The Riding Robot System with 4 DOF Horseback Motions and Healthcare Service for Entertainment

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***Abstract*-This paper describes the riding robot system named by "RideBot-II" which is a riding robot like as a horse. In order to simulate the riding motions, we developed the saddle mechanism which can generate 4 DOF motions including pitch, roll, bounce and slide movement, and also we controlled the riding motions and the intention of horseman. To generate the riding motions with the bodily sensation, we developed Novel Washout Filter and the algorithms for motion control. And also, we developed some health care service for the health care of horseman. A body state index was proposed that evaluates the personal health state from both the measured physiological variables and the surveyed questions. The physiological variables such as weight, blood pressure, heart rate variability(HRV), accelerated state photoplethysmograph (APG), body fat, and happiness index were measured by the specially designed bio-handle system and survey questions. The efficiency of the proposed ride robot is evaluated in the experiments**

Keywords-Riding Robot, Horseback Motions, Entertainment, Healthcare, Riding Motion Control.

I. INTRODUCTION

The research area in robotics that has recently received a great deal of attention is the development of the entertainment and healthcare service robots. Recently several concerns of entertainment robot and increasing technologies are going on [1]. So, the service robots of healthcare and entertainment is one of the concerning area. At present, many research groups have gradually realized the entertainment and healthcare service robots [9]. These kin ds of robot usually have entertaining characteristics [4].

At this moment, the riding robot is a good example of a practical riding robot like as a horse. This kind of robot does not need an excellent artificial intelligence because the rider directly operates the robot. This robot can provide riding sensation of a horse to the operator.

A riding robot should first be able to support sufficient payloads in order to perform the functions including motion of walking, running, and turning of direction. To acquire the payloads and riding motions, the number of axis and power of actuator have to be sufficiently generating the motions. If the rider can not to be sensible the riding of horse, then this kind of human-riding robot system becomes to be evaded from the customers.

Possible tasks of riding robots are the riding entertainment of a horse, enjoying the riding motion include the walking, running, and turning the direction. And also, the checking the health conditions include the personal health states from both measured physical variables and survey questions are good task for operator.

In order to simulate the riding motions of a horse, we developed the 3-DOF saddle mechanism that generates the pitch, roll, and bounce motion for the bodily sensation. And to simulate riding motion with the bodily sensation, we developed Novel Washout Filter (NWF) and the algorithms for motion control.

And also we proposed the body state index (BSI), BSI that evaluates personal health state from both measured physical variables and survey questions for healthcare service[2,3,5]. Six body state indices were defined such as cardiovascular index, stress index, obesity index, management index, happiness index, and riding posture index. Physiological variables such as weight, blood pressure, heart rate variability (HRV), accelerated state photoplethysmograph (APG), body fat, and happiness index ware measured by the specially designed bio-handle system and survey questions. The proposed BSI report and record the rider’s body condition and mental states. The performance of riding motion control strategy and healthcare service was very effective in the experimental evaluation.

This paper is consist of as follows: the chapter 2 presents the hardware construction of developed riding robot system, the chapter 3 describes the bio-handle system and body state index for the healthcare of operator, the chapter 4 shows the experimental results, and the chapter 5 presents the concluding remarks.

II. RIDING ROBOT SYSTEM(RIDEBOT-II)

A. *Riding Motion Analysis*

The riding motions analyzed the real horse’s running motion and the trajectory. Figure 1 shows the experiment of trajectory tracking. In order to track the motions, some gyro-sensors are mounted on the top of saddle and three-axis position data(x-y-z) were tracked on the moving position of the trajectory of saddle. So, we gathered and analyzed the 3-axes trajectory information. Figure 2 shows the 3-axes motion trajectories obtained by the experiments.

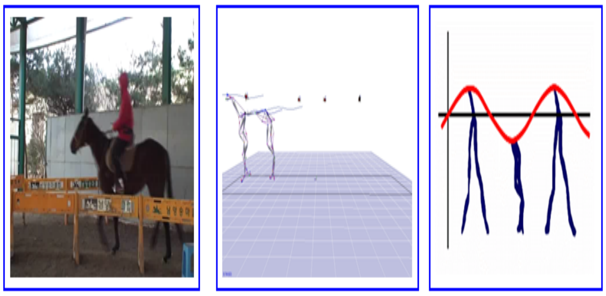

Figure 1 The running motion analysis

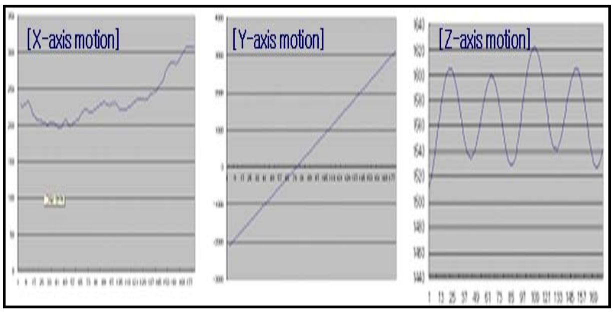

Figure 2 The analyzed running motion of a horse.

B. *Mechanism of RideBot-II*

RideBot-II is a entertainment robot system which can carry a human and simulate a riding motion by using 4 DOFs riding motion control. Height of RideBot-II is 150 cm, weight of 200 kg, 4 DOFs, and aluminum body frame. Since its payload capacity is 110 kg, an ordinary man is able to ride RideBot-II. As joint actuators, BLDC servo linear motors are used to generate sufficient torque and power. In practical riding of a horse, the rider operates horse by using reins and spur. So, the reins and spur were designed and implemented in this robot system. The control architecture of RideBot-II is a distributed control system and we used a Window-based single board computer as the main computer established the real-time control ability. A rider can operate this robot by using a rein and spurs, the sensor devices attached to RideBot-II have micro controllers and transmit the sensor data to the main computer. Figure 3 describes the hardware structure and table 1 shows the configuration of RideBot-II.

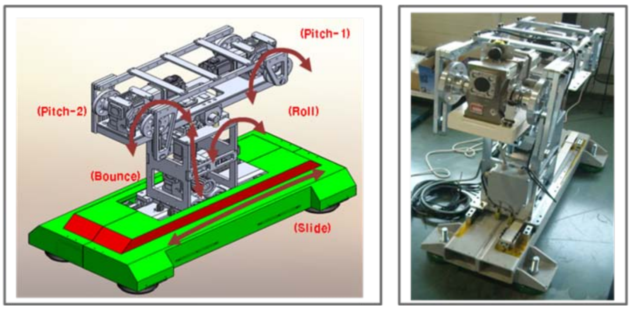

Figure 3 The 4 DOFs mechanism and modeling of RideBot-II

During riding, RideBot-II generates 3 kinds of riding motion. One is the walking, two is running, and the other is turning of direction. The above mentioned motions are controlled by using spur and reins. And we developed the saddle with spring and damper, because the operator can feel be alike a horse. Figure 4 shows the developed saddle structure with spring and damper.

Table 1 Configurations of RideBot

Item	Description
Height	160 cm
Weight	200 kg
DOF	4
Riding Speed	0 – 30 km/h
Actuator	BLDC servo linear motor
Sensors	2-axis spurs 2-axis reins
Operating	Spurs & reins

In order to generate a spring and damping motion in saddle, some springs are by using the universal joint in the center of actions. And also, the bottom of saddle has a limit sensor for the prohibition of excessive bouncing and tilting of saddle. So, the motions including the excessive motions of left or right direction are sensed by the potentiometer at the hinge position of saddle and controlled within the scope of safety. The overall view of RideBot-II is shown by figure 5.

Figure 4 Structure of saddle.

Figure 5 Structure of saddle

C. *Riding motion control*

The riding motions are defined by speeds as follows: walking motion (0-10km/min), canter motion (10-20kim/min), and gallop motion (20-30km/min). And the operator can to change direction of left or right. These motions are generated by 3 BLBC linear servo motors and show in figure 6. And the generated motions are as follows: rolling of saddle (left and right rolling), pitching of saddle (front and rear pitching), and bouncing of saddle (up and down bouncing). The generated motions and control strategy are described in figure 6.

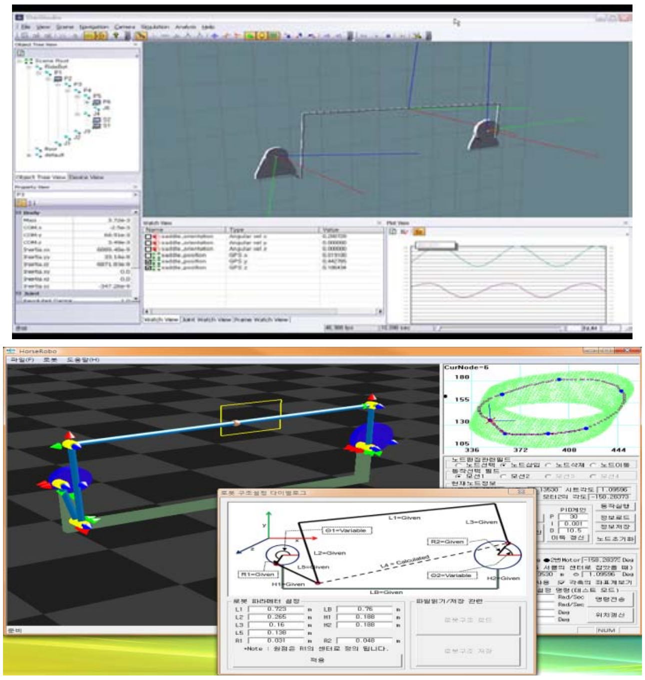

Figure 6 Generated riding motions and real time posture control.

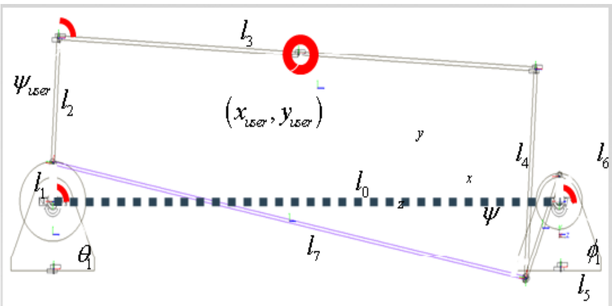

Figure 7 Kinematic model of RideBot-II

The kinematic solutions are as follows Eq. (1) :

$$x_{user} = f_1(\theta_1, \phi_1)$$
$$y_{user} = f_2(\theta_1, \phi_1) \quad (1)$$
$$z_{user} = 0$$

And the solution of the inverse kinematics on RideBot-II is given by Eq. (2)

$$\psi_{roll} = 0$$
$$\psi_{pitch} = \psi_{user} = f_3(\theta_1, \phi_1) \quad (2)$$
$$\psi_{yaw} = 0$$

In order to generate the real time riding motion, we developed the posture control strategy of a real time independent axis control by using the 3 axis inverse kinematics. And the real time posture control algorithms and libraries established by using Windows Multi-Media Timer. RideBot-II have 3-axis linear induction motors and these make three kinds of motions including rolling, pitching, and bouncing, but on the other hand robot can not to simulate like as a horse with bodily sensation. We analyzed and studied the riding motions of a horse, so we developed Novel Washout filter (NWF) by using the variable cut-off frequency. And we derived the variable cut-off frequency, magnitude of NWF, and rotational parameters by using simulation study. And also, we evaluated the performance of NWF by the simulations. Figure 8 shows the configuration of novel washout filter(NWF), figure 9 shows the motion generator, and figure 10 shows the trajectory of saddle respectively.

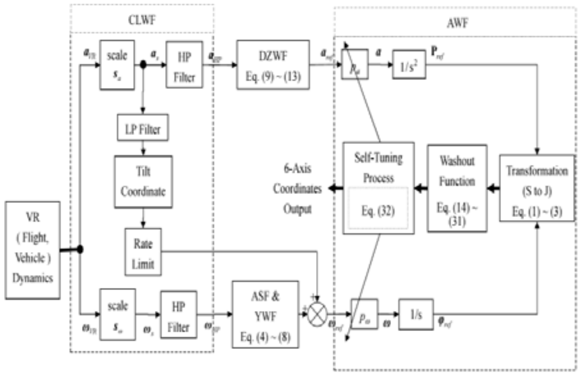

Figure 8 Configuration of Novel Washout Filter.

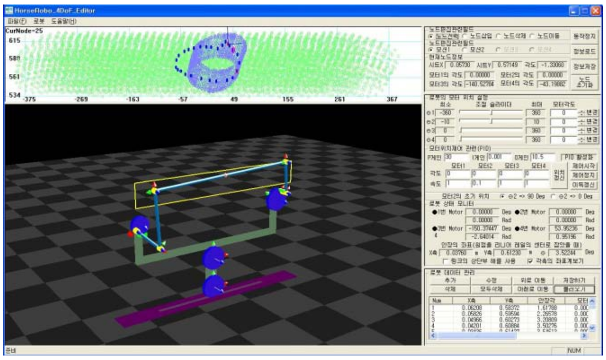

Figure 9 Motion generator for riding motion

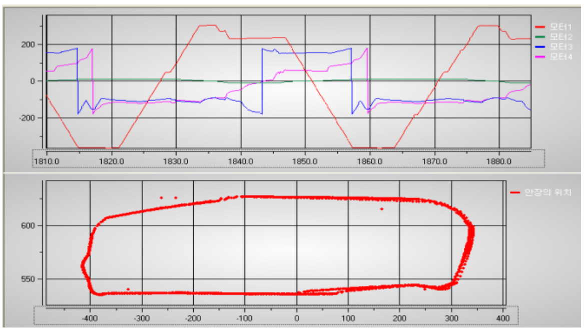

Figure 10 Trajectory of saddle (top) and position of motor (bottom) on the motion generator

III. HEALTHCARE SERVICE

Healthcare service is the important functions of the developed riding robot system. We proposed the body state index (BSI), BSI that evaluates personal health state from both measured physical variables and survey questions. Six body state indices were defined such as cardiovascular index, stress index, obesity index, management index, happiness index, and riding posture index. Physiological variables such as weight, blood pressure, heart rate variability (HRV), accelerated state photoplethysmograph(APG), body fat, and happiness index ware measured by the specially designed bio-handle system and survey questions[6,7,8]. Bio-handle system measured the rider's health condition as shown figure 11. Total BSI was calculated by summing these six indices. Physiological variables such as the blood pressure, heart rate variability, accelerated photoplethysmograph, body fat percentage, and riding posture were non-invasively measured and a survey questionnaire that asks personal health state, exercise intensity, happiness index, and food preference was developed. The survey questionnaires included asking and question by using graphic user interface of touch screen as shown in figure 11.

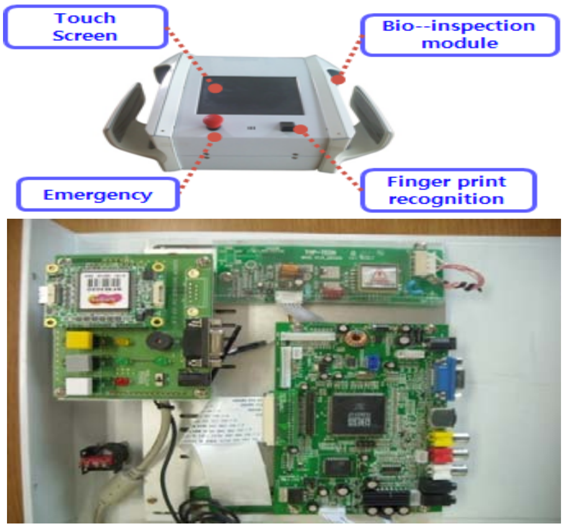

Figure 11 Bio-inspection monitoring system

The recognition accuracy of rider is over 95% by the fingerprint recognition system and BSI information of the rider report and record by using LCD monitor system. The suggested BSI was applied to thirty eight person including 30 patients and 8 normal people with an average age of 51.8. The average BSI was estimated to be 75.1 out of 100 points. Young age group (below 50) and men group showed higher BSI than the aged (over 50) and women groups. The correlation coefficient between the cardiovascular index and stress index was found to be 0.513, which means stress is related to cardiovascular health state.

In this work, we also proposed an advice of training care for personal health by using the analysis of riding exercise effect. In order to make an advice of training care service, we designed the analysis model of riding exercise effect during riding of this robot by computer simulation. And also, we developed the model of training care for personal healthcare by using the analysis of riding exercise effect. This training care model propose some information of rider's health care including the personal riding exercise program based on the standard burning calories and course of racing based on the rider's age and gender. The rider's BSI information and exercise data is recorded in data base.

IV. EXPERIMENTS

In order to evaluate the performance and healthcare service of RideBot-II, we tested the three kind of riding motion like as the trot, canter, and gallop motions. And also, the healthcare services of some users are tested. Figure 12 describes the experimental results of 4-DOF motion control in the three kinds of riding speed. In figure 12, we described the velocity deviation of saddle including gallop, canter, and trot, respectively.

And figure 13 presents the reins device, spur device, bio-handle system, and actuators. The rein device is similar to the real reins of horse, so a rider can to tighten or slacken. If riders pull up reins, then RideBot-II decrease the speed. And if rider pull it towards his left or right, then RideBot-II turn to left or right. The spur device is similar to real spurs of horse. If a rider dig one spurs into the RideBot-II's side, then one increase the speed. The bio-handle device is used by a check up the health condition. User can to grasp bio-handle for a moment then it reports personal health condition. And also user gives the answers of some questions from the user interface program of LCD monitor. Then user can take BSI points from monitor. And figure 14 shows the trajectory of saddle and motor.

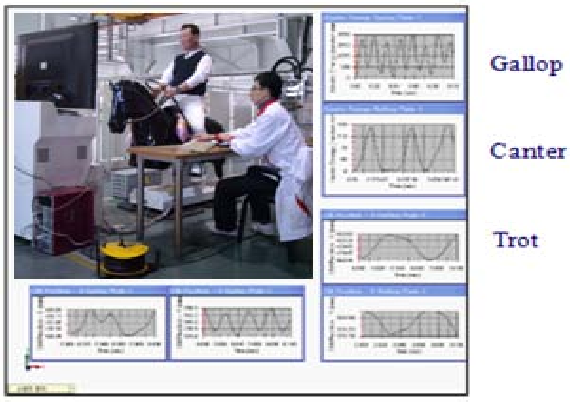

Figure 12 Riding experiments.

Figure 13 System configuration of RideBot-II.

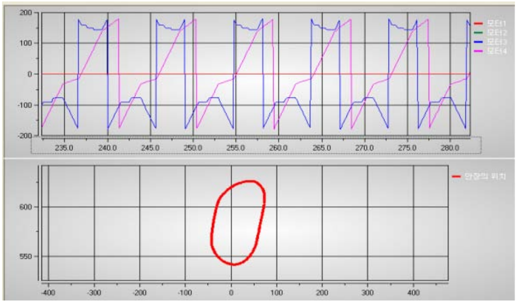

Figure 14 Trajectory of saddle (top) and motor (bottom) on the experiments

V. CONCLUSION

In this paper, we presented a riding robot system like as a horse developed for healthcare and entertainment applications. The developed RideBot-II can to follow the intention of rider using by the rein and spur devices and to simulate the trot, canter, and gallop mode by using the saddle 4 DOFs. And also this RideBot-II have the bio-handle devices which are to check the rider's bio-signals of bio-signals include blood pressure, pulse and something else.

In order to evaluate the performance of RideBot-II, we carried out the experiments on the several riding motions as follows: trot, canter, gallop, and the turning of direction. The experimental results show the reasonable performance and function. The health care services are tested in these experiments. The figure 15 and 16 shows the riding entertainments game function.

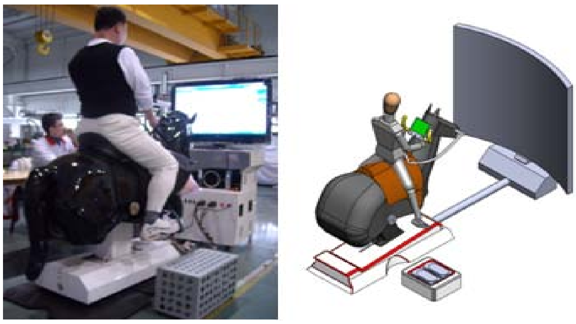

Figure 15 RideBot-II with virtual reality environment.

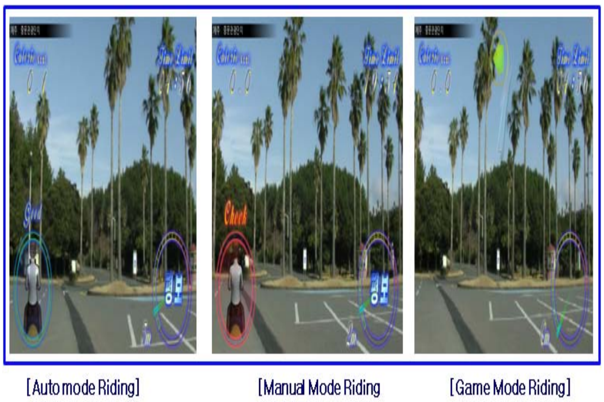

Figure 16 A screen horse racing game

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