Development of Wheelchair Tracking System Using Omnidirectional Camera and Full Color LEDs

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***Abstract*—In this paper, a self-localization method by utilizing an omnidirectional camera and full-color LEDS is described. This method is especially useful in indoor environment in which we cannot receive GPS (Global Positioning System) radio wave. We have been developing this self-localization system to grasp the accurate position of our developed wheelchair in a nursing care facility in order to improve QoL (Quality of Life) of both patients and care givers. In this paper, we implement our self-localization system into the wheelchair and conduct experiments to verify the basic functionality of our developed self-localization system.**

I. INTRODUCTION

We have been developing a wheelchair which is used for improvement of nursing care and patients' QoL. In order to improve the QoL [1]-[3], some sensory devices such as GPS receiver, an image camera, torque sensors were implemented onto our wheelchair (Fig. 1). One of functionalities of our wheelchair is tracking the position of the patient. Generally, a global positioning system known as GPS is utilized for determining the position, however, this technology is basically unavailable in indoor environment. For the self-localization in indoor environment, various methodologies have been developed. Motion capturing systems such as Vicon [4] and OptiTrack [5] can be used for determining wheelchair location, however, they are quite costly at the implementation. Distance based sensors such as LRF [6] are also used for indoor environment, but they have a calibration problem. 2D-code based systems [7] are also used for self-localization, but they also need calibration and registration issues. Wireless signals such as Wi-Fi or Bluetooth are one of candidates to solve the cost problems, but for these techniques, WiFi or Bluetooth devices are needed.

In this paper, we utilize an omnidirectional camera and full color LEDs for determining a position of the wheelchair. Red, green and blue LED's optical patterns are frequency modulated independently and used them for including some kinds of position information. By using the information, the system can acquire all positions of the markers before the calibration, then, wheelchair position tracking can be realized.

II. FULL COLOR LED MARKER

Figure 2 shows our developed full color LED marker which consists of two full color LEDs and a CPU board. Red, green and blue LEDs inside the full color LEDs are controlled their brink frequency in order to represent the marker position.

III. IMAGE AND SIGNAL PROCESSING

A. Position tracking environment

Three markers and a camera are located in an actual environment and the functionality of our proposed system is experimentally inspected (Fig. 3).

B. Image processing

In order to extract RGB values of LED markers in each frame, captured images are processed by following steps:

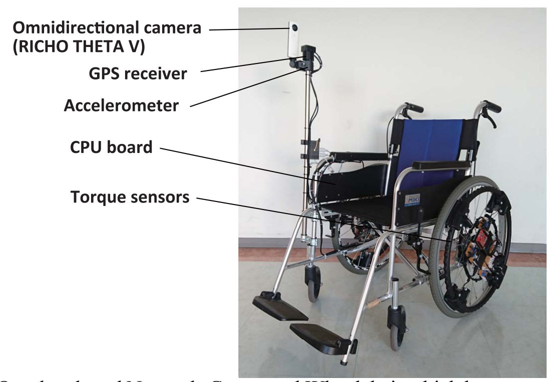

Fig. 1. Our developed Network-Connected Wheelchair which has sensor nodes such as accelerometer, hand-rim torque sensors, etc.

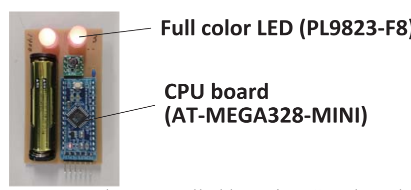

Fig. 2. Full color LED marker controlled by using CPU board emits frequency modulated light.

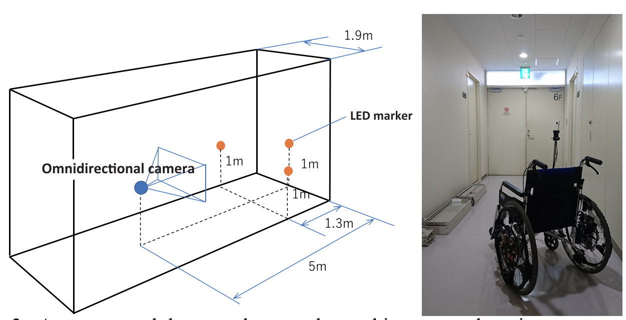

Fig. 3. A camera and three markers are located in an actual environment and conducted experiments for validation of this system.

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[Step 1] Difference image extraction
[Step 2] Grayscale conversion
[Step 3] Binarization
[Step 4] Denoising
[Step 5] Clustering
[Step 6] Masking
[Step 7] Tracking
[Step 8] Averaging

Clusters in each image are tracked referring to positions of feature points in the image. Through the steps above mentioned, RGB values in each cluster in each frame could be acquired (Fig. 4). However, markers are not identified at this time. After this image processing, signal processing is needed.

C. FFT

After image processing, red, green and blue values are extracted from clusters which are generated by using the image processing. After that, these values are processed by FFT with hanning window as time series signals. Through this process, frequency of each cluster is calculated. Thus, we can estimate positions of the LED markers from the frequencies. Finally, we recognize the position of the wheelchair.

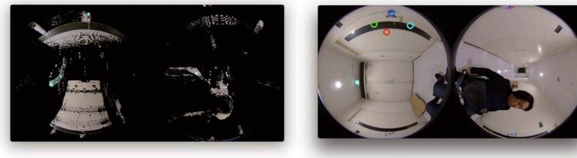
IV. EXPERIMENTAL RESULT

Figure 5 shows an example case when the markers are correctly recognized. The left graphs show RGB values, respectively. In each graph, blue circles show calculated optical pattern based on the procedure above mentioned. The solid line colored by red, green and blue are the waveform processed by the hanning window. The right figures show their frequency spectrums, respectively. From these figures, we can recognize that the frequency of red LED is 2Hz, the frequency of green is 1Hz, and the frequency of blue is 1Hz. Thus, we can extract markers from captured omnidirectional images. From these values, positions of the three markers are derived. Finally, the position of the wheelchair is estimated as 4.56m from the front wall in this case. Since actual position is 5m, this result is reasonable even though there are some error.

V. CONCLUSIONS

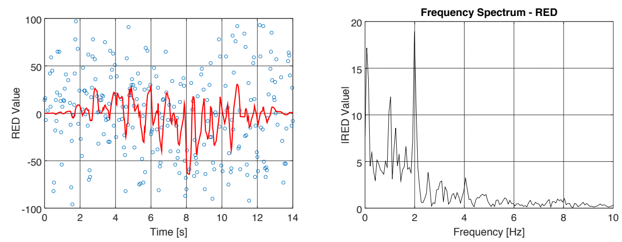
In this paper, a indoor self-localization method was described. In order to grasp the position of our wheelchair in indoor environment, we utilized an omnidirectional camera and full-color LEDs with following procedure; (1) RGB values of the LED were frequency modulated. (2) Clusters were extracted from omnidirectional images by eight steps of processing. (3) Mean RGB values of each cluster were processed by FFT with hanning window. We then could estimate the position of the wheelchair.

(a) Orignal image (b) Defference between two images

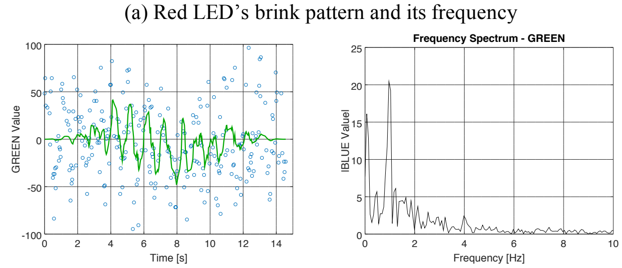


(c) Masked image (d) Recognized markers

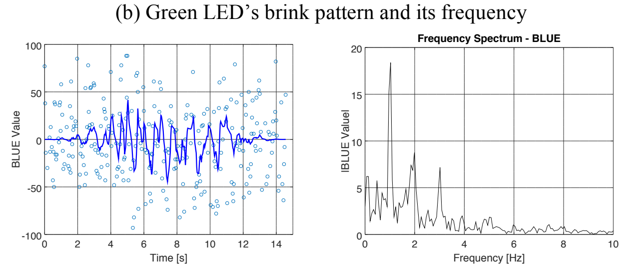
Fig. 4. Omnidirectional images are processed for extracting RGB time series values of LED markers.



(a) Red LED's brink pattern and its frequency



(b) Green LED's brink pattern and its frequency



(C) Blue LED's brink pattern and its frequency

Fig. 5. By processing time series values of color LEDs using FFT with hanning window, makers are extracted from omnidirectional images.

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