Design and Development of an Amphibious Robot with Fin Actuators

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ABSTRACT

Aiming at automatic monitoring of environments in natural coast and tidal flats, we designed and developed an amphibious robot equipped with fin actuators mimicking locomotion of tortoise and sea turtle. We adopted the advantages of these two turtles for a robotic turtle, namely, lift-based swimming mode sea turtles use and quadrupedal locomotion tortoises use. The amphibious robot we designed consists of mainly 4 components, i) leg units, ii) control unit pressure hull, iii) buoyancy adjusting device, and iv) fairing cover. To realize not only three types of swimming motion, but also tortoise-like walking motion, we set up 3 motors at acromioclavicular joint using a differential gear mechanism to independently produce flapping motion, rowing motion and feathering motion, an one motor for elbow joint motion. We selected motors judging from the simulated results on torques around the axes of motors, peak values and effective values of those revolutions. We designed a buoyancy adjusting device by which the robot can realize walking on land and in water, and swimming in shallow water region with breaking waves. We designed a form of fairing cover using CFD computation to minimize the hydrodynamic drag.

KEY WORDS: amphibious robot; fin actuators; rowing motion; feathering motion; flapping motion; elbow joint motion; quadrupedal locomotion.

INTRODUCTION

It has recently been clarified that natural coast and tidal flats play an important role in preserving ocean environments. To protect coastal environments, regular monitoring of these areas is important. Monitoring has previously been done by humans on foot or using boats, but can be dangerous because of breaking waves and rip currents. Monitoring on foot is limited because it cannot be carried out in deep waters, while monitoring by boats is limited to the areas acceptable by water. Automatic monitoring by an amphibious robot is therefore expected to eliminate the safety threats to human monitors and improve operational efficiency. However, if an amphibious robot moves by screws and caterpillars, it won’t be able to move about in areas where certain land conditions exist and will damage the environments of the areas where it moves. An environmentally friendly amphibious robot is thus needed.

Several works have reported the development of amphibious robots. An amphibious snake-like robot ACM-R5(Yamada et al., 2005) can operate both on ground and in water by undulating its long body. The ACM-R5 uses special paddles and wheels mounted around its body to propel itself through water and over ground in a snake-like fashion, generating propulsive force to allow it to glide freely in the tangential direction. The biomimetic amphibious soft cord robot(Wakimoto et al., 2006) which is made of Mekibben actuators and plastic plates, can move both on the ground and in water, undulating its long body. A spinal cord model and its implementation in an amphibious salamander robot(Ijspeert et al., 2007) were studied to demonstrate how a primitive neural circuit for swimming can be extended by phylogenetically more recent limb oscillatory centers to explain the ability of salamanders to switch between swimming and walking. The AQUA(Dudek et al., 2007), an amphibious robot, can swim and walk along the shore and on the bottom of the ocean via motion of fins. It uses six paddles, which act as control surfaces during swimming and as legs while walking. An amphibious walking robot(Tanaka et al., 2006) was developed for shoreline survey. It has 6 legs each of which has 3 joints. It was successful in obtaining the distribution of ground levels from land to shallow water. An amphibious robotic turtle(Low et al., 2007) was built to imitate the locomotion of Cheloniidae, both in water and on the land to achieve operations. The crawling and lift-based swimming gaits were analyzed and implemented in the prototype.

For the field operation of an amphibious robot, it is necessary to have a rigid fuselage with an adequate payload to install a control system and sensors for monitoring of environments. However, we have been studying a biomimetic underwater robot equipped with mechanical pectoral fins from the viewpoint of high maneuverability under disturbances like waves and water currents(Kato and Liu, 2003; Suzuki and Kato, 2005; Kato et al. 2006). Taking the field operation and application of our experiences on the biomimetic underwater robot into account, we decided to develop an amphibious robotic turtle which can not only swim in the sea but also walk on the land for environmental monitoring of natural coast and tidal flat. Turtles which can walk and swim are generally categorized into sea turtles and tortoises, as shown in Fig. 1. Sea turtles have good swimming ability, but poor walking ability because they drag their body on the land, which causes friction on sand. Tortoises, on the other