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Selection Technique for Small Objects on Touch Screens for People with Muscle Tremor

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Abstract
IT services and their corresponding hardware often form a considerable burden towards people suffering from muscle tremor. They either achieve very low levels of effectiveness, efficiency and satisfaction or none at all due to the clear handling restrictions of the hardware. For this target group, a new method of handling this problem has been developed. The input information will be processed uniquely in order to guarantee that the tremor affected movement can still be reliably read as a certain input. The tremor patient will use a wiping technique on a touch screen. Physical deviations caused by the tremor are accepted and do not affect the finding of the intended input spot. Thus, instead of a direct movement the overall input "picture" of the user will be interpreted. Also, the screen surface causes increased frictional resistance which helps to reduce general movement. Specially designed heuristics help to identify the user movement and support barrier free access among the target group.

1 Introduction

Electronic support systems and telemedical services are often the only measures handicapped people may take if they desire to maintain their self determining lifestyle (Eberspächer et al., 2006). Especially people affected by tremor are facing many difficulties using IT Systems, telemedical devices and other user interfaces (Mertens et al., 2009). If the interaction process requires information input by traditional input devices and standard graphical user interfaces (GUI), the average error rate is either very high or the input is not executable at all for the patient (Monesko et al., 2009). This leads to reduced efficiency, effectiveness and satisfaction of the user and adjunctive social isolation because of the hindered maintaining and establishing of contacts (Martínez-Martín, 1998). IT-Systems within the eHealth sector are continuously increasing their usability and many user interfaces consider particular requirements of specific target groups (Korhonen et al., 2003; Sommerlatte, 2008). For the most part those considerations regard limitations of perception, cognition or the total musculoskeletal system (Akram et al., 2007; Kobsa et al., 2009; Rutgersson et al., 2007).

People suffering deficits in their fine motor skills generally do not have adequate support even though many theoretical concepts that address this problem exist. The few existing solutions require extra hardware and therefore reduce the overall mobility as well as they increase the cost factor. A well known method of dealing with this problem is voice interaction, but this technology still requires a sustained time for calibration the system for each individual user (Keshet et al., 2009; Pfister et al., 2008). Also, the use of voice recognition is not feasible in many public situations, due to data security, privacy concerns or background noise. New concepts as eye tracking (Duchowski, 2009; Gollücke, 2009) or brain-computer interfaces (BCI) (Dzaack et al., 2009) offer promising prospects. These still remain in their developing stage currently and most likely will not work without any additional hardware.

The target group for this concept includes primarily elderly and handicapped people, who only possess a limited degree of control for their upper extremities (including all forms of tremor), disregarding its cause, and different problems coordinate the hand-arm apparatus (Plumb et al., 2006). Due to the increasing likelihood with age for such a disease, the requirements of elderly people, operating electronic devices, are carefully considered (Raskin, 2005). In addition to the integrative aspect for handicapped users, economic interests play an important role as well, especially in times of demographic change (AAL, 2006). The increasing number of elderly people that want an independent and self-determined life tends to demand capacities from the health care system that cannot be satisfied with common means of medical care. (Statistisches Bundesamt, 2008). The use within (tele)medical supply contexts (e.g. a telemedical platform monitoring vital functions) may significantly help to reduce the costs to the health care system. Especially in regions with a lower developed infrastructure, new potentials, regarding medical aftercare, occur for those who have previously been excluded from a self determined handling of IT-Solutions and telemedical services due to their tremor. The integrative appliance opens up new vistas to increase the overall quality of life (Wahl et al., 2004). In Germany, approximately 0.5-4% of the population below 65yrs and at least 5% of those above 65yrs are suffering from a tremor (Klaffke et al., 2009). Additional feasible scenarios for application are all interaction procedures with electronic systems via touch screen.

The touch screen may either act as a simple tool of information input and therefore help the user to prompt information with a high ratio of accuracy, or the touch screen may act as a information output as well and the user interface for input will be overlayed on top of the standard software only when interaction is necessary. In addition to the prototypical implementation within a telemedical project, the authors plan the use e.g. with ATMs or ticket machines where a touch screen generally is available. No modifications to the hardware are required, only a software application, which analyses the user input impulses and transforms them into usable user interaction, needs to be installed. Additionally, a touch screen may be installed in a home scenario and used for communication, environmental control or general IT-supported work. For this also, standard technology along the hardware is sufficient.

2 Methodology

The deviation in accuracy entailed by restrictions of motor functions of people interacting with telemedical services when using a computer mouse is compensated with help of a common touch screen. The improvement of efficiency and satisfaction for the interaction of elderly people with computer-based systems via help of direct input devices was already proven (Schneider et al., 2007). The here presented concept adapts and evaluates the assumptions to decrease error probability and associated effectiveness for people suffering of tremor. Therefore the normal tangency of a touch screen is transformed to a swabbing interaction movement. Through this modification additional parameters like direction, speed, acceleration, starting point and drift can be detected which help to estimate the intended choice.

This is realized by not stopping the user's input-movement at the screen border but letting him swab beyond. The detection is solely on the touch screen-surface but because of the sustained movement the tremble does not augment while approximating the target and tracked parameters provide a basis for calculating higher accuracy. Additionally the frictional resistance during the whole interaction process damps the deviation even more and assists the user.

2.1 Design Pattern Approach

The interaction technique is formulated as a design pattern, whose concept has proven good outcomes in the domains of architecture, software engineering and human-computer interaction (Borchers, 2001). A special template for the application area of eHealth has been composed that respects the demands and requirements of the actors and scenarios (Mertens et al., 2009). The adoption of design patterns for the knowledge management helps to prevent the "reinvention" of solutions for specific problems that were already solved in this and in related domains.

2.2 Design Pattern: Tremor Swabbing Away

CONTEXT: People who are unable to perform exact movements, caused through kinetic tremor, often find it very unsatisfying to use electronic devices that are provided with "standard" user interfaces. This further increases the difficulty handling electronic devices when a lack of experience already exists and no satisfying input accuracy is achieved.

TARGET GROUP: This design pattern enables people who face problems coordinating exact movement, for information input via touch screen. This design pattern is applicable for all characteristics of uncontrollable tremor and for people who have a general problem performing precise physical movements. The field of application is not conditioned by the age, but since the probability to be afflicted with tremor increases significantly with rising age, focus is on elderly people. For application of the interaction technique, it is not necessary to involve any medical staff.

USAGE SITE: This design pattern is usable at any location where the user is allowed to use electronic devices autonomously. This is particularly true in most daily life scenarios and many areas of prevention and rehab. For scenarios requiring a high security of input, the system is not usable as a user may not be controlled on the validity of his entries. Implementations in a clinic environment need to consider that the used systems must not emit any restricted radiation and offers a feasible security check when private inputs are demanded.

PROBLEM: Generally the problem of inaccurate inputs from the user may be compensated through an uncommonly large input box on the screen, in order to compensate any tremor movement. This method, however, is limited to medium occurrences of a tremor and will find problems when facing strong tremor symptoms, simply because every screen has a limited size. For a high number of options, this leaves the developer with the only choice of decreasing the box size and therefore unavoidably an increase in the number of wrong inputs.

SOLUTION: In order to make the preferred technical devices accessible to the described target group, the existing user surface is virtually enlarged to guarantee a big enough screen for the actual input. The principal behind this is based on Fitts' Law (Fitts, 1954; MacKenzie et al., 1992), as the virtual depth of the control elements is increased by several degrees. This is realized with a wiping technique which allows the user to move beyond the physical borders of the touch screen. The measure only takes place on the screen; however, with an adjustment towards a floating or wiping movement, the relevant parameters as orientation, speed and starting point may be determined, so that the targeted control unit can be judged with a significantly higher accuracy. The desired selection on the screen is interpolated with a balancing curve. By doing so, the starting point may be chosen freely, as the determined direction and covered way indicate the intended target and are autonomous from other partitions that were crossed with the fingertip. A determination by integrating the touched areas or even pixels would force the user to start his movement in the center. Affirmation or emendations can be accomplished with the help of very simple gestures like swabbing with a clockwise or anti-clockwise direction. An additional increase in precision is given through the continuous contact of the finger with the screen, as the friction coefficient serves as a damping effect on the symptoms of a tremor.

ILLUSTRATION:

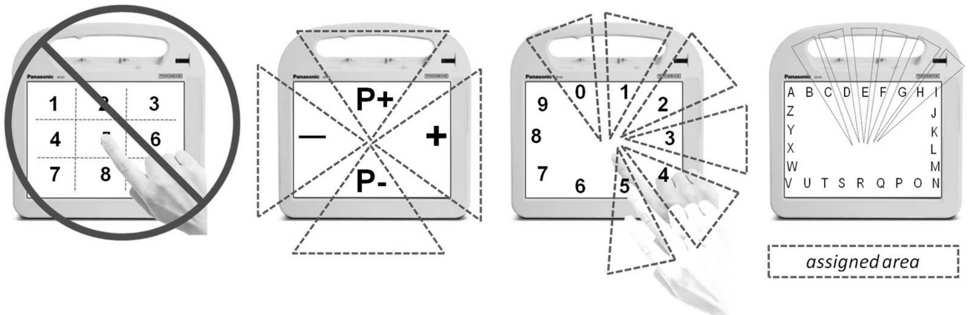

Figure 1. Interaction technique TRABING for a virtual numeric keypad

LIMITATIONS: A use of this design pattern is only given if the patient has a high level of understanding of the standard interaction processes, symbols, numbers and letters used. As the described pattern is mainly an assistance for compensating physical disruptions, a use makes only sense among those people, who still need to have a certain degree of mobility in order to reach towards the screen. Unwanted effects with other third-party systems may be generally excluded since the interaction technique is only an add-on to the software layer. A disproportional physical strain when handling this technology is not expected if the user uses it according to its purpose.

DIRECTIVES: The guidelines and standards that need to be obeyed for this design pattern are mainly dependant on the purpose and classification of the used system. In accordance with the Medical Device Directive (MDD) in Germany the used software must be declared and evaluated as a medical product, a corresponding risk evaluation must be undertaken in order to verify its conformity among the CE classification. Principally the design pattern supports the requirements towards a barrier-free system design and the different standards for usability, e.g. ISO 13407, ISO 14915 or DIN EN 62366.

3 Evaluation

The concept has been developed within a scientific project about establishing a telemedical platform for monitoring of elderly cardiovascular patients during homely rehab (Mertens at al., 2009). As the system offers access to aligned value added services, an adequate interaction technique for all users had to be assured, to allow self-reliant access.

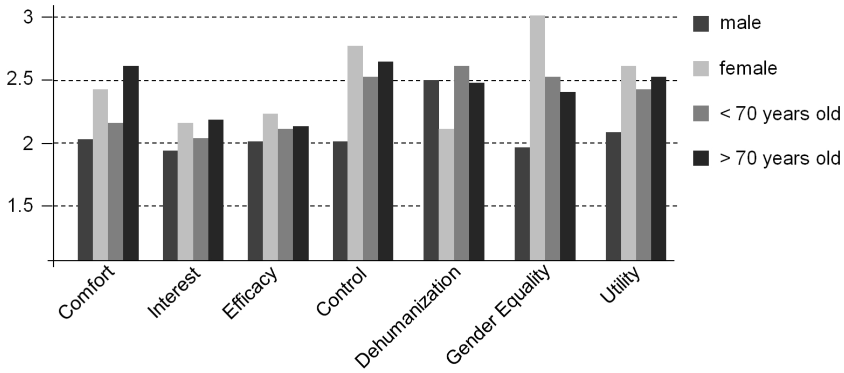

Figure 2. Attitudes of elderly people towards computers

A first evaluation showed high acceptance from the subjects, a learning curve with swift practice effects and a significant improvement of the input procedure for all tremor patients. The testing was performed with 15 seniors, 9 female and 6 male between 56 and 91 years (average age: 72.8 years, SD=6.9) who were afflicted with diverse tremor characteristics. The causation and the origin of the affection were not included, as no ethics vote for a retrospective analysis was consented. In a related survey prior to the trial the subjective attitude towards computers for seven dimensions (Comfort, Efficacy, Gender Equality, Control, Dehumanization, Interest and Utility) was ascertained (see Figure 2). According to this, only two of the participants indicated a daily computer use and just four of them have a PC in their home. The appraisal was accomplished with help of 15 questions that had to be answered by dint of a Likert scaling (Gina et al., 1992). The used apparatus for conducting the trials was a Panasonic Toughbook H1 Mobile Clinical Assistant (MCA) ® with a 10.4" resistive touch display and a resolution of 1024 x 768 pixels.

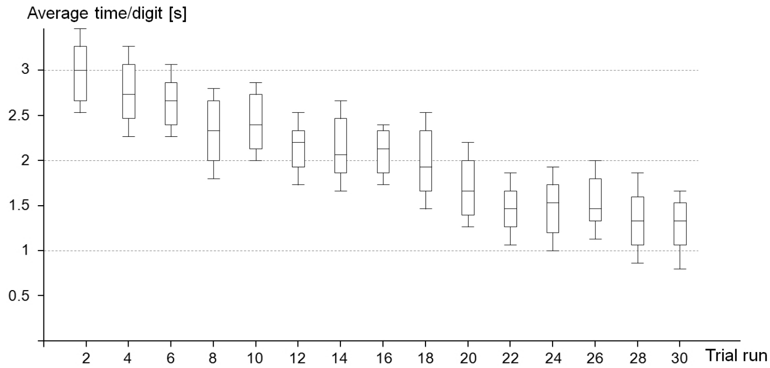

Figure 3. Training curve of 15 elderly users applying TRABING. The average time for entering one digit of a 20-digit number is plotted for the 30 trials/person

The manipulation was solely done by finger touch, no pen was used (see Figure 1). The implemented test cases showed ten numeric digits (0-9) that were arranged equidistant in a circle near to the boundaries of the device. Each trial a new randomized 20-digit number was shown in the middle of the screen and the subjects had to select the numeric digit in strict rotation. The aggregated time for entering a complete 20-digit number was measured, here wrong selections were ignored. The error ratio was regarded by the extended time that was necessary to process the complete number.

The measured execution times show a high stability after the 20th trial for most of the probands (see Figure 3). It turned out that after a short phase of orientation (trial 1-6) the learning process took place (trial 7-21) and after that stable phase regarding the time for entering a digit was attained. The respective average time mainly depends on the degree of muscle tremor, the computer literacy and associated attitude towards the use of computers (see Table 1).

	Comfort	Interest	Efficacy	Control	Dehumanization	Gender Equality	Utility
Comfort	1						
Interest	**.777**	1					
Efficacy	**.798**	.388	1				
Control	**.866**	*.55*	**.931**	1			
Dehumanization	-.075	-.259	-.121	-.151	1		
Gender Equality	-.021	.142	-.014	.169	**-.777**	1	
Utility	*.532*	**.657**	*.575*	*.627*	-.17	-.01	1

Table 1: Correlation of the seven dimensions: Attitudes towards computers of older adults

4 Future Topics

Actually additional parameters, like surface morphology, pen vs. finger, number of parallel symbols (character, numeric) as well as custom-built algorithms for analyzing the tracking data are evaluated to determine the impact on the dependent variables (time, error ration and user satisfaction).

The application of linguistic heuristics is expected to even increase the recall factor as the probability for inputs can be considered. The angle of the sector for each screen compartment may be adjusted flexibly to the input alphabet with help of formula (1).

$$A(s) = \left(\frac{180^\circ}{|I|} \right) + (180^\circ \cdot p(s)) \quad (1)$$

In equation (1) *A()* determines the recommended angle,
s is the symbol, s
I is the sample space and I
p() is the probability for occurrence (see Table 2).
The formula (1) assures that for every symbol a lower bound for the partition size is maintained and therefore all symbols stay attainable. An even better adjustment for a specific sample space can be achieved if sequences are considered and impossible choices are determined based on former input. In case of any input situations where many options are required, these may be designated to the same input area, similar to the T9 method used with mobile phones. According to the actual tremors deviation an ideal compartment size may be identified, allowing a maximum efficiency in the relationship between the error rate and number of simultaneous options.

A	06,51 %	H	04,76 %	O	02,51 %	V	00,67 %
B	01,89 %	I	07,55 %	P	00,79 %	W	01,89 %
C	03,06 %	J	00,27 %	Q	00,02 %	Y	00,03 %
D	05,08 %	K	01,21 %	R	07,00 %	Y	00,04 %
E	17,40 %	L	03,44 %	S	07,27 %	Z	01,13 %
F	01,66 %	M	02,53 %	T	06,15 %	ß	00,31%
G	03,01 %	N	09,78 %	U	04,35 %		

Table 2: Frequency of Occurrence for German Alphabet

5 Conclusion

In summary, this paper reports on three contributions:

(1) Requirement analysis for people with tremor and development of a novel interaction input technique for relevant scenarios which currently are not provided with sufficient solu-

tions. For this, the economic influences coming with demographic change is given special regard with new access to supply potentials of medical care.

(2) Specifications and refinement for the implementation of TRABING. Identification of relevant parameters for an efficient use among the target group mentioned at (1) and following evaluation.

(3) Semi-formal specification with help of design patterns for easier perusal and comprehension. This concept is part of the groundwork for establishing a pattern language for the domain of eHealth. Herewith the formalizing, structuring, propagation and acquisition of expertise for novices as well as mavens can be facilitated.

6 References

Akram, W., Tiberii, L. & Betke, M. (2007). *A Customizable Camera-Based Human Computer Interaction System Allowing People with Disabilities Autonomous Hands-Free Navigation of Multiple Computing Tasks*; Springer.

Ambient Assisted Living (2006). *European Overview Report*: Europe Is Facing a Demographic Challenge: Ambient Assisted Living Offers Solutions, VDI/VDE.

Borchers, J. (2001). *A pattern approach to interaction design*. Chichester: Wiley.

Duchowski, A. T. (2009). *Eye Tracking Methodology: Theory and Practice*, Springer, Berlin, 2nd ed.

Dzaack J., Zander, T.O., Vilimek, R., Trösterer S. & Rötting M. (2009). Brain activity and eye-movements: Multimodal interaction in human-machine systems. In A. Lichtenstein, C. Stößel & C. Clemens (Hrsg.), *Der Mensch im Mittelpunkt technischer Systeme. 8. Berliner Werkstatt - Mensch-Maschine-Systeme*, 7. - 9. Okt. 2009, S. 189-190 und 464-469 [CD], Düssedorf: VDI Verlag.

Eberspächer, J. & Reden, J. von (2006). *Umhegt oder abhängig: Der Mensch in einer digitalen Umgebung*. Springer, Heidelberg.

Fitts, Paul. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. In: *Journal of Experimental Psychology*, volume 47, number 6.

Gina, M.J. & Sherry, L. W. (1992). Influence of Direct Computer Experience on Older Adults´ Attitudes Toward Computers, In: *Journal of Gerontology: Psychological Science*, Vol. 47, no 4, pp. 250-257.

Gollücke, V. (2009). *Eye-Tracking - Grundlagen, Technologien und Anwendungsgebiete*, Grin Verlag.

Keshet, J. (2009). Bengio, S.: *Automatic Speech and Speaker Recognition: Large Margin and Kernel Methods*, John Wiley & Sons.

Klaffke, S. & Trottenberg, T. (2009). *Essentieller Tremor*, www.Charite-Berlin.de.

Kobsa, A. & Stephanidis, C. (2009). *Adaptable and Adaptive Information Access for All Users, Including Disabled and Elderly People*; Pittsburgh, USA.

Korhonen, P. & Paavilainen, A. (2003). Application of ubiquitous computing technologies for support of independent living of the elderly in real life settings; *Ubicomp 2003 UbiHealth workshop*.

MacKenzie, I.S. & Buxton, W. (1992). Extending Fitts´ Law to two-dimensional tasks. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* 1992, P. Bauersfeld, J. Bennett, G. Lynch, Eds. ACM, New York.

Mertens, A., Dünnebacke, D., Kausch, B., Laing, P. & Schlick, C. M. (2009). Innovation of homely rehab with help of telemedical services. In: *IFMBE Proceedings of World Congress on Medical Physics and Biomedical Engineering*, Munich, Springer.

Monekosso, D., Remangnino, P., & Kuno, Y.(2009*). Intelligent Enviroments – Methods, algorithms and applications*. London: Springer.

Martínez-Martín, P. (1998). An introduction to the concept of "quality of life in Parkinson's disease" In: *Journal of Neurology*, Springer, Berlin.

Pfister, B. & Kaufmann, T. (2008). *Sprachverarbeitung: Grundlagen und Methoden der Sprachsynthese und Spracherkennung*, Springer, Berlin.

Plumb, M. & Bain, P. (2006). *Essential Tremor: The Facts*, Oxford Univ. Pr.

Raskin, J. (2005). *The Humane Interface, New Directions for Designing Interactive Systems*. Addison – Wesley.

Rutgersson, S. & Arvola, M. (2007). *User Interfaces for Persons with Deafblindness*, LNCS 4397, Springer.

Schneider, N. Schreiber, S. Wilkes, J. Grandt, M. & Schlick, C. (2007). Investigation of Adaptation Dimensions for Age-Differentiated Human-Computer Interfaces, In: *Universal Access in HCI*, Part I, HCII 2007, 12th International Conference on Human-Computer Interaction ,Beijing, China, Hrsg.: Stephanidis, C., Springer, Berlin.

Sommerlatte, T. (2008). *Technikgestaltung aus Sicht des Nutzers*, Digitale Visionen, Springer, Berlin Heidelberg.

Statistisches Bundesamt, (2008). *Demografischer Wandel in Deutschland - Heft 1: Bevölkerungs- und Haushaltsentwicklung im Bund und in den Ländern*, Onlineveröffentlichung.

Wahl, H. & Naegele, G. (2004). *Zukunft des Alters in einer alternden Gesellschaft: Szenarien jenseits von Ökonomie und Demografie*. Sozialer Fortschritt, 53 11-12.