Inter-University Research Institute Corporation / Research Organization of Information and Systems
National Institute of Informatics

Research portfolio
- selected 10 works -

National Institute of Informatics
Masako Kishida

Deep learning based consensus

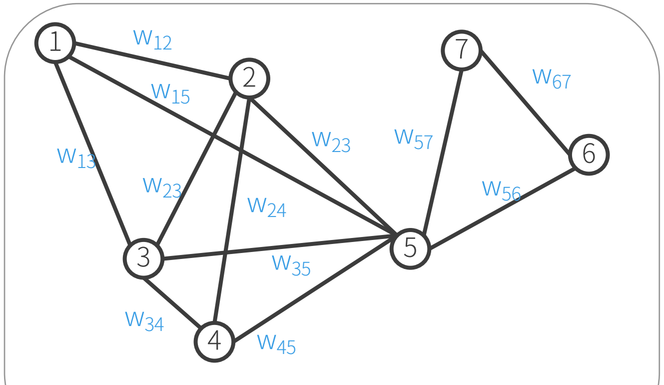
Accelerated average consensus using deep-learning

Problem: Fast convergence of state values are of interest. Given a graph G = (V,E) and initial values of the node, find edge weights of linear algorithm that minimize consensus error

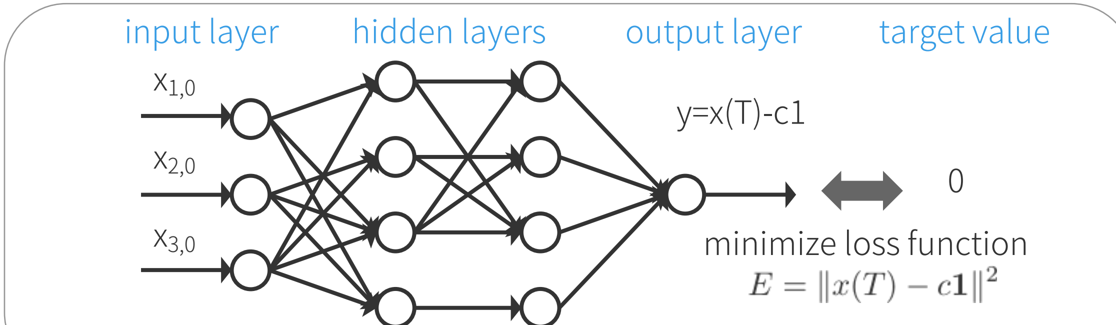
Approach: Use deep neural network with the specified topology corresponding to G

Result:

- 52 times better accuracy achieved (karate network)
- Periodic continuation reduced convergence factors by 25%

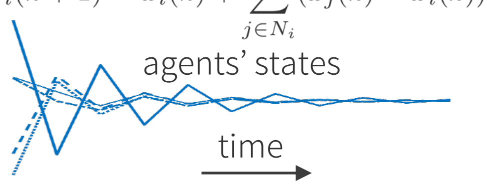


Given graph structure

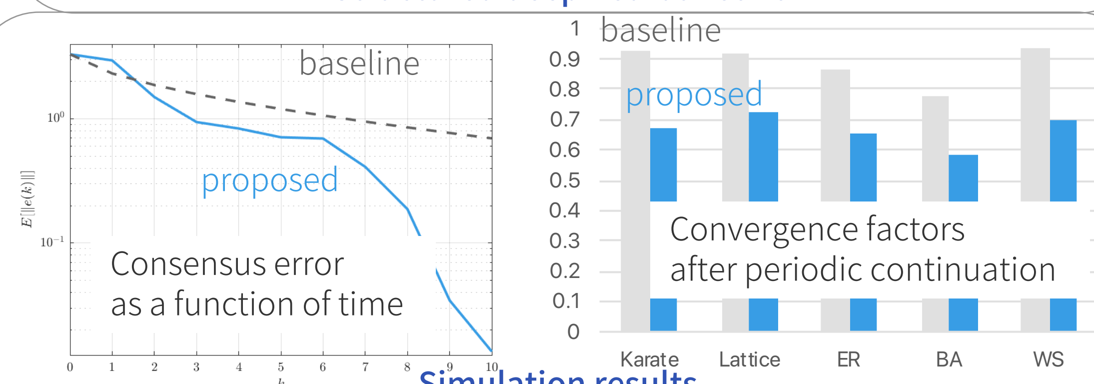


Structured deep neural network

$$x_i(k+1) = x_i(k) + \sum_{j \in N_i} (x_j(k) - x_i(k))$$



linear average consensus protocol



Simulation results

Okawa grant
IET 2019
CDC 2018

Encrypted control system

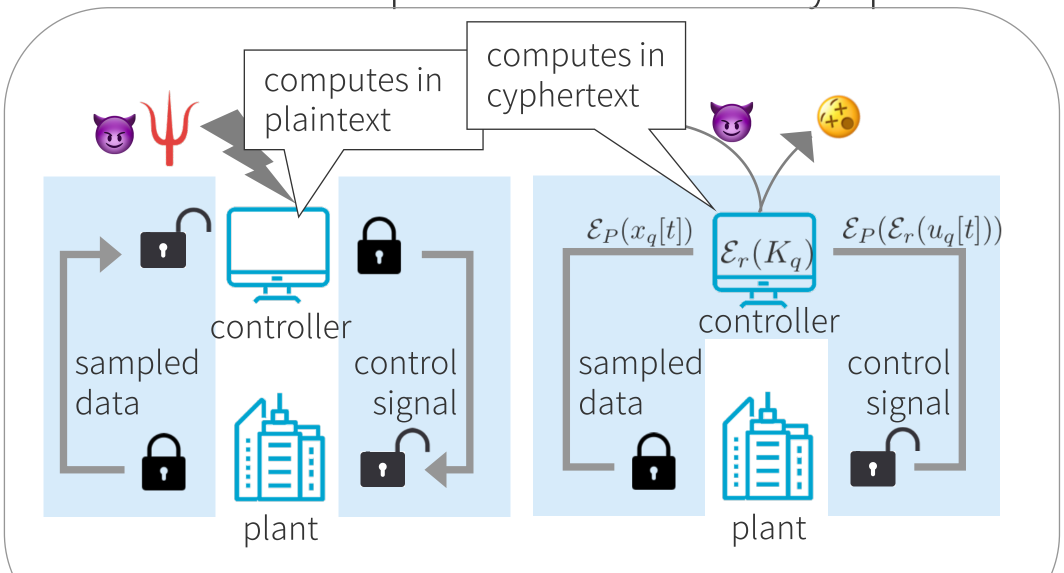
Extended applicability of encrypted control systems

Problem : Protecting the privacy of plant from the controller in networked control system is essential, but applicability of existing algorithms are not only limited to linear systems, but computationally expensive

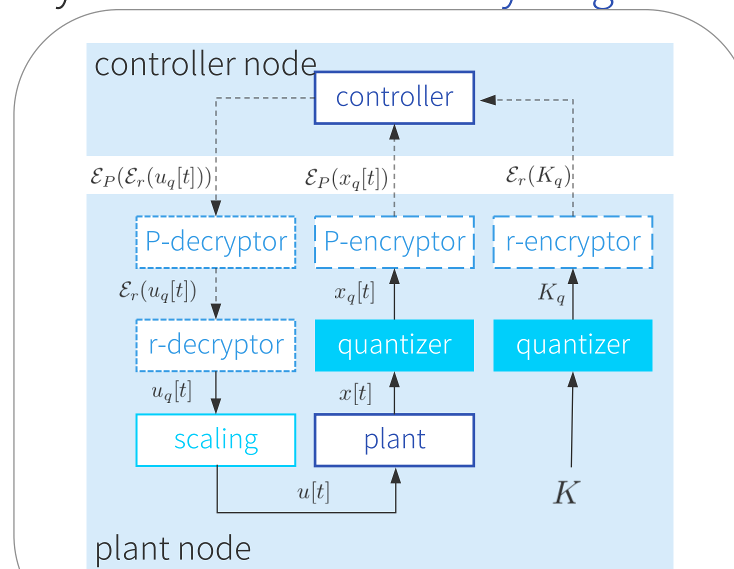
Approach: Use the basis function expansion for nonlinear systems and use quantizers to reduce the computational cost

Result:

- Developed the first ECS algorithm that is applicable to nonlinear systems
- Proved that it is possible to achieve asymptotic stability with ECS of limited key length



Standard use of encryption(left) and encrypted control (right)



A basic signal flow of ECS

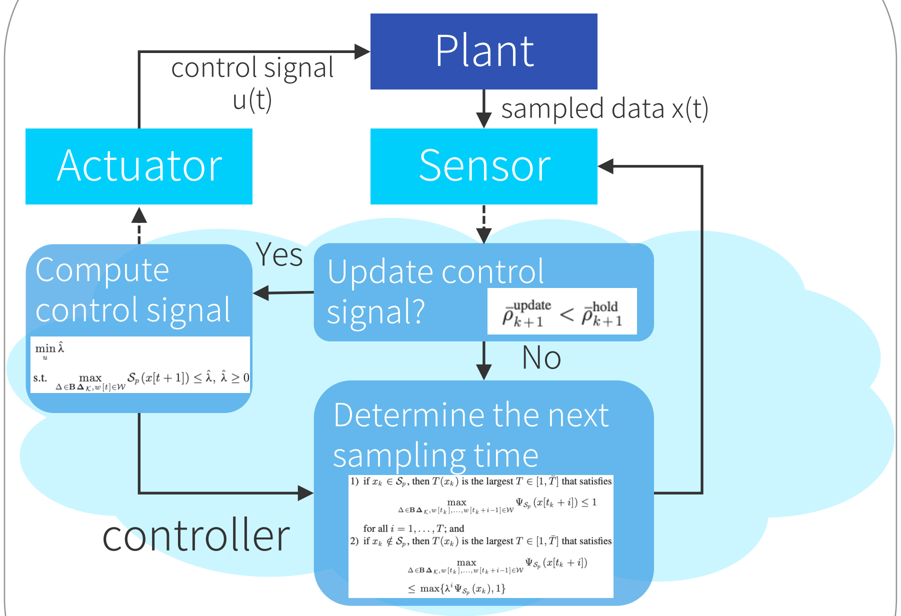
Resource aware control

Reduced communication frequencies to save energy

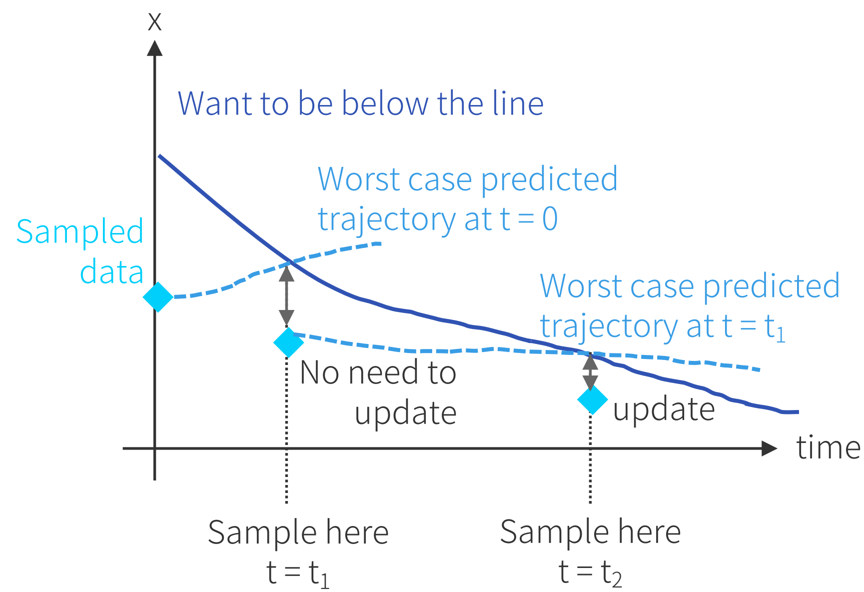
Problem : Networked control systems have limited resource, however, existing control algorithms are inefficient under uncertainties

Approach: Combine self-triggered and event-triggered approaches

Result: Developed algorithms that take into account uncertainties and cost ratios for sensing and actuation to reduce conservativeness



Algorithm overview



Sketch of state trajectory

Sparse control

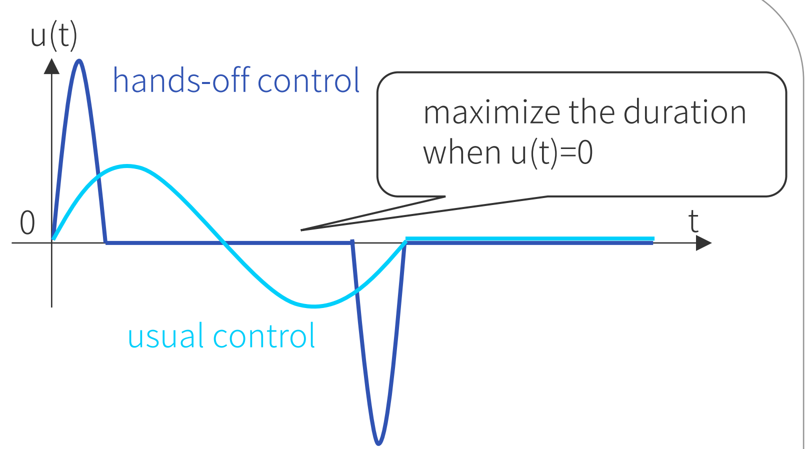
Handled uncertainties and minimized update frequency

Problem: Hands-off controls aim at having a short support of control per unit time to save energy usage. How to deal with uncertainties and avoid frequent switches of control?

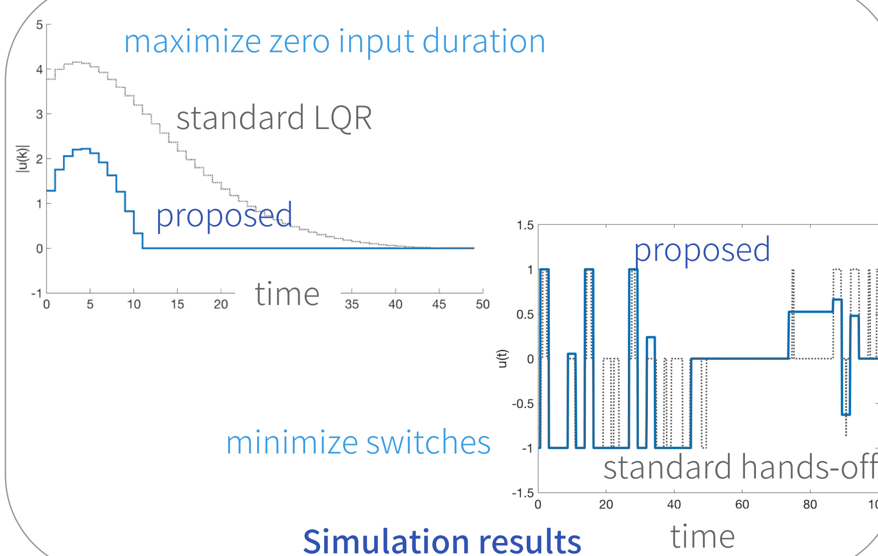
Approach: Formulate the worst-case optimization problem and include the changes in the control signal to the cost function

Result:

- Proposed an approach that handles uncertainties and reduced non-zero input duration to 1/4 of baseline (LQR)
- Proposed an approach that reduces the number of input switches (from 38 to 16)



Hands off control



Simulation results

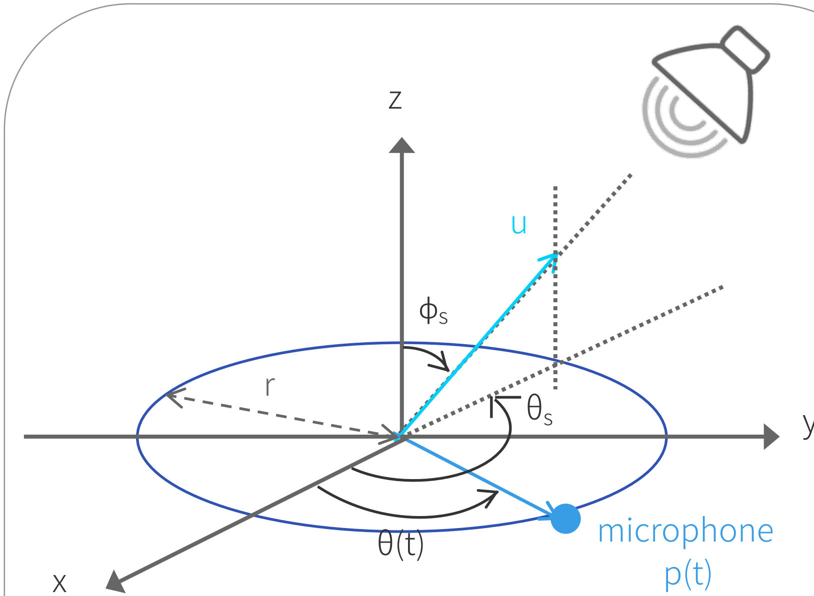
Direction of arrival estimation

Proposed architecture to estimate DoA by one microphone

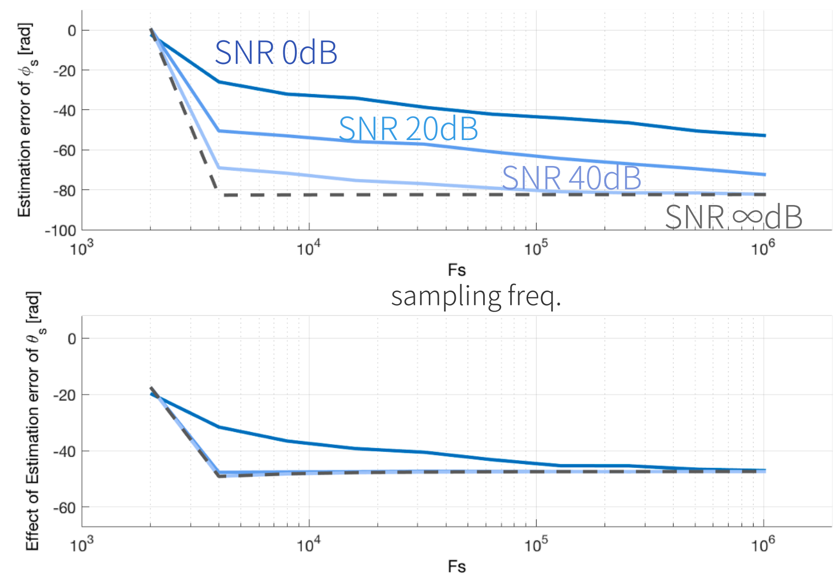
Problem: Usually, DoA estimation is performed using the time difference of wave arrivals between sensors, i.e., requires a microphone array. Is a microphone array necessary?

Approach: Use Doppler effect to obtain modulated signals that contain the DoA information

Result: Derived DoA in an analytical form by moving one sensor along the circumference of a circle. Showed that θ_s and ϕ_s can be found



Proposed structure



Estimation errors at different SNRs

Structured singular value μ

Showed novel applications of μ

Problem: How to analyze systems with uncertainties?

Approach: Restrict the class of uncertain matrices expressed by

$$F_u(M,\Delta)=M_{22}+M_{21}\,\Delta(I\text{-}M11\}\,\Delta^{-1}M_{12}$$

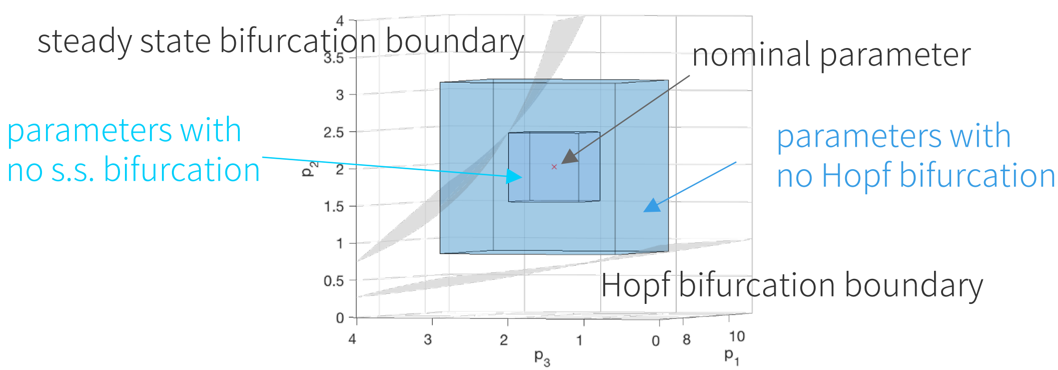
and use structured singular value and its variant.

$$\mu_{\mathcal{K}}(M)=\frac{1}{\sup\{k:\det(I-M\Delta)\neq 0,\forall\Delta\in k\mathbf{B^o}\mathbf{\Delta}_{\mathcal{K}}\}},$$

$$\mathbf{\Delta}_{\mathcal{K}}\ :=\{\mathrm{diag}[\delta_1 I_{r_1},\cdots,\delta_{n_p} I_{r_{n_p}}]:\delta_i\in\mathbb{R}\},\ k\mathbf{B^o}\mathbf{\Delta}_{\mathcal{K}}:=\{\Delta\in\mathbf{\Delta}_{\mathcal{K}}:\bar{\sigma}(\Delta)<k\}$$

Result:

- Expressed the bounds on the eigenvalues of uncertain matrices
- Obtained the non-existence condition of a specific eigenvalue for given set of uncertain matrices and application to bifurcation analysis
- Proved variance, covariance and correlation of interval data can be expressed using μ



Set of parameters satisfying different condition

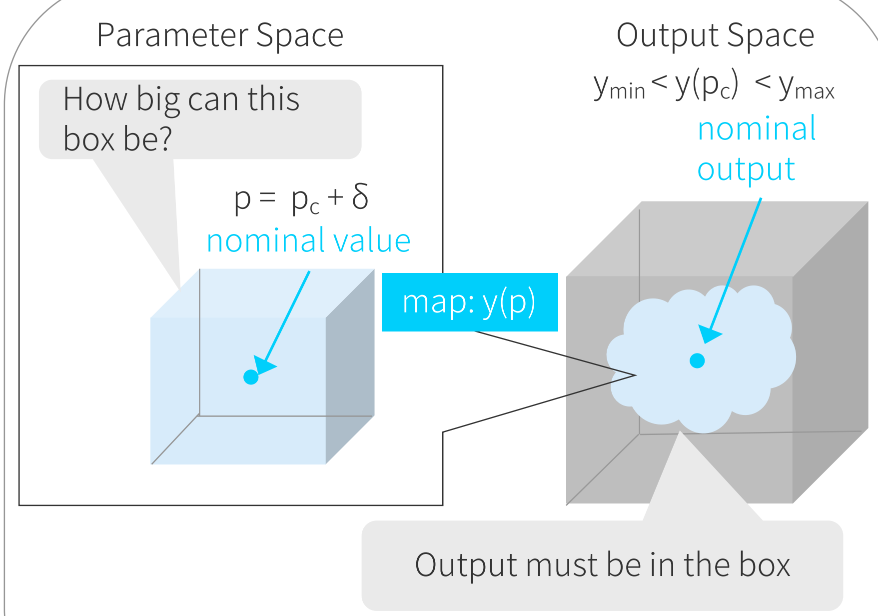
Set of feasible parameters

Obtained a satisfactory parameter set for specified output

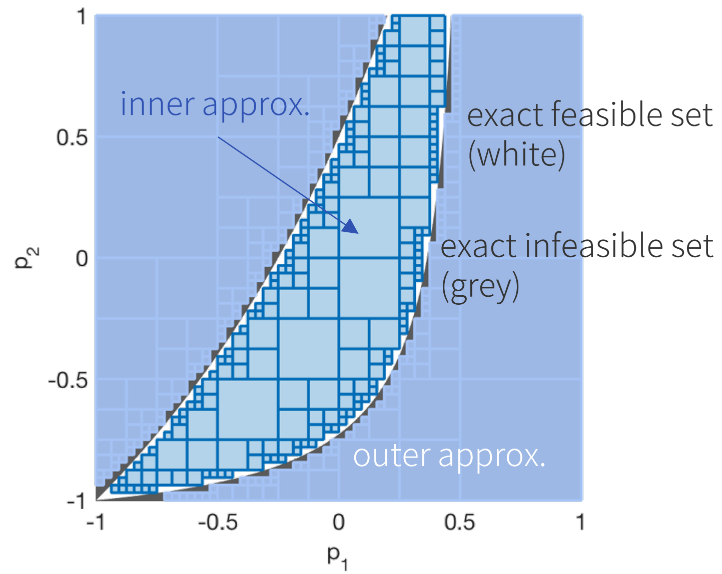
Problem: Given a nonlinear map, finding an exact input parameter set (domain) that satisfies the constraints given on its target set is NP-hard. But such characterization is important to design quality-by-design. How to compute such sets efficiently?

Approach: Use μ and main-loop theorem

Result: Provided efficient algorithms for inner and outer approximations of the set



Intuitive illustration of problem



Inner and outer approximation of feasible set

IEEE TAC 2014

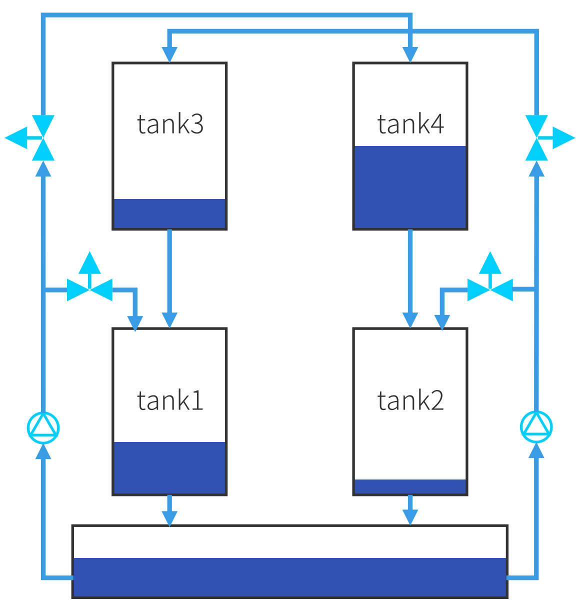
Bounds on uncertainty propagation

Developed algorithms to predict the growth of uncertainties

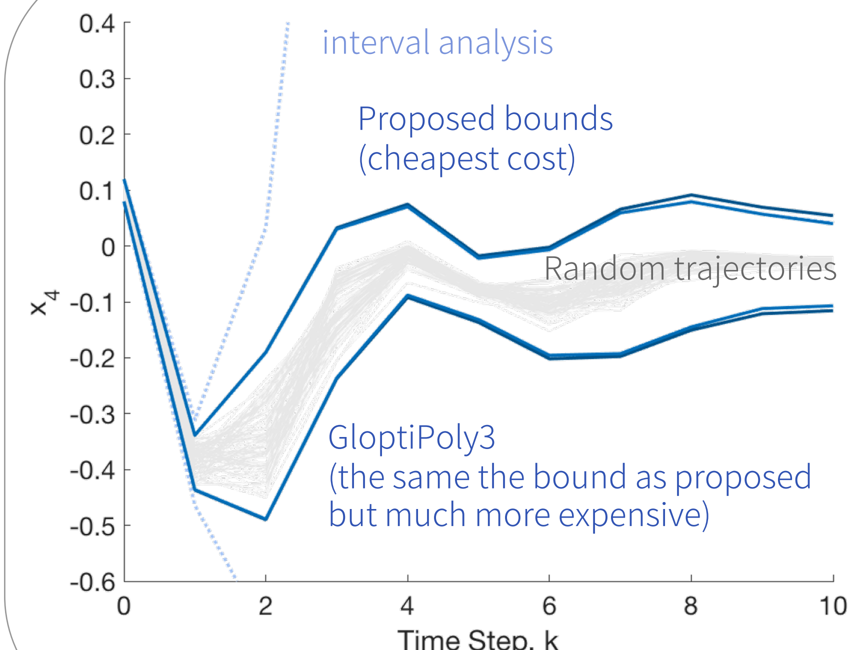
Problem : Finding the exact bounds on trajectories of uncertain dynamical system is NP-hard. But such an estimation is important to design controls. How to compute such bounds efficiently?

Approach: Use μ and main-loop theorem

Result: Algorithms that balance the cost and tightness of the bound



Tank process used for the simulation



Comparison of different methods

Control of partial differential equation

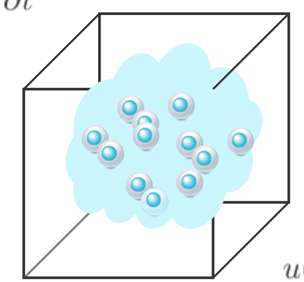
Proposed an approach to solving state-constrained optimal control problem motivated by tissue engineering

Problem: Achieve desired uptake of growth factors to regulate cellular processes

Approach: 2-step optimization: 1. approximate reference with spatial constraints using Fourier series expansions (diffusion process optimization), 2. optimize system parameters (microparticle design)

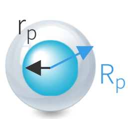
Result: Achieved small errors while satisfying the constraints

$$\frac{\partial C}{\partial t} = D\nabla^2 C - kC + u$$



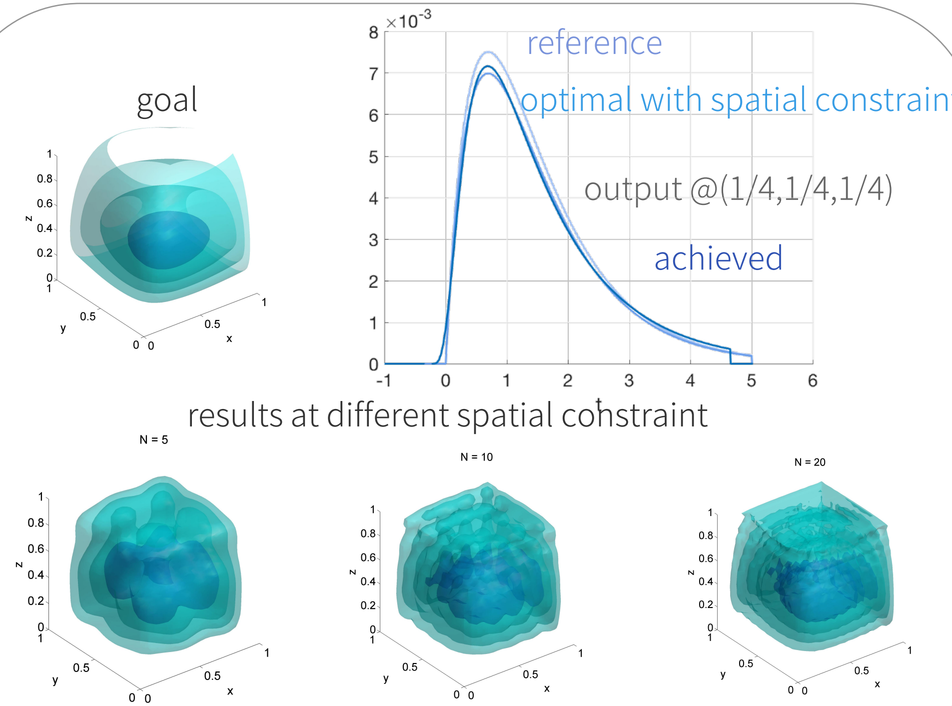
$$u(x,y,z,t) = 4\pi R_P^2 \rho|_{r=R_p}$$

$$J|_{r=R_p} = -\kappa \frac{\partial C_r}{\partial r}\Big|_{r=R_p}$$



$$\frac{\partial C_r}{\partial t} = \kappa\left(\frac{\partial^2 C_r}{\partial r^2} + \frac{2}{r}\frac{\partial C_r}{\partial r}\right)$$

Coupled systems



Simulation results

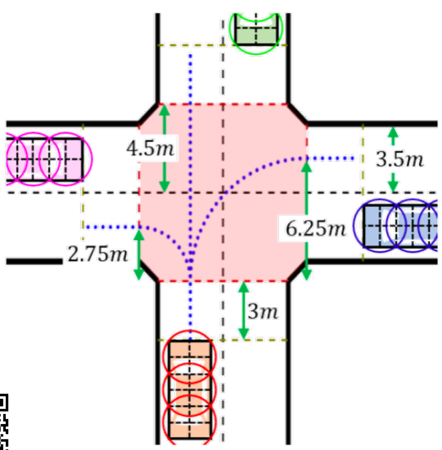
ERATO Metamathematics for Systems Design Project

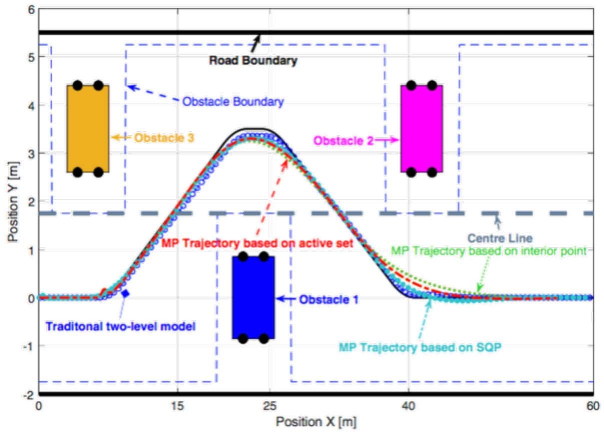
- Aims to extend the realm of formal methods from software to cyber-physical systems and manufacturing
- Lead by Prof. Ichiro Hasuo@ NII
- I'm leading controls team as group sub-leader

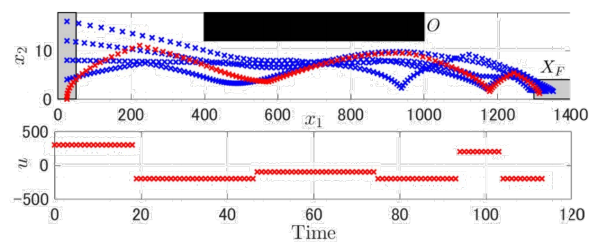
✓ Developed decision making algorithm for autonomous driving with malicious vehicles while maximizing own speed and avoiding collisions with reckless drivers

✓ Developed model-predictive algorithm that integrates path planning and tracking for the best riding experience during lane change

✓ Developed algorithm self-triggered controllers that satisfies reachability and safety specifications for nonlinear systems







https://group-mmm.org/eratommsd/

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https://arxiv.org/abs/1904.10158
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Many post-docs