

Online Adaptation of Autonomous Robots

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Context



Robotics

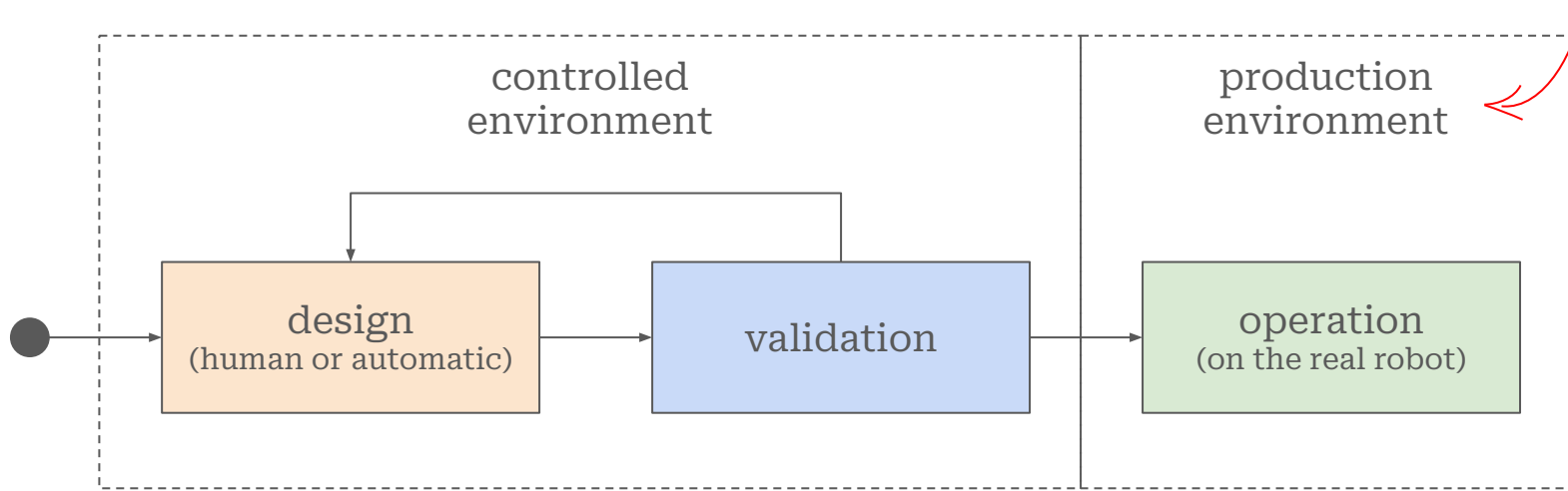
“ *design, construction, and use of machines (robots) to perform tasks done traditionally by human beings.* ”

Encyclopedia Britannica | Britannica

Context – Design of Control System



immutable and known a priori



Context – Design of Control System



Advantages:

- trustable resulting behavior
- predictable performance
- reduced risk of operational damages

Disadvantages:

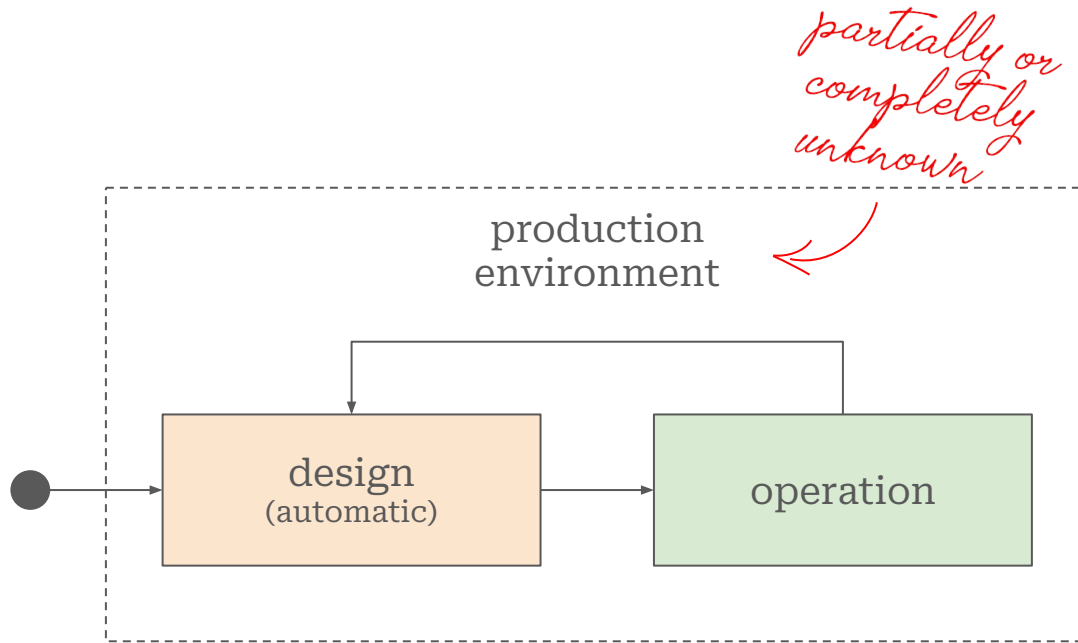
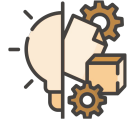
- demanding human work
- operational context must be known or predictable beforehand
- vulnerable to context changes

Goals



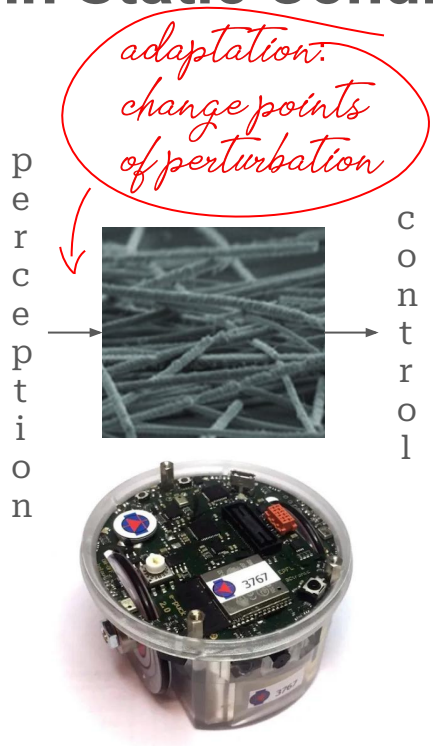
- improve the resilience of robots to changes in:
 - external conditions
 - internal conditions
- permit robot operation in unknown conditions

Proposed Approach





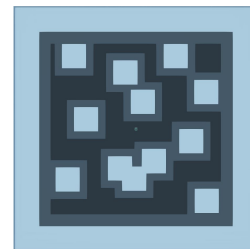
Efficacy in Static Conditions



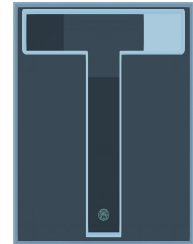
collision avoidance



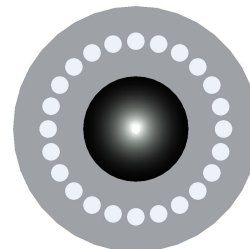
illegal areas avoidance



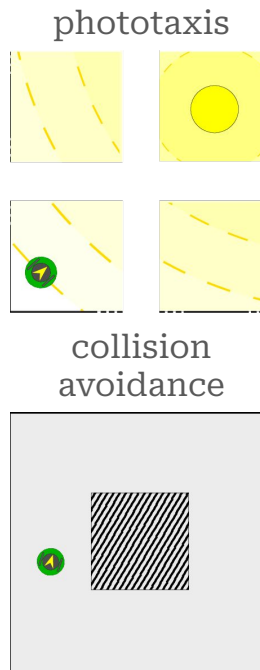
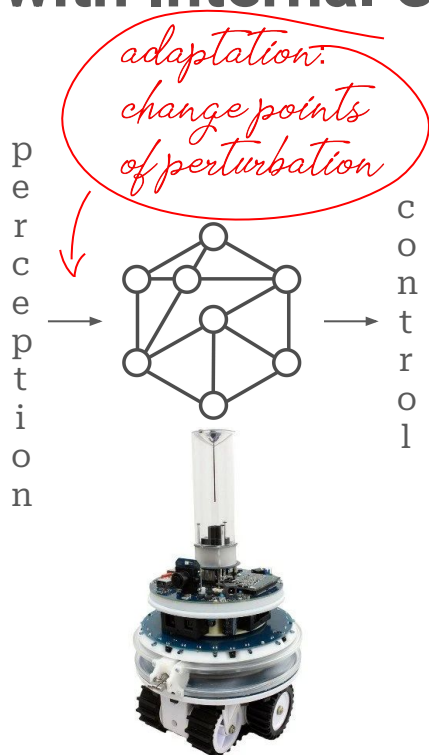
maze navigation



foraging



Efficacy with Internal Changes



Efficacy with Internal Changes

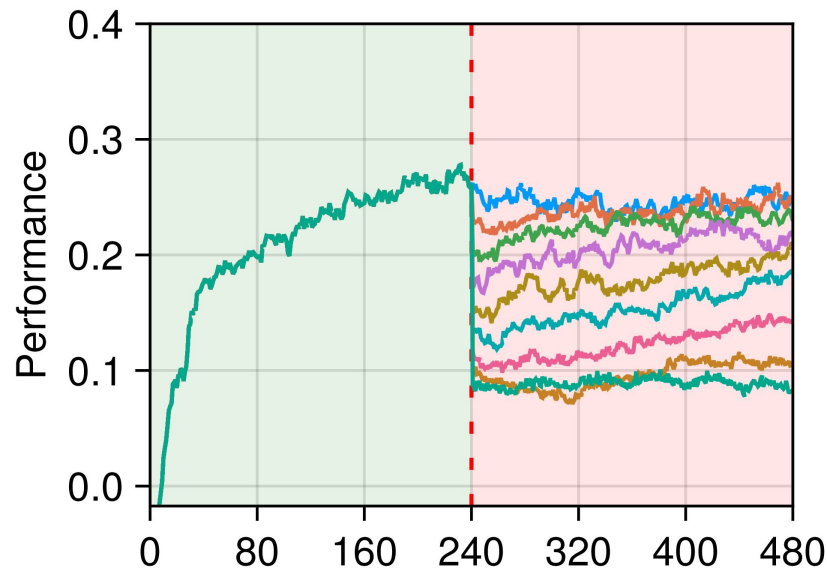


Results:

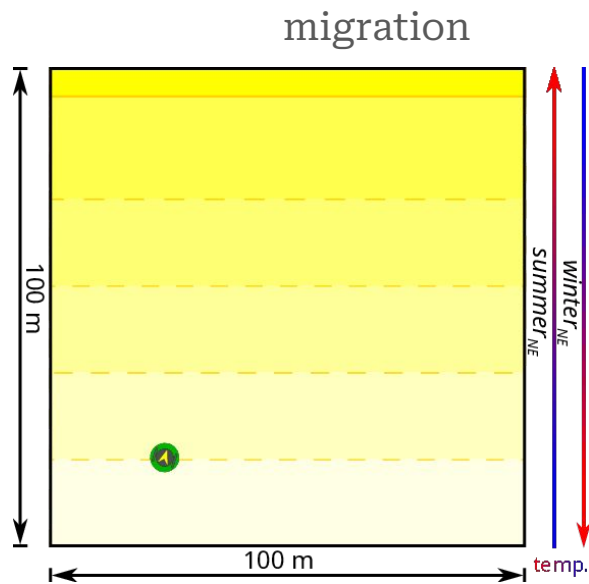
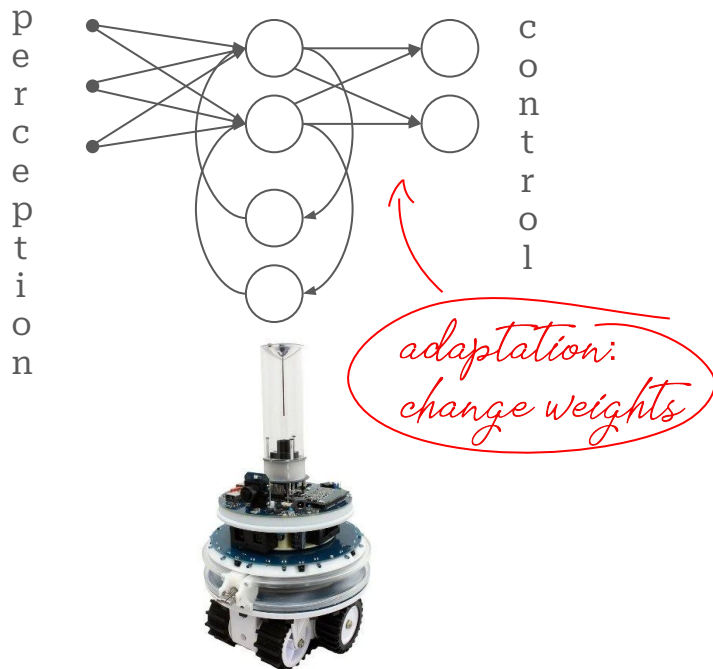
- performance degrades gracefully
- performance recovery after faults
- recovering is faster than learning anew
- recovering requires identifying changes in the performance

Impacts:

- enhanced robot resilience
- enhanced robot autonomy



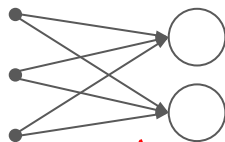
Efficacy with External Changes



Efficacy in Co-Adaptation



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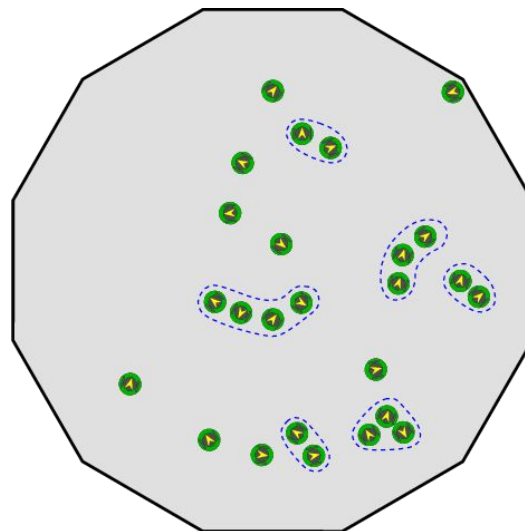


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*adaptation:
change weights*

aggregation and isolation

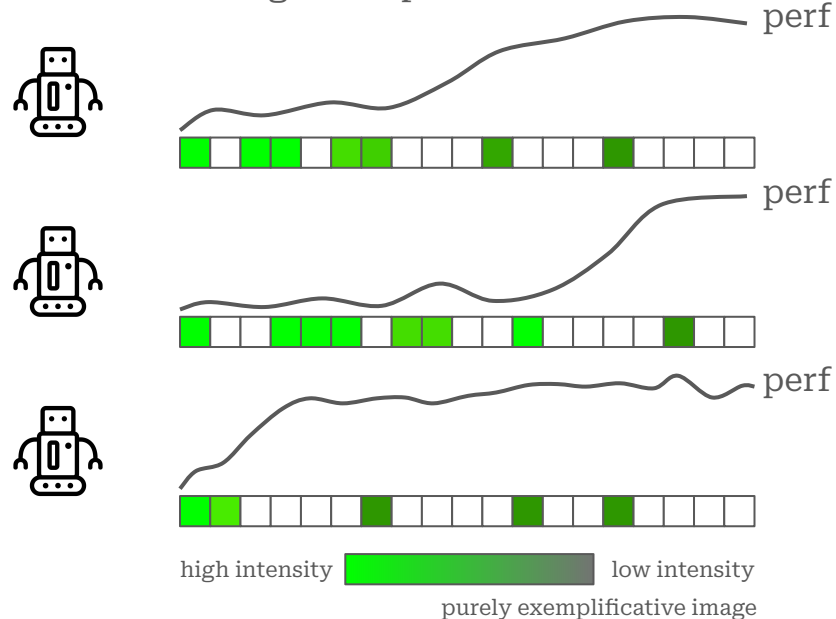


Efficacy in Co-Adaptation



- asynchronous adaptation
- probability to adapt depending on the performance
- intensity of the adaptation depending on the performance
- continuous depreciation of the best self-evaluation

adaptation frequency and intensity according to the performance



Efficacy in Co-Adaptation

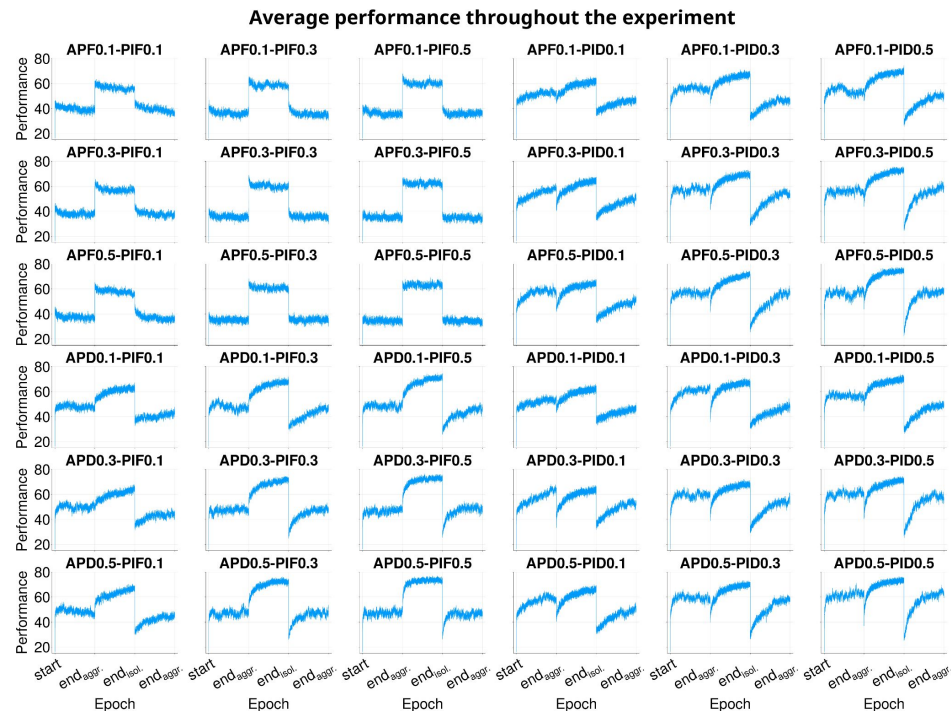


Results:

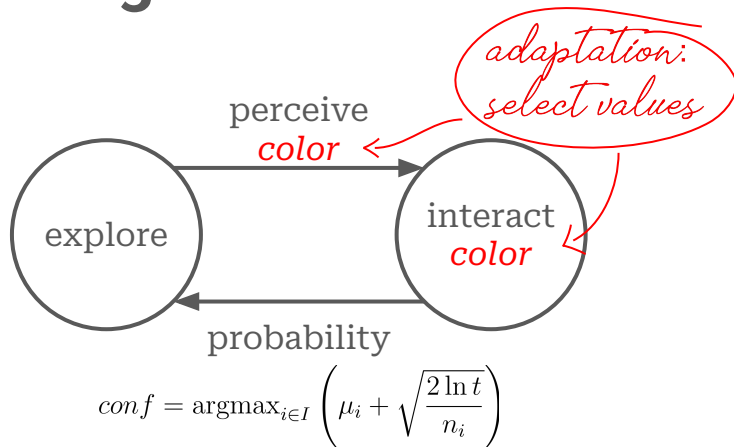
- emergence of a collective behavior from localized, individual learning
- identification of factors enabling co-adaptation

Impacts:

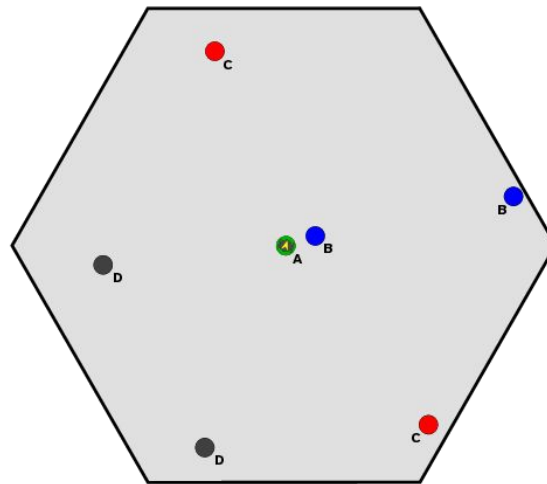
- enhancement of adaptation process



Combining with Automatic Offline Design



$$conf = \operatorname{argmax}_{i \in I} \left(\mu_i + \sqrt{\frac{2 \ln t}{n_i}} \right)$$



Combining with Automatic Offline Design

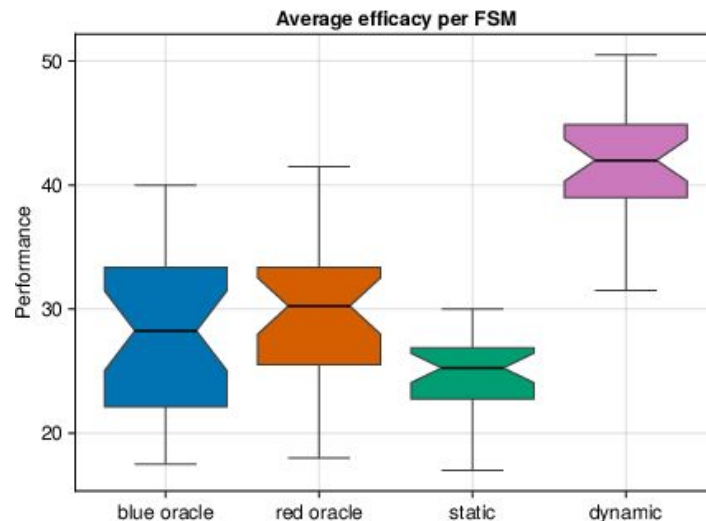


Results:

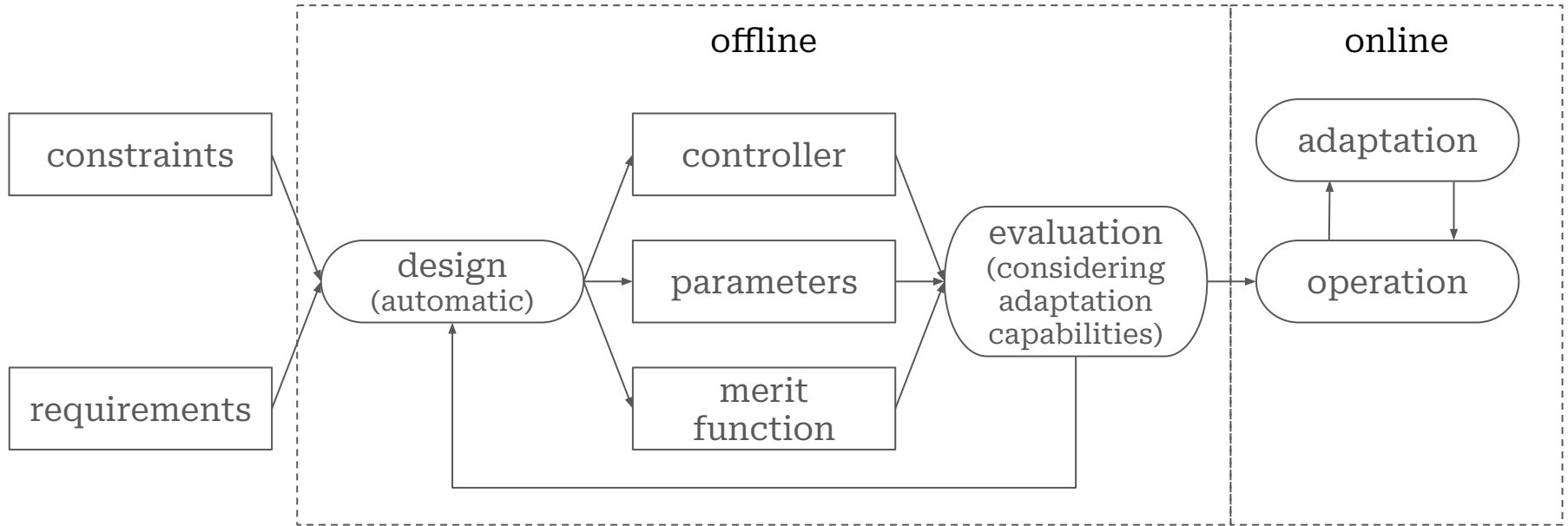
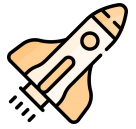
- increased flexibility
- increased reliability

Impact:

- enhance efficacy in partially known conditions
- speed up adaptation



Pipeline of Future Robot Development



Contributions



- identified factors enabling adaptation:
 - possibility to rollback
 - continuous re-evaluation
 - reliable self-evaluation
 - modulated adaptation
- identified difficulties of adaptation:
 - “*situational*” evaluation
 - duration of evaluation phase
- proposed and validated adaptation mechanisms
- improved robot:
 - autonomy
 - resilience
 - effectiveness
- bonus: investigated use of novel, unconventional control systems