

Auxiliary System to Classify Patterns of Patients with Hemiplegia for Transferring Skill of Rehabilitation with Walking Assist Robot

Yuki Ishikawa^{1*}, Qi An¹, Wen Wen¹, Shu Ishiguro², Koji Ohata³, Hiroshi Yamakawa¹, Yusuke Tamura¹, Atsushi Yamashita¹ and Hajime Asama¹

¹ Department of Precision Engineering, Graduate School of Engineering, The University of Tokyo, Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8656, Japan

² Ground Design Works Inc., Tokyo

³ Kyoto University, Kyoto

* Corresponding Author: Tel: +81 3 5841 6486, E-mail: ishikawa@robot.t.u-tokyo.ac.jp

Abstract

Recently, some medical institutions introduce a walking assist robot to improve an efficiency of rehabilitation for patients with hemiplegia. However, the new rehabilitation program with walking assist robot for the patients is not established. Therefore, we define new rehabilitation skills as the rehabilitation methodology to apply the walking assist robot to the patients. By interviewing the expert, we found that the expert classifies the types of the patients by their gait patterns in order to use the walking assist robot correctly. However, it is difficult for non-expert to classify these patterns because this classification skill is still a tacit knowledge. Therefore, our objective is to develop an auxiliary system to classify the types of patients with hemiplegia for transferring skill of rehabilitation for using the walking assist robot properly by translating the explicit knowledge from the tacit knowledge. First, we extracted the skill of the expert by interviewing. Second, we extracted the gait features by observing the movies of the patients' gait. The movies of the patients' gait which are labelled in advance by the expert were used. Then, we arranged the gait features of the difference points due to the type of the patients. In this study, sixteen movies, including four types of the patients, were used. As a result of the interview, the patterns are composed of four types which the expert are defined by the timing of gait event. As a result of the observation of the movies, gait stride, duration of the stance phase, and walking rate were suitable for the criteria of the classification. This rule is correspond with the expert's policy.

Keywords

Walking assist robot, Identification auxiliary system, Patients with hemiplegia, Skill education.

1 INTRODUCTION

Recently, some of medical institutions introduce a walking assist robot to improve an efficiency of rehabilitation for patients with hemiplegia who reacquiring walking ability. It is thought that the walking assist robot gives us a new rehabilitation methodology. For example, the walking assist robot has ability to add some particular torques on patient's joints at an appropriate timing which is difficult for human therapist. Therefore, it is expected to prevail the walking assist robot in the society.

However, the new rehabilitation program for the patients is not established because the system has not been utilized much in a clinical application. It is pointed out that some clinical staffs cannot understand how to use the walking assist robot even if the staffs in medical institutions has already introduced the walking assist robot.

Therefore, we define a new rehabilitation skills as the rehabilitation methodology to apply the walking assist robot to the patients. Generally, the skill education is composed of three parts which skill extraction, skill verification and skill transfer (Nakagawa 2014).

Firstly, we tried to investigate the new rehabilitation skills by interviewing the expert. In this pilot study, these skills

are surveyed by interview of an expert. The study pointed out that the expert classifies the types of patients with hemiplegia by their gait patterns. It is important point to classify types of the patients correctly to use the walking assist robot. The patterns are composed of four types. These types are classified by the timing of gait event, for example knee joint bending at the early stance phase. However, it is difficult to classify these types for non-expert.

Eastlack reported that a repeatability of a result of observed gait analysis by physical therapists is limited (Eastlack 1991). Krebs reported that an observed gait kinetics analysis has high variability between evaluators (Krebs 1985). Though physical therapist analyses gait motion of patients with hemiplegia in clinical environment, the result of evaluation depends on an individual skill and experience due to lack of clear evaluation criteria.

In order to make clear evaluation criteria, some studies reported the methodology. Murlroy investigated that gait patterns of patients with hemiplegia at early-onset and six months later by using cluster analysis (Murlroy 2003). As a result, they reported that knee extension angle on middle stance phase at early-onset, knee extension angle on latter stance phase and knee flexion angle on early swing phase

can be a criteria to classify the patterns. This study focus on the movement of knee joint. However, the movement of knee joint is difficult for non-expert to understand the timing of these types.

In order to develop useful methodology in a clinical situation, an easy way to classify the patients' types is needed. Now these skills are transferred directly from the expert to learners. However this process is not efficient to prevail in the society. Then it is expected to establish indirectly skill transfer system.

Therefore in this study, the objective is to develop an auxiliary system to classify the types of patients with hemiplegia for transferring skill of rehabilitation for using the walking assist robot properly by translating an explicit knowledge from a tacit knowledge. We extract the skill of the expert by detailed interviewing and observation of the actual patients' gait movies.

2 METHODOLOGY

2.1 Skill Extraction by Interview

In this study, a definition of the skill extraction is to understand the expert's skill, including tacit knowledge, and to translate the skill to the understandable words, it is generally called explicit knowledge. We define new rehabilitation skills as the rehabilitation methodology to apply the walking assist robot to the patients. The definition of the expert who has such skill is the person who already use the walking assist robot to the patients in a clinical situation for several years. The methodology to extract the skill is referred to the previous study which extract the nursing skill (Nakagawa 2014).

To extract the skill, we interview the expert. We ask to the expert the important points to decide the way to use the walking assist robot to the patients in a clinical situation. We also repeat the question to know the detail of actual situation and write it down.

In the pilot study, we know that the proper patients' classification is needed to reproduce the expert skill. Moreover, the expert sometimes use an electromyogram on their paralysis side legs. However, the measurement of the electromyogram is not generally used in a clinical situation. Therefore, in this study, we focus on the observed gait patterns of the patients in the next section.

2.2 Classification Skill Extraction by Observation

The patients' gait movies which the expert already classified are observed. First, the features of the patients' gait are extracted by using the observation. Then, the common features of the patients' gait are extracted. The features which are not common between the types of the patients are the important points of classification skill extraction. In the pilot study, the expert pointed out the gait event and the timing are important. Therefore, we measure the duration of the stance phase of patients' paralysis side and non-paralyzed side by using the movie. The duration of the stance phase is defined between the timing of heel strike and the timing of the other side leg's heel strike. The average duration time of three trial of each patients is used. Moreover, the duration ratio and the walking rate are calculated. The definition of the duration ratio is that the duration time of patients' paralysis side divided by that of non-paralyzed side. The definition of the walking rate is a

reciprocal number of the sum of the duration time of the stance phase of patients' paralysis side and non-paralyzed side. The equation is below.

$$DR = \frac{DTp}{DTnp}, WR = \frac{1}{DTp+DTnp}. \quad (1)$$

DR is the duration ratio, WR is the walking rate, DTn is the duration time of the stance phase of patients' paralysis side, and $DTnp$ is the duration time of the stance phase of patients' non-paralyzed side.

As for the patients, the gait movie of sixteen patients which include four types of the expert classification are observed. Four patients of them are the LR type patients who have the problem on the double supporting phase (loading response). Two patients of them are the TS_t type patients who have the problem on the single stance phase (terminal stance). Six patients of them are the PS_w type patients who have the problem on the double supporting phase (pre-swing). Four patients of them are the TS_w type patients who have the problem on the swing phase (terminal stance). The movie consist of about seven gait cycle. Point of view is not fixed and the direction is almost sagittal plane. Frame rate of the movie is 29.97 fps.

3 RESULTS AND DISCUSSION

3.1 Result of Interview

As a result of the interview, we found two important points which are related with the expert decision. First, the expert classifies some types of the patients by their gait patterns and an electromyogram on their paralysis side legs in order to use the walking assist robot correctly. Second, the patients who are suitable for the therapy with the walking assist robot and who are not suitable for the therapy with the walking assist robot exist.

As for gait patterns, the expert consider the four types divided by gait cycle phases event. Concretely the criteria is whether patients' paralysis side knee joint is extension or flexion on the early stance phase. The other criteria is whether patients' trunk bend the body forward or backward on the early stance phase. Furthermore, there are so many criteria to classify the types of patients.

As for the electromyogram on their paralysis side legs, the expert refer the comparison between the timing of gait event and the timing of muscle activation. Concretely the criteria is whether the timing of rectus femoris muscle activation and the timing of biceps femoris muscle activation are proper timing or not. The other criteria is whether tibialis anterior muscle, gastrocnemius muscle, and iliac muscle are activated or not.

It is also shown that the necessary of the proper classification because there the patients who are suitable for the therapy with the walking assist robot and who are not suitable for the therapy with the walking assist robot.

The expert classifies the four types of patients with hemiplegia by their gait patterns. Concretely these four types indicated problems on the double-limb support phase (loading response): LR type, the single-limb support phase (terminal stance): TS_t, the double support phase (pre swing): PS_w, and the swing phase (terminal swing): TS_w, respectively. Figure 1 indicates the timing of these four gait events. These four phase are divided by gait events which are heel contact and toe off. In this study, these four types

of patients are classified by the phase which is the most serious problem. For classification, it is needed to know the status of each phase of the patients.

These types of the patients is correspond with the types of the rehabilitation methods. The expert can detect the patients' types by using his a lot of experience. However, the result of interview is still complicated for non-expert to understand and reproduce. By the observation, we try to find the easier features of detection the types of the patients by using the data which is already classified by the expert.

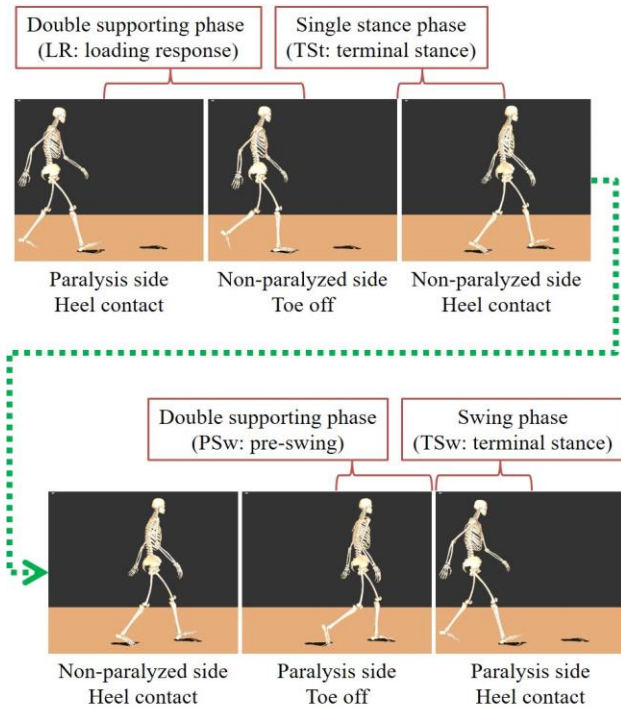


Figure 1: The timing of four types of gait patterns.

3.2 Result of Observation

The features of the each type patients' gait are extracted by using the observation. As a kinematic characteristic compared with healthy people, decreasing the walking speed, shortening the duration of the single paralysis leg's stance phase, lengthening the duration of the double stance phase, shortening the stride, asymmetry of the step width, decreasing the hip extension angle and ankle dorsal flexion angle on the stance phase, and deformity of heel strike. These features are also reported in the previous study (Olney 1996). Therefore, the patients who are investigated in this study have generally symptoms and it is proven that we can extract the generally features of patients with hemiplegia.

Then, the common features of the each type patients' gait are extracted. Figures 2, 3, 4, and 5 indicate the step length of patients' paralysis side and non-paralyzed side of the four types of the patients. Both left and right picture shows the timing of heel strike. The red line indicates the patients' paralysis side leg and the blue line indicates the patients' non-paralyzed side leg in the figures. The orange arrow indicates the approximate step length.

LR type patients and TSt type patients have the different step length of paralysis side and non-paralyzed side. As for LR type patients, the forward step length of paralysis side is smaller than that of non-paralyzed side. As for TSt type patients, the forward step length of is non-paralyzed side smaller than that of paralysis side. On the other hand, PSw

type patients and TSw type patients have the same forward step length of paralysis side and non-paralyzed side. Therefore, the forward step length of paralysis side and non-paralyzed side is one of the criteria of the classification.

Table 1 shows the duration ratio and the walking rate. The table has the average and standard deviation of the duration ratio and the walking rate of each type of the patients.

The data of PSw type patients and TSw type patients which are not distinguished by the forward step length compared. TSw type patients have the duration ratio which is similar to one though PSw type patients have the larger duration ratio. It means that TSw type patients have the similar duration of the stance phase of paralysis side and non-paralyzed side. PSw type patients have the longer duration of the stance phase of paralysis side than that of non-paralyzed side. However, this is not significant difference. This is because two of six TSw type patients have the duration time which is similar one. These two patients walk with their cane. Therefore it is shown the possibility that the patients walking with the cane is not applicable for this method.

As for the walking rate, TSw type patients have larger rate that the other types of patients. Therefore, it can be the criteria to distinguish between PSw type patients and TSw type patients. Moreover, this criteria can be applicable with the patients using the cane because TSw type patients have larger rate than that of PSw type patients with the cane. Therefore, it is shown that the proper classification can be done by using combination of the duration ratio and the walking rate.

Figure 6 shows the summarized results of classification. First, LR type patients and TSt type patients are classified by using the forward step length of paralysis side and non-paralyzed side. Then, PSw type patients and TSw type patients are classified by using the duration ratio and the walking rate. This classification is proven by the expert.



Figure 2: LR type patients.

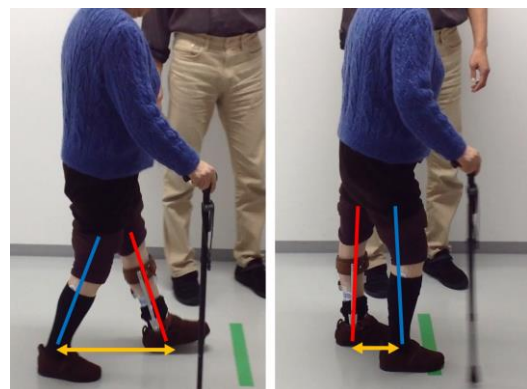


Figure 3: TSt type patients.

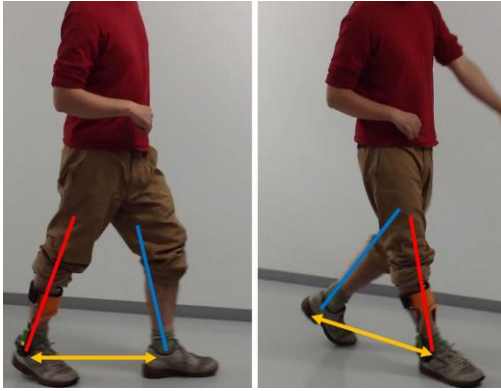


Figure 4: PSw type patients.



Figure 5: TSw type patients.

4 CONCLUSION

To develop an auxiliary system to classify the types of patients with hemiplegia for transferring skill of rehabilitation for using the walking assist robot properly by translating explicit knowledge from tacit knowledge. We

extracted the skill of the expert by detailed interviewing and observation of the actual patients' gait movies. First, we extracted the skill of the expert and we know the importance of classification by the interview. Then, we extracted the easier classification skill of the expert by using observation of the movies. As a result, we can know the classification rule of the four type's patients by using the forward step length of paralysis side and non-paralyzed side, the duration ratio, and the walking rate.

ACKNOWLEDGMENTS

This work was in part supported by JST RISTEX Service Science, Solutions and Foundation Integrated Research Program and Grant-in-Aid for JSPS Fellows 15J07655.

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Table 1: Result of the duration ratio and the walking rate (Mean \pm SD).

	LR	TSt	PSw	TSw
DR: Duration ratio [-]	1.12 \pm 0.26	1.54 \pm 0.46	1.40 \pm 0.27	1.15 \pm 0.13
WR: Walking rate [stride/sec]	0.64 \pm 0.08	0.66 \pm 0.17	0.62 \pm 0.08	0.92 \pm 0.08

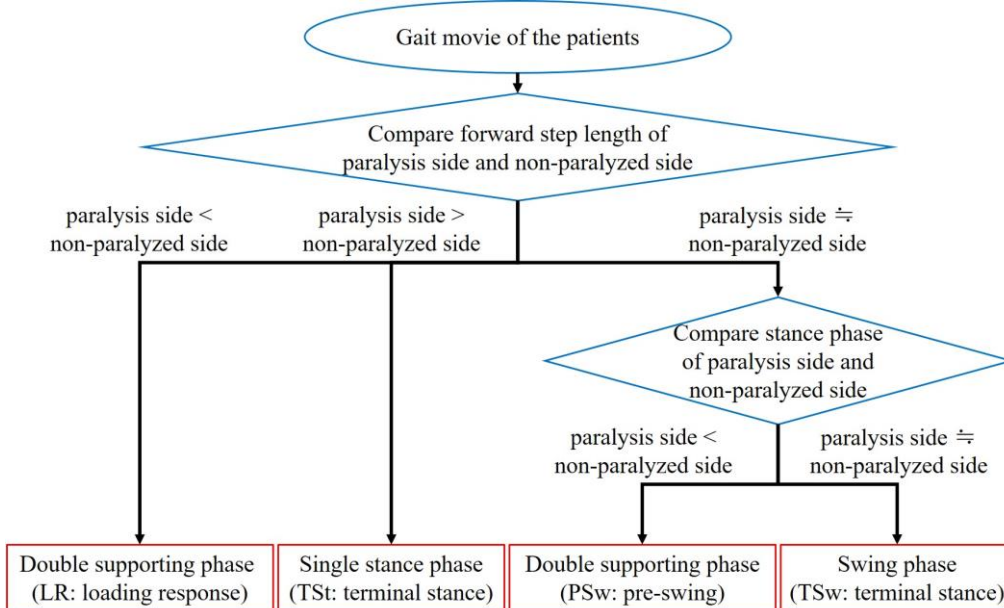


Figure 6: Result of the classification.