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Development of the Electric Wheelchair Hands-Free Semi-Automatic Control System using the Surface-Electromygram of Facial Muscles.

Yuki Yamashita[1], Hiroki Tamura[1], and Koichi Tanno[1]

[1]University of Miyazaki, Miyazaki 889-2192, Japan
(Tel: 81-985-58-7409)

htamura@cc.miyazaki-u.ac.jp

Abstract: The goal of Human-Computer Interface (or called Human-Robot interface) research is to provide humans with a new communication channel that allows translating people's intention states via a computer into performing specific actions. This paper presents a novel hands-free control system for controlling the electric wheelchair, which is based on Bio-signals as surface electromyogram signals. The Bioelectric signals are picked up from facial muscles then the Bio-signals are passed through an amplifier and a high pass filter. Motion control commands (Forward, Left, Right, Forward to the Right, Forward to the left and Stop) are classified by simple rule. These commands are used for controlling the electric wheelchair. However, it is difficult to safety control and fine control using the biological signal only. In addition, we introduce the semi-automatic control system using the laser range scanner. In this paper, we report the introduction of our proposal systems and our experimental results.

Keywords: Surface Electromyogram Signal, Electric Wheelchair, Motion Control Command Rule, Semi-Automatic Control

1 INTRODUCTION

Surface electromyogram signals (abbr. s-EMG) are detected over the skin surface and are generated by the electrical activity of the muscle fibers during contraction [1]. Moved muscle can be presumed by analyzing s-EMG. S-EMG is used to control artificial leg etc. s-EMG recognition of using the conventional neural network is a method which learns the relation between s-EMG patterns and is reproduced using a neural network. Our previous works [2] [3] [4] showed that technique of integrated EMG is much easier and superior than the fast Fourier transform analysis. Integrated EMG is a running average of the rectification s-EMG.

One of the major challenges for prosthesis or Human-Robot Device development is to produce devices to perfectly mimic their natural counterparts. A very popular approach for prosthesis or Robot control is based on the use of Bio-signals (s-EMG, electroencephalogram (abbr. EEG), electrooculogram .,etc). One of them is s-EMG collected from remnant or normal muscles and use them as control inputs for the artificial limb or Robot Device. As these devices, known as s-EMG-based Hands-Free Wheelchair [5][6][7] use a biological signal to control their movements, it is expected that they should be much easier to control [8]. Other techniques have the method of using gesture [9]. However, the system of gesture is not used by the severely handicapped human.

In this paper, we applied to the electric wheelchair hands-free semi-automatic control system for the severely handicapped human using facial muscles s-EMG pattern recognition system. The six motion control commands (Forward, Left, Right, Forward to the Right, Forward to the left and Stop) are classified by our proposal simple rule. In addition, it is difficult to safety control and fine control of the biological signal only, we introduce the semi-automatic control system using the laser range scanner.

We tried the experiment of driving in the course by using our proposal system. The experimental subjects were five healthy men in twenties whose physique looks like. One person was an expert of the system, and others were the inexperienced person. From their experiments, we showed that the control of our proposal system is easy. In addition, the obstacle evading function was added to our system for the speed control and the stop control. We also tested those control

2 ELECTRIC WHEELCHAIR HANDS-FREE CONTROL SYSTEM USING S-EMG SIGNALS[6][7]

Head movement is a natural form of gesture and can be used to indicate a certain direction [5]. Serious disabled people can't move neck and head, but can get face figures. S-EMG is a way of studying facial muscles activities by recording action potentials from contracting fibres. S-EMG can be detected with surface electrodes. Surface electrodes are easy to apply. This is a non-invasive way to record s-EMG while posing no health and safety risk to the users.

Figure 1 shows the formal scheme for the acquisition and analysis of the s-EMG signal for the control organization and flow of information through the system [6][7]. Our system is based on the five features, 1) surface electrodes, 2) Amplifier (INA114P), 3) High pass filter, 4) Personal Computer for s-EMG signal classification and motion control command output, and 5) Electric Wheelchair Control Box.

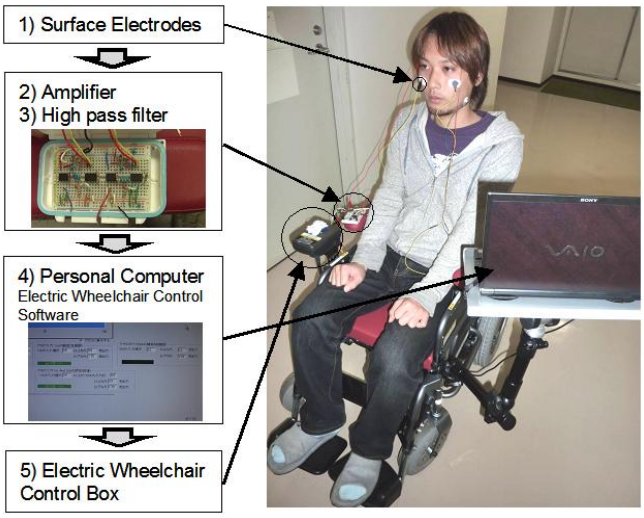

Figure 1. The Flow of Electric Wheelchair Control System using surface s-EMG.

The s-EMG signal detected by surface electrodes is amplified and filtered prior to data acquisition, in order to reduce noise artefacts and enhance spectral components that contain information for data analysis. Two channels of s-EMG signals can be used to recognize face figure movement. 5 Ag/AgCl electrodes are used (two for each channel and one is for ground). In order to remove the DC level and 60 Hz power line noise, the 4th order high pass filter is used. The cutoff frequency of high pass filter is 66.7Hz. In order to effectively filter functions, s-EMG measurement device is used two amplifiers. After filtering and the amplification (about 470 times) stages, the s-EMG signals are digitized (16 bit) and then transferred to the personal computer. The sampling frequency of the measurement data is 1 KHz. And the band is from 0 Hz to 500 Hz. The s-EMG signals are then processed by a classification technique which is based on the combination of 2 class classifier using the threshold. This proposal method is necessary to set the value of threshold of each user. At the finally, the electric wheelchair is controlled by the output command from personal computer using the D/A converter.

The utilized facial movements, motion control command classes and effective channels of bio-signals are defined in Table 1. The electric wheelchair is controlled according to the rule of Table 1. From Table 1, it is easy to select Stop Command in this rule. Because, it is the easiest to perform action to bite and the threshold of the STOP command is smaller than a front command. Therefore, our system is safety, because Stop Command is selected in the false identification case. The inputs for the rules of table 1 classification are given the moving average method process. Moreover, this system doesn't react to the usual blink.

Table 1. The Input Pattern and Classes of Our Rules.

Command	Motion	Active Channel
Turn Right	Wink with right eye	1
Turn Left	Wink with left eye	2
Forward	Bite	1 and 2
Stop	Bite in the state of the Forward, Turn Right and Turn Left Commands	1 and 2 * *These thresholds are smaller than Forward command.
Forward to the Right	Wink with right eye in the state of the Forward Command	1
Forward to the Left	Wink with left eye in the state of the Forward Command	2

3 FUNCTIONAL SAFETY AND SEMI-AUTOMATIC CONTROL

3.1 The Speed Control

The obstacle evading function is important for the safety control of the electric wheelchair. In this paper, we develop the obstacle evasion function using the laser range scanner (HOKUYOU Automatic Co.,Ltd : Classic-URG) for the electric wheelchair safety control. The URG laser range scanner is the most compact obstacle detection sensor with distance measurement principle using laser. Scanning angle of our system is 180° (max 240°). Our system measures the distance by 15° intervals. Figure 2 is image figure.

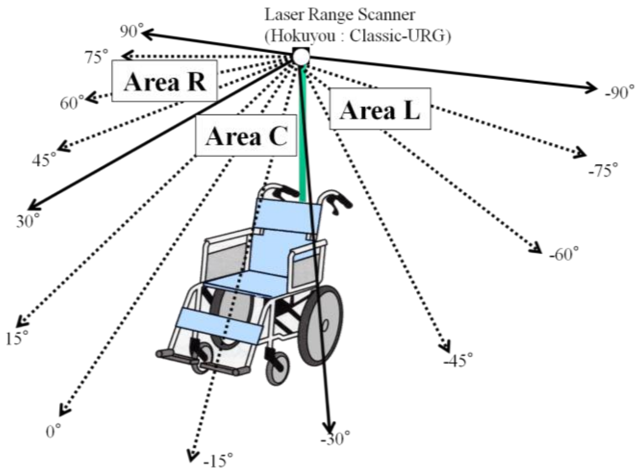

Figure 2. Functional Safety using Laser Range Scanner.

When the obstacle evading function detects the obstacle, our system sounds the alarm and speed control. Speed control is controlled according to the rules of the table 2. Our proposal system could detect about 3.0 meter before obstacle. Our proposal system slows down the speed for evading the obstacle, and wards off a collision. It became easy to evade the obstacle with this function.

Table 2. The Speed Control Rules.

Area R / C / L (0 : no obstacle, 1: obstacle)	Power of Turn Right / Forward / Turn Left (100%:max speed , 0%:stop)
0 /0/ 0	100% / 100% / 100%
0 /0/ 1	100% / 100% / 75%
0 /1/ 0	100% / 75% / 100%
0 /1/ 1	100% / 75% / 75%
1 /0/ 0	75% / 100% / 100%
1 /0/ 1	75% / 100% / 75%
1 /1/ 0	75% / 75% / 100%
1 /1/ 1	75% / 75% / 75%

3.2. The Stop Control

In this subsection, we introduce the safe stop control using the laser range scanner. The electric wheelchair which we developed turns at a radius of 1.5 meter. Therefore, the electric wheelchair cannot work when an obstacle is in the 1.5 meter range. As simple solution, the electric wheelchair stops when a radius of less than 2.0 meters includes an obstacle (Figure 3). Thereby, the electric wheelchair turns safely and can evade an obstacle.

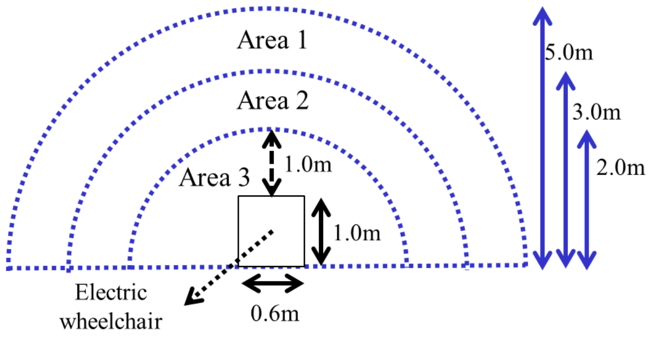

Figure 3. Sensor Measurement Area (Area 1: No control, Area 2: Speed control, Area 3: Stop).

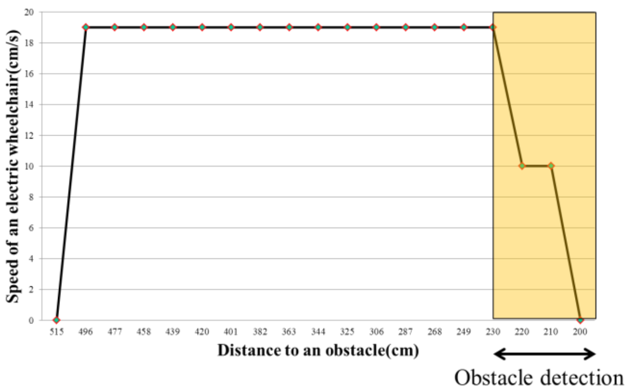

Figure 4. Result of Speed Control Test.

We tried the driving test in the hallway for evaluation of our proposed stop control system. The experiment operated the electric wheelchair toward to wall. The result is shown in Figure 4. From the result, our proposed system was able to detect the obstacle and was able to perform speed control and safe stop.

The electric wheelchair can be controlled in semi-automation by functional safety using laser range scanner. Our proposed system reduces the stress of user. However, our system has still some problems about the discovery of the movement object. These are our future works.

4 EXPERIMENTAL RESULTS

We tried the experiment of driving in the course by using our proposed system. The experimental subjects were five healthy men in twenties whose physique looks similar. One subject was an expert of the system, and others were the inexperienced subject. The driving course is shown in Figure 5. This driving course is about 125 seconds by original electric wheelchair using joystick. The task is to drive the electric wheelchair from position Start to Goal by contraction of facial muscles. The speed of electric wheelchair used low speed (1.0[k meter/hour]). We performed five experimental to each of five subjects. We compare our proposed system by the average time [sec] and the average classification rate [%].

The experimental results are shown in Table 3. The average time of 201 seconds in all, the average classification rate is 98.2 percent. The classification ratio indicates how much the correct command is selected for the total number of commands made by the subjects. From the experiment results, the classification rate of our proposed system and the computer simulation results of paper [10] are similar. The results of inexperienced subjects were almost same as the results of experienced subject. In particular, inexperienced subject S.H has the best results even though the first experiments. The usability of our proposed system was a good result. However, the difference between our proposed system and original electric wheelchair using joystick was 76 seconds.

From these experiments, we think that the control of our proposed system is easy. From these experiment results, the electric wheelchair control system using facial muscles s-EMG is a good system for the severely handicapped human. In addition, we think that the merit of our proposed system does not need a lot of training for user. Moreover, when the obstacle (the road cones) became near, our proposed system was able to be evaded smoothly without Stop command because the speed slowed by the obstacle evasion function. However, this processing reduced the speed.

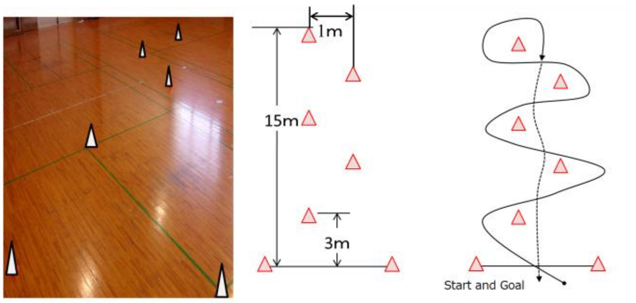

Figure 5. The Driving Course.

Table 3.Experiment Results.

Subject	Time		Classification	
	Average [sec]	Standard deviation	Average [%]	Standard deviation
Experienced subject S.H	188	16.3	94.9 (150/158)	3.07
Inexperienced subject 1 T.B	229	54.1	97.4 (191/196)	2.95
Inexperienced subject 2 T.M	197	20.6	97.5 (196/201)	1.92
Inexperienced subject 3 T.Y	229	13.3	97.2 (243/250)	3.39
Inexperienced subject 4 S.H	164	7.98	100.0 (116/116)	0

5 CONCLUSION

In this paper, we applied to the electric wheelchair hands-free semi-automatic control system for the severely handicapped human using facial muscles s-EMG pattern recognition system. We tried the experiment of driving in the course by using our proposed system. The experimental subjects were five healthy men in twenties whose physique looks like. One person was an expert of the system, and others were the inexperienced person. From these experiments, we showed that the control of our proposed system is easy and our proposed system does not need a lot of training for user.

Our proposed system could also be used by handicapped person without training. Moreover, we think that our proposed system is useful than the system using the EEG signals. In the future works, we plan to develop of algorithm that can be turned more smoothly, improve the obstacle evading function and test the severely handicapped human.

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