# 論文 / 著書情報
# Article / Book Information

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# 論 文 要 旨

THESIS SUMMARY


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| 専攻：<br>Department of | 情報環境学　　専攻 | 申請学位（専攻分野）：<br>Academic Degree Requested | 博士<br>Doctor of　(Engineering) |
| 学籍番号：<br>Student ID Number | | 指導教員（主）：<br>Academic Advisor(main) | 中島　求 |
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）


In spite of a long history of competitive swimming, still, its mechanics have not been fully clarified yet since it is an extremely complicated phenomenon in which a complex human body moves unsteadily with many degrees-of-freedom in the three-dimensional water flow. From this viewpoint, many attempts were made recently to quantify the unsteady fluid forces acting on a swimmer.

The first approach was an experiment involving a human subject. However, this method has problems with insufficient repeatability, physical fatigue of the subject, and difficulty in installing sensors in the subject. Recent advances in computers have stimulated simulation study using computational fluid dynamics (CFD). However, making accurate models of swimming is still difficult because of the unsteady three-dimensional fluid dynamics involved. In addition, the fluid simulation still needs experiments for validation. For all those reasons, some researchers have conducted experiments using physical models such as a robot instead of human subjects. A lot of measuring experiments using physical models have been conducted to date, but there is no full-body experimental platform which can consider interactions between the many segments involved in normal swimming motions. Therefore, the analysis using physical models has been performed on an isolated segment and misleading conclusions could be developed. So the objective of this study was to develop a full-body swimming humanoid robot for research of human swimming.

The design concepts of the swimming humanoid robot were as follows:

a) Waterproof design

b) Imitation of human body geometry: appearance, body proportions, center of mass and specific gravity

c) Realization of swimming motions

d) Half the size of a real human

Since the robot was the swimming experimental platform substituting a human subject, the design concepts a), b) and c) were obvious. The robot size was determined to be half the size of a real human in order to make development easier and to be more convenient when it is operated in experiments. To realize the design concept c), the robot has a total of 21-DOF but the leg doesn't have sufficient degrees of freedom to perform the breaststroke kick, so in this study, realization of the breaststroke is excluded.

Arm motions during swimming are composed of the underwater stroke and recovery stroke. Swimmers perform these two strokes continuously. However, such a continuous stroke motion cannot be realized with a general robot arm which is constructed of a three-rotation sequence of pitch, yaw and roll. Therefore, in this study, the scapular joint was installed on the robot arm based on the idea that the human scapular retraction motion makes it easy to perform an over arm motion. In order to use the scapular joint systematically, we limited the range of the retraction motion to the over arm motions, such as the recovery motion in the crawl stroke. Also, we established methodology to generate swimming motions using the scapular joint and developed an inverse kinematics model of the robot. The efficiency of the scapular joint was validated by simulation of the crawl, back and butterfly strokes. In the simulation, it was confirmed that the robot can rotate its shoulder continuously.

In order to examine the generated swimming stroke motions practically, representatively, the stroke motion of the crawl was observed in the circulating water tank supported by four struts. For the experiment, measurement system of fluid force using the humanoid robot was constructed. The rolling motion during the crawl stroke was generated by the driving mechanism which was connected by the struts. In order to measure the forces acting on the robot, four dynamometers were embedded at the tip of the struts. Through the experiment, we confirmed that the developed humanoid robot could generate propulsive force and we could measure it using the constructed measurement system.

Overall swimming performance of the robot was examined by measuring the roll angle and swimming speed during free swimming. To realize free swimming in the crawl stroke with the developed robot, the upper body of the robot was remodeled. To produce proper buoyancy on the breast part, breast cases were designed and assembled in the body case. In addition, larger motors were installed in the shoulder joints to generate more torque and to achieve faster stroke cycles. Using a human swimming simulation model SWUM, a feasibility study was conducted first and two different models were proposed to perform the free swimming in the crawl stroke. Model I was constructed to produce larger roll movement and Model II was constructed to improve buoyancy for the stable recovery stroke. The two simulation models were realized in actual models with the robot. The crawl stroke was performed successfully by the two models respectively. The roll movement and stroke motions matched well with the simulation model. However, there was a difference in the swimming speed. The swimming speed of robot model was slower than that of simulation model.

備考 ： 論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 2 部提出してください。

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