Motivational Expression of Smart Walker for Rehabilitation Exercise

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Abstract: This paper presents the motivation expressions of Smart Walker, which is intended for use during rehabilitation exercise for the recovery of walking ability. Smart Walker is the application of a robotic system for the elderly. Its main purposes are to improve mobility and maintain balance, though it can also be used as a rehabilitation assistant for patients who have trouble walking as a result of some cause, such as a stroke. The proposed Smart Walker system utilizes tablet devices as an interaction channel and has an expressional modality consisting of a 3D avatar for facial expressions, TTS, and dialog messages. The agent of Smart Walker motivates the patient to undertake rehabilitation exercise more actively using motivational expressions which are determined from metrics related to the user's task performance and degree of faithfulness. To determine the motivational expressions, the user's task performance and degree of faithfulness are quantified and a rule-based decision tree is used.

1 Introduction

As the elderly population is rapidly increasing, many robotic applications have been developed for seniors who lack physical, cognitive, and/or emotional stability. To assist with the physical functions of these individuals, many mobility-assistive devices have been developed. Smart Walker [1] is the application of a robotic system for the elderly. Its main purposes are to improve mobility and help the elderly maintain their balance.

While many assistive robotic systems for the elderly are mainly for physical assistance, some applications have been studied with the aim of assisting cognitive and emotional functions. Socially Assistive Robotics (SAR) [2] is a research area that focuses on assisting people by social interaction rather than physical interaction.

The main motivation of SAR mostly started with rehabilitation tasks. At present, it is expanding to various applications. In most SAR scenarios, the robot evaluates the user's task performance on rehabilitation exercise and attempts to give encouragement [3, 4]. This may have an effect on patients who are required to do repetitive tasks during their rehabilitation exercise because the encouragements can stimulate motivation for repetitive types of rehabilitation exercise.

A similar approach can be realized by an agent of the Smart Walker system for rehabilitation patients. Smart Walker can be used as a rehabilitation assistant for patients who have trouble walking for any reason, such as a stroke. Also, an agent of the Smart Walker system can induce the patient to undertake rehabilitation exercise more actively.

This paper presents the motivational expressions of Smart Walker during rehabilitation exercise for the recovery of the walking ability of its users. The rest of this paper will present the following: Related Works,

2 Related Works

2.1 Smart Walker

While many studies of Smart Walker focused on physical assistance to improve the mobility and balance of patients [5, 6], sensorial/cognitive assistance is considered to provide several benefits [1]. Although there are many Smart Walker applications which provide sensorial/cognitive assistance [7-9], including a health monitoring service [10] while the patient is walking and navigation assistance [11], it is difficult to find studies focusing on rehabilitation exercise.

2.2 Rehabilitation Robotics

Rehabilitation assistance for stroke patients is one of the most suitable applications for robotic systems. Although the rehabilitation tasks stroke patients should perform are very repetitive, supervision by a professional therapist is required. Rehabilitation robots have the advantage of allowing patients to perform rehabilitation tasks independently of a therapist. Also, these robots facilitate more precise motions easily through the application of new movement patterns [12].

For these reasons, many rehabilitation robotic systems are being studied. For upper-limb rehabilitation, patients are required to control a robotic manipulator through their own force [13]. To increase compliance in rehabilitation tasks, several incentive systems have been introduced, such as VR (virtual reality) games [14]. For lower-limb rehabilitation, external devices supporting the patient's legs, such as an exoskeleton [15], have been studied.

On the other hand, several non-contact approaches have been developed. These approaches mostly focus on social interaction to encourage and motivate patients [2, 3, 4].

3 Express Motivational Expressions

3.1 Scenario

A tablet device is installed on Smart Walker as an interaction channel. During rehabilitation exercise, the agent on the tablet device presents proper motivational expression to the patient. For instance, the agent praises the patient when the patient shows good performance. In contrast, the agent generates negative expressions for bad performance. Faithfulness may also be an important criterion to determine positive or negative feedback. The agent on Smart Walker is required to induce and motivate patients to do their exercises faithfully. Scenarios of motivational expressions according to the task performance level and degree of faithfulness are listed on Table 1.

Even the actually Smart Walker is motorized system, in this study passive wheels are used because the proposed expression system is implemented in parallel with the Smart Walker system. In this paper, it is assumed that the localization and track data are given and that the absolute velocity from the encoder is used as a trajectory following the track. Also, other sensors are not considered in this case.

Table 1. Scenarios according to task performance and faithfulness

Task Performance	Faithfulness	Expression
High	High	Praise
High	Low	Push Coax
Low	High	Comfort encouragement
Low	Low	Scold Disappoint

3.2 Evaluation of faithfulness and performance

The user's degree of faithfulness is defined by Eq. (1), which represents the ratio of the actual exercise time to the total time. It is calculated for every period. It is assumed that if the velocity of Smart Walker exceeds a threshold, the patient actually does exercise.

$$f = \frac{T_f}{T} \tag{1}$$

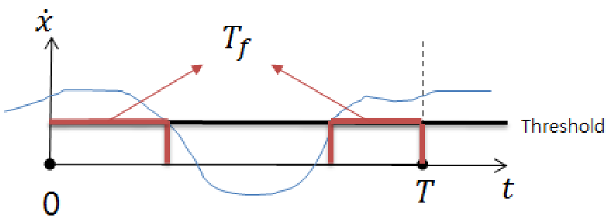


Figure 1. Evaluating user's faithfulness

On the other hand, performance is calculated as the ratio of the integral of the absolute velocity to the goal value.

$$p = \begin{cases} \frac{\int|\dot{x}|}{p_{goal}}, \text{ when } \frac{\int|\dot{x}|}{p_{goal}} < 1 \\ 1, \text{ when } \frac{\int|\dot{x}|}{p_{goal}} \geq 1 \end{cases} \tag{2}$$

3.3 Determining the expressions

The motivational expression is generated at every period. To determine the expressions according to the user's task performance and degree of faithfulness, a rule-based decision tree is used. The decision rules are identical to the contents in Table 1.

4 System

4.1 Hardware

The experiment system is based on a commercial walker platform. Two front casters in the original walker platform are replaced with differential wheels onto which encoders are attached. A microprocessor (LM8962) is used to read the velocity of the two wheels from the encoder signal, and it transfers the velocity data to a laptop computer by serial communication. The laptop computer evaluates the velocity data to select which expression is proper considering the user's performance. The motivational expression is executed on a tablet device (Nexus 7). The laptop computer commands the tablet device to execute the selected expression by USB communication. Figure 2 shows an image of the entire system used here for the experiment.

Figure 2. Figure of the experiment system

4.2 3D avatar character on a tablet device

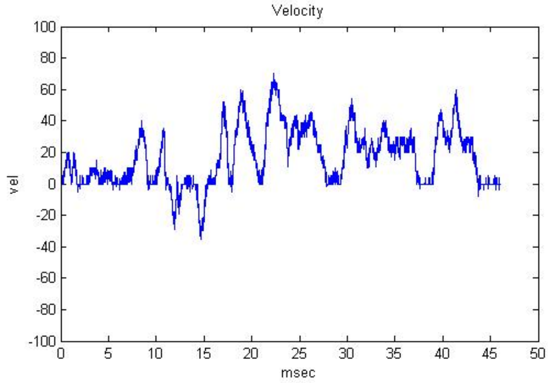
Regarding the mode of expression, a 3D avatar character on a tablet device is used. This application is able to generate facial expressions, dialog messages, and TTS (text to speech). The 3D avatar has 12 DOF (degrees of freedom) at the face, mouse, eyelids, and pupils. All facial components, dialog messages, and TTS messages are scripted in xml format. Figure 3 shows the Ekman's 6 basic emotions expressions [16] of the 3D avatar.

Figure 3. Facial expressions of the 3D avatar character on a tablet device (Ekman's 6 basic emotions)

5 Experiment

An experiment is conducted with a subject. Although the subject in this experiment does not have any trouble walking, this experiment serves to demonstrate the results of the algorithm.

According to the velocity and evaluated faithfulness and performance levels, the motivational expressions of Disappoint, Disappoint, Praise, and Push are sequentially generated.



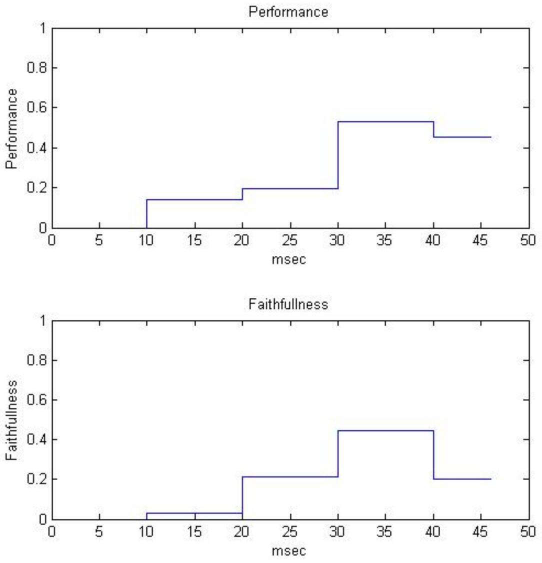


Figure 4. Experiment result

6 Conclusion

6.1 Discussion

In this paper, the motivational expressions for use on the Smart Walker system for rehabilitation are studied. The user's task performance and degree of faithfulness are evaluated from encoder signals. Based on the user's task performance and faithfulness levels, a motivational expression is generated frequently. However, performance and faithfulness are positively correlated. This is caused by the lack of a sensor system.

6.2 Further work

To make the system more effective and increase the validity of research in this area, several improvements are required. The evaluated performance and faithfulness levels are very highly correlated. To use the user's performance and faithfulness as factors in the evaluation, other sensory systems are required to extract this information more precisely.

To improve the levels of enjoyableness and helpfulness, a greater variety of interactions can be included. The current algorithm based on a look-up table is limited to a certain set of interactions. A monotonous frequency is a critical requirement to make the interactions more natural. Also, a greater variety of behavior is required for rehabilitation procedures, such as exercise and relaxation.

User adaptation by feedback can also be appropriate in the rehabilitation domain. Each patient has different criteria pertaining to their levels of performance and faithfulness. Incremental learning would be a proper algorithm for this system.

In this study, it is assumed that the localization and track data are given. To integrate and test the proposed motivational expression algorithm on an actual Smart Walker system in an actual rehabilitation environment, these functions should also be considered. Finally, the proposed system should be evaluated with actual elderly people or with patients who have trouble walking.

Acknowledgement

This work was supported by the R&D Program of MKE/KEIT[10035201, ADL Support System for The Elderly and Disabled].

References

[1] M. M. Martins, C. P. Santos, and A. Frizera-Neto, "Assistive mobility devices focusing on Smart Walkers: Classification and review," Robotics and Autonomous Systems, 2011

[2] D. Feil-Seifer and M. J. Mataric, "Defining socially assistive robotics," in Rehabilitation Robotics, 2005. ICORR 2005. 9th International Conference on, 2005, pp. 465-468.

[3] A. Tapus and M. Mataric, "Socially assistive robots: The link between personality, empathy, physiological signals, and task performance," in AAAI Spring, 2008, pp. 3-4.

[4] J. Eriksson, M. J. Mataric, and C. J. Winstein, "Hands-off assistive robotics for post-stroke arm rehabilitation," in Rehabilitation Robotics, 2005. ICORR 2005. 9th International Conference on, 2005, pp. 21-24.

[5] K.-T. Song and C.-Y. Lin, "A new compliant motion control design of a walking-help robot based on motor current and speed measurement," in Intelligent Robots and Systems, 2009. IROS 2009. IEEE/RSJ International Conference on, 2009, pp. 4493-4498.

[6] Y. Nemoto, S. Egawa, A. Koseki, S. Hattori, T. Ishii, and M. Fujie, "Power-assisted walking support system for elderly," in Engineering in Medicine and Biology Society, 1998. Proceedings of the 20th Annual International Conference of the IEEE, 1998, pp. 2693-2695.

[7] S. MacNamara and G. Lacey, "A smart walker for the frail visually impaired," in Robotics and Automation, 2000. Proceedings. ICRA'00. IEEE International

Conference on, 2000, pp. 1354-1359.
[８] G. Wasson, J. Gunderson, S. Graves, and R. Felder, "Effective shared control in cooperative mobility aids," in Proceedings of the Fourteenth International Florida Artificial Intelligence Research Society Conference, 2001, pp. 509-513.
[９] A. J. Rentschler, R. A. Cooper, B. Blasch, and M. L. Boninger, "Intelligent walkers for the elderly: Performance and safety testing of VA-PAMAID robotic walker," Journal of rehabilitation research and development, vol. 40, pp. 423-432, 2003.
[１０] S. Dubowsky, F. Genot, S. Godding, H. Kozono, A. Skwersky, H. Yu, et al., "PAMM-a robotic aid to the elderly for mobility assistance and monitoring: a “helping-hand” for the elderly," in Robotics and Automation, 2000. Proceedings. ICRA'00. IEEE International Conference on, 2000, pp. 570-576.
[１１] D. Rodriguez-Losada, F. Matia, A. Jimenez, R. Galan, and G. Lacey, "Implementing map based navigation in guido, the robotic smartwalker," in Robotics and Automation, 2005. ICRA 2005. Proceedings of the 2005 IEEE International Conference on, 2005, pp. 3390-3395.
[１２] G. Kwakkel, B. J. Kollen, and H. I. Krebs, "Effects of robot-assisted therapy on upper limb recovery after stroke: a systematic review," Neurorehabilitation and neural repair, vol. 22, pp. 111-121, 2008.
[１３] M. Van der Loos, "Robot-assisted movement training compared with conventional therapy techniques for the rehabilitation of upper-limb motor function after stroke," Arch Phys Med Rehabil, vol. 83, 2002.
[１４] D. Jack, R. Boian, A. S. Merians, M. Tremaine, G. C. Burdea, S. V. Adamovich, et al., "Virtual reality-enhanced stroke rehabilitation," Neural Systems and Rehabilitation Engineering, IEEE Transactions on, vol. 9, pp. 308-318, 2001.
[１５] A. M. Dollar and H. Herr, "Lower extremity exoskeletons and active orthoses: challenges and state-of-the-art," Robotics, IEEE Transactions on, vol. 24, pp. 144-158, 2008.
[１６] P. Ekman, “Emotion in the Human Face”, Cambridge University Press, New York, 1982.