

See the Unseen: Computational Visual Sensing and Display at High Speed

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University of Tokyo

See the Unseen?

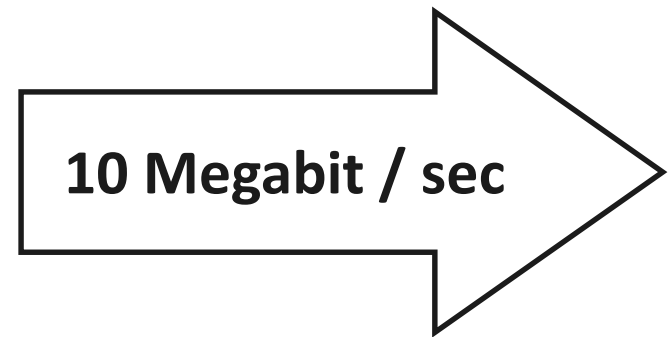
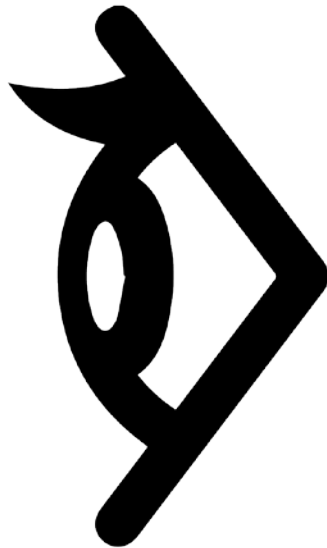
Human eye

High resolution

High dynamic range

Deep depth of field

Two eyes



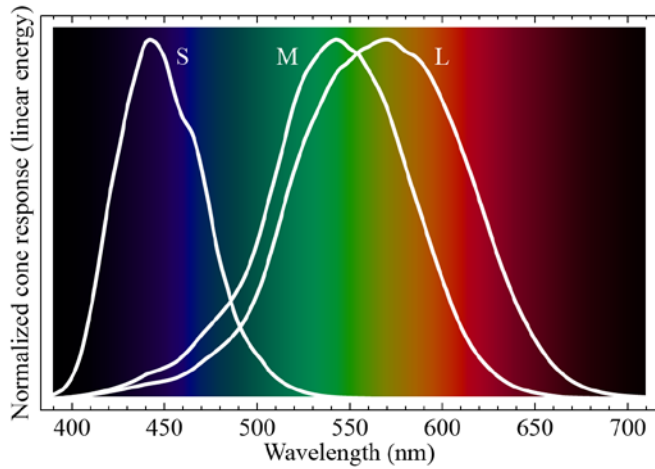
Current Biology, 2006

**Can the real world be
perfectly recognized?**



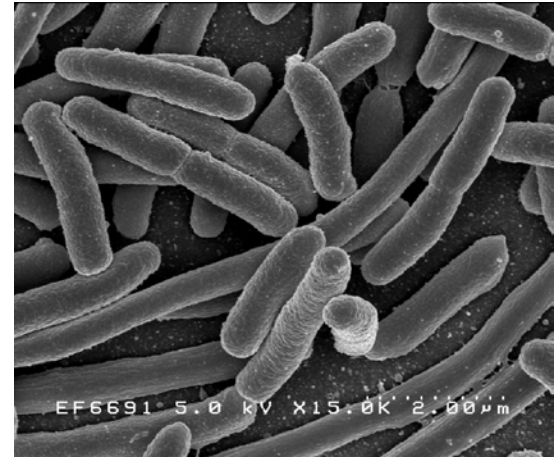
No

The Unseen



wavelength

wikipedia



size

wikipedia



occlusion



<http://wonderfuleengineering.com/>

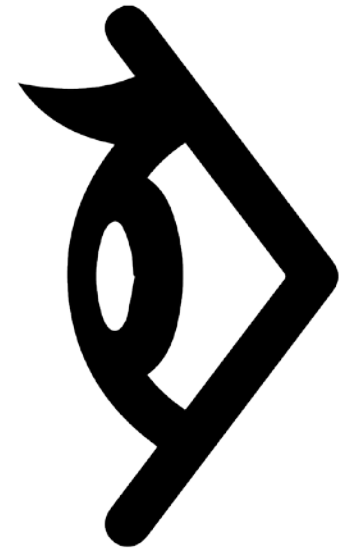
speed

The Unseen: Speed

- Critical flicker fusion rate
 - An intermittent light stimulus appears to be completely steady.



Critical flicker fusion stimulus, YouTube

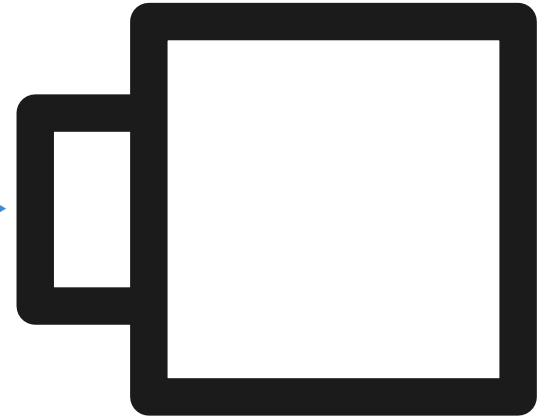
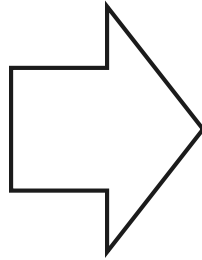
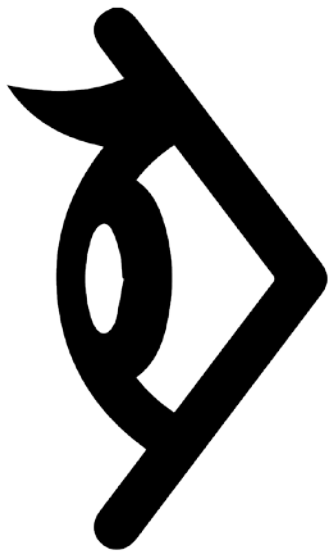


Beyond human eye

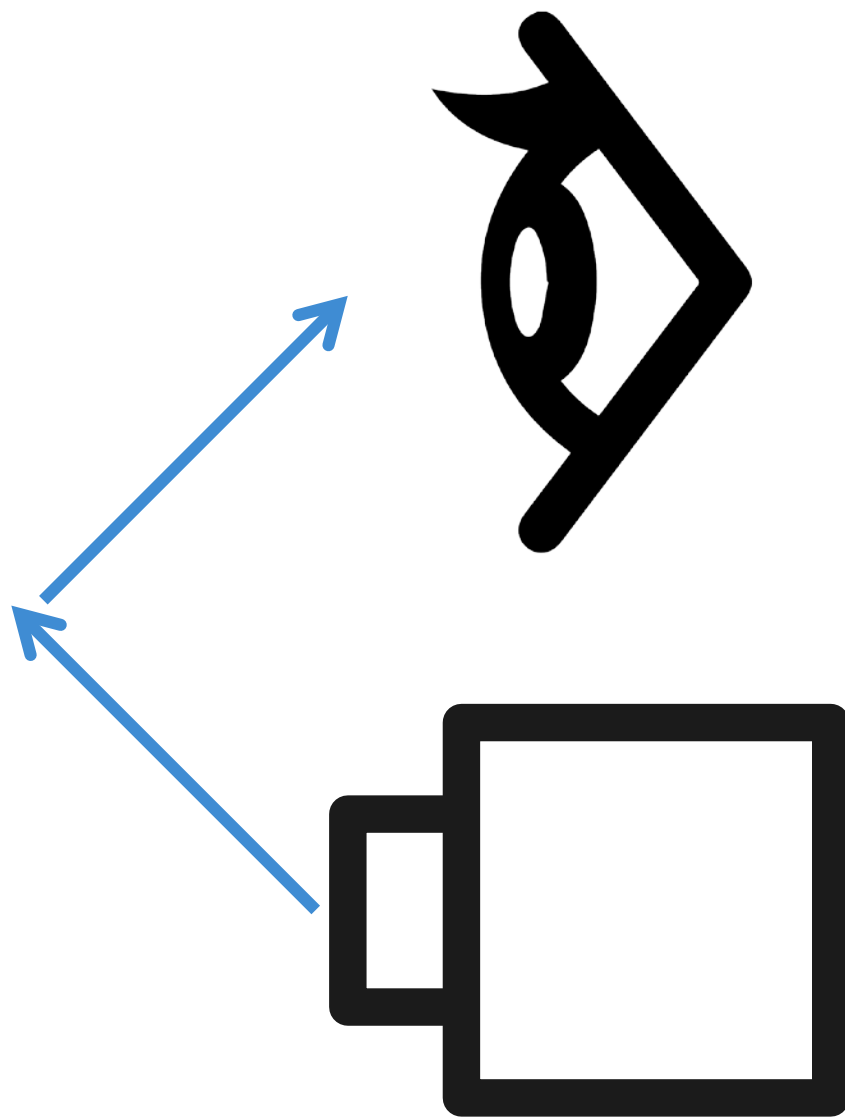
sensing

display

See the Unseen: Computational Visual Sensing at High Speed



See the Unseen: Computational Visual Display at High Speed



How?

For what?

Computational Sensing and Display

- Computations to extract only the **required** information from the **high-speed** scene with **low** latency.
 - Overall design of applications, principles, and devices from **fundamental technologies** to **application systems**
-

Taking full advantage of compute vision, measurement engineering, parallel processing and VLSI technologies



New applications in a variety of fields, including robotics, interfaces, and digital archiving.

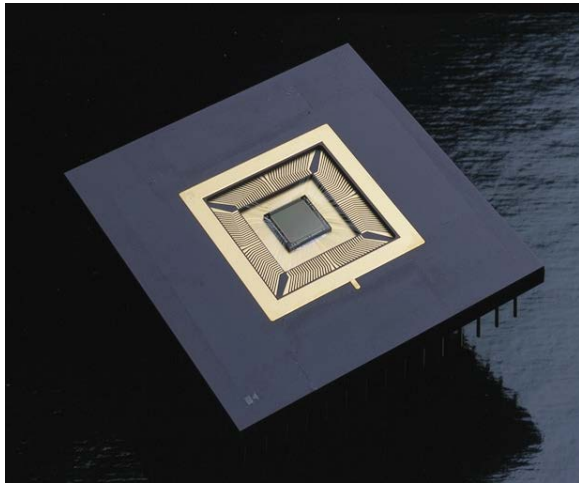
Today's topics

1. Massively-parallel image processing architecture and high-speed visual sensing **fundamental** **sensing**
2. High-speed 3D visual sensing and information reconstruction **fundamental** **sensing**
3. High-speed digital archiving **application** **sensing**
4. System design of human interface using high-speed visual sensing **application** **sensing** **display**
5. High-speed computational displays **fundamental** **application** **display**

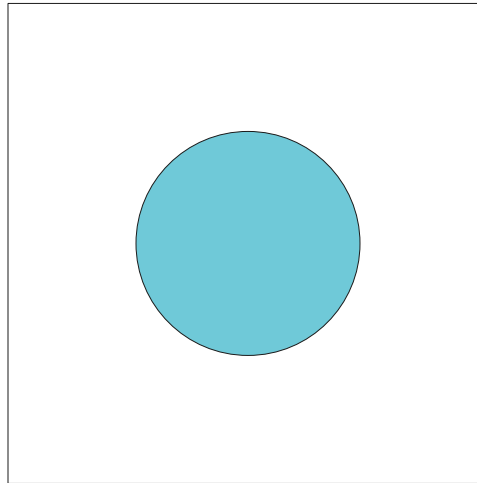
Massively Parallel Image Processing Architecture and High-Speed Visual Sensing

Multi-target tracking

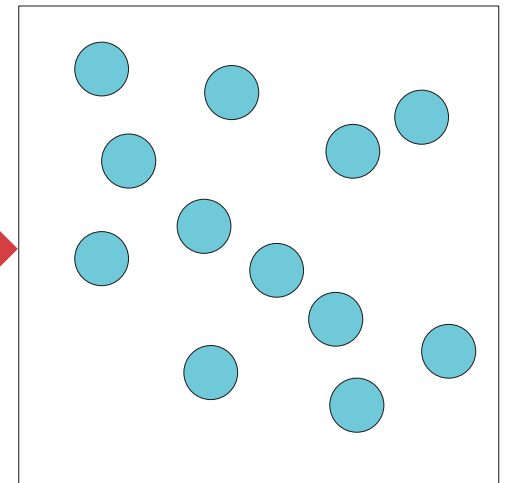
- Parallel algorithm to track multiple targets at 1000 fps
 - High-frame-rate imaging enables the simplification of image processing
 - Massively parallel processing architecture improves the speed performance

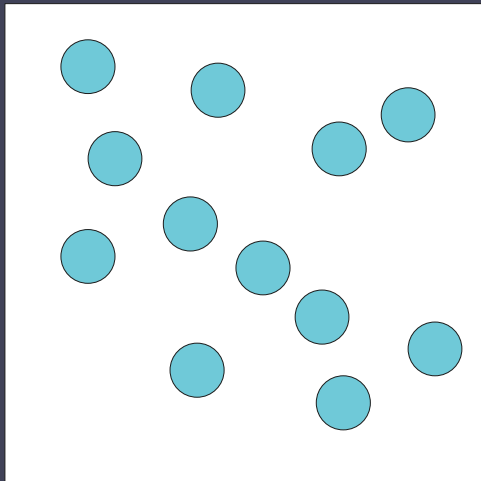


a single



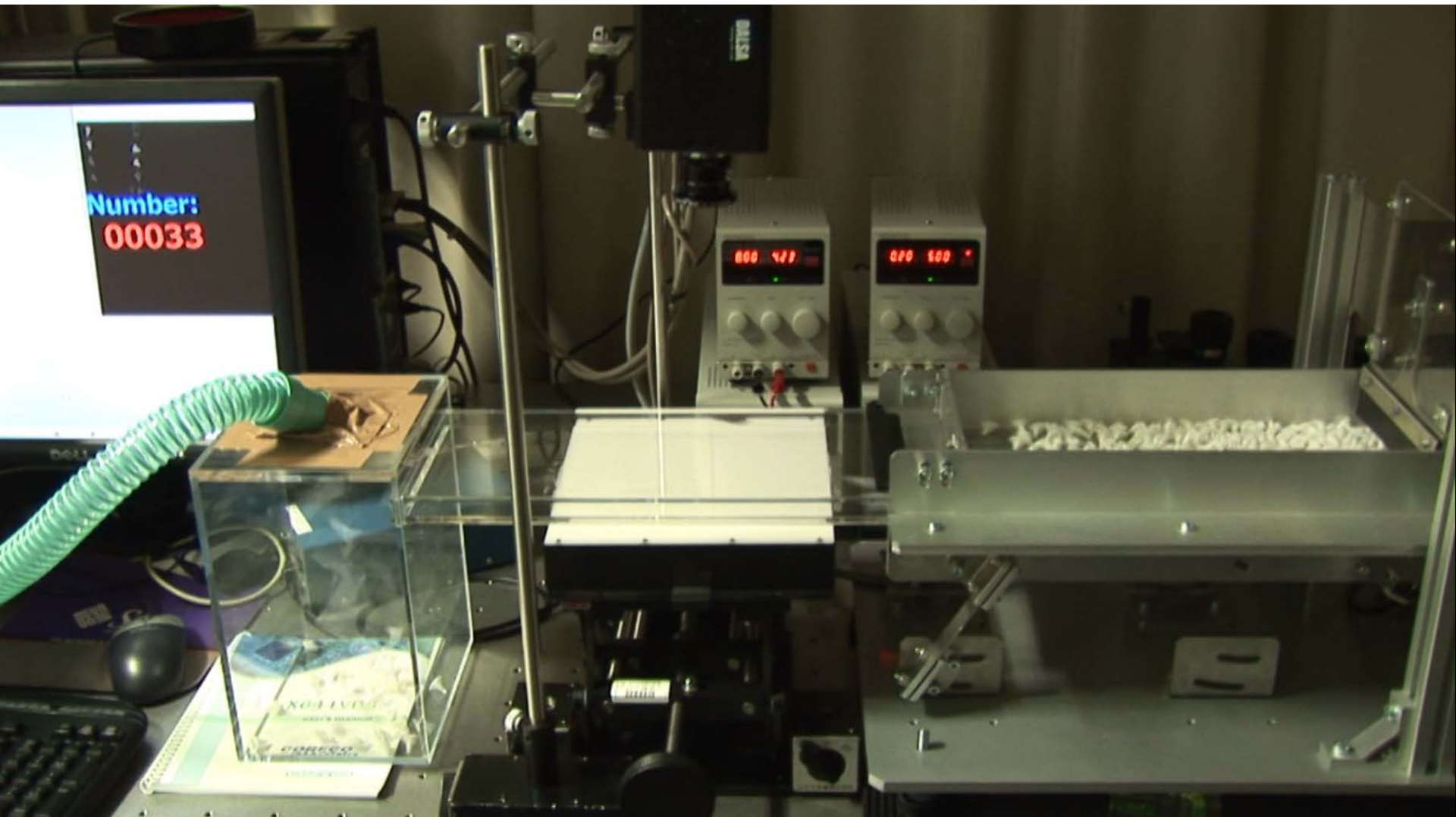
10 targets

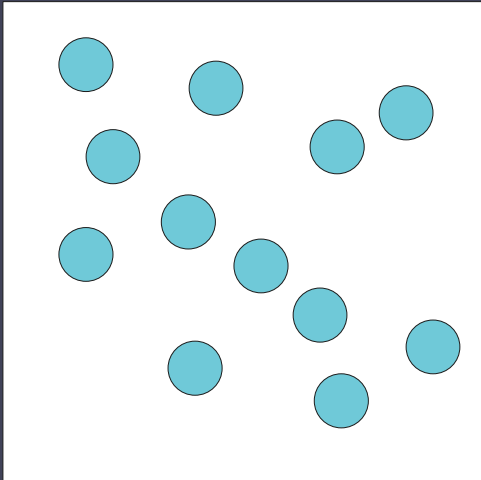




inspection

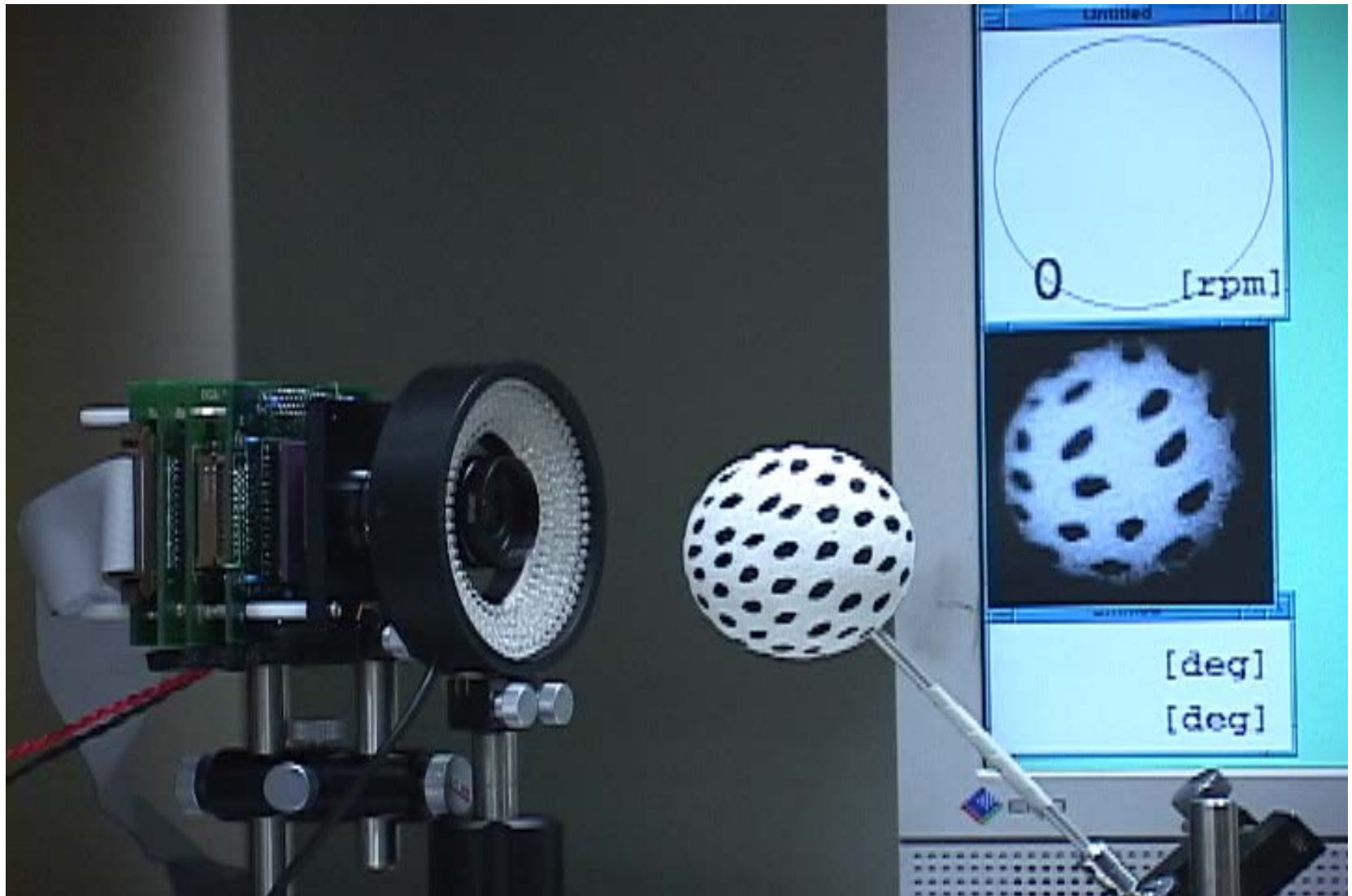
Target Counting with Multi-Target Tracking





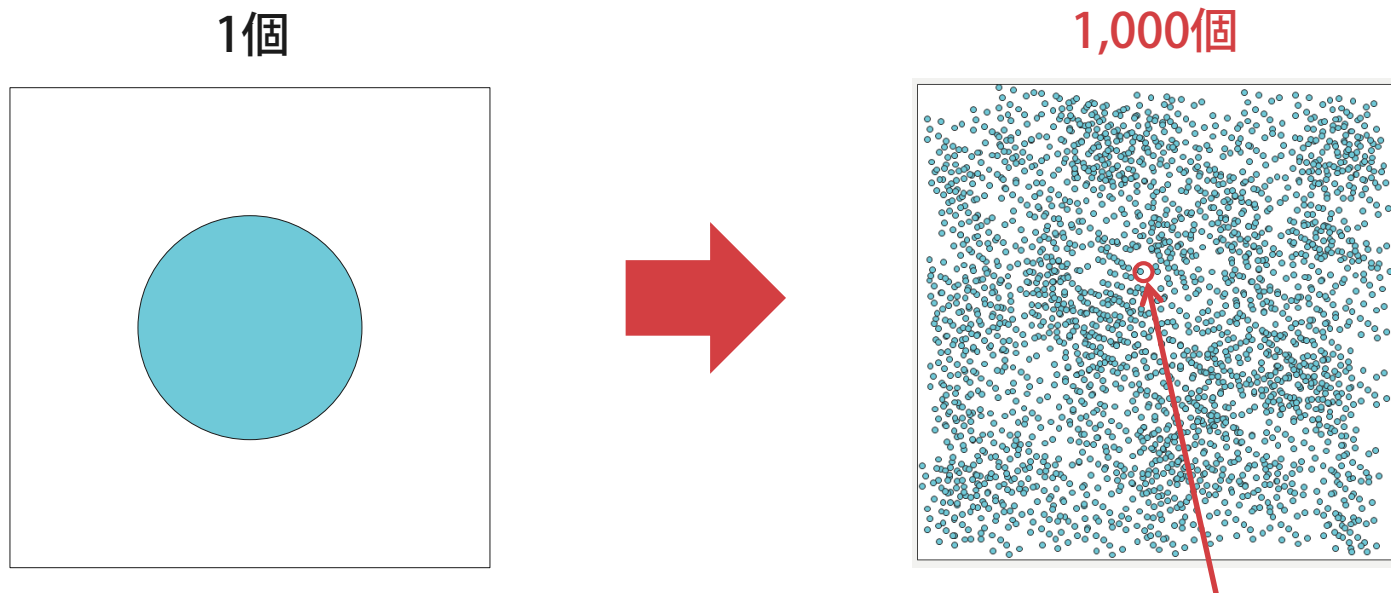
ball

Rotation Measurement up to 1,200rpm



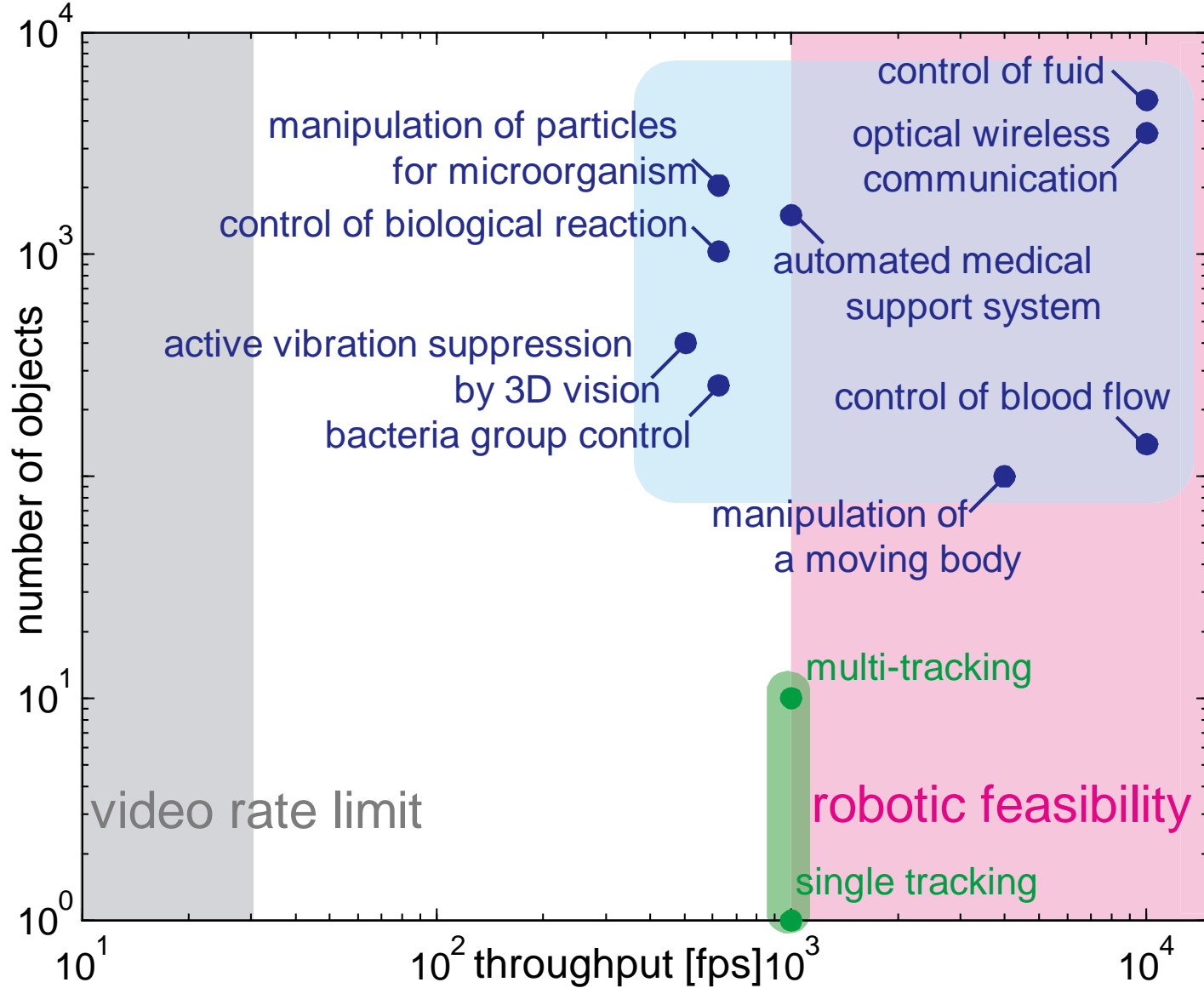
Recognition of 1,000 Target at 1,000 fps

- Parallel algorithm for moment-based object analysis of numerous objects



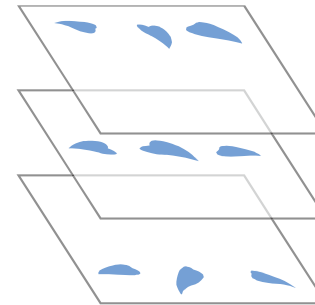
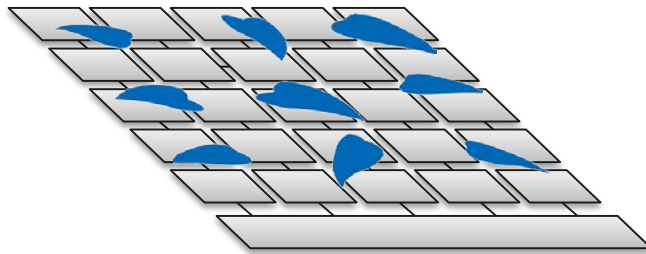
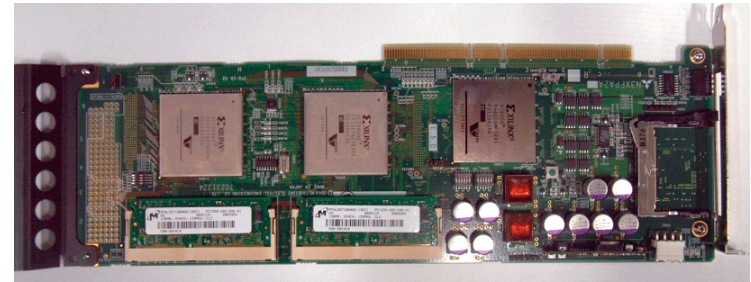
$$m_{ij} = \sum_x \sum_y x^i y^j I(x, y)$$

Applications using Numerous-Objects Measurement

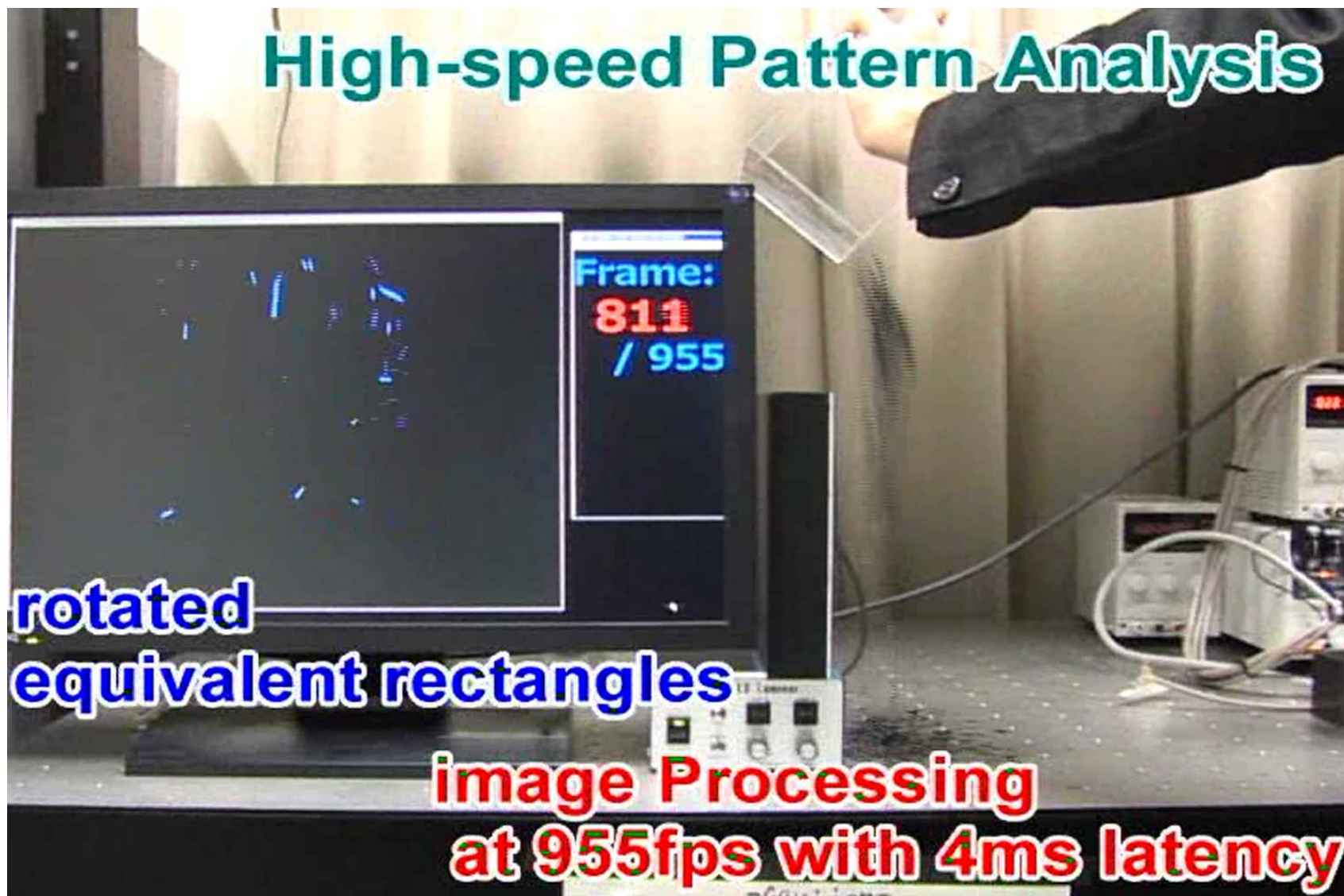


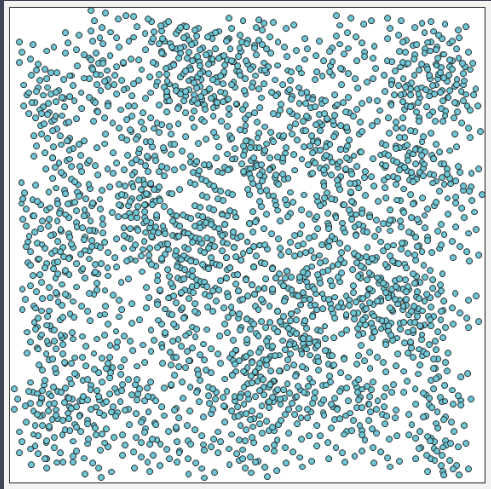
High-speed Vision with Massively Parallel Coprocessors

- Parallel specialized co-processors with a 64 x 64 mesh array
- Object-level parallel algorithm



Recognition of 1,000 Target at 1,000 fps





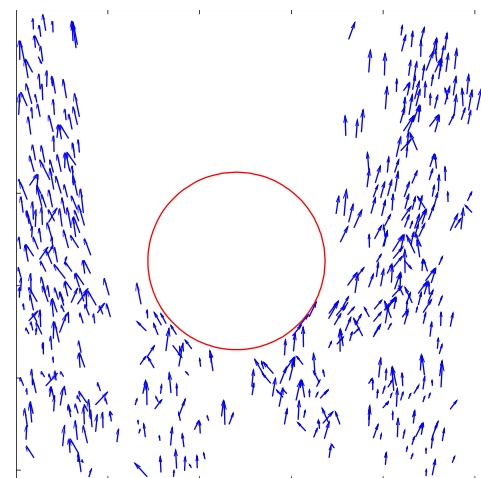
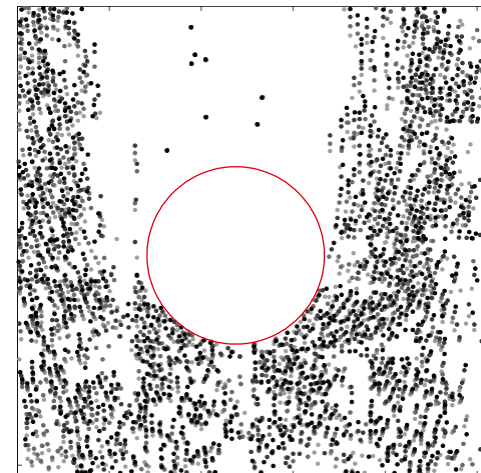
fluid

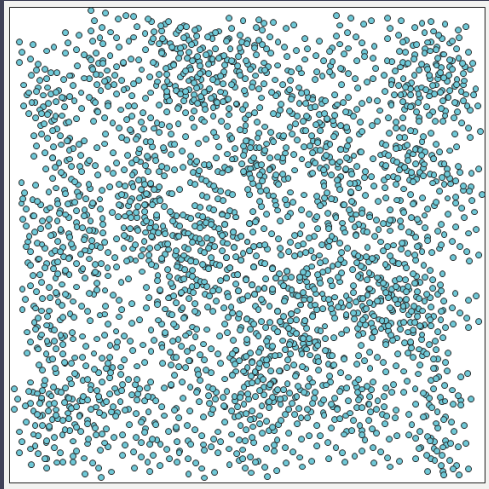
Real-Time Fluid Measurement

Real-time Fluid Sensing

extracted position

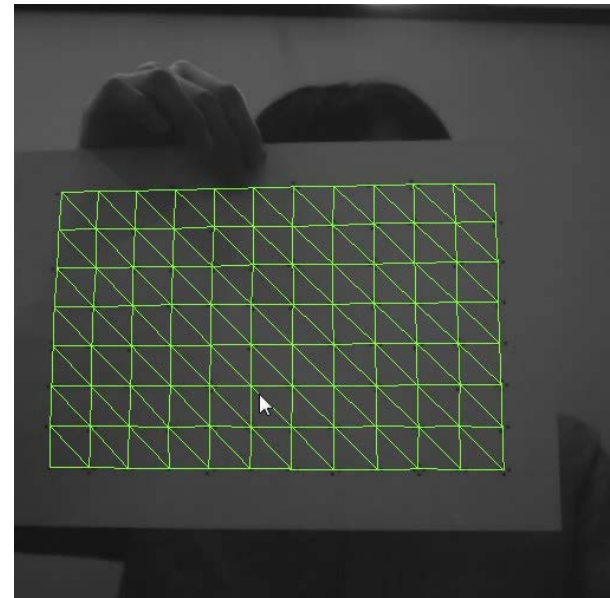
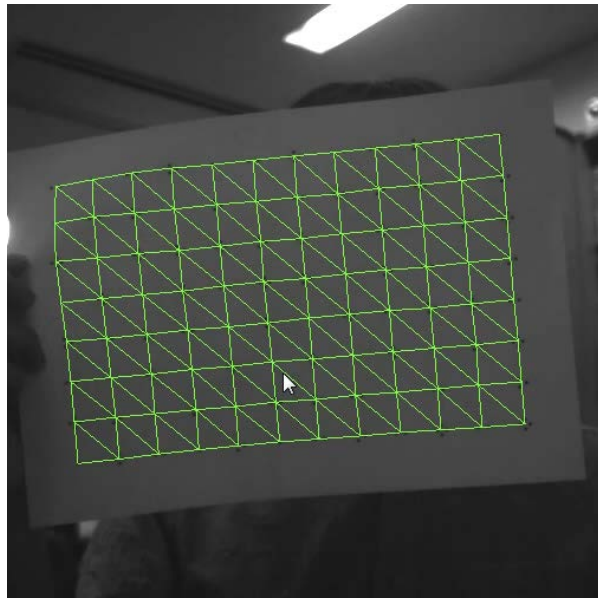
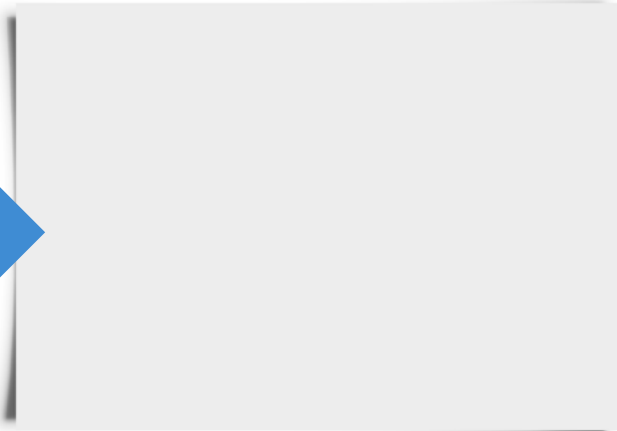
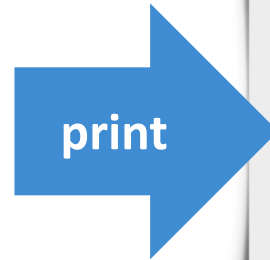
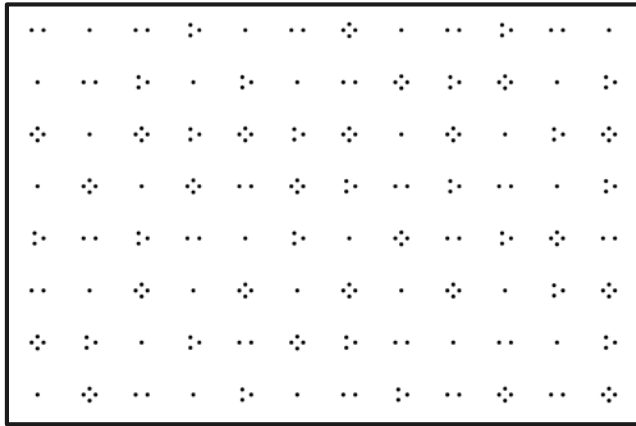
**image Processing
at 955fps with 4ms latency**





deformation

1,000fps Deformation Tracking using a Deformable Dot Cluster Marker



tracking



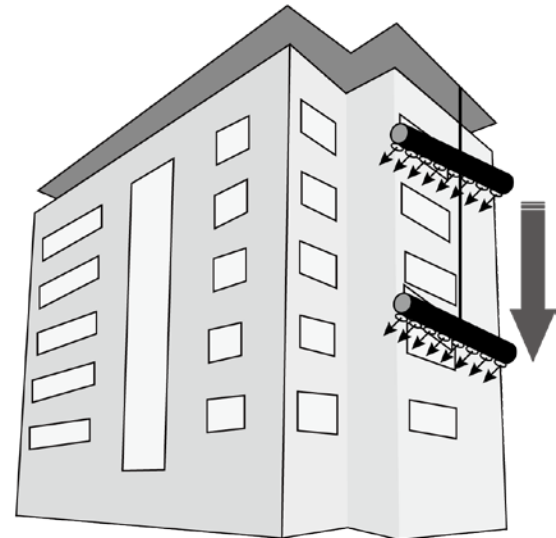
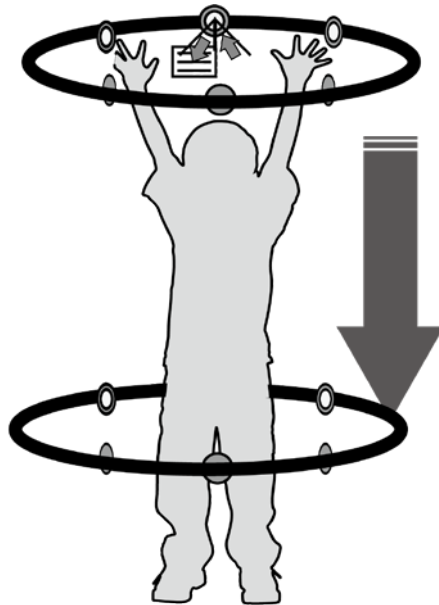
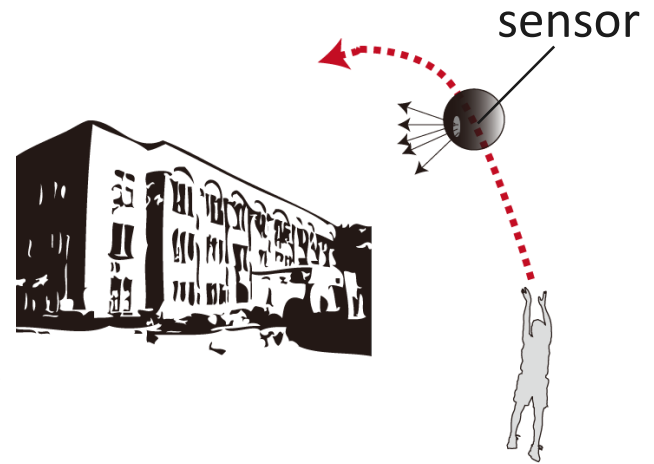
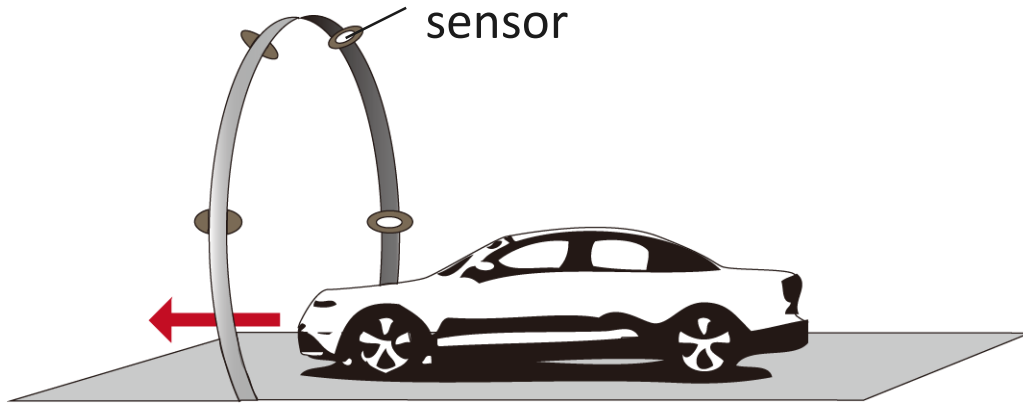
optics

High-speed roll camera: High-speed optical image rotator

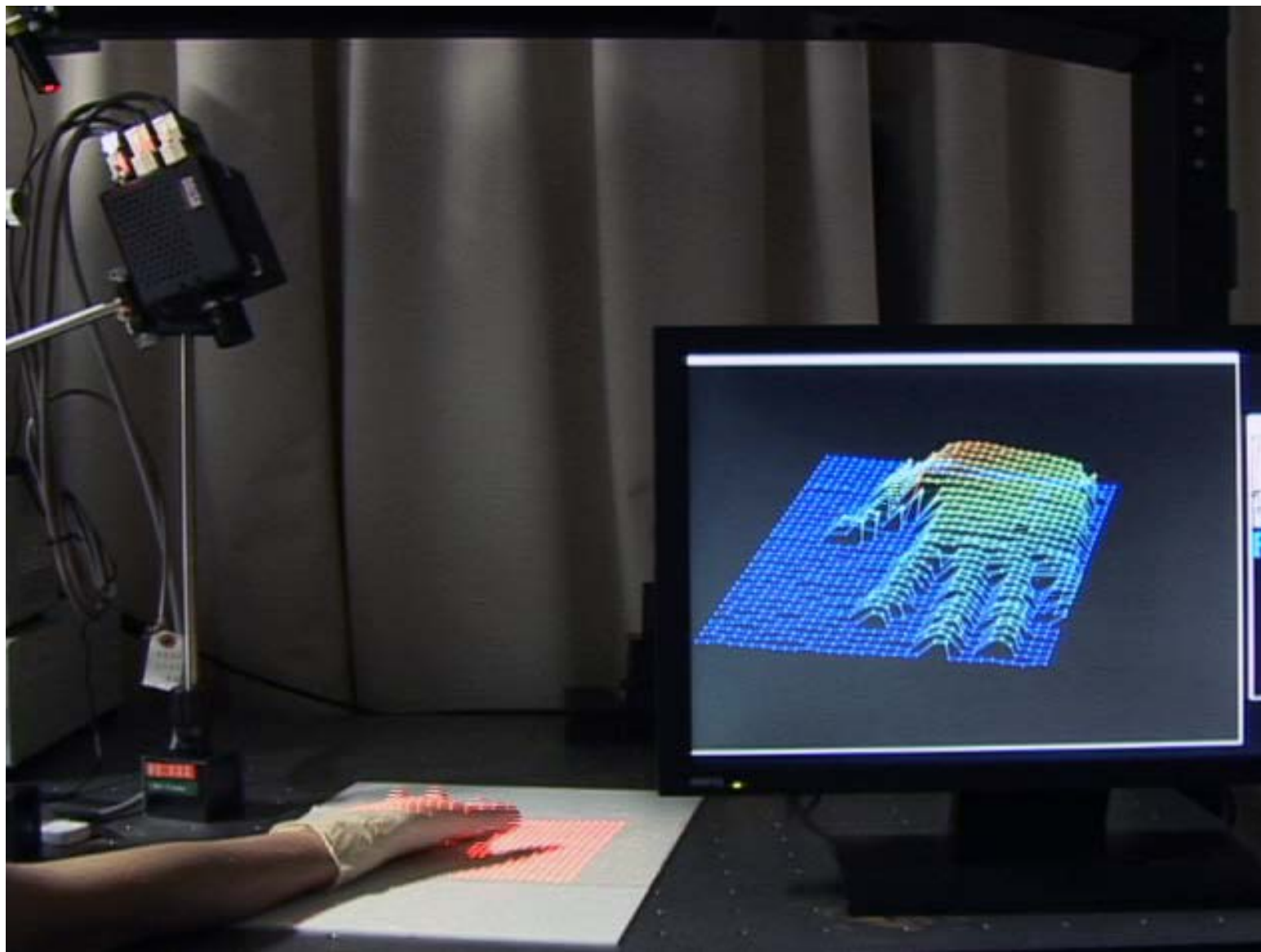


High-speed 3D Visual Sensing and Information Reconstruction

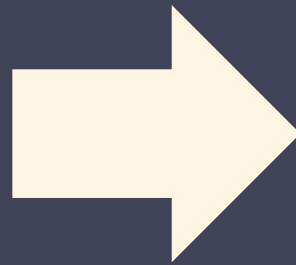
Toward Dynamic 3D Sensing



Real-time Shape Measurement of a Moving/Deforming Object

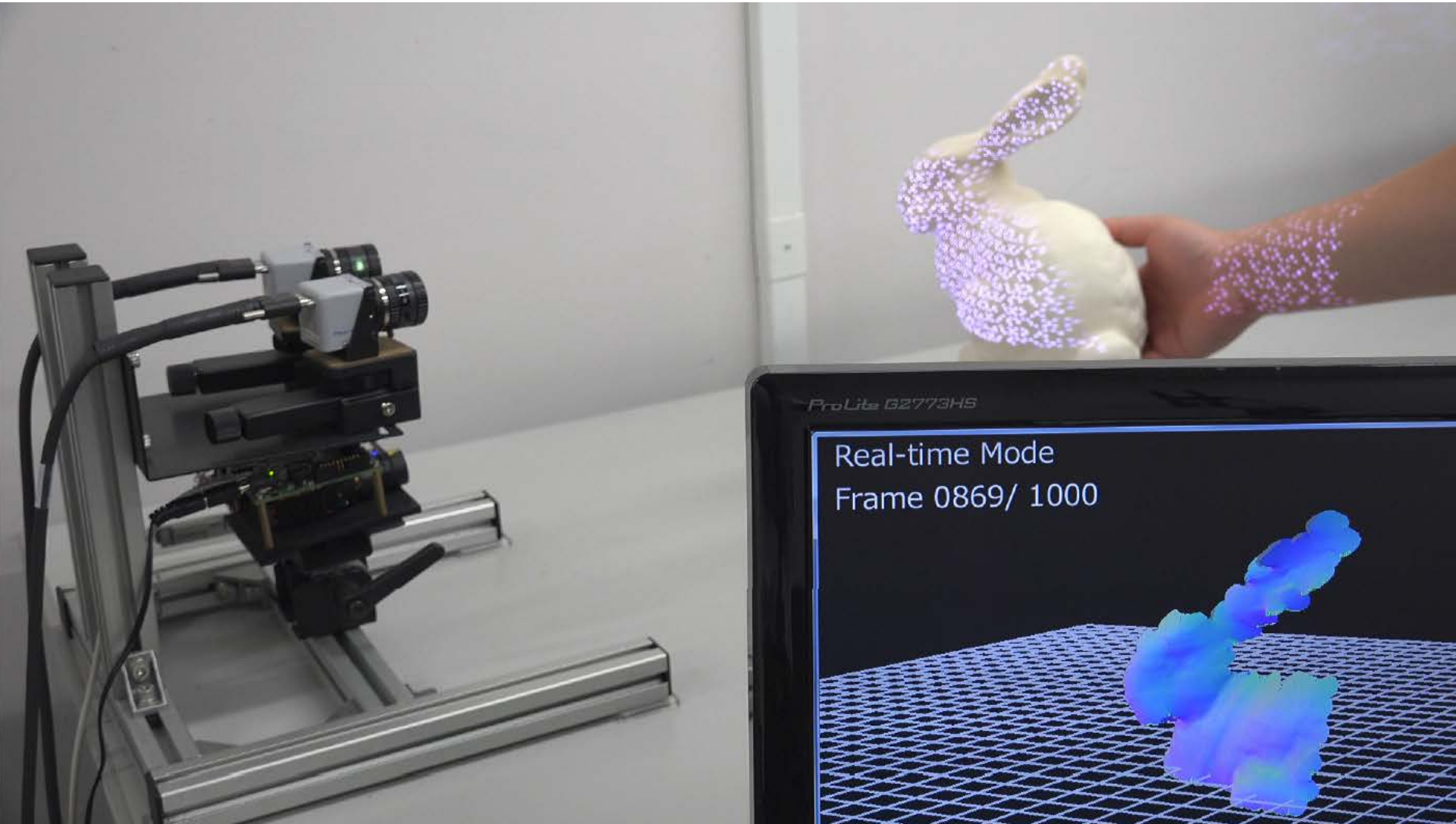


3D shape

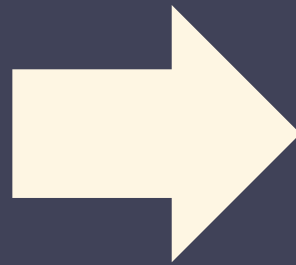


more robust

3D Sensing with Three-view Geometry Using a Segmented Pattern

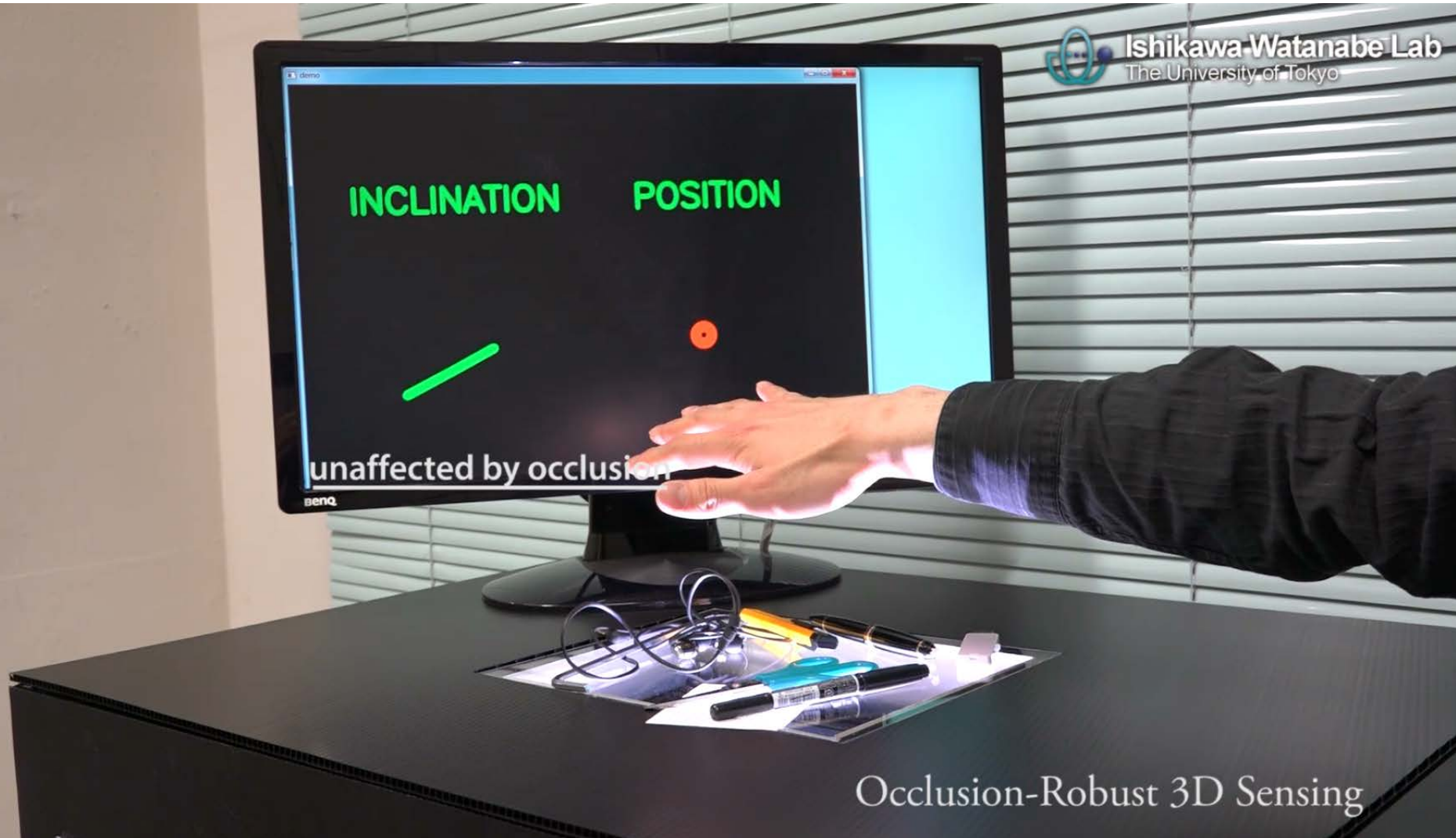


3D shape



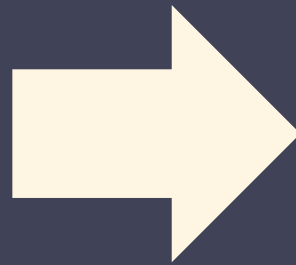
occlusion

Occlusion-Robust 3D Sensing Using Aerial Imaging



Occlusion-Robust 3D Sensing

3D images

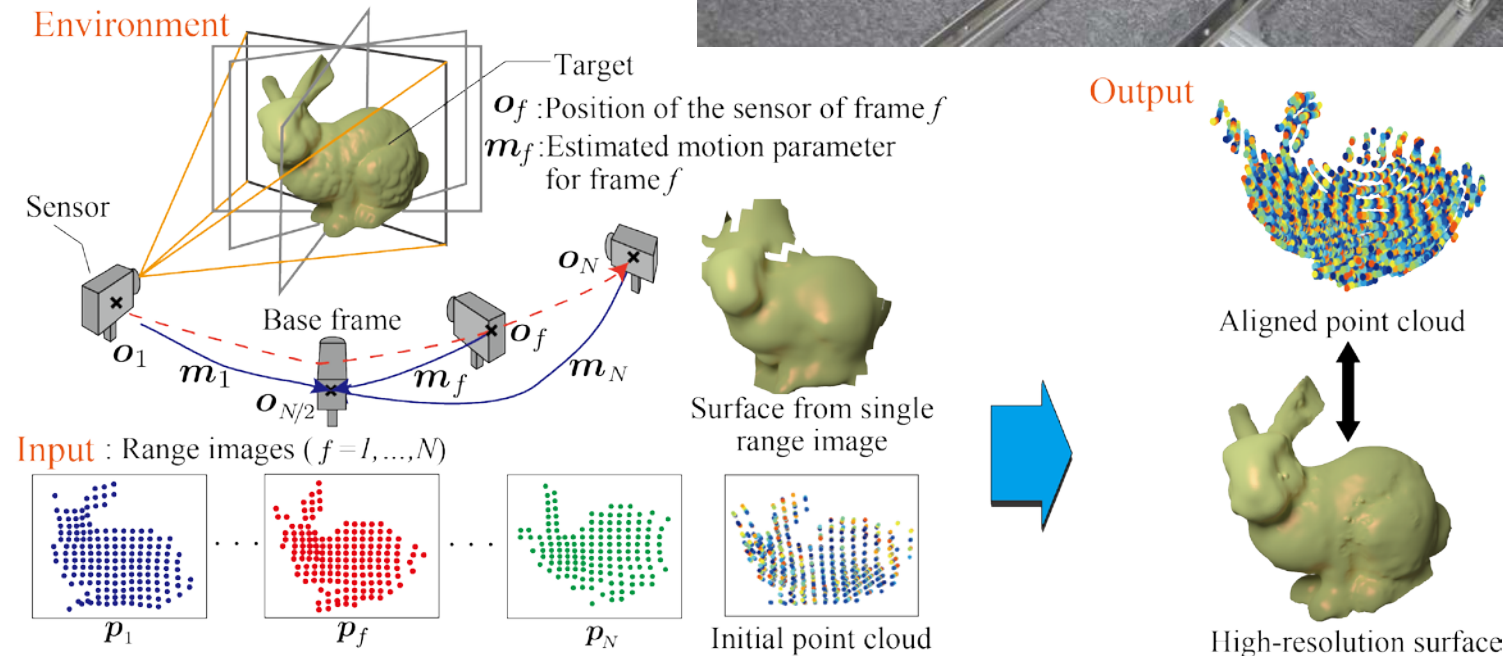


integration

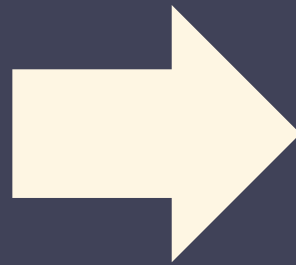
High-Resolution Surface Reconstruction from Multiple Range Images

- Observing a rigid body
- Optimization problem for the surface and motion estimation

$$\min_{M, s} d(\xi(M, u), \tilde{m}(s))$$



3D shape

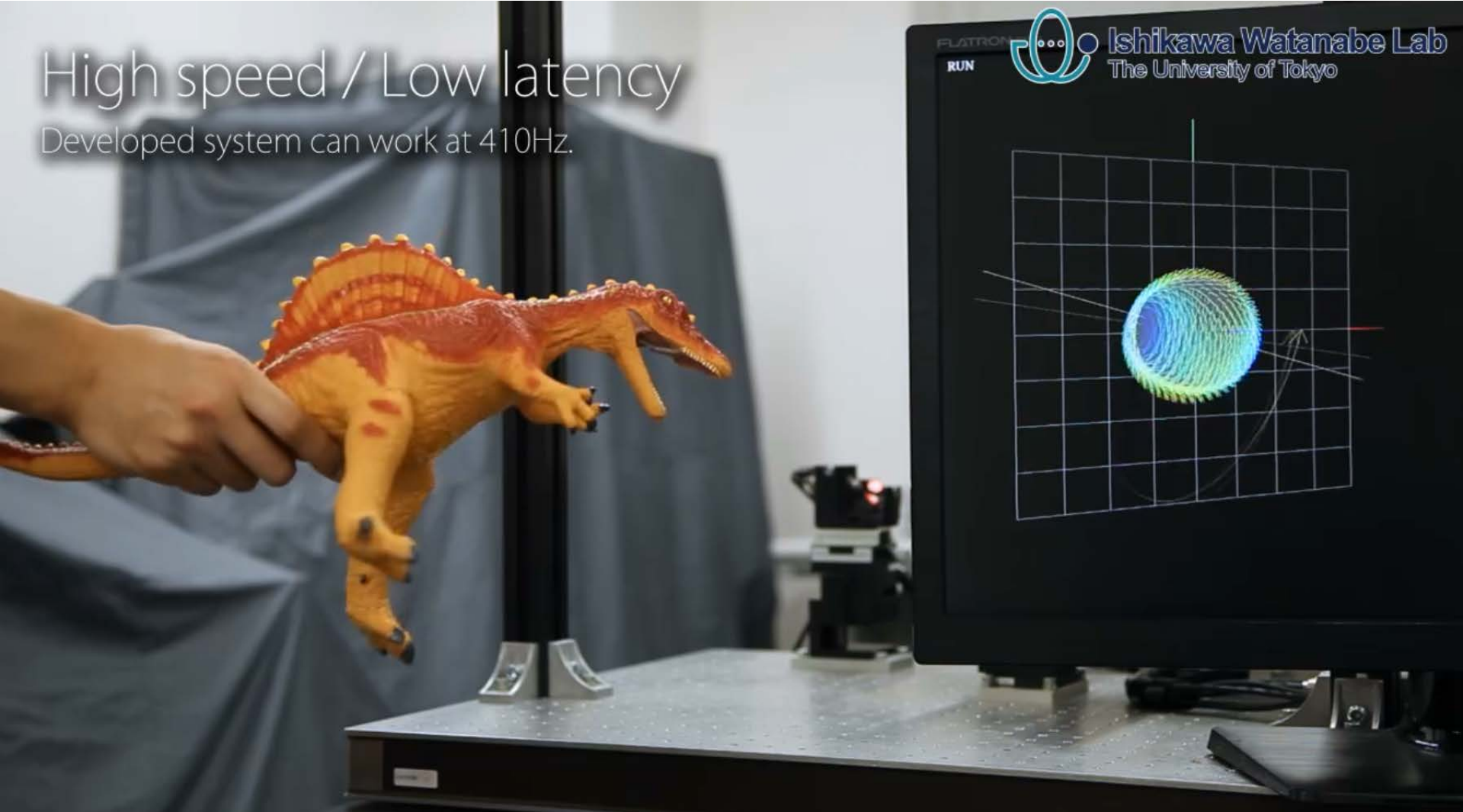


3D motion

3D Motion Sensing of any Object by Using Multiplexed Lasers

High speed / Low latency

Developed system can work at 410Hz.



3D motion



3D shape

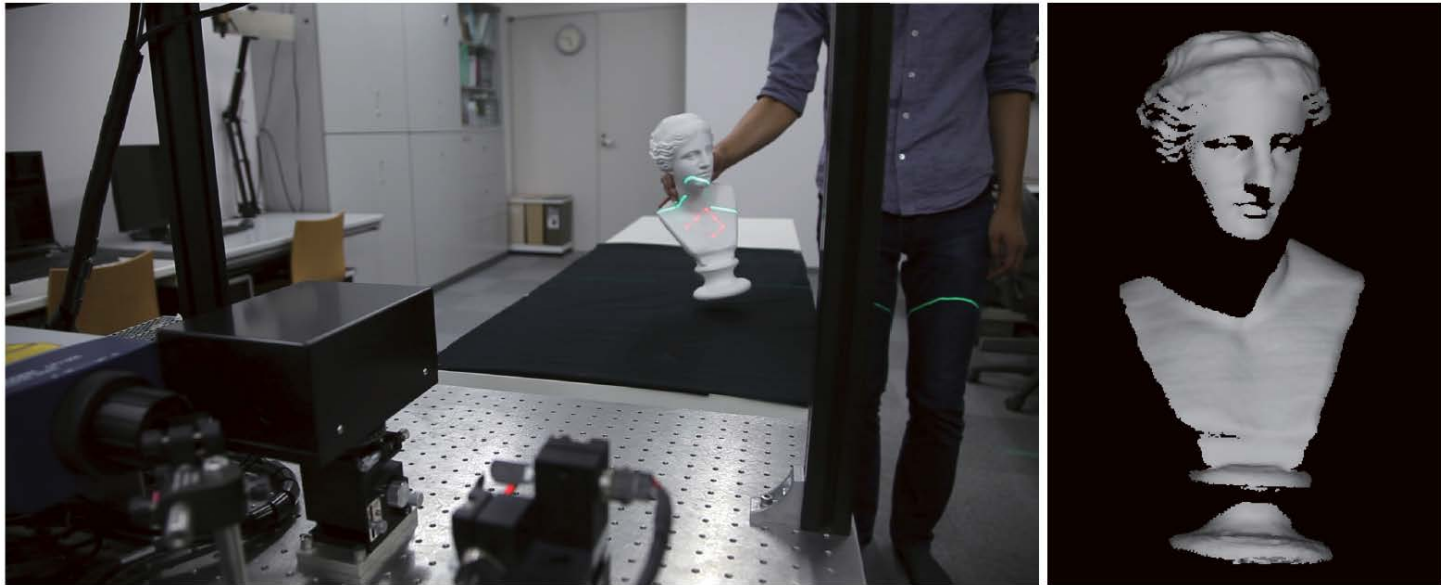
High-resolution Shape and Color Integration using 3D Motion Sensing System

3D shape
reconstruction

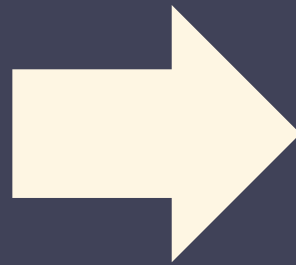
in real time

Combining a depth sensor enables high-resolution 3D scanning of a freely-moving object.

High-resolution Shape and Color Integration using 3D Motion Sensing System

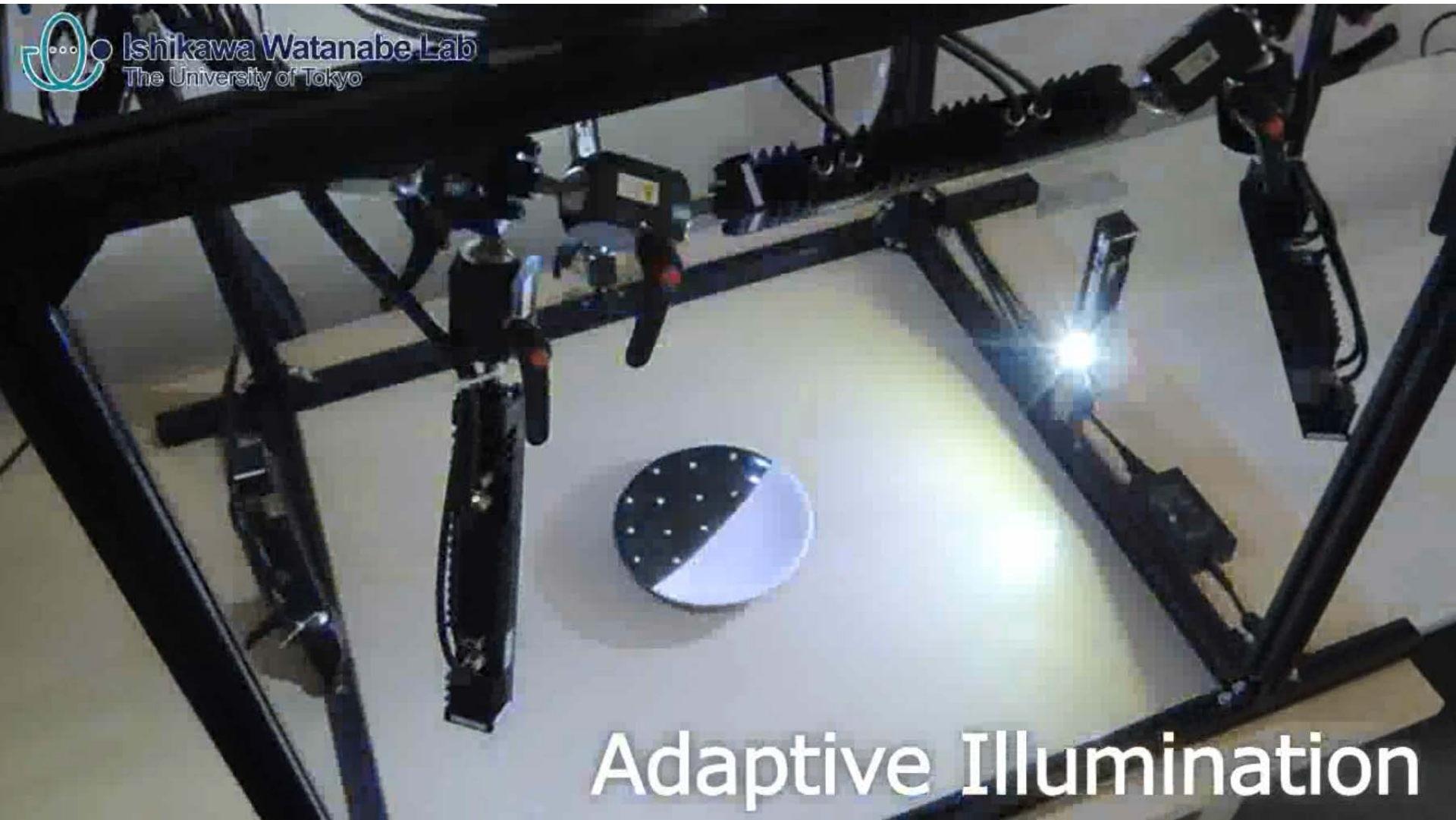


**3D shape
3D motion**



reflectance

Rapid SVBRDF Measurement by Algebraic Solution Based on Adaptive Illumination



Ishikawa Watanabe Lab
The University of Tokyo

Adaptive Illumination

High-Speed Digital Archiving

High-speed Visual Sensing and Digital Archiving

High-Speed
Visual Sensing

meets

Digital Archiving



Conventional strategy

Only valuable object should be selected

Scanning in a static condition



New strategy

Scan all of the objects

Scan at a dynamic condition

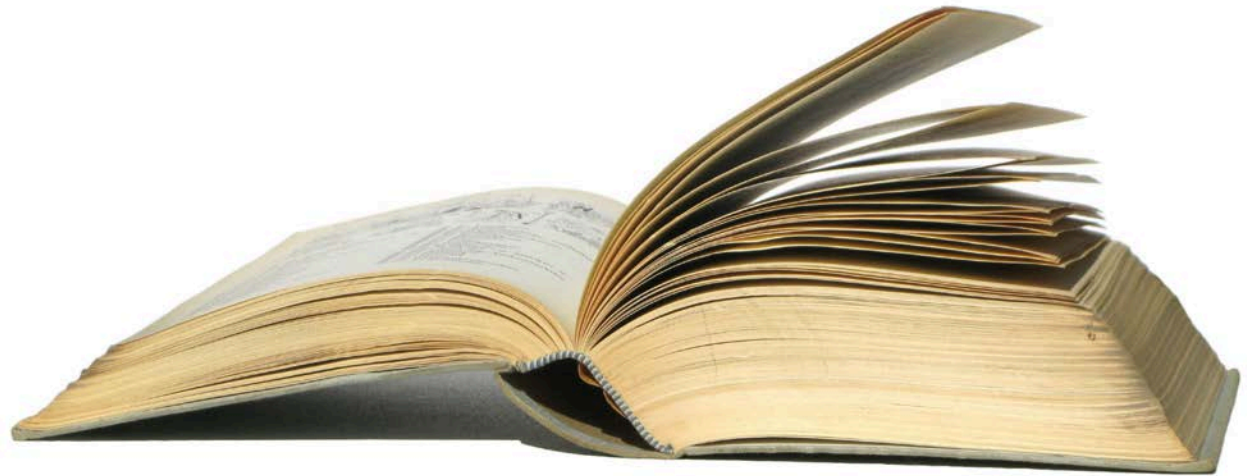
Book Digitization

Digital Archiving

High-speed 3D
Visual Sensing



Book



Demands in Book Digitization

User



library



corporation

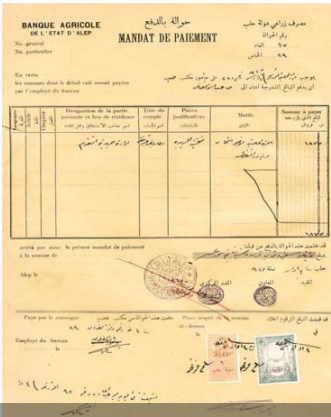


general user

Target



books



official documents



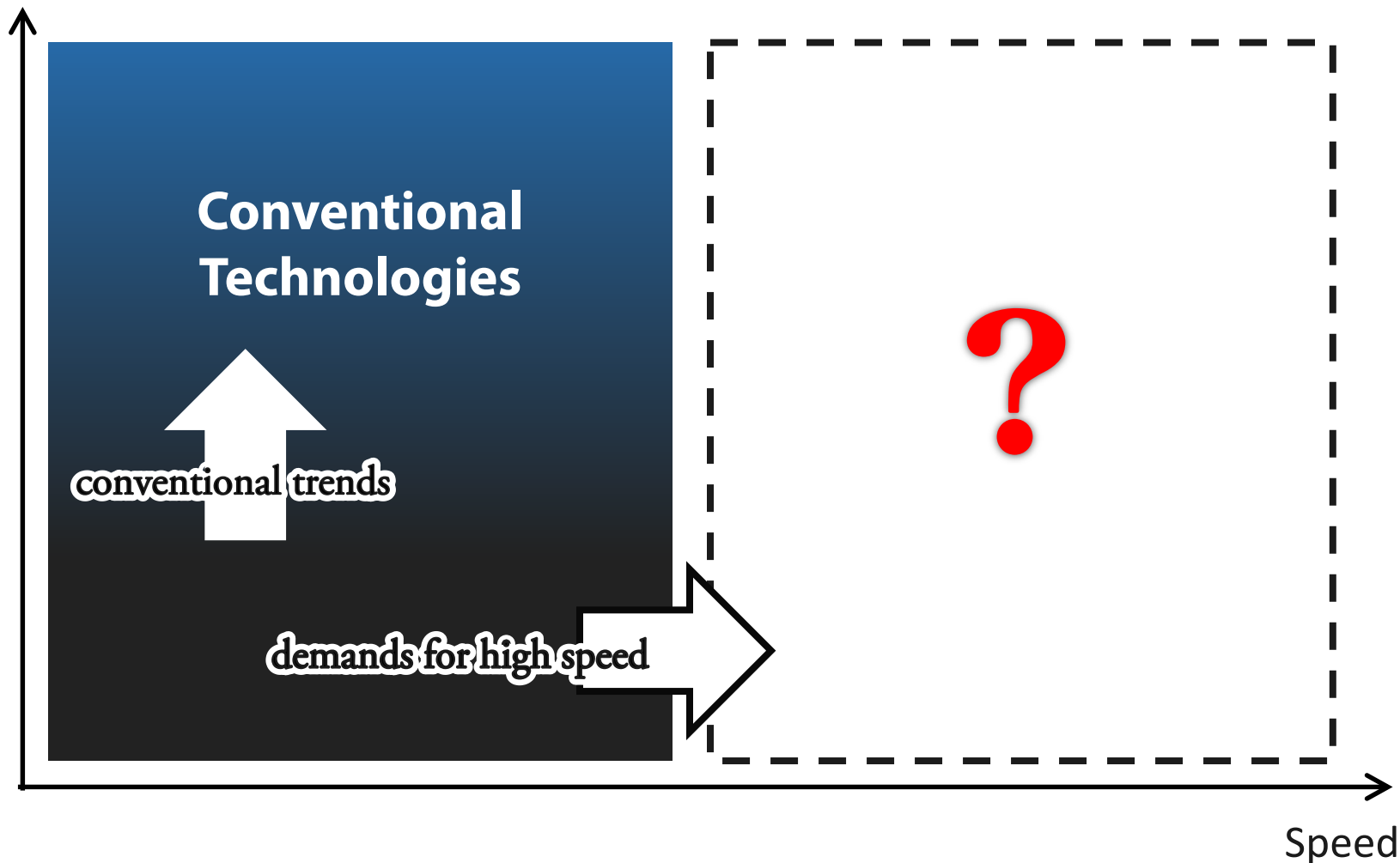
notes

Conventional Book Digitization Technologies

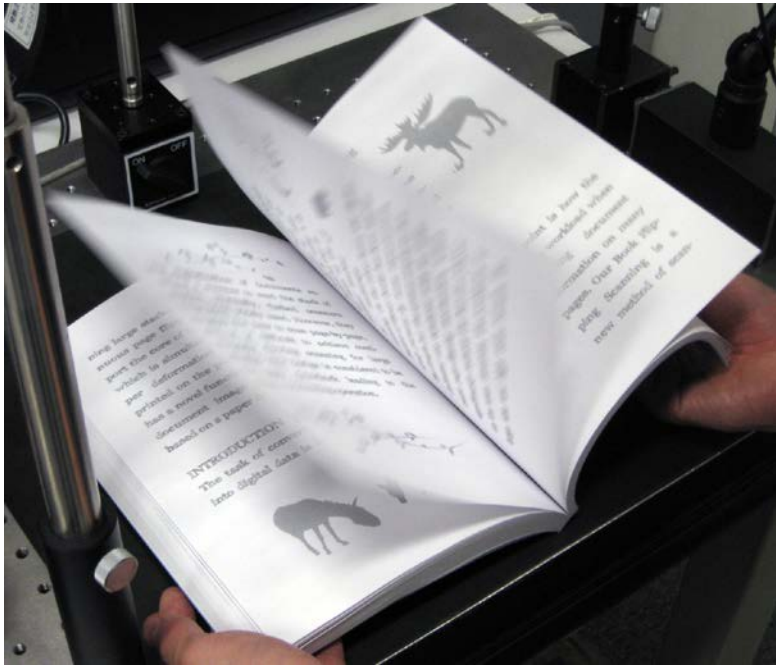
- Flatbed scanner
 - Press a book not to be curved while digitization
- Destruction-type scanner
 - Cut a book for digitization
- What is the bottleneck for speeding up?
 - They observe a book in two dimensional.
 - They do not utilize high-speed motion of a book.

Toward High-Speed Book Digitization

Spatial resolution



New Style for Book Digitization

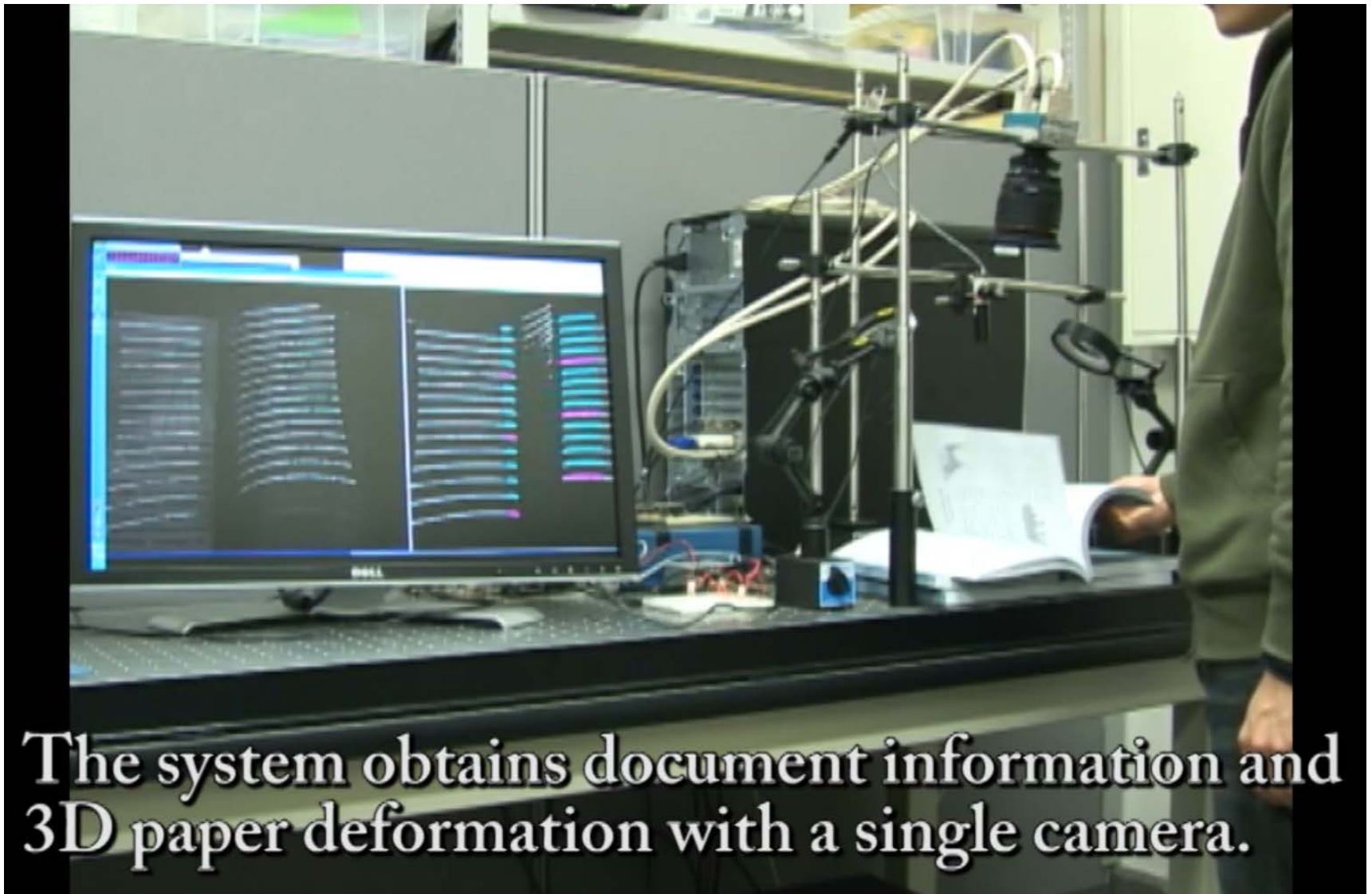


Scan a book **continuously**
without stopping the movement
during the **paper turning** operation

High-speed & easy-to-use technology

Book Flipping Scanning

Proof-of-concept prototype for Book Flipping Scanning



The system obtains document information and 3D paper deformation with a single camera.

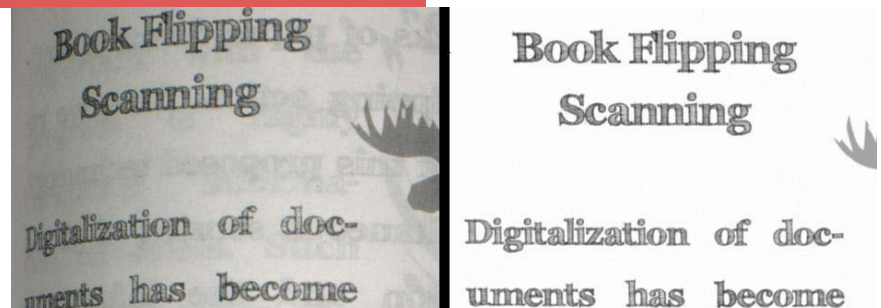
Technological Challenges for Book Flipping Scanning



High-speed and automatic page turning



Scanning based on high-speed visual sensing



High-quality document rectification

**book flipping
scanning**



pager turning

Automatic page turner machine for Book Flipping Scanning



1/50 speed playback

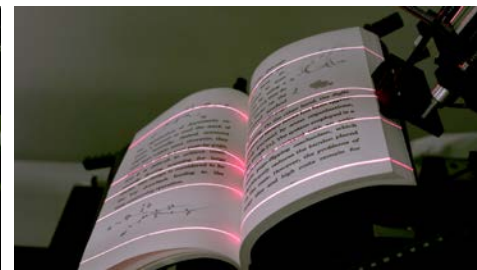
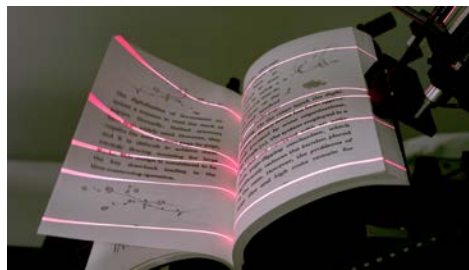
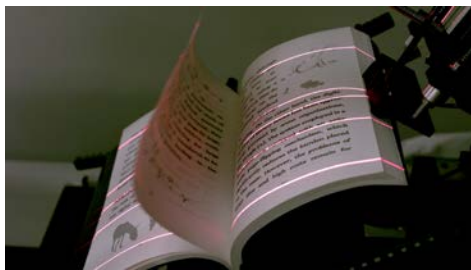
**book flipping
scanning**



**high speed
high definition**

High-Speed and High-Definition Capture for Digitization

- **Adaptive capturing** based on real-time **3D page tracking** and **book status** recognition



**book flipping
scanning**

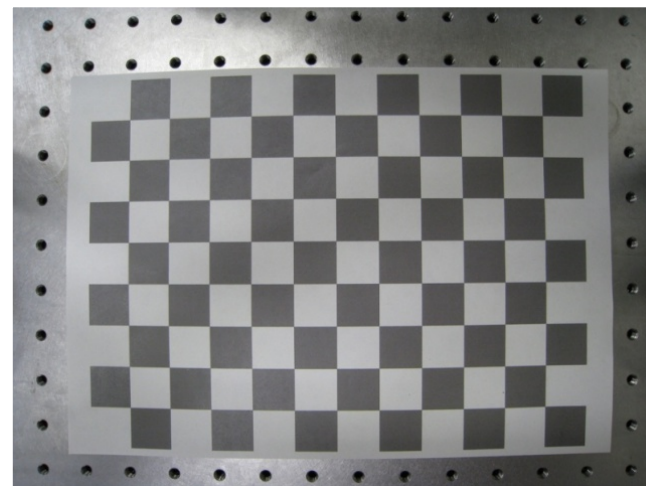
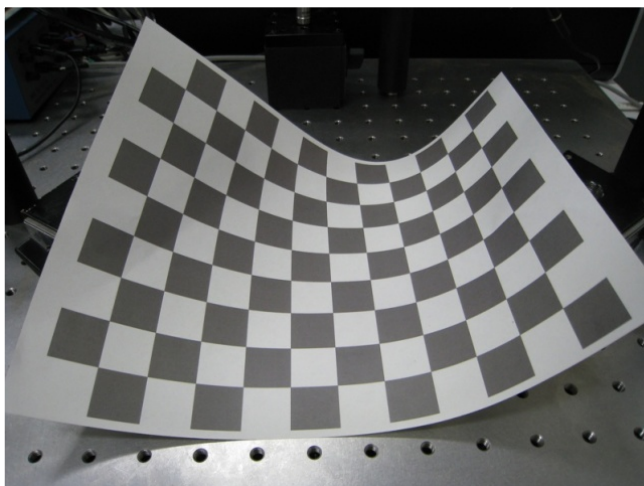
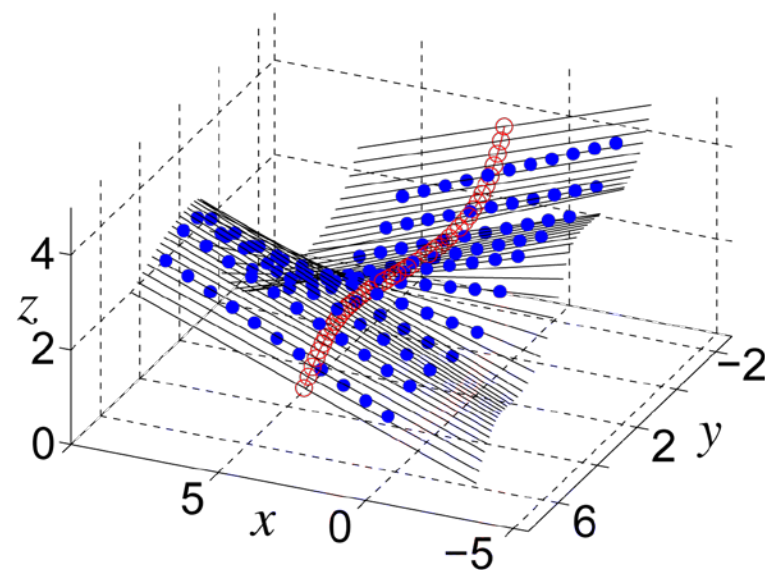


**document
rectification**

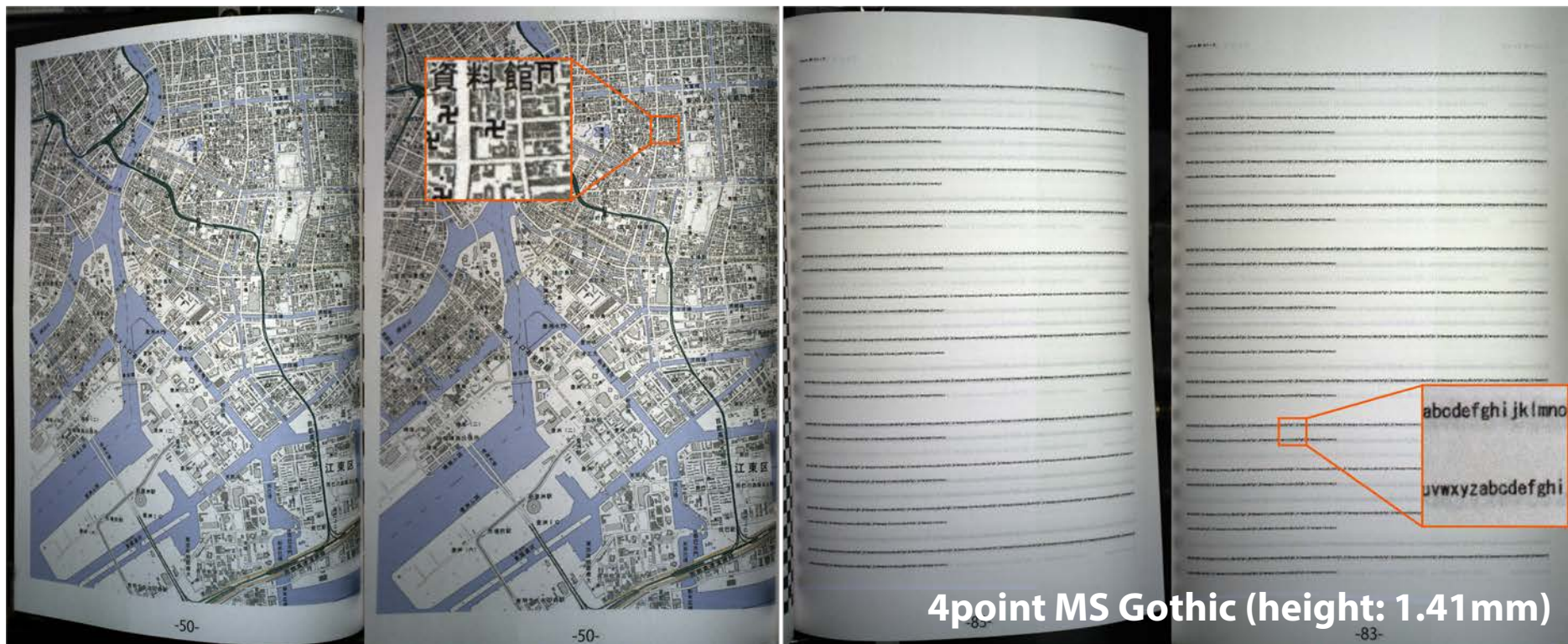
Document Image Rectification using Developable Surface Model

Developable Surface

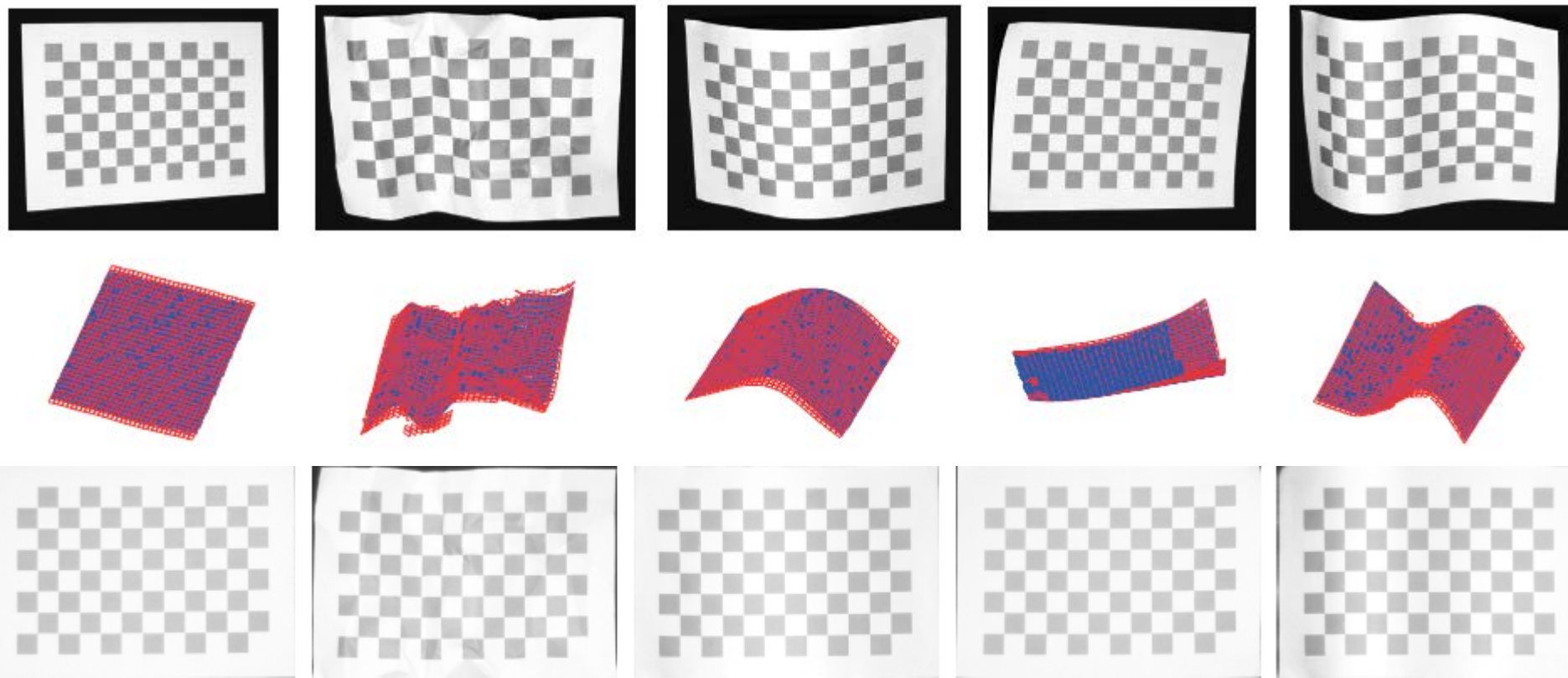
A special non-rigid object that can be developed to a plane without expansion, contraction, or tearing.



Document Image Rectification using Developable Surface Model



High-accuracy rectification using Tiled Rectangle Fragments



- A developable surface is represented by tiling the same size of rectangles.
- More complicated distortions can be rectified.

**book flipping
scanning**

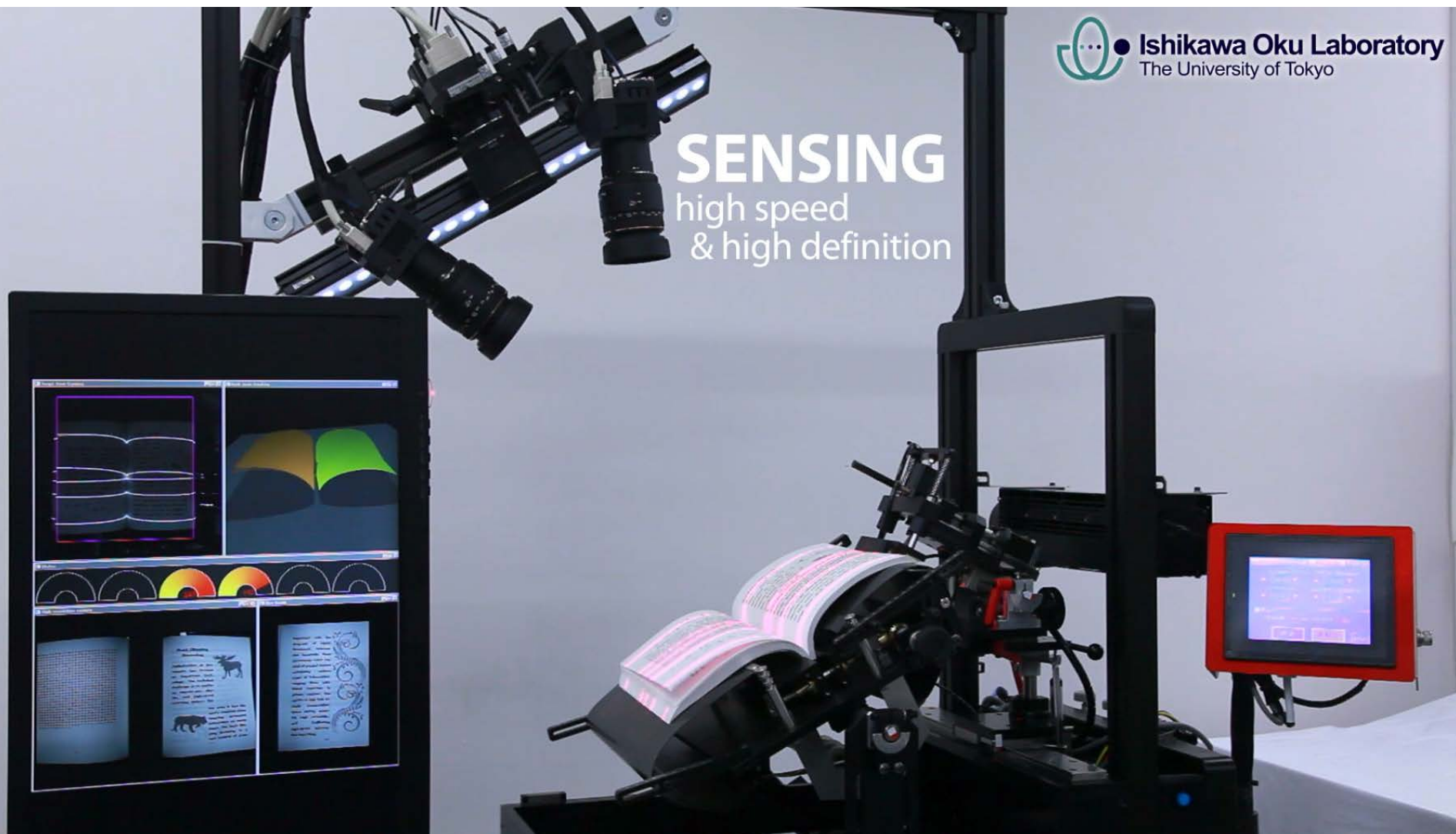


**automatic
high speed
high definition**

BFS-Auto: High Speed & High Definition Book Scanner

 Ishikawa Oku Laboratory
The University of Tokyo

SENSING
high speed
& high definition



[WACV, 2014]

**book flipping
scanning**



more resolution

Document Digitization using a Multi-camera Array



High-speed Book Digitization using a Multi-camera Array

**book flipping
scanning**



mobile

BFS-Solo: High Speed Book Digitization using Monocular Video



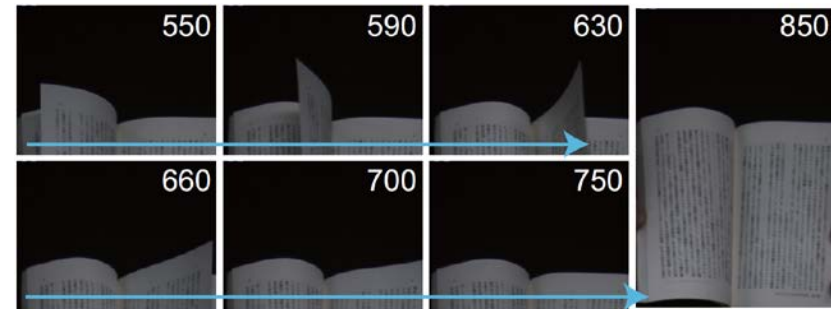
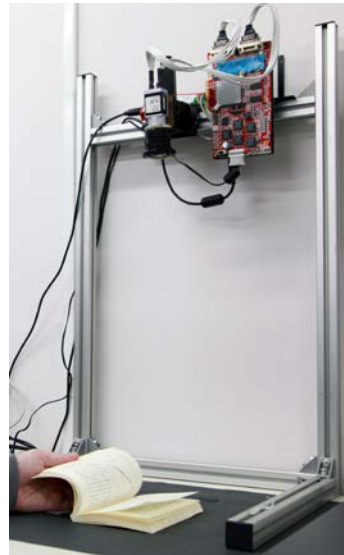
1
Video Recording
of Flipping Page Motion

Flat Page Restoration
from Monocular Video

2

Stand Alone High-speed Vision System with Dynamic Capture Control

- Configuration of the capturing is controlled every frames adaptively based on the results of high-speed image processing.
- High-speed tracking in a limited resolution + High-resolution capture at the best timing



System Design of Human Interface using High-Speed Visual Sensing

**high-speed
visual sensing**

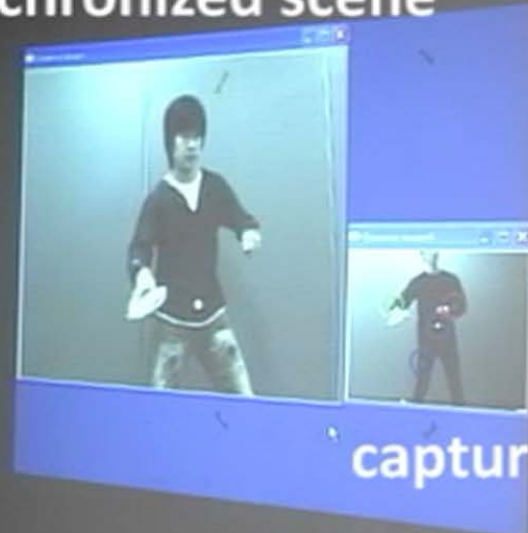


body motion

Synchronized Video

Prototype Demonstration

synchronized scene



captured image

camera

**3D motion
sensing**



controller

Video Game User Interface based on 3D Motion Sensing

Video game UI

 Ishikawa Watanabe Lab
The University of Tokyo

Cardboard can be used as a handlebar controller for a racing game.

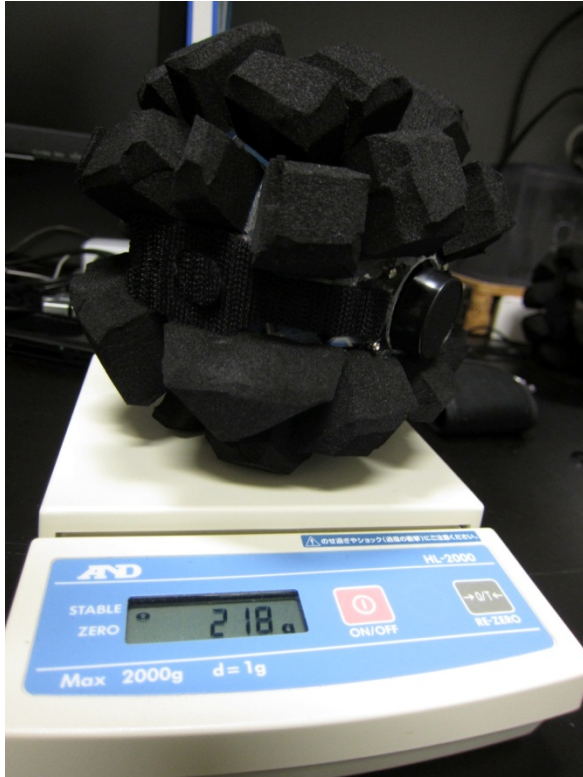
[Trans. Graphics, 2015]

**high-speed
visual sensing**



compact

VolVision: High-speed Capture in Unconstrained Camera Motion

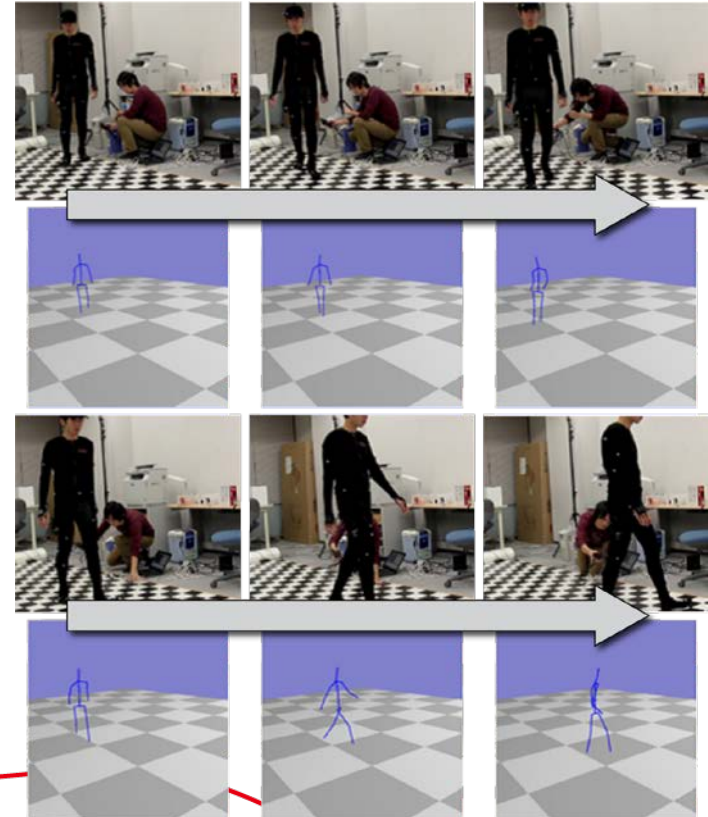
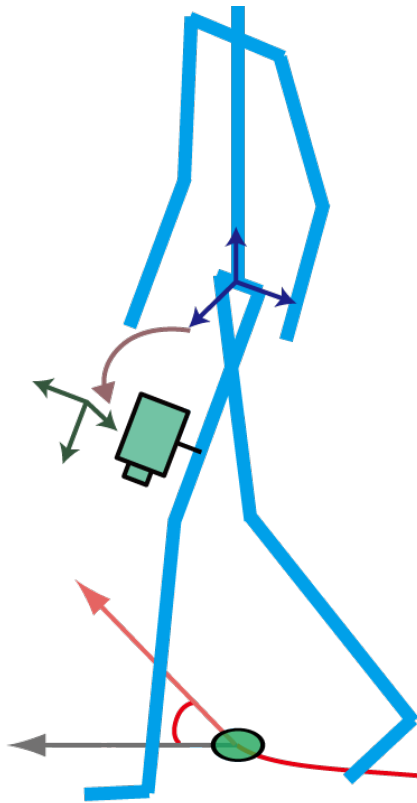


**high-speed
visual sensing**



wearable

Human Gait Estimation Using a Wearable Camera



**high-speed
visual sensing**



**wearable
input**

Anywhere Surface Touch

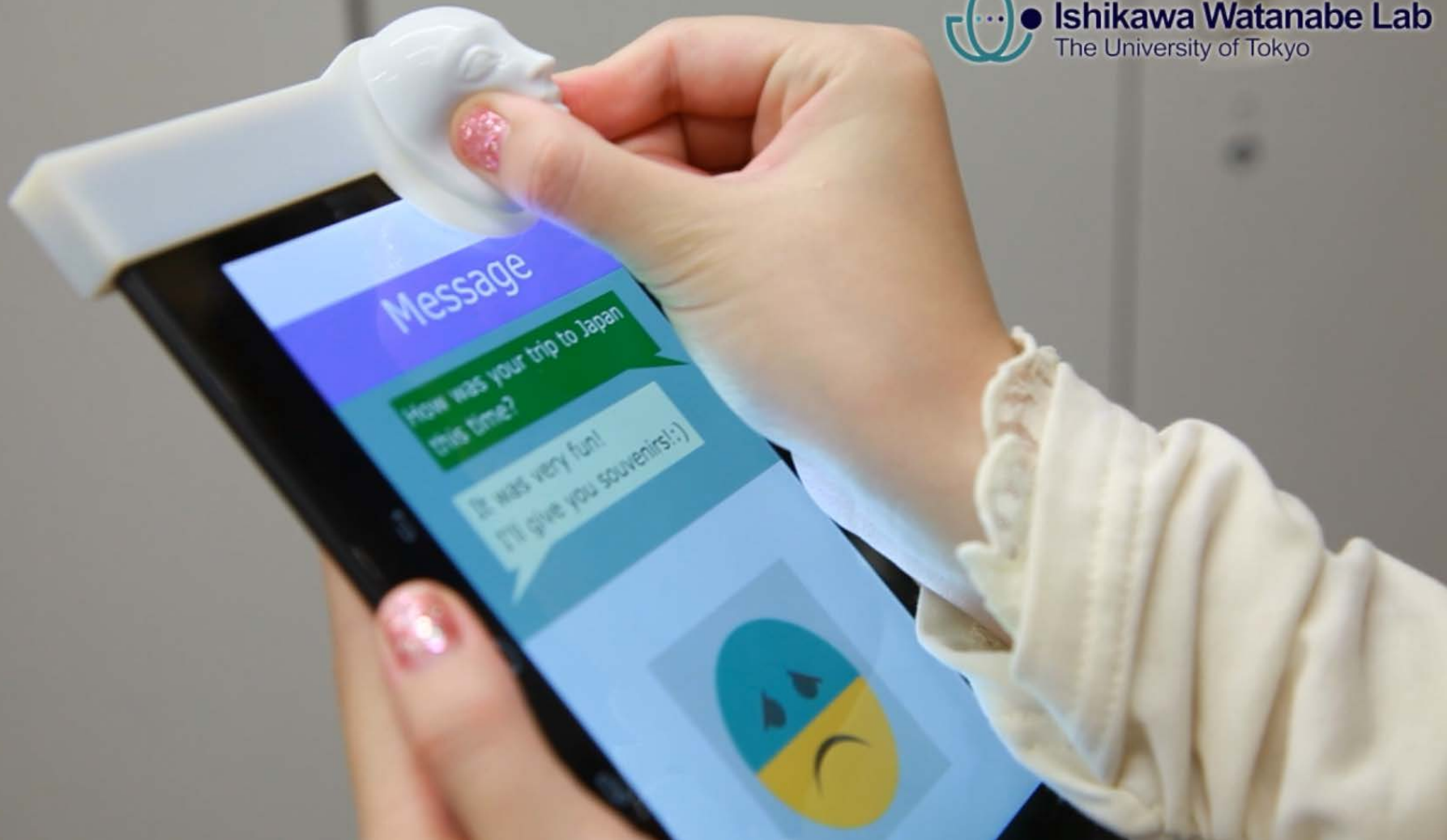


**high-speed
visual sensing**



**shape-changing
interface**

SENSECASE: Physically Augmented Smartphone



High-speed Computational Displays

**high-speed 3D
visual sensing**

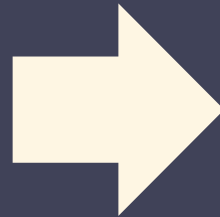


**shape-changing
interface**

The Deformable Workspace: a Membrane between Real and Virtual Space



projector



speed up!

DynaFlash: High-speed 8-bit image projector at 1,000fps with 3ms delay



DynaFlash

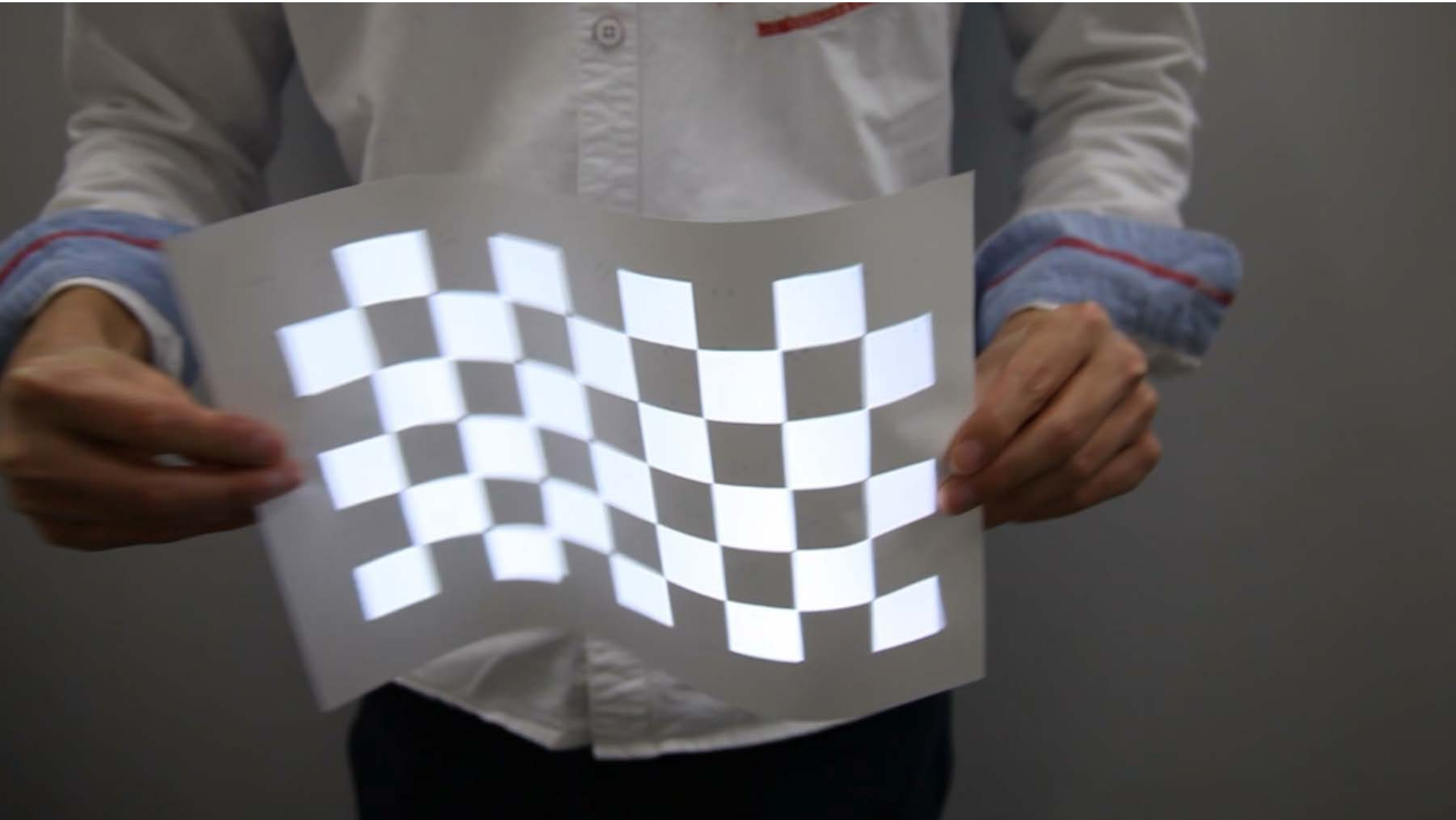
High-speed 8-bit image projector at 1,000fps with 3ms delay

**high-speed
projector**



**deformation
tracking**

Dynamic Projection Mapping onto Deforming Non-rigid Surface



**high-speed
projector**



realistic display

Towards Realistic Display



<http://www.telyuka.com/>

Computer Graphics



<http://thecreatorsproject.vice.com/>

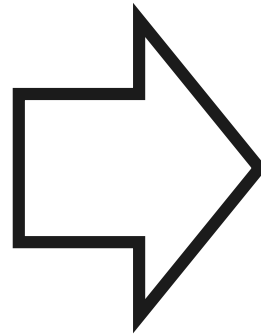
Stop Motion



Towards Realistic Display



If you want to see
metal, then use it!



Physical Object

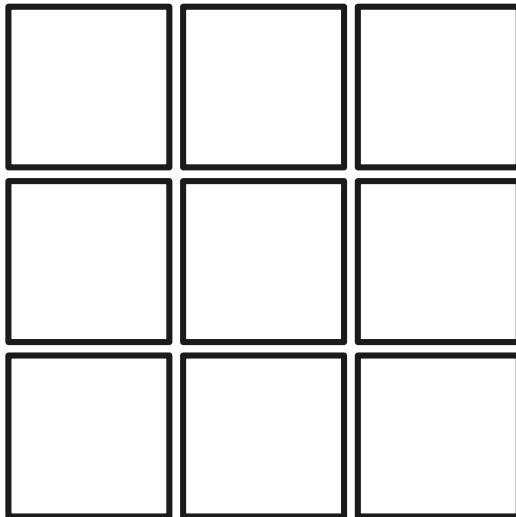
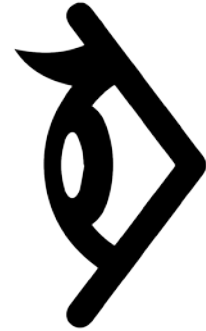
**Computational
Illumination**



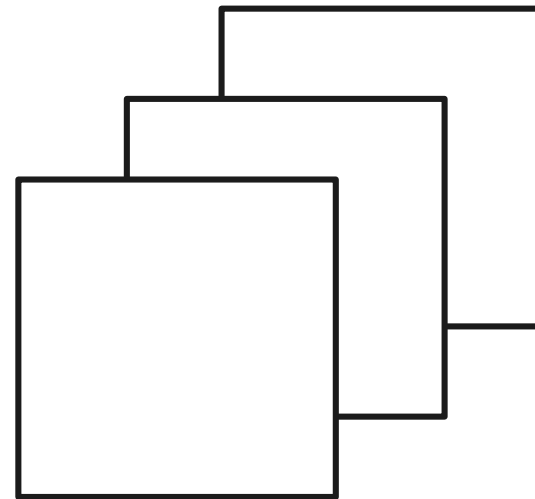
Toward Realistic Display

- Critical flicker fusion rate

- An intermittent light stimulus appears to be completely steady.

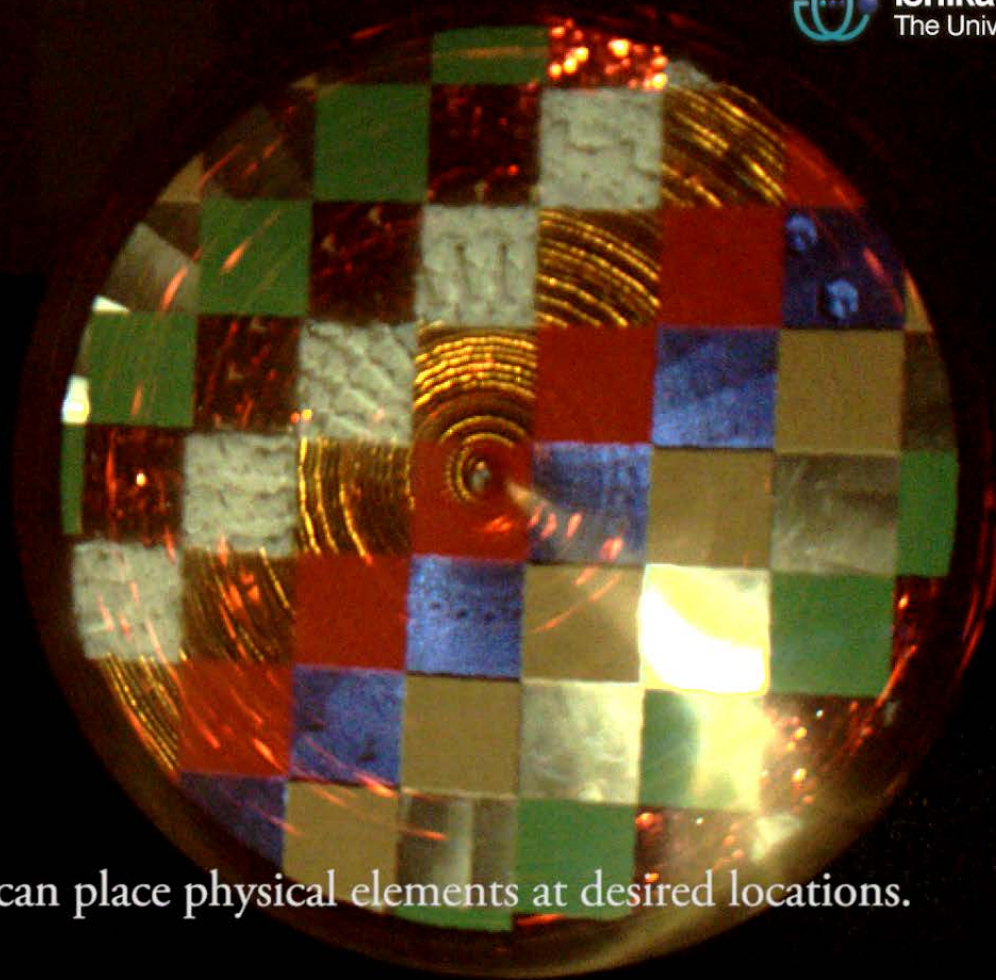


Spatial fusion



Temporal fusion

Phyxel: Display using Physical Objects with High-Speed Spatially Pixelated Lighting



"Phyxel" can place physical elements at desired locations.

ZoeMatrope: A System for Physical Material Design



Ishikawa Watanabe Lab
The University of Tokyo

Motor ON



Accordingly, ZoeMatrope can animate the material characteristics such as color and gloss

Today's topics

1. Massively-parallel image processing architecture and high-speed visual sensing **fundamental** **sensing**
2. High-speed 3D visual sensing and information reconstruction **fundamental** **sensing**
3. High-speed digital archiving **application** **sensing**
4. System design of human interface using high-speed visual sensing **application** **sensing** **display**
5. High-speed computational displays **fundamental** **application** **display**

VISION ARCHITECTURE

- Researches are done by
 - Doctor Course: L. Miyashita, M. Hirano, S. Tabata
 - Master Course: Y. Ataka, K. Ito, K. Saito, S. Tatsuno, H. Nakai, T. Yoshida, C. Yeo
 - OB (Doctor Course): T. Niikura
 - OB (Master Course): R. Yonezawa, M. Yasui, T. Hatanaka, G. Narita, C. Watanabe, K. Matsumoto, S. Noguchi, K. Tada, H. Gohara, M. Kondo, Y. Miura, A. Matsutani, H. Takeoka, H. Shibayama, S. Kubo, H. Ohno, K. Itoyama, T. Nakashima, T. Hatanaka

Additional Information

WEB

<http://www.k2.t.u-tokyo.ac.jp/>

YouTube

<https://www.youtube.com/user/IshikawaLab>



お知らせ

- 平成26年4月1日より、奥高橋先生の異動と渡辺清造先生の兼任に伴い、「石川 奥 研究室」から、「石川 渡辺 研究室」に研究室名を変更しました。

研究コンセプト

センサやロボットの進化、社会現象や心理現象も含めて、現実の物理世界をリアルワールドは、原則的に並列かつリアルタイムの演算処理を有している。その構造と同等の構造を工学的に再現することは、現実世界の理解を促すばかりでなく、応用上の様々な利点をもたらす。従来のシステムをはるかに優越性を生み出すことができ、結果として、まったく新しい情報システムを構築することが可能となる。本研究では、特にセンサ情報処理における並列処理と高速リアルタイム性を高度に実現する研究として、以下を行っている。また、新規高次元の野望にも力を注ぎ、研究成果の技術移転、共同研究、事業化等を様々な形で積極的に推進している。

- 並列の工学的演算処理を有したセンサ・フォーカシングの原理に基づいたシステム・アーキテクチャの構築とその高速知能ロボットの応用に関する研究。特に、視覚センサと触覚センサによるセンサフュージョンに基づく高速知能ロボットの開発並びにその応用としての新機軸の構築。
- 高速画像処理並びに新しいアクティブディスプレイシステムを用いて高速情報処理を実現するタイムシェアードコントロールに関する研究。特に、焦点及びピンチアウト線稿の高速制御技術並びにその応用としての高速運動に対する高速情報処理システムの構築。
- 並列処理に基づく高速画像処理技術(理論:アルリズム、デバイス)並びにその応用システムの実現を目指すビジョン・アーキテクチャの研究。特に、応用指向の高速画像処理システム並びに人間の眼を過かに速く高速性を利用した新しい構造を創造する応用システムの構築。

