The proposal of the agent robot design to realize lifelike motion using the rotary joint

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Abstract: In Human Agent Interaction, designing lifelike motion and shape is important factor to allow a user to perceive an affinity for an agent. But, to imitate structure or behavior of actual living things is not necessarily needed to make a user to perceive animacy.
Most researches on animacy perception use CG animation to evaluate the effect of lifelike motion, and they doesn't design lifelike motion based on an actual mechanical structure and actuator.
In this paper, we describe about the robot which named “Flagella” which was designed to realize lifelike motion using a motor which is a basic actuator of artifact.

1 Background

Method to design shape and motion which give us animacy perception is one of a research theme of importance in human agent interaction.There are many researches designing agent using a similar structure with actual animals like human or dogs. In these researches, they design lifelike behavior based on actual animal's behavior which users have been experiencing. On the other hand, there are some researches designing more abstract shape and motion. Osawa suggests that agent robot using 2-DOF actuator is able to do gesture to communicate with users.[1] Yamaji suggests that a simple gesture of agent robot encourages desirable behavior. [2], In these researches Osawa and Yamaji used box shaped agent robot. Users are familiar with that shape such as dust box and know how to use it.

In many researches on animacy perception, computer graphics animation is used to reveal the motion which gives us animacy perception. Heider & Simmel produced the CG animation of simple geometrical shapes which has a story, and they showed that the examinee recognize geometrical shapes as living things and empathize with them[3]. And, some researchers suggest that some interplay of two simple points is effective to recognize them as living things.[4] Aono examined animacy perception using two-link mechanism, as the simplest mechanism of structural objects.[5]

There are some impediments to perform lifelike motion in the real world. There is a difference in behavior and property between muscles which are basic actuator of living things and motor which are basic actuator of artifact. We have to control some motor to move humanoid's one joint like actual humans do. For this reason, motion design for humanoid is difficult.the property of actuator's acceleration and deceleration is also different, and uniform motion is feasible motion for the motor. Tremoulet and Some researchers show that some types of change in velocity or direction of single mass point are effective to allow the examinee to perceive it as lifelike motion. Though, realizing such change of motion in the real world is difficult.

The approach to design lifelike motion with using the shape which is not similar with animal was researched by Walter. [6] It is reported that many "Roomba" users show attachment to "Roomba", which is disk-shaped cleaner robot that perform uniform linear motion.The agent robot perform bidimensional motion on the floor in these examples.[7]

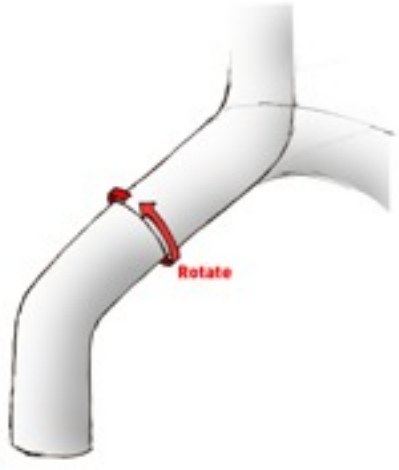
The agent's motion in three dimensions is important in order to communicate with human in the real world. Though, there are few researches which are aimed to verify animacy perception by using 3D motion in the real world. It is because there are some difficulties which to perform 3D motion in the real world. The motion in the real world object is depend on the property of actuator. Designing abstract shape using actuators and mechanical parts is also difficult.

In this paper, we propose the mechanism which produce lifelike motion in 3D space using uniform circular motion which is the basic motion of the motor. Furthermore, we describe about shape and motion of the lifelike robot prototype "Flagella" which was designed using that mechanism.

2 Proposal of the mechanism

As described above, typical actuator of machine is the motor, and one of its important property is that the motor is able to perform stable continuous circular motion around one axis.

Using that feature, we propose the mechanism which is composed with curved pipe-shaped arm and rotary joint which rotate concentrically with the cross-section of the arm.(fig.1)



(fig. 1) The mechanism we propose

The arm is able to rotate not to displace joint's circular cross-section, by precise rotation of the motor. By designing the joint to maintain continuity of each modules at any angles of rotation, the mechanically-coupled structure of these arm modules can behave with maintaining good continuation, which is the one factor of principles of gestalt. We perceive this combination of the modules as a gestalt, by its good continuity. Thus, we perceive it as though the long soft tube which is moving windingly.(fig.2)

(fig. 2) the motion made by the motion

The appearance of robots which consist of hard materials and cables to transfer energy tends to be more complicated than that of animals which is covered all mechanisms under saclike skin.

This mechanism is effective in realizing the simple and abstract appearance like the appearance made by computer graphics.

3 Implementation of “Flagella”

3.1 Fabrication of prototype "Flagella"

We made the robot "Flagella" using the mechanism described in section 2. We designed the prototype to realize that mechanism in the real world, and evaluate its effect. We made it as an art piece to give the opportunity for many people to experience the lifelike motion of that mechanism.

3.2 Shape design and structural design

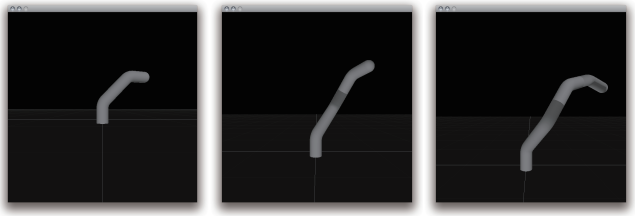
In this section, we describe about the shape design of arm modules of "Flagella".

We adopted the shape of curved pipe which has circular cross-section as the shape of arm module, in order to design the module in simple abstract shape and maintain continuity of the joint. The pipe-shape is made by extruding circular profile along the curved rail. The shape of cross-section at termination point of rail must be a precise circle not to misalign when the motor rotates. The rail's curvature should be zero at the termination point, to realize good continuation.It is ensured that the connection of each pipe-shapes is curvature-continuous (C2-continuous), if the rail's curvature value at termination point is zero. If the rail is the shape of a circular arc, the connection at the connection point is tangent continuous (C1-Continuous). We adopted the arm shape which connects to another module in C2-Continuous because that shape is effective in order to let witness perceive good continuation. We used CG simulation to evaluate the effect of the continuity of modules.

We designed the rail curve of the module based on the bezier spline which the curvature at the termination point is zero and at the mid point is maximum. And we designed the module shape by extruding circle along that rail spline.（fig.3）

(fig. 3) the rail curve and shape of arm module

Individual "Flagella" consist of three modules.We made CG simulation to evaluate the suitable number of the arm modules for "Flagella". We adopted that number considering both the load of the motor and the difference of motion which varies depending on the number of modules.（fig.4）



(fig. 4) The CG simulation to decide the number of modules

3.3 Motion design

In this section, we describe about the method of motion design of "Flagella". We designed the motion aiming to make observer perceive animacy. We adopted uniform circular motion as the basic motion of "Flagella", to evaluate the effect of curved-arm and circular joint mechanism. The rotate range of the joint is restricted in 300 degrees to avoid breaking of wire, and the rotate direction varies randomly. The control program keeps the joint rotating by changing the rotate direction randomly.in order to reduce the load to the motor, the motor rotates by gently acceleration and deceleration.

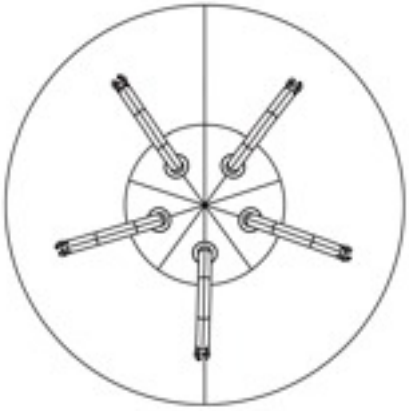
In addition to this basic motion, We designed interplay of each "Flagella" to realize more lifelike motion. The motion which is able to convey the agent's intention to the observer is effective to animacy perception. As described at background, the single object can convey its intention to the observer by changing direction or velocity of the motion. We though adopted the way which use the interplay of some objects, in the design of the motion of "Flagella".

Each arm is placed in the position where the one has the possibility to collide with the other one, and it moves with avoiding the other arm. We developed the motion algorithm based on the potential field method. The robot which behaves by the potential field method moves toward the goal point with avoiding the obstacles. It moves as if it receive the repulsion force by the obstacle. The repulsion force is calculate by virtual potential field. "Flagella" has no sensor to measure the distance between itself and the other arm. The control program calculates the posture and distance of each arm by reading the angle of each servo motor, and decide the repulsion force.The joint rotates toward the goal angle which was determined by the control program, while avoiding other arms.We adopted that behavior to let observer feel that "Flagella" has the intention to move toward the goal point. It is because the motion of the agent with the intention is effective for the lifelike motion.

3.4 Design of the exhibition model

We designed the exhibition model (fig.5) that is placed each arm to the position where has the possibility to collide with each other.One arm is consist of curved pipe-shape three modules, and five arms are placed 72 degrees apart in a circle.(fig.6)

(fig. 5) The exhibition model of “Flagella”



(fig. 6) The arrangement of each arm

4 Evaluation

We exhibited "Flagella" to let many people experience it. We displayed the piece in three exhibitions, We displayed that piece in three exhibitions. These exhibitions are "bones" exhibition which held at popular design museum in Tokyo, "Keio University SFC Open Research Forum", and "XD Exhibition". Latter two exhibitions are research exhibition of Keio University.

We were able to show "Flagella" to many people in a wide age at "bones" exhibition.(fig.7) It is because the "21_21 design sight" where held "bones" exhibition is popular museum, and that exhibition were held over about three month. Furthermore, Many researchers and students came to "Open Research Forum" and "XD Exhibition", and we were able to get some feedbacks about "Flagella" from them.

At these exhibitions, many people who watched "Flagella" said "this seems covered by soft material like rubber". This suggests the mechanism with curved pipe module and the stable circular rotary joint was succeeded to make people feel as if one continuous arm moves windingly.Also, some people said like following. "It is going away from me. Does it hate me?" or "It's approaching toward me. It is watching me?". They said it as if they recognized the intention of "Flagella". "Flagella" has no sensor to recognize human around it, so

it interacts with other arm but does not interact with human.Although, according to the reaction from the observer, the interplay between each arm of "Flagella" is enabled to make the observer feel as if the arm of "Flagella" moves with intention and has some sensor to understand the environment around them.

(fig. 7) The picture of the exhibit of "Flagella" in "bones" exhibition

5 Discussion

It was found that the design of the curved arm module and the continuous rotary joint makes people feel as if one continuous arm is moving windingly. Also it was found that this design method is effective for realize the simple appearance. Furthermore, It was found that the motion avoiding other arms based on the potential field method is effective to make people perceive animacy.

In this research however, we adopted new structure and new motion and we made the agent robot as art piece. We therefore had not do enough experiment like the evaluation of emotion about the effect on animacy perception of the robot yet.

In the future, we will do the experiment to evaluate and get more detailed data. for instance, we show examinees a few motion and examine their impression about the motion, to evaluate the effectivity of the avoiding motion. We decided some parameter, such as the velocity of the motor, the acceleration of the motor, the degree of the arm module's curve, using CG simulation and by reference to feedbacks from several project members. In the future, we will do the experiment to more general examinee using that CG simulation to evaluate the effectiveness of that parameters, velocity, acceleration and curve.

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