Design Exploration of EMBRACE Hardware Spiking Neural Network Architecture

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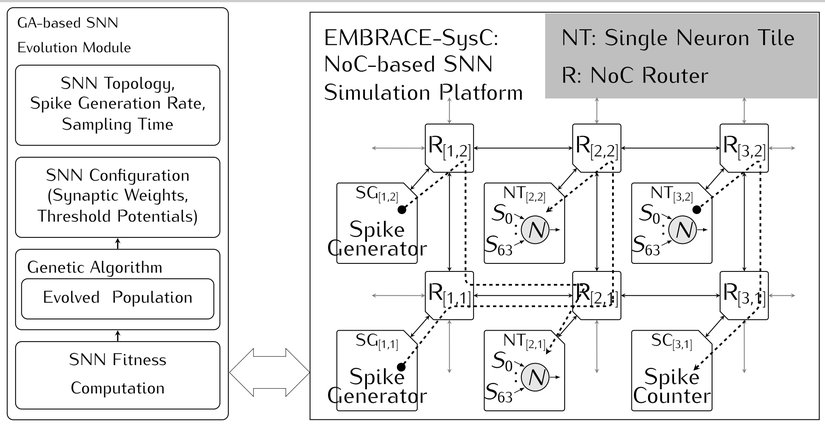
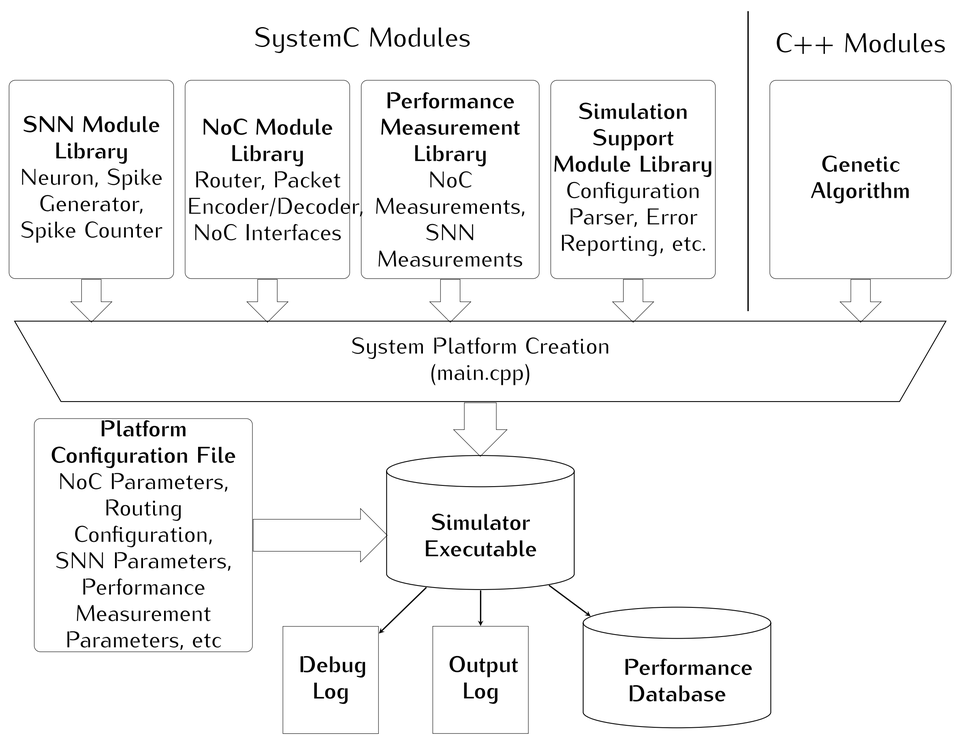
EMBRACE Hardware SNN Architecture Features

- Designed using SystemC simulation based systematic design exploration
- Compact and scalable modular neural tile design
- Low distortion hierarchical NoC architecture for reliable SNN applications
- Modular robotic navigation controller application demonstrated on EMBRACE-FPGA prototype (comprising 448 neuron and 32K synapses on Xilinx Virtex-6 XCVLX240T FPGA)

EMBRACE-SysC Design Exploration Framework



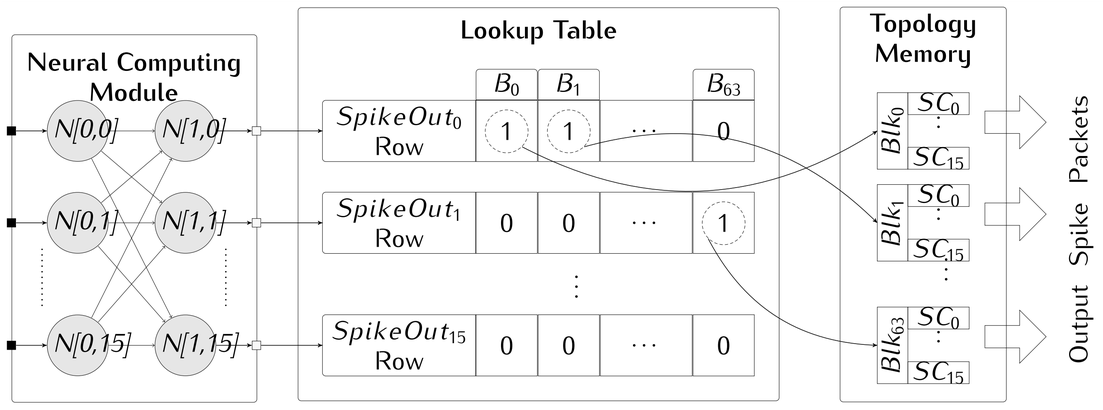
XOR Benchmark SNN Application Simulated with the EMBRACE-SysC Architecture in a 3×2 Mesh Configuration and GA-based SNN Evolution Module



EMBRACE-SysC Modelling and Simulation Flow

- Accurate modelling of spike data traffic and neuron circuit behaviour
- Systematic investigation of performance bottlenecks in the architecture
- Performance comparison and analysis of architectural design choices
- Evaluation of SNN application feasibility prior to hardware prototyping

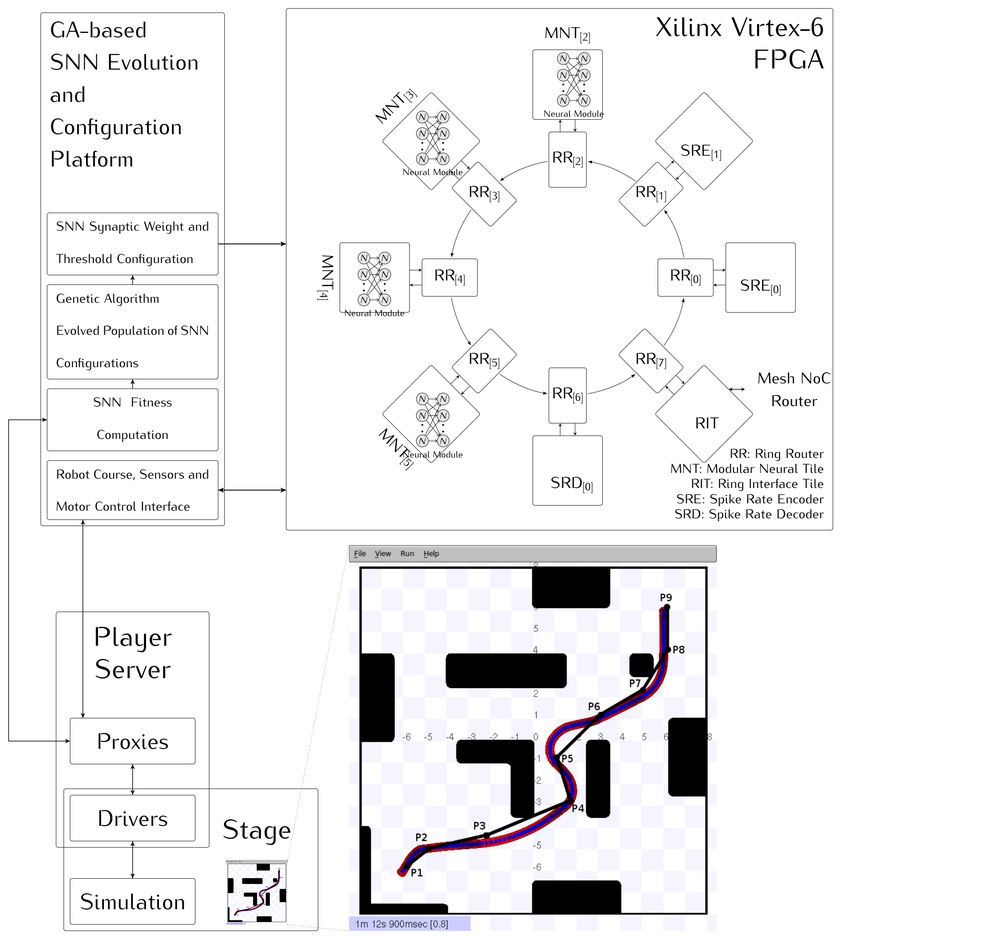
EMBRACE Modular Neural Tile Architecture



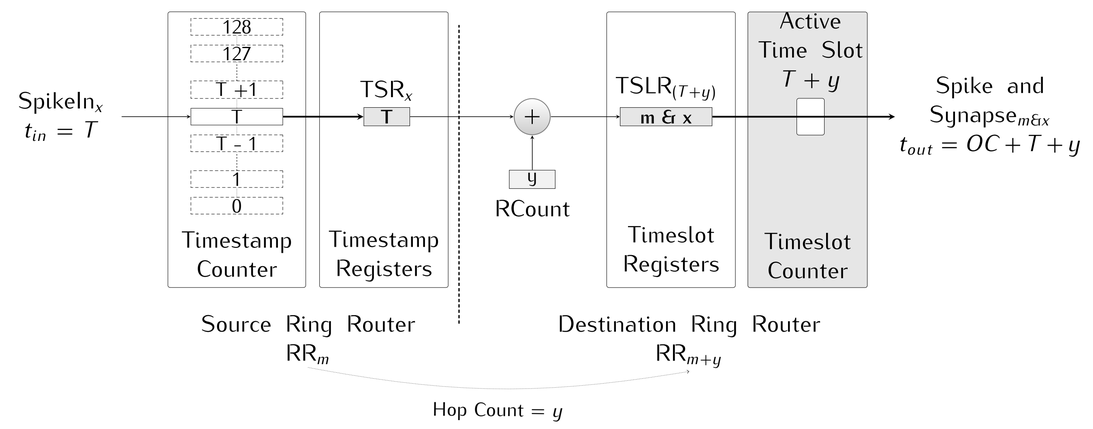
Two layered 16:16 Fully Connected SNN Structure as the Neural Computing Module and the Lookup Table-based Shared Topology Memory Organisation within the Modular Neural Tile

- Compact and scalable modular neural tile architecture for mesh topology NoC based hardware SNN
- Reduces the SNN topology memory requirement of NoC-based hardware SNNs by using a combination of fixed and configurable synaptic connections
- Average 66% reduction in silicon area requirement for practical SNN application topologies

EMBRACE Hierarchical NoC Architecture



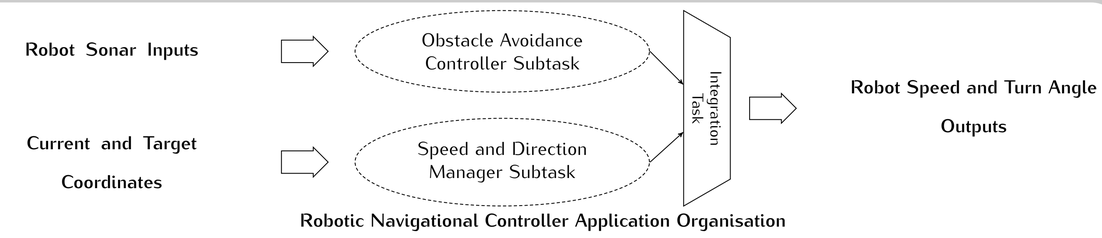
Robotic Controller Evolution Setup Comprising Ring Topology EMBRACE-FPGA Prototype, GA-based SNN Evolution Platform and Player-Stage Robotic Simulation Environment



Fixed Latency Spike Packet Flow Control

- Fixed spike transfer latency ring interconnect within mesh topology NoC architecture
- Novel timestamped broadcast flow control offering high density localised spike transfer
- Eliminates SNN information distortion due to NoC spike latency jitter
- Insures reliable SNN application behaviour for various NoC traffic conditions

Modular Robotic Navigational Controller Application



Robotic Navigational Controller Application Organisation

- Complex multifunctional robotic navigational controller application decomposed into:
  1. Obstacle avoidance controller subtask controls the robot movement for avoiding obstacles
  2. Speed and direction manager subtask steers the robot towards target location
- Application partitioning based on sensory inputs and functionality
- Modular application prototyping technique offers:
  - → **Simplified SNN training**
  - → **Faster application evolution**
  - → **Accurate application behaviour**
  - → **Stepwise knowledge integration**

References

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