Title	ロボットアームの適応制御における計算量の軽減に関する研究
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Citation	
Issue Date	1997-03
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/1052
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A Research of Reducing Computation Rate in Adaptive Control for Robot Manipulators

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February 14, 1997

Keywords: simple adaptive control, multi-variable model reference adaptive system, high-speed control, nonlinear compensator, multi-joint robot .

Abstract

Nowadays, the use of multi-joint/multi-linked robots in industrial world has became widely spread. Various usage of these robots leads to the necessity of high-precision and high-speed motion controllers, and for this reason many researchs are being performed.

Once we plan to build a controller for a robot, usually we use conventional feedback control techniques. First, we estimate the robot model, adjust its parameters, and then calculate the feedback coefficients. However, with these rules, the control accuracy and reliability is very much affected by the numerical expression of the object (robot itself), or influenced by friction, measurement errors, noises, and other disturbances.

To solve these problems, adaptive control methods had been introduced. Two typical examples of this control method are MRACS (Model Reference Adaptive Control System) and STR (Self-Tuning Adaptive Regulator). However, the structures of these controllers are very complicated. For instance, for a single-input single-output plant with n-dimensions, MRACS needs as many as $4n$ integrators.

For these reasons, we introduce Simple Adaptive Control (SAC), a control technique that has a relatively small quantity of calculation in its controller, compared with other methods of adaptive control.

SAC is a new type of model-reference adaptive control technique. Compared with other adaptive control methods like model-reference adaptive control system (MRACS), SAC is more generous and easy to use. The main difference between MRACS and SAC is that, while MRACS can be applied only to system that satisfies SPR condition, SAC only

needs a plant that suffices ASPR condition. For a non-ASPR plant Parallel Feedforward Compensator (PFC) $F(s)$ is usable, such that the augmented plant

$$G_a(s) = G_p(s) + F(s)$$

becomes ASPR.

We found that SAC has some capabilities to give better performance than PID control methods. Thus, we considered this control technique is more suitable for robotic control experiments. For a multi-linked robot, multi-link synchronous control will become a necessity. SAC is expected to reduce interferences between links, and it will be very useful for such this multi-link synchronous control system. We have evaluated the use of Multi Variable SAC (also called MIMO-SAC, Multi-Input Multi-Output SAC). The result was that, MIMO-SAC is very useful for small systems with small number of inputs/outputs. However, unfortunately it is still not suitable for large scaled systems with large number of inputs/outputs. The bigger the system, the number of controller cells (integrators, adders, multipliers, etc.) increases in a quadratic order, and thus the calculation af control signals becomes very complex.

As described above, SAC has a robustness in terms of plant stability condition. Moreover, the assignment of plant transfer characteristics is given in a feedforward loop (from this point SAC takes the form of a 2-DOF[1] control structure). We found that the pattern of the inverse of transfer functions matrix is identic with the connection formation between subsystems.

The feedforward controller takes the form of

$$G_c(s) = G_p(s)^{-1} G_m(s)$$

and thus, if we choose a simple reference model to be tracked, the shape of transfer function matrix of the controller only depends on the inverse of transfer functions matrix of the plant. Using these special characteristics, we can progressively remove the unnecessary controller cells.

The other problem that needs to be solved is that SAC (like MRACS or other methods of adaptive controller) was developed to solve the control problems in linear systems. On the contrary, robot is a typical example of nonlinear system. SAC will not match this condition if it is used without any improvements.

One solution we found is that, if robot dynamics can be described in a quasi-formula

$$\dot{x}(t) = Ax(t) + Bu(t) + h(t, x(t))$$

that split the dynamics into linear and nonlinear parts, then we can build a nonlinear compensator to compensate the robot nonlinearity aggresively. Although this mechanism is mainly expected to compensate the linearity of the robot, it can also be expected to compensate the interferences between links.

To alleviate *chattering* (furious vibration of input signals) that may be occured during the control process, it is also recommended to use PI algorithm in the parameters adjustment mechanism.

[1]degree-of-freedom

To conclude, SAC is a simple adaptive control method that more applicable than other methods of (very complex) adaptive systems. SAC is easy to use in practical experiments, because it only needs the plant satisfies ASPR condition or (even) non-ASPR plant that ASPR-able, comparing with the conventional model reference adaptive systems that require SPR plants.

However, for a large scaled system, the use of MIMO-SAC comes up against a control complexity problem.

In this thesis we introduced how to solve this complexity, and also how to deal with systems with nonlinear characteristics.