Toward Performance Guarantee for Autonomous Mobile Robotic Mission: An Approach for Hardware and Software Resources Management

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Explore Team

Outline

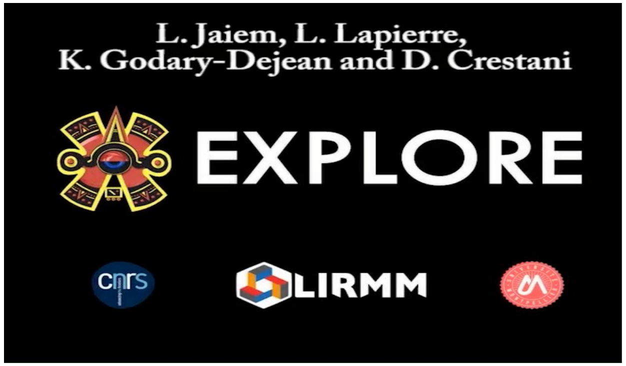
- Performance in Robotics
- The Issue
- Experimental Context
- Strategies
- Methodology
- Performance : Duration – Safety– Energy
- Allocation Algorithm
- Simulation and Experimental Results
- Conclusion and Futures Works

Performance in Robotics

- Industry

- Context
  - Confined Environnement
  - Known- Static
  - Unlimited Energy
- Numerous accepted performance indicators

- Mission

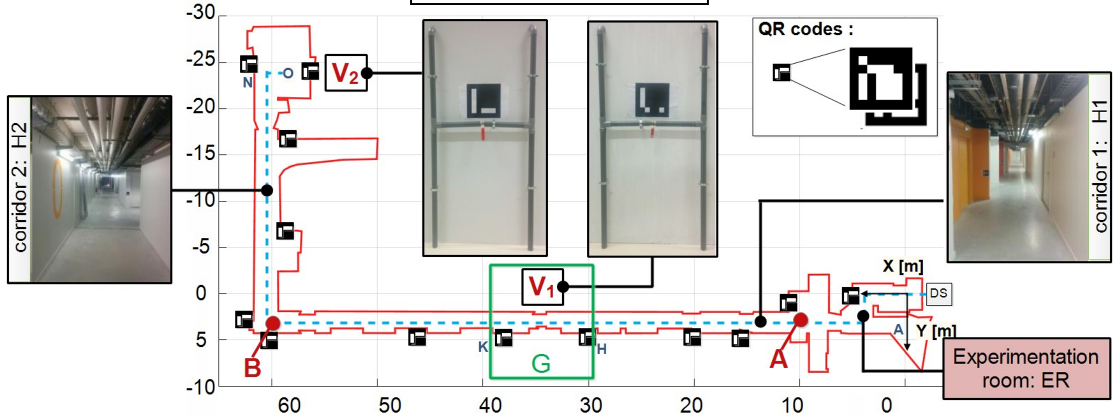


- Context
  - Broad Environnement
  - (Un)known - Dynamic
  - Limited energy
- User oriented indicators

The Issue

MISSION
- Long-term
- Multi-tasks

Dynamic Environnement



Faults hard / soft

How dynamically manage in real time sensors, actuators, control laws, algorithms

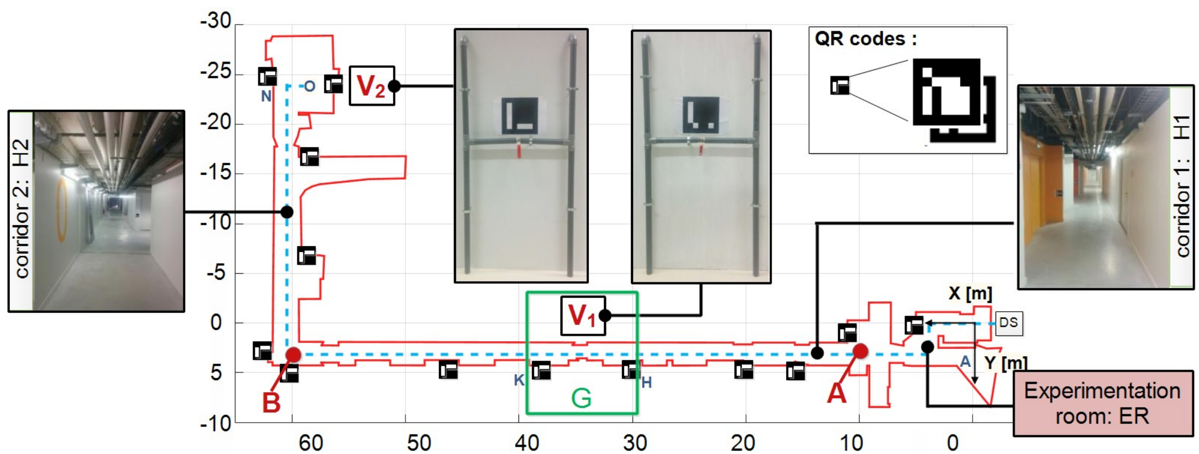
- **Safety** mission
- Used **Energy** ≤ Emax
- ***Localization*** *≤ Lmin*
- ***Stability*** *of the control*
- Mission **Duration**≤ Dmax

Experimental Context

- Hardware Resources

- Software Resources
  - Traveling (A -> B): 7
  - Turn Toward: 1
  - Localization: 3
  - Image Processing: 1

- Mission
  ~ 200 m



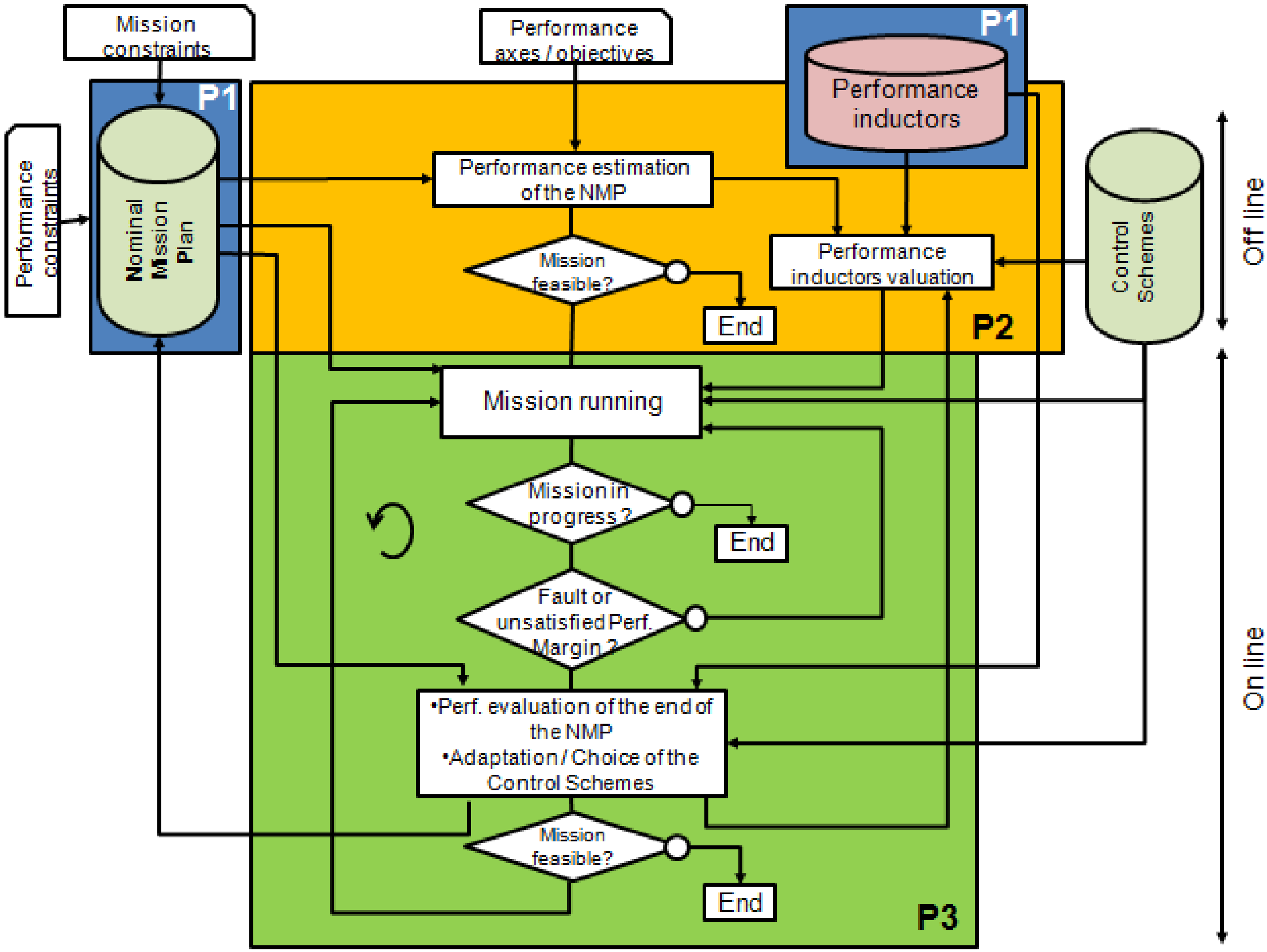
Strategies

- **Marge** : Improve robustness to models and trajectory approximations and to unforseen events (obstacle avoidance).
    - Duration and Energy Margins

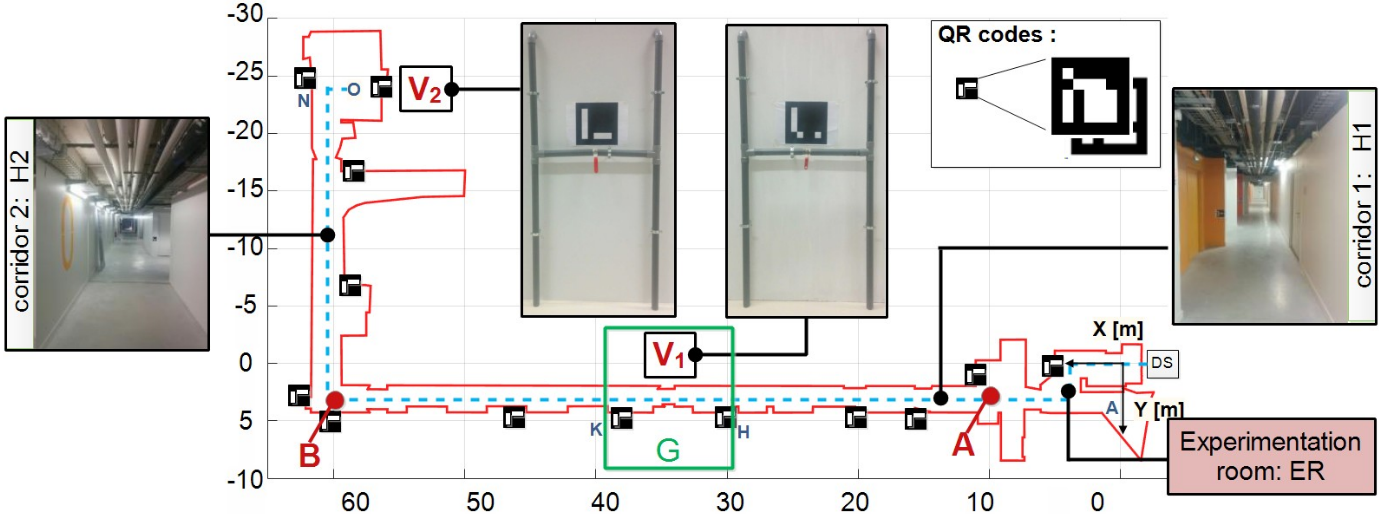
- **S1** : Travelling as fast as possible while being safe.

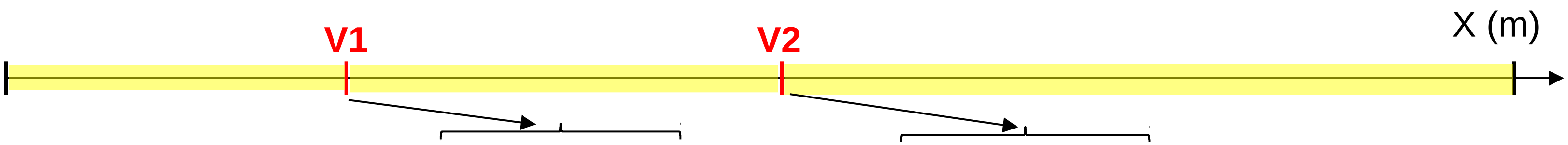
- **S2** : While satisfying energy consumption limits, use the more energetic control schemes because they correspond generally to the more efficicient ones. Moreover they maximize the set of possible solutions.

Methodology



Duration Viewpoint





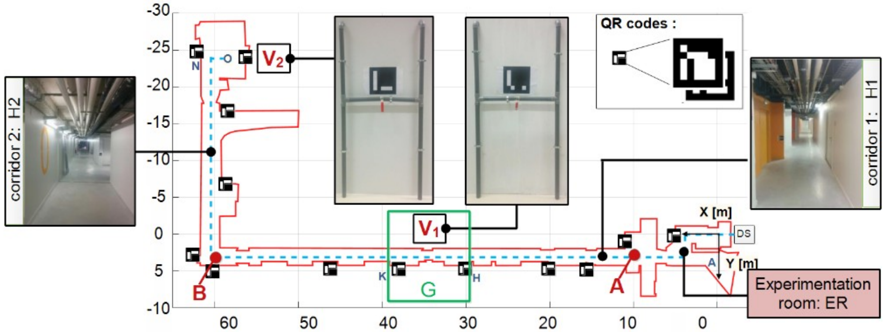
x_{i-1} - x_i (m)	0 - 37	37	37	37	37 - 93.5	93.5	93.5	93.5	93.5 - 187
Objective O_i	DS $\rightarrow$ V1	$\circlearrowleft$	$\bowtie$	$\circlearrowright$	V1 $\rightarrow$ V2	$\circlearrowleft$	$\bowtie$	$\circlearrowright$	V2 $\rightarrow$ DS
Task T_k	FM / L	R/L	VD	R/L	FM / L	R/L	VD	R/L	FM / L
n_{alt_i}	21	2	1	2	21	2	1	2	21
$V_{max}(m/s)$									

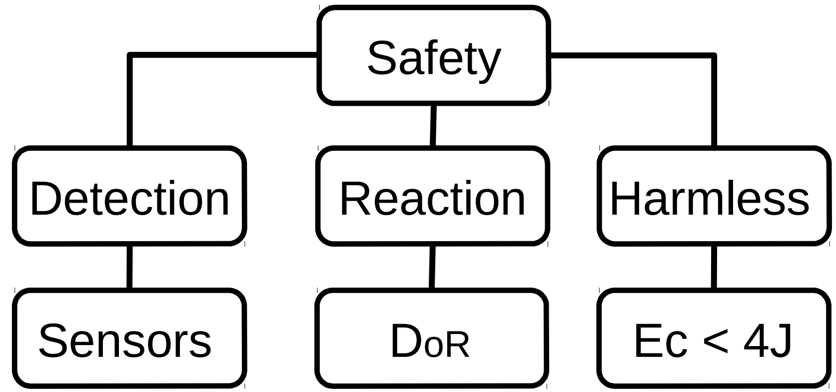
Alternatives = 148 176

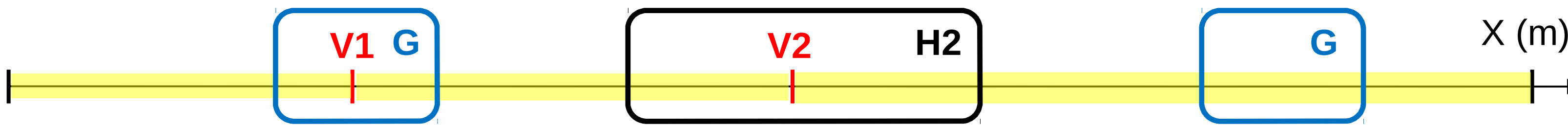
- Vmax(robot) = 0.8 m/s

Impossible in practice

Safety Viewpoint



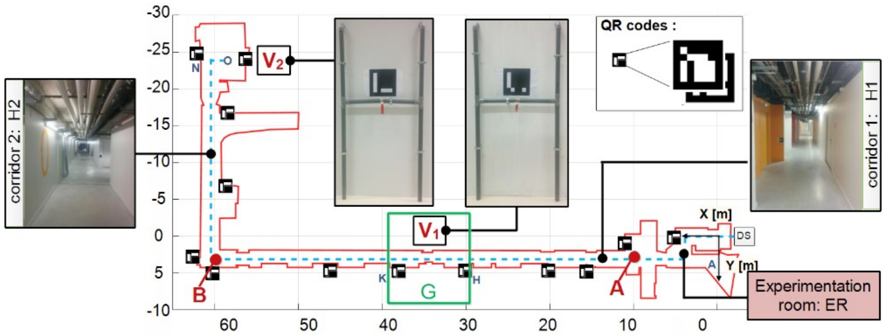


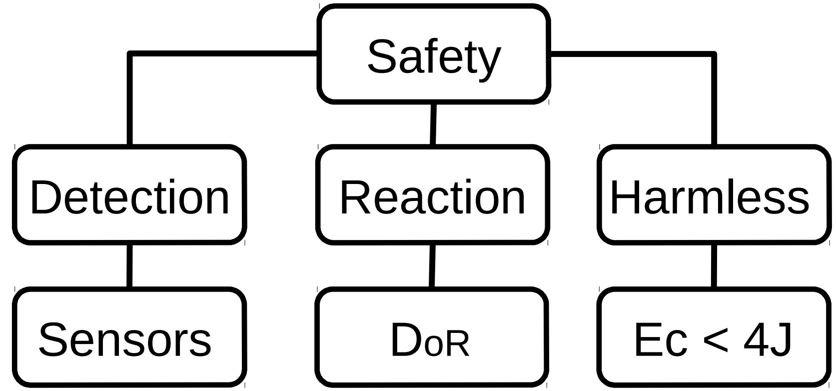


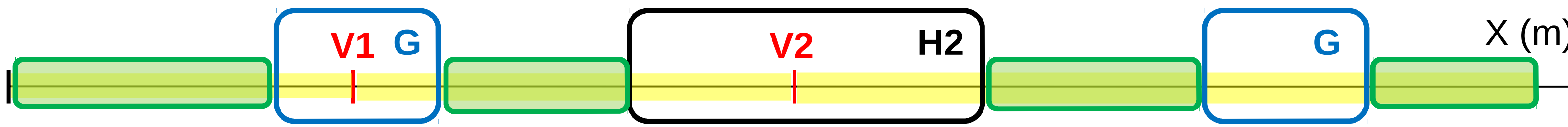
x_{i-1} - x_i (m)	0 - 37			37	37	37	37 - 93.5				93.5	93.5	93.5	93.5 - 187			
Objective O_i	DS → V1			↺	⋈	↻	V1 → V2				↺	⋈	↻	V2 → DS			
n_{alt_i}	21			2	1	2	21				2	1	2	21			
Task T_k	FM / L			R/L	VD	R/L	FM / L				R/L	VD	R/L	FM / L			
$A_k^{c_j}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
n_{alt_k}	21	9	3	2	1	2	9	21	21	7	2	1	2	21	21	9	21
$V_{max}(m/s)$																	

- Vmax(robot) = 0.8 m/s

Safety Viewpoint



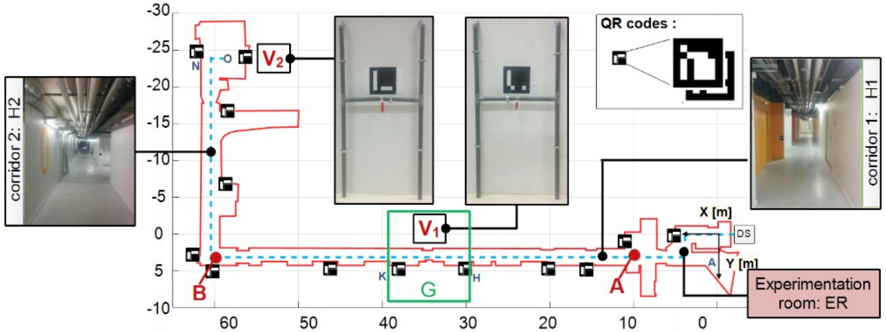


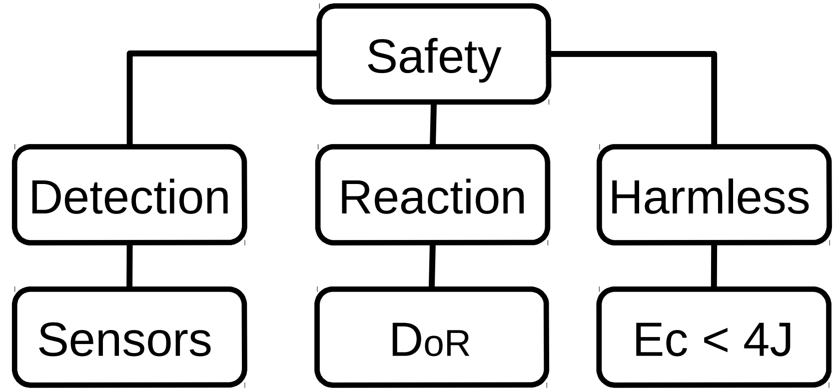


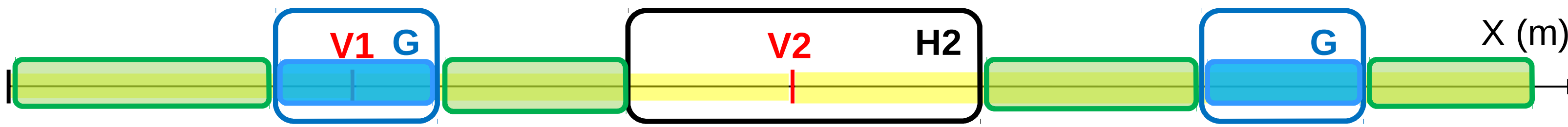
$x_i - x_{i-1}$ (m)	0 - 34			37	37	37	37 - 93.5				93.5	93.5	93.5	93.5 - 187			
Objective O_i	DS $\rightarrow$ V1			$\circlearrowleft$	$\bowtie$	$\circlearrowright$	V1 $\rightarrow$ V2				$\circlearrowleft$	$\bowtie$	$\circlearrowright$	V2 $\rightarrow$ DS			
n_{alt_i}	21			2	1	2	21				2	1	2	21			
Task T_k	FM / L			R L	VD	R L	FM / L				R L	VD	R L	FM / L			
$A_k^{c_j}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
n_{alt_k}	21	9	3	2	1	2	9	21	21	7	2	1	2	21	21	9	21
$V_{max}(m/s)$																	

- Vmax(robot) = 0.56 m/s

Safety Viewpoint







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n_{alt_i}	21			2	1	2	21				2	1	2	21			
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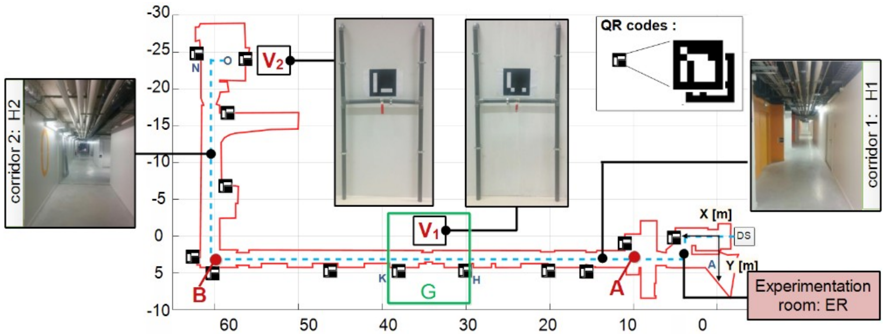
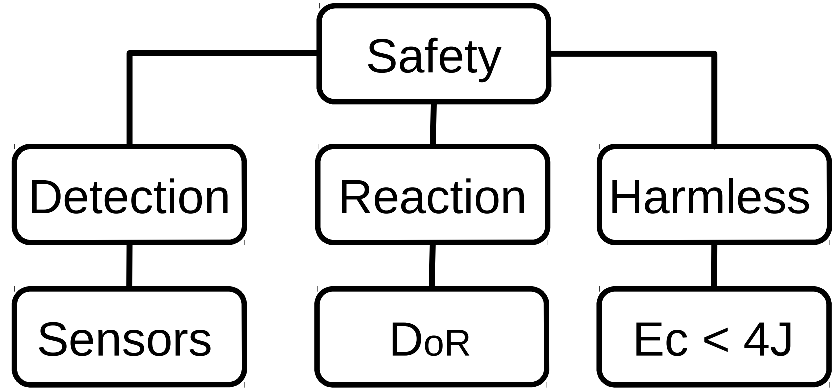
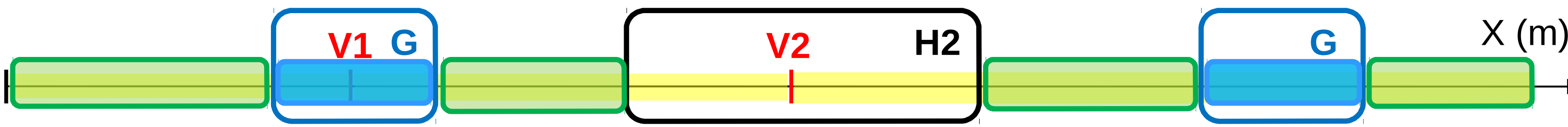
$A_k^{c_j}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
n_{alt_k}	21	9	3	2	1	2	9	21	21	7	2	1	2	21	21	9	21
$V_{max}(m/s)$																	

- Vmax(robot) = 0.46 m/s

Safety Viewpoint







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n_{alt_i}	21			2	1	2	21				2	1	2	21			
Task T_k	FM / L			R L	VD	R L	FM / L				R L	VD	R L	FM / L			
$A_k^{c_j}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
n_{alt_k}	21	9	3	2	1	2	9	21	21	7	2	1	2	21	21	9	21
$V_{max}(m/s)$																	

Alternatives = 21 007 896 742 224

Alternative ?
Energy

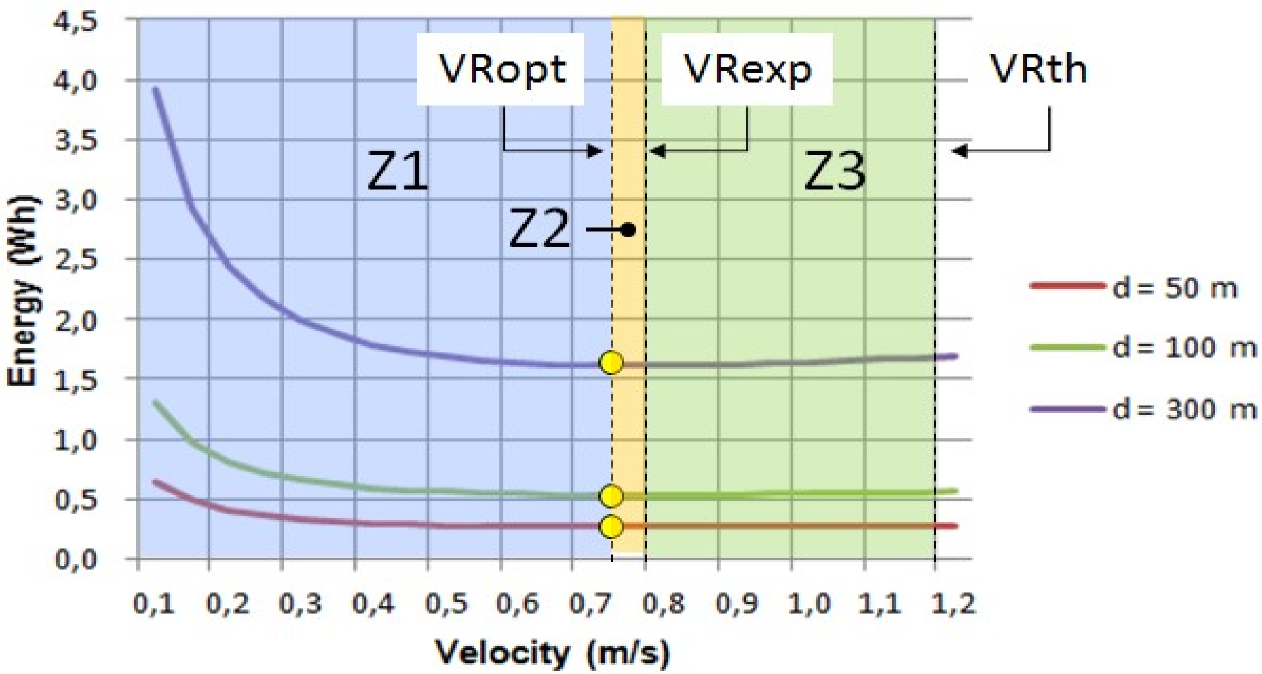
Energy Viewpoint

- Speed and sensors => Energetic cost

Energy Viewpoint

- Speed

$$E_{R_{Motion}}(d, v) = 6.25\ d\ v\ +\ 9.79\ d + \ 3.66\ d/v$$



Energy Viewpoint

- Control schemes – sensors and power consumption
  - Robot battery

$$P_R(CS) = \alpha_1 P_{R_{Motion}}(v) + \alpha_2 P_{R_{US}}(f) + \beta_1 P_{R_{KINECT}} + k_2 \beta_2 P_{R_{LASER}}$$

  - Laptop battery

$$P_L(CS,EC) = P_{L_{Proc}}(CS,EC) + P_{L_{Robot}} + P_{L_{Watt}} + \beta_1 P_{L_{Screen}} + \beta_2 P_{L_{Kinect}} + k_1 \beta_3 P_{L_{Laser}} + \beta_4 P_{L_{Switch1}}(k_2) + \beta_5 P_{L_{Switch2}}(k_3)$$

  - Global hardware identification

	US	LAS	KIN	DC Motion (0.5 m/s)	**Ptotale = P Rob + P Lap (W)**	**%P Rob**	**% P Lap**
FM	1	2	1	1	34,68	50,92	49,08
	0	2	1	1	34,58	50,95	49,05
	1	1	1	1	31,63	48,43	51,57
	0	1	1	1	31,53	48,46	51,54
	1	2	0	1	28,55	51,97	48,03
	0	2	0	1	28,45	52,02	47,98
	1	0	1	1	28,02	46,32	53,68
	0	0	1	1	27,92	46,34	53,66
	1	1	0	1	24,83	50,33	49,67
	0	1	0	1	24,65	50,54	49,46
	1	0	0	1	22,33	45,49	54,51
	0	0	0	1	21,83	46,35	53,65

Energy Viewpoint

x_i - x_{i-1} (m)	0 - 34			37	37	37	37 - 93.5				93.5	93.5	93.5	93.5 - 187			
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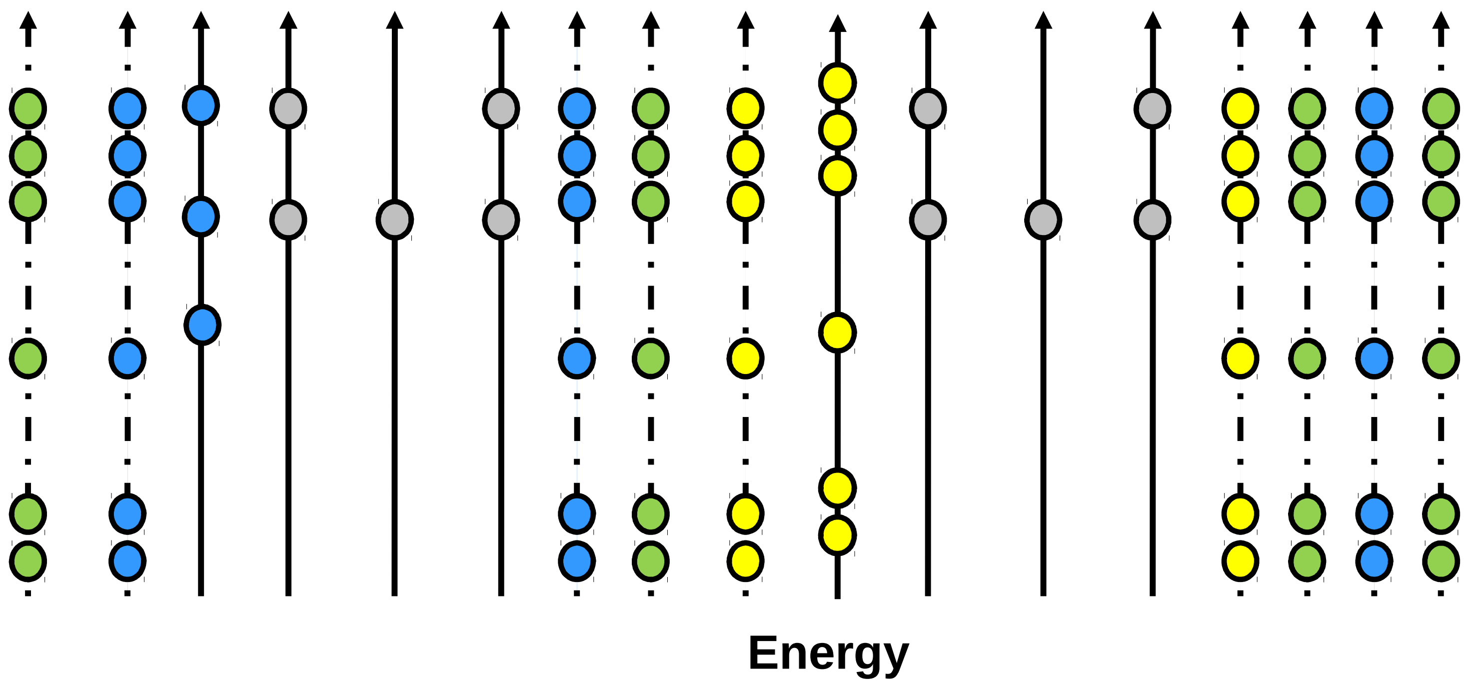
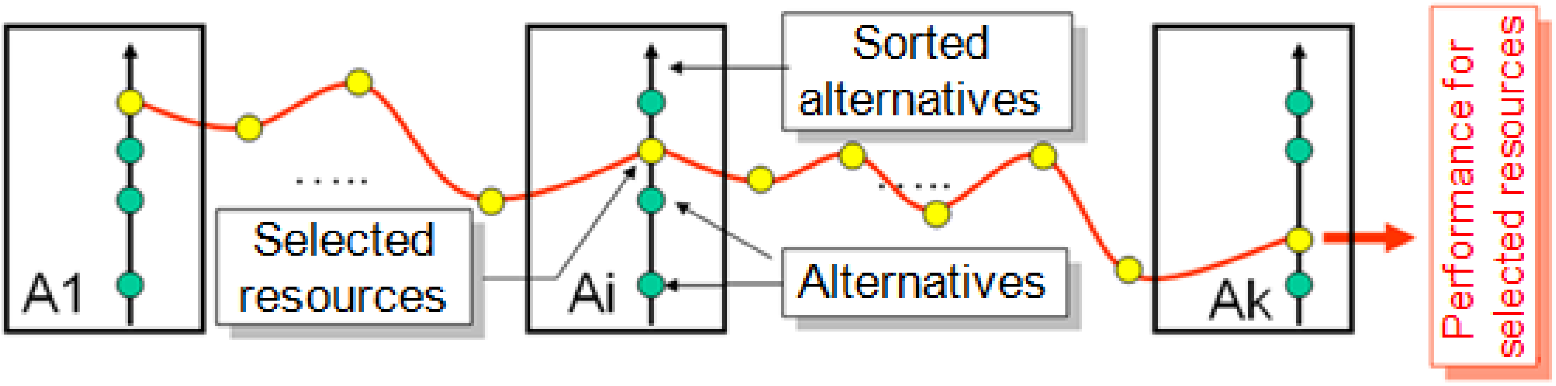
Task T_k	FM / L			R L	VD	R L	FM / L				R L	VD	R L	FM / L			
$A_k^{c_j}$	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
n_{alt_k}	21	9	3	2	1	2	9	21	21	7	2	1	2	21	21	9	21
$V_{max}(m/s)$																	



Allocation Algorithm

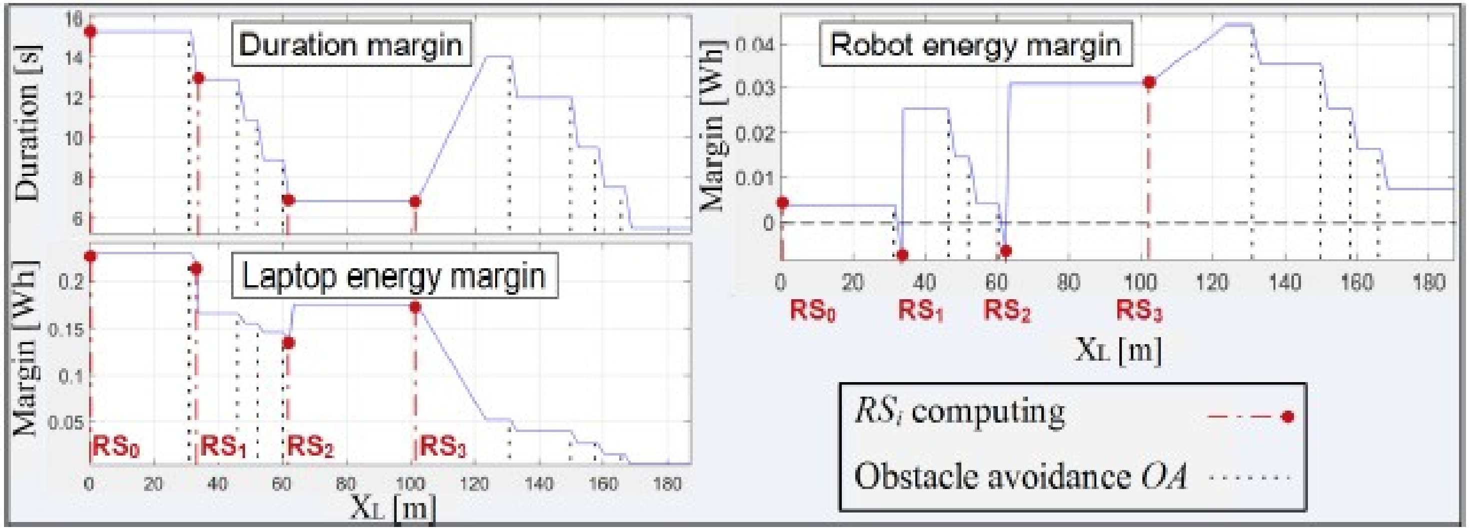
How locally choose and configure the alternatives to use to globally satisfy performance objectives ?

- Multi-criteria Knapsack problem
  - NP-Hard
- Algorithm
  - Linear complexity
  - Good solution with few iterations => Real time



Simulation Results

- Mission Run



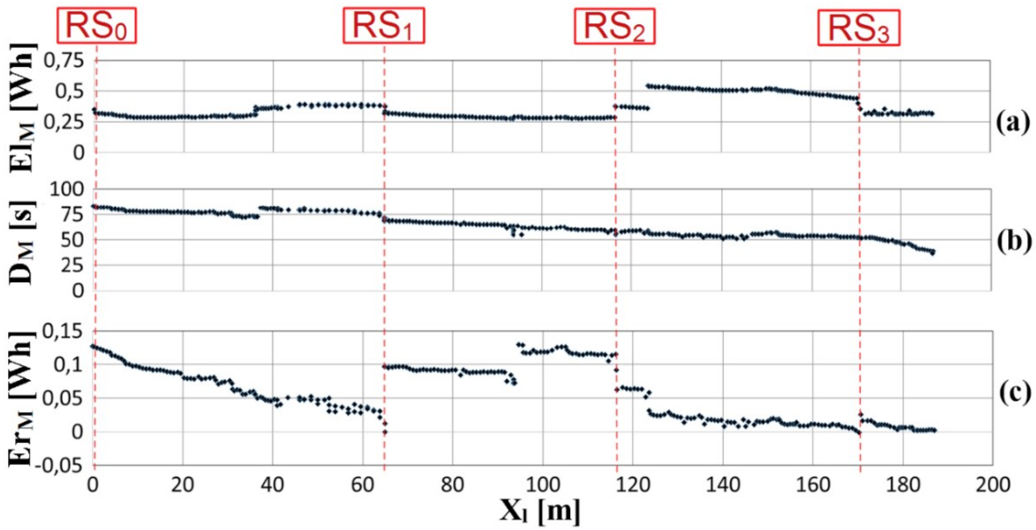
- Resources Allocation

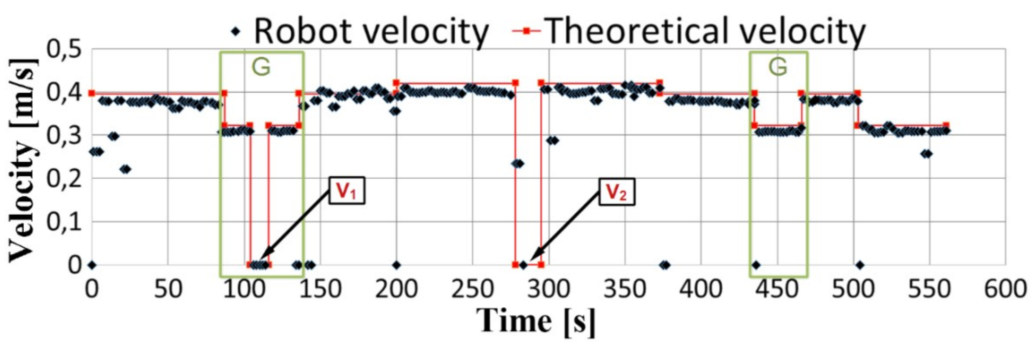
A_k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	$GAI \geq$	IT
RS_0	1	1	1	2	3	2	1	1	1	1	2	3	2	1	1	1	4	$2 \cdot 10^{13}$	724
RS_1		1	1	2	3	2	1	1	1	1	2	3	2	1	1	1	**5**	$1 \cdot 10^{12}$	651
RS_2								1	1	1	2	3	2	1	1	1	**6**	$1 \cdot 10^{9}$	499
RS_3														**7**	**7**	**7**	**7**	$1 \cdot 10^{4}$	187

(1): SMZ-2LAS-US/KIN, (2): OPR/KIN, (3): VALVE ANALYSIS, (4): SMZ-2LAS/KIN, (5): SMZ-US/KIN, (6): SMZ-US/NONE, (7): CENTERING-2LAS-US/GOL

Experimental Results

- Mission Run





- Resources Allocation

A_k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
RS_0	1	1	1	2	3	2	1	1	1	1	2	3	2	1	1	1	4
RS_1								1	1	1	2	3	2	1	1	1	**5**
RS_2														6	6	7	**6**
RS_3																	**7**

AI = {(1): SMZ-2LAS-US/KIN, (2): OPR/KIN, (3): VALVE ANALYSIS, (4): SMZ-1LAS/KIN, (5): PF/KIN, (6): SMZ-1LAS/KIN, (7): SMZ-US/KIN, etc.}

- Mission

Conclusion and Future Works

- Performance for complex long term missions
- Duration, Safety and Energy viewpoints
- Huge combinatorial complexity

- Methodology for resources management (3 axes)
  - Energy management for robot and laptop
- Real time management
  - Fault tolerance (dynamism, hard and soft faults)

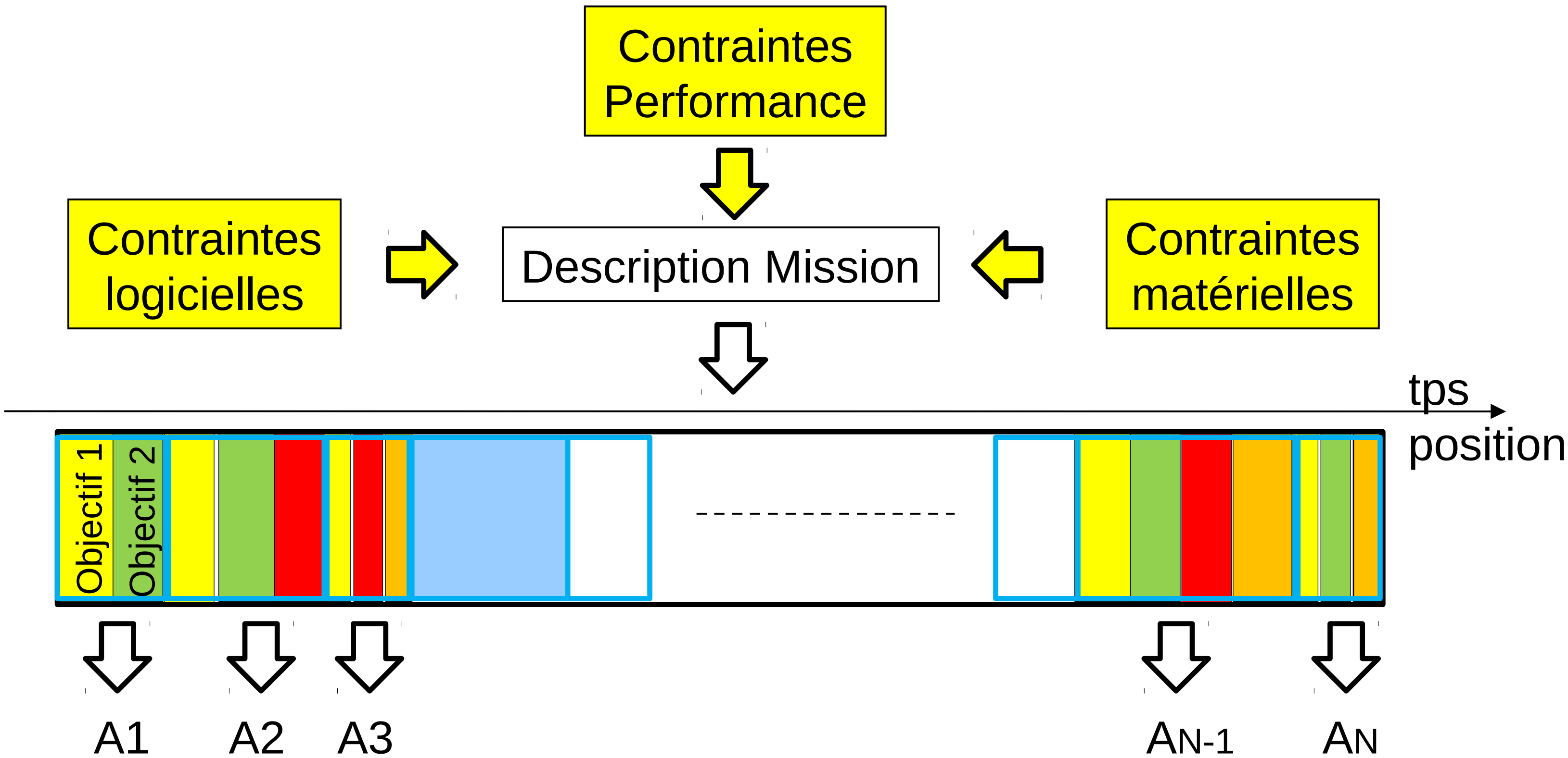
- Future works
  - Localization and stability viewpoints
  - Terrestrial and underwater exploration missions

Patrolling Mission

Pioneer 3DX

Gestion de la Performance

Complexité du Problème

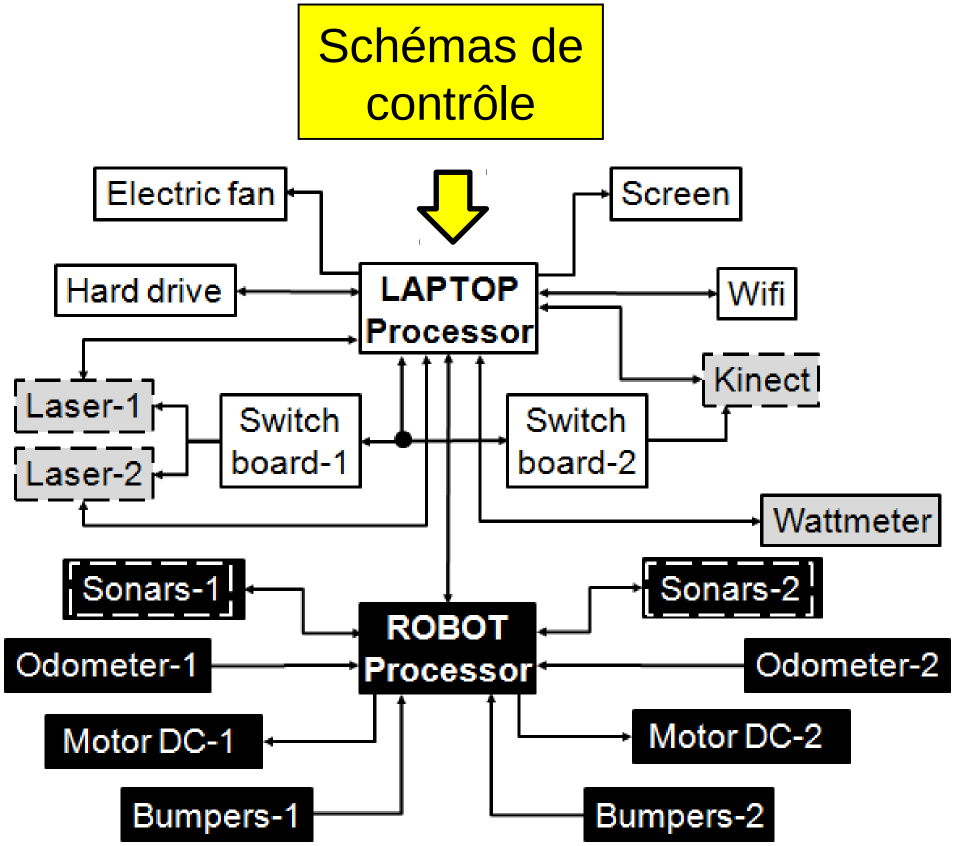


Nbre Total d'Alternatives = $\prod_{i=1}^{N} A_i$

Comment choisir et configurer les alternatives à utiliser de façon à satisfaire les objectifs de performance imposés ?

Modèle Energétique

Problématique



Quelle est la puissance (Energie) consommée au niveau des batteries robot et laptop par chacun des schémas de contrôle envisageable (Algo., capteurs(param.), actionneurs(param)) ?