BodyMaps

Towards 3D Atlas of Human Body

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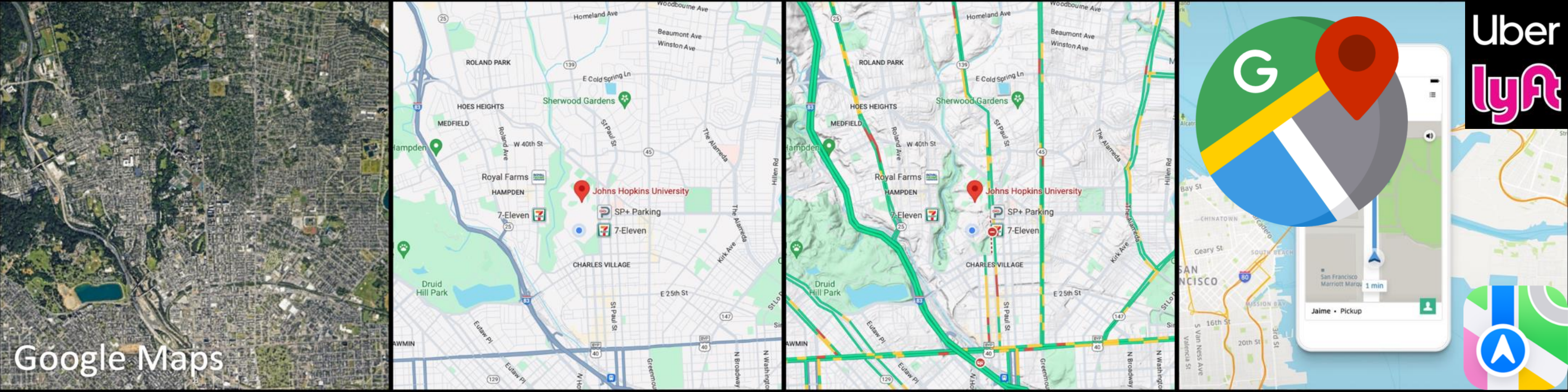
MICCAI 2024 Marrakesh MOROCCO

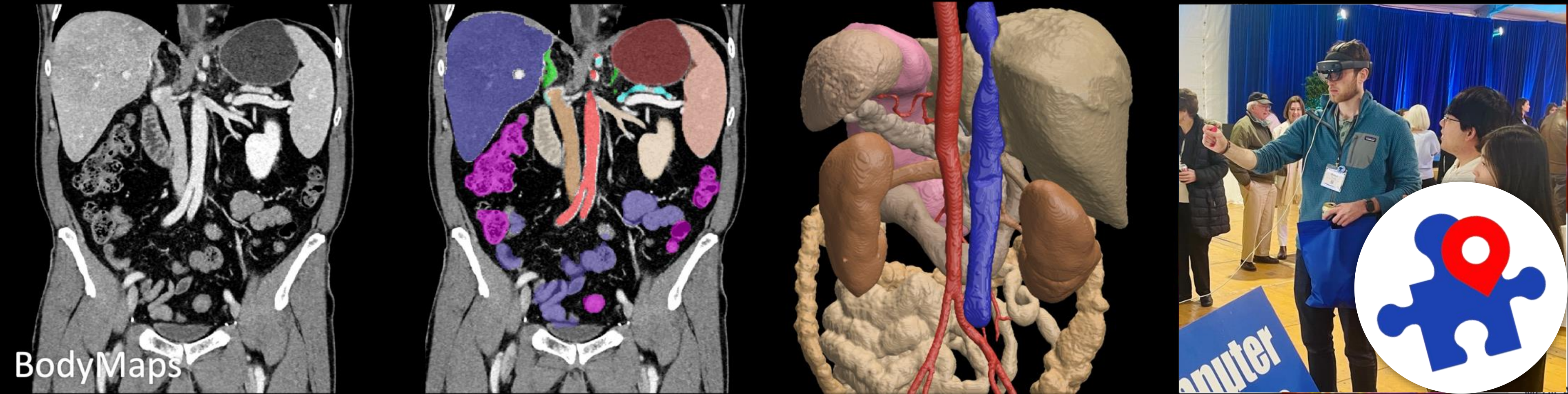
BodyMaps

Towards 3D Atlas of Human Body

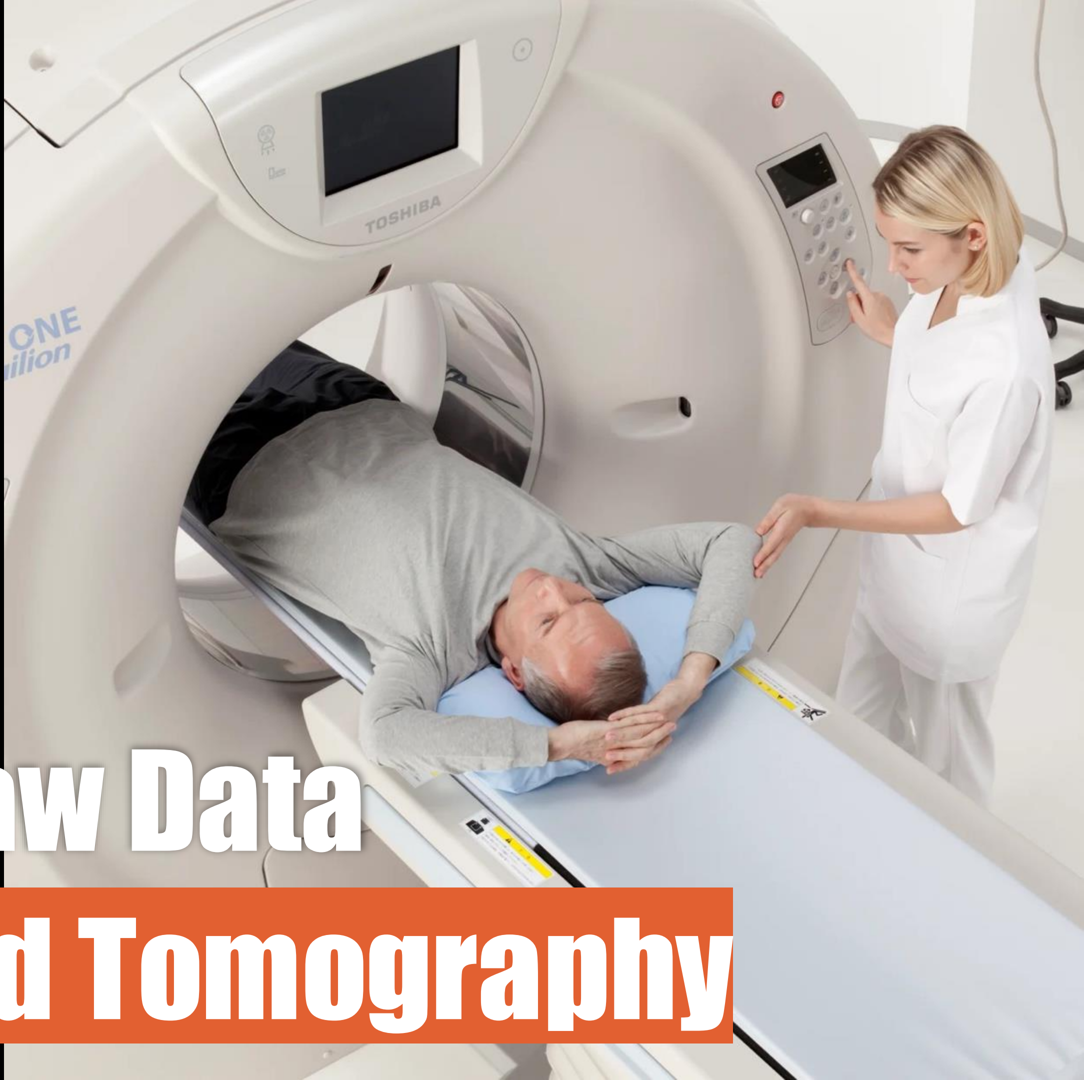

DATA
Latrobe Hall
Hodson Hall
Wyman Quad
Garland Hall
Shaffer Hall
Wyman Park Building
Hackerman Hall
Clark Hall
Bowman Dr
San Martin Dr
Shriver Hall
Concert Series
Decker Quad
Wyman Park Dr
Bowman Dr
Malone Hall
Baltimore Museum of Art
19th-century, modern & contemporary art
Wyman East
JHU South Garage
Wyman Park Dr
S Gate
INFORMATION
Latrobe Hall
Hodson Hall
4 min
0.2 miles
Garland Hall
Shaffer Hall
Wyman Park Building
4 min
0.2 miles
Bowman Dr
San Martin Dr
Clark Hall
4 min
0.2 miles
Decker Quad
Wyman Park Dr
Bowman Dr
Malone Hall
Wyman East
JHU South Garage
Wyman Park Dr
S Gate
KNOWLEDGE
G
Uber
lyft
APPLICATION



Data → Information → Knowledge → Application

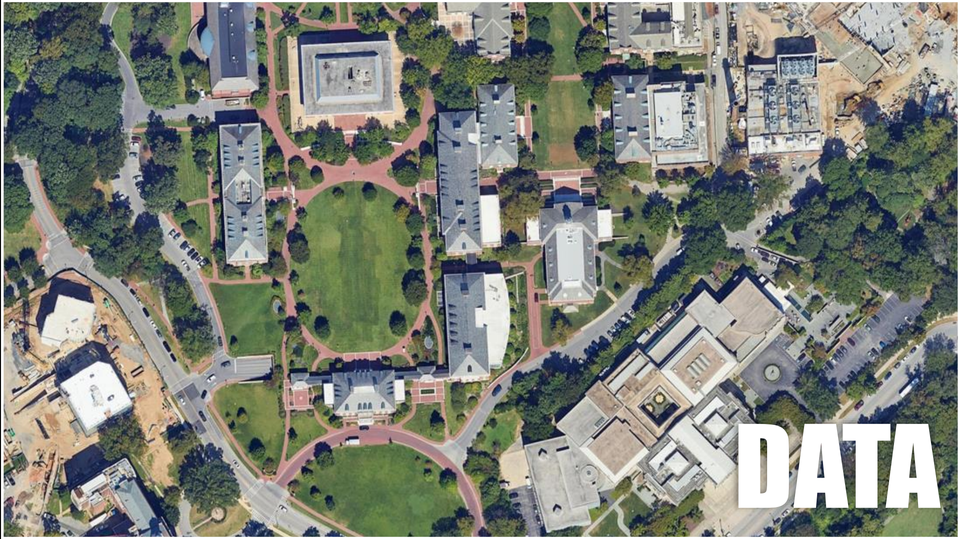



Google Maps Earth
We Map Human Body
Photo by AVRcontent (@AVRcontent)



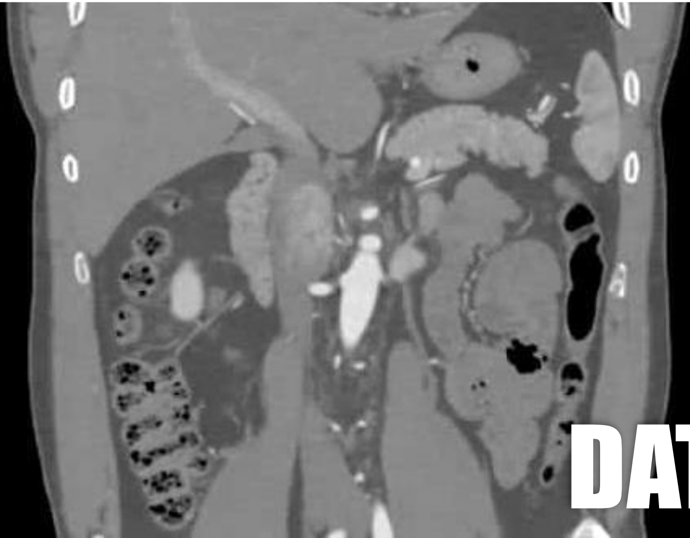
Raw Data

Computed Tomography



DATA

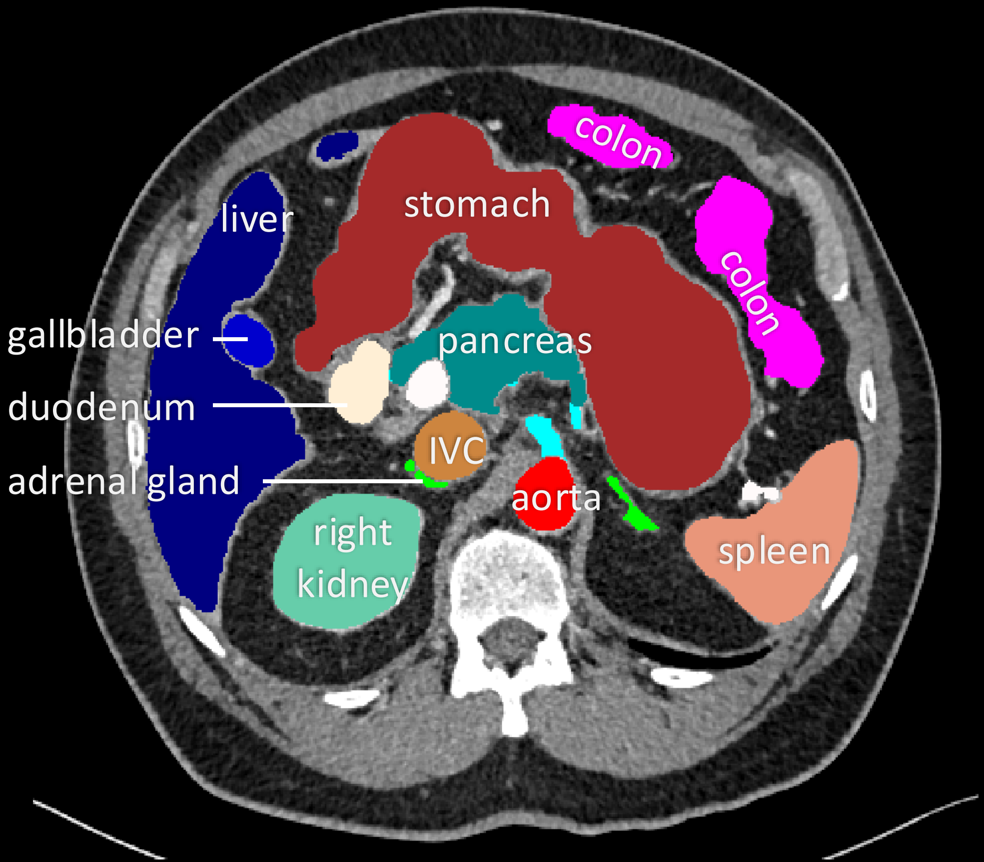
INFORMATION



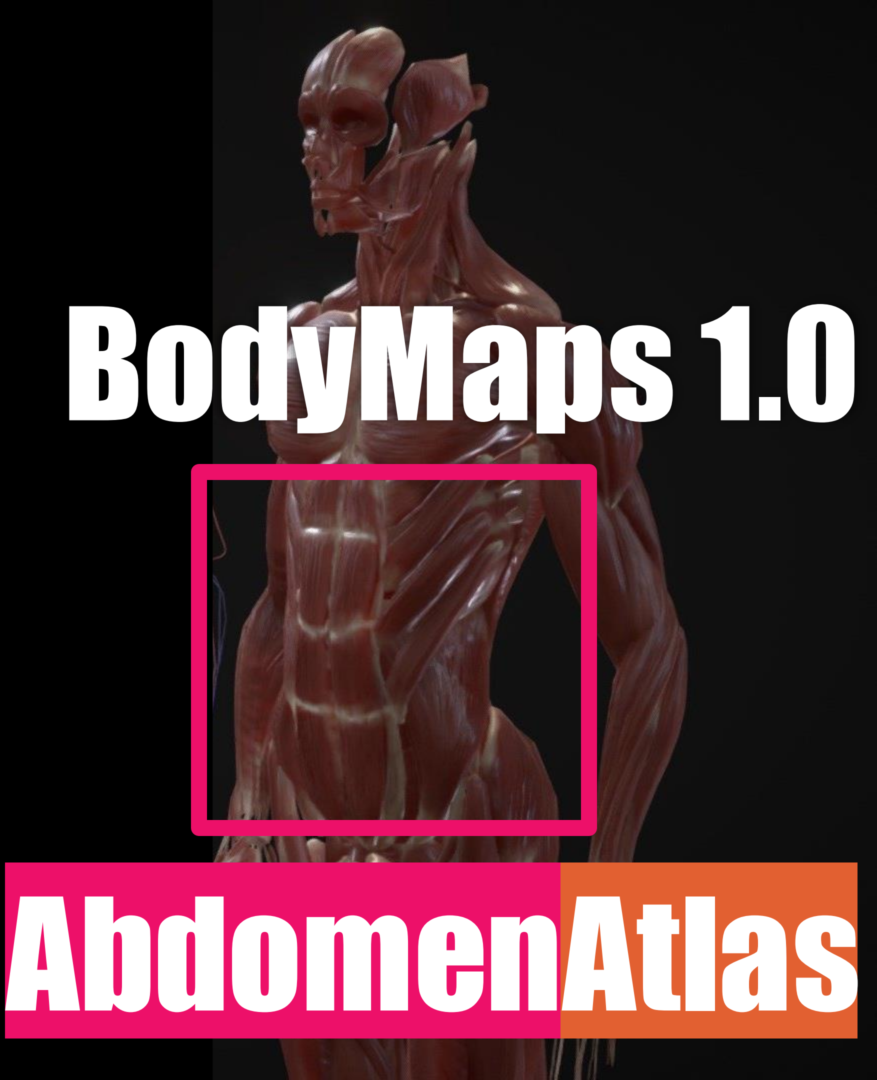
DATA

Annotation

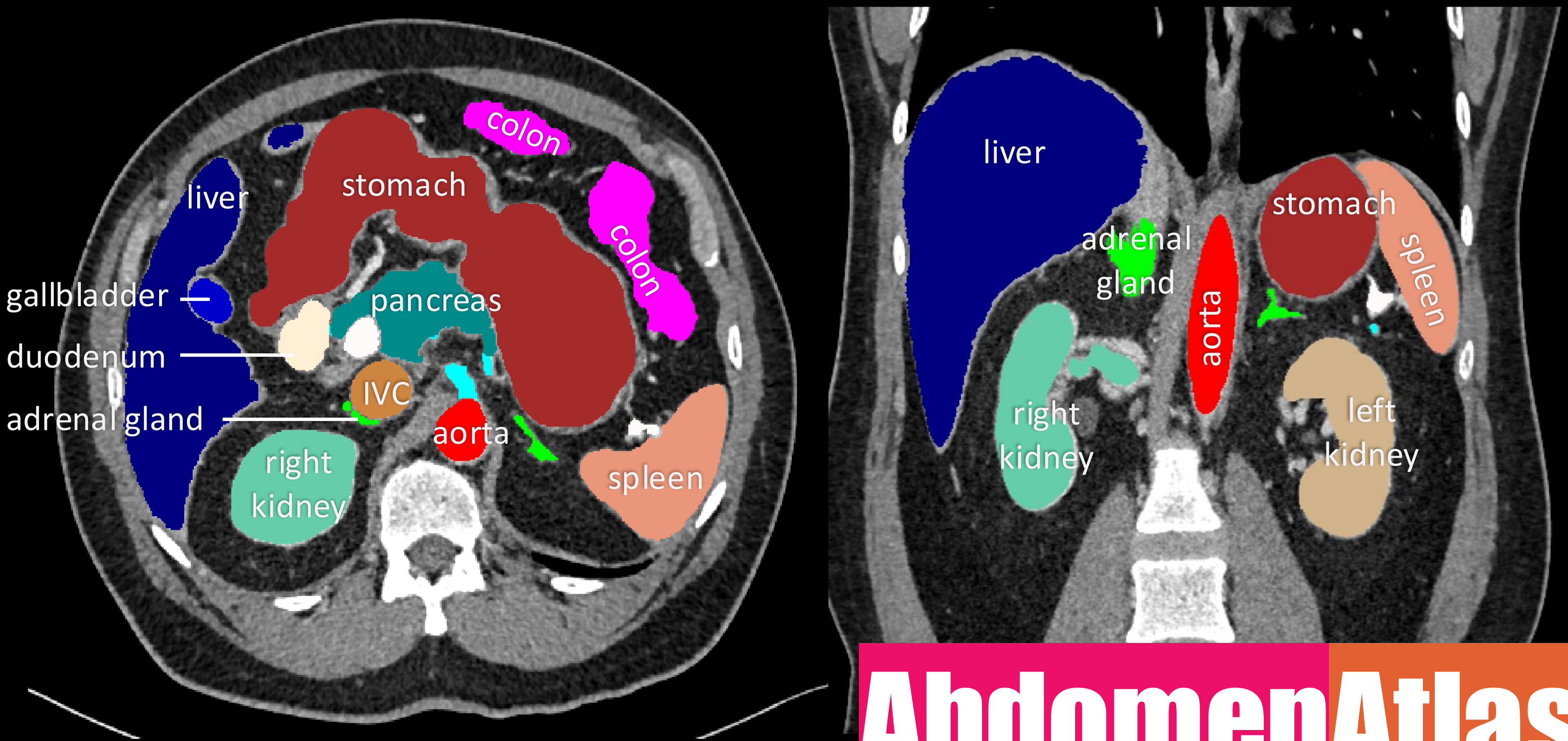
INFORMATION



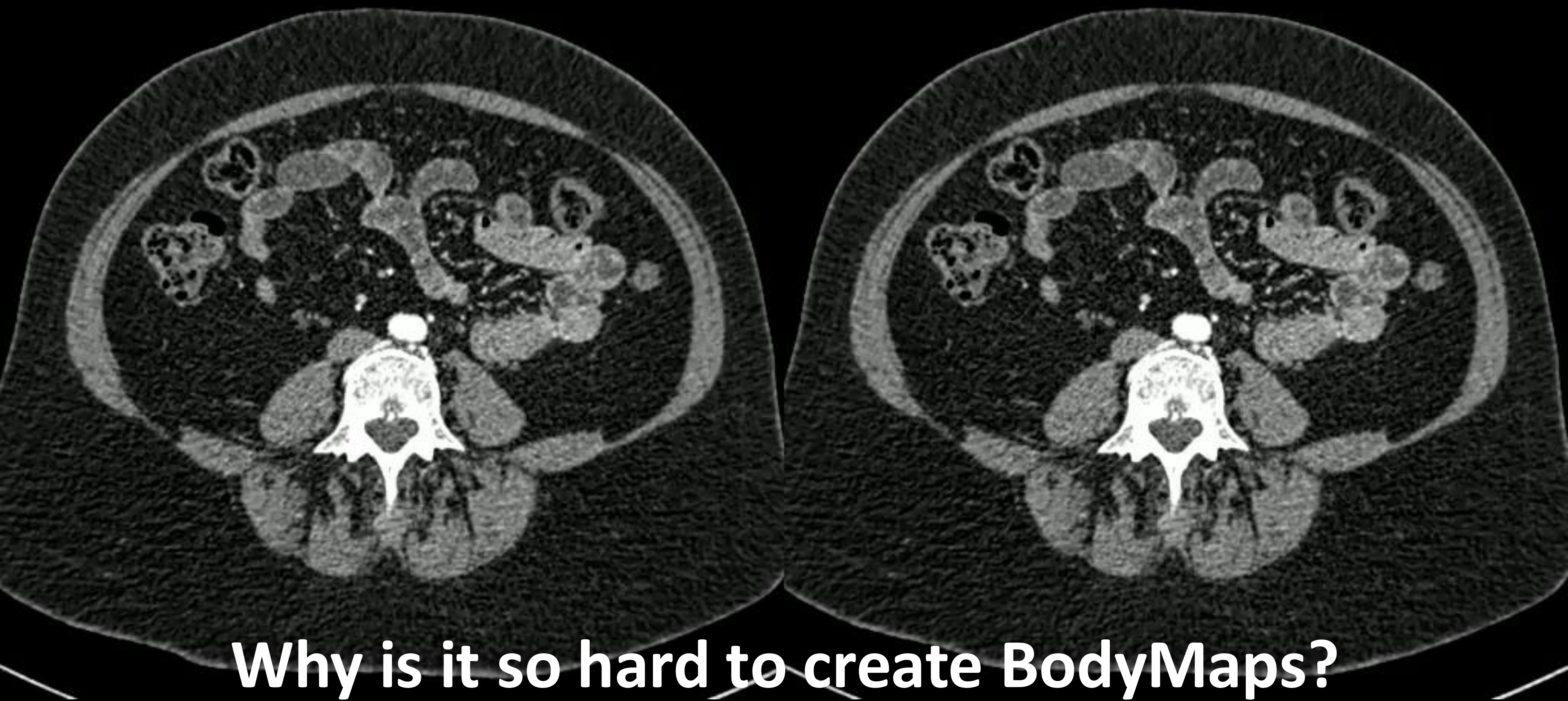
colon
stomach
liver
colon
gallbladder
pancreas
duodenum
IVC
adrenal gland
aorta
right
kidney
spleen



BodyMaps 1.0
AbdomenAtlas



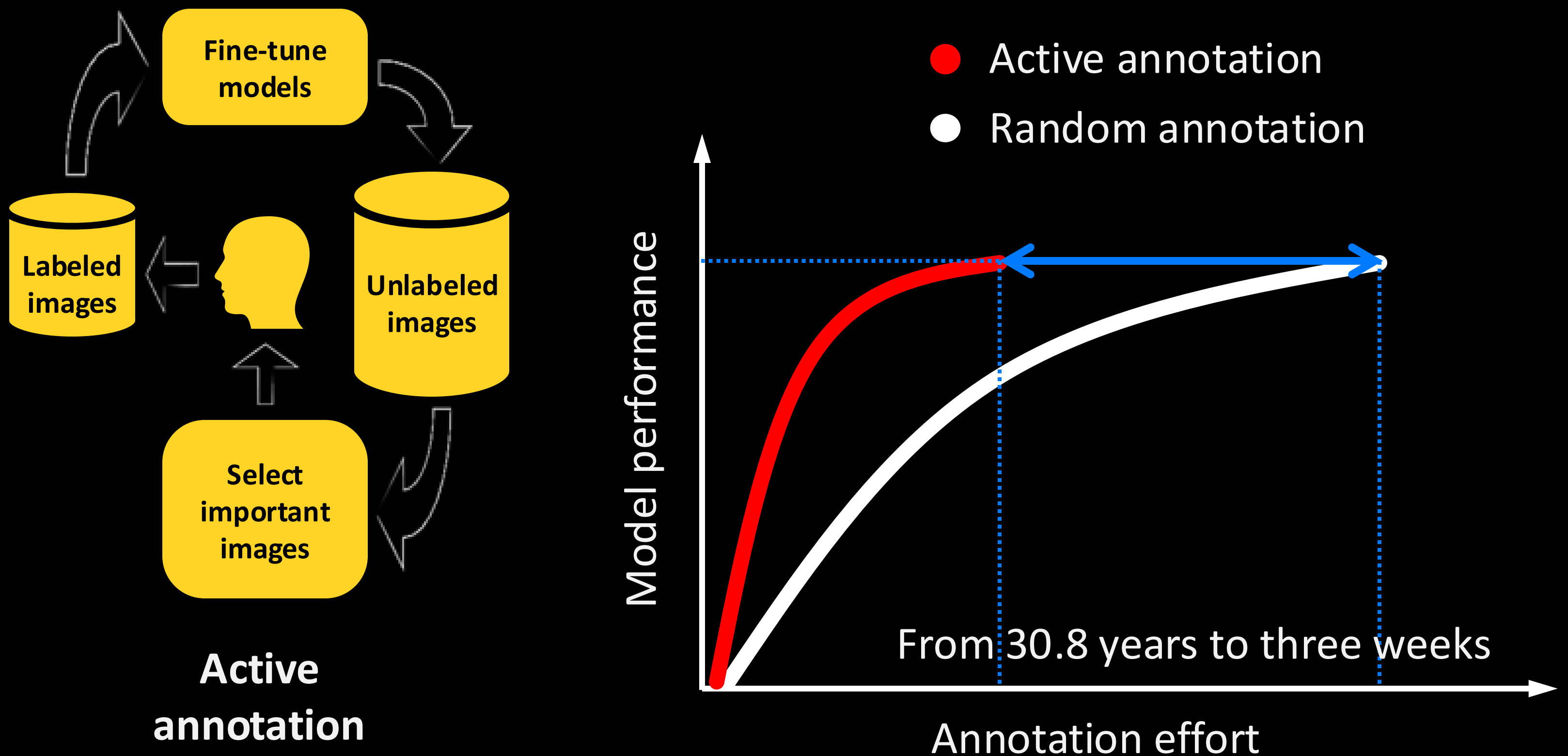
AbdomenAtlas



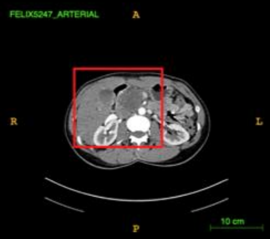
Why is it so hard to create BodyMaps?

30 minutes /organ /CT

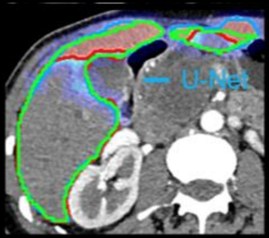
Over 30.8 years to finish annotations for 8,000 CTs


Fine-tune models
Labeled images
Unlabeled images
Select important images
Active annotation
Active annotation
Random annotation
Model performance
From 30.8 years to three weeks
Annotation effort

Entropy



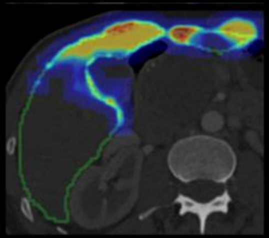
CT Scan



Inconsistency

Uncertainty

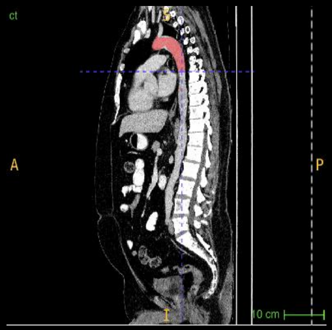
Overlap



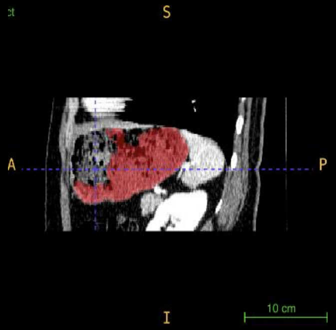
Attention Map

Diversity

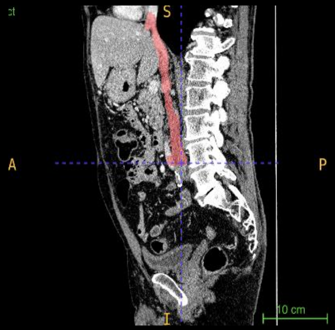
We summarized a **taxonomy** of common errors made by AIs and humans [Qiao et al., RSNA 2023]



Aorta
Inconsistent labeling protocols



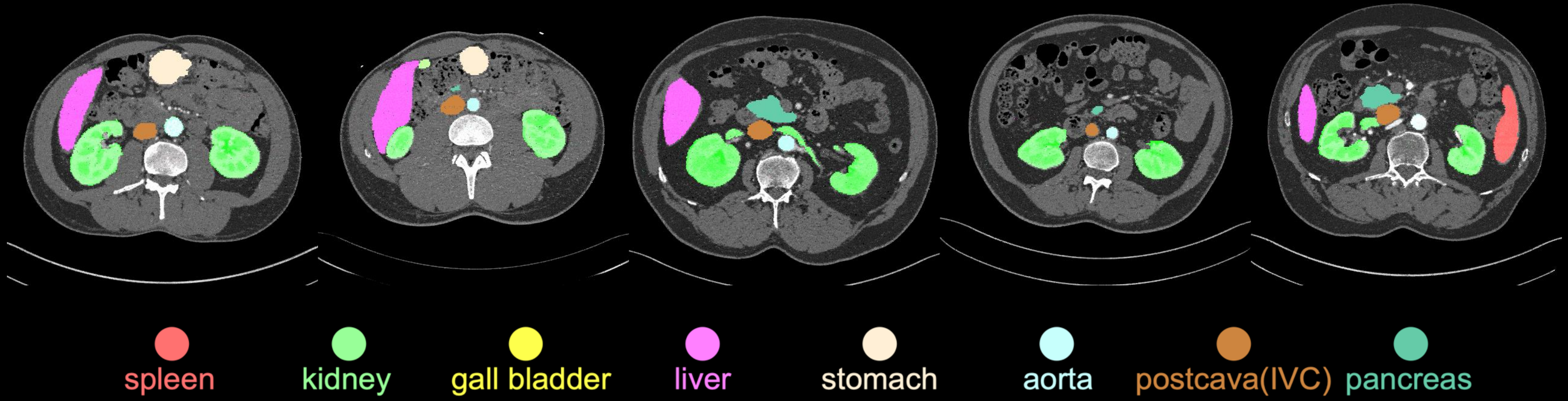
Stomach
uncertainty in empty areas



Postcava
ambiguous & blurry boundaries

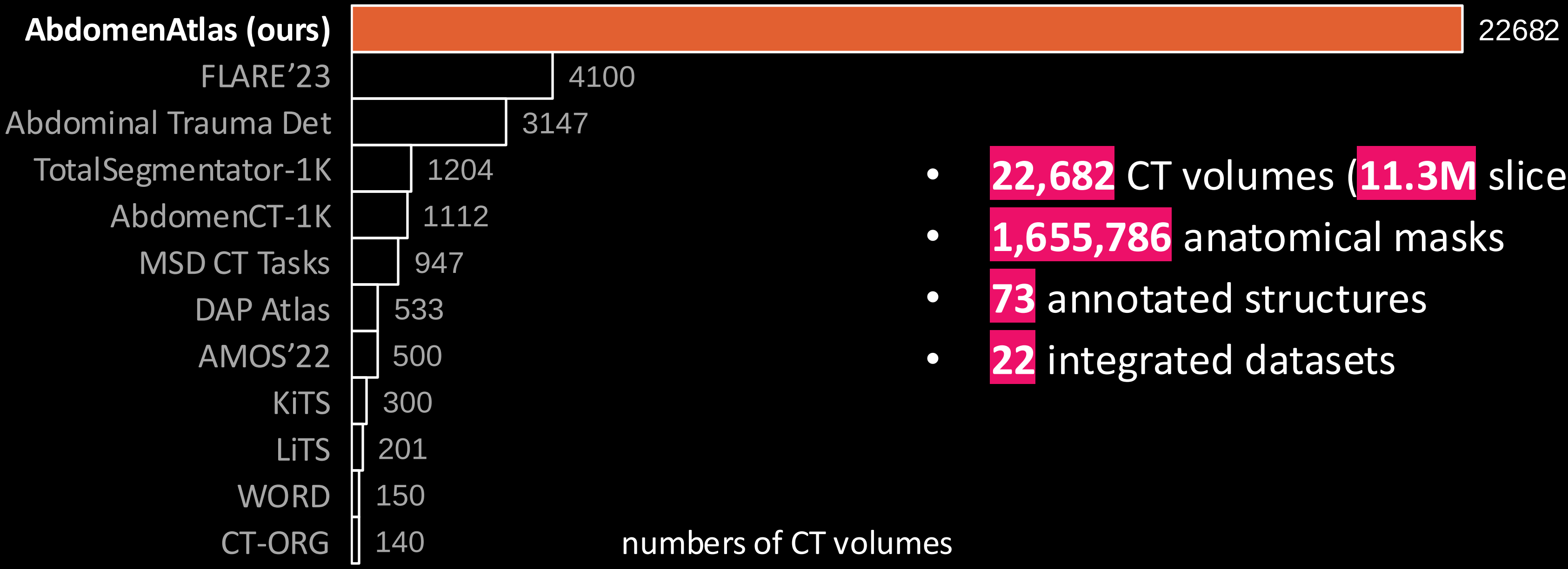
We have released AbdomenAtlas of 9,262 CT volumes and 231K organ masks

[Li et al., ICLR 2024 Oral]



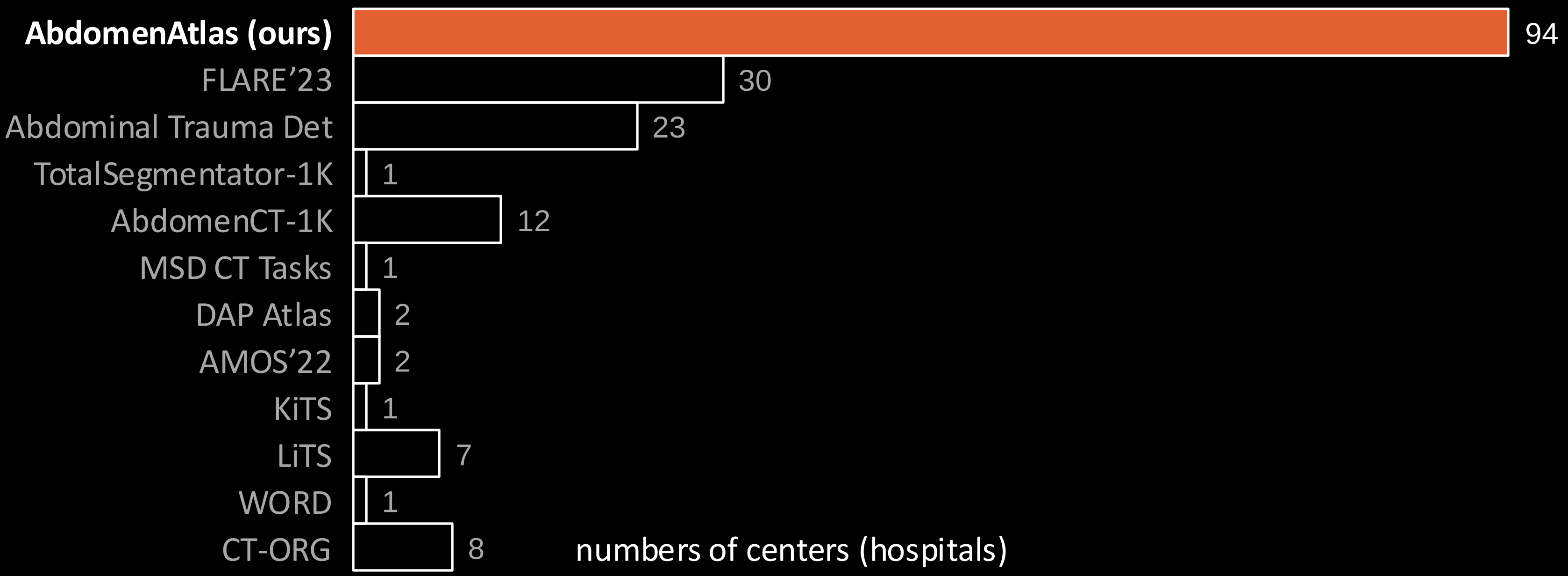
AbdomenAtlas

F1. Multicenter CT scans (11.3M)

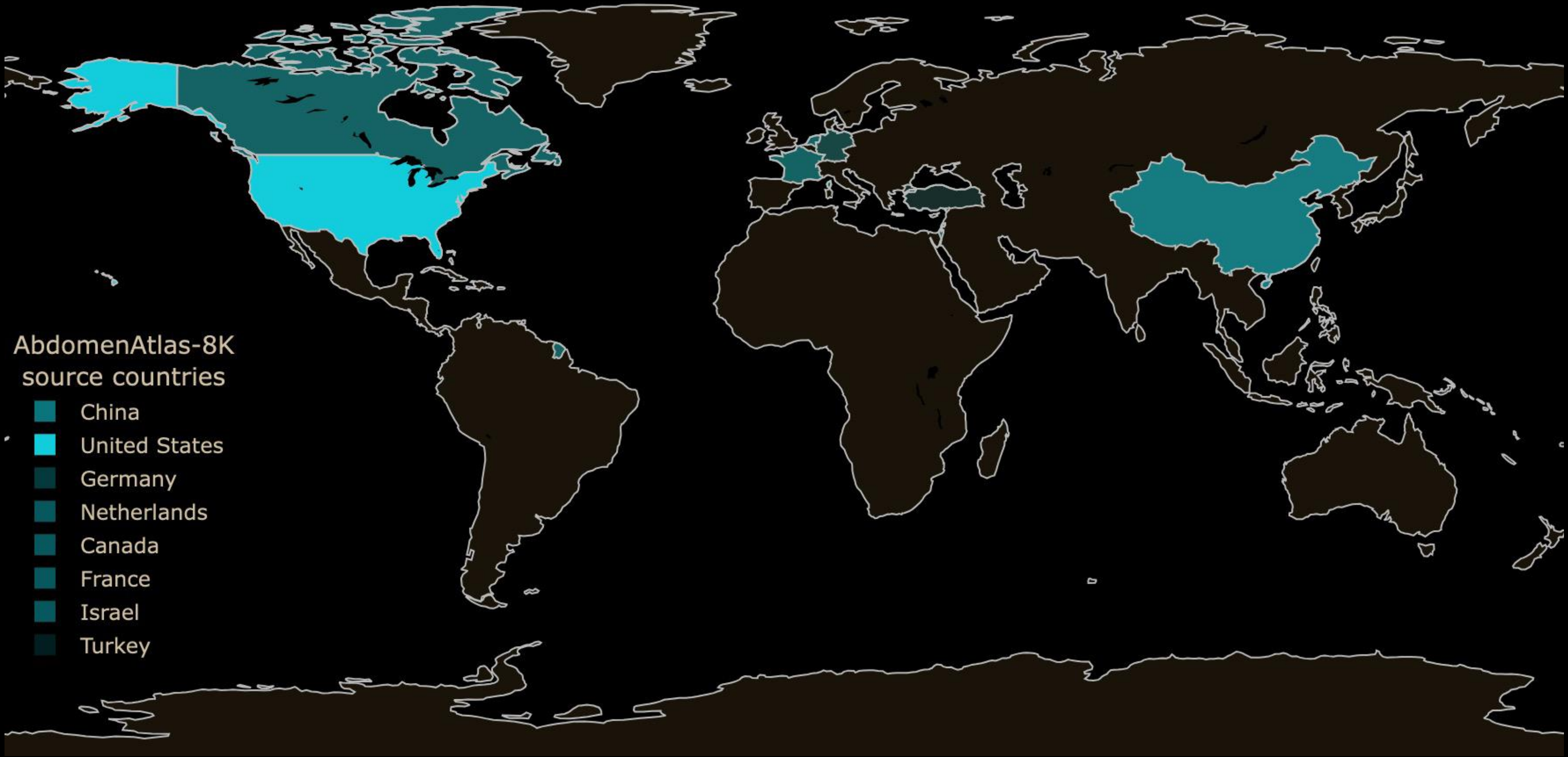


- **22,682** CT volumes (**11.3M** slices)
- **1,655,786** anatomical masks
- **73** annotated structures
- **22** integrated datasets

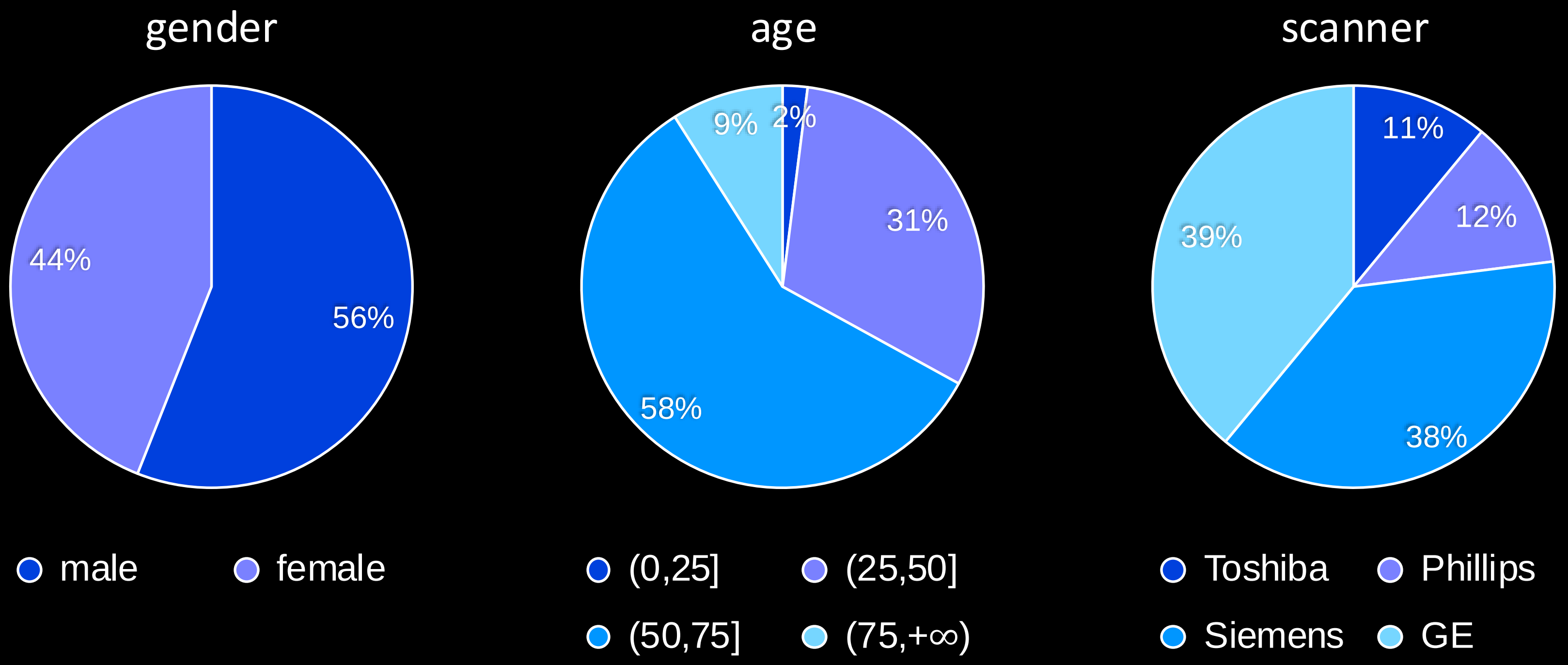
F1. Multicenter CT scans (94 centers)



F1. Multicenter CT scans (19 countries)



F1. Multicenter CT scans (diversity)



F2. Multiple (73) annotated structures

16 Abdominal Organs

gall bladder
kidney left
kidney right
liver
pancreas
spleen
stomach
adrenal gland left
adrenal gland right
bladder
colon
duodenum
esophagus
intestine
prostate
rectum

2 Thoracic Organs

lung left
lung right

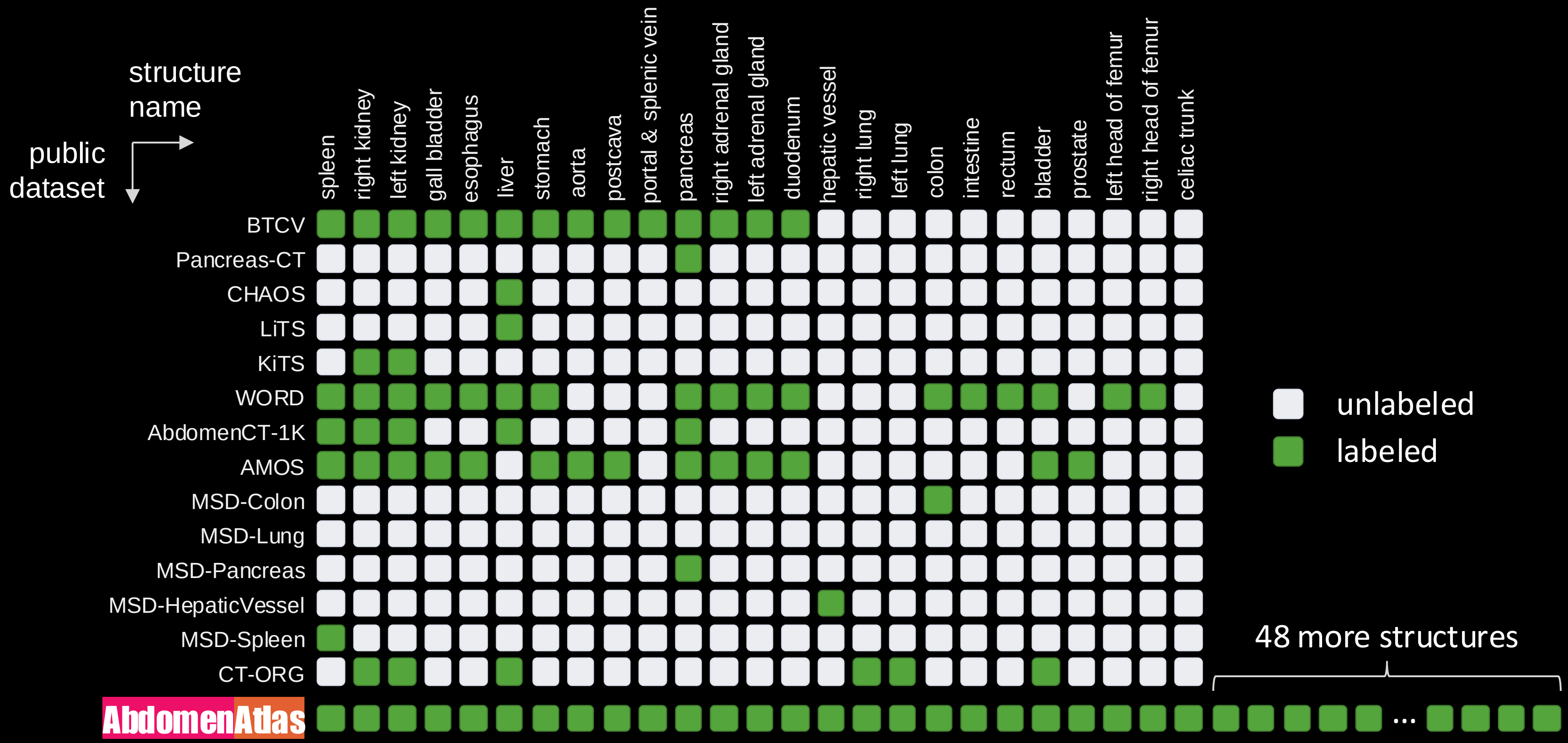
5 Vascular Structures

aorta
celiac trunk
postcava
hepatic vessel
portal & splenic vein

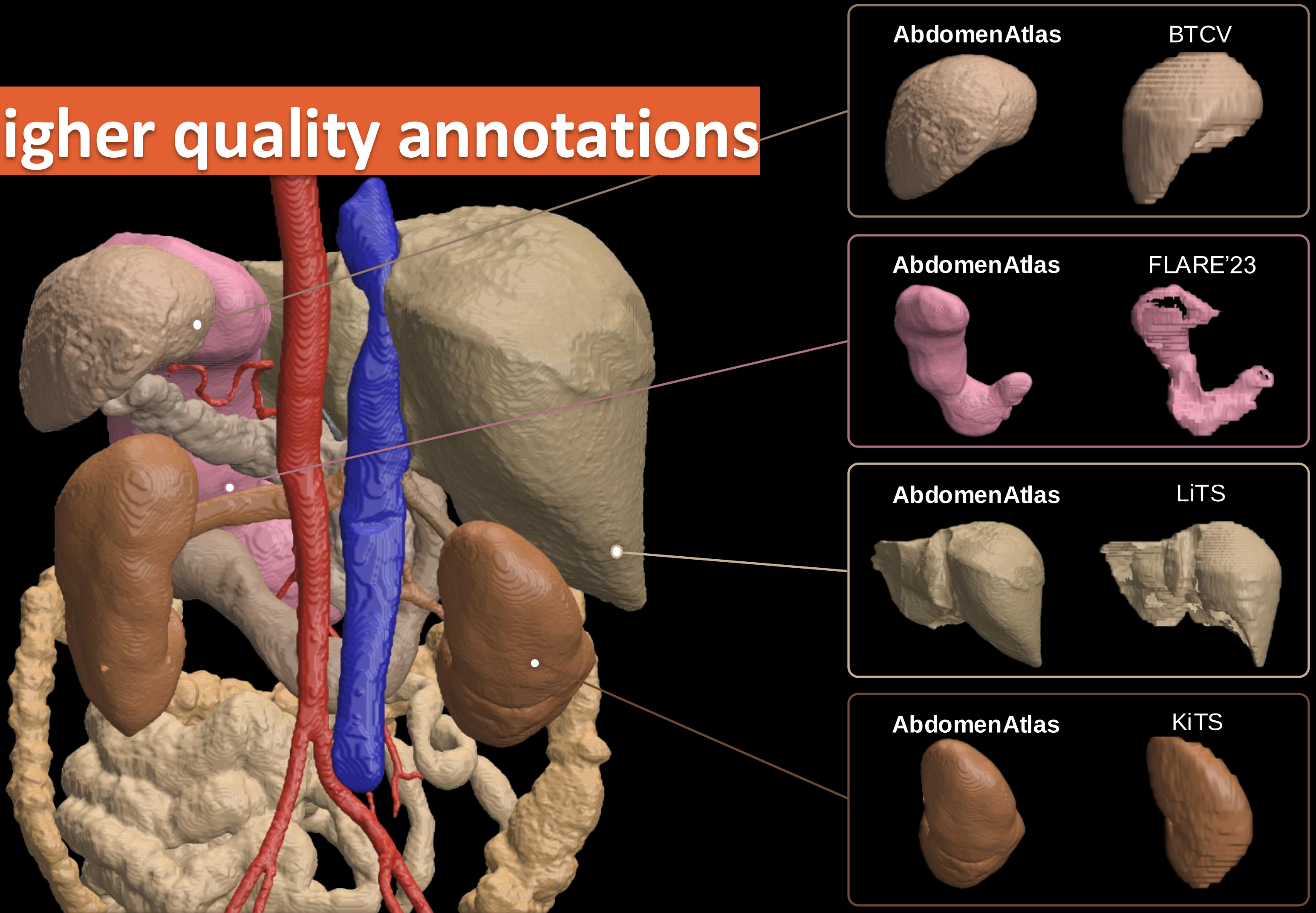
50 Skeletal Structures

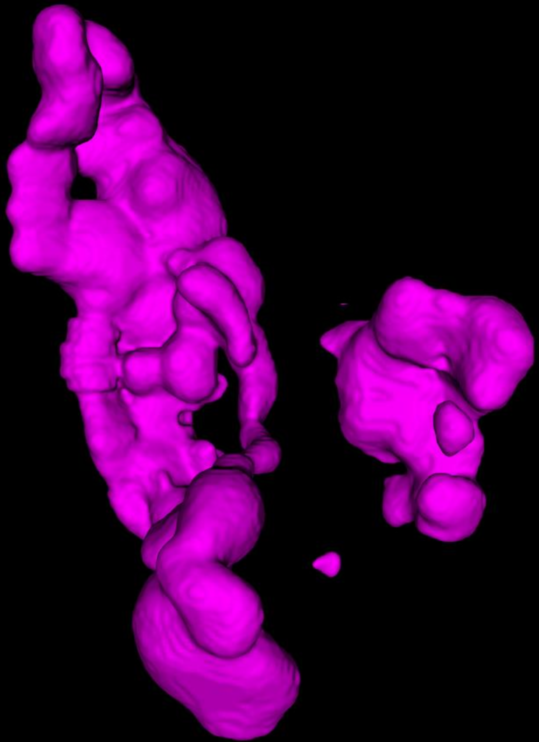
vertebrae L1-L5
vertebrae T1-T12
vertebrae C1-C7
ribs left 1-12
ribs right 1-12
femur left
femur right

F2. Multiple (73) annotated structures



F3. Higher quality annotations

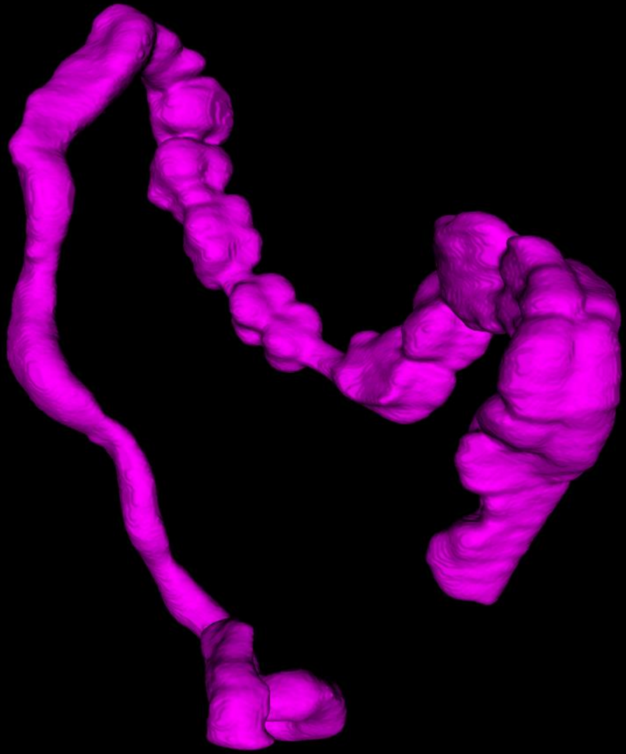




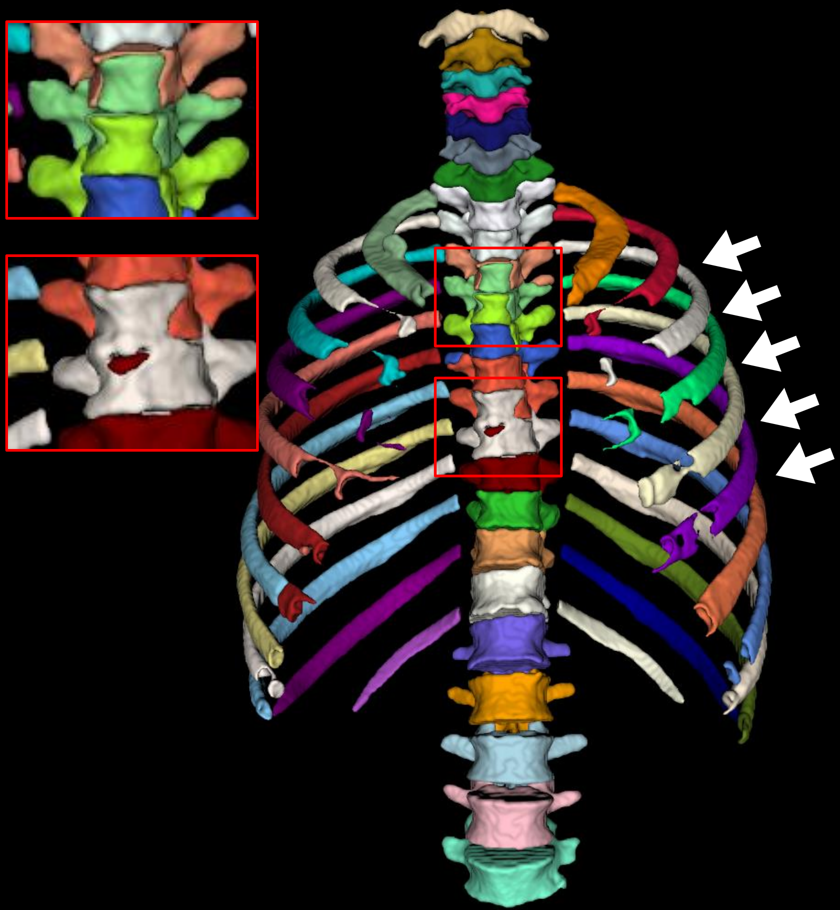
annotated colon in
TotalSegmentator

"The colon contour should include entire wall and lumen of cecum, appendix, ascending colon, transverse colon, descending colon and sigmoid colon **continuously**, as well as any colon lesions. **Adjacent structures** such as small intestine, surrounding fat, mesentery, and omentum should be excluded. The boundary between the ileum and colon is defined by the ileocecal valve. The boundary between the rectum and sigmoid colon is defined by the sigmoid take-off."

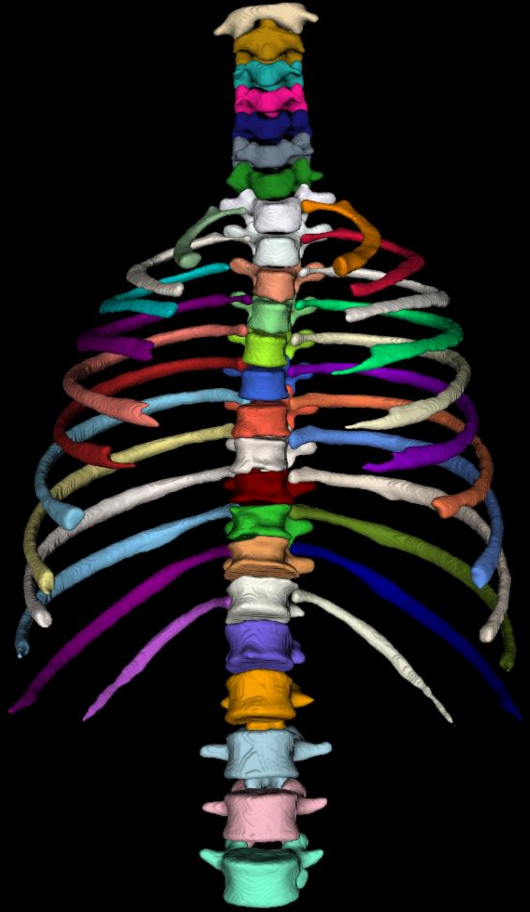
— **Annotation standard** for the colon



annotated colon in
AbdomenAtlas



annotated ribs and vertebrae in
TotalSegmentator



annotated ribs and vertebrae in
AbdomenAtlas

F4. Touchstone

@MICCAI 2024 Challenge

Backbone	Author	Institute	Publication	Backbone	Author	Institute	Publication
U-Net	O. Ronneberger	Uni Freiburg	MICCAI	nnU-Net	Fabian Isensee	DKFZ	Nat. Methods
nnFormer	Hong-Yu Zhou	HKU	TIP	SAT	Ziheng Zhao	SJTU	arXiv
CoTr	Yutong Xie	NPU	MICCAI	Swin UNETR	Ali Hatamizadeh	NVIDIA	MICCAIW
UniverSeg	Victor Ion Butoi	MIT	ICCV	UniSeg	Yiwen Ye	NPU	MICCAI
UNet++	Zongwei Zhou	ASU	TMI	MagicNet	Duowen Chen	ECNU	CVPR
TransUNet	Jieneng Chen	JHU	ICMLW	MedSegDiff	Junde Wu	NUS	AAAI
Swin-Unet	Hu Cao	Huawei	ECCVW	3D UNeXt	Jeya Maria Jose	JHU	MICCAI
DiNTS	Yufan He	JHU	CVPR	……			

So far, **53 groups** have confirmed the contribution—we will invite more authors of **famous backbones** for medical segmentation.

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Code, Dataset, & Model:
https://github.com/MrGiovanni/AbdomenAtlas

Touchstone Benchmark: Are We on the Right Way for Evaluating AI Algorithms for Medical Segmentation?

Pedro R. A. S. Bassi[1,2,3]* Wenxuan Li[1]* Yucheng Tang[4] Fabian Isensee[5,6]
Zifu Wang[29] Jieneng Chen[1] Yu-Cheng Chou[1] Tassilo Wald[5,6]
Constantin Ulrich[5] Michael Baumgartner[5,6] Saikat Roy[5,18]
Klaus H. Maier-Hein[5,30] Paul Jaeger[6,7] Yiwen Ye[8] Yutong Xie[9] Jianpeng Zhang[10]
Ziyang Chen[8] Yong Xia[8] Yannick Kirchhoff[5,18,19] Maximilian Rokuss[5,18]
Pengcheng Shi[11] Ting Ma[11] Yuxin Du[12] Fan Bai[12,13] Tiejun Huang[12,14]
Bo Zhao[20,12] Zhaohu Xing[15] Lei Zhu[15, 16] Saumya Gupta[17] Haonan Wang[16]
Xiaomeng Li[16] Ziyan Huang[20] Jin Ye[21] Junjun He[21] Yousef Sadegheih[22]
Afshin Bozorgpour[22] Pratibha Kumari[22] Reza Azad[23] Dorit Merhof[22,24]
Hanxue Gu[25] Haoyu Dong[25] Jichen Yang[25] Maciej A. Mazurowski[25]
Linshan Wu[16] Jiaxin Zhuang[16] Hao Chen[26] Holger Roth[4] Daguang Xu[4]
Matthew B. Blaschko[29] Sergio Decherchi[27] Andrea Cavalli[2,27,28]
Alan L. Yuille[1] Zongwei Zhou[1]†

[1]Department of Computer Science, Johns Hopkins University
[2]Department of Pharmacy and Biotechnology, University of Bologna
[3]Center for Biomolecular Nanotechnologies, Istituto Italiano di Tecnologia
[4]NVIDIA
[5]Division of Medical Image Computing, German Cancer Research Center (DKFZ)
[6]Helmholtz Imaging, German Cancer Research Center (DKFZ)
Full affiliations are given in Appendix F.

Code, Models & Data: https://github.com/MrGiovanni/Touchstone

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rank	model	organization	average DSC	paper	github
🏆	MedNeXt	DKFZ	89.2	arXiv 2303.09975	Stars 327
🏆	STU-Net-B	Shanghai AI Lab	89.0	arXiv 2304.06716	Stars 269
🏆	MedFormer	Rutgers	89.0	arXiv 2203.00131	Stars 262
🏆	nnU-Net ResEncL	DKFZ	88.8	arXiv 1809.10486	Stars 5.7k
🏆	UniSeg	NPU	88.8	arXiv 2304.03493	Stars 163
🏆	Diff-UNet	HKUST	88.5	arXiv 2303.10326	Stars 149
🏆	LHU-Net	UR	88.0	arXiv 2404.05102	Stars 23
🏆	NexToU	HIT	87.8	arXiv 2305.15911	Stars 55
9	SegVol	BAAI	87.1	arXiv 2311.13385	Stars 212
10	U-Net & CLIP	CityU	87.1	arXiv 2301.00785	Stars 565
11	Swin UNETR & CLIP	CityU	86.7	arXiv 2301.00785	Stars 565
12	Swin UNETR	NVIDIA	80.1	arXiv 2211.11537	Stars 1.8k
13	UNesT	NVIDIA	79.1	arXiv 2303.10745	Stars 1.8k
14	SAM-Adapter	Duke	73.4	arXiv 2404.09957	Stars 120
15	UNETR	NVIDIA	64.4	arXiv 2111.04004	Stars 1.8k

NVIDIA

dkfz.

UCSF University of California San Francisco

NUS National University of Singapore

JOHNS HOPKINS UNIVERSITY

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

HEIDELBERG UNIVERSITY HOSPITAL

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

上海人工智能实验室
Shanghai Artificial Intelligence Laboratory

北京大學 PEKING UNIVERSITY

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

上海交通大學 SHANGHAI JIAO TONG UNIVERSITY

Duke UNIVERSITY

香港中文大學 The Chinese University of Hong Kong

Fraunhofer MEVIS

Stony Brook University

HIDSS 4HEALTH HELMHOLTZ INFORMATION & DATA SCIENCE SCHOOL FOR HEALTH

哈爾濱工業大學(深圳) HARBIN INSTITUTE OF TECHNOLOGY, SHENZHEN

西北工業大學 NORTHWESTERN POLYTECHNICAL UNIVERSITY

RWTH AACHEN UNIVERSITY

KU LEUVEN

HELMHOLTZ IMAGING

ZHEJIANG UNIVERSITY

UR Universität Regensburg

iit ISTITUTO ITALIANO DI TECNOLOGIA

THE UNIVERSITY OF ADELAIDE AUSTRALIA

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

BAAI 智源研究院

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

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Code, Dataset, & Model:
https://github.com/MrGiovanni/AbdomenAtlas

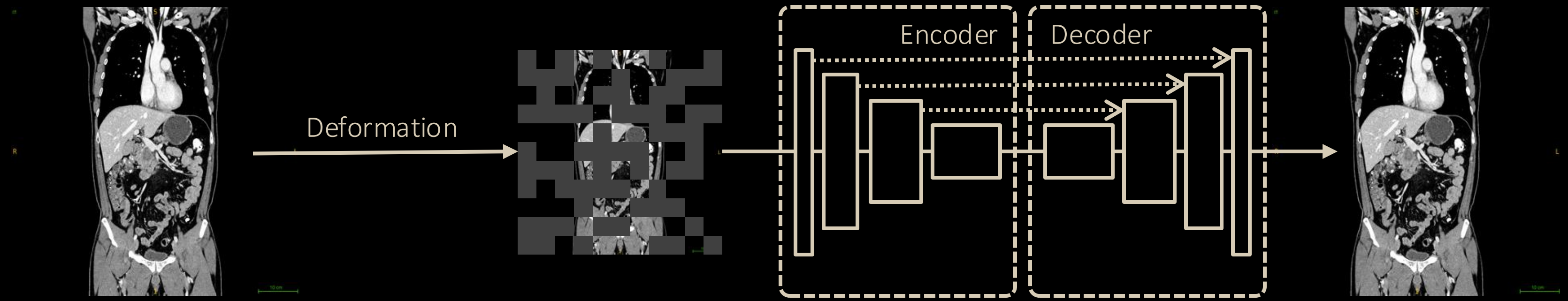
F5. Foundation Models

AI models pre-trained on broad data and can be applied across tasks

SuPreM

Supervised

Pre-trained **M**odels



Option 1. Self-supervised pre-training

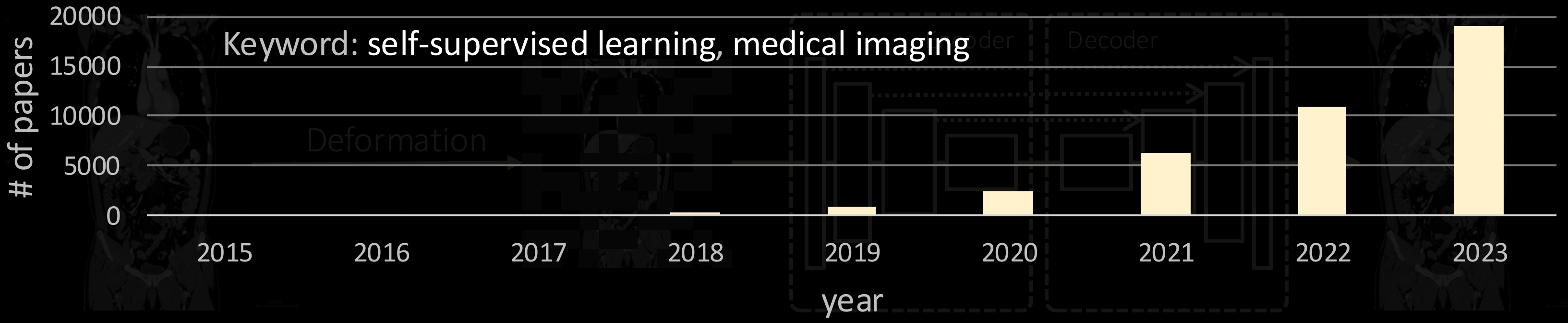
De-noising [Vincent et al., 2010]
Positioning [Doersch et al., 2015]
In-painting [Pathak et al., 2016]
Jigsaw [Noroozi and Favaro, 2016]
DeepCluster [Caron et al., 2018]
Restoration [Chen et al., 2019]

Models Genesis
[Zhou et al., MICCAI 2019]
MICCAI Young Scientist Award
MedIA Best Paper Award

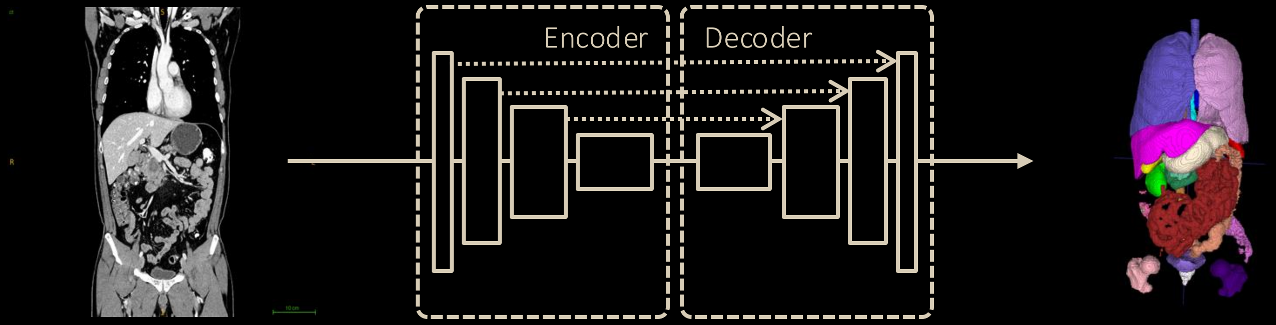
Rubiks Cube
[Zhuang et al., MICCAI 2019]

Swin UNETR
[Tang et al., CVPR 2022]

UniMiSS
[Xie et al., ECCV 2022]



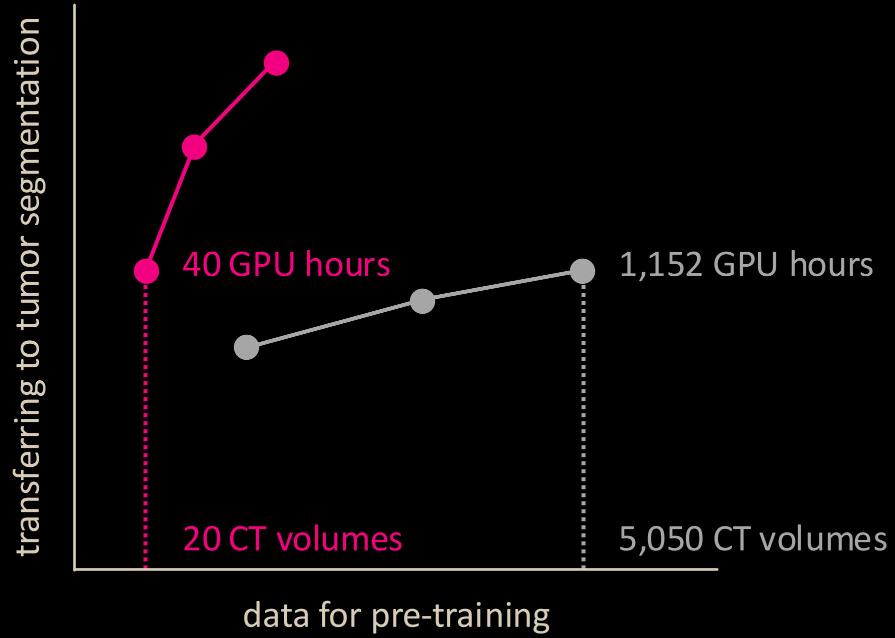
Option 1. Self-supervised pre-training



Option 2. Supervised pre-training

Supervised > Self-supervised

data & computation efficiency



F5. Foundation Models

AI models pre-trained on broad data and can be applied across tasks

Expensive?

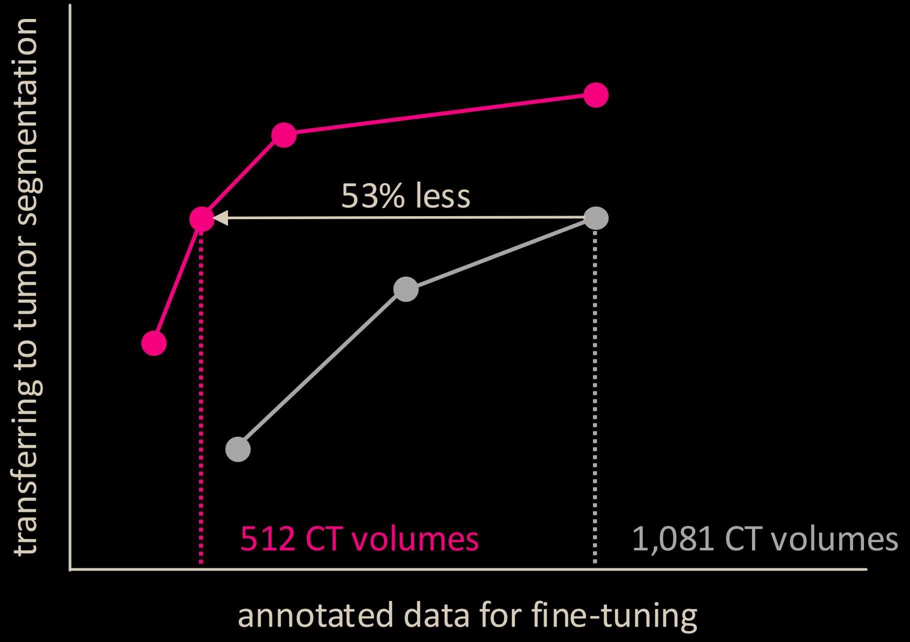
F5. Foundation Models

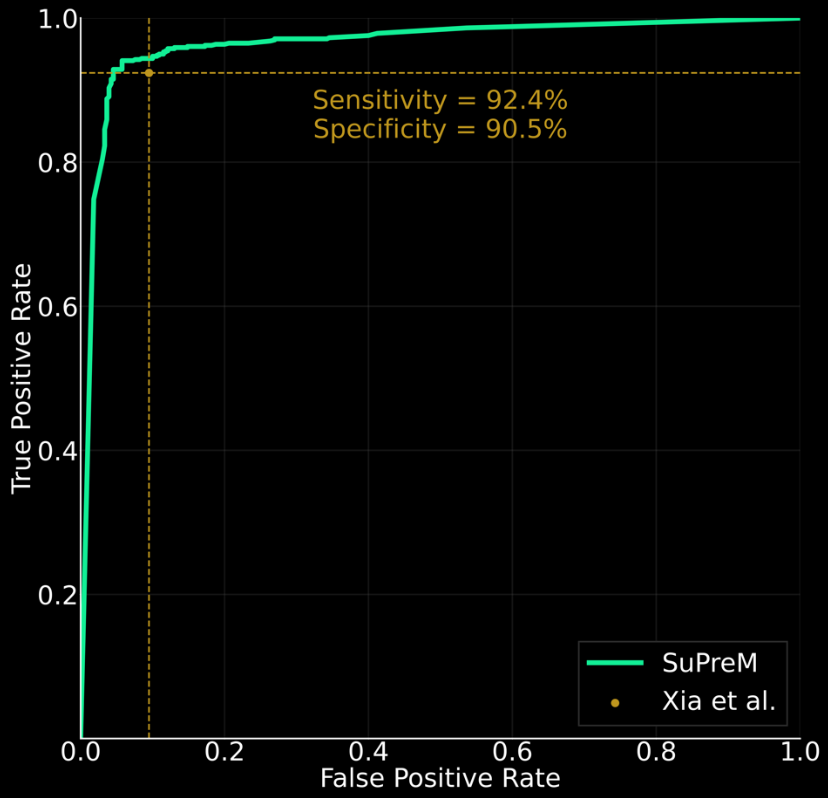
AI models pre-trained on broad data and can be applied across tasks

Annotation-efficient?

Supervised > Self-supervised

annotation & learning efficiency



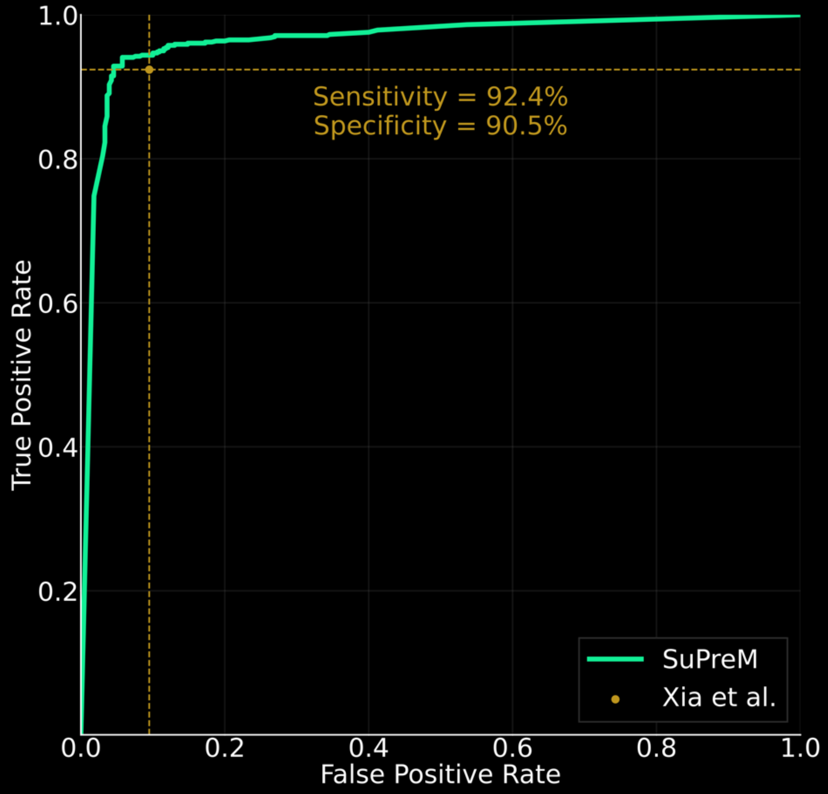


The FELIX Project: Deep Networks To Detect Pancreatic Neoplasms

Yingda Xia[1,†], Qihang Yu[1,†], Linda Chu[2,†], Satomi Kawamoto[2,†], Seyoun Park[2], Fengze Liu[1], Jieneng Chen[1], Zhuotun Zhu[1], Bowen Li[1], Zongwei Zhou[1], Yongyi Lu[1], Yan Wang[1], Wei Shen[1], Lingxi Xie[1], Yuyin Zhou[1], Christopher Wolfgang[3], Ammar Javed[3], Daniel Fadaei Fouladi[2], Shahab Shayesteh[2], Jefferson Graves[2], Alejandra Blanco[2], Eva S. Zinreich[2], Benedict Kinny-Köster[3], Kenneth Kinzler[4,6,7,8], Ralph H. Hruban[5], Bert Vogelstein[4,6,7,8,9], Alan L. Yuille[1,*], Elliot K. Fishman[2,*]

[1]Department of Computer Science, Johns Hopkins University; [2]Department of Radiology and Radiological Science, Johns Hopkins Medicine; [3]Department of Surgery, New York University; [4]Department of Oncology, Johns Hopkins Medicine; [5]Department of Pathology, Johns Hopkins Medicine; [6]Ludwig Center, Johns Hopkins University School of Medicine; [7]Sidney Kimmel Comprehensive Cancer Center, Johns Hopkins University School of Medicine; [8]Sol Goldman Pancreatic Cancer Research Center, Johns Hopkins University School of Medicine; [9]Howard Hughes Medical Institute, Johns Hopkins Medical Institutions

Abstract Tens of millions of abdominal images are performed with computed tomography (CT) in the U.S. each year but pancreatic cancers are sometimes not initially detected in these images. We here describe a suite of algorithms (named FELIX) that can recognize pancreatic lesions from CT images without human input. Using FELIX, >90% of patients with pancreatic ductal adenocarcinomas were detected at a specificity of >90% in patients without pancreatic disease. FELIX may be able to assist radiologists in identifying pancreatic cancers earlier, when surgery and other treatments offer more hope for long-term survival.



Extending Supervised Pretraining on Large Organ Dataset to Universal Lesion Segmentation

Yannick Kirchhoff, Maximilian R. Rokuss, Saikat Roy, Klaus H. Maier-Hein
German Cancer Research Center (DKFZ), Heidelberg, Germany

Method Description:

Our method uses a lightweight nnUNet [1] pretrained on a large organ segmentation dataset. We used supervised pretraining on the Abdomen Atlas 1.0 [2,3] dataset with 8 annotated organs over 5000 CT samples. Our work demonstrates that we can efficiently train the smallest possible models to learn robust representations of CT images from a large organ database which does not have any label overlaps with the ULS23 labelset. Our priority is not solely about reaching the very best Dice score. Instead, we aim for a very lightweight design while maintaining comparable accuracy.

References:

[1] Isensee, Fabian, et al. "nnU-Net: a self-configuring method for deep learning-based biomedical image segmentation." Nature methods 18.2 (2021): 203-211.

[2] Qu, Chongyu, et al. "Abdomenatlas-8k: Annotating 8,000 CT volumes for multi-organ segmentation in three weeks." Advances in Neural Information Processing Systems 36 (2024).

[3] Li, Wenxuan, Alan Yuille, and Zongwei Zhou. "How well do supervised models transfer to 3d image segmentation?." The Twelfth International Conference on Learning Representations. 2023.

F6. Personalized atlas for patients

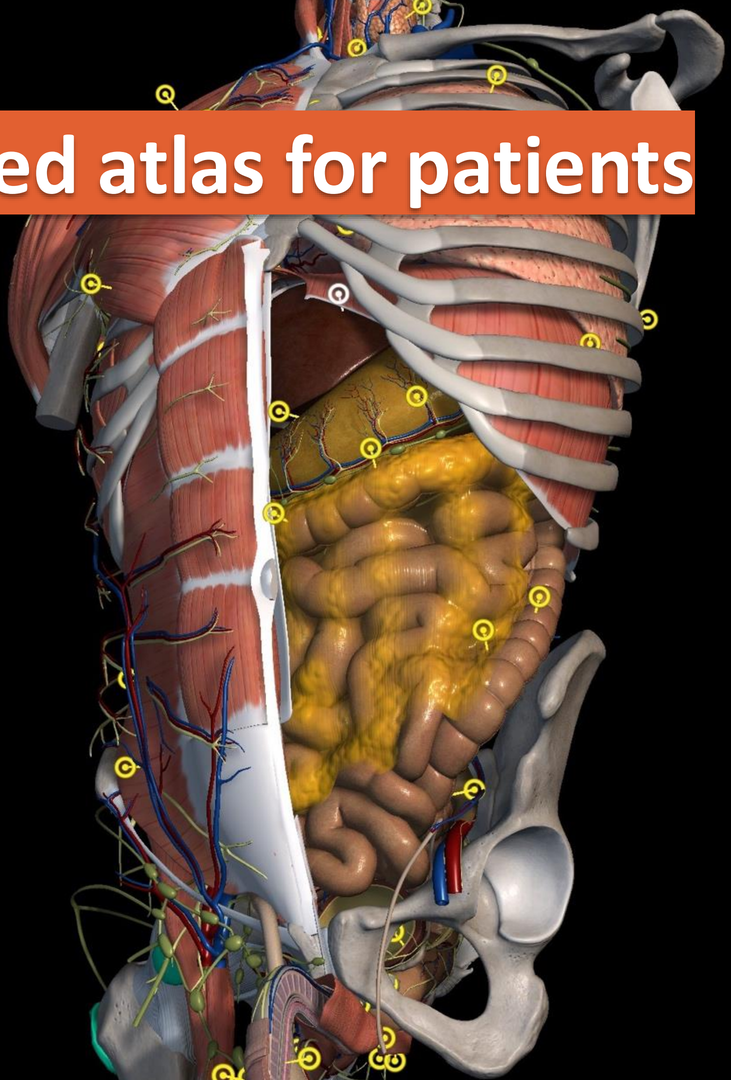
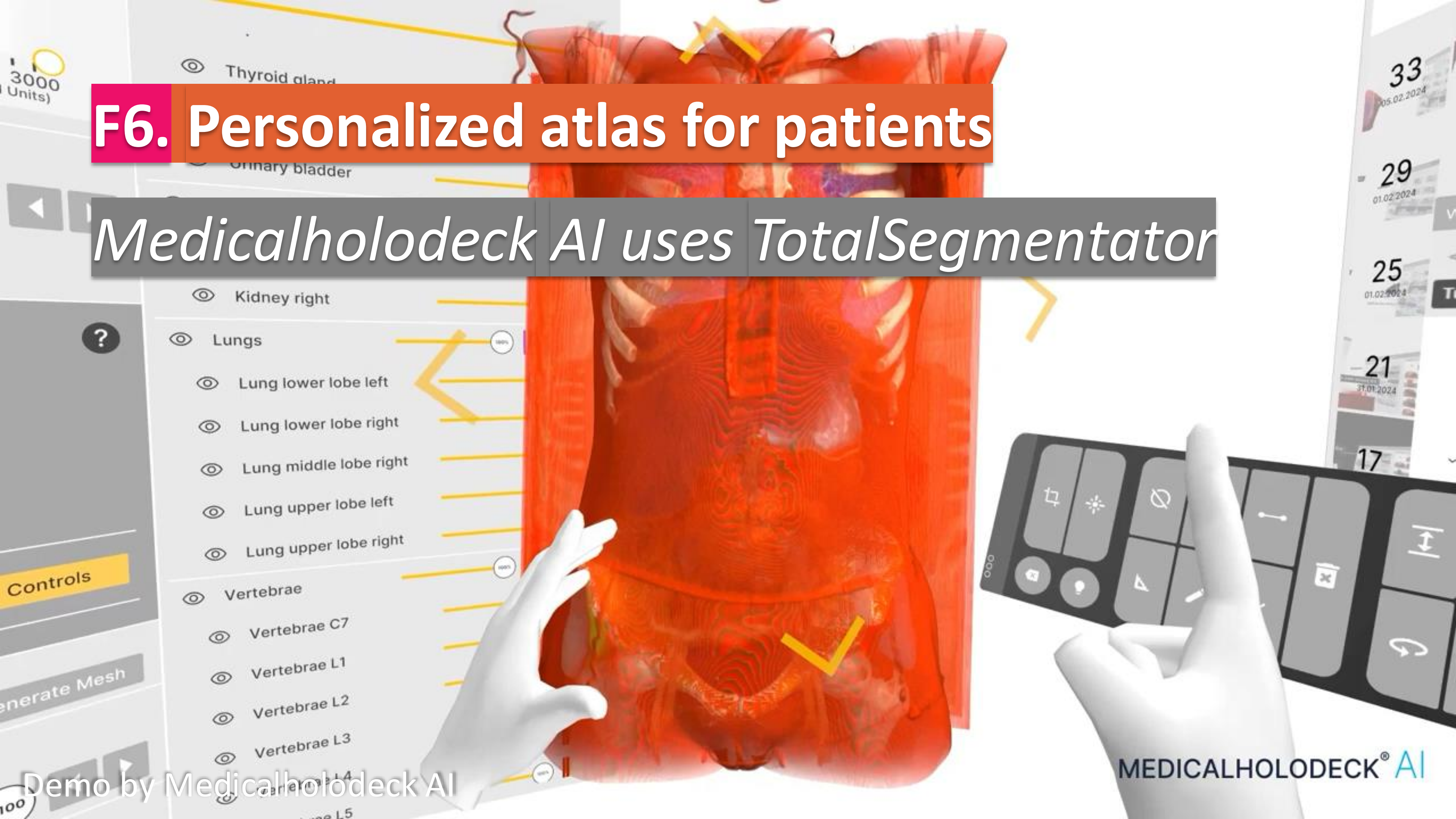


Photo by Anatomy 3D Atlas

F6. Personalized atlas for patients

Medicalholodeck AI uses TotalSegmentator



Demo by Medicalholodeck AI

F6. Personalized atlas for patients

F6. Personalized atlas for patients

F6. Personalized atlas for patients

F6. Personalized atlas for patients

External Collaborators

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Challenges: Towards 3D Atlas of Human Body

IEEE International Symposium on Biomedical Imaging (ISBI'24)
International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI'24)

Become Part of the BodyMaps Project?

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Post

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AI and Radiologists Unite to Map the Abdomen

Hopkins researchers have leveraged the synergy between medical professionals and artificial intelligence algorithms to create the largest annotated multi-organ dataset to date.

"While a dataset of this size would have taken an experienced human annotator almost 31 years to fully annotate, the team completed this task in only three weeks."

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Code, Dataset, & Model:
https://github.com/MrGiovanni/SuPreM

Thank you!

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