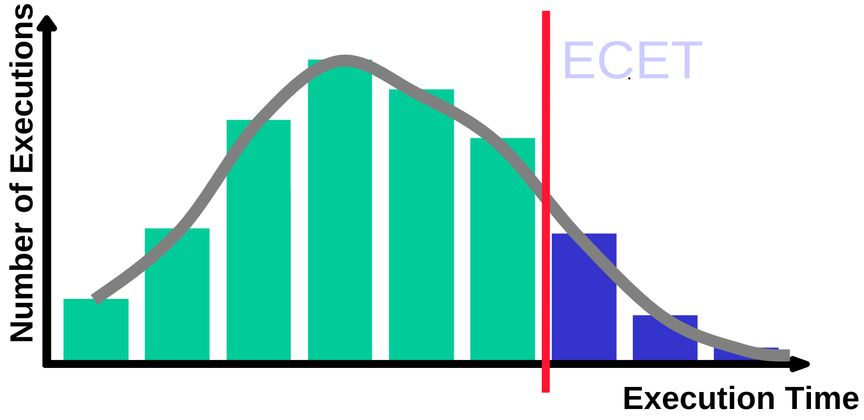
Real-Time (Paradigms) (37)

$ECET_{t,p}$ of task-instance *t* of task τ with probability *p*

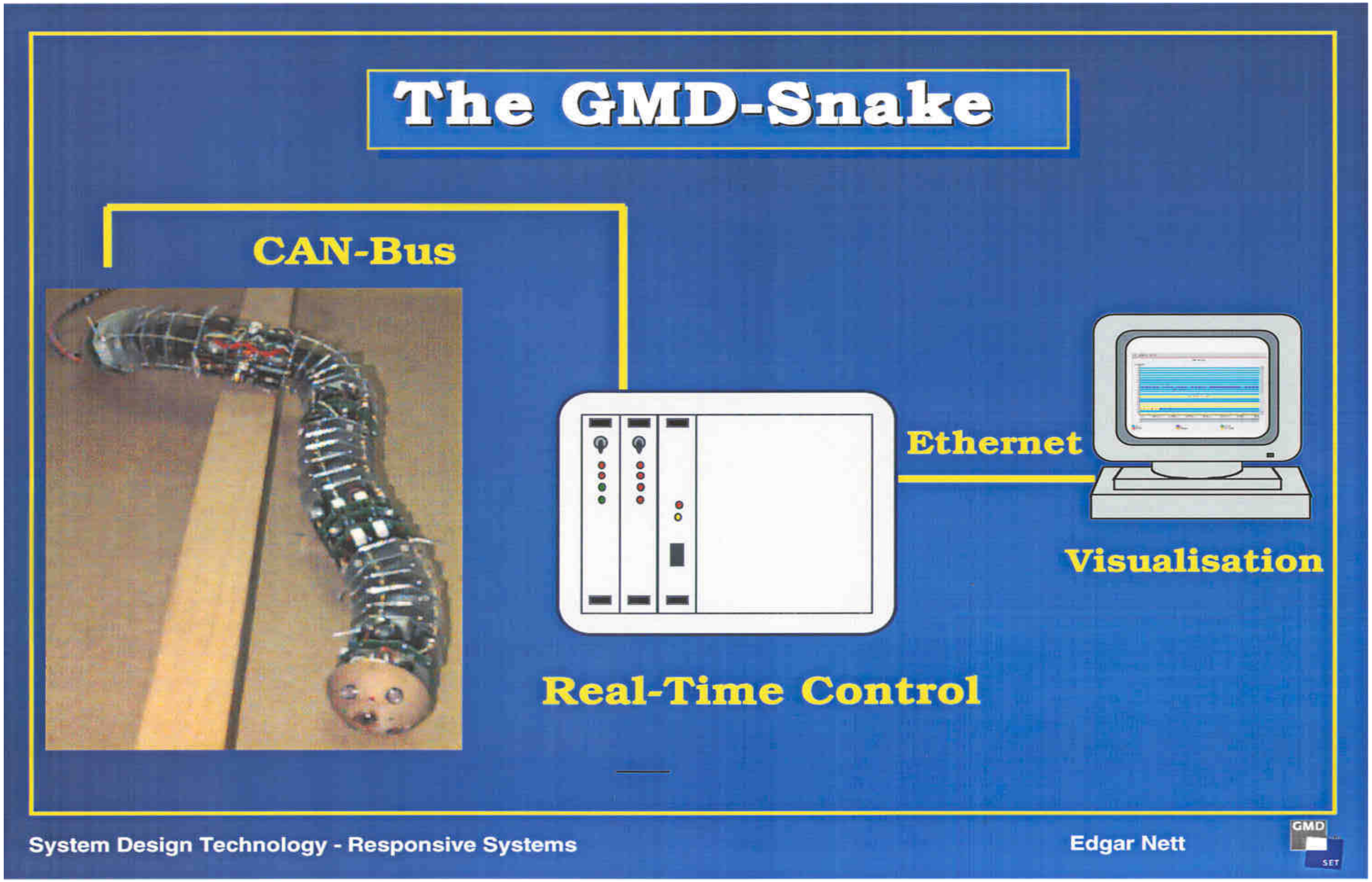
- CPU-time required to complete task-instance *t* with probability *p*
- *p*-quantile of the probabilistic density function of τ's execution time

$ECET_{t,k,n}$ - The minimal execution time that was needed to successfully complete at least *k* out of the last *n* most recent executions of τ.

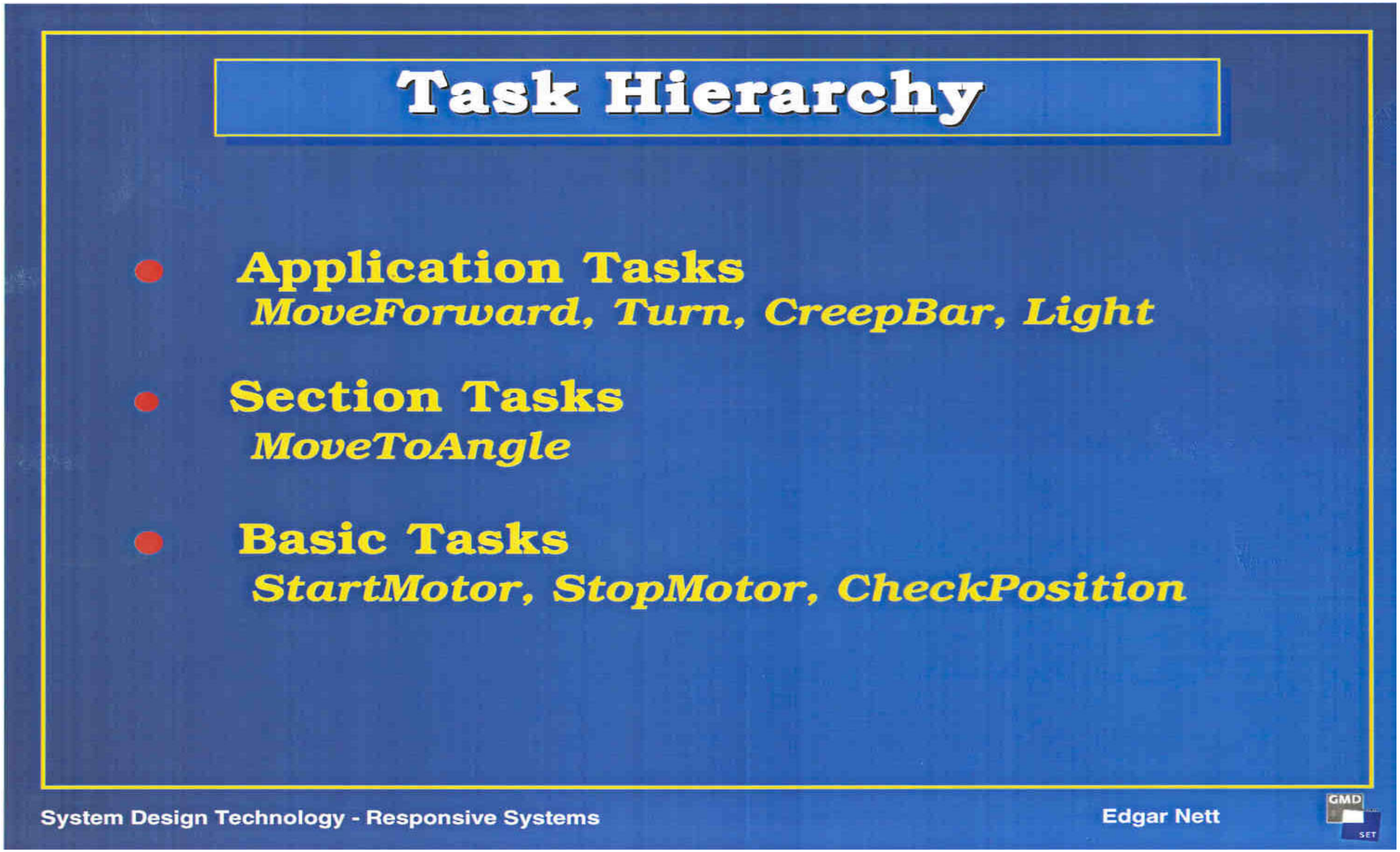
- A statistic quantity



Real-Time (Paradigms) (39a)



Real-Time (Paradigms) (40)



Real-Time (Paradigms) (41)

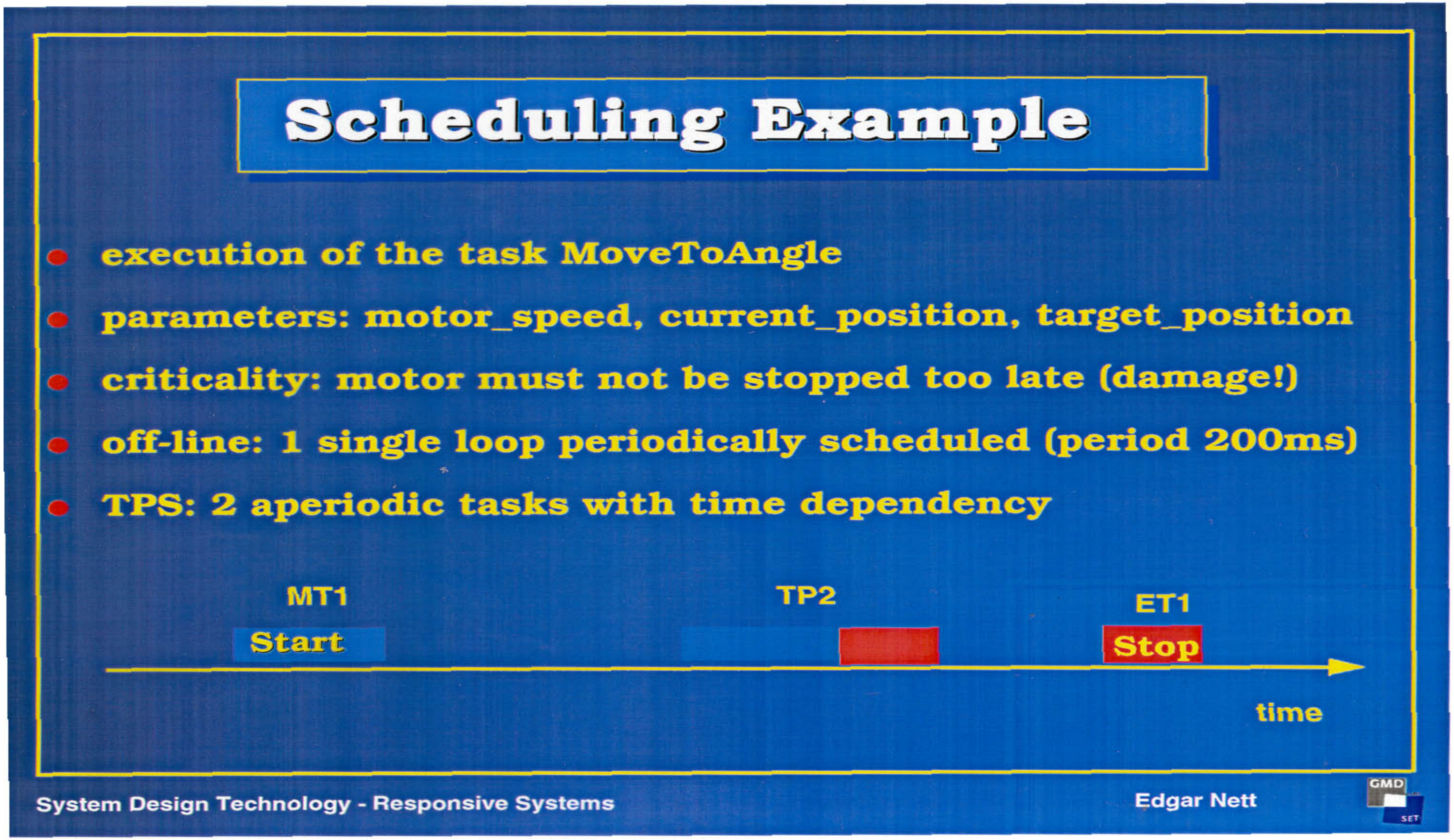
Timing Constraints:

- Calibration messages each 40 ms
- Polling angle sensor each 80 ms
- StopMotor (situation dependent)

Task Classification (Example):

- Hard: Calibration task
- Critical: MoveToAngle task
- Soft: Light task

Real-Time (Paradigms) (42)



Real-Time (Paradigms) (43)

Example (Cont´d)

Task: MoveToAngle (45 degrees)

WCET for Start resp. CheckPositon: 16 ms

computed duration for move: 2 sec

Resource consumption:

off-line: 10 x 16 ms = 160 ms within 2 sec reserved

TPS: 2 x 16 ms = 32 ms within 2 sec reserved

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Real-Time (Paradigms) (44)

Example (Cont´d)

Problem: motor speed is not constant

depends on: direction (up, down, left, right), current position, and simultaneous moves in other sections

- off-line: worst case approach, i.e. maximum speed has to be assumed)
- TPS: on-line adaptation possible: if motor would stop too early,then, schedule an additional CheckPosition, if possible

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Real-Time (Paradigms) (45)

Real-Time (Paradigms) (46)

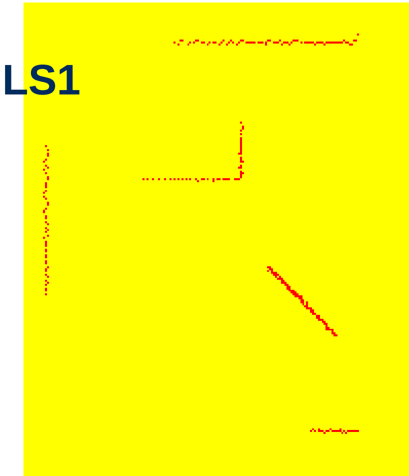
External Reviewers

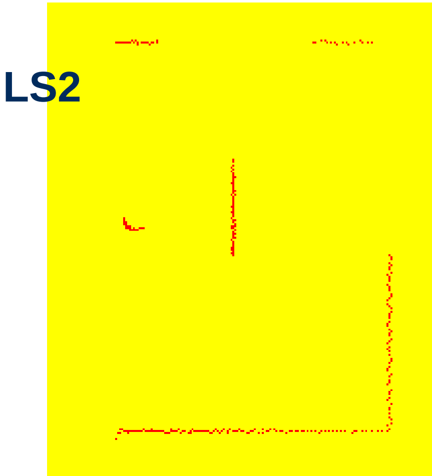
Application Example: Motion Control

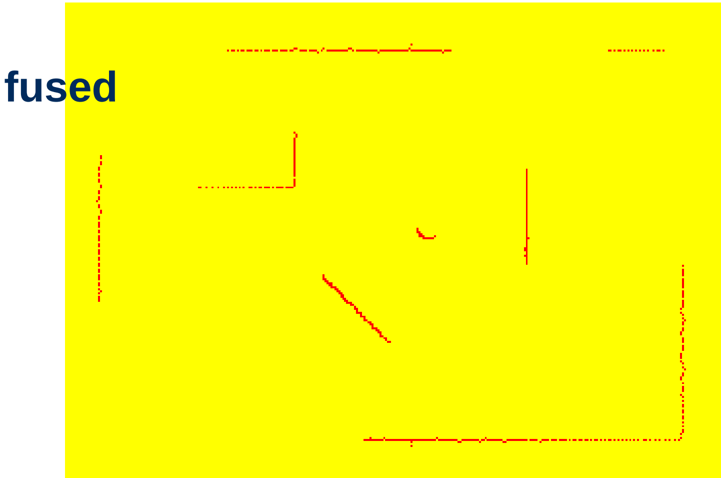
Motion Control

- is one of the most important tasks of mobile embedded systems
- is subject to real-time and reliability requirements
- heavily depends on the sensory input

- Single sensors have a partial, inaccurate view
- Distributed sensor fusion allows achieving a more complete and accurate perception of the environment



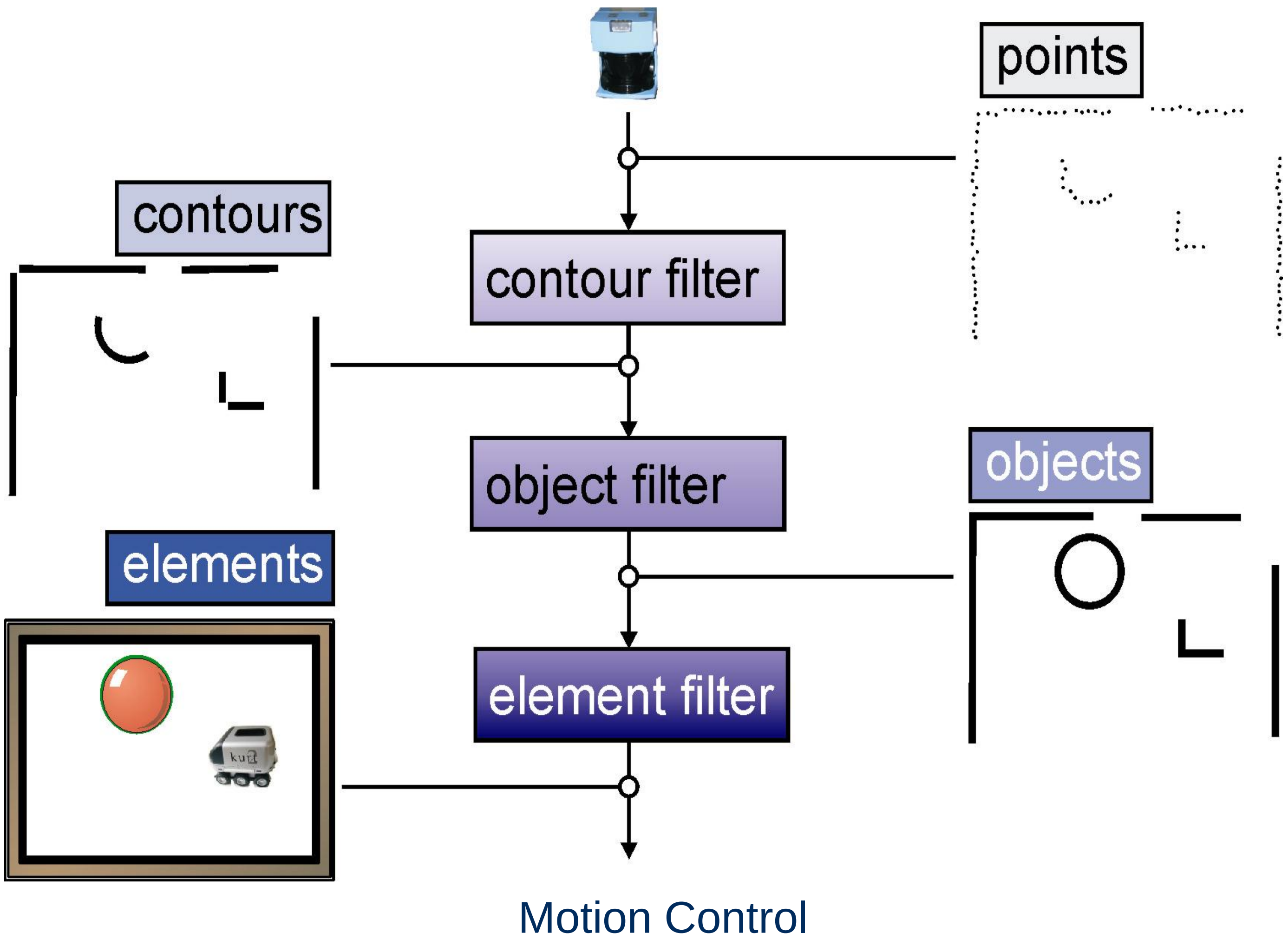




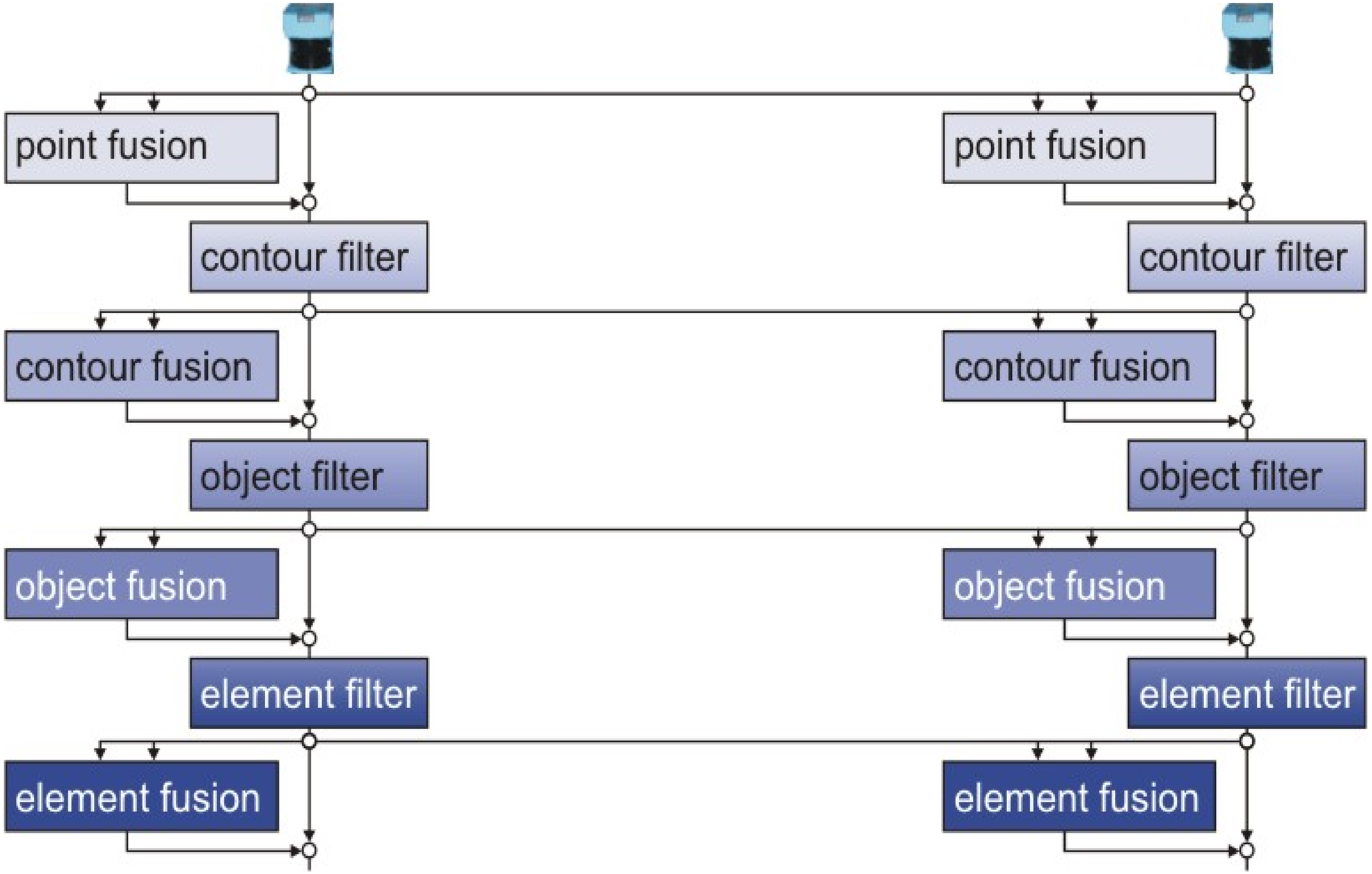
Example: RoboCup

- Getting wide acceptance as standard benchmark for team robotic
- Annual world and national championships in robot soccer
- Research done as part of a nationwide DFG-program „Cooperating teams of mobile robots in dynamic environments“

Sensor Data Processing –
Filters and Abstraction Levels

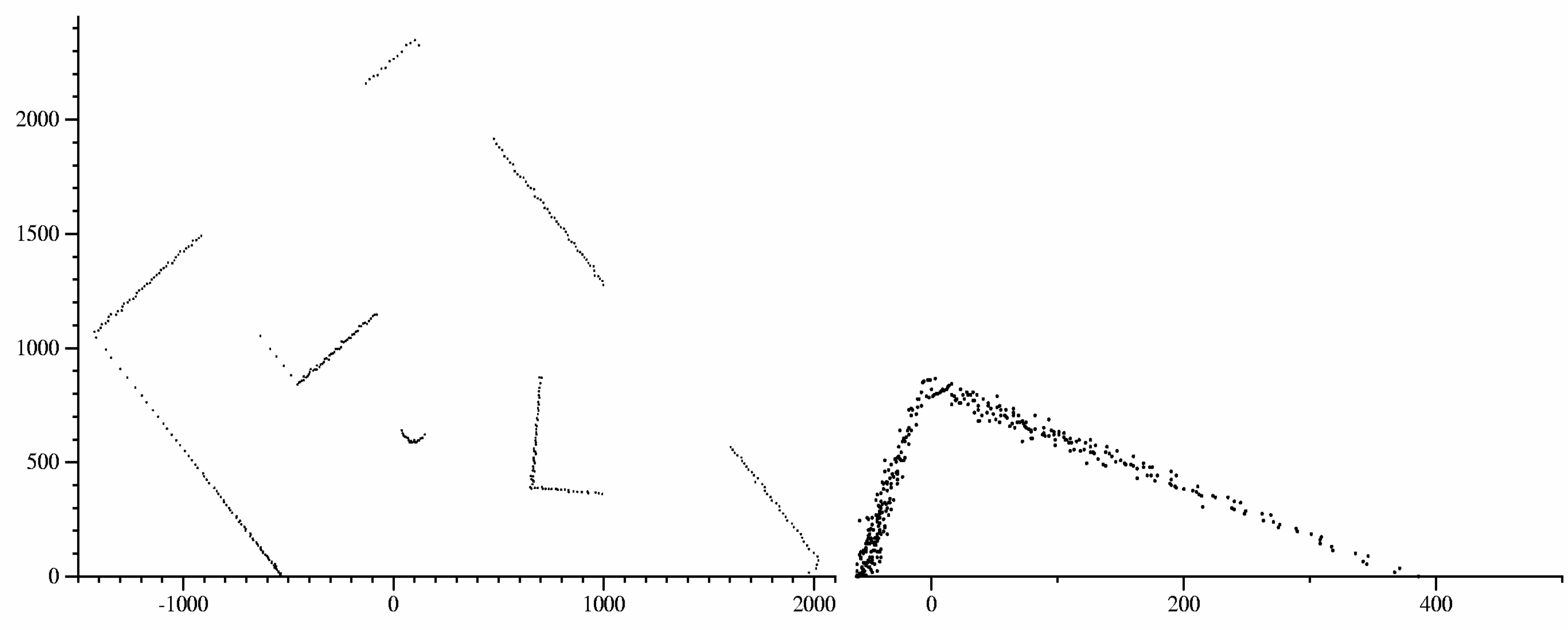


Sensor Data Processing - Multi-Level Sensor Fusion

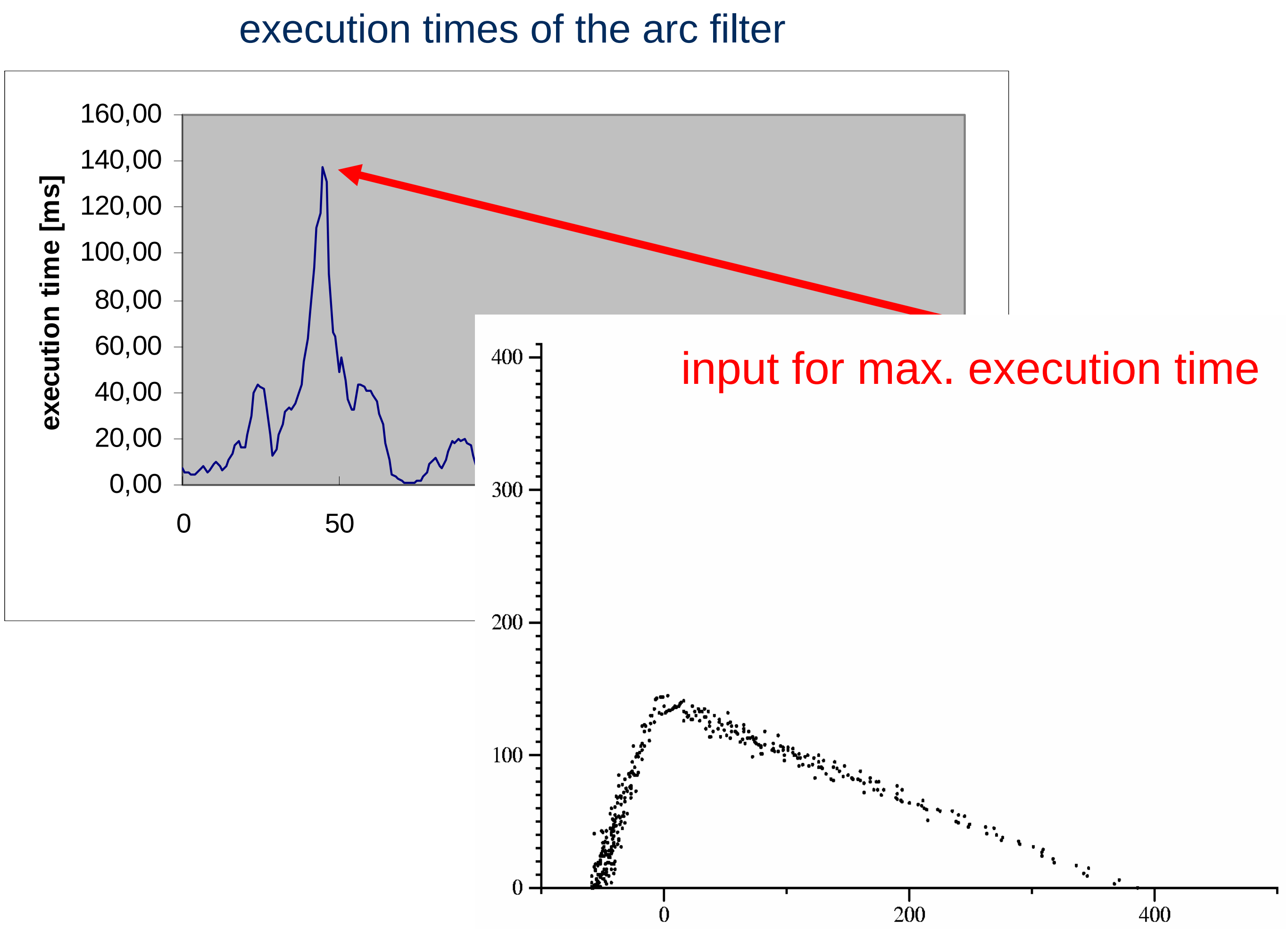


Environment-Dependent Execution Times of the Filter Modules

- Execution times depend on input size
- Execution times depend on input content

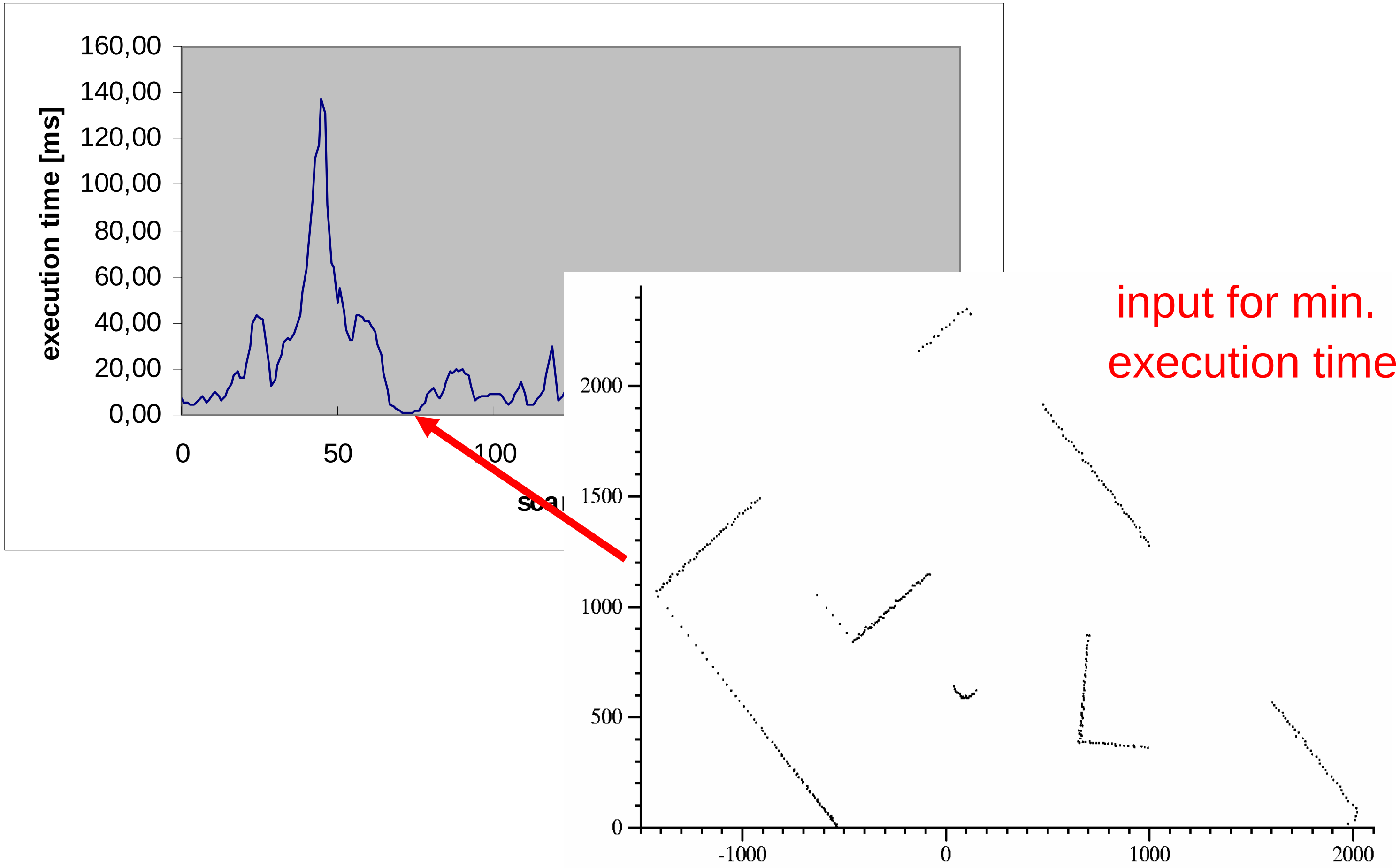


Environment-Dependent Execution Times of the Filter Modules (cont'd)

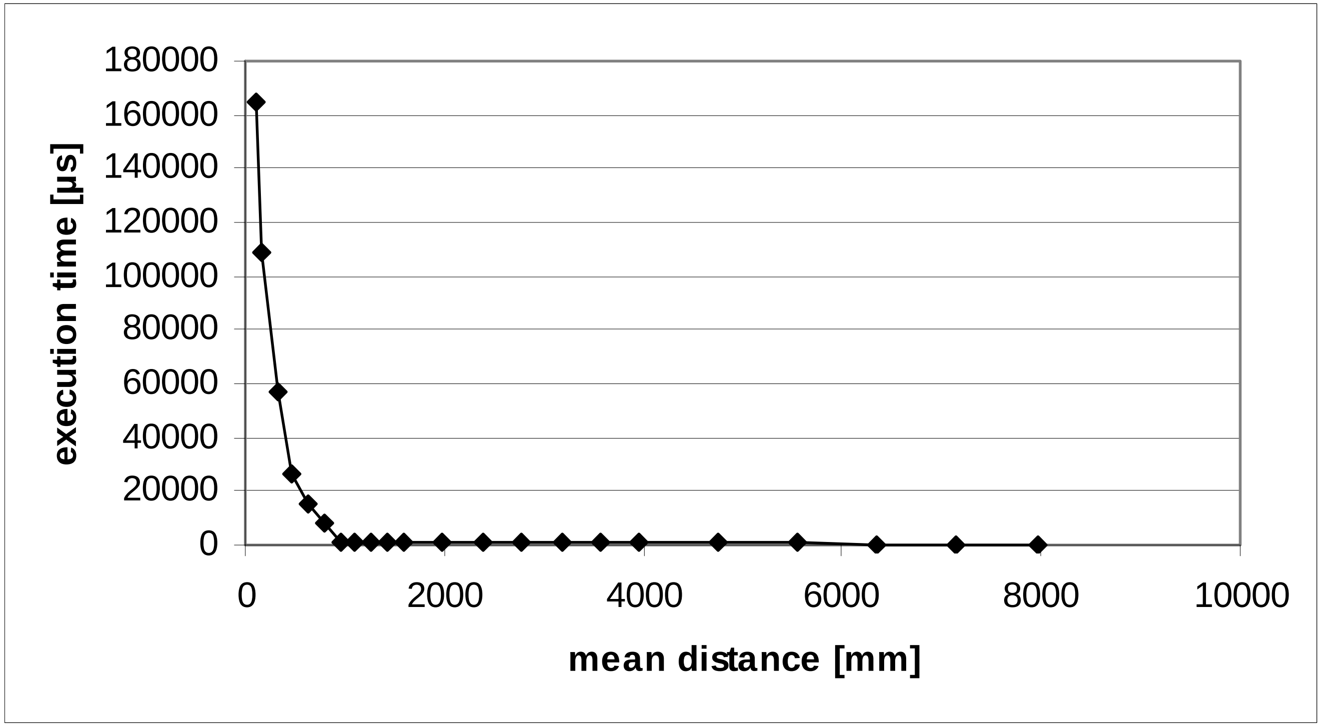


Environment-Dependent Execution Times of the Filter Modules (cont’d)

execution times of the arc filter



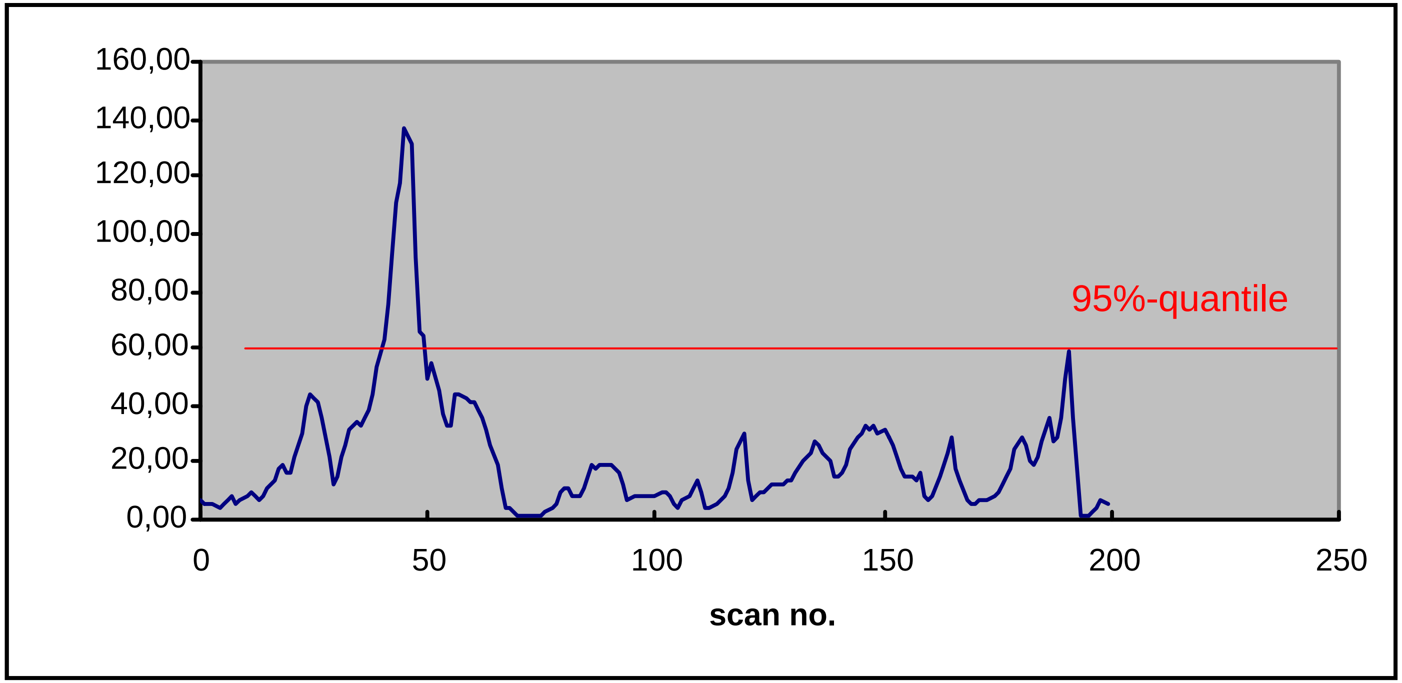
Contour Filter: Execution Time vs. Mean Distance



- Execution times > 57ms are only observed for distances < 32cm

Environment-Dependent Execution Times of the Filter Modules (cont’d)

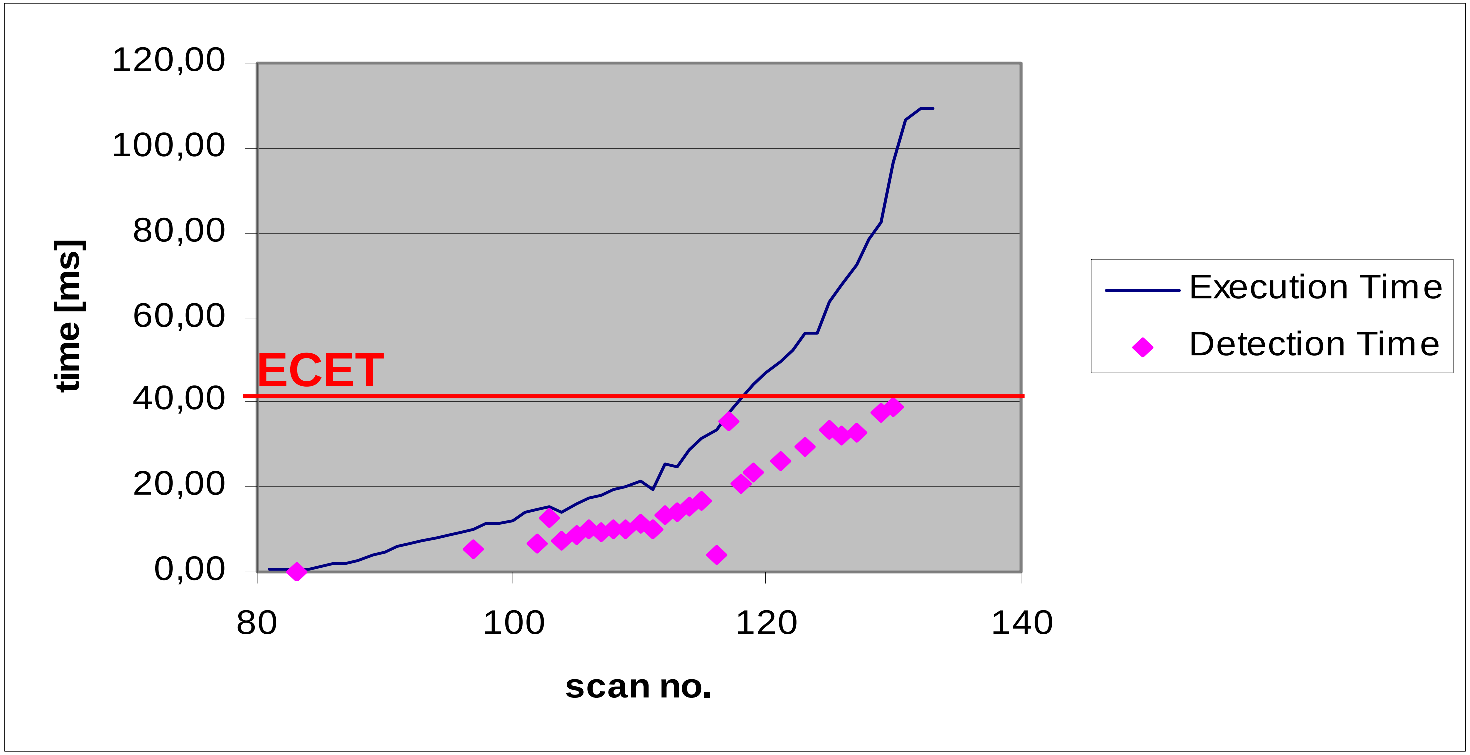
execution times of the arc filter



→ Scheduling WCETs is not a viable solution to achieve a predictable timing behavior of the filter modules!

Functional Redundancy in the Arc Filter

- The arc filter evaluates potential ball positions
- Only the best estimate is relevant to higher layers (corresponds to ball)



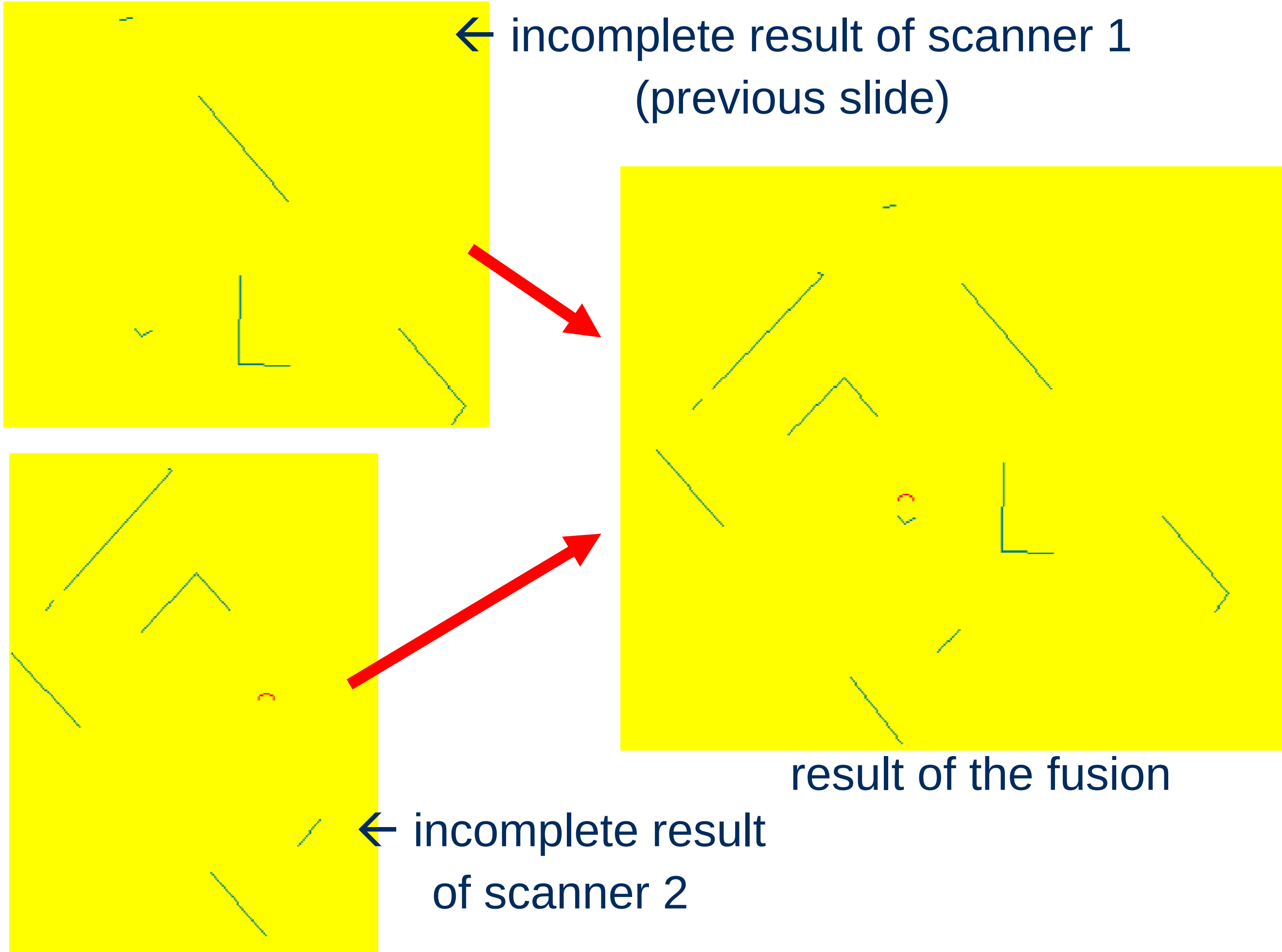
Structural Redundancy in the Edge Filter

- Aborted instances deliver results for a fraction of the scene
- Incomplete results are valuable input for the sensor fusion

Zur Anzeige wird der QuickTime™
Dekompressor „“
benötigt.

Structural Redundancy – Distributed Fusion

- Environment is observed by several, distributed sensors
- Fusion complements missing results from one sensor by results from others

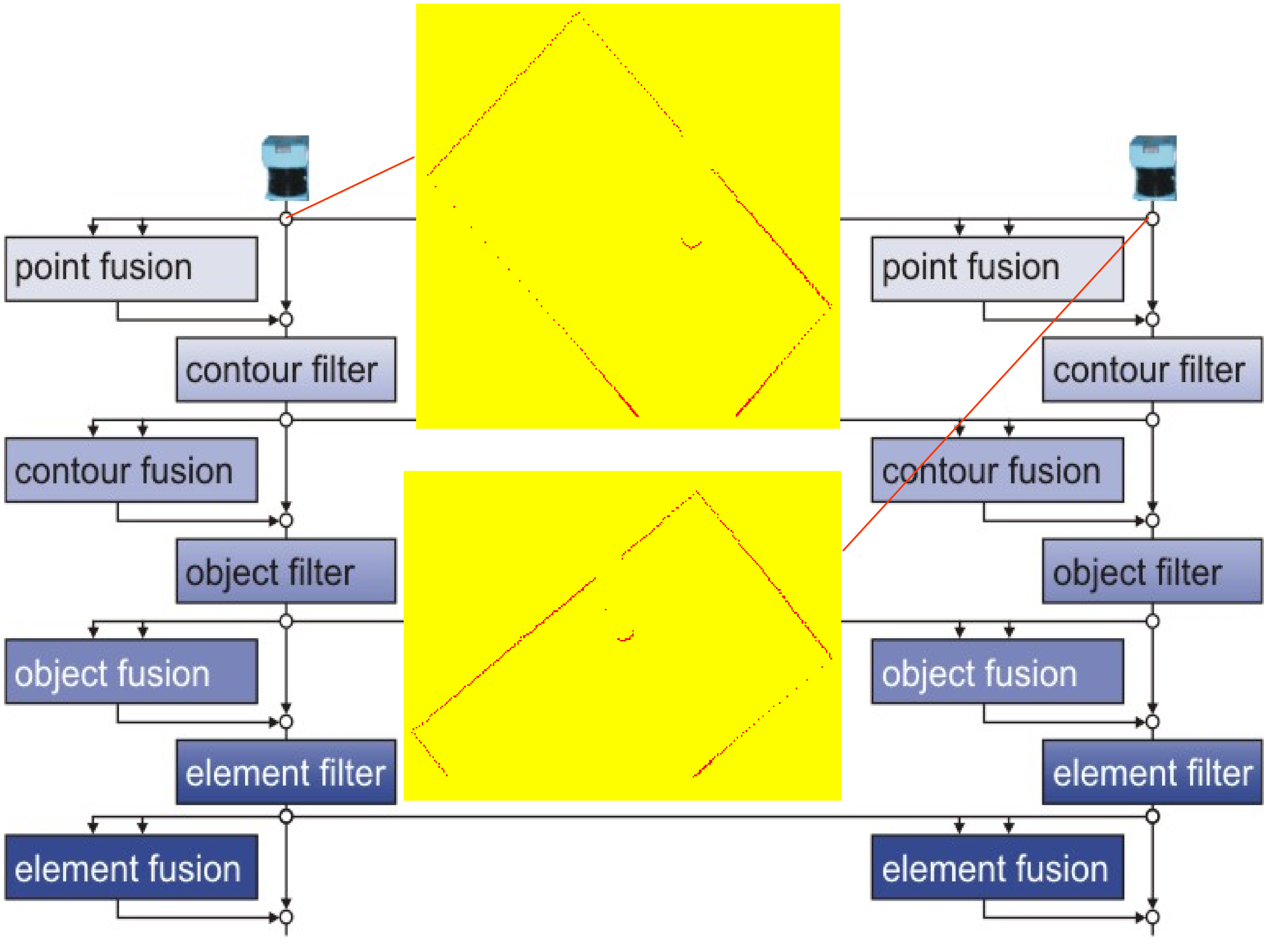


Application-Level Adaptation

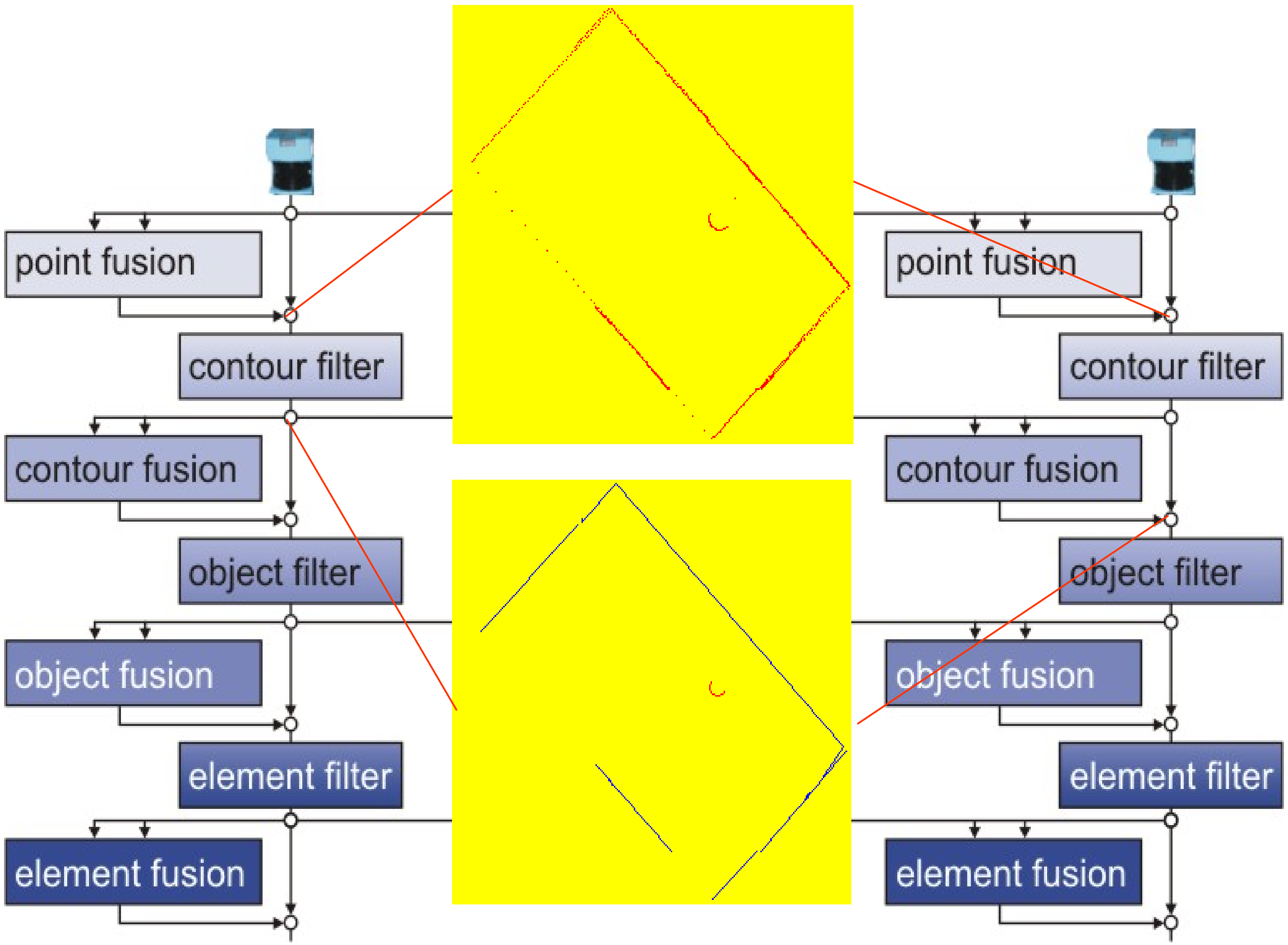
- Raising the fusion level allows reducing system load
  - Reduced execution times (CPU load)
  - Reduced data volume (network load)
- Raising the fusion level may decrease accurateness of results

		2 scanners			3 sanners			
		execution times [µs]		data volume [byte]	execution times [µs]			data volume [byte]
point fusion	point fusion	10304			20427			
	arc filter	13157			63093			
	edge filter	1436			2216			
	obect filter	2570			3708			
	element filter	77			98			
	sum	27544		11616	89542			17424
contour fusion	arc filter	3398	3688		3398	3688	5428	
	edge filter	577	578		577	578	465	
	contour fusion	1955			3253			
	object filter	1636			2067			
	element filter	70			77			
	sum	7927		1384	11290			1912

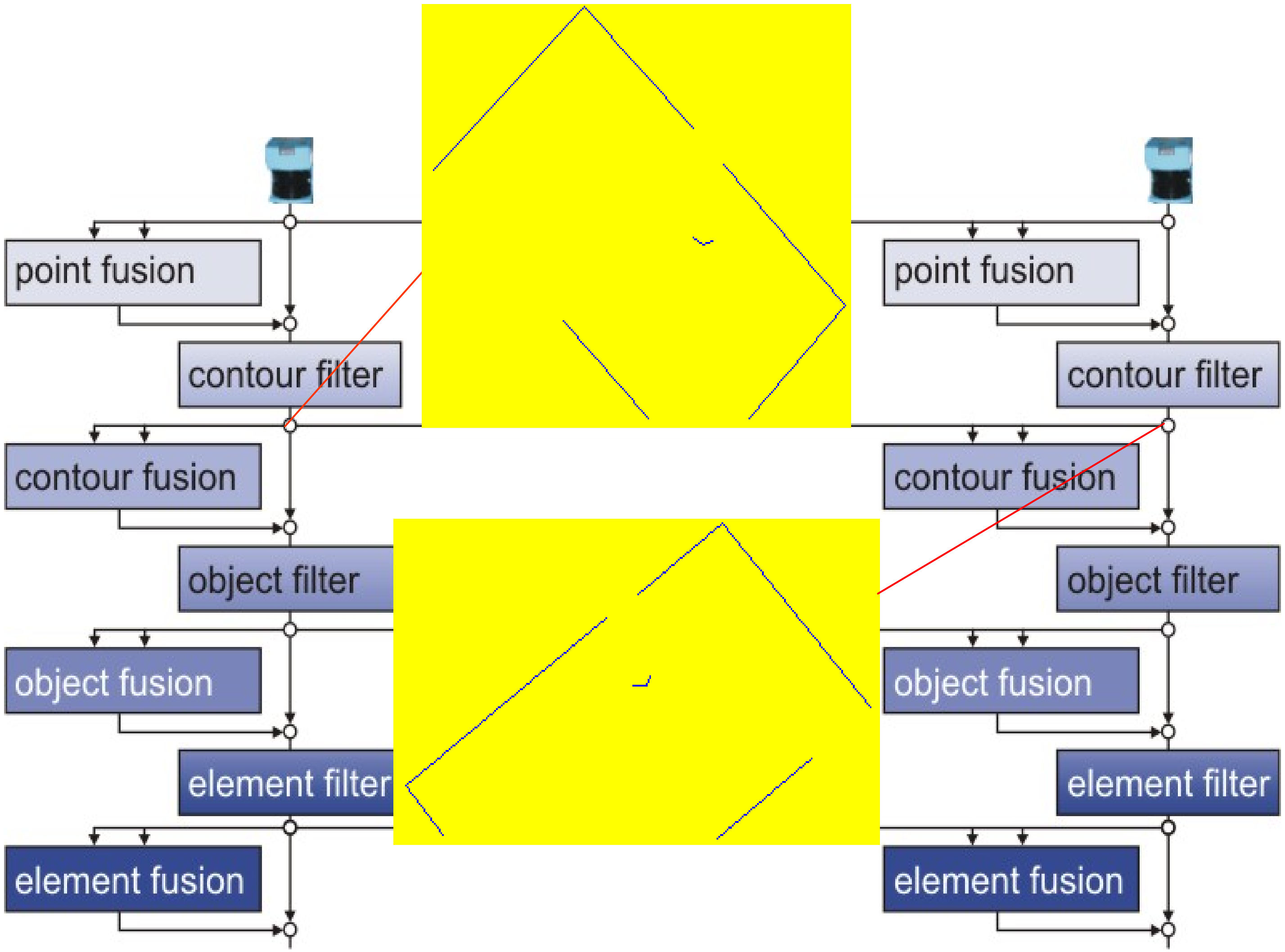
Application-Level Adaptation: Accuracy Tradeoff



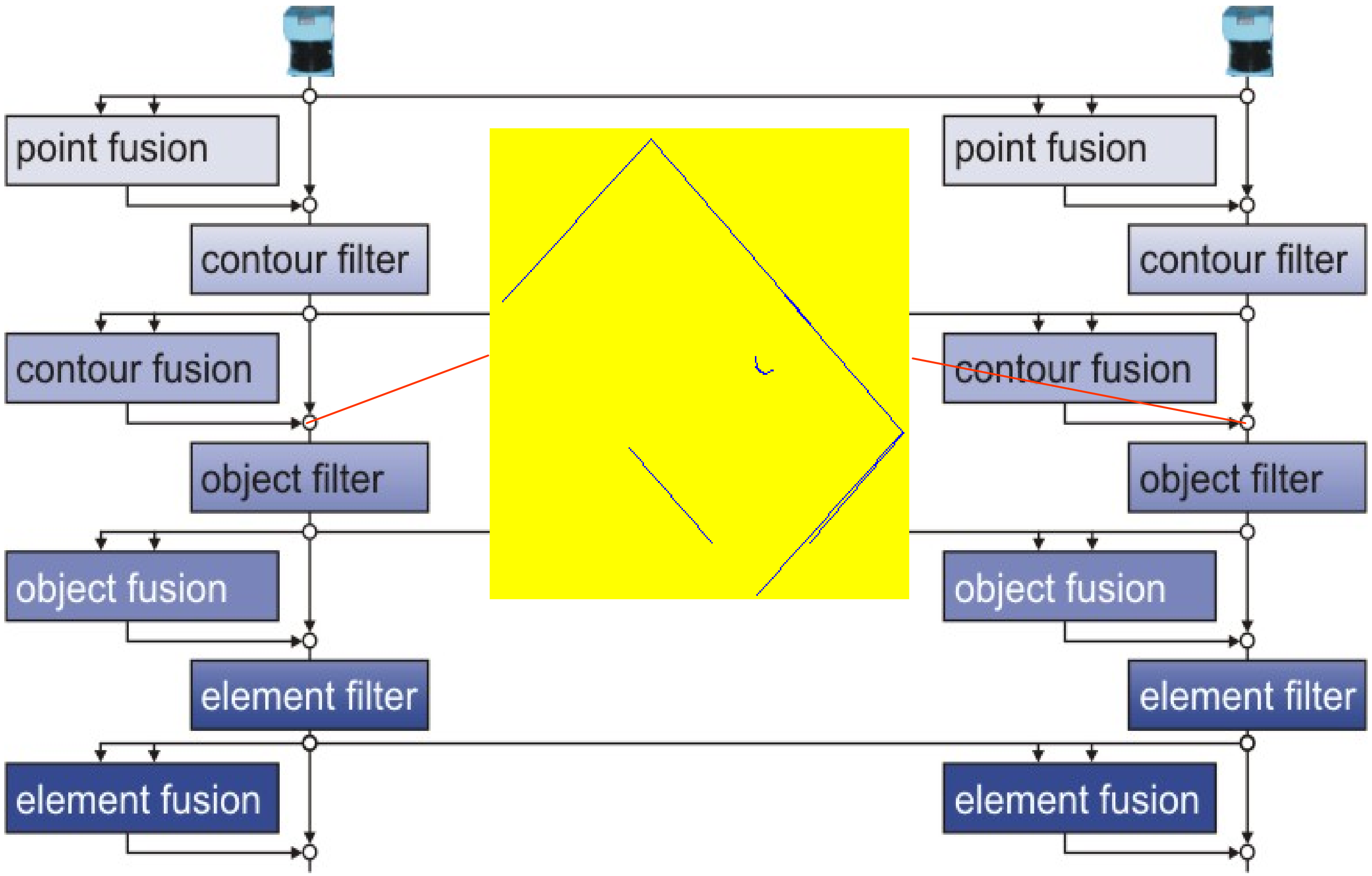
Application-Level Adaptation: Accuracy Tradeoff (cont'd)



Application-Level Adaptation: Accuracy Tradeoff (cont’d)



Application-Level Adaptation: Accuracy Tradeoff (cont'd)



Exploiting Inherent Redundancy

- To tolerate transient faults (short term peaks), use application-inherent redundancy
  - Functional redundancy within the module instances
    - → Design modules as any-time algorithms
  - Structural redundancy within the executions of the sensor fusion
    - → Combine results from distributed sensors
  - Time redundancy within a sequence of executions
    - → Schedule a frequency above the minimum
- To tolerate permanent faults (persistent overload), use application-level adaptation (graceful degradation)
  - TAFT supports detection of persistent overload
  - Application-level adaptation allows lowering system load