On Approximate Diagnosability of Metric Systems

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Introduction

- Diagnosability corresponds to the possibility of detecting faults within finite delays
- Extensively investigated in the communities of discrete event systems, continuous control systems and also hybrid systems
- Current literature assume the exact knowledge of state of output variables except for

[Lunze, M&C-00] J. Lunze. Diagnosis of quantized systems based on a timed discrete–event model. IEEE Transactions on Man and Cybernetics – Part A: Systems and Humans, May 2000

[De Persis, CDC-13] C. De Persis. Detecting faults from encoded information. IEEE Conference on Decision and Control, 2013

This is limiting in concrete applications where sensors introduce errors in the state/output measurements

Introduction

Related literature

[Lunze, M&C-00] J. Lunze. Diagnosis of quantized systems based on a timed discrete–event model. IEEE Transactions on Man and Cybernetics – Part A: Systems and Humans, May 2000

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Main issues

- [Lunze, M&C-00] and [De Persis, CDC-13] investigate diagnosability for quantized systems and model faults as additional inputs to the system
- [De Persis, CDC-13] considers discrete–time linear systems where faults are detected provided that they belong to an appropriate class of functions
- [Lunze, M&C-00] considers continuous–time nonlinear systems and detection is achieved in a stochastic setting

Introduction

Here:

- General class of **metric systems** able to model both discrete and continuous dynamics arising in complex heterogeneous systems as for example CPSoS

- Novel notion of **approximate diagnosability** that considers explicitly measurements corrupted by errors always introduced by non-ideal sensors in a real environment

- Relations between approximate diagnosability of metric systems that are in **approximate simulation**

- Application to approximate diagnosability of **nonlinear control systems** (with an infinite number of states and of inputs)

Outline

- Metric Systems
- Approximate diagnosability
- Main result
- Application to nonlinear control systems
- Example
- References and conclusions

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Systems

[Tabuada, Springer-09]

Definition

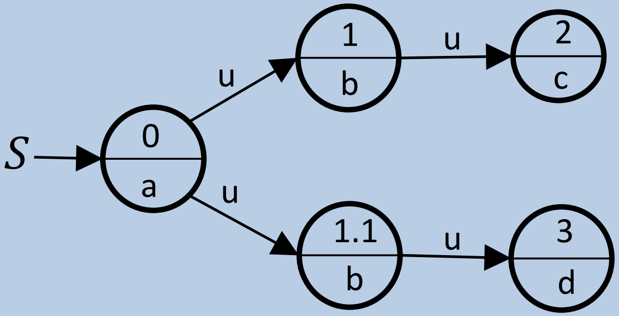
A system is a tuple

$$S = (X, X_0, U, \longrightarrow, Y, H)$$

where:

- X is the set of states
- $X_0 \subseteq X$ is the set of initial states
- U is the set of inputs
- $\longrightarrow \subseteq X \times U \times X$ is the transition relation
- Y is the set of outputs
- $H: X \rightarrow Y$ is the output function

We denote $(x, u, x') \in \longrightarrow$ by $x \xrightarrow{u} x'$



Systems

[Tabuada, Springer-09]

Definition

Given a system

$$S = (X, X_0, U, \longrightarrow, Y, H)$$

and a sequence of transitions of S

$$x(0) \xrightarrow{u(0)} x(1) \xrightarrow{u(1)} \dots \xrightarrow{u(l-1)} x(l)$$

with $x(0) \in X_0$

- The sequence

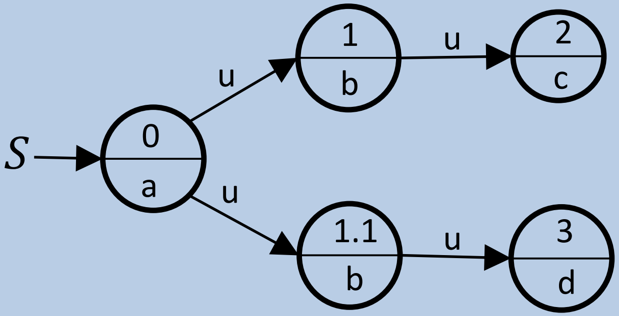
  $$x(.): x(0), x(1), \dots, x(l)$$

  is called a state run of S

- The sequence

  $$y(.): H\big(x(0)\big),\ H\big(x(1)\big), \dots, H(x(l))$$

  is called an output run of S



a state run:

$$x(.):\ 0, 1, 2$$

corresponding output run:

$$y(.):\ a, b, c$$

Systems

[Tabuada, Springer-09]

Classification:

A system $S = (X, X_0, U, \longrightarrow, Y, H)$ is

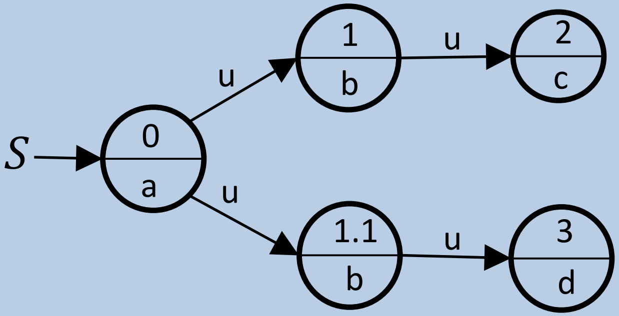
- countable if X and U are countable sets
- symbolic if X and U are finite sets
- deterministic if for any $x \in X$ and for any $u \in U$ there exists at most one transition

  $$x \overset{u}{\longrightarrow} x',$$

  and nondeterministic, otherwise
- metric if X is equipped with a metric

Remark

Metric systems useful in modeling heterogenous dynamics arising in e.g. CPSoS



System S is:

- countable
- symbolic
- nondeterministic
- metric with metric $\boldsymbol{d}(x_1, x_2) = \|x_1 - x_2\|$

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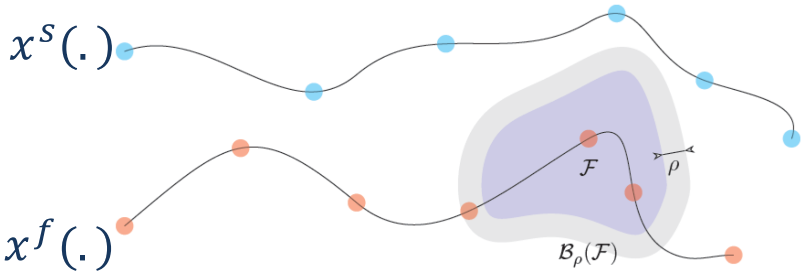
Approximate diagnosability

Given a metric system S, a set of faulty states $F \subseteq X$ and a desired accuracy $\rho \geq 0$

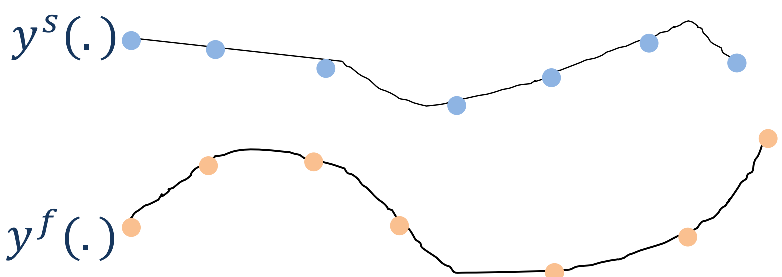
System S is (ρ, F)-diagnosable if

for any pair of state runs $x^f(.)$ and $x^s(.)$ of S such that

- $x^f(.)$ reaches F in finite time
- $x^s(.)$ does not reach $B_\rho(F)$ in finite time



the corresponding output runs are different within a finite delay Δ



Approximate diagnosability

Definition

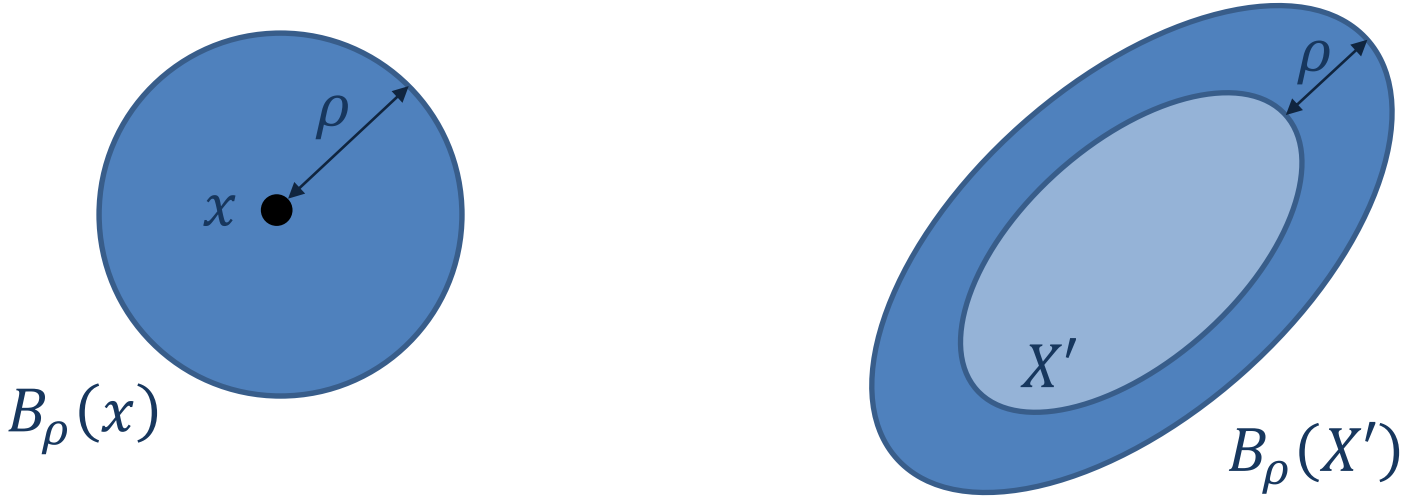
Consider a metric system

$$S = (X, X_0, U, \longrightarrow, Y, H)$$

with metric $\boldsymbol{d}$, and denote for any $\rho \geq 0$, $x \in X$ and $X' \subseteq X$

$$B_\rho(x) = \{x' \in X | \boldsymbol{d}(x, x') \leq \rho\}$$

$$B_\rho(X') = \bigcup_{x' \in X'} B_\rho(x')$$



Approximate diagnosability

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Consider a metric system

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$$B_\rho(x) = \{x' \in X | \boldsymbol{d}(x, x') \leq \rho\}$$
$$B_\rho(X') = \bigcup_{x' \in X'} B_\rho(x')$$

Consider a set $F \subseteq X$ of faulty states of S with $F \cap X_0 = \emptyset$.

Given a desired accuracy $\rho \geq 0$, system S is (ρ, F)-diagnosable if:

There exists a finite delay $\Delta \in \mathbb{N}$, such that for any pair of state runs $x^f(.)$ and $x^s(.)$ of S for which there exists $t \in \mathbb{N}$ such that

- $x^f(t) \in F$ and $x^f(t') \notin F$ for all $t' \in [0; t-1]$
- $x^s(t'') \notin B_\rho(F)$ for all $t'' \in [0; t+\Delta]$

the corresponding output runs $y^f(.)$ and $y^s(.)$ are different at some t$' \in [0; t+\Delta]$

Approximate diagnosability

When $\rho = 0$ approximate diagnosability boils down to exact diagnosability as in [De Santis & Di Benedetto, Autom-2017], see also the overview [Zaytoon & Lafortune, ARC-13] and references therein.

Checking approximate diagnosability:

Proposition

For nonblocking metric symbolic systems S, the notion of approximate diagnosability can be checked with

- Space computational complexity $O(card(X)^2)$
- Time computational complexity $O(card(X)^5)$

Proof

Slight extension of algorithms proposed in [De Santis & Di Benedetto, Autom-2017] from exact diagnosability to approximate diagnosability. Details are reported in the paper

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Approximate simulation

[Girard & Pappas, TAC-07]

Definition

Consider $S_i = (X_i, X_{0,i}, U_i, \longrightarrow_i, Y_i, H_i), i = 1{,}2$ with X_1 and X_2 subsets of some set X with metric $\boldsymbol{d}$ and let $\varepsilon \geq 0$ be a given accuracy. A relation

$$R \subseteq X_1 \times X_2$$

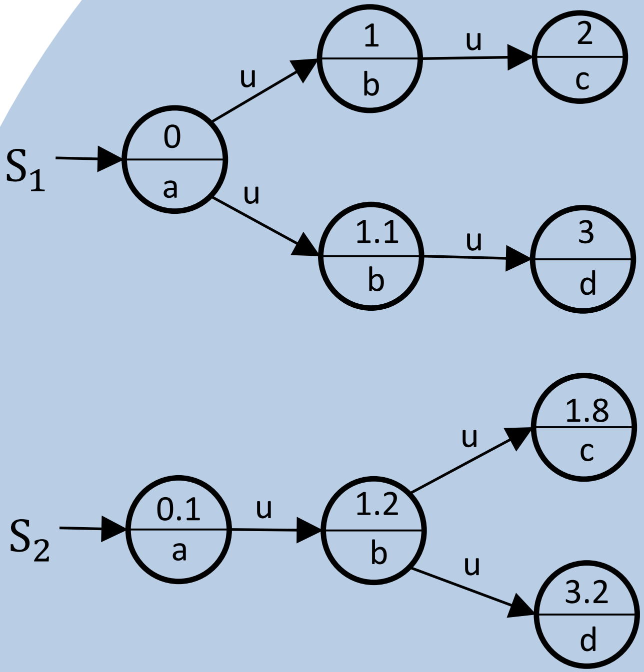
is an ε-approximate simulation relation from S_1 to S_2 if

1. $\forall x_1 \in X_{0,1}\ \exists x_2 \in X_{0,2}$ such that $(x_1, x_2) \in R$
2. $\forall (x_1, x_2) \in R,\ \boldsymbol{d}(x_1, x_2) \leq \varepsilon$
3. $\forall (x_1, x_2) \in R,\ H_1(x_1) = H_2(x_2)$
4. $\forall (x_1, x_2) \in R$, if $x_1 \xrightarrow{u_1}_1 x'_1$ then $x_2 \xrightarrow{u_2}_2 x'_2$ such that $(x'_1, x'_2) \in R$

Metric system S_1 is ε-simulated by metric system S_2, denoted

$$S_1 \preccurlyeq_\varepsilon S_2$$

if there exists an ε-approximate simulation relation from S_1 to S_2



$$R = \{(0{,}0.1), (1{,}1.2), (1.1{,}1.2), (2{,}1.8), (3{,}3.2)\}$$

$$S_1 \preccurlyeq_{0.2} S_2$$

Approximate bisimulation

[Girard & Pappas, TAC-07]

Definition

Consider $S_i = (X_i, X_{0,i}, U_i, \longrightarrow_i, Y_i, H_i), i = 1,2$ with X_1 and X_2 subsets of some set X with metric $\boldsymbol{d}$ and let $\varepsilon \geq 0$ be a given accuracy. A relation

$$R \subseteq X_1 \times X_2$$

is an <u>ε-approximate bisimulation relation</u> between S_1 and S_2 if

1. R is an ε-approximate simulation relation from S_1 to S_2
2. the inverse relation R^{-1} of R, i.e.

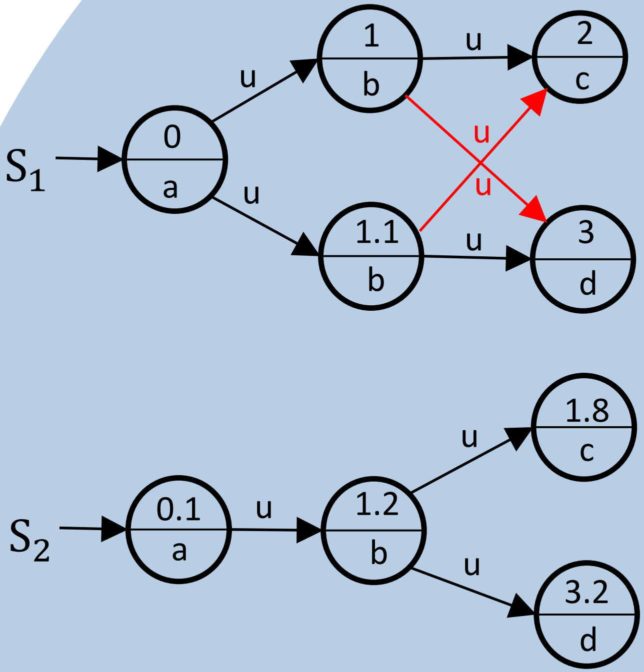
$$R^{-1} = \{(x_2, x_1) \in X_2 \times X_1 \,|(x_1, x_2) \in R\}$$

is an ε-approximate simulation relation from S_2 to S_1

Metric systems S_1 and S_2 are <u>ε-bisimilar</u>, denoted

$$S_1 \simeq_{\varepsilon} S_2$$

if there exists an ε-approximate bisimulation relation between them



$R = \{(0,0.1), (1,1.2),$
$(1.1,1.2), (2,1.8), (3,3.2)\}$

$S_1 \simeq_{0.2} S_2$

Main result

Theorem

Consider two metric systems $S_i = \left(X_i, X_{0,i}, U_i, \longrightarrow_i, Y_i, H_i\right), i = 1{,}2$ with X_1 and X_2 subsets of some set X with metric $\boldsymbol{d}$ and suppose that $S_1 \preccurlyeq_{\varepsilon} S_2$ for some accuracy $\varepsilon \geq 0$. Consider a set $F_1 \subseteq X_1$ of faulty states for S_1 and define the set

$$F_2 = B_{\varepsilon}(F_1) \cap X_2$$

of faulty states for system S_2.
If S_2 is (ρ_2, F_2)-diagnosable for some accuracy $\rho_2 \geq 0$ then, S_1 is (ρ_1, F_1)-diagnosable for all $\rho_1 \geq \rho_2 + 2\varepsilon$.

- This result allows checking approximate diagnosability of a metric system S_1 on the basis of approximate diagnosability of S_2 if $S_1 \preccurlyeq_{\varepsilon} S_2$
- When S_2 has fewer states than S_1, it can be useful to reduce computational complexity in checking approximate diagnosability of S_1 by using S_2

Main result

- **If one is able to construct a symbolic metric system approximating a continuous or hybrid control system Σ (with an infinite number of states) in the sense of approximate simulation, our result allows checking approximate diagnosability of Σ on the symbolic system**

- Symbolic models approximating continuous or hybrid control systems are extensively studied, see e.g. [Tabuada, Springer-09] and references therein

- Papers working with approximate simulation that fit the framework of this paper are

  - [Pola et al., TAC-16; Pola et al., Autom-08] proposing symbolic models for incrementally stable nonlinear systems

  - [Zamani et al., TAC-12], for possibly unstable nonlinear systems

  - [Girard et al., TAC-10], for incrementally stable switched systems

  - [Pola & Di Benedetto, TAC-14], for piecewise affine systems

We now apply our results to incrementally stable nonlinear systems as studied in [Pola et al., TAC-16]

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Approximate diagnosability of nonlinear systems

Consider the discrete-time nonlinear control system

$$\Sigma: \begin{cases} x(t+1) = f\big(x(t), u(t)\big), \\ y(t) = [I_p \quad 0]x(t), \\ x(0) \in \boldsymbol{X}_0, x(t) \in \mathbb{R}^n, u(t) \in \boldsymbol{U}, y(t) \in \mathbb{R}^p, t \in \mathbb{N} \end{cases}$$

where:

- $x(t)$ state, $u(t)$ input, $y(t)$ output at time $t \in \mathbb{N}$
- $\mathbb{R}^n$ state space
- $\boldsymbol{X}_0 \subseteq \mathbb{R}^n$ set of initial states and assumed to be compact
- $\boldsymbol{U} \subseteq \mathbb{R}^m$ set of inputs, assumed to be compact and containing the origin
- $\mathbb{R}^p$ output space with $p < n$
- $f: \mathbb{R}^n \times \mathbb{R}^m \to \mathbb{R}^n$ vector field, assumed to be continuous and s.t. $f(0,0) = 0$
- I_p identity matrix in $\mathbb{R}^p$

Given a set of faulty states $F \subseteq \mathbb{R}^n$ of Σ and a desired accuracy $\rho \geq 0$, how to check (ρ, F)-diagnosability of Σ?

Approximate diagnosability of nonlinear systems

Metric systems representation of control system $\boldsymbol{\Sigma}$:

Given Σ define the metric system

$$S(\Sigma) = (X, X_0, U, \longrightarrow, Y, H)$$

where

- $X = \mathbb{R}^n$
- $X_0 = \boldsymbol{X}_0$
- $U = \boldsymbol{U}$
- $x \xrightarrow{u} x'$ if $x' = f(x, u)$
- $Y = \mathbb{R}^p$
- $H(x) = [I_p \quad 0]x$ for all $x \in X$

Remarks:

- System $S(\Sigma)$ is metric; we choose metric $\boldsymbol{d}(x_1, x_2) = \|x_1 - x_2\|$
- System $S(\Sigma)$ is deterministic and **not symbolic**
- System $S(\Sigma)$ preserves many important properties of Σ as for example reachability properties

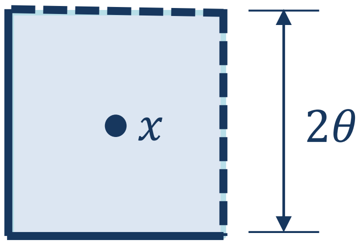
In the sequel we say that $\boldsymbol{\Sigma}$ is $(\boldsymbol{\rho}, \boldsymbol{F})$-diagnosable if $\boldsymbol{S}(\boldsymbol{\Sigma})$ is so

Approximate diagnosability of nonlinear systems

Discrete abstraction of Σ:

Given $\theta > 0$ and $x = (x_1, x_2, \dots, x_n) \in \mathbb{R}^n$ define the set

$$B_{[-\theta,\theta[}(x) = [x_1 - \theta, x_1 + \theta[\times [x_2 - \theta, x_2 + \theta[\times \cdots \times [x_n - \theta, x_n + \theta[$$



Approximate diagnosability of nonlinear systems

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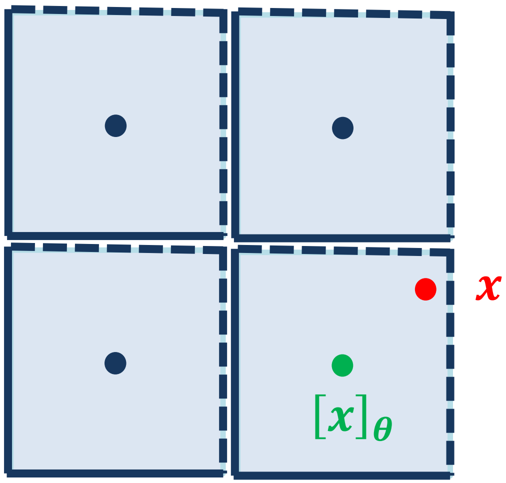
The collection of sets $B_{[-\theta,\theta[}(x)$ with x ranging in $2\theta\mathbb{Z}^n$ is a partition of $\mathbb{R}^n$



The (uniform) quantizer in $\mathbb{R}^n$ with accuracy θ is the function

$$[\ \dots\ ]_\theta : \mathbb{R}^n \to 2\theta\mathbb{Z}^n$$

associating to any $x \in \mathbb{R}^n$ the unique vector $[x]_\theta \in 2\theta\mathbb{Z}^n$ such that $x \in B_{[-\theta,\theta[}([x]_\theta)$

Approximate diagnosability of nonlinear systems

Discrete abstraction of $\boldsymbol{\Sigma}$:

Given a state quantization $\eta > 0$ and an input quantization $\mu > 0$ define

$$S_{\eta,\mu}(\Sigma) = (X_{\eta,\mu}, X_{0,\eta,\mu}, U_{\eta,\mu}, \longrightarrow_{\eta,\mu}, Y_{\eta,\mu}, H_{\eta,\mu})$$

where

- $X_{\eta,\mu} = [\mathbb{R}^n]_\eta$
- $X_{0,\eta,\mu} = [\boldsymbol{X}_0]_\eta$
- $U_{\eta,\mu} = [\boldsymbol{U}]_\mu$
- $\xi \xrightarrow{v}_{\eta,\mu} \xi'$ if $\xi' = [f(\xi, v)]_\eta$
- $Y_{\tau,\eta} = [\mathbb{R}^p]_\eta$
- $H_{\eta,\mu}(\xi) = [I_p \quad 0]\xi$ for all $\xi \in X_{\eta,\mu}$

Remarks:

- System $S(\Sigma)$ is metric; we choose metric $\boldsymbol{d}(x_1, x_2) = \|x_1 - x_2\|$
- System $S(\Sigma)$ is **countable** and deterministic

Approximate diagnosability of nonlinear systems

Discrete abstraction of Σ:

We make the following assumption

(A) Control system Σ is incrementally input-to-state stable

Proposition

Under (A), metric system $S_{\eta,\mu}(\Sigma)$ is symbolic

Proposition

Under (A), for any desired accuracy $\varepsilon > 0$ there exists a choice of the quantization parameters $\eta, \mu > 0$ such that $S(\Sigma)$ and $S_{\eta,\mu}(\Sigma)$ are ε–bisimilar

We now use $S_{\eta,\mu}(\Sigma)$ to study approximate diagnosability of Σ

Approximate diagnosability of nonlinear systems

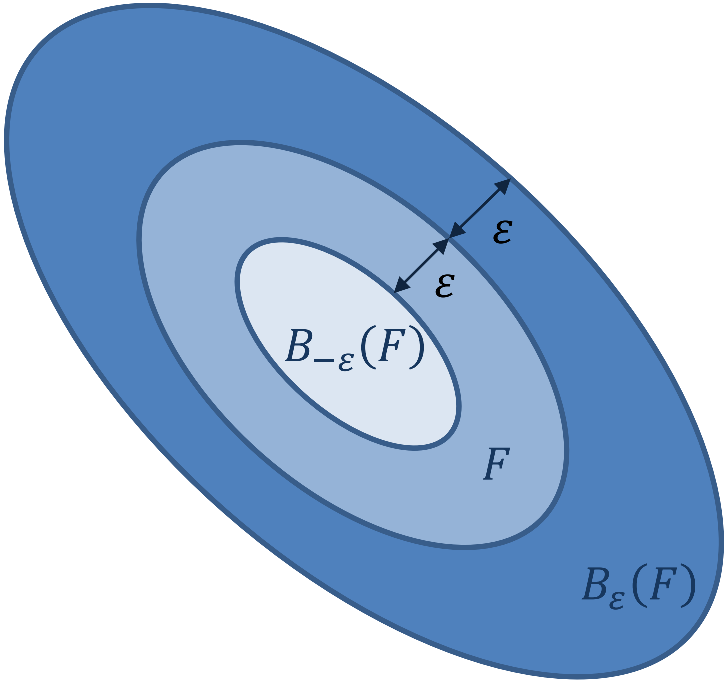
Corollary

Consider a set $F \subseteq X$ of faulty states of Σ with $F \cap \boldsymbol{X}_0 = \emptyset$ and define

$$F_\varepsilon = B_\varepsilon(F) \cap [\mathbb{R}^n]_\eta$$

$$F'_\varepsilon = B_{-\varepsilon}(F) \cap [\mathbb{R}^n]_\eta$$

$$B_{-\varepsilon}(F) = \{x \in F | B_\varepsilon(x) \subseteq F\}$$



Approximate diagnosability of nonlinear systems

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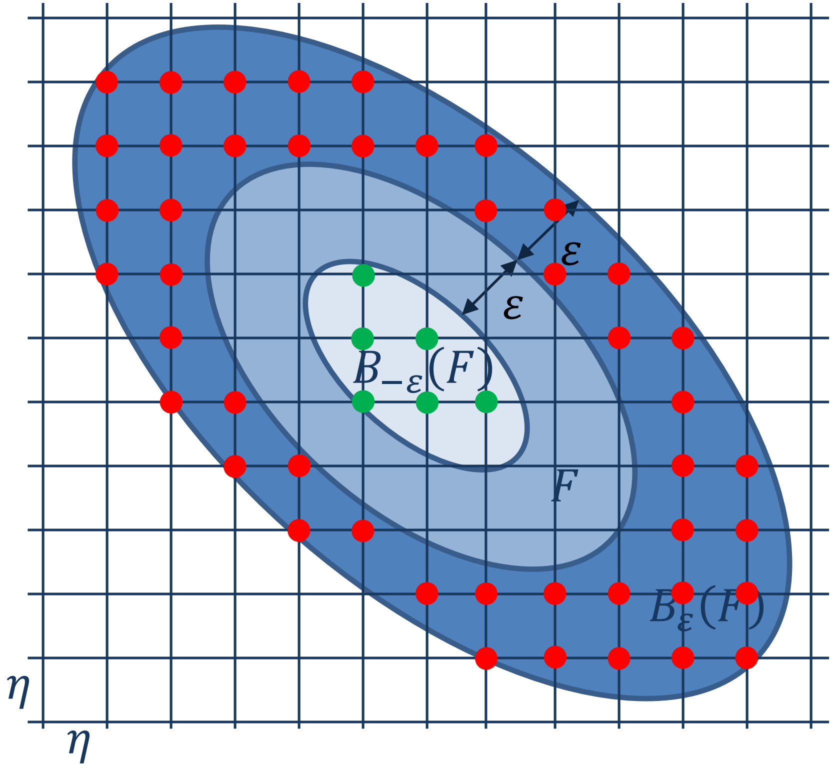

Approximate diagnosability of nonlinear systems

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$$B_{-\varepsilon}(F) = \{x \in F | B_\varepsilon(x) \subseteq F\}$$

Suppose that assumption (A) holds and for any desired accuracy $\varepsilon > 0$ pick quantization parameters $\eta, \mu > 0$ such that $S(\Sigma)$ and $S_{\eta,\mu}(\Sigma)$ are ε–bisimilar. Then:

- If $S_{\eta,\mu}(\Sigma)$ is $(k\eta, F_\varepsilon)$-diagnosable for some $k \in \mathbb{N}$ then Σ is (ρ, F)-diagnosable, for any $\rho > 2\varepsilon + k\eta$
- Suppose that F is with interior and $\varepsilon > 0$ is such that $F'_\varepsilon \neq \emptyset$. If Σ is (ρ, F)-diagnosable for some $\rho \geq 0$, then $S_{\eta,\mu}(\Sigma)$ is $(k'\eta, F'_\varepsilon)$-diagnosable, for any
$$k' > \min\{h \in \mathbb{N} | \rho + 2\varepsilon \leq h\eta\}$$

Remark

First statement can be used to check if Σ is approximately diagnosable while second statement (in its logical negation form) to check if Σ is not approximately diagnosable

Outline

Example

Consider the following nonlinear control system:

$$\Sigma: \begin{cases} x_1(t+1) = 0.15(\cos(x_1(t)-1)) + 0.18(\mathrm{sech}(x_2(t)-1)) + u \\ x_2(t+1) = 0.22\sin(x_2(t)) + 0.25\tanh(x_1(t)) \\ y(t) = x_1(t) \end{cases}$$

with $x(0) = (x_1(0), x_2(0)) \in \boldsymbol{X}_0$, $u(t) \in \boldsymbol{U} = [-2.5, 2.5]$

- It is possible to show that Σ is incrementally input-to-state stable
- For a desired accuracy $\varepsilon = 1$ by picking $\eta = 0.045$ and $\mu = 0.01$ we get that $S(\Sigma)$ and $S_{\eta,\mu}(\Sigma)$ are ε–bisimilar

Example

We consider two cases:

- **For $X_0 = [-1.25,1.25] \times [6.75,8.55]$ and $F = [-2.8,2.6] \times [-0.1,0.1]$ we get that**
  Σ is (ρ, F)-diagnosable, for any $\rho > 2.09$
  Details:
  - $S_{\eta,\mu}(\Sigma)$ is $(2\eta, F_\varepsilon)$-diagnosable
  - $S_{\eta,\mu}(\Sigma)$ is with 1,145 (accessible) states and 64,782 transitions
  - time of computation for constructing $S_{\eta,\mu}(\Sigma)$ = 10.313 min
  - time of computation for checking $(2\eta, F_\varepsilon)$-diagnosability of $S_{\eta,\mu}(\Sigma)$ = 4.0127 h

- **For $X_0 = [6.75,8.55] \times [-1.25,1.25]$ and $F = [-1.1,1.1] \times [-1.1,1.1]$ we get that**
  Σ is not (ρ, F)-diagnosable, for any $\rho < 0.07$
  Details:
  - $S_{\eta,\mu}(\Sigma)$ is not $(46\eta, F'_\varepsilon)$-diagnosable
  - $S_{\eta,\mu}(\Sigma)$ is with 1,141 (accessible) states and 64,662 transitions
  - time of computation for constructing $S_{\eta,\mu}(\Sigma)$ = 10.972 min
  - time of computation for checking $(46\eta, F'_\varepsilon)$-diagnosability of $S_{\eta,\mu}(\Sigma)$ = 2.315 h

Computations performed on a laptop with CPU Intel Core i7-4510U @ 2.4 GHz, RAM 8GB

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References

- **[De Persis, CDC-13]** C. De Persis. Detecting faults from encoded information. IEEE Conference on Decision and Control, 2013
- **[De Santis & Di Benedetto, Autom-2017]** E. De Santis and M.D. Di Benedetto. Observability and diagnosability of finite state systems: a unifying framework. Automatica, 81:115–122, July 2017
- **[Girard et al., TAC-10]** A. Girard, G. Pola, and P. Tabuada. Approximately bisimilar symbolic models for incrementally stable switched systems. IEEE Transactions of Automatic Control, 55(1):116–126, January 2010
- **[Girard & Pappas, TAC-07]** A. Girard and G.J. Pappas. Approximation metrics for discrete and continuous systems. IEEE Transactions on Automatic Control,52(5):782–798, 2007.
- **[Lunze, M&C-00]** J. Lunze. Diagnosis of quantized systems based on a timed discrete–event model. IEEE Transactions on Man and Cybernetics – Part A: Systems and Humans, May 2000
- **[Pola et al., Autom-08]** G. Pola, A. Girard, and P. Tabuada. Approximately bisimilar symbolic models for nonlinear control systems. Automatica, 44:2508–2516, October 2008
- **[Pola et al., TAC-16]** G. Pola, P. Pepe, and M.D. Di Benedetto. Symbolic models for networks of control systems. IEEE Transactions on Automatic Control, 61(11):3663–3668, November 2016
- **[Pola & Di Benedetto, TAC-14]** G. Pola and M.D. Di Benedetto. Symbolic models and control of discrete–time piecewise affine systems: An approximate simulation approach. IEEE Transactions of Automatic Control, 59(1):175–180, January 2014
- **[Tabuada, Springer-09]** P. Tabuada. Verification and Control of Hybrid Systems: A Symbolic Approach. Springer, 2009
- **[Zamani et al., TAC-12]** M. Zamani, M. Mazo, G. Pola, and P. Tabuada. Symbolic models for nonlinear control systems without stability assumptions. IEEE Transactions of Automatic Control, 57(7):1804–1809, July 2012
- **[Zaytoon & Lafortune, ARC-13]** J. Zaytoon and S. Lafortune. Overview of fault diagnosis methods for discrete event systems. Annual Reviews in Control, 37(2):308–320, 2013

Conclusions

In this paper

- General class of metric systems
- Novel notion of approximate diagnosability
- Relations between approximate diagnosability and approximate simulations
- Application to approximate diagnosability of nonlinear control systems

Further work

Efficient algorithms for checking approximate diagnosability of nonlinear control systems

... thanks!

On Approximate Diagnosability of Metric Systems

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