Managing software variability for dynamic reconfiguration of robot control systems

UNIBG

Davide Brugali

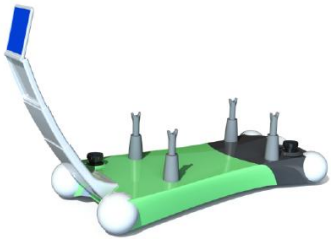
University of Bergamo, Italy

Outline

- Managing software variability for :
  1. Reducing software development costs
  2. Enforcing NF-Requirements at runtime

- Challenges in software variability management

The cost of software development for service robots



container-transporting robot

care utensil robot

floor-cleaning robot

NIKOLAUS BLÜMLEIN

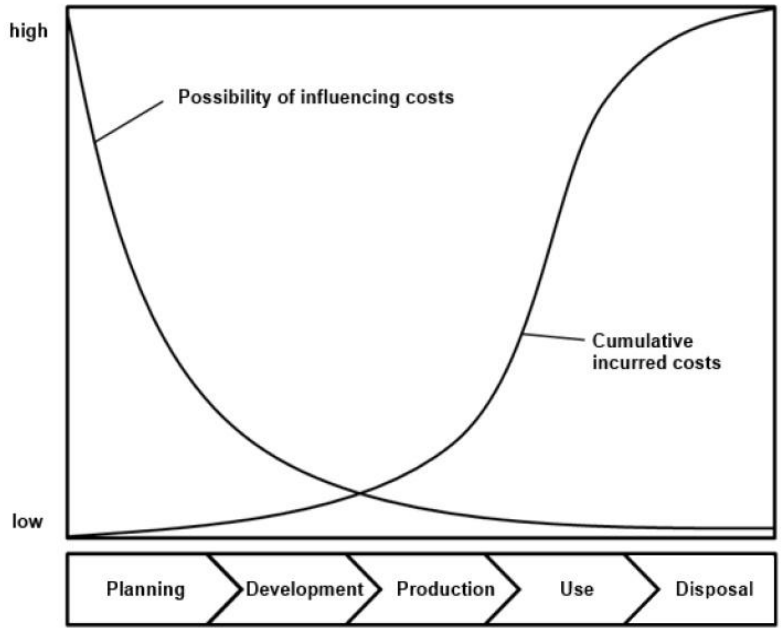
Function-based Cost Estimation for Service Robot Prototypes in Early Design Phases

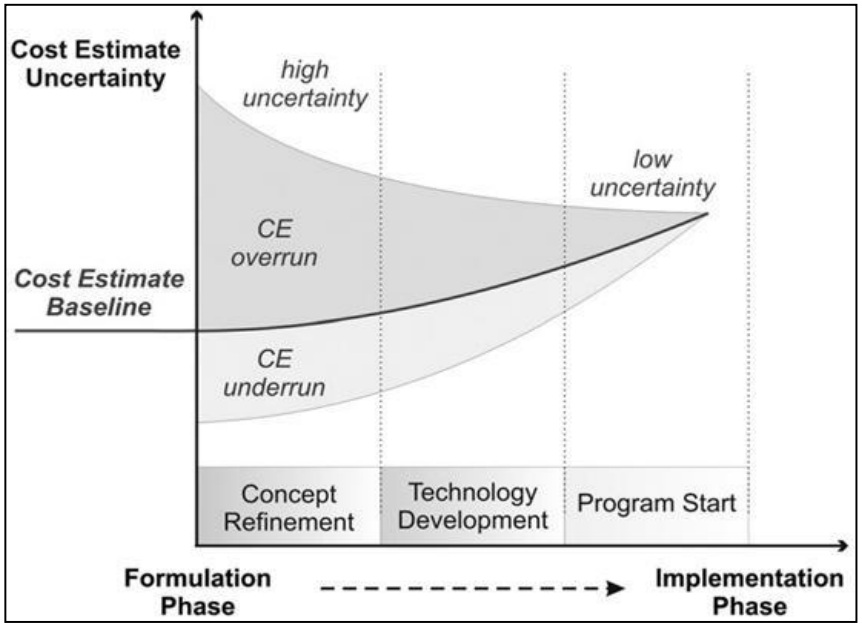
Universität Stuttgart

Fraunhofer IPA

Cost type	Expected value	Standard deviation
Material (per unit)	121,389.58 €	11,183.26 €
Hardware installation (per unit)	21,900.00 €	13,950.00 €
Administration	36,575.00 €	1,741.67 €
Software development	5,814,611.29 €	972,242.91 €
Software installation (per unit, not for prototype)	568.18 €	190.91 €
System designing	1,456,657.64	378,552.25 €

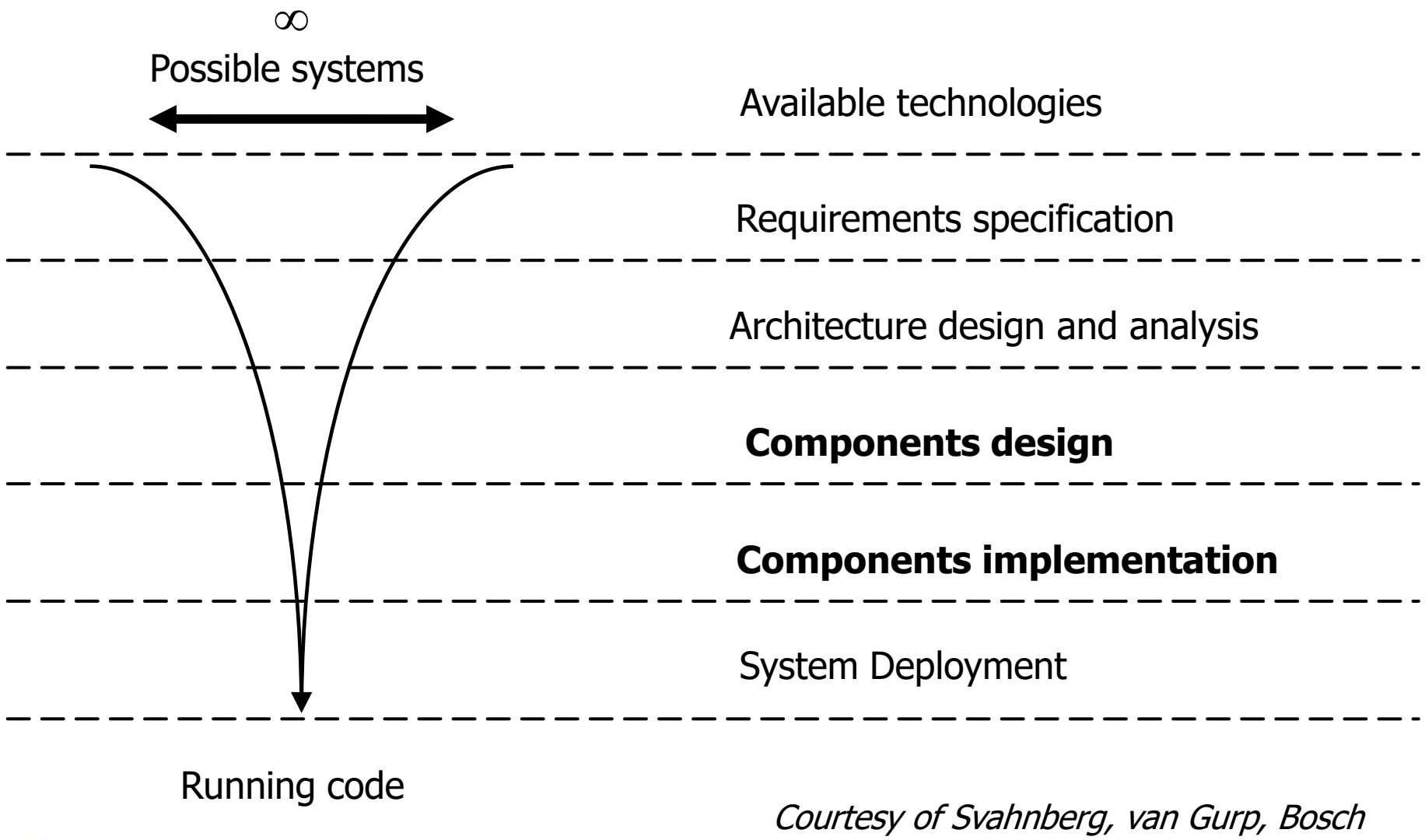
The cost of software development for service robots





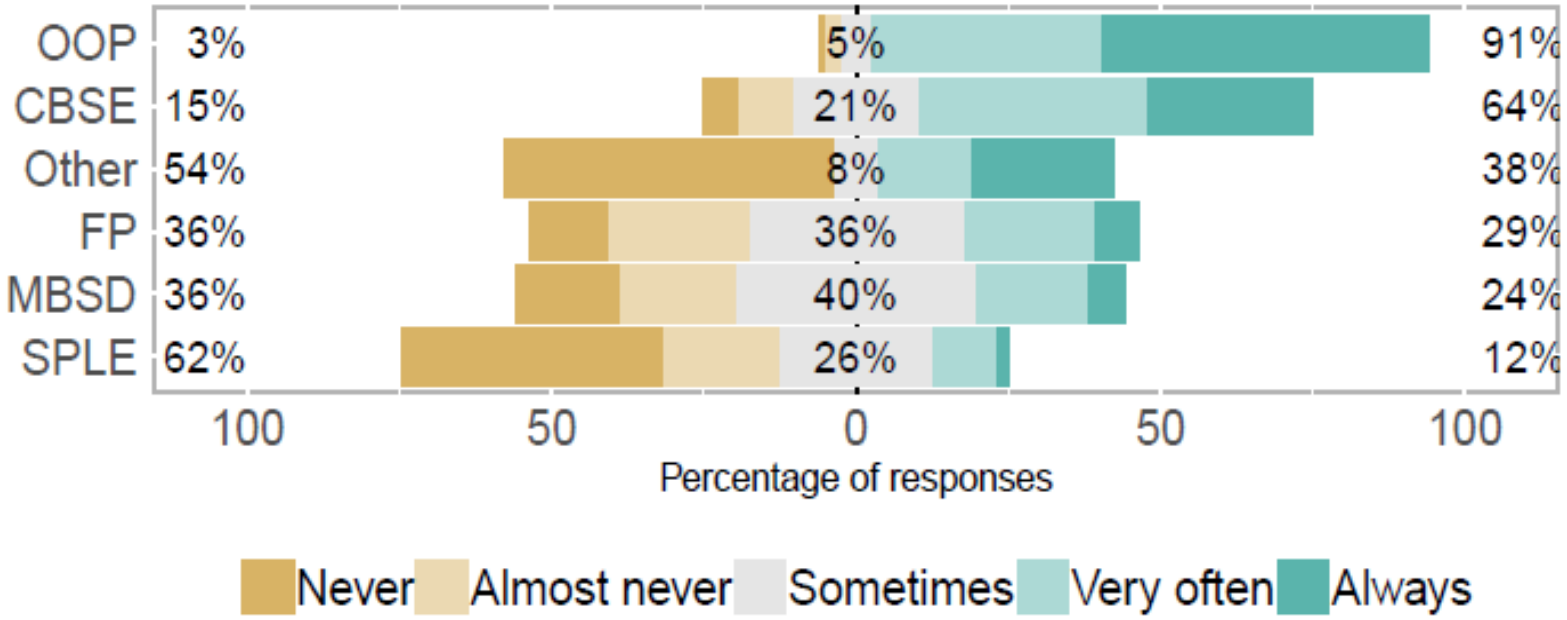
- up to 90% of the life-cycle costs are influenced by decisions taken in early development phases
- the cost estimate uncertainty is higher in early phases
- the majority of the costs are incurred during production, and use (i.e. maintenance)

Current practice : single system development



Courtesy of Svahnberg, van Gurp, Bosch

Current practice

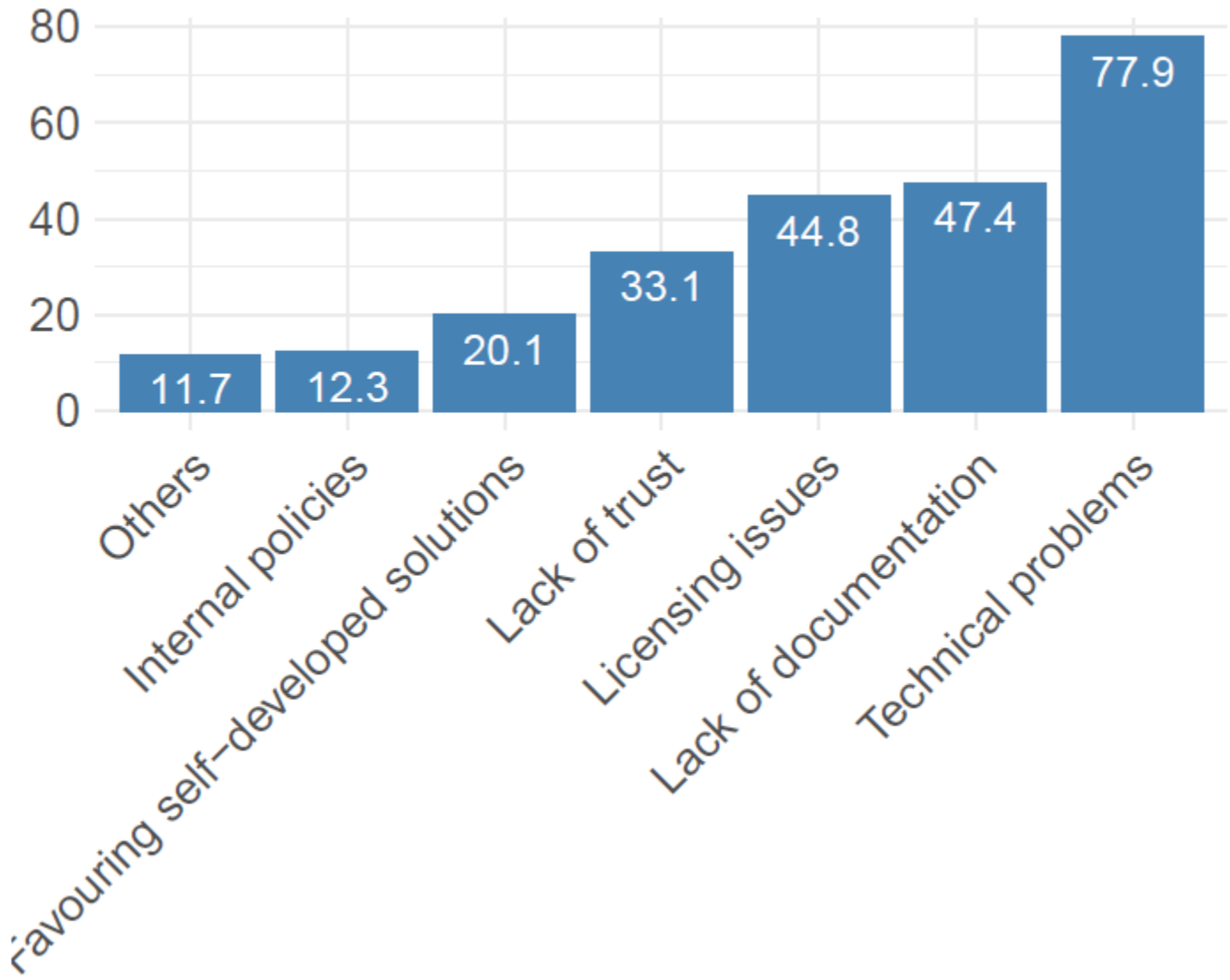


Variability Modeling of Service Robots: Experiences and Challenges

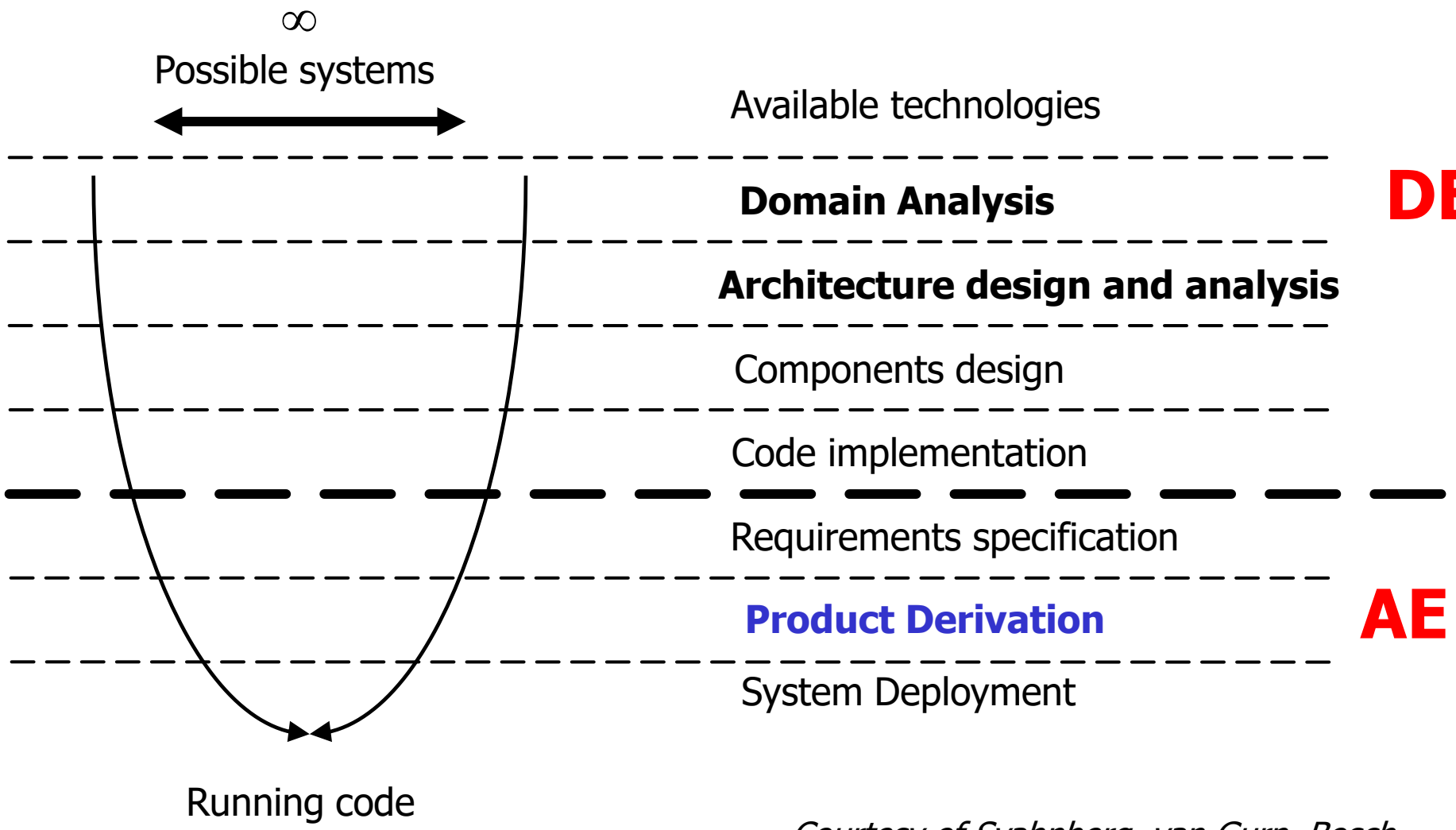
Sergio García, Daniel Strüber, Davide Brugali, Alessandro Di Fava, Philipp Schillinger, Patrizio Pelliccione, Thorsten Berger

13th International Workshop on Variability Modelling of Software-Intensive Systems, February 6-8, 2019, Leuven Belgium

Reasons for NOT REUSING software components

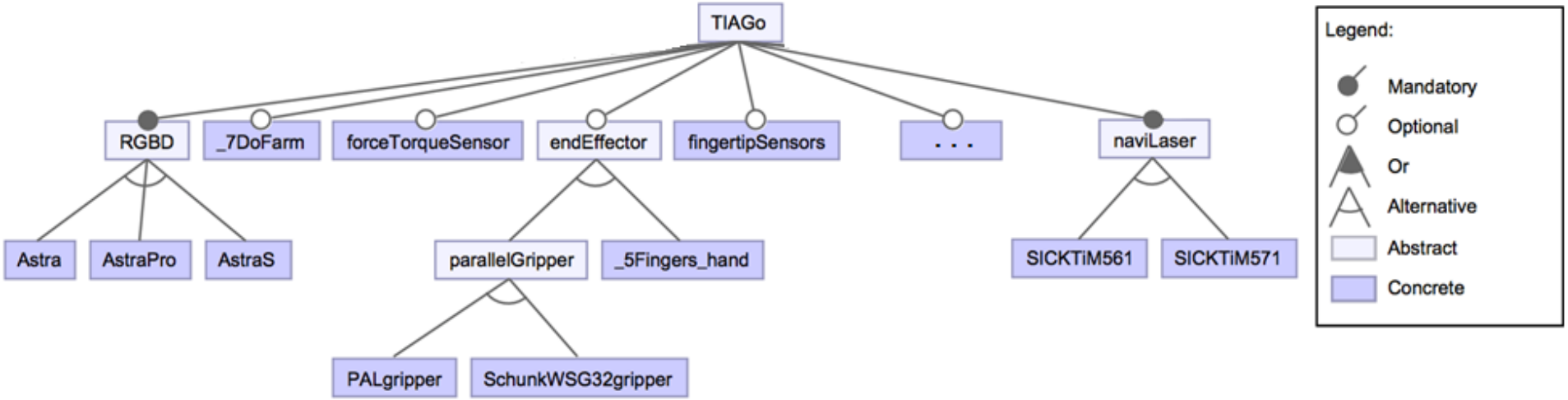


Software Product Lines



Courtesy of Svahnberg, van Gurp, Bosch

Robotic variability : Hardware



Robotic variability : Task

Logistic

Housekeeping

Social interaction

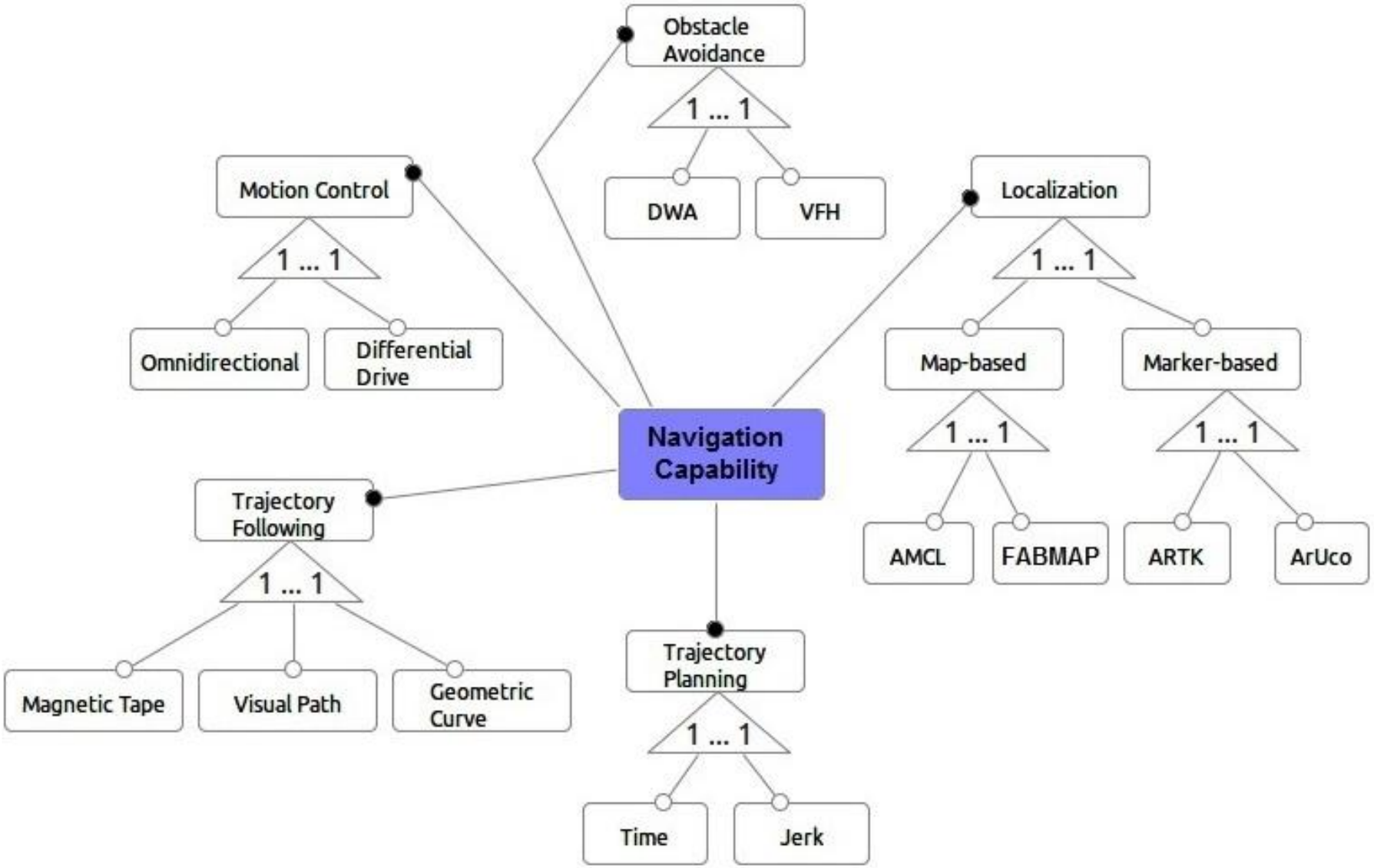
Robotic variability : Environment

Mostly static

Highly dynamic

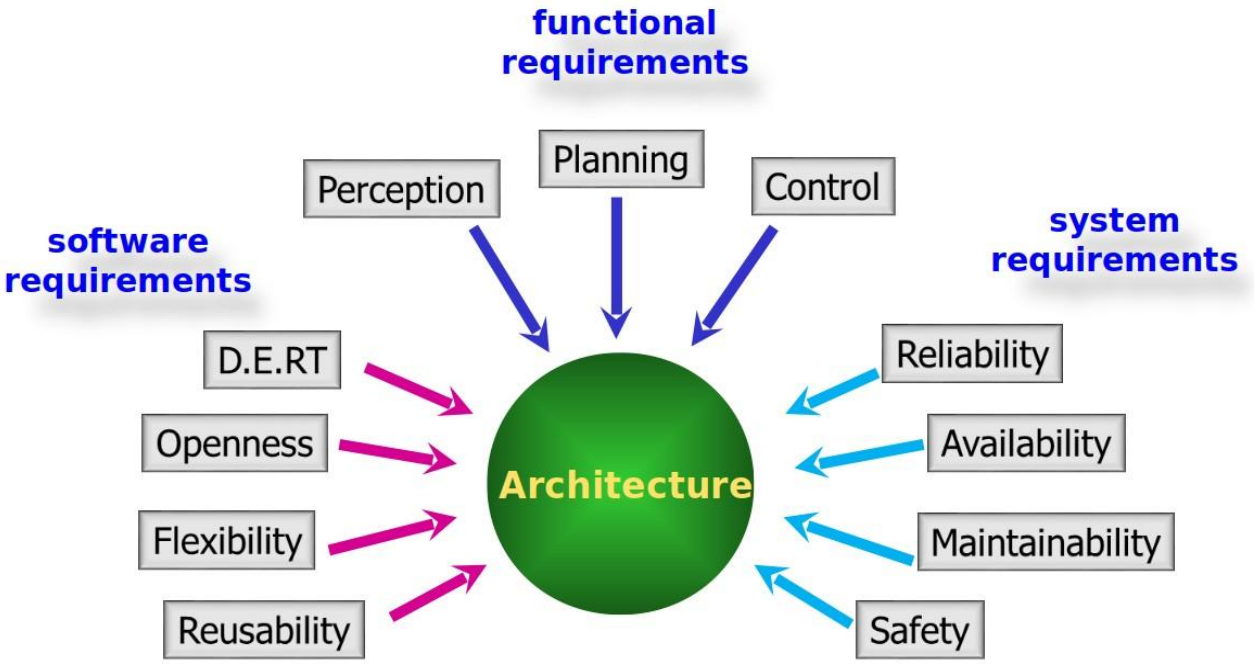
Outdoor

Robotic variability : Capabilities

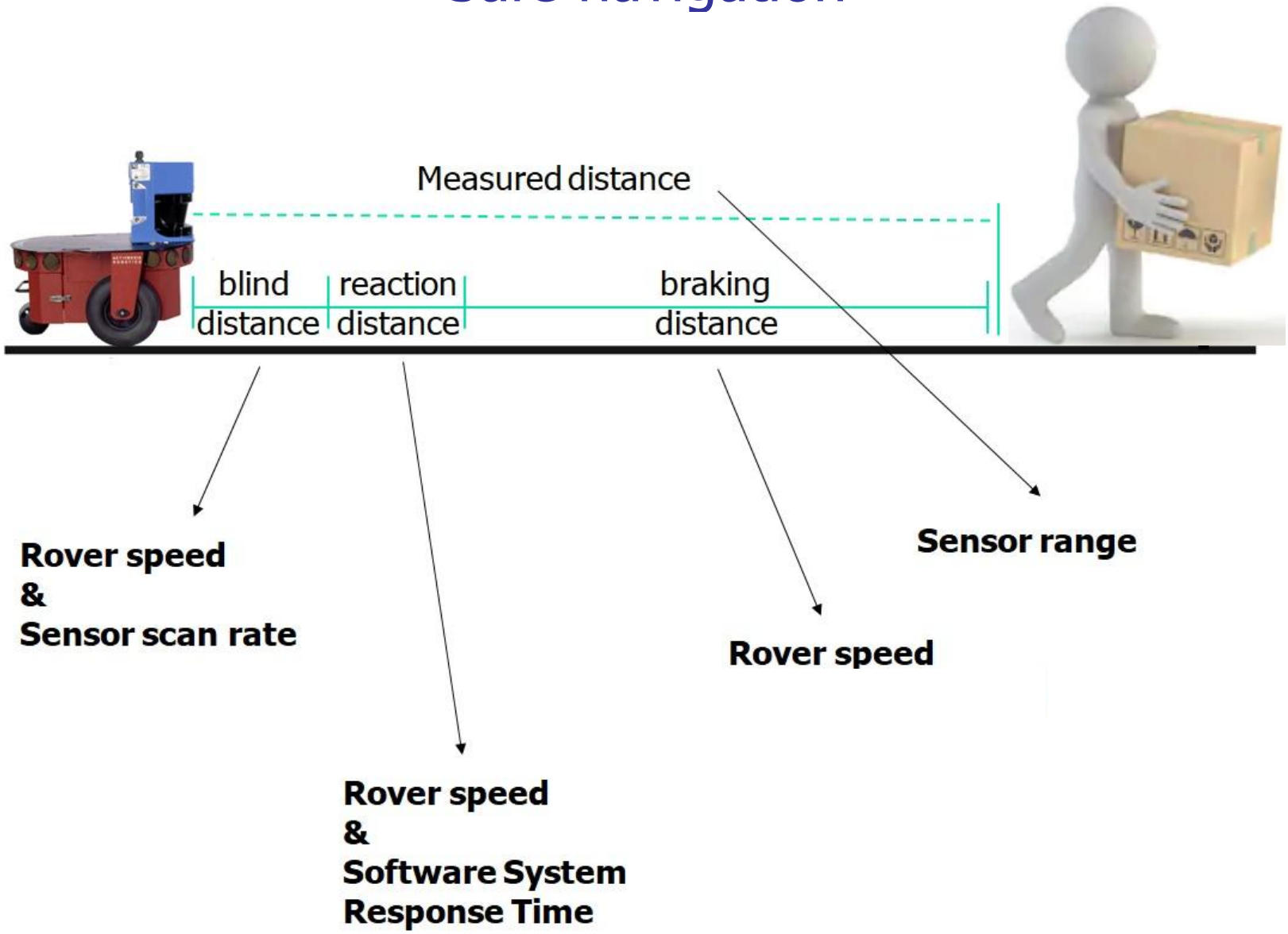


Challenges

1. To identify *Domain-specific software architectures*
   - that capture robotic variability and
   - allow assessing system-level quality aspects



Safe navigation



Logistics Scenario

Requirements :

- the robot transports fragile medical items
- the corridors are not crowded (mostly static)
- the path is marked with visual landmarks

Configuration :

- Trajectory planning : jerk-limited
- Obstacle avoidance : DWA
- Localization : Aruco markers

Logistics Scenario

Requirements :

the robot transports fragile medical items

the corridors are not crowded

the path is marked with visual landmarks

use a laser range finder and a geometric map

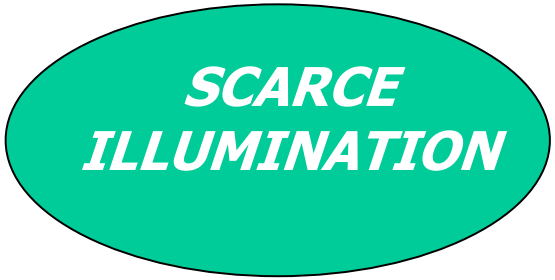
Configuration :

Trajectory planning : jerk-limited

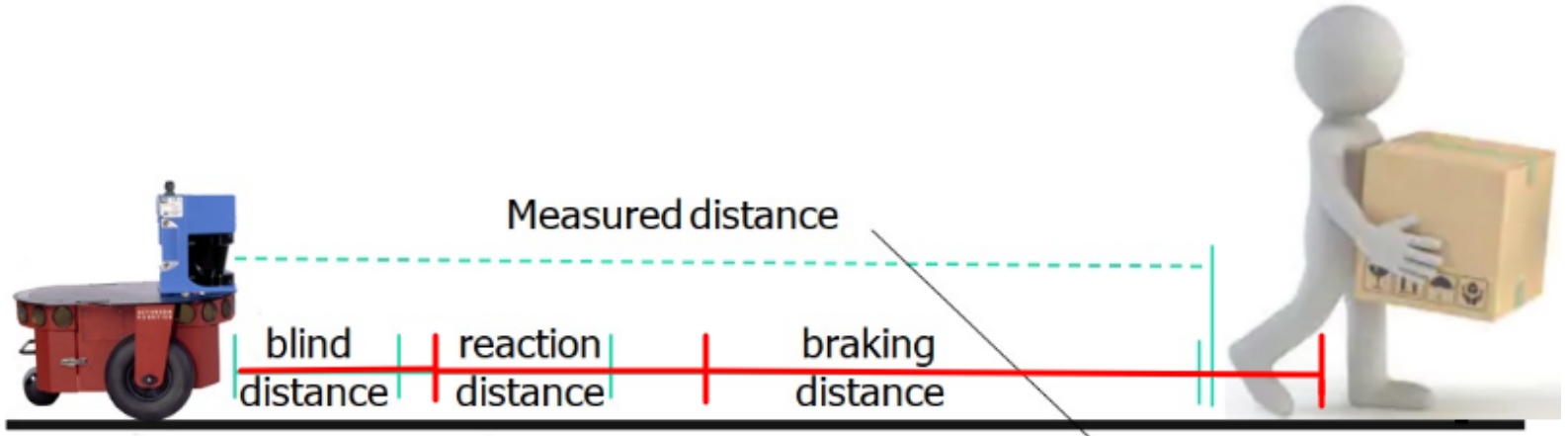
Obstacle avoidance : DWA

Localization : Aruco markers

Localization : AMCL



Safe navigation



Rover speed & Sensor scan rate reduced

Rover speed & Software System Response Time increased

Rover speed should be reduced

Sensor range

Response Time Analysis of System Variants

	Software								Hardware					Response Time (sec)
	Obstacle Avoidance		Trajectory Following		Localization		Obstacle Detection		Rover		Sensors			
	DWA	SND	DD	OD	GM	VM	AB	DB	PI	YO	HL	KDS	BSC	
	D	D	-	-	D	D	D	D	-	-	-	D	D	
$Variant_1$	x		x		x		x		x		x			2.17
$Variant_2$	x		x		x		x		x		x			2.15
$Variant_3$	x			x		x	x			x			x	1.96
$Variant_4$	x			x	x			x		x	x			2.16
$Variant_5$	x			x	x		x			x	x			3.91
$Variant_6$	x		x		x		x		x			x		2.15
$Variant_7$	x		x		x		x		x				x	2.16
$Variant_8$		x	x		x		x		x		x			2.19
$Variant_9$		x	x		x		x		x		x			2.18
$Variant_{10}$		x	x			x	x		x		x			1.98
$Variant_{11}$		x	x		x			x	x		x			2.18
$Variant_{12}$		x		x	x		x			x	x			3.89
$Variant_{13}$		x	x		x		x		x			x		2.17
$Variant_{14}$		x	x		x		x		x				x	2.16

Model-based development of QoS-aware Reconfigurable Autonomous Robotic Systems
Brugali D., Mirandola R., Capilla R., Trubiani C.
2018 Second IEEE International Conference on Robotic Computing

Challenges

1. Modeling NF-Requirements for configurable systems

- Modeling the relationship between NF-Requirements and System Variants
- Defining Modeling languages

Modeling and Analysis of safety requirements in robot navigation with an extension of UML MARTE

Brugali D. 2018 IEEE International Conference on Real-Time Computing and Robotics

2. Analysis of NF-Requirements for configurable systems

- To apply analysis methods to each configuration leads to combinatorial explosion.

Conclusions

- Variability management for :
  - Reducing development costs
  - Enforcing NF-Requirements at runtime
- Paradigm shift
  - From single system development to SPL
  - Emphasis on Architectures not on Components
- Challenges
  - Designing Domain-specific architectures
  - Modelling and analysis of NF-Requirements for reconfigurable systems

Thank you

Questions ?

UNIBG

Davide Brugali

University of Bergamo, Italy