Reactive Scheduling of Computational Resources in Control Systems

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2. Integration with Kalman
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   - Results
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   - Conclusion
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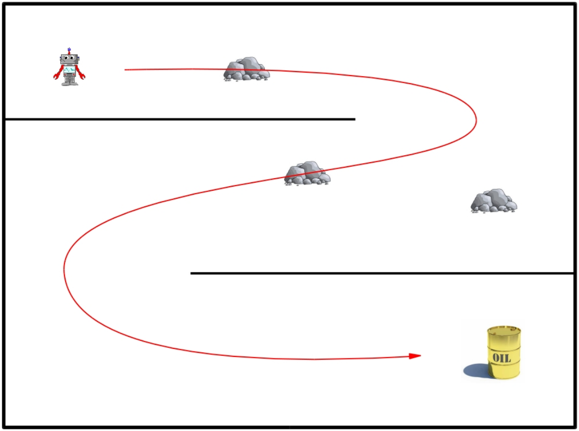
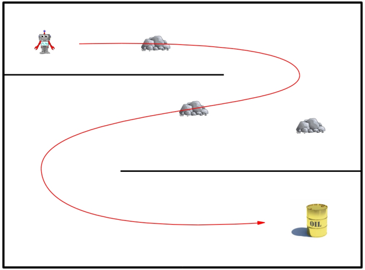
An control problem example



Robot navigation

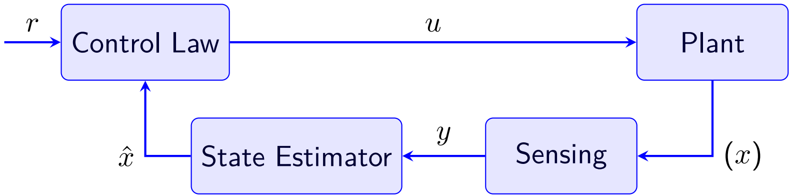
An control problem example



The Objectives

- The robot need to reach the target point **fast** and **safely**
- The robot have on-board camera for **obstacle-avoidance**
- The robot use GPS for **navigating**

The Traditional Solution



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Constant time steps + periodic tasks

time steps

figure+

Task	Period	Deadline
Check for obstacles	10ms	1.5ms
Check GPS position	10ms	0.5ms
Control Law	2ms	0ms
. . .		

The Main Software Design Problems

Task	Period	Deadline
Check for obstacles	10ms	1.5ms
Check GPS position	10ms	0.5ms
Control Law	2ms	0ms
...		

The design problems from our point of view

- **All the tasks are highly coupled**: *any change or addition of some task require to consider all other tasks requirements*
- **Static and inefficient scheduling**: *the table is defined for the worst case* *talk about related work on this direction*
- **No consideration of the environmental conditions**: it is a cyber-physical system after all

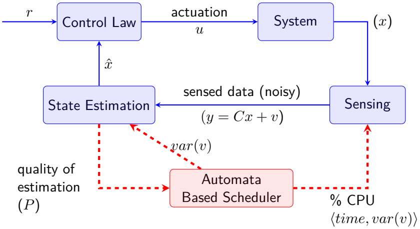
The Goal

In this thesis we design an **reactive** scheduling framework for real-time systems

Required features:

- **Independent** and **composable** requirements
- **Control objective based** requirement interface
- Environment **adoptive** scheduler

The Proposed Architecture



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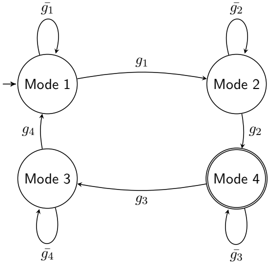
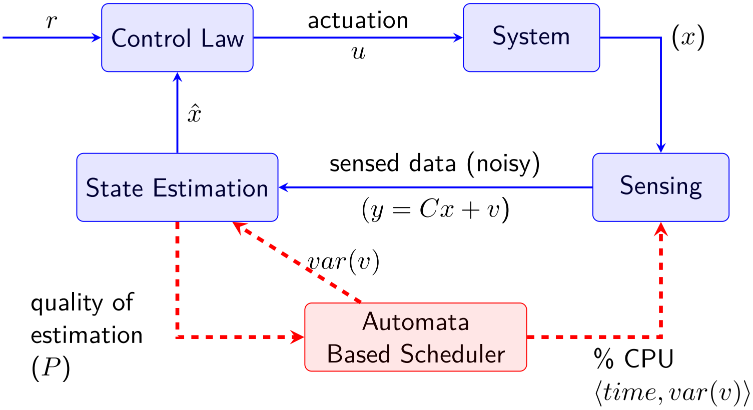


System Design
The Proposed Architecture

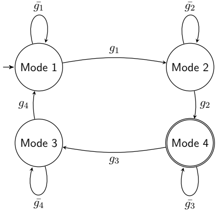
Explain that the scheduler is involve in the control loops



Automata-Based Specification Interface

The Proposed Architecture

maybe add a word about RTcomposer and GameComposer



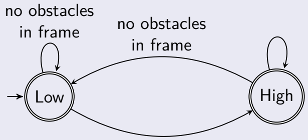
Why Automata

- **Lite:** minimal resource consumption at run-time
- **Composable**: easy to compose independent components
- **Automata theory built in:** allows for tools such *GOAL*
- **Expressiveness**

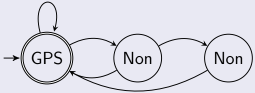
Example of Guarded Automata

The Proposed Architecture

Obstacle avoidance component



GPS navigation component



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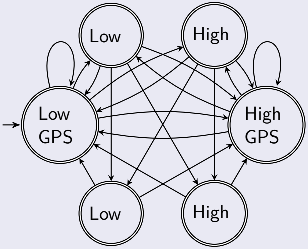
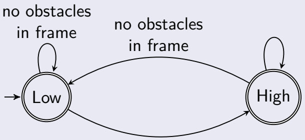
Composed guarded automata



Simplifying the Guarded Automata

The Proposed Architecture

Mode-based guarded automata (for good intuition)



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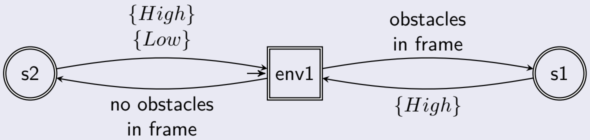
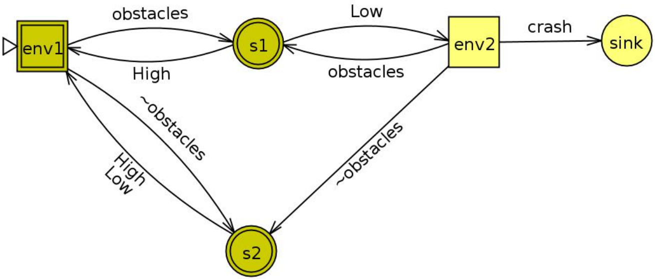
The automata in practice (best match ω-word theory)

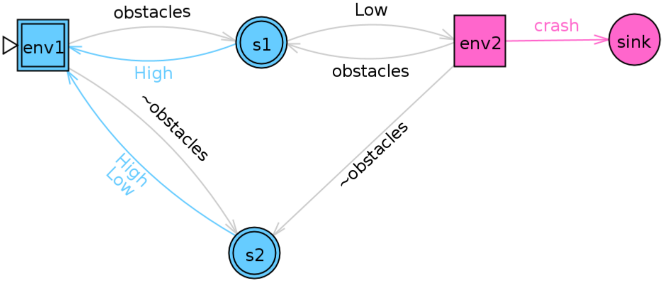


Q: How to create the guarded automata? By wining Büchi games

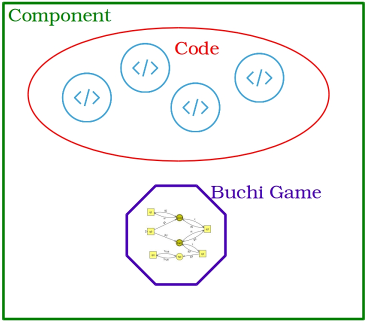
Büchi game remainder



Büchi game remainder



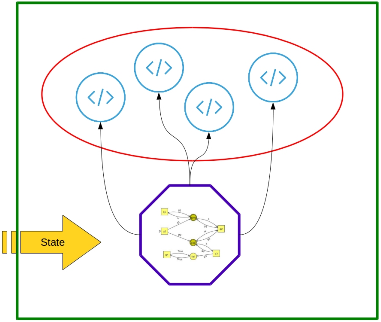
A Component in the System



Component Definition ($\langle T, G\rangle$)

- A set of subroutines (functions code)
- A Generalize Büchi Game

A Component in the System

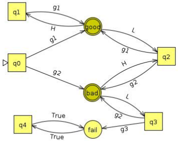


The Büchi game ($G = \langle A, \langle P_{sched}, P_{env} \rangle \rangle$)

- Is played in turns by the **environment** and the **scheduler**
- Represent the **interaction** between the scheduler and the environment reaction

Scheduling Büchi Game

A Component in the System



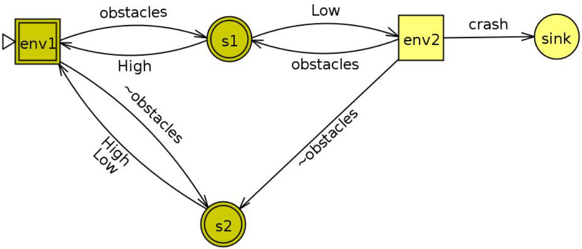
Scheduling Büchi Game

- **Alternating turns**
- Scheduler alphabet is $\Sigma_{schd} = 2^T$
- Environment alphabet is $\Sigma_{env} = \mathbb{R}^n$ (*scheduler feedback variables*)
- There is an Edge for any **possible** environmental outcome
- The **scheduler feedback variables** can be any environment-depended value
- Environment player plays first

Example - Büchi Game

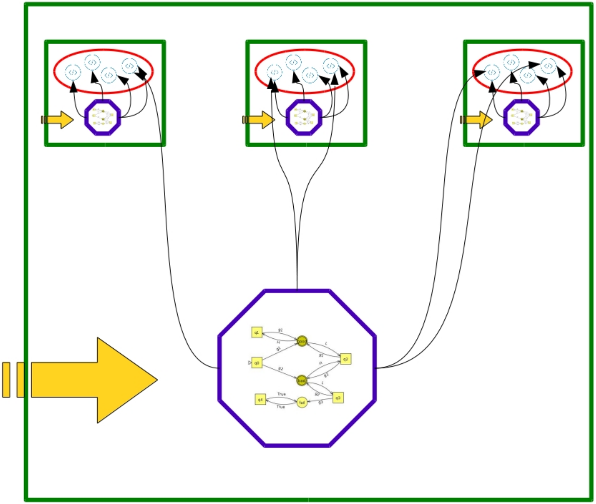
A Component in the System

The Büchi Game of the obstacles avoidance component:

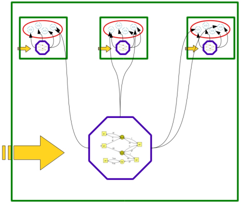


- The objectives of the component is to avoid obstacles
- The scheduler **win** ⇔ the corresponding word $\omega \in \mathcal{L}(A)$ ⇔ the component achieved his **objectives**

Component Composition



Component Composition



Requirements

- A game $(G = \langle A, \langle P_s, P_e \rangle\rangle)$ correspond to all the components
- The game of Component is $G_i = \langle A_i, \langle P^i_s, P^i_e \rangle\rangle$
- $\omega \in \mathcal{L}(A) \Leftrightarrow \forall i : \omega(i) \in \mathcal{L}(A_i)$

TODO: how to present the composition details?

TODO: show the scheduler work: 1. find wining strategy 2. simultaneously walk through the strategy automata

Explain the concept of estimate the errors the simulation 1. mission definition2. scheduling objectives3. how we review the results (the x axis)4. add a video 1. why not Kalman2. how we use complementary filter3. the linearize model in x / roll axis4. update state (equations) the automata and their results instead of with Related Work review of similar papers: A table with few papers

Thanks