AMOEBA-I: A Shape-shifting Mobile Robot for Search and Rescue Application

To enhance the mobility and flexibility of the tracked mobile robot through changing the shape in the unstructured environments, a shape-shifting mobile robot, AMOEBA-I, has been developed. With three tracked modules, AMOEBA-I has nine locomotion configurations and three of them are symmetrical configurations. The key advantage of this design over other mobile robots is its adaptability and flexibility because of its various configurations. It can change its configuration fluently and automatically to adapt to the environments or missions. Modularized structure of control system is proposed and designed for AMOEBA-I to improve the fault tolerance and substitutability of the system. Such kind of structure possesses excellent mobility and high flexibility under various urban environments including stairs, narrow space, obstacle, uneven debris and underground garage. Being small, portable, and remotely controlled, AMOEBA-I has potential applications in areas such as urban search and rescue (USAR) and environment reconnaissance.

To improve the environmental adaptability of the search and rescue robots, we have proposed a novel shape changeable structure, named “AMOEBA-I”, as shown in Figure 1. Figure 1(a) gives a brief description of AMOEBA-I’s mechanism. It has three modules, two link arms, two Pitch joints and two Yaw joints. This type of structure, with offset joints at the modules’ lateral sides and with the link arm between the adjacent modules, has enough flexibility to change shape. The module body is a mobile system while the link arm and joints play important roles in shape shifting process. Take two adjacent modules of AMOEBA-I, Module A and Module B, as an example, in Figure 1 (b), the link type with two modules is in a line type, while in Figure 1 (d), it is in a row type. From line type to row type, both the Yaw joint and Pitch joint rotate 180 degrees in sequence.

Figure 1: Shape shifting principle of AMOEBA-I

AMOEBA-I has a modularized structure as shown in Figure 2, in which the timing pulleys are used as the track and the rubber track shoes have been stuck on the extern side of the track. The rubber track has both springiness and toughness to meet the need in various kinds of terrains. To improve the climbing ability of the robot, high, thick and discrete track shoes or track teeth, have been equipped. As shown in
Figure 2, a single-module is mainly composed of a link arm, a track driving system, an offset Yaw joint driving system, a Pitch joint driving system. It has three DC motors that is one drives the track, one is for Pitch joint, and the rest is for Yaw joint. The motors are packed in the center box. Chain transmission device has been used in Pitch joint and track’s driving, while the Yaw joint uses bevel gear pairs. Timing pulleys are used to driving the wheels forwards and backwards. The link arm and the link handle are used to connect and disconnect the adjacent modules. A three-module robot, AMOEBA-I, is repeatedly composed of such kind module as shown in Figure 3.

![Figure 2: Structure of a single standard module.](image)


The mechanical characters of the shape-shifting robot can be generalized as:

1) It has a lot of non-isomorphic configurations. Its configuration can change automatically to adapt to the environment. It can pose line type and row type easily. For instance it can pass the narrow space and the hole in line and move on uneven terrain safely or steering easily in row.

2) It is modularized and manually reconfigurable. The modular robot has satisfied maintenance and interchangeableness. Each single-module has the ability of moving. It is reconfigurable in urgent need.
3) It can resist against water and dust. With special consideration in design, it can work in more hostile environments.

4) It is small, light weight and easy to carry. Most important, the robot has several compact configurations fitting for different packages.

The shape-shifting robot has a wide potential application in extreme hazardous environments for its flexibility. For instance, when in search and rescue operation, the rescue robot are hoped to carry as many tasks as possible and to travel in as many environments as possible. The shape-shifting robot has the ability to form many kinds of configurations to meet the requirements. Being a 7-DOF system, AMOEBA-I can pose many kinds of configurations for its redundancy. In this paper, we only take its locomotion configurations into consideration. The locomotion configuration has all the tracks contact to the ground in parallel. As shown in Figure 4, AMOEBA-I has nine kinds of locomotion configurations. And three of them are symmetrical configurations: the line type in Figure 4(a), the triangle type in Figure 4(e), and the row type in Figure 4(i). AMOEBA-I can change its configuration to adapt to various environments and tasks.

Figure 4: Available locomotion configurations of AMOEBA-I
Various configurations greatly improve the flexibility, mobility and adaptability of AMOEBA-I. Many kinds of terrains are considered to be difficult for the general robot to traverse. We choose the typical terrains shown in Figure 5 to test the mobility of AMOEBA-I in different configurations.

(a) stairs                      (b) narrow space                                    (c) debris
(d) snowfield                  (e) underground garage          (f) grassland              (g) obstacle

Figure 5: Experiments on various terrains.

References


