

Fault Tolerant Morphogenesis

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Remaining Deliverables

D3.8 - Integrated Artificial Immune System for Homeostatic Operation M48

(UNİYORK)

D5.15 - Final integrated report on fault-tolerant, homeostatic swarms, self-assembling and autonomous morphogenesis M48

(UWE, UNİYORK, INRIA, UNIGRAZ, USTUTT)

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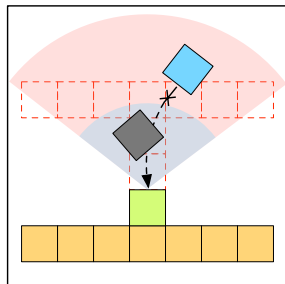
D3.8 - Integrated Artificial Immune System for Homeostatic Operation M48
(UNİYORK)

D5.15 - Final integrated report on fault-tolerant, homeostatic swarms, self-assembling and autonomous morphogenesis M48
(UWE, UNİYORK, INRIA, UNIGRAZ, USTUTT)

Task 4.5 - *Towards a self-healing, homeostatic swarm (UNİYORK)*

Task 4.6.3 - *Fault-tolerant autonomous morphogenesis (UWE)*

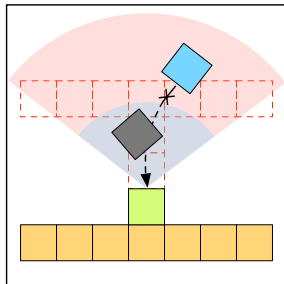
1. Analysing the reliability of UWE's morphogenesis controller
2. Investigating the effects of specific failures in simulation
3. Using the findings to design an improved, fault tolerant controller



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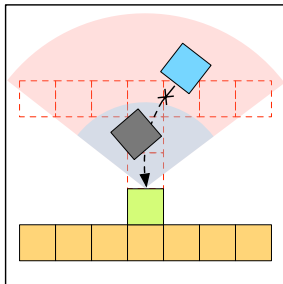


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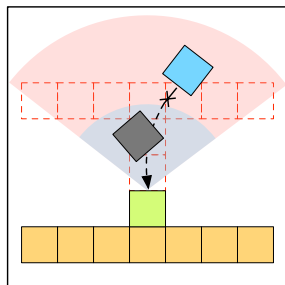
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Reliability Analysis

Failure Mode and Effect Analysis (FMEA)

- ▶ Inductive approach to reliability analysis
- ▶ For every component in the system, identify specific **hazards**
- ▶ Identify the **effects** that these hazards have on the system

Fault Tree Analysis (FTA)

- ▶ Deductive approach to reliability analysis
- ▶ Given a general event of interest (**effect**)
- ▶ Identify the specific causes (**hazards**) of the event
- ▶ And the logical sequence of secondary events leading up to it

Failure Mode and Effect Analysis

- ▶ Seven hazards identified
- ▶ Three components of the morphogenesis controller:
 - ▶ Exploration (EXP)
 - ▶ Self-assembly (ASM)
 - ▶ Self-disassembly (DIS)
- ▶ Two recruitment strategies:
 - ▶ Single-entry (SE)
 - ▶ Multiple-entries (ME)
- ▶ H_T and H_W identified as the most detrimental

Hazard	Description
H_M	Motor failure
H_R	IR remote receiver failure
H_S	IR sensor failure
H_L	IR LED failure
H_T	Total systems failure
H_D	Docking element failure
H_W	Wired communication failure

	H_M	H_R	H_S	H_L	H_T	H_D	H_W
EXP	e_1	e_1	e_1	-	e_1	-	-
ASM	E_1	e_2	E_1	E_1	E_1	-	E_1
DIS	E_2	-	E_2	-	E_2	E_2	E_2
SE	-	-	-	-	E_1	-	E_1
ME	-	-	-	-	E_1	-	-

e_1 - reduction in the number of capable robots

e_2 - delay in the assembly of an organism

E_1 - stall in the assembly of an organism

E_2 - stall in the disassembly of an organism

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SE	-	-	-	-	E_1	-	E_1
ME	-	-	-	-	E_1	-	-

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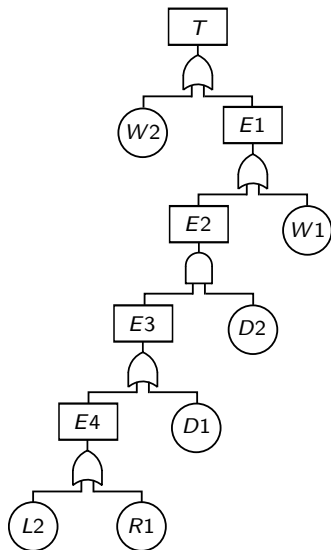
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Fault Tree Analysis

- ▶ Tree constructed to analyse (a subset of) the causes of a stall in the assembly of an organism
- ▶ Three two component combinations and two single component causes identified
- ▶ Weak point identified during the transfer of information between recruiting and docking robots
- ▶ Again, highlights the importance of reliable wired communications



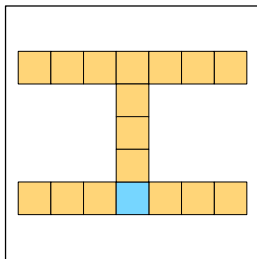
Analysing the Reliability of a Self-reconfigurable Modular Robotic System

- ▶ Analyse the morphogenesis controller using FMEA and FTA
- ▶ Compare FMEA and FTA as aids to the design of fault tolerant collective robotic systems
- ▶ Compare the recruitment strategies in terms of fault tolerance
- ▶ Based upon analysis, suggest improvements to the controller

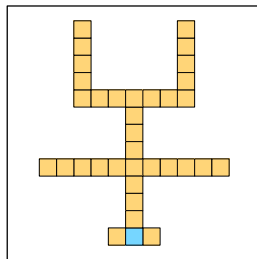
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Simulation Experiments

- ▶ When performing reliability analysis we did not consider:
 - ▶ External hazards - e.g. the effects of interference
 - ▶ Transient (or repairable) failures
- ▶ The effects of these hazards were investigated in simulation
- ▶ Two different organism shapes were investigated:



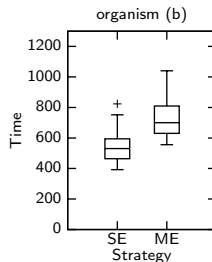
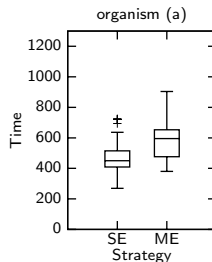
(a)



(b)

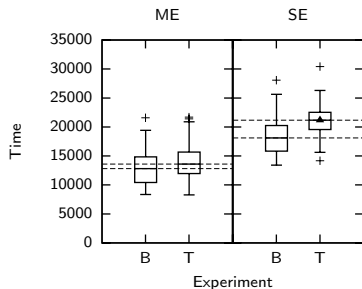
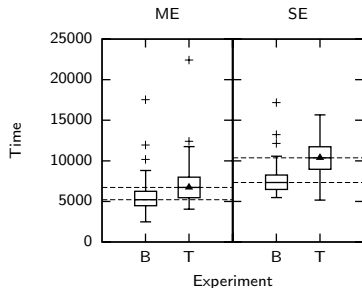
External hazards

- ▶ Hazard - interference around the recruiting sites
- ▶ The mean time to recruit a single module may be used as a measure of interference
- ▶ When employing the single entry strategy modules take less time to recruit
- ▶ Indicating that interference is less of an issue with the single entry strategy



Transient failures

- ▶ A total systems failure may be considered analogous to a robot running out of energy
- ▶ A robot that runs out of energy is a repairable hazard
- ▶ Time to completion was measured with (T) and without (B) failures
- ▶ Transient failures have less effect on systems utilising the multiple entries strategy



Future Work

D5.15 - Final integrated report on fault-tolerant, homeostatic swarms, self-assembling and autonomous morphogenesis M48

- ▶ Improving the fault tolerance of the morphogenesis controller (in collab. UWE) - based upon findings of analysis
- ▶ Particularly within the scope of energy management
- ▶ Extended analysis with view of journal publication
- ▶ Implementation of AIS algorithms using real data

D3.8 - Integrated Artificial Immune System for Homeostatic Operation M48

- ▶ Single architecture for integrated immune algorithms