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Reconfigurable Robots: Opportunities and Challenges

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Abstract— All around the world there is an enormous increase in technological development and its technique implementation, other than human some of the machineries are involved in various work field starts from agricultural to military. In recent development robots are majorly used in automobile industries for engine block making, assembling, painting, quality checking, etc. Reconfigurable robots are in the sense that they can change their own shape by rearranging constituent modules. The robot must have ensure that robust, fast and parallel responses to change in the environment. The aim of this study is to point out future challenges of reconfigurable robotics which have a potential to lead to various applications.

Keywords— Reconfigurable, Robots, Automobile, Challenges in robots, Modules.

I. INTRODUCTION

Robots have achieved a great success in the world of engineering applications. Robots can be moved with various fields of applications, but reconfigurable robot can be changed in the shape, different posture, depends on the task environments. It can be in global shaped formations adapted to the kinetic motions. These robots are having robustness, great versatility, low cost and reliability. There are two types of robots, one is homogeneous structure, it means single module type, and other is heterogeneous systems, which includes multiple module type along with sensors, wheels, Camera and battery.

The main features of the reconfigurable robots:

Light weight, small size, flexible (less than 5kg),

Smooth on the road, uneven pavement, and slope for smooth operation,

With communication ability,

It can change information between master control,

Strong perception capability,

Autonomous

Fiona Higgins, et al [1] identified several ideas for swarm robotics that present some unique challenges in security. In particularly swarms of robots potentially employ different types of communication channels; have special concepts of identity and exhibit adaptive emergent behavior which could be modified by an intruder.

Javaid Khurshid and Hong Bing-rong [2] described that the military forces always try to use new gadgets and weapons for reducing the risk of their causalities and to defeat their enemies in Navy, Army and Air forces. The homeland security, causality reduction during combat and cost savings has pushed robots and robotic research onto the fast-track for government spending. The expected result is that future military forces will employ a variety of robotic devices for reconnaissance and surveillance, logistics and support, and offensive operations. Many more discoveries, applications, and business opportunities will result from the application of robotics in the service of military operations.

M. Freese et al [3] described that the swarm robotics is a novel approach to the coordination of large numbers of robots and has emerged as the application of swarm intelligence to multi-robot systems. The main motivations behind the approach are the characteristics and major coordination mechanisms. The task should be hard or impossible to be carried out by a single robot, the cooperation of a group of robots should be essential, or the deployment of a group of robots should improve the performance / robustness of the handling of the task. David G.Duff and Mark Yim [4] described that the self-reconfigurable robots promise, great versatility, robustness and low cost. ‘Poly-bot’ is a modular robot. It provides large interchangeable modules. Three types of Polybot have been developed. Generation G1 (having 32 modules) is simple and quick, Generation G2 (having 32 modules with self-reconfiguration capability) is having additional robustness strength and Generation G3 (having 200 modules) is under progress. Young–Sik Kwam and Jong-Hoon [5] described a motion planning modular indoor pipeline inspection robot, which is used in 80mm-100mm diameter. It is foldable by using embedded four-bar mechanism and compression of a spring connected to the four-bar allows the robot to maintain contact with the pipelines. It passes through multiple elbows or T-branch with the collaboration of two modules and also accommodates the pipeline size. Edwardo F.et al [6] described that the detection of

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buried landmines for humanitarian demining purposes. Now it is mainly performed by human operators. Potential mines are located using metal detectors or by hand probing methods. The probe used is generally just a sharp stick or bayonet which is inserted into the ground at an angle not greater than 40 degree to the horizontal at 2cm intervals until some resistance is encountered. Clusters of well-organized robots may work better than single machines. They suggested some strategies for particular application, likely food industry, and the use of odor sensor may be the possible solution it also requires further investigation. Kurokawa et al (7) described the three dimensional self reconfiguration and whole body locomotion. Several locomotion patterns in various structures were designed also describes metamorphosis of a regular structure, generation of walkers from the structure, locomotion and re assembling the structure.

Eric Schweikardt (8) presented modular self reconfigurable robot along with a design and controllable actuators and control algorithms. Several challenges to miniaturization are discussed, focusing on power and actuation requirements for large networks of modular robots.

II. OPPORTUNITIES IN ROBOTS

There are several studies and investigations have been developed on robots for real time problems. Many researchers are interested in developing various types of task and capability in the physical world. It can control motion executed in parallel lattice structure in simple configuration. It can also more easily scalable to more complex systems. In real-world applications, robots are required to perform locomotion, manipulation, and self-reconfiguration tasks in the presence of obstacles and in an uncontrolled environment,

Military
Monitoring
Disaster relief
Space
Search and rescue
Medical
Fire fighting
Commercial applications

A. Versatility

These systems are potentially more adaptive than conventional systems models. The ability to robot reconfigure permits a robot or a group of robots to desirable and reassembles machines to form new tasks, such as changing the form of a legged robot to a snake robot and then to a rolling robot.

B. Robustness

The robot parts are interchangeable, that means, within a robot between different robots. It can also replace faulty parts autonomously leads to self repair its faulty.

C. Low cost

These type robots can potentially lower in overall cost by making many copies of one type modulus. So it is economical in sale. One set of modulus, saves cost through reuse and re-generate of the system.

III. CHALLENGES IN ROBOTS

In spite of the above developments, large numbers of humans are engaged in ground operations to carry out the missions like attacking a terrorist camp, thwarting intrusion in the border, tackling smugglers in the mid-sea. These activities can result in heavy human causalities. If we replace the human by using reconfigurable robots, unnecessary causalities can be avoided. To personal cost savings either in operations or in support with results reduction in life-cycle cost. However, the robot should posses the various capabilities that the humans have namely:

Effective communication,
Intelligence,
Changing the posture,
Ability to adjust the loss of member(s)
To reduce work load of man-power
To improve decision making index tailed loads

A. Challenges In Planning And Control

Parallel motion for large-scale manipulation and locomotion with and without obstacles,

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Optimal (time, energy) reconfiguration planning with and without obstacles,
Robustly handling a variety of failure modes, from misalignments and dead units (not responding and / or not releasing) to units that behave erratically,
Determine the optimal configuration for a given task and environment,
Efficient and scalable communication among multiple units

IV. CHALLENGES IN ENVIRONMENT

A. Big Systems

Most systems of modular robots have been small in number, especially compared to, For example, the number of components in a living cell. The physical demonstrations of such key system will require rethinking method.

B. Self-Repairing Systems

Besides reconfiguring itself into a new shape, a system comprised of modular robots would be able to recover from serious damage, such as that which might result from an external collision or internal failure.

V. CHALLENGES IN LOCOMOTION

In locomotion, the environment is fixed and the robot moves by impairing force to the environment. In manipulation, the robot's arm is fixed but moves objects in the workspace by impairing force to them. Locomotion of the robots and its kinematics and dynamic properties:

A. Stability

1) Geometry and the number of contact points
2) Centre of gravity
3) Static and dynamic stability
4) Inclination of terrain

B. Characteristics Of Contact

1) Contact of the points
2) Path size /shape
3) Friction

VI. HARDWARE STRUCTURES AND COMPONENTS OF ROBOTS

A. Hardware Structures

Reconfigurable robots consists of some primary structural actuated unit and potentially additional specialized units such as grippers, feet, wheels, cameras, payload, energy storage and generation units. They are basically in three structures

1) *Lattice:* This structure has been arranged in some regular patterns, such as simple cubic. It makes planning the motions of when and where to move modules and interchanging one form to other form in possible motions is easy to represent by a computer, but difficult because the space of possible sequences grows exponentially with the number of modules.
2) *Chain:* Chain or tree structure has units that are connected together in tree topology or a string. This tree or chain can fold up to become space filling, but the underlying structure is serial. Chain types have been connected together in a string.
3) *Mobile:* It has units that are the environment to maneuvers amount and it can either take up to form complex chain or lattice or form a number of smaller robots.

B. Parts Of The Robot

The reconfigurable robots in outdoor environment are air, land and sea, which have more difficult tasks in controlling and operating challenge in the robot field**.**

1) *Sensor:* These robots must have an accurate sensing of their environments, allowing the robotic systems to receive its surroundings thus permit to controlled movement. It has various types of sensors adopted in these robots.
2) *Platform:* It provides the locomotive utility infrastructure and power to the robot system. In this, configuration has very strong influence on the level of autonomous will achieve in a structured environment.
3) *Control:* Hardware and software control elements provide a robot with the capability to act as type of control by neutral network, artificial intelligence, multiple robot collaboration etc.,

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4) *Human machine interface:* This robot's nature is to form Tele-operation to its higher level of autonomy. It changes the classical joystick, and monitor control panel will be replaced with more natural means of communications in the desired goals to a robot.
5) *Communication:* The central command in order to provide the clear picture of the battle field, as well as, secretly of getting commands is the important part of any robot or man.
6) *System Integration:* System integration is the choice of system level, structure, configuration, sensors, and components through continuous design and situation provides significance with robot system.

C. Locomotion of the robots

In this type of robot needs good weather conditions to operate any equipment safely and reliability. So, these robots have been used in water and land etc.., and this kind of robot will have better locomotion in these environments. Most of the locomotion mechanisms have been inspired by their biological systems. In this system succeeds in moving through a wide variety of harsh environments**.** Type of environment includes Structure and Medium (air, water, and soft, hard).

D. Types of robots

1) *Rolling Robots:* Its construction is very simple when compared to others. In this, robot is very fast, very efficient, simple to build and easy to control.
2) *Walking Robots:* This robot can be dealt with almost any kind of terrain. It is very smoothness in movement. But it cannot move fast because its complexity of the system. Currently lot of researches is going on about this robot. It can walk, climb and stands up and down.
3) *Flying Robots:* These robots are very small which can be manually operated. Unmanned planes are being used as spying force and combat missions. This type of robot has locomotion problems in the rough terrain and its slow speed will be overcome**.**
4) *Swimming Robots:* Some robots are needed to keep the sea boundaries safe from floating mines or attack by submarines and so we are in need of autonomous robots, space robots, lunar robots, etc.
5) *Autonomous Robot:* These robots can perform desired tasks in unstructured environments without human guidance continuously. Many kinds of robots have these types of robots are used for particular task only, so cost of the robot will be more. But reconfigurable robots are used to change the shape, to adopt in the environments (situation) after that again come to retain the shape.

E. Reconfigurable Model of robots

1) *Polybot:* It is a chain and self reconfigurable system. All the sides of the module are constructed cubical in shape (roughly). It has one rotational DOF. This type has many modes of locomotion such as walking, climbing, biped, legged, and snake etc. This module has brushless flat motors with harmonic drive mechanism.
2) *Molecules:* It is built to physically demonstrate kinematics self production. Each module has 0.65 kg cube with 100mm long edges and one rotational DOF

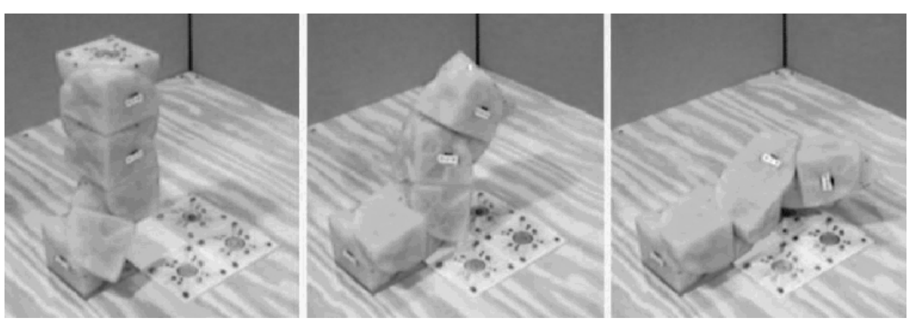

Fig. 1 Polybot

3) *Superbot:* It is hybrid lattice structure. The modules have three DOF (pitch, yaw, and roll). It can connect to each other through are one of the six identical connections.

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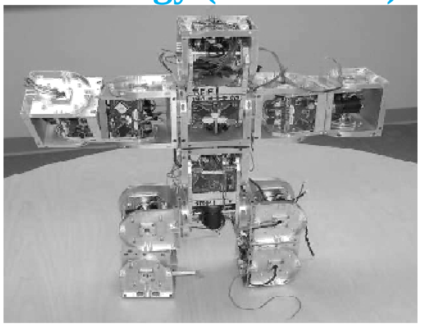

Fig. 2 Superbot

4) *Mitche:* It is also a modular lattice system; it is capable of arbitrary shape formation. This system achieves self assembly by disassembly and has robust operation. This connection mechanism provided by switchable magnetism

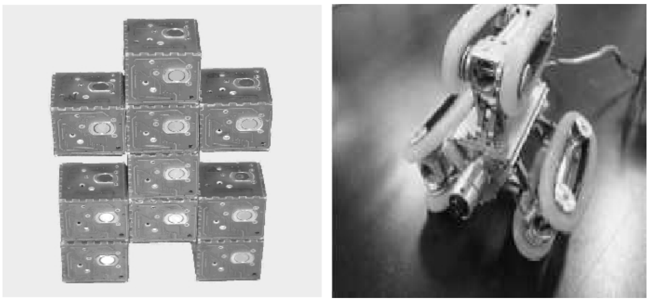

Fig 3 Mitche and Pipeline robot

So far there are many researchers attempted to manufacture robots and its subsequent developments made as on now up to industrialization. Table I shows the list of self reconfigurable robots from past history stating its class and Degree of Freedom. The various application robots system is shown in Fig. 1, 2 & 3.

TABLE I
LIST OF SELF RECONFIGURABLE ROBOTS

System	Class	DOF	Author	Year
Cebot	mobile	various	Fukuda	1988
Polybod	chain	2-3d	Yim	1993
Metamor phic	lattice	3-2d	Chirikjian	1993
Fracta	lattice	3-2d	Murata	1994
Tetrabot	chain	1-3d	Hamilin	1996
3d Fracta	lattice	6-3d	Murata	1998
Molecule	lattice	4-3d	Kotay andrus	1998
Conro	chain	2-3d	Will and shen	1998
Polybot	chain	1-3d	Yim	1998
Vertical	lattice	2d	Suh	1998
Crystal	lattice	4-2d	Hosakaw	1999
I-Cubes	lattice	3d	Unsal	1999
M-Tran	hybrid	2-3d	Murata	2002
Atron	lattice	1-3d	Stoy	2003
Swarm bot	mobile	3-2d	Mondada	2003
Super bot	hybrid	3-3d	Shen	2003
Stochasti c 2D	Stochasti c	0-3d	White	2004
Yamor	chain	1-3d	Ijspeert	2005
Mitche	lattice	1-2d	Bus	2006

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VII. CONCLUSIONS

Reconfigurable systems have the promise of making significant technological advances to the field of general robots which promises a high value, high versatility and high robustness may be lead to a radical change in automation. In this study concludes future challenges of reconfigurable robotics which have the potential to lead to various applications. The proposed challenges are to built a robots are as follows,

Build the highest structure possible

Lift an object as high as possible

Traverse the largest gap.

Maximum possible DOF for particular application.

However it may be the robot making itself has its own problem, for a particular application the selection of materials, sensor selection and control unit selection always varies. So the applications are wider in area, the possible improvement already made in a particular domain does not helps to improvement of other applications.

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