A Bio-Inspired Modular Robot for Mutual Position Detection based on Relative Motion Recognition

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Abstract

One of key goals of disaster response and relief robots is to acquire knowledge about the situation that would be either dangerous or inaccessible to human operator. However, the robot is difficult to acquire tele-operations from the operator. A disconnected communication link and no-visual control situation are frequently happened in disaster areas. Moreover, disaster scenarios are typically spatially distributed, so we may need an intelligent robot that has functions such as autonomy, cooperation, and collective behaviors. Thus, we propose the bio-inspired modular robot named as ARTHROBOT so as to support emergency responders. ARTHROBOT can assemble or disassemble process based on the proposed mobile algorithms.

Keywords: *Bio-inspired, Modular robot, Autonomy, Cooperation, Collective Intelligence, Disaster response and relief*

1. Introduction

A recent progress and equipment in robotic technologies helps to search and rescue the human in disaster scenarios [1, 2]. A robot can gather data in places that would be either dangerous or inaccessible to human operators so as to acquire correct knowledge about the situation of the emergency and to improve the safety of the human. Advanced sensors and tools attached on the robot should be used in the emergency situation where humans cannot or should not go. However, the robot is typically not under the visual control of the operator. A robot also should not react properly in various situations of disaster while moving at high speed on rugged grounds. Establishing and connecting a communication network is very difficult in disaster area. Robots should have functions such as autonomy, cooperation and collective behaviors to search and rescue the human in spatially distributed area [3, 4]. Therefore, we propose a bio-inspired modular robot named as ARTHROBOT that are widely used in snake-like robot or multi-joint robot [5, 6]. Because it can pass through the narrow space in line and can overcome the obstacle in its way. Being hyper-redundant, modularized and reconfigurable, we have the proposed ARTHROBOT that has widely applications. The main key advantage of the design is its adaptation ability to the environments through various assembling and disassembling configurations.

The rest of the paper is organized as follows. We introduce system configurations of ARTHROBOT in details in Section 2. We propose mobile algorithms of ARTHROBOT such as a navigation algorithm and the relative motion recognition by detecting mutual position of multi-modular robots then show the test results in Section 3. Finally, we conclude the paper in Section 4.

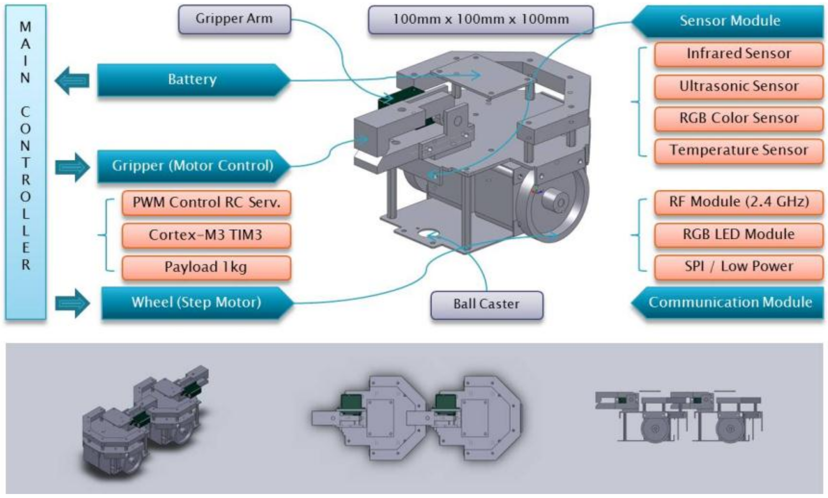
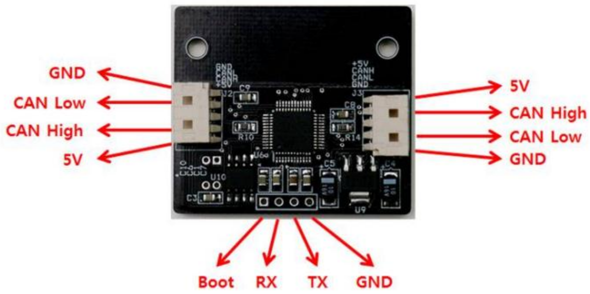


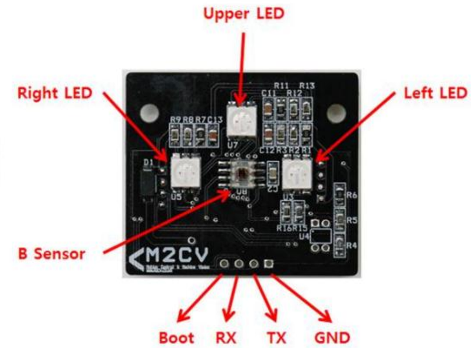
Figure 1. System Configuration and Mechanical Design of ARTHROBOT

2. System Configurations of ARTHROBOT

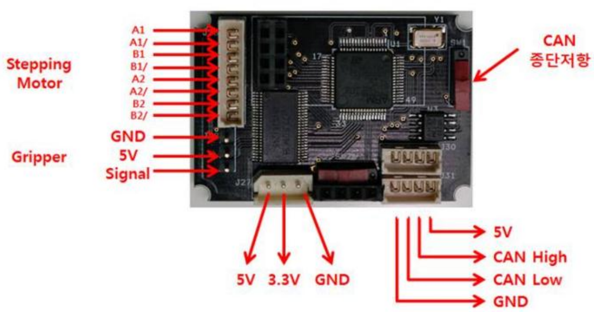
The developed ARTHROBOT consisted of a main controller and components such as a sensor module, a communication module, a motor module, and a battery as shown in Figure 1 to supporting assemble, disassemble, or collective behaviors. Particularly, we design the parts of ARTHROBOT as follows. First, the main controller generates the pulse after receiving the moving command from the host then transmits the generated pulse into a stepping motor drive to making a motion control of ARTHROBOT by checking the over-current of a motor. Figure 2(a) shows a designed stepping motor driver module. Second, a LED-RGB sensor module communicates directly with a micro-controller by using 3 full LED colors (i.e., Upper, Right, and Left LED in Figure 2(b)) for making a communication between modular robots. A LED-RGB sensor module converts a light intensity to frequency to supporting a specified operation such as assembling or disassembling of modular robots by displaying different colors of RGB. Figure 3(a) shows an example of relative responsibility of RGB colors based on the wavelengths. The normalized output frequency (F_0) can maximize when optical axis is equal to zero if angular displacement is equal for both aspects in simulation about the light intensity depending on the distance of a modular robot as shown in Figure 3(b). Third, a main controller module communicates with a LED-RGB sensor through CAN 2.0B interface and performs a RF communication with nRF24L01P module that is performed between virtual mother robot and modular robots to make some roles in formation of modular robots and to receive moving commands from mother robot as shown in Figure 2(c). Fourth, for improving energy efficiency, a designed power manager module has a solar cell input part as shown in Figure 2(d). In particular, a power manager module adds the power input part into the board to solve the heating problem caused by miniaturization of the robot. Finally, the modular robot configures a network between a main controller and sensor modules depending on topologies of a network and CAN 2.0B interface communication. For instance, a main controller sends a message to a LED-RGB sensor. A LED shows an On/Off signal then a RGB sensor reads the value of light intensity. A CAN I.D. resends a message to a main controller by converting the light intensity to frequency. Based on this repetitive process, all modules can communicate each others.



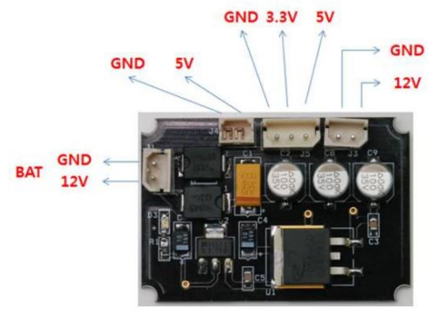
(a) Stepping driver module



(b) Implemented LED-RGB sensor module

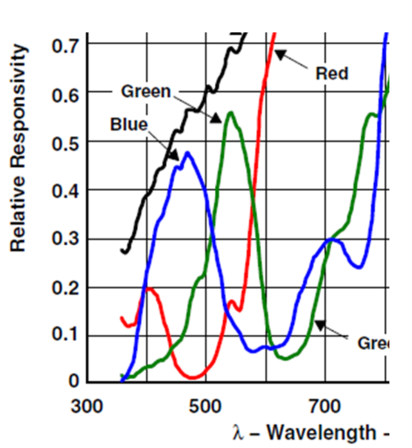


(c) A main controller module

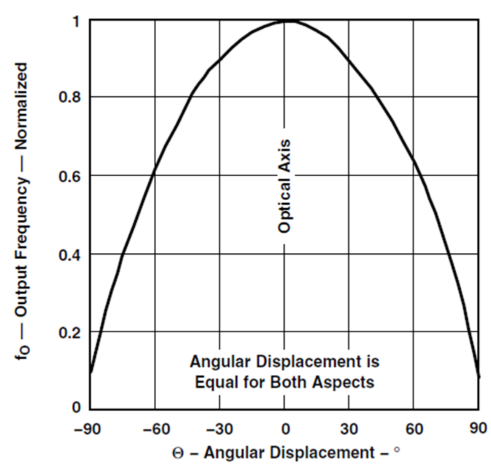


(d) A power manager module

Figure 2. A Main Controller Module and Sensor Modules



(a) Relative responsibility depending on three RGB colors



(b) Normalized output frequency based on optical axis

Figure 3. Response Characteristics of 3 LED-RGB Sensor Modules

3. A Mutual Position Detection of ARTHROBOT

In this section, we propose a navigation algorithm of a modular robot for making modular robots in line. We then define a mutual position detection of a modular robot based on the LED-RGB sensor. This process can recognize the relative motion of a modular robot by using the proposed mobile checking algorithm. Finally, we test cases by using information of different full LED colors. We compare the distance of the recognition of a sensor by checking a light intensity of LED and by checking a light intensity of the reflection on the floor.

3.1. A Navigation Algorithm of ARTHROBOT

Depending on the pattern and the color of a sensor, ARTHROBOT can communicate with other ARTHROBOT in mission area. A virtual mother robot sends the command to modular robots for performing assembling/disassembling operation. In this case, modular robots make a line, color sensor computes the distance of a navigation, and each modular robot integrates itself based on the order of CAN I.D. of sensor modules.

3.2. A Mutual Position Detection based on Relative Motion Recognition of ARTHROBOT

We calculate the light intensity of LED-RGB sensors to supporting a cooperative operation (i.e., mutual position detection and relative motion recognition) between modular robots. We define almost 18 different situation's information based on the light intensity of LED-RGB sensor. In particular, we separate the colors of a RGB sensor into maximum 256 levels for performing a mission in specified area. We send various types of a message based on the location information of a modular robot and different colors of RGB sensor to virtual mother robot. Figure 4 shows a flow of mutual position detection using three different LED colors. For instance, we define three RGB sensor as a seed robot color (i.e., Red), a finder robot color (i.e., Green), and an obstacle robot color (i.e., Blue). A finder robot looks for selected seed robot and the seed robot continuously scans green value of the finder robot. The seed robot recognizes an oncoming finder robot then turns on the Red LED in specified position for location tuning. The finder robot assembles with the seed robot by following a light intensity of a green LED. Mobile checking is performed to assembling/disassembling ARTHROBOT.

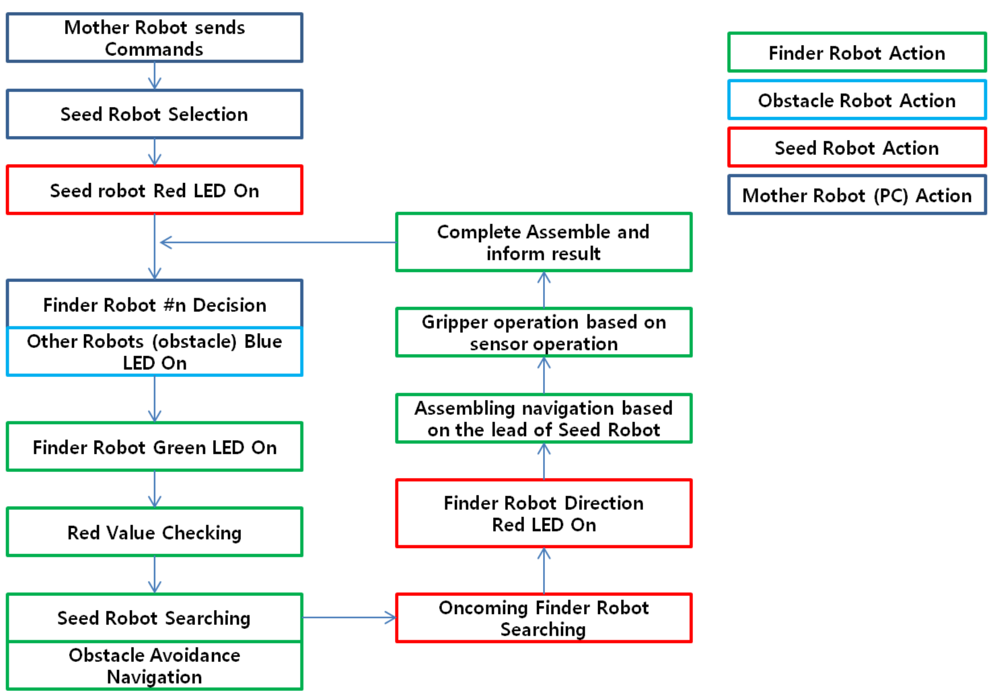
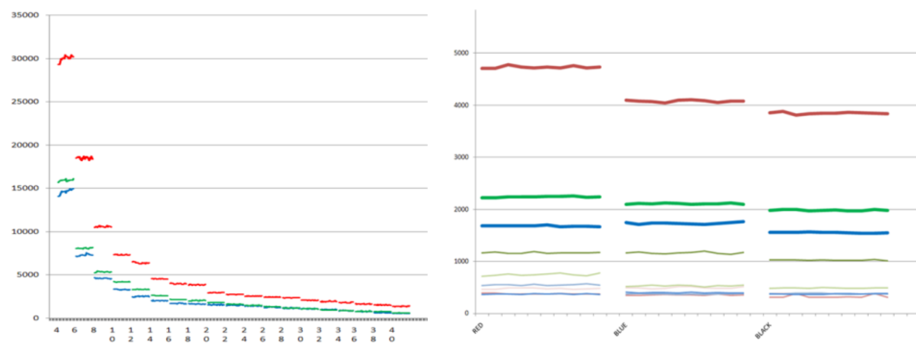


Figure 4. A Mobile Checking for Mutual Position Detection based on Relative Motion Recognition

3.3. Test Results

We test two cases by using information of different full LED colors. We compare the distance of the recognition of a sensor by checking the light intensity of a LED and by checking the light intensity of the reflection on the floor. As a result of tests, the light intensity of three LED colors is inversely decreased when we compare three LED-RGB sensors as shown in Figure 5(a). Based on the result of Figure 5(b), All LED has low light intensities if the floor color is black. This result explains the light intensity of a LED-RGB sensor can be affected by the around light and the color of the background.



(a) A light intensity of LED depending on the distance of the recognition

(b) A light intensity of LED depending on the color of reflections on the floor

Figure 5. The Two Test Results for Relative Motion Recognition of Modular Robots based on the Light Intensity of LED

4. Conclusion

Until now, we introduced a bio-inspired robot named as ARTHROBOT. In particular, we defined and described system configurations of ARTHROBOT. Based on the developed robot, we proposed mobile algorithms for making modular robots in line and the mutual position detection based on relative motion recognition. According to the results of tests, the proposed method can support relief and rescue operations in inaccessible disaster areas using its adaptation ability to the environments.

Acknowledgements

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