University of Tsukuba

筑波大学
計算科学研究センター
Center for Computational Sciences

2021/6/7(Mon) 13:00-17:00 計算メディカルサイエンス第１回全体ミーティング (online)

3DCGバーチャル手術
3D-CG Virtual Surgery

亀田 能成（筑波大学 計算科学研究センター・計算メディア分野・教授）

北原 格（筑波大学 計算科学研究センター・計算メディア分野・教授）

宍戸 英彦（筑波大学 計算科学研究センター・計算メディア分野・助教）

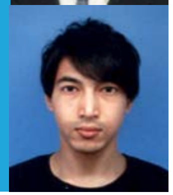
Chun XIE（筑波大学 計算科学研究センター・計算メディア分野・研究員）

Yinghao WANG （筑波大学ヒューマニクス学位プログラム 2年）

Pragyan SHRESTHA （筑波大学エンパワーメント情報学プログラム 1年）





本日の内容

- 北原 格（計算科学研究センター／計算メディア分野）

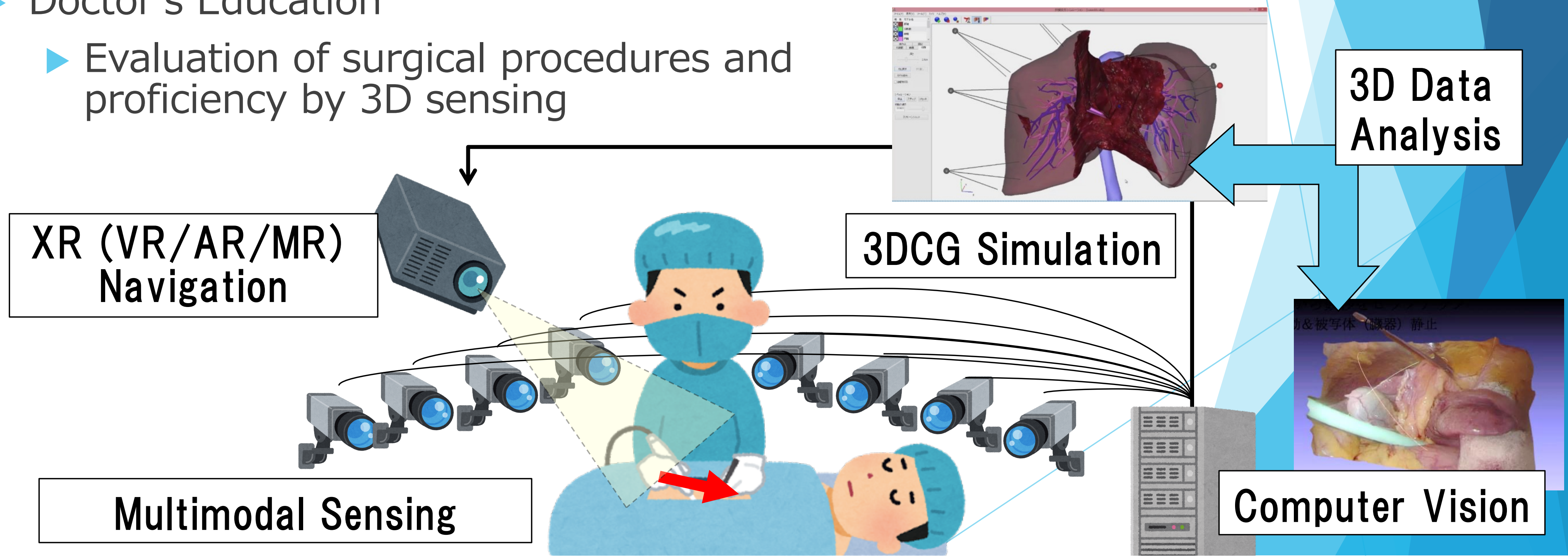
  3DCGバーチャル手術の活動報告と
  3D Surgical Vision への展開

- Pragyan SHRESTHA（エンパワーメント情報学プログラム）

  Tomographic Reconstruction of Bone from
  Multi-View X-Ray Images Using Planar Markers

3D-CG Virtual Surgery

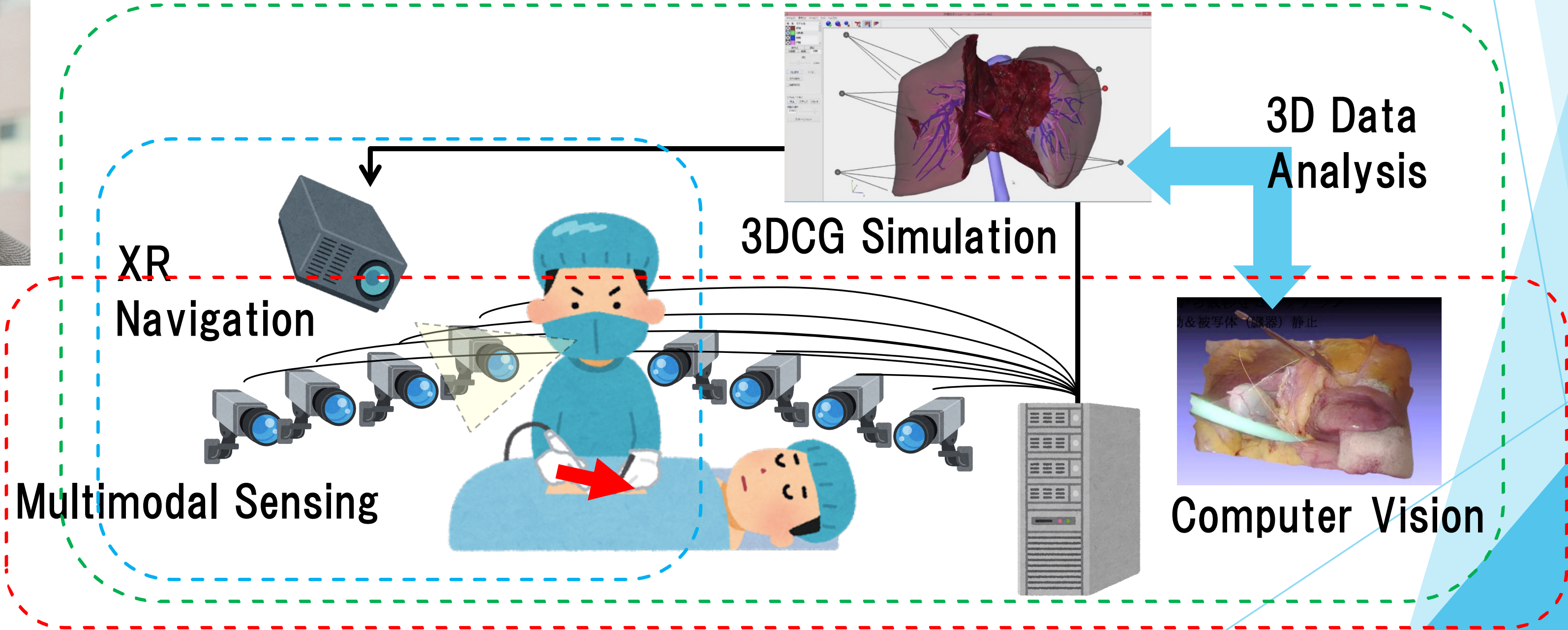
- Improving instruction level
  - Integration of 3D simulation and onsite navigation
- Elimination of surgeon shortage
  - VR/AR remote treatment, advanced skill passing
- Doctor's Education
  - Evaluation of surgical procedures and proficiency by 3D sensing



R&D team (1st gen.)

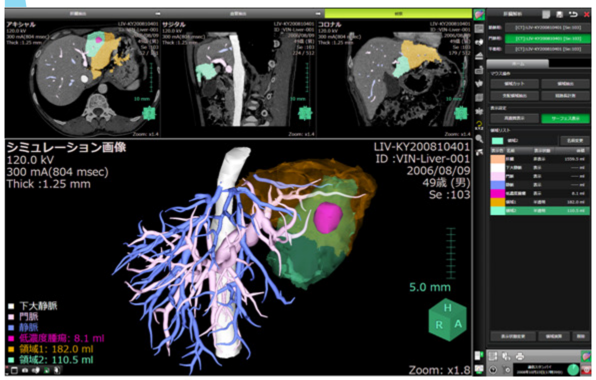
Development and practice of VR surgical operation support
Yukio Ohshiro (Tokyo medical university)

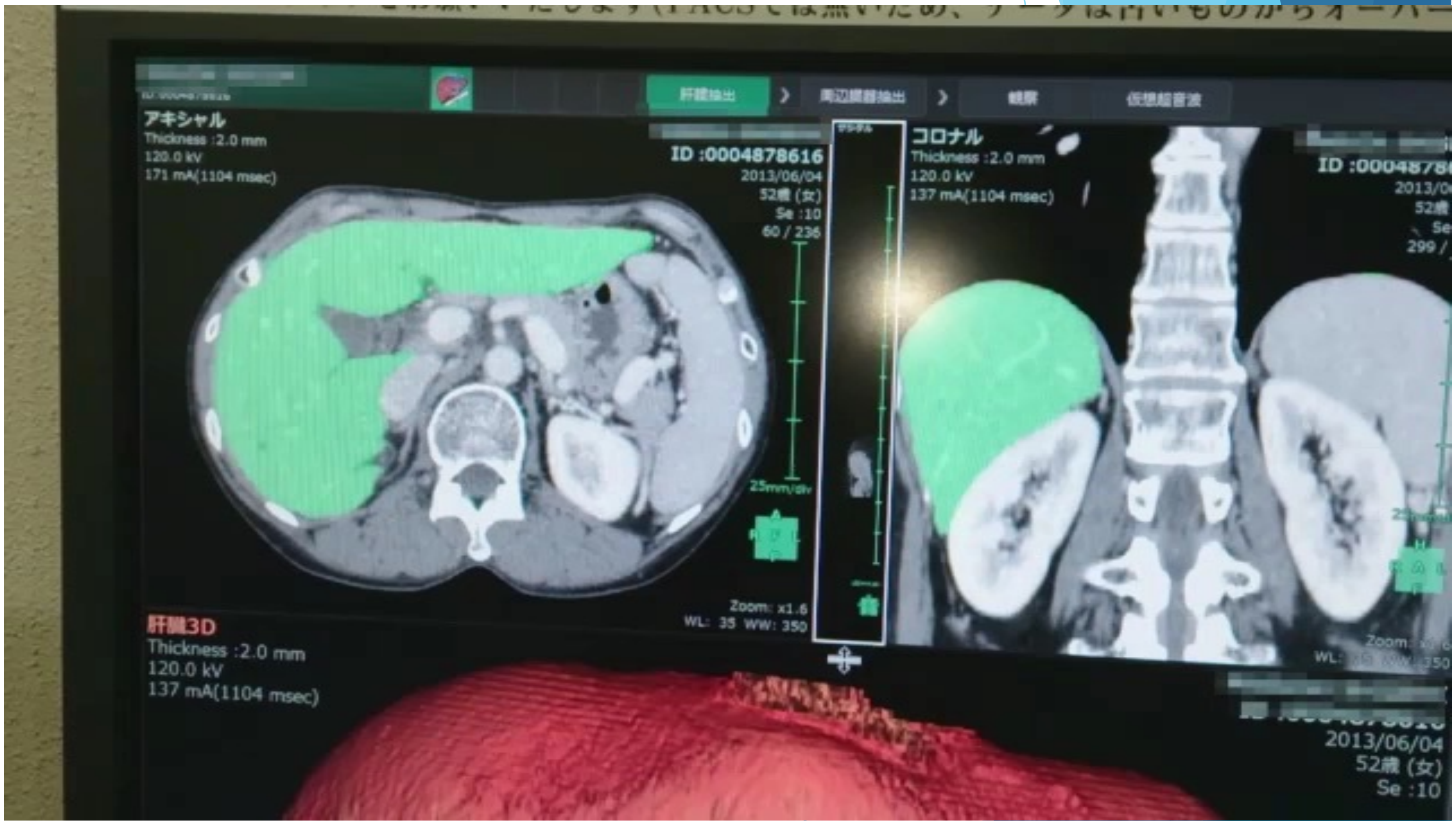
Work assistance using Haptic VR
Hiroaki Yano (Uni-Tsukuba)



3D modeling and analysis for medical scene
Itaru Kitahara (Uni-Tsuuba, CCS)

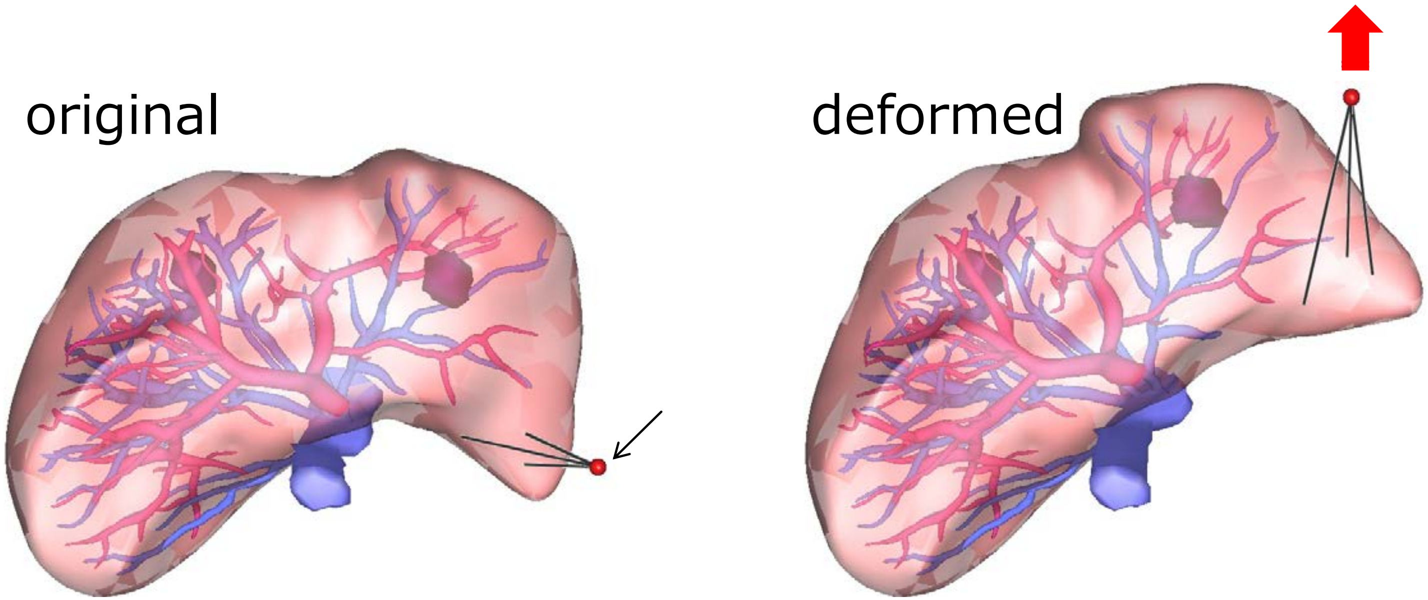
3D organ model constructed from CT

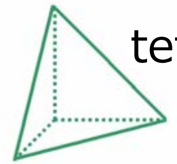




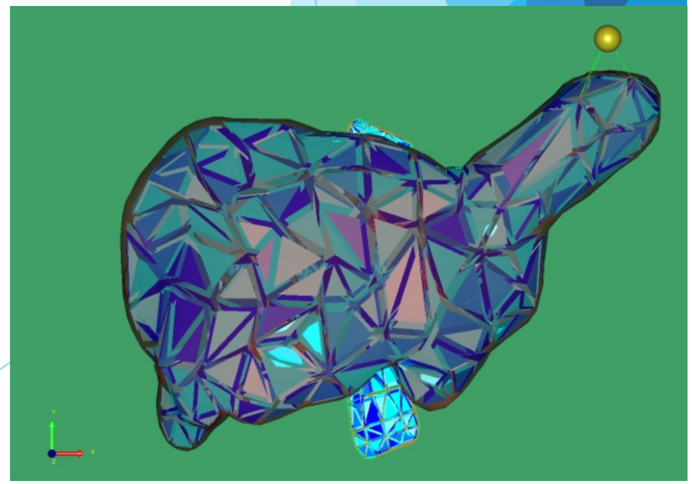
SYNAPSE VINCENT （FUJI FILM）

Deformable 3D-CG liver model





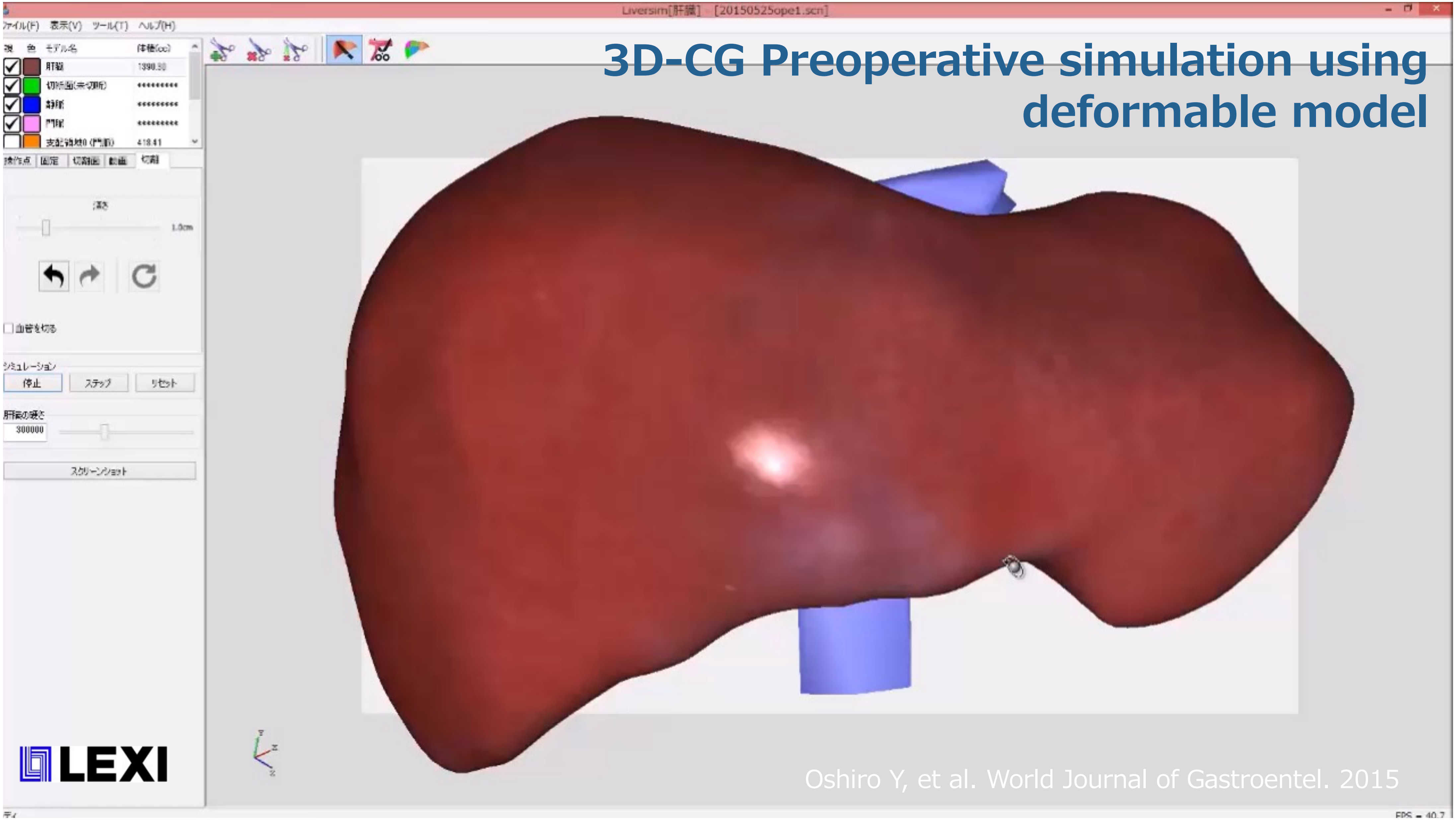
- **Physical simulation by “finite element method”**



Representation
in tetrahedron

LEXI

3D-CG Preoperative simulation using deformable model



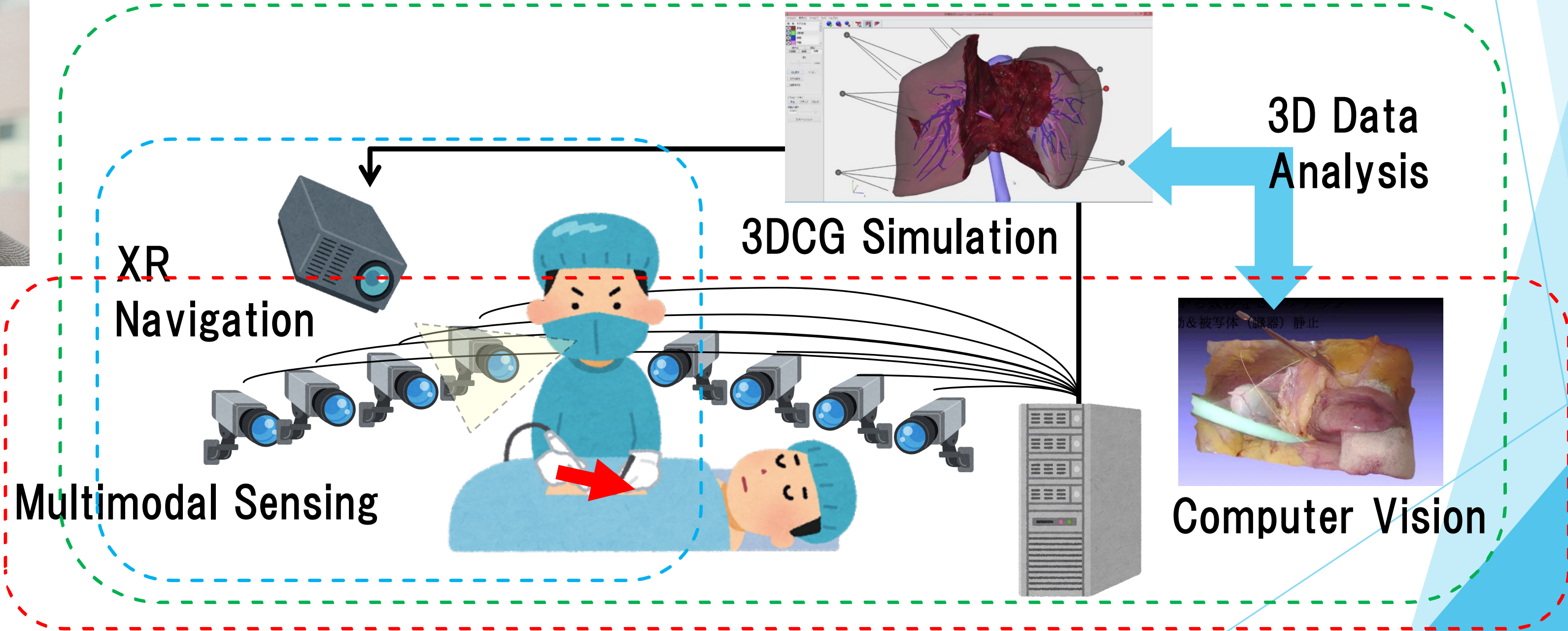
Oshiro Y, et al. World Journal of Gastroentel. 2015

Overlay Projection

R&D team (1st gen.)

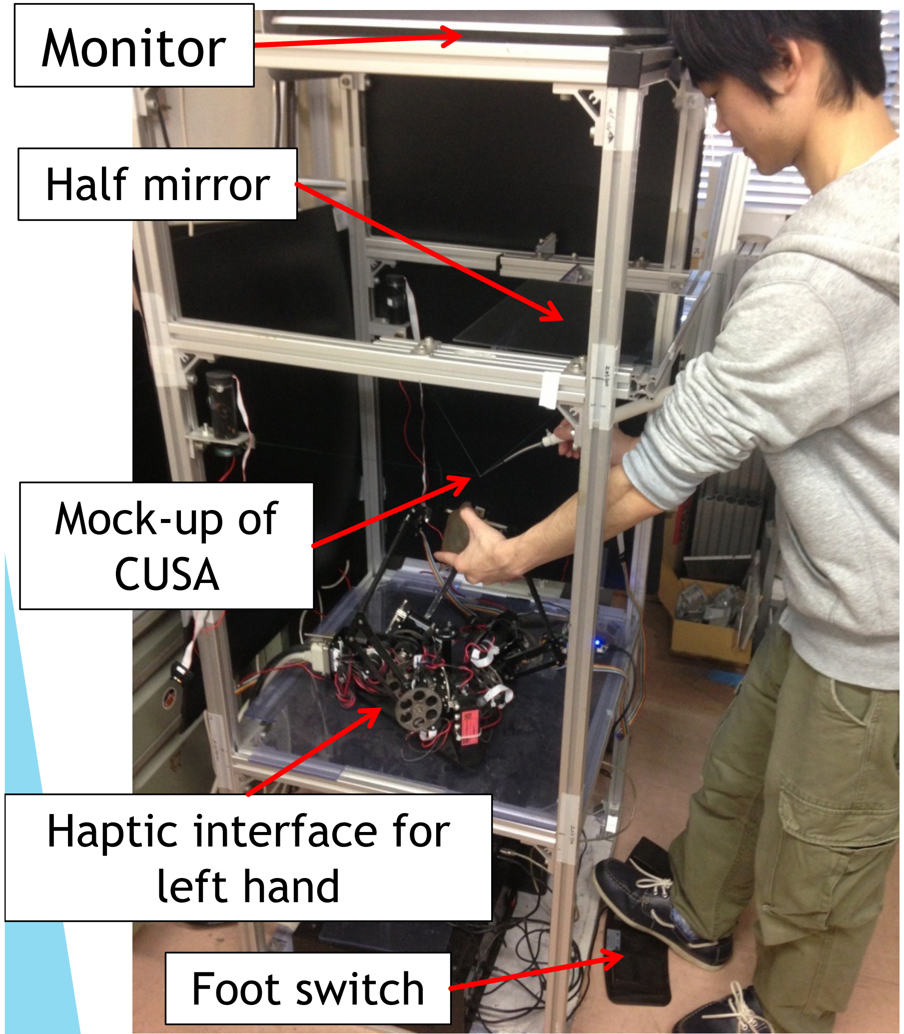
Development and practice of VR surgical operation support
Yukio Ohshiro (Tokyo medical university)

Work assistance using Haptic VR
Hiroaki Yano (Uni-Tsukuba)

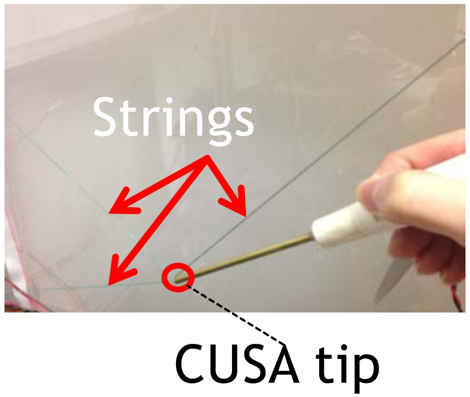


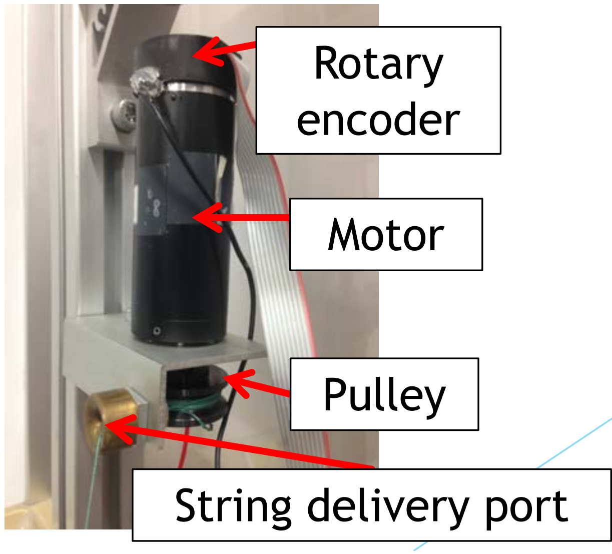
3D modeling and analysis for medical scene
Itaru Kitahara (Uni-Tsuuba, CCS)

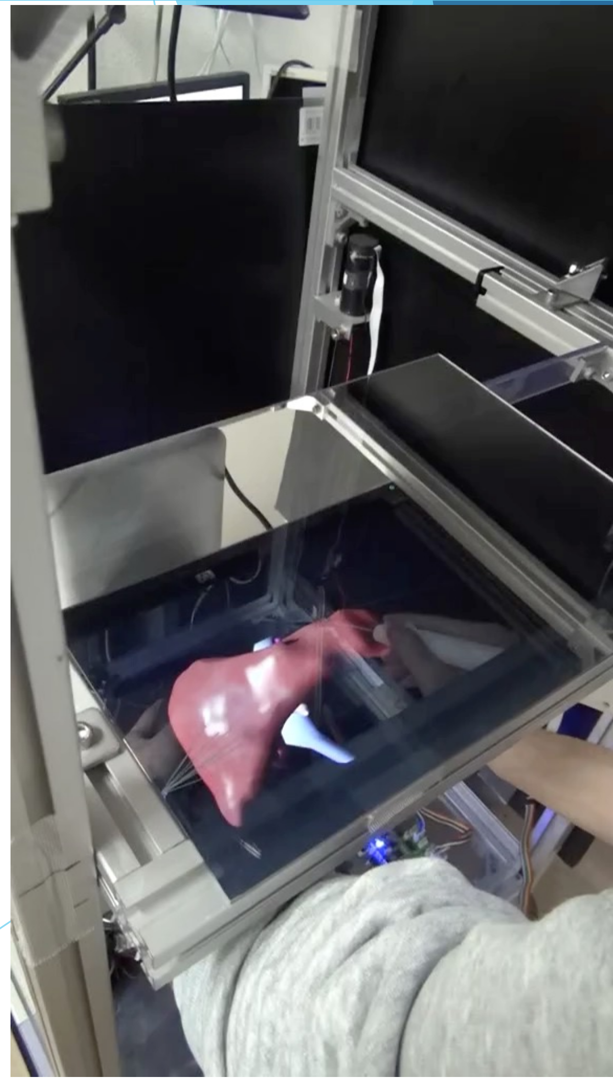
Force sense display using strings



CUSA:超音波手術器



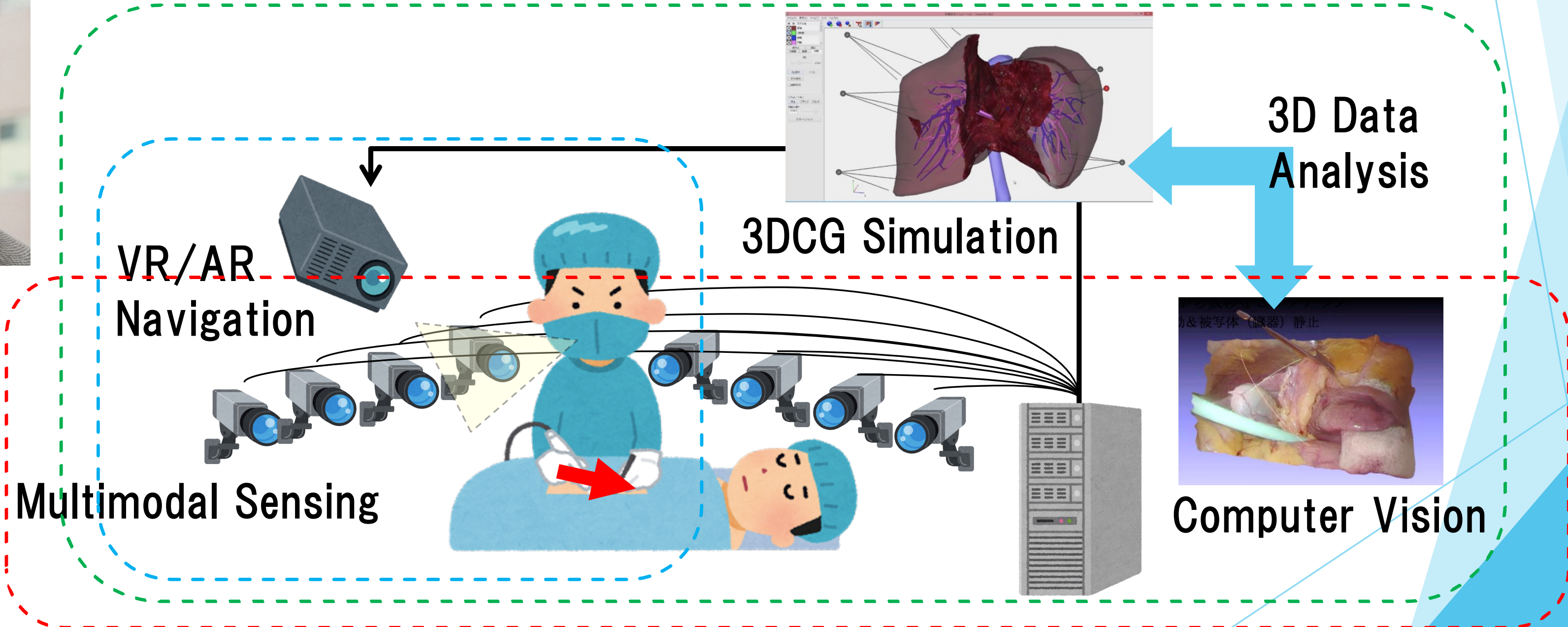




R&D team (1st gen.)

Development and practice of VR surgical operation support
Yukio Ohshiro (Tokyo medical university)

Work assistance using Haptic VR
Hiroaki Yano (Uni-Tsukuba)



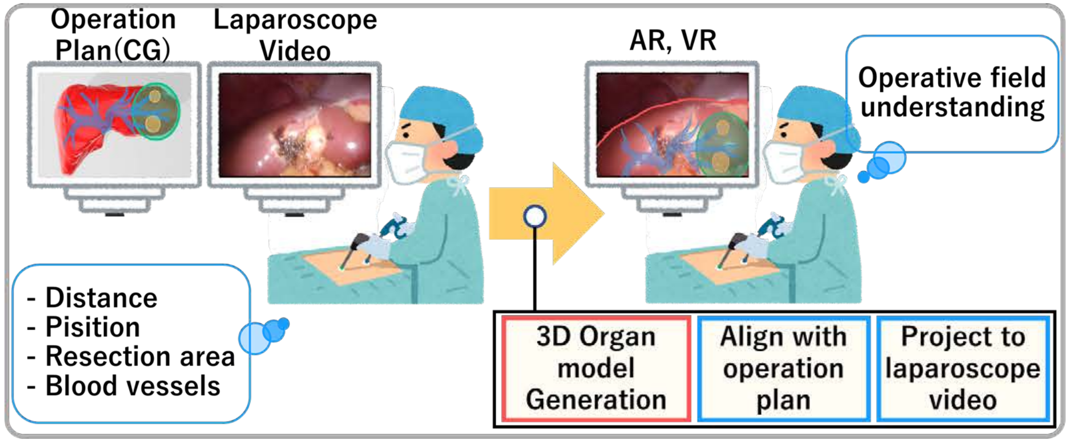
3D modeling and analysis for medical scene
Itaru Kitahara (Uni-Tsuuba, CCS)

Laparoscopic surgery

- Minimally invasive procedure.
- Operative area's state is checked on a display.

Pros.
- Small incision range.
- Quick postoperative recovery.

Cons.
- Difficult to grasp the 3D spatial relationships.
- Acquiring surgical skills is time consuming.



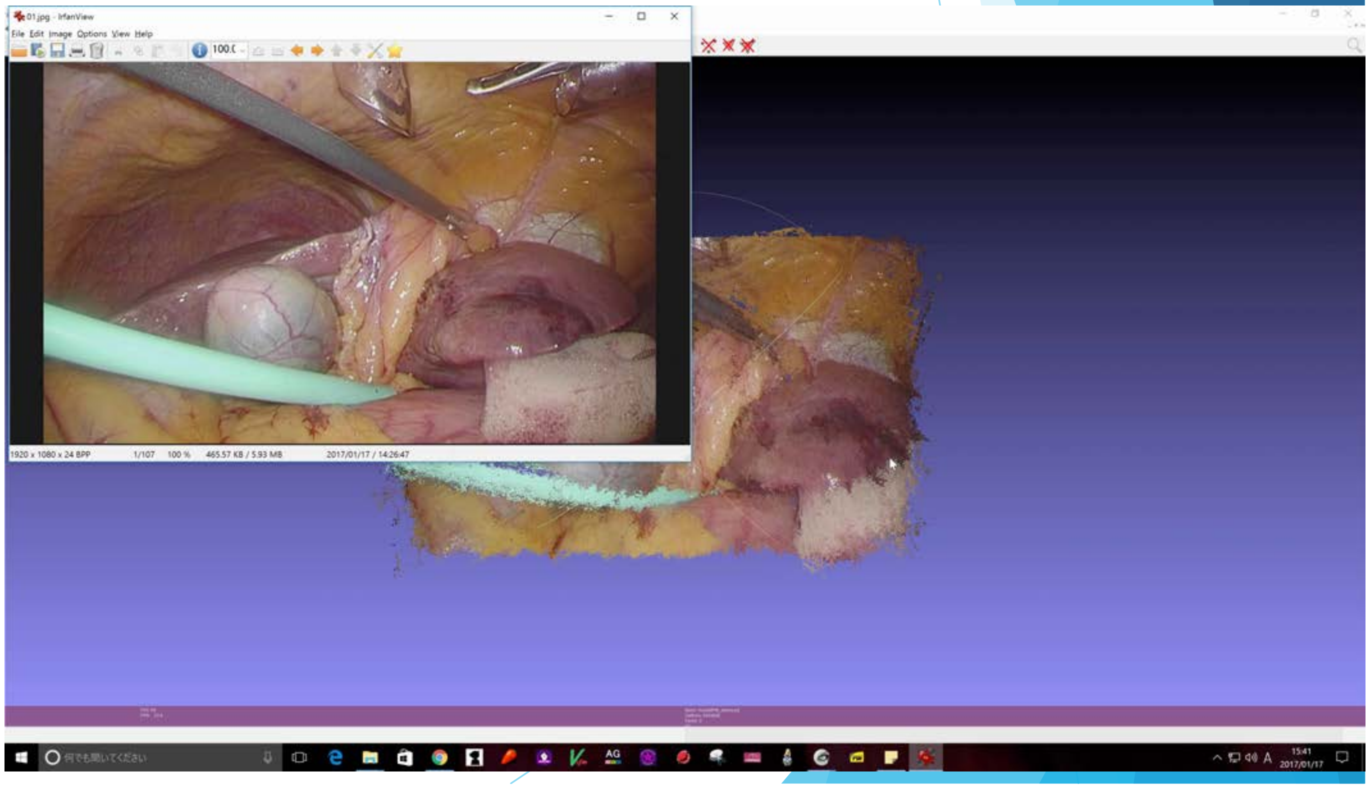
3D Organ Modeling

Support to recognize and understand the situation in the abdominal cavity.

3D organ modeling from a laparoscopic video

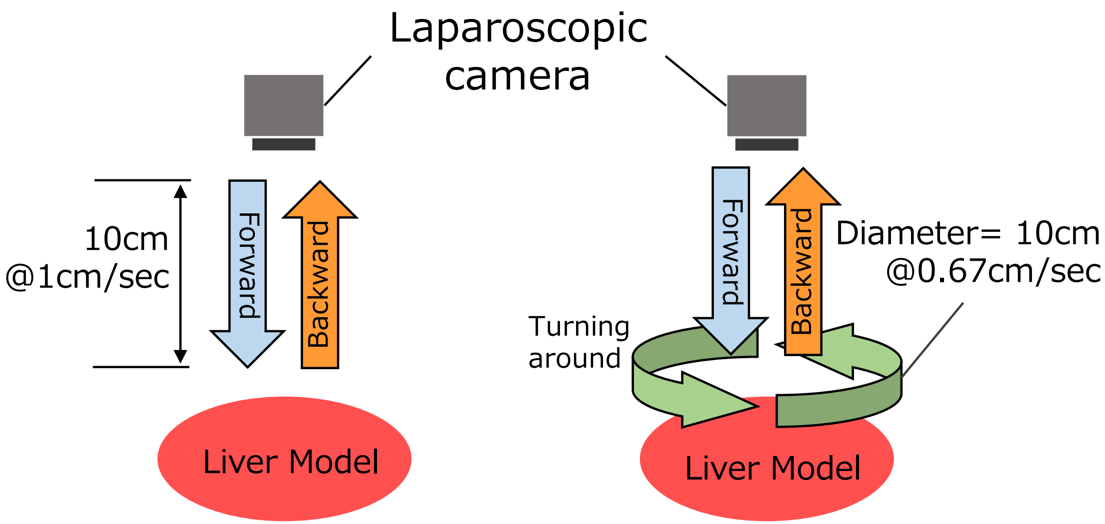
- Pick up a few seconds from laparoscopic surgery video.
- Camera movement & Static subject (organ) → Multi-view image

- Modeling using
  3D photogrammetry
  “SfM”(Structure from Motion)
- Items to be considered
  - Camera motion
  - Specular reflection
  - Lens distortion

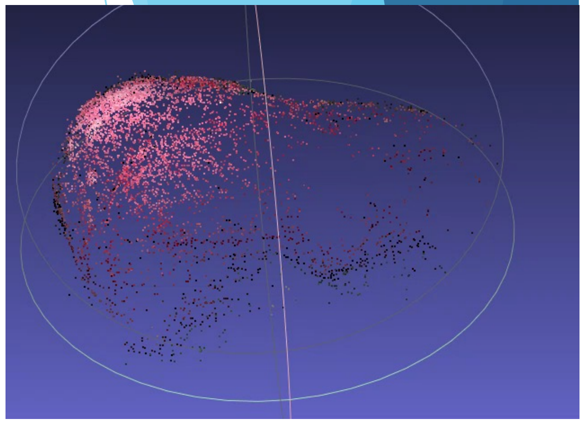


Movable area of a Laparoscopic camera

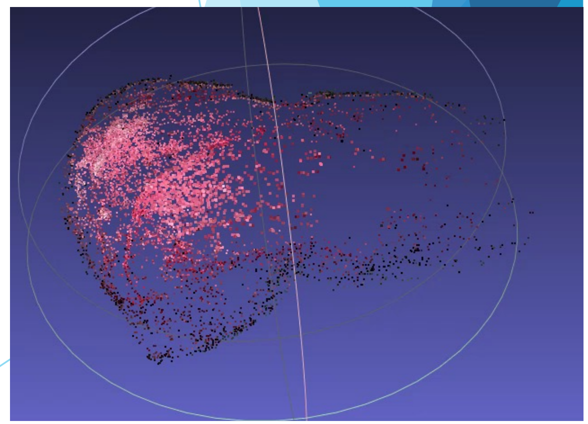
- In the human body, the movable area of a laparoscopic camera might be limited.
- Investigating how the limitation of movement affects the 3D reconstruction results.



Back and Forward **6-DoF camera motion**



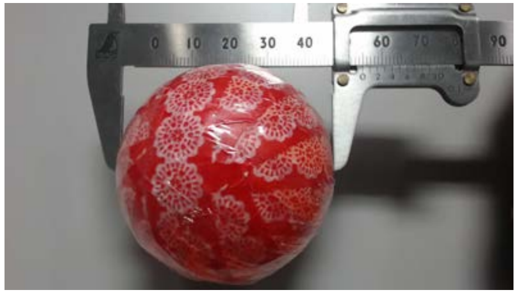
Only Back and Forward (Num of Point Clouds: 6,282)

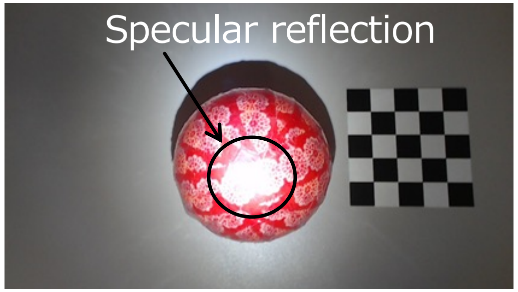


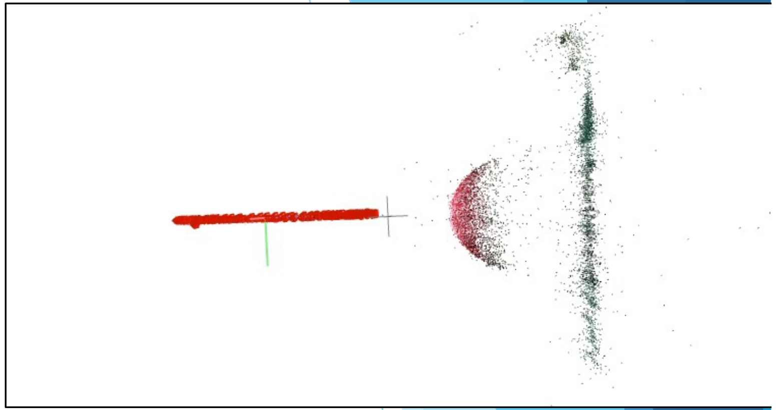
6-DoF Camera Motion (Num of Point Clouds: 10,778)

Influence of specular reflection

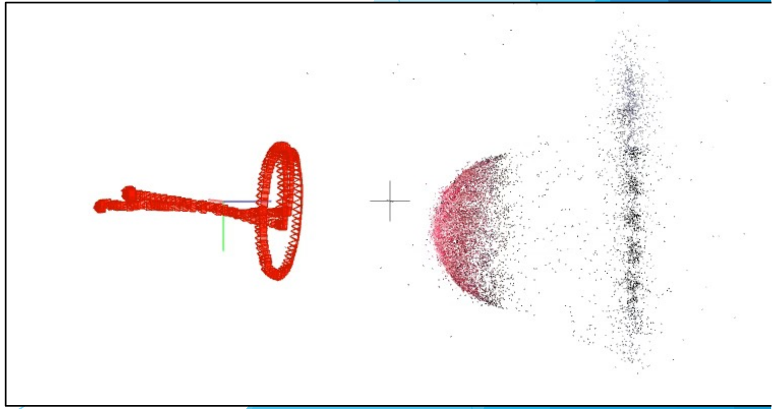
- Surface reflection of organ
  - specular reflection component is strong.
- Question
  - How does the specular reflection affects accuracy of 3D reconstruction?







Back and Forward Camera Motion

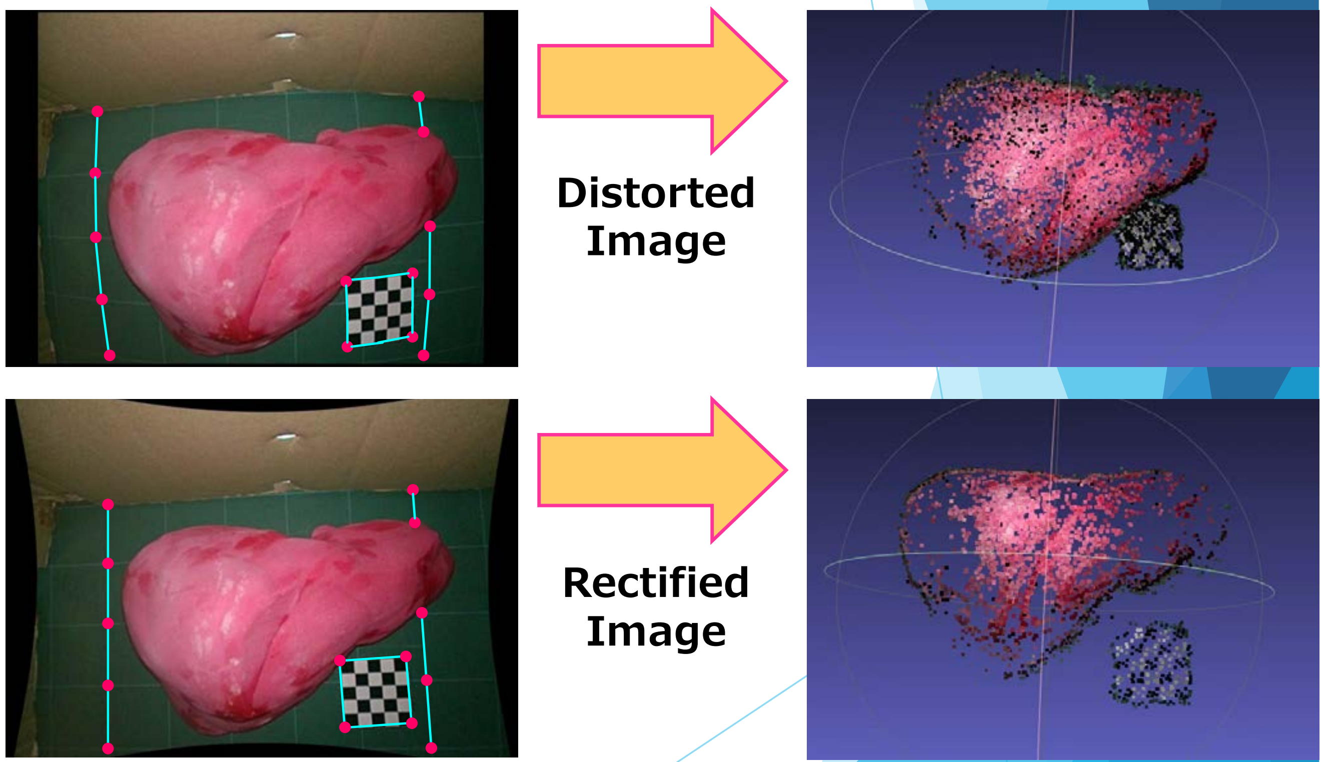


6-DoF Camera Motion

Specular reflected region is miss-reconstructed with the back and forward camera motion.
→ 6-DoF camera motion is important.

Influence of lens distortion

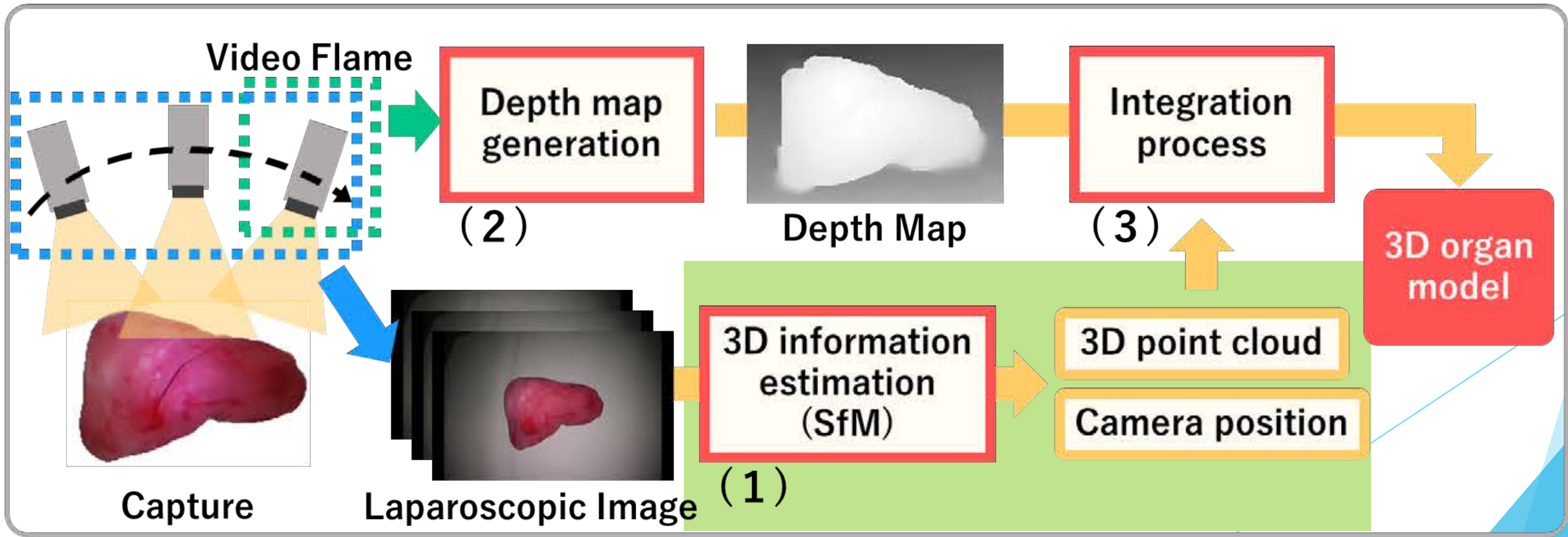
- FoV (Field of view) of Laparoscopic camera should be wider as possible.
- Lens distortion.
- Investigating the influence of the lens distortion.



Lens distortion should be rectified by camera calibration in advance.

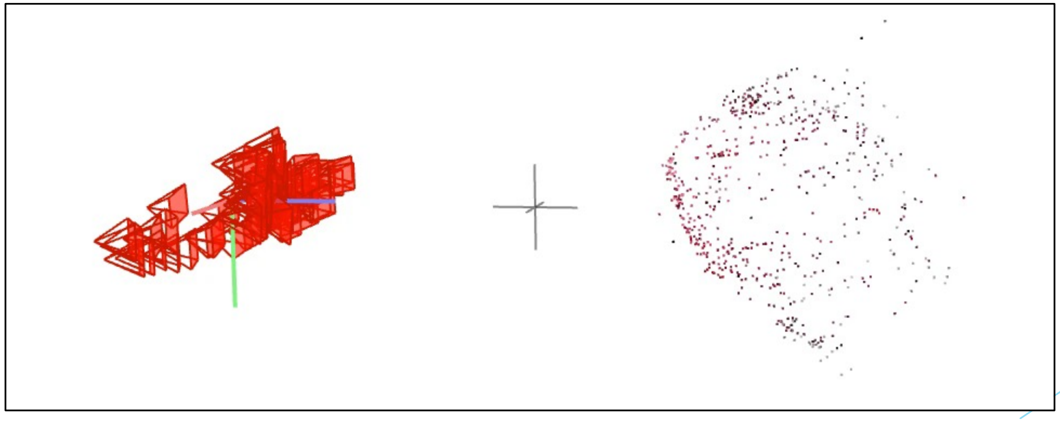
3D shape reconstruction from a laparoscopic video

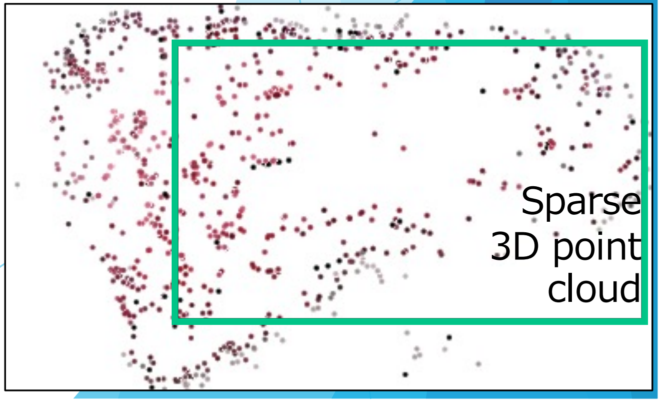
1. <u>Sparse 3D point cloud reconstruction</u>
   - Structure from Motion (SfM)
2. Depth image generation by Deep Learning
   - from the monocular laparoscopic image.
3. Dense 3D modeling
   - Combining the depth image and 3D point cloud.



Sparse 3D point cloud reconstruction

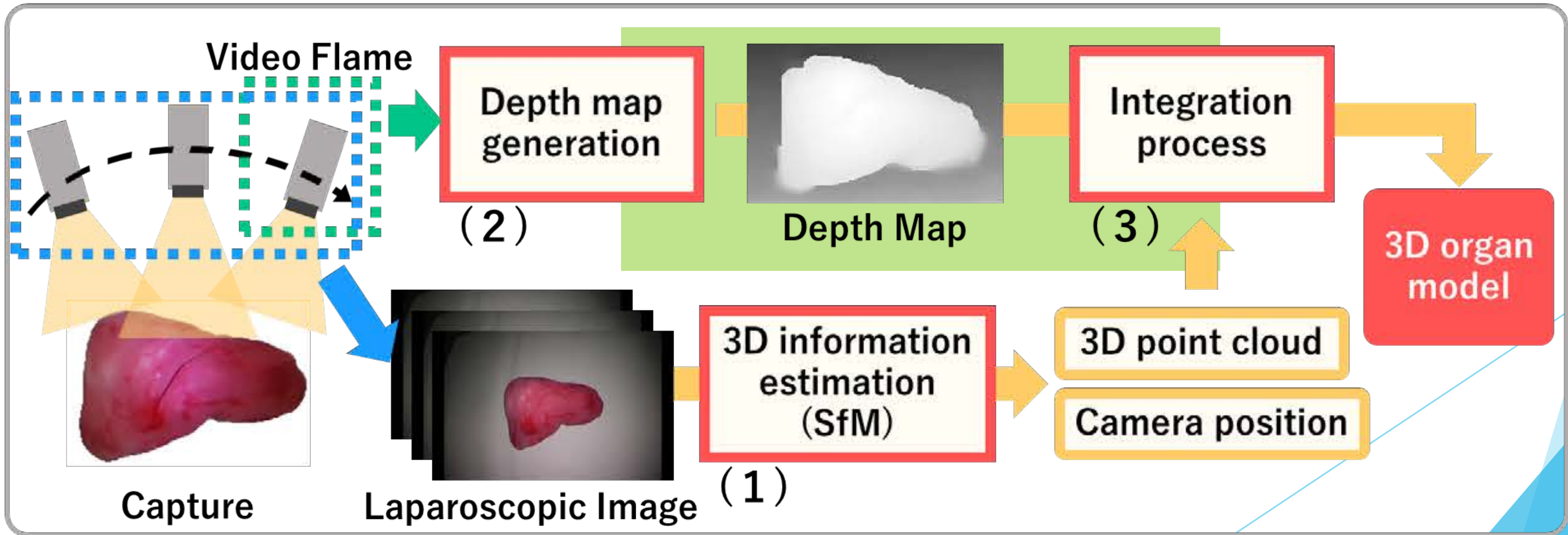
- By using SfM
  - Reconstructing overall shape of the organ.
- Point clouds are estimated for image feature points.
  - Poorly textured area
    - Sparse point clouds
  - Organ is generally low-textured.





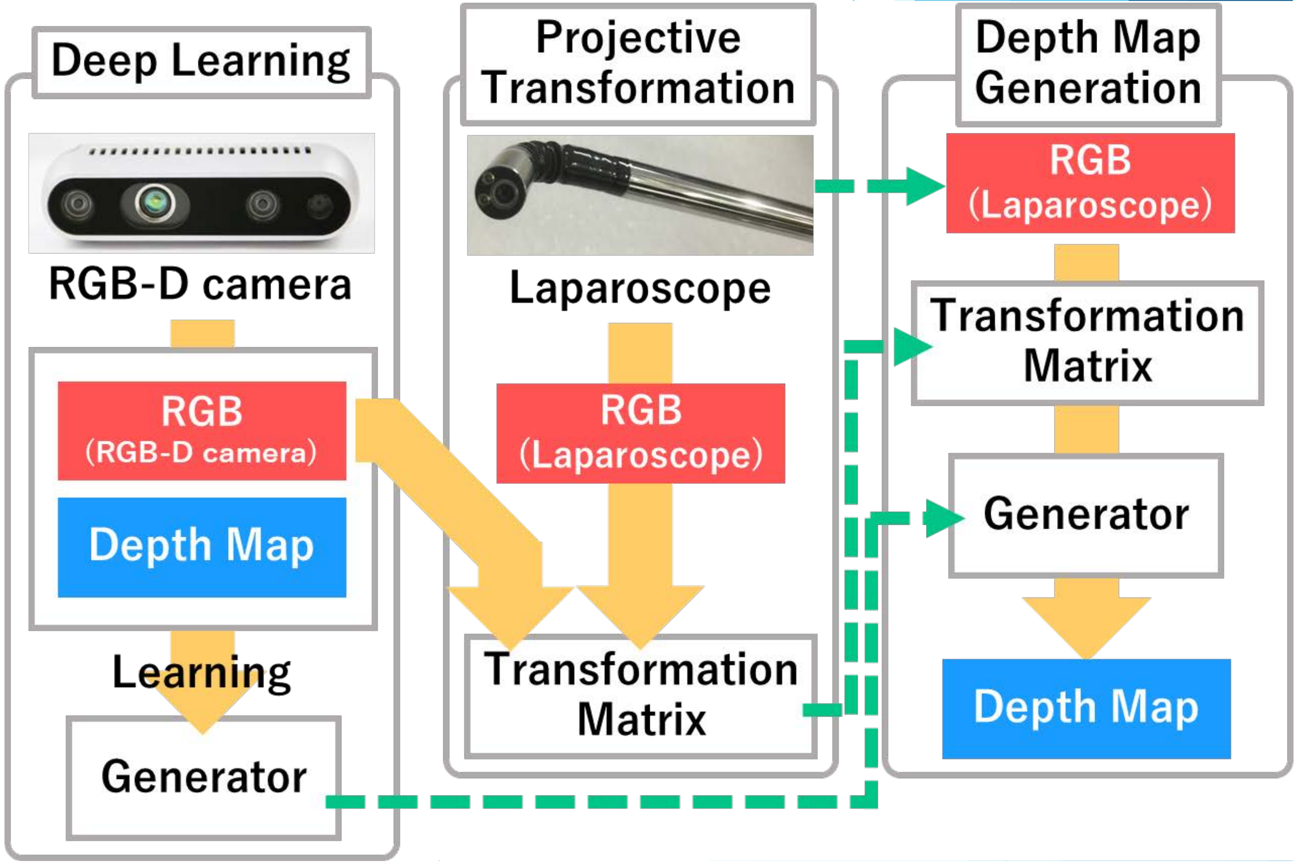
3D shape reconstruction from a laparoscopic video

1. Sparse 3D point cloud reconstruction
   - Structure from Motion (SfM)
2. Depth image generation by Deep Learning
   - from the monocular laparoscopic image.
3. Dense 3D modeling
   - Combining the depth image and 3D point cloud.



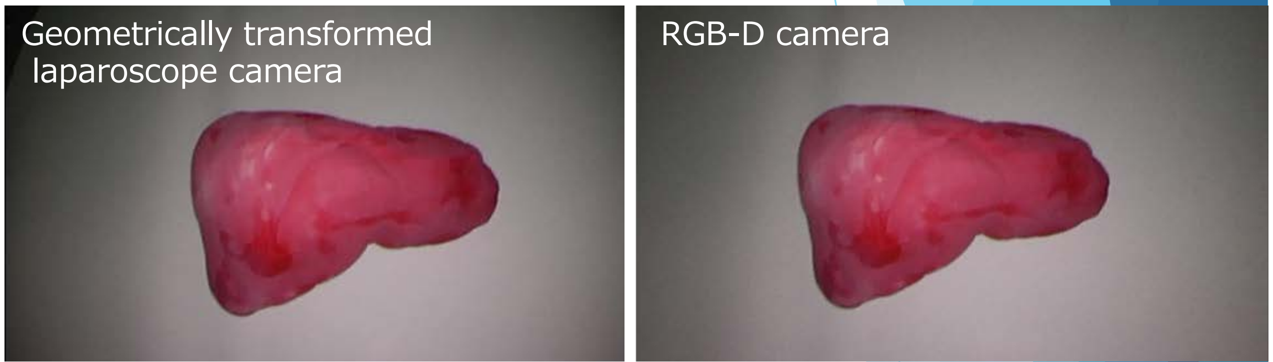
Depth image generation from monocular images

- Depth image generation from monocular laparoscopic images
  - “geometrical transformation”
  - “depth generation” based on Deep Learning (DL).



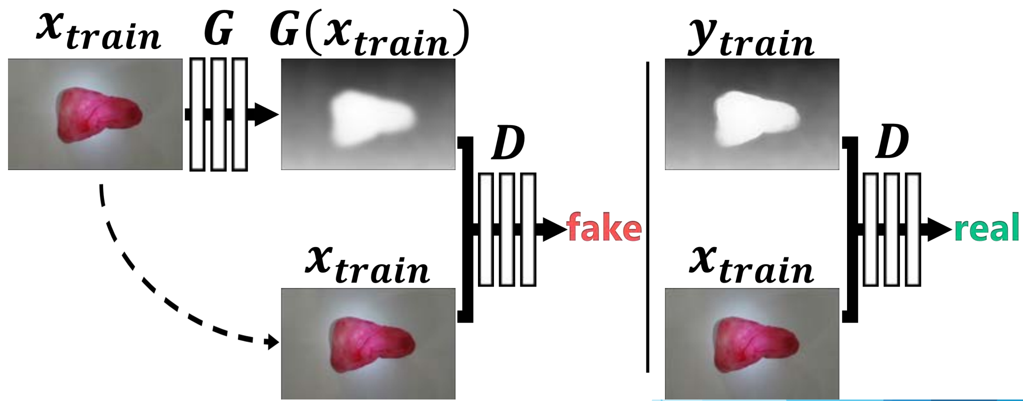
Geometrical transformation between RGB-D and laparoscopic camera

- Camera parameters of each camera: different
- Unify the appearance of laparoscopic images with RGB-D images
    1. Shooting a calibration board.
    2. Correcting lens distortion.
    3. Correspondence search.
    4. Estimating the projective transformation matrix.

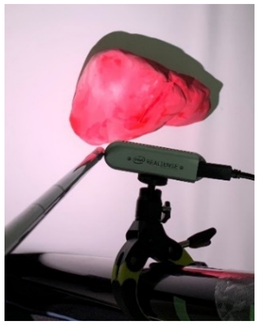


Depth generation by Deep Learning

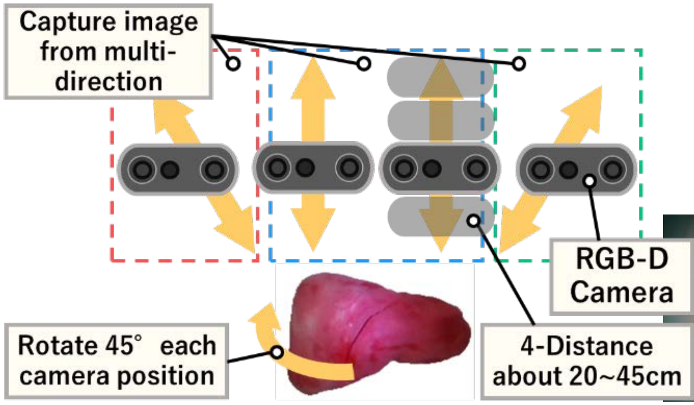
- Conditional generative adversarial networks (cGAN)
  - ***G*** (Generator), ***D*** (Discriminator)
  - After ***G*** and ***D*** learn by competing each other using sufficient training data, ***G*** can generate a depth image from an RGB image.

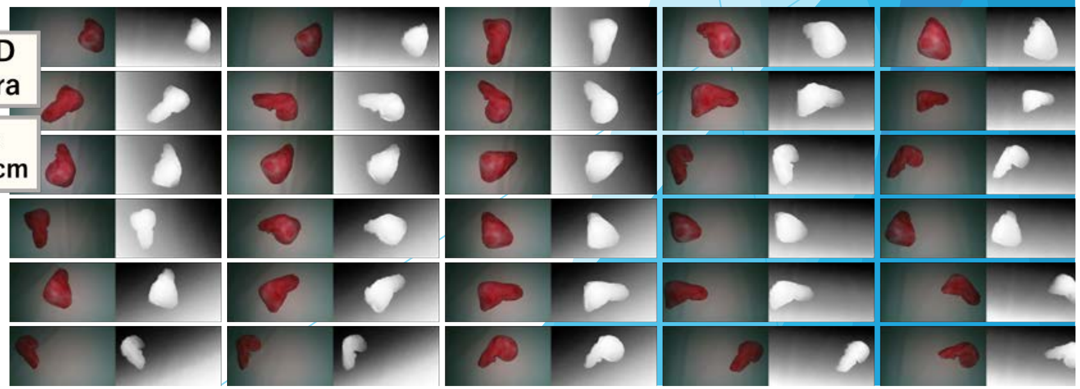


[RGB-D dataset]



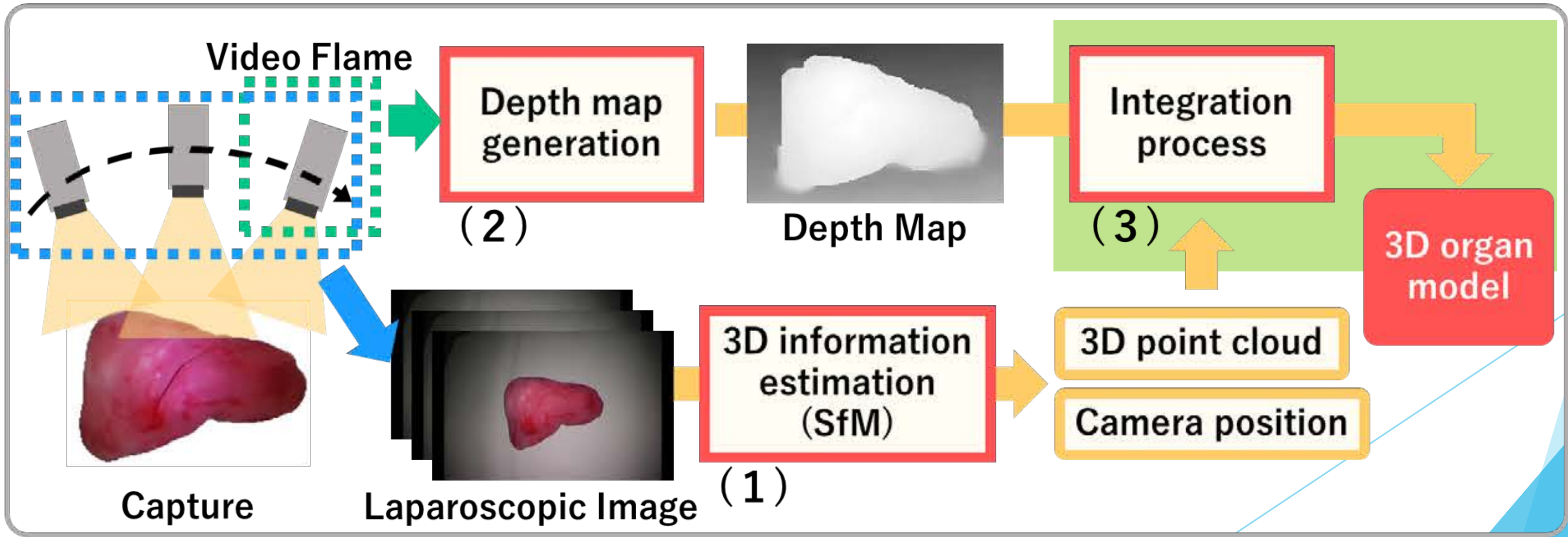
Training dataset is constructed using an RGB-D camera.





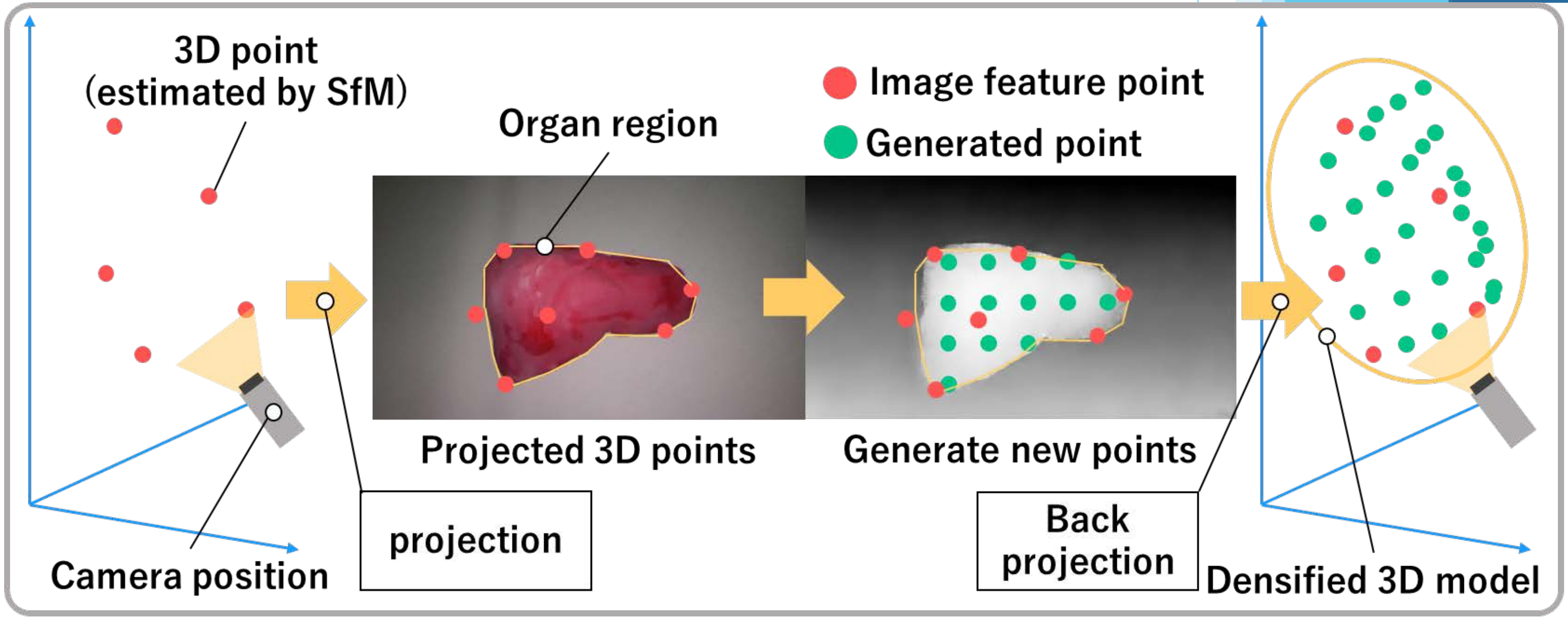
3D shape reconstruction from a laparoscopic video

1. Sparse 3D point cloud reconstruction
   - Structure from Motion (SfM)
2. Depth image generation by Deep Learning
   - from the monocular laparoscopic image.
3. Dense 3D modeling
   - Combining the depth image and 3D point cloud.



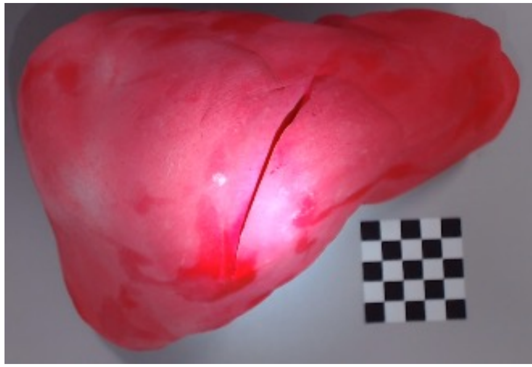
Combining depth image and 3D point cloud

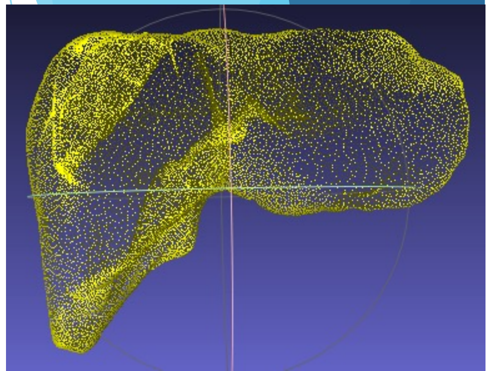
- Densifying 3D point clouds with depth image
  - Acquire the correspondence between the 3D point cloud and the depth image.
  - Estimate the scale value between them.
  - Calculate 3D coordinates of each pixel of the depth image using the scale value [Back projection]



Experimental environment

- Subject: Organ phantom model
  - A plaster model of the liver
  - Ground-Truth
    - CT data of the original liver
  - Evaluation
    - Comparison of the generated model and ground-truth



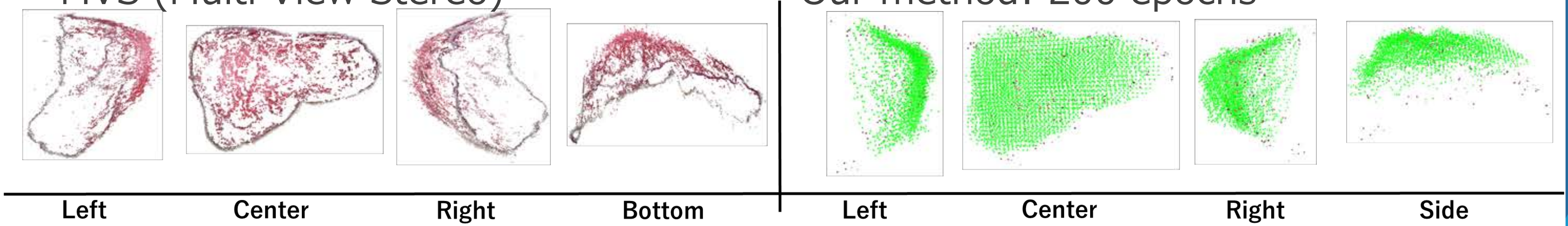


- Shooting equipment
  - Laparoscopic camera
    - Curved tip: OLYMPUS LTF S190-10
    - Image-processor: OLYMPUS VISERA Elite-II
    - 1080p(Full-HD) @ 60fps
  - RGB-D camera
    - Intel Realsense D435
      - RGB: 1920 pixels x 1080 pixels
      - Depth: 1280 pixels x 720 pixels

Evaluation of generated 3D model

- Densification of sparse point cloud generated by SfM
- Comparison targets

MVS (Multi View Stereo) | Our method: 200 epochs



- Evaluation index of the generated model
  - ICP(Iterative Closest Point) with Ground-truth (CT data)
  - RMSE (Root Mean Square Error)

ICP value of densified organ model

Model	Num of points	RMSE (cm)
Proposed	4716	1.90
MVS	**16754**	**0.40**

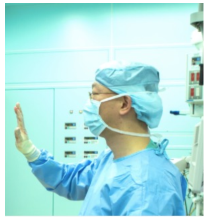
Standard deviation (%) of each model for each size of cube

Cube size (cm)	0.25	0.50	0.75	1.00
Proposed	**0.039**	**0.039**	**0.038**	**0.042**
MVS	0.075	0.075	0.067	0.060

R&D team (1st gen.)
“3D CG Virtual Surgery

3D-CG Virtual Surgery

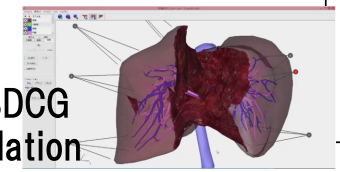
Hiroaki YANO
(Uni-Tsukuba)

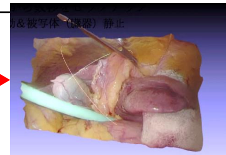


Yukio OHSHIRO
(Tokyo Med.Univ)

Itaru KITAHARA
(Uni-Tsukuba, CCS)

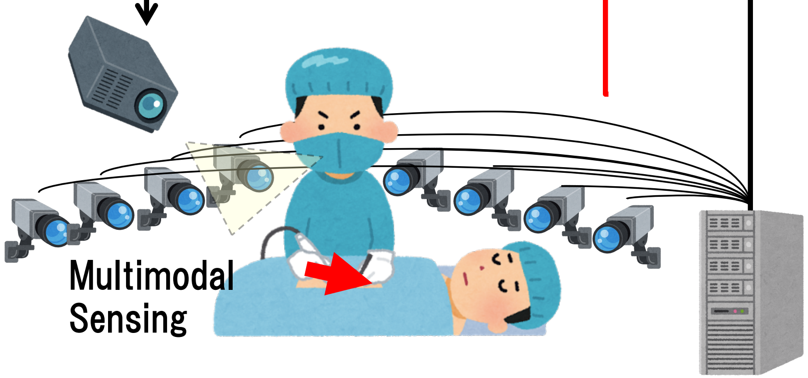
3DCG
Simulation





Computer Vision

XR Navigation



Multimodal
Sensing

【外部資金】

1. 2018-2021 科研基盤(B)「柔軟臓器の形状推定と術前モデルへの実時間位置合わせを行う肝手術ナビゲーション開発」代表：大城幸雄（東京医科大学茨城医療センター）
2. 2021-2022（申請）AMED 橋渡し研究シーズB「骨折手術における次世代ナビゲーションシステムの開発と臨床応用」、代表：吉井雄一（東京医科大学茨城医療センター）
3. 2021-2024（申請） 科研基盤(B)「中空リング型多視点カメラのAI制御による直視下手術ナビゲーションシステム開発」、代表：橋本真治（筑波大学医学医療系）

1. Ryosuke Maekawa, Hidehiko Shishido, Yoshinari Kameda, Itaru Kitahara, "A Dense 3D Organ Modeling from a Laparoscopic Video," IFMIA2021, 2021 [Best Paper]
2. 前川凌佑，宍戸英彦，亀田能成，坂本堪亮，大城幸雄，北原格，"単眼腹腔鏡映像からの3次元臓器モデル生成手法", DIA2020，2020 [研究奨励賞]
3. 前川凌佑，宍戸英彦，亀田能成，坂本堪亮，大城幸雄，北原格，"腹腔鏡映像からの臓器3次元モデリングのための深層学習によるワンショットデプスマップの生成", CVIM研究会, 2019
4. 前川凌佑，宍戸英彦，亀田能成，坂本堪亮，大城幸雄，北原格，"３次元臓器CGモデル生成に適した腹腔鏡映像撮影条件の検討", 第27回日本コンピュータ外科学会大会, 2018

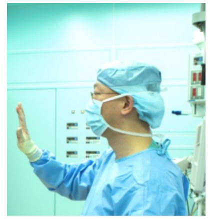
R&D team (2nd gen.) toward "3D Surgical Vision"

Surgical AR Navigation
（プロジェクションマッピング等を用いた直感的ARナビゲーション）

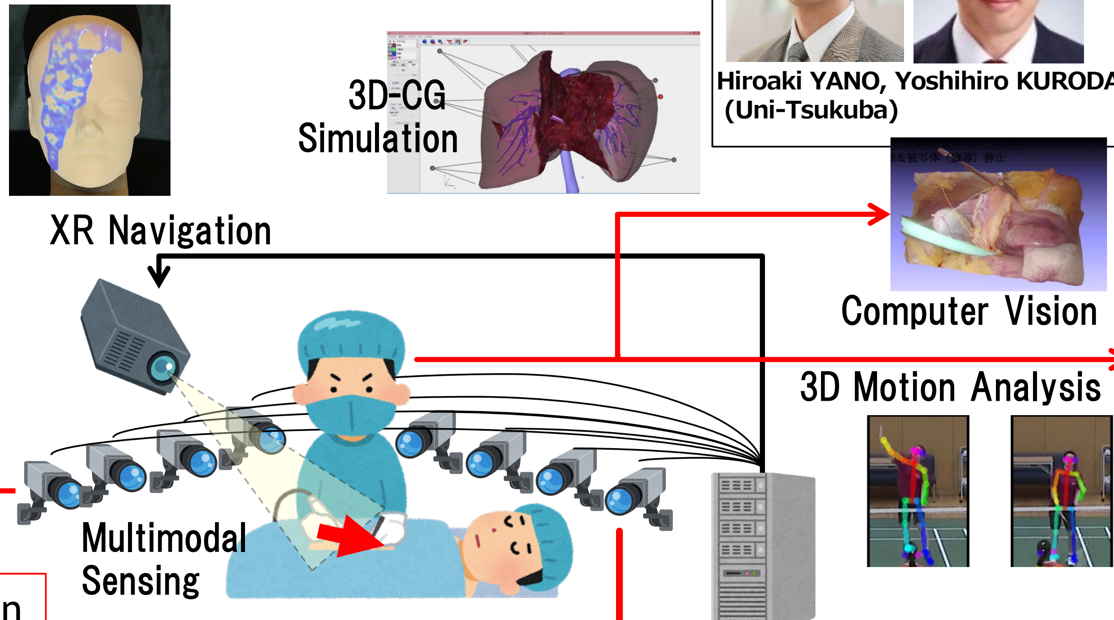

Chun XIE
(Uni-Tsukuba, CCS)

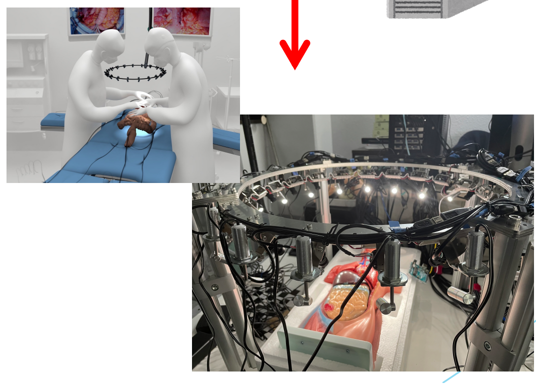
3D-CG Virtual Surgery






Hiroaki YANO, Yoshihiro KURODA (Uni-Tsukuba)
Yukio OHSHIRO (Tokyo Med.Univ)
Itaru KITAHARA (Uni-Tsukuba)



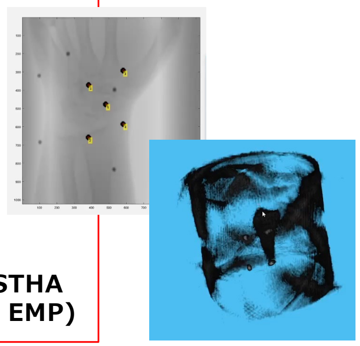


Medical Human Sensing
（人物行動分析の医学応用）


Hidehiko SHISHIDO
(Uni-Tsukuba, CCS)

3D Bone Shape Reconstruction
（X線画像からの骨形状復元）

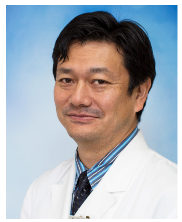
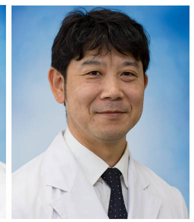




Yuichi YOSHII
(Tokyo Med.Univ)

Pragyan SHRESTHA
(Uni-Tsukuba, EMP)

Surgical Arena（撮り逃しのない手術記録）

Yinghao WANG
(Uni-Tsukuba, HX)

Tatsuya ODA, Shinji HASHIMOTO
(Uni-Tsukuba, Hospital)