# VSS Robust Adaptive Control Including a Self-Tuning Controller for a Rotary Inverted Pendulum

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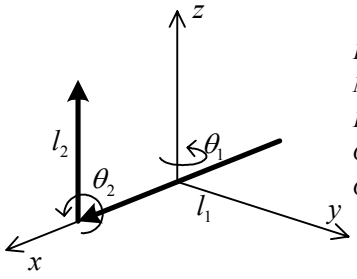
So many papers with respect to the stabilization of the inverted pendulum are reported, because it is typically unstable system and is well used as example to verify many control theories. However, few approaches consider the inverted pendulum as unknown parameter system.

This paper proposes a new VSS (Variable Structure System) robust adaptive control system including a self-tuning controller for a rotary inverted pendulum as shown in Fig.1 whose whole parameters are unknown. The control system prepares two kinds of adaptive controllers as shown in Fig. 2, and the stabilization of inverted pendulum is achieved by separating the system to two parts of the pendulum and the rotary arm. The rotational angle of the pendulum is stabilized by tracking type's VSS adaptive control method, and the rotary arm is simultaneously stabilized by STC (self-tuning control) system that assures the boundary reference angle of the pendulum. It is then not sufficient to construct STC system by using only adjustable parameter of VSS adaptive control system.

Therefore, whole basic parameters are recursively estimated in order to realize STC system by using LS (least squares) parameter adaptive law, and it is achieved by superposing the perturbation signal to the stable adaptive control input on limited short interval. Furthermore, STC system designs LQ controller by developing an efficient QR method for real time operation.

Finally, the validity of the proposed system is demonstrated through some numerical simulations and practical experimental result (which is shown in Fig. 3). The rectangular wave (i. e. the amplitude of wave form is bipolar of 1.0 ampere and the period is 1.0 second) is used for the parameter estimation as the perturbation signal, which is superposed to the adaptive control input until passage of 4 seconds after starting the experiment.




*Link length* : $l_1, l_2[m]$
*Mass* : $m_1, m_2[kg]$
*Inertia* : $I_1, I_2[kgm^2]$
*Center of balance* : $a_1, a_2[m]$
*Gravity acceleration* : $g[m/s^2]$

Fig. 1. Diagram of the rotary inverted pendulum

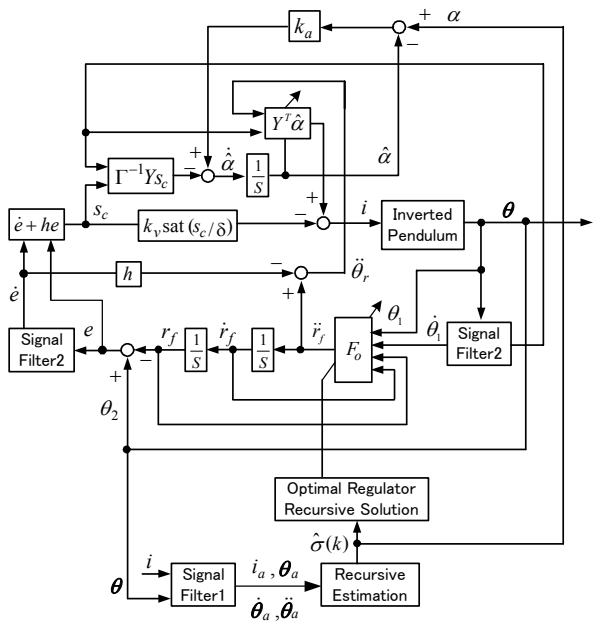



Fig. 2. Block diagram of VSS adaptive control system

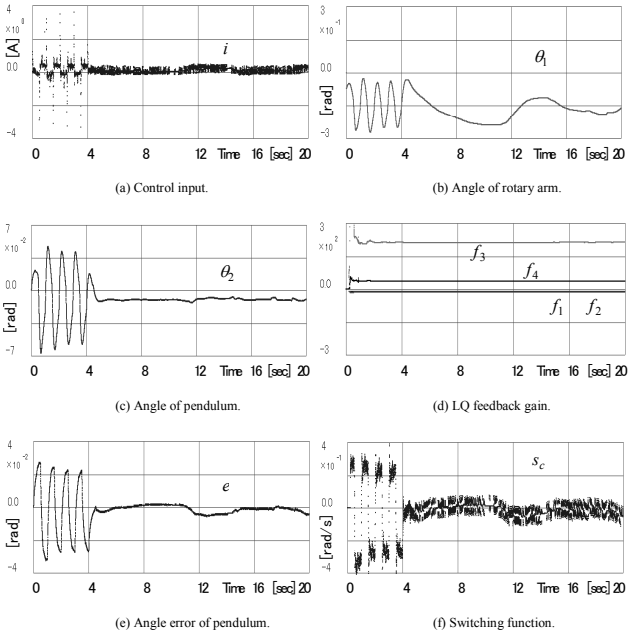



Fig. 3. Experimental result