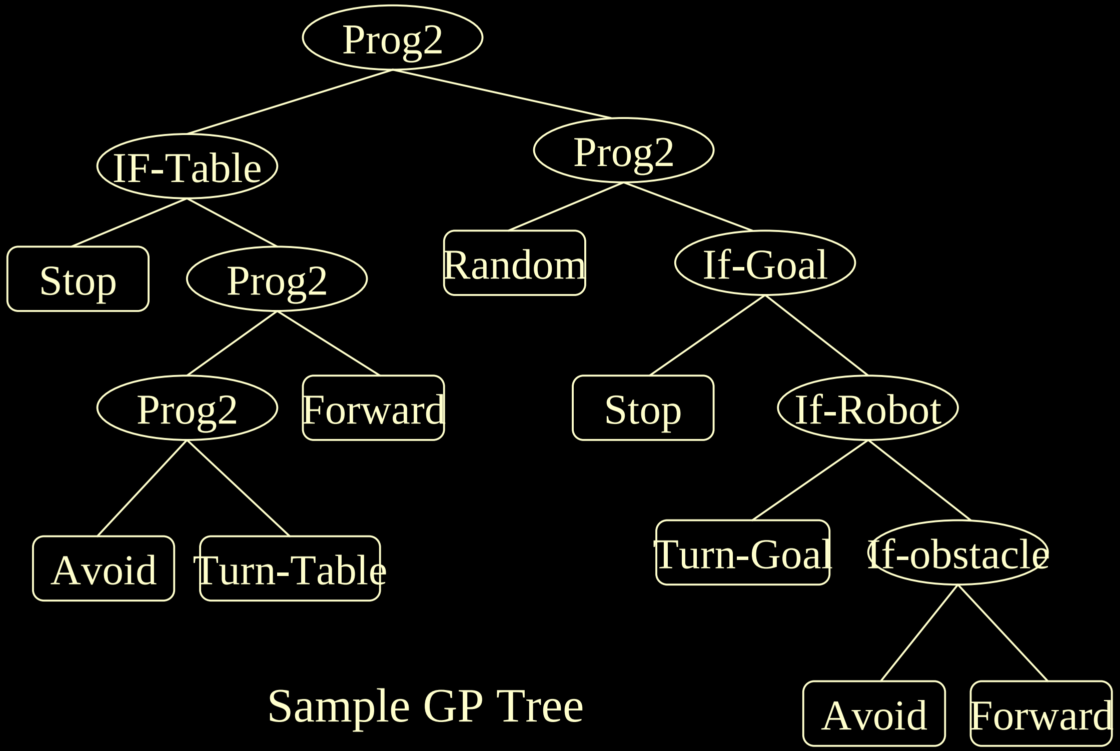
Genetic Programming of Process Decomposition Strategies for Evolvable Hardware

Outline

- Genetic Programming (GP)
- Evolvable Hardware (EH)
- Hardware Evolution of GP Trees
- Context Switching
- Implementation and Experiments
- Conclusion and Future Work

Genetic Programming (GP)

This is a program for a mobile robot



Sample GP Tree

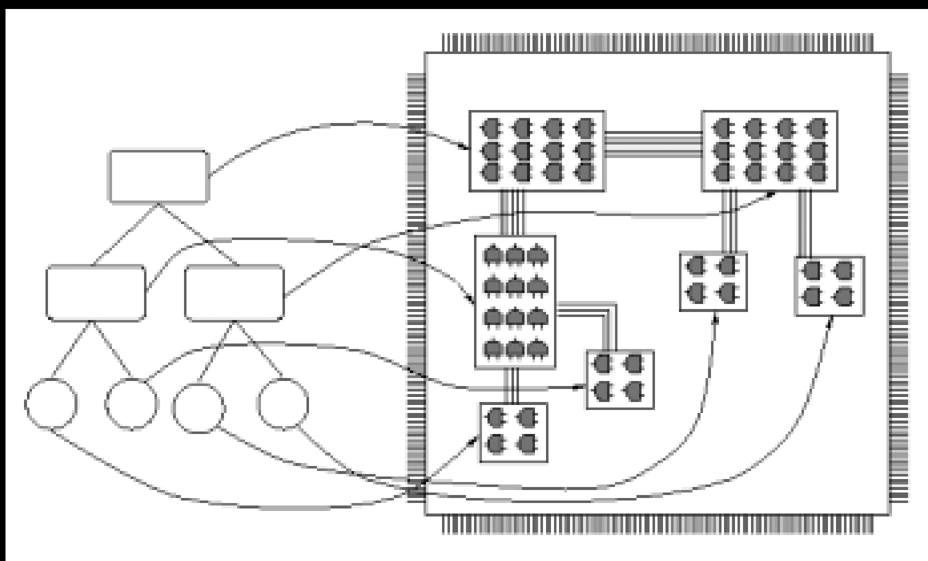
- \+ Automatic evolution of computer programs
- \+ Tree-structured chromosomes
- \+ Expressive power
- \+ Generality
- \+ Easy to incorporate prior knowledge

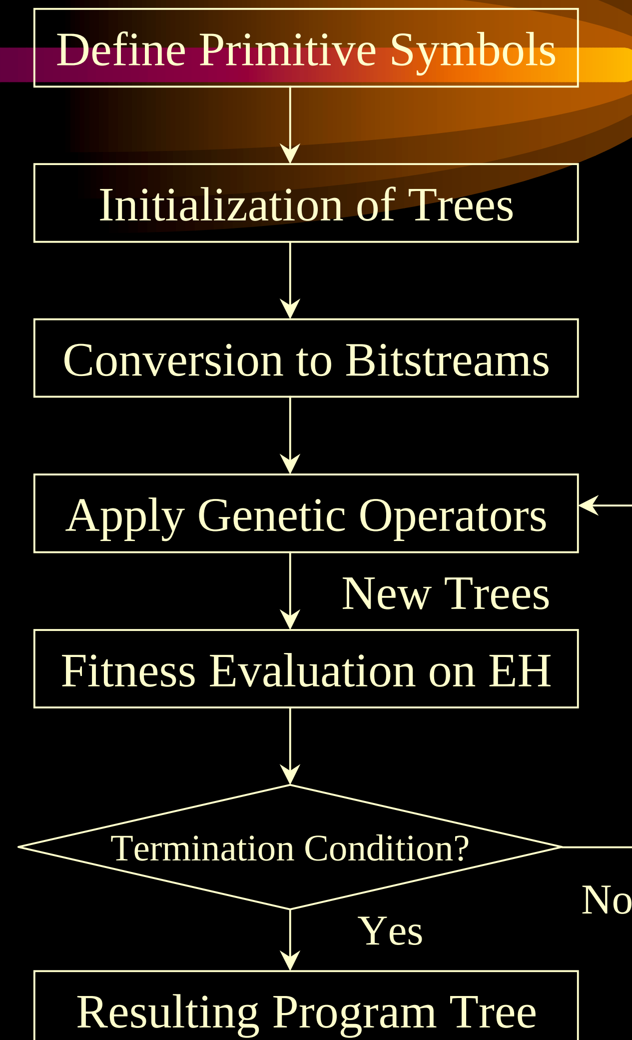
- – Time complexity (fitness evaluation)
- – Space complexity

Evolvable Hardware (EH)

- Run-time reconfigurability
- Higher performance than general-purpose processors
- More flexible than ASICs
- On-line learnability
- Customization

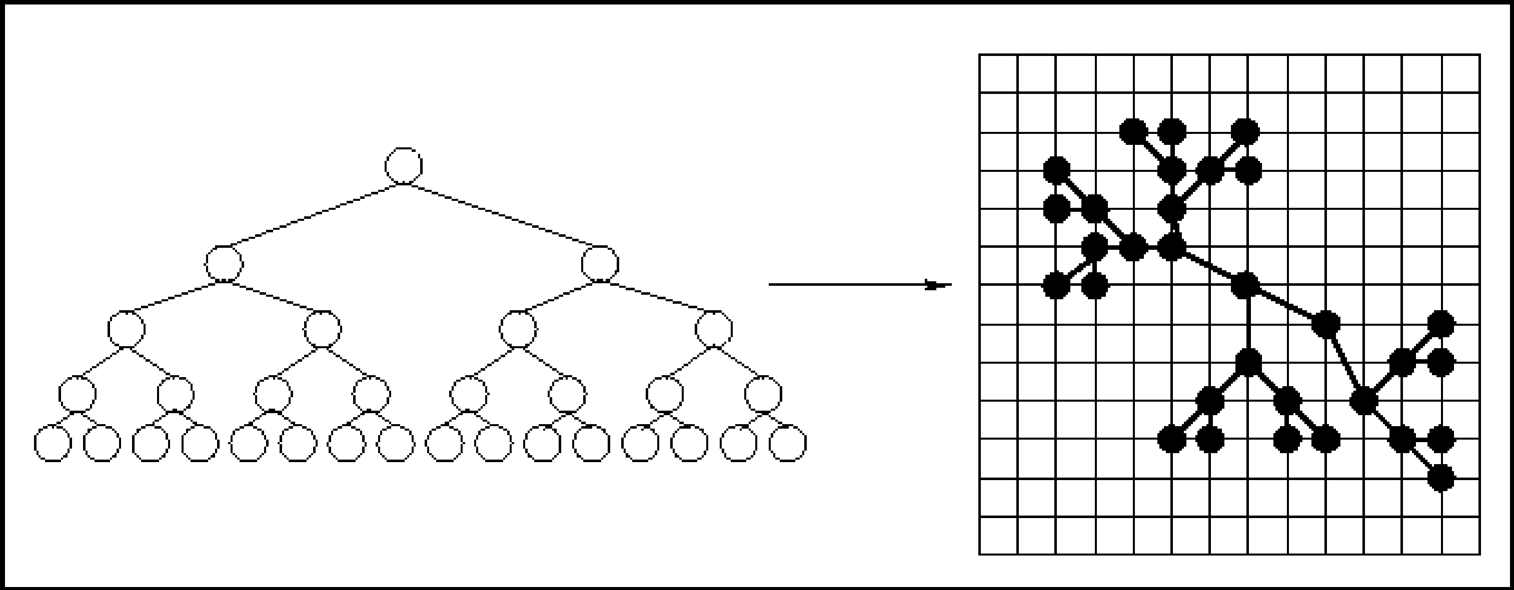
Hardware Evolution of GP Trees



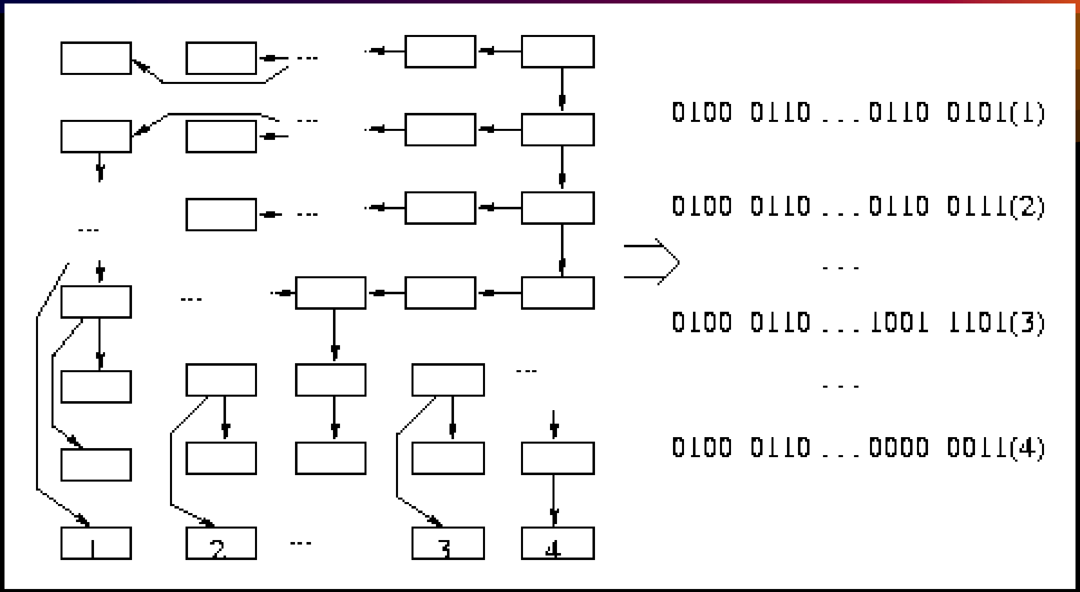


Difficulty in Hardware Evolution of GP Trees

- On-chip representation of tree structures
- Routing problem
- Hardware resource utilization



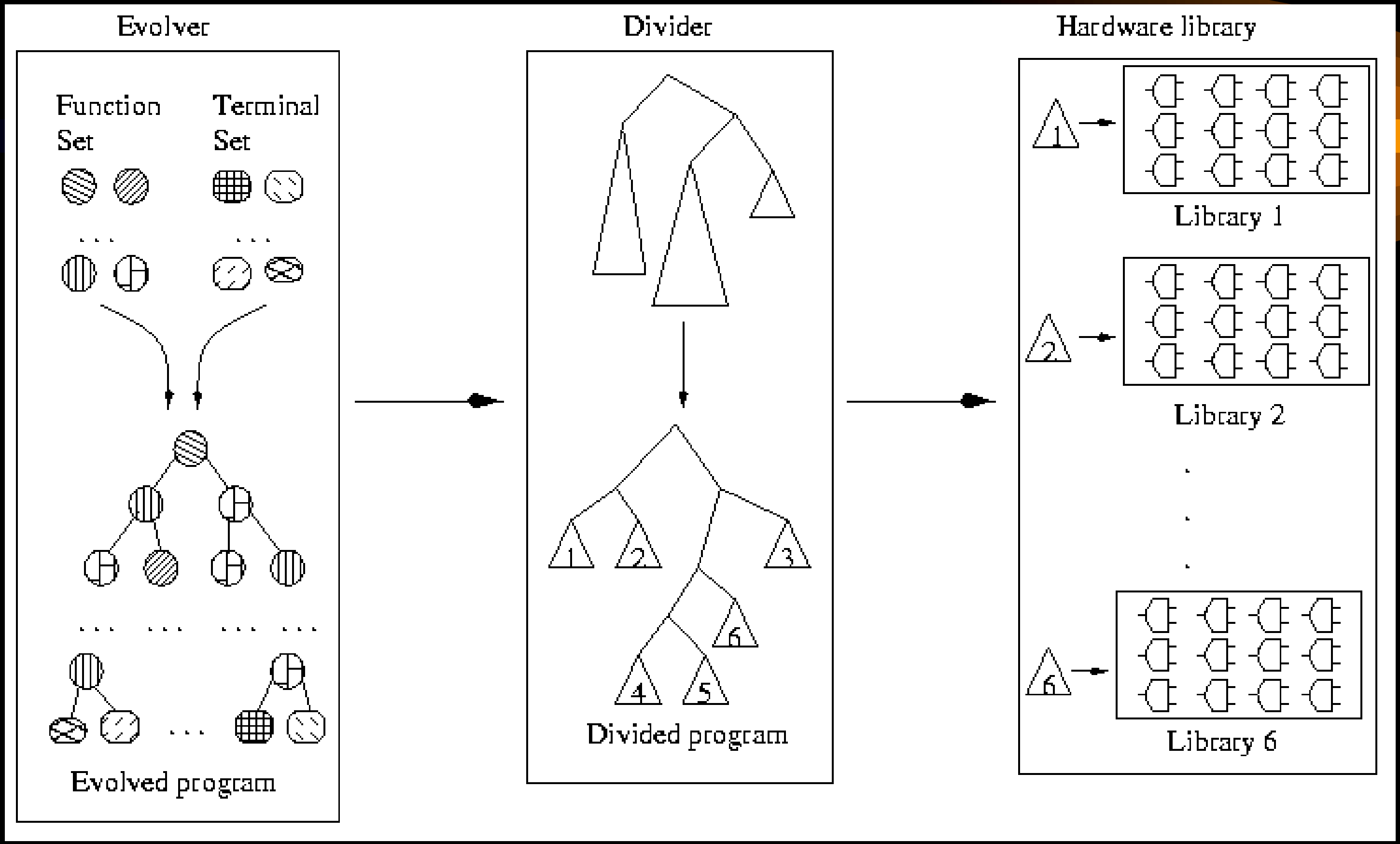
First Approach: Linear Representation



- Comparison of resource utilization

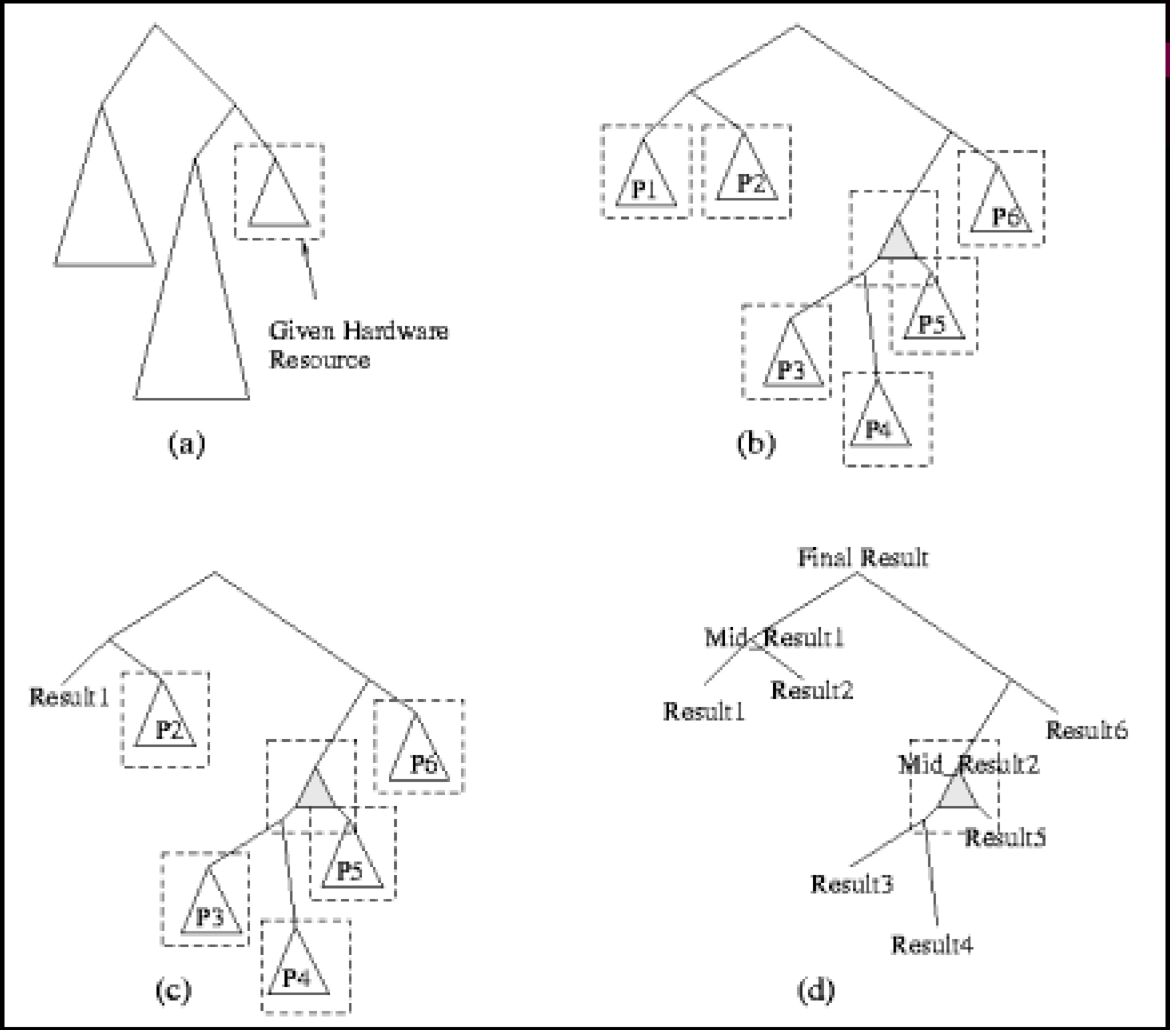
	Tree Represenatation	Linear Representation
Total Resource	80.9%	86.7%
Placement Resource	37.8%	49.2%

Second Approach: Context Switching



- Separate implementation of subtrees of a GP tree
- Reduction of redundancy
- Better utilization of chip resources

Context Switching: Process Decomposition



- A GP Tree is decomposed into a number of sub-trees.
- Based on the resource necessity of sub-trees.
- Number of nodes in the sub-tree

Context Switching: Hardware Library

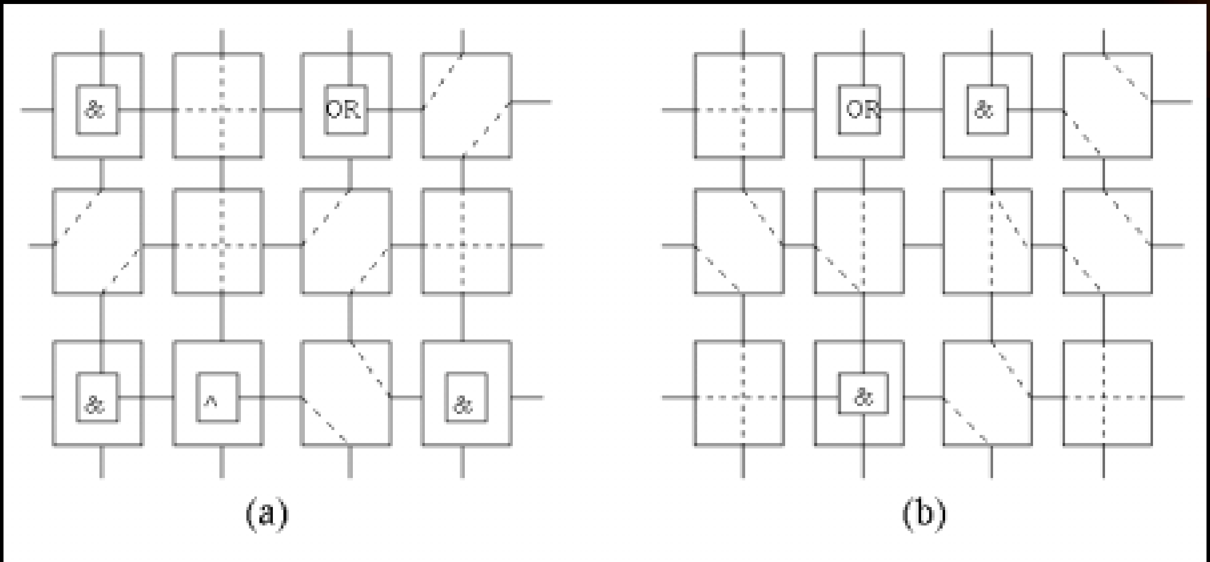
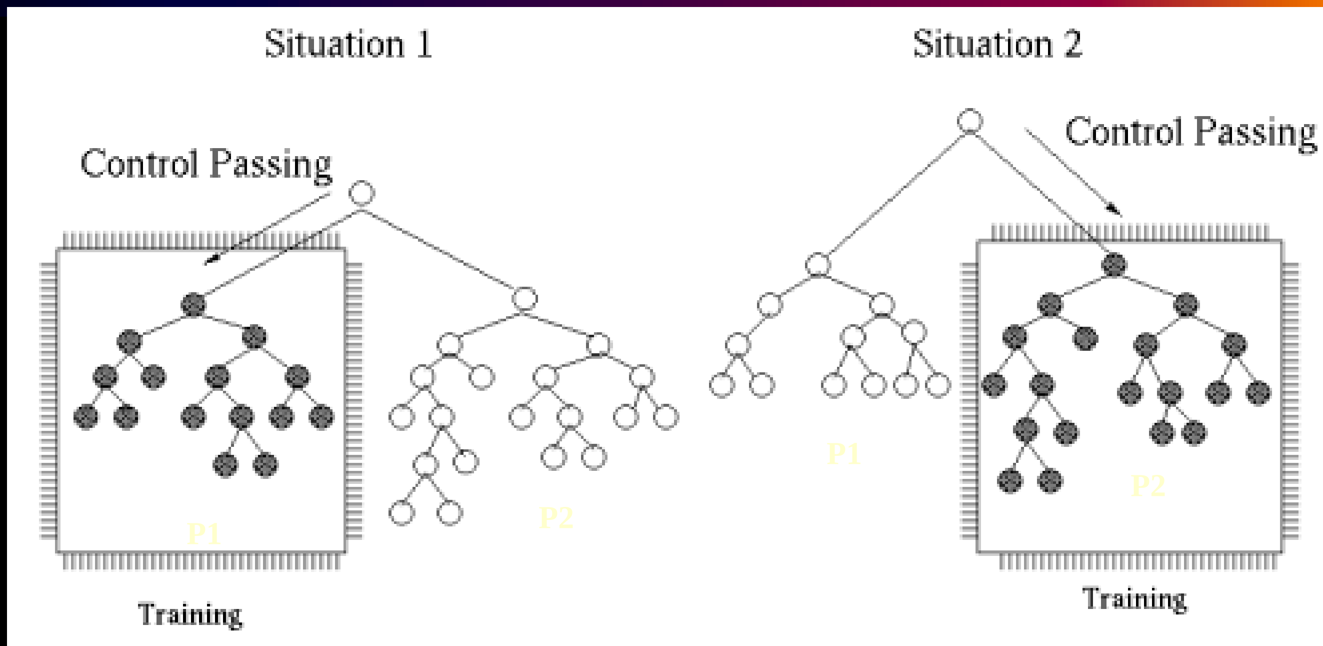


Illustration of hardware library

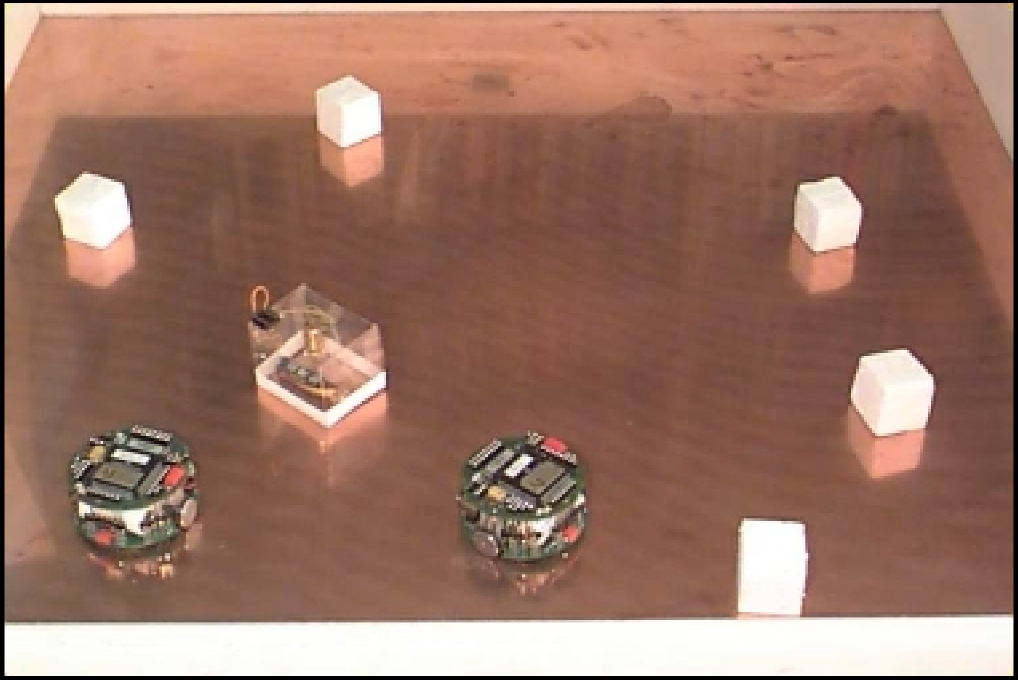
- Library: storage of hardware configuration information for subtrees
- Nodes of a GP tree are interchangeable
- Drawback
  - Possibility of resource waste

Training of GP Trees with Context Switching



- A sub-tree is chosen depending on the input values.
- Then, this sub-tree is trained by varying and selecting fitter subtrees.

Test Bed: Evolving Controllers for Autonomous Robots



- Transportation of an object to the goal (light)
- Cooperation of two robots
- Khepera
- Xilinx XC6216

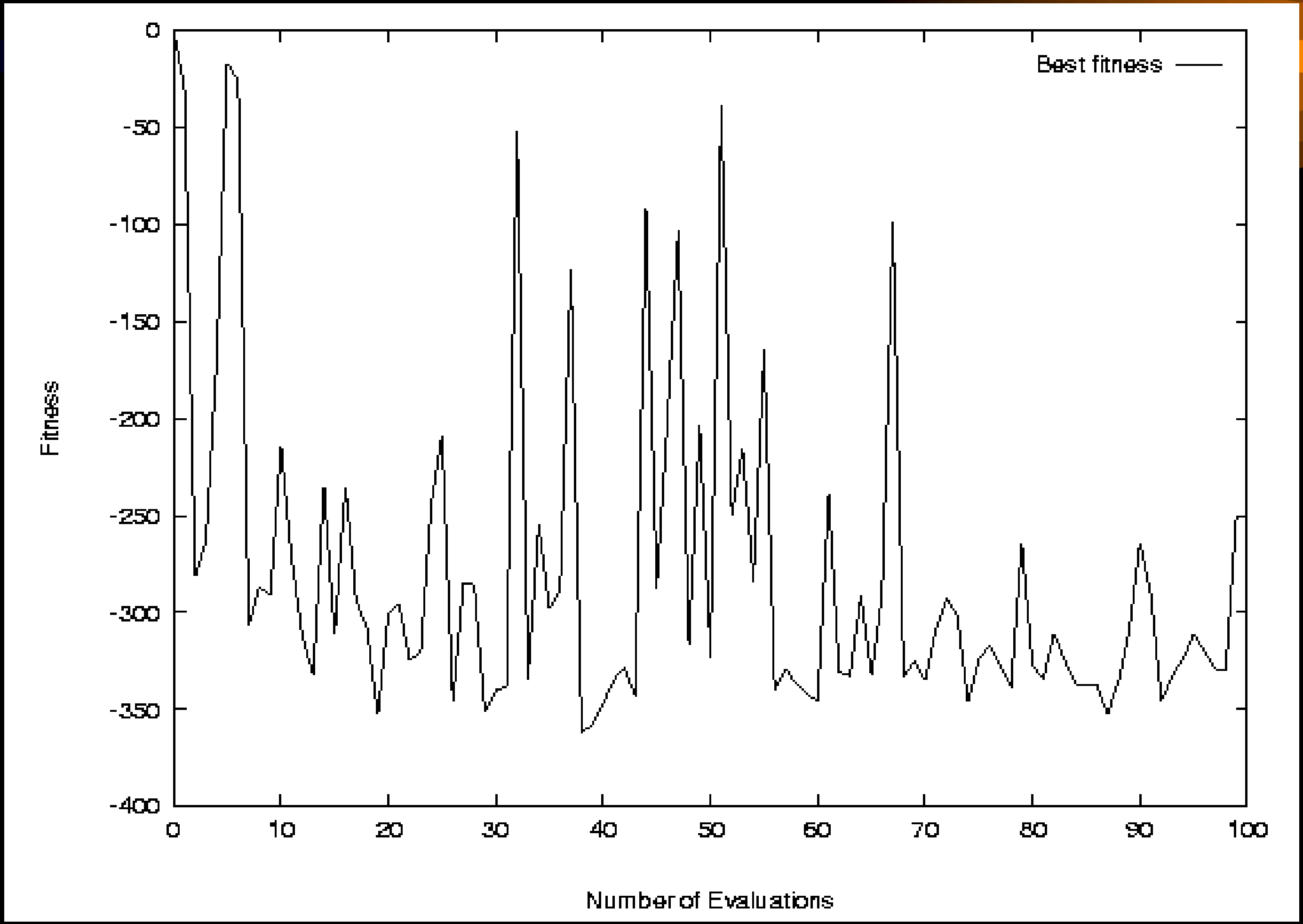
Setup of GP for Robot Control

- Function nodes
  - *IF_OBJ, IF_GOAL, IF_FORWARD, IF_OBS1~4*
- Terminal nodes
  - *MOVE_FORWARD, MOVE_FORWARD & TURN_LEFT, MOVE_FORWARD & TURN_RIGHT, MOVE_BACKWARD,TURN_LEFT, TURN_RIGHT, RANDOM*
- Fitness function

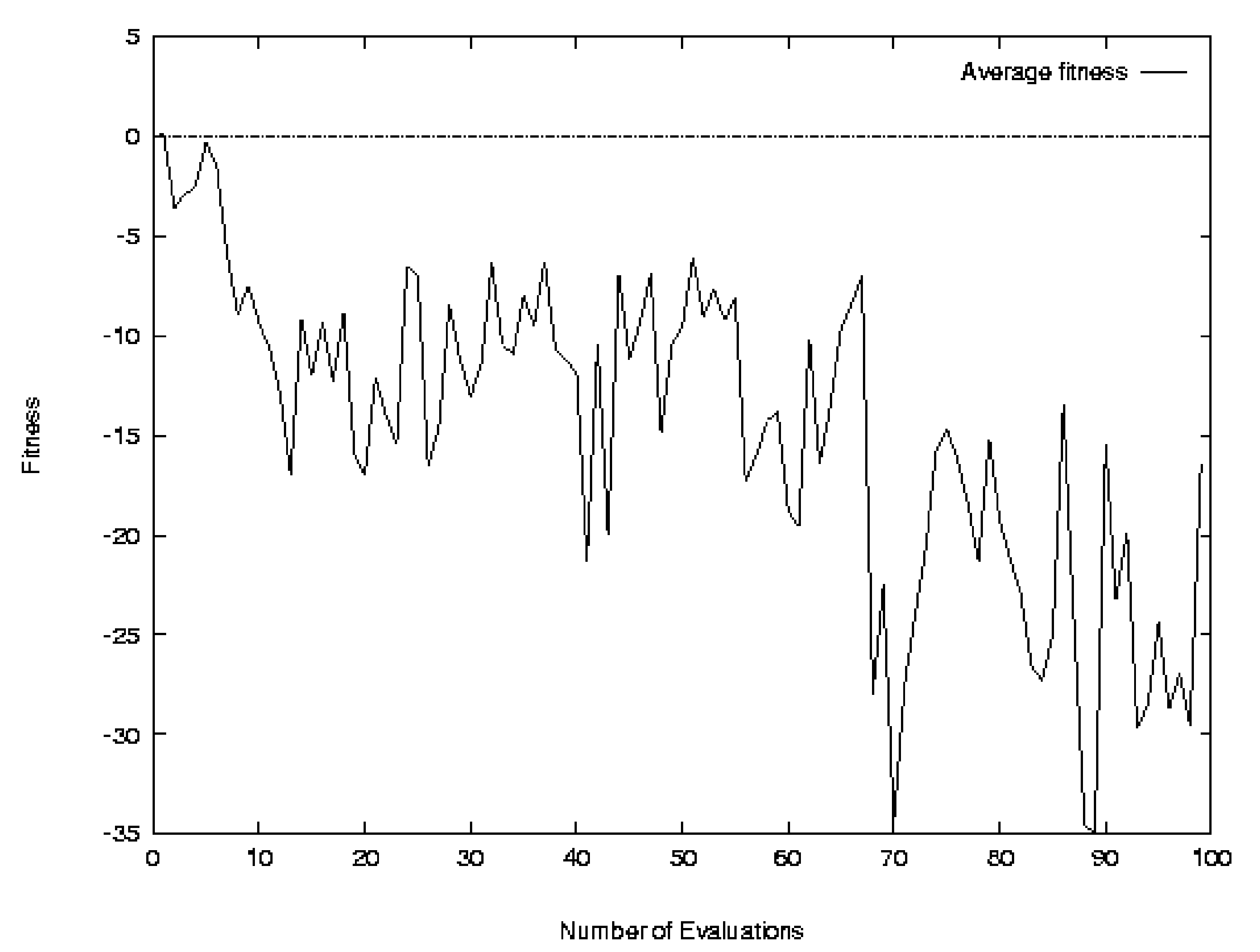
(1) $F_{new} = F_{old} + w_1 \times (\#collisions) + w_2 \times (\#steps)$

(2) $F_{new} = F_{old} + w_1 \times (\#miss) + w_2 \times (\#steps) + vision \times w_3$

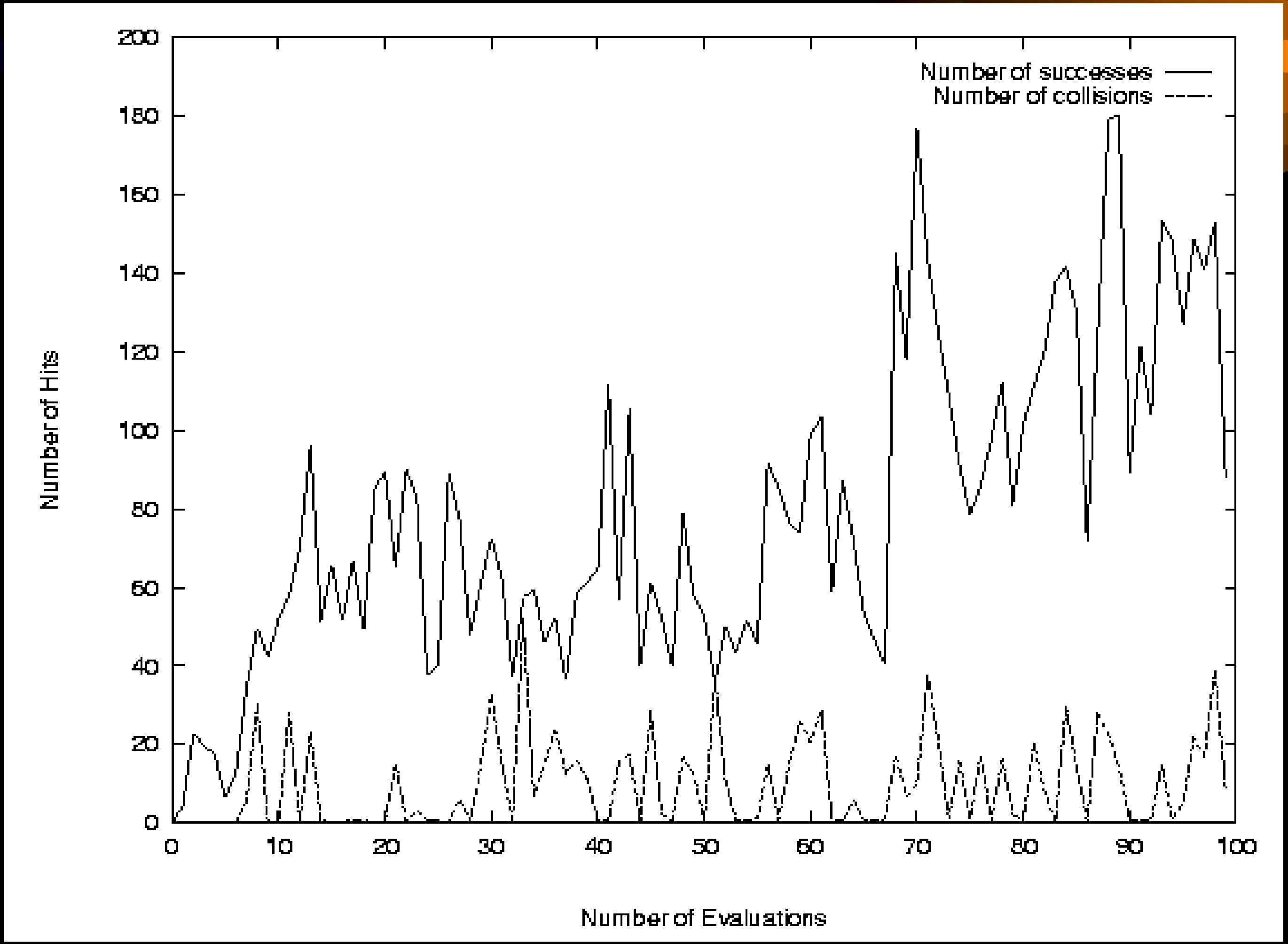
Experimental Results: Best Fitness



Experimental Results: Average Fitness



Experimental Results: Hits



Conclusion and Future Work

- Presented a method for evolving GP trees on EH
- Speed-up by reducing fitness evaluation time
- The larger the training set, the higher the speed-up factor
- Possibility of special-purpose GP hardware
- Appropriate for on-line hardware learning
- Further possibility of resource utilization in evolving GP trees on EH

Sources

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