UMR CNRS 8201

Milestone about “Fuzzy control”

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Where I come from…

UMR CNRS 8201

70 Researchers, 20 Administrative staff, 70 PhD and Postdocs

Identity | Human-centered Safety, Mobility and Interacting Systems

“Fuzzy milestone” As a matter of introduction

“Fuzzy theory is wrong, wrong, and pernicious. What we need is more logical thinking, not less. The danger of fuzzy logic is that it will encourage the sort of imprecise thinking that has brought us so much trouble. **Fuzzy logic is the cocaine of science**.”
Professor **William Kahan** UC Berkeley

“Fuzzification’ is a kind of scientific permissiveness. It tends to result in socially appealing slogans unaccompanied by the discipline of hard scientific work and patient observation.”
Professor **Rudolf Kalman** Univ Florida (1972 cited in [Zadeh 2011])

“Fuzziness is probability in disguise. I can design a controller with probability that could do the same thing that you could do with fuzzy logic.”
Professor **Myron Tribus**, UCLA (Bayesian) on hearing of the fuzzy-logic control of the Sendai subway system IEEE Institute, may 1988.

And for the 90’s control community in France it was even **worse**…

Well… “Fuzzy” will have 50 years in 2015

As a matter of summary… with some “*fuzzyness*”

Fuzzy control: the pioneers, the first applications

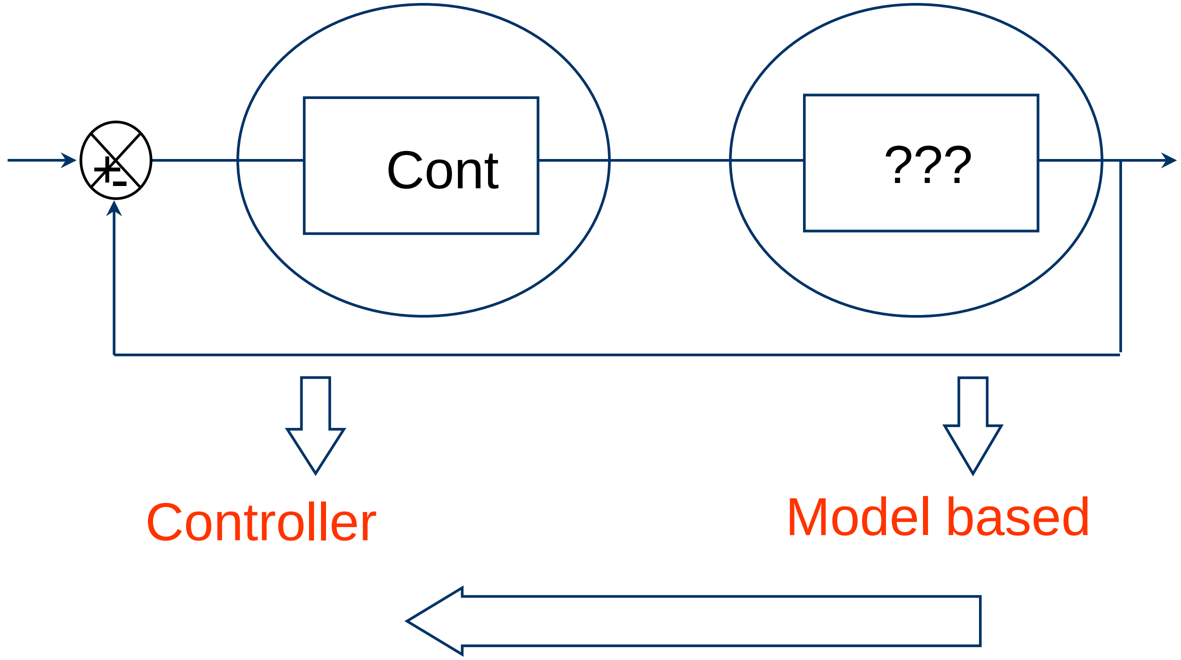
Limitations, getting “older”

How to go further?

Is Fuzzy dead?

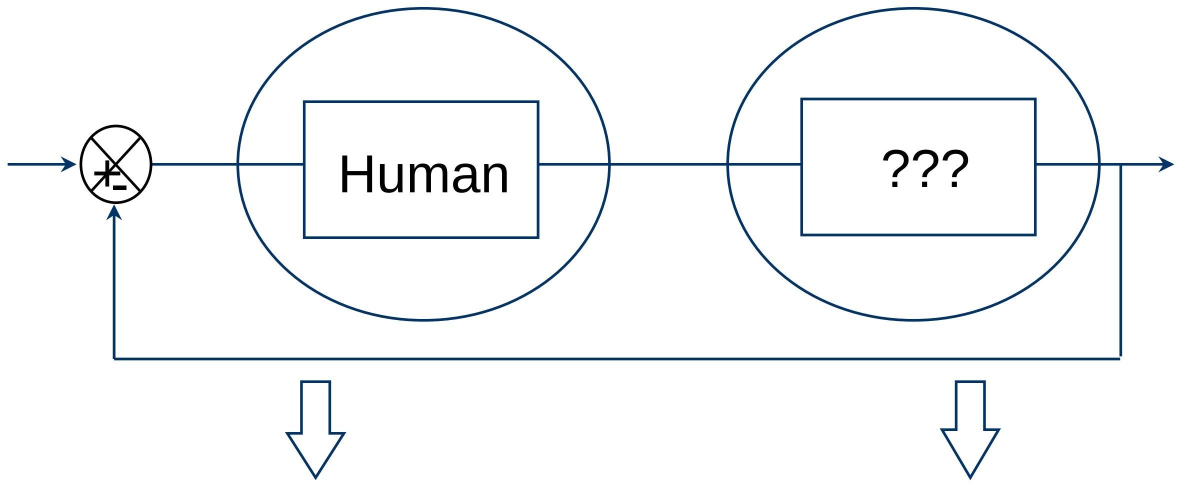
Tracks

"Classical" approach of control



Goals: performances, robustness

Historical approach of fuzzy control



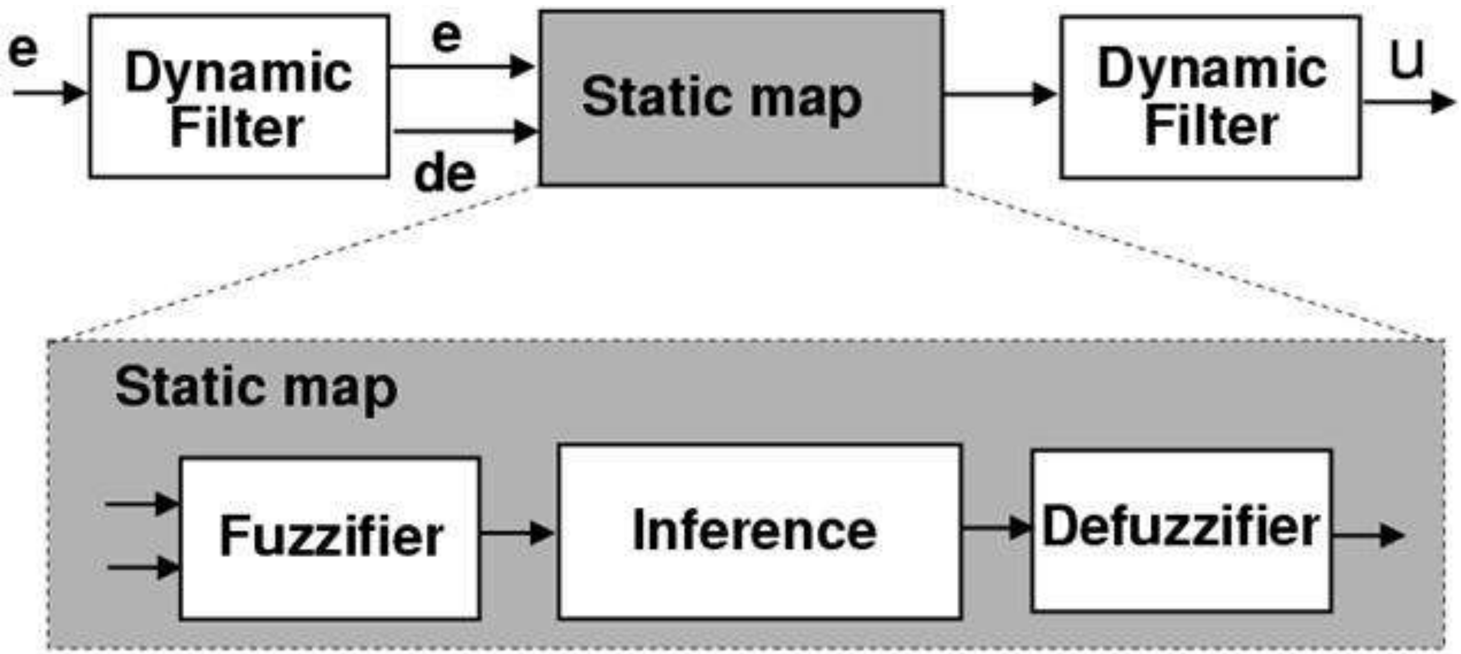
Fuzzy controller

Highly complex systems and/or hard to model, identify

Rules based on knowhow

Experts knowledge capture

Historical approach of fuzzy control

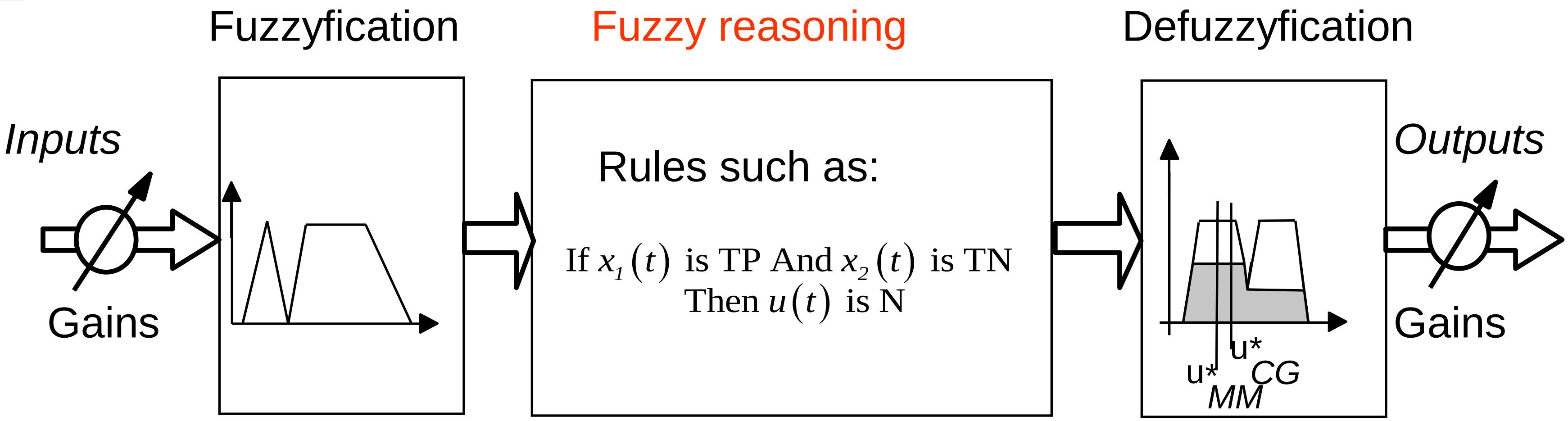


Nonlinear mapping from control to output

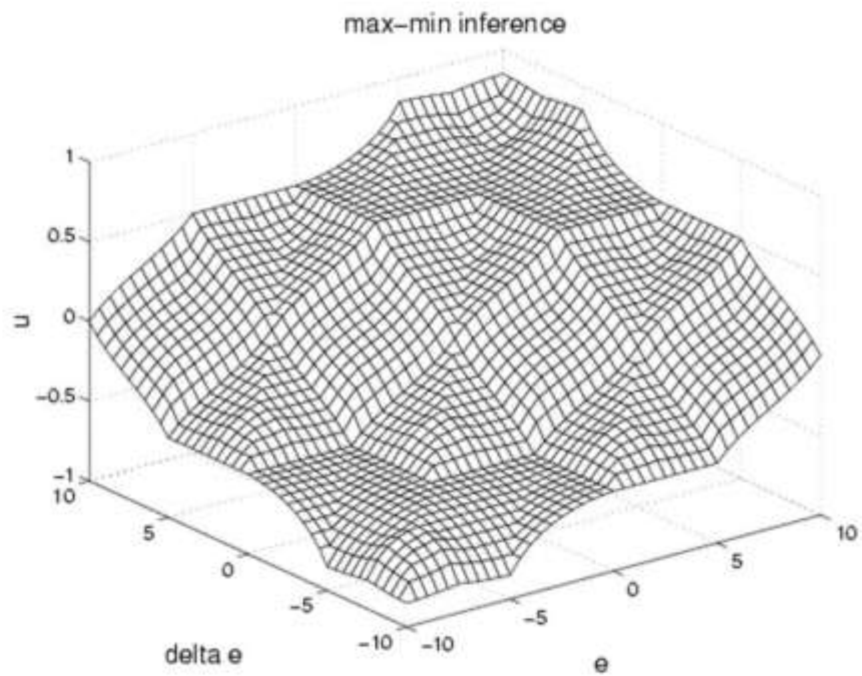
For example: $u(t) = f\left(\varepsilon(t), \Delta\varepsilon(t)\right)$

And by sake of comparison with linear control → FC-PD

Historical approach of fuzzy control

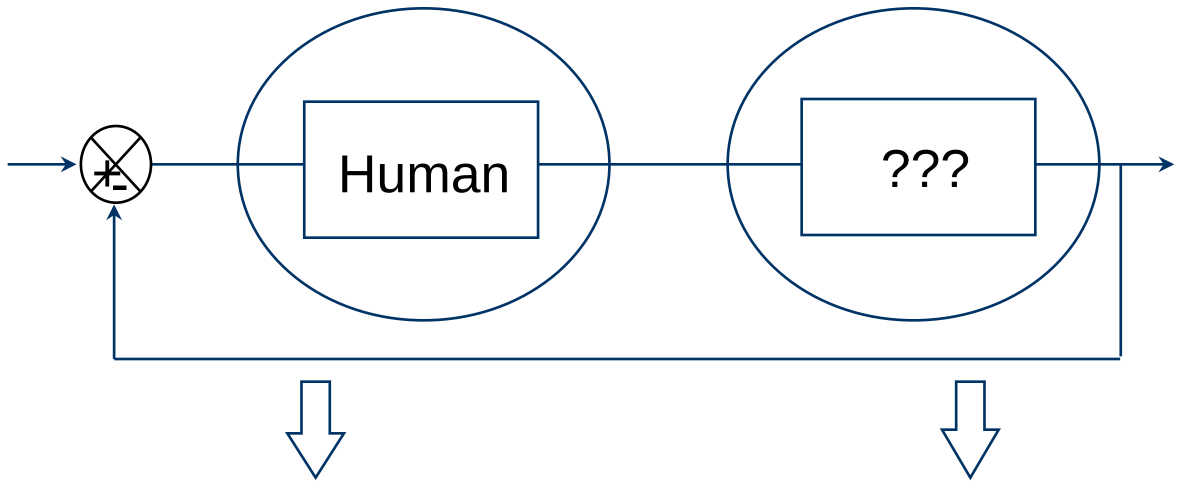


$$u(t) = f\left(\varepsilon(t), \Delta\varepsilon(t)\right)$$



Nonlinear mapping between control and error → replaces the usual "plane" from linear PI

Historical approach of fuzzy control



Fuzzy controller

Highly complex systems and/or hard to model, identify

Rules based on knowhow

Experts knowledge capture

Tuning: need for optimization step or for adaptive mechanism

Fuzzy control history

Ebrahim MAMDANI Imperial College of Science, Technology and Medicine, University of London (passed 2010)

Mamdani, E.H., “Advances in the linguistic synthesis of fuzzy controllers”, International Journal of Man-Machine Studies, Vol. 8, pp. 669-678, 1976

1st known application:
Homblad, P. & Ostergaard, J-J. (1982) "Control of a cement kiln by fuzzy logic", in M.M. Gupta and Elie Sanchez, eds., *Fuzzy Information and Decision Processes* pp. 398-399, Amsterdam: North Holland.

Adaptive control using mechanism to modify the rule base in real-time
T.J. Procyk, E.H. Mamdani “A linguistic self-organizing process controller Original”
Automatica, Volume 15, Issue 1, January 1979, Pages 15-30

Fuzzy control history: the SOC

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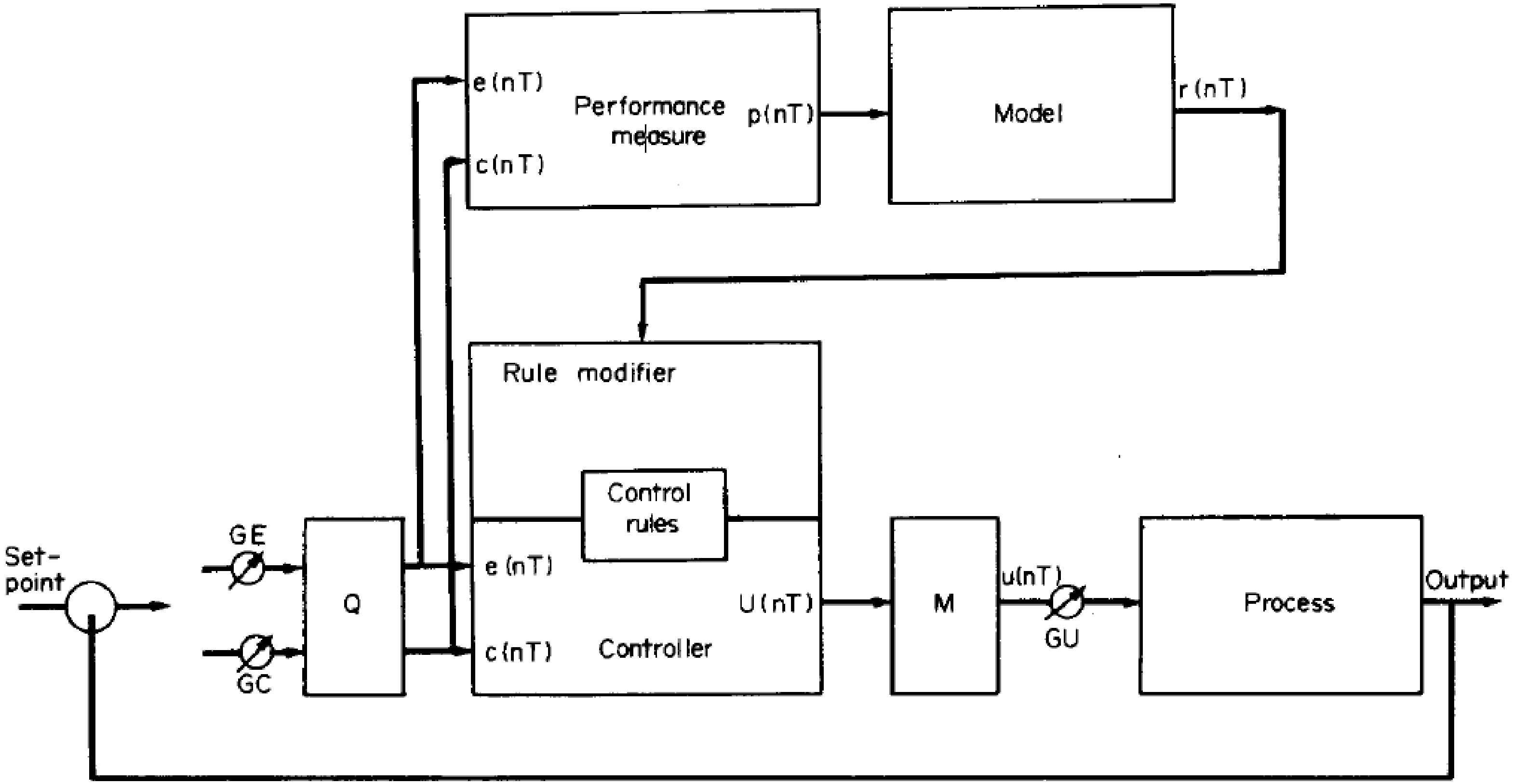

Fuzzy control history: the SOC

A “simple” model for variations: mapping Δy/Δu (Jacobian)

SOC tested on numerous models in simulation (already reinforcement learning!)

Linear SISO
Linear MIMO
+ delays

NL with saturations

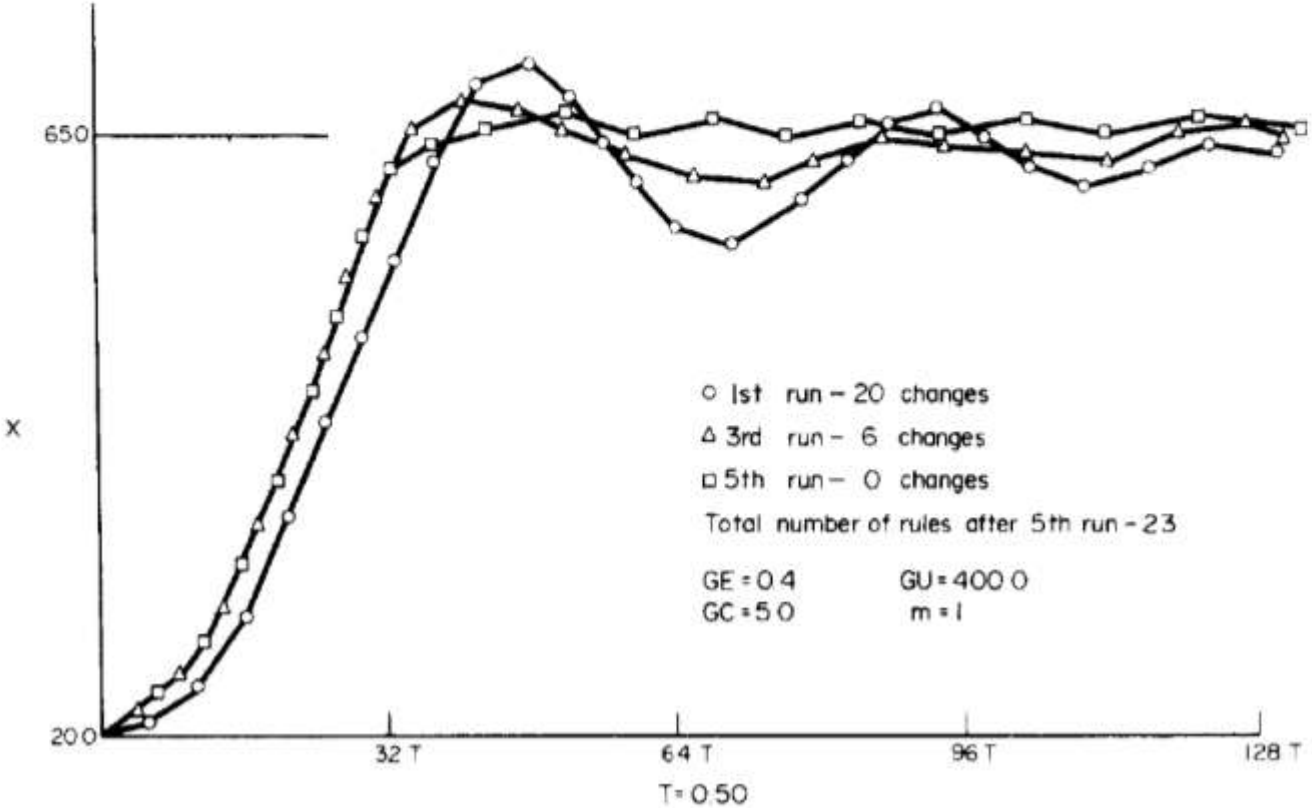

FIG. 5. Process 2—a system defined by the characteristic equation

$$\ddot{X} + 0.1X\dot{X} + 0.375X = 0.00375U$$

where $0 < U < 1000$ and $0 < X < 100$.

Applications : Sendaï Metro (Japan) 1987

Seiji Yasunobu, Univ Tsukuba

A Fuzzy Control for Train Automatic Stop Control
Seiji YASUNOBU, Shoji MIYAMOTO (Hitachi)

GOALS: security, comfort and stop precision

HITACHI Engineers: comparisons with “classical” controllers on 300,000 simulations and 3000 real-time tests

Stop precision divided by 2.5, comfort criterion x2 and consumption gain of 10%

Applications : Sendaï Metro (Japan) 1987

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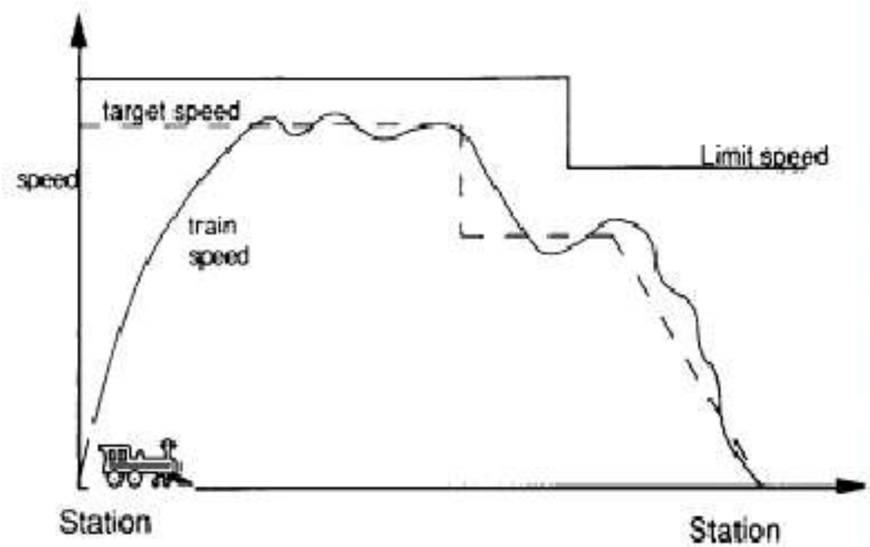
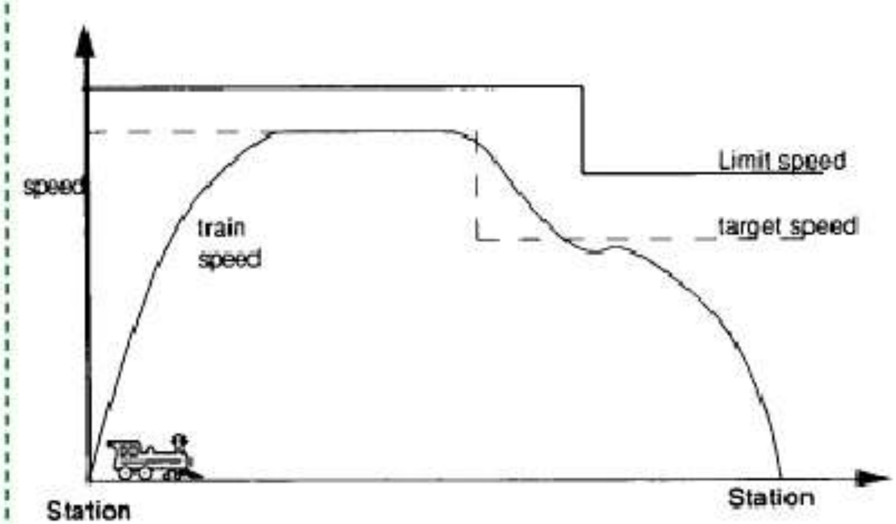
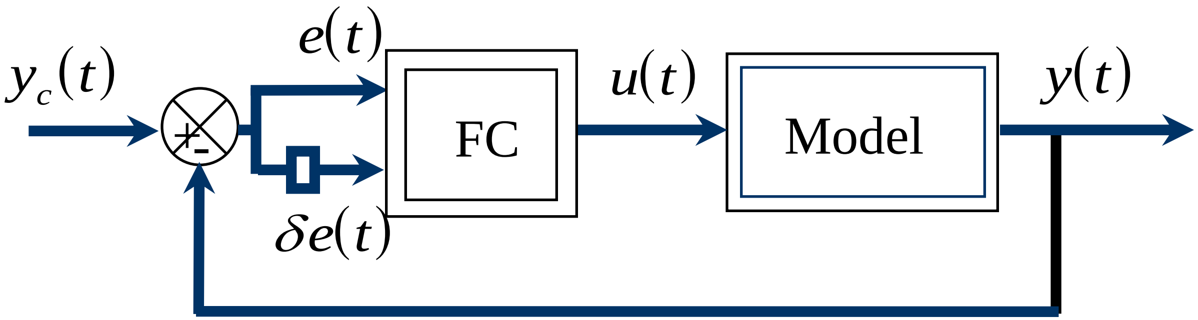




Historical approach of fuzzy control

Nonlinear extension of linear controllers.

Output feedback approach



- FC-P, FC-PD, FC-PI, FC-PID
- FC-adaptive

Many works comparing linear/fuzzy “like” linear
[Boverie et al., 1991] [Vidolov & Melin 1993] [Pigeon 1993]

Equivalences [Siler 1989] [Ying & al. 1993] [Foulloy & Galichet 1994]

Historical approach of fuzzy control

1988 Japan → Laboratory for International Fuzzy Engineering (LIFE) 45 industrials (the only European was VW)

Thousands of applications

Washing machines, cameras (Canon), vacuum cleaner (Matsushita) ...

Micro-waves oven, conditioner (Mitsubishi), showers...

Train, lifts, helicopter...

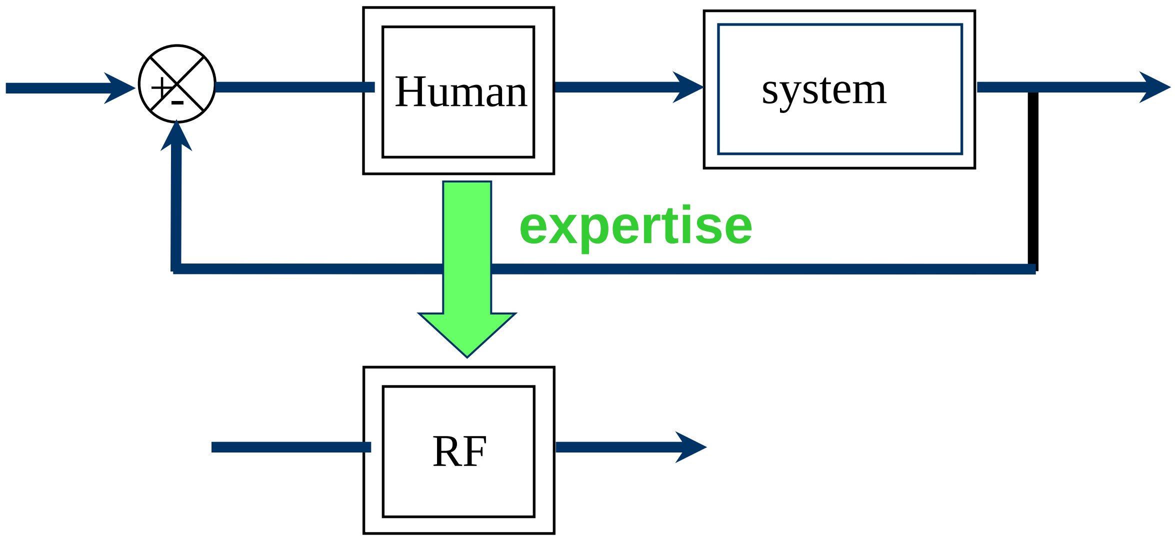
"counting"> 5000 [Jamshidi 1995]
Recent paper about fuzzy control applications [Precup & Hellendorn 2011]

Number of fuzzy-logic-related patents issued and applied in Japan: **7,149**
Number of fuzzy-logic-related patents issued in the United States: **21,878**
Number of fuzzy-logic-related patents applied in the United States: **22,272**

(Data compiled by Dr. B. Tadayon, CEO, Z Advanced Computing TM, Inc.)
http://www.cs.berkeley.edu/~zadeh/stimfl.htm

Fuzzy control: the limits

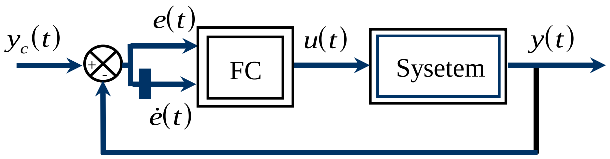
Highly complex systems and/or hard to model, identify



Stability ? Robustness?

Problem: NOT « model-based »

Fuzzy control: the limits



Input/output methods

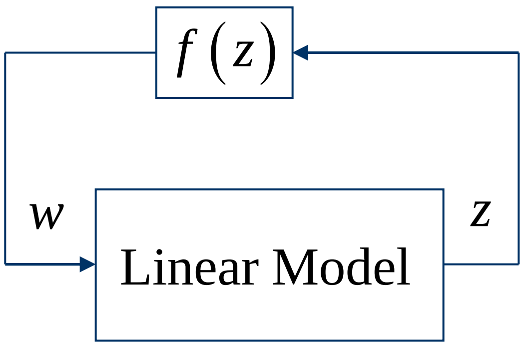
⇨ Circle Criterion, Conicity Criterion [Ollero et al., 1993]

- linear model only: reduced interest

- PB : transform the nonlinear model:
a nonlinear part + a linear part

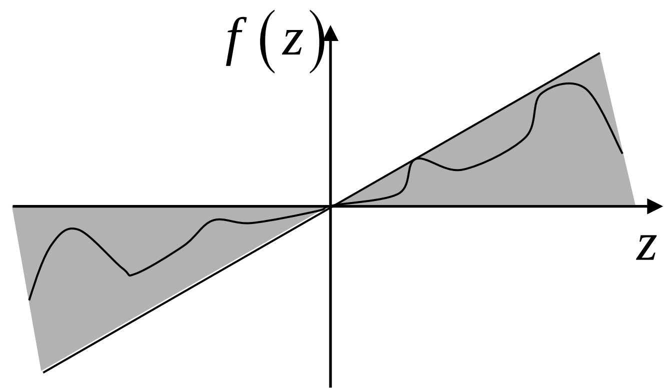
Anibal Ollero - Professor at the Ingeniería de Sistemas y Automática Department, University of Seville, Spain

Fuzzy control: the limits



[Melin et al. 1998]

$$f:\mathbb{R}^q \to \mathbb{R}^q \text{ is in } S=\left\{f(z),\, z^T f(z)\geq 0,\ f(0)=0\right\}$$



Input/Ouput Methods

$$\frac{dx}{dt}=f(\mathbf{x})+Bu$$

$$u=\Phi(\mathbf{x})$$

Criteria based on Jacobian matrix
→ Necessary Conditions

As a matter of summary… with some fuzzyness

Fuzzy control: the pioneers, the first applications

Limitations, getting “older”

How to go further?

Is Fuzzy dead?

Tracks

I – Fuzzy control: going further

Brunovski form
$$\begin{cases} \dot{x}_n = f(\mathbf{x}) + g(\mathbf{x})u \\ y = x_1 \end{cases}$$

[Li-Xin Wang 1994]

$$x^T = \begin{bmatrix} x_1 & \dot{x}_1 & \dots & x_1^{(n-1)} \end{bmatrix} \qquad u = \frac{1}{g(\mathbf{x})}\left(-f(\mathbf{x}) + y_m^{(n)} + k^T e\right)$$

Takes profit from universal approximation property:

$$f(\boldsymbol{x}) = \boldsymbol{w}_f^T(\boldsymbol{x})\theta_f^* + \varepsilon_f(\boldsymbol{x})$$

$\boldsymbol{w}_f(\boldsymbol{x}) \rightarrow$ Fuzzy vector of basis functions

$\theta_f^* \rightarrow$ Optimal (unknown) vector of parameters

$\varepsilon_f(\boldsymbol{x}) \rightarrow$ Approximation error

I – Fuzzy control: going further

Brunovski form $\begin{cases} \dot{x}_n = f(\mathbf{x}) + g(\mathbf{x})u \\ y = x_1 \end{cases}$ [Li-Xin Wang 1994]

$$x^T = \begin{bmatrix} x_1 & \dot{x}_1 & \dots & x_1^{(n-1)} \end{bmatrix} \qquad u = \frac{1}{g(\mathbf{x})}\left(-f(\mathbf{x}) + y_m^{(n)} + k^T e\right)$$

Indirect fuzzy adaptive control: fuzzy models used for approximating the system, i.e. $f(\mathbf{x})$ and $g(\mathbf{x})$

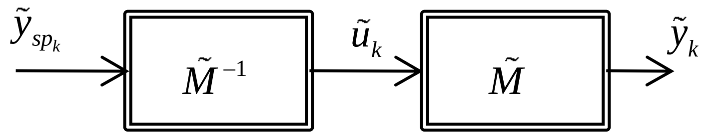
$$u = \frac{1}{\hat{g}(\mathbf{x})}\left(-\hat{f}(\mathbf{x}) + v + k\,s\right)$$

Direct fuzzy adaptive control: : fuzzy models used for approximating the control

$$u = \hat{u}(\mathbf{x})$$

II – Fuzzy control: going further

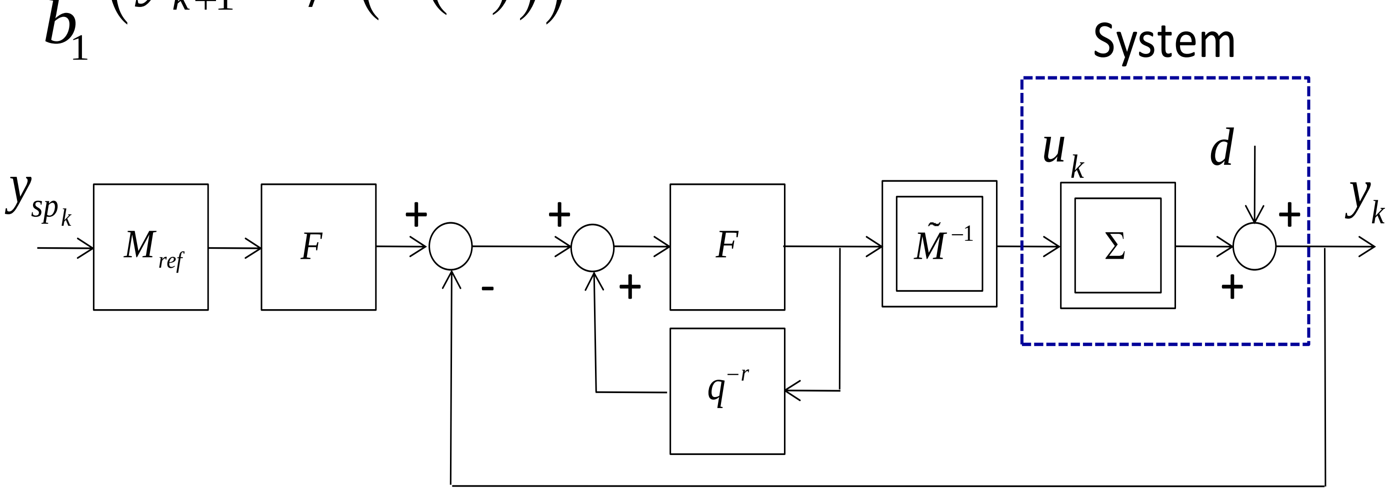
Model inversion



Rule by rule [Babuska et al. 1995], using optimization tools [Park et Han 2000]
A more recent tentative with Piecewise Bilinear Modeling of Nonlinear Systems [Eciolaza & Sugeno 2012].

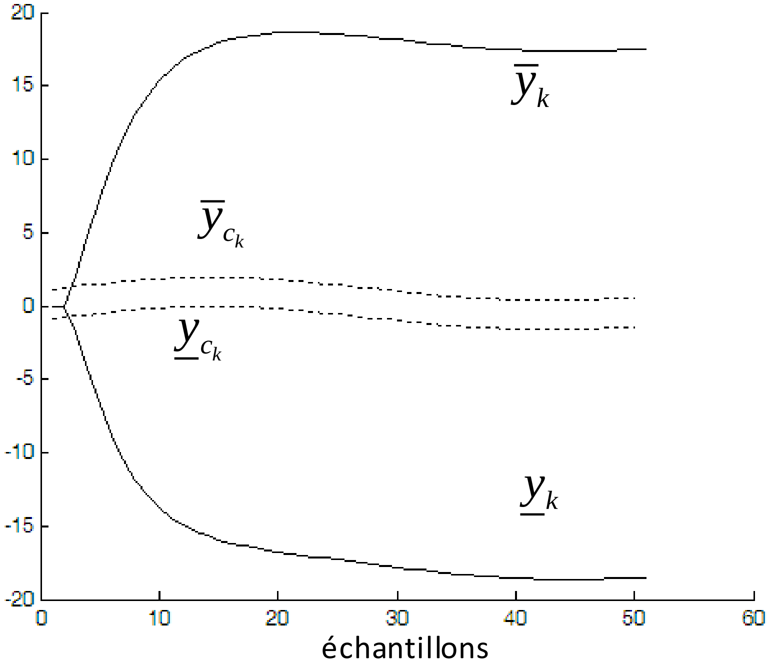
For minimum phase systems:

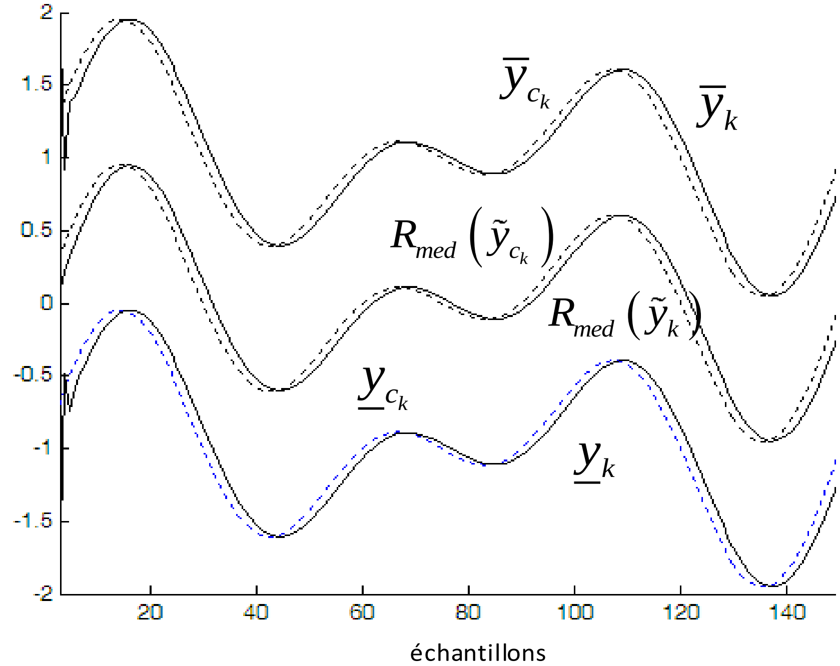
$$\tilde{u}_k = \frac{1}{\tilde{b}_1}\left(\tilde{y}_{k+1} + \tilde{\psi}\left(\tilde{z}\left(k\right)\right)\right)$$



II – Fuzzy control: going further

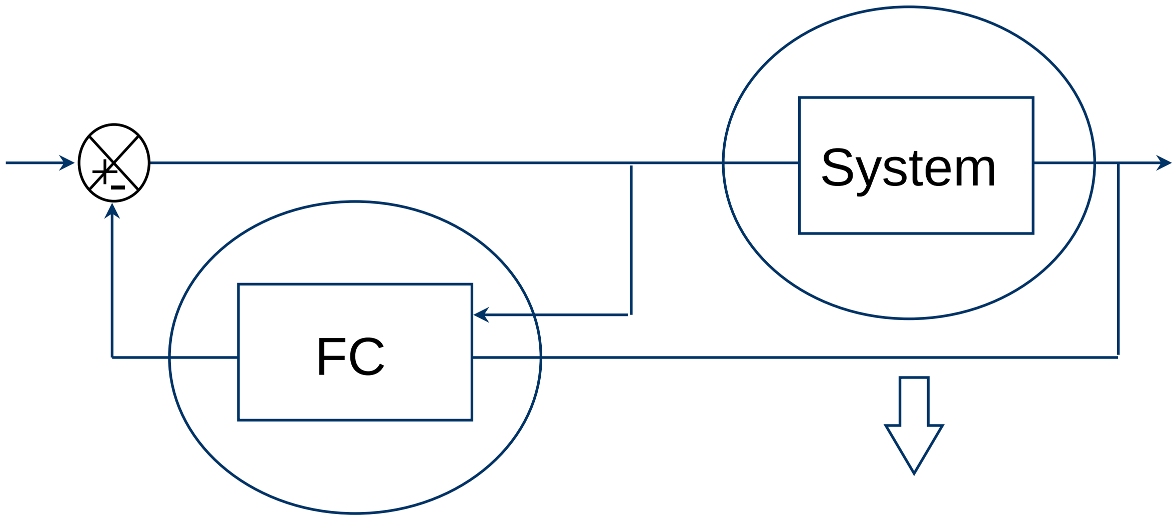
Do not overestimate the solutions → "exact" solution procedures when "possible" [Boukezzoula et al.2006], best "approximate" solution problem [Lamara et al. 2011]





$$\tilde{u}_k = \frac{1}{\tilde{b}_1}\left(\tilde{y}_{k+1} + \tilde{\psi}\left(\tilde{z}\left(k\right)\right)\right)$$

III – Fuzzy control: going further



Nonlinear Fuzzy TS via identification or “directly”

Property :

Universal approximation

[N’guyen & al. 1993]

[Castro, 1996]

FC synthesis with stability and performances properties

Takagi-Sugeno fuzzy models

[Takagi & Sugeno 1985] multi-model vision

Coming from “classical” fuzzy models rule based:

Rule i : If $z_1(t)$ is $F_1^i(z_1(t))$ and ... and $z_p(t)$ is $F_p^i(z_p(t))$

Then Linear model description

Takagi-Sugeno fuzzy models

[Takagi & Sugeno 1985] multi-model vision

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Rule i : If $z_1(t)$ is $F_1^i(z_1(t))$ and ... and $z_p(t)$ is $F_p^i(z_p(t))$

Then Linear model description

Transfert

$$y_i(t) = A_i(q)y(t) + B_i(q)u(t-nk) + \theta_{i0}$$

State Space

$$\begin{cases} \dot{x}(t) = A_i x(t) + B_i u(t) \\ y(t) = C_i x(t) \end{cases}$$

⇨ linear models blended together with *nonlinear functions*

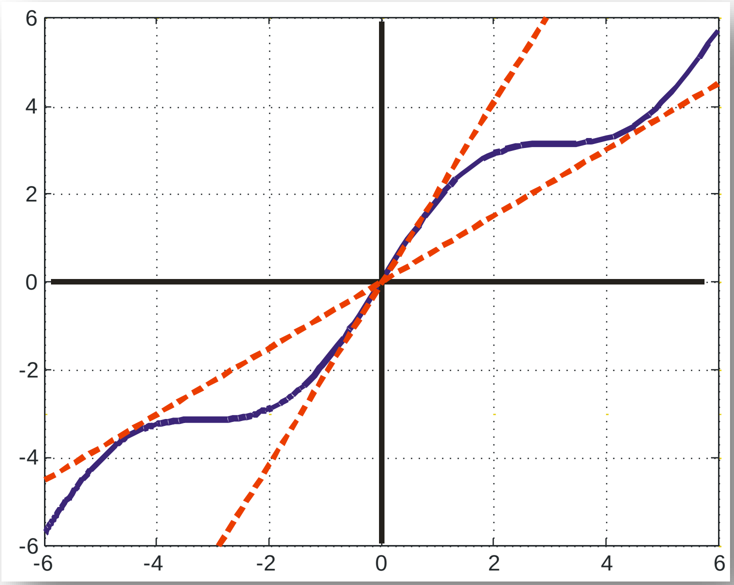
⇨ Nonlinearities in the premises.

TS: sector nonlinearity approach

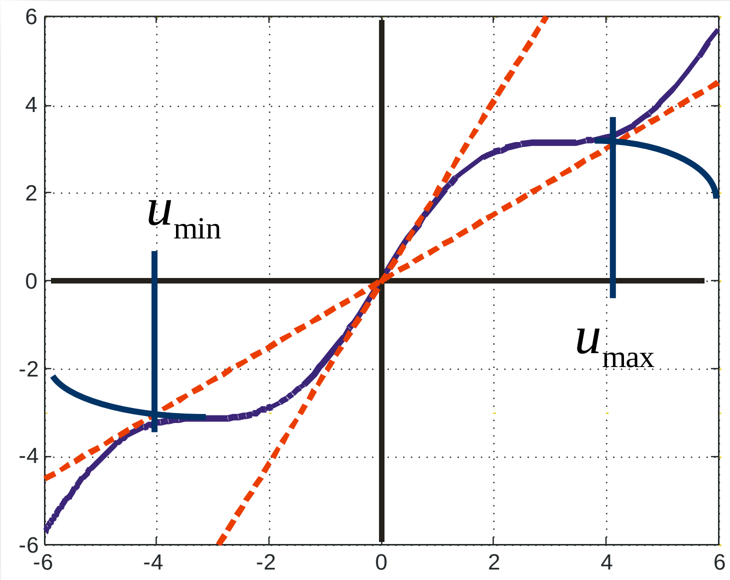
$$h_i\left(z(t)\right) \geq 0, \sum_{i=1}^{r} h_i\left(z(t)\right) = 1$$

$$\begin{cases} x(t+1) = \sum_{i=1}^{r} h_i\left(z(t)\right)\left(A_i x(t) + B_i u(t)\right) \\ y(t) = \sum_{i=1}^{r} h_i\left(z(t)\right) C_i x(t) \end{cases}$$

Direct from NL to TS: Sector Nonlinearity Approach [Tanaka et al. 1996]



Global

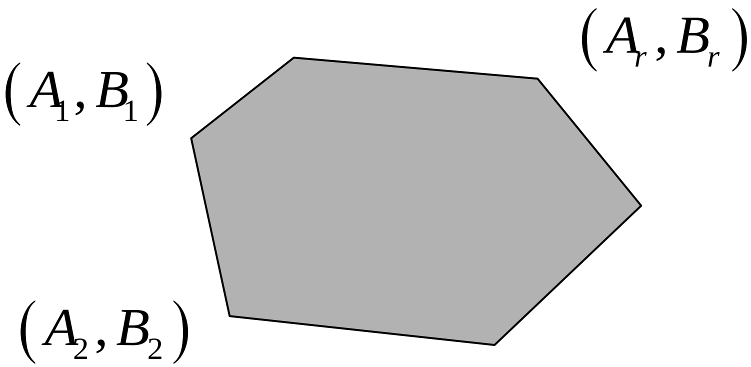


Local: in a compact set $[u_{min}, u_{max}]$

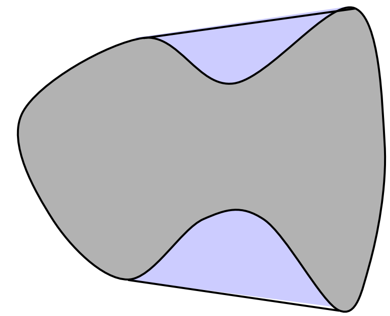
Takagi-Sugeno fuzzy models

$$h_i\left(z(t)\right) \geq 0, \; \sum_{i=1}^{r} h_i\left(z(t)\right) = 1 \qquad x(t+1) = \sum_{i=1}^{r} h_i\left(z(t)\right)\left(A_i x(t) + B_i u(t)\right)$$

Polytopic point of view



Convex hull:



Small example: $$\begin{bmatrix} x_1(k+1) \\ x_2(k+1) \end{bmatrix} = \begin{bmatrix} 0.5 & 2\sin^2\left(x_1(k)\right) \\ 2-2\sin^2\left(x_1(k)\right) & 0.5 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix}$$

$$\sin^2\left(x_1(k)\right) \in [0,1]; \quad \sin^2\left(x_1(k)\right) = 0 \times \left(1-\sin^2\left(x_1(k)\right)\right) + 1 \times \sin^2\left(x_1(k)\right)$$

$$\begin{bmatrix} 0.5 & 2\sin^2\left(x_1(k)\right) \\ 2-2\sin^2\left(x_1(k)\right) & 0.5 \end{bmatrix} = h_1(x_1)\begin{bmatrix} 0.5 & 0 \\ 2 & 0.5 \end{bmatrix} + h_2(x_1)\begin{bmatrix} 0.5 & 2 \\ 0 & 0.5 \end{bmatrix}$$

Robust stability

Discrete time LTI model $x(t+1)=A(\delta)x(t),\ x(0)=x_0,\ x(t)\in\mathbb{R}^n,\ A(\delta)\in\Gamma$
where Γ is an arbitrary *uncertain set*

Robust stability: the DTLTI uncertain model is said to be robustly stable if

it is asymptotically stable for all $A\in\Gamma$

Problem: the set of all stable matrices **is not** a convex set

Simplest polytope: A_1 ——— A_2

$$A_1=\begin{bmatrix}0.5 & 2\\ 0 & 0.5\end{bmatrix},\ A_2=A_1^T=\begin{bmatrix}0.5 & 0\\ 2 & 0.5\end{bmatrix},\ A=\frac{1}{2}\left(A_1+A_1^T\right)=\begin{bmatrix}0.5 & 1\\ 1 & 0.5\end{bmatrix}$$

$$\lambda_i(A_1)=\lambda_i(A_2)=0.5,\ i=1,2 \text{ and } \lambda_1(A)=-0.5,\ \lambda_2(A)=1.5$$

ATTENTION: Stability at the vertices **DO NOT** imply stability of the convex set…

Quadratic Stability of Discrete TS models

Unforced discrete TS: $x(t+1)=\sum_{i=1}^{r} h_i(z(t))A_i x(t) = A_z x(t)$

Quadratic Lyapunov function: $V(x)=x(t)^T Px(t),\ P=P^T>0$

$$\Delta V(x)=x^T(t)\left(A_z^T P A_z - P\right)x(t)<0 \underset{\substack{Schur\\complement}}{\Leftrightarrow} \begin{bmatrix} -P & (*) \\ PA_z & -P \end{bmatrix} = \sum_{i=1}^{r} h_i(z(t)) \begin{bmatrix} -P & (*) \\ PA_i & -P \end{bmatrix} < 0$$

With the convex sum property: $h_i(z(t))\geq 0,\ \sum_{i=1}^{r} h_i(z(t))=1$

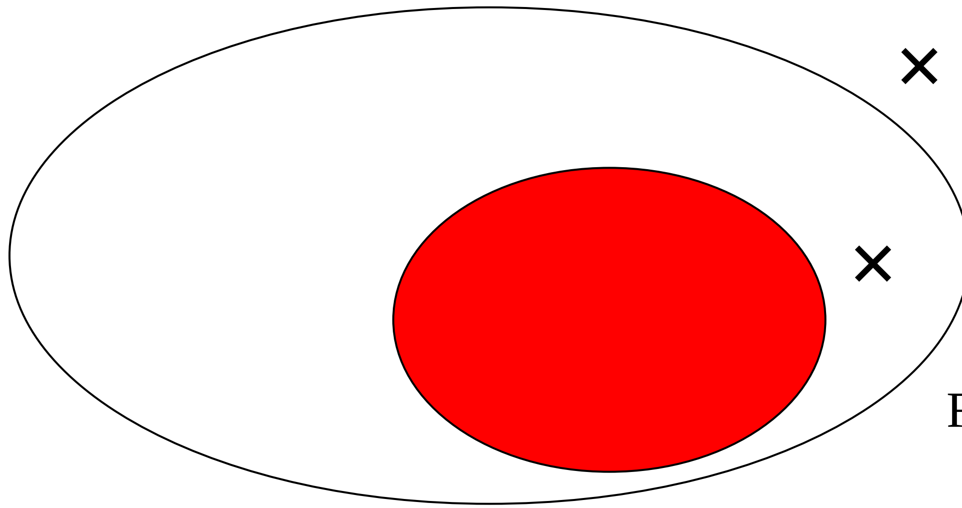
Theorem (Tanaka and Sugeno 92): the unforced DTS is GAS if there exists a matrix P such that the LMI problem holds:

$$\begin{bmatrix} P & A_i^T P \\ PA_i & P \end{bmatrix} > 0,\ i=1,\ldots,r$$

Remark: strictly *equivalent* to quadratic stability of LTI uncertain model

Main goal

Lower the conservatism and guarantee better performance / robustness



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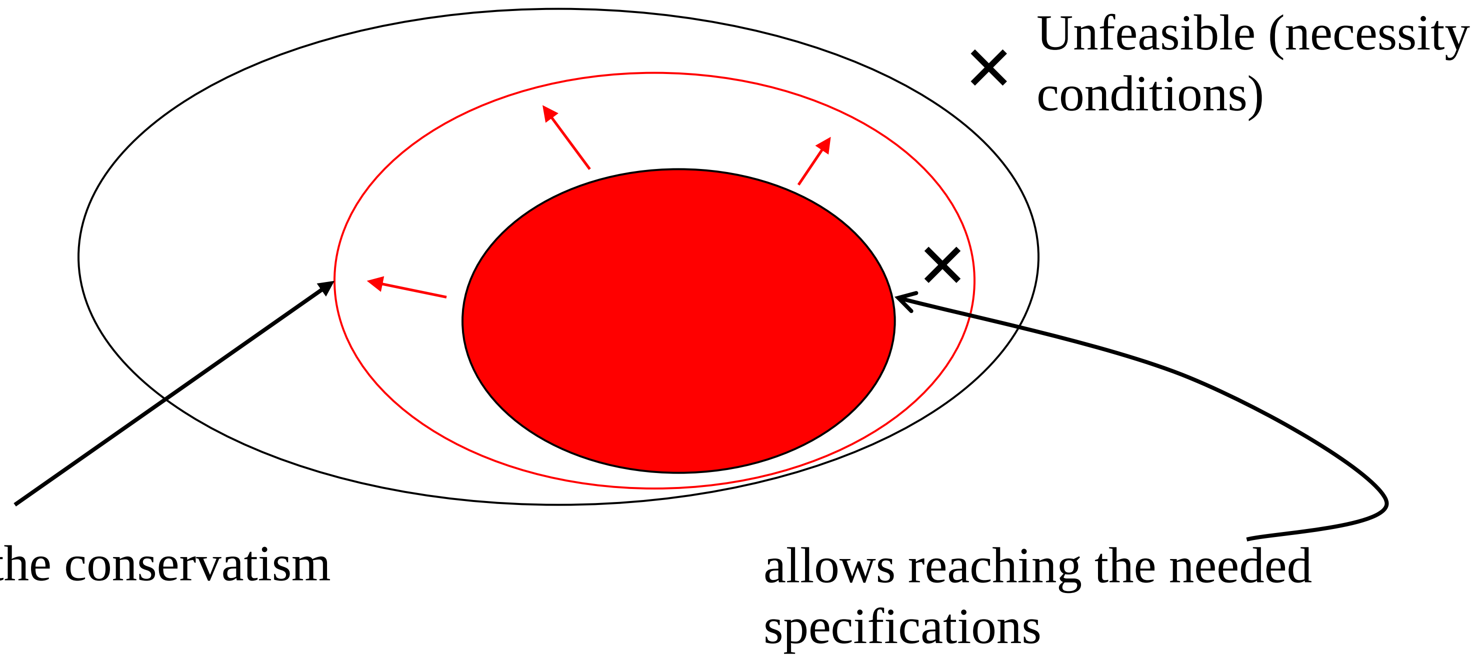


Several ways:

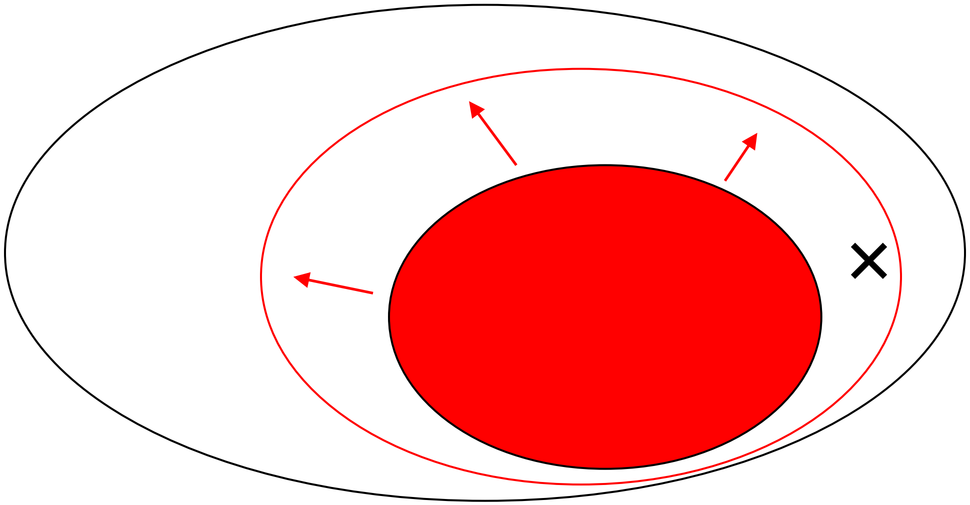
- Using relaxations (Kim & Lee 01, Liu & Zhang 04, Teixeira et al. 03)

$$h_i \geq 0,\ i = 1, \ldots, r,\ \sum_{j=1}^{r} h_i = 1,\ \sum_{i=1}^{r}\sum_{j=1}^{r} h_i h_j \Upsilon_{ij} < 0$$

Asymptotically **closed** via Polya’s theorem (Sala & Ariño 07)

Main goal

Lower the conservatism and guarantee better performance / robustness



Several ways:

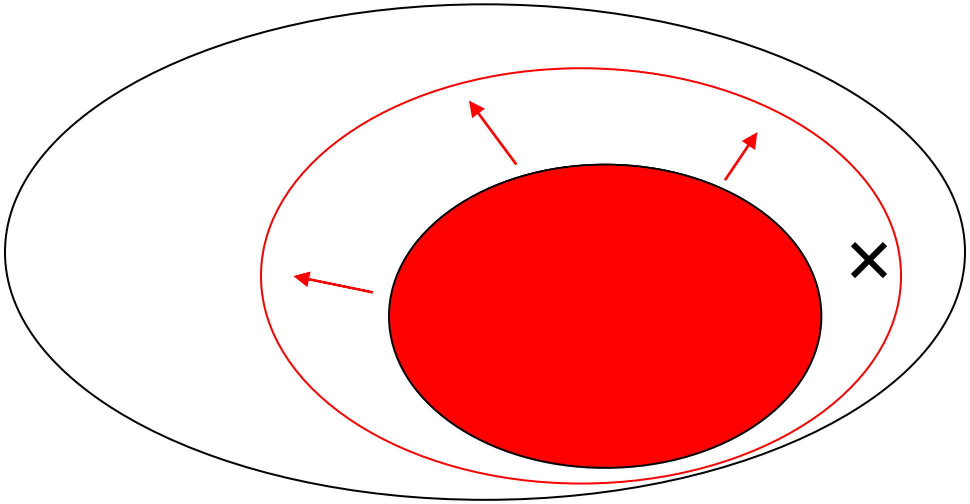
Modifying the Lyapunov function: (Johansson et al. 99, Feng 03)

piecewise $V(x) = x(t)^T P_i x(t), P_i = P_i^T > 0 \quad x \in \Omega_i$

Restriction : no improvement in the case of Sector Non Linearity approach
therefore, specific TS models under consideration

Main goal

Lower the conservatism and guarantee better performance / robustness



Several ways:
Modifying the Lyapunov function:

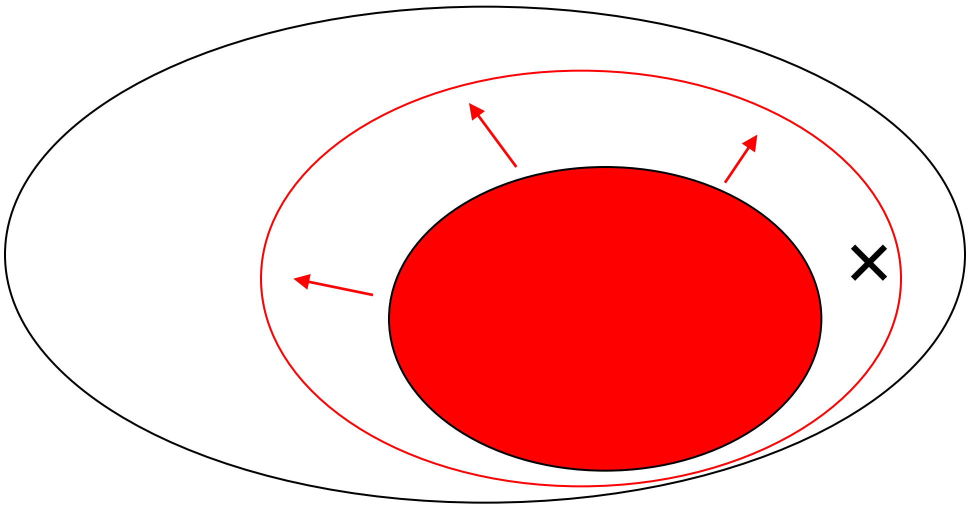
Non quadratic $V(x) = x(t)^T \sum_{i=1}^{r} h_i(x) P_i x(t),\ P_i = P_i^T > 0$

(Blanco et al. 01, Tanaka et al. 01, Guerra & Vermeiren 04)

Restriction : In the continuous case no real improvement excepted special case
Path independent Lyapunov function (Rhee & Won 06)

A focus on the discrete case

Lower the conservatism and guarantee better performance/robustness



Modifying the Lyapunov function:

Non quadratic $V(x) = x(t)^T \sum_{i=1}^{r} h_i(x) P_i x(t),\ P_i = P_i^T > 0$

$$u(x) = \sum_{i=1}^{r} h_i(x) F_i \left(\sum_{i=1}^{r} h_i(x) P_i \right)^{-1} x(t)$$ (Guerra & Vermeiren 04)

Choice of the Lyapunov function

Multiple sum extension of NQLF

$$V(x) = x^T \left(\sum_{i_1=1}^{r} \dots \sum_{i_s=1}^{r} h_{i_1}(z(t)) \dots h_{i_s}(z(t)) P_{i_1 \dots i_s} \right) x$$

[Ding 06]
[Ding et al 10]
[Kim et al 11]

Non Quadratic Lyapunov function (NQLF)

$$V(x) = x^T \left(\sum_{i=1}^{r} h_i(z(t)) P_i \right) x$$

[Blanco et al. 01]
[Tanaka et al. 01]
[Guerra et al 04]
[Mozelli et al. 06]

Quadratic Lyapunov function (QLF)

$$V(x) = x^T P x$$

Piecewise Lyapunov function (PWLF)

$$V(x) = x^T P_q x, \quad x \in X_q$$

[Johansson et al 99]
[Feng et al. 01]

Why decreasing each step?

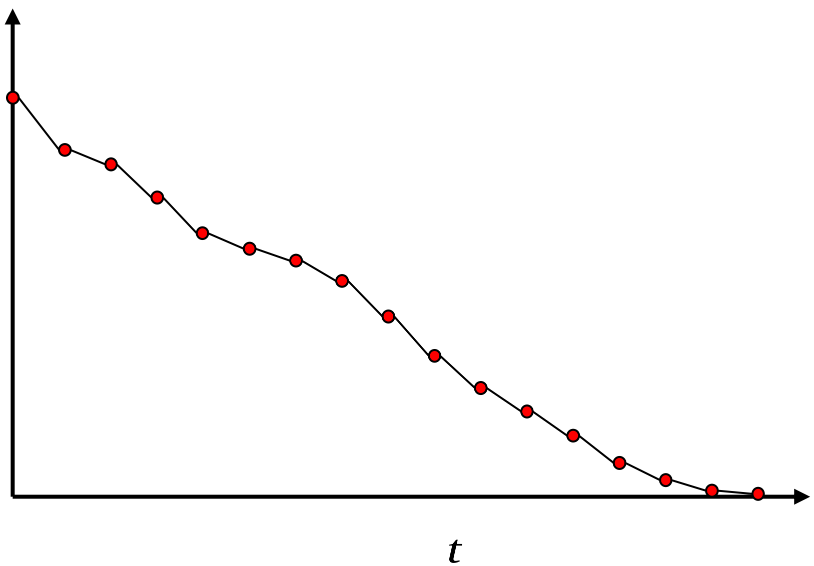
[Kruszewski & Guerra 05]

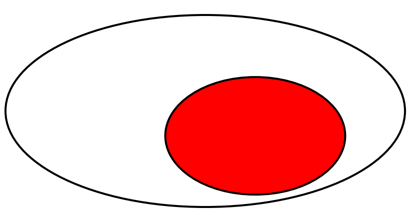
- Modifying the stability criteria

Classical approach

$$\forall x(t) \quad V\left(x(t+1)\right) - V\left(x(t)\right) < 0$$

$V\left(x(t)\right)$





Why decreasing each step?

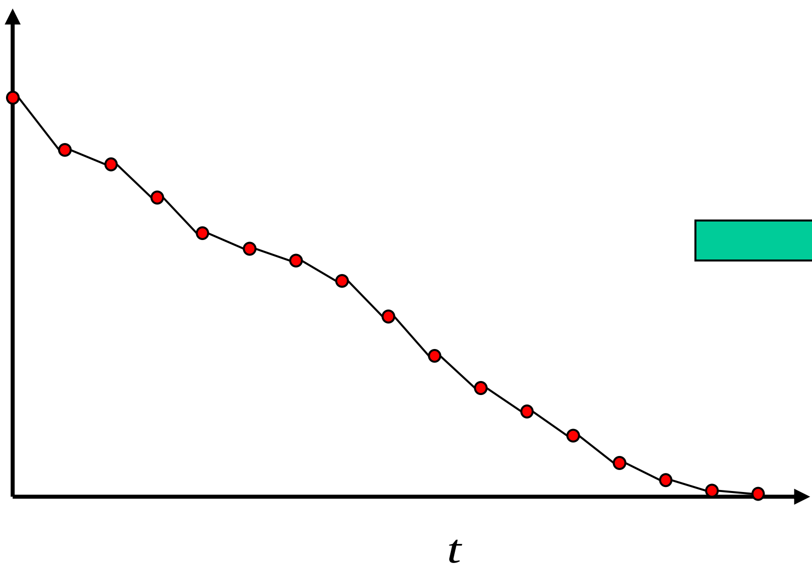
[Kruszewski & Guerra 05]

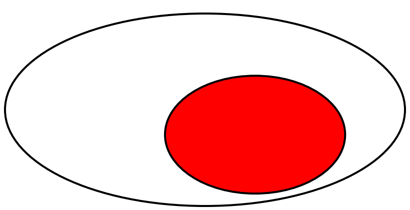
- Modifying the stability criteria

Classical approach

$$\forall x(t) \quad V\big(x(t+1)\big) - V\big(x(t)\big) < 0$$

$V\big(x(t)\big)$

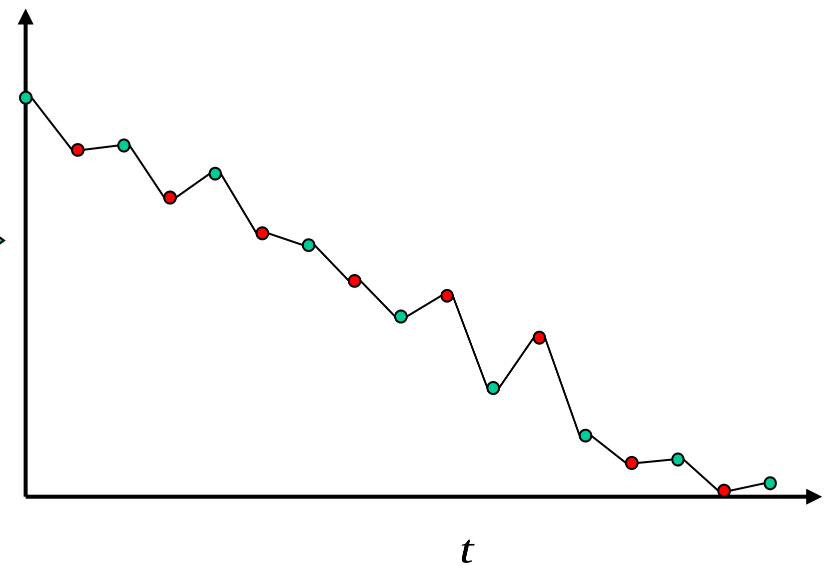


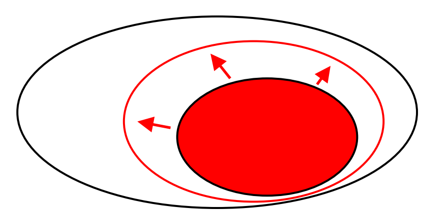


k-sample approach

$$\forall x(t) \quad V\big(x(t+k)\big) - V\big(x(t)\big) < 0$$

$V\big(x(t)\big)$



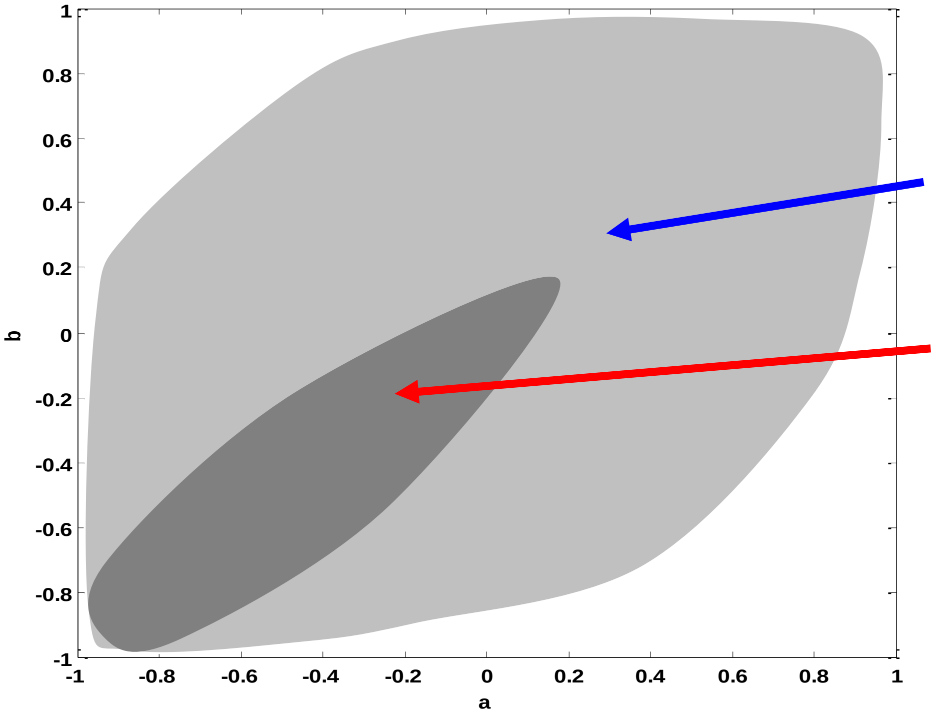


Can be applied on any problem in the discrete case

Example: stability

$$A_1 = \begin{bmatrix} a & -0.5 \\ 0 & -0.86 \end{bmatrix} \qquad A_2 = \begin{bmatrix} 0.87 & 0 \\ -0.5 & b \end{bmatrix}$$

The candidate Lyapunov function is: $V(x) = x^T P x$



$$\Delta_4 V(x(t)) = V(x(t+4)) - V(x(t)) < 0$$

$$\Delta V(x(t)) = V(x(t+1)) - V(x(t)) < 0$$

Solution set for two values of k

Choice of the Lyapunov function

Variation over k-samples

$$V(t+k)-V(t)\le 0,\ k>1$$

[Kruszewski et al 05]
[Guerra et al. 09]

Multiple sum extension of NQLF

$$V(x)=x^T\left(\sum_{i_1=1}^{r}\cdots\sum_{i_s=1}^{r}h_{i_1}(z(t))\ldots h_{i_s}(z(t))P_{i_1\ldots i_s}\right)x$$

[Ding 06]
[Ding et al 10]
[Kim et al 11]

Non Quadratic Lyapunov function (NQLF)

$$V(x)=x^T\left(\sum_{i=1}^{r}h_i(z(t))P_i\right)x$$

[Blanco et al. 01]
[Tanaka et al. 01]
[Guerra et al 04]
[Mozelli et al. 06]

Quadratic Lyapunov function (QLF)

$$V(x)=x^T P x$$

Piecewise Lyapunov function (PWLF)

$$V(x)=x^T P_q x,\quad x\in X_q$$

[Johansson et al 99]
[Feng et al. 01]

Choice of the Lyapunov function

Variation over k-samples

$$V(t+k)-V(t)\leq 0,\; k>1$$

Multiple sum extension of NQLF

$$V(x)=x^T\left(\sum_{i_1=1}^{r}\dots\sum_{i_s=1}^{r}h_{i_1}(z(t))\dots h_{i_s}(z(t))P_{i_1\dots i_s}\right)x$$

Multiple sum extension of Delayed NQLF

$$V(x)=x^T\left(\sum_{i_1=1}^{r}\dots\sum_{i_s=1}^{r}h_{i_1}(z(t-1))\dots h_{i_s}(z(t-n))P_{i_1\dots i_s}\right)x$$

Non Quadratic Lyapunov function (NQLF)

$$V(x)=x^T\left(\sum_{i=1}^{r}h_i(z(t))P_i\right)x$$

Delayed NQLF

$$V(x)=x^T\left(\sum_{i=1}^{r}h_i(z(t-1))P_i\right)x$$

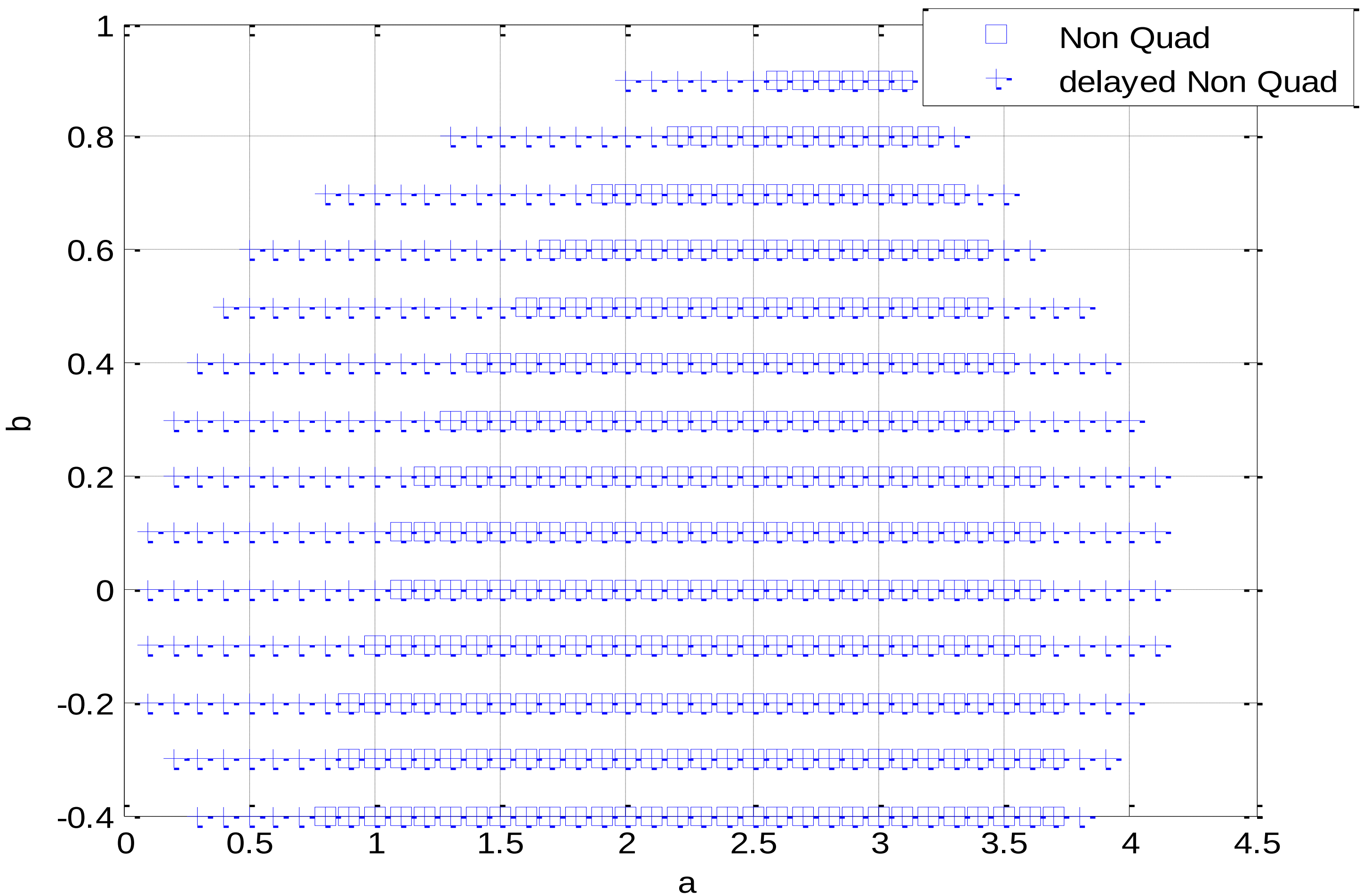
Quadratic Lyapunov function (QLF)

$$V(x)=x^TPx$$

New Observer design : Results

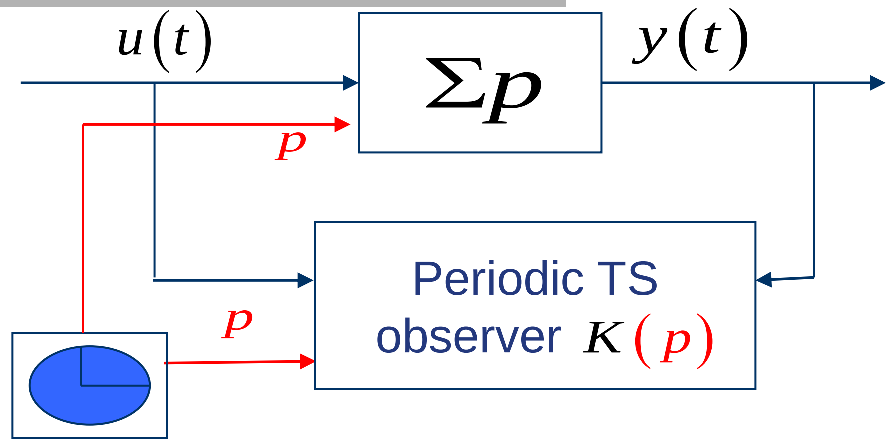
Example: Consider the following TS model with a and b are free parameters.

$$A_1 = \begin{bmatrix} 2.5 & 1 \\ 0.5 & 2 \end{bmatrix} \quad A_2 = \begin{bmatrix} 0.5 & 0 \\ 2.5 & a \end{bmatrix} \quad B_1 = B_2 = \begin{bmatrix} 1 & 0 \end{bmatrix}^T \quad C_1 = \begin{bmatrix} b & 1 \end{bmatrix} \quad C_2 = \begin{bmatrix} 1 & 1 \end{bmatrix}$$



[Kerkeni 2011]

IC engine cylinder pressure estimation



Cylinder by cylinder estimation

Periodic TS model

$$\begin{cases} x(t+1) = A_{z(t)}^{(c)} x(t) + B_{z(t)}^{(c)} u(t) \\ y(t) = C_{z(t)}^{(c)} x(t) \end{cases}$$

$$c = t \bmod p$$

Periodic TS observer

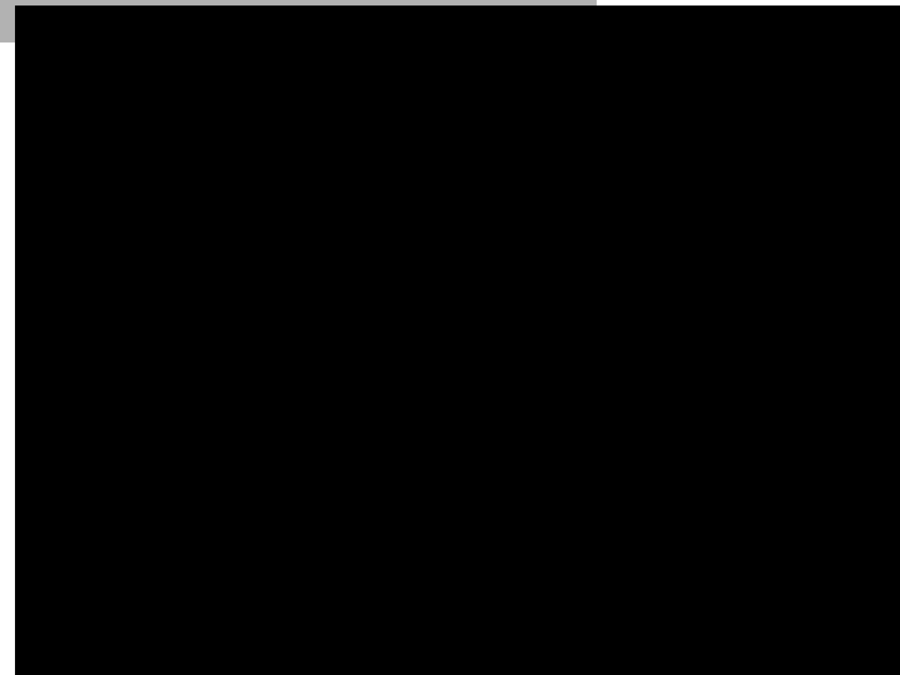
$$\begin{cases} \hat{x}(t+1) = A_{z(t)}^{(c)} \hat{x}(t) + B_{z(t)}^{(c)} u(t) + S_{z(t)}^{(c)^{-1}} K_{z(t)}^{(c)} \left(y(t) - \hat{y}(t) \right) \\ \hat{y}(t) = C_{z(t)}^{(c)} \hat{x}(t) \end{cases}$$

Structure of LMI constraints

$$S_j^{(m)} \in \mathbb{R}^{7\times 7}$$

$$\Omega_{ij}^m = \begin{bmatrix} -\tilde{P}^{(m)} & (*) \\ S_j^{(m+1)} A_i^{(m)} - K_j^{(m)} C_i^{(m)} & -S_j^{(m)} - \left(S_j^{(m)}\right)^T + \tilde{P}^{(m)} \end{bmatrix}$$

Fuzzy applications → plenty



Robotics and control, a very close history

Trajectory planning
Obstacle avoidance

Lumenosys
making connections in robotics and AI

Cooperative robotics

language for prog
humanoid robot

As a matter of summary… with some fuzzyness

Fuzzy control: the pioneers, the first applications

Limitations, getting “older”

How to go further?

Is Fuzzy dead?

Tracks

Fuzzy control: the community

Annual international conference Fuzz'IEEE / WCCI (~200 attendants)
International Journals IEEE Trans. On Fuzzy Systems (2012 IF 4,26)
Fuzzy Sets and Systems (2012 IF 1,8)

IFAC Technical Committee 3.2 (Chair Antonio Ruano)
IFAC ICONS triennial

But also any IFAC Journal, conf + IEEE SMC, TAC …

Prof. Robert Babuska (TU Delft)

Prof. Antonio Sala (PU Valencia)

Jong-Hwan Kim KAIST (Seoul)

Prof. FENG, Gang (Gary) Hong Kong

H.K. Lam King's College, UK

Some tracks…

Type II Fuzzy sets - Jerry Mendel, Pr Univ South California

Mixing with reinforcement learning
Franck Lewis Pr Univ Texas at Arlington

Problems:

- high sized systems
- output feedback with performances
- networked systems

Any way to come back to Human? Man in the loop?
Is there any place/need for fuzzy mathematical tools (uncertainty, linguistic…)

We need new tools, new ideas, new gaps

Future events of TC 3.2

IFAC CESCIT

MARIBOR Slovenia 22-24 June 2015

2nd CESCIT conference

IFAC Conference on Embedded Systems, Computational Intelligence and Telematics in Control

Univerza v Mariboru

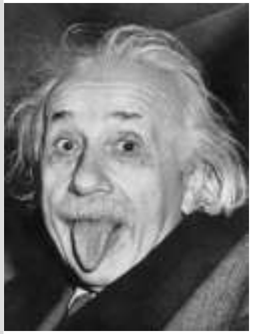
http://cescit2015.um.si/ Deadline for receipt of papers: **20 October, 2014**

4th IFAC Conference on Intelligent Control and Automation Science - **ICONS 2016**

1 proposition in Reims, France (K. Guelton)

Some answers

“Only those who attempt the absurd can achieve the impossible.” Maurits Cornelis Escher



“If we knew what it was we were doing, it would not be called research, would it?”

“The truth is rarely pure and never simple.”
Oscar Wilde

Thank you