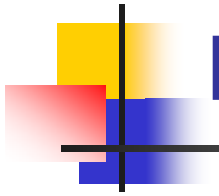
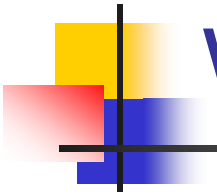


Biologically Inspired Hardware System

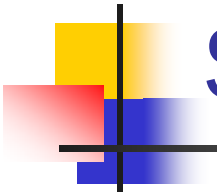
- What is Bio-Inspired System?
- Why do we need Bio-Inspired System?
- How to implement Bio-Inspired System in the electronic system?



What is Bio-Inspired System?

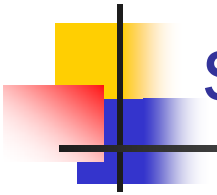
- It is a kind of artificial systems which uses the basic principles developed by nature.
- Bio-Inspired hardware system relates the natural principles with the capabilities of electronic system.

Why do we need Bio-Inspired System?

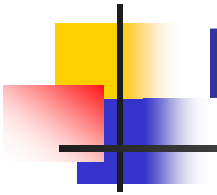


- Electronic systems are increasingly used in safety critical system.
- A safety critical system demands the electronic system have a very low failure rate and fault tolerance.
- Bio-Inspired systems have inherent fault tolerance due to their adaptive native.

How to implement Bio-Inspired system in the electronic system?



- Reconfigurable Hardware, such as FPGAs, make it possible to implement Bio-Inspired system in the electronic system.

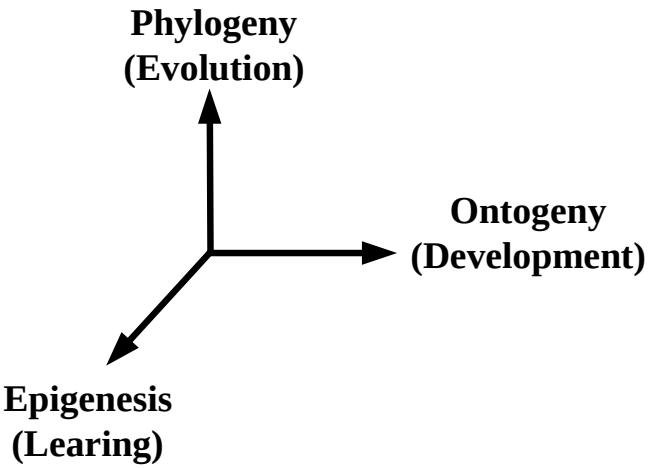


Bio-Inspired Hardware System

- The POE Model
- Embryonics
- Immunotronics
  - Immuno-Embryonics

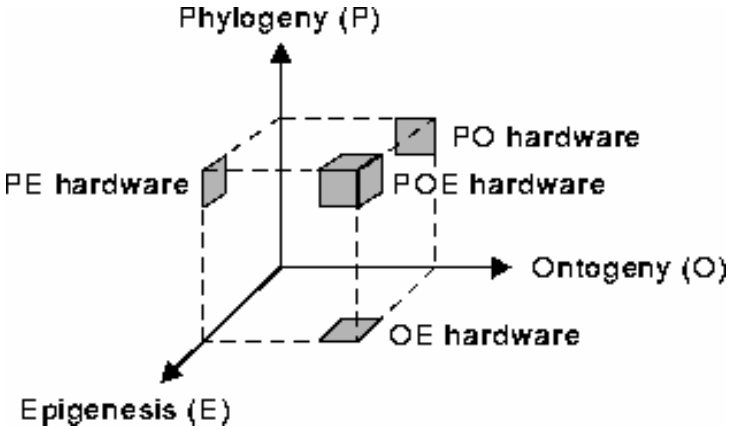
The POE Model (1)

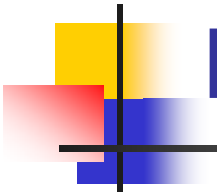
- There are three methods of life progression on earth have been identified:
  - Phylogeny (P)
  - Ontogeny (O)
  - Epigenesis (E)



The POE Model (2)

- The space of Bio-Inspired systems were plotted along three axes: Phylogeny (P), Ontogeny (O), and Epigenesis.





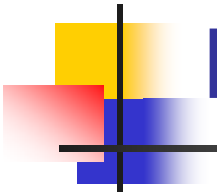
Embryonics: (1)

- Embryonics is inspired by the embryonic development of living beings. (embryological electronics)

- Embryonics attempts to use the features of nature to develop a new family of multi-cellular FPGAs that will show the properties of self-repair and self-healing.

Embryonics: (2)

- There are two group researchers who are currently developing the embryonics system:
  - Swiss Federal Institute of Technology;
  - University of York.



Embryonics: (3)

- The four layers of the Embryonics project undertaken by the Swiss Federal Instite of Techonology.
  - Population level;
  - Organismic level;
  - Cellular level;
  - Molecular level.

Embryonics: (4)

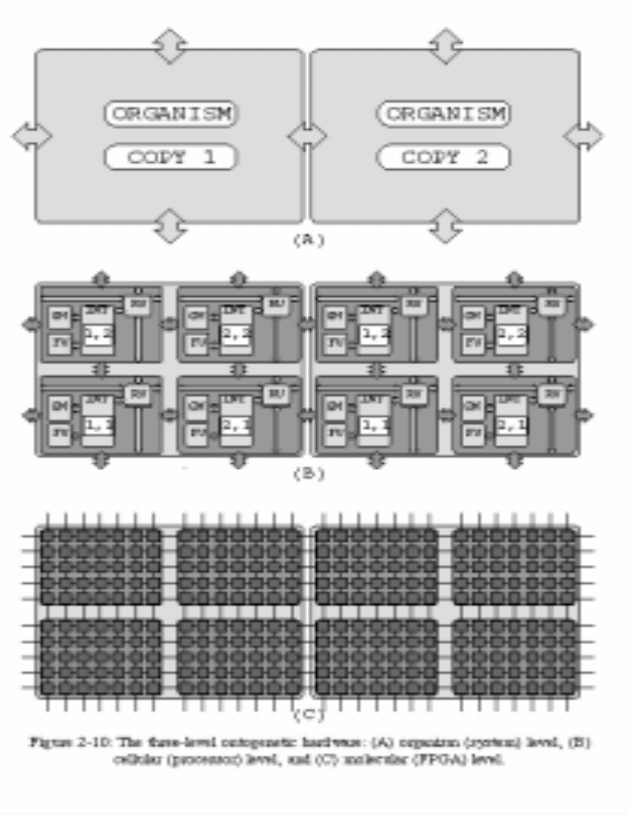
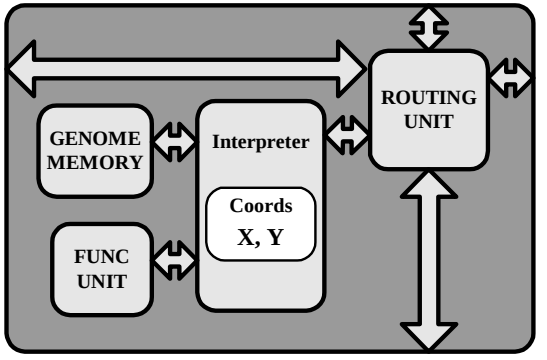


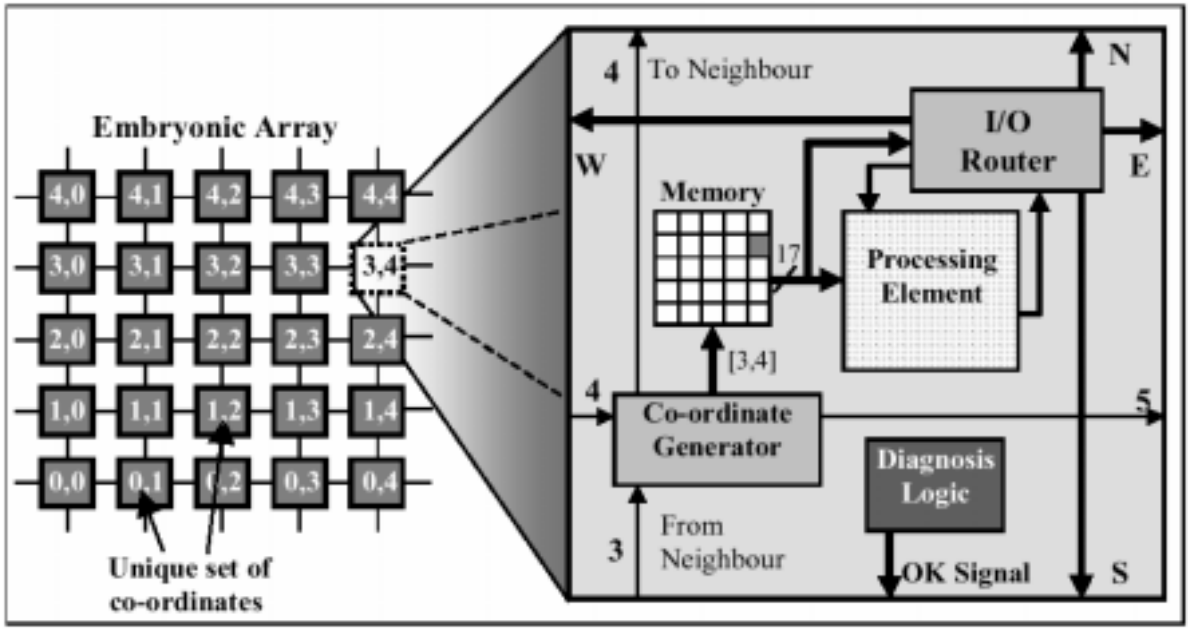
Figure 2-10: The three-level ontogenetic hardware: (A) organism (system) level, (B) cellular (processor) level, and (C) molecular (FPGA) level.

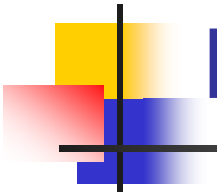


Embryonics: (5)

- The two layers of the Embryonics project undertaken by University of York:
  - Organismic level;
  - Cellular level.

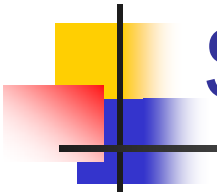
Embryonics: (6)





Embryonics: (7)

- Embryonics system can achieve the three fundamental features
  - Multi-cellular organisation;
  - Cellular division;
  - Cellular differentiation.

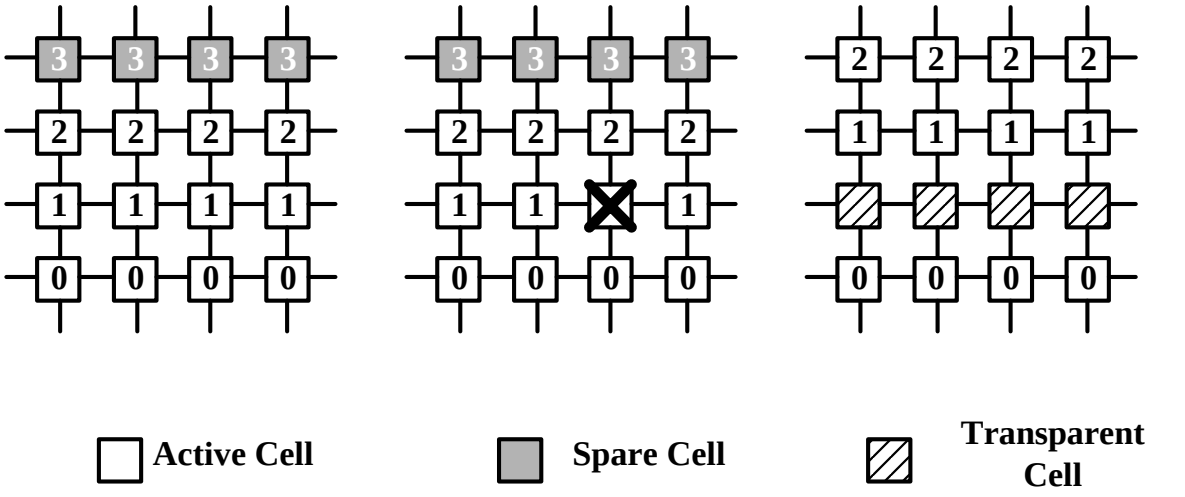


Self-repair:

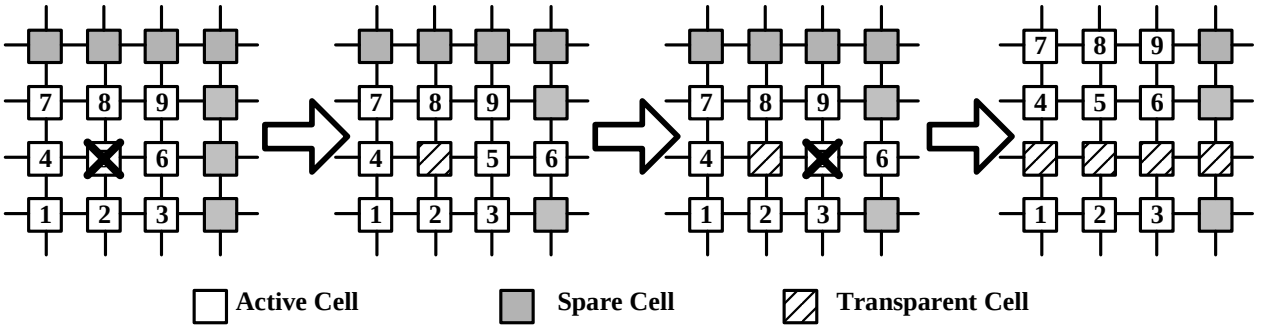
- Embryonics system can realize the function of self-repair on the intra-cellular level with reconfiguration.

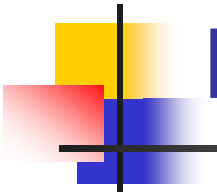
- Reconfiguration strategies:
  - Row-elimination
  - Cell/Molecule-elimination

Row-elimination



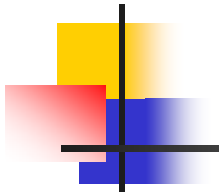
Cell-elimination





Human Immune System

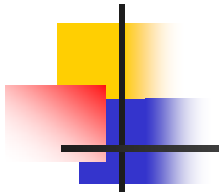
- The human immune system can recognise and attack any foreign cell or molecule:
  - It has independent network in the body;
  - It is distributed all the body;
  - It can learn and remember from past experiences what it should attack.



Immunotronics (1)

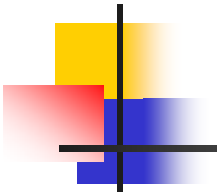
- Immuntronics (immunological electronics) is a new area of bio-inspired hardware system.

- It uses immune system to detect and correct the faults in electronic hareware.



Immunotronics (2)

- How to distinguish between self and non-self status of cells?
  - In electronic system, the invading organisms can be considered as fault;
  - The self status is the normal operation;
  - The non-self status is the error operation or fault.



Immunotronics (3)

- The steps of Immunotronics:
  - Data Gathering
  - Tolerance condition generation
  - Fault monitoring
  - Recovery

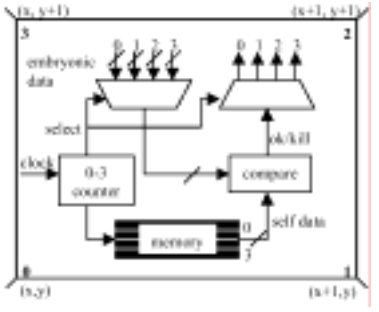
Immuno-Embryonics (1)

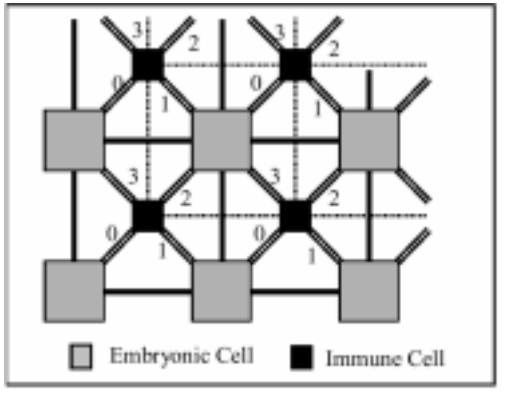
- Immuno-Embryonics assembles the principles and ideas conceived in Immunotronics and Embryonics.

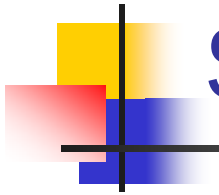
- It uses antibody to detect the fault of embryonics cells.

Immuno-Embryonics (2)

- Architecture of Immuno-Embryonics:
  - Use antibody cell to detect the embryonics cell.







Summary

- Bio-Inspire hardware system can be classified with POE model.
- There are two models implemented in electronic system:
  - Embryonics
  - Immuno-Embryonics

Future Work

- Further study of digital system
- Architecture design of novel electronic ‘cell’
- Design a multi-cellular architecture