Project report

on

Morphius: A Self-reconfiguring modular robot that navigates through cracks and debris for inspection

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by

Kazi Ruman
Nambisan Ameya
Tiwari Simran

under the guidance of

Dr. Preetida V. Jani

Department of Electronics & Telecommunication Engineering

Bharatiya Vidya Bhavan's
Sardar Patel Institute of Technology
Munshi Nagar, Andheri-West, Mumbai-400058

Abstract

Modular robots are essentially arrays of kinematically-constrained simple robots with few degrees of freedom. They can attach to or detach from each other and form a modular structure or a configuration as per the need. There are many conceivable applications of modular robots in fields like space exploration, automation, consumer products, and so forth.

Our primary goal is to narrow down on problems in rescue operations in disaster zones which include inspection, rescue, exploration, mapping and navigation. The existing technology in this field consists of robots with homogenous modules which are not currently able to be used in disaster struck area for inspection of the area. To improve their performance, we introduce heterogeneity in its structure making it possible to design versatile, application tailored modules. Each module will independently be able to perform a specific task depending on the attribute/characteristic given. At the same time all the modules will communicate and share their data with each other to collectively accomplish the goal.

Contents

List of Figures

1 Introduction

1.1 Motivation

In the past two decades around 10 lakh deaths have been reported worldwide due to earthquakes, landslides, storms and hurricanes and almost 1.5 lakhs were only from India. Over 15% of these were late deaths - deaths due to injuries that become prominent with the passage of time - could have been avoided had disaster management been more efficiently carried out. Doctors refer to this time as the golden hour, which is the period of time after a traumatic incident during which immediate medical assistance can save a person's life. Some injuries hemorrhage, brain injuries and internal bleeding deteriorate rapidly. So it is necessary to keep the time lag between injury and treatment bare minimum.

Rescue operations conducted worldwide mostly employ trained professionals and dogs. Equipments such as video cameras and high sensitivity listening devices are used in order to locate a person moving or responding to rescuers calls.[9] Often holes are dug to allow these devices to be inserted through obstructing walls and debris. Further the process of extrication takes longer making the entire process to extend to over 24 hours, depending on the scale of destruction. These environments pose a risk to even the lives of rescuers as there is imminent danger of a further collapse especially in case of earthquakes which may be followed by aftershocks. Recent reports prove the usefulness of robots in these fields as they enable rescuers to analyse the environment remotely. They had better speed and did not require much manpower. But because of their large size and power requirements, these robots are not efficient enough. This is where the concept of multi robot systems can be used. Due to the increasing demands in functionality, adaptability and robustness engineering innovations brought forth the idea of multi robot systems - systems which work in a distributed manner to complete a task. These robots too had limitations because of their fixed shapes and sizes. Inspired by biological systems, scientists proposed the use of self organizing modular robotic system.[1]

1.2 Objectives

Aim of developing 'Morphius' is to provide a suitable faster assistance for the rescue operations in disaster struck areas such as tornadoes and earthquakes. So, we divided the project into discrete objectives. The objectives of our project include:

- Designing of a Modular Robotic System (MRS) with heterogeneous modules.
- Development of a robust inter-module connection mechanism for the modules such that exerted shear forces are endured.
- Establishing wireless communication between modules such that maximum coverage area is achieved.
- Determining the best possible path and configuration for each scenario while completing the rescue operation.
- Improving the speed of MRS by using wheels for locomotion and minimising the number of transformations required to achieve a configuration.
- Attributing decision making capability so that the robot becomes autonomous and only needs human surveillance.

2 Literature Survey

The most important thing in a rescue operation is the speed at which the help arrives to the victims. Flexibility to reach the remote location is another key aspect which decides the efficiency rescue operations and rate at which the injured people are provided with medical care. The technology has been consistently evolving toward providing a solution for such scenarios. There have been multiple attempts to provide a robotic solution to such areas. There are key terms associated with such systems. The research is required to go through all the attempts that have been made and to step upon already developed solutions and rectify their limitations and faults to make them efficient and better the desired application.

2.1 Basic terminology & concepts related to MRS

To understand already developed series of modular robots, it is important to understand the key terms and definitions related to modular robotic systems(MRS). "Modular Robotic Systems: Characteristics and Applications - A detailed report "[1] covers overall terminology related to the MRS and also provides key insights in the field of modular robotics. The four fundamental components that define a modular robotic systems are Module, Information, Task and Environment (MITE). This report also discusses about the problems associated with certain systems and their feasibility.

It is also necessary to classify the robotic system in standardized format depending on the four components (MITE)[1]. We can create different types of MRS by varying these components. There are about 94 developed modular robots existing today each one having unique features and mechanism.

2.2 Existing MRS

Analysis of different existing modular robotic systems provides different perspective with which a particular problem was solved. Analyzing the particular problem and designing the system accordingly by considering the variable, dependent and independent parameters is the key to get an optimum MRS. Following are two of the most advanced MRS existing today.

2.2.1 M-TRAN III:

Design inspired by locomotion of reptiles, M-TRAN III [5]was developed in 2007 as a successor of M-TRAN II (2003) and original M-TRAN (2000). Homogeneous modules made of same shape and mechanism to connect. It uses most of modern technology of wireless communication through it's different modules.

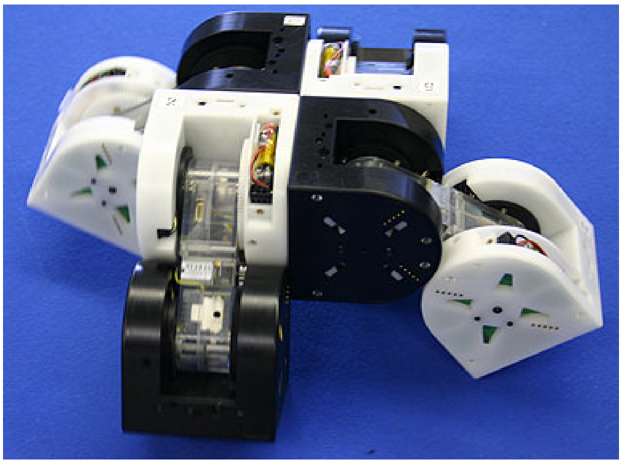

Figure 1: M-TRAN III[5]

The shape of each module gives M-TRAN huge flexibility of different morphologies by combining itself with other similar modules.. Because of reptile locomotion, M-TRAN is comparatively slower than others.

2.2.2 Room Bots:

EPFL University project developed for different morphology and heavy lifting. The design is sturdy, large and can hold up large weights. Room bots are helpful in heavy load lifting and can be used to transport heavy loads. Room bots[8] have lesser flexibility compared to M-TRAN III. Because of the heavy torque lifting motors, room bots have to compromise on the size of each module. As the size increases, it reduces the probability of going through narrow holes and cracks.

Figure 2: Room bots[8]

As we can see, M-TRAN III compromised on speed to get more flexibility, whereas Room Bots compromised on size of each module to get more heavy lifting. Each modular robotic system has to find a balanced system to solve a certain problem. For a particular application we can compromise on the components that won't affect the performance of the system as much. If we can provide a solution by bypassing such factors, we can achieve our desired goal.

3 Problems in current technology

Existing technologies include M-TRAN III[5], SMORES[3], SQ-BOT[6], UBot[10] among many others and have distinctive features like size, locomotion mechanism, structure, behaviour etc. For example, CONRO[2] modules which are small, self-sufficient and relatively homogeneous module and have automatic inter-locking capabilities. They can change their configurations in a very short time but their locomotion is not suited for the environmental conditions of the problem stated. They lack the decision making capabilities and consist of relatively homogeneous modules which decreases the number of distinct configurations the robot can attain.

Heterogeneity is essential in such applications as they increase the accessibility and functionality of the system. Having modules of different sizes and with different attributes makes the system cost effective and reliable at the cost of algorithm complexity. The existing systems are not deplorable in practical environments due to constraints on their locomotion and/or structure. And those which can be employed in such conditions are either expensive, slow and lack the decision making capability. Thus there is a requirement of a cost-effective and robust design for the application.

4 Proposed Solution

The key objective of our project is to design a modular robot tailored for our application. This system will have heterogeneous modules - each with a specialized function and shape. This enables the robot to maintain its versatility allowing it to be used in similar scenarios like rescuing people in earthquake, landslide or hurricane struck area by navigating through the debris. The different sizes increase their mobility and accessibility which is of utmost importance in such sensitive areas.

Also each module can operate independently provides us with an extra degree of freedom. These modules can communicate the information gathered with other modules and reconfigure themselves as per the need. A trade-off, tailored for our application, will be achieved between algorithm complexity, reconfiguration time and increased functionality.[4][7] Thus making the robot resourceful at the same time more cost effective.

Key features of Morphius:

- Self-reconfigurable
- Improved speed
- Increased size flexibility
- Inter module communication
- Decision making capability
- Independent self-sustainable modules

5 System Design

The present system includes microprocessor to control the base module which receives signal from an app via bluetooth low energy - BLE. Rechargeable Lithium-Ion battery was chosen so that bot can work for long duration and can be recharged again.

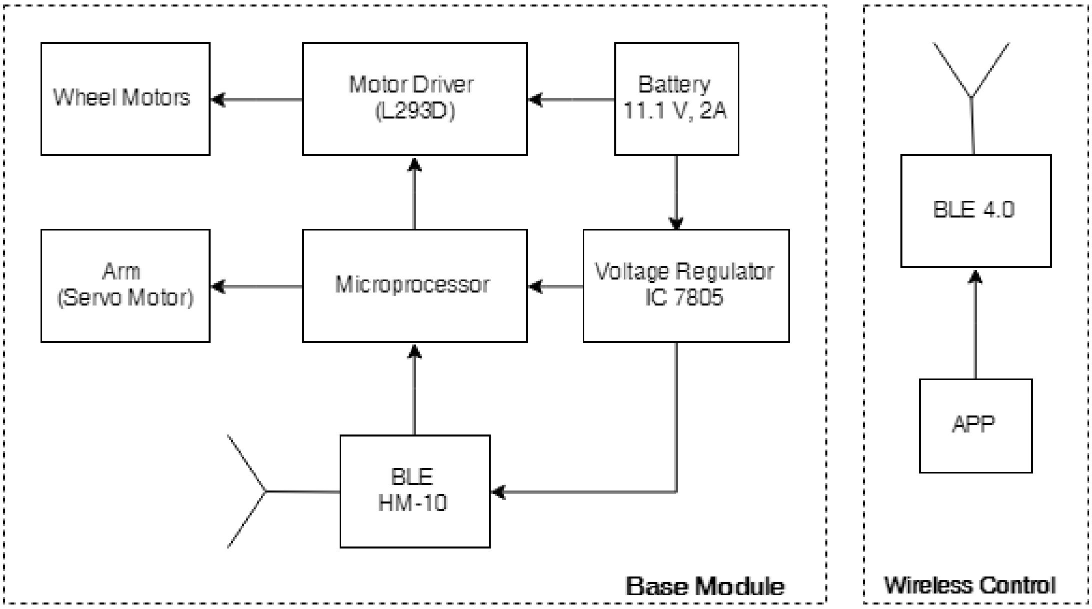

Figure 3: Block Diagram of the system

- Motors:
  - Single BO Motor used for the main locomotion of first prototype. Fast and lightweight hence, suitable.
  - A servo motor having high torque of 5KG used for arm mechanism such that it can lift heavy modules.
- Battery:
  - Lithium-Ion rechargeable battery providing 11.1V and 2Amps of current.
  - Used as power of source for entire base module.

- Voltage Regulator:
  - IC7805 was used to provide 5V supply to the microprocessor from the supply of 11.1V battery.
  - Also provides supply to BO motors, BLE and Servo Motors
- BLE (Bluetooth Low Energy):
  - HM-10 mudule for BLE was used. Based on Bluetooth 4.0
  - Consumes very less energy, fasteer and better than HC-05
- Microprocessor:
  - Arduino NANO based on ATMEGA was used as the central microprocessor.
  - Controls pwm for Servo and Wheel motors. Also receives messages through BLE.
- App:
  - Built in library of EVO was used for app development
  - Provides UI interface to control the base module
  - Sends integer values to Microprocessor via BLE

How does it work?

- These are the steps the system follows:

1. BLE on the base module and phone's bluetooth get paired
2. App sends a signal in the form of integers through phone's BLE
3. Microprocessor receives signal throgh BLE and compares it
4. Output according given out by the microprocessor on output pins
5. The output pins connected to different modules and motors respond accordingly

6 Progress

In this stage our focus has been on the hardware implementation of the system. Using the MITE framework, different hardware components required for our application was examined. The following objectives have been worked upon:

- The backbone design of the system has been developed after considering different features from existing technologies.
- A prototype of the base module was developed in order to understand and analyze the structural stability and the complexities involved.
- Speed, acceleration and deceleration optimization for smoother locomotion
- Wireless communication between the module and android application has been tested.
- Power budgeting of a single module
- Various connection mechanisms to enhance the robustness of the structure were analyzed

Problems faced

- Balancing Center of Mass by aligning the connection mechanism accordingly thereby preventing module from toppling.
- Size and placement of wheels for stability and speed enhancement.
- Establishing communication and speed control
- Alignment of DC motor and wheels for balanced motion

7 Further Planning

November 2018
First Week

Phase 2

- Optimization of base module
- Prototype of connection mechanism

February 2019
Third Week

Phase 3

- Development of other connectable heterogeneous modules
- Wireless communication amongst modules
- Development of reconfiguration algorithm

April 2019
First Week

Phase 4

- Image processing through Eye Module and analysis of terrain
- Algorithm for deciding optimal path and configuration

References

[1] Hossein Ahmadzadeh, Ellips Masehian, and Masoud Asadpour. Modular robotic systems: characteristics and applications. *Journal of Intelligent & Robotic Systems*, 81(3-4):317–357, 2016.

[2] Andres Castano, Wei-Min Shen, and Peter Will. Conro: Towards deployable robots with inter-robots metamorphic capabilities. *Autonomous Robots*, 8(3):309–324, 2000.

[3] Jay Davey, Ngai Kwok, and Mark Yim. Emulating self-reconfigurable robots-design of the smores system. In *Intelligent Robots and Systems (IROS), 2012 IEEE/RSJ International Conference on*, pages 4464–4469. IEEE, 2012.

[4] Robert Fitch, Zack Butler, and Daniela Rus. Reconfiguration planning for heterogeneous self-reconfiguring robots. In *Intelligent Robots and Systems, 2003.(IROS 2003). Proceedings. 2003 IEEE/RSJ International Conference on*, volume 3, pages 2460–2467. IEEE, 2003.

[5] Haruhisa Kurokawa, Kohji Tomita, Akiya Kamimura, Shigeru Kokaji, Takashi Hasuo, and Satoshi Murata. Distributed self-reconfiguration of m-tran iii modular robotic system. *The International Journal of Robotics Research*, 27(3-4):373–386, 2008.

[6] Ch S Sankhar Reddy, Anita Agrawal, KR Anupama, et al. Sq-bot-a modular robot prototype for self-reconfiguring structures. In *Robotics: Current Trends and Future Challenges (RCTFC), International Conference on*, pages 1–6. IEEE, 2016.

[7] Masahiro Shimizu, Takuma Kato, Max Lungarella, and Akio Ishiguro. Adaptive reconfiguration of a modular robot through heterogeneous inter-module connections. In *Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on*, pages 3527–3532. IEEE, 2008.

[8] Alexander Spröwitz, Rico Moeckel, Massimo Vespignani, Stéphane Bonardi, and Auke Jan Ijspeert. Roombots: A hardware perspective on 3d self-reconfiguration and locomotion with a homogeneous modular robot. *Robotics and Autonomous Systems*, 62(7):1016–1033, 2014.

[9] Mark Yim, David G Duff, and Kimon Roufas. Modular reconfigurable robots, an approach to urban search and rescue. In *Proceedings of the 1st International Workshop on Human-friendly Welfare Robotics Systems, Taejon, Korea*, 2000.

[10] Jie Zhao, Xindan Cui, Yanhe Zhu, and Shufeng Tang. A new self-reconfigurable modular robotic system ubot: Multi-mode locomotion and self-reconfiguration. In *Robotics and automation (ICRA), 2011 IEEE International Conference on*, pages 1020–1025. IEEE, 2011.