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New Application Areas Made Possible by High Speed Vision

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Hierarchical Parallel System

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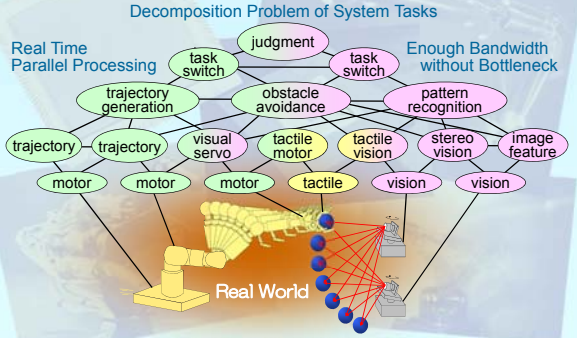
Hierarchical Parallel Distributed System with High Speed Vision

Decomposition Problem of System Tasks



Task Decomposition

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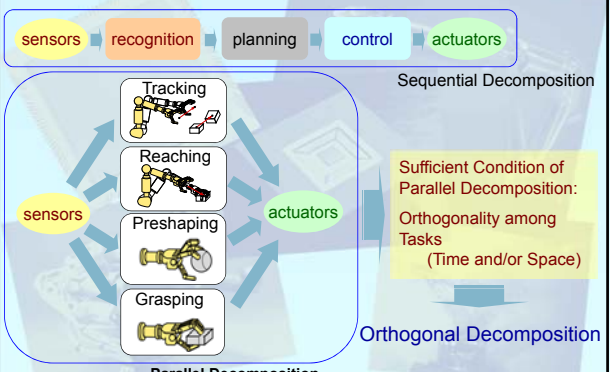

Sufficient Condition of Parallel Decomposition:

Orthogonality among Tasks (Time and/or Space)

Orthogonal Decomposition

Dynamics Matching

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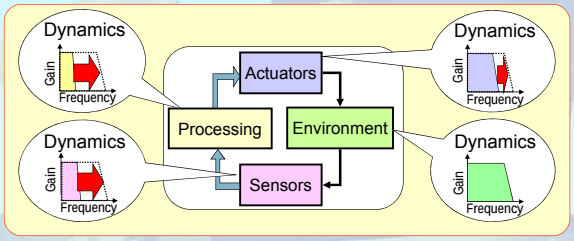

Artificial elements, i.e. sensors, actuators, and processing modules should be designed for realizing enough dynamics matched with the dynamics of object and environment.

→ Performance up of sensors, actuators, and processing modules

→ Keep the sampling theorem

High Speed Image Processing

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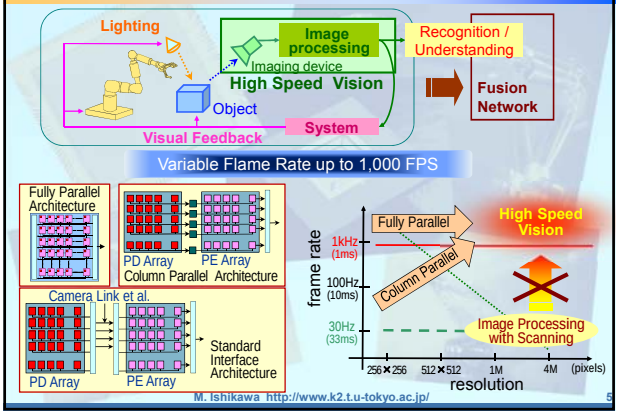

Architecture of Vision Chip

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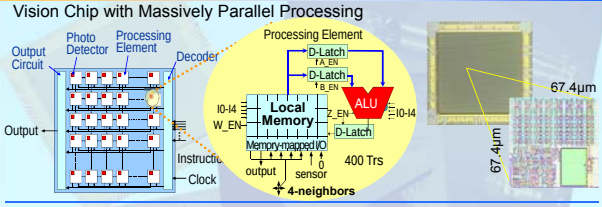
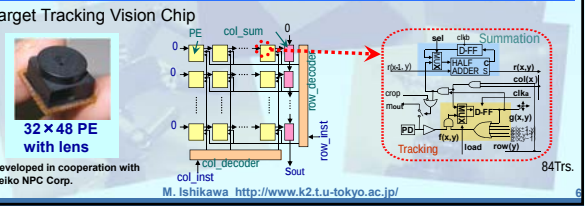
Vision Chip with Massively Parallel Processing

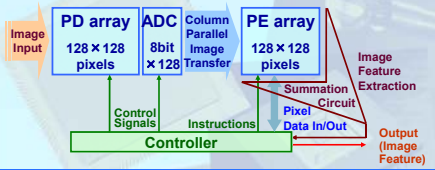


Target Tracking Vision Chip



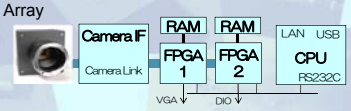
Imager + PE Array

Column Parallel Vision with Massively Parallel Processing



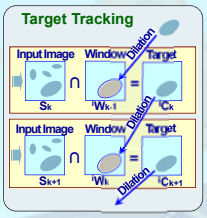
Developed in cooperation with Hamamatsu Photonics K.K.

Imager + Reconfigurable PE Array

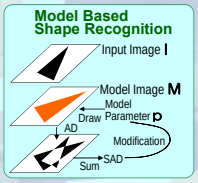


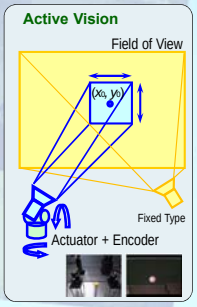
1,280×1024 pixels 500 fps
1,280× 512 pixels 1,000 fps
Interface: Ether net, USB, etc.
Camera Link Full (650MB/s)

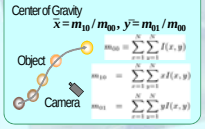
High Frame Rate Vision

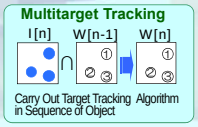


High Frame Rate Makes Algorithms Simple!
Sampling Theorem in Image Space





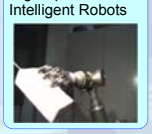




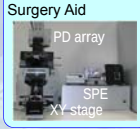
Applications

Human Interface
Input Devices for Computers / Games

Robotics
High Speed Intelligent Robots



Bio / Medical
Remote Medical Care Surgery Aid

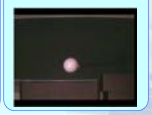


Inspection
High-Throughput Product Lines

Vehicle
Intelligent Vehicle ITS / Air Craft

Security
Human Tracking Motion Detection

Media
Object Tracking Video Control



Nano / Micro Machine
Position Control
Object Detection

e-Books
High Speed Scanning

Other Applications where VIDEO rate vision is slow.

High Speed Gesture UI 1

Gesture Recognition

16×16 pixels
1,000 fps
Active Vision
(1994)

Wearable Computer
Ubiquitous Computing
Game / TV Control
Multi Modal Interface

Non-Touch, Cable Free,
High Speed, 3D Input

Perfect Understanding of Human Behavior

Game Control by Gesture

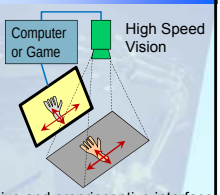
32×48 pixels
1,000 fps
(2002)
Sub-pixel resolution has been performed.

Mouse Operation by Gesture

High Speed Gesture UI 2

High Speed and Low Latency Gesture Recognition

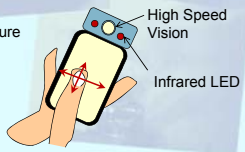
1,000 fps
30ms Total Latency



immersive and proprioceptive interface

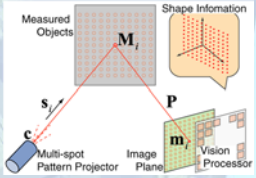
Type in the Air

154 fps
Finger Gesture
Clicking
Typing
3D Input



Multi Target Tracking

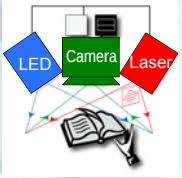
1,000 Objects Tracking at 1,000 FPS



Template Matching for 1,000 Objects

Book Flipping Scanning

Structured Light
3D Shape Measurement
Image Reconstruction



Dynamic Imaging

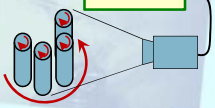
Throwing Camera

High Speed Camera
224 × 64 pixel,
1,000 fps
Mosaicking

Inspection of Rotating Can Surface

Surface Print Inspection
1,000 fps
1280 × 512 pixel
Mosaicking

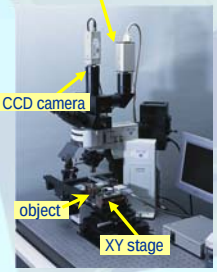
View of a Developed Surface



Micro Visual Feedback

- Microscopic Target Tracking
- Visual Feedback Control of X-Y Stage
- 1ms Feedback Rate

- Microscope Surgery Aid
- Biological Experiment / Inspection
- Nano/micro Machine Control

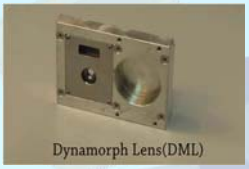


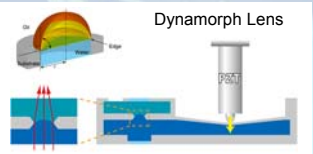
Small Object Tracking (Paramesium) (Ascidian Spermatozoa)

Elimination of Tremor (Surgery Robot)

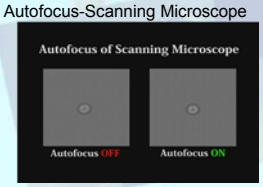
Variable Focus Lens

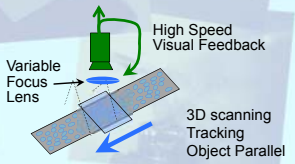
High Speed Variable Focus Lens





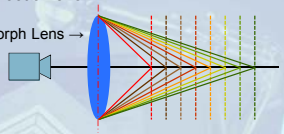
Autofocus-Scanning Microscope





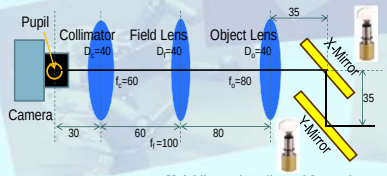
High Speed Adaptive Optics

All In-Focus Image by Using Variable Focus Lens



Focus Scan at 8,000 Hz → 1,000 fps All In-Focus Image

Saccade Mirror: High-speed Gaze Control System

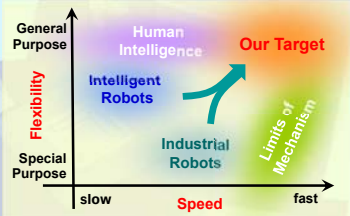


High Speed Robotics

Robot is a dynamic information fusion system which consists of sensor, processing, and actuator.

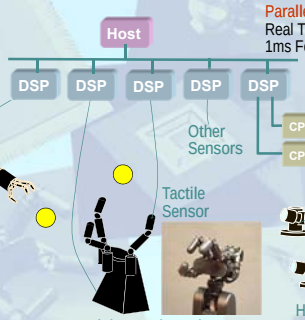
Human is not a final target of robotics.

Robot should be:
→ **more intelligent than humans**
→ **too fast to see**



Challenge to the Theoretical Limits (Sampling Theorem)
Challenge to the Intelligence (Dynamics of Intelligence)
Elimination of Bottleneck (Development of Devices)
Static Control→ Dynamic Control (High Performance)

1ms Sensor Fusion System



Parallel Processing System
Real Time Processing
1ms Feedback Rate

High-speed Arm
Max speed: 5m/s
Max acceleration: 6g

High-speed Hand
3 Fingers, 8DOF, 800g, 180deg/0,1s

High Speed Vision
Resolution: 128x128, 8bit
Processing rate: 1KHz

High Speed Robot Arm

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Batting Robot

Swing Mode Local Feedback + **Hitting Mode** Target Tracking

Batting-Throwing Robots

Collision Avoidance

World Coordination

Local Coordination

Dynamic Catching

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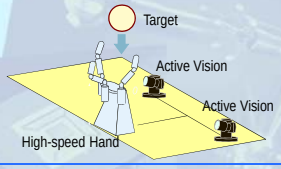
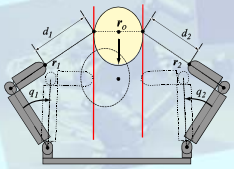
Dynamic Catching Using High Speed Vision



Raw Egg Catching



Dynamic Manipulation 1

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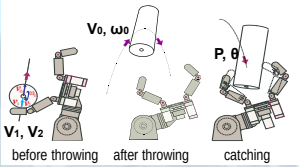
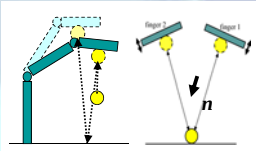
Regrasping



Dribbling



Dynamic Manipulation 2

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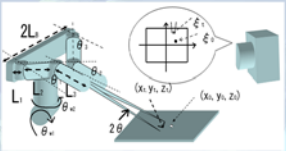
Catch in the Air



Manipulation of Flexible Materials

Rope Knotting

Cloth Folding

High speed motion with visual feedback makes tasks so Simple.

Application Systems

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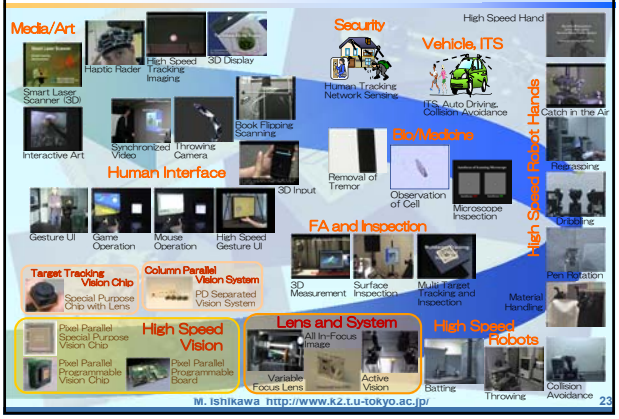

Future of High Speed Vision

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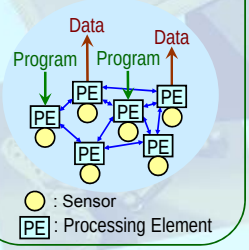
Distributed Smart Sensor
VLSI Integration (SoC Sensor)
Network Technology
Parallel Processing



In the next decade

Smart Vision and System
- Increase of Number of Sensors
- High Performance Computing and Network
- Progress in Semiconductor Technology

- Increase Space Density and Time Density
- Huge Number of Distributed Network Nodes
- Adequate Sampling and Processing Speed

Faster and More Intelligent !