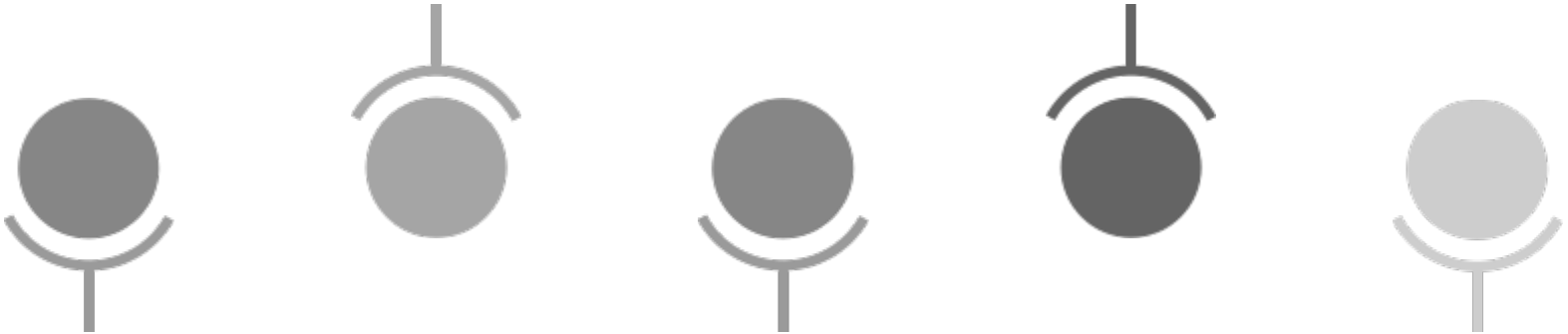
Clinical and Translational Imaging Informatics Project (CTIIP)

Speaker Series Presentation

July 6, 2016

Objective

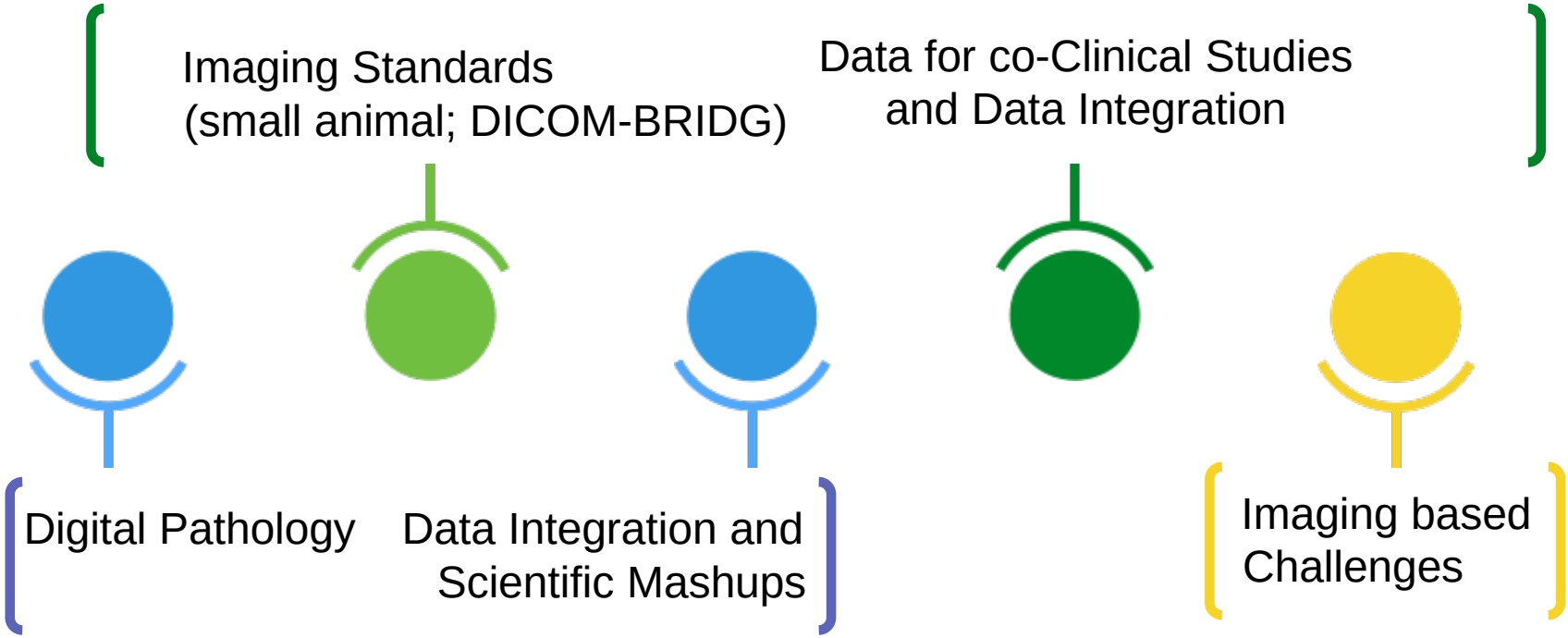
Standards, Infrastructure for
Pre-Clinical and Co-Clinical Studies



Interoperability and Integration
with Digital Pathology Studies

Evaluate with Integrative
Pilot Challenges

Approach


Imaging Standards
(small animal; DICOM-BRIDG)
Data for co-Clinical Studies
and Data Integration
Digital Pathology
Data Integration and
Scientific Mashups
Imaging based
Challenges

Aim 1

Improve Digital Pathology Tools and establish an Integrative Query System

- Enable caMicroscope to
  - Directly serve whole slide pathology images from the majority of digital pathology vendors.
  - Execute basic image analysis algorithms
  - Propose and develop specifications and tools for image annotation and markup.
- Explore data mashups between image-derived information, clinical, and molecular data

PI: Dr. Ashish Sharma, Emory University

Co-PIs: Dr. Joel Saltz, Stonybrook University

Dr. Fred Prior, University of Arkansas Medical Sciences

Aim 2

- Improving Standards in Imaging
  - Enable DICOM* compliance of small-animal imaging by including it in the DICOM standard
  - Coordination of two ISO standards by including DICOM* references in the BRIDG** Imaging subdomain

    PI: Dr. David Clunie, Pixelmed

- Provide data including DICOM-compliant animal images for development and evaluation of data integration strategies

  PI: Dr. Robert Cardiff, University of California Davis

* Digital Imaging and Communications in Medicine (*DICOM*) Standard

** Biomedical Research Integrated Domain Group (BRIDG) Model,
BRIDG is a collaborative effort engaging stakeholders from CDISC, HL7, ISO, NCI, and FDA

Aim 3

Establish an Imaging Challenge Management System utilizing existing tools and execute pilot challenges in

- Clinical Imaging
- Preclinical/co-clinical Imaging
- Digital Pathology

PI: Dr. Jayashree Kalpathy-Cramer, Massachusetts General Hospital

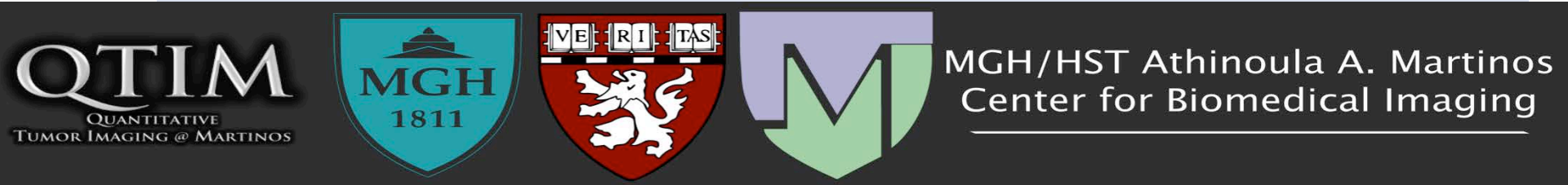
Co-PIs: Dr. Daniel Rubin, Stanford University
Dr. Ashish Sharma, Emory University

MedICI: an Infrastructure for Challenges

Jayashree Kalpathy-Cramer, PhD

Athinoula A. Martinos Center for Biomedical Imaging,

Massachusetts General Hospital, Boston, MA



Aim 3

Establish an Imaging Challenge Management System utilizing existing tools and execute pilot challenges in

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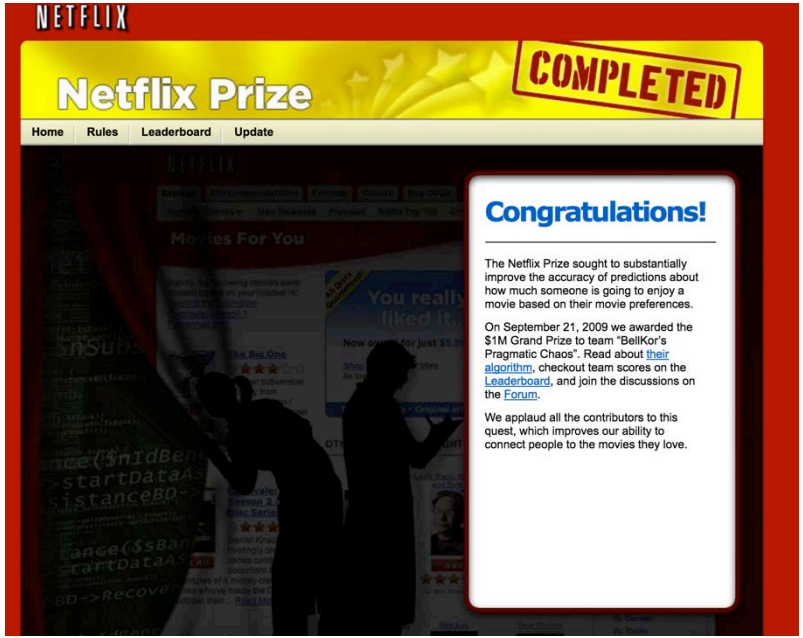
- Digital Pathology

PI: Dr. Jayashree Kalpathy-Cramer, Massachusetts General Hospital
Artem Mamanov, Karl Helmer, Massachusetts General Hospital

Co-PIs: Dr. Daniel Rubin, Stanford University
Dr. Ashish Sharma, Emory University

Challenges are a popular means of engaging the community in problem solving



Competition Name	Reward	Teams	Deadline
Heritage Health Prize Identify patients who will be admitted to a hospital within the next year using historical claims data. (Enter by 06:59:59 UTC Oct 4 2012)	$500,000	1353	3 years ago
GE Flight Quest Think you can change the future of flight?	$250,000	173	3 years ago
Flight Quest 2: Flight Optimization, Milestone Phase Optimize flight routes based on current weather and traffic.	$250,000	129	2 years ago
Flight Quest 2: Flight Optimization, Main Phase Optimize flight routes based on current weather and traffic.	$220,000	121	2 years ago
Flight Quest 2: Flight Optimization, Final Phase Final Phase of Flight Quest 2	$220,000	33	2 years ago
Second Annual Data Science Bowl Transforming How We Diagnose Heart	$200,000	192	3 months ago

http://www.netflixprize.com/index

https://www.kaggle.com/competitions

Self driving cars

THE DARPA GRAND CHALLENGE: TEN YEARS LATER

March 13, 2014

Autonomous vehicle challenge led to new technologies and invigorated the prize challenge model of promoting innovation

At the break of dawn on March 13, 2004, 15 vehicles left a starting gate in the desert outside of Barstow, Calif., to make history in the DARPA Grand Challenge, a first-of-its-kind race to foster the development of self-driving ground vehicles. The immediate goal: autonomously navigate a 142-mile course that ran across the desert to Primm, Nev. The longer-term aim was to accelerate development of the technological foundations for autonomous vehicles that could ultimately substitute for men and women in hazardous military operations, such as supply convoys.

- Ushered in the self driving era

Why (prize) challenges?

- Why does DARPA sometimes turn to prizes instead of conventional means of encouraging progress, such as by funding activities through contracts and grants?
  - Prizes Encourage Thinking Outside the Box: Unlike grants and contracts, which are awarded in the hope that the recipient will be successful, prizes allow a funder to establish an ambitious goal without having to predict who or which approach is most likely to succeed, making way for novel approaches that might otherwise seem too risky to pursue.
  - Prizes Encourage Broad Participation: Prizes attract a wide array of potential solvers to tackle a problem and not just the usual experts in a given field.
  - The Economics Are Great: Prize purses are paid out only if someone succeeds, and in many cases, the amount of time and money invested by multiple teams as they vie for a prize exceeds the size of the prize purse itself.

http://www.darpa.mil/work-with-us/public/prizes

THE OPEN GOVERNMENT PARTNERSHIP

SECOND OPEN GOVERNMENT NATIONAL ACTION PLAN FOR THE UNITED STATES OF AMERICA

December 5, 2013

5. Promote Innovation Through Collaboration and Harness the Ingenuity of the American Public

Creating a more Open Government and addressing our Nation's most challenging issues requires an informed and active citizenry. Recognizing the value of the American public as a strategic partner in addressing some of the country's most pressing challenges, the United States will work to more effectively harness the expertise, ingenuity, and creativity of the American public by enabling, accelerating, and scaling the use of open innovation methods across the Federal Government, including commitments to:

- **Create an Open Innovation Toolkit.** In 2014, the Administration will convene an interagency group to develop an "open innovation toolkit" for Federal agencies that will include best practices, training, policies, and guidance on authorities related to open innovation, including approaches such as incentive prizes, crowdsourcing, and citizen science.

- **New Incentive Prizes and Challenges on Challenge.gov**. The U.S. Government champions the use of challenges, prizes, and competitions to catalyze breakthroughs in national priorities. Launched on September 2010, Challenge.gov has hosted more than 300 crowdsourcing competitions, and the platform has been used by more than 50 Federal departments and agencies. The website will continue to provide public listings of new competitions offered by the Administration to engage citizens in solving difficult problems to help agencies achieve their missions.

- **Increased Crowdsourcing and Citizen Science Programs.** Public participation in scientific research, one type of crowdsourcing known as "citizen science", allows the public to make

Challenge.gov
Government Challenges, Your Solutions

CHALLENGES | PRIZEWIRE | ABOUT | CONTACT | LOG IN | SEE HOW IT WORKS

NEWEST CHALLENGES

Sort

Search

702 Competitions Found

2016 CDFI Fund Prize Competition

$1,000,000 in prizes

The CDFI Fund is seeking new ways to increase CDFI Investments in Underserved Rural Communities

Open Until Jul 29, 2016

Posted by:
Department of the Treasury

Vascular Tissue Challenge

$500,000 in prizes

A first-to-demonstrate challenge to create thick, human vascularized organ tissue surviving 30 calendar days

Open Until Sep 30, 2019

Posted by:
National Aeronautics and Space Administration

$100,000 for Start a SUD Startup

NIH
National Institute on Drug Abuse

$100,000 in prizes

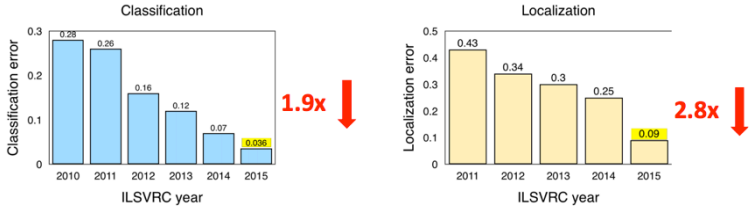
The goal of this Challenge is to enable biomedical scientists to test the hypothesis that their research idea can be fostered into…

Open Until Sep 16, 2016

Posted by:
National Institute on Drug Abuse

ImageNet Large Scale Visual Recognition Challenge (ILSVRC)

- Widely successful challenge for image classification
- ImageNet database
  - Over 15M labeled high resolution images
  - 21841categories
  - Collected from web and labeled by Amazon Mechanical Turk
- ILSVRC
  - Annual competition of image classification at large scale
  - 1.2M images in 1K categories
  - 10x improvement in 5 years



http://image-net.org/challenges/talks/ILSVRC2015_12_17_15_clsloc.pdf

Challenges have been successful in a number of areas including cancer genomics

Boutros *et al. Genome Biology* 2014, **15**:462
http://genomebiology.com/2014/15/9/462

Genome Biology

OPINION

Toward better benchmarking: challenge-based methods assessment in cancer genomics

Paul C Boutros[1,2,3] ... [8*]

Abstract

Rapid technological development has created an urgent need for improved evaluation of algorithms for the analysis of cancer genomics data. We outline how challenge-based assessment may help fill this gap by leveraging crowd-sourcing to distribute effort and reduce bias.

Why "challenges" in medicine?

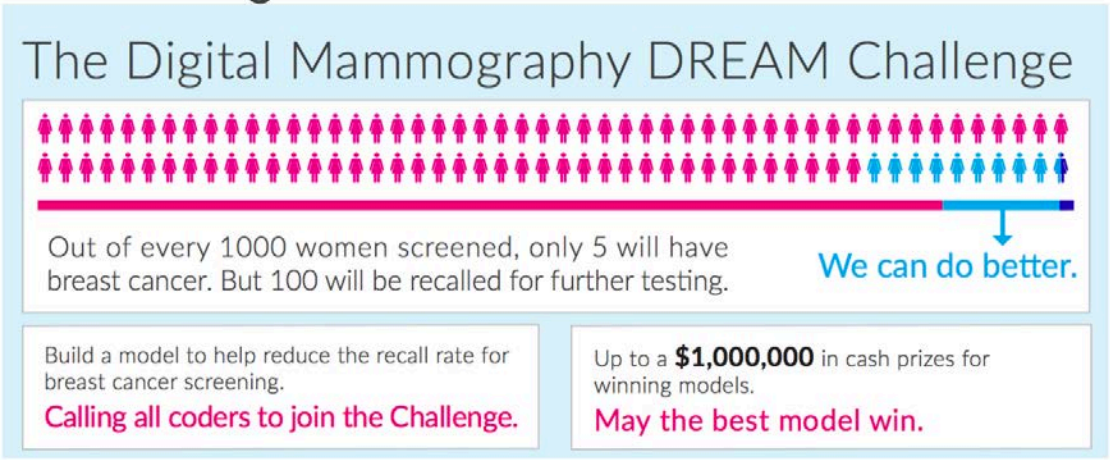
- Reproducibility is an issue in all aspects of medicine
  - Algorithm performance often not replicated by other sites
- Access to clinical data of sufficient variety can be a challenge for (computational) scientists developing algorithms
- Can evaluate the performance of techniques on real, noisy clinical data
- Test data (sequestered) can provide indication of algorithm generalizability to unseen data
- Allows for cross-pollination of methods from other domains
- Best algorithms can be translated into commercial products

Coding4Cancer

Challenges for improving cancer screening

The Digital Mammography ... » 2 - Challenge Overview

2 - Challenge Overview



https://www.synapse.org/#!Synapse:syn4224222

What is a "challenge"?

- Impartial group of scientists (govt./commercial org) organizes a 'challenge' to solve a (clinical relevant) problem
  - Meaningful question
  - Well curated, representative dataset
  - Well established evaluation metrics
- Typically split into a training dataset, a validation dataset (optional) and test dataset
  - Test data withheld from challenge participants and used for final evaluation
- Leaderboards can provide real-time feedback to participants based on the validation dataset
- Final results based on (gold-standard, preferably independent) test dataset
- Such a design closely reflects the actual difficulties faced by real-world users trying to determine whether **an algorithm generalizes to unseen cases**

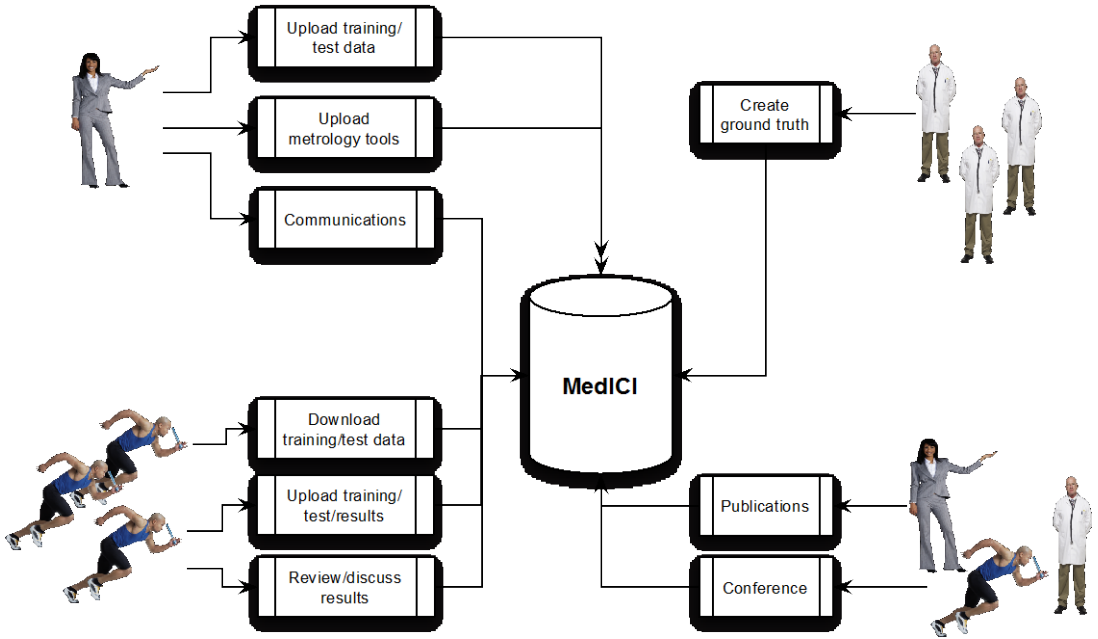
Where are challenges conducted?

- At annual conferences sponsored by scientific societies
  - The Medical Image Computing and Computer Assisted Intervention Society (MICCAI) has held “grand challenges” since 2007
  - International Symposium on Biomedical Imaging (ISBI)
  - SPIE
- On commercial platforms
  - Kaggle
  - TopCoder
  - Sage/Synapse
- Within Organizations such as Quantitative Imaging Network (NCI) and Quantitative Imaging Biomarker Alliance (RSNA)

How are challenges typically conducted?

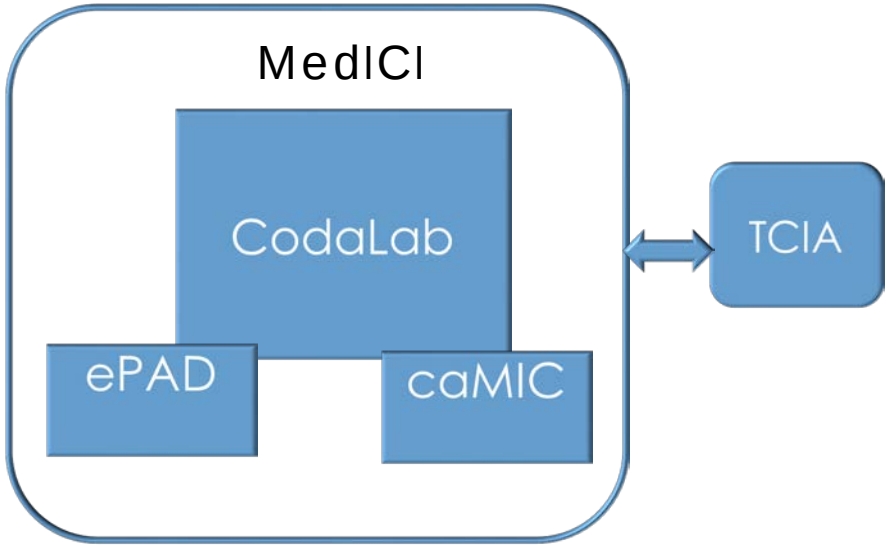
- Organizers identify a "challenge"
- Organizers generate/identify "ground truth" for training and test data
- Organizers define evaluation metrics
- Organizers announce challenge
- Interested participants register and download data
- Participants apply their methods to the training data and obtain results. If satisfactory, participants apply methods to test data
- Upload results test data results
- Results made available to community ("leader board"), perhaps at conference
- Prizes can be awarded

System overview



MedICI: a challenge management software suite

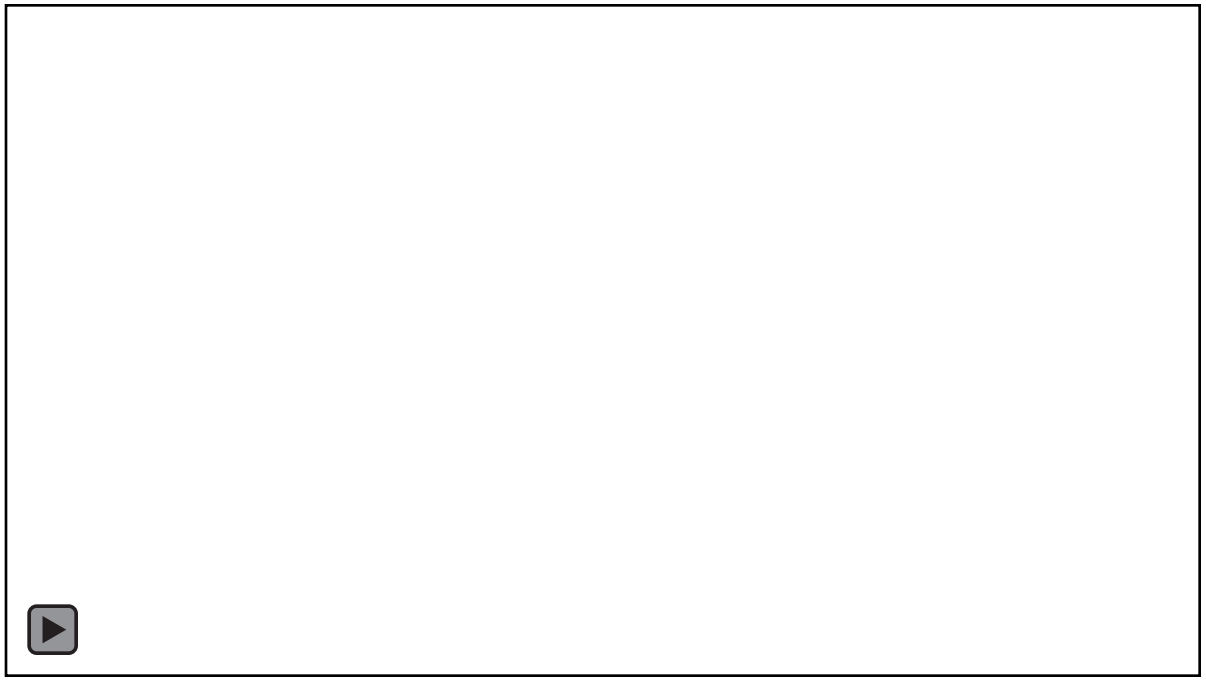
- Goals:
  - Facilitate challenge organization
  - Facilitate challenge participation
  - Support imaging (radiology, pathology) and genomic challenges
  - Statistical analysis
  - Visualization of results
  - Open source, flexible
  - Support integration with TCIA/TCGA



CodaLab

- Open source project created by Microsoft Research and now owned by OuterCurve Foundation
- Worksheets and Competitions
- Hosted on github
- Based on Python/Django framework
- Developed based on work from machine learning community
- Good for user management
- Hosted version available at CodaLab.org

Challenge organization



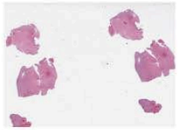
Front page

MICCAI 2015 CBTC

Worksheets Competitions Help Sign In

Competitions

Search... Search



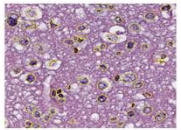
Combined Radiology and Pathology Classification

Organized by artem

This challenge is to evaluate the performance of automated classification algorithms when information from two types of imaging data – Radiology ...

Jul 01, 2015-*No end date*

2 participants



Segmentation of Nuclei in Pathology Images.

Organized by artem

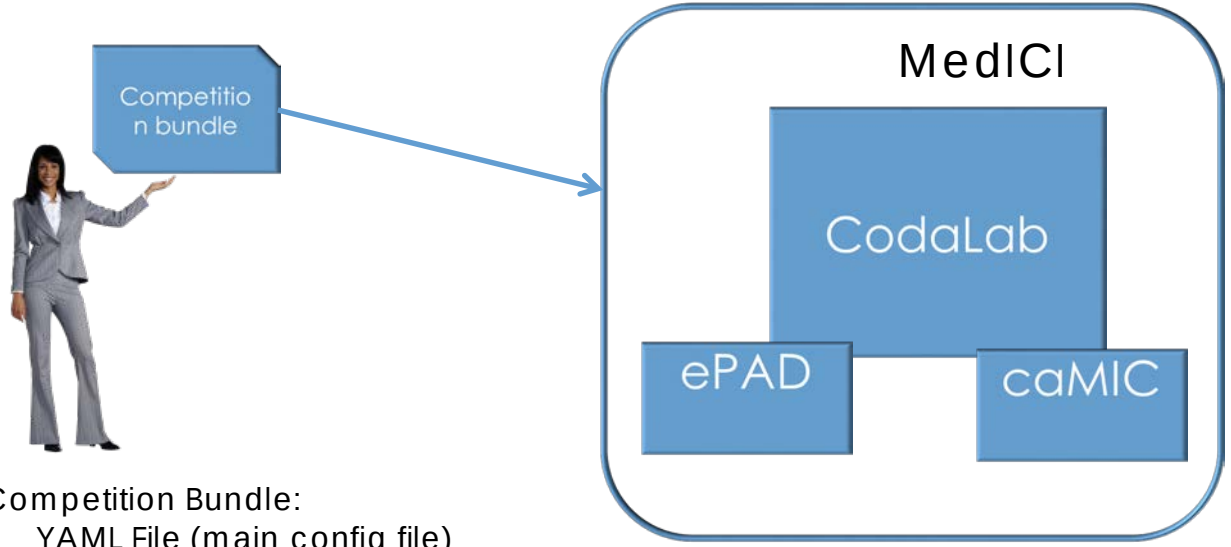
This challenge is to evaluate the performance of algorithms for detection and segmentation of nuclear material in a tissue image.

Jul 01, 2015-*No end date*

3 participants

Learn how to create your own competition.

Setting up a competition by an organizer



Competition Bundle:

- YAML File (main config file)
- HTML files describing various pages
- Data (optional at this stage)
- Ground truth (optional at this stage)
- Phases (optional at this stage)
- Scoring Metrics(optional at this stage)
- Enter name of TCIA Shared list in competition setup (optional at this stage)
- All setup is done in CodaLab, no specific setup of ePAD and caMIC is needed

Organizing a challenge

- Upload basic “bundle”
  - Include yaml config file
- Upload evaluation
  - Ground truth
  - Evaluation program (executable, python script)

```
competition.zip
  |- competition.yaml
  |- data.html
  |- evaluation.html
  |- logo.jpg
```

Here are the contents of the reference.zip file:

```
reference.zip
  |- answer.txt (Contains: 3.14159265359)
  |- metadata   (Contains: This is the authoritative result.)
```

Here are the contents of the program.zip file:

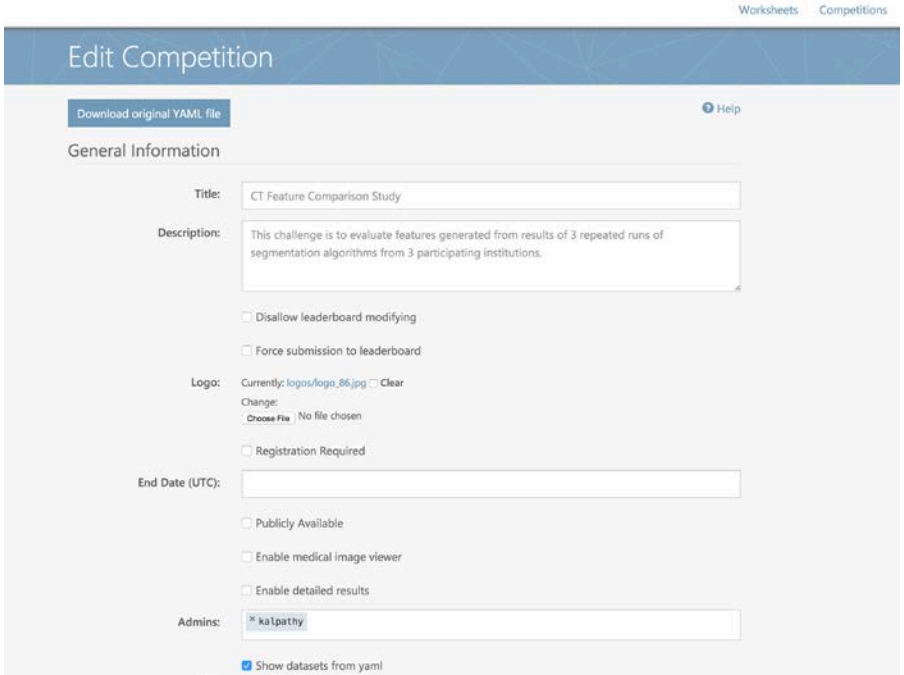
```
program.zip
  |- evaluate.py (The actual evaluation code to run)
  |- metadata     (Syntax and information needed to run)
  |- readme.txt (Contains notes about the evaluation program)
  |- setup.py (Enables py2exe to build a windows executable of the evaluate.py script)
  |- Supporting modules and libraries (if required).
```

The program.zip metadata file contains command syntax to use, along with a short description:

```
command: python $program/evaluate.py $input $output
description: Example competition evaluation program.
```

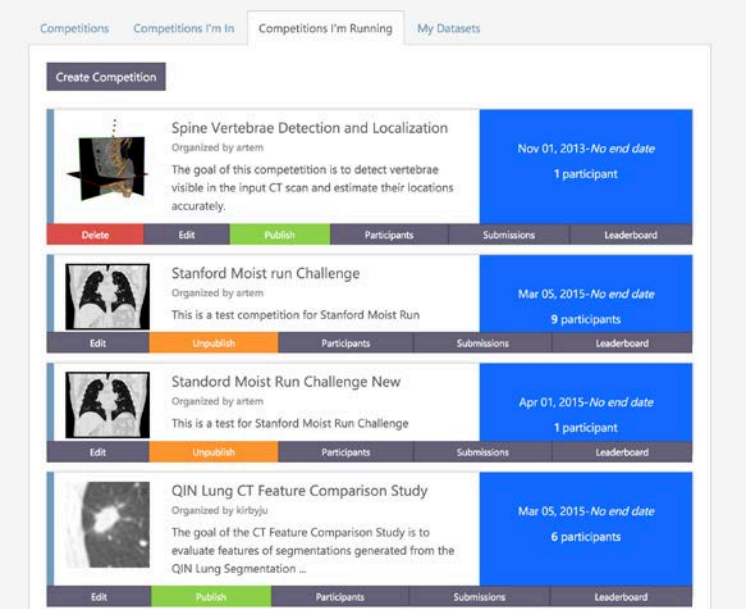
Editing a challenge

- Can be edited through web interface

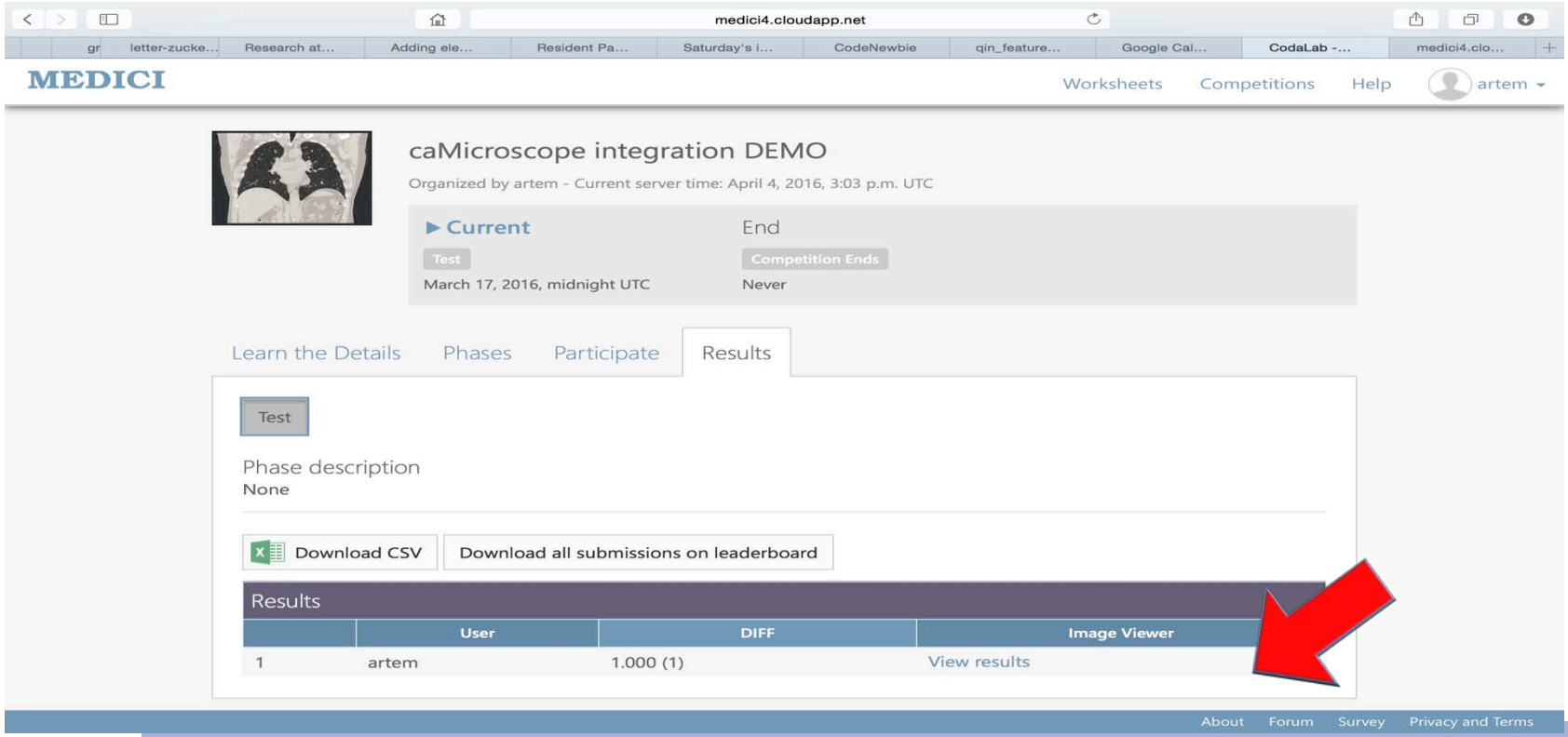


Publish/unpublish

- Challenge can be created without making it visible to public
  - Only other organizers can view it



Integration of caMicroscope with CodaLab



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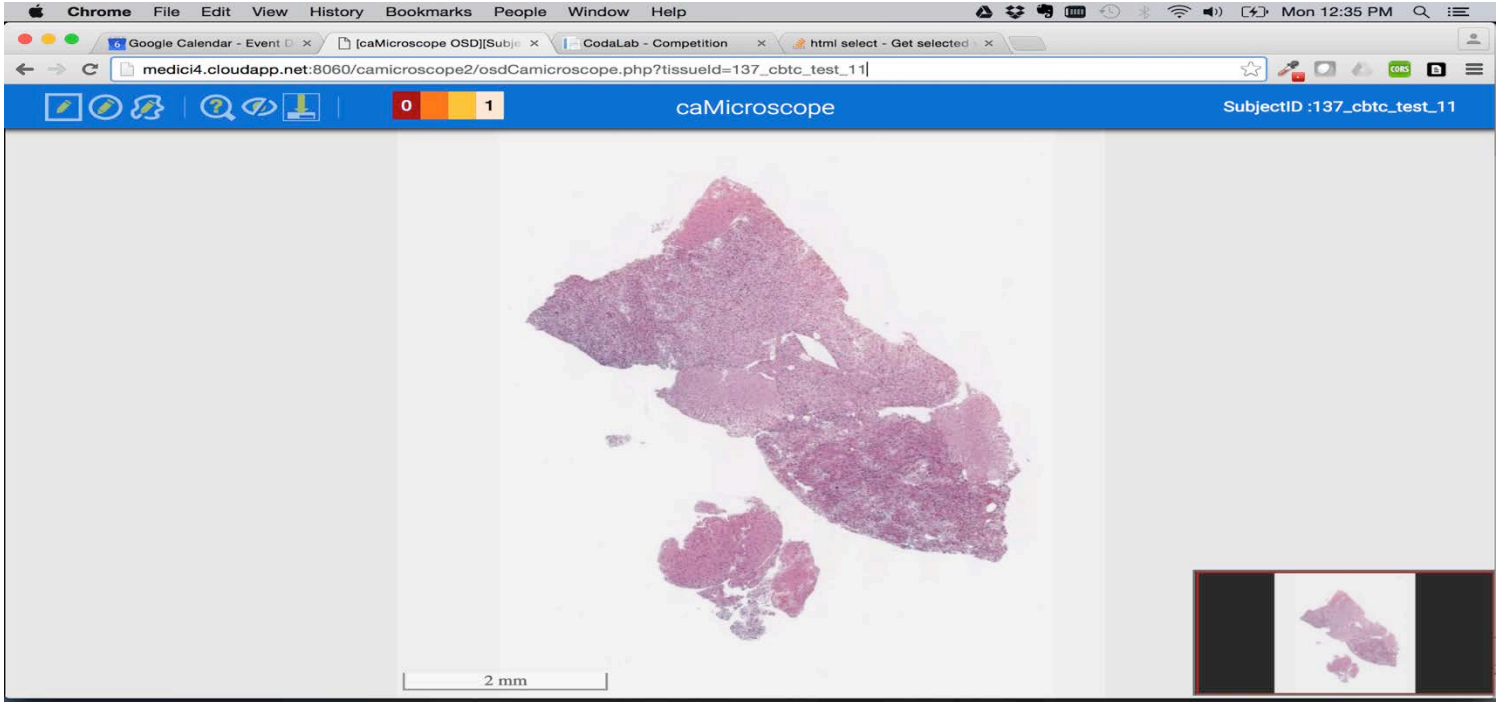
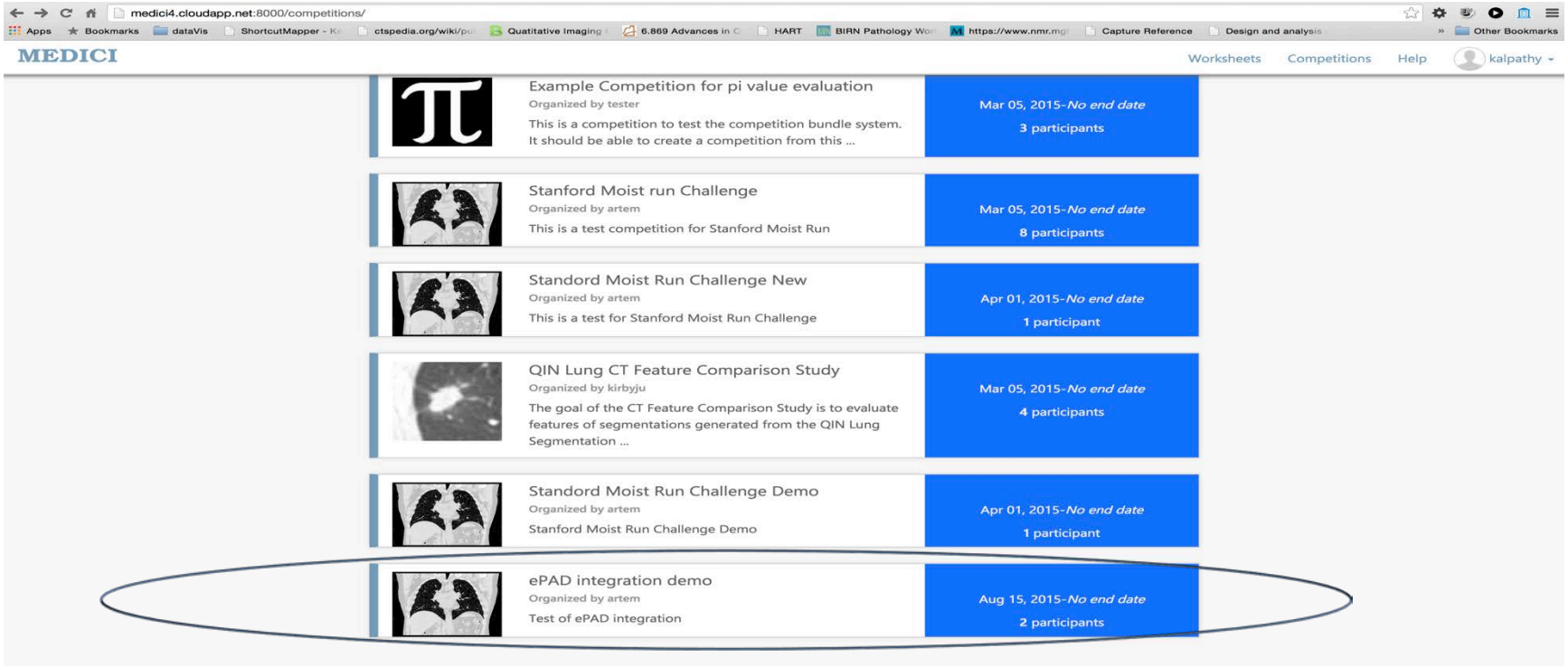
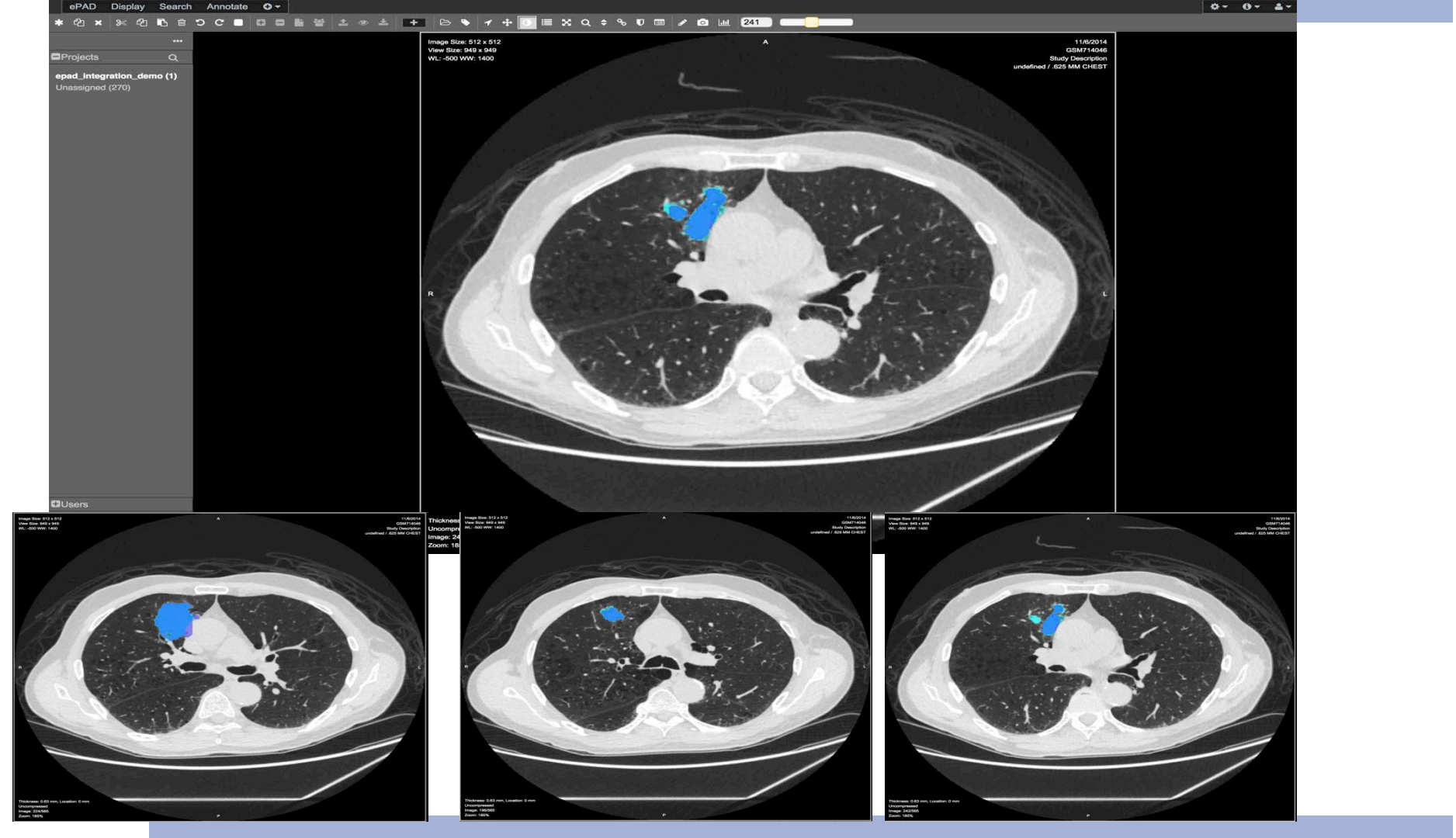


ePAD integration



ePAD on Azure VM using Docker


ePAD
Display
Search
Annotate
Projects
epad_integration_demo (1)
Unassigned (270)
Users
Image Size: 512 x 512
View Size: 949 x 949
WL: -500 WW: 1400
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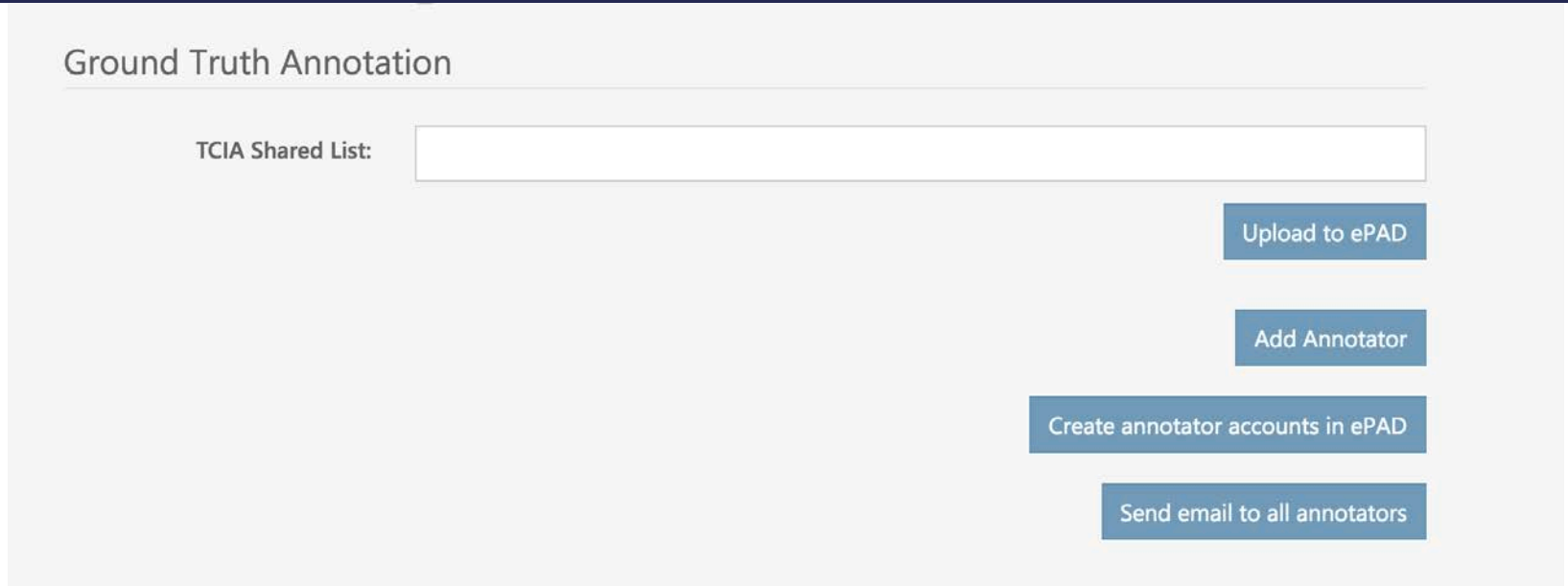
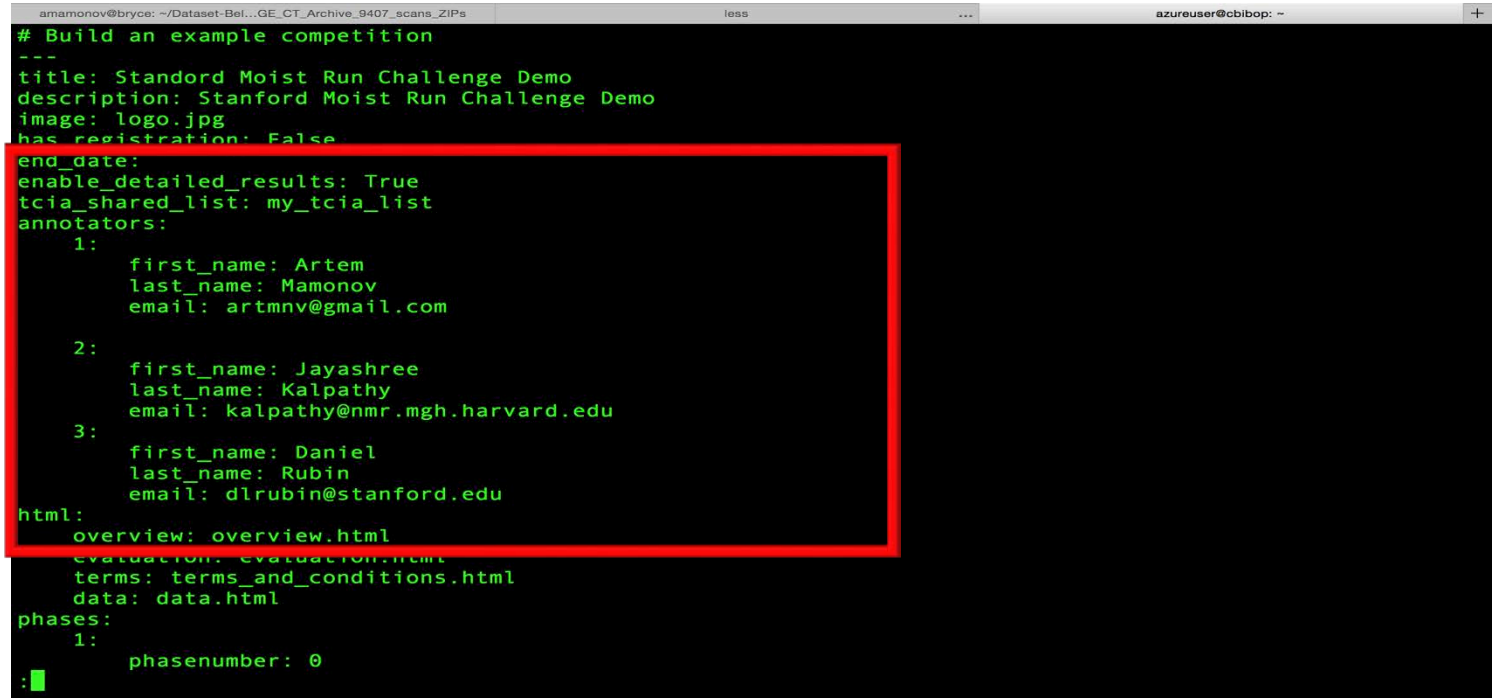
TCIA

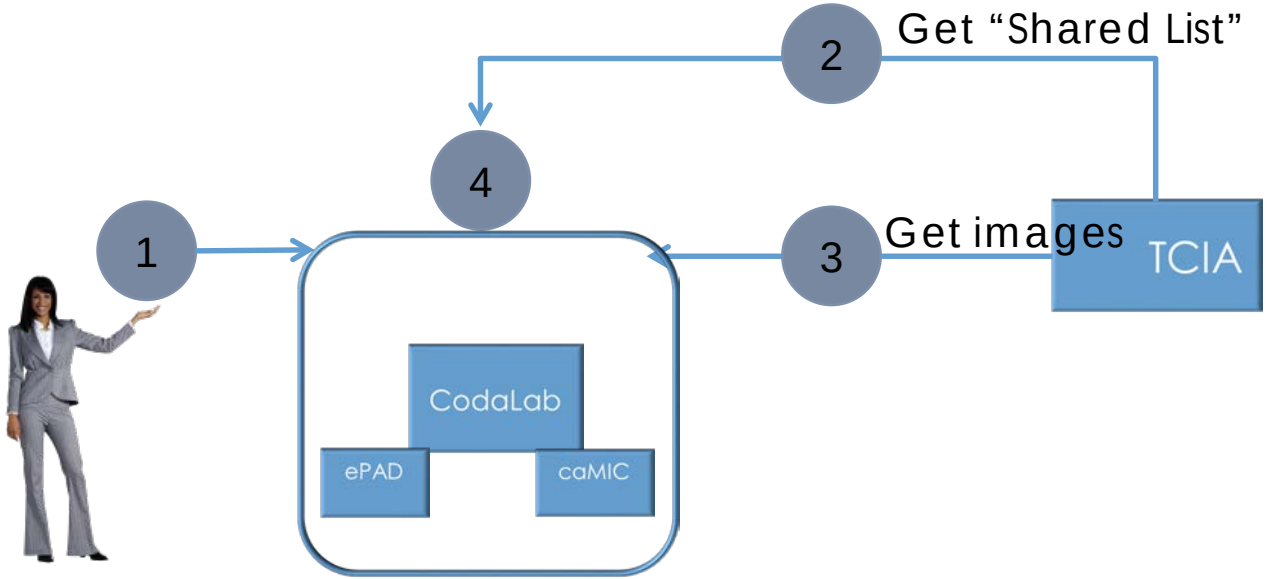


- Integration with TCIA

Integration with TCIA



Creating Ground Truth



1

Organizer provides a name of the shared list in the web interface of a competition

2

CodaLab retrieves a shared list from TCIA using REST call and parses it to obtain Series UIDS

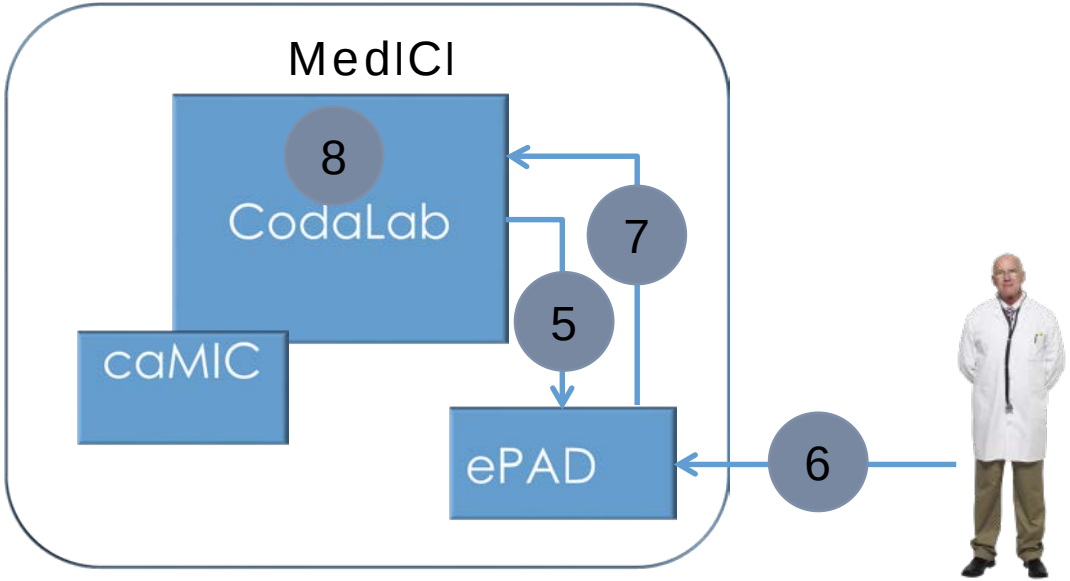
3

CodaLab downloads images from TCIA using REST call and Series UIDs

4

CodaLab de-identifies images and stores them in Codalab

Creating Ground Truth, cont'd



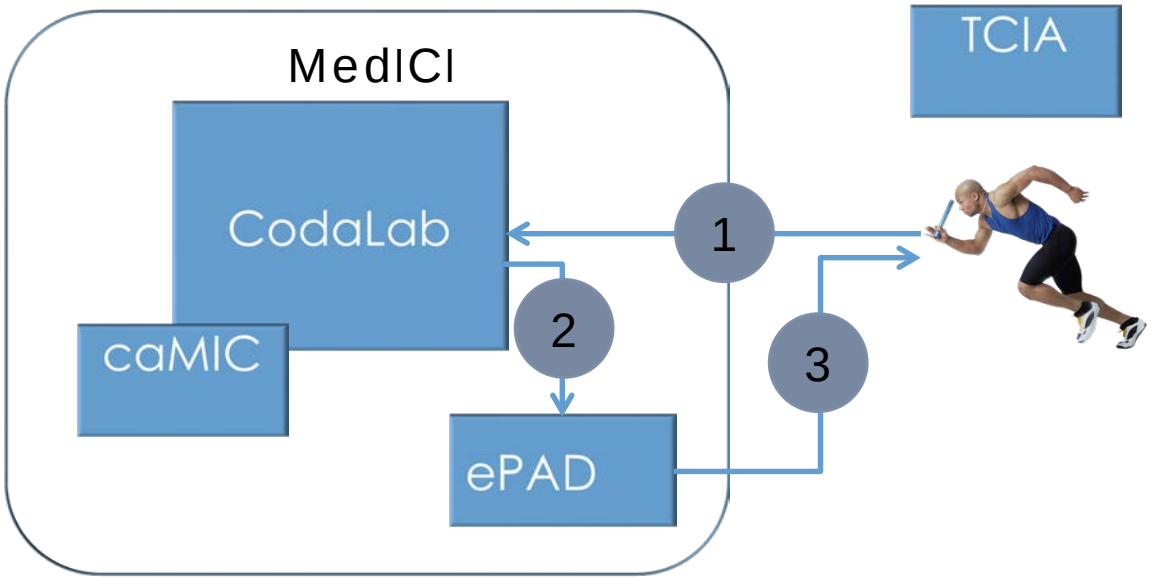
5 CodaLab uploads de-identified images to ePAD using REST call

6 Experts annotate Images in ePAD

7 Segmentation objects are sent to CodaLab using REST call

8 These segmentation objects are used as "ground truth" in a competition

Visualizing results



1

Competition participant uploads results and clicks on “View results” link in the Results section

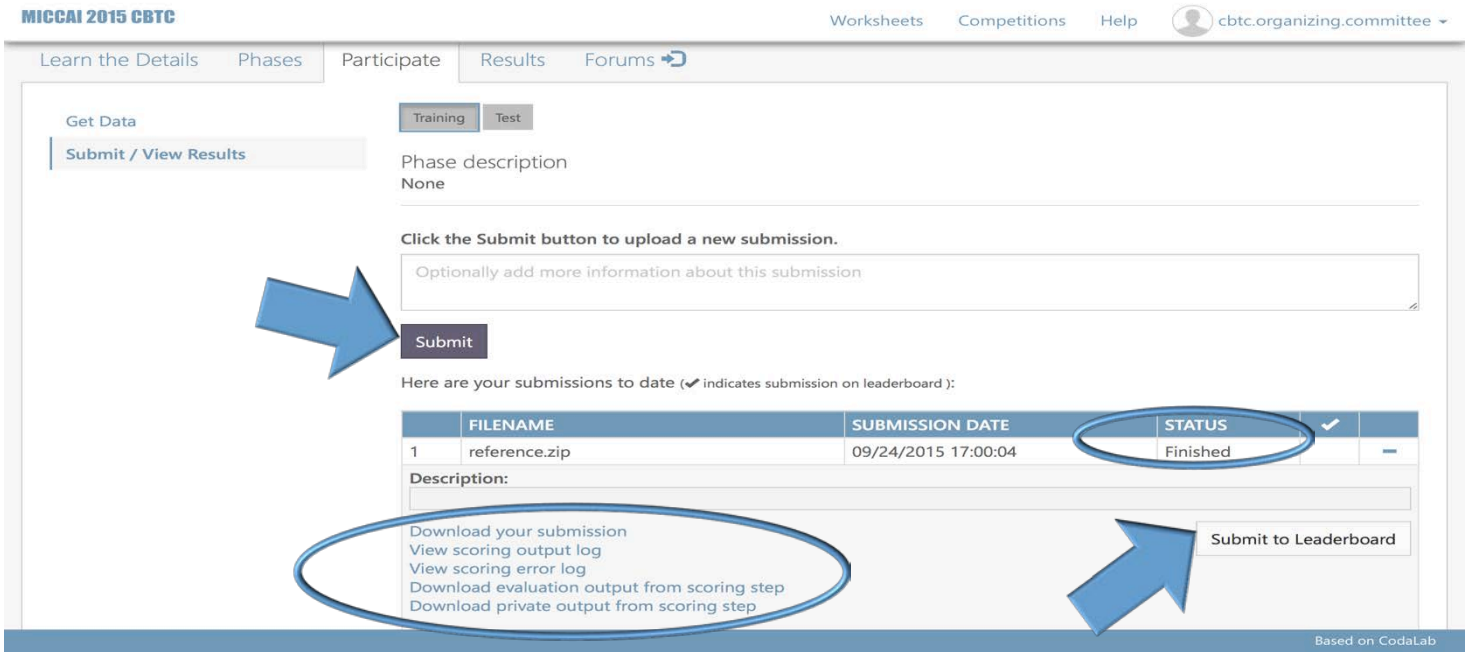
2

CodaLab uploads segmentation results and ground truth to ePAD using REST call

3

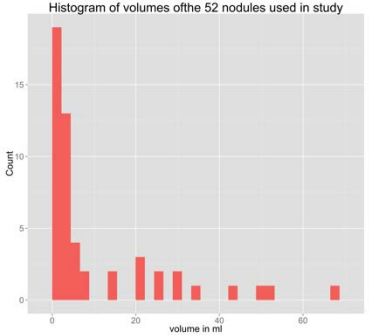
CodaLab authenticates a user with ePAD and opens an ePAD window for a participant to view the results

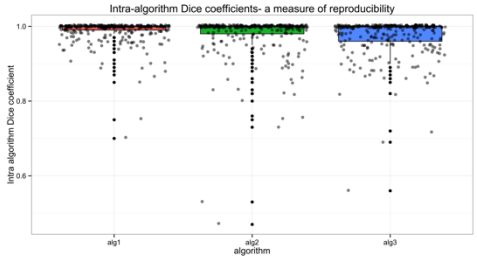
Submitting results for automatic evaluation

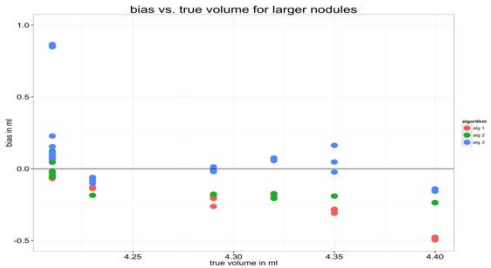


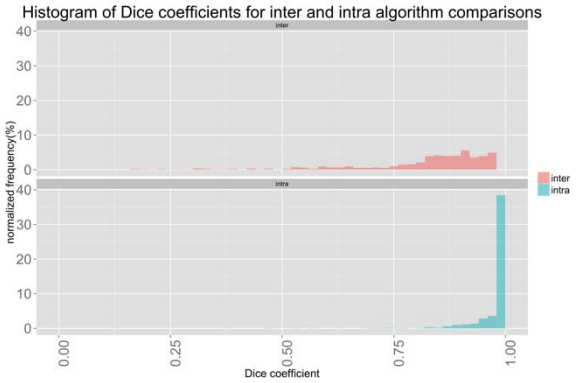
Statistical package integration

Integration with R for statistical analysis and interactive data visualization

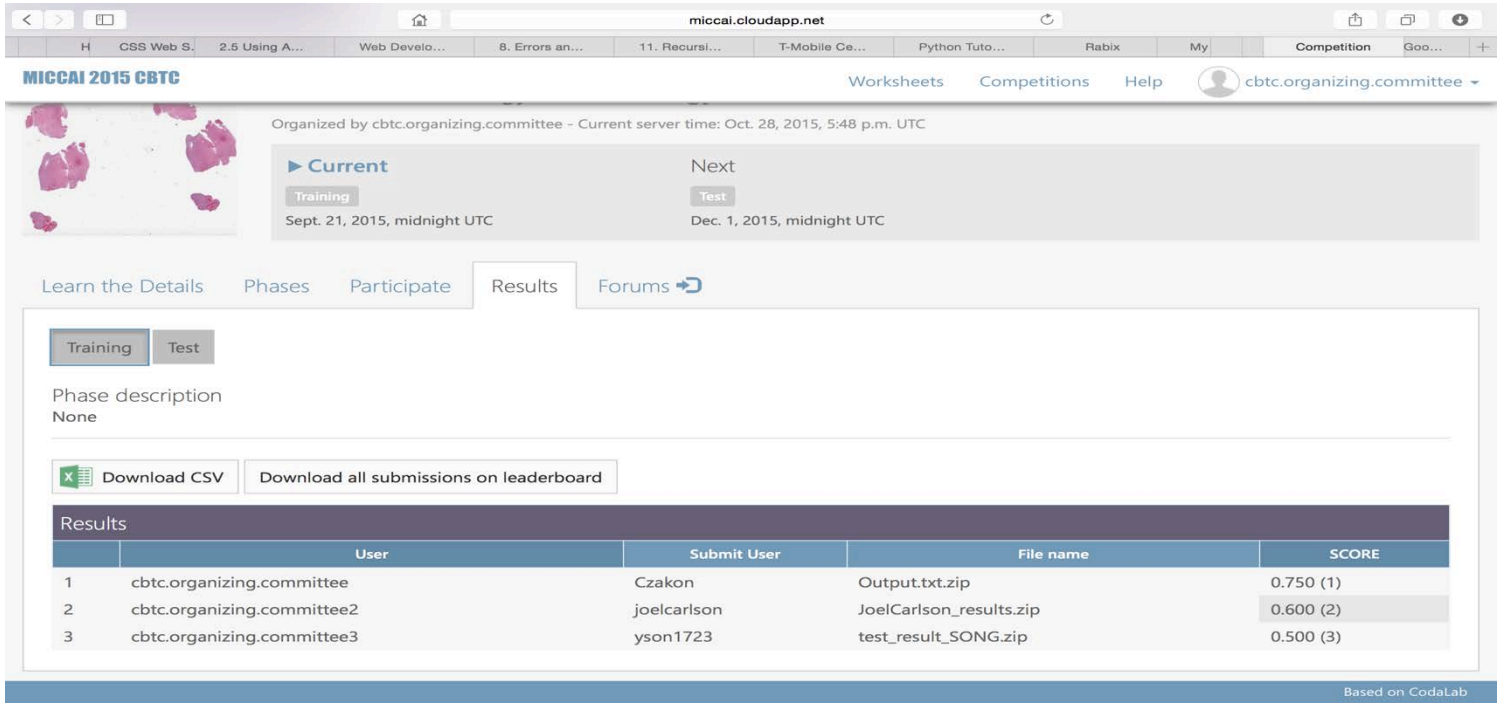








Leaderboard



Forum

- Of emails (w
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QINLABS

My Competitions Help artem

QIN BMMR - Breast MRI Metrics of Response Forum

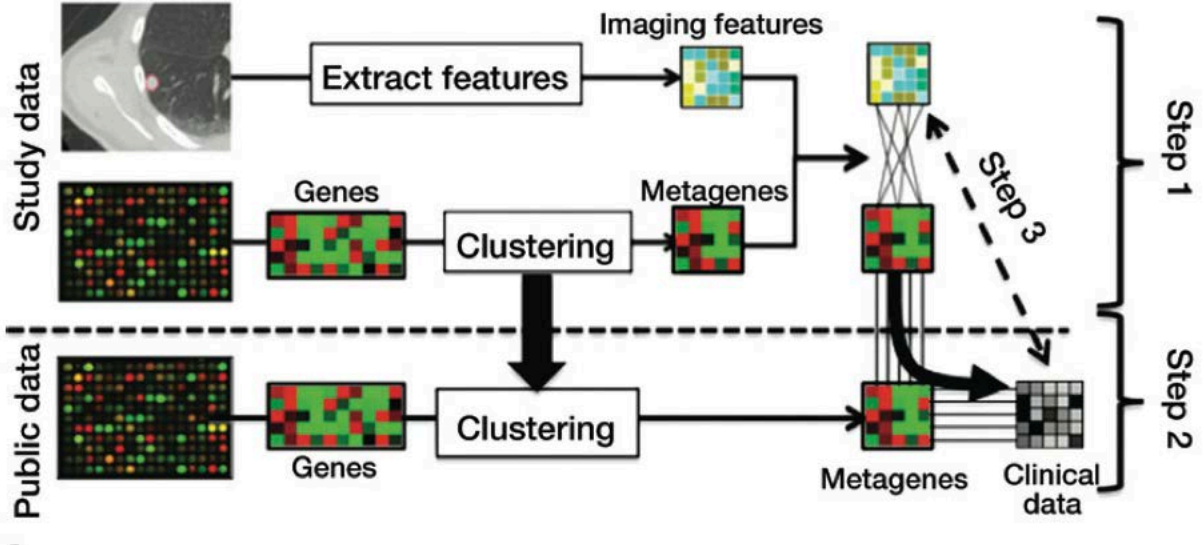
Go back to competition

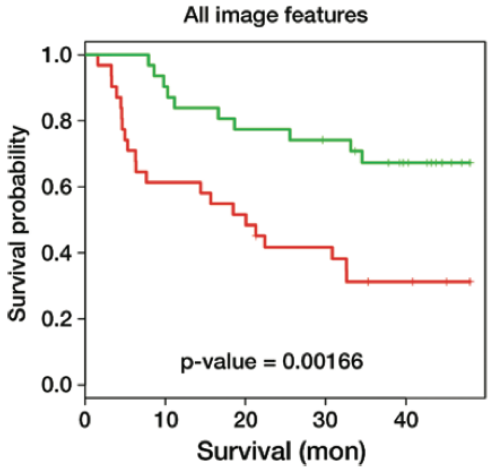
Start a new topic

Title	Started by	Date created	Latest post	Posts
QIN_BMMR_Training DCEonly_HRknown	dlrubin	Jun 28, 2016	6 days, 8 hours	4
ROI (Lesion Segmentation)	acheerla	Jun 27, 2016	1 week	2
Tumor Segmentation	acheerla	Jun 28, 2016	1 week	2
Metadata / directories: too many or not enough T1 directories	FiReTiTi	Jun 17, 2016	1 week, 5 days	6
44 exams not in shared list	UC	Jun 14, 2016	2 weeks, 5 days	5
Inter-regimen cases 1224 and 1230 slices mis-aligned between pre and post images	UC	Jun 14, 2016	2 weeks, 5 days	4
Test set: problem in number of pre and post contrast files	baishali	May 28, 2016	3 weeks, 1 day	5
question about number of result submissions for test set	UC	May 27, 2016	1 month	2
Information about the directories downloaded	FiReTiTi	May 07, 2016	1 month, 2 weeks	5
DCE exams with unexpected number of image files	UC	May 13, 2016	1 month, 2 weeks	2
BR-15 MR1 seems corrupted	UC	May 10, 2016	1 month, 3 weeks	2

Radiogenomics
(Radiopathagenomics...)

- Radiomics
- Genomics
- Clinical prediction/out comes





Gevaert et al, Radiology, 2012

How are image features derived?

- Clinicians provide semantic input
  - Binary
  - Scale
  - e.g. LIDC, VASARI
- Mathematical descriptors (based on tumor segmentation)
  - Texture, shape, intensity, SIFT…
  - Segmentation can be manual or automatic

Barriers to scaling up radiomics/radiogenomics studies

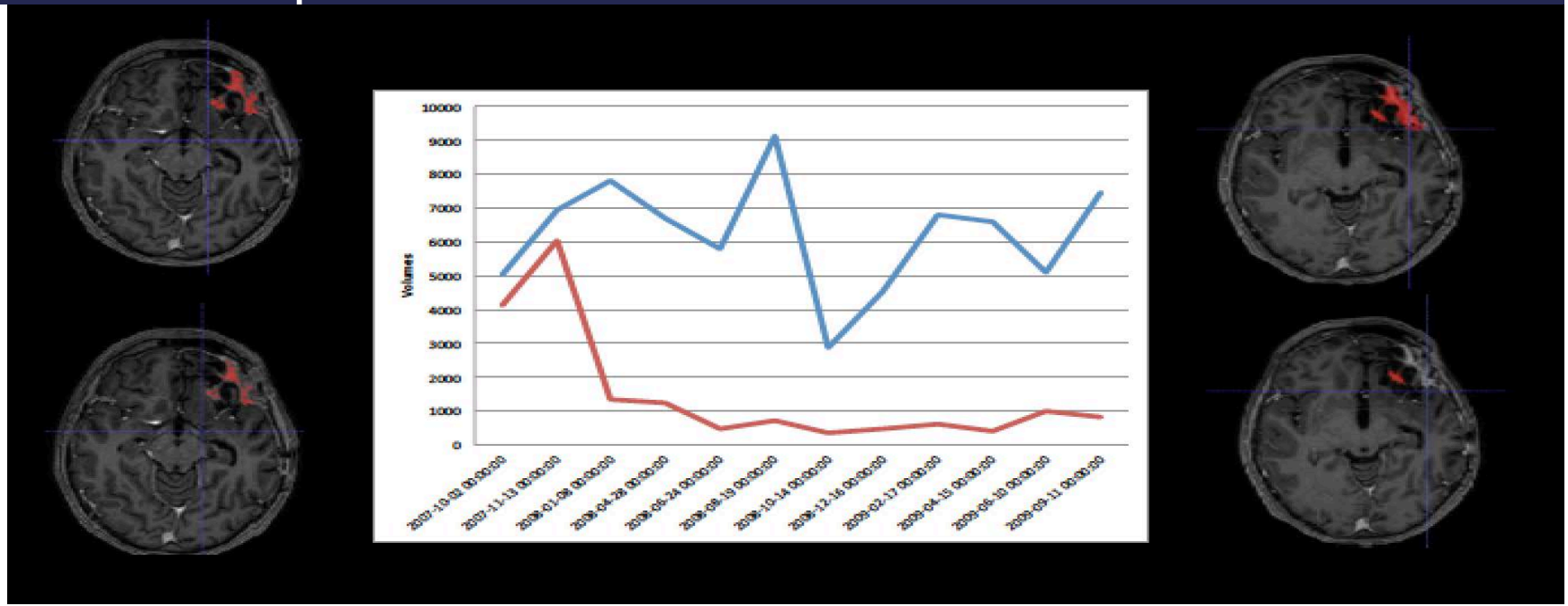
- Access to large datasets
  - TCIA/TCGA have lowered the barrier
- Interoperability of annotations
  - AIM/DICOM-SEG/DICOM-SR
  - Controlled terminology (e.g. RadLex)
- Generation of imaging annotations
  - Segmentation often basis of feature extraction
  - Need scalable means of generating segmentations and annotations

Human annotations

- Challenging to scale up process of human annotations
  - Although very successfully demonstrated for TCIA datasets, not typical
- Time consuming and subject to lack of inter-rater agreement
  - LIDC demonstrated some of these issues and the need for adequate QA and process well
  - “71 lesions received “nodule >3 mm” marks from at least one radiologist; however, all four radiologists assigned such marks to only 24 (33.8%) of these lesions. “
- Generate consensus for experts?
- Explore use crowd sourcing to get more annotations?
  - Cell Slider (CRUK) demonstrated the power for “citizen science”

Armato et al, Acad Radiol, 2007

Example case: Would the choice of reader affect the response assessment/radiomics features?



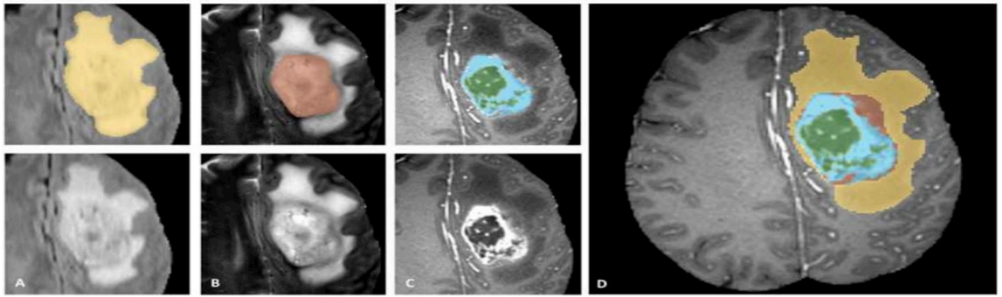
Why automated?

- Manual annotations are
  - Subjective
  - Time consuming
    - 1D or 2D typically
  - Expensive
- Computational techniques and hardware are evolving rapidly
- Can extract more characteristics than just size

MICCAI Brain tumor segmentation challenge

- Organized by academics, NCI
  - Dozens have participated at MICCAI and used data subsequently
  - 100+citations since 2015
- Being run since 2012
  - Had 3-4 experts label volumes
- In 2014, added data from TCIA-GBM collection
  - Test labels were machine generated (not optimal)
- 2015 added expert labels
  - 2 experts
- 2016 -longitudinal data, additional datasets
- ”deep learning” demonstrating excellence performance

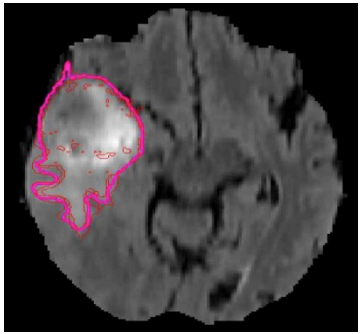
Manual Segmentation (4 labels)

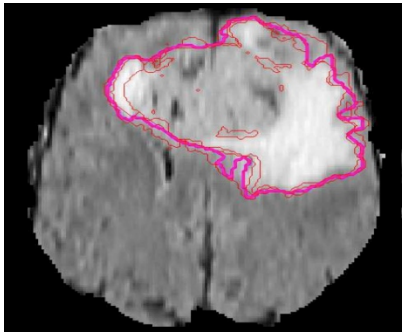


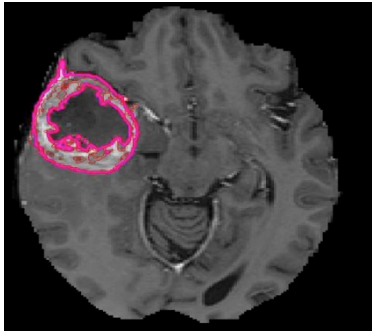
- Manual annotation through expert raters:
- the whole tumor visible in FLAIR (A),
- the tumor core visible in T2 (B),
- the enhancing active tumor visible in T1c (blue),
- surrounding the cystic/necrotic components of the core (green) (C). The segmentations are combined to generate the final labels (D): edema (yellow), non-enhancing solid core (red), active core (blue), non-solid core (green).

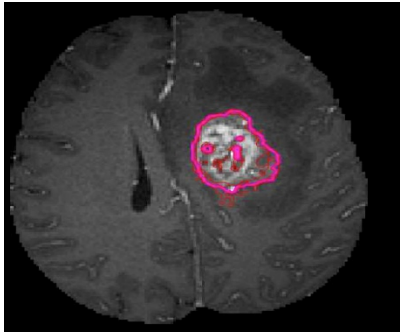
Menze, Jakab, Bauer, Kalpathy-Cramer et al, 2014, IEEE Trans. Med. Imaging

Example slices with output of segmentation algorithms

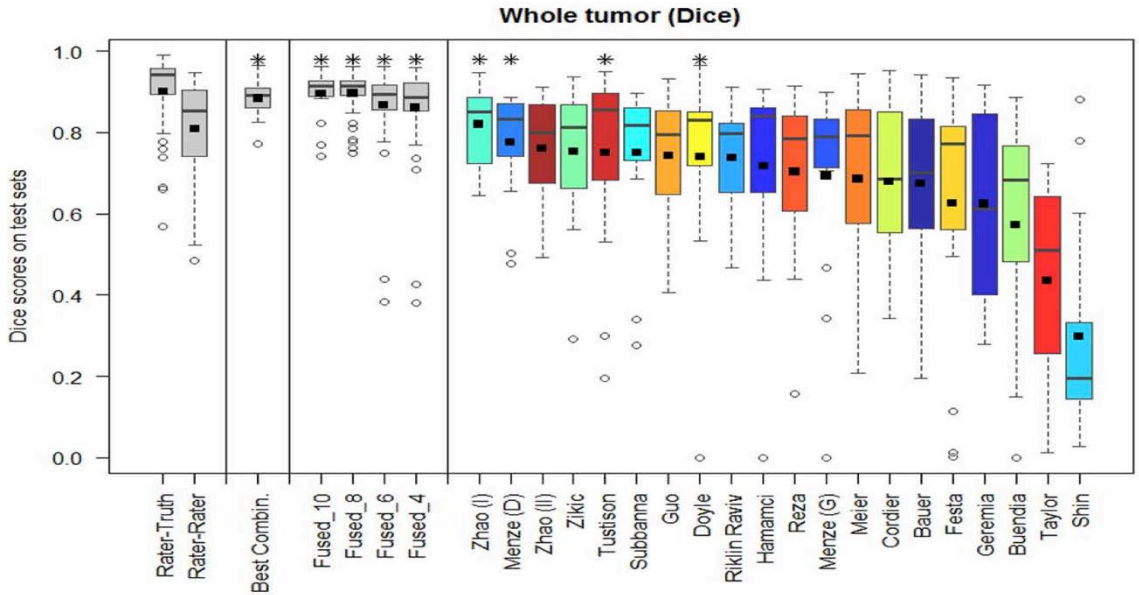








Results of computer generated labels



- Improvement by combining best methods

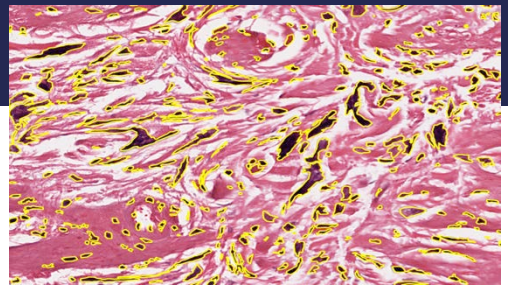
BraTS challenge output

- Over 100 research publications (conference papers, manuscripts)
- Robust open-source segmentation methods for MR brain tumor segmentation
- Expert segmentations of ~20-50 cases in TCIA
- Consensus segmentations of all brain tumor cases back to TCIA (in 2016)
- Continued resource to the community

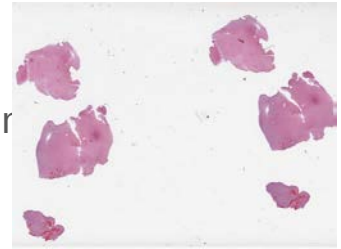
Challenge organizer perspective

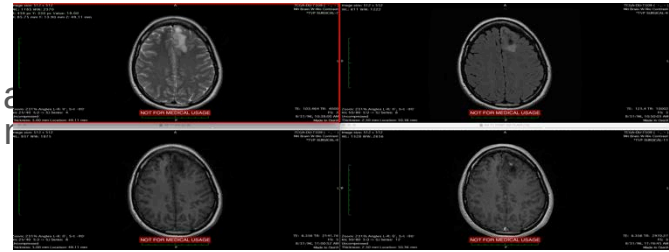
- Potential for being a great resource to the community
  - Benchmark to compare improvements in field
  - Get participation from non-experts in field
  - Opportunity to build community
- However, can be very time consuming
  - Mixed academic value (not necessarily research but potential for large number of citations)
  - Communication is large factor in success of challenge
  - Infrastructure and resources are critical

MICCAI CBTC 2015



- Nuclear segmentation in pathology images:
  - image tiles from whole slide tissue images
  - For training set nuclei in each tile have been manually segmented
  - http://miccai.cloudapp.net:8000/competitions/37
- Joint radiology/pathology classification challenge:
  - Classify Low grade glioma cases from TCIA (LGG) into Oligoder and Astrocytoma
  - Training data consists of “ground truth” classification
  - Training set consists of 32 cases.
  - Test set consists of 20 cases.
  - Combined Radiology and Pathology Classifica (http://miccai.cloudapp.net:8000/competitio

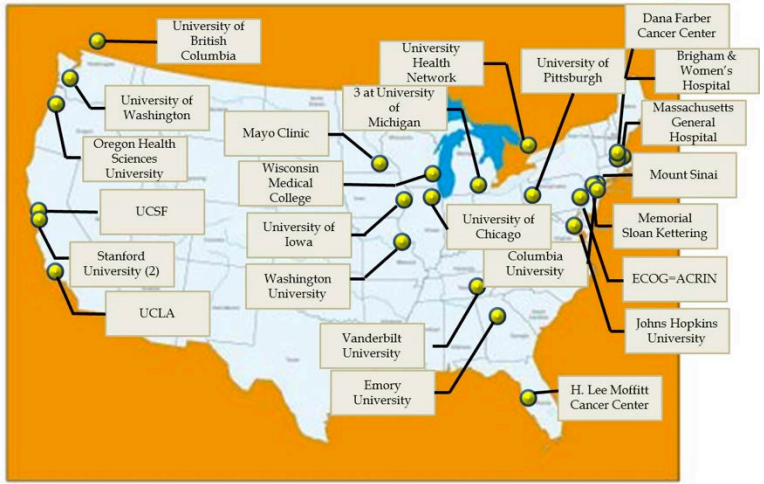




Ongoing and upcoming challenges

- MICCAI 2016
  - Joint radiology pathology challenge
  - Radiomics challenge (head and neck)
    - Prize: publication!
  - Radio-pathomics challenge (liver mets)
  - Breast CAD (mammography)
- Digital pathology challenge
- QINLabs
  - Breast challenge
  - CT feature challenge
  - ~6-10 new challenges planned for next cycle

Quantitative Imaging Network

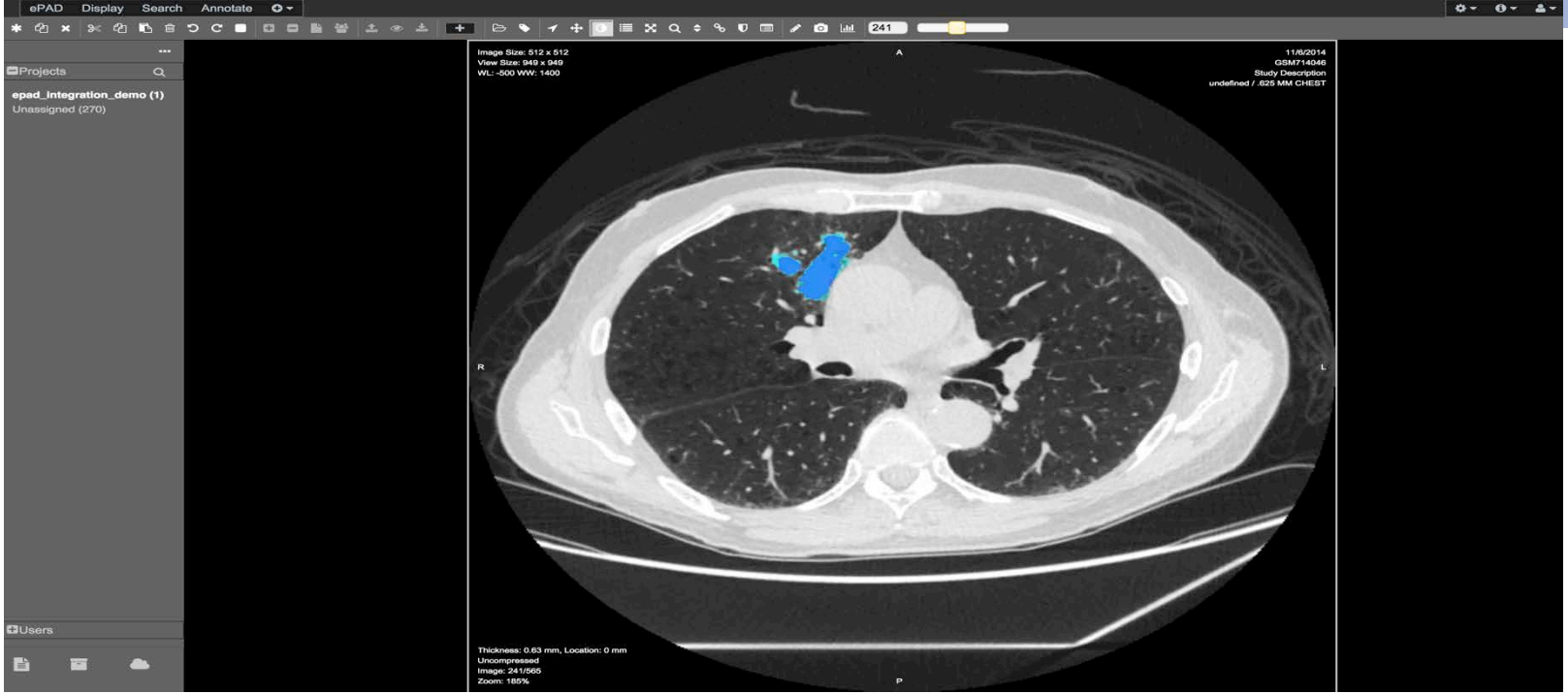


The network is designed to promote research and development of **quantitative imaging** methods for the **measurement of tumor response** to therapies in clinical trial settings, with the overall goal of facilitating clinical decision making.

Grant arose from the collaborative projects as part of QIN

QIN challenge: Lung nodule segmentation

- 52 lesions from 41 CT studies
- 33 to µl to 57 ml and demonstrated a diversity of shapes from round through spiculated.
- Three algorithms, each submitted 3 repeat segmentations per nodule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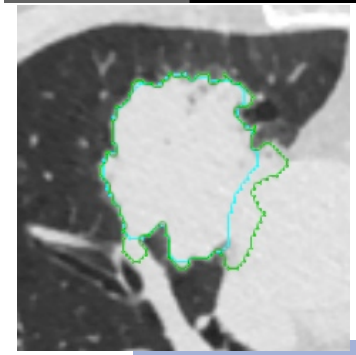
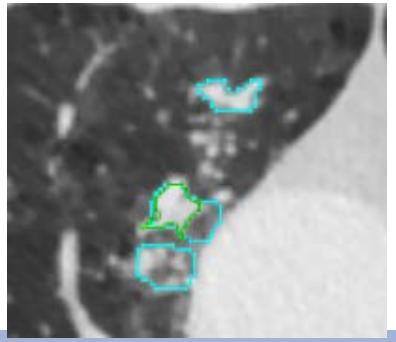


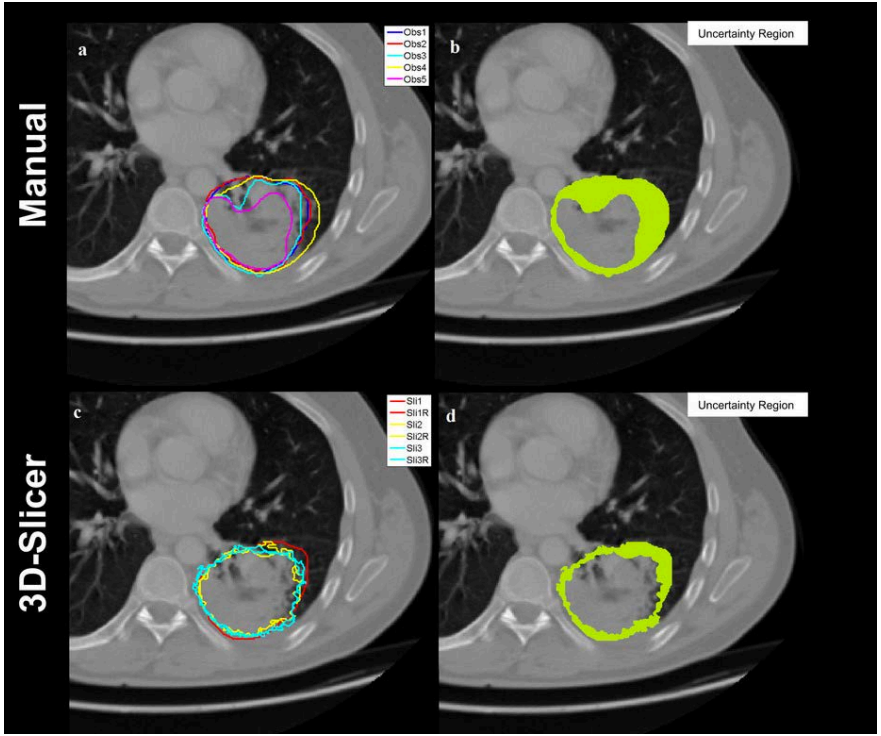


Output of challenge

- CT volumes in TCIA (existing collections)
- Segmentations in TCIA (in DICOM-SEG format)
- Segmentations can be used for radiomics and radiogenomic studies (underway in QIN)
  - Stability of features
  - Correlation between features
  - Identify “habitats” or sub volumes based on features

Features can be sensitive to segmentation

- Reduced uncertainty with machine assisted segmentation

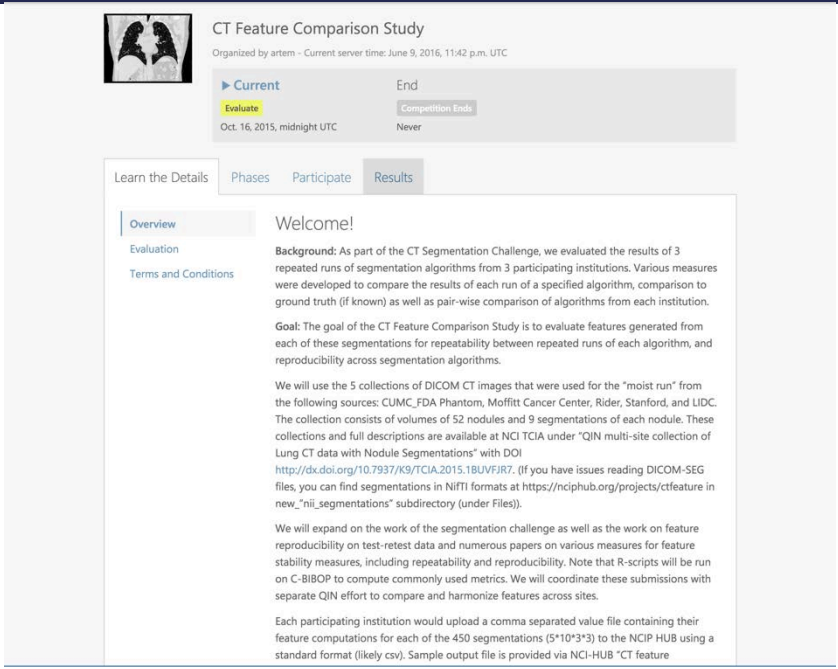


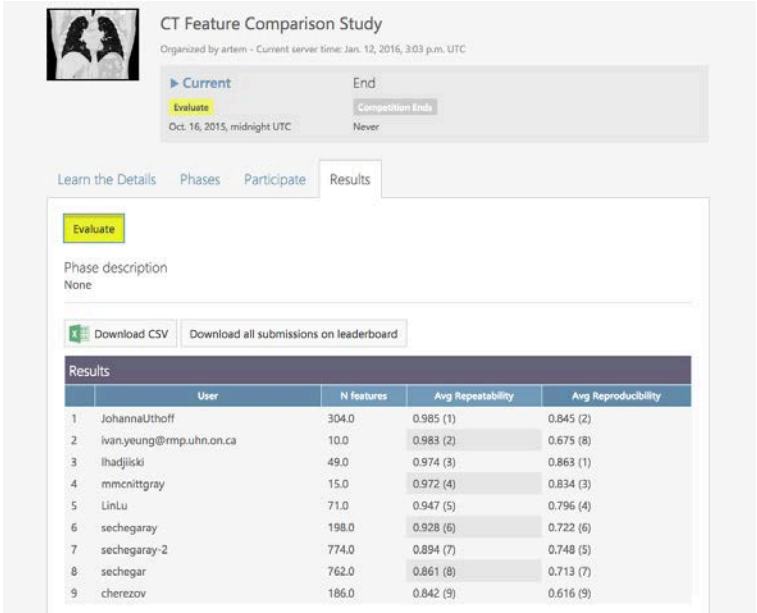
Velazquez et al, Sci. Rep. 2013

QIN Feature comparison challenge

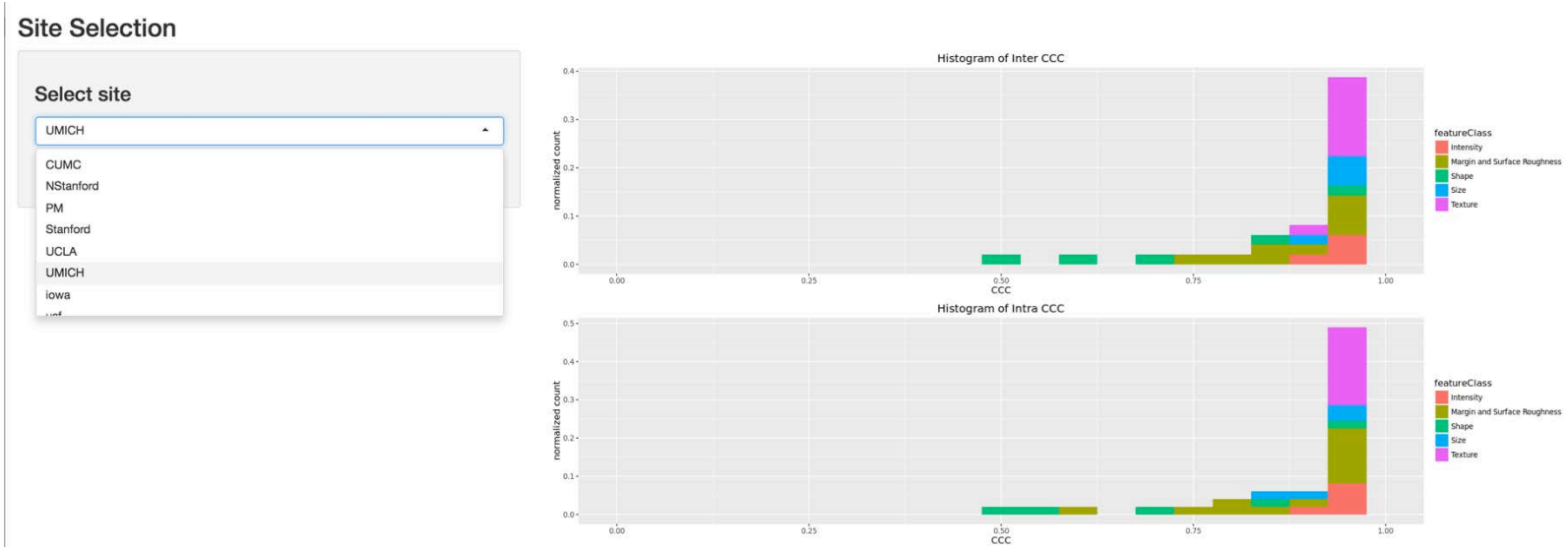
- “Radiomics” pipelines allow for the quantification of imaging characteristics
  - Can be used in outcomes research
  - Radiogenomics
  - However, features can be sensitive to segmentation
- 8 QIN sites participated
- 10-300 features per site

CT Feature challenge



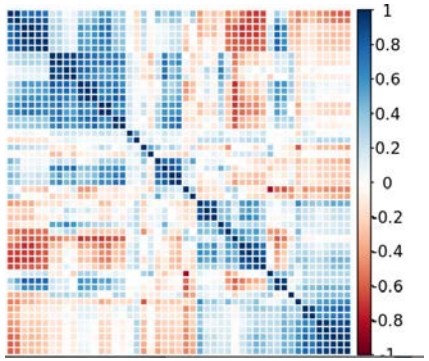


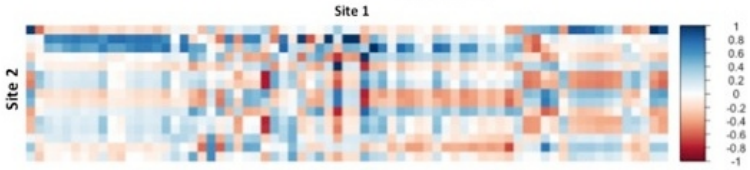
Results



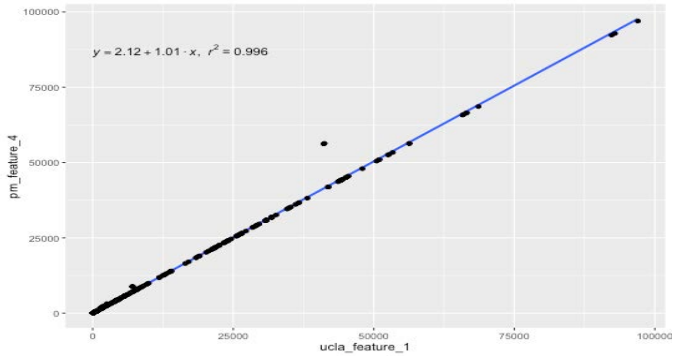
- Feature stability with respect to segmentation

Results





c. Example of heat map of correlation between features submitted between two sites highlighting the high correlation of features across implementation



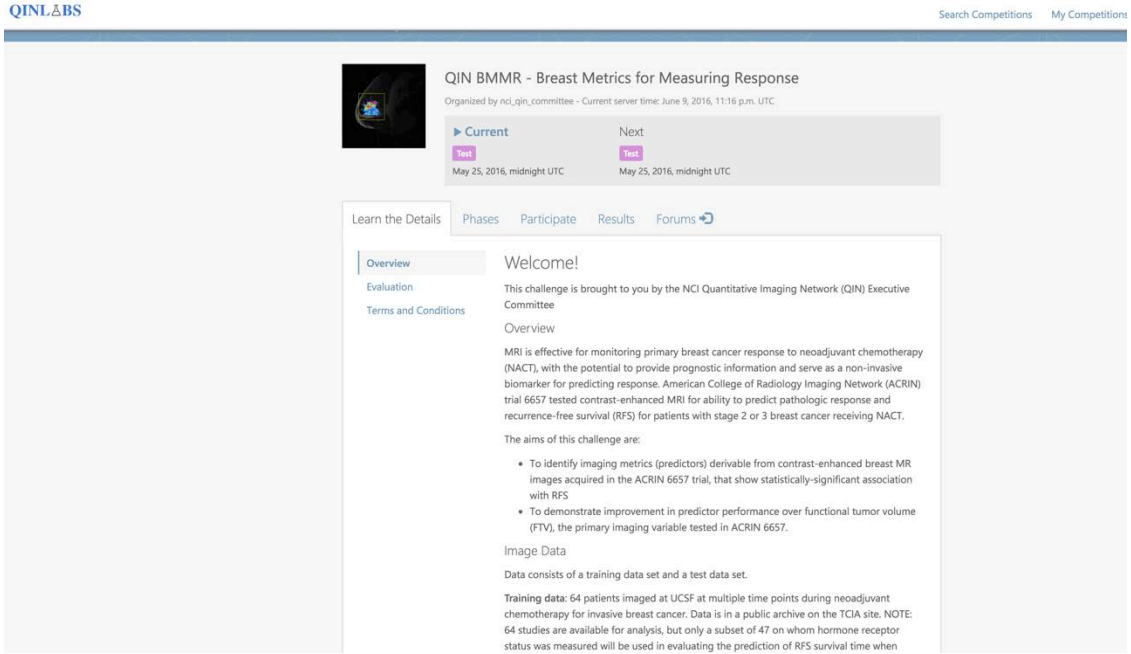
4	feature_4	PM	Size		Volume	3D	no	1
1	feature_1	UCLA	Size	Volume	volume	3D	No	N/A

- Inter and intra-site correlation of features

QIN BMMR challenge (clinical trial data)

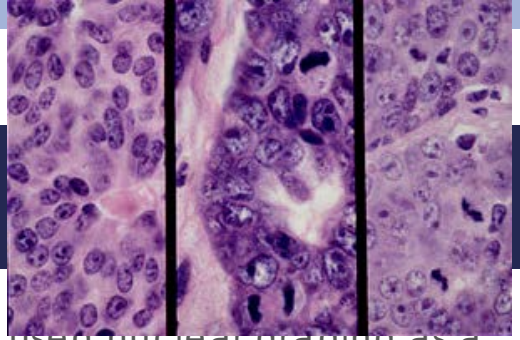
- The aims of this challenge are:
  - To identify imaging metrics (predictors) derivable from contrast-enhanced breast MR images acquired in the ACRIN 6657 trial, that show statistically-significant association with RFS
  - To demonstrate improvement in predictor performance over functional tumor volume (FTV), the primary imaging variable tested in ACRIN 6657.

QIN BMMR challenge



- QIN challenge led by Nola Hylton, data from ISPY/ACRIN trial

‘tis in the nuclei



- **BACKGROUND**: Pathologists and bioinformatitians have used nuclear grading as a critical part of evaluating the structure of Breast Cancers. Some analysts claim to be able to use nuclear characteristics for prognostication (Axelrod). At the present time, tumor nuclear characteristics are subjectively graded by the pathologists. Many types of GEMM have distinctive nuclear and cytoplasmic characteristics which are readily identified by an experienced pathologist. The challenge is to codify these characteristics and relate them to the biology of the animal.

- **OBJECTIVE:** The objective is to develop and test algorithms capable of distinguishing between the nuclear phenotypes from different mouse genotypes.

- **RESOURCES:** A panel of WSI from four GEMM mouse genotypes

- **CHALLENGE**: Using the nuclear attributes of six GEM models, identify the genotype of unknown HUMAN and MOUSE panels.

Cardiff et al 2001 PMID: 1887859

Lessons Learned

- We need to work together!!
- "our finding **further reinforces the notion that crowd-sourced collaborative competitions are a powerful framework for developing robust predictive models by training an ensemble model aggregated across diverse strategies employed by participants**. ", Bilal et al, PLOS Computational Biology, 2013
- Ensemble methods (often) outperform individual models
  - "Our experience with the Netflix competition showed that the most successful model is an ensemble of multiple predictors", Bell et al, SIGKDD Explorations, Vol9
  - "ensemble models trained across multiple user submissions **systematically outperform individual models** within the ensemble", Bilal et al, PLOS Computational Biology, 2013
- Combining expert knowledge with machine learning can be valuable
  - "**machine learning methods combined with molecular features selected based on expert prior knowledge** can improve survival predictions compared to current best-in-class methodologies", Bilal et al, PLOS Computational Biology, 2013

Lessons Learned

- Need to agree upon authorship and roles early on.
- Need to make it worth the while to participate in a challenge.
- Incentives (in bioinformatics)
  - Cash Prizes
  - Publications
  - Academic Glory?

Boutros et al, 2014

The best-performing methods will be applied retrospectively to over 10,000 cancer genomes stored in CGHub, and the results will be distributed to the research community. Moreover, the top-scoring methods will be made available as open source tools, allowing users around the world to process their own data with the same pipelines validated and used by the ICGC and TCGA. Nature Publishing Group has stepped up to coordinate publication models stemming from the Somatic Mutation Calling Challenge. Challenge-assisted peer review and early editorial feedback will help identify publishable themes that cut across multiple approaches. The involvement of major journals introduces the possibility of reaching a broad audience and raises the impact and exposure of contestant contributions, thereby increasing incentives and overall morale.

Summary

- Challenges and benchmarks can be important in image analysis for radiology and digital pathology, radiomics and radiogenomics.
- Reviewed challenge infrastructure and requirements to host and participate in challenges.
- Discussed past and upcoming challenges that focus on topics in radiology, radiomics and radiogenomics.

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- CBIIT
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- TCIA
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Dedication: Dr. Laurence Clarke

- Dr. Larry Clarke was absolutely instrumental in providing the vision, enthusiasm and drive for this project.

https://spie.org/about-spie/press-room/spie-member-news/in-memory-laurence-clarke-nci-imaging-cancer