

高速3次元センシングの実現 とその新応用

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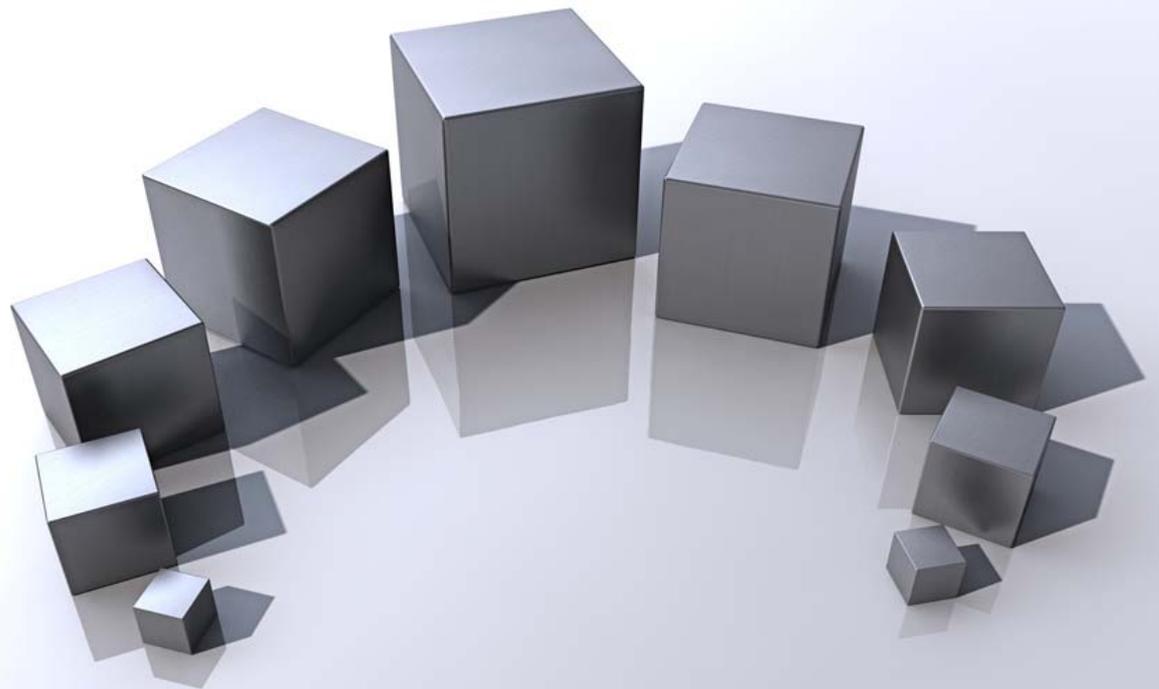
<http://www.k2.t.u-tokyo.ac.jp/>



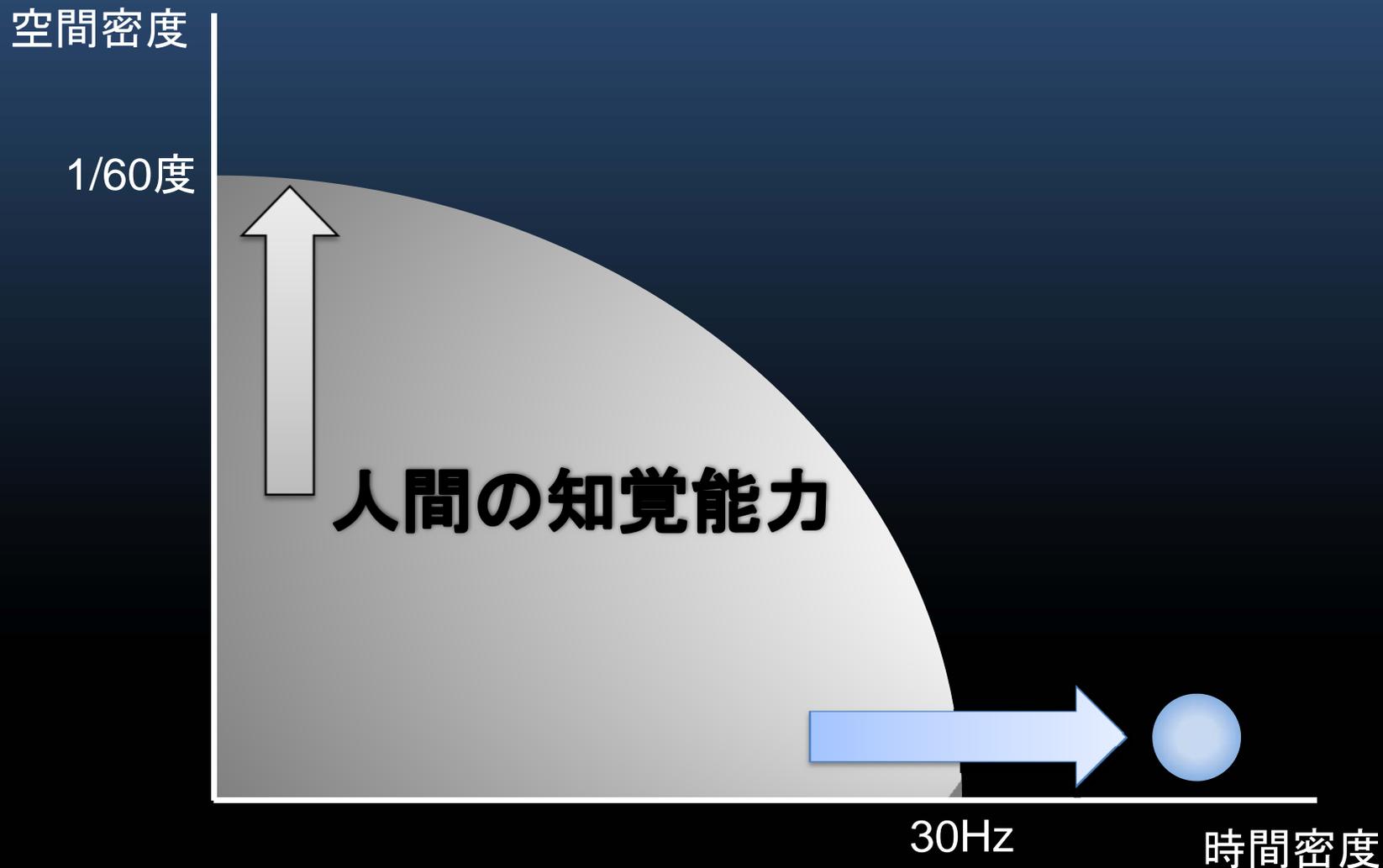
1秒間に1,000回

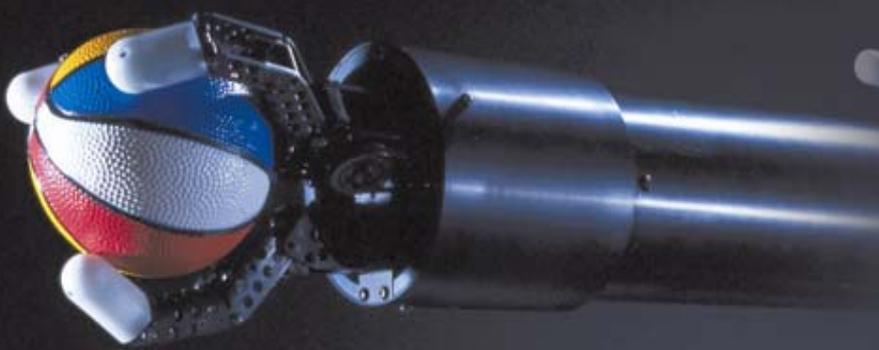


運動・変形物体 の3次元形状



アンコンシャスセンシング



A close-up of a robotic arm holding a colorful ball with red, blue, yellow, and white segments. The arm is metallic and has a gripper mechanism.

秒間1,000回センシング

ロボティクス

A full view of a robotic arm with a gripper mechanism, positioned against a dark background. The arm is metallic and has a complex joint structure.

秒間1,000回センシング

車載応用



秒間1,000回センシング

検査



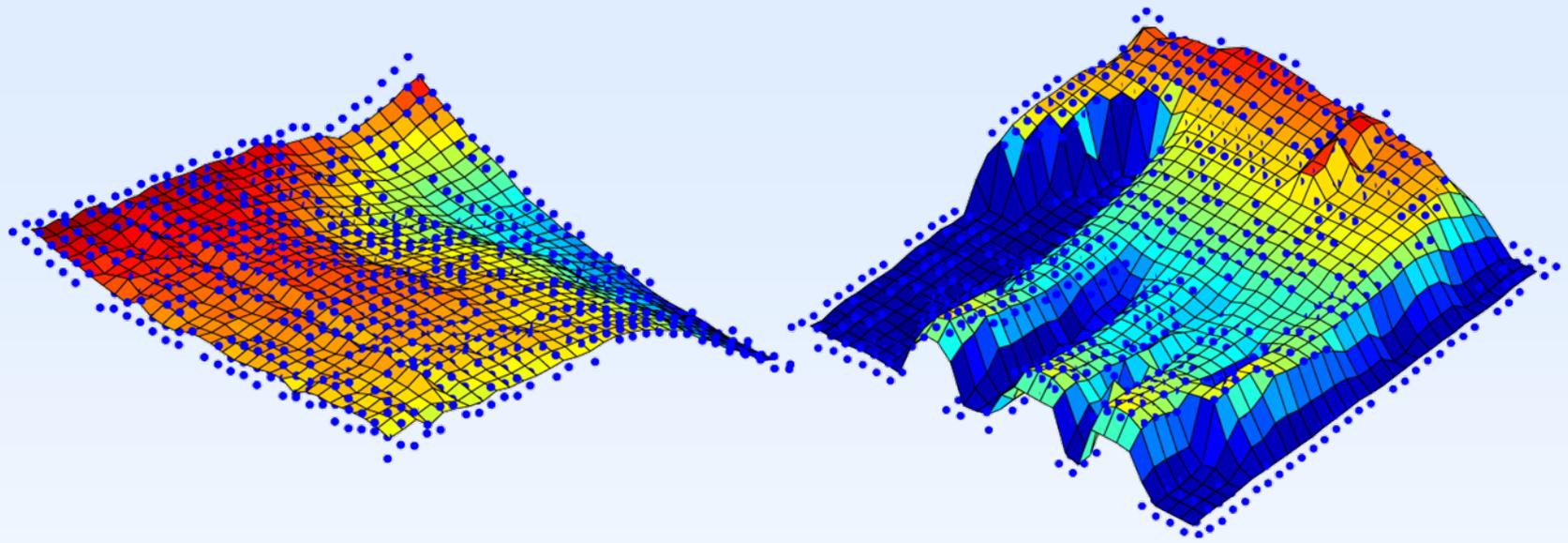


秒間1,000回センシング
ユーザインターフェース

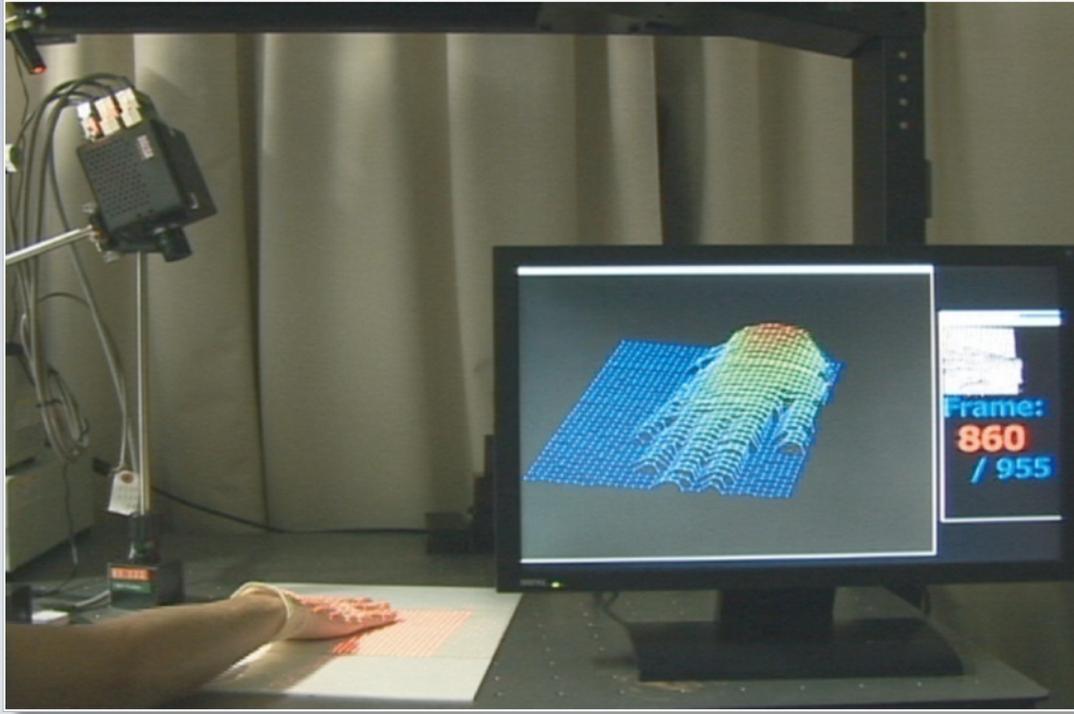
A photograph of surgeons in an operating room. One surgeon in the foreground is wearing a blue surgical cap and mask, and is using a device labeled 'LUXTEC' on a patient's head. Another surgeon is visible in the background, also in full surgical attire. The scene is brightly lit, typical of an operating room.

秒間1,000回センシング

医療応用



運動・変形物体の リアルタイム3次元センシング



スループット 955 fps
レイテンシ 4.5 ms

高速3次元センシングシステム

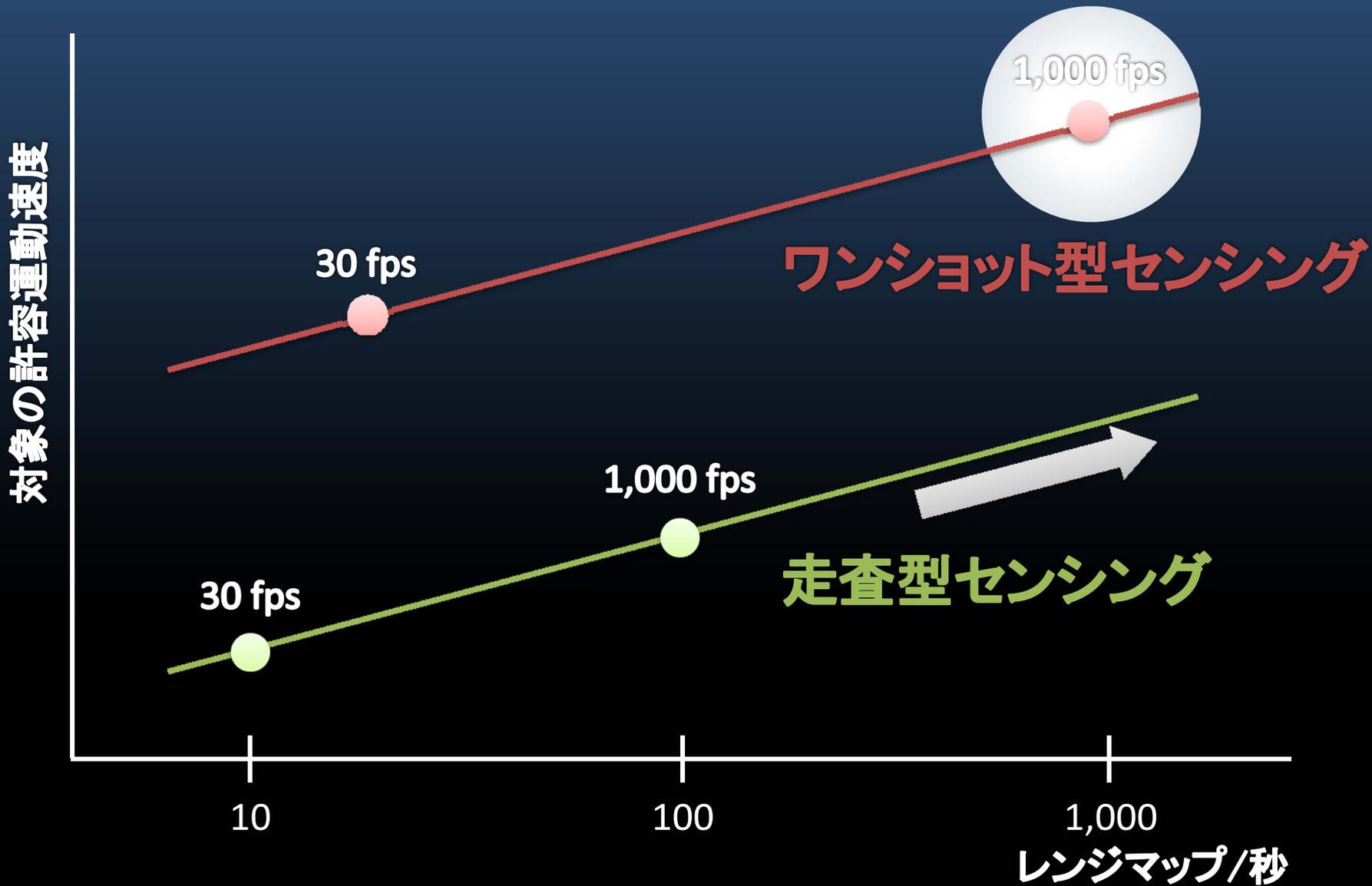


ワンショットモデリング

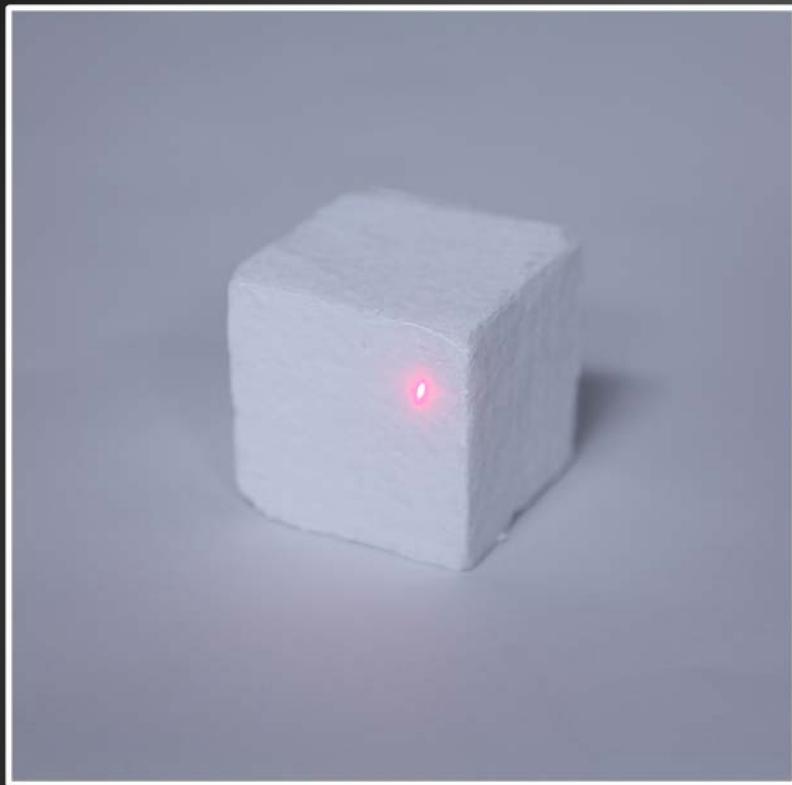
高フレームレート
イメージング

高速画像処理

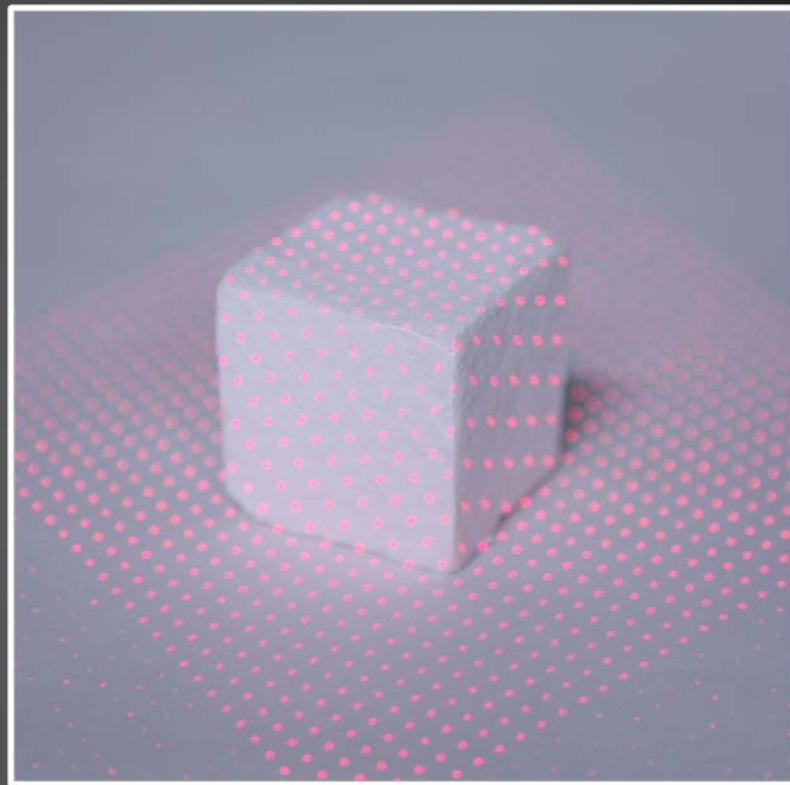
アクティブステレオにおける戦略



シングルスポット

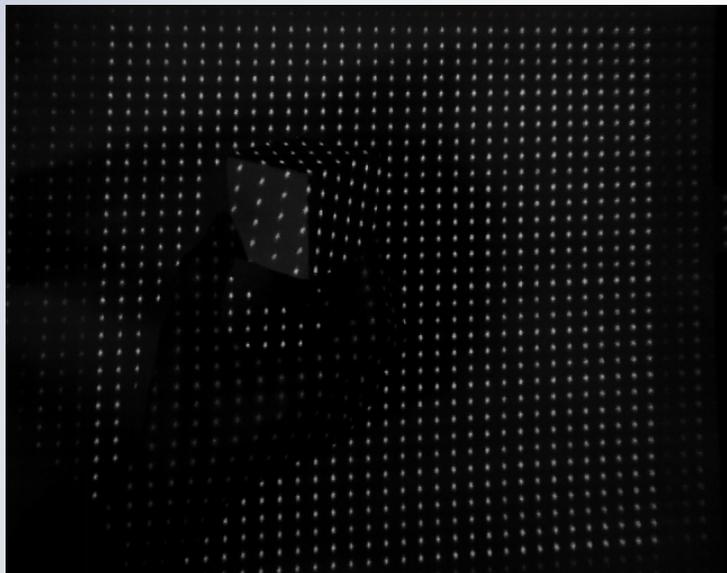


マルチスポット



$$\begin{aligned}PX &= \omega u \\ X &= O + \delta v\end{aligned}$$

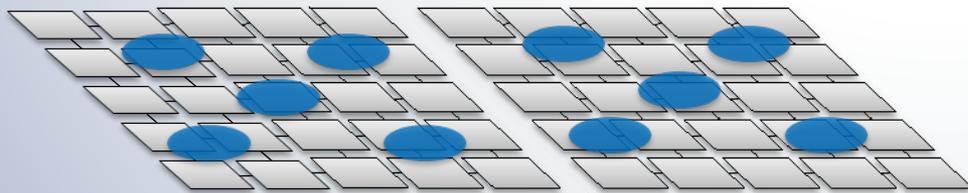
1,000fps 画像処理



処理能力
の不足

4,096完全並列プロセッサ

多点解析アーキテクチャ

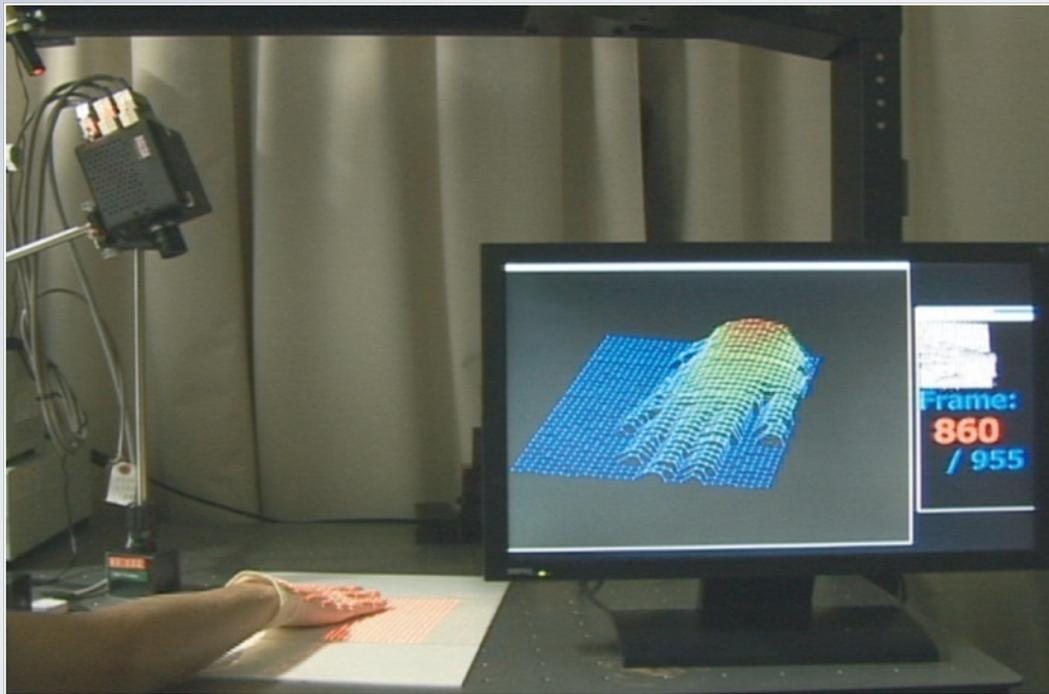


2基



運動・変形物体の リアルタイム3次元センシング

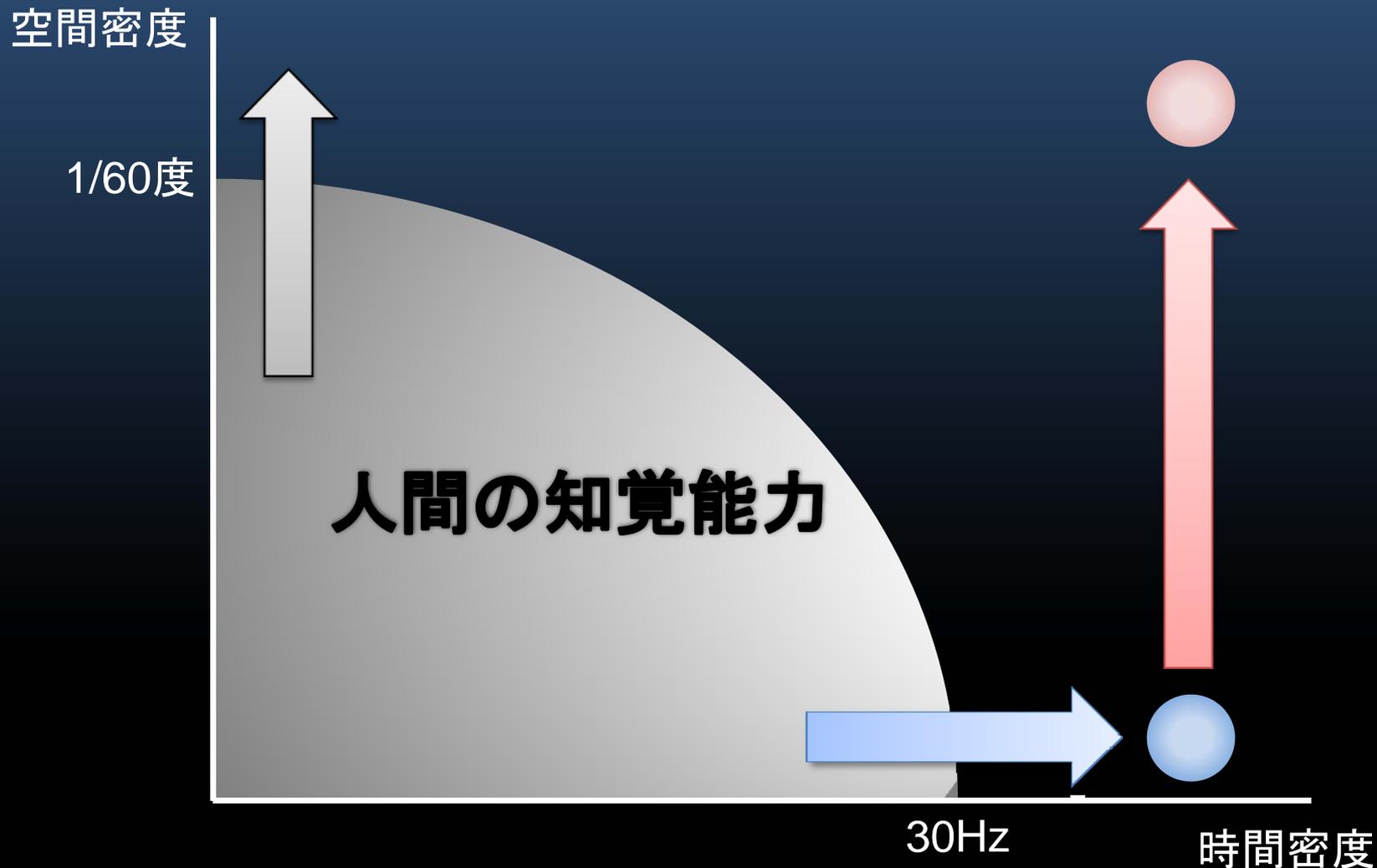
Demonstration



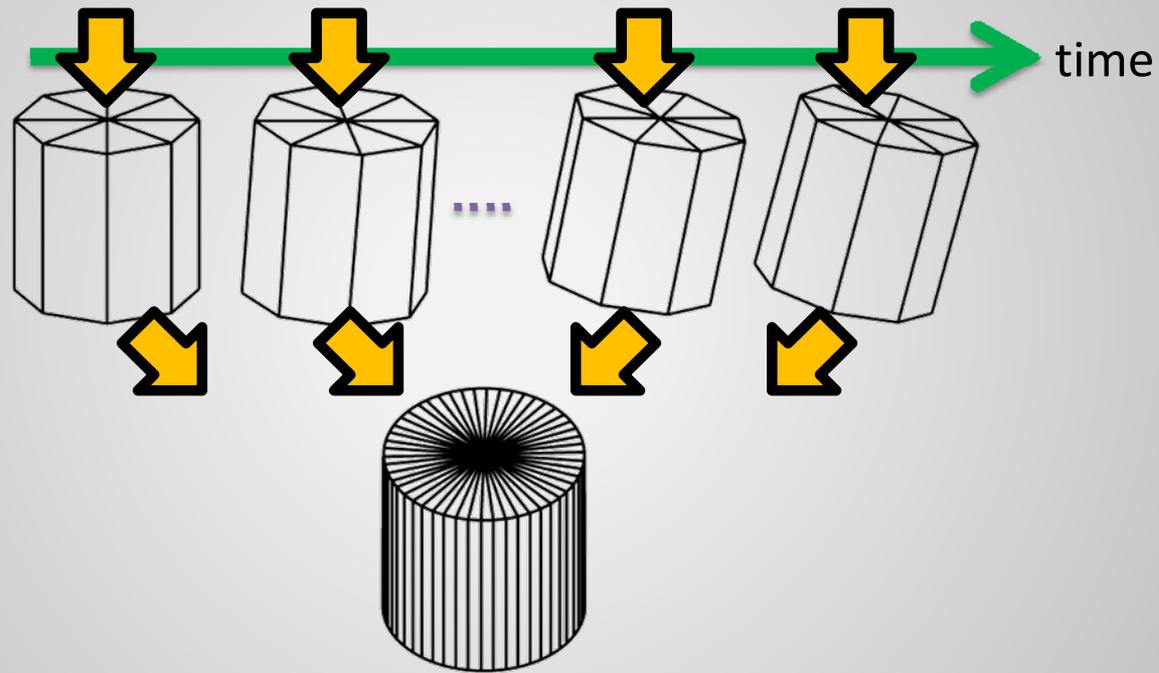
空間解像度の向上

ハードウェアの限界を超える

アンコンシャスセンシング

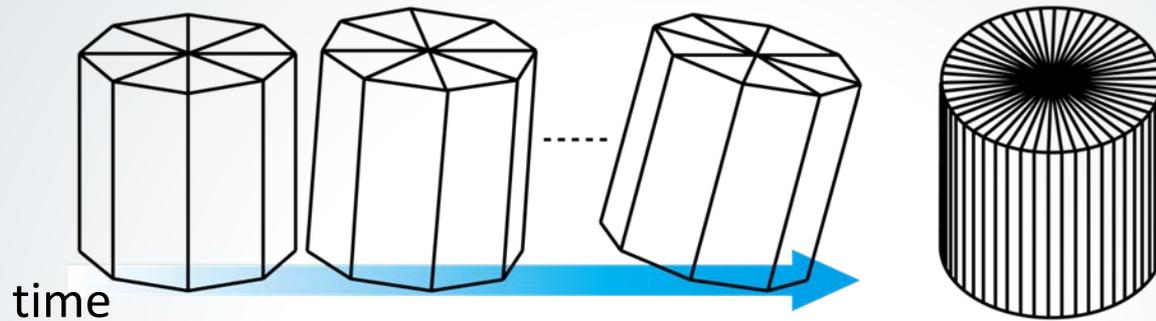


時系列統合



異なる対象表面の離散化

復元のプロセス



取得された距離画像

(m_1, m_2, \dots, m_N)

高解像度曲面

ξ

剛性変換

(s_1, s_2, \dots, s_N)

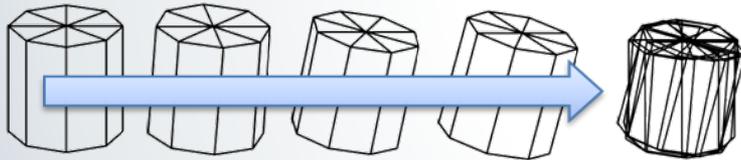
形状パラメータ

M

問題の定式化

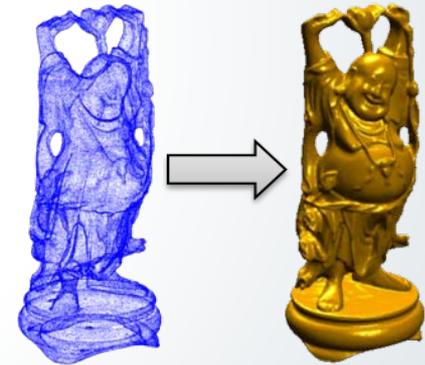
タスク1

復元形状との距離が最小となるように、距離画像の位置を合わせる



タスク2

距離画像との距離が最小となるように、復元形状を推定する



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



連続曲面の数式モデル

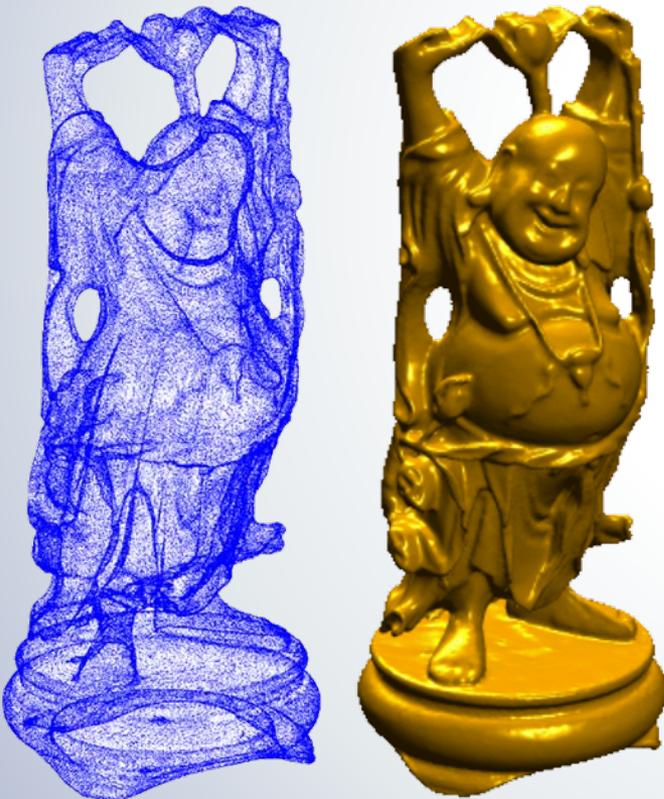
陰関数曲面

空間をスカラー場で表現

$$f(\mathbf{m}) = 0$$

$$f(\mathbf{m}) = p(\mathbf{m}) + \sum_{i=1}^{N_B} \lambda_i \phi(|\mathbf{m} - \mathbf{m}_i|)$$

Radial Basis Function

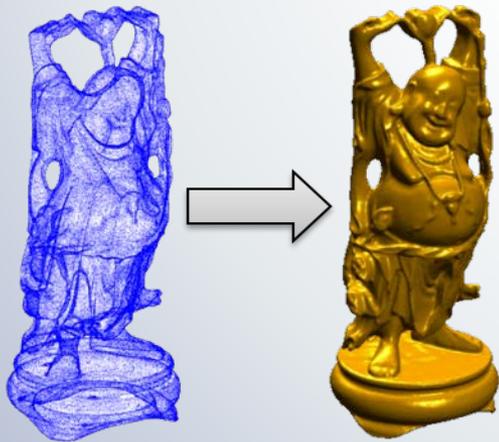
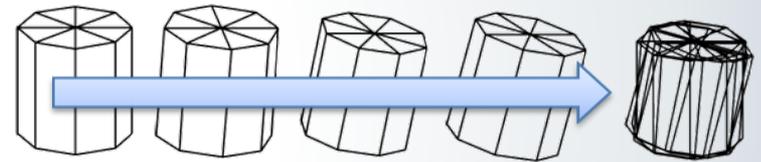


反復解法による同時推定

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

陰関数曲面を用いた運動推定

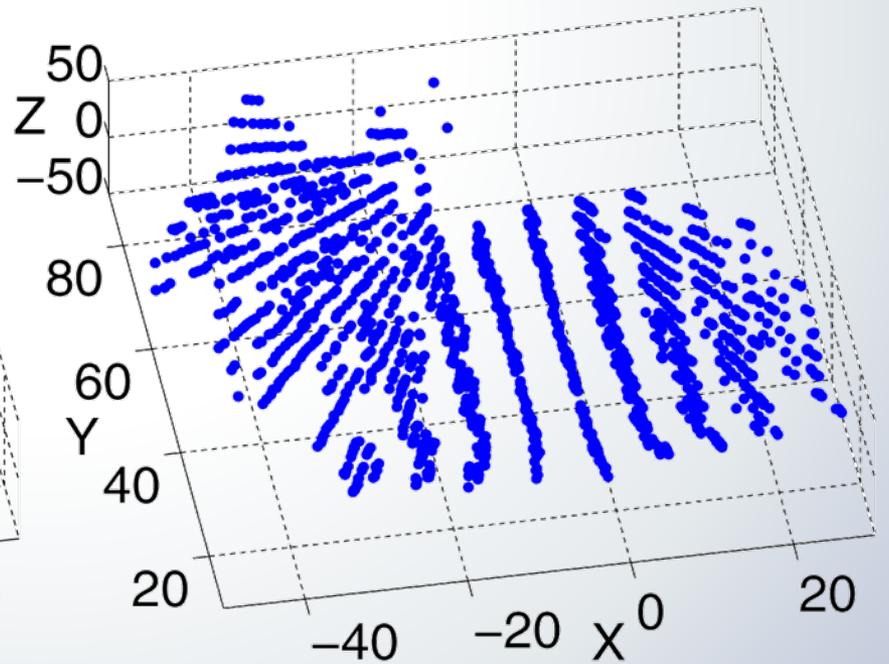
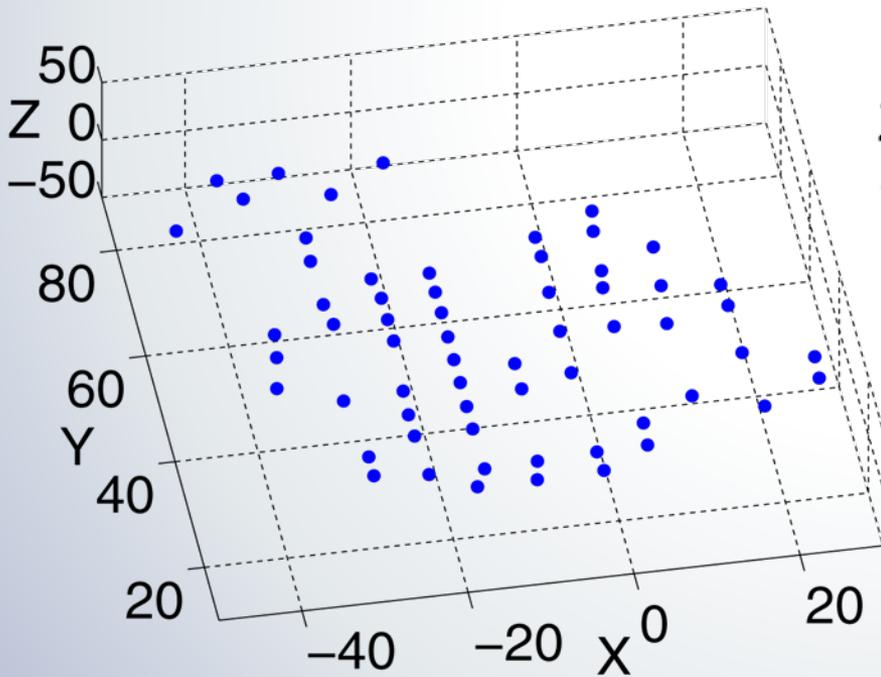
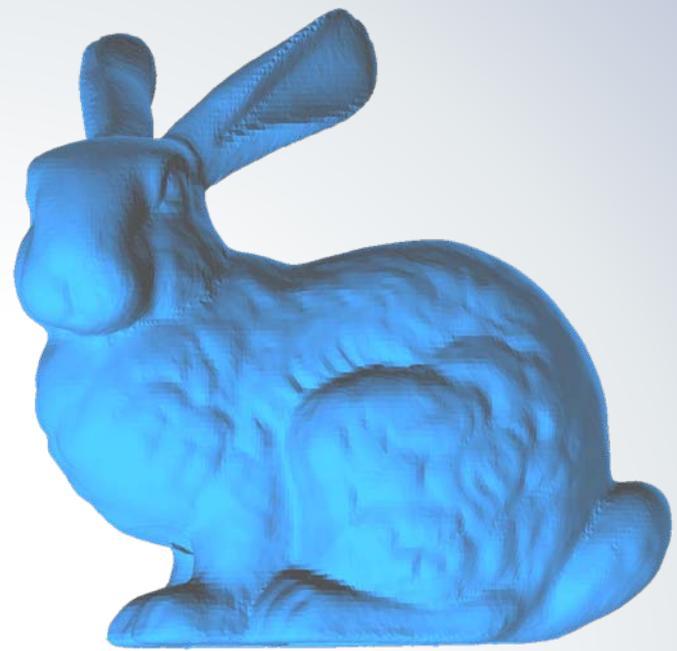
$$\min_{s_f} \sum_{i \in L'_f \text{ inliers}} f(\tilde{m}_{f,i}(s_f))^2$$

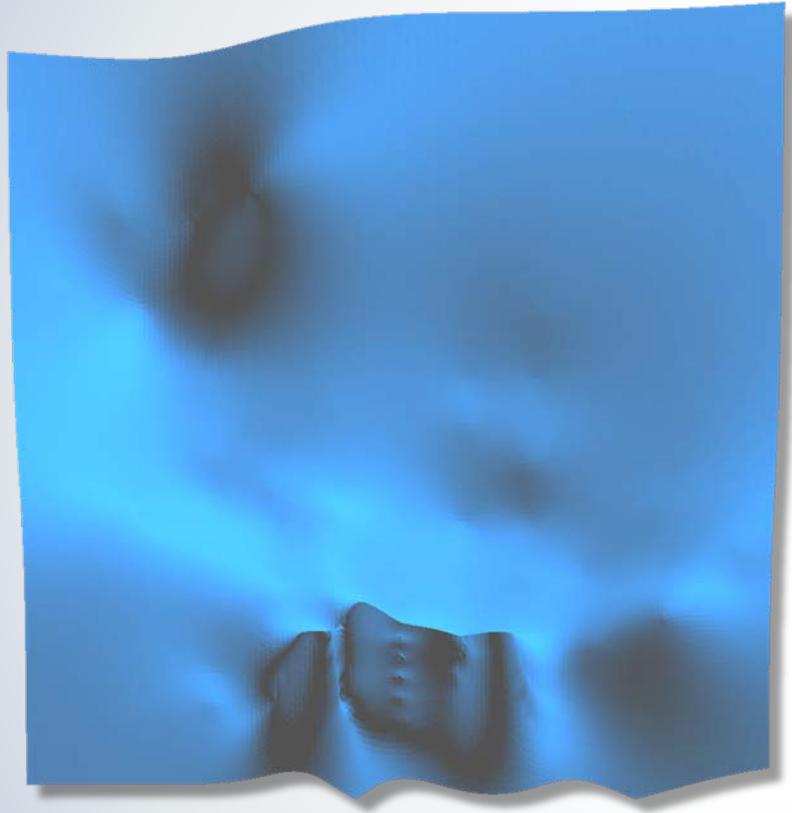
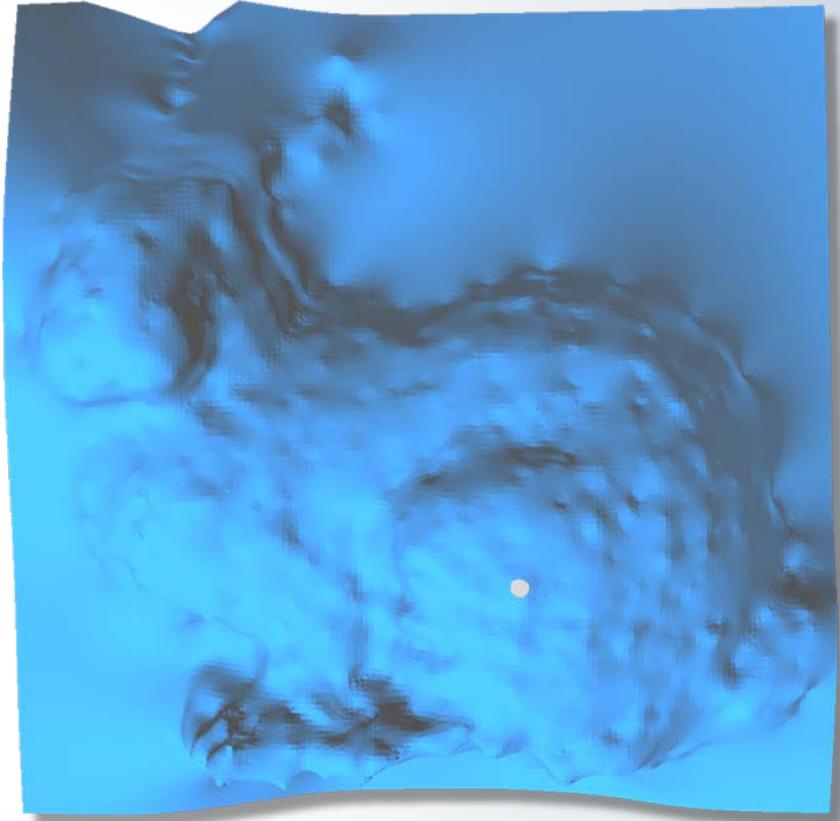


連続曲面を有する形状の復元

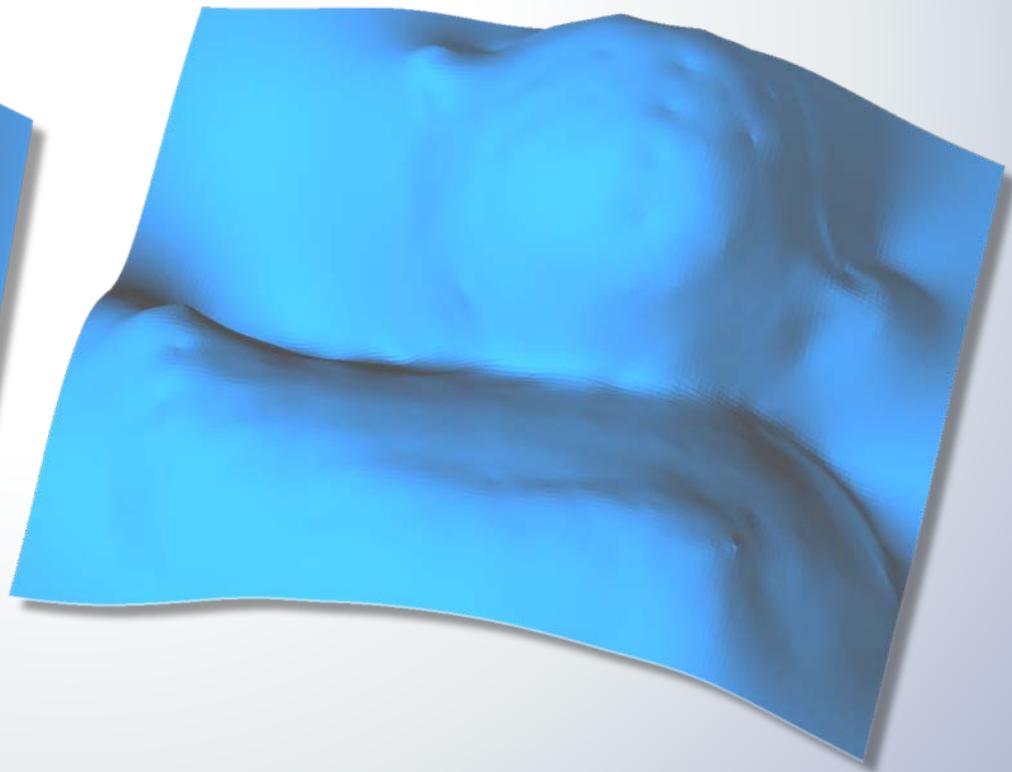
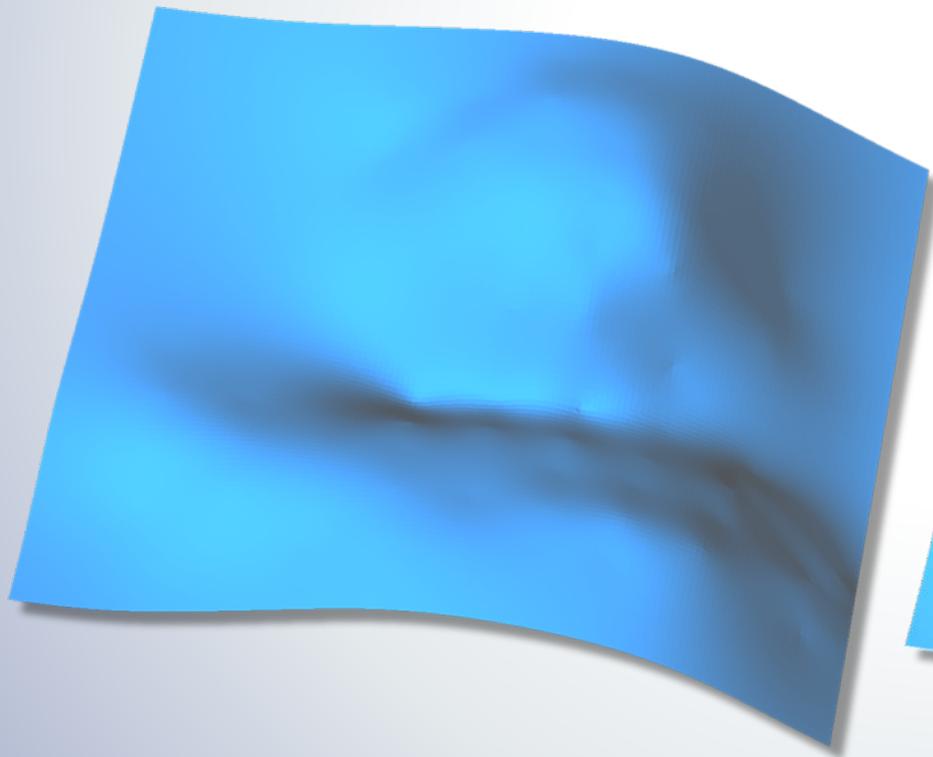
$$\min_f \|f\|^2 + \sum_{f=1}^N \sum_{i=1}^{L_f + \alpha} \frac{1}{\rho_f} (f(\tilde{m}_{f,i}(s_f)) - f_{f,i})^2$$

Stanford Bunny

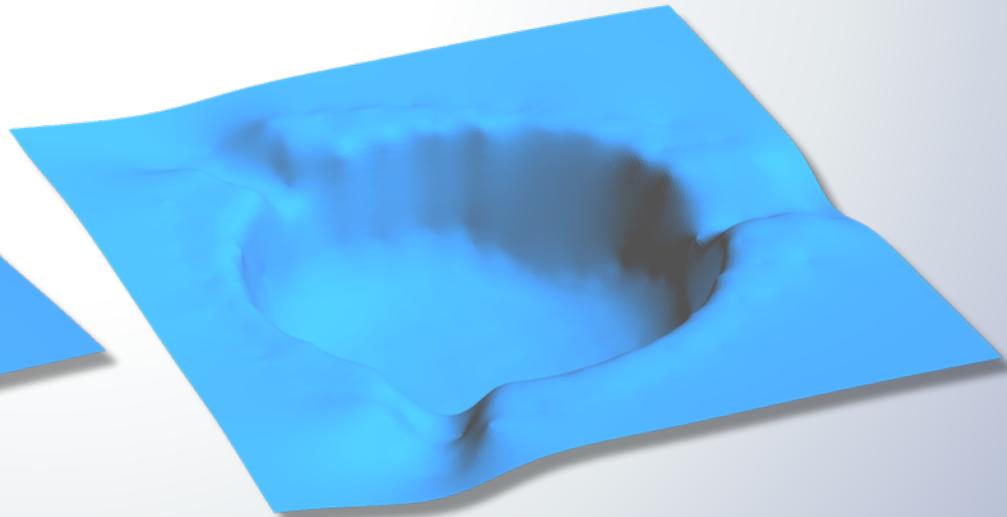
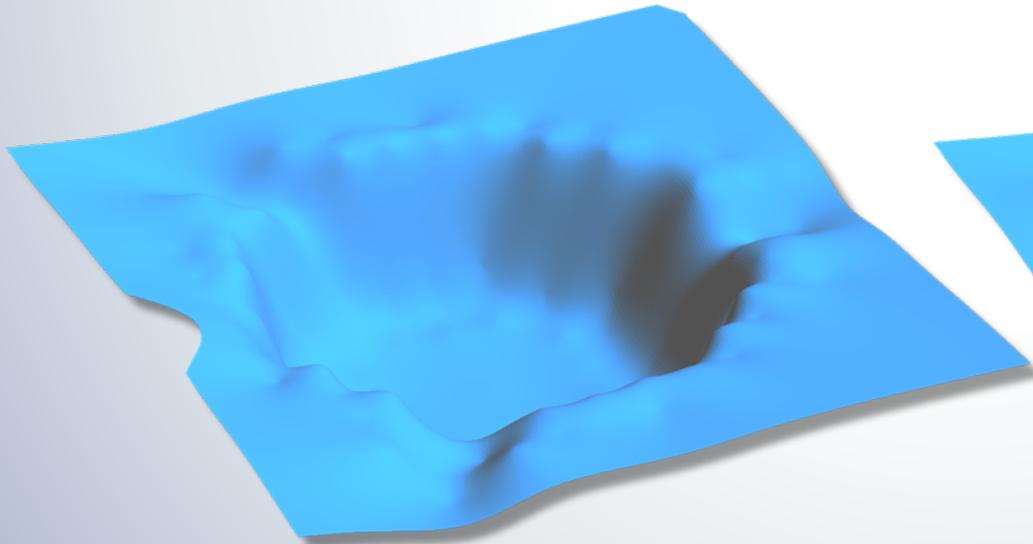




小鳥の人形



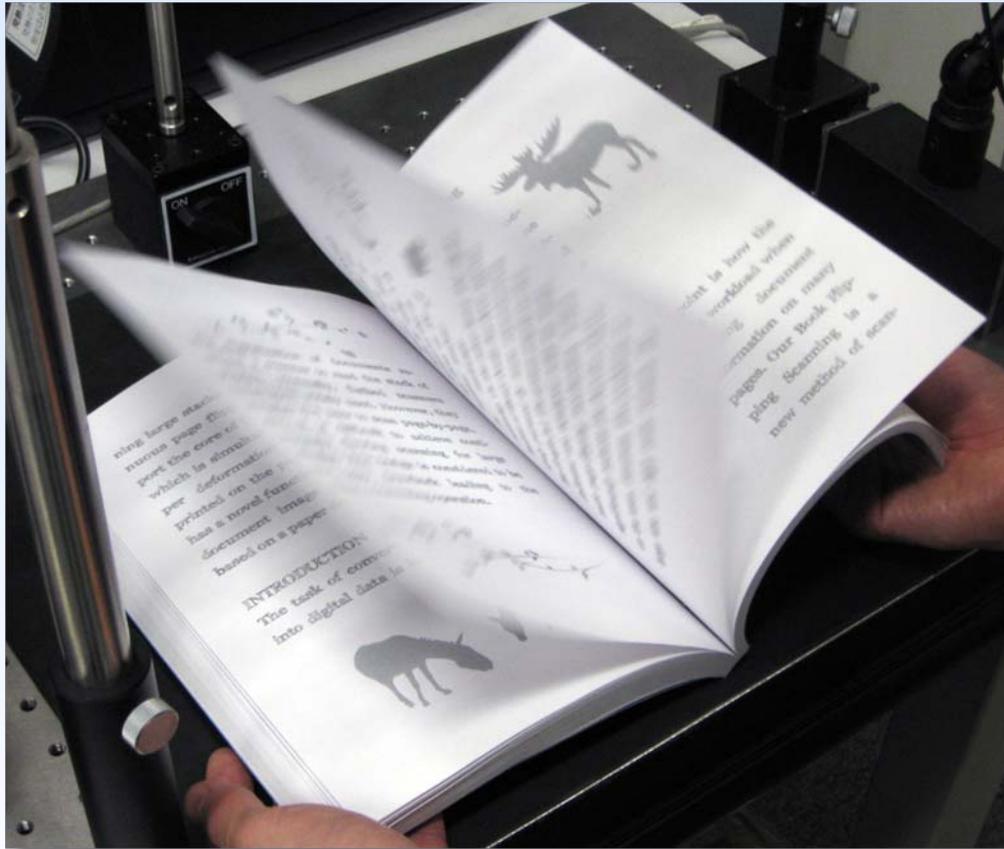
灰皿



運動・変形物体の
3次元センシング

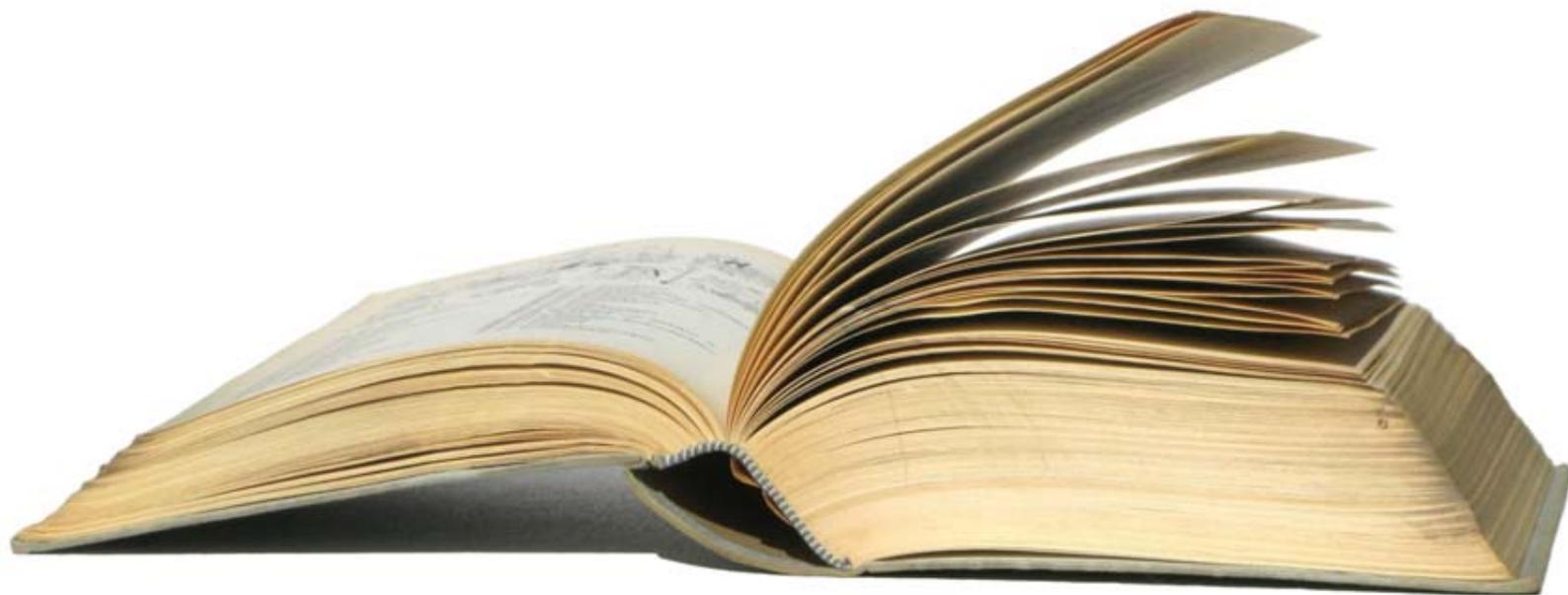


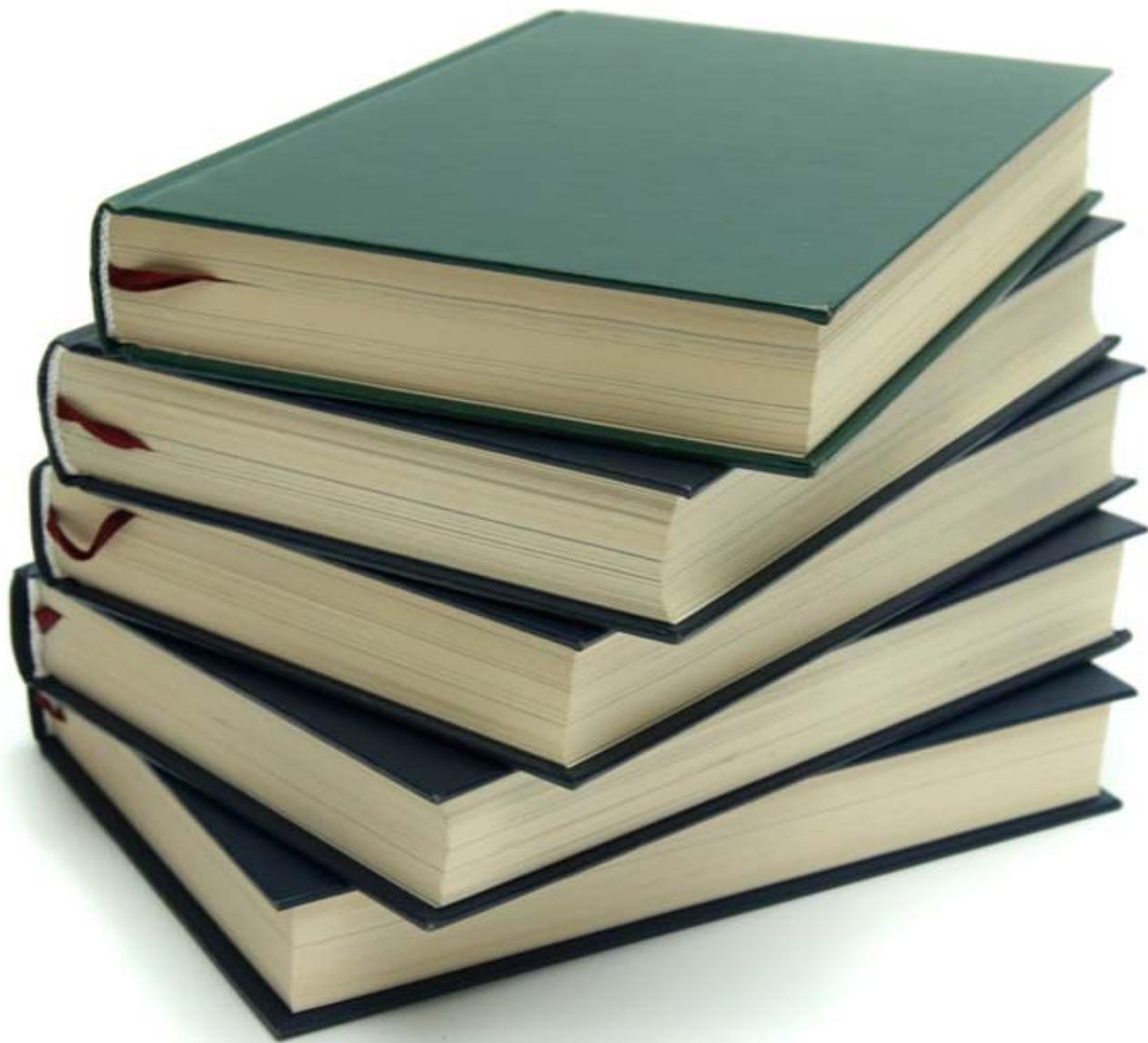
新応用



Book Flipping Scanning

書籍のデジタル化





A wide-angle photograph of a modern library interior. The space is filled with long, light-colored wooden bookshelves that are densely packed with books. In the foreground and middle ground, there are several study tables with metal frames and white tops, each equipped with a small lamp. The background shows more bookshelves and a few people in the distance, suggesting a large, active library environment. The lighting is warm and focused on the study areas.

膨大な量の書籍の電子化

831万冊

東京大学図書館の蔵書数
(2004年度調べ)

Book Flipping Scanning

コンセプト

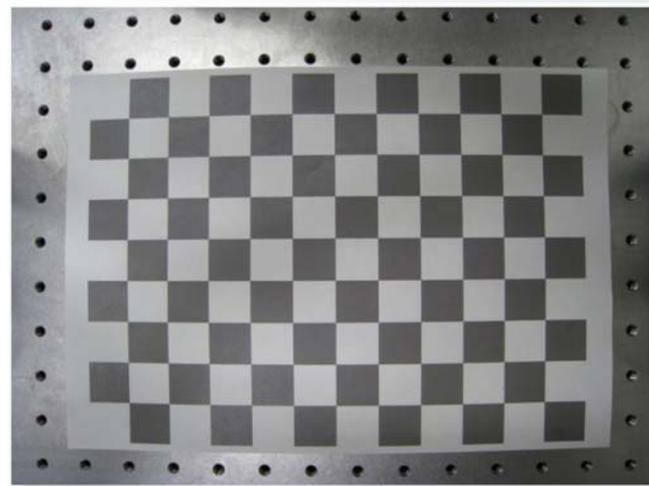
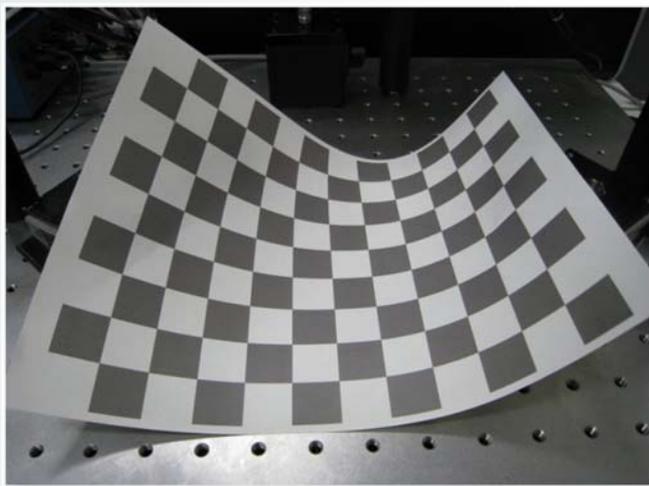
Book Flipping Scanning

プロトタイプ

Book Flipping Scanning

センシングイメージ

変形の推定と平坦化



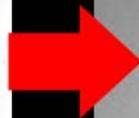
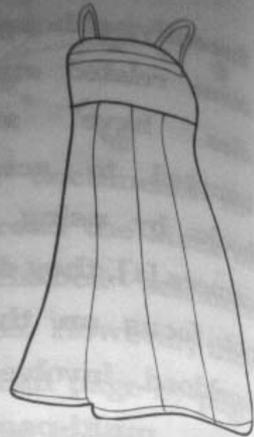
可展面

伸縮・断裂することなく平面に展開することができる曲面

$$M(s, t) = \gamma(s) + t \frac{\gamma''(s) \times \gamma'''(s)}{|\gamma''(s) \times \gamma'''(s)|}$$

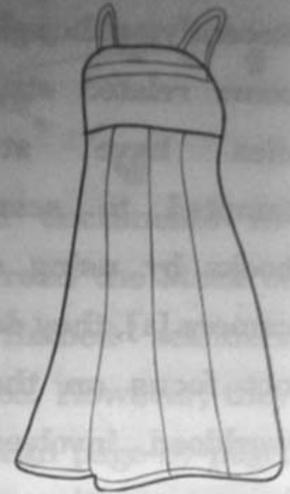
personal use.

In this study, we target a high-speed scanning technology with a simple interface. We consider that the breakthrough is in the design of the method of reading multiple pages. Our proposed approach is based on a novel scanning technique that reads pages continuously while a user rapidly flips the pages. We call this scanning method Book Flipping Scanning. A conceptual image showing how this technology might work is shown in Figure 1. The technological challenges are described in the next section.



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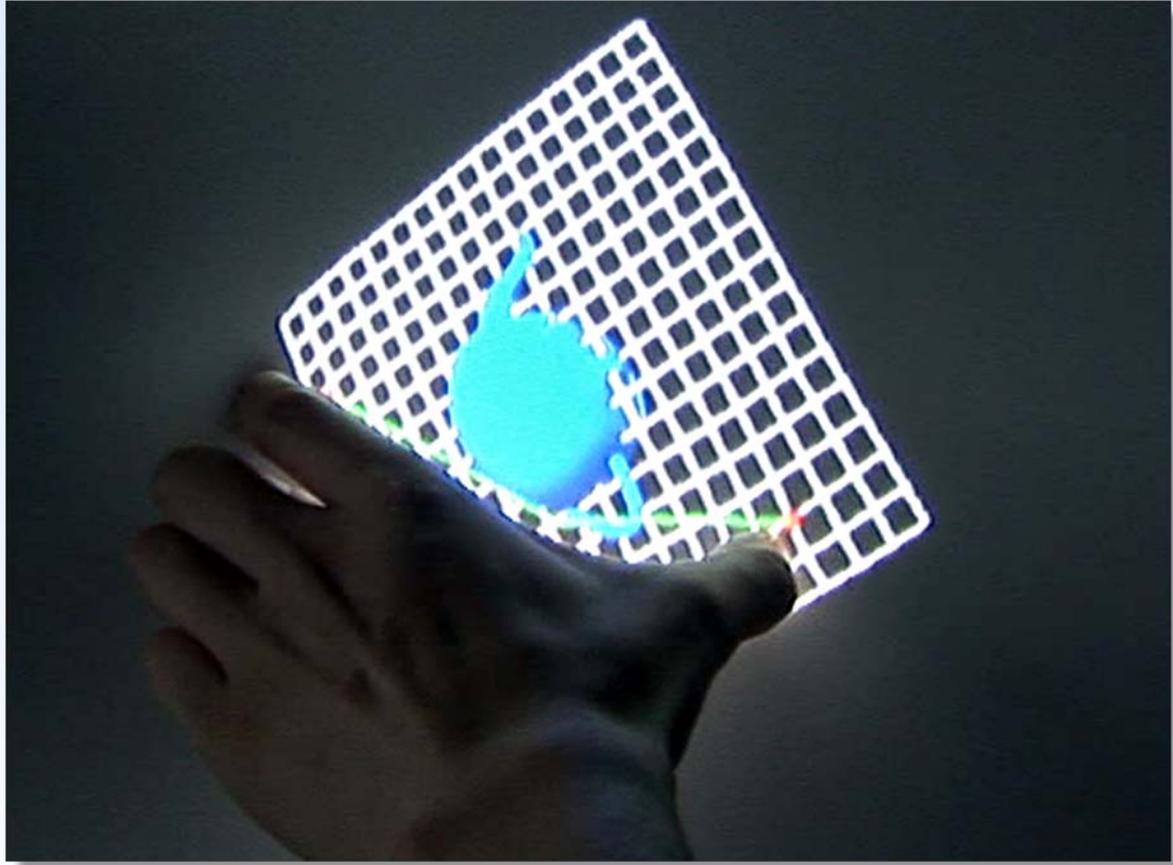
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運動・変形物体の
3次元センシング

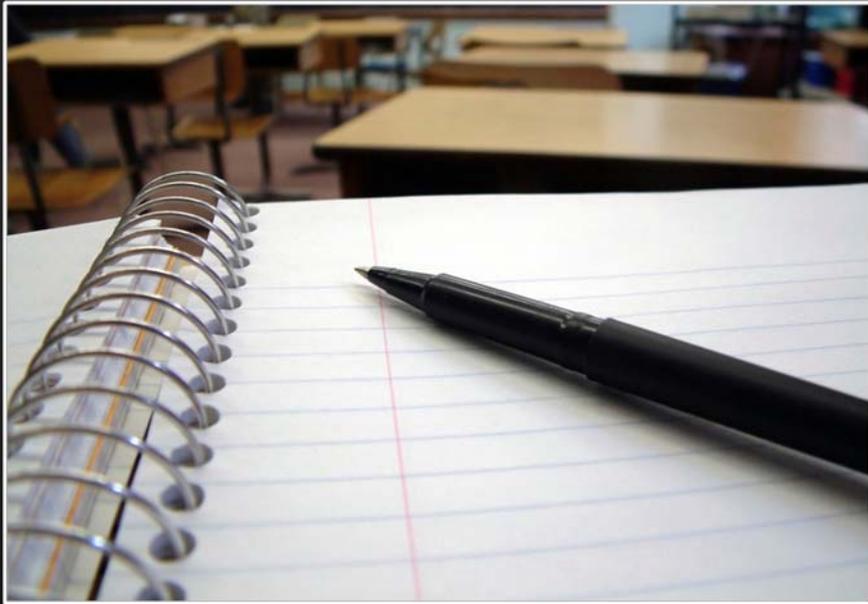


ユーザインターフェース



DEFORMABLE **V**ORKSPACE

絵を描いてください



ボールを動かしてください



現実の物体

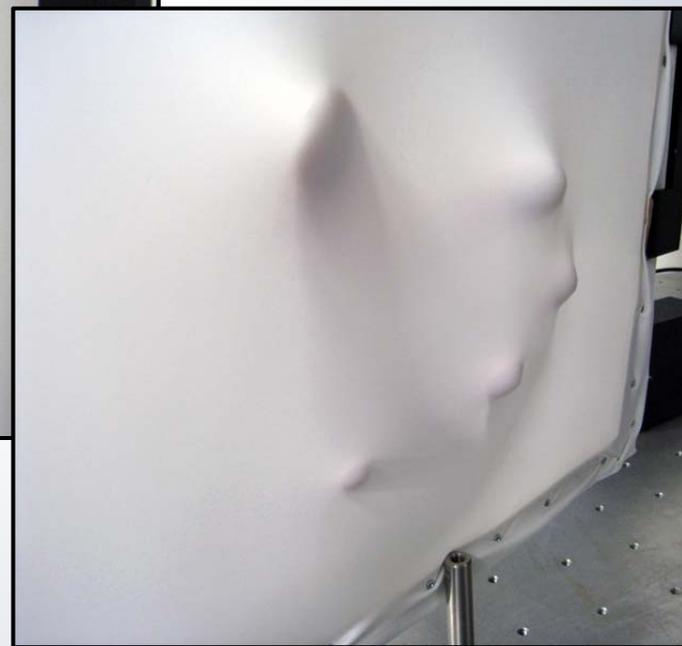
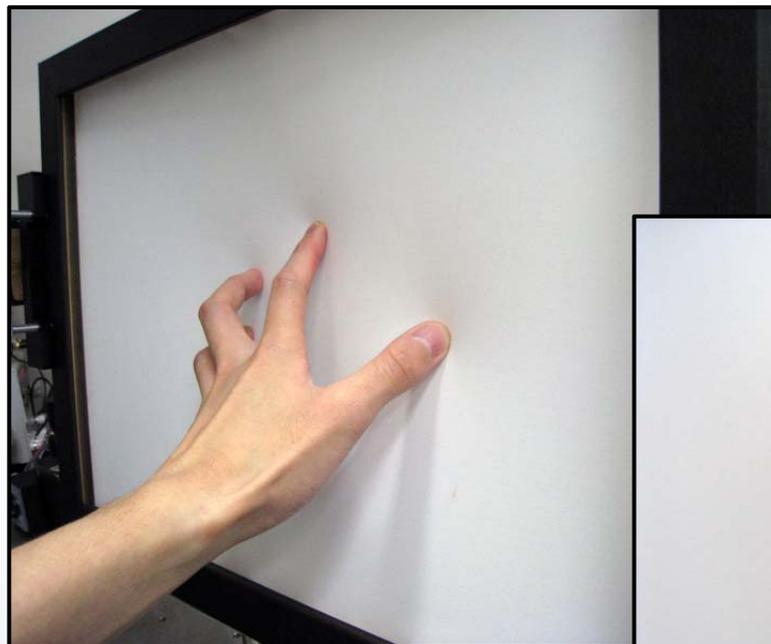


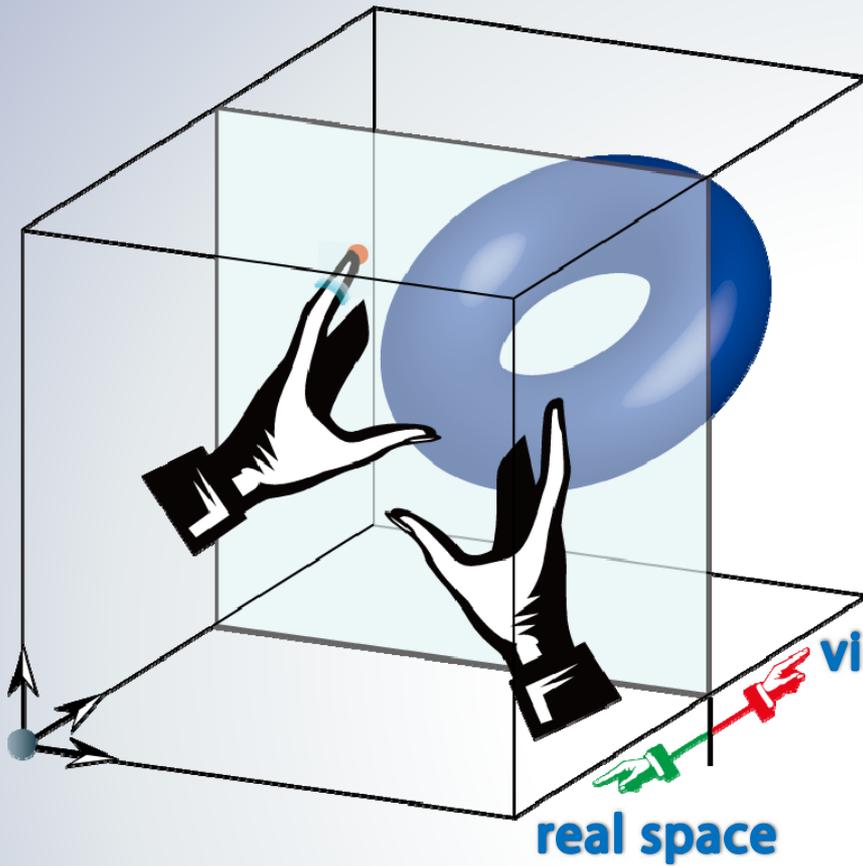
仮想の物体



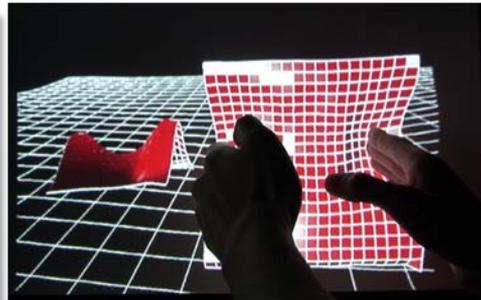
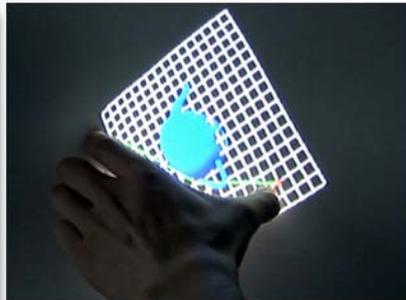
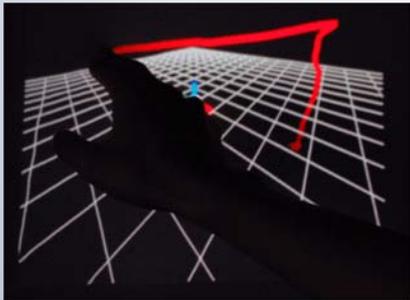
変形スクリーン

映像提示 + 操作入力

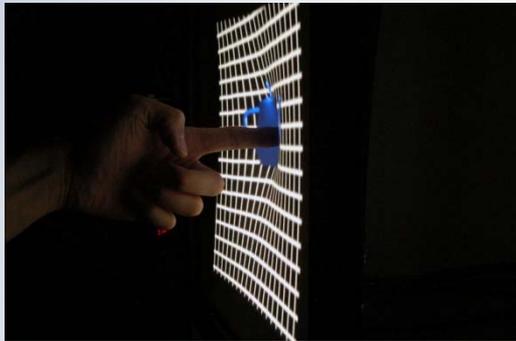




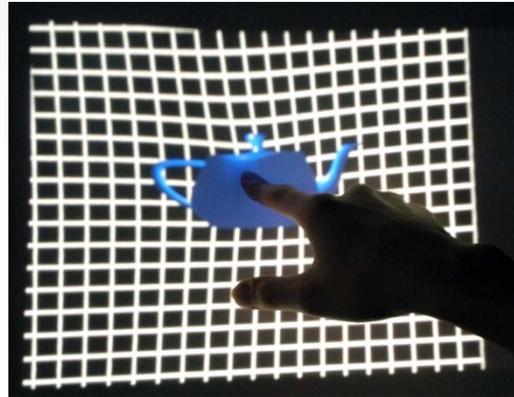
Deformable Workspace



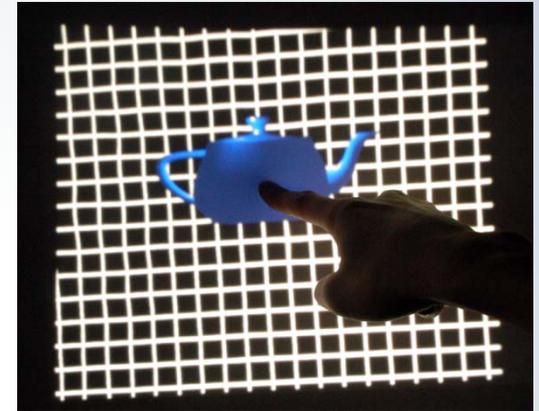
画像の歪み補正



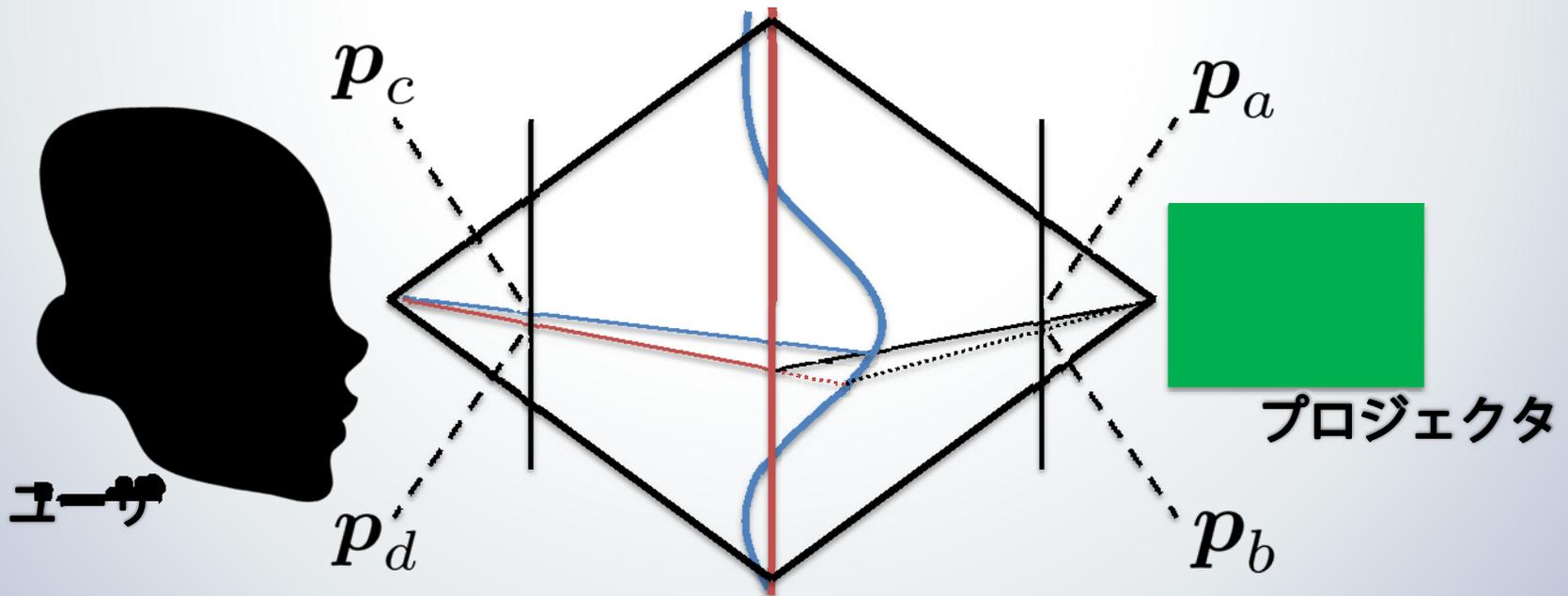
側面



補正なし



補正あり



Deformable Workspace

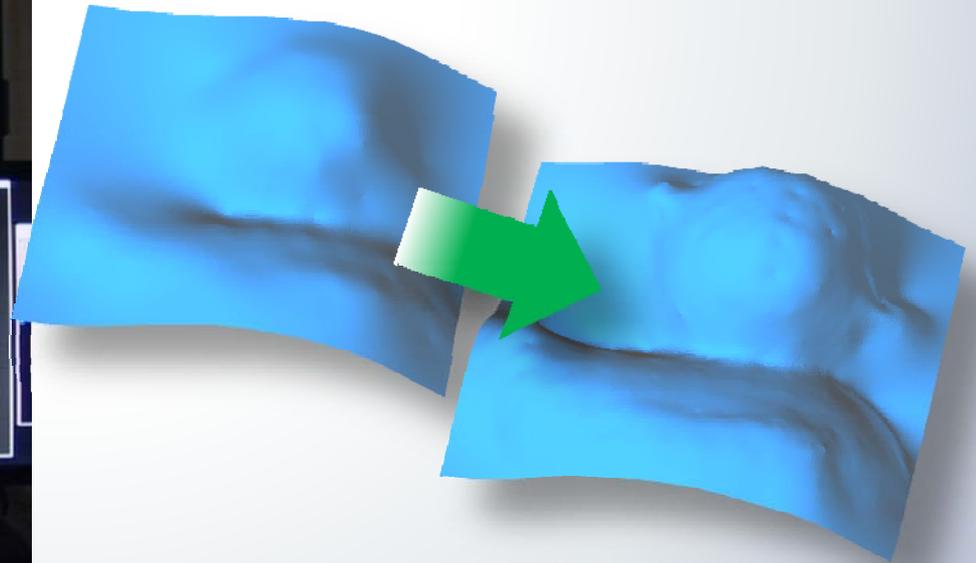
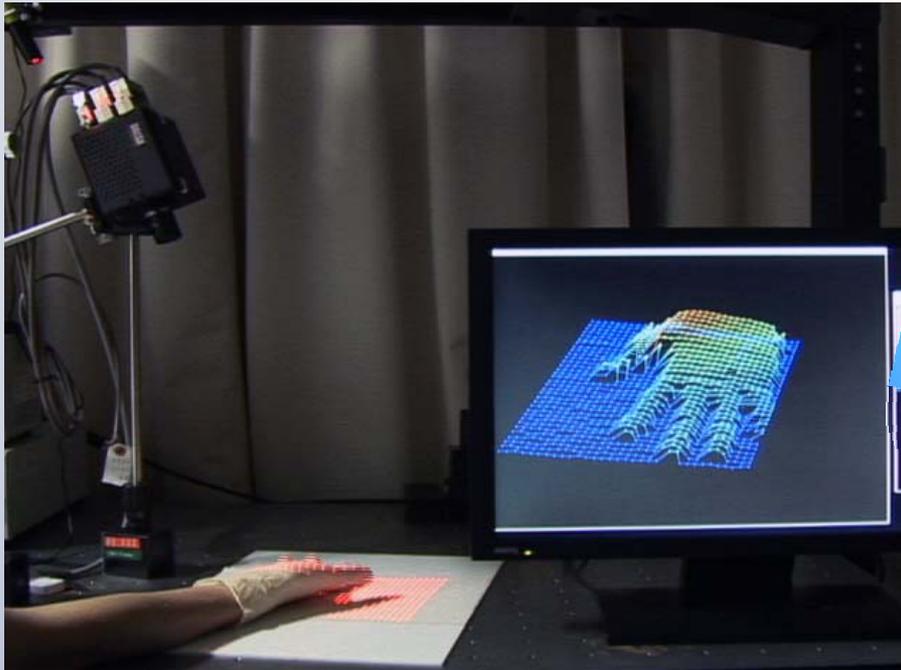
Demonstration

運動・変形物体の リアルタイム3次元センシング

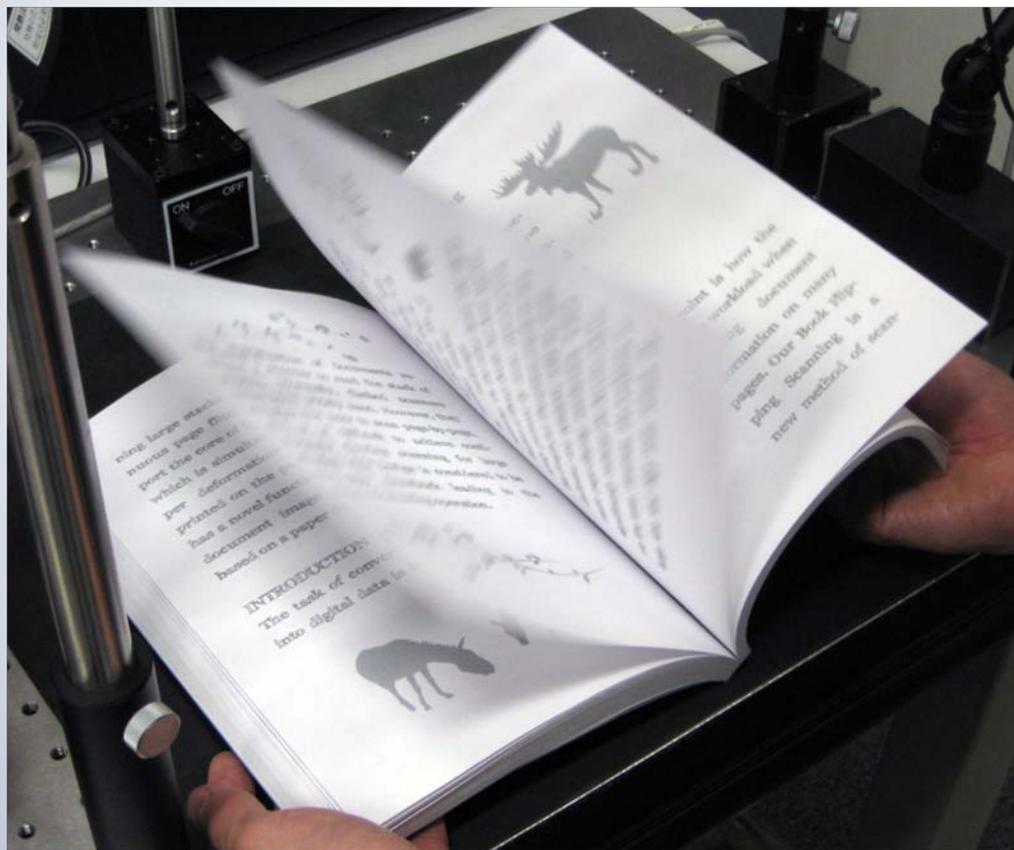
運動・変形物体

高速

解像度の向上



Book Flipping Scanning

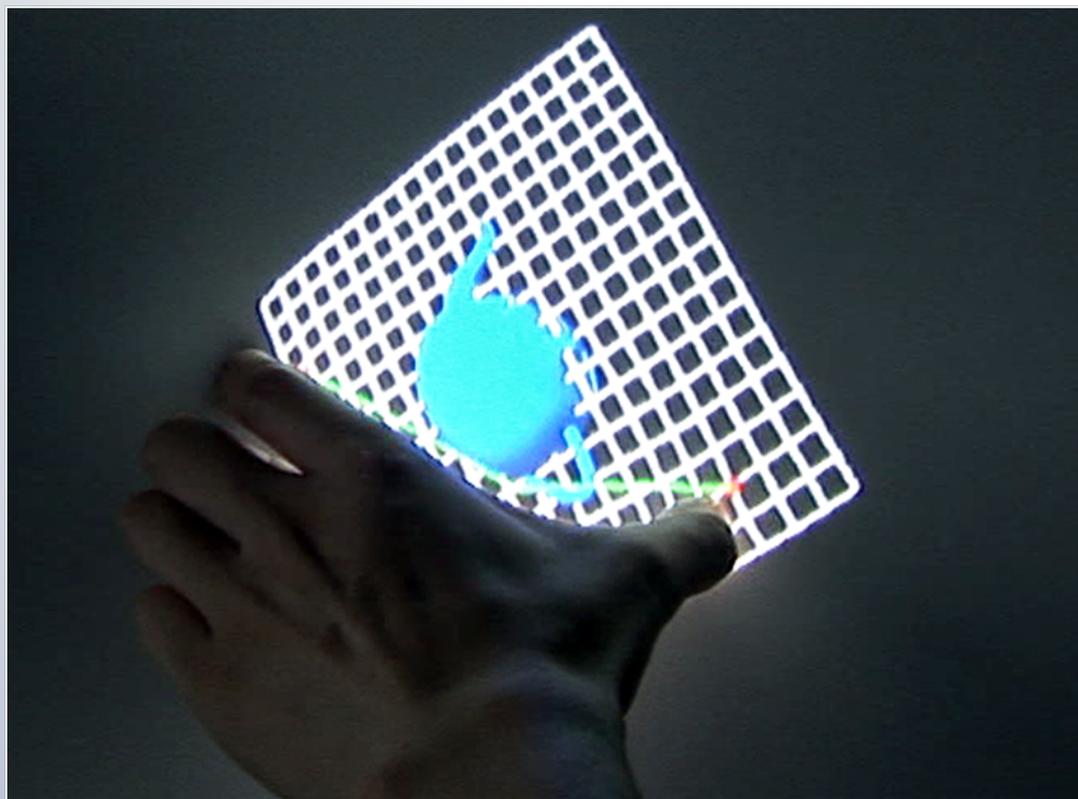


書籍のデジタル化

高精度な平坦化

**めくり動作中に
スキャン**

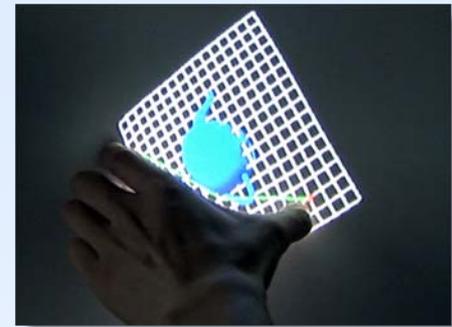
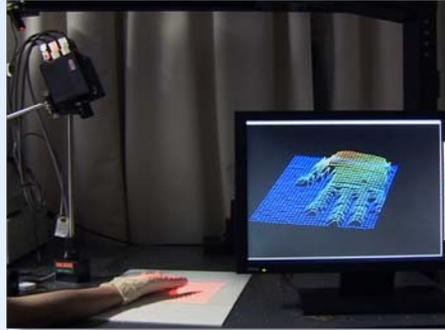
DEFORMABLE WORKSPACE



仮想物体の操作

**インタラクティブ
ディスプレイ**

変形スクリーン



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

高速3次元センシングの実現 とその新応用

