SenseMaker

IST2001-34712

Martin McGinnity
University of Ulster

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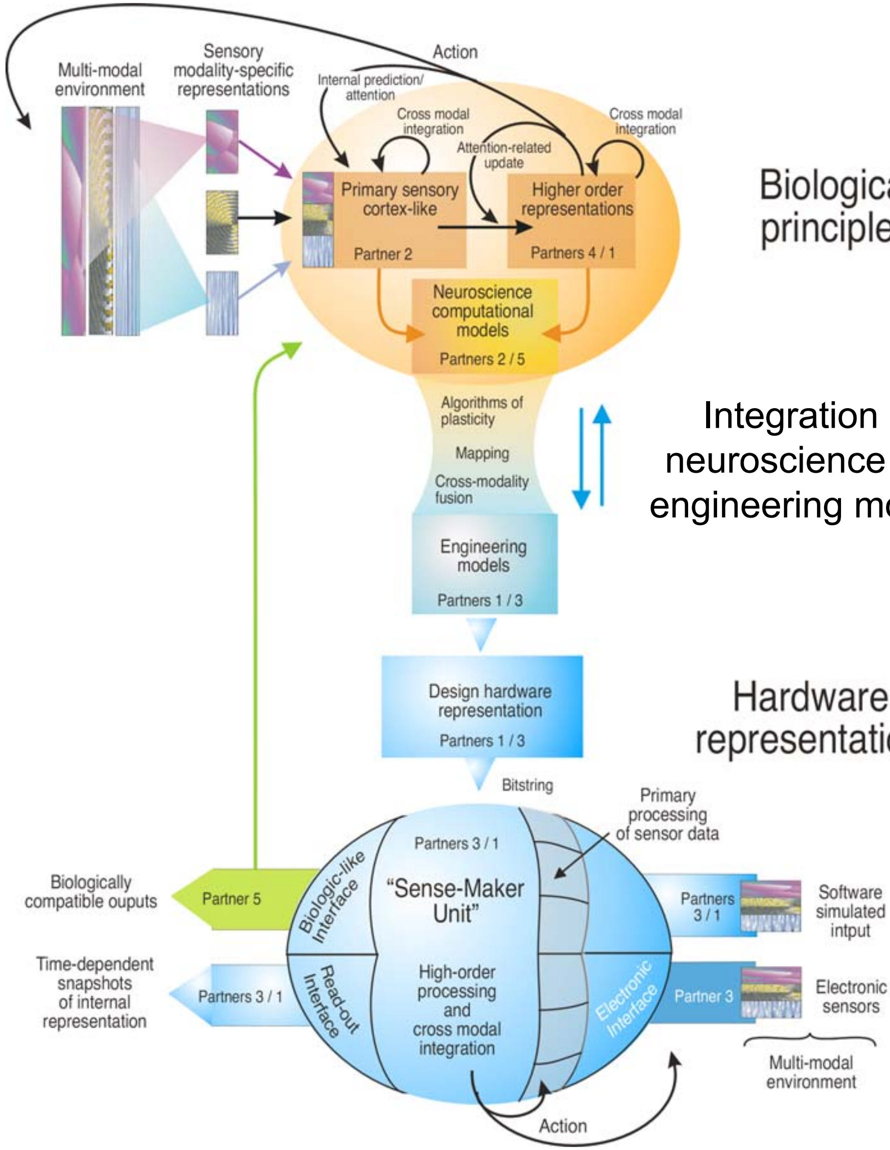
Project Objectives

- To design and implement an intelligent computational system, drawing inspiration from biological principles of sensory receptor and nervous system function
- To conceive and implement electronic architectures that can merge sensory information from different modalities into a unified perceptual representation of the environment
- To explore a better understanding of information processing and function in the adult brain
- To achieve a higher level of communication between computer scientists, engineering, physics, psychology, and biological researchers

Overview of Project

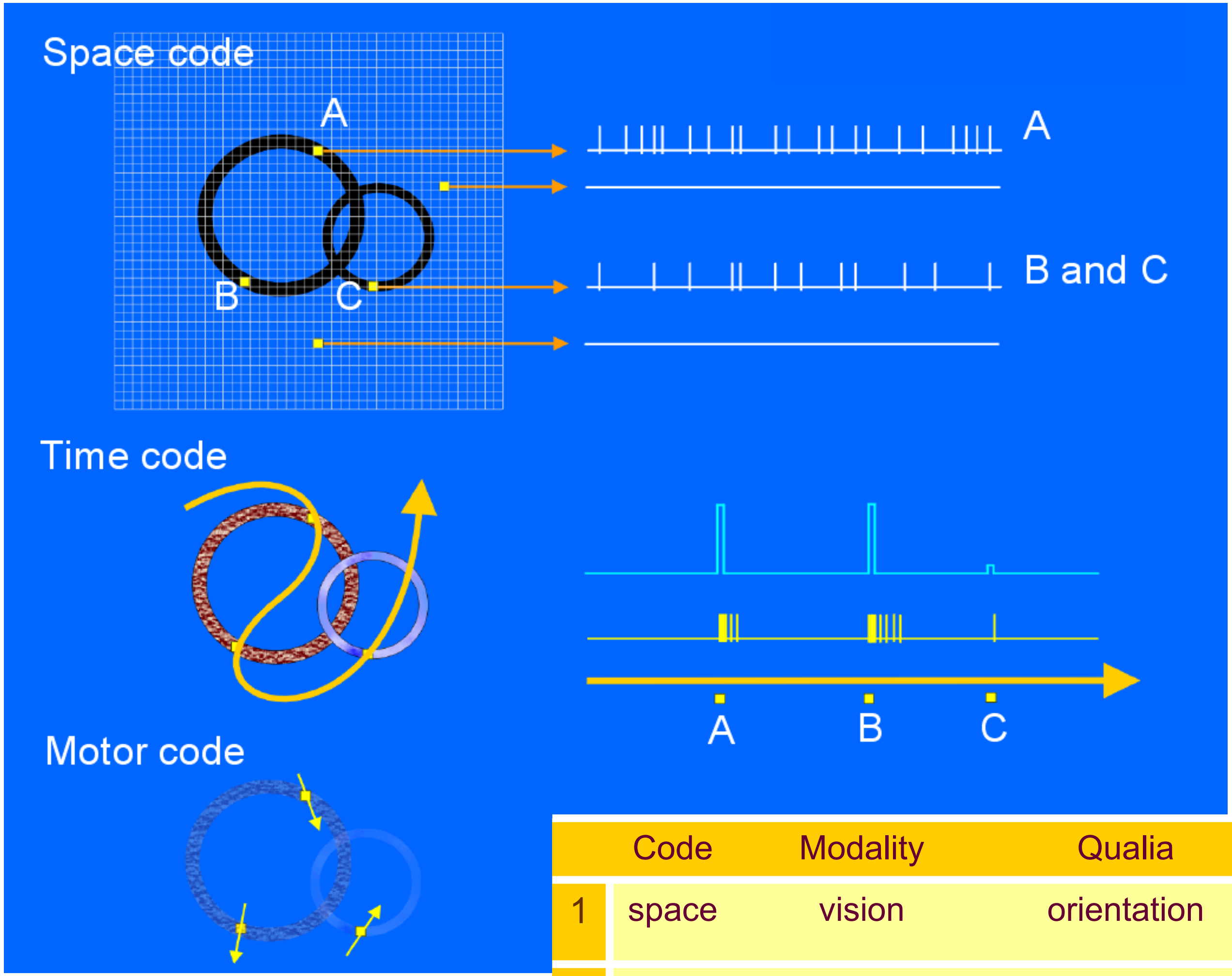


Biological principles

Integration of neuroscience and engineering models

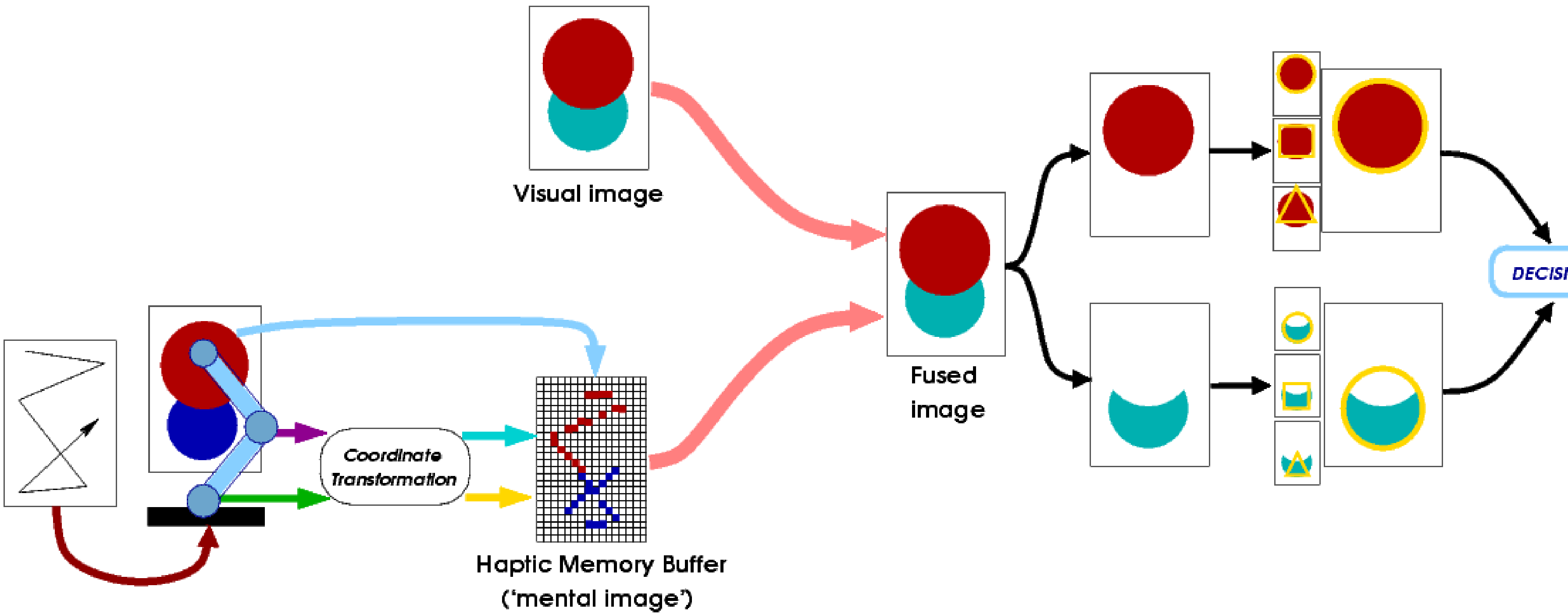
Hardware representation

Cross-modal integration: The Two-Ring Problem



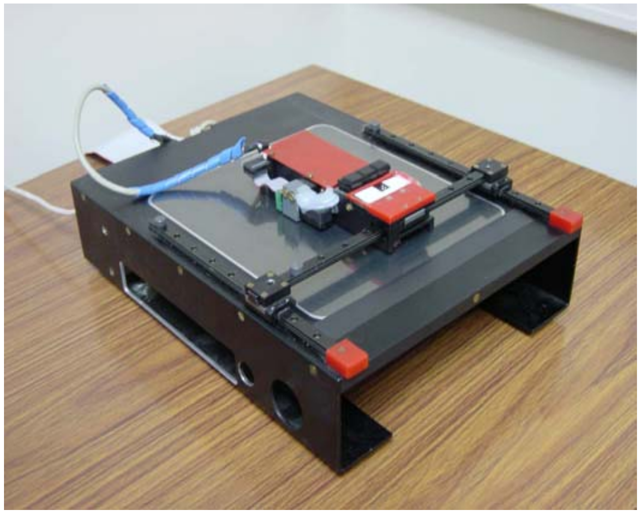
	Code	Modality	Qualia	Level	Acquisition
1	space	vision	orientation	global	parallel
2	time	touch	texture	local	sequential
3	motor	proprioception	direction/motion	local	sequential

Solving the Two-Ring Problem with the SenseMaker System

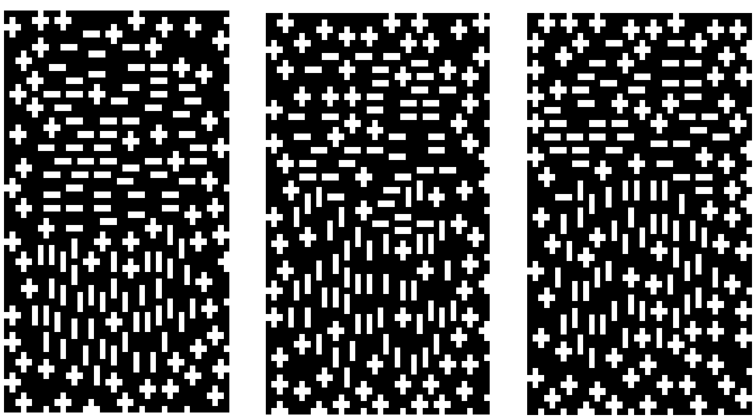


Psychophysical Investigation of the ‘Two-ring’ problem

Apparatus: Virtual Tactile Display (VTD); developed by UHEI partners

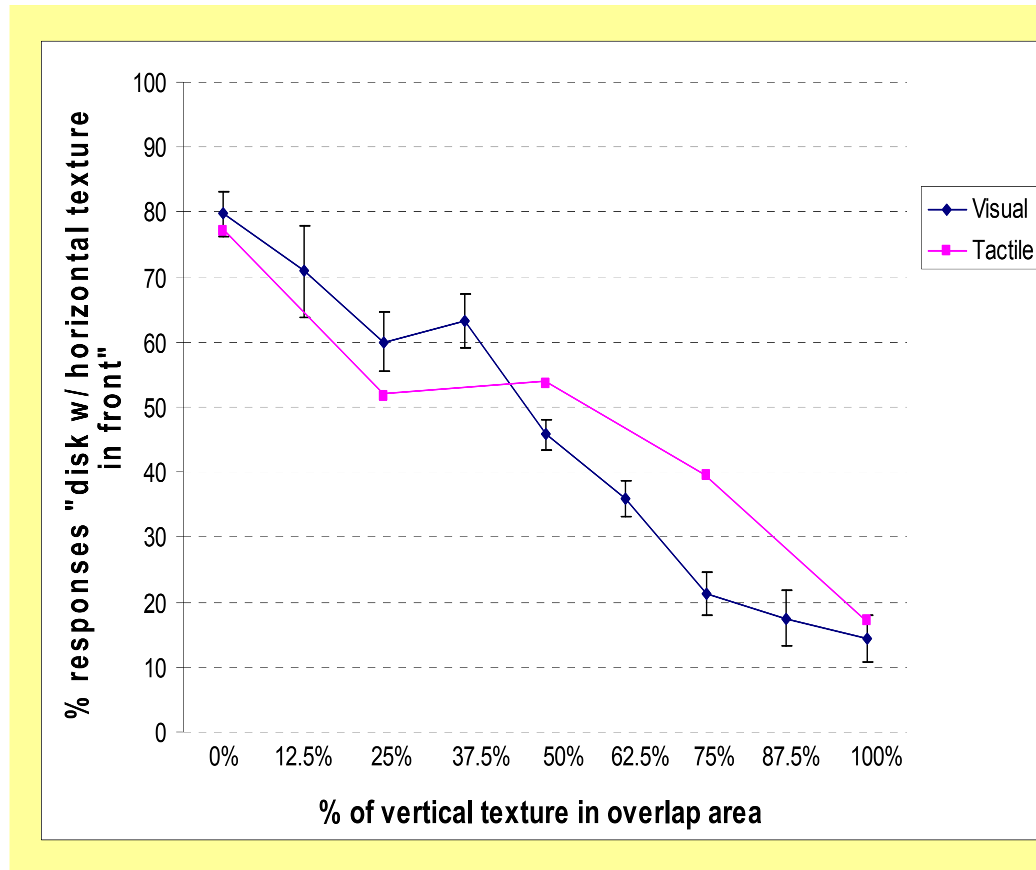


0% vertical 50% vertical 100% vertical



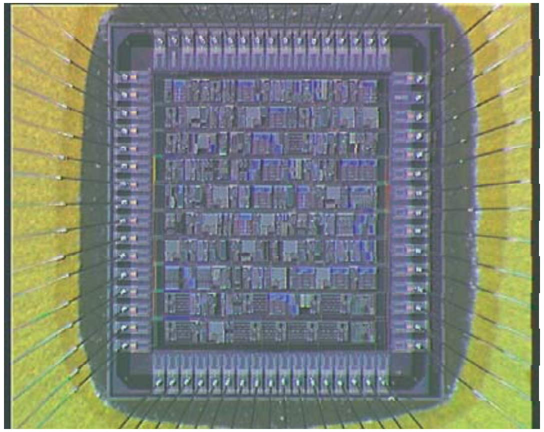
Stimuli: Visual and tactile continua

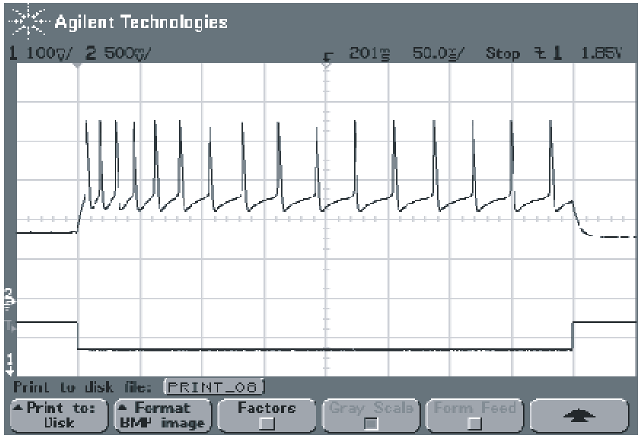
Results: Categorical perception of visual and tactile textur
continua



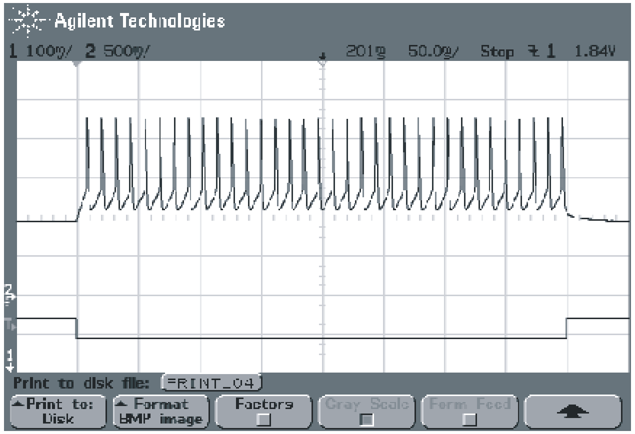
Silicon IC Neural Units

Custom circuits are developped to compute in real-time HH-like neuron and kinetic synapses models *(analog design mode - Bipolar and MOS transistors - photograph: area of the die 4mmx3mm, 2k devices)*





Regul
Spikin
(RS)
neuro



Fast
Spikin
(FS)
neuro

Oscilloscope hardcopies:
- Upper plot: membrane voltage output
-Lower plot: input stimulation voltage (inv. prop. to the stim. current)

SMU2 : FPNN Architecture

- a fully populated backplane has been produced
- Network tests are under way
- 16 Local PowerPC CPUs are running embedded Linux, total memory of up to 16 Gbytes
- FPNN ASIC interface on network module is working
- universal high-level software framework is available since July 2003 to configure and operate the SMU1, SMU2 and the later SMU3 system
- first experiments with SMU2 are in the preparation phase

The SMU2 system. One crate provides:

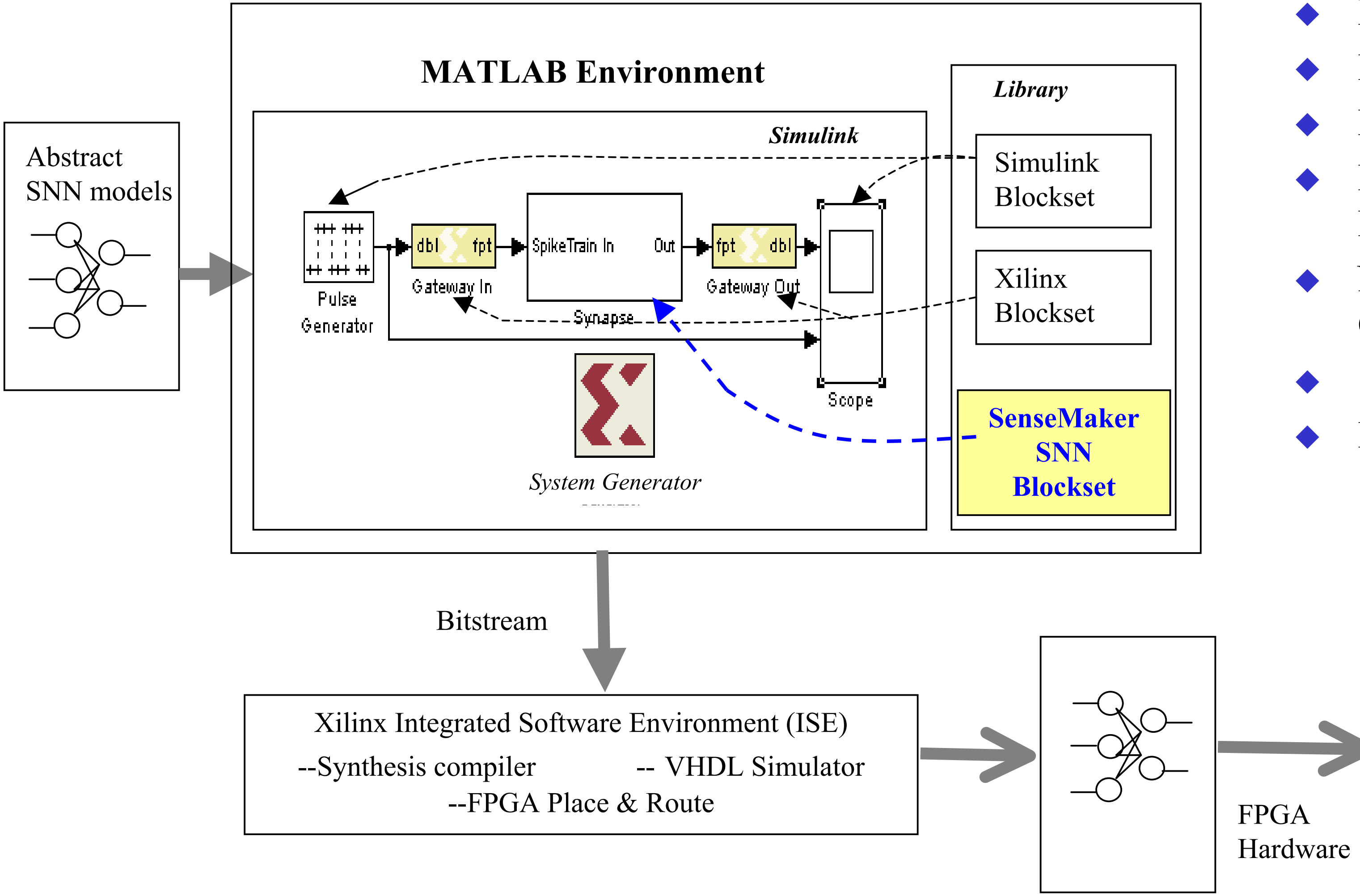
- **16** network modules
- **4096** binary neurons
- **524288** analog synapses

Largest full-custom hardware neural network ever build.

SMU3 chip -Implementing low-level biological principles in VLSI

- technology: UMC 0.18µm, 6 metal, 1 poly
- 384 to 768 neurons, about 100000 synapses
- neuron model: modified integrate-and-fire with conductance based synapses
- fully analog network core
- time scale factor 10^{-5}: 10 ns chip-time equals 1 ms in real-time
- short-term synaptic depression and facilitation: analog on-chip
- spike-time-dependent-plasticity: on-chip (analog measurement with digital weight adjustment)
- operation in the the SMU2 system framework
- independently programmable model parameters (at least E_l, E_x, E_i, V_t, V_r, g_m, t_{ref}, t_s)

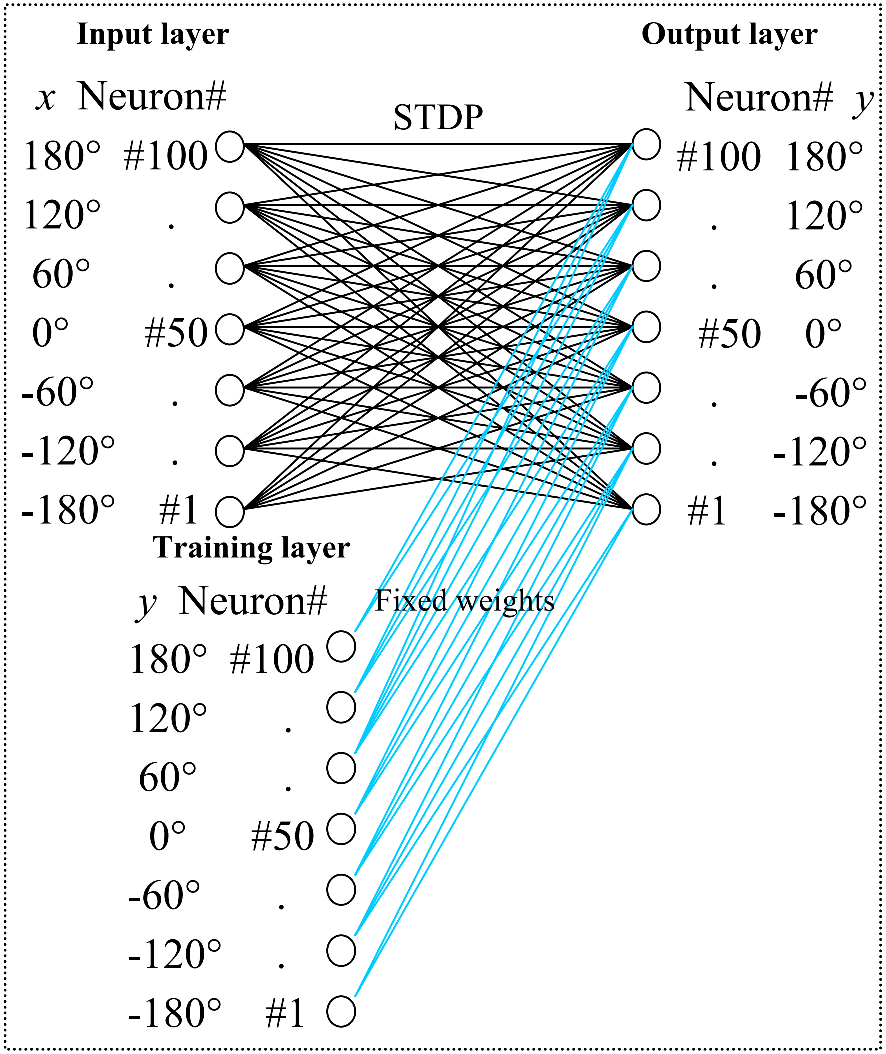
Design environment for Spiking Neurons and STDP on FPGAs

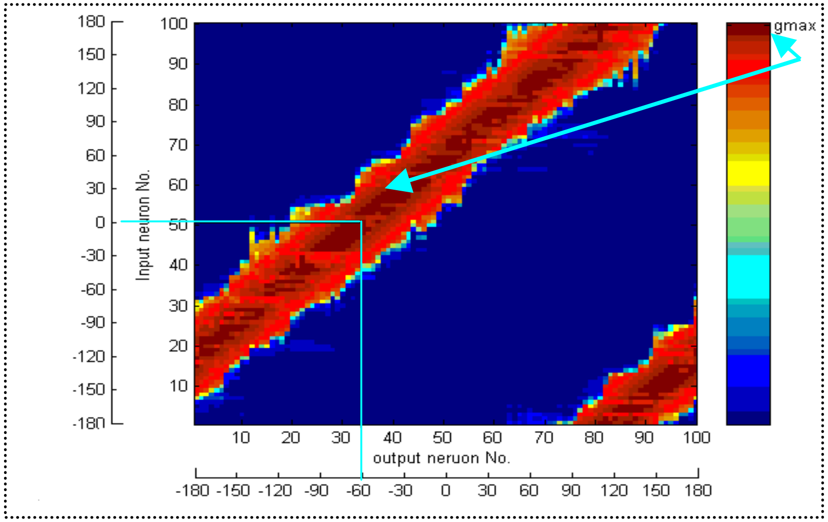


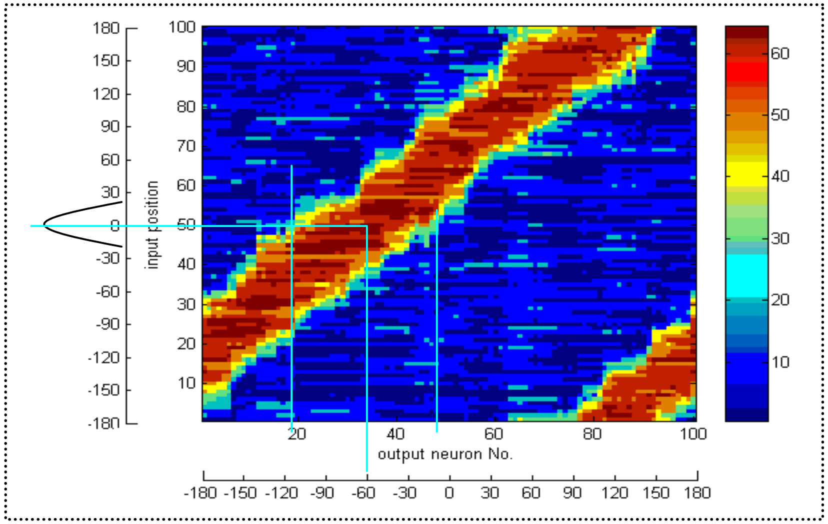
- Modular Syster
- Extendable
- Flexible
- Rapid Prototyping
- Numerous I/O Options
- Standalone
- Embedded System Solutio

BenNuey PC104 Platform

Example implementation of a module of the SenseMaker system - Matlab







Achievements

- Established a paradigm for comparing human and machine performance in merging of sensory codes
- Established task-dependent principles for higher level processing
- Developed an analog-digital simulator to translate biological model in ASIC representation
- Development of large scale spiking neural network, incorporating STDP learning, in analog ASIC
- Implementation of large scale spiking neural networks, incorporating STDP learning, in digital FPGAs – software-hardware trade-off.