Combining Quantitative and Qualitative Models with Active Observations for better Diagnoses of Autonomous Mobile Robots

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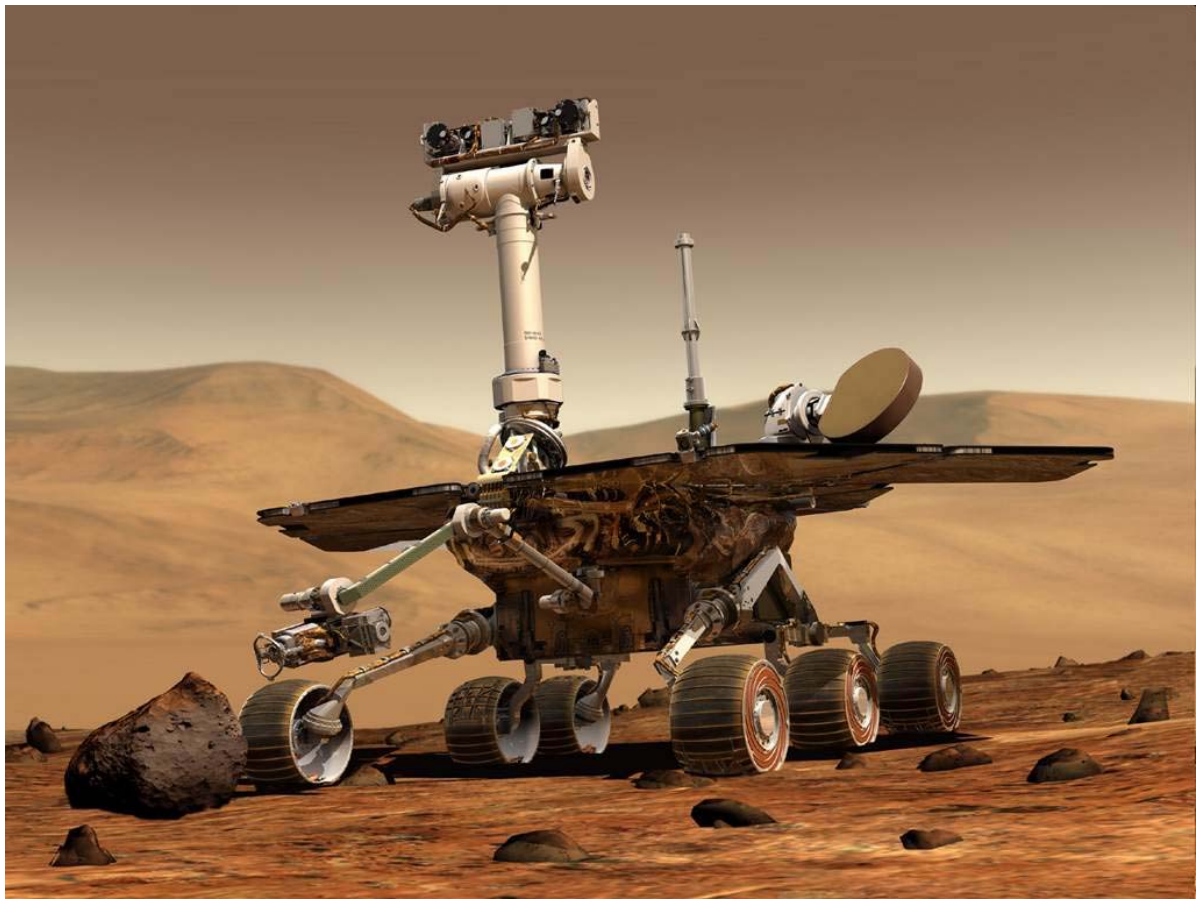
Who will here find and repair faults?



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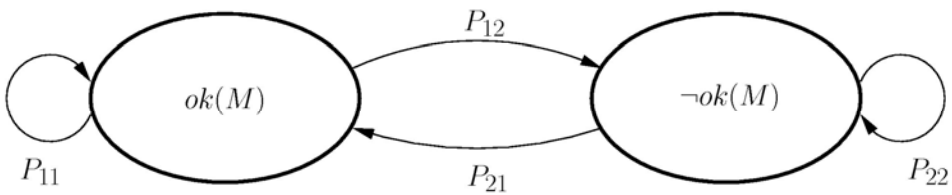
Motivation

- faults at runtime in hardware and software are not totally avoidable
- automatic detection and localization desired for autonomous systems with no or limited possible intervention
- complex systems comprises parts with diverse properties
- diverse methods to perform diagnosis
  - quantitative (e.g., robot drive) or qualitative (e.g., control software)
  - output with different semantic, temporal or spatial properties
  - different views on a system
- the methods in general are consistency-based

Quantitative Modeling

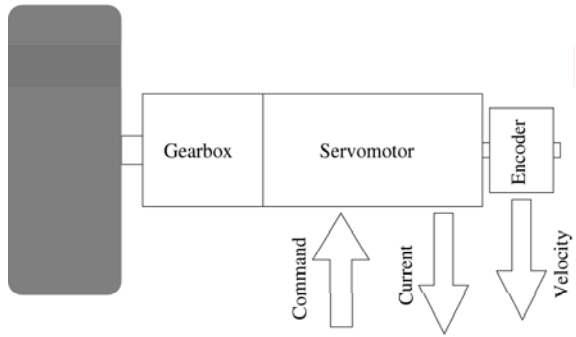
- modeling and monitoring
  - probabilistic hybrid automata [Hofbaur 2005]
  - discrete states model the operational mode (incl. faults)
  - models of the dynamic of the system in each mode
  - continuous states represents the dynamic world
  - discrete and continuous inputs and outputs
- fault detection and localization
  - multi-hypothesis tracking
  - find the most probable operation mode (nominal or faulty)
- properties
  - capable to deal with continuous observations and uncertainty
  - general reasoning is difficult

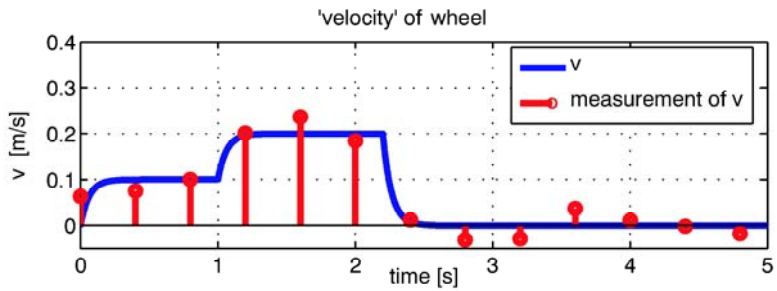
Quantitative Example

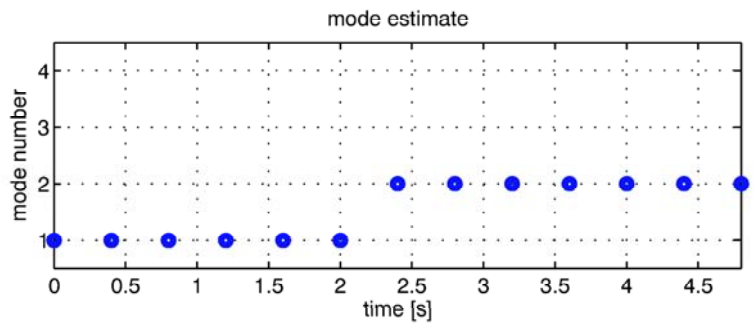


$$\dot{\omega} = \frac{1}{\tau}\omega + u + W \qquad (\neg ok(M))$$

$$\dot{\omega} = \frac{1}{\tau}\omega + W \qquad (ok(M))$$



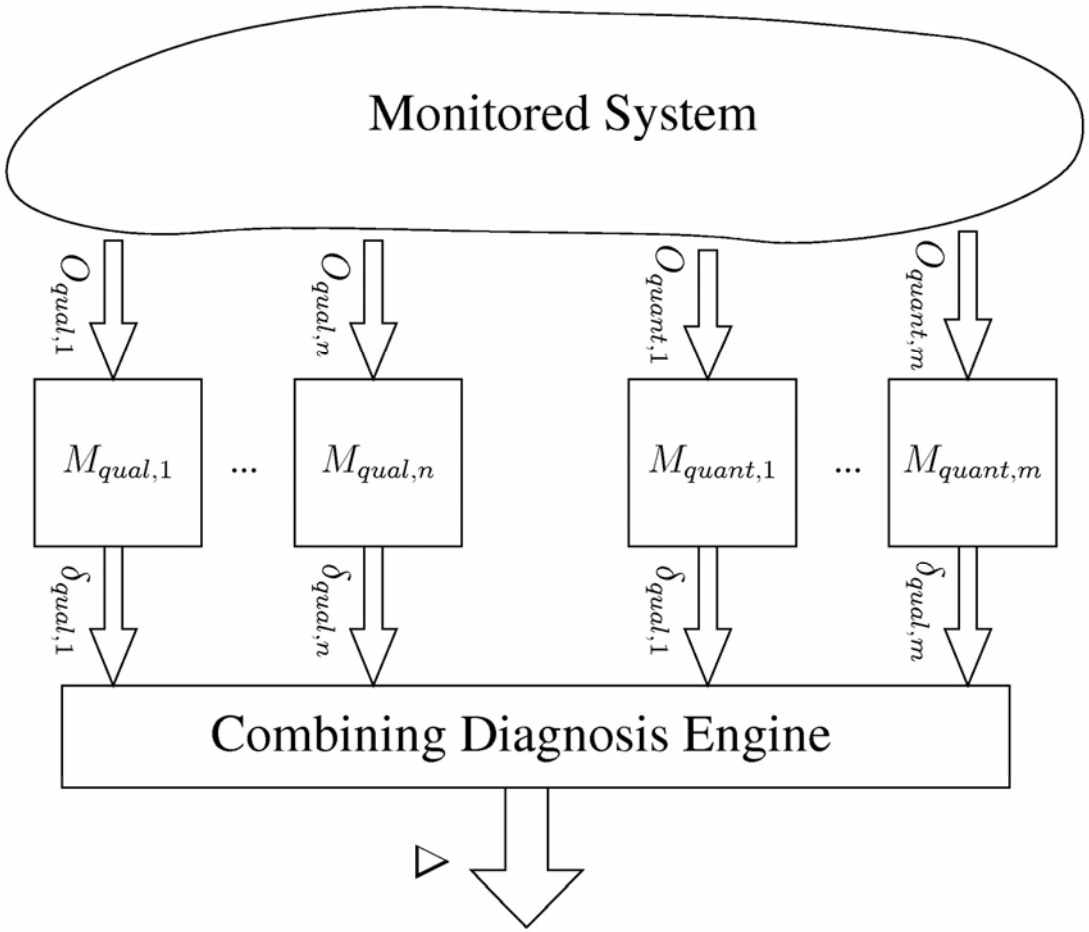




Qualitative Diagnosis

- modeling and monitoring
  - models and observations as logical clauses [Reiter 1987]
  - Horn clauses for efficiency reasons
  - component-based modeling schema
- fault detection
  - inconsistency in the logical theory
- fault localization
  - systematic resolve of the inconsistencies (retract assumptions)
- properties
  - needs discrete observations
  - general reasoning, adaptation and combination is more easy

Combined Diagnosis



Open Issues (1)

- different temporal granularity
  - different frame-rates and sample points of observations
  - delays from filtering and reasoning
  - synchronization to avoid inconsistencies
- different diagnosis granularity
  - different semantic level
  - filtering to integrate quantitative observations
  - abstraction and symbol grounding
  - mixed approached needed

Open Issues (2)

- spatial distribution
  - diagnosis about different parts of the system
  - combination to detect dependent faults
  - needs meta-model
  - approaches exist for the same semantic
- competing diagnosis
  - different estimated root cause
- performance
  - diagnosis in general expensive
  - tradeoff flexibility versus complexity
  - knowledge compilation

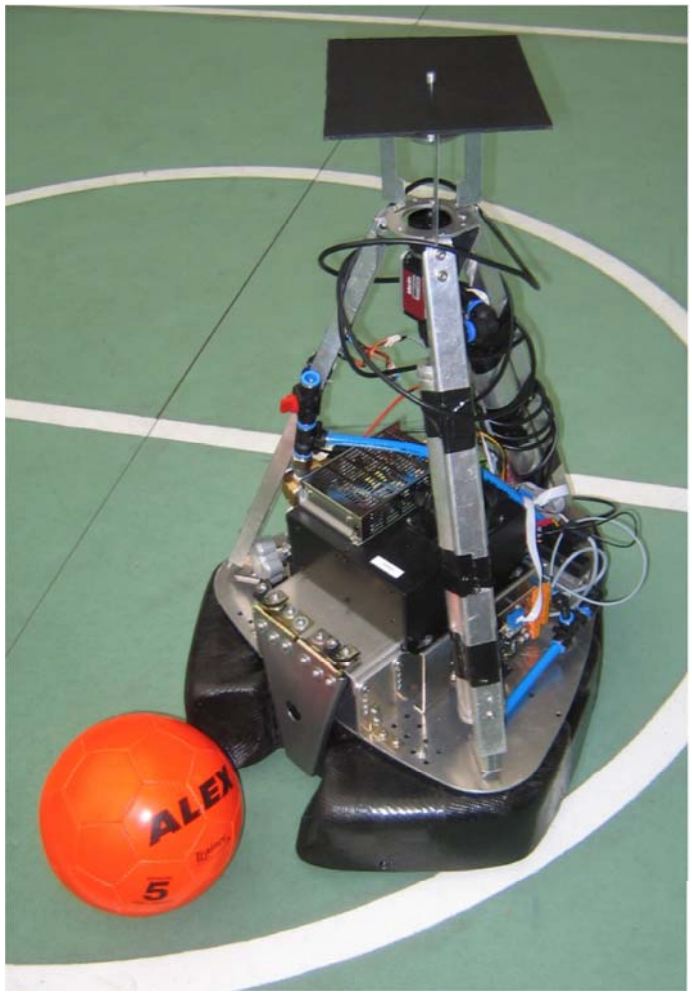
Conclusion

- automated detection of faults are desired for autonomous systems
- model-based reasoning solves the task
- different modeling schemas
  - qualitative
  - quantitative
- combination of different diagnoses
  - handling of different properties
  - better diagnoses due to different views
- active observations
- open issues
  - different semantic and temporal granularity

Thank you for your attention !
Any questions ?

Principles of MBD

- needs
  - a model of the behavior of the system (qualitative or quantitative)
  - actual observations of the systems
  - reasoning techniques (logical inference or probabilistic state estimation)
- detection
  - detect faults via inconsistencies
- localization
  - localizes the root cause by the resolving of inconsistency (qualitative models)
  - localizes the root cause by multi-hypothesis tracking (quantitative models)


ALEX
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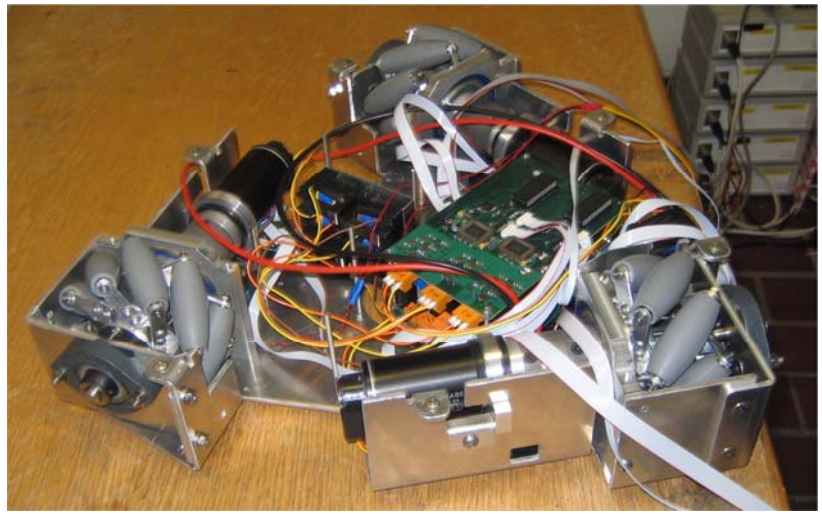

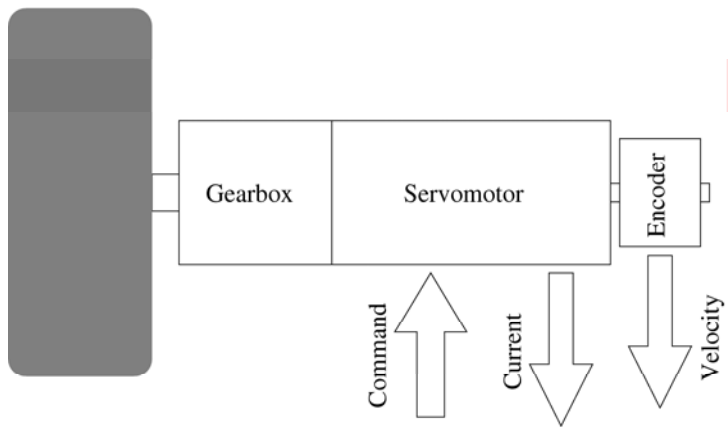
Gearbox
Servomotor
Encoder
Command
Current
Velocity