ADDRESSING THE NEEDS FOR IMAGE PROCESSING IN CLINICAL AND RESEARCH ENVIRONMENTS

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What's at the medical center?

- Monroe Carell Jr. radiology department
- Vanderbilt University Medical center radiology department
- VUIIS, Human Imaging Core, Center for Computational Imaging
- Vanderbilt School of Engineering and the MASI lab

1. Outline

- Medical image processing requires techniques for, on one hand, clinical environments, and on the other, research environments.
- What are the shared underlying principles?
- How does one optimize computational resources for either environment?

An image could be defined as "spatial-specific measurements of signal". But the images themselves may be pruned down into discrete chunks for "classification", or "information".

2. Medical Imaging

- radiology
- tomography
  - volume pixels ("boxels")
- time-dependence
  - evolution of volumetric measurements
- complex-valued images

2.1. **Complexity of medical images.** How large is imaging data?

- 8847360×256 data points for a frame of 4K video.
- 30852096×256 data points for a frame of an fMRI, with 10 images each study, with 30+ studies each day, with 10+ studies simultaneously.

How diverse?

> Most PACSs handle images from various medical imaging instruments, including ultrasound (US), magnetic resonance (MR), Nuclear Medicine imaging, positron emission tomography (PET), computed tomography (CT), endoscopy (ES), mammograms (MG), digital radiography (DR), phosphor plate radiography, Histopathology, ophthalmology, etc. `https://en.wikipedia.org/wiki/Picture_archiving_and_communication_system`

- fMRI
- optical imaging
- μPET
- μSPECT

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Challenges of clinical imaging?

To understand the differences in *goals and principles* between clinical and research imaging, consider MR perfusion imaging at Vanderbilt.

clinical	research
occasionally used by non-experts	implemented by experts
needs to be standardized	can be optimized, trashed, revised
needs to be effective *every time*	needs to be effective *only prior to publication*
aims to study *individual patients*	aims to study *populations as groups*
privacy matters	sharing data is desirable
context matters	context still matters

2.2. **Picture Archiving and communication systems (PACS).**

> A picture archiving and communication system (PACS) is a medical imaging technology which provides economical storage and convenient access to images from multiple modalities (source machine types). Electronic images and reports are transmitted digitally via PACS; this eliminates the need to manually file, retrieve, or transport film jackets, the folders used to store and protect X-ray film. The universal format for PACS image storage and transfer is DICOM (Digital Imaging and Communications in Medicine). `https://en.wikipedia.org/wiki/Picture_archiving_and_communication_system`

Radiologists rely on PACS to organize *the reading of imaging studies.*

How are images catalogued?

- patient identification via medical record numbers (MRN)
- chronological identification via accession numbers (ACC)
- within Radiology Imaging Systems (RIS)

Hence, clinical systems are not built to accept queries for metadata for research, e.g., asking for all male, 50–70 years old, patients with brain tumors; or asking for tumors of a certain grade/size/development; or asking for every image of a pancreas.

	clinical	research
workflow	image, process, analyze	image, archive, process, manage, analyze

2.3. **Underlying workflows.** Here's the "research workflow" at Vanderbilt. (Take it as an analogy.)

- XNAT is the PACS replacement for research data: "XNAT is an extensible open-source imaging informatics software platform dedicated to imaging-based research."
- DAX integrates images from XNAT through ACRE and REDCAP `https://github.com/VUIIS/dax/wiki/DAX-installation`
- ACRE (?)
- REDCap is a research database respecting HIPAA regulations, yet also serves as a dashboard for "tracking progress" (?).

DAX pulls tasks from REDCap, pulls data from XNAT, then pushes images through an image processing module, then organizes images for review.

2.4. **BioVU.** While writing the grant, why (not) propose a couple extra tissue samples? or blood samples?

BioVU at Vanderbilt designed *ImageVU* to assimilate

- clinic notes

- demographics
- medications
- vitals
- billing notes
- outpatient encounters
- blood and tissue samples

from 220000 patients as metadata for images in XNAT.

How can a PI obtain data from ImageVU? TODO. Consider the following data request template: 1. Obtain IRB approval.

What's available with ImageVU? With radiology AI? The state of the art in 2019 gives:

- We can practically capture, store, and process large quantities of MRI and CT data.
- We have robust methods for labelling clinical data.
- We can process images with morphometry and morphology.
- image processing and EMR analyses are complementary for

Applications? Consider object recognition for classification, or segmentation.

- liver cancer (assigning probability to the classification of benign/malignant lesions)
- lesion detection in images (indeterminate pulmonary nodules)
- neurological phenotypes of heart failure dementias
- multi-atlas segmentation (optic nerves, functional regions of the brain)
- rapid protoyping, splenomegaly segmentation

By assigning to each image metadata classifying *all* organs visible in the image, a researcher can query (finally) for all images of a pancreas.

2.5. **Case-by-case image processing.** We'd like an untrained clinician to have techniques for $N = 1$ samples. Consider the following functional flow diagram.

```
IMPAX --strip PHI--> intermediate note <--iterate--> ACRE --> IMPAX (and decision)
```

3. Summary

- Medical images are heterogeneous, carry (potentially) rich metadata, and are meaningless without context.
- HPC aides large $N = 220000$ and individual $N = 1$ datasets.

4. Questions

1. What ethical responsibilities do developers have for designing "decision-assisting" medical image processing?
2. Could you comment on the standardization of medical imaging? Is the XNAT, DAX, ACRE workflow portable? Is DICOM portable?
   - Probably DICOM is a "race to the bottom", in terms of standardizing heterogeneous data?
   - XNAT, DAX, ACRE is vendor agnostic, and implemented with open source software.
3. After the talk, we wondered: Why did we not discuss methods for classifying organs in medical images?

4.1. **helpful links.**

- `https://en.wikipedia.org/wiki/Picture_archiving_and_communication_system`
- `https://www.xnat.org/about/xnat-implementations.php`
- `https://github.com/VUIIS/dax/wiki`
- `https://www.ncbi.nlm.nih.gov/pubmed/26143202`