Development of a Mouthpiece Type Remote Controller for People with Disabilities --- Basic Investigation of the Specifications and Characteristics of the Remote Controller ---

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Abstract. Persons with disabilities from cervical level spinal cord injuries have difficulty with activities of daily living, such as turning switches ON or OFF and driving powered wheelchair. A variety of operation devices have been developed for people with such serious disabilities: voice or breath control, head motion control and eye movement control systems etc. for example. Each has its own merits and disadvantages respectively, but a need still exists to develop other types of device interfaces. Tongue movement control is also an option and is one of solutions applied to several assistive devices for persons with disabilities. In this study, we have tried to develop a mouthpiece-type remote controller for those with serious disabilities. This remote controller has passive Radio Frequency Identification transponders, with no batteries required.

In order to develop the mouthpiece remote controller, we need to know the basic characteristics of the RFID and what type of Radio Frequency Identification should be applied to this mouthpiece remote controller. Therefore, we investigated the basic characteristics of the RFID transponders, including 134.2 kHz and 13.56 MHz type. The Maximum Communication Range was measured under three environmental conditions of the atmosphere, water and meat. Every RFID transponders of 134.2 kHz and 13.56 MHz type has enough MCR under each condition. Then we developed a trial mouthpiece type remote controller using 13.56MHz transponders. This trial remote controller was also evaluated with the same tests. The results indicated that this trial controller has performed satisfactorily and may be applied safely to the mouthpiece-type remote controller for people with serious disabilities.

To make sure that the trial controller was able to control a powered wheelchair, we first tried to operate a remote-controlled model car. TR3-MD001E was used as the RFID identifier system. NI 9263 and cRIO 9014 were used to control the model car. With this system, we succeeded in operating the model car by pushing the switches on the mouthpiece remote controller with the tongue. It was suggested that possibility of this system can be applied to new assistive devices for people with serious disabilities.

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Keywords. Activities of Daily Living, Assistive Technology, Cervical Spinal Cord Injury, Human Interface Controller, Muscular Dystrophy, RFID, Remote Controller, Spinal Cord Injury,

Introduction

Persons with Disabilities (PWD) have a difficult time completing their activities of daily living. People who have cervical level spinal cord injuries (SCI) or muscular dystrophy (MD) cannot move or walk by themselves. In most cases, these individuals have paralysis in more than one extremity, causing mobility restrictions. This means, some tasks are very hard for some of them to complete, such as moving their hands and fingers when they try to drive a powered wheelchair and/or reaching their hands to activate switches when they need to turn room lights ON or OFF. Therefore, when designing new assistive devices and their interfaces, much consideration must be given to PWD and which systems work best for them.

Among the assistive device interfaces used to control powered wheelchairs for people with cervical-level SCI, chin control systems are very popular. Also in the past decades, many researchers have investigated and developed special tools and devices interfaces such as: voice control systems [1-4], breath control systems, head motion control systems [5-9], and eye motion control systems [10-13] for these people with serious disabilities. Each device interface has its own merits and disadvantages respectively.

For people with MD and SCI of high level, chin control systems might be uncomfortable, since they may not be able to move their necks, heads or chins. For the same reason, head motion control systems would not be appropriate interface devices. Voice control systems are one solution, because most of the people who have cervical cord injury may be able to speak. In recent years, voice recognition technology has been improving rapidly. However, many issues remain with this technology. One well-known issue for voice recognition technology is making the distinction between a "voice command" and the background "noise of normal conversation." This is a hard task to overcome and confusing these two types of speech is unsafe for the user. For the user's safety and accuracy of control, we probably need to wait for further improvements in voice recognition technology.

These kinds of interface devices are controlled by a body part that is not paralyzed. Usually, motion, movement, pressure, sound and/or force are useful to activate switches and devices. Therefore, when develop these interface devices, we need to know which body parts can be moved voluntarily. Basically, people with cervical SCI and MD can move their eyes, mouth, teeth and tongue voluntarily. Thus many interface devices are activated with eye or mouth movement. Tongue movement has not been tried with these devices as much, even when tongue control was adequate. When using the tongue to activate an interface or controller, the controller has to be battery powered and inserted in the mouth. But, these batteries are extremely toxic, so they should not be placed into the mouth. This is why only a few researchers have tried to study and develop tongue control interface systems [14-20].

In this study, we have focused on tongue movement to develop a new remote controller for PWD. This remote controller is a mouthpiece type with Radio Frequency Identification (RFID) transponders that do not require batteries. The merit of this mouthpiece remote controller is that no batteries are used and thus, toxicity from the
battery acid does not pose a threat to the user. However, the disadvantage of using RFID is that it is very susceptible to the environment. The characteristic of communication ranges of the RFID are influenced by the environment of atmosphere, water, skin, and presence of adipose tissue. Therefore, to develop this remote controller, we needed to know the basic characteristics of the RFID transponder. The aim of this paper was to investigate the basic characteristics of the RFID transponders, and develop a new mouthpiece type remote controller operated by tongue. We then evaluated the characteristics of our newly developed remote tongue.

1. Design Specification and Mechanism

In previous studies, many authors had considered putting a remote controller into the mouth was undesirable. But in this study, we focused on the tongue movement to activate a remote controller for PWD. However, the tongue is the one body part that most PWD can adequately move. Therefore, we have tried to develop this new remote control interface that did not require batteries or an electrical current supply. To solve this issue, we use RFID (Radio Frequency IDentification) techniques. Two types of RFID transponders are available: active and passive transponders. Active transponders need to have batteries to transmit their ID codes, but passive transponders do not need batteries. Passive transponders generate electricity by electromagnetic induction. Therefore, if they can receive electromagnetic radiation transmitted from the RFID reader (the main body of the RFID recognition device), passive transponders can generate electricity by themselves, and then they can transmit their own ID codes. In this study, passive transponders were applied to the remote controller, since they do not require batteries.

The mouthpiece type remote controller can be inserted into the mouth, and the reading antenna of the RFID transponders would be arranged near the user’s cheek or under his or her chin. The main body of the RFID identifier system would be placed on the back of PWC. The mouthpiece remote controller has four RFID IC chips and four switches. When users want to drive the wheelchair forward, they press the forward switch on the remote controller with their tongues. Only while they keep pressing the switch will the wheelchair keep moving forward. When the user releases his or her tongue from the switch, the wheelchair stops. This operation style should be natural and easy to use. On the other hand, the currently available RFID transponder has an IC chip with an antenna (Figure 1-A). While in the communication area of the read antenna, the RFID transponder generates and transmits its own ID code automatically. Therefore to apply RFID transponders to this remote controller, every transponder has to have its own switch to transmit or it does not transmit the ID codes as Move Commands (Figure 1-B). This mouthpiece remote controller would be attached to the upper jaw like a plate of false teeth. We planned that the size of the mouthpiece remote controller should be 40mm*50mm (wide * depth) or less. The size of 40mm*50mm of circuit board is too small to place four IC chips, four switches and four antennas (Figure 2-A). To miniaturize the mechanism, the circuit board has only one antenna, and the four IC chips share the one antenna (Figure 2-B).
2. Material and Methods

The communication ranges of the RFID are affected by environmental factors like moisture, water, skin and adipose tissue. The communication range of high frequency RFID is farther, but the low frequency RFID's range is shorter. Then again, the high frequency RFID is strongly affected by water, human's skin and adipose tissue. Because, high frequency electromagnetic radiation is attenuated by water, skin, and/or adipose tissue, it loses its power. Therefore, in developing the mouthpiece remote controller, we needed to know the basic characteristics of the RFID and determine which type RFID should be used in this mouthpiece remote controller.

To investigate the basic characteristics of the RFID transponders, two types of 134.2 kHz transponders and two 13.56 MHz transponder were chosen. A Glass mounting type transponder (A) and Disk type transponder (B) were used with the 134.2 kHz, Film type transponder: (C) and Plastic mounting type transponder: (D) were used with the 13.56 MHz transponder (Table 1 and Figure 3). As the RFID identifier system for 134.2 kHz and 13.56MHz, RI-STU-MB2A (Texas Instruments Incorporated, USA) and TR3-MDO0IE (Takaya Corporation, Japan) were used (Figure 4). Three types of antennae were also used, the stick type antenna was for the 134.2 kHz transponders, the flat panel type was used with the 13.56MHz transponder, and the hand held antenna was also used with the 13.56MHz type transponder.

To evaluate the influence of moisture and adipose tissue, three atmospheric conditions of water and meat were investigated. The maximum communication range (MCR) of every transponder was measured under each condition of atmosphere, water (Figure 6-(A)) and meat (Figure 6-(B)). Similar experiments were used with the trial mouthpiece remote controller that we developed.

<table>
<thead>
<tr>
<th>Type of transponders</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI-TRP-RR2B</td>
<td>134.2 kHz</td>
</tr>
<tr>
<td>RI-TRP-W9QL</td>
<td>134.2 kHz</td>
</tr>
<tr>
<td>RI-I03-112A</td>
<td>13.56 kHz</td>
</tr>
<tr>
<td>RF-HDT-DBVV</td>
<td>13.56 kHz</td>
</tr>
</tbody>
</table>

![Figure 1. Schematic diagram of mouthpiece remote controller circuit.](image1)

![Figure 2. Arrangement of switches and antennas for mouthpiece remote controller circuit.](image2)
3. Results and Discussions

3.1. Basic Investigation of the Characteristics of the RFID Transponders on the Market

The result of the MCR of each transponder is presented in Table 2. The MCR of every transponder ranged from 130mm to 240mm. The MCR of transponder (A): glass mounting was shorter than with the other transponders, the MCR was from 130 to 135 mm in the each condition of atmosphere, water and meat. The MCR of transponder (B)
Table 2. Results of Maximum Communication Ranges of transponders on the market under the condition of in the atmosphere, water and meat

<table>
<thead>
<tr>
<th>Condition</th>
<th>Frequency</th>
<th>Type of Transponder</th>
<th>Communication Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>134.2kHz</td>
<td>Glass Mounting</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disk Type</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>13.56MHz</td>
<td>Film Type</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastic Mounting</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>134.2kHz</td>
<td>Glass Mounting</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disk Type</td>
<td>165</td>
</tr>
<tr>
<td>Water</td>
<td>13.56MHz</td>
<td>Film Type</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastic Mounting</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td>134.2kHz</td>
<td>Glass Mounting</td>
<td>135</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disk Type</td>
<td>175</td>
</tr>
<tr>
<td>Meat</td>
<td>13.56MHz</td>
<td>Film Type</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plastic Mounting</td>
<td>180</td>
</tr>
</tbody>
</table>

was from 165 to 185 mm. The transponder (C) showed from 210 to 240 mm as the MCR. The MCR of transponder (D) was from 180 to 195mm. The MCR results of 134.2 kHz type transponder were shorter than 13.56MHz type's, but they were satisfactory for this system. Transponder (C) and (D) also obtained good results, notwithstanding they are high frequency types and are easily attenuated by existence of moisture, water, skin or fat.

In this study, we needed to select a suitable transponder type for the mouthpiece remote controller. The results displayed showed that every transponder had satisfactory performance. However, in recent years, the low frequency RFID of 134.2 kHz is not often used in the industrial fields in Japan. The 13.56 MHz transponders or those with higher frequencies are generally preferred for use with industrial products in Japan. Therefore, we considered that 13.56MHz type should be apply to the mouthpiece remote controller.

3.2. Investigation of the Characteristics of the Trial Remote Controller

According to the basic investigation of above, we have tried to develop a mouthpiece type remote controller with four channels; 1) go to forward, 2) backward, 3) right turn and 4) left turn) using 13.56MHz RFID transponders. Figure7-(A) and (B) show the schematic drawing and photo of the trial remote controller we developed (first version). This has four IC chips, four switches and one antenna. This one antenna is shared among four IC chips.

We also investigated the basic characteristics of this trial remote controller in the same conditions. The results these trials of the MCR for the trial remote controller in are displayed in Table 3. The MCR of each of the four IC’s was measured and calculated to the mean MCR with minimum and maximum value (mean (Min-Max)). Mean MCR of each condition was from about 150mm to 240mm. This result suggested that the trial remote controller has satisfactory performance to use as mouthpiece remote controller for PWD.
Table 3. Results of MCR (Maximum Communication Ranges) of trial remote controller under the conditions of the atmosphere, water and meat.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Communication Range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>151.3 (135 - 185)</td>
</tr>
<tr>
<td>Water</td>
<td>241.3 (220 - 260)</td>
</tr>
<tr>
<td>Meat</td>
<td>197.5 (150 - 250)</td>
</tr>
</tbody>
</table>

3.3. Operation Test of Mouthpiece Remote Controller for Driving a Model Car

To make sure that this trial remote controller was able to control a powered wheelchair, we first tried to operate a crawler type remote controlled model car (Tamiya Inc., Japan). TR3-MDO01E (Takaya Corporation, Japan) was used as the RFID identifier system. The NI 9263 and cRIO 9014 (National Instruments, USA; referred to as cRIO) were used to remotely control the model car (Figure 8). The trial mouthpiece remote controller was inserted in a user's mouth and was fixed on the upper jaw using a denture stabilizer (basically it is used for stabilizing an artificial tooth). The RFID reader antenna was set beside or under the user's chin. The RFID identifier device was connected to the cRIO. The cRIO was also connected to original operational amplifier (referred to as OP-amp). This OP-amp amplifies the output voltage from cRIO. We developed a program to control this system using Lab-view (National Instruments, USA), one of Graphical Language. The special program for this system was executed on the cRIO. Using this program, the cRIO identified the ID codes that were transmitted from mouthpiece remote controller we developed, then it outputted the voltage to the amplifier to operate the model car (Figure 9).

With this system, we succeeded in operating a model car by pushing the switches on the mouthpiece remote controller by tongue. This test also identified some problems and issues with the mouthpiece remote controller. Some of the switches were hard to push by tongue. The switch for backward was located at the center of the remote
controller. This switch was easy to push and was operated adequately. On the other hand, the forward switch was not as comfortable to push. Some user could not reach the forward switch their tongues. We had set a type of threshold on the middle of the four switches to avoid pushing the wrong switch. This threshold was too high so it obstructed attainment of the forward switch. Another issue was that the size and the arrangements of switch buttons needed to be redesigned. With regard to the circuit board of the mouthpiece remote controller, the hard circuit board could not be bent to fit to the users' upper palate. This stiffness also was unpleasant for some users.

To compensate for these issues, we have been trying to improve the mouthpiece remote controller. The height of the threshold set beside the switches needed to be lowered. Arrangement of the four switches was also reconsidered. The size and the stiffness of the switch buttons were also redesigned so they could be easily pushed. To fit the mouthpiece controller to the users' mouth, a flexible circuit board was applied to next version of the mouthpiece remote controller.

4. Conclusions

To develop a mouthpiece remote controller for persons with severe disabilities, the basic characteristics of the RFID currently available on the market were investigated. Then we developed a new type of mouthpiece type remote controller using RFID that did not require a battery. This trial mouthpiece remote controller was also investigated. The MCR and mean MCR were measured in the environmental conditions of the atmosphere, water and meat.

1. The MCR of transponders on the market (134.2 kHz and 13.56 MHz) were from 130mm to 240mm.
2. Authors developed a trial mouthpiece type remote controller with RFID.
3. Mean MCR of trial remote controller with 13.56MHz RFID was from about 150 mm to 240 mm and it showed satisfactory performance.
4. Authors succeeded in operating a model car by pushing the switches on the mouthpiece remote controller by tongue.
5. It was suggested the possibility of that this system can be applied to the mouthpiece remote controller for people with severe disabilities.

Acknowledgments

We would like to acknowledge and thank every person for their cooperation and suggestions. We also would like to acknowledge that this study was supported by following projects.

2. Japan Science and Technology Agency (05-021).

References


