Mechanism and Scenario Design of an Intelligent Arm-Wrestling Machine System

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Abstract: The report of the Korean National Statistics Office shows that Korea has been emerging as an elderly society rapidly, and it will burden the Korean society with excessive social welfare cost for the aged in the near future. If we can help the aged to live healthy in some ways, the social burden for the health care of the aged will be lessened. In order to help physical and mental health of the elderly person, we have developed an exercise apparatus called intelligent arm wrestling machine system. This paper presents the mechanism and scenario of the proposed intelligent arm wrestling machine system. The proposed mechanism and scenario are peculiar. In particular, the proposed scenario determines randomly who will win between the man and the robot and generates a game process that the arm-wrestler cannot predict in advance.

Keywords: Arm wrestling, Mechanism, Scenario, Silver welfare, Robot

1. INTRODUCTION

The report of the Korean National Statistics Office shows that Korea has been emerging as an elderly society, as its aging population increased sharply in recent decades with the elderly index recorded as 35 percent well over the standard 30 percent for an aging society. Declining youth population will bring about an acute work force shortage in the near future and burden our society with social welfare cost excessively. Our society ought to spend more on health care and welfare for the aged. If we can help the aged to live healthy in some ways, the social burden for the health care of the aged will be lessened.

Arm wrestling is a widespread sport in North America and Europe that gives lots of fun to human. Fig. 1 shows a picture that a grandfather beats his son and his grandson cheers the match. This picture creates a warm family atmosphere with the grandfather healthy physically and mentally. However, the civilized modern society has unfortunately a trend toward the nuclear family, and the elderly feel more and more lonely. If we build an arm wrestling machine with a little intelligence, it will give the elderly lots of fun and help the elderly to keep their health partially.

Fig. 1 Warm family enjoying arm wrestling

In order to help physical and mental health of the elderly, we have developed a peculiar exercise apparatus called an intelligent arm wrestling machine. This paper presents the mechanism and scenario of the proposed intelligent arm wrestling machine system.

Several arm-wrestling devices have been patented as amusement devices and as devices for developing and strengthening wrist and arm muscles [1-7]. Fig. 2 shows an arm wrestling machine (United States patent) that is driven mechanically, and Fig. 3 shows an arm wrestling machine (United States patent) that is driven hydraulically. Fig. 4 shows a mechanical arm wrestling machine (Korea patent). Fig. 5 shows an arm wrestling game machine (Japan patent) that is driven electrically (by a motor).

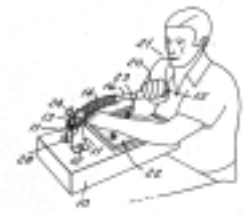

Fig. 2 Arm wrestling unit (US 3947025)

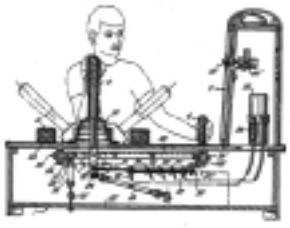

Fig. 3 Strength training amusement device for simulating arm wrestling (US 4805900)

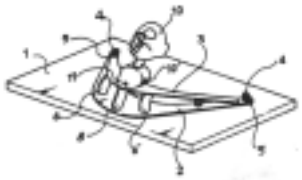

Fig. 4 Arm wrestling amusement device (KP 20-1996-0006642)

Fig. 5 Muscular force strengthening device for arm wrestling (JP 2002017891)

However most of these devices are simple mechanical devices with some electronics, or devices that can play simple games even if they have force generation mechanisms with electric motors. The proposed intelligent arm wrestling machine

in this paper composed of delicate components including servo motor, planetary gear train, torque sensor, angle detection sensors, PC as well as mechanical arm with hand, and can control torque and angular position and velocity together. Furthermore it can generate an intelligent scenario of arm wrestling according to the force generation pattern of human arm. The proposed mechanism and scenario are peculiar. In particular, the proposed scenario determines randomly who will win between the man and the robot and generates a game process that the arm-wrestler cannot predict in advance.

Section 2 describes system concepts, Section 3 presents the mechanism of the systems and Section 4 proposes an intelligent arm-wrestling scenario. Section 5 concludes the paper.

2. SYSTEM CONCEPTS

In the amusement game room, we can see a simple arm-wrestling machine such as Fig. 6. This machine generates a torque set by an arm-wrestler before the game. If the arm-wrestler can generate more torque than the set torque, he will win, and if not, he will lose. The operation of this machine is simple and there is no intelligence in the machine. If we can add some intelligence in the machine, the arm-wrestling game will give much more fun to people and especially to the elderly.

Fig. 6 Simple arm-wrestling machine

The proposed arm-wrestling machine is conceptually like Fig. 7. In Fig. 7, one arm-wrestler of Fig. 1 is replaced with a robot with a little intelligence. Final purpose is to include arm wrestling function to the Silvermate robot shown in Fig. 8, which can determine gaming process and winning or losing a match according to the recognition of human's facial expressions. For example, if an elderly person is unhappy, the probability of the robot to win the game decreases. If he is in a happy mood, the probability of the robot to win the game increases, and the arm-wrestler experiences more challenges. However, in this paper, we make the system that determines the winning or losing randomly using random number generations, and make the system to be influenced by the will of the arm-wrestler to win the match. The will of the arm-wrestler is decided by the force pattern that the arm-wrestler generates.

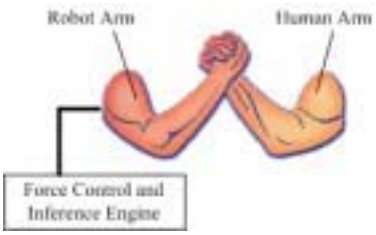

Fig. 7 Conceptual view of the proposed system

Fig. 8 Silvermate robot

First step to design this arm-wrestling system is to obtain torque data that the arm-wrestler can generate. Since we cannot find data on torque information for this kind of system in the literature, we have carried out experiments such as Fig. 9 using a scale. In Fig. 9, a scale is attached on the wall, and an arm-wrestler pushes it in the same fashion with arm wrestling. Reasonable maximum torque for the elderly has been determined to be 40 N·m from the data gathered from the experiments shown in Table 1.

Fig. 9 Experiment for gathering torque information at arm wrestling

Table 1. Experimental results of arm wrestling torque

Person 1	12×9.8×0.3 ≅ 35 N·m
Person 2	10×9.8×0.3 ≅ 29 N·m
Person 3	9×9.8×0.3 ≅ 26 N·m
Person 4	14×9.8×0.3 ≅ 41 N·m

3. MECHANISM OF THE SYSTEM

In order to realize an intelligent arm wrestling of the previous section, we propose the following mechanism shown in Fig. 10. The mechanism in Fig. 10 is composed of a servomotor, a reduction gear, a torque sensor, and three inclinometers. An arm with a hand will be attached in front of the mechanism of Fig. 10. Samsung Fara AC servomotor with 600 W [8] is selected for the proposed system, which has 5.7 N·m rated output torque and 2,500 pulses/rev encoder. The reduction gear is necessary for increasing torque from the servomotor. The reduction gear should have low backlash and friction for good performance of position and force control of the system.

In this research, we select a harmonic drive shown in Fig. 11 [9], which has 1/11 reduction ratio, 1 arc min backlash, 45 N·m rated load torque, and 1.8 N·m output starting torque. The torque sensor shown in Fig. 12 is necessary for force feedback control, which has 98 N·m rated capacity. Fig. 13 shows the selected inclinometer that has ±30° measuring range, 0.005°

resolution, 0.3 sec response time. Inclinometers are necessary for initializing the angular position of the machine arm.

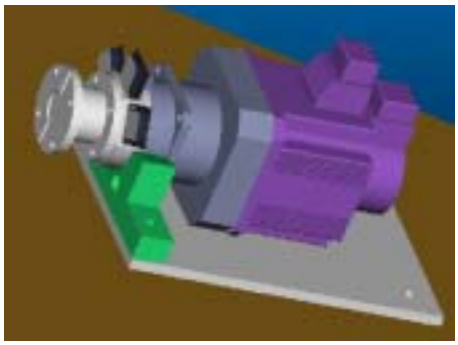

Fig. 10 Mechanism of the proposed system

Fig. 11 Sectional view of the harmonic drive

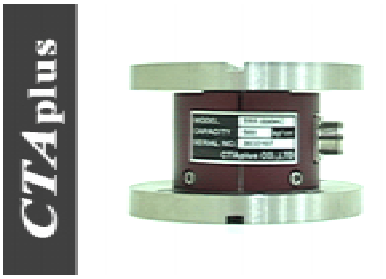

Fig. 12 Torque sensor

Fig. 13 Inclinometer

The whole system including an arm wrestling table and an arm with a hand is shown in Fig. 14.

Fig. 14 The whole system proposed

4. INTELLIGENT GAME SCENARIO

Arm wrestling is not strictly a "strength" sport as people often think, because technique and speed are both very important. Therefore, to build an intelligent arm-wrestling machine requires creating intelligent game scenarios.

In the proposed scenarios, the will of the arm-wrestler for the match affects the winning probability of the game, and the robot performs the similar game pattern with human. The scenario gathers information on the present arm position, human-arm's force, time progression and the amount of force increment through several sensor outputs, and generates the type of classes according to the rules (that is, gathered information). It is based on the reasoning with uncertainty in which victory or defeat is not predetermined but is varying according to the pattern of the game progression. In addition, the safety of the participant is considered at the scenario production.

Scenario is in progress using a value called winning point that quantifies the will of arm-wrestler for the match. Winning point 0 implies no will to win the game, and winning point more than 100 implies full will for that.

At the beginning the arm-wrestler can select a character at the monitor that he wants to fight. Each character has different original force capacity. The actual force capacity of the character varies from –10 % to 10 % of the original force capacity of it using random number at the initialization process. During performing arm-wrestling, the robot can increase its force up to 50 % of its capacity according to human-force. When arm-wrestling starts, initial winning point is calculated using Eq. (1) from the measured value of human-force.

$$(\text{initial human-force} - \text{initial robot-force})/(\text{initial robot-force}) \times 100 = \text{initial winning point} \quad (1)$$

If this initial winning point is equal to or bigger than 0, Scenario Function selects an appropriate human-winning scenario according to the winning point and random number generation. If the initial winning point is less than 0, Scenario Function selects an appropriate robot-winning scenario according to the same method. After some time duration by the scenario, Scenario Function reruns via looping, which determines who will win again.

Within the loop, Point Calculation Function recognizes the changes of human force and arm angle, and updates the winning point according to the rules that are based on the amount of changes in force and angle. Also, if the change of the winning point is less than 5 at the end of one scenario, a scenario for human's will test (test scenario) is performed. At this test scenario, changes in force and angle are measured, and the winning point is updated by Point Calculation Function.

Point Calculation Function updates winning point using sensor signals according to simple crisp logic or fuzzy logic [10].

Flow chart for the above scenario is shown in Fig. 15. Fig. 16 shows the flow chart of Scenario Function.

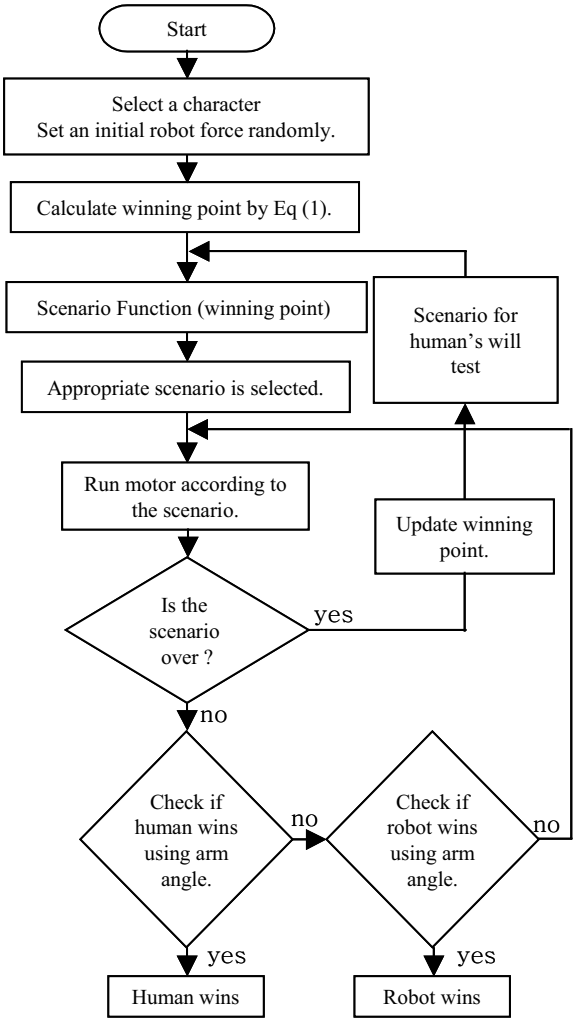

Fig. 15 Flow chart of the whole scenario.

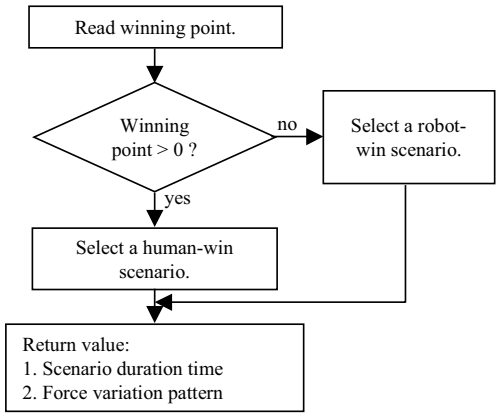

Fig. 16 Flow chart of Scenario Function

4.1 Human-winning scenarios

Human-winning scenarios are composed of 5 classes. The selection among 5 classes is accomplished using winning point and random number. The random number generated between -10 and 10 is added to winning point, and then a scenario is selected according to the new winning point. As the winning point is bigger, the scenario with low number is selected. Five scenarios in which human wins are as follows.

Scenario 1. Make force difference big and rapid. In this scenario, force difference between human and robot is set to 10% ~20% of human force, and robot force decreases rapidly as time passes. Duration time of the scenario is set to 1~2 sec.

Scenario 2. Make force difference big and slow. In this scenario, force difference between human and robot is set to 10% ~20% of human force, and robot force decreases slowly as time passes. Duration time of the scenario is set to 1~2 sec. In this case, robot force cannot be decreased to the final value at the end of the scenario.

Scenario 3. Make force difference small and rapid. In this scenario, force difference between human and robot is set to 0% ~10% of human force, and robot force decreases rapidly as time passes. Duration time of the scenario is set to 1~2 sec.

Scenario 4. Make force difference small and slow. In this scenario, force difference between human and robot is set to 0% ~10% of human force, and robot force decreases slowly as time passes. Duration time of the scenario is set to 1~2 sec. In this case, robot force cannot be decreased to the final value at the end of the scenario.

Scenario 5. Make human and robot force same. In this scenario, duration time of the scenario is set to 1~2 sec.

4.2 Robot-winning scenario

Robot-winning scenarios are also composed of 5 classes. The only change in five robot-winning scenarios is "robot force increases" instead of "decreases" in five human-winning scenarios. Selection process is same with the case of human-winning scenarios.

4.3 Scenarios for human's will test

To give some variations and fun at arm wrestling, we add a function that robot tests human's will to win the match. Each time normal scenario ends, variation of winning point is checked. If the variation is less than 5, a scenario for human's will test (called test scenario) is performed. If it is equal to or bigger than 5, then test scenario is skipped. In test scenario, a random number is generated between 0 and 10, and one scenario among the previous 8 scenarios (robot-win or human-win scenarios) is selected according to the generated random number. The only difference between normal scenarios and test scenarios is that duration time is 0.5 sec instead of 1~2 sec.

5. CONCLUSION

In order to help physical and mental health of the elderly, we have developed an exercise apparatus called an intelligent arm wrestling machine. This paper presents the mechanism and scenario of the proposed intelligent arm wrestling machine. The proposed mechanism and scenario are peculiar in the sense that the mechanism includes a planetary harmonic drive and a torque sensor that enables force feedback control, and the scenario includes intelligent functions such that winning and losing at arm wrestling is determined randomly, and human's will for the match in the middle of the game affects the result. In the scenario, a value called winning point is adopted for managing arm-wrestling progression.

ACKNOWLEDGMENTS

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