学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

Self-recovery Strategy for Multi-legged Robot with Damaged Legs
(故障脚を有する多脚型ロボットの自己復帰手法)

Due to the flexibility of multi-legged robots, they can be applied in several applications in which regular wheel-based robots are not suitable to perform. However, multi-legged robots require a number of sophisticated sensors and actuators to achieve the goals. In general, multi-legged robots can perform properly with the controllers programmed by users, but there are some failures occurring when some sensors and actuators are no longer available. The legged robots are nonfunctional after getting damaged since the prior control strategies cannot be employed to operate efficiently with transferred models.

Self-recovery method can overcome this problem by finding alternative behavior of robot. The techniques utilized to assist the self-recovery strategy can be divided into main three categories as follow:

•Robot Structure: One of the strategies to compensate the robot be able to move again is the design of robot structure. With different types of shapes and structures, multi-legged robots can be controlled in different manner to achieve the desired goal. The robot developed with concerning of damage recovery can provide beneficial outcomes when the robot get damaged. In some cases, the robot structure limits the possibility of performing recovery actions. Hence, the well-designed structure of multi-robot is required.

•Fault Diagnosis: It is ambitious for the broken robot to function without knowing the current model. Leg-loss identification is a significant process to assist the damaged robots to discover the new, present models. If the system failures is examined, it is helpful to create new actions based on the updated models.

•Recovery Behavior: In hazardous areas where humans cannot enter, there is no possibility to repair the robot manually in the place in which it is broken. Recovery behaviors play an important role in this state to move the damaged robot heading back to the repair station or the accessible areas. Since the robot's supply source will be decayed as time goes by, the effective actions should be executed with the broken robot. Thus, recovery behaviors have to be designed with due consideration to act efficiently.

According to the strategies to assist the damaged robot as stated, this study is detailed as following Chapters:

Chapter 1: The overview of research background is written here to describe the concept and the useful purposes of this study. Motivation and contributions of this thesis are explained as well. Moreover, the limitation and delimitation of this study are stated in this chapter.

Chapter 2: The novel structure model of quadruped robot has been proposed. The caterpillar-inspired quadruped robot (CIQR) is developed to imitate the caterpillar crawling locomotion when the robot has a small number of active legs. The caterpillars' proleg is added on the robot limb to improve the ability

to move after some parts of robot got damaged. This lets the legged robot become movable even if it has only one leg. However, the structure of legs have to be designed circumspectly due to the face that the proleg can limit the reachable space of robots leg while operating with normal quadruped gaits. In this paper, the new shape of robotic leg is designed with inspiration of caterpillar and optimized using PSO algorithm. The fitness function of PSO is set as the distance that robot can travel in both crawling and trotting gait.

Chapter 3: This chapter analyzes fault detection methods for legged robot with broken legs and joint motors. The PSO-based Leg-loss Identification method (PLI) is detailed here. The PLI method uses only on-board sensors that lets robot become more versatile. Particle swarm optimization is utilized to optimize the fitness function that is set as the resemblance of candidate models and actual damaged robot. The acoustic-based fault diagnosis for legged robots (AFL) is developed to detect the abnormalities of joints. Sound of servo motors are recorded simultaneously while a multi-legged robot is executed to perform specific actions. The results show that both proposed methods can detect the fault parts properly with the broken robot in the experiments.

Chapter 4: The development of new bio-inspired locomotion method is conducted to help the legged robot that has a small number of legs to be able to move again after getting damage. The concept is based on the movement of mudskipper in the nature. Self-learning mudskipper-inspired movement algorithm (SLMIM) is proposed in this study. The reinforcement learning method, Q-learning, is integrated to improve the adaptability of locomotion. The results show that the proposed method is feasible to employ with the damage robot that has two legs.

Chapter 5: The whole conclusions of this study are presented here, and the further studies that can be conducted and improved are drawn in the final chapter.