COMMERCIAL APPLICATIONS

by

Masaki Togai
Togai InfraLogic, Inc

Fuzzy Logic Workshop
14 November 1990

N93-31441

29

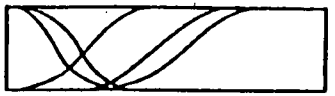
INTERNATIONAL PAPER

S2-67
163076
p. 36

CARTOONS

Nihon-zone

Leigh & Leigh



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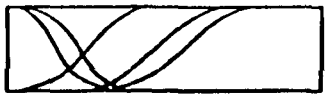
ARTIFICIAL INTELLIGENCE ON A CHIP

Fuzzy Logic

Is Well Suited For Handling

Non-Linear, Time-Varying, and/or Ill-Defined Problems



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Japanese Companies Employing Fuzzy

Canon	SLR camera focusing	P
	Stepper control	P
Casio	Clean room temp & humidity control	P
Daidan	Gas cooling plant	P
Fuji Electric	Chemical mixer	P
	Waste burning plant	P
Hitachi	Sendai Subway control	P
	Elevator control	P
Idec Izumi	GaAs crystal growth	D
Ishida Instruments	Automatic measuring	P
Leon Auto Machinery	Food processing	P
Nippon Steel	Iron mill control	P
Maruman	Golf club selection	P
Mycom	Robotic controllers	D
Meiden-sha	Dredging control	P
	Machine control	P
Minolta	Camera focusing	D
Mitsubishi Chemical	Cement kiln control	P
Mitsubishi Electric	Elevator control	P
	Plasma Etching	P
Mitsubishi Heavy	Air-conditioning systems	P
Matsushita (Panasonic)	Temperature controllers	P
Nissan Motor Company	Automatic transmission	D
	ABS braking system	D
Nuclear Power Corp	Nuclear power plant control	D
Omron	Factory controllers	P
	Robotic controllers	D
	Camera stabilizers	D
Ricoh	Camera focusing	D
	Voice Recognition	D
Sanyo	Camera iris control	P
Seiko	Design expert system	D
Subaru	Automatic transmission	P
Toshiba	Elevator control	P
	Product design expert system	D
Yamaichi Securities	Stock trading	P
Yokogawa Electric	Digital measurement systems	P

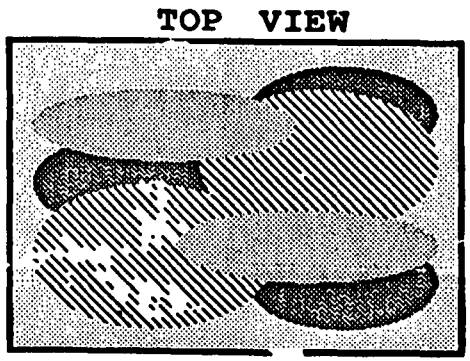
P - Production
D - Development

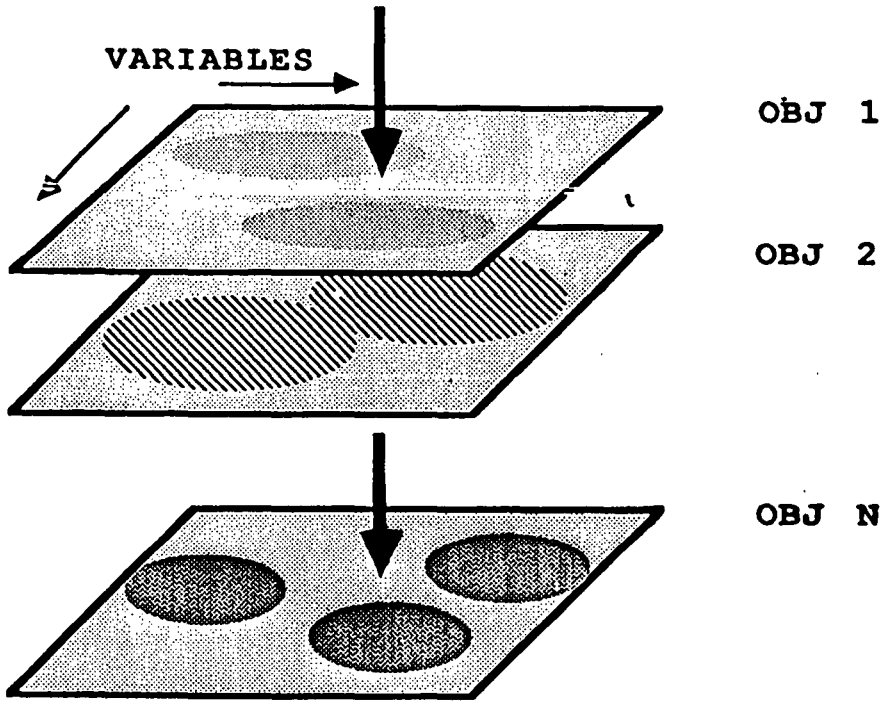
SUITABLE APPLICATION AREA OF FUZZY THEORY

	SUITABLE PROBLEMS		
	Man-Machine Interface Problem	Time-varying dynamics/non-linear problem	Classification problem
Problems of conventional approach	•Difficult to express control objecitives numerially •Evaluate the control result by human feeling	•Plant dynamics varys in time •Plant is non-linear ↓ overshoot oscillatior	•Action to be taken is not clear •Cannot describe all solutions for possible patterns ↑ speed/hardware limitations
Applications	Sendai subway Suspension control Crane control Automatic transmission	Temperture control of A/C, plant, etc. Position control of a hard-disk head Auto-cruise	Auto-iris/auto-focus Hand-written character recognition Automatic transmission

TOGAI INFRALOGIC, INC.

CHARACTERISTICS OF FUZZY CONTROL





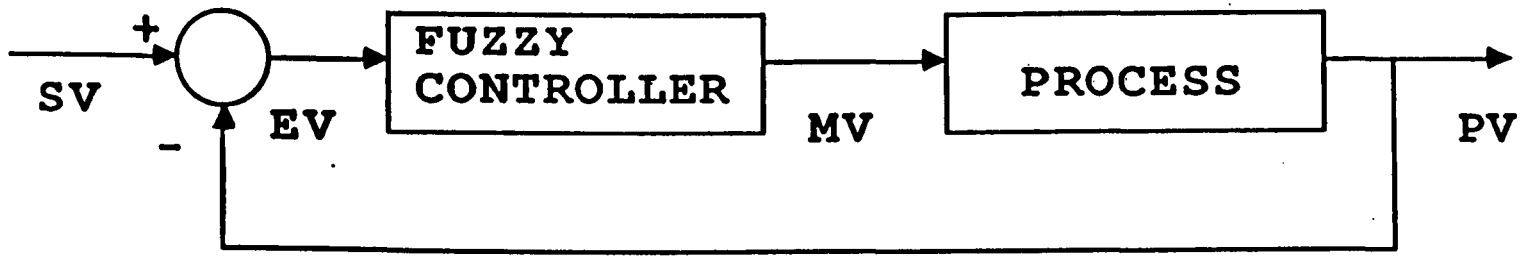
PARALLEL/DISTRIBUTED CONTROL

CHARACTERISTICS OF FUZZY CONTROL

- PARALLEL/DISTRIBUTED CONTROL
- PRODUCTION RULES (IF-THEN)
  - SIMPLE KNOWLEDGE REPRESENTATION
  - MIXED PREMISE EVALUATION
  - EXCEPTION HANDLING
- QUALITATIVE EXPRESSIONS

→ IMPROVEMENT ON QUALITY & ROBUSTNESS

FUZZY CLOSED-LOOP CONTROLLER



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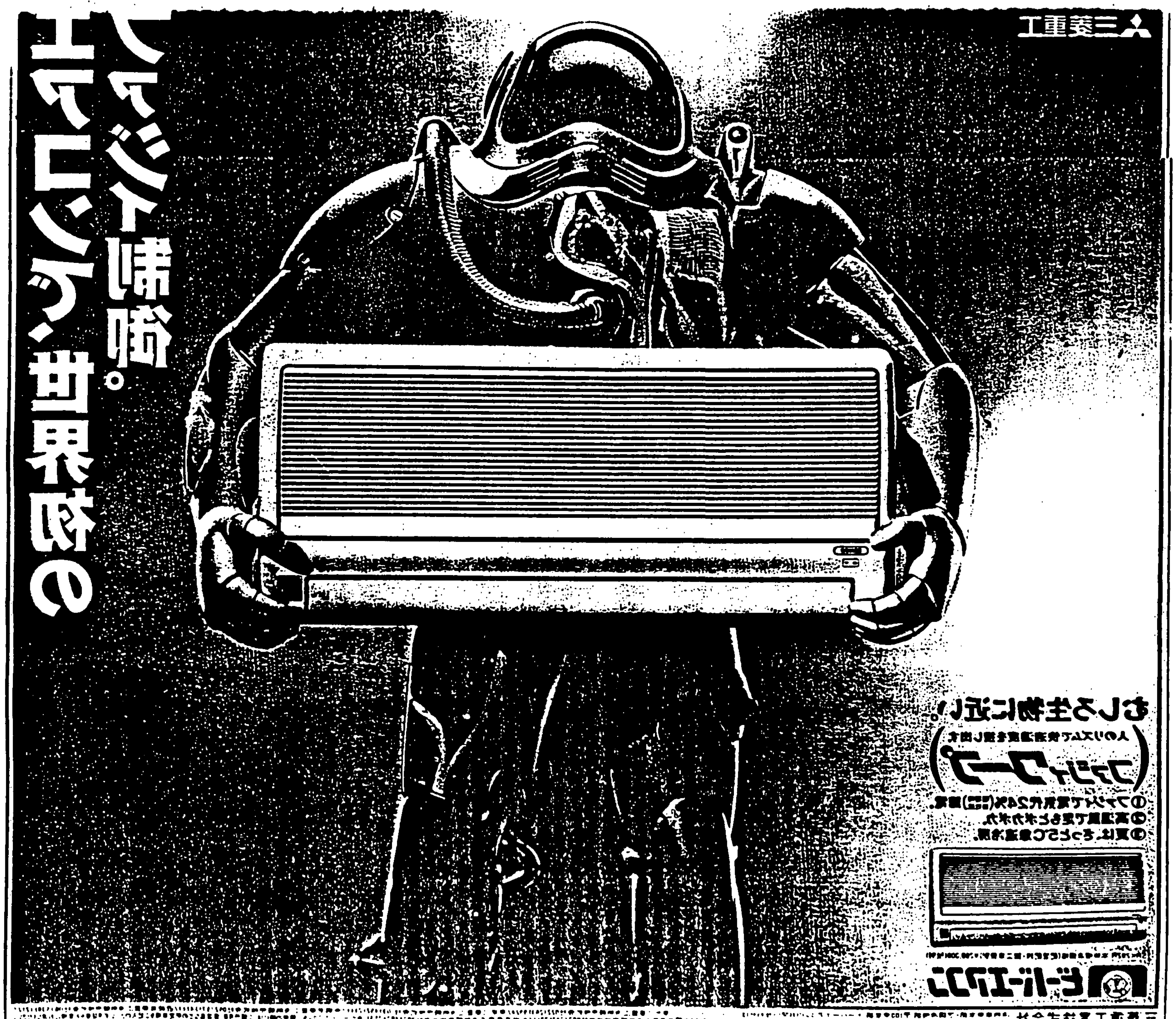
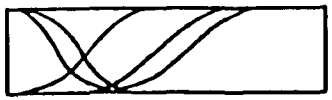
KYOTO-3



三菱重工
エアコンで、世界初の
ファジイ制御。
むしろ生物に近い。
ビーバーエアコン
三菱重工業株式会社



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Mitsubishi Heavy Air Conditioner

April 1988 First Design

Simulation by Summer

Production October 1989

Togai InfraLogic, Inc.
ARTIFICIAL INTELLIGENCE ON A CHIP

Mitsubishi Heavy Air Conditioner

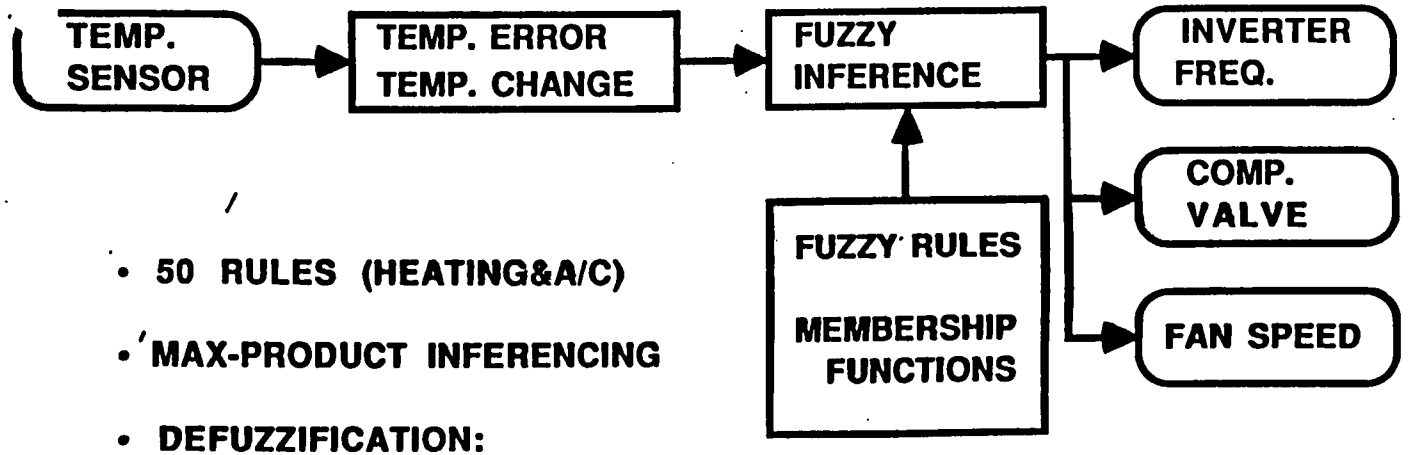
Room Heating and Cooling Times Reduced by 5X

Temperature Stability Increased by 2X

Overall Power Savings of 24%

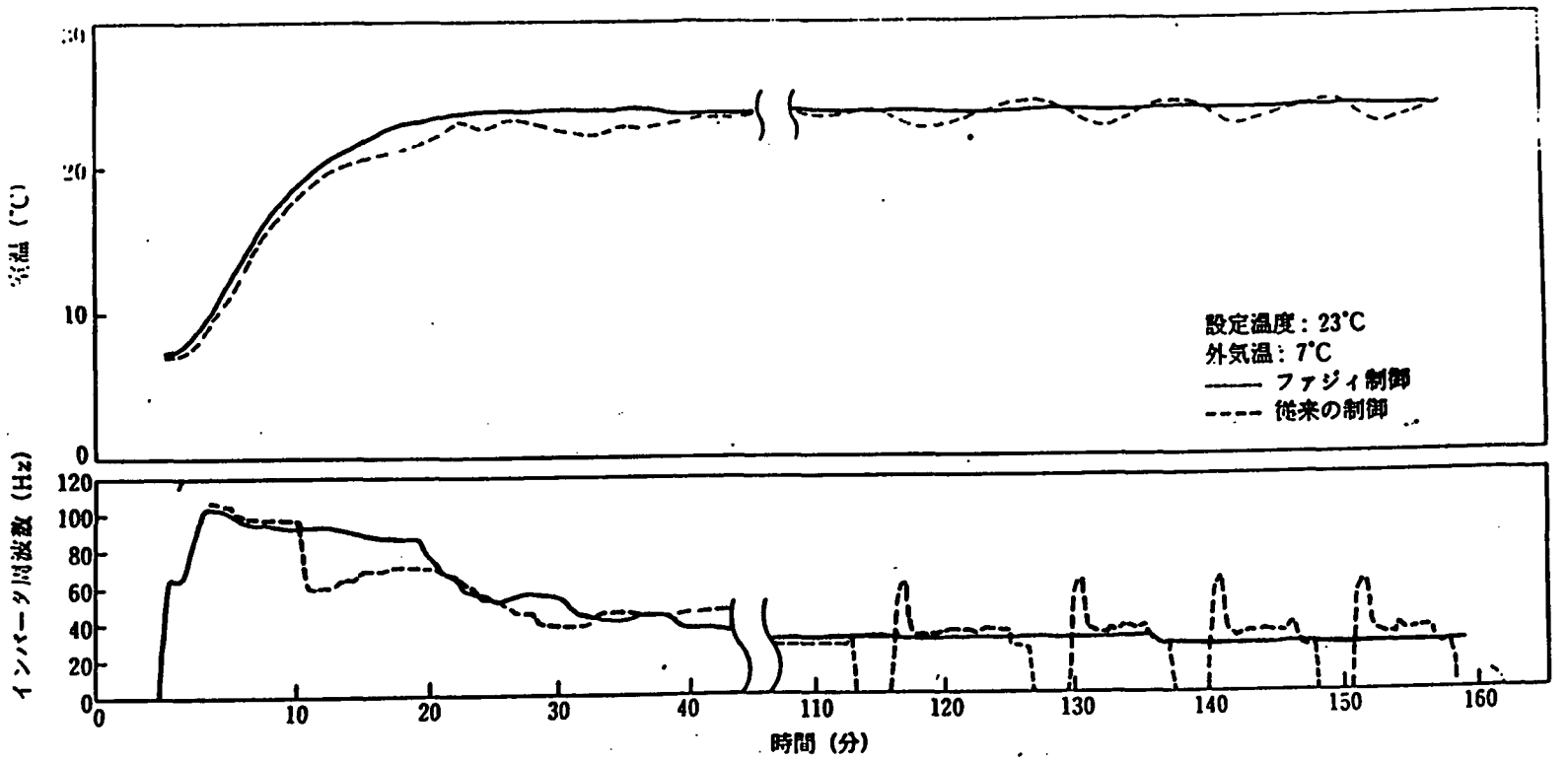
Reduced the Required Number of Sensors

FUZZY INVERTER AIR CONDITIONER SYSTEM

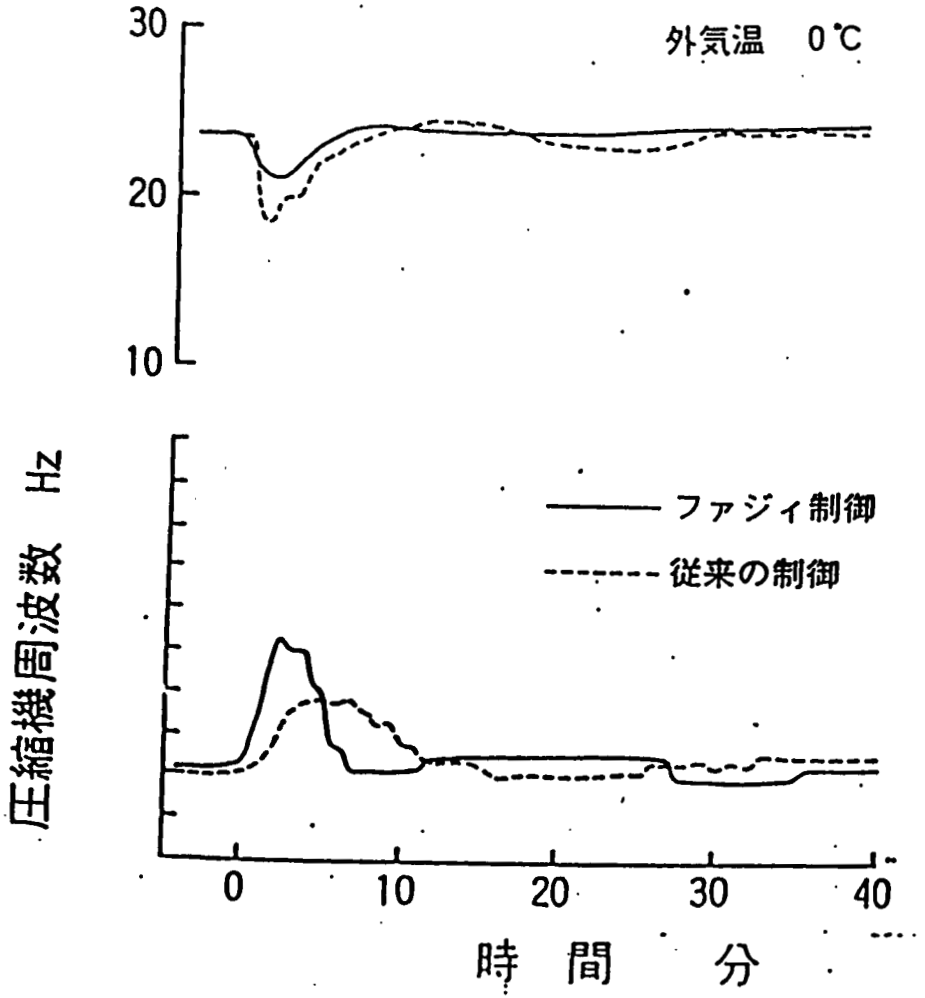


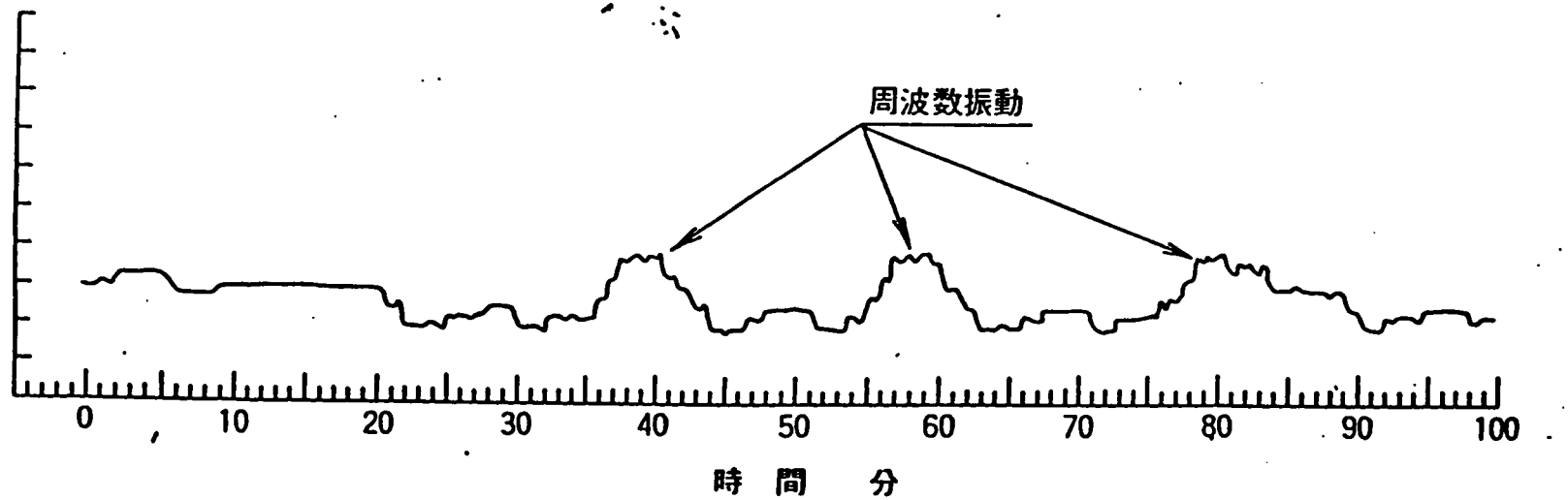
- 50 RULES (HEATING&A/C)
- MAX-PRODUCT INFERENCING
- DEFUZZIFICATION: CENTROID METHOD

Mitsubishi Heavy Air Conditioner

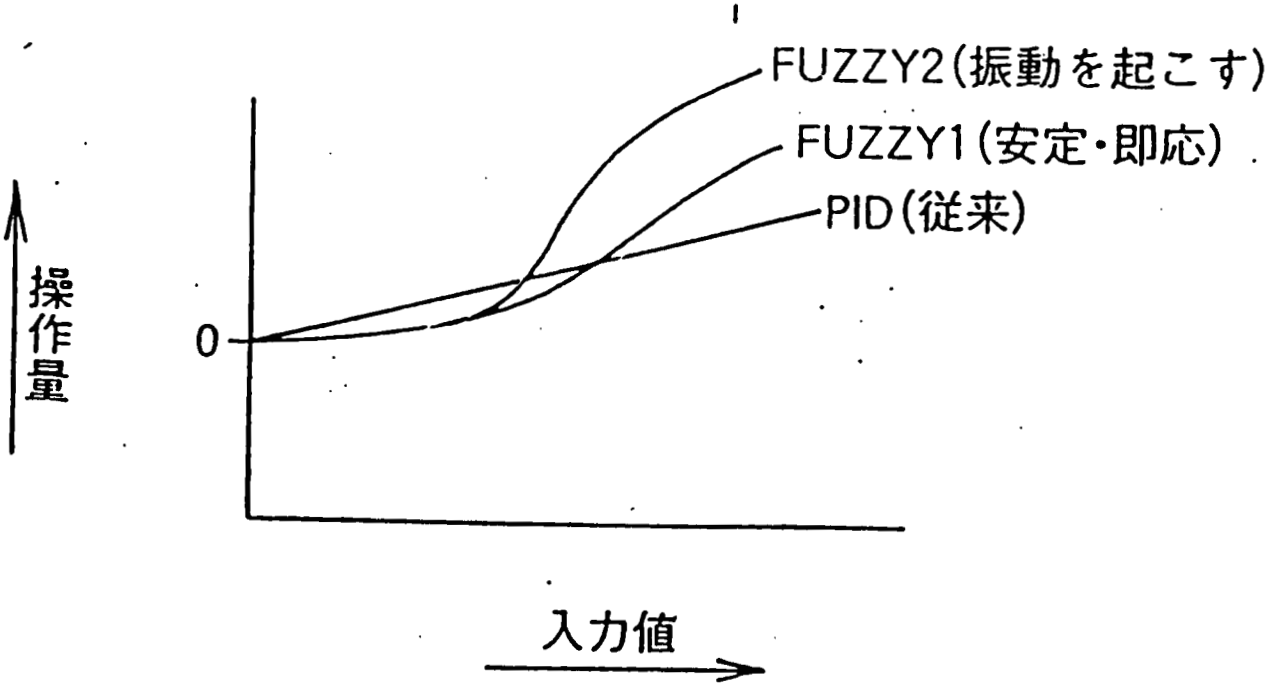


Mitsubishi Air Conditioner




圧縮機周波数 Hz
周波数振動
0
10
20
30
40
50
60
70
80
90
100
時 間 分

考察

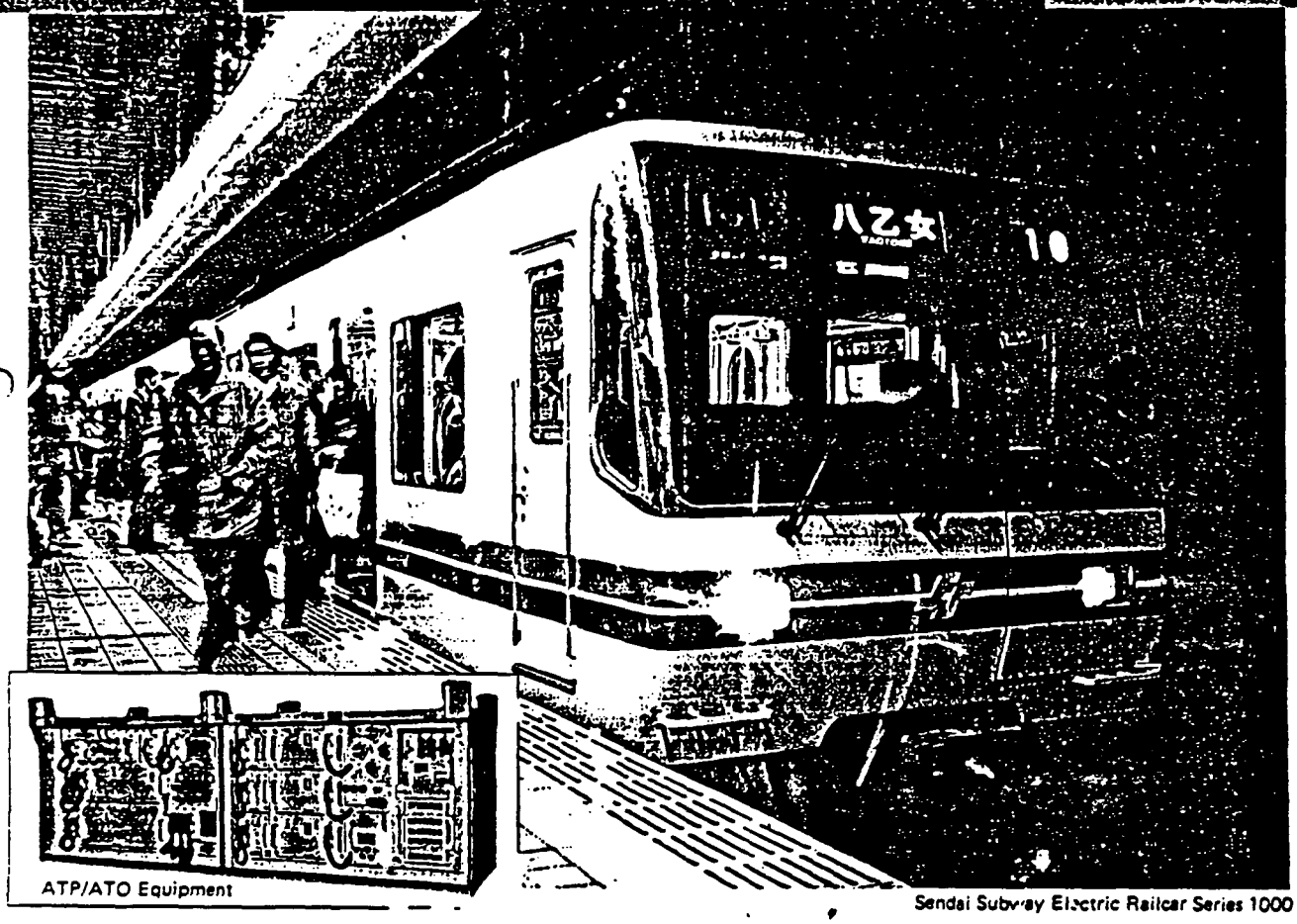


JAPANESE RAILWAY INFORMATION

RAILWAY SYSTEMS and Components

36

February 1988



ATP/ATO Equipment

Sendai Subway Electric Railcar Series 1000

Automatic Train Operation System Based on Fuzzy Control

Introduction

Regular research of the automation of train operation began in around 1960 in Japan, and various tests with real cars were conducted for confirming functions of basic elements such as constant speed automatic operation control, train automatic stop control at predetermined location, and train interval control.

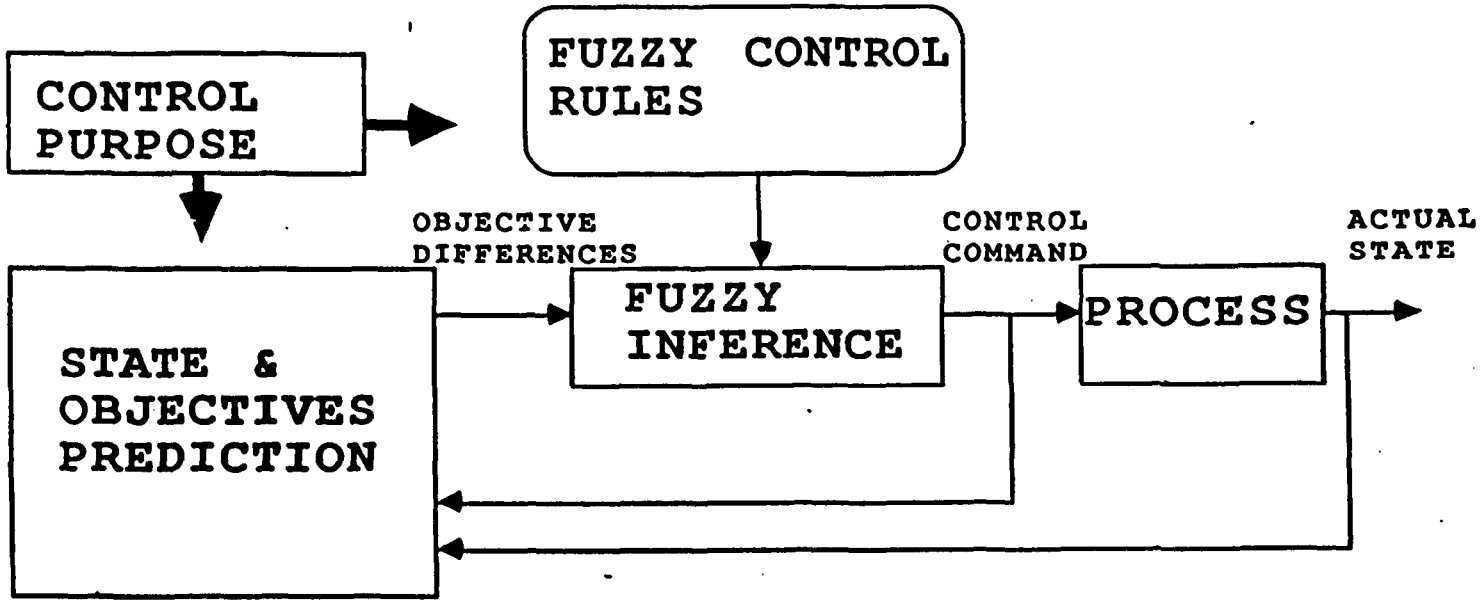
In the last half of the 1960's, ATO devices were applied to the test cars for the Shinkansen bullet train and the monorail vehicles for the 1970 World Exposition held in Osaka, Japan.

Starting from 1968, ATO devices for remote control were adopted in diesel hydraulic locomotives operated in steel works, and saving labor and securing safety were realized.

In the 1970's, the ATO devices were used in many subway cars and vehicles of automated guideway transportation systems, and many improvements were made.

Recently research on application of fuzzy control to automatic operation of subway cars was started. Revenue service of the subway line of Sendai Municipal Transportation Bureau was started in July, 1987, and smooth and accurate automatic operation has been realized by employing ATO devices based on fuzzy control.

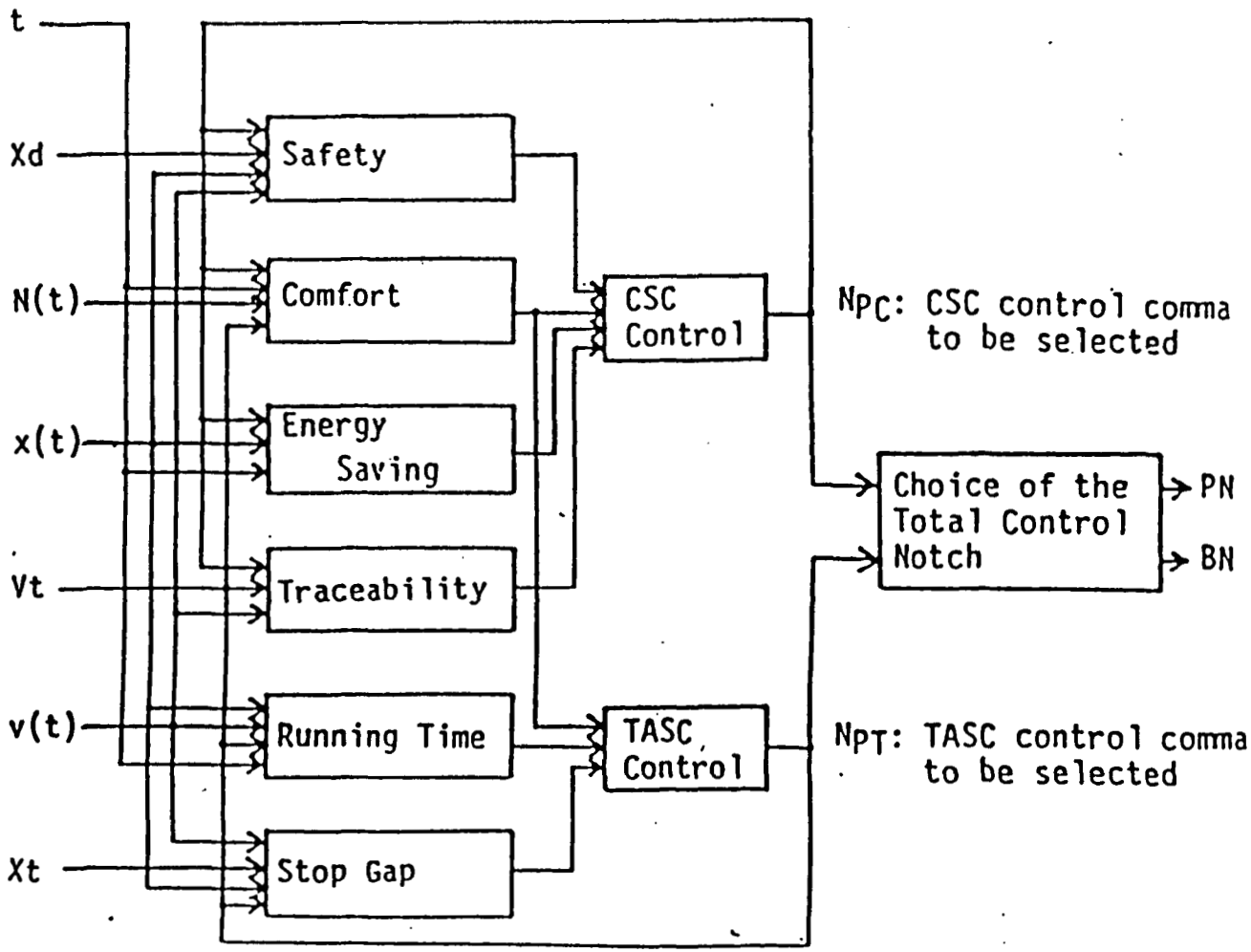
PREDICTIVE FUZZY CONTROL



SENDAI SUBWAY CONTROLLER

TOGAI INFRALOGIC, INC.
KYOTO-5

The Sendai Subway System



Structure of Fuzzy ATO algorithm

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The Sendai Subway System

First Proposed to the Government 1978

Granted Permission to Operate After:
3,000 Empty Subway Runs
300,000 Simulations

Began Operation in 1986

Hitachi Granted Contracts for Tokyo Subway 1991

Togai InfraLogic, Inc.
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The Sendai Subway System

Performance Improvements

- Improvement in Stop Gap by 3X
- Reduction in Power Settings by 2X
- Overall Reduction in Power by 10%

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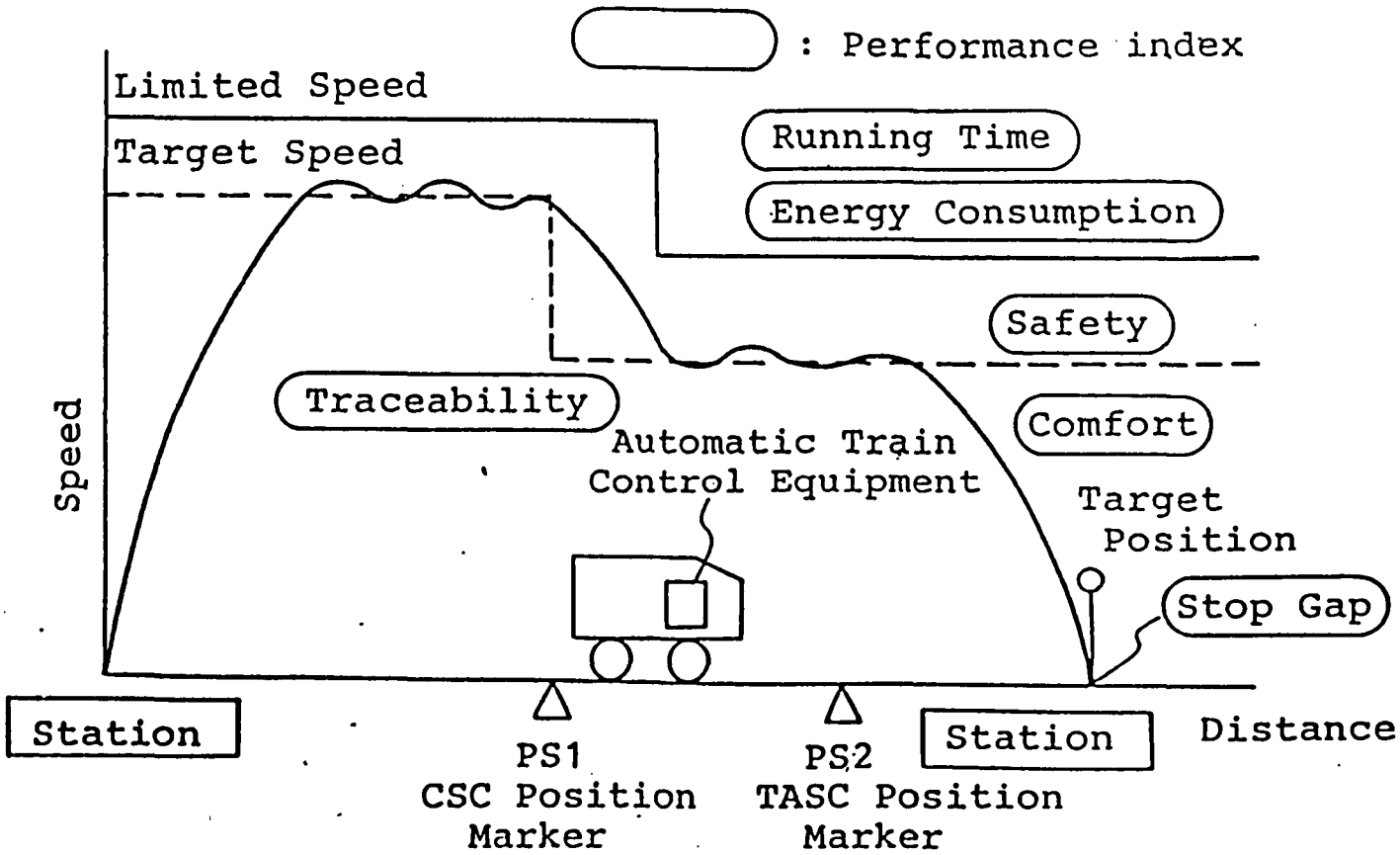
ARTIFICIAL INTELLIGENCE ON A CHIP

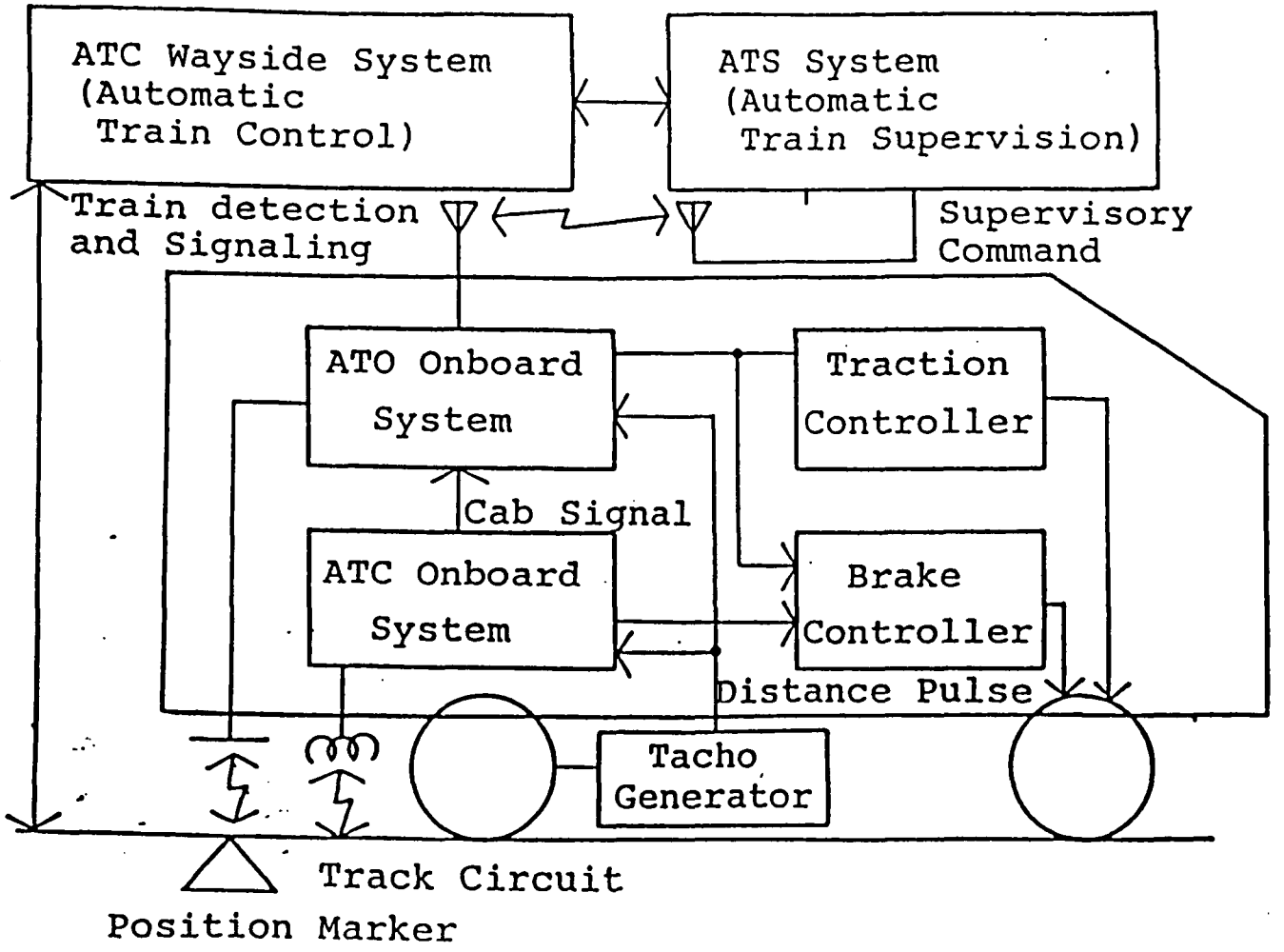
The Sendai Subway System



Outline of automatic train operation

view02

The Sendai Subway System



Typical configuration of ATO

The Sendai Subway System

Table 1 Symbols

t	: time (sec)
$x(t)$	: location of train (m)
$v(t)$	: velocity of train (km/h)
$N(t)$	: control command notch
$X(t)$	: target position of next station (m)
V_t	: target speed (km/h)
T_t	: predicted running time (sec)
X_d	: forward location where the maximum speed limit is lower (m)
t_s	: time to reach X_d point (sec)
X_k	: ending location of coasting (m)
$X_z(v)$	: beginning point of TASC zone (m)
$t_z = (X_z(v)-x(t))/v(t)$	: time to TASC zone (sec)
t_c	: elapsed time from last notch change (sec)
N_c	: degree of last changed notch
N_p	: control command notch to be selected
$V_p(N_p)$	: predicted speed when N_p notch is selected (km/h)
V_e	: velocity allowance range (km/h)
$X_p(N_p)$	: predicted stop position if N_p notch is selected (m)
X_e	: allowance of stop gap (m)

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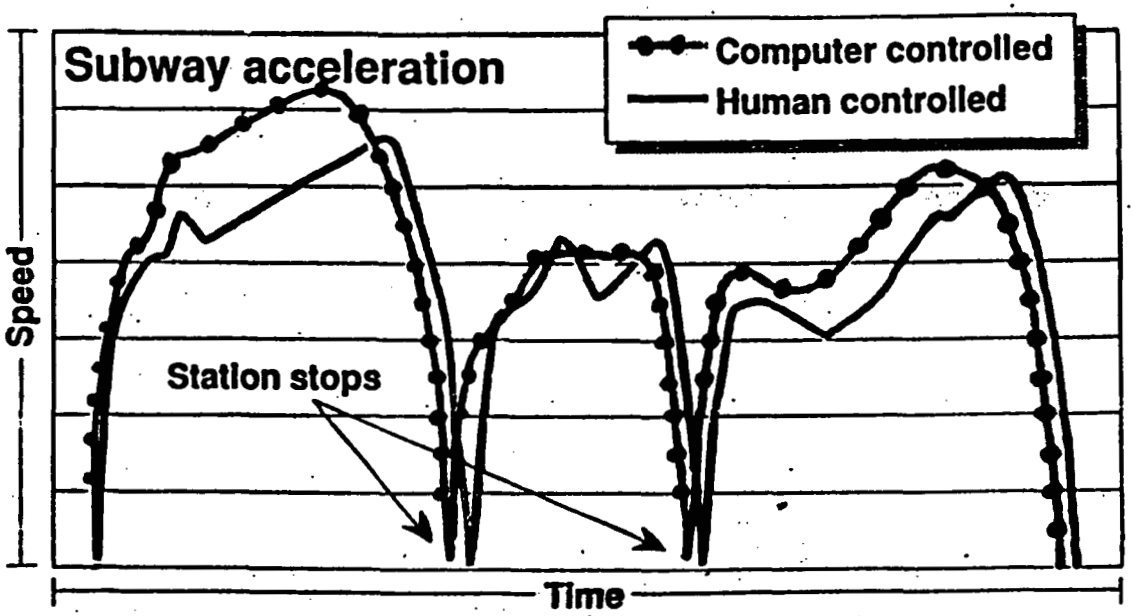
ARTIFICIAL INTELLIGENCE ON A CHIP

The Sendai Subway System



Source: Togai Infralogic Inc.

The Register

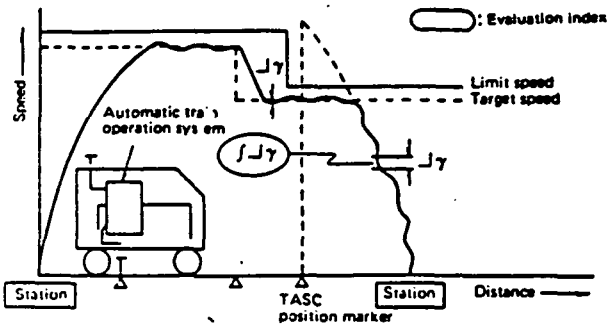


Fig. 1 Outline of automatic train operation by PID control

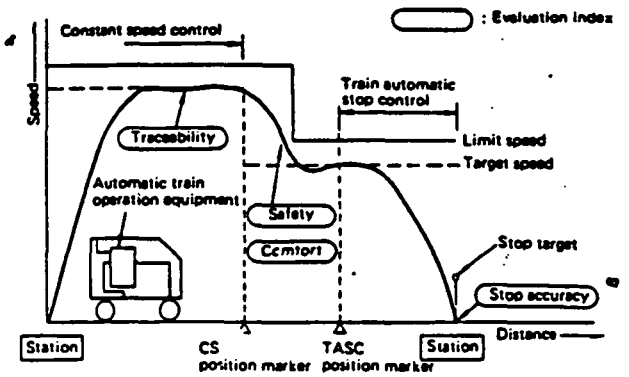


Fig. 2 Outline of automatic train operation by fuzzy control

Theory of Fuzziness & Fuzzy Control

The theory of fuzziness was first proposed in 1965 by professor L.A. Zadeh of the University of California at Berkeley.

The theory of fuzziness deals with a set with ambiguous boundary instead of an ordinary set. In the conventional Boolean set comprising "0" and "1," the boundary of an individual set can be clearly distinguished, but the fuzzy set is characterized by the fact that the boundary between the inside and outside of the set is not obvious.

The fuzzy control is based on the fuzzy set theory which was developed for determining the quantity of subjective fuzziness of human being and for making objective evaluation of the fuziness possible, and thereby eliminating fuzzy portions as much as possible.

In the conventional automatic operation system, train operation is performed by a control based on PID Control (Proportional Integral and Differential Control) so that target speed pattern predetermined for each operating section can be followed. In this conventional automatic train operation, accurate operation can be achieved in a manner of following the predetermined speed pattern. However, in actual practice, there are many kinds of changes of running conditions such as gradient etc. of track and the braking force of rolling stock. Therefore, to follow the target speed, it is necessary to send control commands frequently for acceleration and brake application. As a result, smooth operation is apt to become difficult, and riding comfort is likely to be degraded. Moreover, an accuracy of train stopping at predetermined locations of stations cannot be determined through the logic of the control system. Accordingly dispersion should be checked by computer simulation or tests using real cars. This kind of problem occurs because the train operation characteristics as a controlled system are not well adapted to its control system. The characteristics of running train vary complicatedly and non-linearly in response to changes in the external situation. In the conventional control method, complicated controlled systems, were dealt with approximating then to simple linear models, and only the follow-up to predetermined speed pattern was taken into account in the evaluation related to control. That is, the conventional control was unable to properly respond to changes in the situation.

On the other hand, in the fuzzy control, the results of certain running operations being considered are predicted in advance as the same as actual decisions made by a

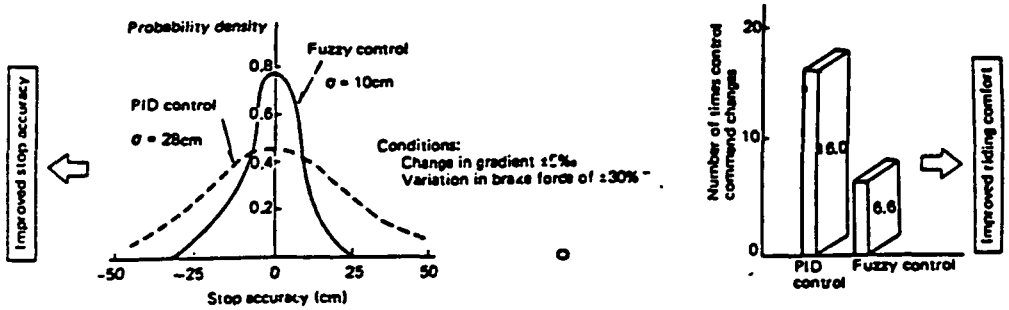


Fig. 3 Comparison of the results between fuzzy control and PID control (stop accuracy and number of times control command changes)

The Sendai Subway System

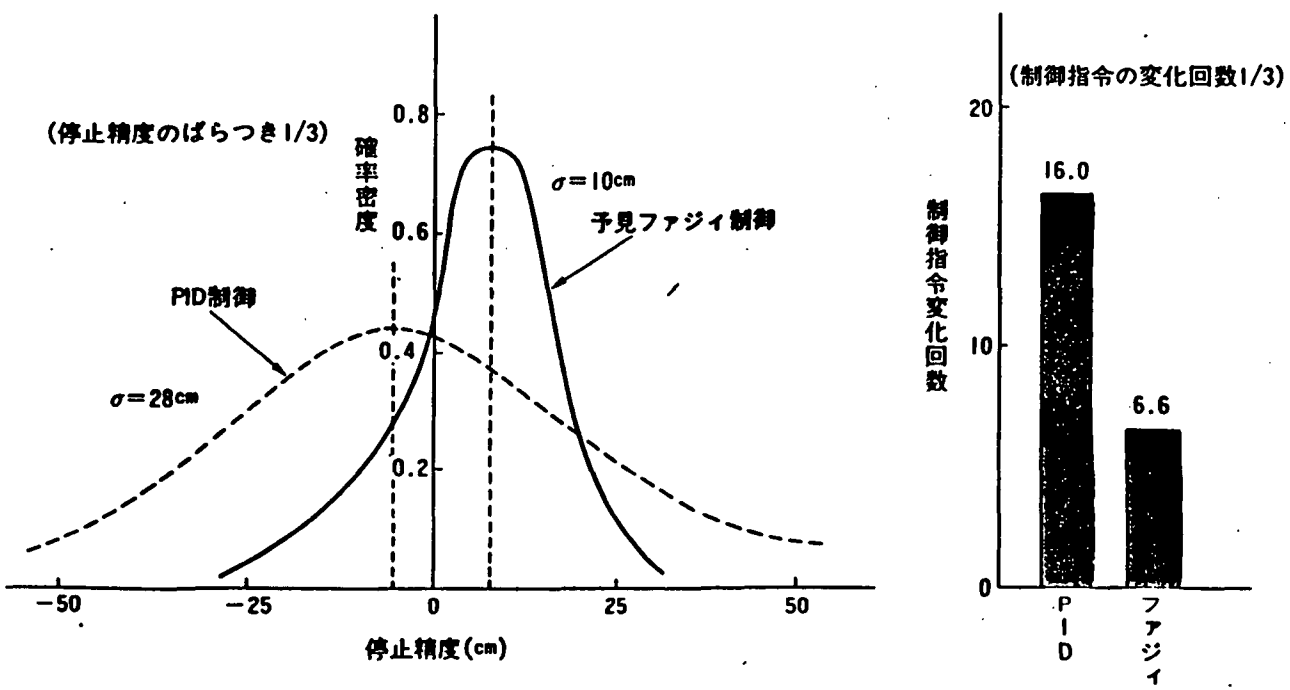


図6　停止精度と乗り心地の評価(菅野道夫著「ビジネスマンのためのファジィ読本」より)

Stop-Gap and Power Settings

A Capital Cities/ABC, Inc. Publication

AUTOMOTIVE
ELECTRONICS REVIEW

VOL. 2, NO. 15 SEPTEMBER, 1990 $2.50

Nissan Close To Introducing Fuzzy Logic Transmission Controller

by ANDREA SAXER

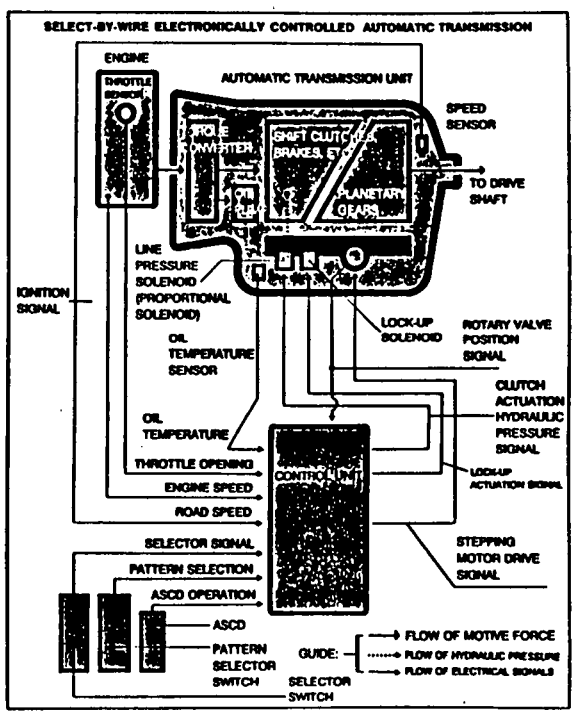
Soon—in the next year or so—Nissan will start selling cars programmed with a new, extra smart transmission control, popularly known as fuzzy logic. Speculation is that inference-based control logic will debut on Nissan's 300 ZX, the company's premier performance car, and perhaps on its Infiniti Q-45 luxury sedan.

Industry Analyst Roger Steciak, San Jose, CA, reported Subaru and Mazda are seriously pursuing the same smart control technique. He predicted a two- to three-year time frame for this to happen, at most.

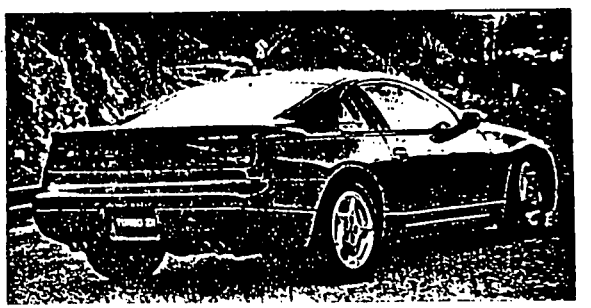
Like Nissan, Subaru will apply fuzzy logic to transmission control. Mazda is testing it for application in collision avoidance systems. In Mazda's case, Steciak expected a long lead time, as much as ten years, since legal approvals for its system will require extensive testing.

Hiroshi Takahashi, research engineer at Nissan's Central Engineering Laboratories, Yokosuka, Japan, said Honda and Isuzu are working on fuzzy logic for automotive electronic controls as well. Engine control, with its

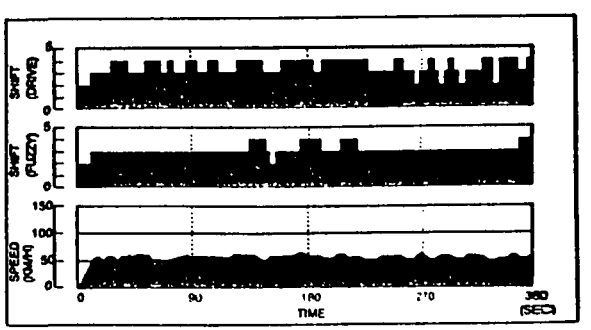
Please, see Fuzzy Logic, p. 12



CONCEPTUALLY SPEAKING: The Nissan Arc-X concept car has a control schema that could incorporate fuzzy logic, according to Hiroshi Takahashi, a research engineer at Nissan's Central Engineering Laboratories, Yokosuka, Japan.



COULD IT BE THE FIRST? Will the transmission in Nissan's 1991 300 ZX be the first production car to be controlled by fuzzy logic?



WHAT A DIFFERENCE: More shifting, less comfort. Honda studied shift scheduling and found that gears were shifted less when the transmission was controlled by fuzzy logic rather than a traditional program. The comparison chart comes from a paper (#905049) presented by Honda Research and Development Engineers Sakai, Arai, Hasegawa, Sakaguchi and Iwaki at the International Federation of Automotive Engineering Societies in Turin, Italy, in May. Call the Society of Automotive Engineers, Warrendale, PA, 412-776-4841, for a copy.

House Committee OKs 400% IVHS Funding

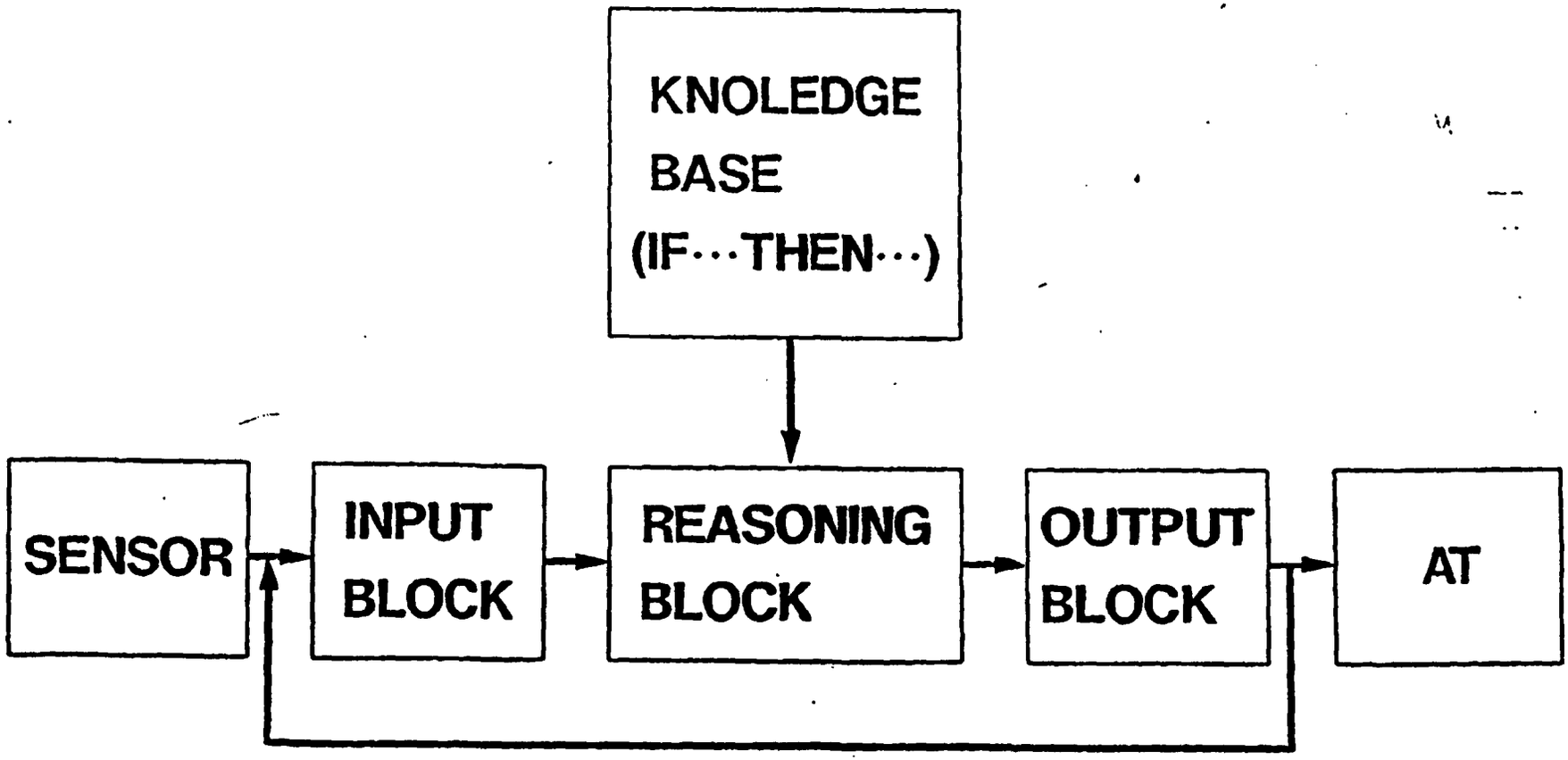
Toyota J1850 IC Contract

Togai InfraLogic, Inc.
ARTIFICIAL INTELLIGENCE ON A CHIP

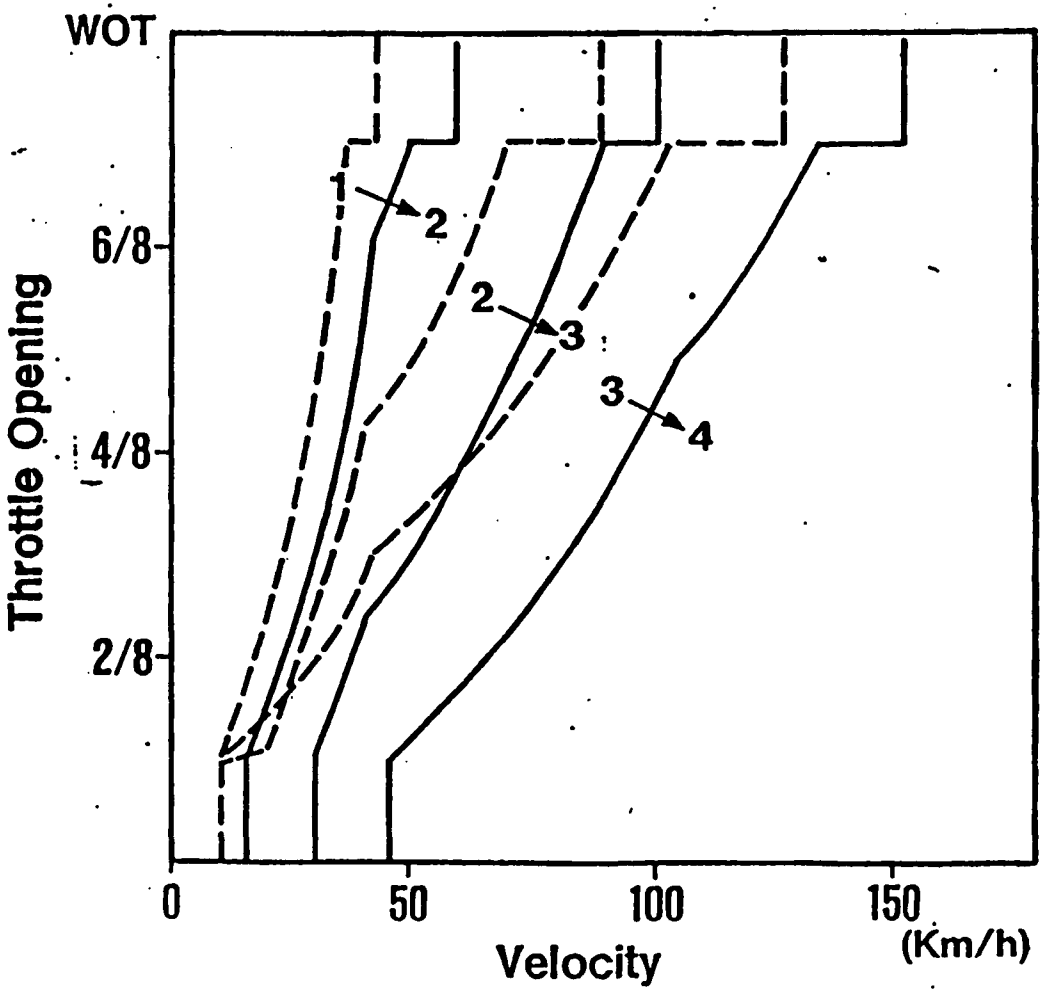
Automatic Transmission

Objectives:

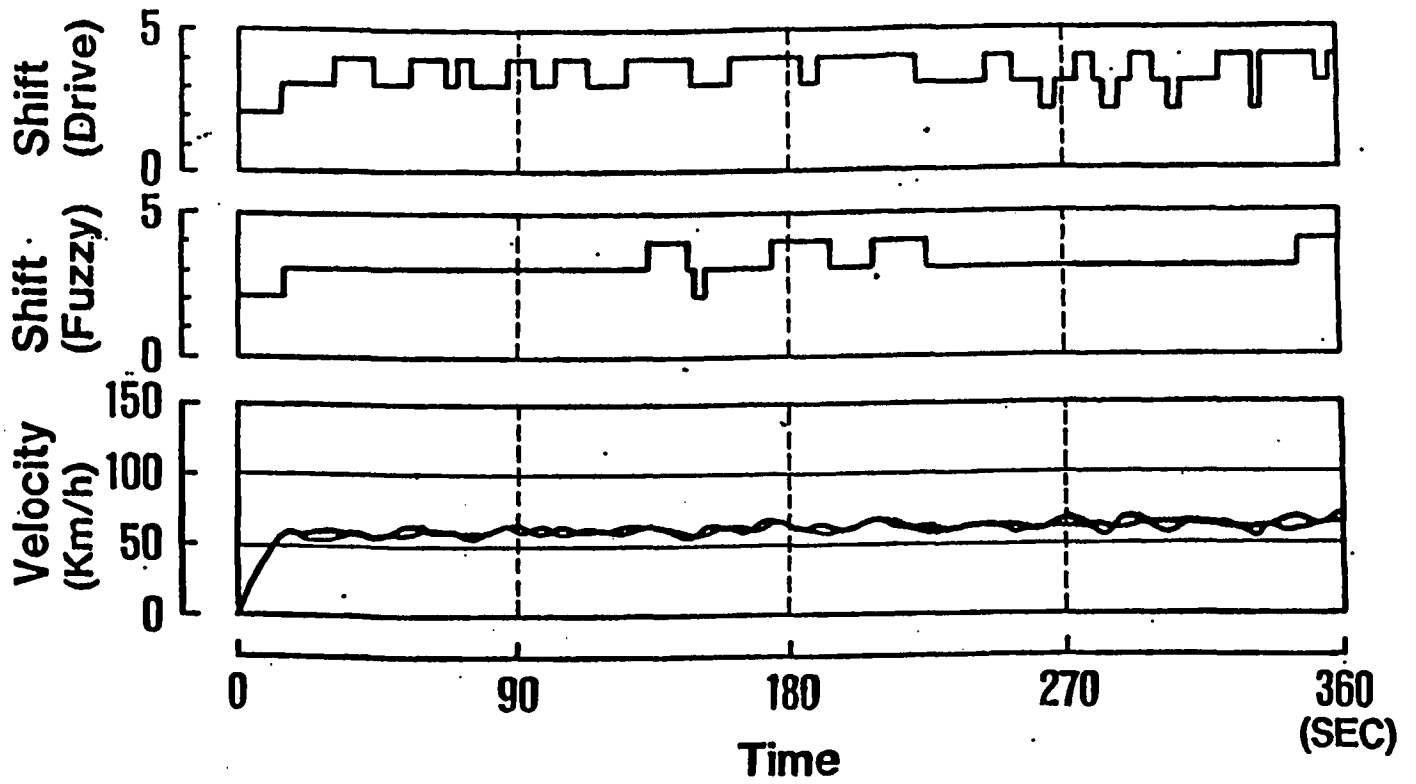
- Smoother Ride
- Increased Fuel Savings
- Less Wear


KNOLEDGE
BASE
(IF···THEN···)
SENSOR
INPUT
BLOCK
REASONING
BLOCK
OUTPUT
BLOCK
AT

Automatic Transmission



Automatic Transmission



Body/Chassis

Nissan Patents 'Fuzzy Logic' ABS, Gearbox

By ANGELA G. KING

TROY, Mich. — Nissan Motor Co. Ltd. has received U.S. patents on an anti-lock brake system and a transmission that incorporate "fuzzy logic" computer programming.

Designed to automate human reasoning, fuzzy logic programming offers various possible solutions, using graded or qualified statements, to a problem rather than the precise yes-or-no solution of strict logic widely used in the electronics industry, according to Lofti A. Zadeh, who first developed the concept of fuzzy reasoning in the mid-1960s.

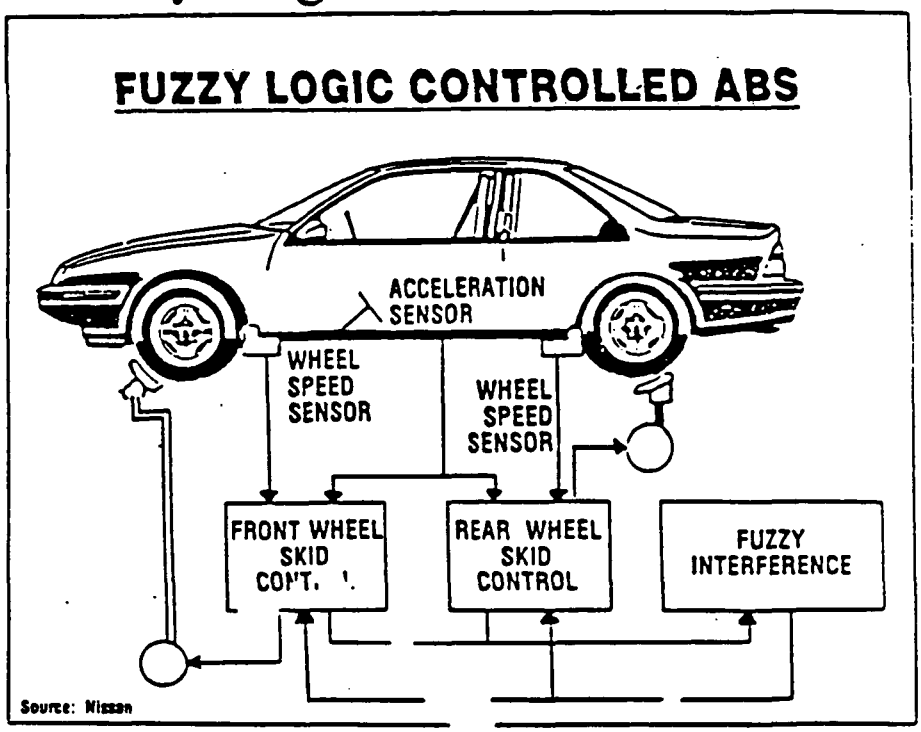
Mr. Zadeh is currently a Professor of Computer Science in the Electrical Engineering and Computer Science department at the University of California at Berkeley.

A Nissan spokesman said engineers are still developing the brake and transmissions systems, and no introduction dates have been set. Nissan has developed a fuzzy logic program and is now looking to see if it can be applied to its patented transmission and brake system designs, he explained. Fuzzy logic programming, according to the company, would enhance brake and transmission system performance with improved control flexibility.

Nissan is developing an automatic transmission in which fuzzy logic computer programming is used to electronically shift gears in a manner similar to a driver who weighs different factors to manually shift gears.

WITH A CONVENTIONAL automatic transmission, electronic sensors detect vehicle speed and throttle opening, and gears are shifted based on the predetermined value of these factors. According to Nissan, this type of system is incapable of always providing satisfactory control performance to a driver because it provides at most only about three different shift patterns.

But the Nissan fuzzy control transmission, (patent number 4,841,815), is more flexible and provides a driver with more control performance because it is operated by sensors that assign values to numerous variables, including vehicle speed, throttle opening, acceleration and the rate of change of the throttle opening. Each value is given a weight, and the weights are calculated to make the decision on whether to shift gears.



ANTHROPOMORPHIC: Nissan's fuzzy logic program is designed to apply human reasoning characteristics to the control module of its patented ABS design.

Where conventional ABS incorporate sensors that detect vehicle and wheel speed, the Nissan system's (patent number 4,842,342) control unit measures these variables in addition to derivatives of wheel speed with respect to time and derivatives of vehicle speed with respect to time. As in the transmission, certain signals in the brake system are assigned weighted values that determine the frequency of ABS brake actuation.

In a paper entitled "Making Computers Think Like People," Mr. Zadeh explained that fuzzy logic allows computers to handle such imprecise human concepts as "small," "big," "young" and "old" by describing them in ranges of numbers instead of exact terms.

DEVELOPMENT OF FUZZY logic in the early 1970s by Ebrahim Mamdani, a control engineer at Queen Mary College in London, and Seto Assilian, Mr. Mamdani's student at that time, has led to growing interest in the use of this theory in such applications as industrial process control and automobile engine control, said Mr. Zadeh.

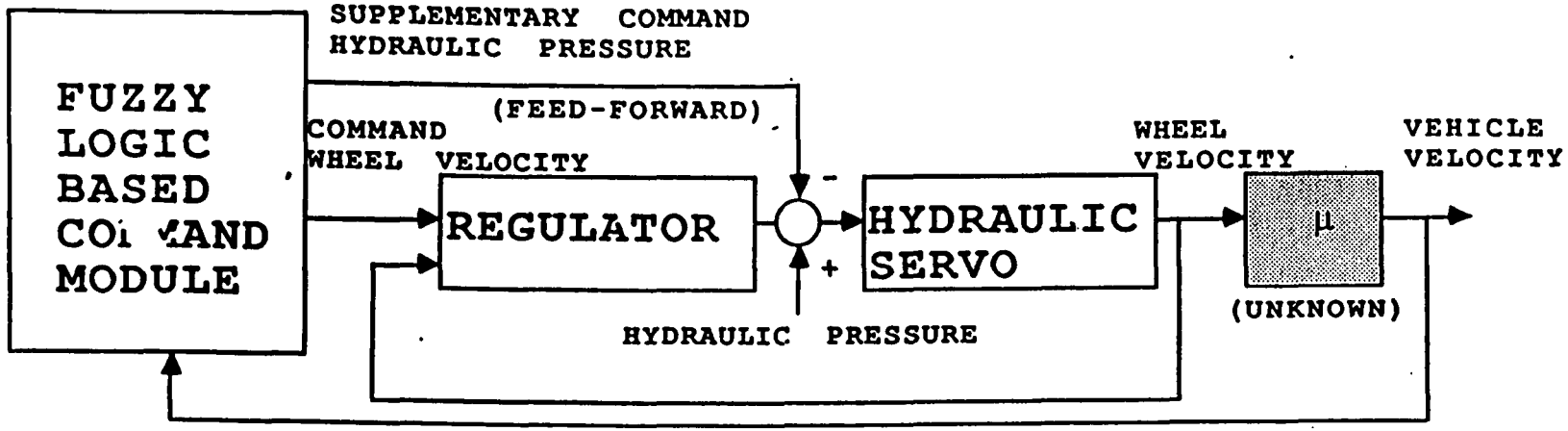
Japan in particular has shown a great deal of interest in fuzzy logic. Research is being conducted in Japan in the application of this system in such areas as vehicle control at the Tokyo Institute of Technology's Sugeno Laboratory, and robot control at Hosei University's Hirota Laboratory.

In March, Japan's Ministry of International Trade and Industry established the Laboratory for International Fuzzy Engineering Research (LIFE), a group that consists of 48 member Japanese firms, including Nissan.

A fuzzy system developed by Hitachi, also a member of the new LIFE organization, is already used to control subway trains in Sandai, Japan.

Fuji Heavy Industries Ltd., the maker of Subaru cars, is developing an advanced form of electronic continuously variable transmission, called the ECVT-II, that also uses fuzzy controls. The ECVT-II is not in production now and is not expected to appear in an automobile before model year 1991, according to a spokesman at Subaru of America, Cherry Hill, N.J.□

FUZZY LOGIC-BASED COMMAND SYSTEM FOR ABS



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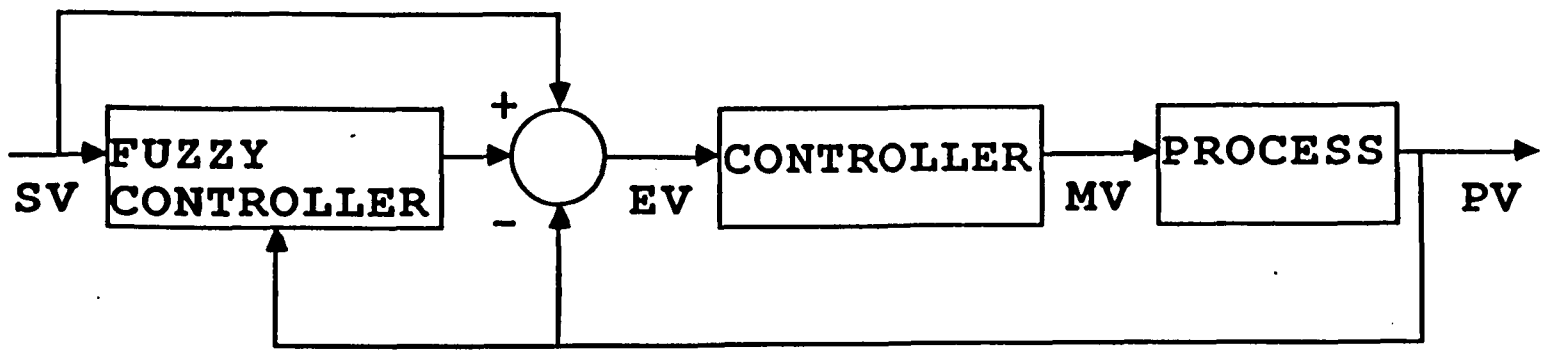
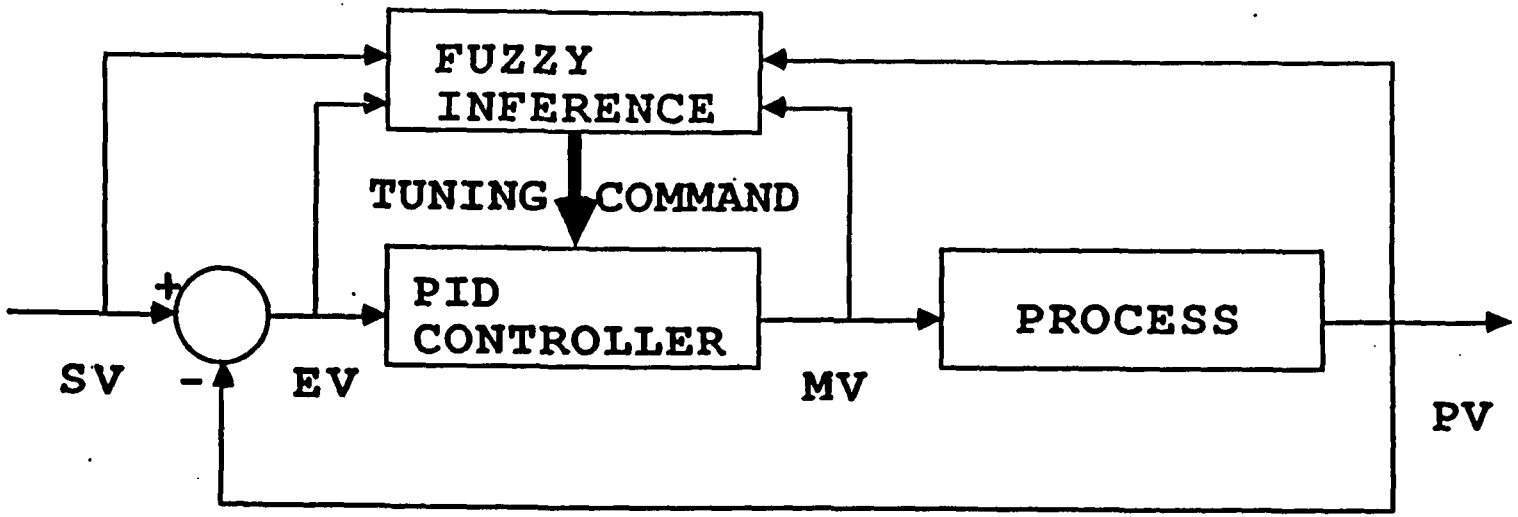
FUZZY FEED-FORWARD CONTROLLER



FUZZY AUTO-TUNING SYSTEM



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