Research for an Adaptive User's Intent-Detection Method for the Use in Rehabilitation Robots

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Abstract: In this paper, research on how to make an adaptive algorithm for user's walking intent detection is presented. User's intent detection is the most critical problem in rehabilitation robots designed to help paraplegic patients. It is very difficult to overcome this problem in the dynamic environments. The idea of adaptive method is the combination of machine learning technics. Grammatical evolution is used to evolve C++ codes related user's intent detection. Dynamic time wrapping is used in appraiser which is in charge of a fitness function for the evolutionary process.

Keywords: Rehabilitation Robot, User's Intent Detection, Adaptation, Genetic Algorithm, Symbolic Regression, Dynamic time wrapping

I. INTRODUCTION

Recently, many researches related to helping the disabled and elderly are conducted. Most popular is the area of wearable robots. A wearable or exoskeleton robot is a robot which one can wear like a second skeleton. Representative researches are HAL[1], and ReWalk[2]. HAL was initially designed to augment muscle power of the elderlies but its abilities were extended to walking assistance for paraplegia patients. Another well-known robot is ReWalk, developed by Argomedtec, Israel. ReWalk uses tilt sensors, attached to the torso, and force sensors, located in the robot's soles, to detect the user's intent. The robots mentioned above succeeded in detecting the user's intent, but they have their limitations. The reason for this is that the robots have only been applied to experimental scenarios. Daily life or dynamic environments are much more difficult since several unexpected situations can arise.

In this paper, we propose an adaptive method to detect user's intent in dynamic and daily environments. In order to acquire a proper method, we combined two methods, symbolic regression and dynamic time wrapping.

II. DEFINITION OF USER'S INTENT DETECTION

Before developing a method for adaptive user's intent detection, intent detection for both robot and human has to be defined. In the case of wearable robots, 'the decision at what time which action should be performed is dependent on the users and the actions selected by the user are simply conducted by robot'. In other words, the robot's role can be limited to detecting signals WHAT and WHEN from users and then executing the according behavior. The problem of detecting behavior intention could thus be regarded as a user's intent detection problem. It can be defined mathematically as follows:

$$\mathrm{f}(x_t, \mathrm{s}_t) \rightarrow x_{x+1} \quad (1)$$

$$x_t \in \{state_1, state_2, state_3, \dots, state_n\} \quad (2)$$

$$s_t = [fl_1\ fl_2 \dots ms] \quad (3)$$

In equation (1), function f is the function of user's intent detection. This function computes the state x at time t+1 using the current state x_t and the sensor values s_t as input. The new state x_{t+1} can be the same or different to the previous state. Using the new state, the robot determines and conducts its next behavior.

III. RESEARCH FOR AN ADAPTIVE USER'S INTENT METHOD

Two phases are introduced, one which is a training phase and the other which is an adaptation phase for the proposed method.

Furthermore, the system is organized as shown in Fig. 1. In the training phase, an intention estimator, detecting the user's intent, is developed by grammatical evolution (GE)[3] with off-line sensor data. After development,

this block detects the user's intent from the inputs of the robot's current state and the sensor data at time t. The intention estimator is continuously adapted by GE throughout the robot's task. This phase is called the adaptation phase. In the adaptation phase, a dynamic time wrapping algorithm is used as a fitness function of the intention estimator in an intention estimator appraiser block.

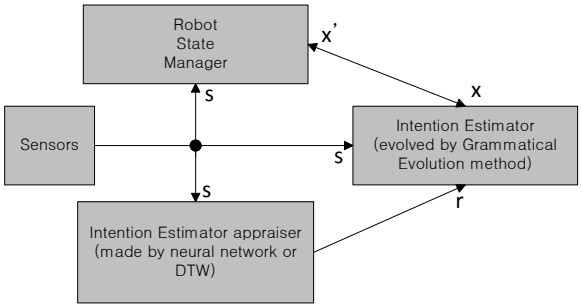

Fig. 1. The block diagram of proposed method

1. Grammatical Evolution

Grammatical evolution (GE) is a sort of symbolic regression method evolving the program code using a genetic algorithm and a Backus-Naur form (BNF). A BNF is a meta language to describe the syntax of programming languages. BNF grammars are defined and binary chromosomes evolved to make the program code of the intention estimator.

2. Dynamic Time Wrapping

Dynamic time wrapping is used to make the fitness functions for the genetic algorithm described above in the adaptation phase. This algorithm has the specialty of measuring similarities between two sequences which may vary in time or speed. In this paper, the similarities between previous and current foot sensor patterns would be detected by this algorithm.

IV. EXPERIMENTS PLAN

To verify our proposed method, experiments are planned using 16 force sensing register (FSR) sensors, located in foot part of rehabilitation robots. Two different experiments will be conducted.

In the training phase experiment, off-line sensor data is used to make the intention estimator function. This data includes 16 FSR values and the result of user's intent detection. A grammar that generates programs for an intention estimator is given below.

<code> ::= <line><code> | <line>
<line> ::= <lhs>=<rhs>; \n
<lhs> ::= <var> | <state>
<state> ::= state
<var> ::= r[0]|r[1]|…|r[13]
<rhs> ::= <arg1> <op> <arg2>
<arg1> ::= <var> | <sensor>
<sensor> ::= s[0]|s[1]|…|s[15]
<arg2> ::= <const> | <var> | <sensor>
<const> ::= <pm>0x<hex><hex><hex>
<pm> := +|-
<hex> ::= 0|1|…|f
<op> ::= + | - | * | & | BITOR | ^ | << | >>

The genetic algorithm setting to be used in the training phase is as follows.

- The generation size is 5000.
- Single-point crossover with probability 0.9
- Bitwise mutation with probability 0.01
- The population size is 500.

In the adaptation phase experiment, we decrease the generation size to 20 and the population size to 3 in order to get the fast evolution. The intention estimator appraiser is used as fitness function of the grammatical evolution.

VI. CONCLUSION

An adaptive user's intent detection method is proposed in this paper. By combining two machine learning method and dividing the process of evolution into two phases, we expect to acquire an adaptive method to detect user's intent. In the future, we will apply this method to our robot and verify its effectiveness.

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