WALL SHAPE RECOGNITION USING LIMIT SWITCH MODULE

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ABSTRACT

We have researched a gondola typed robot system for building façade maintenance. Its main application is to paint on building façade. To apply a robot system to the painting tool, recognition of building wall shape should be preceded. In this paper, we proposed a limit switch module as a mechanical sensor method. As experiments, we applied the proposed module to window and obstacle on wall with attitude reference sensor (ARS) and laser height sensor (distance sensor).

KEYWORDS

gondola robot, building facade, wall shape, limit switch

1. INTRODUCTION

There are many people who work on high-rise building. They hang themselves on ropes and work at decades meter high in the air. Stress and fear for danger always press them. Number of such workers has decreased, but requirement has increased. Labour cost for building wall maintenance has also increased.

Many researches have tried to help them. A robot with suction pads moves on glass wall to clean it [1, 2]. Built-in guide rail provides stable robot navigation method to access building façade [3]. We have researched a gondola-typed robot system [4-7]. As sensor system, we proposed a height sensor system [5] and window detection algorithm [6, 7]. The basic approach is to keep people away from building façade. Vertical location control and horizontal balance control is applied on our gondola robot system. Painting nozzles and cleaning rotary brushes are established.

In this paper, we will suggest another sensor system. It is a mechanical sensor module using limit switch for wall shape recognition. Two limit switches with different stroke sense the same place for wall and obstacle. There are three states with sensor output. First is that there is wall and no obstacle. We call it as ‘ordinary wall’. Second is both limit switches are off. It means there is a window in front of the sensor module. Third is an obstacle make the two limit switch on because the obstacle is close to the sensor module.

Additionally, the sensor module uses only mechanical sensors. It is very important to guarantee robust sensor system. Limit switches has already been used for long time, and its robustness is proven.

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In Chapter 2, we will show the meaning of wall shape recognition. In Chapter 3, our suggested limit switch module will be introduced. Experimental result and relevant discussion will be in Chapter 4.

2. WALL SHAPE FOR AUTONOMOUS WALL PAINTING ROBOT

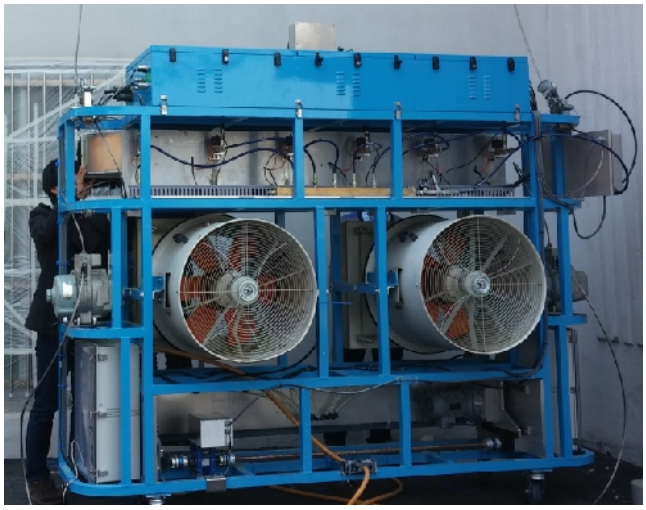

Figure 1. G-BMR Release 5 (R5)

Fig. 1 is fifth release of our gondola robot platform (G-BMR R5). Its width is 3.5 m, and the painting width is 3.2 m. There are six painting nozzles controlled by solenoids. They spray single color paint at concrete wall. The system purpose is to paint single color on wide concrete wall fast. Two endless winders are actuated to keep horizontal balance. This horizontal balance is an important factor to get proper painting quality on the wall. Two suction fans generate contacting force between the gondola frame and the building wall [8]. These fans provide two control factors. First is to keep horizontal balance on orthogonal direction of endless winders. Second is to guarantee the distance between wall and paint nozzle.

For painting with six painting nozzles, the nozzles should be controlled in accordance with building wall shape. We defined the wall as three categories. First is ordinary concrete wall. Second is obstacle on wall. Third is window. The criterion of classification is the distance from the gondola to the wall.

The reason we use three classes is that we only aim to paint on the ordinary wall. Other wall classes are out of our aim of painting. In other words, the main goal of the wall shaping recognition is to identify the wall to be paint. The method is to identify the distance from gondola frame.

We have already researched a window detection algorithm using visual sensor [6, 7]. However, the proposed sensor module has different approach. Most of all, this approach use only mechanical sensors. Amount of information is smaller than other laser or visual sensors, and this mechanical sensor is robust to environmental threat such as humidity, sun light, and sprayed paint by robot.

3. LIMIT SWITCH MODULE

3.1. Module Component

At fig. 2, there are two limit switches in limit switch module. Their combination is translated to building wall shape information. The ARS sensor and the height sensor are used to mapping to 3D localization of the robot. If ARS sensor and height senor are attached to other place of the gondola, the sensor data is need to send to this limit switch module process algorithm.

The main point of the limit switch module is that two limit switches have different purpose and setting. Fig. 2 (b) is the limit switch for wall that has longer stroke and senses the window areas. Fig. 2 (c) is the sensor for obstacles has shorter stroke to sense only obstacles which is closer than ordinary wall.

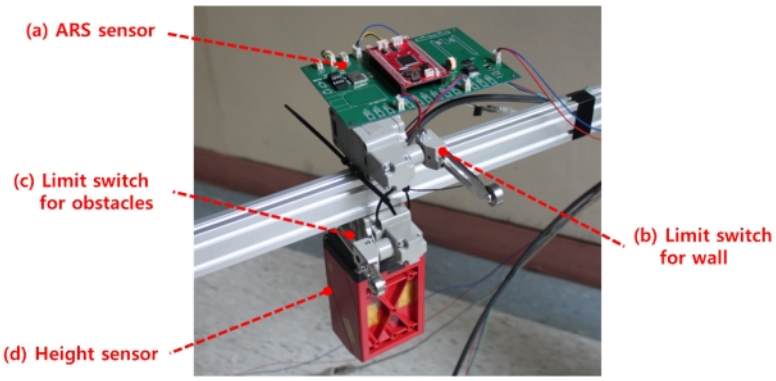

Figure 2. Limit Sensor Module.

3.2. Limit Switch Scenarios

Fig. 3 is a case that the gondola is on ordinary wall. Only the limit switch for wall is on. The limit switch for obstacle is off. Based on these two limit switch sensor values, we can decide that the robot is on ordinary wall. Because ordinary wall is recognized, the paint nozzle on gondola (Fig. 3 (d)) is on. Note that the painting procedure is executed when the gondola goes down. Therefore , limit switch installation is set to satisfy it.

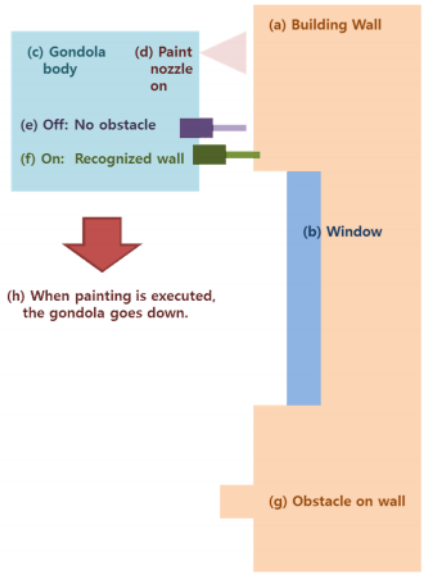

Figure 3. Movement on Ordinary Wall

If the gondola is on window area, the two limit switches are off simultaneously as shown in Fig. 4. Because the gondola is on window area, the paint nozzle on Fig. 4 (d) is off. When the gondola robot goes through window area, we turn off the suction fans for preventing the gondola frame to hit the window glass. Therefore, two limit switches can be off.

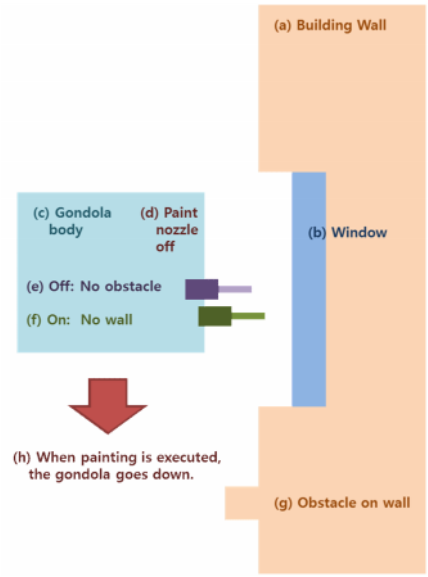

Figure 4. Movement on window space

At the obstacle on wall, the two limit switches are on. Note that the obstacle on wall is defined as something on the wall which is closer to the gondola than ordinary wall. For example, security grill can be sense by this approach. There may be concrete ribs on the wall, and they should be painted with the same color. After adjusting the stroke of obstacle limit switch not to sense concrete ribs, the paint can be sprayed on the concrete ribs.

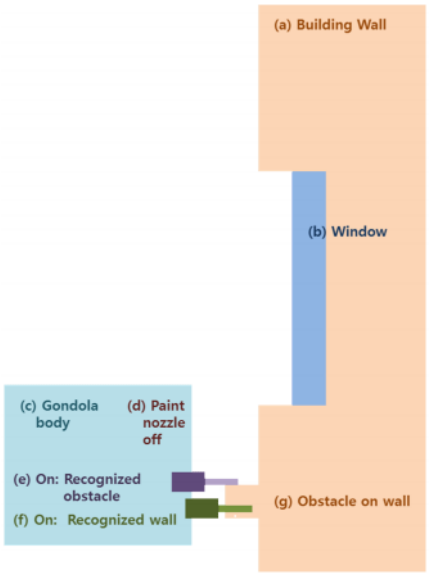

Figure 5. Movement on Wall Obstacle

On top view of the gondola robot system, the limit switch modules are installed as shown in Fig. 6. We assume that there are no windows and no obstacle that smaller than paint nozzle spray width. Our specification of nozzle width is 30 cm, and overlay of paint is required for paint quality. Therefore, limit switch modules on left and right of each nozzle can determine on and off state of the paint nozzle. If third limit switch module sense a window or an obstacle, second and third paint nozzles should be off.

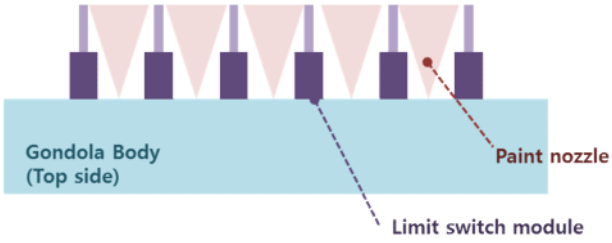

Figure 6. Horizontal installation of limit switch modules

4. EXPERIMENTAL RESULT

The proposed limit switch module of Fig. 2 is applied to a window and an obstacle shown in Fig. 7. This window is installed about 7 cm sunken. The obstacle is a stainless steel cover for valves in wall, and about 3 cm protruding and 35 cm height.

(a) (b)

Figure 7. (a) Window on wall (b) Obstacle on wall (Stainless steel valve cover)

Figure 8 is sensor data when the limit switch module was applied on the window. At the same height, the limit switch state is toggled. On limit switch graph labelled as 'Switching', bottom state means both limit switches are off, and middle means the wall limit switch on.

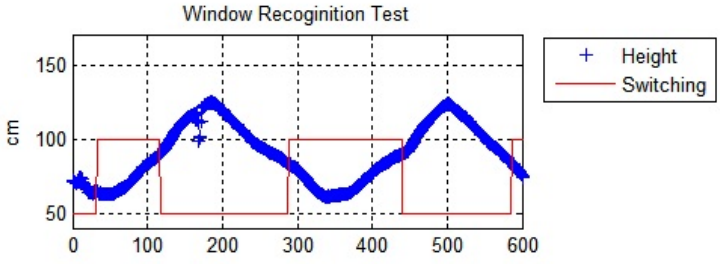

Figure 8. Sensor data on window

Figure 9 is output of the limit switch module on obstacle. There are two toggled points on limit switch graph, and they are 131 cm and 95 cm on height graph, respectively. The gap of sensed height by the limit switch module and measured height by ruler is 1 cm for 35 cm high obstacle.

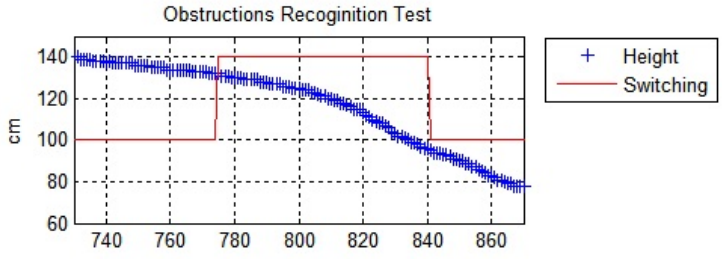

Figure 9. Sensor data on obstacle

5. CONCLUSIONS

Limit switch is widely used mechanical sensor at robotics and factory automation. We applied this sensor to the gondola-typed building maintenance robot system to recognize the wall shape. With this sensor data, we will control the painting tool nozzles to protect windows and react to obstacles on the wall. Two limit switches sense the wall and the obstacle respectively. By adjusting stroke of limit switch, the sensor module can be applied to various environments. At

experiment with the height sensor and ARS sensor, we can verify the location specifying performance of the sensor module about change of wall state.

As future work, we are researching how to apply this module to the gondola system compact and easy-to-maintenance. With other sensor system we researched, we will design fail-safe scenarios about the gondola robot system.

ACKNOWLEDGEMENTS

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