【Grant-in-Aid for Scientific Research (S)】

Broad Section J

Title of Project : Highly efficient transportation and sports movements utilizing the in-body storage of mechanical energy in humanoid robots

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【Purpose and Background of the Research】

In the present super-aging society, one of serious issues is a decrease in the working population. This has been boosting the use of robots in factories and houses. Humanoid robots have a shape similar to that of humans and are expected to work in various environments designed for humans. In recent years, the performance of humanoid robots has been rapidly improving, while increasing their mechanical output. As the output of the whole body of the humanoid robot increases, however, the size and mass of the robot inevitably increases, thereby requiring greater energy to move. In the motion generation, active driving of body parts is generally performed by the energy sequentially supplied by electricity. In contrast, humans move very efficiently. Human limbs become thinner and lighter with less muscle compared the proximal part (trunk). Limbs are dynamically driven with sizable inertial forces by large muscles located proximally, while storing and releasing potential energy passively by the elastic tendons located distally. In the present research, we will clarify the mechanisms of such efficient energy utilization strategy of humans then realize it in a newly designed humanoid robot with the humans' norm in terms of active work generation, passive elastic energy use, and the coexistence of action/relax sequence. The goal is to design a humanoid robot that consumes far less energy during movements and to achieve remarkable athletic performance and transportation capacity.

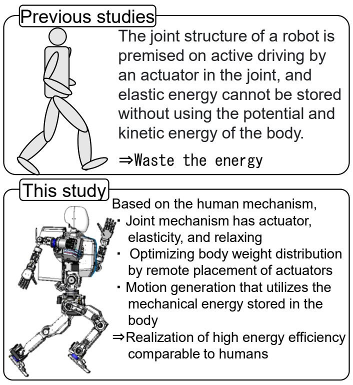

Fig. 1 Abstract

【Research Methods】

To achieve the above goals, five priority issues of research are performed such as (A) establishment of energy consumption minimum motion generation method with three-form conversion of mechanical energy, (B) development of high-power joint mechanism capable of exerting, elasticity, and relaxing, (C) development of a lightweight limb structure with human norms using a transmission mechanism, (D) verification of the effect of different sports forms on energy efficiency, and (E) realization of highly energy-efficient transportation work.

In the motion generation method, the control method for maintaining stability that we have proposed is extended to generate motion with low energy consumption.

In the structure of existing robots, the actuator that is the drive source of the joint often performs only active drive, and it is necessary to place it near the joint to be driven. By learning from human structure, we will establish a design method that allows a drive source that can exert elasticity and weakness to be placed at a position farther than the driven joint, especially beyond other joints.

Using the proposed methods, we propose a new high-energy-efficient exercise when humans exercise. By reflecting the physical parameters of each human being, we propose exercise movements suitable for each individual regarding the ratio of muscle strength and elasticity / passivity and verify the effectiveness.

【Expected Research Achievements and Scientific Significance】

In the past research on humanoid robots, many studies aimed at improving athletic ability such as exertion, speed, and balance ability have been conducted, but improvement of energy efficiency is indispensable for practical use. To solve this problem, it requires an approach from both aspects of motion control and structure, and in this study, we aim to use them together. By clarifying the contributions of motion control and structure, it is possible to form the basis of the design and operation method of humanoid robots in consideration of energy consumption.

Furthermore, new attempts to utilize robot technology for humanoids in sports science will lead to the construction of new training methods that enhance human performance.

【Publications Relevant to the Project】

・ Takuya Otani, Kenji Hashimoto, Takaya Isomichi, Akira Natsuhara, Masanori Sakaguchi, Yasuo Kawakami, Hun-ok Lim and Atsuo Takanishi, “Trunk motion control during the flight phase while hopping considering angular momentum of a humanoid,” Advanced Robotics, vol. 32, Issue 22, pp. 1-10, 2018.
・ Hiroki Mineshita, Takuya Otani, Masanori Sakaguchi, Yasuo Kawakami, Hun-ok Lim and Atsuo Takanishi, “Jumping Motion Generation for Humanoid Robot Using Arm Swing Effectively and Changing in Foot Contact Status,” Proceedings of the 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 3823-3828, 2020.

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