PerkLab research methodology overview

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PerkLab

- About 20-25 members
- From computer science, electrical engineering, and mechanical engineering departments and medical school
- 1/4 undergrad
  1/4 Masters
  1/4 PhD, postdoc
  1/4 faculty, staff research engineers – continuity

Research focus:
- Percutaneous interventions
- Image guidance
- Tool navigation
- Translational research

Scope

From algorithms to tools

- Can it be done?
  - Prototypes
- Is it worth doing?
  - **Tools for translational research**
- Standard of care
  - Commercially available clinical "devices" with regulatory approval

Ron Kikinis, Harvard SPL, 2012

Reproducible research – theory

- Scientific method: propose hypothesis, prove it by experiments
- Mistakes, bias, … => repeatability
- Full specification

  Victoria Stodden, Enabling reproducible research: licensing for scientific innovation
  - Research paper
  - Data (with description the data, how it was acquired, processed, including the source code that was used for processing, …)
  - Experiment (source code, instructions, parameters, …)
  - Results (source code, documentation, data, …)
- Reduced duplicate efforts, higher credibility, higher quality outcome, community, …

J.P.A. Ioannidis,
***Why Most Published Research Findings are False**,*
PLoS Med 2(8), 2004

Reproducible research – practice

- By default openly available source code, full documentation, all data
- Permissive license – no strings attached
  - BSD: redistribution, modification, ... all allowed
    - Provided as is
    - Don't use the author name for endorsement
    - Don't remove the license
- Can we afford to give away all these?
  - Full disclosure mostly delayed until publication
  - Exceptional ideas are patented before publication
  - Maintain competitive advantage by continuous improvement
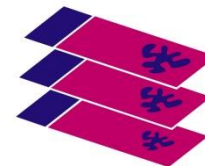 - We get *a lot* in return

Industry best practices

- Brought in by industry-trained staff members
- Adopt procedures that increase quality & productivity
- Keep overhead at the minimum
  - Usually no need to comply to external regulations (Health Canada, FDA, CE, …)
- Learning these: investment with a short payback period

Planning, design, implementation

- Web-based, integrated project management:
  - [GitHub](): unlimited public repositories for free; free private repositories for university research labs
  - Tools: revision control, code review, bugtracking, project boards, releases, website hosting; very limited: messaging, discussion
- Automated build and API documentation generation ([CMake](), [Doxygen]()), [tutorials]()
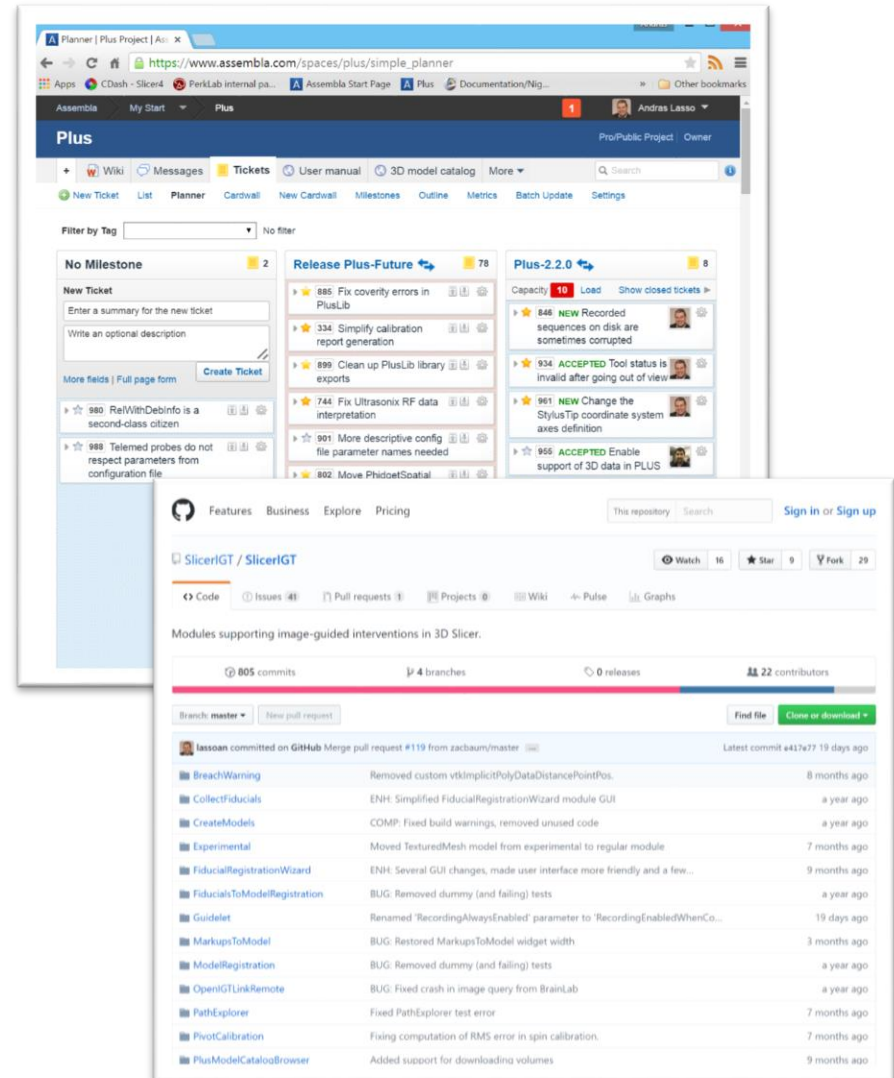
Verification

- Automatic continuous and nightly build and test (CTest)
- Web-based dashboard (CDash)
- Automatic GUI testing with QtTesting: record&replay Qt events
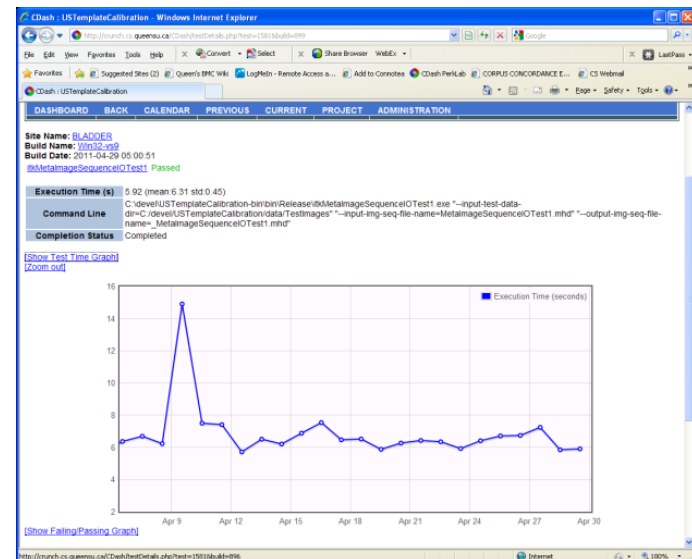
*CTest results reported on* [CDash](#)

Validation

- Fidelity levels: Simulated < Synthetic phantoms < Animal tissue (butcher shop) < Cadaver < Patient
- Ethics approval: required for human subject studies, evaluation on patient cases

Phantoms
- Hard tissue (bone): 3D printed, with Barium coating for X-ray visibility
- Soft tissue: water based (agar, gelatin), PVC, silicon
- Skin: super soft silicon rubber
- Vessels: rubber tubes
- Targets, validation points

http://perk-software.cs.queensu.ca/plus/doc/nightly/modelcatalog/
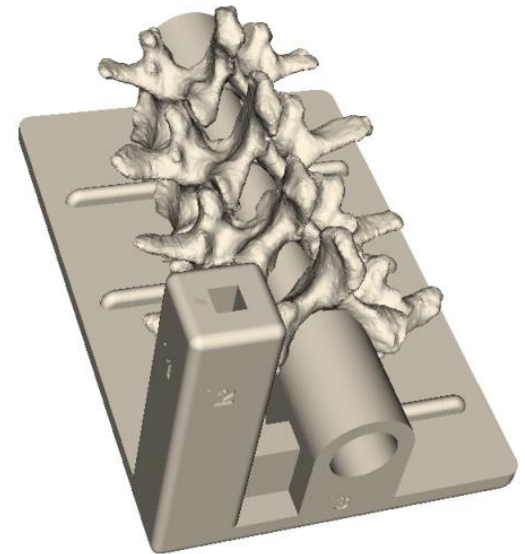
Software platform

Without an application platform	**Building on an application platform**
• Each application is developed from ground up	• Core functionalities are already implemented
• Completely new software is developed for each problem/procedure/device	• New software modules can be developed for specific needs
• Significant work is needed to integrate new, advanced algorithms	• Many new, advanced algorithms are available
	• Well-supported with a large user and developer community

👍 Quick start.
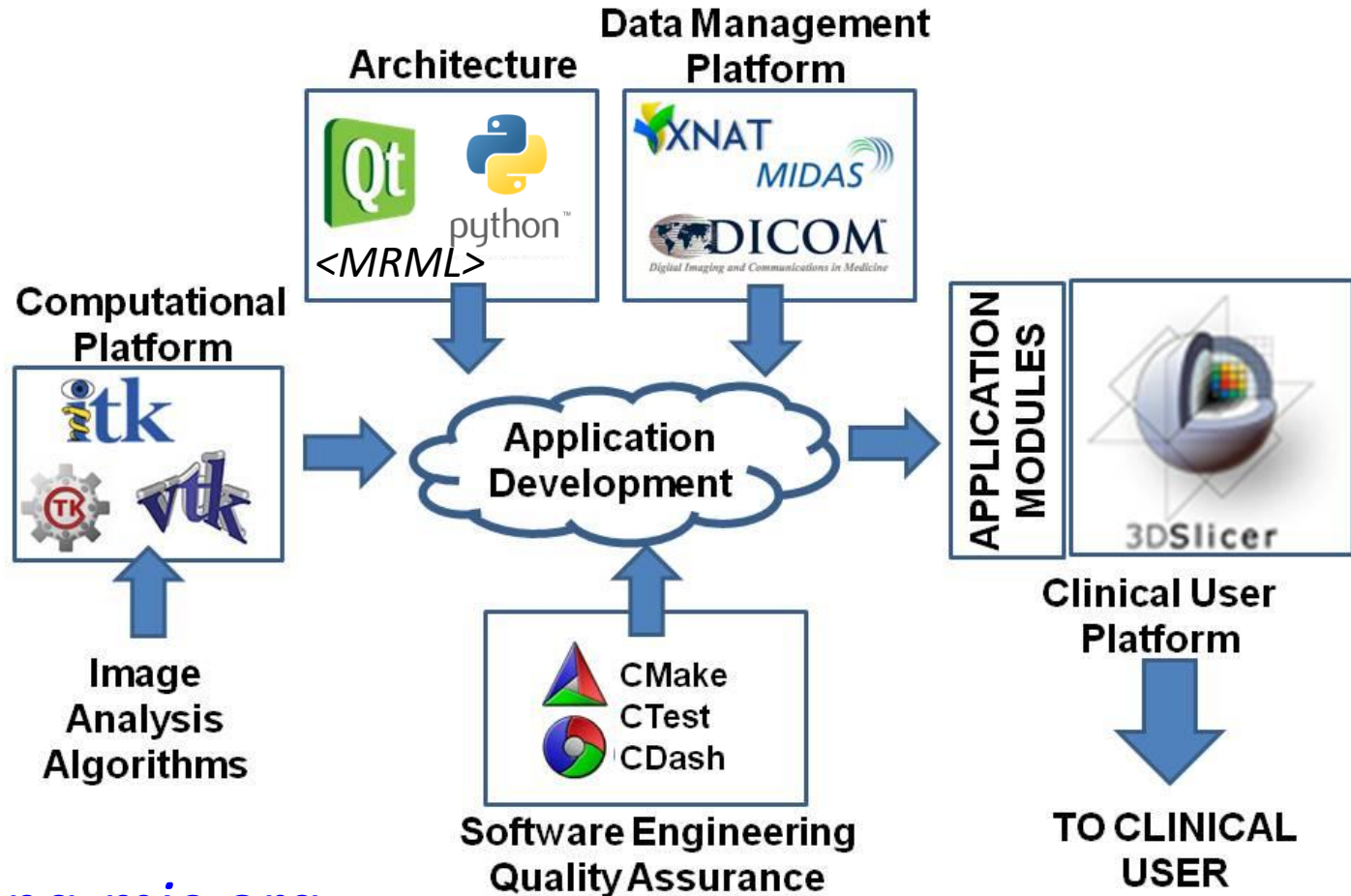
👎 Huge waste of time, money, and effort overall.

👎 Investment at the beginning: learning.

👍 Minimal wasted efforts.

3D Slicer and the NA-MIC Kit

www.na-mic.org

PerkLab systems overview

Slicelets
(custom Slicer applets)

| LumpNav | ... | ProstateNav | ... | Gel dosimetry |

Slicer
extensions

SlicerIGT

| Breach warning |

| Pivot calibration | Model registration | ... | Tool watchdog |

SlicerRT

| DICOM-RT import | Dose volume histogram | ... | Dose comparison |

3D Slicer

| Visualization | Registration | Segmentation | ... | Quantification |

| OpenIGTLink | | DICOM |

VTK, ITK, CTK, QT, DCMTK, …

PLUS

| Calibration, synchronization, pre-processing, simulation, record&replay | OpenIGTLink |

| Device interface |

software
hardware

| Surgical microscopes, endoscopes | Ultrasound scanners | Navigation systems | Robotic devices, manipulators | MRI, CT, PET scanners |

hundreds of devices (imaging, position tracking, various sensors, and manipulators)

Building on a platform

LINES OF SOURCE CODE - ILLUSTRATED THROUGH LUMPNAV

Python 9.9%
ITK 13.1%
Numpy 6.8%
DCMTK 5.2%
3DSlicer core 3.5%
CTK 1.7%
VTK 27.6%
SlicerIGT 1.6%
Qt 29.2%
BrainsTools ext 1.3%
Plus toolkit 1.4%
SlicerIGT ext 0.2%
LumpNav ext 0.01%
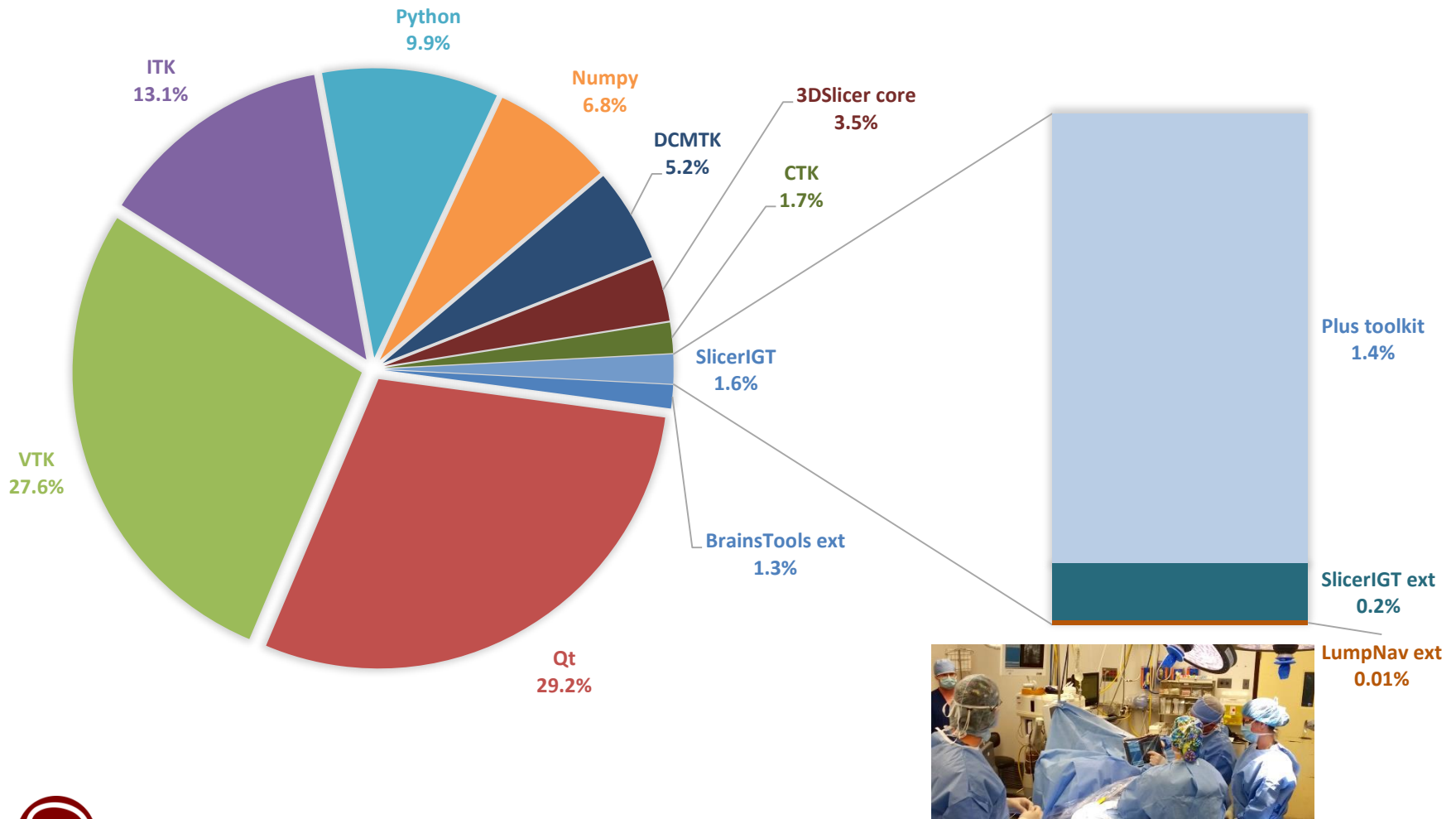
Summary

Translational research

Reproducible research

Industry best practices

Building on one platform

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