

# A metabolic subsumption architecture for cooperative control of the e-puck

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# Background

**YCCSA:** York Centre for Complex Systems Analysis

**PLAZZMID:** Research into bacterial GA, incorporating HGT, regulation, transposons etc.

**TRANSIT:** Promotes Trans-disciplinary research - offers summer scholarships

## Summary

- We seek *community control* of the *individual robot*
- We use an *artificial chemistry* as the framework for this.
- Sensor data and Actuator rates are represented as *quantities* of very simple *agents*
- The signal pathway is controlled via a series of artificial *enzymes*
- These interact to form a *metabolic controller*
- We compare this with a *Subsumption architecture*
- Similar performance, plus metabolic controller is more amenable to *evolution*

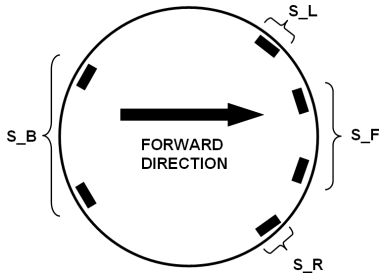
# E-Puck



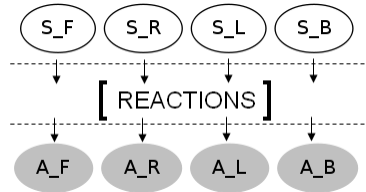
## E-puck boards:

- Micro-controllers handle the low-level control of actuators and sensors
- Top speed:  $0.1 \text{ ms}^{-1}$
- Sensor range:  $0.12 \text{ m}$
- Response in  $0.83 \text{ s}$ , or collision

# E-Puck metabolism

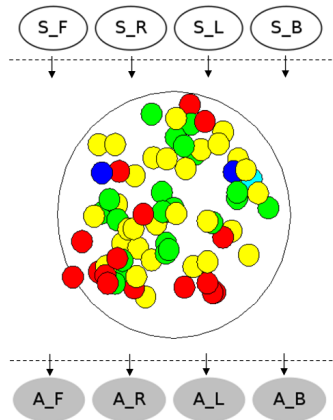
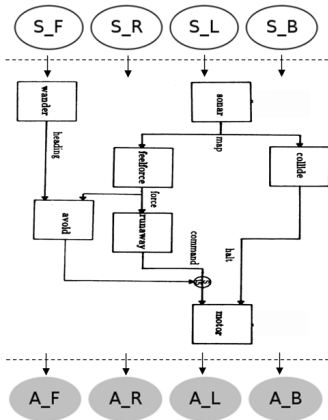


E-Puck sensor arrangement



The control task

# Conceptual comparison



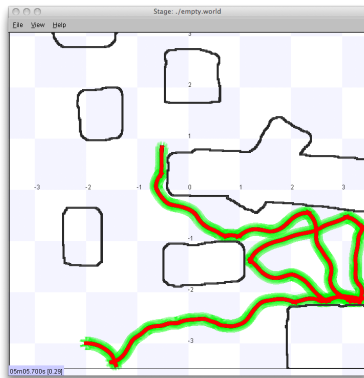
# Player-Stage

## Player:

- Network server for robot control
- Provides a clean and “simple” interface to the robot’s sensors and actuators

## Stage:

- Stage simulates mobile robots, sensors and objects in a 2D environment.

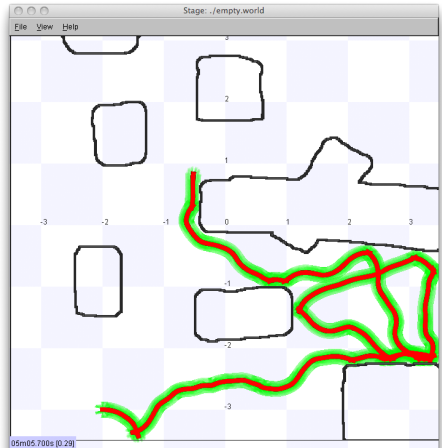


# The Subsumption Architecture

- This is our experimental ‘control’
- A simple 2-layer architecture:
  - AVOID behaviour: lowest level. Collision avoidance.
  - WANDER behaviour: 2nd level. Allows the robot to explore.
- AVOID can override WANDER if collision is imminent

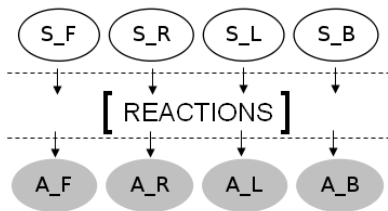
# Subsumption Architecture

- Player-stage simulation,  
red = robot  
green = sensor range
- No collisions

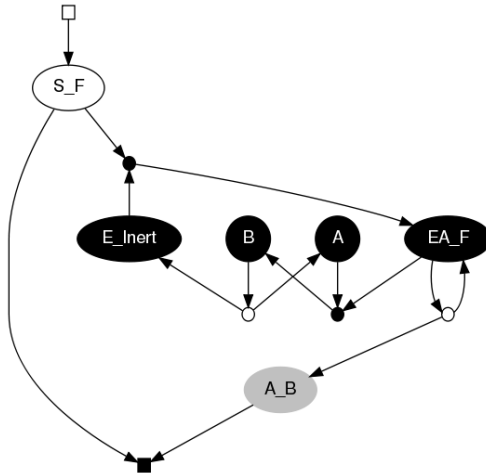


## Components of The Metabolic Circuit

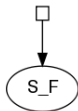
Reaction	Rule format	network symbol
<b>Influx:</b>	$\emptyset \rightarrow A$	◻
<b>Binding:</b>	$A + B \rightarrow C$	●
<b>Dissociation:</b>	$A \rightarrow B + C$	○
<b>Decay:</b>	$A \rightarrow \emptyset$	■



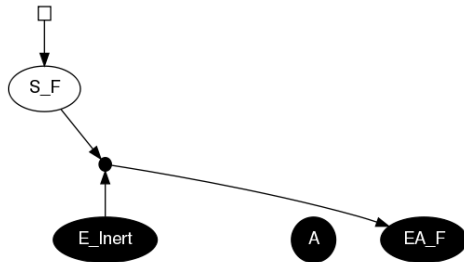
# Metabolic AVOID for 1 sensor



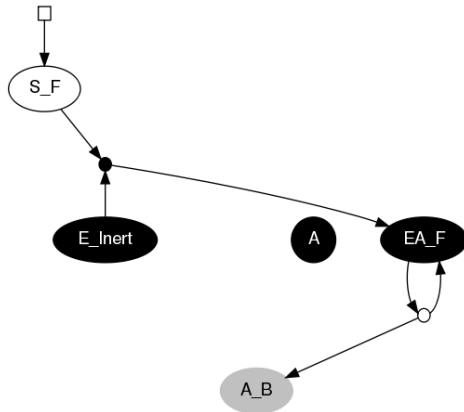
## Metabolic AVOID for 1 sensor



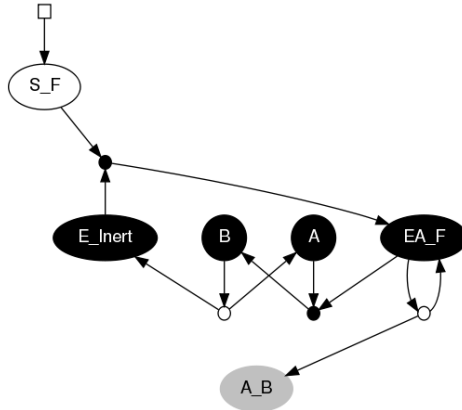
## Metabolic AVOID for 1 sensor



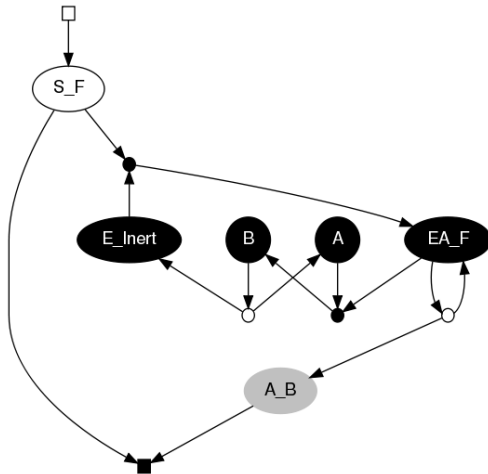
# Metabolic AVOID for 1 sensor



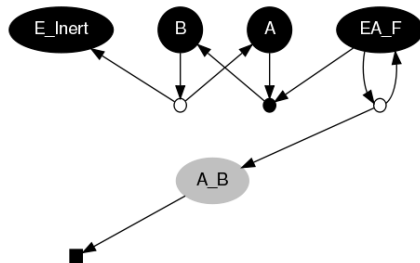
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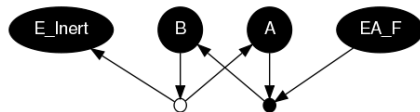
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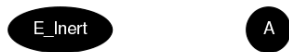
# Metabolic AVOID for 1 sensor



## Metabolic AVOID for 1 sensor

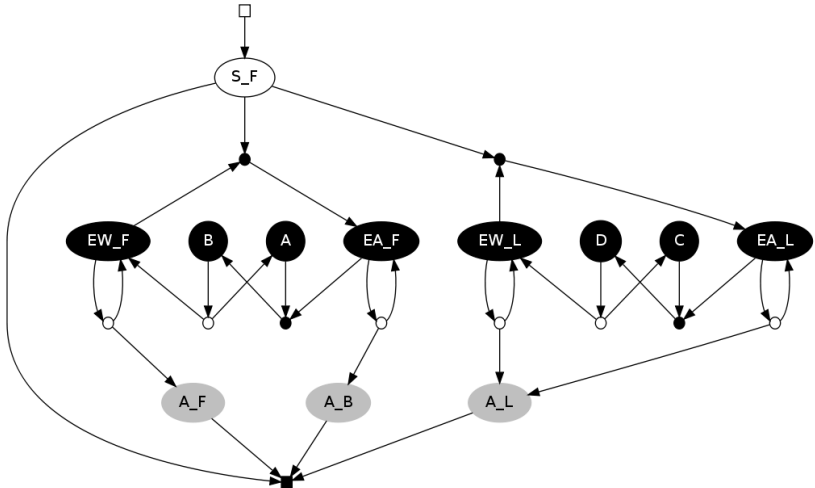


# Metabolic AVOID for 1 sensor

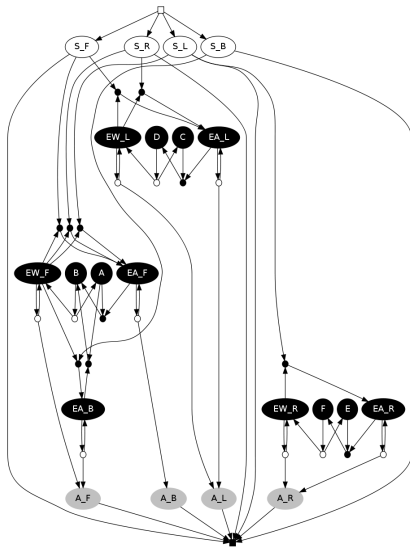


# Metabolic AVOID for 1 sensor

# Metabolic WANDER and AVOID for 1 sensor



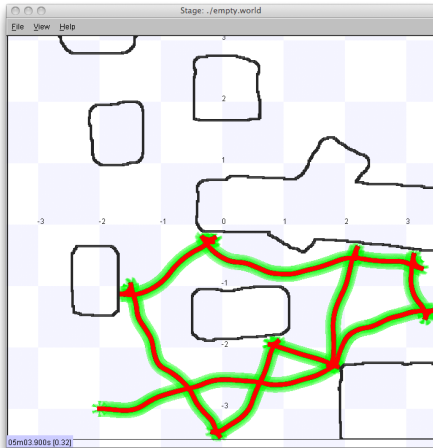
# Complete Metabolic Network



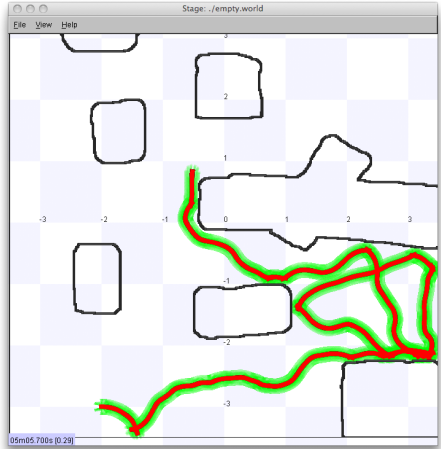
# Metabolic rates

Reaction	Rate	Reaction	Rate
<i>Actuator signals for WANDER</i>		<i>Actuator signals for AVOID</i>	
$EW.F \rightarrow EW.F + A.F$	0.8	$EA.F \rightarrow EA.F + A.B$	0.9
$EW.L \rightarrow EW.L + A.L$	0.16	$EA.B \rightarrow EA.B + A.F$	0.9
$EW.R \rightarrow EW.R + A.R$	0.16	$EA.L \rightarrow EA.L + A.L$	0.9
		$EA.R \rightarrow EA.R + A.R$	0.9
<i>Switch to AVOID behaviour</i>		<i>Reversion to WANDER</i>	
$EW.F + S.F \rightarrow EA.F$	0.9	$EA.F + A \rightarrow B$	0.1
$EW.L + S.F \rightarrow EA.L$	0.9	$EA.B + A \rightarrow B$	0.1
		$B \rightarrow A + EW.F$	0.1
$EW.F + S.R \rightarrow EA.F$	0.7	$EA.L + C \rightarrow D$	0.1
$EW.R + S.R \rightarrow EA.R$	0.7	$D \rightarrow C + EW.L$	0.1
$EW.F + S.L \rightarrow EA.F$	0.7	$EA.R + E \rightarrow F$	0.1
$EW.L + S.L \rightarrow EA.L$	0.7	$F \rightarrow E + EW.R$	0.1
$EW.F + S.B \rightarrow EA.B$	0.1		
<i>Decay of actuators</i>		<i>Decay of sensors</i>	
$A.F \rightarrow \emptyset$	0.15	$S.F \rightarrow \emptyset$	1
$A.B \rightarrow \emptyset$	0.05	$S.B \rightarrow \emptyset$	1
$A.L \rightarrow \emptyset$	0.1 2	$S.L \rightarrow \emptyset$	1
$A.R \rightarrow \emptyset$	0.1 2	$S.R \rightarrow \emptyset$	1

## Player-stage simulations



metabolic



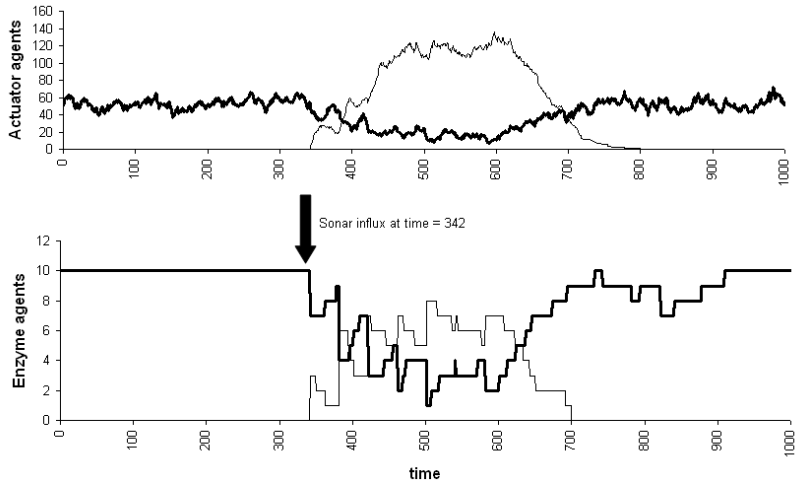
subsumption

## Speeds & Collisions

	Subsumption			metabolic
Max speed (preset)	0.3	0.15	0.15	0.15
Average speed (recorded)	0.15	0.15	0.075	0.075
Median area covered for 5 runs of duration 5 minutes	6,264	6,491	3,460	3,574
collisions out of 50 wall encounters	<b>11</b>	<b>4</b>	<b>0</b>	<b>4</b>

**Table:** Area (in pixels) covered by the control systems and collisions for 50 wall encounters.

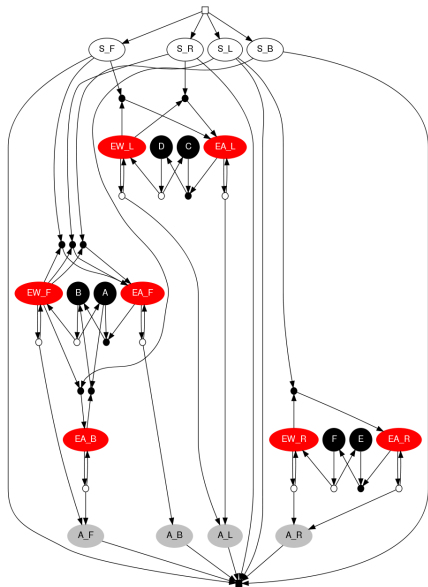
# Metabolic subsumption



## Further work

- Further hand-tuning of the metabolic network
- Principles of metabolic circuit design
- Run on a *real* e-puck
- Implementation in an *evolvable* chemistry

# Evolvable metabolites:



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