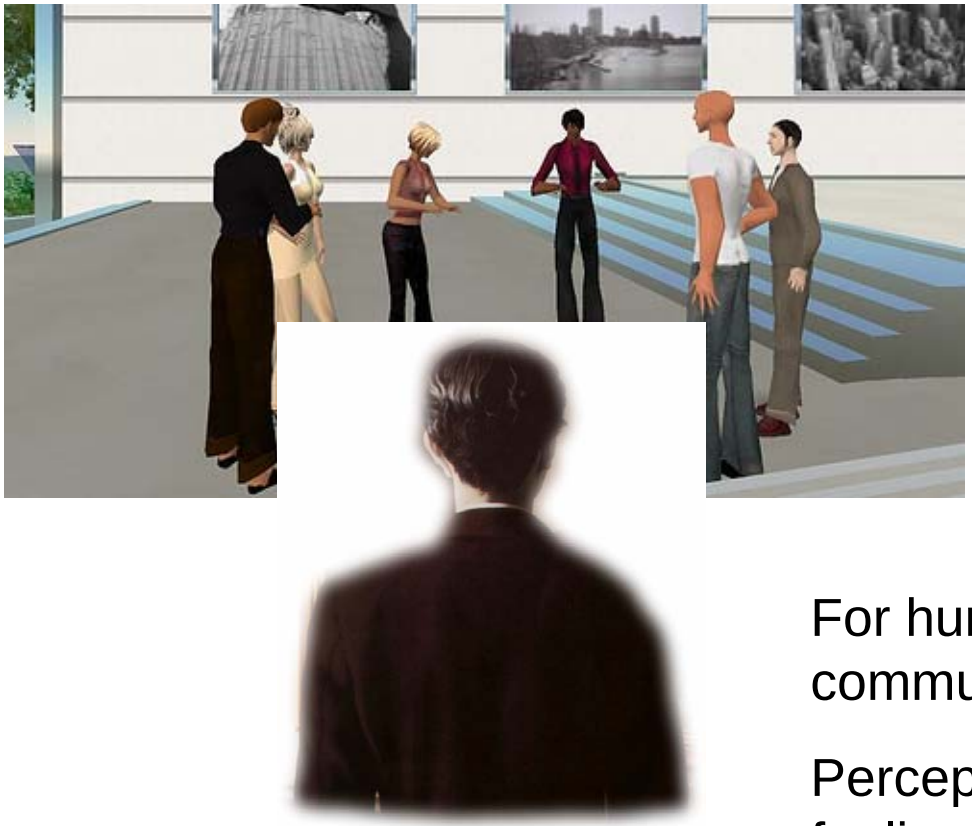
A psychologically-inspired brain model architecture for nano-functional-device-based intelligent systems

Tadashi Shibata

The Department of Electrical Engineering
and Information Technology

The University of Tokyo

Joining the Meeting with Avatoars



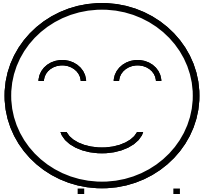
For human-like natural communication:

Perception of gestures, expressions, feeling/mental state ……..etc.

Human-brain like electronic systems are essential.

Nano Device Era

- Quantum effect manifest itself



  - Enhanced functionality in miniscule devices
  - Prodigious amounts of elements in a small area
- Stochastic
  - Variability problem

- Not for Boolean-logic-based systems

Nano Device Era

- Quantum effect manifest itself
  - Enhanced functionality in miniscule devices
  - Prodigious amounts of elements in a small area
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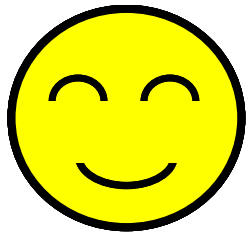
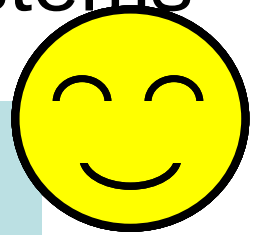
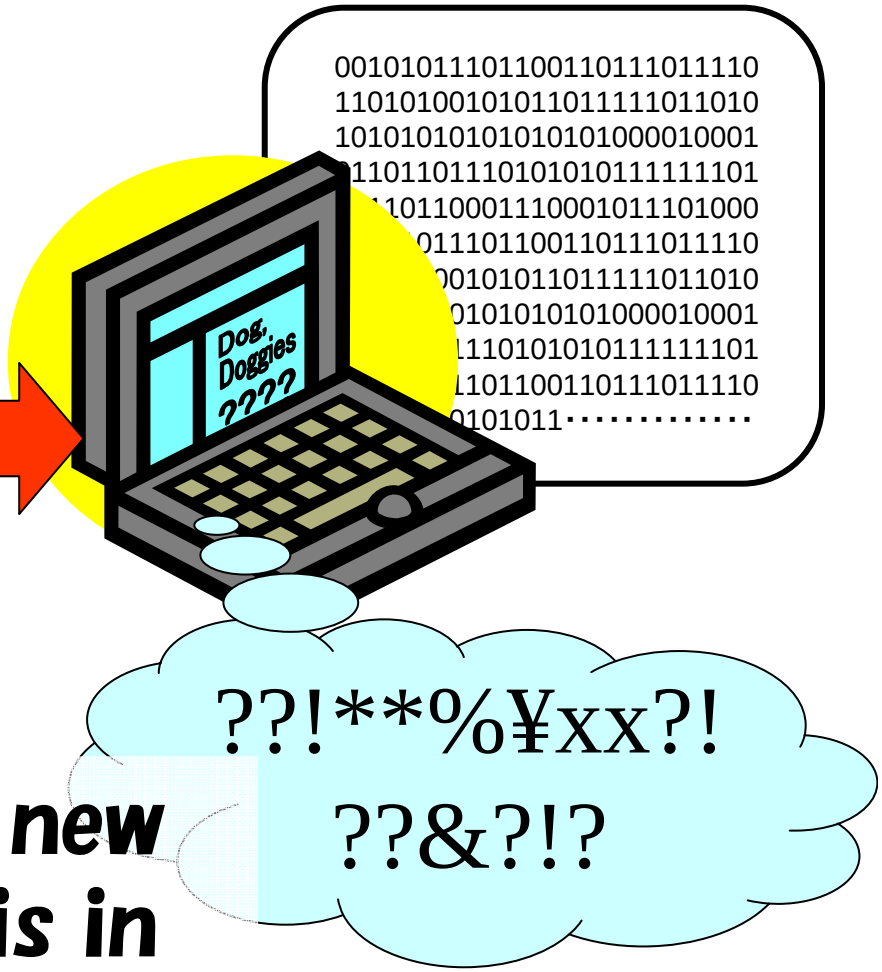




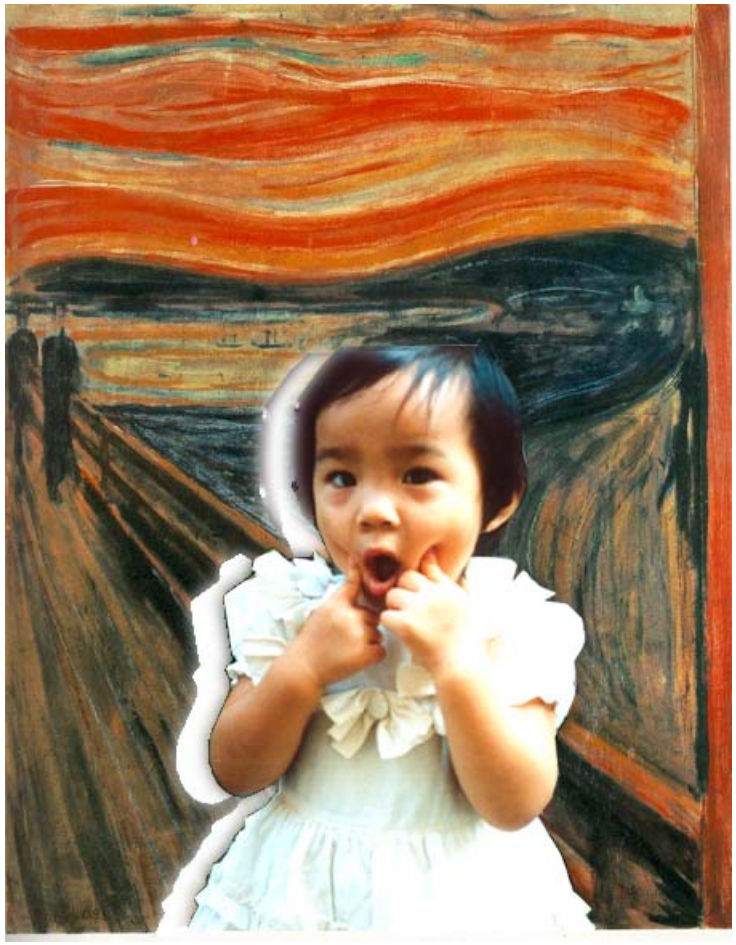
Nano Devices for Brain-like Computing Systems

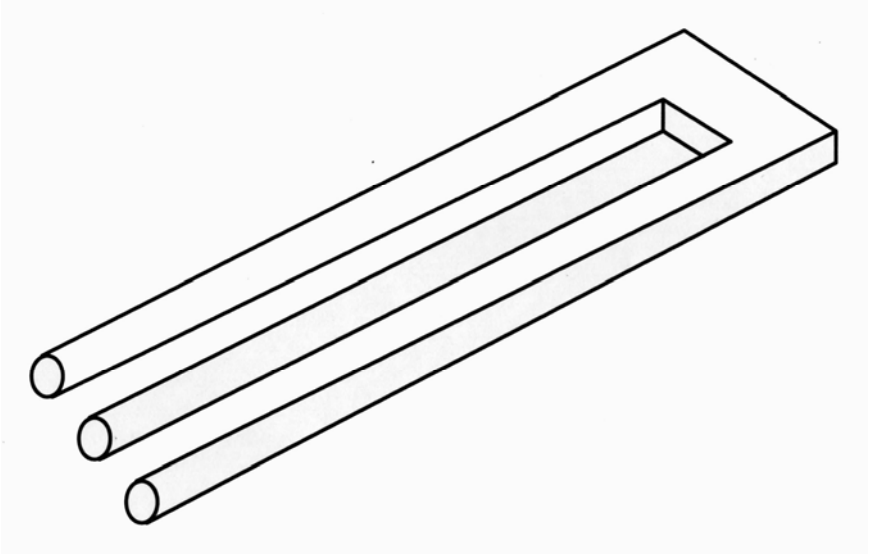
Where doggies ?...



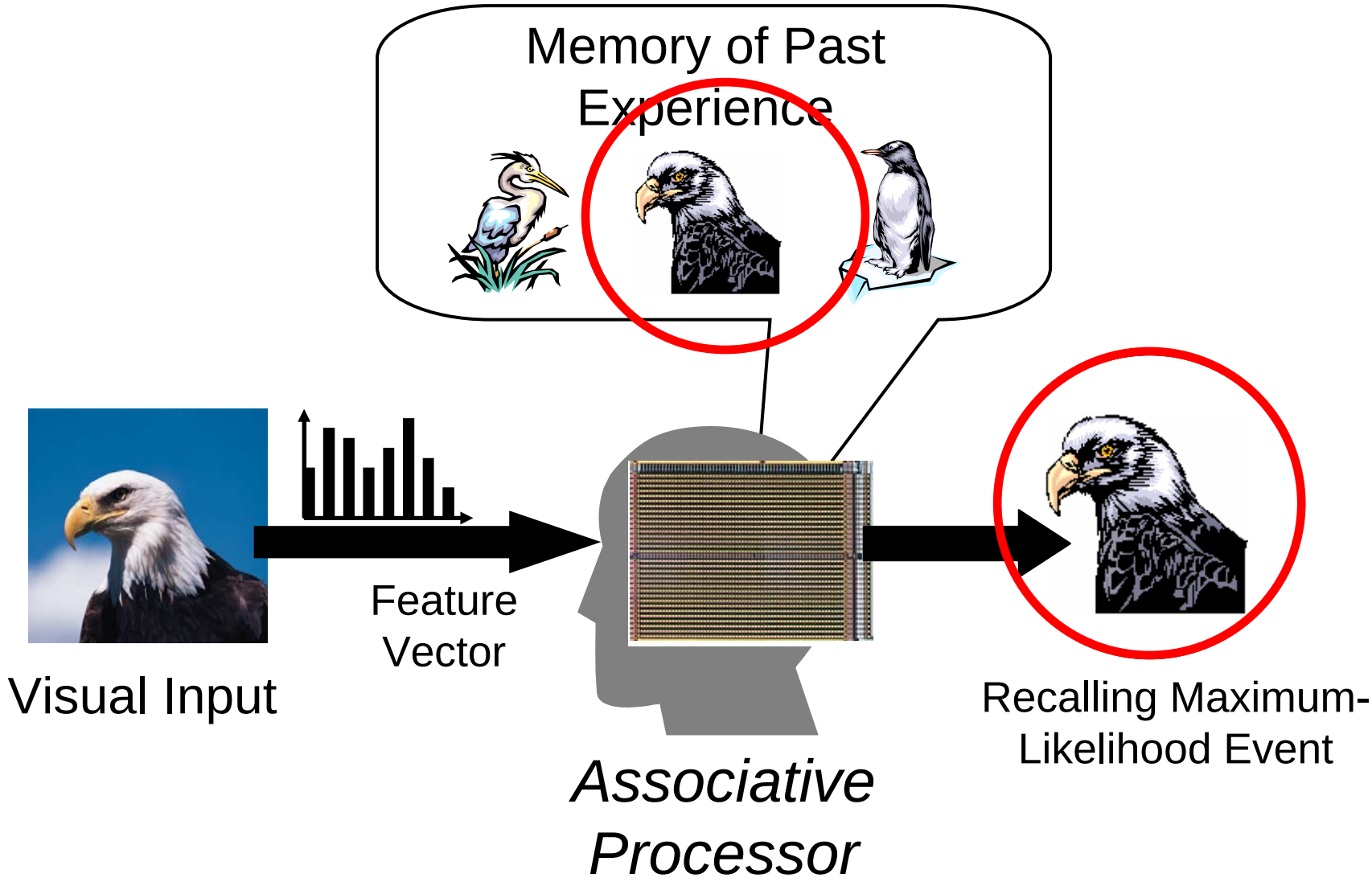
Not Boolean logic, but a new paradigm in computing is in critical demand!!

Automatic Recalling of Past Experience in Subconscious Processing

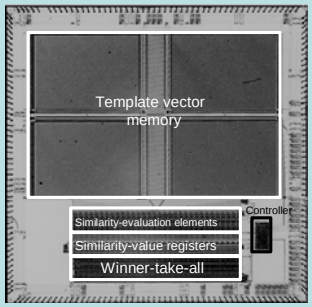


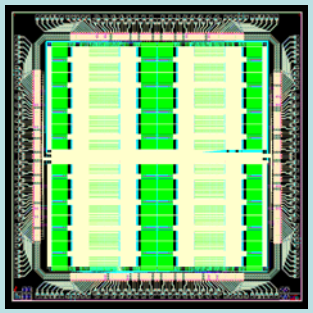


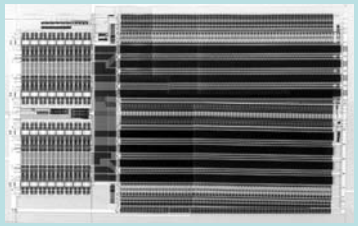
Psychological Brain Model



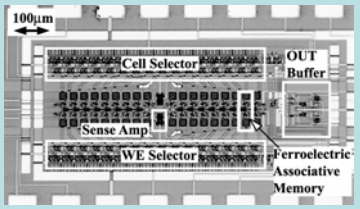
Search for the Most Similar



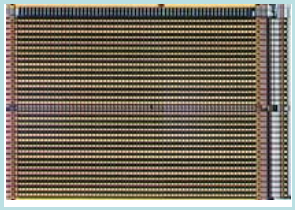




(Analog Flash)



(Ferro-Electric Memory)

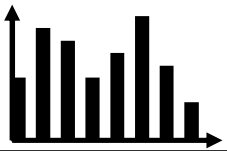


(Resonance Circuits)

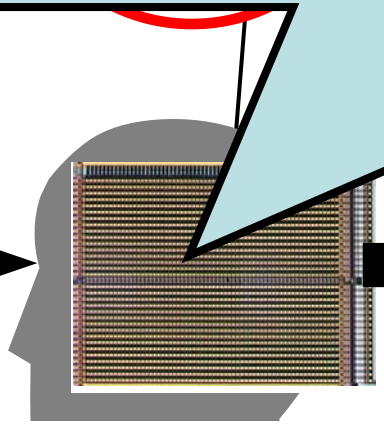
Digital VLSI

Analog VLSI

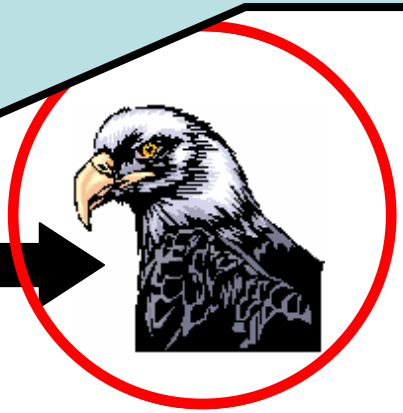
Visual Input



Feature Vector



Associative Processor

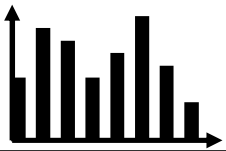


calling Maximum-likelihood Event

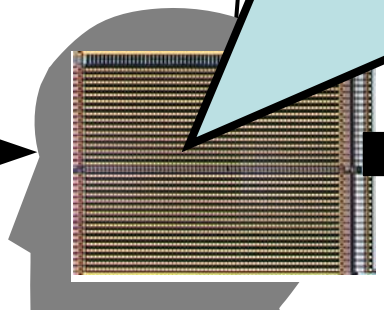
Search for the Most Similar

Association
||
Correlation

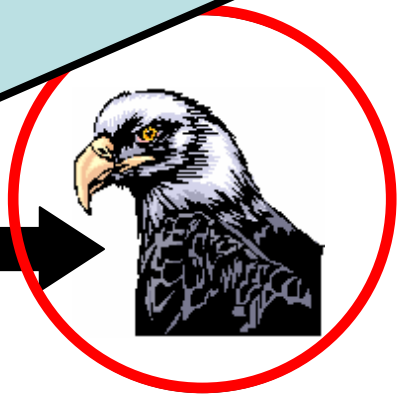
Visual Input



Feature Vector



Associative Processor



calling Maximum-likelihood Event

Correlation is the Key Concept

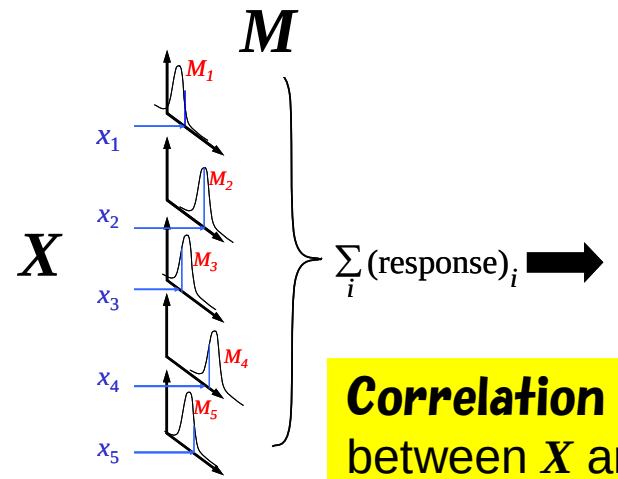
- ***Correlation*** to the Past Experience
  - Associative memory retrieval
  - Recognition & Understanding
- Spatial ***Correlation*** of Local Pixel Intensities
  - Edge detection
  - Image feature representation
- Temporal ***Correlation*** of Moving Images
  - Motion field generation
  - Motion undestnding

etc. etc. etc. …….

Correlation by Nano Functional Devices

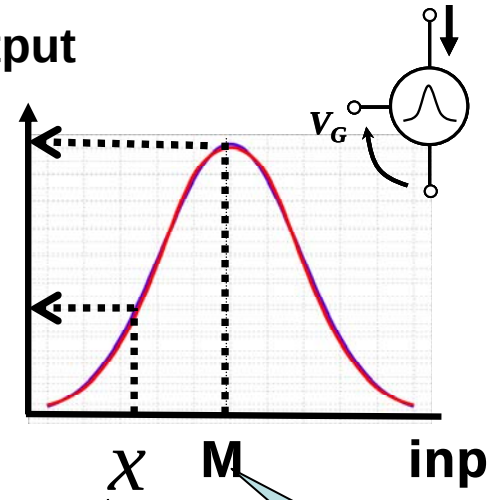
Quantum Resonance Characteristics for **Correlation**

(T. Yamasaki, T. Shibata, iscas 2001)



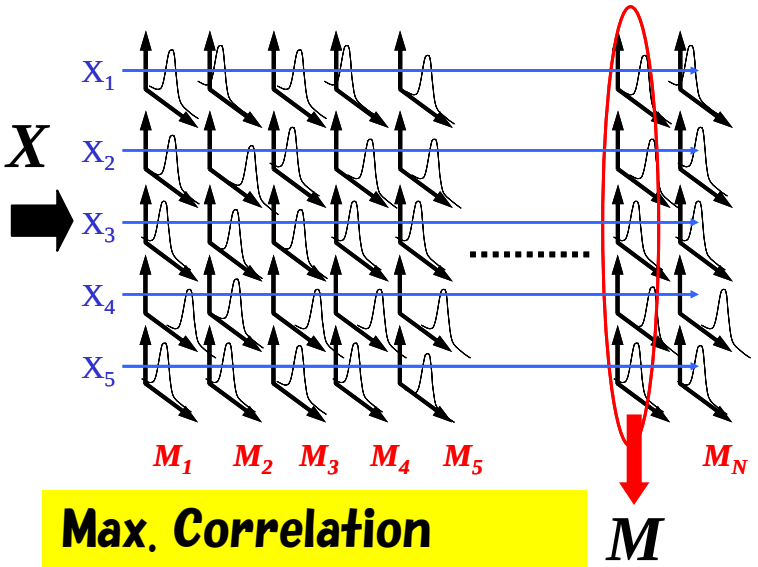
Correlation
between X and M

Correlation



Input Data

Memorized Template

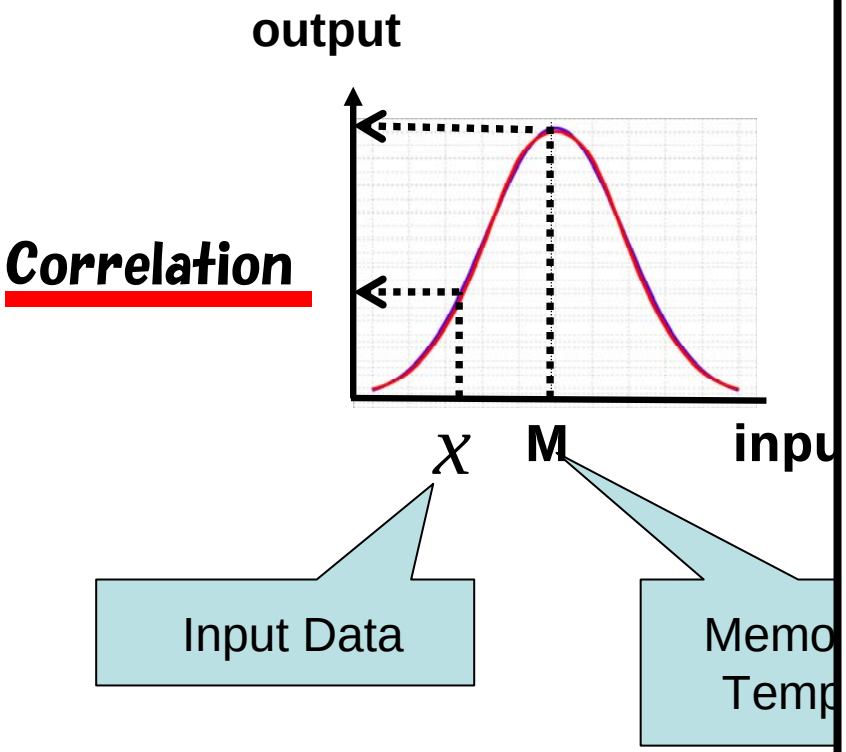


Max. Correlation
yields memory retrieval

Correlation by Na

Quantum Resonance Characteristics for **Correlati**

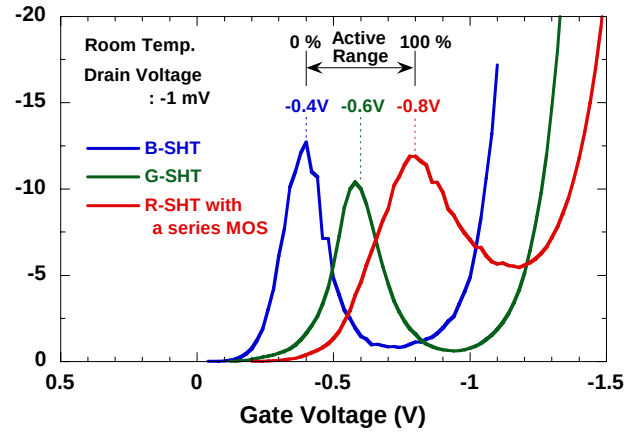
(T. Yamasaki, T. Shibata, iscas 2001

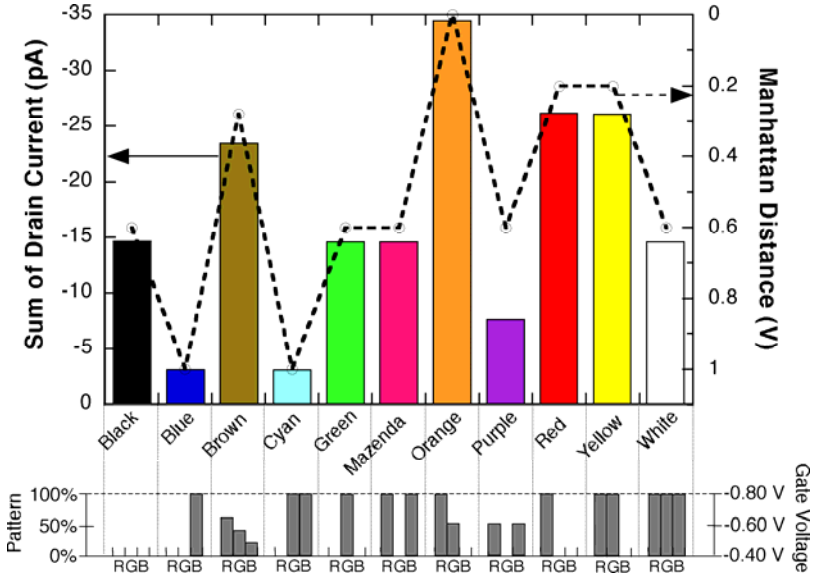


Color Cognition by Single-Electron Transistor Associative Processor

Prof. T. Hiramoto (U. Tokyo)

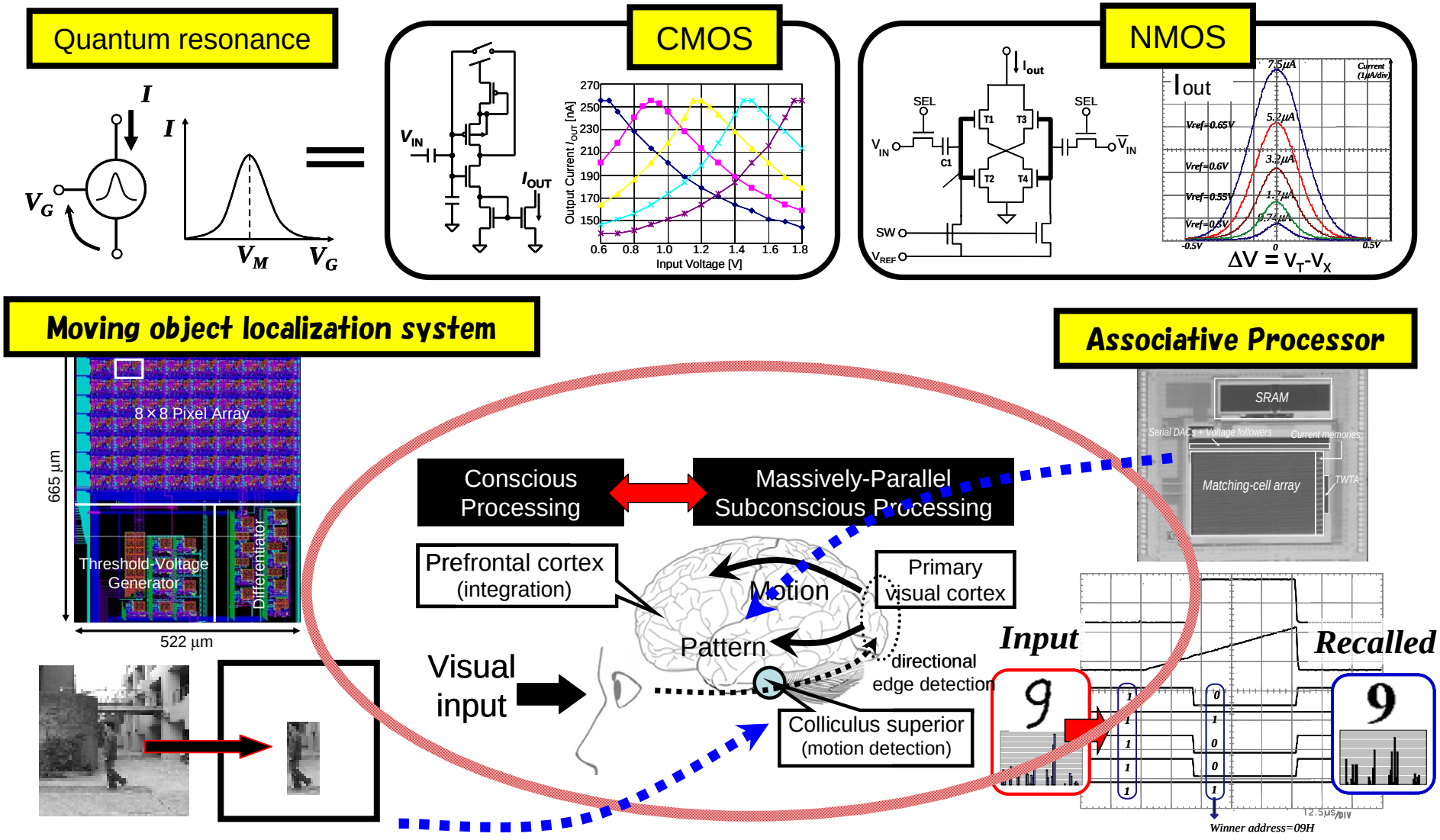
(M. Saitoh et al., IEDM, p. 187, 2004)

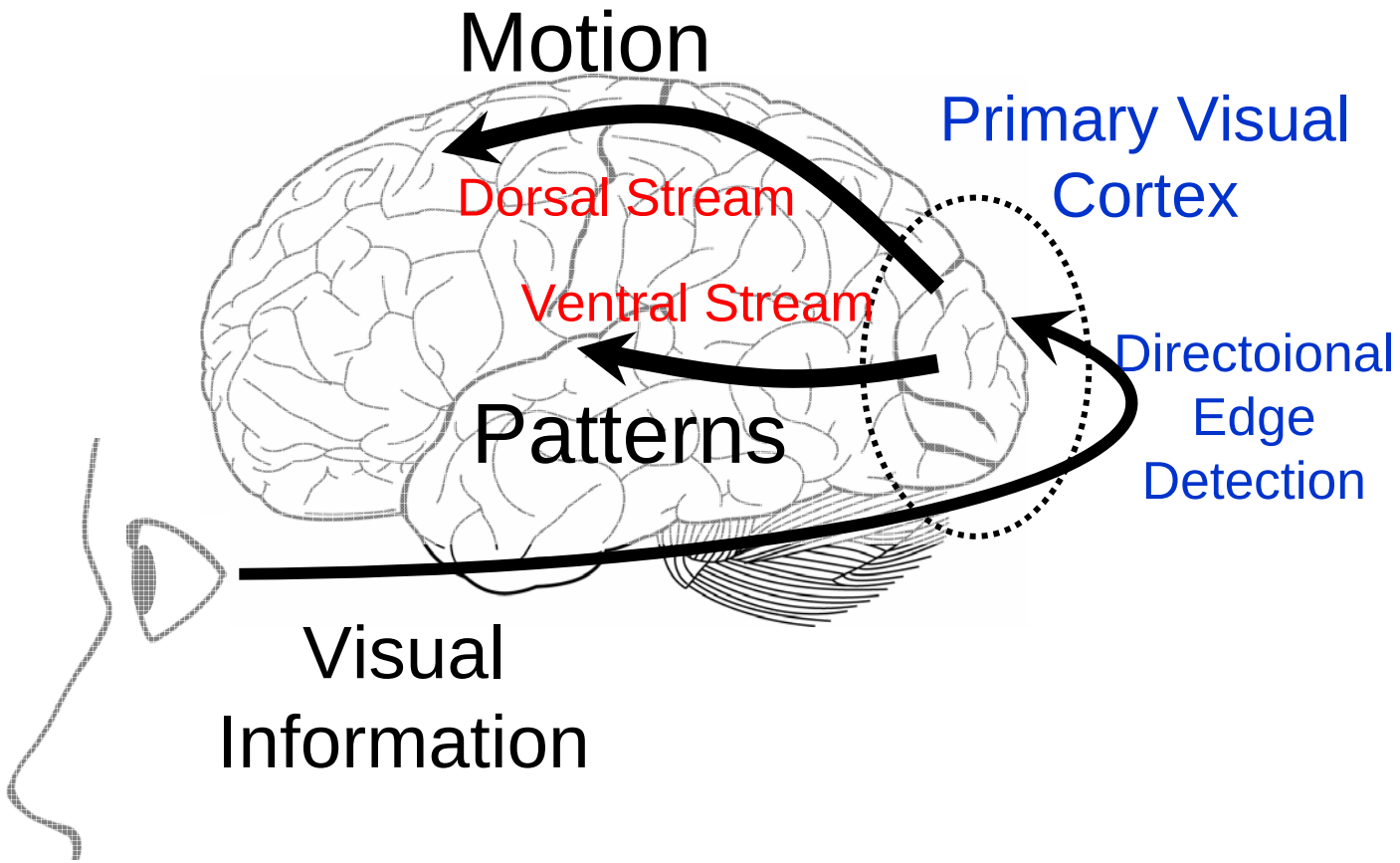




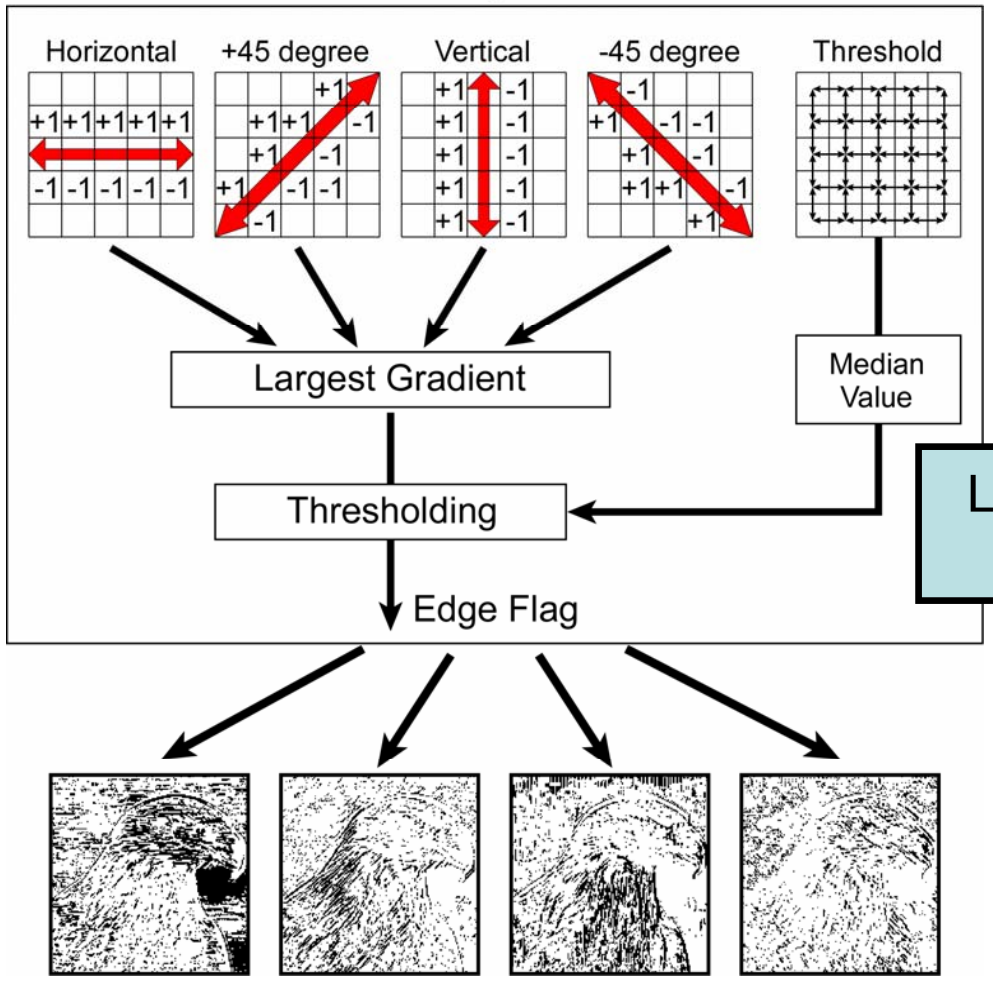
“A Psychologically-Inspired Brain Model Architecture for Nano Functional-Device-Based Intelligent Systems”

Tadashi SHIBATA, The University of Tokyo




Motion
Primary Visual Cortex
Dorsal Stream
Ventral Stream
Directoional Edge Detection
Patterns
Visual Information

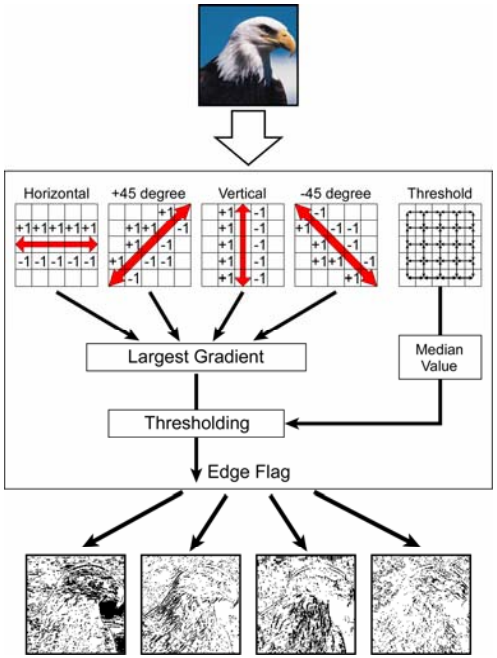
64X64 Recognition Window

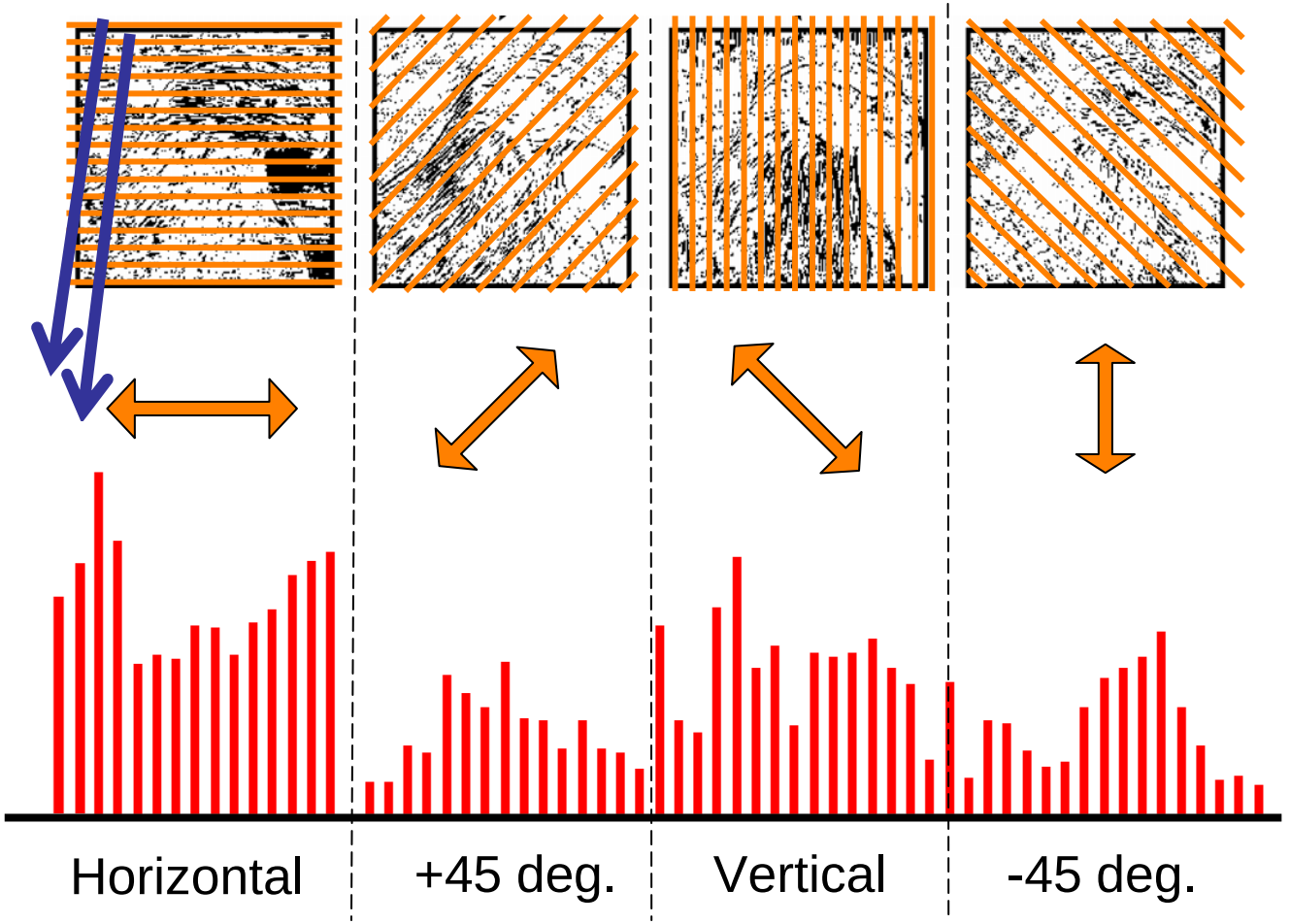


Locally Adaptive Threshold

Projected Principal-Edge Distribution (PPED) Vectors

T. Shibata, M. Yagi, and M. Adachi, Proc. 2nd Int. Conf. Information Fusion, California, July, 1999.





Applications Examples

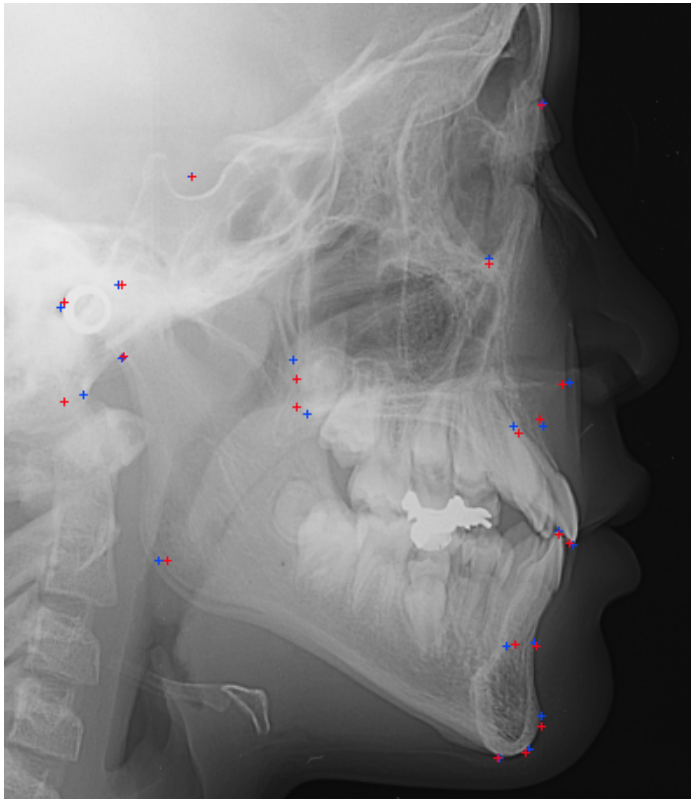
Static Image Perception

- Hand-written pattern and character recognition
- Medical radiograph analysis
- Face detection & identification
- Hand gesture recognition
- Landscape recognition

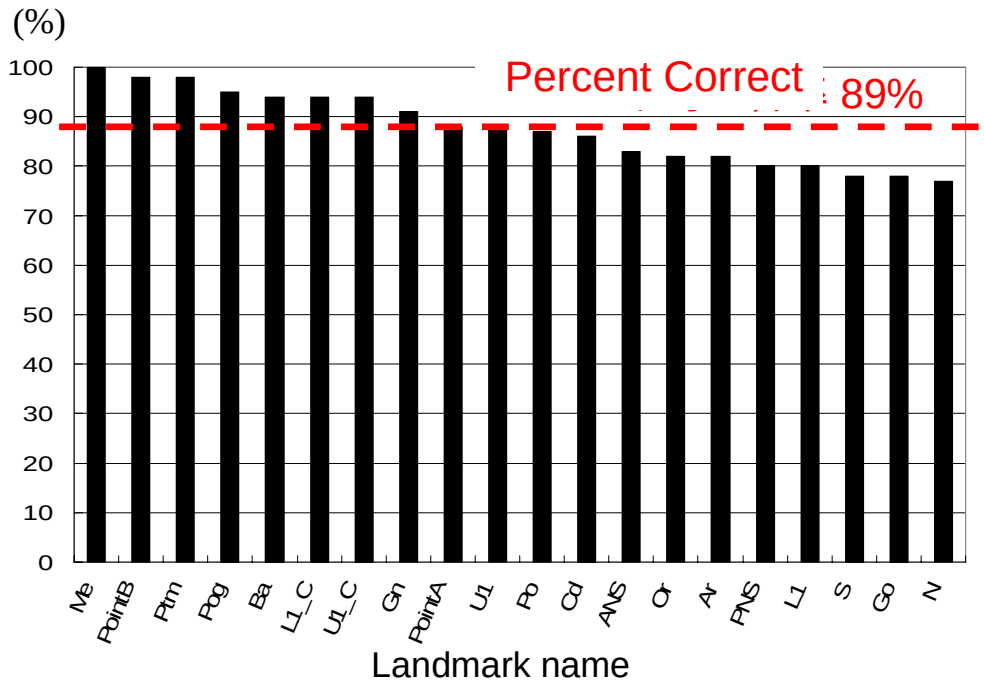
Moving Image Perception

- Ego-motion detection
- Object tracking
- Gesture perception

Cephalometric Landmark Identification

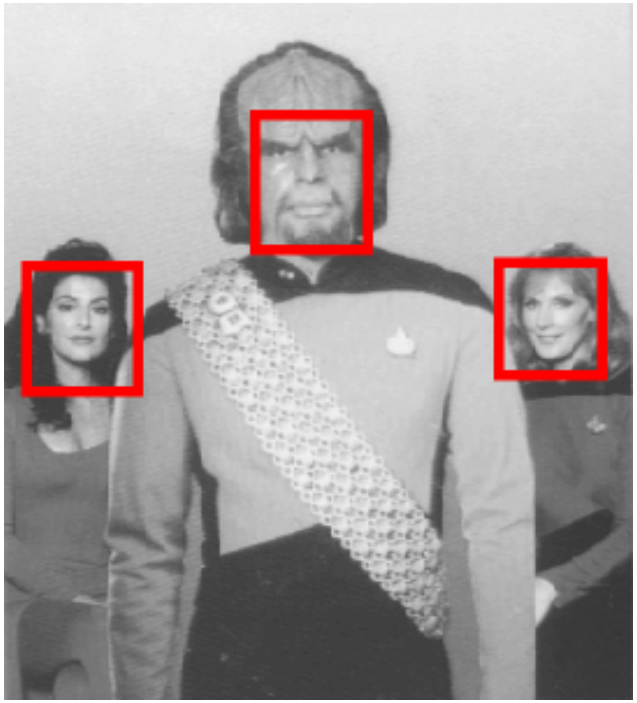


Location Identification: 100%

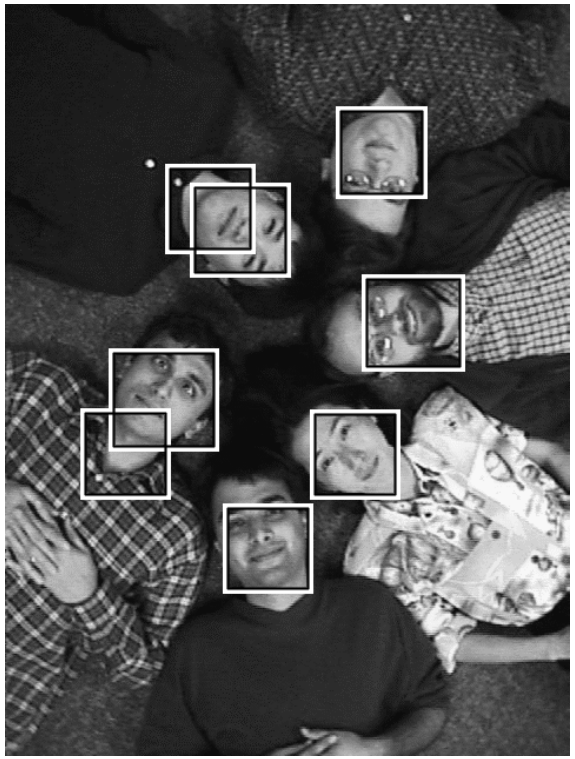


In collaboration with Prof. K. Takada, Dept. Dentistry, Osaka University

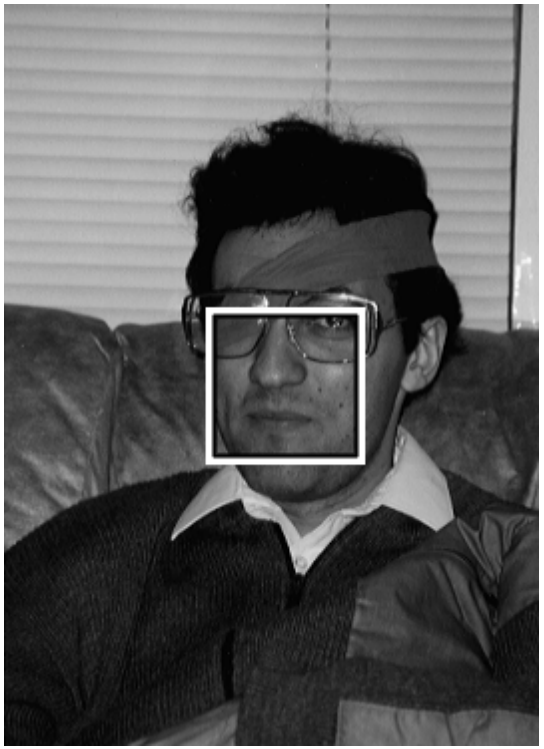
Robustness in Detection



Scaling

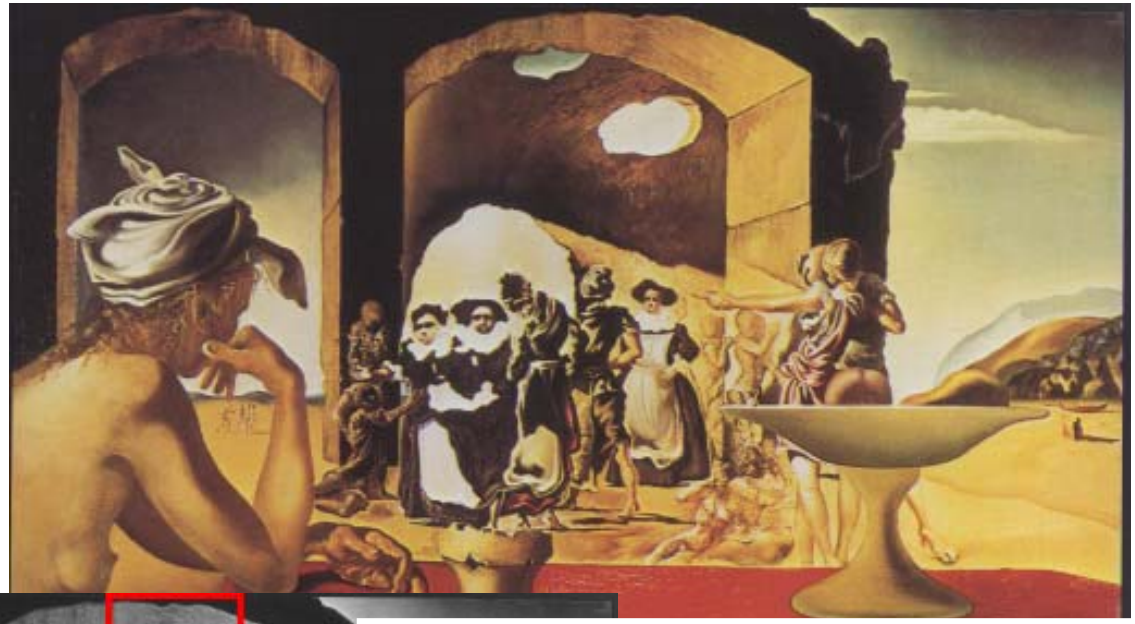


Rotation

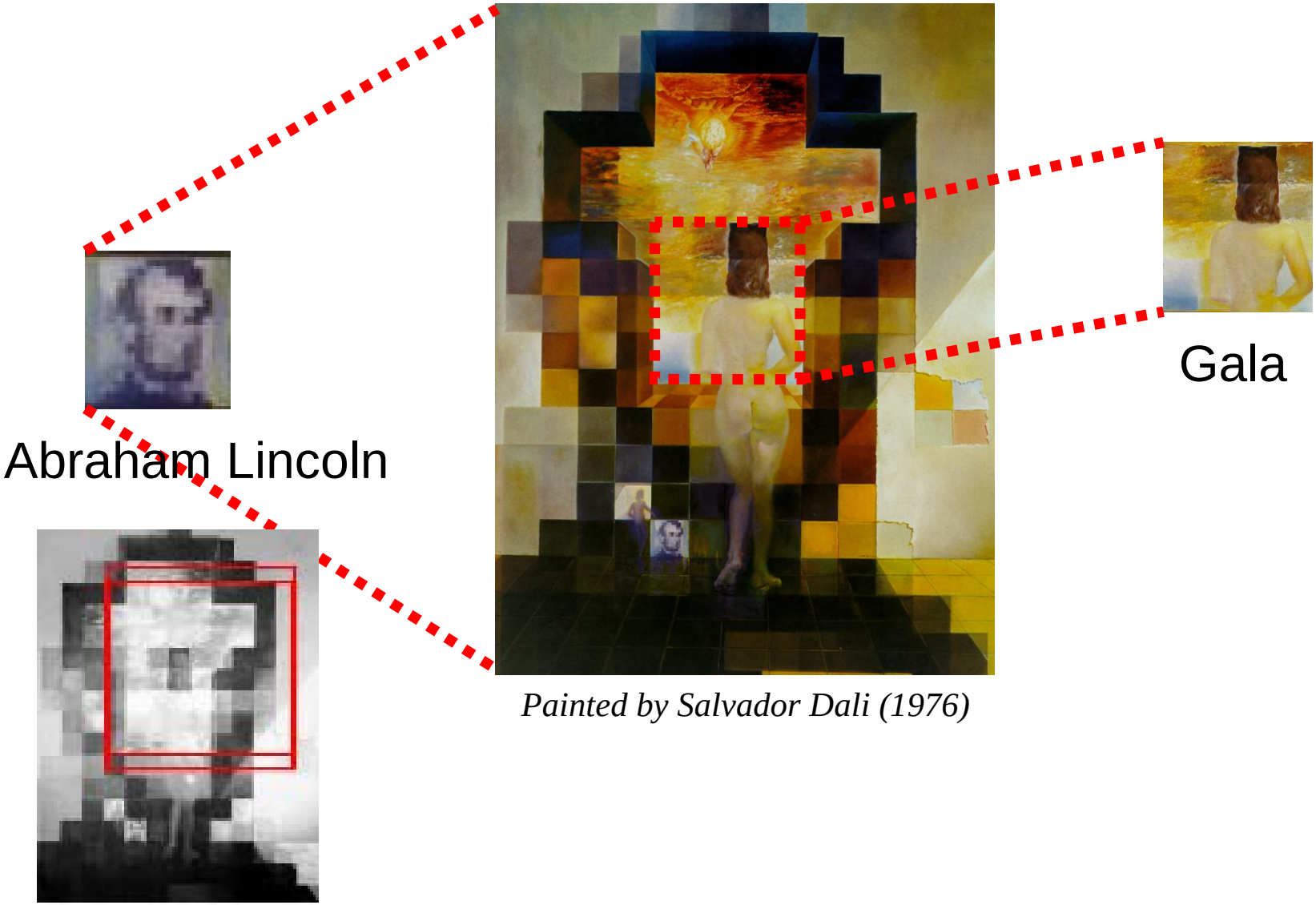


Occlusion

"Face" Samples are from 300 Japanese people（HOIP Data Base）



Multi-Resolution Image Perception



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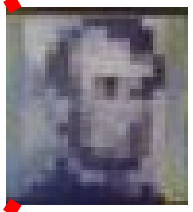
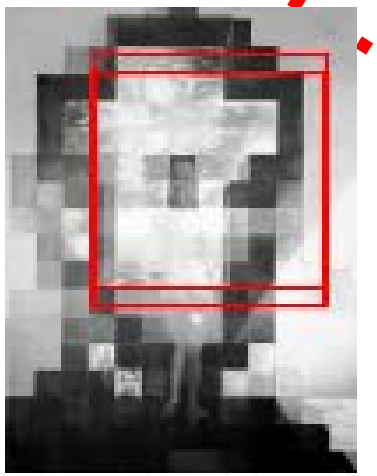
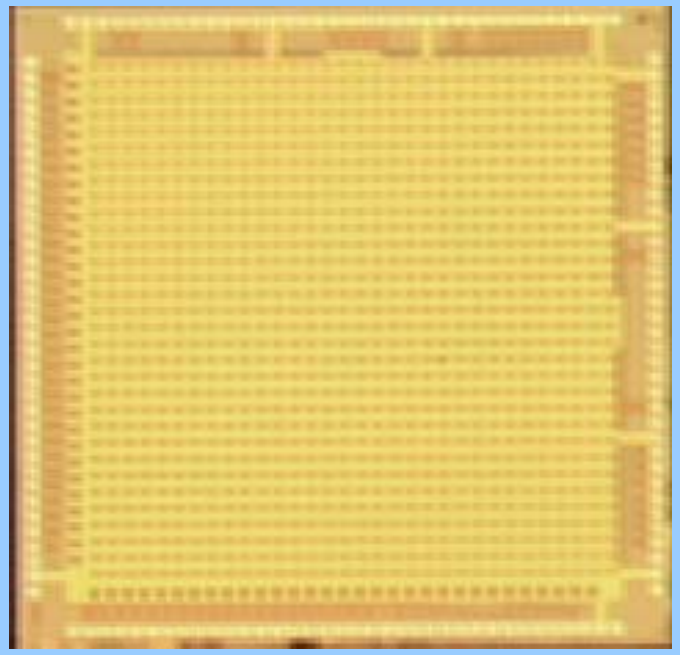


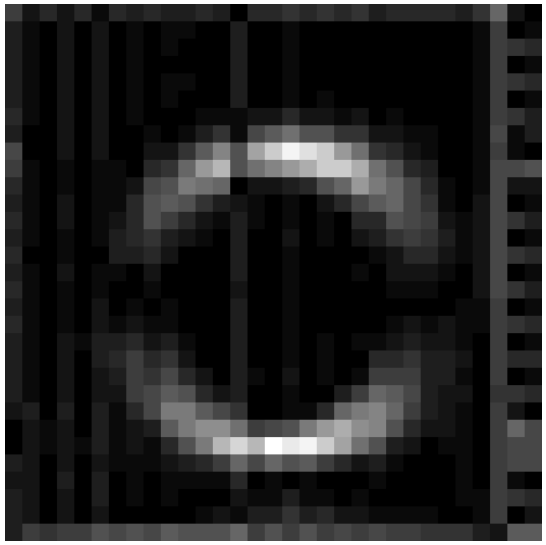
Abraham Lincoln



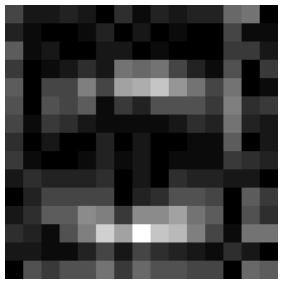
CMOS Image Sensor for
Variable-Resolution Edge Detection
Employing “Self-Similitude Architecture”
(N. Takahashi et al. ISCAS 2008)



Light Bulb Imaging (Horizontal Edge)

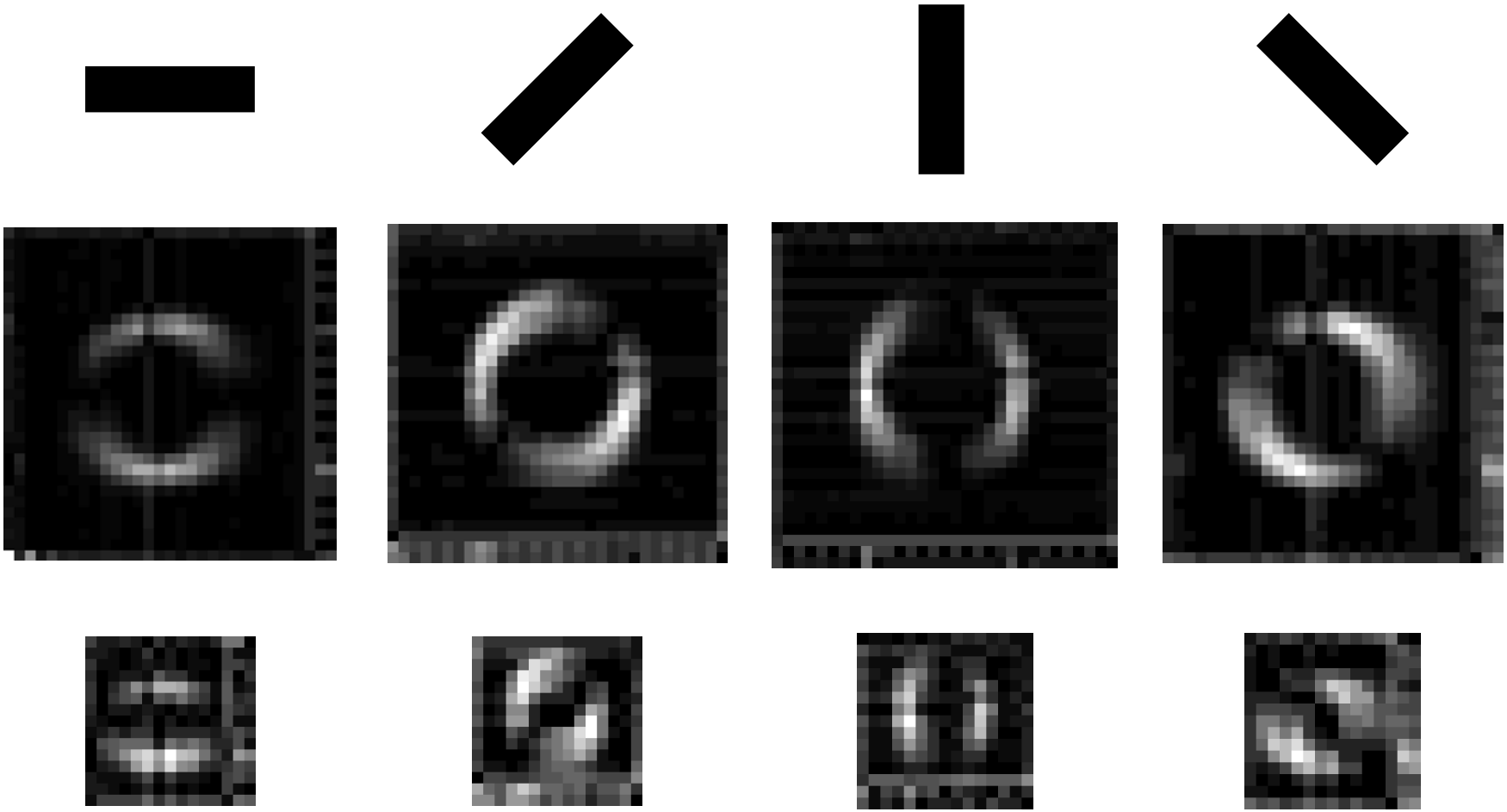


Full Resolution

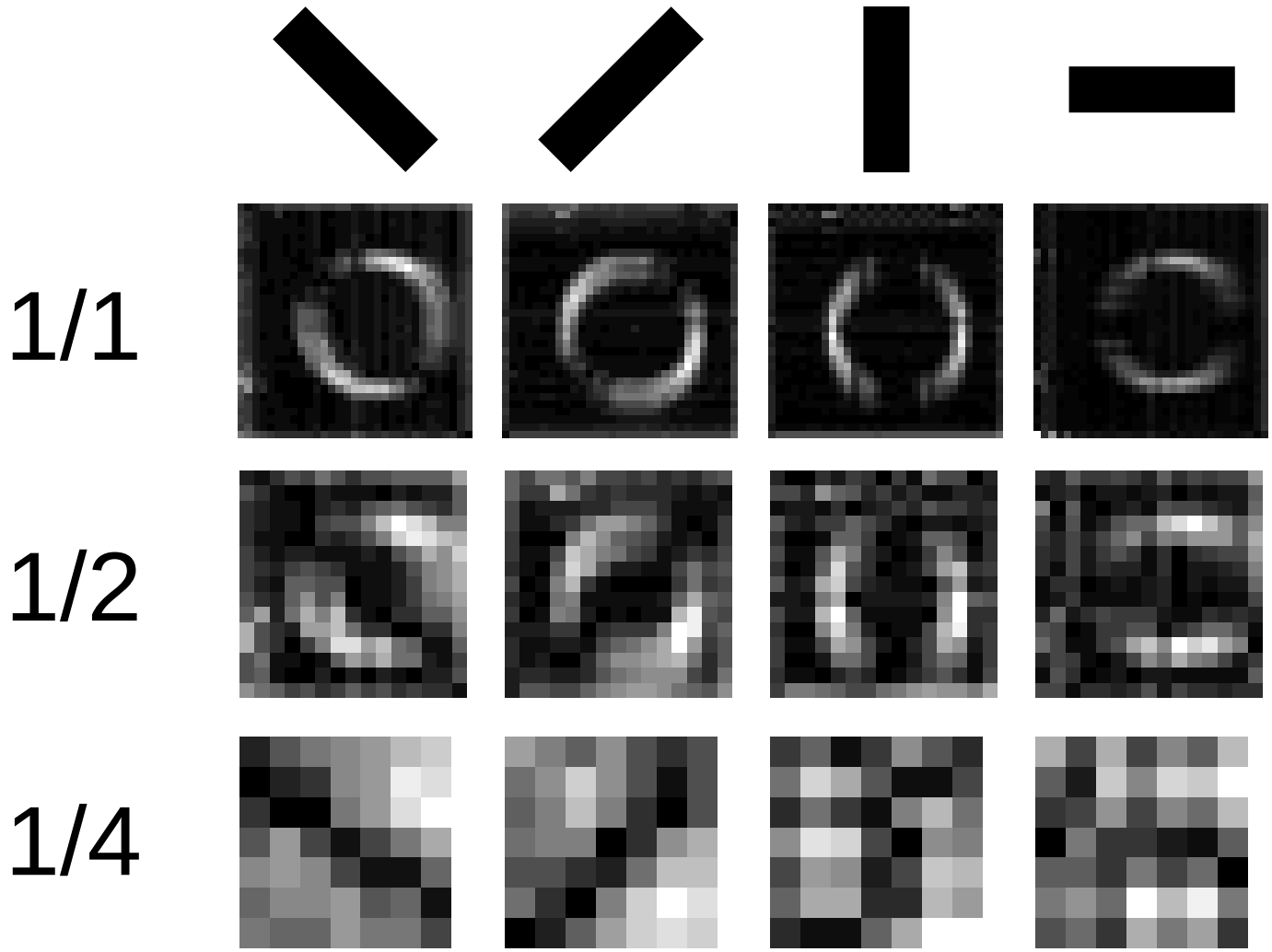


1/2 Resolution

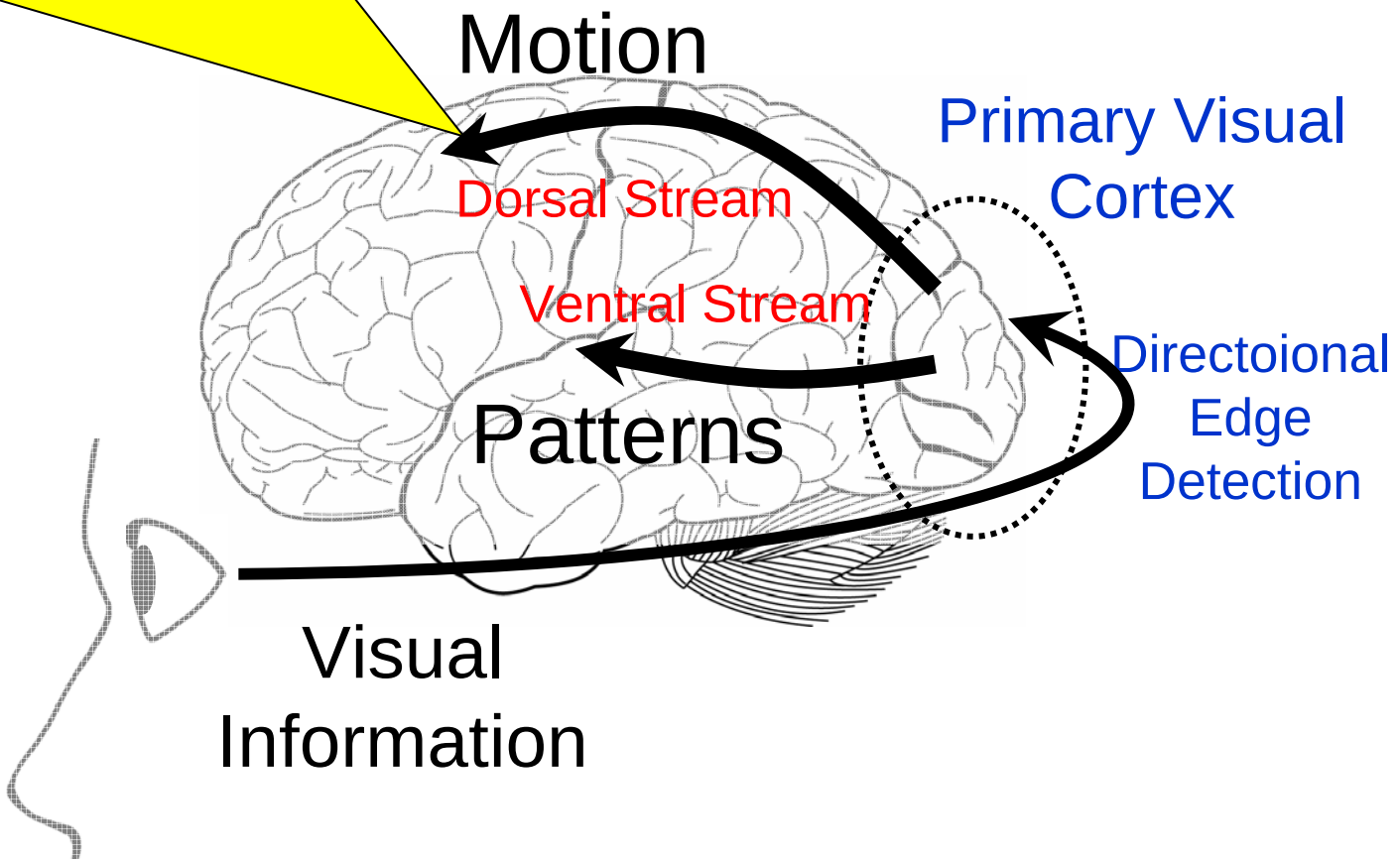
Light Bulb Imaging



Edge Filtering Images



Feature-Based Motion Field Generation Using Directional Edges

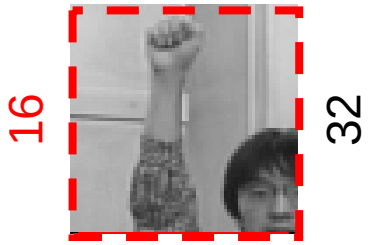


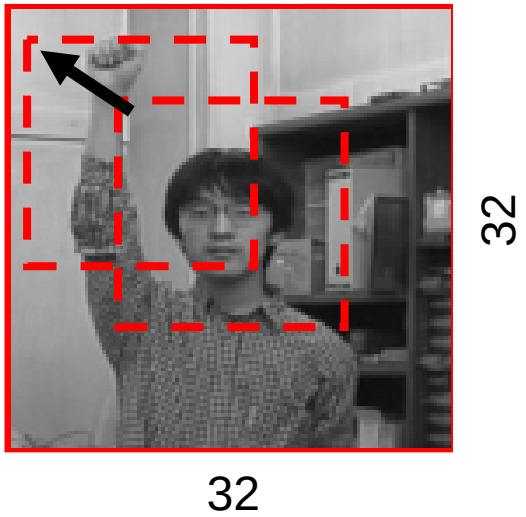
Feature Based Motion Vector Detection (Block Matching)

Search Area

@ t

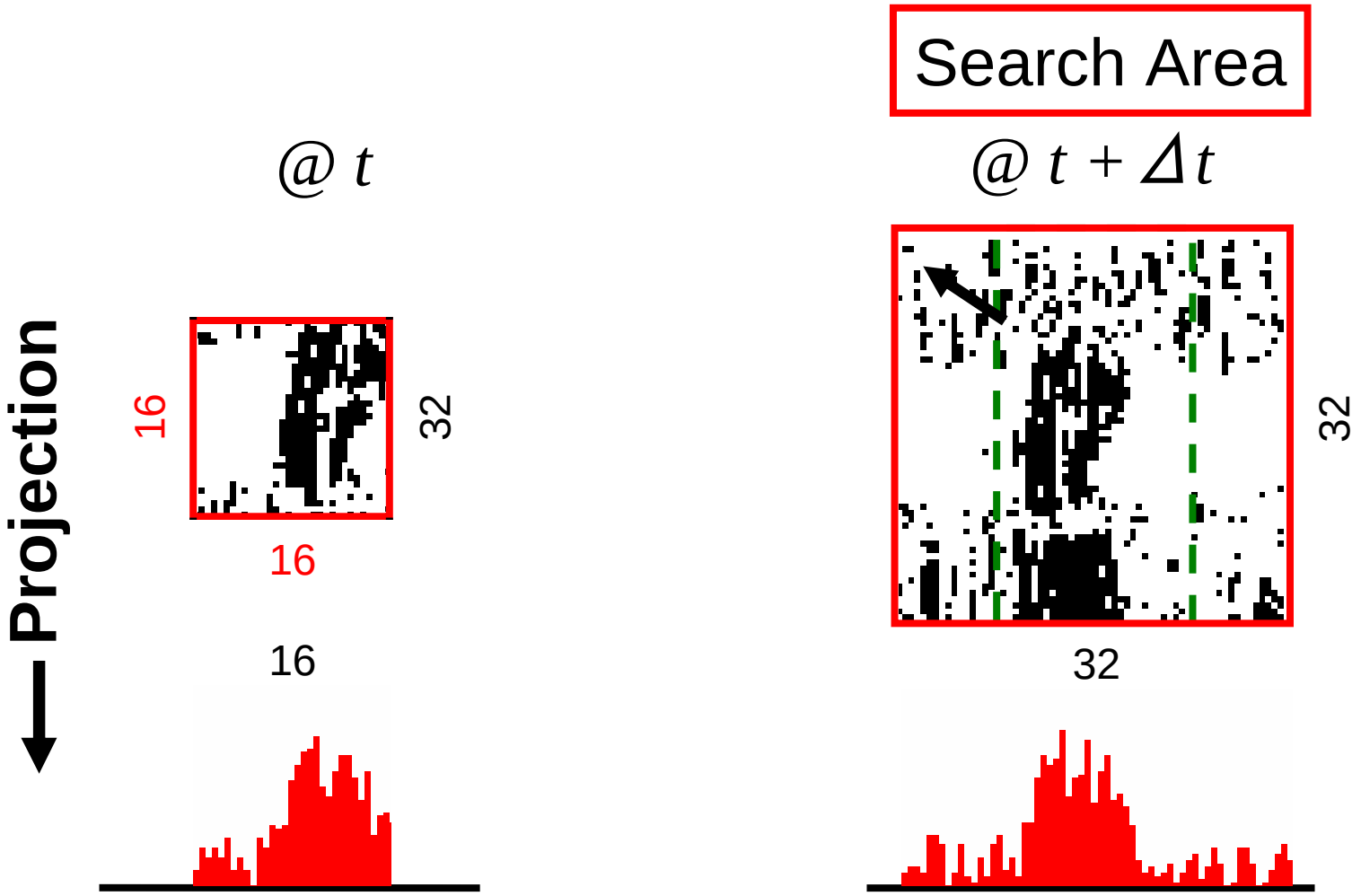
@ $t + \Delta t$





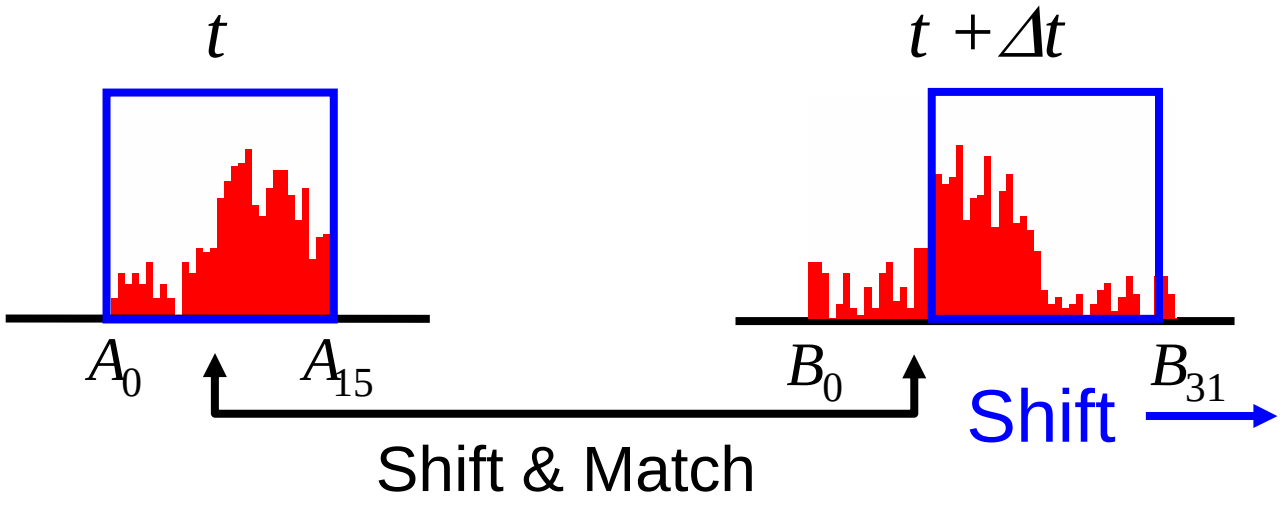
$O(N^2)$: *Computationally very expensive*

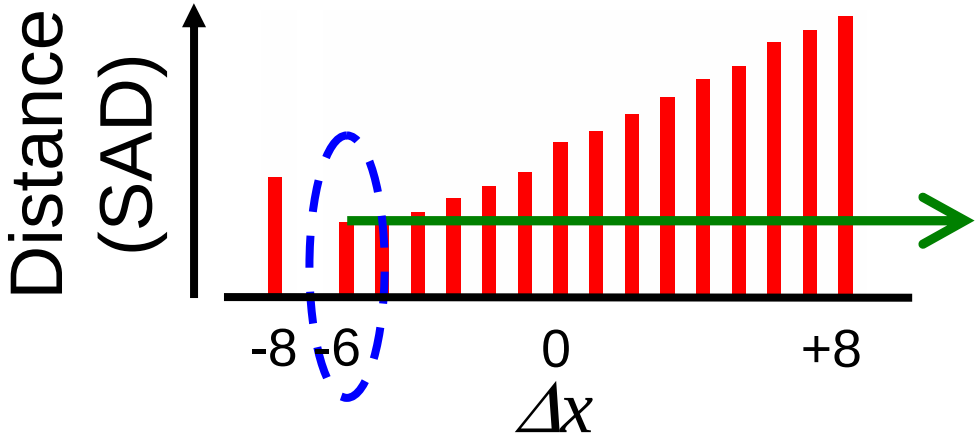
Feature Based Motion Vector Detection (Block Matching)



Shift & Matching of Directional Edge Histograms

J. Hao and T. Shibata, ICASSP 2006

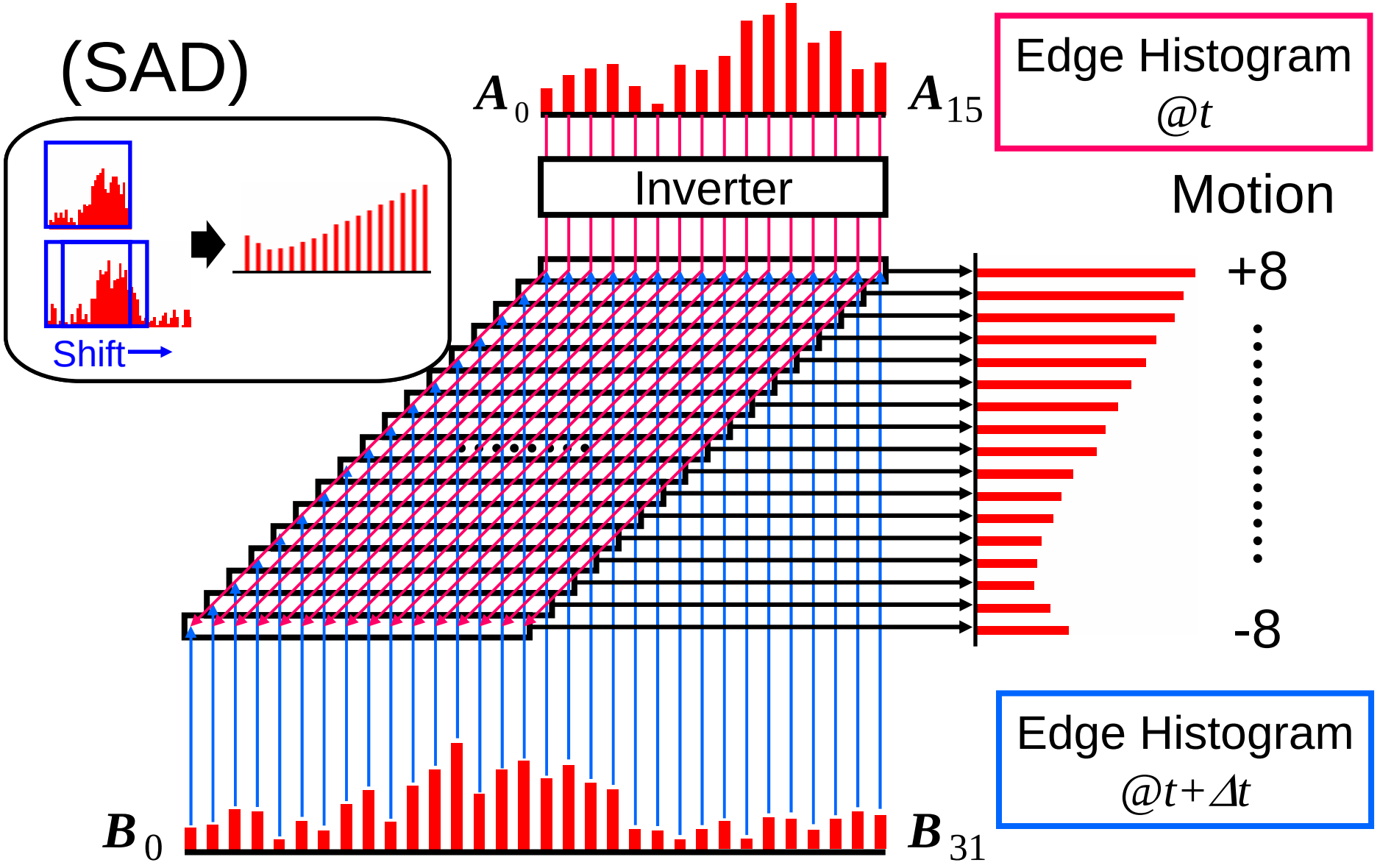




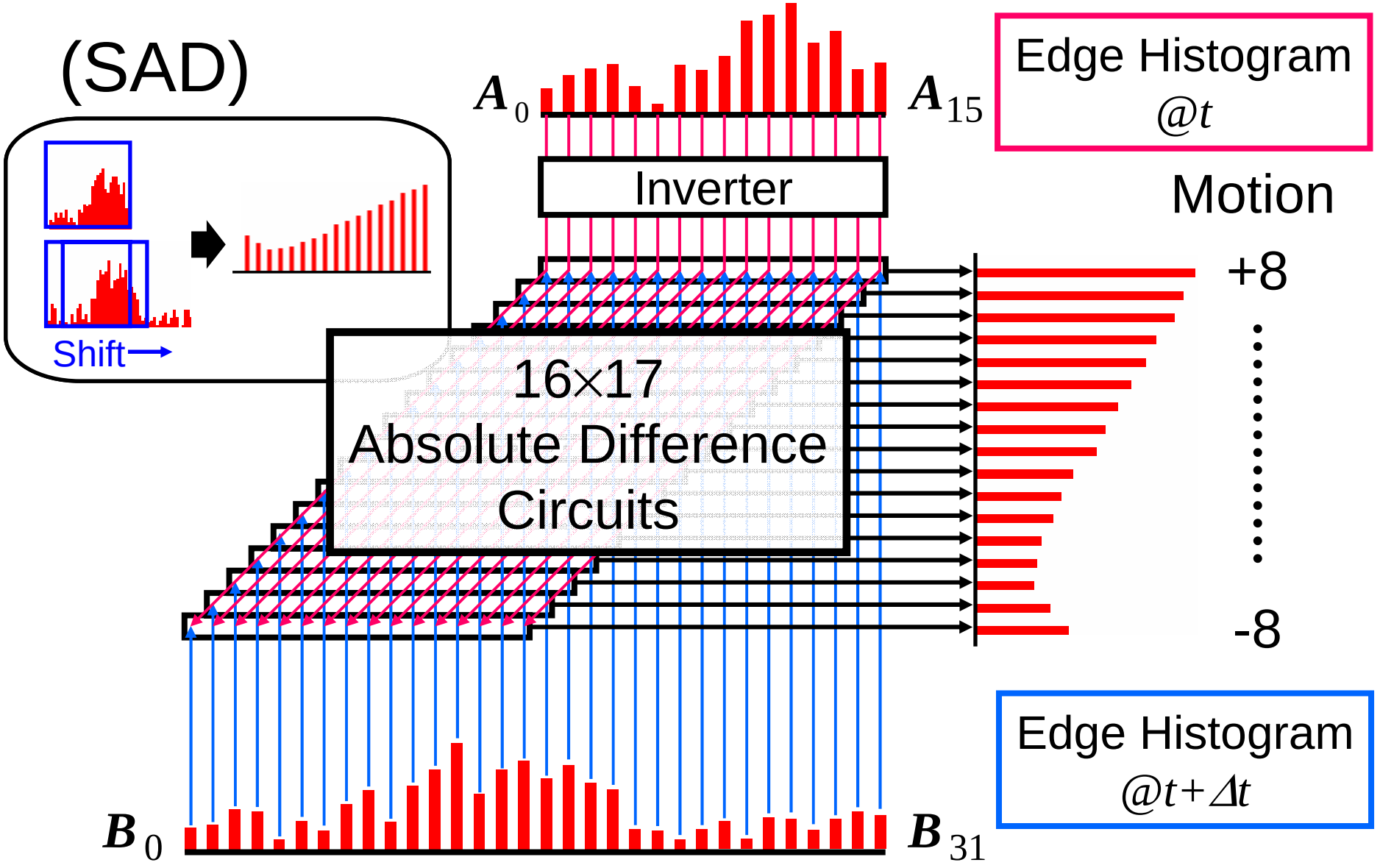
Motion Vector:
the best matched location.

$O(N)$

Fully Parallel Shift & Matching Circuit

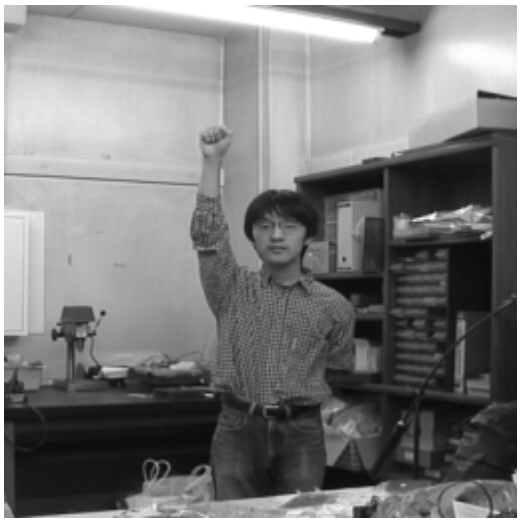


Fully Parallel Shift & Matching Circuit



Chip Measurement Results

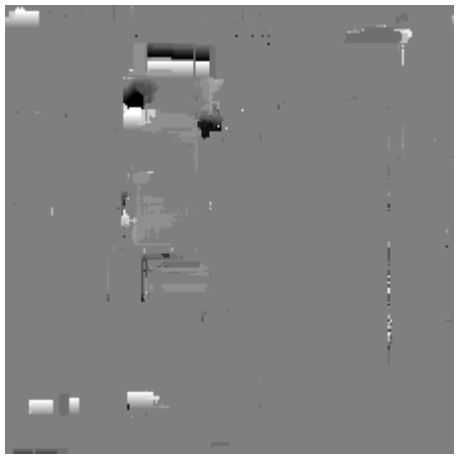
Original Image

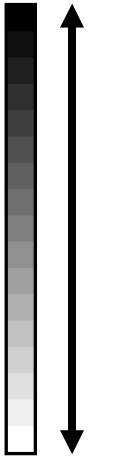


x - Motion

-8 +8

y -Motion

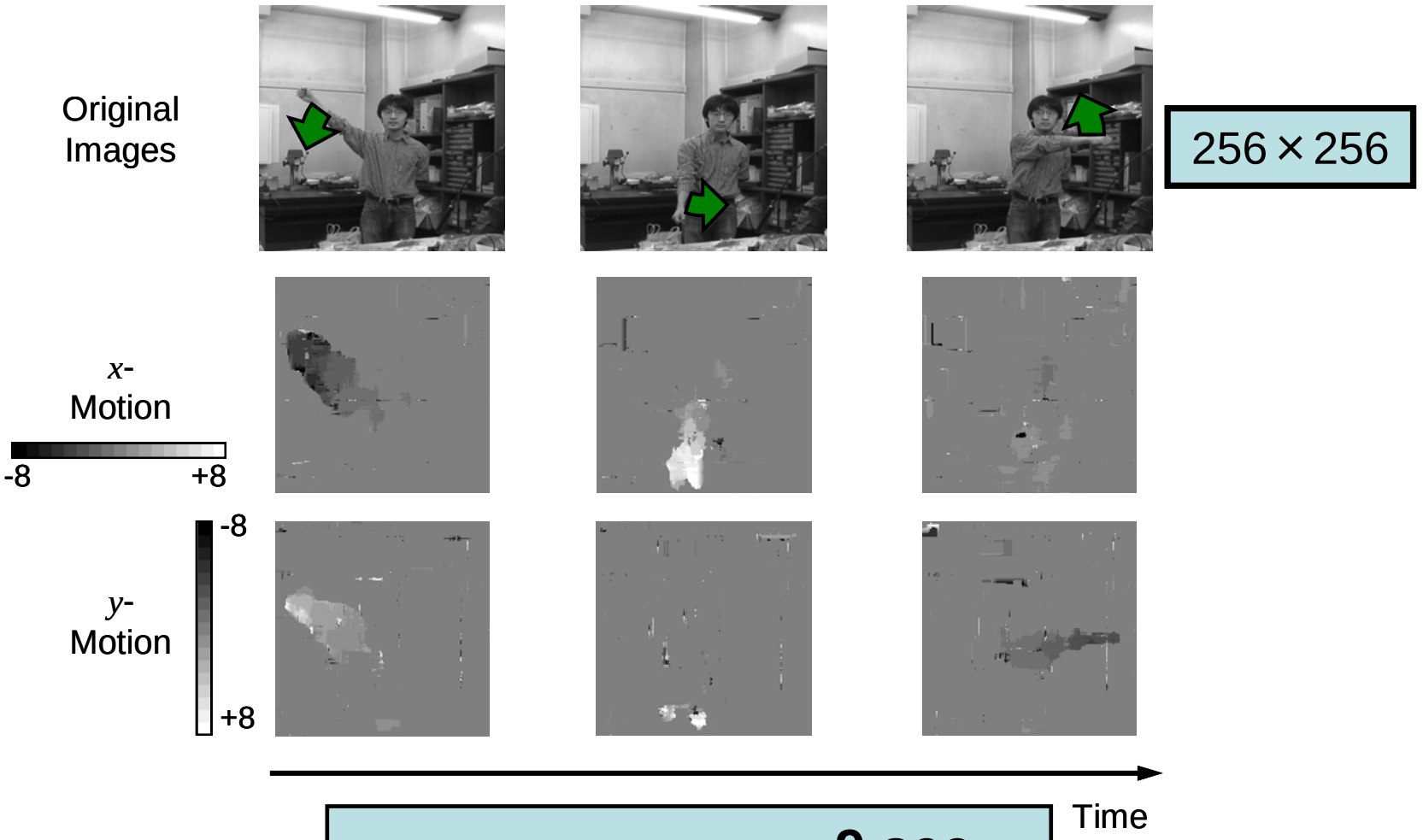




-8 +8

@20MHz
97Frames in 1Cycle

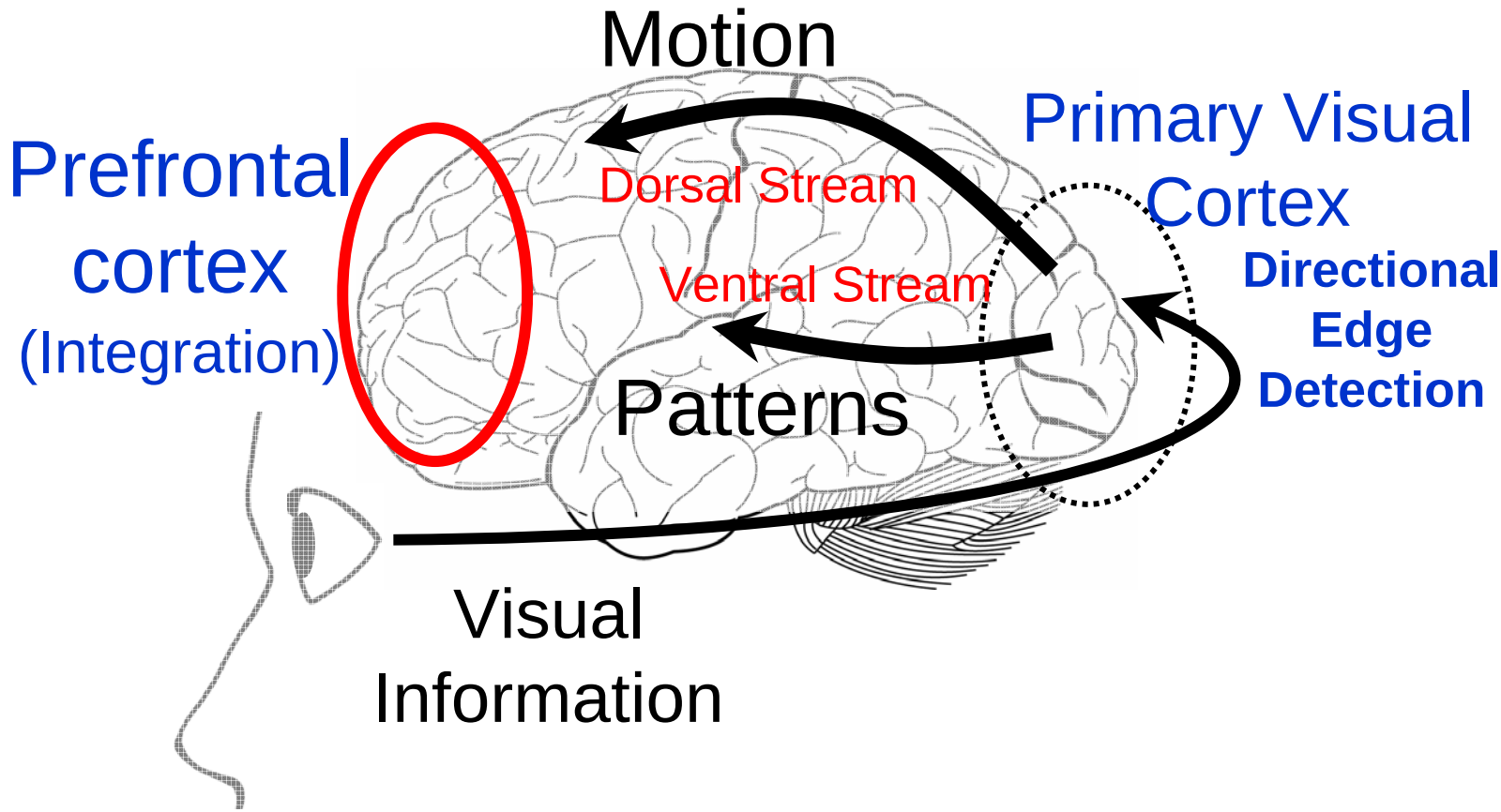
Measurement Results



Regular CPU @2.8GHz	**9 sec**
Present Chip @20MHz	**5.8 ms**

Conscious Processing

Massively Parallel Unconscious Processing



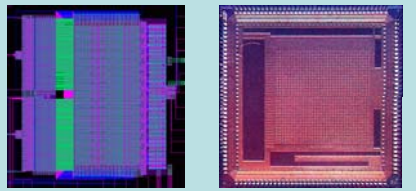
Conscious Processing

Massively Parallel Unconscious Proc

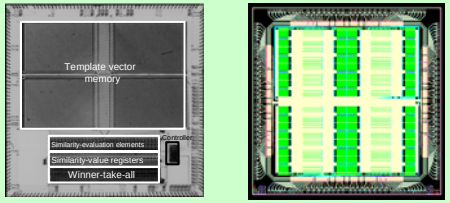
Motion

Prefrontal cortex

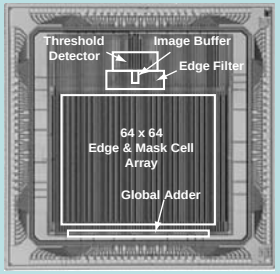
(Integration)



Motion field generator chips

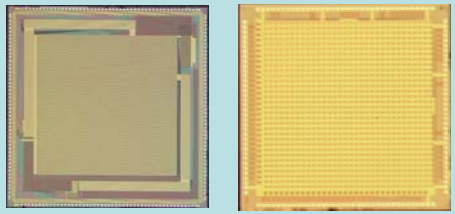


Associative processors for perception

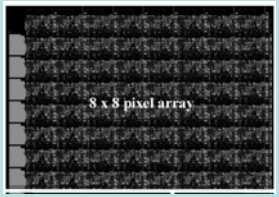


Edge detection & vectorization

"If-then-else" type processing by general purpose CPU



CMOS image sensor chips for filtering



Moving object detection & localization

Conclusions

- Nano functional devices for *brain-mimicking system*.
- *"Correlation" by resonance* characteristics:
  - Associative memory retrieval
  - Edge detection, Motion detection
  - Image recognition, Behavior recognition
- *Unconscious mind processing by massively-parallel architectures* of nano-functional devices: overall judgment of the situation matters (non rigorous logic).
- Conscious mind processing by traditional CPUs.