Contemporary Engineering Sciences, Vol. 9, 2016, no. 19, 915 - 923
HIKARI Ltd, www.m-hikari.com
http://dx.doi.org/10.12988/ces.2016.6693

Implementation of Optimal Snow Melting System with Advanced Image Processing and Snow Drift Analysis Algorithm

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Abstract

Current snow melting system is used to melt ice and snow on the road. Snow melting system determines the operation based on using temperature and humidity. In order to make the snow melting system operate more efficient, there is a need for apprehension of snowdrift status and quantity of heavy snow as well as the temperature and humidity data. This thesis composed the sensor data processing part by adding the wind speed sensor along with the existing temperature-humidity sensor based on microcontroller. Also, added the image processing part to analyze the snowdrift of actual road surface. Sensor data processing part and image data processing part enabled the accurate analysis of snowfall and snowdrift of the actual road surface. In addition, we applied correction method of analysis snowdrift condition that mixed with debris on the road surface. This method enabled system operation much efficient. Furthermore, Using Wi-Fi module of image processing part, the snow melting system enables the connection of internet when adapting the actual snow melting system and operated with snow melting system which adapted the IoT technology.

Keywords: micro-controller, snowdrift, image processing, snow melting system, IoT

1 Introduction

Conventional snow melting system normally operates by using road temperature data and humidity data. However, even though snow is not detected but humidity and temperature conditions matches, snow melting system heat the road surface and causes the waste of electricity. This thesis, in order to detect accurate snowdrift, we used raspberry pi micro-controller and camera module to compose the snow melting system image processing part and obtained real time image of road where snow melting system is installed and consist of the image processing technology to improve the system operation judgment standard based on detection of actual snow. Also, we adopted difference image method to separate existing background image to detect snow on outdoor road surface and analyzed histogram of the obtained image to judge the snow drift and calculated amount of snow drift on the road surface; set of standard snowdrift for the snow melting system operation is more efficiently. In addition, if the debris in the road surface is added or temperature is rise, we show that snow drift can be corrected. By using Wi-Fi module on the main board of image processing part, we enabled the real time internet connection. This has enabled the actual snow melting system to collect sensor data and image data from installed section and also the communication between each other's. So we propose upgraded snow melting system which enabled internet connection and communication with sensor data which is the main technology of IoT.

2 IoT application to snow melting system

This thesis improved snow melting system by applying Iota technology. IoT(Internet of Things) refers to a technology connecting to internet through embedded communication function in sensors and objects. [1] Figure 1 shows the IoT based snow melting system proposed in this thesis. When materializing IoT, the communication technology for the achievement, fusion and transmission of high rank sensor data is the core technology. The existing snow melting system has determined the operation of snow melting system by obtaining two simple data; temperature and moisture which made it difficult to understand the overall snow drift before operating the actual system. This thesis has supplemented wind speed sensor to improve the understanding of climate condition, and in order to detect the actual snow, supplemented image process part using image sensor (camera module) on the outdoor road environment.

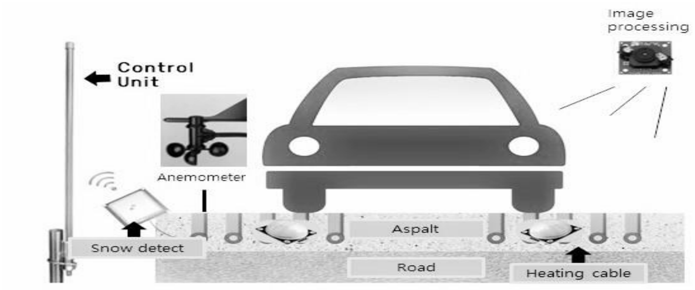
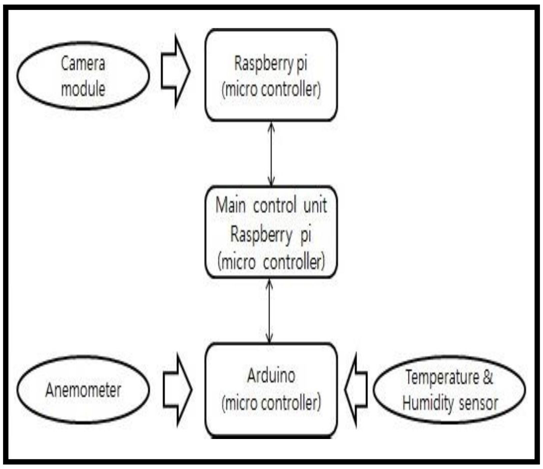


Fig1. IoT based snow melting system composition

3 Composition of snow melting system hardware

Figure2 shows hardware block diagram and figure3 shows a composed hardware image. In order to obtain the sensor data, we used the Arduino micro controller to main board with temperature humidity sensor and wind speed sensor and composed the sensor data process part, and composed the image data process part by connecting camera module with raspberry pi micro controller. [2] The main board of image process part used raspberry pi 2 micro controller. This main board is based on 32BIT ARM CortexA7 core process. By connecting camera module to raspberry pi board, the upgraded snow melting system obtains the image data from the road surface. Camera module is connected to CSI of main board (Camera Serial Interface) and installed with CMOS image sensor from Omnivision Company. It is specialized with its small size and able to shoot 6Mega Pixel still cut, and supports the video recording mode. [3] Also, using another raspberry micro controller enables the control and communication of sensor data process part and image process part. This composes a hardware interface for obtaining image data of real time road surface.



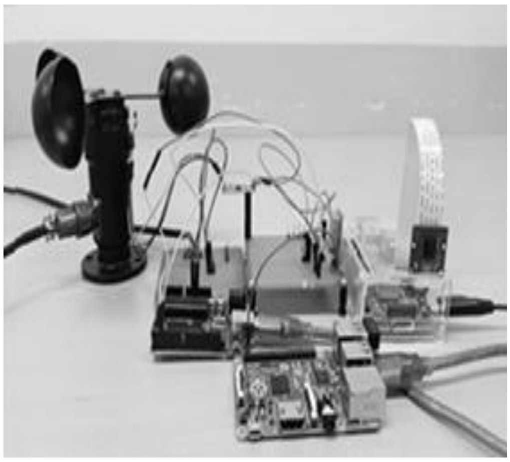


Fig2. System block diagram Fig3. Actual system composition image

4 Design of advanced algorithm for image processing and snow drift analysis

Figure 4 shows the operation algorithm of the upgraded snow melting system. It compares road temperature and road humidity to setting temperature and setting humidity on real time. When the temperature and humidity condition matched, it measured wind speed, and if there was no change in temperature and humidity due to wind speed, it analyzed the image of the section where snow melting system is installed through image process part and detects snow. In order to detect snow, we utilized two image processing method; difference image and histogram. Difference image processing method is a method which calculates the difference of obtained image and preset background image and evaluates the subtraction by utilizing the calculation of image. The method set the road surface image when not snowing, and records the image from the time for image analysis and conduct subtraction to check the snow crystal. However, the image is composed of pixel, and each pixel has various values. Histogram is a table which provides with the number of pixel with specific value in the image.[4] the specific value refers to the brightness of each pixel in the image. Histogram in grey level is composed of the range of brightness from 0 to 225, and provides with distribution graph of brightness value for each pixel in the image. 0 brightness value is the darkest and 255 is the brightest. Using difference image histogram which separated the background and road surface image in order to detect snow, we conducted analysis of pixel distribution map of each brightness value. When snow is detected during the image processing, it obtains the SNY(amount of snow drift on the road surface measured initially) based on SNX(setting amount of snow drift to decide the operation of snow melting system) to operate the system if SNY is larger than SNX. Also, in order to consider the change of snow drift on real time, it obtains the SNYn(nth outdoor road surface snow drift) to consider the case of SNY larger or smaller than SNYn. If SNYn is larger than SNY, the system starts operating. On the other hand, if SNYn is smaller than SNY, the case can vary in these two scenarios; first, when the amount of snow drift is decreased by the stacked foreign substances, second, when the snow melts due to the rise of temperature. In first case, which the outdoor temperature is lower than 0 degree Celsius, there was no change in temperature but occurred distortion of amount of snow drift due to the accumulation of foreign substances. In this case, by measuring SNXc(revised value of snowdrift) the system revises the distorted snowdrift and maintains the operation of system. In second case, which the outdoor temperature is higher than 0 degree Celsius and the SYYn is smaller than SNX, the SNYn is smaller than standard snowdrift due to melted snow; the operation of snow melting system is cancelled. Every algorithm of snow melting system repeats operating after preset interval period of time based on the characteristics of installed snow melting system.

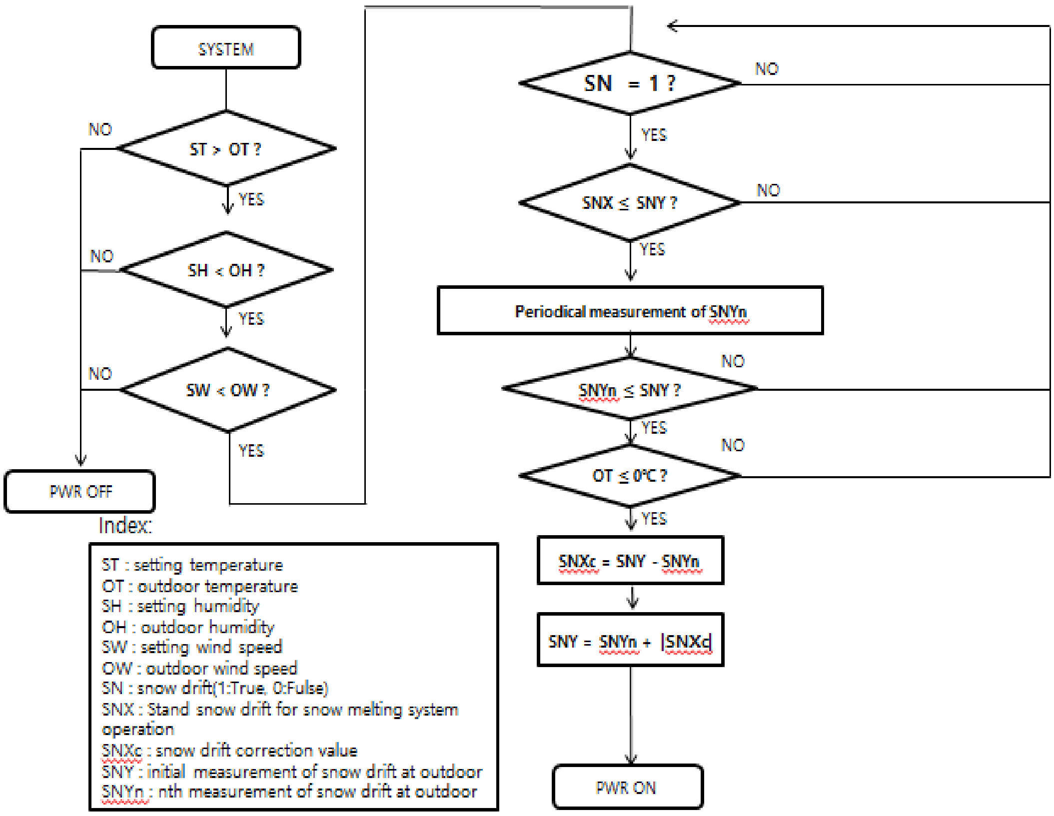


Fig4. snow melting system operation algorithm considering the alteration of snow drift

5 Experiments

Conventional snow melting system operating condition is 25 degree Celsius and 30% humidity. Because wind speed sensor data is analog, we adopted formula 1 described below to convert the wind speed value into digital. Also, we hypothesized change in temperature for case when there is wind faster than 5m/s. using 10bit ADC function as voltage value of analog output to convert it digital and adopted wind speed calculation method by [5]:

$$v\ (\text{windspeed}) = 6 \times \text{analogvoltage} \times \frac{5}{1023} \qquad (1)$$

Table 1 shows the outdoor temperature, humidity and wind speed data measured during experiment. The change in temperature and humidity influenced by wind speed is detected. Wind speed of 2m/s does not influence the actual real time temperature change.

Table1. Wind speed and temperature, humidity data

measured time	Temperature(℃)	Humidity (%)	Wind speed(m/s)
1	25	49%	2
2	24.5	48%	2
3	25	50%	2.2
⋮	⋮	⋮	⋮
48	25	50%	2.1
49	24	48%	2.1
50	24.5	48%	2

So we recorded the still image at the image process part in order to detect snow crystal on actual outdoor road surface and adopted the difference image method. Figure5 shows background image, figure 6 shows obtained image, and figure 7 shows difference image. [6]

Fig5. Background image

Fig6. Obtained image

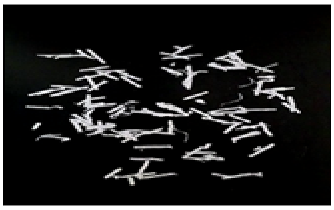


Fig7. Difference image

Figure 8 shows the histogram distribution map of background image, and figure 9 shows histogram of difference image. Pixels of background image and difference image are generally dark. We can clearly the background pixel of difference image and show the dark (it is same about background) and white snow. Also, the darkest brightness which is 0, is 46245 pixel, the largest value, the snow crystal pixel data which is composed of brightness from 190-225 is much smaller than background pixel with 0 brightness and too hard to be visible. Also, to obtain the amount of snowdrift, we had to obtain pixel number data through analysis of difference image histogram. In order to find a standard brightness value for clear distinction of snowing section from the bright background to dark background, we adopted image banalization method. Banalization of image is a method that binary-code based on critical brightness value to set the pixel with bigger brightness value as 1 and set the pixel with smaller brightness value as 0. By adopting various critical brightness values, we verified that when the brightness value is 60, the separation of snow crystal and background is most clear. In other words, pixel with over brightness value of 60 in difference image is snow. In order to verify the accurate snow drift, the pixels with bigger critical value in difference images are all added up to find out the extent of snow in the image.

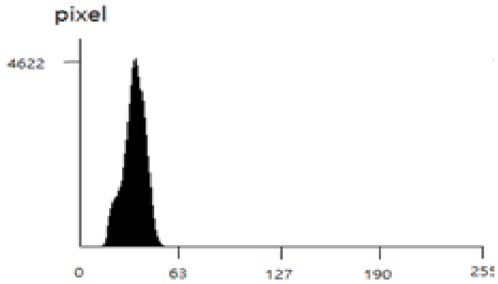


Fig 8. Histogram of background image

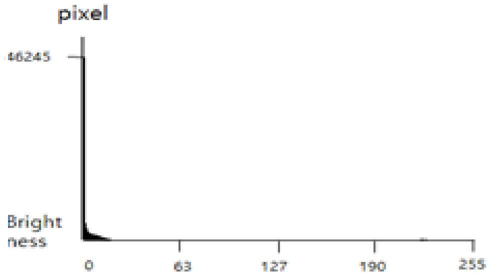


Fig 9. Histogram of difference image

The difference image in Figure 7 is composed of 320 × 240 (76800) pixel, and able to verify that the snowdrift is about 9.2%. We assumed the changed circumstance due to foreign substance to conduct a snowdrift revision experiment based on SNX (standard snowdrift for snow melting system operation) 5%. The figure 6 below increased the black foreign substances in specific ratio to the figure 4 with no foreign substances to set up a circumstance with change of snowdrift and conducted experiment. As we can see in table 2, we operate snow melting system in all 4 images because their experimental condition shows larger SNY than SNX. In order to measure the real time convergence, we measured SNYn and distinguished outdoor temperature because SNYn is smaller than SNY. The measured temperature is lower 23 degree Celsius which is the set up temperature for experiment so the condition for temperature matches, but for the distorted amount of snowdrift due to different amount of foreign substances, we adopted newly revised value of snowdrift, the SNXc and revised. [7]

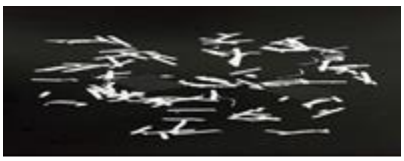


Fig10. Snow drifts level1

Fig11. Snow drift level2

Fig12. Snow drifts level3

Fig13. Snow drift level4

Table2. Wind speed and temperature, humidity data

picture	SNX	SNY	SNYn	SNXc
Fig 10	5%	9.2%	8.5%	0.7%
Fig 11			7.9%	1.3%
Fig 12			7.0%	2.2%
Fig 13			6.1%	3.1%

6 Conclusion

The snow melting system installed on the actual outdoor road surface during winter season decides operation by judging the road surface circumstance without considering the accurate detection of snow, which leads to the inefficiency of the system operation when the actual snow does not exist on the road surface. [8] Also, the comprehensive understanding toward snow drift in the section where system is installed was quiet difficult. Therefore, in order to improve the accuracy of operation judgement standard, this thesis supplemented with wind speed sensor to supplement the sensor data for the operation standard, obtained image of outdoor road surface where snow melting system is actually installed, and used the difference image method to distinguish background image and obtained image, which ultimately led to the accurate detection of snow drift image. Adding up to this, we enabled the system to set the standard snow drift in accordance with the environment of installed section and after understanding the increased or decreased snow drift on real time due to the change of temperature and foreign substances on the surface, the accuracy and efficiency operation standard of snow melting system can be improved through the revision. Hereby, the fragmentary operation standard of existing snow melting system is conquered, and was able to understand the comprehensive snow drift circumstance of outdoor road surface through detecting the actual snow. [9] Also, in order to improve the operation standard, we made it possible to obtain various sensor data and the image processing part utilized wireless internet to manage the overall snow melting system based on web. Hereby, this thesis proposes efficient snow melting system composition and operation algorithm which will allow one to understand the comprehensive snow drift circumstance by systematically connected snow melting system in various sections and ultimately overcome the inefficient power loss from the malfunction of existing snow melting system. [10]

Acknowledgements. "This research was financially supported by the Ministry of Education (MOE) and National Research Foundation of Korea (NRF) through the Human Resource Training Project for Regional Innovation (No. 2014H1C1A1066414)."

“This was supported by Korea National University of Transportation in 2016.”

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Received: April 15, 2016; Published: August 12, 2016