Standardizing AI Annotations The DICOM Way

David Clunie, MBBS, FRANZCR(Ret), FSIIM

PixelMed Publishing, LLC

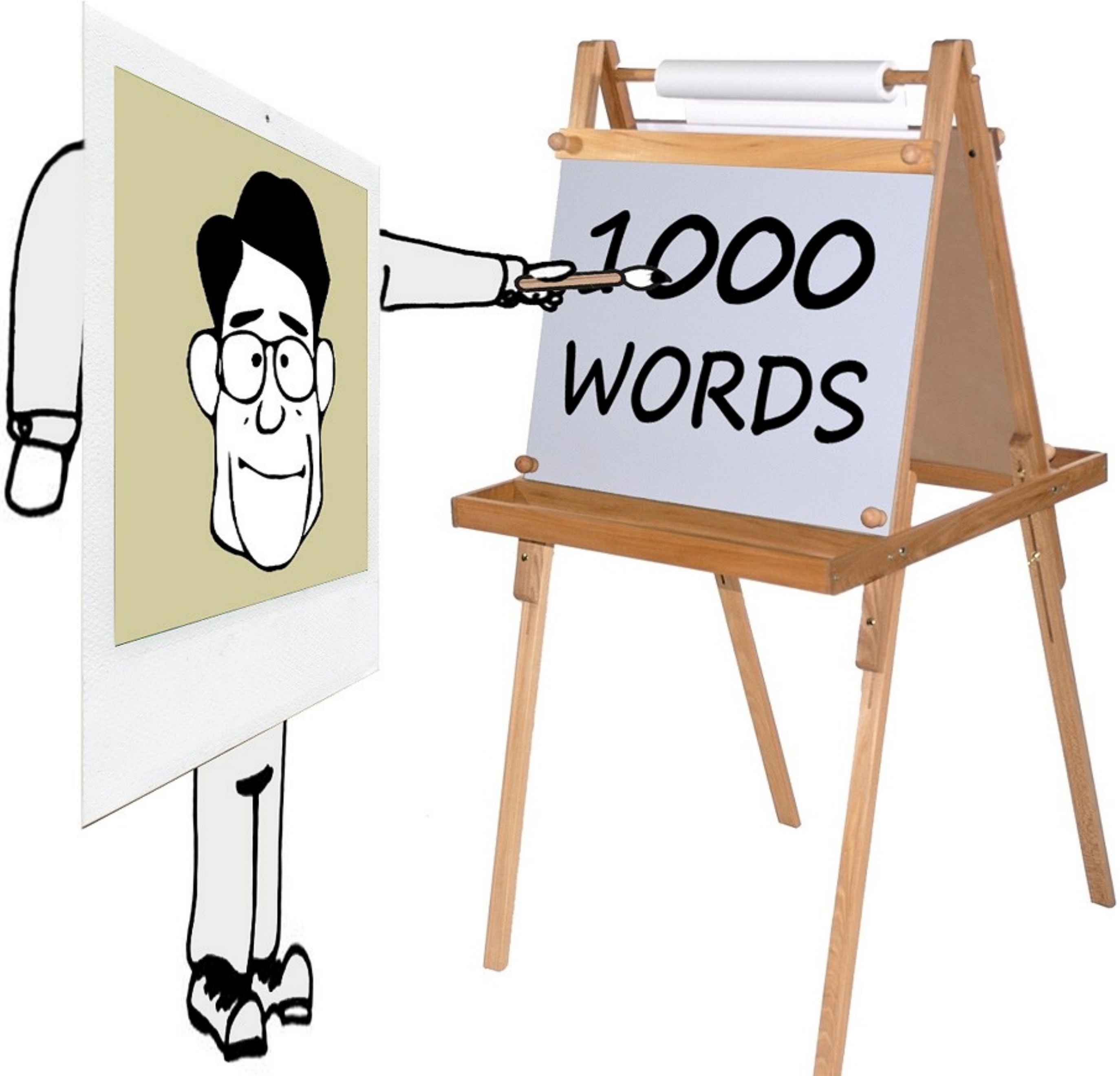
#CMIMI18

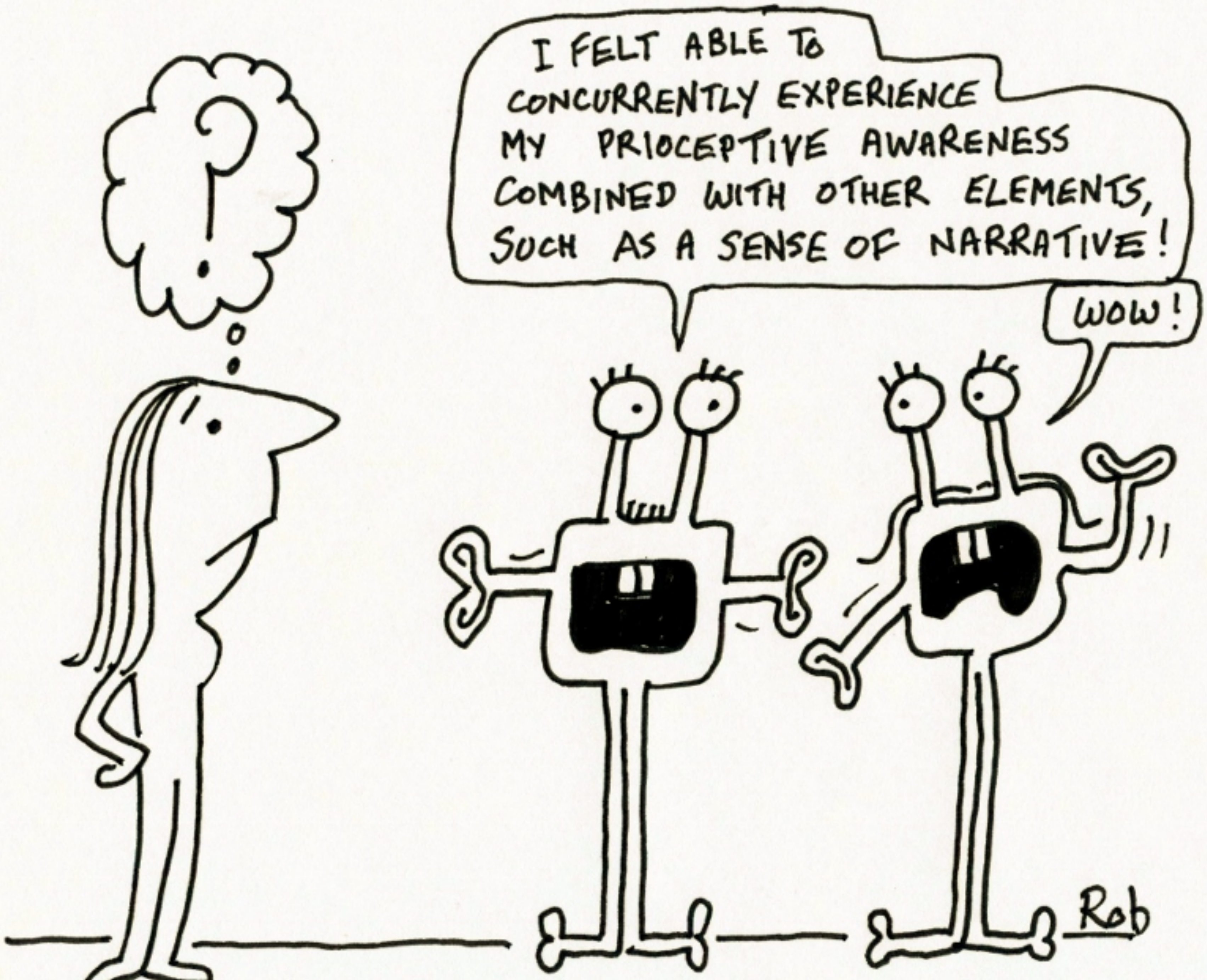
Disclosures

- Editor of the DICOM Standard (NEMA Contract)
- Owner of PixelMed Publishing, LLC
- Author of book on DICOM Structured Reporting
- Consulting for GE, Carestream, MDDX (Bioclinica), Curemetrix, HCTS, Hologic
- Supported by NIH U24CA180918 QIICR, NCI Leidos BOA 29XS219 Task Order #05

Outline

- Background
  - radiologists and annotations
- Annotation use cases
  - in general and for AI
  - definition and different types of annotation
- DICOM Encoding
- Workflow and DICOM
- Beyond radiology
- Gaps and future improvements


1000
WORDS


?
I FELT ABLE TO CONCURRENTLY EXPERIENCE MY PRIOCEPTIVE AWARENESS COMBINED WITH OTHER ELEMENTS, SUCH AS A SENSE OF NARRATIVE!
WOW!
Rob


EVERYTHING
SUCKS!
NETFLIX | FEB 16

A Picture Is Worth A Thousand Words:

Needs Assessment for Multimedia Radiology Reports in a Large Tertiary Care Medical Center

Lina Nayak, MD, Christopher F. Beaulieu, MD, PhD, Daniel L. Rubin, MD, MS, Jafi A. Lipson, MD

Rationale and Objectives: Radiology reports are the major, and often only, means of communication between radiologists and their referring clinicians. The purposes of this study are to identify referring physicians' preferences about radiology reports and to quantify their perceived value of multimedia reports (with embedded images) compared with narrative text reports.

Materials and Methods: We contacted 1800 attending physicians from a range of specialties at large tertiary care medical center via e-mail and a hospital newsletter linking to a 24-question electronic survey between July and November 2012. One hundred sixty physicians responded, yielding a response rate of 8.9%. Survey results were analyzed using Statistical Analysis Software (SAS Institute Inc, Cary, NC).

Results: Of the 160 referring physicians respondents, 142 (89%) indicated a general interest in reports with embedded images and completed the remainder of the survey questions. Of 142 respondents, 103 (73%) agreed or strongly agreed that reports with embedded images could improve the quality of interactions with radiologists; 129 respondents (91%) agreed or strongly agreed that having access to significant images enhances understanding of a text-based report; 110 respondents (77%) agreed or strongly agreed that multimedia reports would significantly improve referring physician satisfaction; and 85 respondents (60%) felt strongly or very strongly that multimedia reports would significantly improve patient care and outcomes.

Conclusions: Creating accessible, readable, and automatic multimedia reports should be a high priority to enhance the practice and satisfaction of referring physicians, improve patient care, and emphasize the critical role radiology plays in current medical care.

Key Words: Multimedia reports; radiology reporting; digital images; communication; radiology practice.

Structured Radiology Reporting: Are We There Yet?[1]

Curtis P. Langlotz, MD, PhD

Given the prominent role that information technology will play in the future of health care delivery, the potential benefits of structured reporting systems now seem more relevant than ever. These systems may lead to rapid

cohort design. The same 25 brain magnetic resonance (MR) imaging cases were reviewed in two distinct phases by two separate groups of residents: a control group and an intervention group. The MR imaging cases contained a representative

No, we are not f♥king there yet...

and other universal truths of parenting

Andrew Willis • Robin Swift

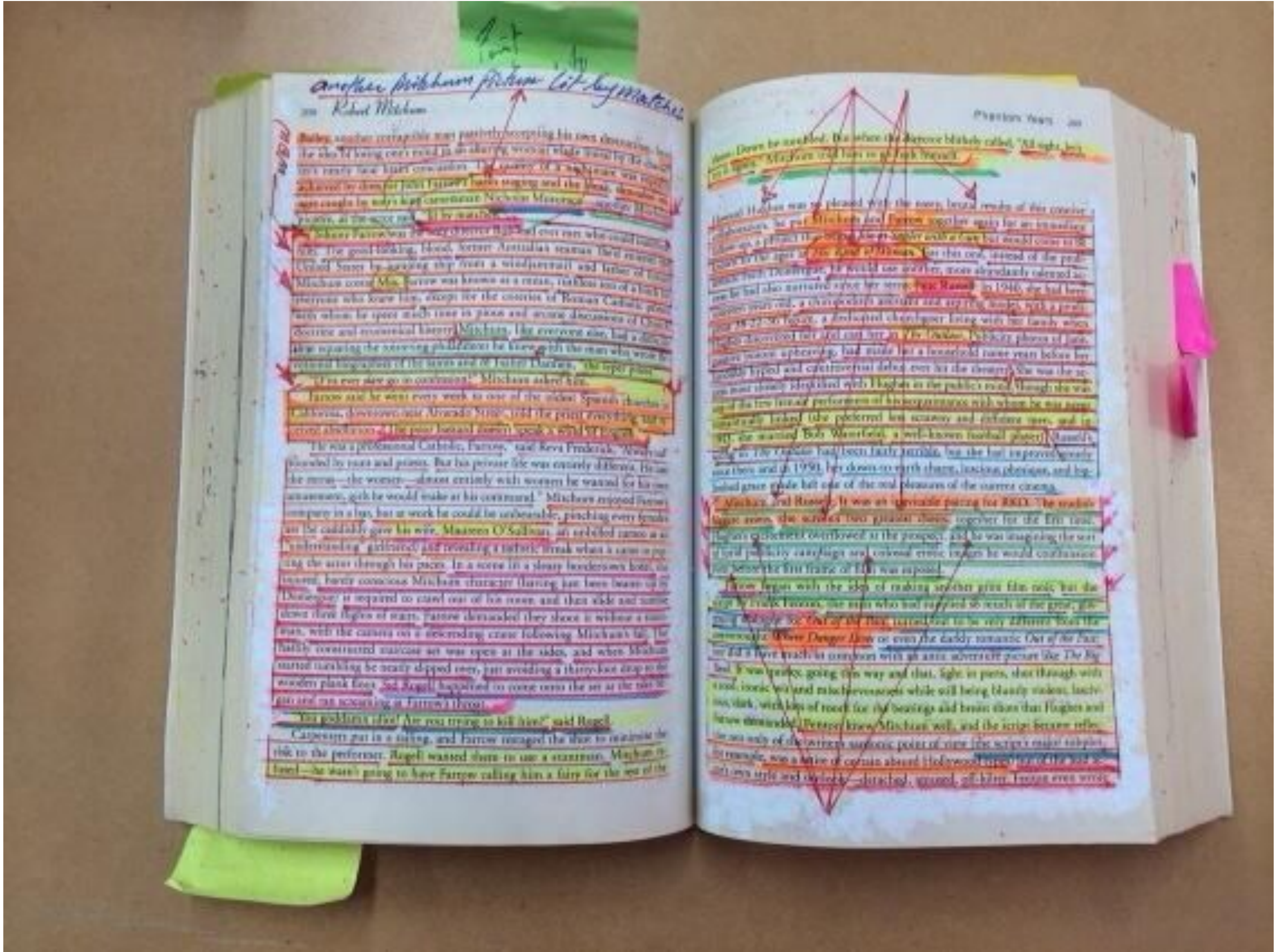
No, we are not f♥king there yet...


HOW DO WE
GET THERE FROM HERE?
BEAWESOMEDAILY.COM


HAVE
Realesation
AND THEN...
TEAM
2x
MARKETING
15% - ???
A. B. C.
idea
plan
activities
analisis
money is pursuit
PRODUCT
CONSUMERS
25% time
INTERNET
MAIN
LOADING TO SERVER
A. 640.320.00
B. 144.000.00
C. 286.000.00
D. 255.500.00
E. 540.000.00
SUCCESS!
THINK
OUTSIDE
THE BOX
€ ⇋ % ⇋ $
CLOUD
WORK
100%
25%

Use Cases – Non-AI or AI, Use versus Re-Use

- Clinical Use Cases
  - Non-AI
    - communicate – rad-tech, rad-rad, radiologist-clinician, multidisciplinary team meetings
    - preserve state – for priors (where, what, what size, …)
    - legal record
  - AI
    - automated result output prior to human read (traditional mammo CADe, triage, priority)
    - human defined selection for targeted AI
- Re-use Use Cases
  - Non-AI
    - retrospective and prospective research
    - education
  - AI
    - Non-AI annotations used for AI training/testing
    - AI annotations used for a different AI application training/testing


another Mitchum picture lit by matches
Robert Mitchum
Phantom Years

Use Cases – What is an "Annotation" anyway?

- **Annotation**: *"a note of explanation or comment added to a text or diagram"*
- **Label**: *"a classifying phrase or name applied to a person or thing [especially one that is inaccurate or restrictive 😀]"*

- ***NOT*** **Markup**: *"a set of tags assigned to elements of a text to indicate their relation to the rest of the text or dictate how they should be displayed"*

distinguish semantics from visual representation

"meaning" for machines not just humans

Use Cases – Level of Granularity

- Patient/Case
- Imaging Study
- Series/Acquisition
- Image
- Frame (pixel data array at one place in space/time/…)
- Region ("of interest" – ROI)
- Single point (label each/every voxel/pixel)

Use Cases – Qualitative, Quantitative

- Qualitative
  - categorical – shape = round, …
- Ordinal
  - roundness – scale of 1 to 5
- Quantitative
  - morphology – size (diameter, volume, ...)
  - quantity – signal intensity, attenuation coefficient, ...
  - numerical features – entropy of GLCM, fractal dimension, …
  - on transformed variants – registered, resampled, filtered, wavelet, …
  - units – absolute and relative (to what – reference region, population)
  - derivation – mean, max, …
  - method – model, fitting, sampling, binning, …

Use Cases – Concept Representation

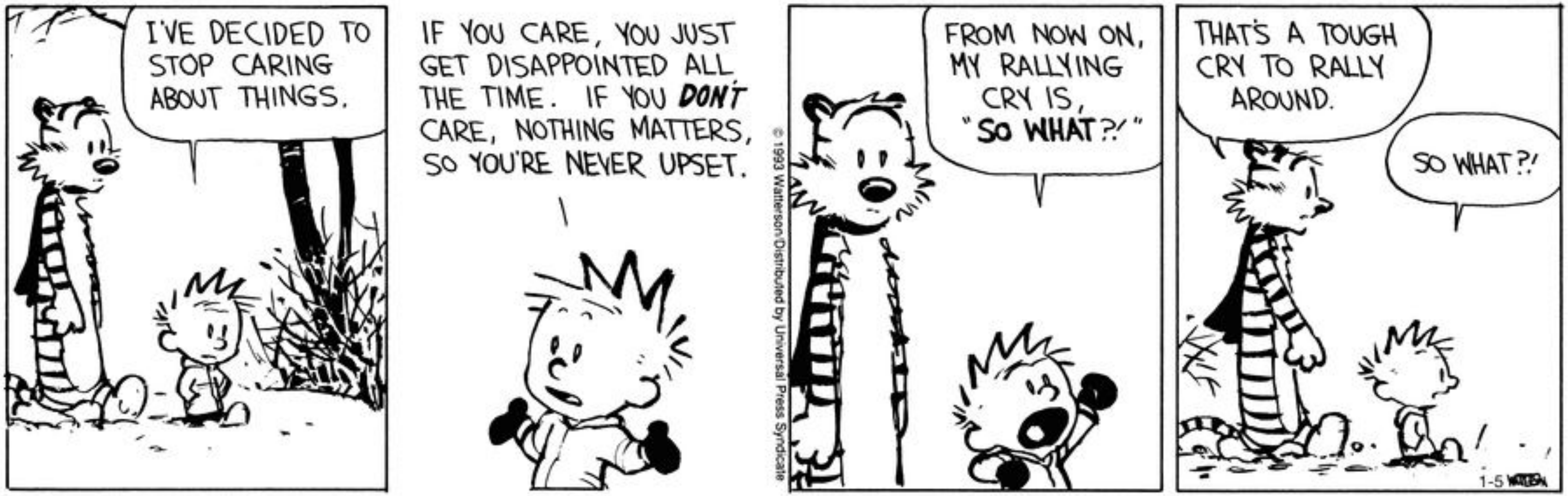
- Single concept
  - e.g., “round shape”; “42”
- Name-value pair
  - e.g., “shape” = “round (generic)”, “round shape”; “ultimate question” = “42”
- Coded versus text
  - SRT:M-02100 (SCT:42700002) v. languages: “qaab wareegsan”, “圆形”
  - synonyms (“round” v. “circular”), case, punctuation (“Shape, round”), …
- Same concepts in different classifications
  - SCT:42700002, NCIt:C48348, RadLex:RID5799
  - Metathesaurus (mapping): UMLS:C0332490

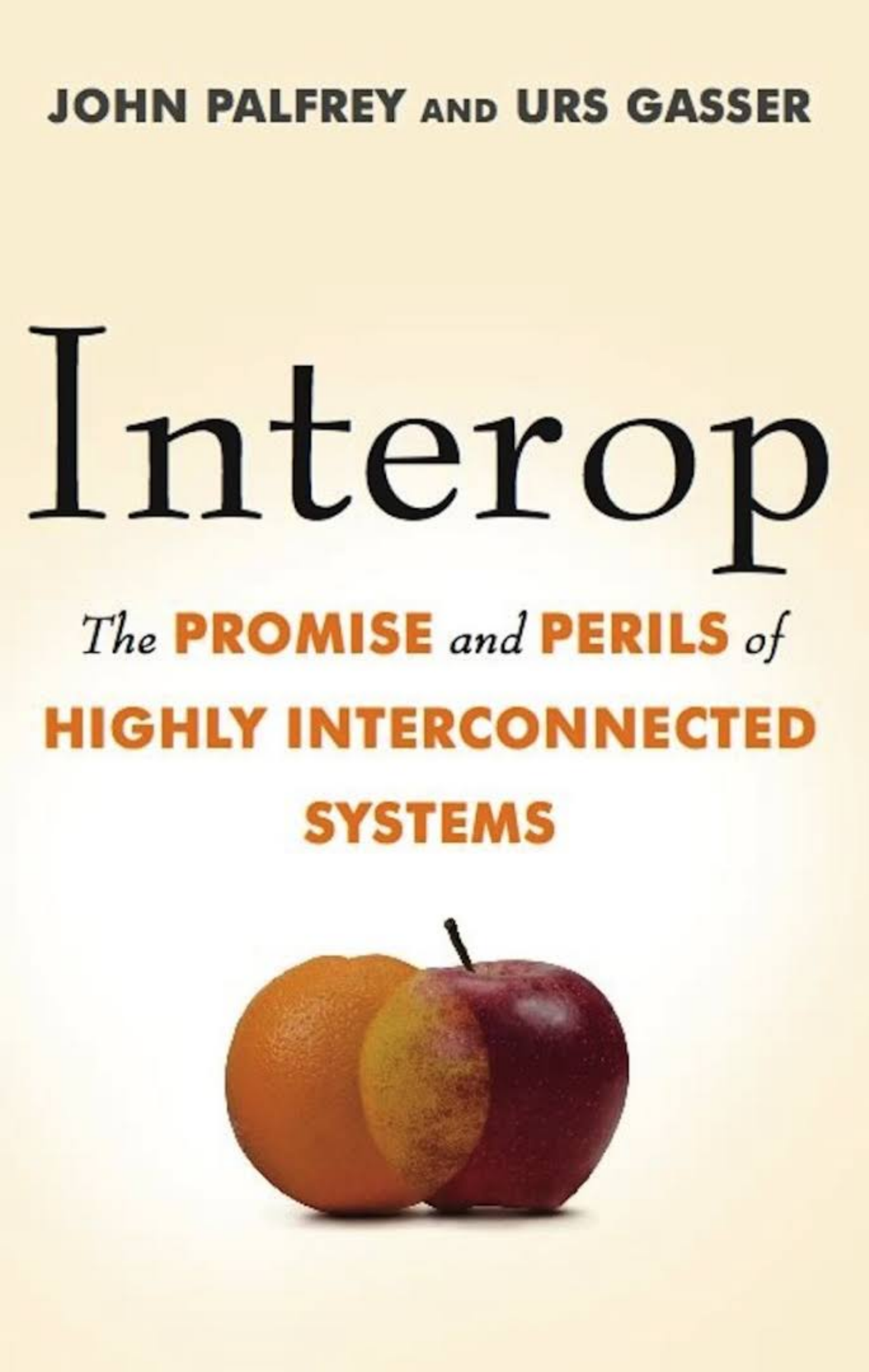
Use Cases – Localization Representation

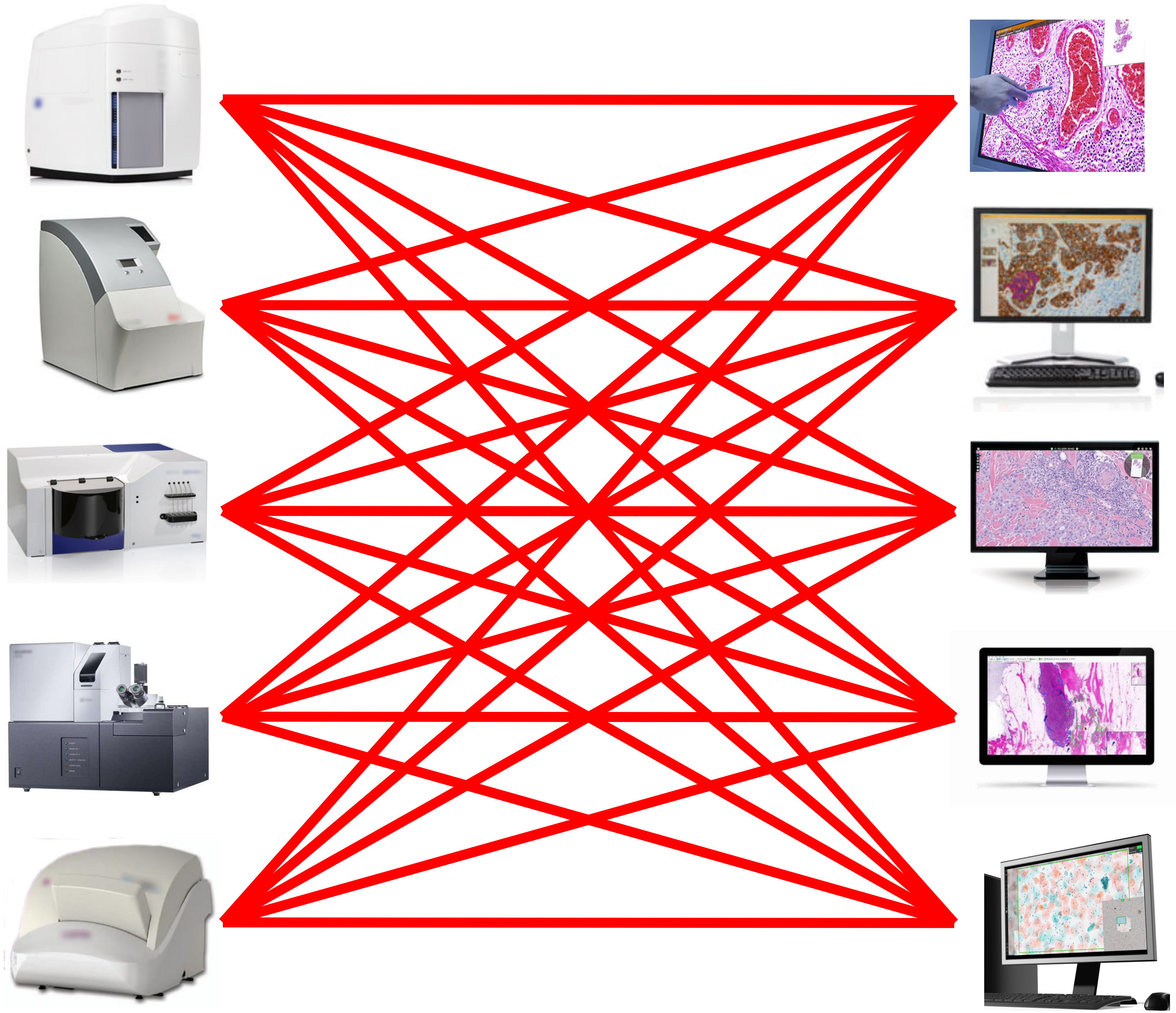
- Patient/Case – Patient/Specimen Identifier
- Study, Series, Image – Unique Identifiers (UID, UUID)
- Frame – UID + frame number/offset
- ROI
  - contours - image (2D) or space (patient, 3D) relative
  - temporal coordinates (frame #, relative/absolute time)
  - segmentations (bitmap, partial occupancy, probability)
- Single point (each/every voxel/pixel)
  - parametric maps (bitmap, scaled integer, floating point)
- Transformations
  - rigid (affine), non-rigid (deformation field, spline, …)

SO WHAT?

WHO CARES?

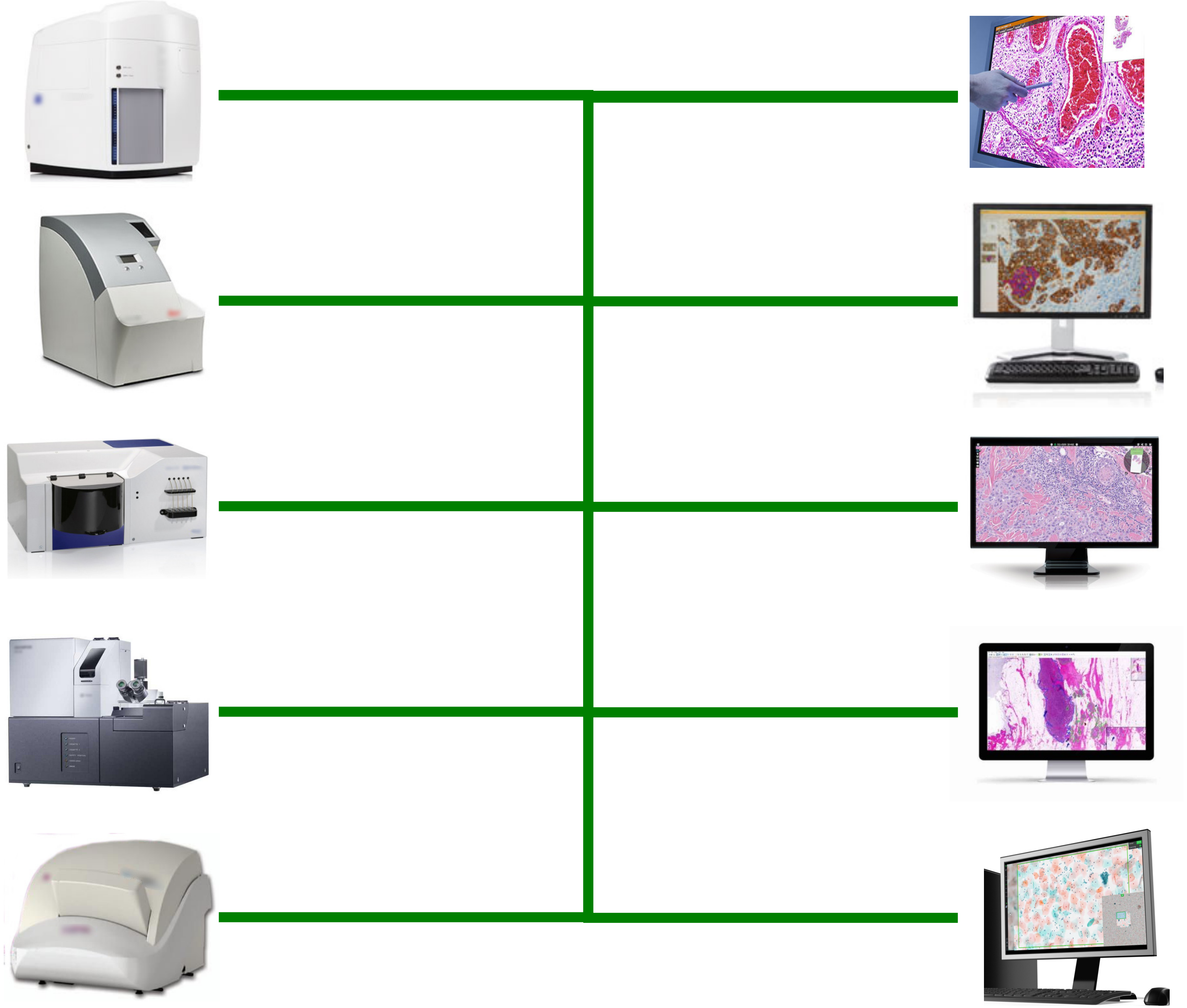



JOHN PALFREY AND URS GASSER
Interop
The PROMISE and PERILS of
HIGHLY INTERCONNECTED
SYSTEMS



DICOM[SM]

Digital Imaging and Communications in Medicine



Where DICOM fits in

- DICOM “in”
  - obviously all (radiology) images start out as DICOM
    - can be rearranged from multiple single files to single multi-frame DICOM file (happier algorithm developers)
  - “metadata” in DICOM “headers” are “annotations” too
    - e.g., Series Description = “T1 axial post-Gd”, B value = 1000
    - can be better structured/coded (retrospectively), e.g., Acquisition Contrast = T1
    - phase to cleanup/canonicalize multi-site data DICOM attributes
    - do not discard known-safe vendor private data elements during de-identification – may be useful for unanticipated re-use cases

Where DICOM fits in

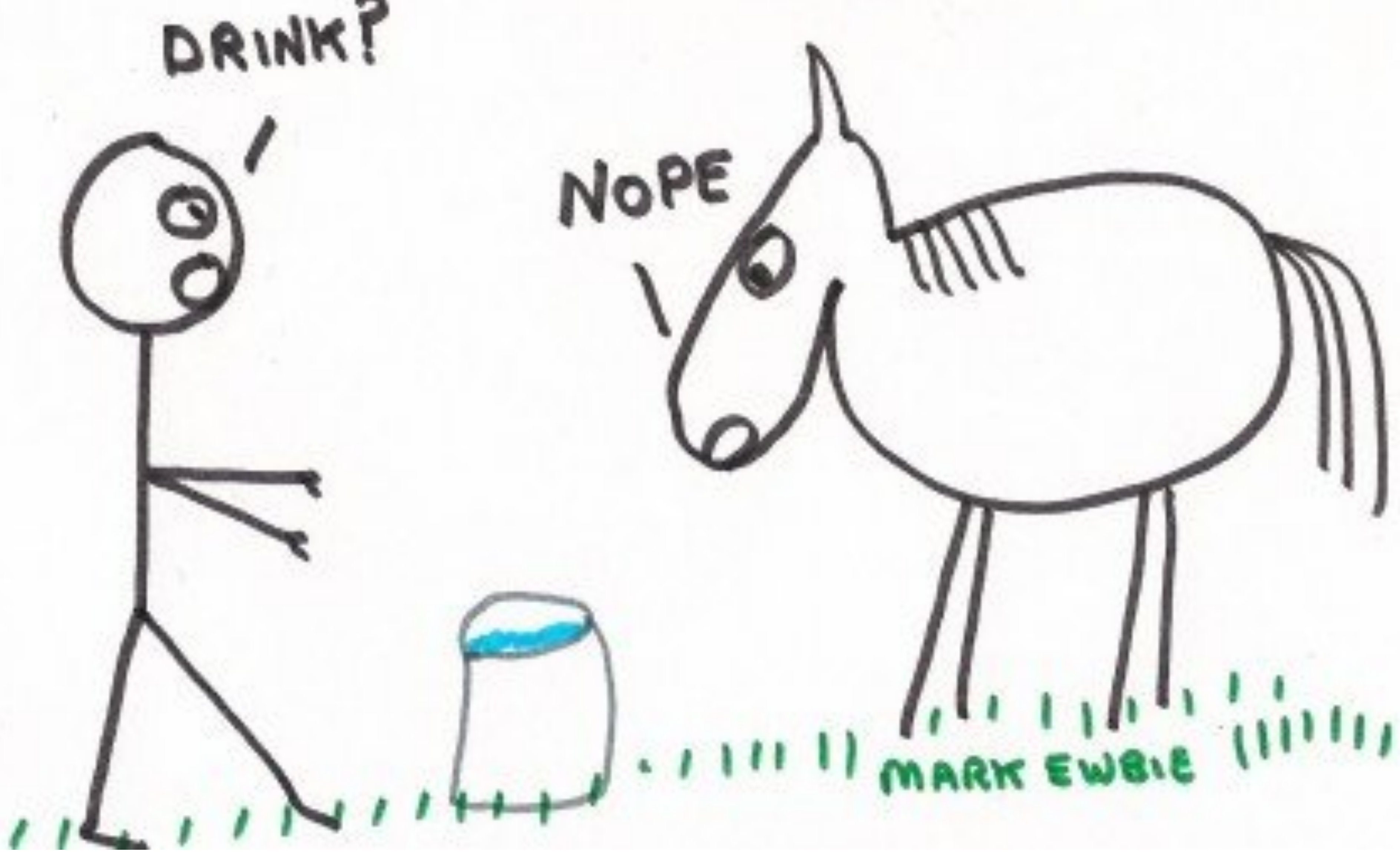
- DICOM “out”
  - ***All types of annotation*** (including processed images) can be shared as DICOM
  - Pros:
    - allows re-use of clinical imaging/annotation systems
    - can be stored/shared/indexed in off-the-shelf DICOM archives (e.g., TCIA)
    - can be created/viewed/analyzed by (some) OTS DICOM tools, viewers, …
    - not just a bunch of poorly labeled/organized files on somebody’s disk
    - self-describing/identifying – contains (pseudonymous) identifiers
  - Cons:
    - requires more attention to de-identification (if clinical origin)
    - requires use of DICOM toolkits/libraries to create/access
    - requires more attention to preservation/propagation of “composite context” (identities and UIDs) in processing pipeline (e.g., to restore identifiers from images to results)
    - more complex and arcane than making it up as you go along

Confessions of a Content Creator:

I Don't Care About Data

UNTHINKABLE

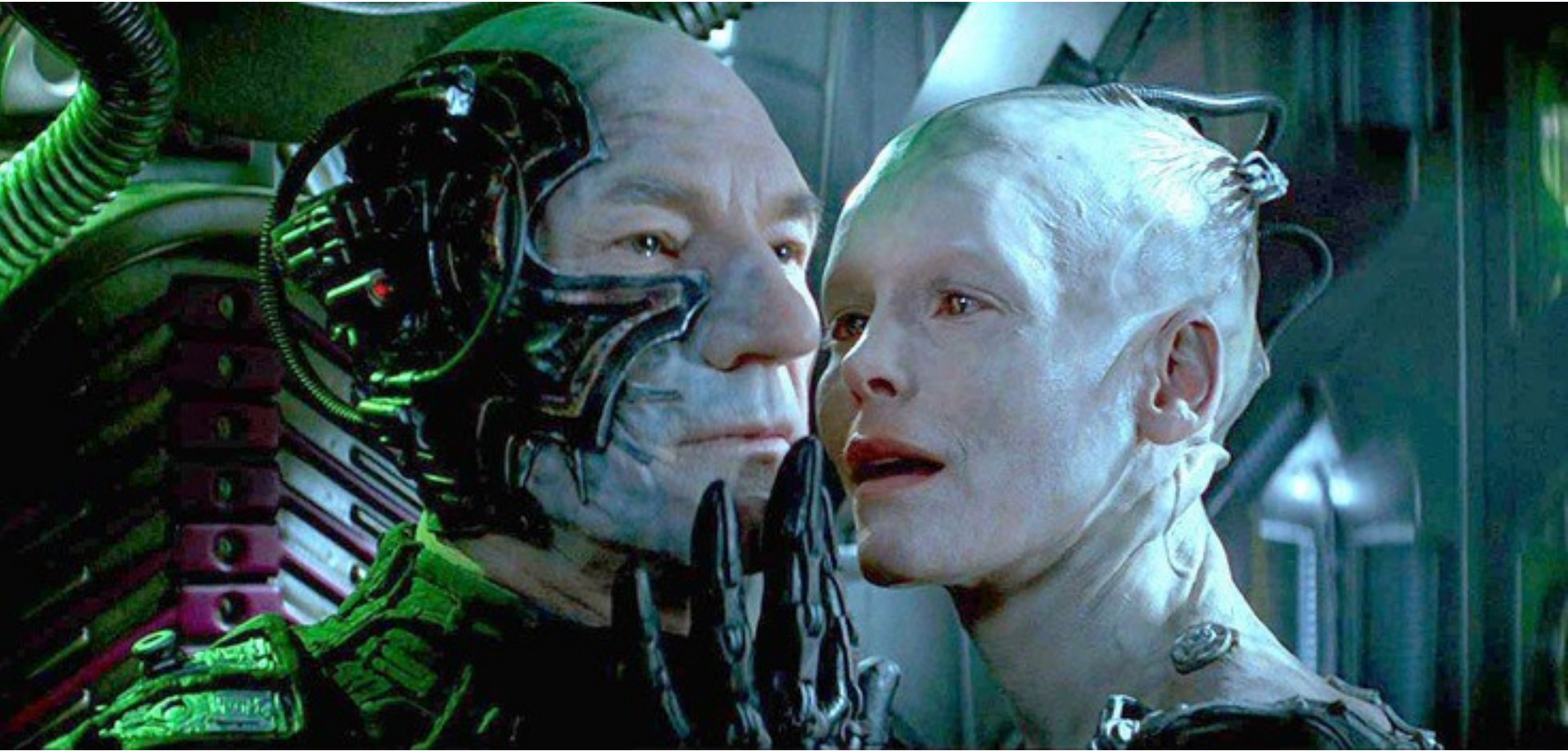
UNTHINKABLE.FM


DRINK?
NOPE
MARK EWBIE

AI CHANGES THE GAME

Annotation (interoperability) matters now

- Previously:
  - little incentive to annotate
  - few tools to create or view annotations
  - annotation interoperability was a low priority for product managers
  - presentation rather than semantics were the priority for annotation tools
- Now:
  - semantic annotations have (real monetary) value beyond primary use case
  - recognition of existence of unanticipated re-use cases
  - annotations are expensive to create/recreate retrospectively
  - more expensive to process if proprietary rather than OTS standard
  - AI-generated annotations need to be interoperable for display
  - “interactive” AI requires interoperable annotation exchange
  - AI vendors unlikely to be the same as scanner/PACS vendors – mix and match



DICOM and Annotations – Then to Now

- Bad ways in DICOM, historically:
  - Burned in graphics and text
    - including screen shots
  - Overlay graphics and text
    - in pixel data, header or separate object
  - Presentation states
    - still only graphics and text (no semantics)
    - currently very popular in clinical PACS

DICOM and Annotations – Then to Now

- Good ways in DICOM – standardized for ages, variable use
  - Structured Reports (SR)
    - tree of codes, numbers, 2D, 3D & temporal coordinates, references, …
    - basis for Ultrasound, Cardiovascular, Mammo CAD, radiation dose
    - Key Object Selection (KOS) – flags key images with text/coded label
  - Segmentation (SEG or DSO)
    - rasterized – bitmap, probability, occupancy; coded property/anatomy; ROI, atlases (i.e., pixel level categorical annotation), …
    - surface mesh (rarely used)
  - Radiotherapy Structure Sets (RTSS)
    - 3D coordinates, some component semantics, few quantities (volume)
    - widely used in RT planning and re-used in workstations, e.g., for PET

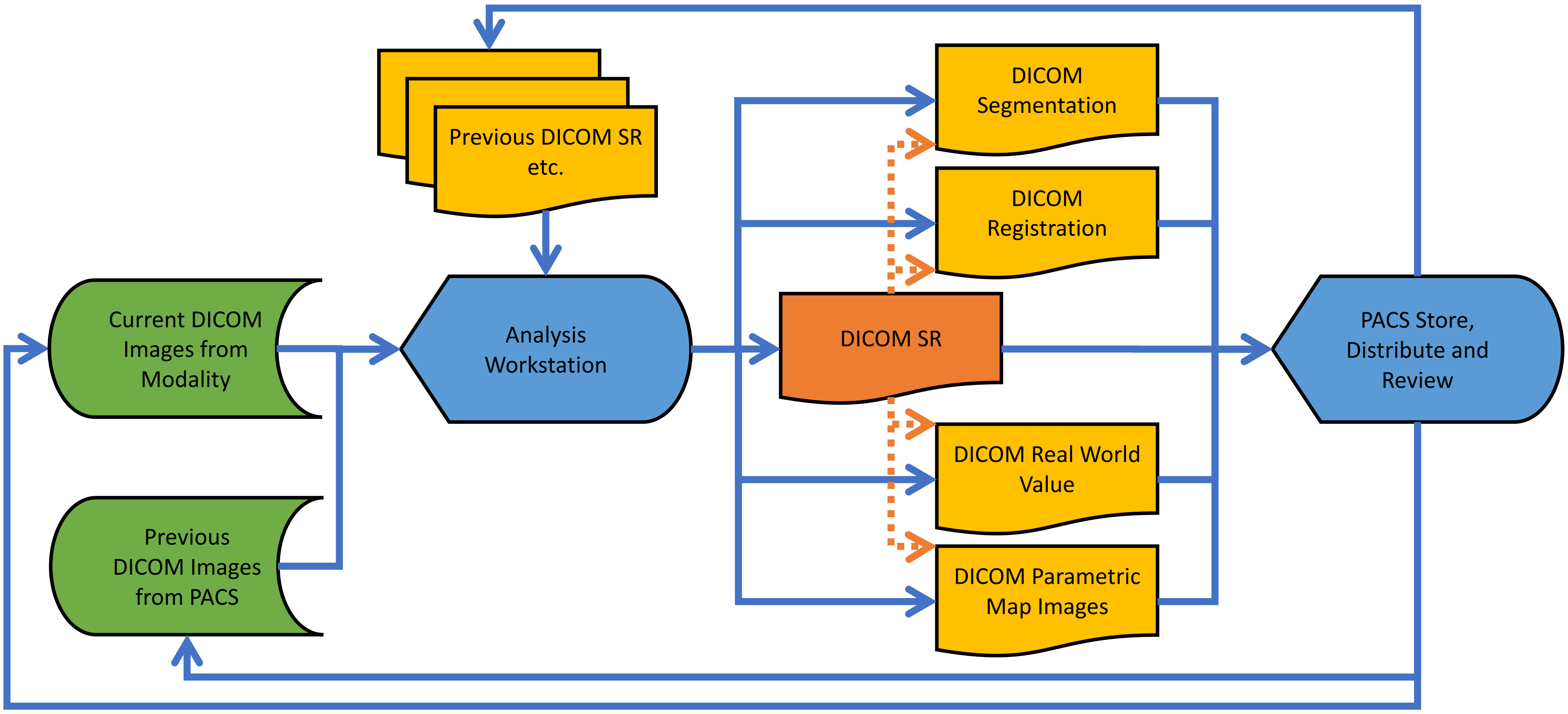
DICOM and Annotations – Then to Now

- Relatively new things in DICOM
  - Real World Value Maps
    - coded way to describe voxel values (beyond Rescale Type)
    - retrofitted to all existing DICOM images
    - form of “annotation” that makes pixel values semantically meaningful
  - Parametric Maps
    - RWVM combined with floating point or scaled integer pixels
  - Second-generation Radiotherapy annotations
    - Conceptual Volumes – “grammar” for combining contours, segmentations

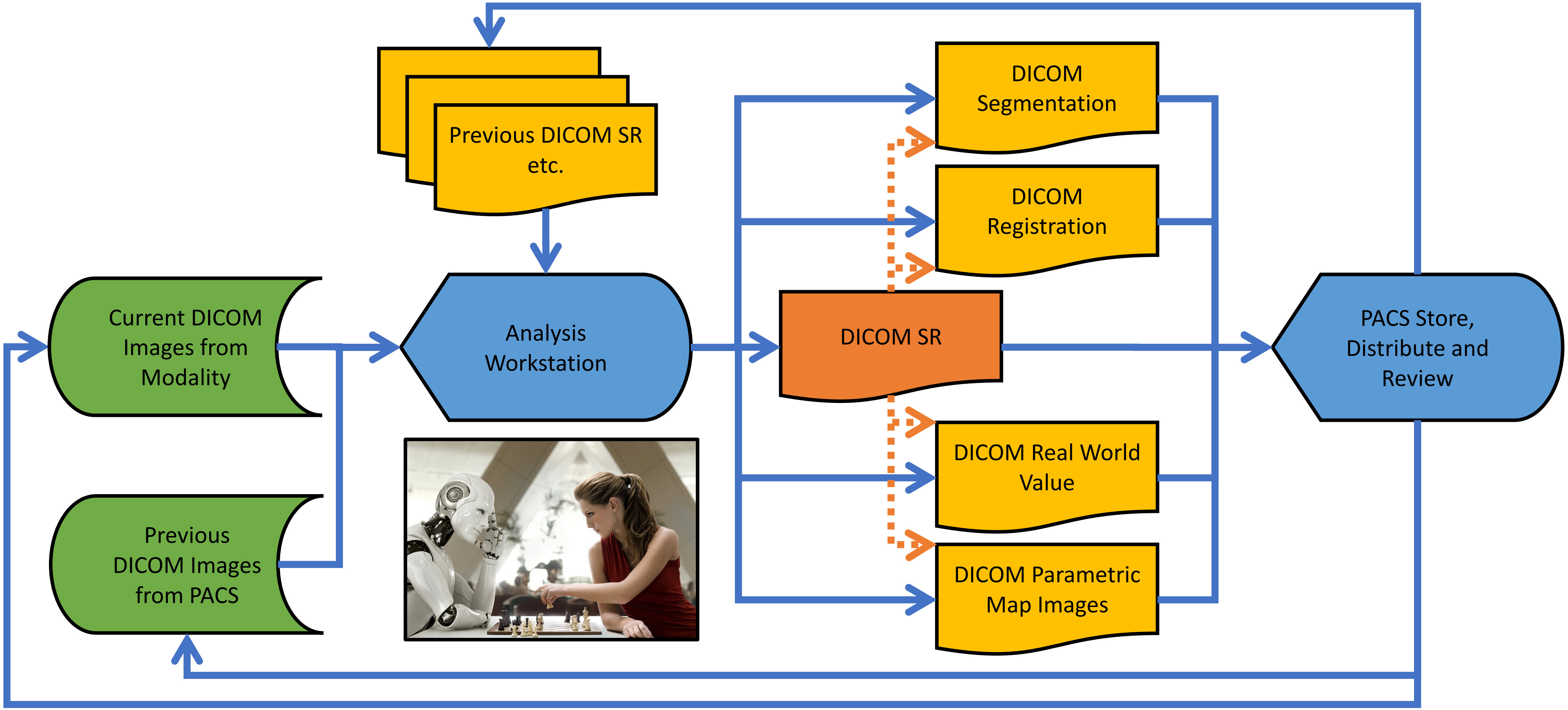
DICOM and Annotations – Then to Now

- Related DICOM IODs
  - Fiducials
    - markers with shape and location
  - Registration
    - rigid
    - deformable
    - well-known frames of reference (e.g., atlases)

Putting it all together …



Putting it all together …



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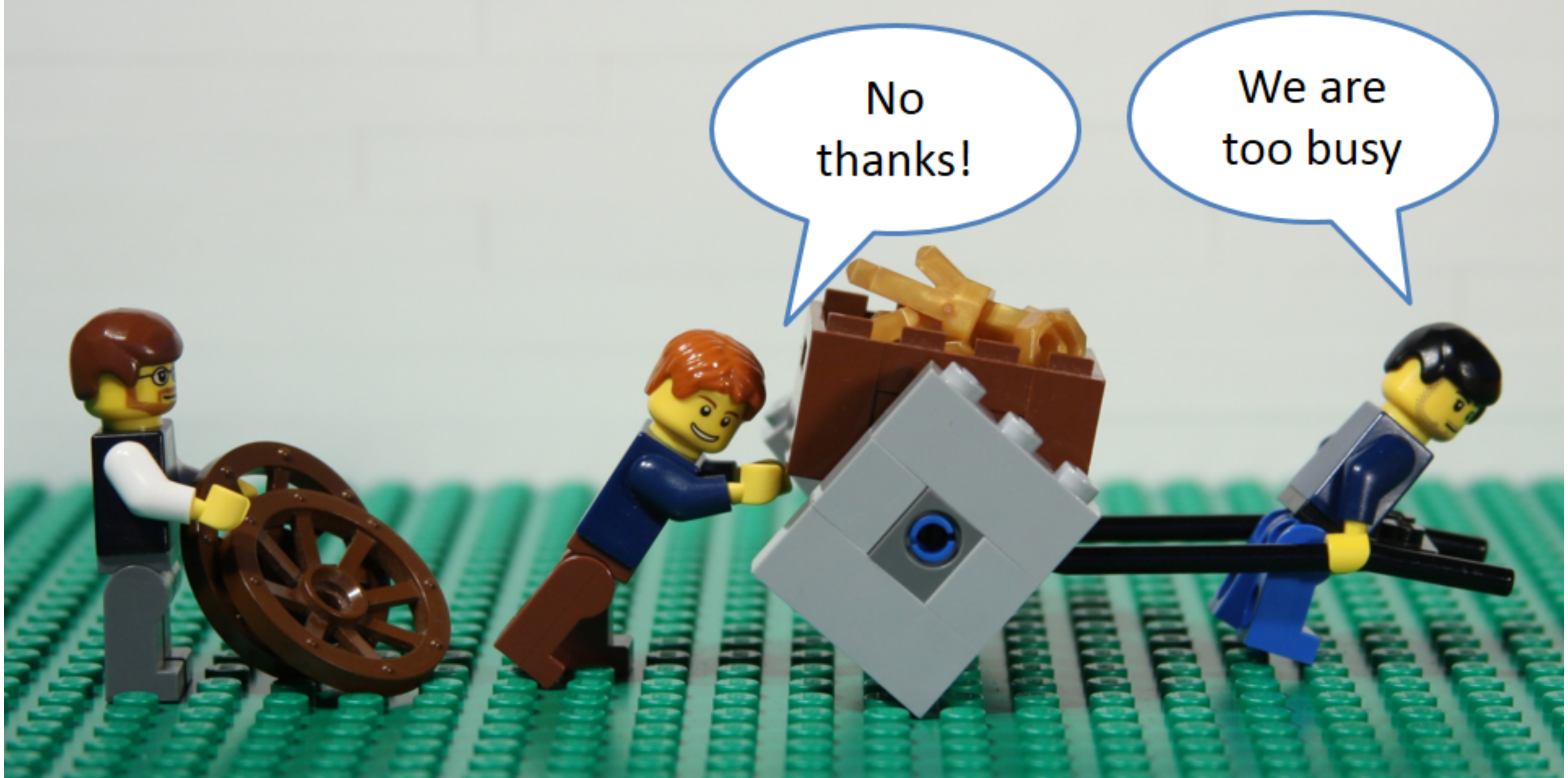
YES
NO

Are you too busy to improve?



Håkan Forss @hakanforss http://hakanforss.wordpress.com

This illustration is inspired by and in part derived from the work by Scott Simmerman, "The Square Wheels Guy" http://www.performancemanagementcompany.com/

Too busy? – No problem, we supply tools

- Store and regurgitate
  - OTS commercial and open source DICOM archives as well as PACS
  - most modern systems will handle any new or old DICOM object
  - unlike ancient PACS, which rejected things they could not view
  - this increasing flexibility driven by “vendor neutral archive”, “universal viewer” and “deconstructed PACS” phenomena
- DICOM annotation objects are just like images
  - some actually are “images” (segmentations, parametric maps)
  - non-images all share common “composite context” encoding (e.g., patient/study/series/equipment identification/description)

Too busy? – No problem, we supply tools

- Creation
  - long history of ultrasound, mammo CAD, radiation dose, key object SR authoring
  - increasing SEG and SR support in toolkits (esp. open source)
  - extraction/propagation/merging of composite context
  - merging descriptions of metadata created in XML or JSON into DICOM object content (included coded descriptions) – easier than hand-coding in programming language
- Transcoding
  - of other formats, proprietary, academic, and project-specific
  - other structured annotation formats into DICOM SR (e.g, AIM via PS3.21 mapping)
  - segmentations and label maps in other formats into DICOM SEG
  - parametric maps in other formats into DICOM Parametric Maps
  - single frame DICOM image sets into multi-frame single DICOM files

Too busy? – No problem, we supply tools

- Access
  - annotation objects can be queried/retrieved using traditional DICOM network protocols widely supported by many toolkits
  - DICOMweb (WADO-RS, QIDO-RS, …) protocols increasingly supported by archives and are just like any other HTTP request (can use curl, postman, as well as DICOM toolkit utilities)
  - DICOMweb payloads (XML and JSON metadata) and separate bulk data access increase accessibility and simplify parsing
- Viewing and Analysis
  - toolkit support for extracting metadata and structured content into generic XML, JSON, CSV
  - more viewers support display of DICOM SEG superimposed on underlying reference images
  - some viewers can display content of DICOM SR objects rendered into hierarchical plain text, HTML or PDF – few (if any) can "tabulate" content into user friendly form
  - voice dictation systems have long been able to ingest DICOM SRs, extract content and make available "merge fields" in dictation templates

Interoperable communication of quantitative image analysis results using DICOM standard

Andrey Fedorov[1], Daniel Rubin[2], Jayashree Kalpathy-Cramer[3], Justin Kirby[4], David Clunie[5], Michael Onken[6], David Flade[7], Pattanasak Mongkolwat[8], Rajesh Venkateraman[9], Jan Bertling[10], Steve Pieper[11], Ron Kikinis[1]

[1]Brigham and Women's Hospital, [2]Stanford University, [3]Massachusetts General Hospital, [4]NCI Fredrick, [5]PixelMed Publishing, [6]OpenConnections GmbH, [7]Brainlab, [8]Mahidol University, [9]Eigen Medical, [10]Hermes Medical, [11]Isomics Inc

RSNA 2015 NOVEMBER 29 – DECEMBER 4 McCORMICK PLACE, CHICAGO

See this poster online to bookmark or share with your colleagues: https://goo.gl/0WGmqm or scan the QR code!

Introduction

As quantitative imaging (QI) is gaining momentum in research and commercial platforms, it becomes important to support its usage scenarios:

- **Clinical workflows**: storage of the analysis results on PACS alongside the imaging data; longitudinal followup of the patient with quantitative imaging across workstations.
- **Research workflows**: validation of imaging biomarker analysis tools; community repositories of the analysis results; secondary analysis of data.

Various types of derived data important in quantitative imaging research include image annotations (points, distance measurements, contours, labeling of image voxels), parametric maps and numeric results of the quantitative measurements.

Image segmentation is a key preprocessing task concerned with defining a region of interest for subsequent analysis and quantitation. It is therefore of critical importance to support interchange of the segmentation results.

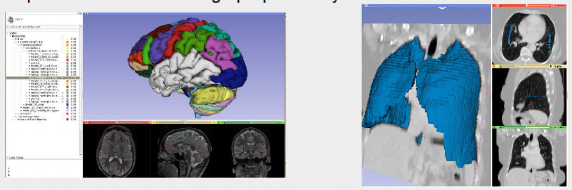
Digital Imaging and Communication in Medicine (**DICOM**) is the standard used ubiquitously for communicating image data. Although DICOM provides the means to also describe *derived* image-related information, thus far it has found very limited acceptance in the quantitative imaging community.

As a step towards improving QI analysis results interoperability, we investigate the use of DICOM Segmentation Storage SOP Class (DICOM SEG) for communicating image segmentation results.

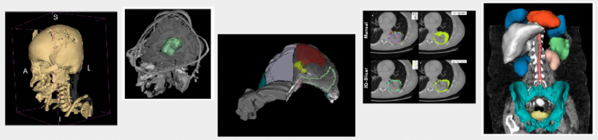
Image Segmentation and Quantitative Imaging

Image segmentation is concerned with labeling areas of the image into distinctive regions. These regions can correspond to pathology areas, organs, or identify regions of general interest, to support for example

- volumetric assessment of tumor burden
- quantification of the metabolic of functional activity within the ROI
- quantification of the image properties by means of the radiomics features



Segmentation tools vary in complexity, typically need to be customized to the specific problem, and can be manual, semi-automatic or automatic.



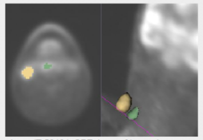
DICOM for Image Segmentation Storage

DICOM SEG is the preferred way of communicating segmentations represented as labeled voxels. Some of the important features supported include:

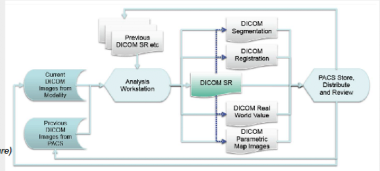
- size efficiency with multi-frame storage and bit encoding
- structured terminology for encoding semantics
- binary and fractional segmentation (e.g., probability maps)
- encoding of the presentation (color)
- multiple voxel occupancy

Being part of the DICOM object "family", integrates with other types of data:

- patient and study composite contexts, frame of reference maintained
- references source image data
- can be referenced from the measurement documents (DICOM SR)



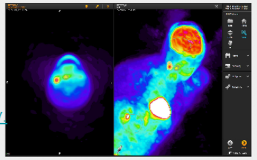
Region = (T-53131, SRT, base of tongue)
Category = (M-01000, SRT, Morphologically Altered Structure)
Type = (M-80003, SRT, Neoplasm, Primary)



Workstation Support of DICOM SEG

Workstations evaluated (commercial products are in italics):

- 3D Slicer X, http://slicer.org
- ePAD v1.7, http://epad.stanford.edu
- AIM on ClearCanvas v4.0.6.4, http://www.ict.mahidol.ac.th/research/Imaging-Informatics
- *Brainlab PDM 2.2*
- *Siemens syngo.via VA30A_HF06*



Segmentations of PET tumor and reference regions from the TCIA QIN-HEADNECK collection created using 3D Slicer tools as visualized in the Brainlab workstation.

See the up-to-date version of the evaluation spreadsheet at https://goo.gl/nPm3aU or scan the QR code.

Below: summary of the DICOM SEG ingestion and display test: import and display segmentation produced by the "source" workstation as image overlay in the the "sink" workstation. In the table below green color means "sink" can import and visualize objects from the source workstation, red means source objects cannot be displayed.

		Sink				
		3D Slicer	ePAD	Brainlab	ClearCanvas AIM	Siemens syngo.via
Source	3D Slicer					
	ePAD					
	Brainlab					
	ClearCanvas AIM					
	Siemens syngo.via					

Disclaimer: the workstations evaluated do not necessarily represent the complete list of workstations that support DICOM SEG, although we attempted to contact a number of major vendors.

- Know of a workstation/toolkit supporting DICOM SEG but not listed?
- Want to learn more or get help adopting DICOM SEG?
- Have sample DICOM SEG datasets you would like to contribute?

We would LOVE to hear from you!

Please email andrey.fedorov@gmail.com

Support in Developer Toolkits

DCMTK - DICOM Toolkit (C++, free open source)

DICOM@OFFIS

http://dcmtk.org

- high-level abstractions for initializing and interacting with SEG (functional groups, image frames)
- attribute-level validation
- helper APIs, propagation of the relevant attributes from the image dataset
- query and retrieval of SEGs with DICOM networking
- used by 3D Slicer

PixelMed Toolkit (Java, free open source)

http://www.dclunie.com/pixelmed/software/

- classes providing abstractions to support interaction with SEG
- used by ePAD

dicom3tools (C++, free open source)

- *dciodvfy* tool for validating DICOM SEG IOD compliance

Sample Datasets and Community Adoption

- Sample datasets used in this evaluation are publicly available
- DICOM SEG is the recommended format for communicating segmentation results generated by the teams participating in the NCI Quantitative Imaging Network (QIN).
- Several collections of the NCI Cancer Imaging Archive (TCIA, http://thecancerimagingarchive.net) contain various segmentation results stored as DICOM SEG objects:
  - QIN-HEADNECK: longitudinal PET/CT, head&neck cancer, tumor and lymph node segmentations
  - LIDC-IDRI: CT, lung cancer, tumor segmentations obtained using various tools
  - NSCLC Radiogenomics: CT, lung cancer, tumor segmentations
  - QIN Lung CT: CT, lung cancer, tumor segmentations obtained with different tools
  - QIBA CT-1C: CT phantom segmentations
  - RIDER Lung CT (QIBA CT-1B Round 2)

See the up-to-date version of the evaluation datasets at https://goo.gl/lDgDhi or scan the QR code

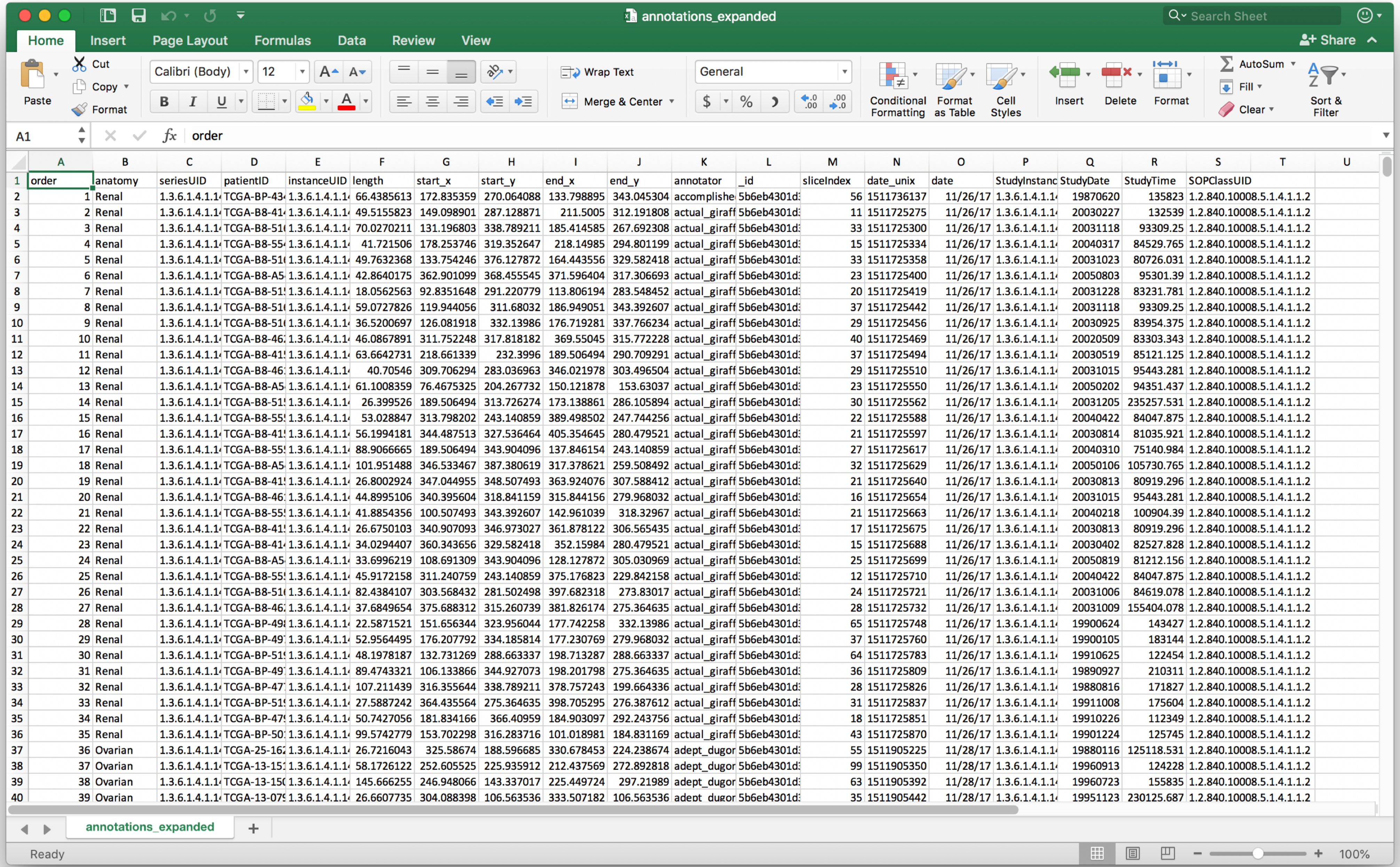
Acknowledgements

This work was supported in part by the National Institutes of Health through the grants U24 CA180918 (QIICR), U01 CA142555, U01 CA190214 and U01 CA140206.

QIICR quantitative image informatics for cancer research

Practical implementation example

- Crowds Cure Cancer project at RSNA 2017 (http://doi.org/10.7937/K9/TCIA.2018.OW73VLO2)
- Booth and mobile app to find mass and draw longest diameter on liver, kidney, lung and ovarian tumors on TCIA DICOM images
- Sent a CSV file with all annotation coordinates and lengths, and metadata including patient, study, series, instance identifiers of images
- Created two XSLT stylesheets
  - extract cells from CSV table into XML files, one for each row (annotation) – driven by column headers
  - convert extracted row cells into DICOM SR instance of DICOM TID 1500 Measurement Report encoded as PixelMed toolkit specific XML format
- Applied existing open source PixelMed toolkit XML to DICOM SR converter
- Validated DICOM SRs that had been created
  - ran automated DICOM SR validator in PixelMed toolkit (knows about TID 1500 since QIICR project)
  - visually inspected dumps of DICOM SR content with PixelMed and dicom3tools toolkit utilities and rendered SR coordinates and measurements on images using PixelMed tool
- One morning's work (leveraging familiar toolkits and techniques and stylesheets used from other projects as a starting point)
- Plan is to to put back into TCIA along with the already publicly accessible images



order	anatomy	seriesUID	patientID	instanceUID	length	start_x	start_y	end_x	end_y	annotator	_id	sliceIndex	date_unix	date	StudyInstanc	StudyDate	StudyTime	SOPClassUID
1	Renal	1.3.6.1.4.1.1	TCGA-BP-43	1.3.6.1.4.1.1	66.4385613	172.835359	270.064088	133.798895	343.045304	accomplishe	5b6eb4301d	56	1511736137	11/26/17	1.3.6.1.4.1.1	19870620	135823	1.2.840.10008.5.1.4.1.1.2
2	Renal	1.3.6.1.4.1.1	TCGA-B8-41	1.3.6.1.4.1.1	49.5155823	149.098901	287.128871	211.5005	312.191808	actual_giraff	5b6eb4301d	11	1511725275	11/26/17	1.3.6.1.4.1.1	20030227	132539	1.2.840.10008.5.1.4.1.1.2
3	Renal	1.3.6.1.4.1.1	TCGA-B8-51	1.3.6.1.4.1.1	70.0270211	131.196803	338.789211	185.414585	267.692308	actual_giraff	5b6eb4301d	33	1511725300	11/26/17	1.3.6.1.4.1.1	20031118	93309.25	1.2.840.10008.5.1.4.1.1.2
4	Renal	1.3.6.1.4.1.1	TCGA-B8-55	1.3.6.1.4.1.1	41.721506	178.253746	319.352647	218.14985	294.801199	actual_giraff	5b6eb4301d	15	1511725334	11/26/17	1.3.6.1.4.1.1	20040317	84529.765	1.2.840.10008.5.1.4.1.1.2
5	Renal	1.3.6.1.4.1.1	TCGA-B8-51	1.3.6.1.4.1.1	49.7632368	133.754246	376.127872	164.443556	329.582418	actual_giraff	5b6eb4301d	33	1511725358	11/26/17	1.3.6.1.4.1.1	20031023	80726.031	1.2.840.10008.5.1.4.1.1.2
6	Renal	1.3.6.1.4.1.1	TCGA-B8-A5	1.3.6.1.4.1.1	42.8640175	362.901099	368.455545	371.596404	317.306693	actual_giraff	5b6eb4301d	23	1511725400	11/26/17	1.3.6.1.4.1.1	20050803	95301.39	1.2.840.10008.5.1.4.1.1.2
7	Renal	1.3.6.1.4.1.1	TCGA-B8-51	1.3.6.1.4.1.1	18.0562563	92.8351648	291.220779	113.806194	283.548452	actual_giraff	5b6eb4301d	20	1511725419	11/26/17	1.3.6.1.4.1.1	20031228	83231.781	1.2.840.10008.5.1.4.1.1.2
8	Renal	1.3.6.1.4.1.1	TCGA-B8-51	1.3.6.1.4.1.1	59.0727826	119.944056	311.68032	186.949051	343.392607	actual_giraff	5b6eb4301d	37	1511725442	11/26/17	1.3.6.1.4.1.1	20031118	93309.25	1.2.840.10008.5.1.4.1.1.2
9	Renal	1.3.6.1.4.1.1	TCGA-B8-51	1.3.6.1.4.1.1	36.5200697	126.081918	332.13986	176.719281	337.766234	actual_giraff	5b6eb4301d	29	1511725456	11/26/17	1.3.6.1.4.1.1	20030925	83954.375	1.2.840.10008.5.1.4.1.1.2
10	Renal	1.3.6.1.4.1.1	TCGA-B8-46	1.3.6.1.4.1.1	46.0867891	311.752248	317.818182	369.55045	315.772228	actual_giraff	5b6eb4301d	40	1511725469	11/26/17	1.3.6.1.4.1.1	20020509	83303.343	1.2.840.10008.5.1.4.1.1.2
11	Renal	1.3.6.1.4.1.1	TCGA-B8-41	1.3.6.1.4.1.1	63.6642731	218.661339	232.3996	189.506494	290.709291	actual_giraff	5b6eb4301d	37	1511725494	11/26/17	1.3.6.1.4.1.1	20030519	85121.125	1.2.840.10008.5.1.4.1.1.2
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13	Renal	1.3.6.1.4.1.1	TCGA-B8-A5	1.3.6.1.4.1.1	61.1008359	76.4675325	204.267732	150.121878	153.63037	actual_giraff	5b6eb4301d	23	1511725550	11/26/17	1.3.6.1.4.1.1	20050202	94351.437	1.2.840.10008.5.1.4.1.1.2
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15	Renal	1.3.6.1.4.1.1	TCGA-B8-55	1.3.6.1.4.1.1	53.028847	313.798202	243.140859	389.498502	247.744256	actual_giraff	5b6eb4301d	22	1511725588	11/26/17	1.3.6.1.4.1.1	20040422	84047.875	1.2.840.10008.5.1.4.1.1.2
16	Renal	1.3.6.1.4.1.1	TCGA-B8-41	1.3.6.1.4.1.1	56.1994181	344.487513	327.536464	405.354645	280.479521	actual_giraff	5b6eb4301d	21	1511725597	11/26/17	1.3.6.1.4.1.1	20030814	81035.921	1.2.840.10008.5.1.4.1.1.2
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20	Renal	1.3.6.1.4.1.1	TCGA-B8-46	1.3.6.1.4.1.1	44.8995106	340.395604	318.841159	315.844156	279.968032	actual_giraff	5b6eb4301d	16	1511725654	11/26/17	1.3.6.1.4.1.1	20031015	95443.281	1.2.840.10008.5.1.4.1.1.2
21	Renal	1.3.6.1.4.1.1	TCGA-B8-55	1.3.6.1.4.1.1	41.8854356	100.507493	343.392607	142.961039	318.32967	actual_giraff	5b6eb4301d	21	1511725663	11/26/17	1.3.6.1.4.1.1	20040218	100904.39	1.2.840.10008.5.1.4.1.1.2
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28	Renal	1.3.6.1.4.1.1	TCGA-BP-49	1.3.6.1.4.1.1	22.5871521	151.656344	323.956044	177.742258	332.13986	actual_giraff	5b6eb4301d	65	1511725748	11/26/17	1.3.6.1.4.1.1	19900624	143427	1.2.840.10008.5.1.4.1.1.2
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33	Renal	1.3.6.1.4.1.1	TCGA-BP-51	1.3.6.1.4.1.1	27.5887242	364.435564	275.364635	398.705295	276.387612	actual_giraff	5b6eb4301d	31	1511725837	11/26/17	1.3.6.1.4.1.1	19911008	175604	1.2.840.10008.5.1.4.1.1.2
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37	Ovarian	1.3.6.1.4.1.1	TCGA-13-15	1.3.6.1.4.1.1	58.1726122	252.605525	225.935912	212.437569	272.892818	adept_dugor	5b6eb4301d	99	1511905350	11/28/17	1.3.6.1.4.1.1	19960913	124228	1.2.840.10008.5.1.4.1.1.2
38	Ovarian	1.3.6.1.4.1.1	TCGA-13-15	1.3.6.1.4.1.1	145.666255	246.948066	143.337017	225.449724	297.21989	adept_dugor	5b6eb4301d	63	1511905392	11/28/17	1.3.6.1.4.1.1	19960723	155835	1.2.840.10008.5.1.4.1.1.2
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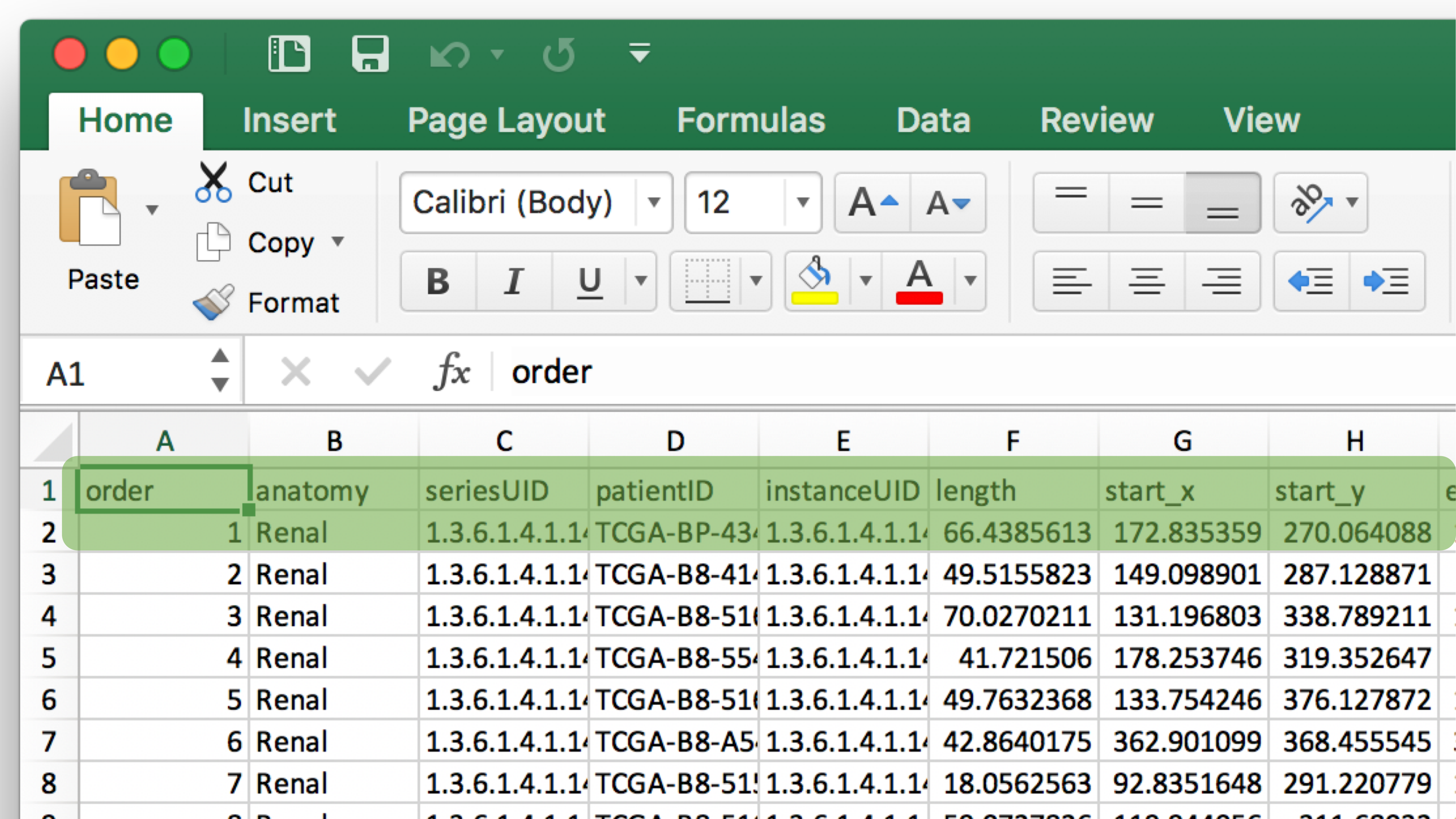
Courtesy of Jayashree Kalpathy-Cramer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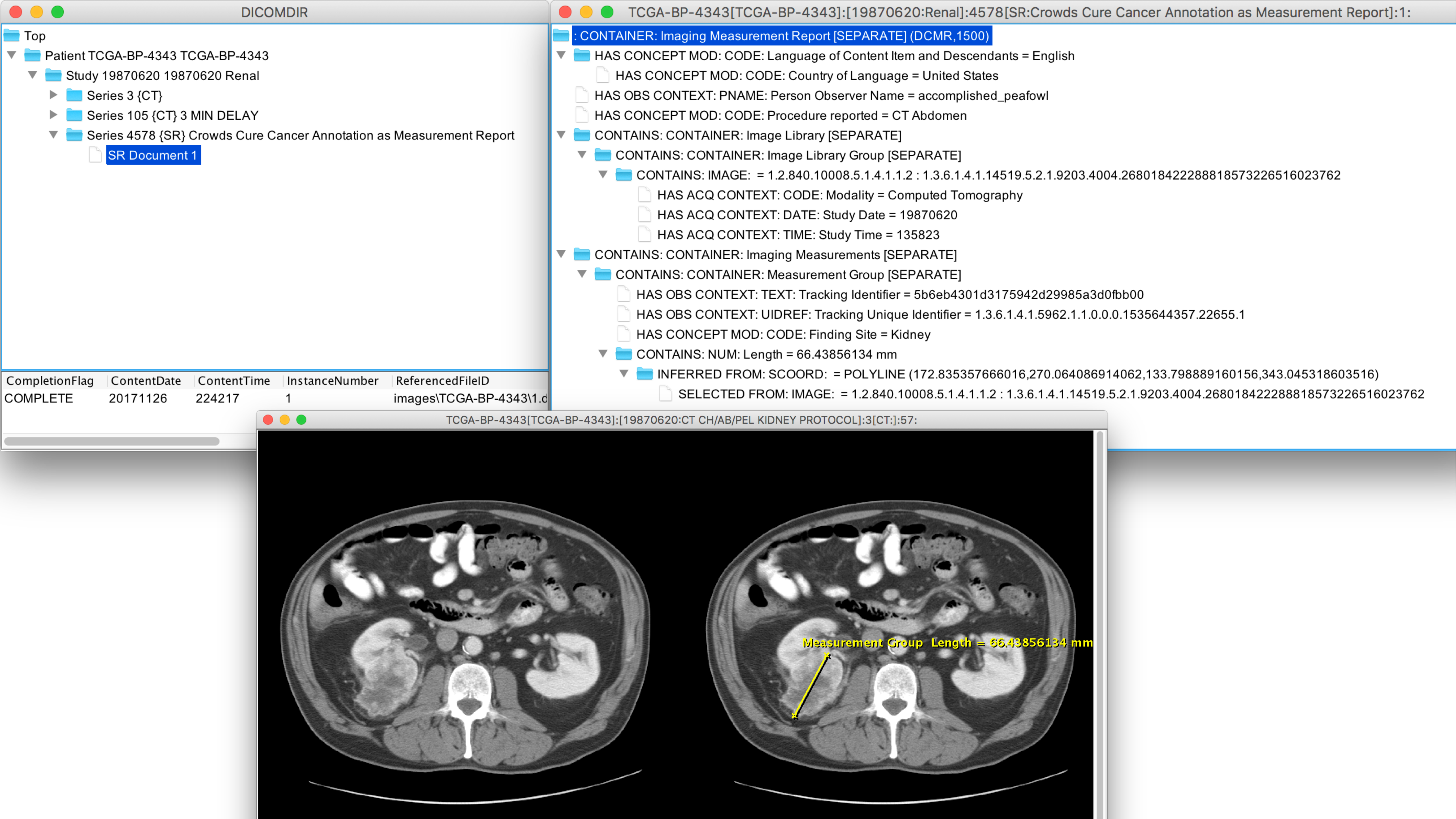
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(126010,DCM,"Imaging Measurements") [SEPARATE]
CONTAINER: (125007,DCM,"Measurement Group") [SEPARATE]
 HAS OBS CONTEXT: TEXT: (112039,DCM,"Tracking Identifier") = "5b6eb4301d3175942d29985
 HAS OBS CONTEXT: UIDREF: (112040,DCM,"Tracking Unique Identifier") = "1.3.6.1.4.1.59
 HAS CONCEPT MOD: CODE: (G-C0E3,SRT,"Finding Site") = (T-71000,SRT,"Kidney")
 CONTAINS: NUM: (G-D7FE,SRT,"Length") = 66.43856134 (mm,UCUM,"mm")
>1.5.1.4.1: INFERRED FROM: SCOORD: = POLYLINE {172.835357666016,270.064086914062,133.
     >>>>>1.5.1.4.1.1: SELECTED FROM: IMAGE: = (1.2.840.10008.5.1.4.1.1.2,1.3.6.1.4.1
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Terminal — -tcsh — 140×37

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(0x0002,0x0013) SH Implementation Version Name   VR=<SH>   VL=<0x0010>  <PIXELMEDJAVA001 >
(0x0008,0x0016) UI SOP Class UID         VR=<UI>   VL=<0x001e>  <1.2.840.10008.5.1.4.1.1.88.22>
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(0x0008,0x1090) LO Manufacturer's Model Name     VR=<LO>   VL=<0x0022>  <XSLT from annotations_expanded.csv>
(0x0008,0x1111) SQ Referenced Performed Procedure Step Sequence          VR=<SQ>   VL=<0xffffffff>

(0x0010,0x0010) PN Patient's Name        VR=<PN>   VL=<0x000c>  <TCGA-BP-4343>
(0x0010,0x0020) LO Patient ID    VR=<LO>   VL=<0x000c>  <TCGA-BP-4343>
(0x0010,0x0030) DA Patient's Birth Date          VR=<DA>   VL=<0x0000>  <>
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(0x0020,0x000e) UI Series Instance UID   VR=<UI>   VL=<0x002c>  <1.3.6.1.4.1.5962.1.3.0.0.1535642467.22502.1>
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Terminal — -tcsh — 140×37

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[graythin:NCI/CrowdsCureCancer/converttoDICOMSR] dclunie% dcdump dicomsrfiles/1.dcm
(0x0002,0x0000) UL File Meta Information Group Length     VR=<UL>   VL=<0x0004>  [0x000000bc]
(0x0002,0x0001) OB File Meta Information Version          VR=<OB>   VL=<0x0002>  [0x00,0x01]
(0x0002,0x0002) UI Media Storage SOP Class UID   VR=<UI>   VL=<0x001e>  <1.2.840.10008.5.1.4.1.1.88.22>
(0x0002,0x0003) UI Media Storage SOP Instance UID         VR=<UI>   VL=<0x002e>  <1.3.6.1.4.1.5962.1.1.0.0.0.1535642467.22502.1>
(0x0002,0x0010) UI Transfer Syntax UID   VR=<UI>   VL=<0x0014>  <1.2.840.10008.1.2.1>
(0x0002,0x0012) UI Implementation Class UID       VR=<UI>   VL=<0x0016>  <1.3.6.1.4.1.5962.99.2>
(0x0002,0x0013) SH Implementation Version Name   VR=<SH>   VL=<0x0010>  <PIXELMEDJAVA001 >
(0x0008,0x0016) UI SOP Class UID         VR=<UI>   VL=<0x001e>  <1.2.840.10008.5.1.4.1.1.88.22>
(0x0008,0x0018) UI SOP Instance UID      VR=<UI>   VL=<0x002e>  <1.3.6.1.4.1.5962.1.1.0.0.0.1535642467.22502.1>
(0x0008,0x0020) DA Study Date    VR=<DA>   VL=<0x0008>  <19870620>
(0x0008,0x0021) DA Series Date   VR=<DA>   VL=<0x0000>  <>
(0x0008,0x0023) DA Content Date          VR=<DA>   VL=<0x0008>  <20171126>
(0x0008,0x0030) TM Study Time    VR=<TM>   VL=<0x0006>  <135823>
(0x0008,0x0033) TM Content Time          VR=<TM>   VL=<0x0006>  <224217>
(0x0008,0x0050) SH Accession Number      VR=<SH>   VL=<0x0000>  <>
(0x0008,0x0060) CS Modality      VR=<CS>   VL=<0x0002>  <SR>
(0x0008,0x0070) LO Manufacturer          VR=<LO>   VL=<0x0008>  <PixelMed>
(0x0008,0x0080) LO Institution Name      VR=<LO>   VL=<0x0000>  <>
(0x0008,0x0090) PN Referring Physician's Name     VR=<PN>   VL=<0x0000>  <>
(0x0008,0x1010) SH Station Name          VR=<SH>   VL=<0x0004>  <NONE>
(0x0008,0x1030) LO Study Description     VR=<LO>   VL=<0x0006>  <Renal >
(0x0008,0x103e) LO Series Description    VR=<LO>   VL=<0x0034>  <Crowds Cure Cancer Annotation as Measurement Report >
(0x0008,0x1090) LO Manufacturer's Model Name      VR=<LO>   VL=<0x0022>  <XSLT from annotations_expanded.csv>
(0x0008,0x1111) SQ Referenced Performed Procedure Step Sequence          VR=<SQ>   VL=<0xffffffff>

(0x0010,0x0010) PN Patient's Name        VR=<PN>   VL=<0x000c>  <TCGA-BP-4343>
(0x0010,0x0020) LO Patient ID    VR=<LO>   VL=<0x000c>  <TCGA-BP-4343>
(0x0010,0x0030) DA Patient's Birth Date          VR=<DA>   VL=<0x0000>  <>
(0x0010,0x0040) CS Patient's Sex         VR=<CS>   VL=<0x0000>  <>
(0x0018,0x1000) LO Device Serial Number          VR=<LO>   VL=<0x000e>  <9723613413261 >
(0x0018,0x1020) LO Software Version(s)   VR=<LO>   VL=<0x0004>  <0.1 >
(0x0020,0x000d) UI Study Instance UID    VR=<UI>   VL=<0x0040>  <1.3.6.1.4.1.14519.5.2.1.9203.4004.100545948082587796019777812429>
(0x0020,0x000e) UI Series Instance UID   VR=<UI>   VL=<0x002c>  <1.3.6.1.4.1.5962.1.3.0.0.1535642467.22502.1>
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(0x0020,0x0011) IS Series Number         VR=<IS>   VL=<0x0004>  <4578>
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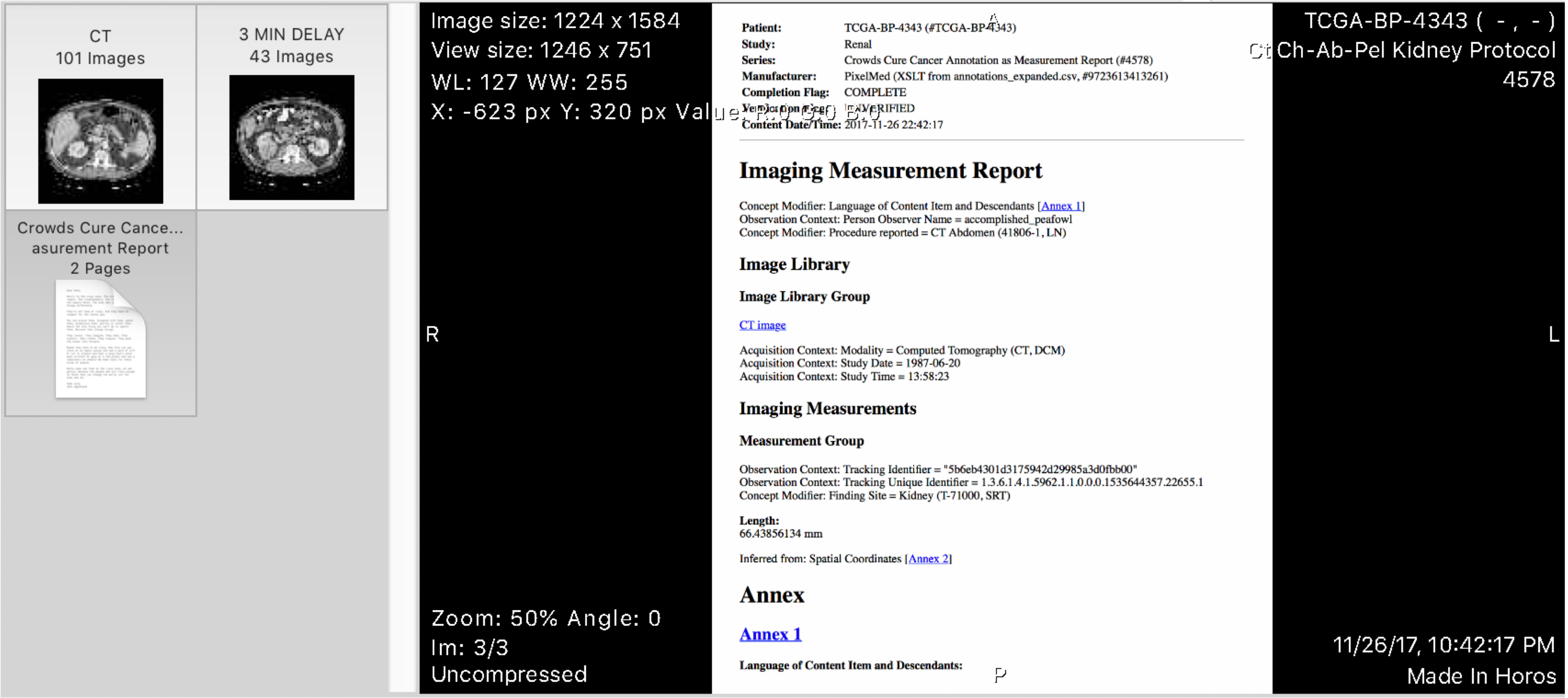
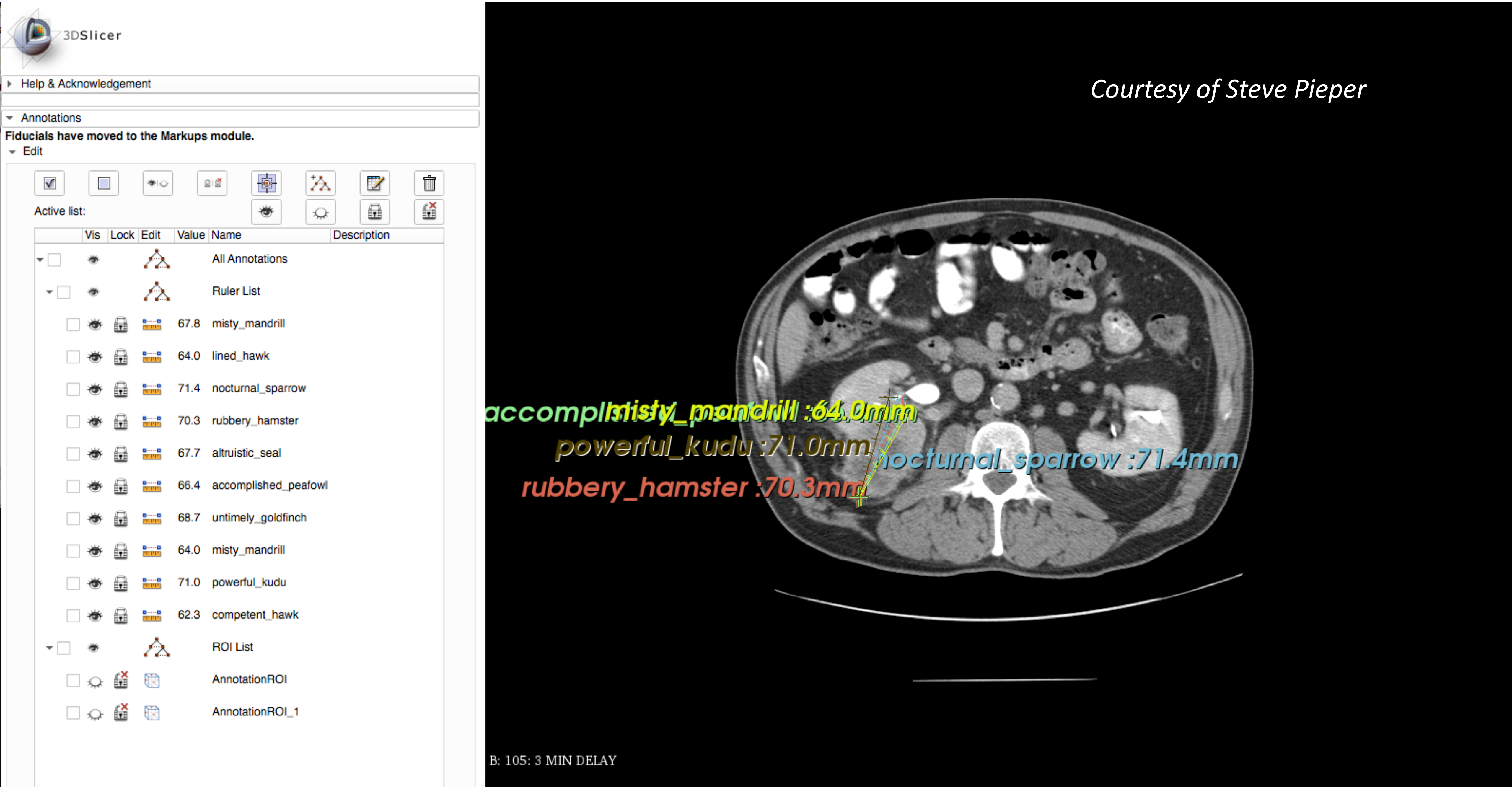

CT
101 Images
3 MIN DELAY
43 Images
Crowds Cure Cance...
asurement Report
2 Pages
Image size: 1224 x 1584
View size: 1246 x 751
WL: 127 WW: 255
X: -623 px Y: 320 px
R
Zoom: 50% Angle: 0
Im: 3/3
Uncompressed
Patient: TCGA-BP-4343 (#TCGA-BP-4343)
Study: Renal
Series: Crowds Cure Cancer Annotation as Measurement Report (#4578)
Manufacturer: PixelMed (XSLT from annotations_expanded.csv, #9723613413261)
Completion Flag: COMPLETE
Content Date/Time: 2017-11-26 22:42:17
Imaging Measurement Report
Concept Modifier: Language of Content Item and Descendants [Annex 1]
Observation Context: Person Observer Name = accomplished_peafowl
Concept Modifier: Procedure reported = CT Abdomen (41806-1, LN)
Image Library
Image Library Group
CT image
Acquisition Context: Modality = Computed Tomography (CT, DCM)
Acquisition Context: Study Date = 1987-06-20
Acquisition Context: Study Time = 13:58:23
Imaging Measurements
Measurement Group
Observation Context: Tracking Identifier = "5b6eb4301d3175942d29985a3d0fbb00"
Observation Context: Tracking Unique Identifier = 1.3.6.1.4.1.5962.1.1.0.0.0.1535644357.22655.1
Concept Modifier: Finding Site = Kidney (T-71000, SRT)
Length:
66.43856134 mm
Inferred from: Spatial Coordinates [Annex 2]
Annex
Annex 1
Language of Content Item and Descendants:
TCGA-BP-4343 (- , -)
Ch-Ab-Pel Kidney Protocol
4578
L
11/26/17, 10:42:17 PM
Made In Horos

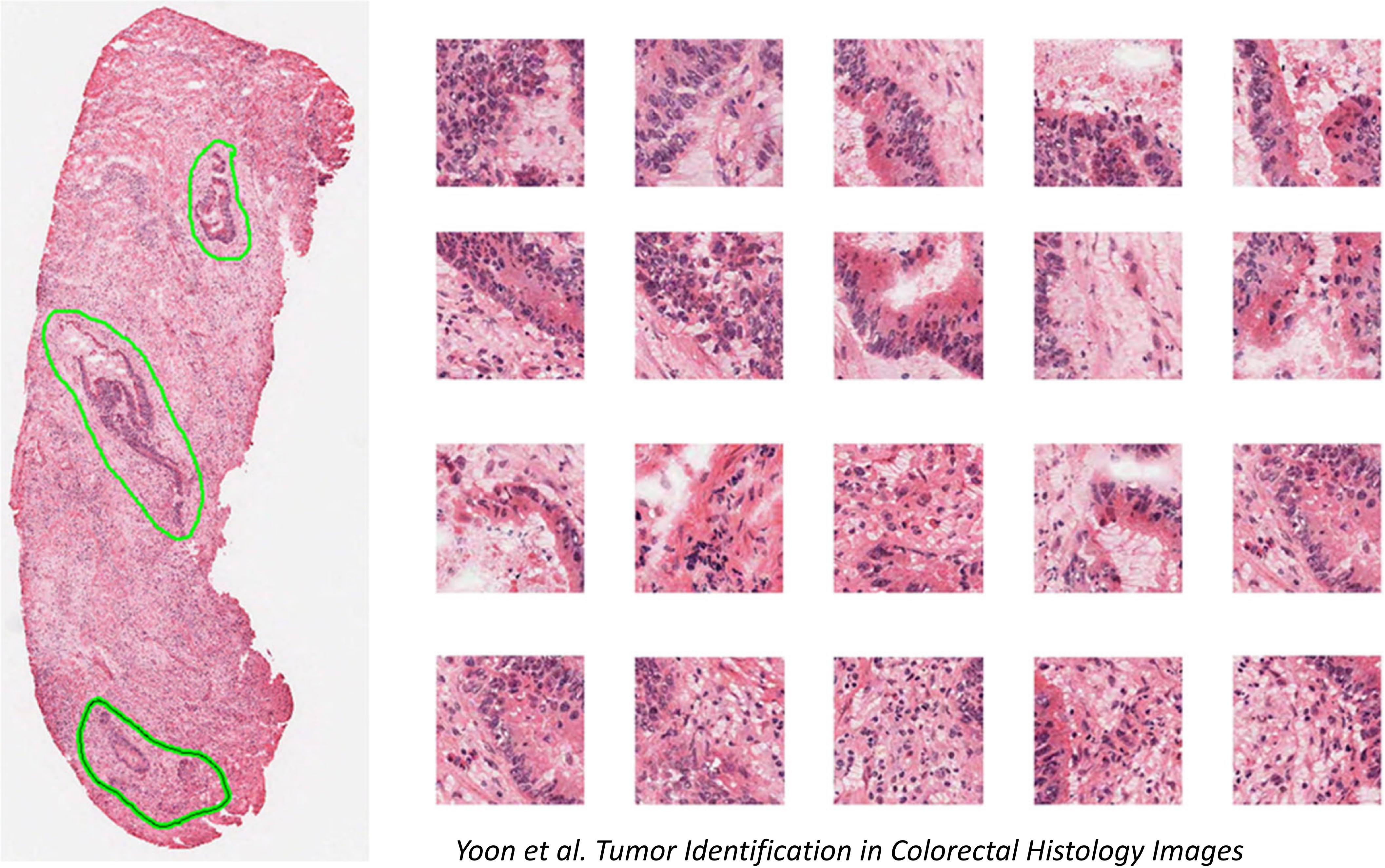

3DSlicer
Help & Acknowledgement
Annotations
Fiducials have moved to the Markups module.
Edit
Active list:
Vis Lock Edit Value Name Description
All Annotations
Ruler List
67.8 misty_mandrill
64.0 lined_hawk
71.4 nocturnal_sparrow
70.3 rubbery_hamster
67.7 altruistic_seal
66.4 accomplished_peafowl
68.7 untimely_goldfinch
64.0 misty_mandrill
71.0 powerful_kudu
62.3 competent_hawk
ROI List
AnnotationROI
AnnotationROI_1
Courtesy of Steve Pieper
misty_mandrill :64.0mm
powerful_kudu :71.0mm
nocturnal_sparrow :71.4mm
rubbery_hamster :70.3mm
B: 105: 3 MIN DELAY

Annotation workflow and use cases

- Traditional “box under the table/in back room” (“headless”)
  - acquire images -> process -> send both to PACS for reader
  - “push workflow” (“unmanaged”) familiar from Mammography CADe
  - cloud variants and large data volumes add security/timing challenges
  - data to algorithm or algorithm to data
- Interactive (virtually “embedded”)
  - user views images -> selects task/frames/ROI -> requests CAD -> see result
  - user expects immediate response (or likely will not use)
  - responsiveness may depend on prearranged proximity of data & algorithm
  - standard payload not only for results but request as well
  - standard protocol for command and control of request/progress/complete

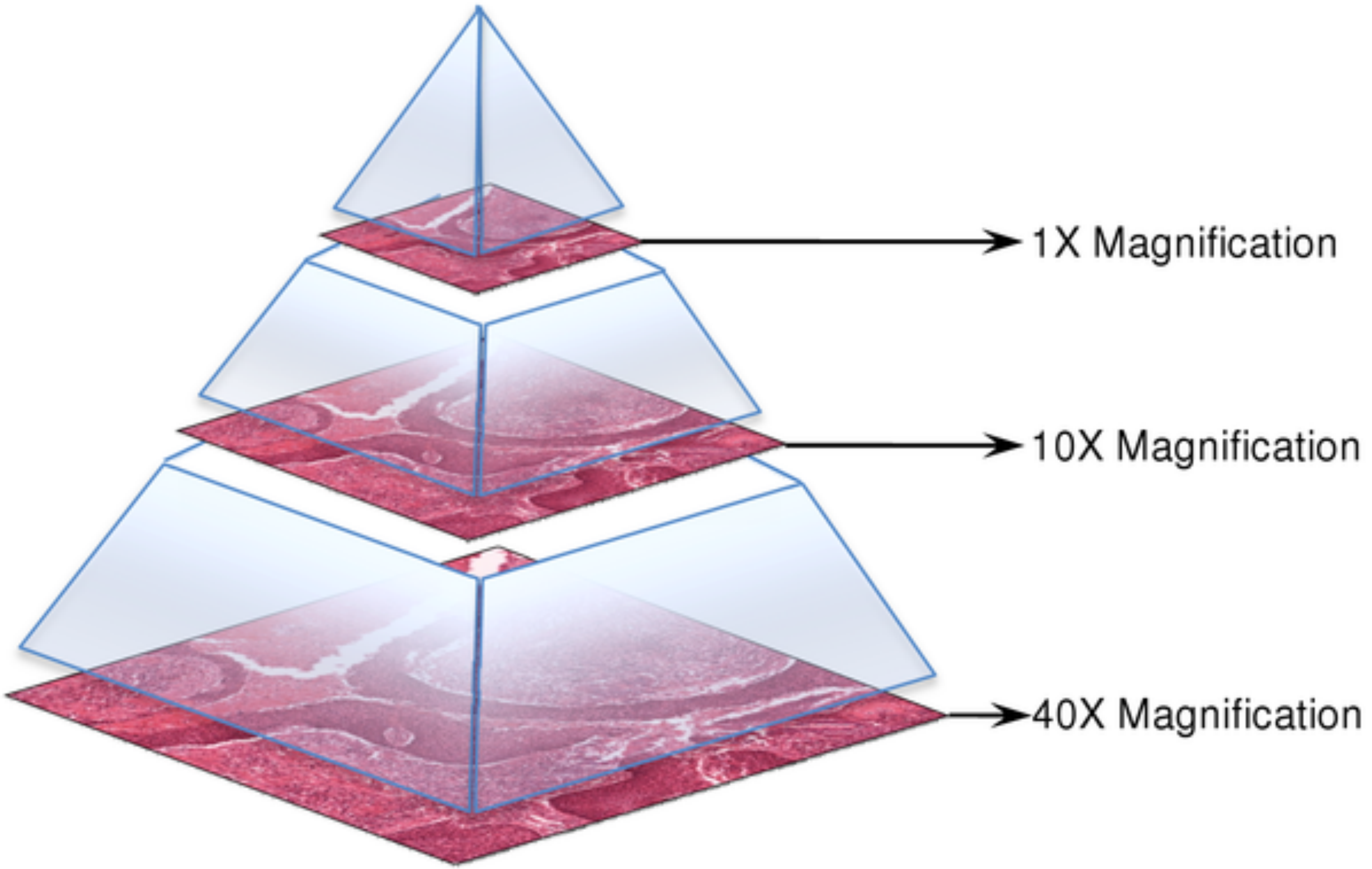
Annotation workflow standards

- Standard payload for images in/out & results (DICOM)
  - for visualization – "pretty picture" screen shots and presentation states
  - semantically meaningful – segmentations, parametric maps, SR
- Standard protocols to choose from:
  - DICOM – Unified Procedure Step (UPS) and DICOMweb UPS-RS variant
  - IHE – Invoke Image Display (IID) – HTTP request to view specified study(ies)
  - HL7 – synchronized applications – CCOW and now FHIRcast
  - DICOM Application Hosting – SOAP-based, never popular; revisit RESTfully?
- "Push" unmanaged request – image timeout, UPS N-CREATE, IHE IID
- "Pull" from worklist – UPS C-FIND or UPS-RS, do work and update status
- Fetch payload – DICOM C-MOVE/C-GET or WADO-RS (metadata)
- Return result – DICOM C-STORE or STOW-RS
- Security – transport (TLS), authentication (Kerberos, SAML, JWT, OAUTH)



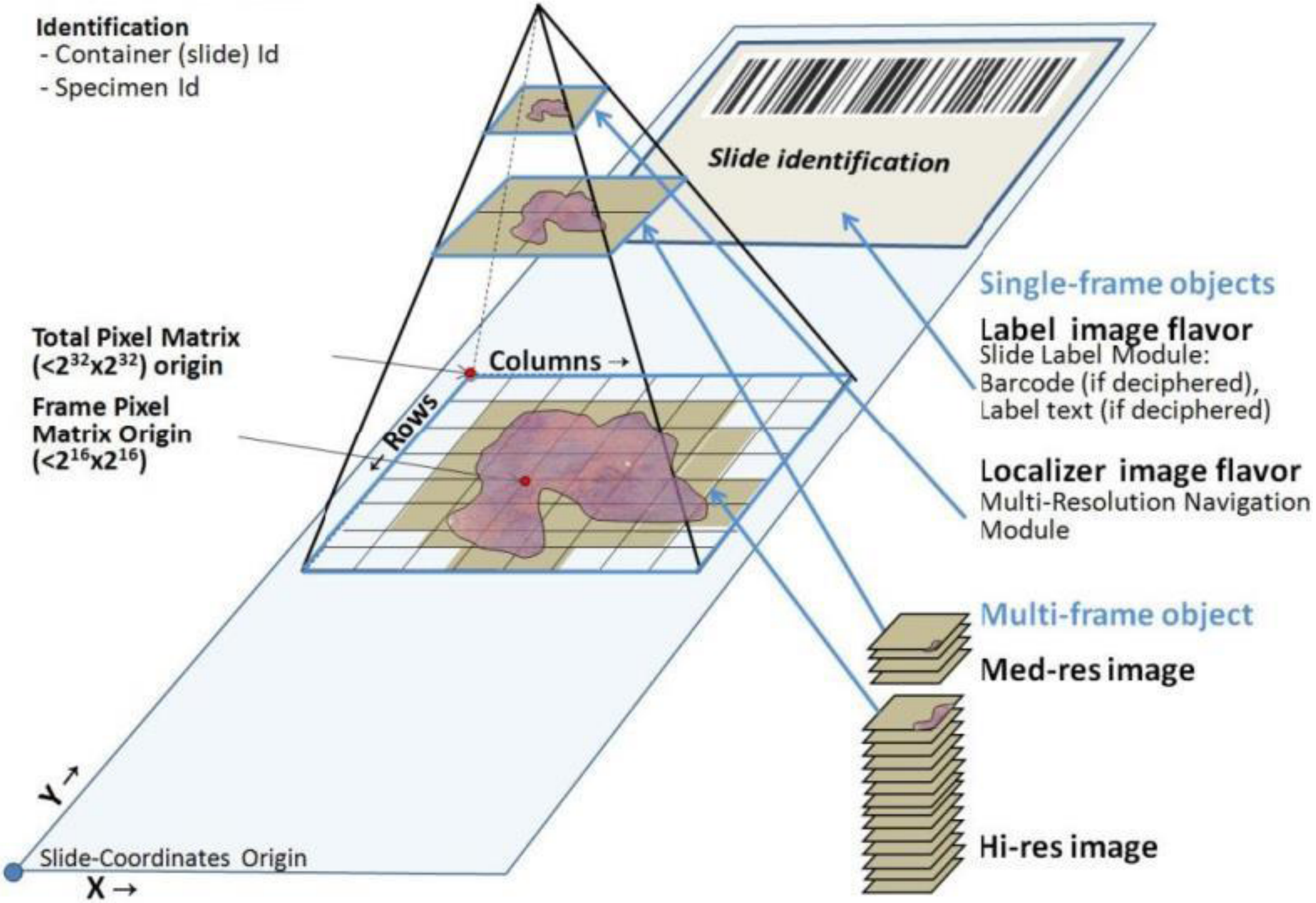
Yoon et al. Tumor Identification in Colorectal Histology Images Using a Convolutional Neural Network. J Digit Imaging. 2018 Jul 31;1–10.

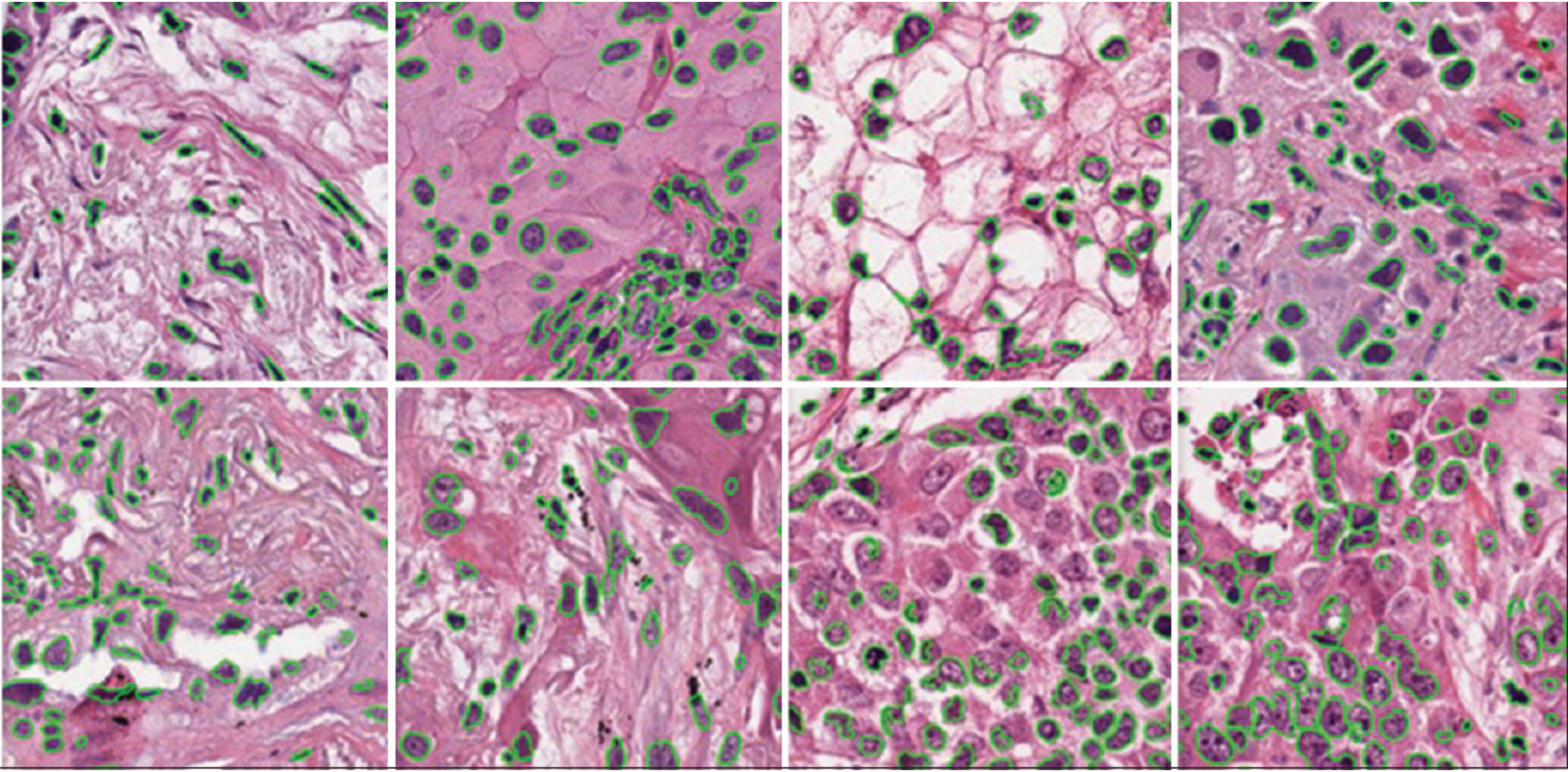
An illustration of how digital slides are stored in a pyramid structure.



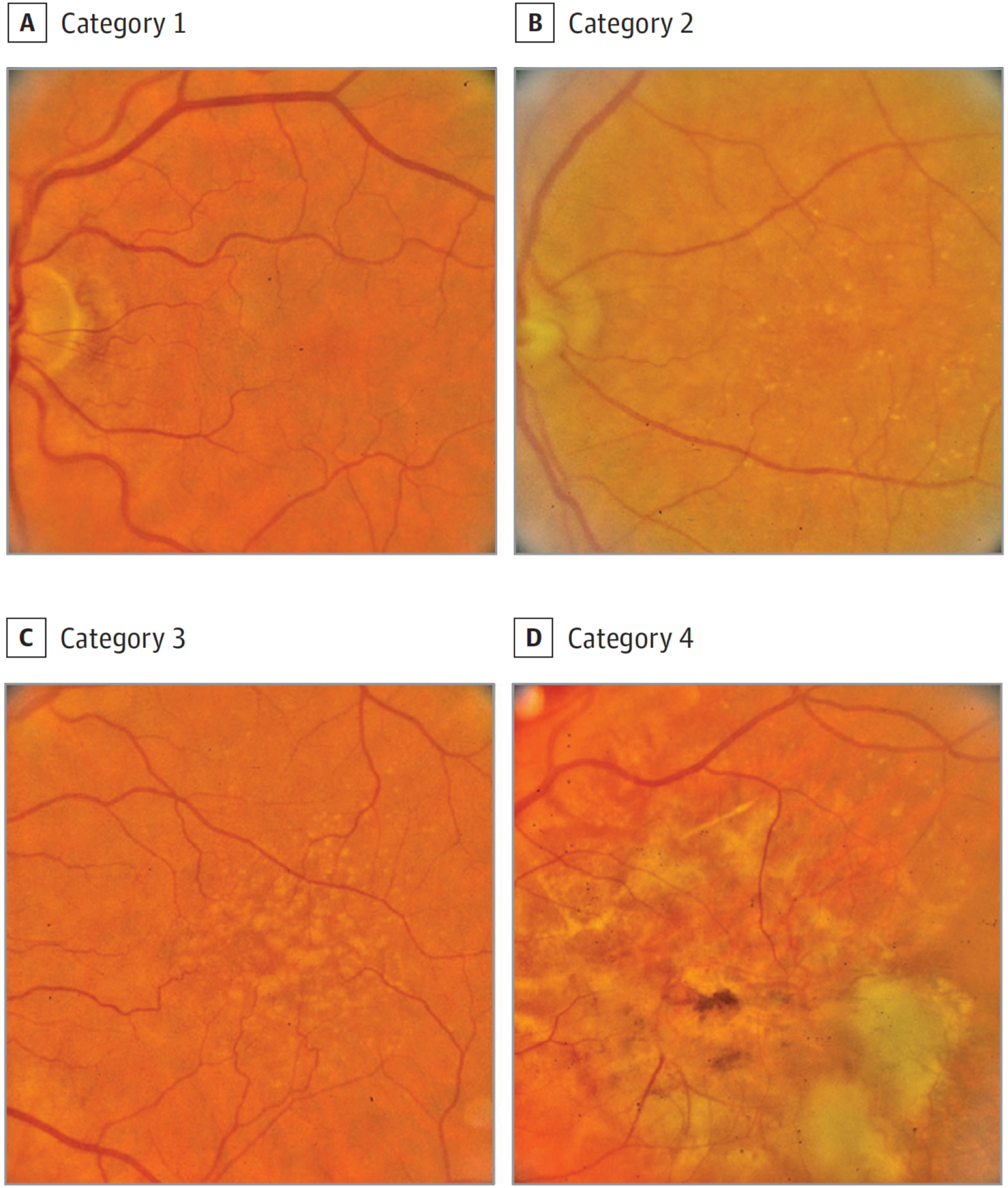
Wang Y, Williamson KE, Kelly PJ, James JA, Hamilton PW (2012) SurfaceSlide: A Multitouch Digital Pathology Platform. PLOS ONE 7(1): e30783. https://doi.org/10.1371/journal.pone.0030783
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0030783

Garcia-Rojo et al. 2016





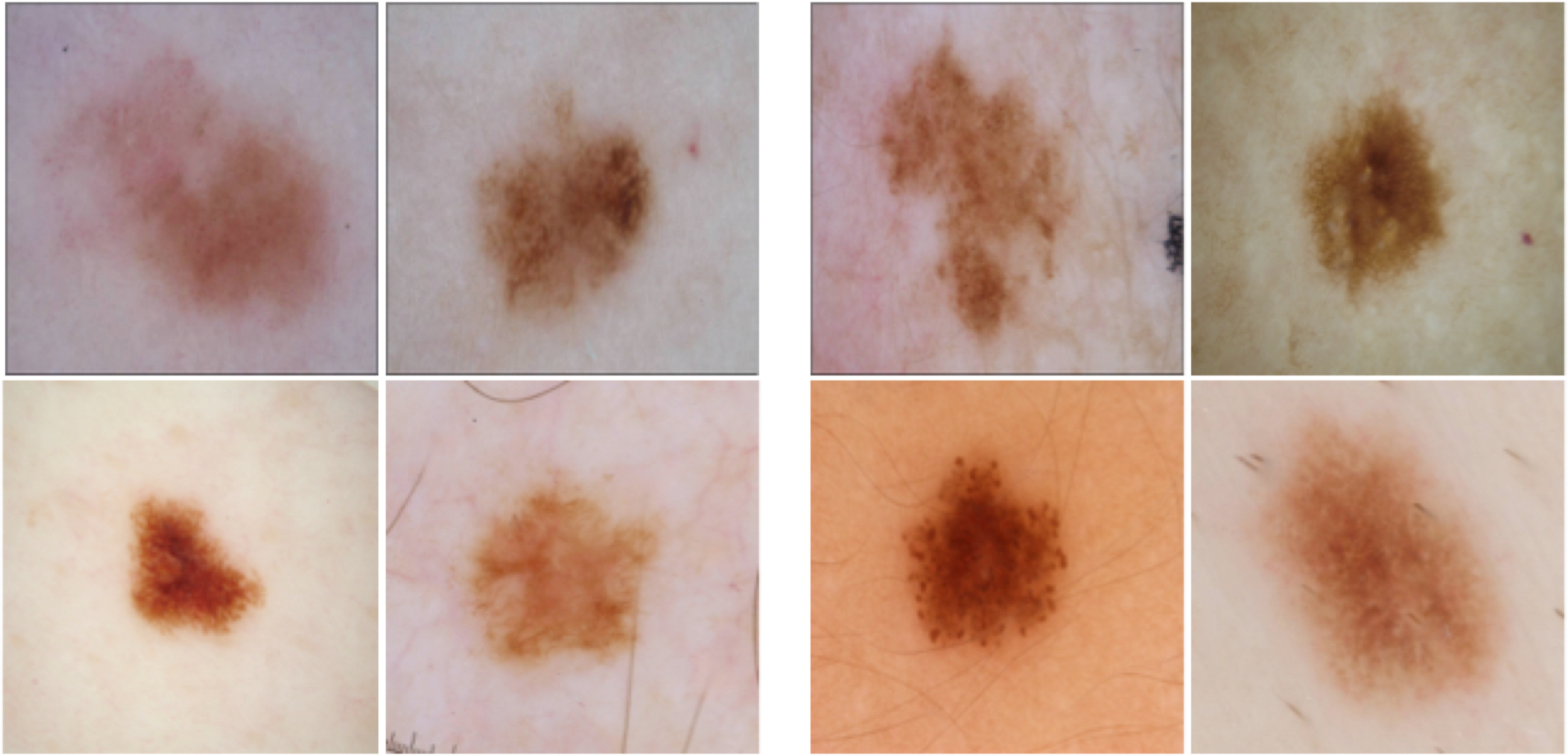
Wen et al. A methodology for texture feature-based quality assessment in nucleus segmentation of histopathology image. JPI. 2017.



Burlina et al. Automated Grading of Age-Related Macular Degeneration From Color Fundus Images Using Deep Convolutional Neural Networks. JAMA Ophthalmol. 2017 Nov 1;135(11):1170–6.

Melanoma

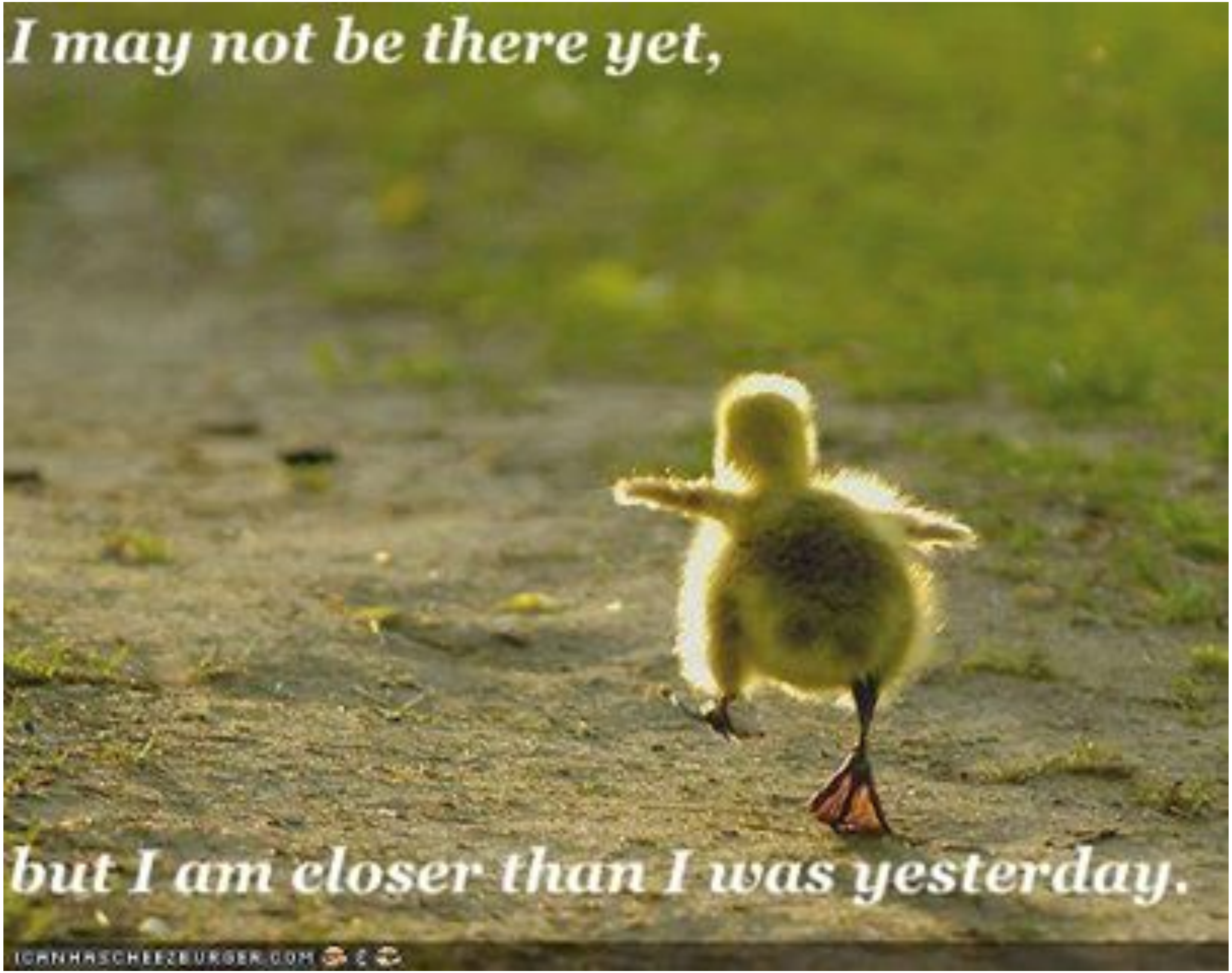
Benign



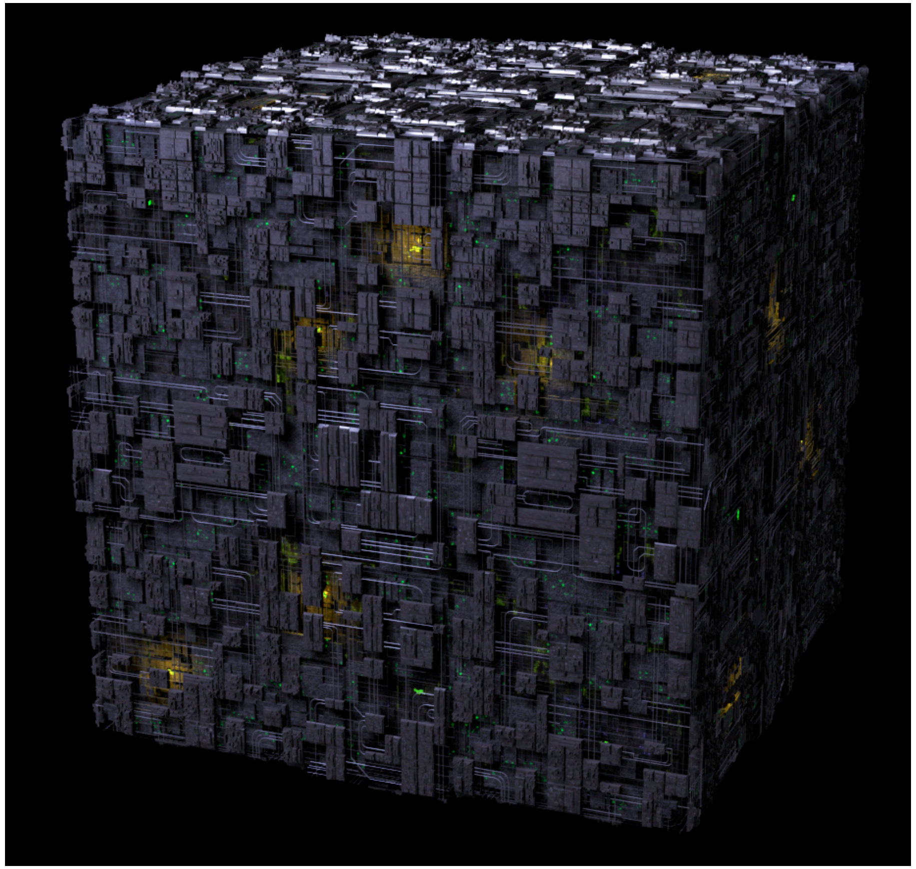
Gutman D et al. Skin Lesion Analysis toward Melanoma Detection: A Challenge at the International Symposium on Biomedical Imaging (ISBI) 2016, hosted by the International Skin Imaging Collaboration (ISIC). arXiv:160501397.

DICOM – Gaps and Future Improvements

- Extending Segmentation and Parametric Maps to tiled images for Whole Slide Imaging (CP 1830)
  - Plane Position (Slide) macro instead of Plane Position (Patient)
- DICOM query or DICOMweb RESTful API for annotation access?
  - “spatial” queries, e.g., all annotations that intersect defined frame/region
- More compact representation of very large numbers of contours?
  - e.g., all nuclei, all membranes in WSI (versus SEG bit-plane representation)
- Explicit Label Map rather than Segmentation bit planes?
  - in SEG object have one bit-plane per segment (label), each as a frame
  - in traditional label maps, one multi-valued voxel where each voxel is an index whose value represents a segment (label)
  - same semantics but “gratuitously” different representation – convenience?
- Always need more coded concepts
  - e.g., more texture features – all of IBSI (CP 1764)


I may not be there yet,
but I am closer than I was yesterday.

How long until you are assimilated?



DICOM

Digital Imaging and Communications in Medicine

“we will add your biological and technological distinctiveness to our own”

“your culture will adapt to service us”

“resistance is futile”