Towards QA Protocol Standardization through Online Collaborative Systems

Rodney D. Wiersma

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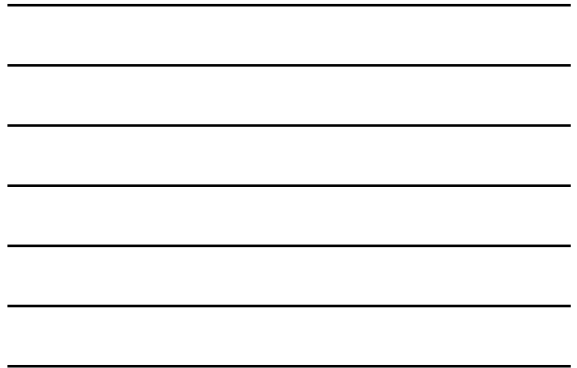CHICAGO

Disclosures

- Parts of this research has been licensed to Luca Medical Systems

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- Very complicated machines that if not operating properly could cause serious injury to patients.

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American Association of Physicists in Medicine (AAPM) Guidelines

- TG-51 LINAC Dose Output

- TG-66 QA for CT scanners

- TG-114 MU Calculations

- TG-119 Treatment planning systems

- TG-120 IMRT QA

- TG-142 medical linear accelerators

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Task Group 142 report: Quality assurance of medical accelerators

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Daily QA ~ 30 minutes

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Monthly QA ~ 4 hours

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Yearly QA ~ 4 days

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The report of Task Group 100 of the AAPM: Application of risk analysis methods to radiation therapy quality management

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Some key points from TG-100

To prevent failures in RT a QA program should have:
- Standardized procedures.
- Adequate staff, physical, and IT resources.
- Adequate training of staff.
- Maintenance of hardware and software resources.
- Clear lines of communication among staff.

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QA Standardization

Procedure standardization
- Well tested QA procedures that are uniformly used across different medical centers to ensure patient safety and to allow comparison of results.
- **STATUS: partially addressed**
  - *Task groups have limited user input and feedback.*
  - *Do not keep pace with rapid technology changes.*

Data standardization
- a common vocabulary is needed to communicate between people and computer systems.
- **STATUS: not addressed**

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Paper

- **Data is safe with redundant backup systems.**
- **Data can be easily extracted remotely for analysis.**
- **Many types of data (DICOM) can be stored.**
- **Complex algorithms can be used on the QA system.**
- **The QA system is operating system independent.**
- **Data is in a standardized format allowing comparison across multiple institutes.**
- **Data taking procedures are standardized.**

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Excel

- **Data is safe with redundant backup systems.**
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Software

PIPSPRO SOFTWARE

DoseLab

Yes We Do
RITG142
Just what you want

- **Data is safe with redundant backup systems.**
- **Data can be easily extracted remotely for analysis.**
- **Many types of data (DICOM) can be stored.**
- **Complex algorithms can be used on the QA system.**
- **The QA system is operating system independent.**
- **Data is in a standardized format allowing comparison across multiple institutes.**
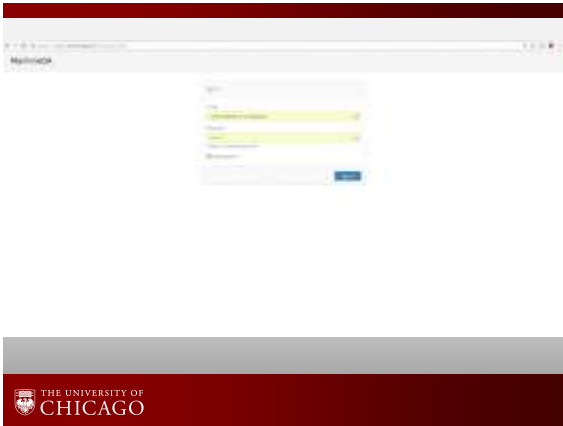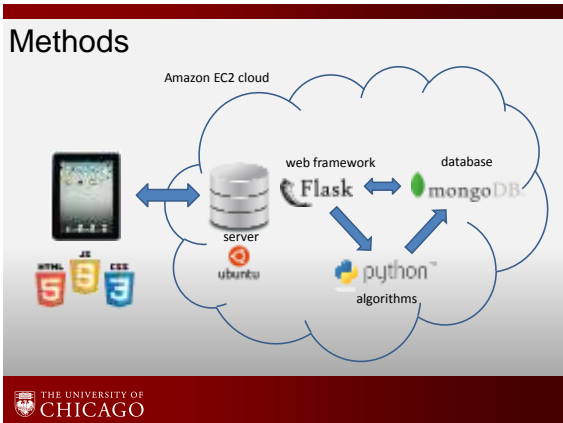- **Data taking procedures are standardized.**

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Methods

Amazon EC2 cloud

web framework

database

server

algorithms

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Legal and Security

- From discussions with HIPAA and IT groups data storage on a cloud server is permissible provided that there is absolutely no chance of patient data residing on the cloud.
- Encrypted communications (HTTPS).
- Weak passwords forbidden.
- Passwords are encrypted.
- Login attempts are rate limited.
- Cross-Site Request Forgery (CSRF) protection.
- Non-SQL database avoids SQL injection.
- Automatic daily backups of database.

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Data Standardization

- Need a method to find specific QA data across many user submitted QA records.

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Ontology

- *Traditionally a branch of philosophy that deals with questions concerning what entities exist and how such entities may be grouped, related within a hierarchy, and subdivided according to similarities and differences.*

- *Describes a set of entities and their relationships (X marriedTo Y; or A works for B; or C located in D, etc).*
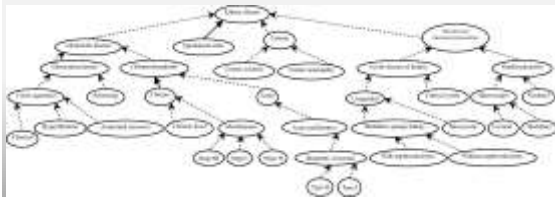
Parmenide (515 BC) was among the first to propose an ontological characterization of nature.

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Taxonomy

- *Taxonomy is a hierarchy of concepts*

- Systemized Nomenclature of Medicine - Clinical Terms (SNOMED-CT)
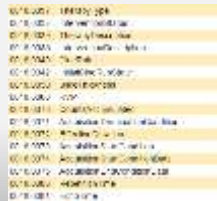

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International Classification of Diseases (ICD)
- Concepts: 12,417
- Depth: 4 levels
- Relations: 12,416

Medical Subject Headings (MeSH)
- Concepts: 80,689
- Depth: 14 levels
- Relations: 112,463

Systemized Nomenclature of Medicine (SNOMED)
- Concepts: 440,408
- Depth: 16 levels
- Relations: 440,408

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Digital Imaging and Communications in Medicine (DICOM)

- It was developed by the DICOM Standards Committee, whose members are part of the American College of Radiology (ACR) and The National Electrical Manufacturers Association (NEMA).

- NEMA holds the copyright to this standard.

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Folksonomy

- Classification system based on keywords that establish categories without stipulating or necessarily deriving a hierarchical structure of parent-child relations among different tags.

- Widely used on the internet for classifying photos, videos, podcasts, tweets, scientific papers and others (Flickr and Twitter).

- Tags are a single word electronic label.

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Data Standardization

- A QA input parameter is defined as a **combination** of lower case tags. Example: "image" "mv" "contrast"

- The hypothesis is: *The total amount of parameters need to define all QA inputs will converge to a finite set over time.*
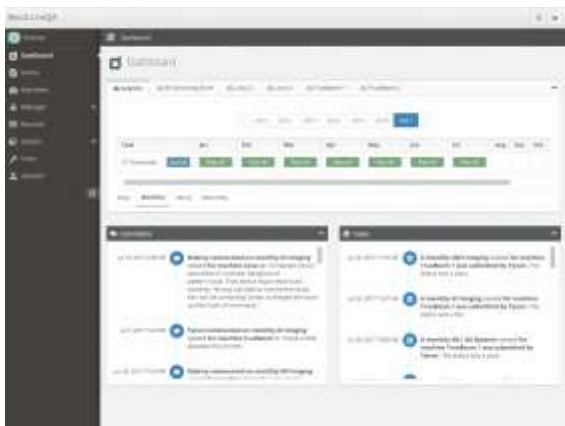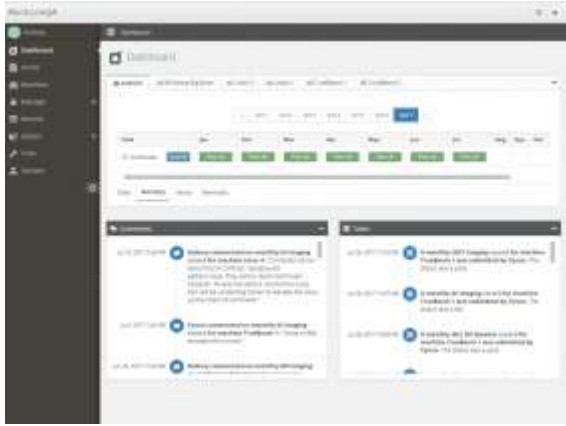
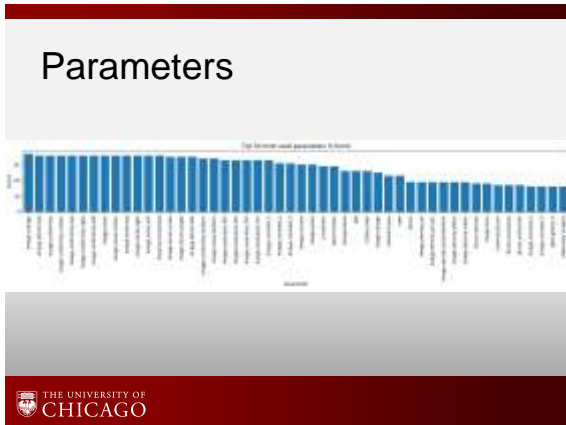THE UNIVERSITY OF
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Tags

- To make QA data human friendly in terms of searching and identification a combination of predefined 'Tags' are attached to each QA input parameter.

- To prevent misspellings, synonyms, singular/plural and compound words only certain people can create tags.
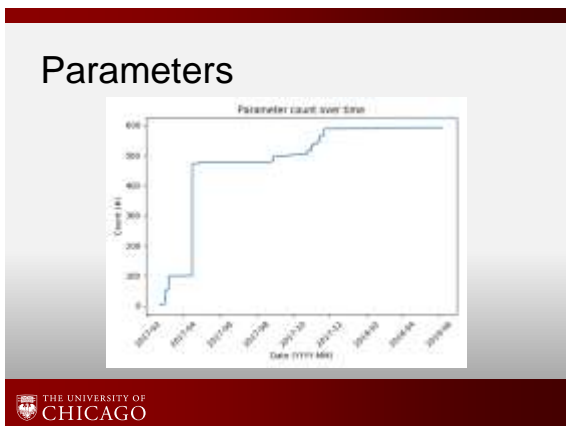
class Tag:
    id = 12-byte hexadecimal (507f1f77bcf86cd799439011)
    name = 20 character string (image, contrast, etc...)

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Tags

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Tags

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Parameters

- Parameters form the entire basis of the QA system.
- Each QA input is tied to a specific parameter.

class Parameter:
    id = 12-byte hexadecimal (507f1f77bcf86cd799439011)
    type = file, number, string, etc.
    tags = A **combination** of tags (image, mv, contrast, etc...)

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Parameters

Parameters

Procedure Standardization

- QA protocols (forms) can be easily created by any user or groups of users (social collaboration).

- All forms can be shared with the group or community.

- Preexisting QA forms can be either forked or upgraded.

- Metrics are used to track the performance of QA forms to indicate popularity.

- The hypothesis is: *Through multiple user collaboration certain forms will gain widespread popularity and form a type of QA standardization.*

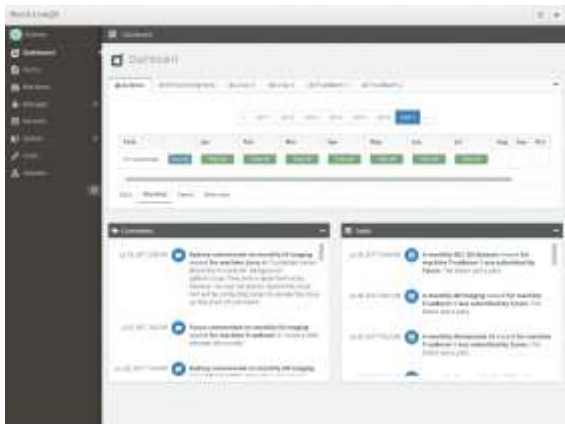THE UNIVERSITY OF
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Forms

- Forms can be considered a box that hold a set of parameters.
- All users can create or modify forms.
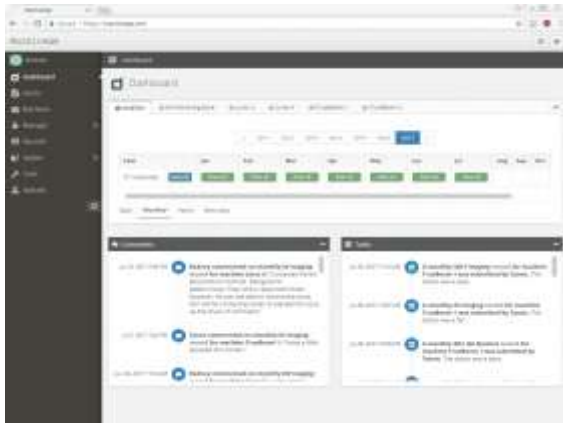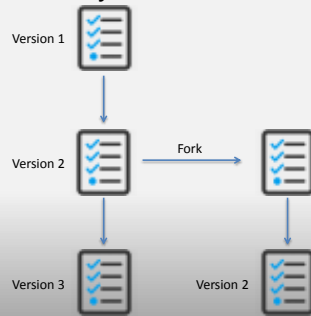- The owner can set sharing privileges.

class Form:
    author = the owner
    sharing = private, group, institute, or public
    devices = a list of compatible devices (truebeam, trilogy,)
    tags = a list of tags (mv, mechanical, dosimetry, etc.)
    version = version of form

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Form Version Control System

- Users can socially collaborate on building QA protocols.
- Users can comment on forms.
- Any changes to a form that is in use will result in a new version.
- To customize a form a user must first fork it.

Version 1

Version 2 → Fork →

Version 3   Version 2

Database

- Structured Query Language (SQL) must have a fixed schema. Issues with dynamically changing content.

Database

- MongoDB was first released in 2009 and is a schema less database system.

- Instead of tables each entry is similar to a Javascript Object Notation (JSON) like object.

- The number of fields, content and size of the document can be differ from one document to another.

- Allows embedding of data files (DICOM, JPEG, PDF, etc.).

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Tasks

- Tasks assign a form and users to a machine.
- Created by the group manager.
- Allow notification to task members (e-mail) when a task is completed.
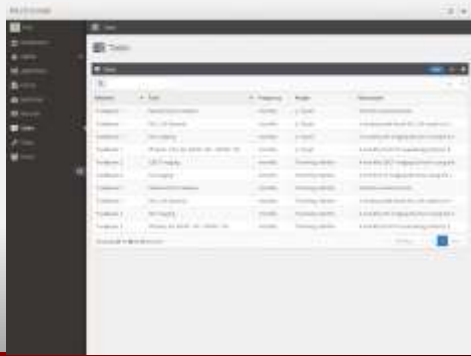
```
class Task:
    form = a specific form
    machine = a specific machine
    users = a list of users assigned to the task
```
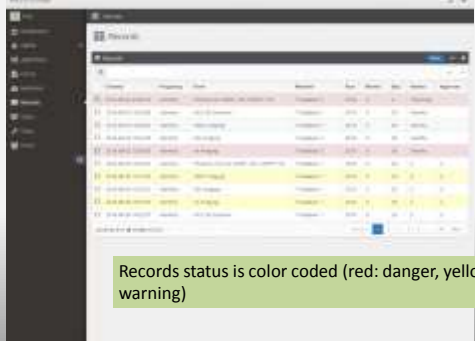
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Records

- Save a QA task's values to the database.
- Created by all users.

```
class Record:
    author = the user who created the record
    approver = the user who approved the record
    form = the form
    machine = the specific machine QA was performed on.
    status = pass, warning, fail, or incomplete
    values = list of parameters together with associated inputs.
```
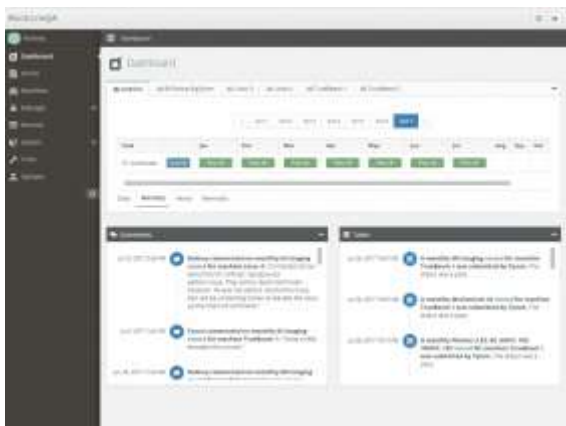
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Records status is color coded (red: danger, yellow: warning)

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Modules

- Any user can contribute algorithms provided that they are written in Python.

- Algorithms are run as asynchronous jobs based on a queue system in order not to interfere with web site responsiveness.

- Communication of data between algorithms and the website are through JSON.

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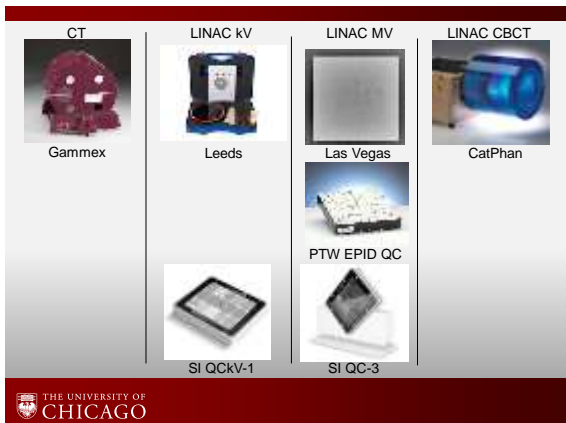---

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Universal phantom algorithm

- Use of Scalable Vector Graphics (SVG) is an XML-based vector image format for two-dimensional graphics.

- Allows both phantom structure and function to be defined in a single file.

```
<svg height="180" width="180">
    <circle id="body" type="body" shape="circle" cx="90" cy="90" r="90" />
    <circle id="contrast_1" type="contrast" margin="2" width="2" shape="circle" cx="38" cy="59" r="3.75" />
    <circle id="contrast_2" type="contrast" margin="2" width="2" shape="circle" cx="47.5" cy="47" r="3.75" />
    <circle id="contrast_3" type="contrast" margin="2" width="2" shape="circle" cx="60" cy="37.5" r="3.75" />
    <circle id="intensity_center" type="intensity" shape="circle" cx="120" cy="90" r="3.75" />
    <circle id="intensity_top" type="intensity" shape="circle" cx="90" cy="21" r="3.75" />
    <circle id="intensity_right" type="intensity" shape="circle" cx="159" cy="90" r="3.75" />
    <circle id="intensity_bottom" type="intensity" shape="circle" cx="90" cy="159" r="3.75" />
    <circle id="intensity_left" type="intensity" shape="circle" cx="21" cy="90" r="3.75" />
    <rect id="mtf" type="mtf" shape="rect" x="46" y="79" width="11" height="22" />
</svg>
```

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Conclusion

- A unified QA data management system has been successfully created and put into clinical use.

- Online social collaboration has shown to be effective at forming QA protocols.

- To test the concept of social standardization of QA protocols more medical centers and users need to added to the system.

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Acknowlegments

- All my colleagues at the University of Chicago

- The pylianc project by James Kerns
  https://github.com/jrkerns/pylinac

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