Perelman School of Medicine University of Pennsylvania

Penn Center for Musculoskeletal Disorders

PCMD MicroCT Imaging Core Learning Lunch Series

Deep Learning for MicroCT Image Segmentation via Dragonfly

April 28th, 2022

PCMD MicroCT Imaging Core

(Management team: X. Sherry Liu, Yilu Zhou)

Invited speakers:

Dr. Ryan Locke from Dr. Robert Mauck's group (Penn McKay Lab)

Ranhui Xi from Dr. Marco Tizzano's group (Penn Dental)

PENN Center for Musculoskeletal Disorders

McKay Orthopaedic Research Lab University of Pennsylvania

Penn Center for Musculoskeletal Disorders (P30-AR069619)

Outlines

- Brief introduction of our core facility
- Recent progress of our video tutorials, automated services
- The Dragonfly software & our new workstation
- Dragonfly application highlights from Dr. Ryan Locke (Dr. Robert Mauck's group, Penn McKay Lab)
- Dragonfly application highlights from Ranhui Xi (Dr. Marco Tizzano's group, Penn Dental)
- Q & A

µCT Imaging Core Resources

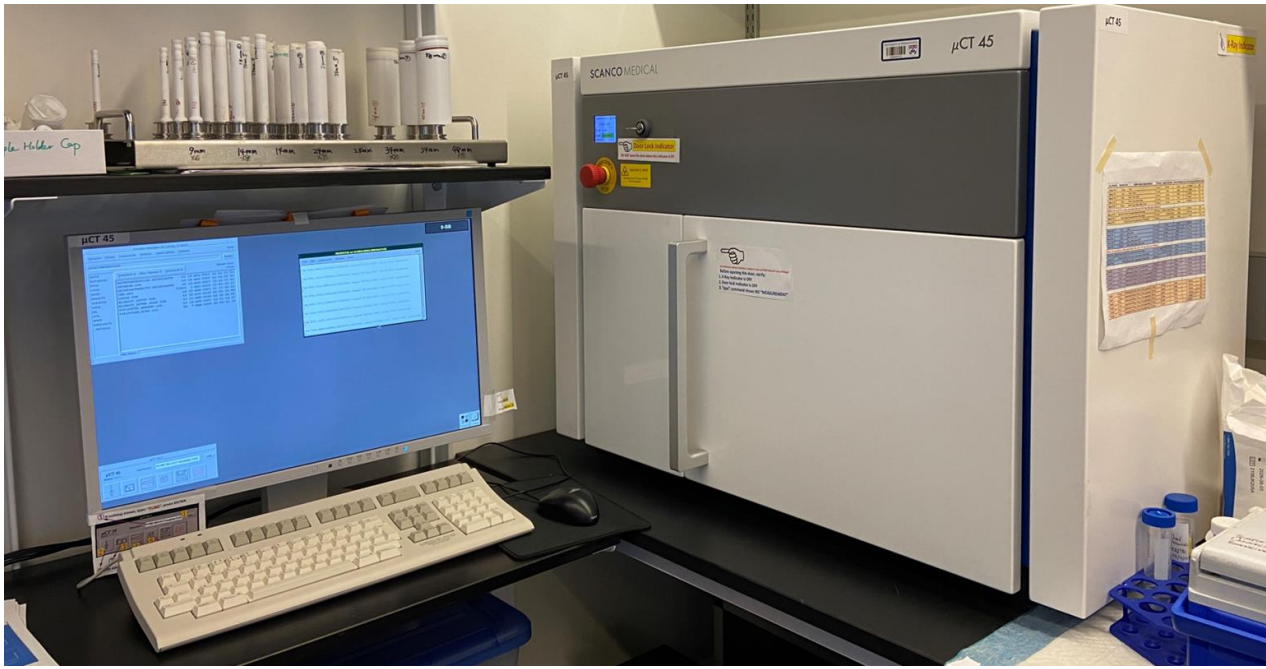
	Model	Location	Scan Size (ØxL;mm)	Voxel Size (µm)	Applications
1	µCT 35	Stemmler Hall	37.9 x 120	3.5-72	High resolution *ex vivo* scans
2	µCT 45	Stemmler Hall	50 x 120	3.0-100	High resolution *ex vivo* scans
3	vivaCT 40	Stemmler Hall	38.9 x 145	10.5-76	High resolution *in vivo* scans for small animals
4	vivaCT 80	Stemmler Hall	80 x 145	10.4-76	High resolution *in vivo* scans for small animals
5	µCT 50	PVAMC/TMRC	50 x 120	0.5-100	Ultra high resolution (sub-micron) *ex vivo* scans
6	vivaCT 75	PVAMC/TMRC	79.9 x 145	21-150	*In vivo* scans for small animals; *ex vivo* scans for large specimens
7	XtremeCT II	CTRC	140 x 200	60-82	Clinical scans for peripheral skeleton

Ex vivo (Specimen) Scanners

- µCT 35 (Purchased in 2012)
  - Voxel sizes: 3.5 µm, 6 µm, 10 µm, 15 µm, 18.5 µm

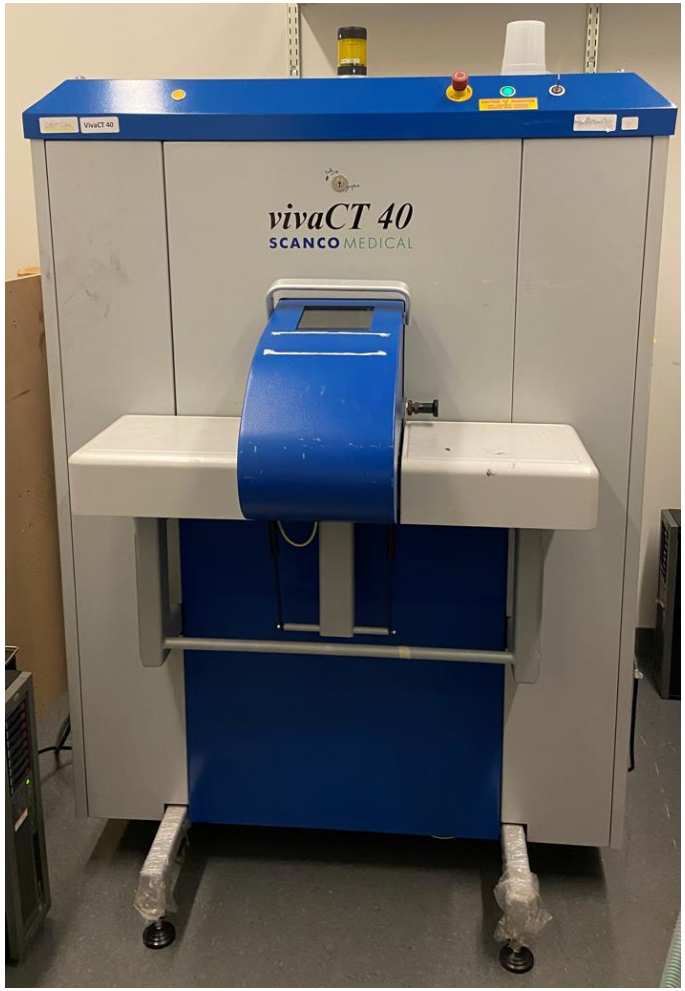
Ex vivo (Specimen) Scanners

- µCT 45 (Purchased in 2019 ***new!***)
  - Voxel sizes: 3 µm, 4.5 µm, 7.4 µm, 10.4 µm, 14.6 µm
  - Carousel system supporting 20 sample holders
  - "Air" filter for scanning low density materials
  - "Copper" filter for scanning metal implant



In vivo Scanners

- vivaCT 40 (Purchased in 2010)
  - Voxel sizes: 10.5 µm, 12.5 µm, 15 µm, 17.5 µm, 19 µm

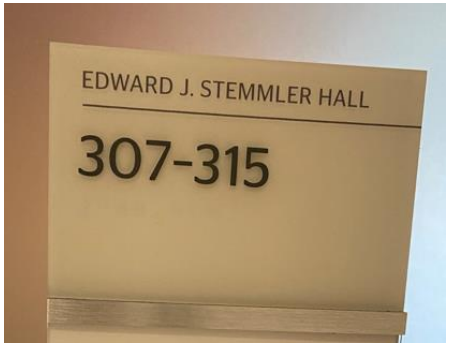


In vivo Scanners

- vivaCT 80 (Purchased in 2018 ***new!***)
  - Voxel sizes: 10.4 μm, 11.6 μm, 13 μm, 16.1 μm, 20.8 μm, 26 μm
  - Internal heating device to keep animal warm
  - Camera to monitor animal's breathing
  - Ex vivo scan for specimen from large animals or human cadaver

MicroCT Analysis PC

- 2 PCs for MicroCT Analysis (315 Stemmler)
  - Windows 10 platform
  - Either remote or onsite access
  - Scanco software



Video Tutorials & Instruction Documents

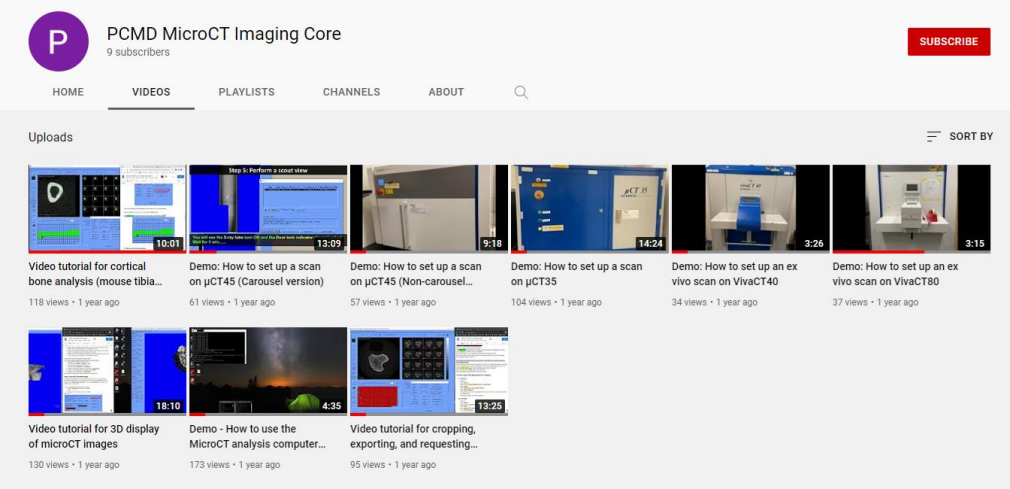
https://www.med.upenn.edu/pcmd/mctimagingcore/user-tutorials.html
https://www.youtube.com/channel/UCzznR9Fdv-3kjEX7miwsi0A

Video Tutorials:

Our YouTube channel: https://www.youtube.com/channel/UCzznR9Fdv-3kjEX7miwsioA/

µCT scan setup:

1. How to set up a scan on µCT35 (PDF download) (Video download)
   https://www.youtube.com/watch?v=QUtoQqlYJ8o
2. Demo: How to set up a scan on µCT45 (Recommended: Carousel version)
   (PDF download) (Video download)
   Note: To use this Carousel version, please remove the sample holder on the rotation stage.
   https://www.youtube.com/watch?v=fzlfffR5XyE
3. Demo: How to set up a scan on µCT45 (Non-carousel version) (PDF download) (Video download)
   Note: To use this Non-carousel version, please remove all sample holders on the carousel.
   https://www.youtube.com/watch?v=JEoLn1i9EjE
4. How to set up an ex vivo scan on VivaCT40 (PDF download) (Video download)
   https://www.youtube.com/watch?v=sxvTV4bvosw
5. How to set up an ex vivo scan on VivaCT80 (PDF download) (Video download)
   https://www.youtube.com/watch?v=HdQYWwjulXM



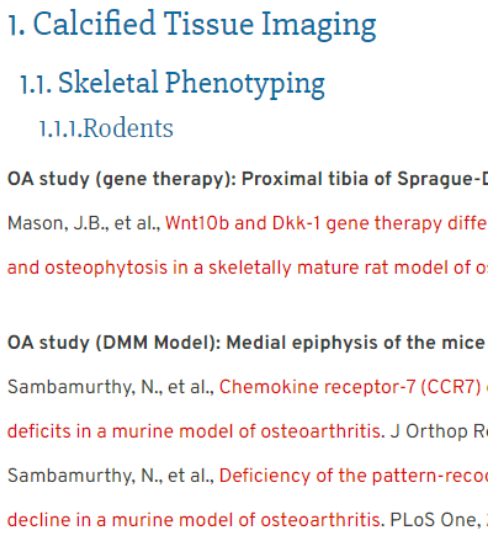
µCT viewing & analysis:

1. How to use "microCT Analysis" computers (PDF download) (Video download)
   https://www.youtube.com/watch?v=qHHcB6KJJe4
2. Tutorial for cropping, exporting, and requesting microCT images (PDF download) (Video download)
   https://www.youtube.com/watch?v=umRF6ODcQqQ
3. Tutorial for 3D display of microCT images (PDF download) (Video download)
   https://www.youtube.com/watch?v=YdQSo41rgR8
4. Tutorial for cortical bone analysis (mouse tibia midshaft) (PDF download) (Video download)
   https://www.youtube.com/watch?v=B4OE9X8Bkwg

Publications from our users

- Our users have published over 230 journal articles on their µCT projects.
- Selected publications with detailed µCT protocols for other users to cross reference:

  https://www.med.upenn.edu/pcmd/mctimagingcore/publications.html



1. Calcified Tissue Imaging

1.1. Skeletal Phenotyping

1.1.1.Rodents

OA study (gene therapy): Proximal tibia of Sprague-D

Mason, J.B., et al., Wnt10b and Dkk-1 gene therapy diffe

and osteophytosis in a skeletally mature rat model of o

OA study (DMM Model): Medial epiphysis of the mice

Sambamurthy, N., et al., Chemokine receptor-7 (CCR7)

deficits in a murine model of osteoarthritis. J Orthop R

Sambamurthy, N., et al., Deficiency of the pattern-reco

decline in a murine model of osteoarthritis. PLoS One,

2. Non-calcified Tissue Imaging

2.1. Cartilage Imaging

Cartilage repair: Osteochondral specimens from

Friedman, J.M., et al., Comparison of Fixation Techni

Weightbearing Porcine Large Animal Model. Cartila

Pfeifer, C.G., et al., Age-Dependent Subchondral Bo

Part C Methods, 2017. 23(11): p. 745-753.

Patel, JM., et al., Resorbable pins to enhance scaffo

1947603520962568.

3. In Vivo Small Animal Imaging

Reproducibility and Radiation study: Mice distal f

Zhao, H., et al., Reproducibility and Radiation Effect

Mouse Lumbar Vertebra and Long Bone. Ann Biome

Bone remodeling study: Longitudinal *in vivo* scan

de Bakker, C.M.J., et al., Minimizing Interpolation Bia

Structure and Dynamics. Ann Biomed Eng, 2016. 44

Reproduction cycles study: Longitudinal *in vivo* sc

de Bakker, C.M., et al., Adaptations in the Microarchi

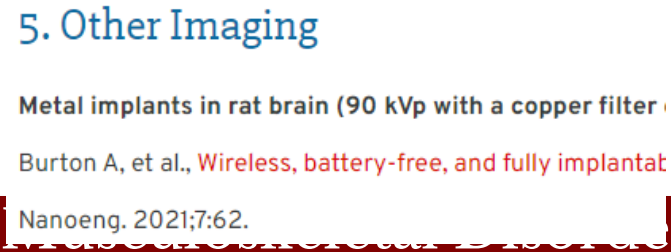
Response to Multiple Reproductive Cycles in Rats. J

4. Clinical Imaging

HR-pQCT scanner (XtremeCT II), human tibia

Zhao, X., et al., Feasibility of assessing bone mat

One, 2017. 12(3): p. e0173995.



5. Other Imaging

Metal implants in rat brain (90 kVp with a copper filter

Burton A, et al., Wireless, battery-free, and fully implantat

Nanoeng. 2021;7:62.

Automated Services

- File request: fully automated service sharing MicroCT files to users (running 7/24)
- Auto compiling microCT results into Excel sheet

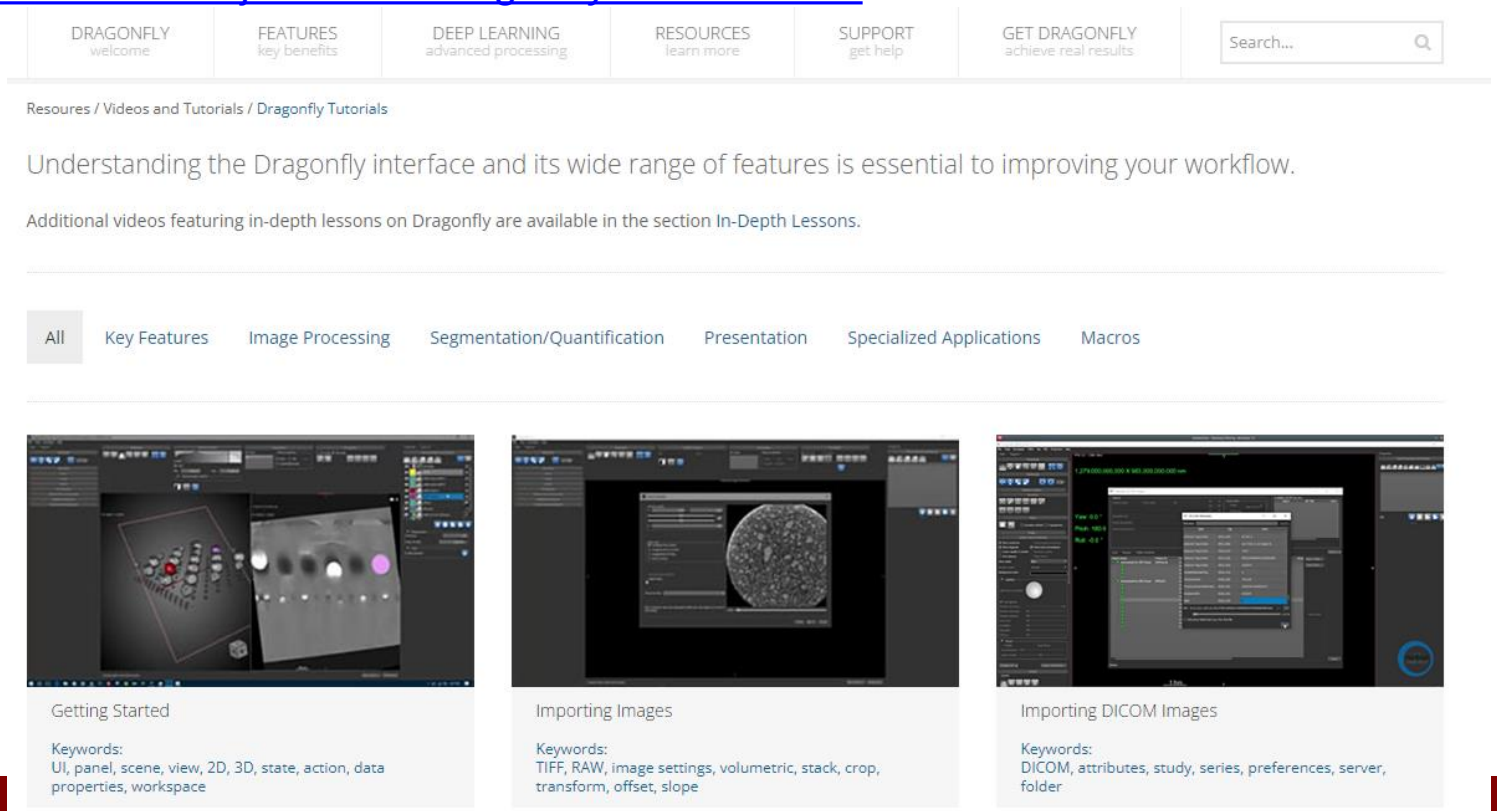
https://www.med.upenn.edu/orl/uct/assets/user-content/secure/User_file_request%20(v2020.01).xlsx

- Sample realignment/reorientation request: fully automated service help users to do sample realignment (running 7/24)

https://www.med.upenn.edu/orl/uct/assets/user-content/secure/Sample_Realignment_request(v2020.01).xlsx

Dragonfly Software

- Free non-Commercial License https://www.theobjects.com/dragonfly/get-non-commercial-licensing-program.html
- Supports many image formats:
  dcm, tif, Scanco aim, czi, raw, pic, img, etc…
- Training video tutorials available
  https://www.theobjects.com/dragonfly/tutorials.html



Dragonfly Workstation

- New workstation for Dragonfly software (324 Stemmler)
  - Windows 10 platform
  - PMACS account required (either remote or onsite access)
  - Hard drive: 18 TB
  - Memory: 128 GB
  - GPU: NVIDIA RTX 3090 (Ready in June)