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3D 스캐닝 임베디드 시스템 설계*

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3D Scanning Embedded System Design

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〈Abstract〉

It is the approach of embedded system design that finds 3D scanning technology to analyze a real object or environment to collect data on its shape and appearance. 3D laser scanning developed during the last half of 20th century in an attempt to accurately recreate the surfaces of various objects. 1960s, early scanners used lights, cameras, and projectors to carry out the scanning in the lacks of performance which encountered many difficulties with shiny, mirroring, or transparent objects. The 3D scanning technology has leveled-up with helpful of embedded software platform research and design. In this paper, First we designed the hardware of laser/camera setup and turntable moving part which is the base of object. Second, we introduced the process of scanning 3D data with software and analyzed the resulting scanned image on the web server. Last, we made the 3D scanning embedded device with 3D printing model and experimented the 3D scanning performance with Raspberry Pi.

Key Words : 3D Scanner, Laser Scanning, Embedded System, Node.js, Raspberry Pi

Ⅰ. 서론

3D scanners are very analogous to cameras. Like cameras, they have a cone-like field of view and can only collect information about surfaces that are not obscured. While a camera collects color information about surfaces within its field of view, a 3D scanner collects distance information about surfaces within its field of view. The data produced by a 3D scanner describes the distance to a surface at each point in the picture. This allows 3 dimensional position of each point in the picture to be identified.

3D laser scanning developed during the last half of the 20^{th} century in an attempt to accurately recreate the surfaces of various objects. The early scanners used lights, cameras and projectors to perform this task.

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Due to limitations of the devices, it often took a lot of time and efforts to scan objects accurately. After 1985, they were replaced with scanners that could use white light, lasers and shadowing to capture a object's surface. In this paper, we designed the hardware which has stepper motors, laser modules and Pi camera and experimented 3D laser scanner with web server based for the purpose of gathering the real time scanning information[1-5].

Ⅱ. 3D laser scanning history

With the advent of computers, it was possible to build up 3D scanning system for a highly complex model. In the middle of 1980, the some industry developed a contact probe to create a precise model to be created, but it was so late. Therefore, experts started developing optical technology. Using light was much faster than a physical probe. This also allowed scanning of soft objects which would be threatened by probing. At that time, three type of optical technology were available:

- Point, which is similar to a physical probe in that it uses a single point of reference, repeated many times. This was the slowest approach as it involved lots of physical movement by the scanner.
- Area, which is technically difficult. This is demonstrated by the lack of robust area systems.
- Stripe, the third system was soon found to be faster than point probing as it used a band of many points to pass over the object at once, which was accurate too. Therefore, it was satisfied with two demands for speed and precision.

So stripe was clearly the way forwards, but it soon became apparent that the challenge was one of software. To capture an object in three dimensions, the sensor would make several scans from different positions. The challenge was to join those scans together, remove the duplicated data and sift out the surplus that inevitably gathers when you collect several million points of data at once.

By the mid-nineties they had developed into a full body scanner. In 1994, 3D Scanners launched REPLICA which allowed fast, highly accurate scanning of very detailed objects. Meanwhile Cyberware were developing their own high detail scanners, some of which were able to capture object colour too, but despite this progress, true three-dimensional scanning with these degrees of speed and accuracy remained elusive.

While these optical scanners were expensive, Immersion and Faro Technologies introduced low-cost manually operated digitizers. These could indeed produce complete models, but they were slow, particularly when the model was detailed. By this time, 3D models were united in their quest for a scanner, which was: accurate, fast, truly 3 dimensional ,capable of capturing colour surface, and realistically priced.

In 1996, 3D Scanners took the key technologies of a manually operated arm and a stripe 3D scanner - and combined them in ModelMaker. This incredibly fast and flexible system is the world's first Reality Capture System. It produces complex models and it textures those models with colour. we experimented the color 3D scanning technique[6-10].

Ⅲ. 3D scanner design patterns

We tested the active scanning technique which use some kind of radiation or light and detect its reflection in order to probe an object or environment. Therefore, we designed the embedded platform for laser/camera settings with raspberry pi 3 and software for processing the gathering data with 3D scanner.

3.1 Hardware Setup

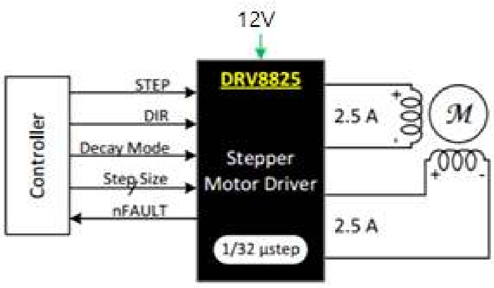
In this paper, embedded platform controller used raspberry pi 3 which has the following platform features. Especially, we used the web server for remote's controlling and monitoring 3D scanning results, and the client embedded scanner platform.

<Table 1> Platform Features

		Features			
		CPU	Memory	Network	B/T
FunctIons	maIn	1.2 GHz 64-bits Quad -core ARMV8	1 GB RAM	802.11n Wireless LAN	Bluetooth 4.1
	sub	Camera Interface (CSI)	Micro - SD 32GB	VideoCore IV 3D graphic core	B/T Low Energy

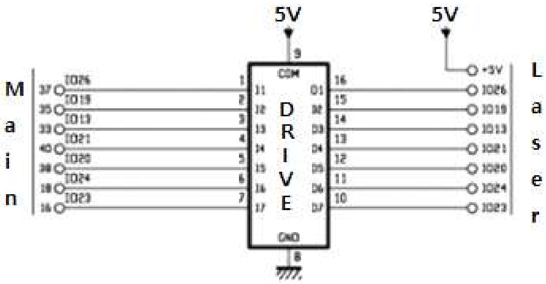
The hardware platform is consisted with turntable driving circuits, laser modules, and camera parts. The turntable driving controller used DRV8825 like <Figure 1>.

The interfacing circuits between driver circuits and main controller need 12V voltage to actuate stepper motor which is with unipolar driving method.



<Fig 1> Driving circuit with DRV8825

The 5V laser pointer module is connected with ULN2003BN which is darlington transistor package for driving high current as like <Figure 2>.

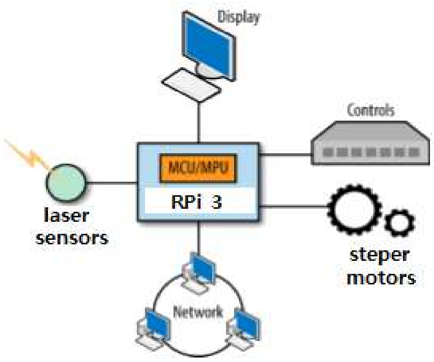


<Fig 2> Laser sensor module circuit

We used two laser sensors for gathering the data of object's surface information via darlington transistor module for amplifying the driving currents. The power supply voltage is 9~12V for providing stepper motor power between VMOT and common pins.

3.2 Software Setup

We configured the building blocks of embedded platform as like <Figure 3>. In many cases, its core is a micro controller unit that is connected to laser sensors, WiFi network and driving circuits.



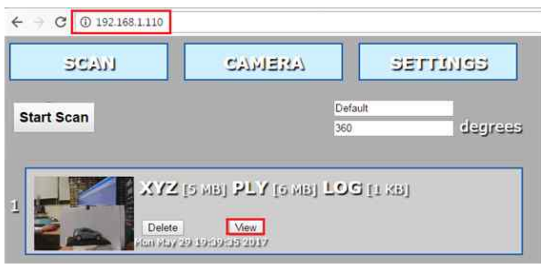
<Fig 3> Building blocks of 3D scanner

We used WiFi networking which provides much more flexibility. Wireless connections have steadily been making progress over the last decade. Afterwards, we will study the login and password for a secured WiFi connection of 3D scanner.

In this paper, the UI layout is consisted with following details of <Figure 4>. The result of 3D scanner is confirmed with any web browser of desktop computer.

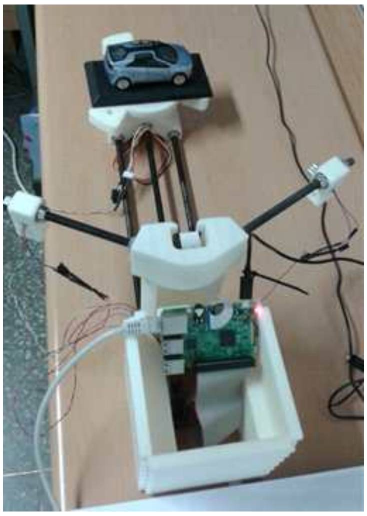
If someone want to replace the IP address and environment setting, it is possible to adapt new variable setting. For example, we selected the camera mode between still and video modes, frames per revolution, laser selection with single or double usages, and saving files for XYZ or PLY modes.

<Figure 4> has shown the layout of UI design of 3D scanner. We placed the menu of SCAN, CAMERA and SETTING. Especially the scanned result image could be saved by XYZ or PLY files for verifying and printing 3D printer later on. Here, we could connect web server with 192.168.1.110 on the web browser.



<Fig 4> 3D scanner UI layout

The 3D embedded scanner system has shown in <Figure 5>. We made 3D model in the Lab and combined parts with bolts and screw. The target object is a model car which has many discontinuities and contours because it has many difficulties of scanning[11-15].



<Fig 5> 3D scanner Platform

Ⅳ. Scanning Procedure

3D laser Scanning can generally be categorized into three main categories; time of flight, phase shift, and laser triangulation. These laser-scanning techniques are typically used independently but can also be used in combination to create a more versatile scanning system. In this paper we used time of flight technique with C programming language.

The time of flight 3D laser scanner is an active scanner that uses laser light to probe the subject. At the heart of this type of scanner is a time-of-flight laser rangefinder. The laser rangefinder finds the distance of a surface by timing the round-trip time of a pulse of light. A laser is used to emit a pulse of light and the amount of time before the reflected light is seen by a detector is timed. Since the speed of light c is known, the round-trip time determines the travel distance of the light, which is twice the distance between the scanner and the surface. If t is the round-trip time, then distance is equal to (c.t/2). The accuracy of a time-of-flight 3D laser scanner depends on how precisely we can measure the time (t):3.3 pico seconds (approx.) is the time taken for light to travel 1 millimeter.

The laser rangefinder only detects the distance of one point in its direction of view. Thus, the scanner scans its entire field of view one point at a time by changing the range finder's direction of view to scan different points. The view direction of the laser rangefinder can be changed either by rotating the range finder itself, or by using a system of rotating mirrors. The latter method is commonly used because mirrors are much lighter and can thus be rotated much faster and with greater accuracy. Typical time of light 3D laser scanners can measure the distance of 10,000~100,000 points every second. Time of flight devices are also available in a 2D configuration. This is referred to as a Time of flight camera.

Time of flight and triangulation range finders each have strengths and weaknesses that make them suitable for different situations. The advantage of time of flight range finders is that they are capable of operating over very long distances, about kilometers. These scanners are thus suitable for scanning large structures like buildings or geographic features. The disadvantage of time of flight range finders is their accuracy. Due to the high speed of light, timing the round-trip time is difficult and the accuracy of the distance measurement is relatively low, about millimeters. Triangulation range finders are exactly the opposite. They have a limited range of some meters, but their accuracy is relatively high.

Time of flight scanners accuracy can be lost when the laser hits the edge of an object because the information that is sent back to the scanner is from two different locations for one laser pulse. The coordinate relative to the scanners position for a point that has hit the edge of an object will be calculated based on an average and therefore will put the point in the wrong place. When using a high resolution scan on an object the chances of the beam hitting an edge are increased and the resulting data will show noise just behind the edges of the object. Scanners with a smaller beam width will help to solve this problem but will be limited by range, as the beam width will increase over distance. Software can also help by determining that the first object to be hit by the laser beam should cancel out the second. The <Figure 6> shows the result of 3D scanning with a model car[16-21].

<Fig 6> 3D scanning image

Ⅴ. Conclusion

In this paper, we implemented the 3D scanning embedded system with WiFi wireless communication under Raspberry Pi 3 model platform. Especially we directly designed the 3D scanner system and made the embedded platform. At this point we acknowledged a certain level of 3D scanning technology. Afterwards, we would enhance the performance of 3D scanning platform with adapting various technologies including in this fields.

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