Non-contact 3D measurement system for furnace wall maintenance support

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ABSTRACT

There is a submerged combustion type waste fluid incinerator in the waste fluid processing equipment. This incinerator can process the waste fluid in harmless condition. This gushes the high temperature combustion gas generated by combustion in the liquid all at once, and is the liquid processing equipment of the combustion gas bubble to which the heat conduction and the absorption of the combustion gas element are effectively carried out by direct contact with gas and liquid. The high temperature combustion gas give damaged to furnace wall of this equipment. As this equipment is operating all day long, it is necessary to inspect it at some constant intervals. In this research, the development of measurement device which automatically checks the furnace wall of this equipment by uninhabited is aimed.

The Kinect sensor is marketed by Microsoft Co. LTD., which has the functions of RGB camera, IR camera, the Depth sensor and Multi-array microphone. The inspection system in the submerged combustion type waste fluid incinerator is developed by using this function.

The system was constructed with Kinect sensor by using the model furnace for the inspection evaluation. The 3D data and CCD color image of the in-furnace were obtained by using this system. As processing software, PCL was used, which is a large-scale 3D point cloud operating open source program. This open source program has function of the model making, filtering, registration and the object detecting, the 3D point cloud model making. In the construction of the whole 3D model of closed space, RTAB-Map was used, which is a RGB-D Graph SLAM approach based on a global Bayesian loop closure detector.

In conclusion, the system unit was developed, which can inspect the state of each part in the incinerator by using Kinect sensor, RTAB-Map and PCL. The 3D model of the partial inspected incinerator is made by using PCL, and the whole 3D model is made by RTAB-Map.

KEYWORDS: Kinect, PCL, RTAB-Map, Non-contact measurement, 3D-image processing
1. INTRODUCTION

In this research, the purpose is to develop the system to inspect the submerged combustion type waste fluid incinerator. The state of inspection is that the worker set up scaffolding, and inspect by visual observation without using inspection device. Therefore, the measurement device which automatically inspect the furnace wall of this equipment by uninhabited is developed, in this research.

![Figure 1: Cycle of this system](image1)

2. ABOUT SUBMERGED COMBUSTION TYPE WASTE FLUID INCINERATOR

There is a submerged combustion type waste fluid incinerator in the waste fluid processing equipment. This gushes the high temperature combustion gas generated by combustion in the liquid all at once, and is the liquid processing equipment of the combustion gas bubble to which the heat conduction and the absorption of the combustion gas element are effectively carried out by direct contact with gas and liquid.

![Figure 2: Process of incinerator](image2)
The 3D model of submerged combustion type waste fluid incinerator and the real picture of interior of this incinerator are shown at Figure 3.

![Figure 3: Submerged combustion type waste fluid incinerator](image)

**3. FLOW OF THE DEVELOPMENT**

In this research, the purpose is to develop the unmanned and automated inspection system to inspect submerged combustion type waste fluid incinerator. Therefore, the device and software is developed.

In development of device, it is thought that rotated mechanism and vertical mechanism is introduced to this device, in order to inspect the interior of incinerator. In this device, the internal whole of incinerator can be inspected by rotational motion and linear motion.

In development of software, the presence of the defect is inspected by **Kinect** and partial inspection is done by **PCL**, overall inspection is done by **RTAB-Map**.

![Figure 4: Flow of the development](image)
4. DEVELOPMENT ENVIRONMENT

4.1. About Kinect
The Kinect sensor is put on the market by Microsoft Co. LTD., which has the functions of
RGB camera, IR camera and the depth sensor. The RGB camera and the depth sensor
function of this device are applied to the inspection system on the surface of the furnace wall.

![Kinect v2](image)

Figure 5: Kinect v2

4.2. About PCL
"PCL" is abbreviation of “Point Cloud Library" and this software is a large-scale 3D point
cloud operating open source program. The function of the model making, the filtering,
registration and the object detecting is used in this study.

4.3. About RTAB-Map
RTAB-Map (Real-Time Appearance-Based Mapping) is a RGB-D Graph SLAM approach
based on a global Bayesian loop closure detector. In this research, the whole 3D model of
closed space is obtained by using RTAB-Map.

5. MEASURING THE PSEUD-MODEL OF INCINERATOR BY KINECT
In order to experiment with Kinect, pseud-model of incinerator was made. The target
incinerator is made by brick, so this pseud-model was mainly made by brick. The size of a
brick is 215×100×60m. The brick displayed lengthwise assumes it the wall of the
incinerator. The part which the brick fell out of means a defect.
The pseud-model of incinerator is shown in Figure 7.
The color image obtained by Kinect is shown in Figure 8. When it is really used in incinerator, the color image is obtained by lighting up the inside with a light. The presence of the defect is inspected by this function. The display of Kinect Fusion is shown in Figure 9. Then Kinect Fusion is the function to build 3D model by depth information, IR information and other factor measured by Kinect.

6. **DESIGN OF THE INSPECTING SYSTEM**

As a design of the inspecting system, the program using PCL was made.

As the algorithm included in PCL,
- Visualization  
  To visualize of the 3D data
- Filtering  
  To process the point cloud.
- Registration  
  To align point cloud
- Mesh  
  To create the mesh model

is used to process the data obtained by Kinect.
The result of having output 3D model data obtained by Kinect Fusion as a 3D point cloud model by making program using PCL is shown in Figure 10. The detailed inspection can be done by output as 3D point cloud model.

Registration is to combine the part which is common to target data by detection and alignment. The procedure of Registration is shown below.

First, detecting the characteristic point of 3D model’s point cloud is done. The algorithm using in this procedure is PFH(Point Feature Histogram).

Second, primary alignment is done by the rough characteristic point's corresponding. By this procedure, the processing time is reduced, and precision is improved. The algorithm using in this procedure is SAC-IA(Sample Consensus Initial Alignment).

At last, precision alignment is done. By this procedure, the point cloud's correspondence becomes more high precision. The algorithm using in this procedure is ICP(Iterative Closest Point).
In this research, the 3D model of the whole interior of incinerator is created by Registration with 3D data obtained by Kinect.

The two images of 3D model before processing is shown in Figure 11.

The image which aligned two upper images by Registration is shown in Figure 12. This result shows that two 3D models are aligned accurately. It is thought that the 3D model of whole interior of incinerator can be created by this function. However, many data are necessary because quantity of movement is small. Therefore, it is thought that data size gets heavy and time for processing becomes long.
7. **3D MESSUREMENT AND EVALUATION**

As the 3D measurement and evaluation, the 3D model of closed space by RTAB-Map is created. The 3D model is created in the real time by aligning with characteristic point of information that was provided before a little than current information and the current information. The picture of RTAB-Map is shown in Figure 13. Real time image and characteristic point is shown at the upper left. The result of loop detection is shown at the middle left. The depth image is shown at the lower left. And the result of 3D scan is shown at the right.

![Figure 13: Picture of RTAB-Map](image)

The 3D mode of laboratory output by PCL which was acquired by RTAB-Map, and reference image is shown in Fig. 14.

![Figure 14: Laboratory output by PCL](image)
This result shows that the 3D model of the whole closed space can be created when the target is the closed space. The measurement in the laboratory experiments as an test, and intends to really use this function in an incinerator.

8. CONCLUSIONS
- The system which inspect the state of each part in the incinerator by using Kinect sensor and PCL was developed.
- The 3D model of the partial inspected incinerator is made by using PCL, and the 3D model of whole laboratory is made by RTAB-Map.
- The device which installs Kinect sensor and drives will be developed.
REFERENCES
