MARKERLESS RAPID SPACE REGISTRATION TECHNIQUE USING DEPTH CAMERA FOR USE IN SHIPBUILDING

[1]WONHYUK LEE , [2]KYUNG-HO LEE, [3]JAE-JOON LEE, [4]BYEONG-WOOK NAM

1,2,3,4Naval Architecture & Ocean Engineering, Inha University, Republic of Korea
E-mail: [1]leamit512@gmail.com; [2]kyungho@inha.ac.kr; [3]jooninara@gmail.com; [4]nbw0519@naver.com

Abstract - Recently, a system that combines AR technology for the purpose of providing design information has been demanded so that the field worker can increase the work efficiency in the installation, inspection, and maintenance stages. For this purpose, marker based AR technology is used in the field but heterogeneity occurs because accurate mapping between information is not done. In addition, design information is input to the marker, due to the nature of industry such as shipbuilding and plant, the design range is very wide and the size of the actual product is large, so there are limitations in applying the marker. Therefore, to overcome these limitations, a markerless based AR is applied. This study first developed the pipe system that occupies the most part of shipbuilding and offshore plant design part, and used Depth camera for 3D space recognition, space filter for object recognition, and object recognition technology. Also, the test was conducted through a simple test block, and the validity of the system was verified

Keywords - Depth based; Markerless; Augmented reality; Point Cloud; RGB-D; Pipeline.

I. INTRODUCTION

During the design process in the shipbuilding and offshore plant industry, some pipelines may not be correctly installed or assembled according to CAD data. These pipelines are not only contrary to the designer's original intentions, but also can cause problems throughout the pipeline system. Generally, this problem is caused by the mistake of the operator or the lack of communication between the designer and the operator, and AR-based technologies are being introduced to solve this problem.AR is a technology to visualize virtual information in the real world. It can improve the existing working environment by providing the work information to the worker rather than the drawing, and can also improve the work efficiency and understanding.

The piping system is a member that occupies the most important part of the members constituting the ship, and is a member that allows the fuel, fresh water and the like to move. Errors in these components can have a significant impact on the safety and reliability of the ship. In order to solve such an error, systems employing AR technology for various purposes such as piping manufacturing and installation are being developed.[1]

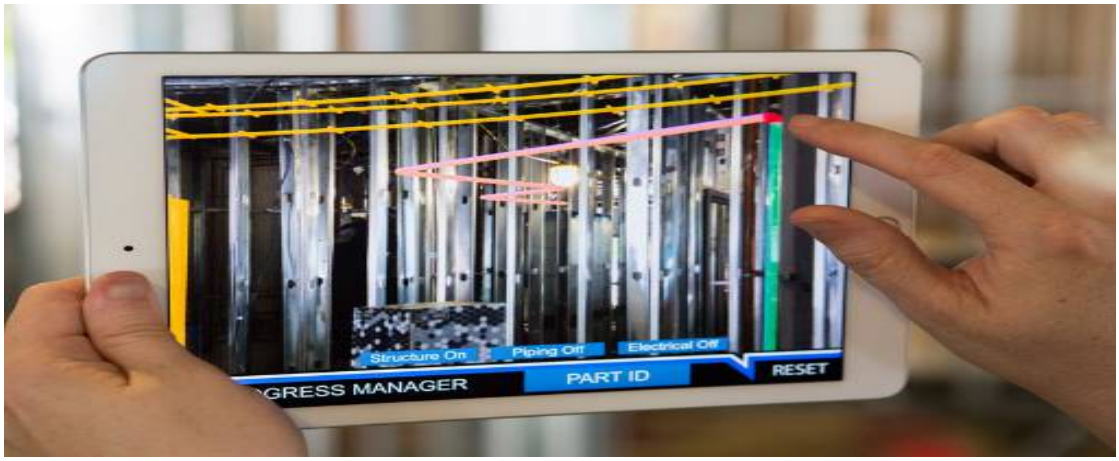

Fig.1. Index AR Solution.

Figure 1 shows the piping installation system created by Index AR Solution, showing the piping installed in a place not yet installed. With this system, the operator can view the pipe information required to perform the work without drawing.[2]However, this is an AR marker-based technology that estimates the position and orientation of the operator. AR technology is classified into a marker method and a markerless method as a method for obtaining three-dimensional coordinates of a camera for a certain point or object in the real world. Marker method Extracts the 3D information entered in the 2D image, finds the feature point, and the camera recognizes it.That is, it is a method of recognizing a simple image plane (2-D) and overlapping information thereon.The marker AR recognizes the shape easily, accurately and quickly

and generates the event accordingly. However, due to the constraint that markers are needed, there are limitations in applying them to specific industrial complexities.AR marker technology cannot be traced when the markers disappear from the camera field of view in tracking the markers, and it is difficult to attach the markers depending on the places. Because it uses 2-D based image processing method, it reacts sensitively to the size of the darkness and the marker, and a complicated mathematical processing technique is needed to solve it.In addition, the information of the pipe to be checked must be manually inputted into the marker, and additional troublesome to manage it occur.[3]

In order to overcome the limitations of these marker technologies, researches are being actively pursued to solve the difficulties of marker tracking through markerless AR technology.Various techniques such as GPS tracking and 3D object tracking are proposed for markerless technology.

The GPS technique has a tracking error due to inaccuracies between the address and map of the GIS (Geographic Information System) as well as the inaccuracy (10 to 30m error) of the sensors used by the civilian. [4] The 3D object tracking technology extracts the key points of the 3D objects, obtains the rotation and movement information of the 3D objects, and tracks the objects in real time. [5,6]However, since the method of extracting feature points of 3D objects is accompanied by complicated mathematical formulas, it is difficult to satisfy AR system performance of real-time image tracking.In addition, the reliability of the system is degraded in the process of modifying the algorithm to improve the performance. This system retrieves 3D spatial information, searches 3D objects through various image filtering methods, and real - time tracking. It improves the performance of existing methods and improves reliability by using RANSAC algorithm and ICP algorithm.

Stereo based on passive sensors and 3D scanners based on active sensors, structured light patterns, and depth cameras are used to import 3D information. Although the passive sensor method has an advantage that depth information can be obtained by using only a focused image, there is a problem that accurate depth information of the scene can not be obtained when the depth information is insufficient, and the performance of the algorithm is low due to high complexity of the used algorithm. [7-9] The Depth camera, which is an active sensor type, is a method of measuring the depth of an image by calculating the return time reflected by an object by sprinkling a number of lasers. In this system, Depth camera is used to obtain a more accurate depth image of the program.Depth It uses the point cloud data obtained from the camera to recognize the three-dimensional space and recognizes a specific object (piping) in the space.In addition, it is a system that can intuitively show the design information to the field worker by overlapping the design information about the object on the actual model. To do this, we used space matching, spatial filter, object recognition technology, and developed a pipeline recognition system prototype.

II. DEPTH BASED RECOGNITION PROCEDURE FOR PIPELINE

A. Define Recognition process

The Depth Based Markerless AR system consists of three parts as shown in Fig.2

First, 3D spatial information is retrieved in the form of Point Cloud as a Depth based system. Since there is too much total spatial data scanned through the camera, noise removal is performed to import only the Point-Cloud data corresponding to the target model.

The second is to create a CAD model based on the target model. Converts the generated CAD model to Point Cloud format. The transformed model is called “Design-Point-Cloud”.

Finally, the RANSAC algorithm is applied to accurately recognize the target model pipeline. Since the pipeline is generally made in cylinder form, the RANSAC algorithm is applied to the cylinder model, and the pipeline model of the Point Cloud format obtained through it is called "Scanning Point Cloud". Then, the ICP algorithm is used to track the Scanning-Point-Cloud, and the CAD model, Design-Point-Cloud, is matched on the model.

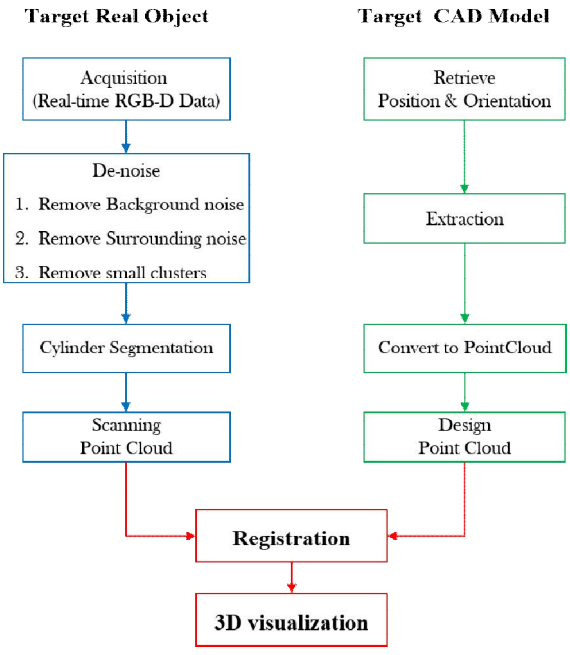

Fig.2. Recognition Procedure

B. Acquisition

Depth camera has separate image camera and depth sensor. Depth sensor has depth information, but RGB-D data does not exist, and image camera is a 2D image camera that we usually use.

In this system, the image is converted into the

XYZ-RGB format in order to utilize the noise removal method to be applied later. As shown in Fig. 3, all the scenes including the target model (pipeline) Are scanned in the combined RGB-D 3D point cloud form.XYZ is three-dimensional coordinate information, and RGB is color information.

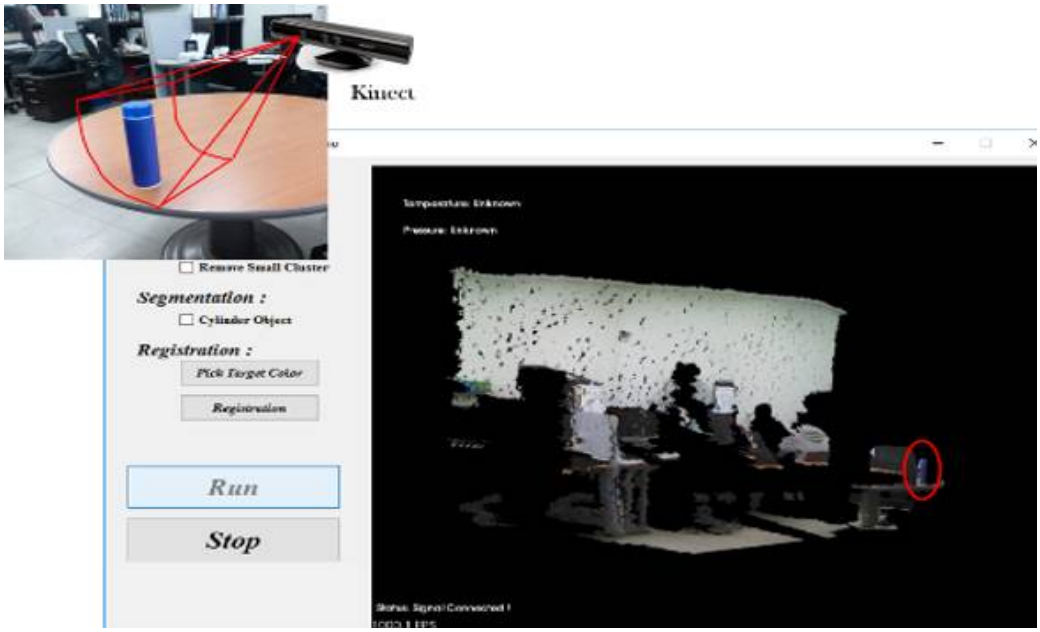

Fig.3. Raw RGB-D point cloud data from Kinect

C. Remove Background Noise

Since the data of the target model occupies only a very small area in each single frame of point cloud data, it is essential to remove the noise except the model area data. Filtering is performed using depth information to minimize unnecessary areas around the model.

The Z axis of the camera represents Depth information, and the maximum viewing distance of the camera is set to Z_max and the minimum viewing distance is set to Z_min. Each variable was subjected to various experimental procedures to obtain an appropriate depth range. If the Z-axis is deformed as shown in Fig. 4, the X and Y axes are changed according to the angle of view of the camera.The specific permissible field of view range is set through the above process, and unnecessary areas other than the permissible range are removed.

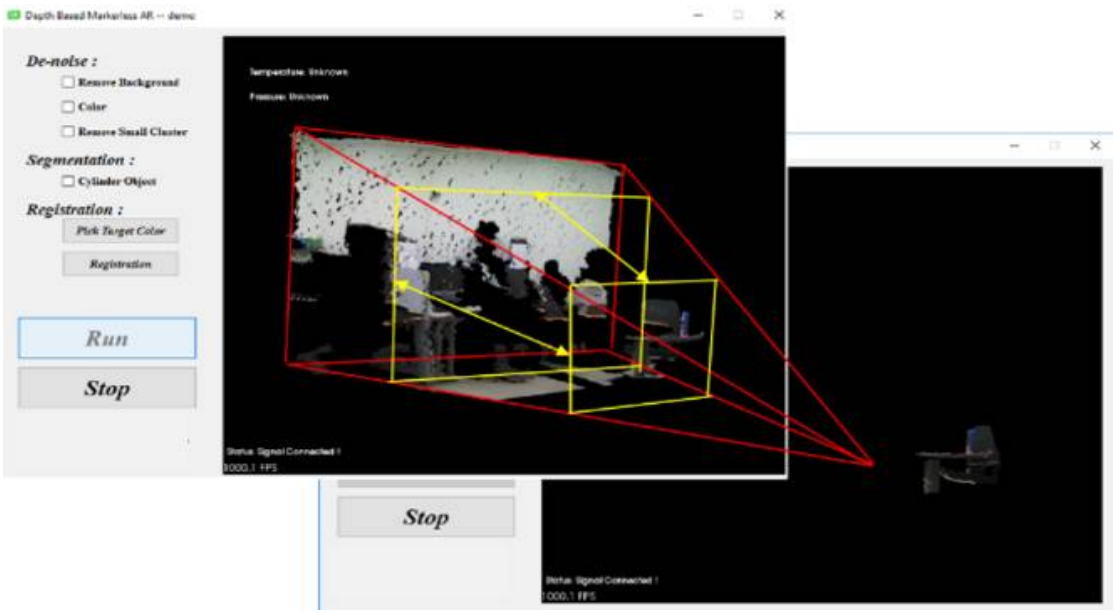

Fig.4. Remove Background: (left) before; (right) after

D. Remove Surrounding Noise

Utilizes the color information of the points to eliminate unwanted data noise that remains near the target model. Set the brightness contrast color range of the target model, and remove any noise other than the points existing within this color range.

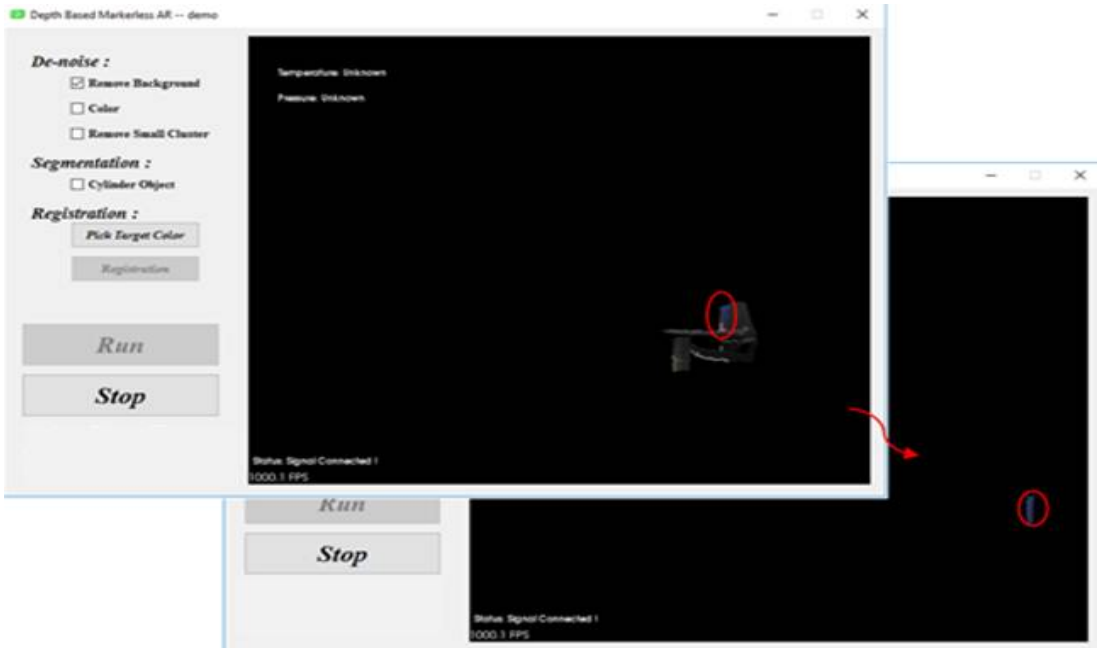

Fig.5. Remove Surrounding Noise

The RGBI color space is defined by a 4 * 4 matrix, as shown in Figure 6, and is determined by four planes, utilizing R (red), G (green), B (blue), and I (transparency). The RGB color space is easy to represent specific coordinates or pixel values, but is very difficult to set the desired color range. In addition, in setting the color range of the actual pipe model, it is necessary to set the color range in which the lightness and saturation are taken into consideration, which requires a very complicated mathematical processing process. This process is difficult to meet the requirements of the AR requiring real-time processing.

The HSV color space is cylindrical, as shown in Figure 6, and utilizes Hue(Color), Saturation, and Value(Brightness). The HSV color space is clearly distinguishable from chromaticity and brightness, making it easy to express a feeling of contrast or texture, and has proved to be a mathematical formula that is easier to detect than RGB.[7-8] Therefore, this system sets the color range by converting from RGV to HSV color space for accurate model matching and performance improvement.

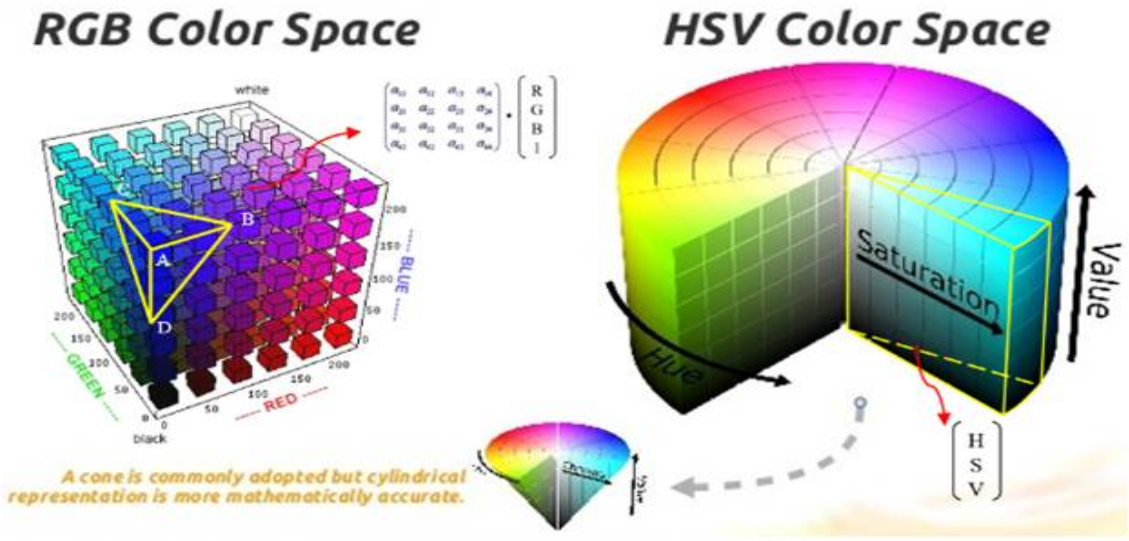

Fig.6. RGB color space vs HSV color space

$$H = \begin{cases} 0 & if\ B \le G \\ 360 - \theta & if\ B \ge G \end{cases}$$

$$\theta = \cos^{-1}\left\{ \frac{1/2 \times [(R-G)+[R-B)]}{[(R-G)^2 + (R-B)(G-B)]} \right\}.$$

$$S = 1 - \frac{3}{(R+G+B)}[\min(R,G,B)]$$

$$V = \frac{1}{3}(R+G+B)$$

E. Remove Small Cluster

There are some small noises remaining in the neighborhood except the target model because there are cases where the scanner is misleading or the color of surrounding objects is similar to the model. Since all of these clusters are composed of points, we set the number based on the number of specific points and remove clusters composed of a number of points lower than the set number as shown. In order to find the correct model parameters through the RANSAC algorithm in the future, it is necessary to reduce noise around the model as much as possible to maintain fast performance and reliability. [9]

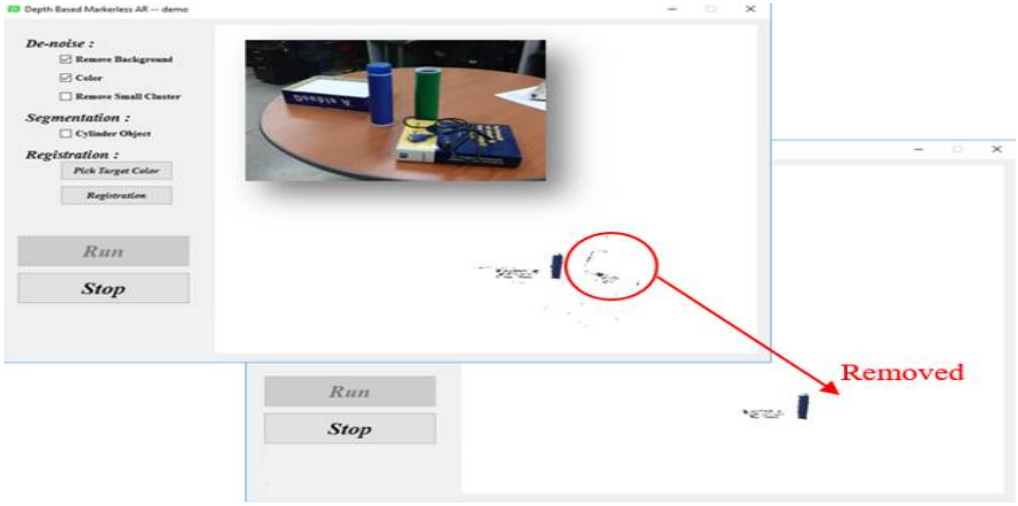

Fig.7. Remove small cluster: (left) before, (right) after

E. Segmentation

Most of the noise has been removed by previous work, but there are still noise clusters in the vicinity of the model. This noise is left when the size of the cluster is larger than or equal to the size of the target model pipe. To overcome these noises and to recognize the target model well, we apply the RANSAC algorithm (RANOM SAmple Consensus) algorithm.

RANSAC is an algorithm that determines optimal model parameters from noise-intensive measurement data. It constructs a mathematical model from randomly selected data and determines whether the model is suitable based on the ratio of the remaining data satisfying the model. In this case, the data satisfying the model is referred to as "inlier", and those not as "outlier" are referred to as "outlier". Since the pipeline, which is the target model of this study, is composed mainly of cylinders, the RANSAC algorithm is applied to the cylinder model. The spacing between the model and the inlier is set to 5cm and the radius interval is set to 2 ~ 8cm. As a result of setting the Iteration value to 1000, As shown in Figure 8, we could find the shape of the pipeline (cylinder), which is a perfect target model, ignoring small noises near the object. This is called “Scanning-Point-Cloud”. [10-11]

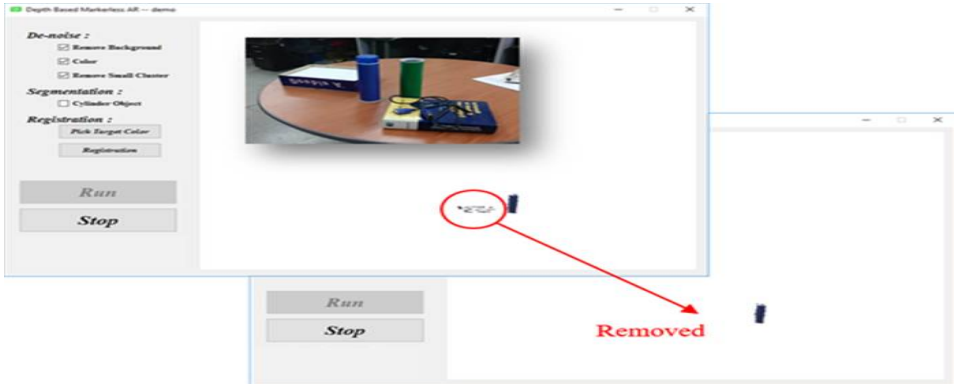

Fig.8. Cylinder model segmentation: (left) before, (right) after

G. Recognition

Finally, we tried to match Design-Point-Cloud (CAD model) to Scanning-Point-Cloud (target model).In order for the two data to be matched as one complete model, it is necessary to acquire the distance image from various directions and synthesize them. In this case, it is necessary to find out the relationship between the movement and the rotation conversion between the two data.

The ICP algorithm uses the initial values of the coefficients obtained through the method using the prior information or the moment, etc., of the camera position even in a situation where the correspondence relation between the two data is not known. The closest point is assumed to be a temporary correspondence point, and the pair of such temporary correspondence points is improved by an iterative method.

This system improves reliability by providing an Iteration value of 150 and shows that the Design-Point-Cloud (CAD model) tracks and matches the Scanning-Point-Cloud (target model) using the ICP algorithm.If there is no additional movement of the camera or the object, the matching is done well. This system is based on the real-time image rather than the fixed image form, because the objective is to obtain information about the pipe in the field. [13]

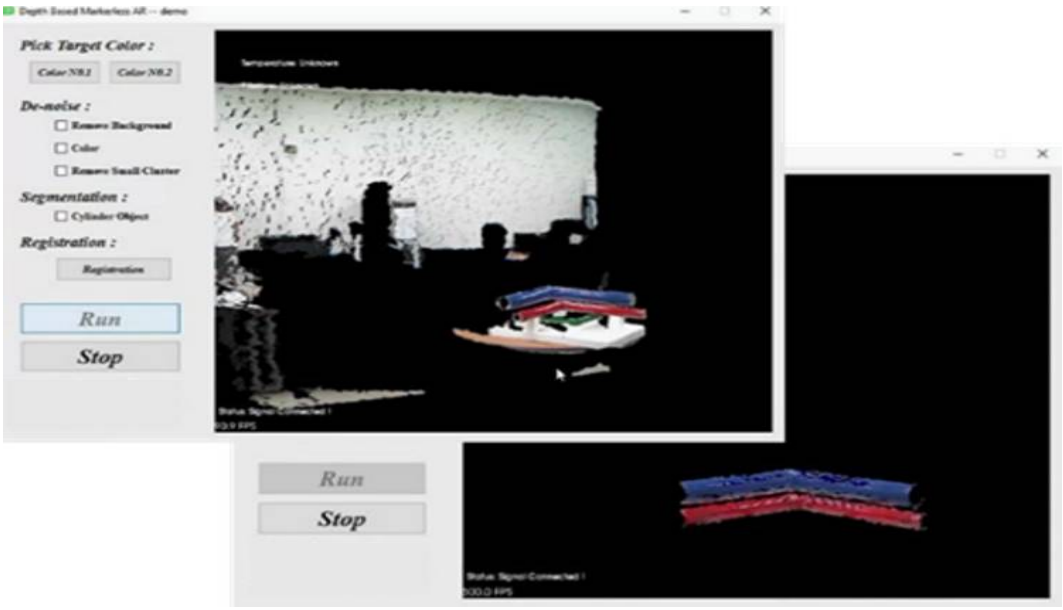

Fig.10. Pipeline Recognition

III. PROTOTYPE IMPLEMENTATION

In order to apply the system method, we constructed a real pipeline model for Pipeline 's Recognition test as shown in Fig 11.

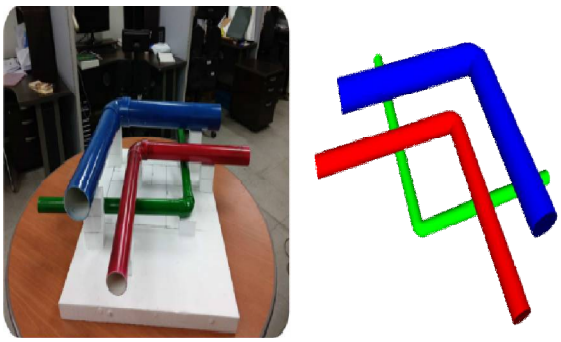

Fig.11. Target Real Pipeline Model (left); Target Design CAD Data (right)

A. Point Cloud Converter

There must be at least two Point Cloud Data models to use the ICP algorithm. Since the general CAD model exists only in the Mesh, the CAD data are first transformed into '.stl' format and converted to the Point Cloud form as shown in Fig.12. This is called “Design-Point-Cloud”.

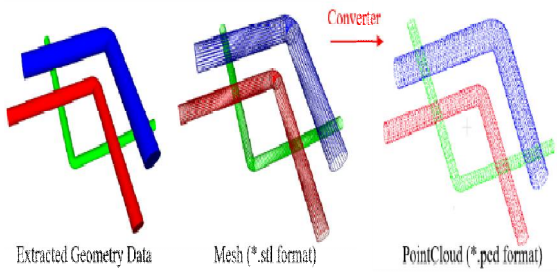

Fig.12. Point cloud converter

B. Development environment

Development environment information is shown in Figure13. In this study, Real-time RGB-D point cloud was captured by Kinect. Cloud Compare and Meshlab did a large of favor in creating the virtual content. And PCL library was embedded in every aspect of this application. Besides that, this application is programmed in C++, and GUI is support by QT.

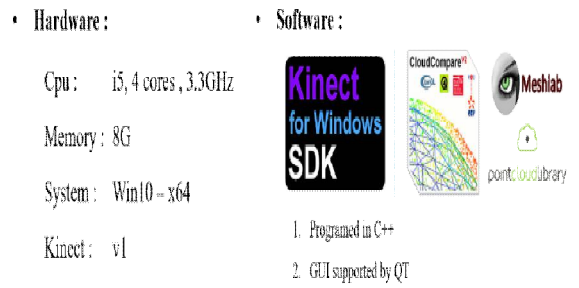

Fig.13. Development Environment

C. Prototype result

Figure 14 shows a prototype pipeline recognition system. When the "Registration" button is pressed, the CAD model is dynamically traced to the target model as shown in the figure.

When the Depth camera or pipeline is fixed, we can confirm that it is well matched to the CAD model and the target model. Even if there is camera or pipeline motion, we can confirm that the target model is dynamically reconfigured by tracking in real time.

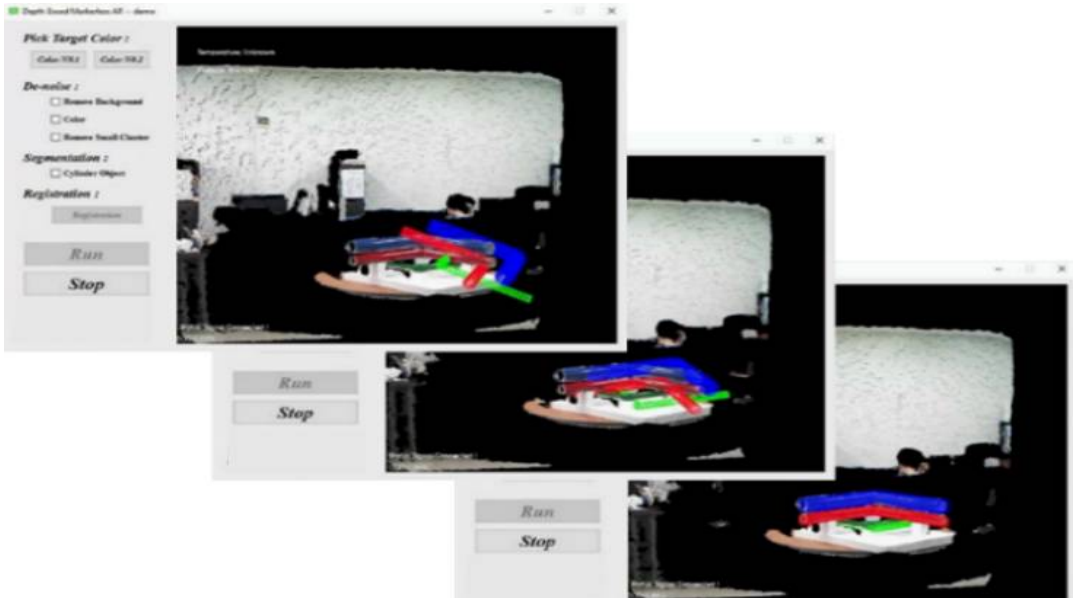

Fig.14. Pipeline Recognition & Overlaying with Design CAD Data

CONCLUSIONS

This system has developed AR marker based shape recognition system to solve the limitations of systems used in pipe inspection or maintenance using existing marker technology. Existing systems have difficulty in constantly tracking markers. Therefore, this system uses depth - based point cloud technology to solve these limitations by using spatial registration, spatial filter and object recognition method, and it improves utilization more than existing marker based system.

This system recognizes the model and can provide the work information to the operator. It can be used in piping installation, maintenance and inspection. In addition, it is expected that the system will be developed as a system that recognizes various shapes through interworking with servers and provides the necessary information to the operator without the hassle of markers and without any special prior work. In addition, it is expected that it will be possible to develop a system that recognizes various shapes through interlocking with servers and provides the necessary information to the operator, eliminating the troubles of markers and special prior work.

Future developments will be tested on various pipe models, and bi-directional communication between designers and operators will be improved through real-time markerless recognition.Also, it was confirmed that performance degradation is caused when converting the system image into XYZ-RGB format when outputting the system image. Since we use the parametric method which attempts to match one model to the current one, we converted the image to XYZ-RGB format for noise filter and output the image, but we will focus on performance improvement by switching to non-parametric method later.

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