eMorph: towards neuromorphic robotic vision

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Information technology has not yet delivered artificial systems that can compare with biology in reliably, robustly and efficiently extracting information from the often noisy and ambiguous real world, and interacting with the world by generating appropriate behaviours.

Asynchronous, event-driven, space variant visual sensors

Goal: to design asynchronous, data-driven, biologically inspired, vision sensors with non-uniform morphology, using analog VLSI neuromorphic circuits

Tracker Motion Sensor
- measures contrast, spatial and temporal derivative and velocity of moving edges
- comprises circuits that implement a model of "selective attention" for a smart readout

Simulation of velocity circuits. Response to an edge traveling across two pixels at different speeds. The velocity is calculated as time to travel across neighboring pixels.

High level event-driven visual algorithms

Goal: to develop a supporting data-driven asynchronous computational paradigm for machine-vision that is radically different from conventional image processing

Optical flow
Event-driven sensors transmit information about local changes in their field of view at the time they occur. The optical flow is updated for each event resulting in extremely sparse computation over time and space.

Estimated optical flow: Events at $t_{i+1}$ events computed

Events from a bouncing ball: Consecutive "frames" of accumulated events

The computation is frame-less and from optical flow at $t_{i+1}$, events computed

Space-time representation of a rotating white disk with a black bar. Bar orientation estimated by the events-based (+) and by the frame-based (-) optical flow algorithms versus the true bar orientation over time.

System integration

Goal: to validate the system on the humanoid robot iCub fitted with the neuromorphic sensors, and controlled by the asynchronous machine-vision algorithms in real-time behavioral tasks

Visual system integration
We developed a series of printed circuit boards to integrate the iCub event-driven sensors and dedicated processors.

iCub navigation
We developed an autonomous vehicle with 6 holonomic, omnidirectional wheels.

Dedicated embedded AER hardware

Goal: to develop dedicated embedded infrastructure supporting efficient processing of asynchronous data

SPARC-compatible general purpose Address-Event processor with 20-bit 10ns-resolution asynchronous sensor data interface in 0.18µm CMOS

eMorph will deliver a methodology for event-driven artificial vision on a robotic demonstrator, giving the chance to the robotic community to have a ready-to-use platform to directly interact and experience the power of neuromorphic tools.

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Publications

Bartolozzi, C. and Indiveri, G., Selective Attention in Multi-Chip Address-Event Event Sensors, 2009
Bartolozzi, C., Fasnacht, D.B. and Indiveri, G., A PCI based high-fanout AER mapper with 2 GiB RAM look-up table, 0.8 us latency and 66MHz output event-rate, Conference on Information Sciences and Systems (CISS 2011), 2011.

Fasnacht, D.B. and Indiveri, G., A PCI based high-fanout AER mapper with 2 GiB RAM look-up table, 0.8 us latency and 66MHz output event-rate, Conference on Information Sciences and Systems (CISS 2011), 2011.

Benosman, R., Ieng, S., Clercq, C., Bartolozzi, C., Asynchronous Frameless Event-based Optical Flow, IEEE Transactions on Neural Networks (submitted)

Visual Primitives

Spatial derivative

Temporal derivative

noise reduction

spatial contrast

pixel illumination

temporal contrast

periphery

fovea and periphery

Visual System

Asynchronous Logic

Chip block diagram

Address Decoder

Address Encoder

Termporal Defector

Address-Event Array

Address Generator

Sporran Generator

Reset

BG Power Down

DVS L

BGCommands

BG Powers

SPARC
compatible

general
purpose

AER Processor

with
20-bit
10ns
resolution

asynchronous

sensor
data
interface

in
0.18µm
CMOS

Log Polar Mapping

Space variant event-driven sensor prototype

temporal contrast

pixel illumination

spatial derivative

noise reduction

fovea and periphery

System integration

iCub navigation

We developed an autonomous vehicle with 6 holonomic, omnidirectional wheels.