EFFECTIVENESS OF MORSE CODE AS AN ALTERNATIVE CONTROL METHOD FOR POWERED WHEELCHAIR NAVIGATION

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ABSTRACT

We applied Morse code as an alternative input method for powered wheelchair navigation to improve driving efficiency for individuals with physical disabilities. In lab trials performed by four testers, it demonstrated significant improvement in driving efficiency by reducing the driving time, compared to traditional single switch wheelchair navigation.

INTRODUCTION

Powered wheelchairs are an alternative mobility aid for many people with physical disabilities. However, some people who have severely impaired motor functions or have a combination of multiple disabilities have found it difficult or impossible to use powered wheelchairs independently [1, 2] due to their lack of access to a conventional input device like a joystick. There have been a variety of research efforts to accommodate this population, including voice recognition [3], eye tracking [4], machine vision [5, 6], electroencephalography [7], electromyography [8], motion recognition [9-11] and single switch scanning [12]. However, because user needs and abilities are extremely diverse, there remains a need for additional input modalities. In this paper we apply Morse code as an alternative input method for powered wheelchair navigation, and evaluate its effectiveness by collecting preliminary data through experimental tests.

MORSE CODE

Morse code was invented by Samuel F.B. Morse and Alfred Vail in 1838 as a method of transmitting textual information, using binary signals. The current version of International Morse Code encodes mouse pointer movements and clicks as well as all keys on the computer keyboard [13]. Morse code uses a time series of binary tones denoted by *dot* and *dash* to represent characters and commands and, coupled with a switch-based adaptive interface, has long been recognized as an alternative input method for people with physical disabilities [14-22]. In fact, it has been reported that experienced users with disabilities could enter 20 to 30 words for a minute [23]. In addition to input speed, Morse code has many advantages over other approaches: For example, it requires relatively less motor control; it does not require a scanning interface; and, most importantly, it can become a sub-cognitive process like touch typing.

For this reason, Morse code has been studied by several researchers [17, 20-22, 24-26] as an alternative input method for people who are not able to use conventional input devices. However, Morse code has not gained in popularity due to its inherent challenges, including a limited number of clinicians who know Morse code, a steep learning curve for new users, no visual feedback, the need to accurately time switch presses and increased cognitive effort. In addition, while most research has focused on using Morse code as an input method for computer access and augmentative and alternative communication devices, we are unaware of any research focusing on mobility aids.

We developed a Morse code based control method for powered wheelchair navigation, called MCWN, to improve driving efficiency for individuals with physical disabilities, and evaluated the effectiveness of MCWN compared to traditional single switch wheelchair navigation (SSWN).

The following hypotheses were tested:

1. Wheelchair navigation using a Morse code based control method would significantly increase the number of switch presses required to complete a navigation task compared to SSWN.
2. Wheelchair navigation using a Morse code based control method would significantly decrease the time taken to complete a navigation task compared to SSWN.

METHODS

Design Criteria

The following four design principles were considered to minimize the drawbacks of using Morse code as an input method and to maximize its merits:

1. MCWN should minimize the effort needed to generate wheelchair control commands using a Morse code emulator. As shown in Table 1, we met this criterion by establishing our own optimized code system which limits the length of each code to 2 bits.

	Standard Morse Code	MCWN
Forward	.-..-	..
Backward	.--..	.-
Left Turn	.-.-.--	-.
Right Turn	.-.-.	--

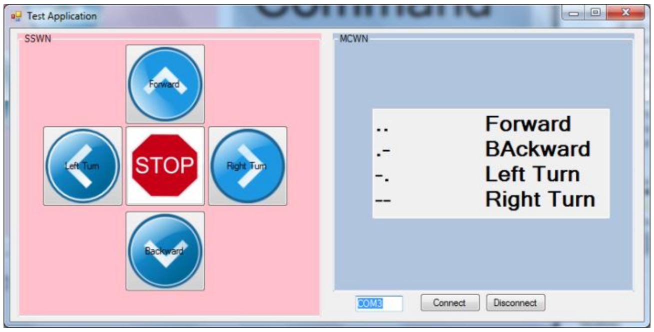
Table 1. standard Morse code vs. MCWN

2. MCWN should be able to keep the user from generating unintended commands. We satisfied this requirement by addressing the timing issue. The standardized Morse code defines timing rules to specify characters or commands. For example, the duration of a dash is three times as long as the duration of a dot. Each dot or dash is followed by a short silence, equal to the dot duration [13]. This can cause people with impaired motor functions to make many errors. Our approach overcame these challenges by adopting the concept of *threshold* and *time-out*. The distinction between a dot and a dash is based on whether the duration of each switch press exceeds a time threshold. Since each command is two bits long, so commands cannot be accepted prematurely. If the time after an initial switch press exceeds a pre-determined threshold, the first switch press is discarded.
3. MCWN should allow the users to cancel the current operation immediately whenever they want to. We met this criterion by making the system stop the motors with an initial switch press at any time.
4. MCWN should be compatible with existing input methods to ensure maximum adaptation to user needs. In order to meet this requirement, we used the same device used in a traditional single switch scanning interface.

Instruments

Based on the above design criteria, we developed a prototype system, using a LEGO® Mindstorms™ robotic kit, and test software, as shown in Figure 1 and Figure 2. The mockup wheelchair powered by two servo motors was controlled by the software using Bluetooth 2.0 communication. The software, written with the C# programming language, was also used as an input method emulating either a Morse code emulator or a single switch scanning interface.

Figure 1. Mockup Wheelchair



..	Forward
.-	BAckward
-.	Left Turn
--	Right Turn

Figure 2. Test Software

Data Collection

Lab trials were performed by 4 non-disabled testers. In the lab trials two different navigation conditions, MCWN vs. SSWN, were compared. The software automatically alternated between MCWN and SSWN for each trial.

Two different driving courses were designed for the test (Figure 3), each of which was a 3x1.5 meter enclosed rectangular area. In each course, eight obstacles were placed in predefined locations [12]. In order to complete the navigation task, each tester had to start at a designated position, navigate through the obstacle course, turn around at a specified turning point, and return to the start of the course. During the task, he or she had to negotiate obstacles, changing directions several times.

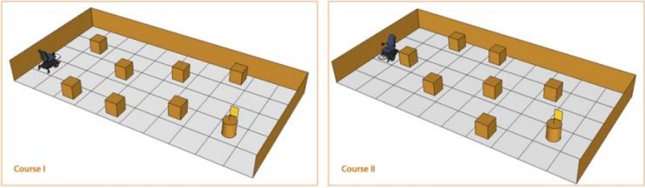


Figure 3. Opened-up View of Driving Courses

Each tester was asked to complete the navigation task a total of 4 times (once for each combination of course and experimental condition). The order of experimental conditions and courses was randomized. While testers were performing the navigation tasks, the computer recorded performance data, including how many times the tester pressed a switch and how long it took to complete the trial.

RESULTS

The results from each tester are reported in Table 2. Friedman's test as a non-parametric alternative to one-way repeated measure analysis of variance was used to compare the number of switch presses and the time taken to complete the navigation task. The statistical significance level was set to .05.

Case	Number of Switch Presses				Completion Time (sec)			
	1st two trials		2nd two trials		1st two trials		2nd two trials	
	MCWN	SSWN	MCWN	SSWN	MCWN	SSWN	MCWN	SSWN
1	105	51	99	49	104	131	98	121
2	91	49	93	55	98	110	93	115
3	83	46	85	56	89	110	96	125
4	89	48	81	44	90	122	86	111
Q_1	84.5	46.5	82	45.3	89.3	110	87.8	112
Q_2	90.5	48.5	89	52	94	119	94.5	118
Q_3	101.5	50.5	97.5	55.8	102.5	128.8	97.5	124

Table 2. Case Summaries of the Test

Significant main effects were detected in both the number of switch presses ($\chi^2(3) = 9.6$; $p = .022$) and completion time ($\chi^2(3) = 9.9$; $p = .019$). In order to find the pattern of difference for each of them, post-hoc analysis with Wilcoxon's Signed-Rank Tests was performed with a Bonferroni correction applied. The average number of switch presses under the MCWN condition was significantly greater than under SSWN ($Z = -2.54$; $p = .011$). The average completion time under the MCWN was significantly shorter than in SSWN ($Z = -2.52$; $p = .012$). No significant difference on both the number of switch presses and the driving time was detected in both MCWN and SSWN between two courses. In summary, while MCWN demonstrated significant improvement in drive efficiency by reducing the driving time to 21.4% of SSWN, it was shown that MCWN required much more switch presses (79.3%) than SSWN.

DISCUSSION

Single switch scanning is one of the least efficient ways to operate a powered wheelchair. Issues with single switch wheelchair navigation include: frequent stops to counteract drift and to negotiate obstacles, increased driving time and frustration and fatigue in challenging environments such as narrow hallways. Researchers have demonstrated significant improvement in a single switch wheelchair navigation task by significantly reducing the number of switch presses, using smart wheelchair technologies [12, 27]. However, their approach did not make a significant difference in driving time. Our research suggests that MCWN can be used as a complementary control method for a smart wheelchair by significantly reducing the driving time. Although no learning effect was detected due to the small number of trials, it is expected that driving time with MCWN will further improve with practice.

This preliminary study relied exclusively on a small number of non-disabled testers and a mockup system. It is definitely necessary to validate these results with disabled participants using an actual device in a follow-up study.

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