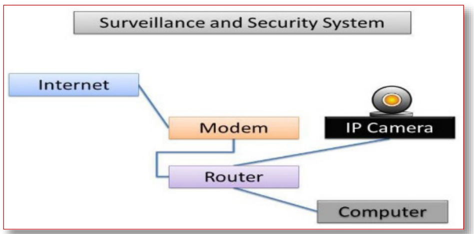

Figure 6. Surveillance and security system – block diagram. Source: Compiled by authors

The camera is used as vision sensor that can recognize the environment. First of all, we determined the influence and optimal position from the self–replicating printer. In the controlling and monitoring center we can follow the 3D printing and terminate the process. This method provides a chance to prevent the accidents related to 3D printer.

CONCLUSION

The reference self–replicating 3D printer and the surveillance and security system are important starting points for further researches in robotics and building automation system. In our case, the target objects are residents and 3D printer whose position is of high importance for the security system of the building. The Building Mechatronics Research Centre has a unique security system with object tracking IP cameras and sensors as well. The camera is used as vision sensor that can recognize the environment. First of all, we determined the influence and optimal position from the self–replicating printer. In the controlling and monitoring center we can follow the 3D printing and terminate the process. Previously we used the system to study higher energy consumption awareness through the examination of the consumer's behaviors and stored every data of the Building Automation System (BAS) in data bases. 3D printing is a disruptive force in manufacturing, but with the benefits come safety risks.

Acknowledgement

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