Varying skill prameter based on error signal and its effect

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Abstract

In this paper, we proposed an adaptive skill element based on error signal. We assume that human progress their skills of actions based on errors, then an inverse dynamic of human motion have to changes. Human controller consists from feedback element (FB) and feed forward element (FF) and their elements cooperate to control actions. Under the assumption, we vary the connection of FF and FB by error signal. We propose the index function for change of a skill parameter. From results of the numerical simulations for the varying skill parameter with index function, we consider that the position error given by our vision changes the skill element and we confirm that the position error is the one of the estimate function for the improvement in our skill.

Keyword: skill element, Kawato–model, adaptive changing.

1 Introduction

Many models that describe the human dynamics have been proposed in recent year and two types in the models are generally known [1, 2]. While one type does not need an inverse model of human dynamics for arm action, the system based on the model does not include feedforward loop[4]. First type model assumes that we only control a motion of our arm by feedback element. Under the assumption, the inverse model is not used. On the other hand, another type model has a feedforward loop and feedback loop systems which control the motion dynamic. The feedback loop has an effect on stability and the feedforward loop relates to skill. While the feedforward element gets an internal model of process by repeating action or training, the feedback control element is made through process of growth. Therefore the feedback loop compensates a robust stability. Then we can make actions like walk, run or throw well. If we want to attain to higher performance for actions or skills, however, we usually have to exercise. This says that we design the motion model by training and we move on prediction for motion. Under the assumption, Kawato model is well known as a representative human motion model[5]. The model proposed that learning of feedforward element is promoted in brain so that the error of feedback loop decreases. The model is based on an assumption such that the feedforward element changes by experiences so that we can obtain the higher skill by training. Therefore, we regard the feedforward element as an internal model of a task. Furthermore, after giving the model, we think that the connections in feedback loop and feedforward loop are changed by an element. The element is called as a skill element in this paper. We assume that a miss for task alters the connections. We make the skill element adapt by the error, between a reference trajectory and the moving of the arm and we research how the adaptive changing is efficient in decreasing the error.

In this paper, we investigate an effect of varying skill parameter based on error signal in numerical simulations. We change the element in a feedforward loop by a visual error signal which represents the difference between a reference position and an arm position. From results of the numerical simulations, we consider that the position error given by our vision changes the skill element and we confirm that the position error is the one of the estimate function for the improvement in our skill.

We start with a simple feedback and feedforward configuration, in which feedforward element is made in a brain by experience or training. Above mentioned element can be regarded as a process of getting the skill. Furthermore the element includes the inverse model of a human dynamics. On the other hand, the feedback loop has two elements such that a controller model and an arm model. The controller is simply given by the PID elements. We change the skill element $a(t)$ by a function based on the error $e(t)$. We assume that we modify the error by information from our eyes and the sense of touch. Furthermore we believe that we learn the skill from our memory of the error so that our experiences improve our skill and decrease mistakes in our movements. On the other hand, we correct the output error by the position error. For their reasons, we proposed a index function for varying skill element which consists from a error term for our experience and our memory.

We perform numerical simulations to illustrate the effect of the varying skill element and we change the element $a(t)$ based on the output error in order that how the varying skill element influent convergence of error.

This paper is organized as follows. In Section 2, we introduce the Kawato–model and propose the index function for varying skill parameter. Section 3 explains a condition of the simulations and discusses the simulation results. In the last section, we presents a conculusion and future work.

2 Arm dynamical model

We start with a simple feedback and feedforward configuration (see Fig.1), in which feedforward element is made in a brain by experience or training. Above–mentioned element can be regarded as a process of getting the skill. The element includes the inverse model of a human dynamics. On the other hand, the feedback loop has two elements such that a controller model and an arm model. The controller is simply given by the PID elements and the arm dynamical model is given by

$$m\ddot{x}(t) + b\dot{x}(t) = ku(t), \tag{1}$$

where $u(n)$ is an input signal from brain, $x(n)$ is an arm position, m is a load, b is a muscle and k is an amplitude of the signal from brain. feedback loop includes an axonal delay L_1 and a delay of vision L_e. Since human model must assure the stability, the controller in a human has to compensate for the time delay elements. The element proving the closed loop stability is modeled by a smith predictor such as

$$\frac{e^{-Ls} - 1}{ms^2 + bs},$$

where delay term L is given by the approximate number of the L_1 and L_e. The feedforward element is usually given by an inverse model of human dynamics given by

$$\frac{ms^2 + bs}{k}.$$

Since the inverse model is not causal system. Because of this reason, we use the pseudo inverse

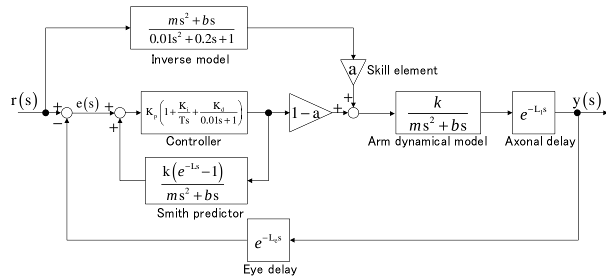

Fig. 1 Block diagram of a human dynamical model.

model given by

$$\frac{ms^2 + bs}{0.01s^2 + 0.2s + 1}.$$

We change the skill element a by a function based on the error $e(t)$ under the assumption that we modify the error by information from our eyes and the sense of touch given by figure2. We believe that we learn the skill from our memory of the error. Our experiences improve our skill and decrease mistakes in our movements. On the other hand, we correct the output error by the position error. For their reasons, we give the varying skill element $a(t)$ as

$$a(t) = a\left\{ w\frac{|e|}{|e|+1} + (1-w)\left(1 - \frac{\int_0^t |e|d\tau}{\int_0^t |e|d\tau + 1}\right)\right\} \tag{2}$$

where w is a positive constant and the function $|e|/\left(|e|+1\right)$ is a related term of the output error. The another function $\int_0^r |e|d\tau / \left(\int_0^r |e|d\tau + 1\right)$ represents the memory term for our experience. We assume that our skill makes a progress by repeating action and many errors. Under the assumption, we think that the skill element for the memory $\int_0^r |e|d\tau / \left(\int_0^r |e|d\tau + 1\right)$ goes to 1 and we get the term by $1 - (\int_0^t |e|d\tau)/(\int_0^t |e|d\tau + 1)$.

3 Simulation results

We perform numerical simulations to illustrate the effect of the varying skill element. First we make a simulation for $a = 0$ in order that we show the performance of feedback factor. The other parameters in the simulation are given by $m = b = K = 1$ and $k_p = 25$, $k_i = 1/5$, $k_d = 6/5$, $T = 1$, respectively. The delay time L_1 , L_e and L are 0.03[s], 0.02[s] and 0.05[s] and the reference trajectory r is a step function. The simulation result of an only feedback element is given by figure 3. The figures show that the feedback controller affects the response speed and feedforward element reduces the response. For the influence of the feedforward element, we give the delay L in a smith predictor by $L = 0.15$, which is not equal to $L_1 + L_e$. Figure 4 is a result for

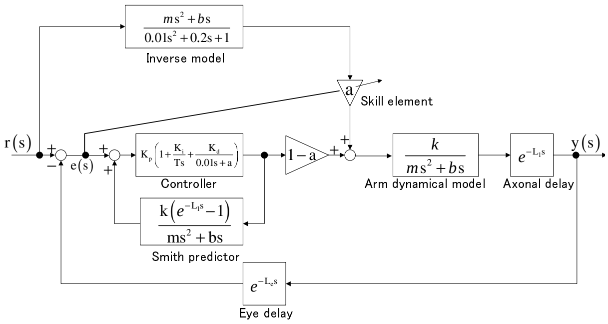

Fig. 2 Block diagram of a human dynamical model with changing skill element.

$L = 0.015$. The output of $a = 0, a = 0.3, a = 0.5$ and $a = 0.9$ are given by solid line, wave line, dot and dotted line respectively. The result says that we move our arm smoothly by feedforward element. Next we change the element a based on the output error. Figure 2 shows the block diagram and the estimation for adaptive changing $a(t)$ is given by equation(2) where w is a positive constant and we give the constant by Table 1. We change the element near constant $a = 0.7$ and the reference trajectory r is given by a square signal with period 12[s] in order to research an effect for the skill in reputation action. Figure 5 to figure 8 show the errors of an arm position. The broken lines, the dotted lines and the solid lines in these figures are results for reference trajectory positions, the positions with constant skill element a and the positions with adaptive changing elements. As compared with the constant skill element, the adaptive varying skill element decreases the output error. Especially the results indicate that the change of a based on our memory of error is efficient at our repeat action and the constant skill element results say the memory of the error more influences the repeating action than a position error.

4 Conclusion

In this paper, We have presented an efficiency of the adaptive varying skill element by numerical simulations. The index function of varying for the skill element $a(t)$, we used the sum of two type error function which is for the position error and the memory of error. For the simple task such as repetition motion, the change of a based on the failure of our motion affect human motion. Particularly it is very validity that the feedforward element is added under a estimation for $\int_0^r |e|d\tau / \left(\int_0^r |e|d\tau + 1\right)$ when the delay L in a smith compensation does not get a correct value as $L_1 + L_e$. The error of position converges to a reference position with the memory of the error though the best parameters in the controller are not given. We are studying to investigate other function.

Table 1 positive constant w

	(i)	(ii)	(iii)	(iv)
w	0	0.2	0.5	1

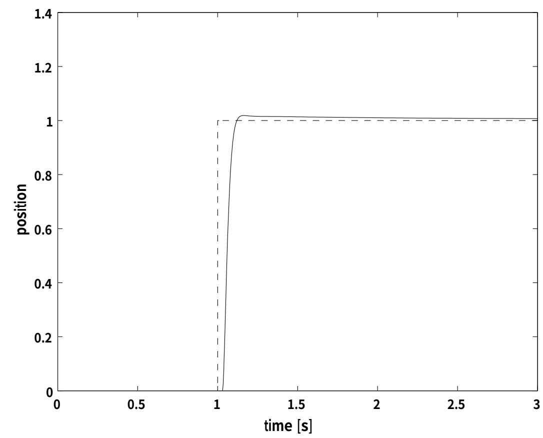

Fig. 3 Position for $a = 0$

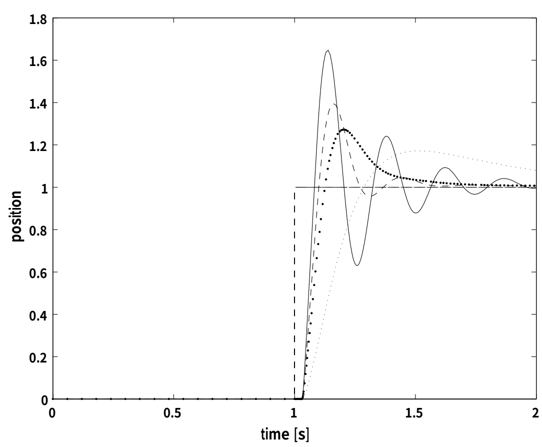

Fig. 4 Position for $L = 0.015$; $a = 0$:solid line, $a = 0.3$:wave line, $a = 0.5$:dot and $a = 0.9$: dotted line.

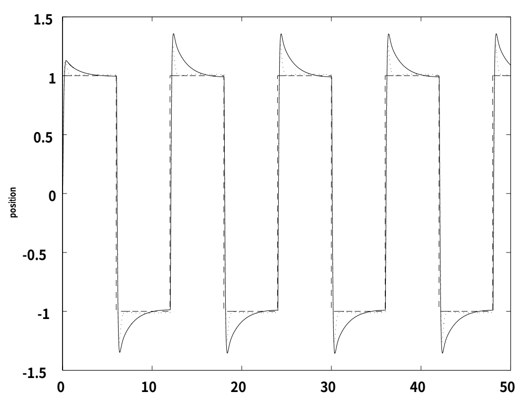

Fig. 5 Position for $w = 1$.

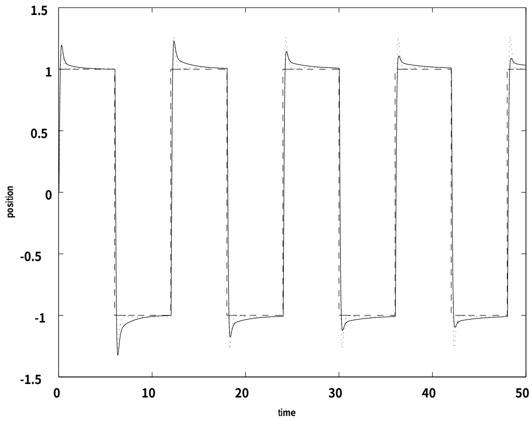

Fig. 6 Position for $w = 0.2$

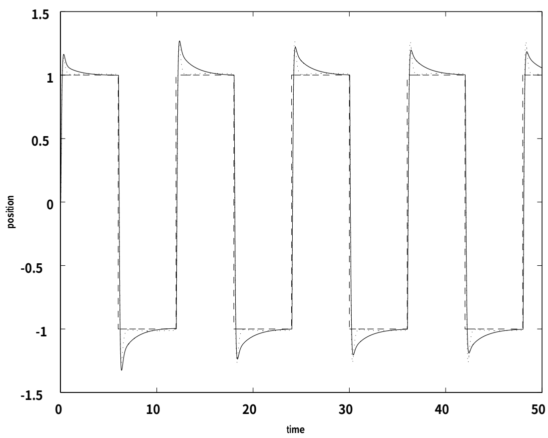

Fig. 7 Position for $w = 0.5$

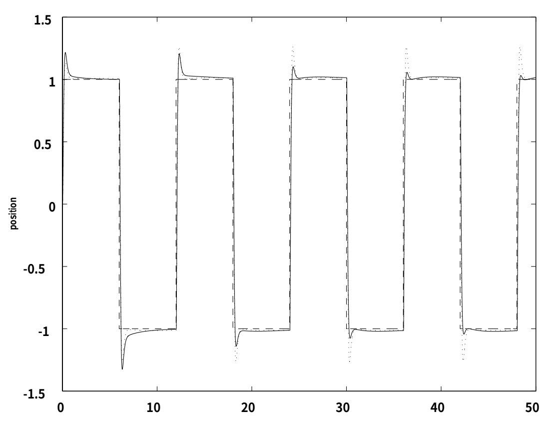

Fig. 8 Position for $w = 0$

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