SEP CONACYT
Consejo Nacional de Ciencia y Tecnología

México D. F., a 7 de enero de 1999.

DR. WEN YU LIU
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SAN PEDRO ZACATENCO
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Presente

Ref. : 28070 - A LA PASIVIDAD ACERCA A NEURO SISTEMA DE CONTROL

Con relación al proyecto de referencia que fue sometido al procedimiento de evaluación por concurso en la convocatoria 1998, me es muy grato comunicarle a usted, que el comité del área correspondiente después de analizar las evaluaciones externas sobre el mismo, emitió el dictamen de que sea apoyado por el CONACYT para su realización.

Se anexa el acta de dictamen.

Así mismo, le solicito en caso de haber cambiado, los nombres completos del Titular de la Institución y/o el administrador del proyecto.

Atentamente

Fis. Jesús Cervantes Servín
Subdirector de Evaluación

ccp. Dr. Jaime Martuscelli. Director Adjunto de Investigación Científica.
Dr. Marcial Bonilla Marín. Director de Apoyo a la Investigación.
Institución.

Passivity Approach to Neuro Control System

CONACyT-28070A 1998-2000

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Resume (110)

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In recent years, learning-based control using neural networks has emerged as a viable tool for the control of nonlinear systems with unknown dynamics, but the lack of a model for the controlled plant makes hard to obtain theoretical results on the stability and performance of neuro control system. There are not many results on stability analyses of neuro control in spite of successful applications of neural networks. Only a few results published regarded identification error and tracking error analysis using Lyapunov-like method. But the boundness of these errors cannot assure all the signals at any point in the closed-loop system are bounded. Also, if there exist disturbance and unmodeled dynamics, the stability of closed-loop system (robustness) is very important for control system analysis. But for closed-loop this analysis is almost impossible because of lacking of the system model.

A promising approach to stability analysis of such neuro control systems may be the passivity framework, since it can lead to general conclusions on the stability of broad classes of nonlinear control systems, using only some general characteristics of input-output dynamics of the controlled system and the input-output mapping of the controller. Because passivity theory deals with nonlinear control systems whose controller characteristics can be poorly defined, usually by means of sector bounds, but it offers elegant solutions for the proof of absolute stability of such systems.

On the other hand, passivity approach is very effective for stability analysis of nonlinear system. Some nonlinear systems can be rendered passive by a state feedback control which is depended on the system model. If the nonlinear system are totally unknown, only the input-output dates are available, passifying this system is a big challenge for control engineer. A reasonable method is to use neural networks to identify the unknown nonlinear system, then a passifying control is employed to the

neural networks. If the identification error is bounded in some zone, this passifying control should also passify the unknown nonlinear system.

To the best of our knowledge, the internal stability of neuro control (all signals are bounded in closed-loop) and passifying an unknown nonlinear system have not yet been established in the literature. In this study we assume that: the system is absolutely unknown and the states of the system are measurable.

To finish this project we need to combine the two popular methods together: Neural Networks and Passivity. When we study the internal stability of neuro control, we need passivity method because passivity only need input and output properties, and neural network do not need the model of the nonlinear system either. So passivity is a very effective tool to study the closed-loop system of neuro control. When we passify an unknown nonlinear system, neural network is also very useful. Because until now maybe neural networks is most effective tool to model a unknown nonlinear system. Neural networks may model any nonlinear function any accuracy if we select the hidden layers big enough, we can design a controller to passify this neural network and employ it to the real nonlinear system.

We will reach following results: (1) Propose a new weight-update laws to guarantee the internal stability of neuro control. Use passivity method to proof this results. So this neuro controller is more safety. (2) Propose a passive feedback controller which is not depended on the nonlinear mode. We only use its inputs and outputs to construct a neuro identifier and a passive controller. This passive feedback controller is general, it is suitable for a large class of nonlinear system. (3) We will present two software package with MATLAB, one is stable neuro controller; another one is passive feedback controller for a class of nonlinear systems.

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Object of the project (5)

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Propose a new weight-update laws to guarantee the internal stability of neuro control..

Propose a passive feedback controller which is not depended on the nonlinear mode.

We will present two software package with MATLAB, one is stable neuro controller; another one is passive feedback controller for a class of nonlinear systems.

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ANTECEDENTES (300)

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In many application, learning-based control using neural networks has emerged as a viable tool for the control of nonlinear systems with unknown dynamics. This model-free approach is presented as a nice feature of neural networks, but the lack of a model for the controlled plant makes hard to obtain theoretical results on the stability and performance of neuro control system, for a engineer it is very important to assure the neuro controller is stable in theory before he apply it to a real system. The application of neural networks to automatic control is usually for building a model of the plant (identification), then on the basis of this model to design a control law, or use neural networks as a controller (direct neuro control). There are not many results on stability analyses of neuro control in spite of successful applications of neural networks. There are only a few results published regarding identification error and tracking error analysis using Lyapunov-like method. But the boundness of these errors cannot assure all the signals at any point in the closed-loop system are bounded. Also, if there exist disturbance and unmodeled dynamics, the stability of closed-loop system (robustness) is very important for control system analysis. The existing results are only on identification errors analysis and input-output stability proof. To the best of our knowledge, the internal stability of neuro control (all signals are bounded in closed-loop) has not yet been established in the literature.

Passivity is an input-output property of nonlinear system. A passive system can easily stabilized by a simple feedback control, for example, high gain feedback. The passivity method plays an important role of stability analysis of nonlinear system in past three decades. Recently, a new interest has emerged in robust control and adaptive control of nonlinear system. In certain conditions a feedback control can be designed to make the nonlinear system passive (feedback passive). This controller is strongly depend on the structure of the nonlinear system. For example, if the nonlinear system is partly known, only some linear parameters are unknown, an adaptive passive approach may be used; if there exists unmodeled dynamic, a robust passive approach may be used. But if the nonlinear system is completely unknown, there is no any results about how to passify this system.

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METODOLOGIA (250)

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To analyze the internal stability of neuro control and passifying an unknown nonlinear system, we need to combine the two popular methods together: Neural Networks and Passivity.

The internal stability analysis of neuro control is almost impossible with general tools because of lacking of the system model. However many neuro control can be viewed as nonlinear control framework characterized by a bounded continuous input-output mapping with some properties. A promising approach to stability analysis of such neuro control systems may be the passivity, since it can lead to general conclusions on the stability of broad classes of nonlinear control systems, using only some general characteristics of input-output dynamics of the controlled system and the input-output mapping of the controller. Passivity theory deals with nonlinear control systems whose controller characteristics can be poorly defined, usually by means of sector bounds, but it offers elegant solutions for the proof of absolute stability of such systems. For example, if the system is passive and it is zero-state detectable, any output feedback may stabilize the equilibrium of the nonlinear system. For this reason the framework of passivity theory is very convenient for stability analysis of nonlinear control systems based on neural networks.

When we passify an unknown nonlinear system, neural network is also very useful. Because until now maybe neural networks is most effective tool to model a unknown nonlinear system. The static neural network may be used for the nonlinear function approximation, the passive equivalence controller will be designed based on this neural network because the nonlinear functions are unknown. The dynamic neural network may be used as model the whole nonlinear system, we can design a controller to passify this neural network, and after to employ it in the real nonlinear system. Because neural networks may model any nonlinear system in any accuracy if the hidden layers is big enough, only a small modeling error is exists, this unmodeled dynamic can be deal with robust passivity framework.

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OBJETIVOS Y METAS (300)

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INFRAESTRUCTURA Y APOYO TECNICO DISPONIBLE (170)

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1. This project will be done in the section of automatic control of CINVESTAV, here we have many professors work on passivity and neural network, we already get many results in these areas. This condition is very important for the theory study.
2. In this section we have several experimental devices can be used, for example experimental robots, inverse pendulum, etc. We can apply the new algorithm to these equipment. The application

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CALENDARIO ACTIVIDADES CUATRIMESTRAL (60)

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This project is two years:

1. Prepare stage (2 months): in this period we will propose a basic framework which may combine passivity approach with neuro control system
2. Algorithm study and theory analysis (10 months): we will use passivity method to study several neural network and use neural network to study passive equivalence of unknown nonlinear system.
3. Simulation (6 months): in this period we will use Matlab_Simulink toolbox to design a software package, and modify the algorithm if the simulation results are not satisfied.
4. Apply the new control algorithm on the real system (6 months): we will apply the simulation package to some real system, such as robots, inverse pendulum, etc. It is very important to testify the effectiveness of the control algorithms

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RESUMEN DEL PROTOCOLO EN INGLES (60)

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In recent years, learning-based control using neural networks has emerged as a viable tool for the control of nonlinear systems with unknown dynamics, but the lack of a model for the controlled plant makes hard to obtain theoretical results on the stability and performance of neuro control system. There are not many results on stability analyses of neuro control in spite of successful applications of neural networks. There are only a few results published regarding identification error and tracking error analysis using Lyapunov-like method. But the boundness of these errors cannot assure all the signals at any point in the closed-loop system are bounded. Also, if there exist disturbance and unmodeled dynamics, the stability of closed-loop system (robustness) is very important for control system analysis. But for closed-loop this analysis is almost impossible because of lacking of the system model.

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DESGLOSE FINANCIERO

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MANTENIMIENTO DE EQUIPO MAYOR 20,000
(GREATER EQUIPMENT MAINTENANCE)

HONORARIOS POR SERVICIOS PROFESIONALES 40,0000
(HONORARY BY PROFESSIONAL SERVICES)

V I A T I C O S 20,000
(viaticum)

PASAJES 20,000
(PASSAGER)

GASTOS DE TRABAJO DE CAMPO (EXPENSES OF FIELD WORK)	50,000
EDICIONES E IMPRESIONES (ISSUES AND IMPRESSIONS)	30,000
SERVICIOS EXTERNOS Y COMERCIALES (EXTERNAL AND COMMERCIAL SERVICES)	40,000
CUOTAS DE INSCRIPCION (REGISTRATION QUOTAS)	20,000
PROFESORES VISITANTES (VISITOR TEACHERS)	60,000
BECAS PARA PROYECTOS DE INVESTIGACION (SCHOLARSHIPS FOR INVESTIGATION PROJECTS)	0
ARTICULOS, MATERIALES Y UTILES DIVERSOS (ARTICLES, MATERIAL AND VARIOUS EQUIPMENT)	40,000
DOCUMENTOS Y SERVICIOS DE INFORMACION (DOCUMENTS AND INFORMATION SERVICES)	15,000
L I B R O S	5,000
ANIMALES PARA RANCHO Y GRANJA (ANIMAL FOR MESS AND FARM)	0

EQUIPO DE LABORATORIO 11,000
(LABORATORY EQUIPMENT)

EQUIPO DE COMPUTO 20,000
(EQUIPMENT OF COMPUTED)

HERRAMIENTAS Y ACCESORIOS 30,000
(TOOLS)

TOTAL-> 410,000