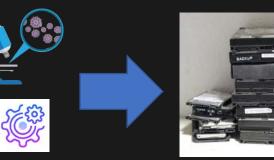
Web Image Processing Pipeline (WIPP) and Polus Services

¹Nathan Hotaling & ²Peter Bajcsy ¹National Center for Advancing Translational Sciences (NCATS) NIH ²Information Technology Laboratory (ITL) NIST

Foundational Problem

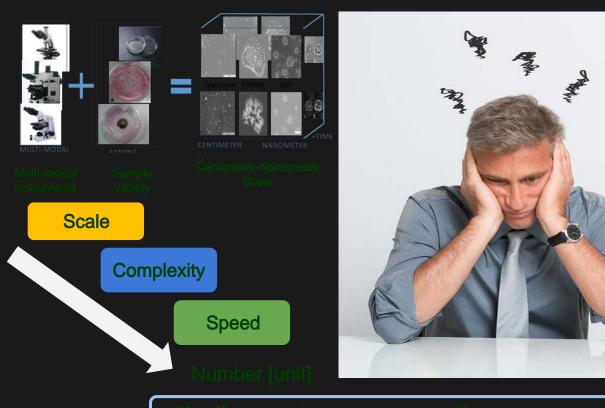
How can a biologist harness petabytes of image data to derive quantitative measurements and gain meaningful insights?







NIST Measurement: It is not just a number!



CHECKLIST

- Trusted
- Traceable
- Repeatable
- Searchable
- Immutable
- Persistent
- Verifiable by human
- Accessible to multiple parties

hallenge: Incorporate all measurement attributes

Institutional Challenges

Software Features for

- Users
- Developers
- System Administrators

Data Independent User Desired Features

	Automated Data Ingestion	Fast Data Previews	GUI- Workflows and Analysis	Hierarchical Catalog GUI	Collaborative Sharing & Coding	Advanced Automated Analysis	Simple Metadata Association	Easily Extensible	Native Broad Support	Scales Easily & Efficiently	Built-in Traceability and Reproducibility	Secure
Ingestion + OMERO/OpenBIS · CryoSpark + Pythor	2	2	3	3		3		3	3	2	2	
Ingestion + OMERO/OpenBIS · IMOD + MATLAE	2	3		3		3	2	3	3	2		
Ingestion + Columbus + Palantir/Spotfire/etc.	2	3	3	3	2	3	3		2	3	2	3
Ingestion + Midas + CMake + VTK + ITK + Paraviewer	2	3			3	3		2	3	2	0	
Polus/WIPP 3.0	3	3	3	3	3	33	3	3	3	3	3	3

link to Sheet

Partially Supported

Fully Supported

Data Independent Developer Desired Features

	Open Source	Robust Code Documentation and Installation	Access to All Feature and Resource APIs	Well Documented APIs	Long Term Legacy Support APIs	Easy to Customize GUI	Simple Multi- Lingual Plugins Support	Open Plugin Repository	Easy & Automated Porting of Plugins	Native Broad Microscope Support	Collaborative Sharing/ Coding	Scales Easily & Efficiently
Ingestion + OMERO/OpenBIS · CryoSpark + Pythor	3	3	2	2	2	0	0	3		3		2
Ingestion + OMERO/OpenBIS · IMOD + MATLAE		2	2	3	2	0	0	3		3		2
Ingestion + Columbus + Palantir/Spotfire/etc			2	3		0	2		0	2	2	3
Ingestion + Midas + CMake + VTK + ITK + Paraviewer	3	3	3	3	3	0	0	3	0	3	3	2
Polus/WIPP 3.0	3	3	3	3	2	3	3	3	3	3	3	3

ink to Shee

Partially Supported

Fully Supported

Not Supported

	Simple Automated Deployment	Generalizable & Flexible Deployment	Well Documented Deployment Instructions	Simple & Robust Reporting, Patching, & Updates	Application Performance Management	System Resource Management	User Utilization Management	Role Based Access Control (UI, plugins, storage, compute)	API Management	Vulnerability Management	Capacity Management
Ingestion + OMERO/OpenBIS · CryoSpark + Pythor	2	2	2								
Ingestion + OMERO/OpenBIS · IMOD + MATLAE	2	2	2					2			
Ingestion + Columbus + Palantir/Spotfire/etc.	2	2	2					2			
Ingestion + Midas + CMake + VTK + ITK + Paraviewer	2		2								
Polus/WIPP 3.0	3	3	3	2	3	3	3	2			2

Partially Supported

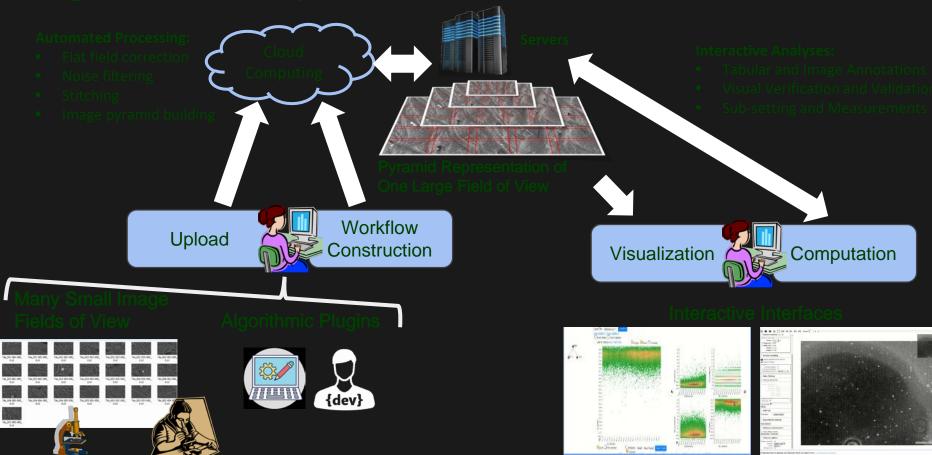
Fully Supported

Technical Approach

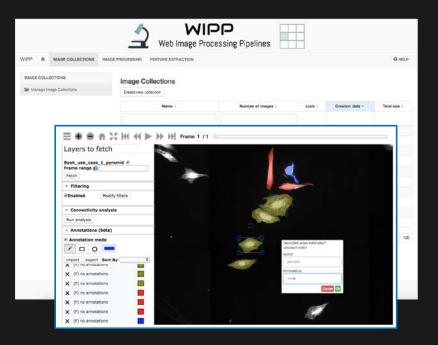
The computational and institutional challenges cannot be addressed without the nvolvement of communities of stakeholders

- Open Source Web Image Processing Pipeline (WIPP)
- Cloud service called Polus

High-Level Perspective on WIPP

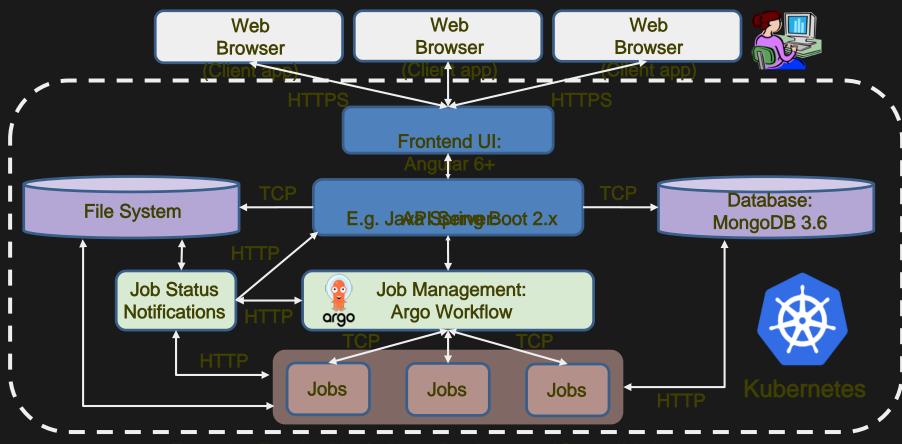


WIPP: Client - Server System - Image Processing + Analysis



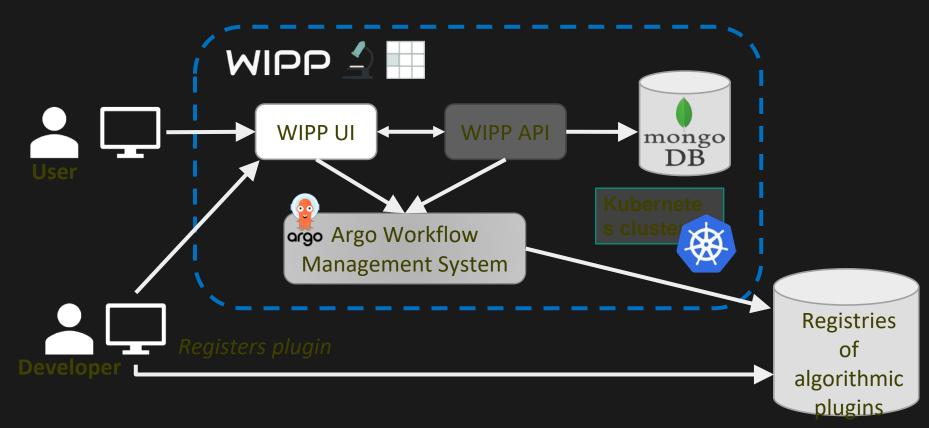
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WIPP 3.0 ClientServer Architecture



Focused on Functionalities for Users, Developers, and System Administrators

WIPP 3.xx Architecture



Containerization and Orchestration Technologies

• Docker



"Docker containers wrap up software and its dependencies into a standardized unit for software development that includes everything it needs to run: code, runtime, system tools and libraries."

- Kubernete
 - S



"Kubernetes is an opensource system for automating deployment, scaling, and management of containerized applications. Production-Grade Container Orchestration."

Container Workflow Technologies

Argo Workflows



"Argo Workflows is an open source container-native workflow engine for orchestrating parallel jobs on Kubernetes."

	WORKFLOW DETAILS				
1	Workflows / demo-0606-227nbw				ф
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	demo-0606-227	NAME	demo-0606-227nbw.demo-0606-2-pyr		
	demo-D606-2-pyr	TYPE	Pod		
		PHASE	Succeeded		
	✓ demo-0606-227	START TIME	2019-06-06T18:13:31Z		
		END TIME	2019-06-06T18:13:40Z		
		DURATION	00:09 min		
		YAML	GS		

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Name	"title": "Thresholding plugin", "author": "Mohamed Ouladi & Peter Bajcsy",		
Search by name	"institution": "National Institute of Standards and Technology", "repository": "https://github.com/usnistgov/WIPP-thresholding-plugin",		
1WIPP Image assembling Plugin	"website": "https://imagej.net/Thresholding", "citation": null, "description": "Thresholding methods from image,".		
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wipp/wipp-thresh-plugin

By wipp • Updated 3 months ago

https:// WIPP thresholding plugin based on Image/Fiji thresholding methods.

Container Linux x86-64

Plugin Component: Docker Image

WIPP plugin as a Docker image available on DockerHub

booker hub	Q Search for great content (e.g., mysql)	Explore	Sign In	Pricing	Get Started
	wipp/pyramid-building 🔂 By wipp • Updated 2 months ago Efficient pyramid building from stitched field of views.				t Pulls 6 ف
Overview	ags				
	erly mount host directories and then we need to provide pyramid b ional environment variables can be set to enable logging. Sage	uilding		er Pull Co ser pull	mmand wipp/pyramid-l 🗖
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Docker image definition (Dockerfile)

24 li	ines (18 sloc) 734 Bytes
1	FROM wipp/pyramid-building:1.0.0
2	LABEL maintainer="National Institute of Standards and Technology"
3	
4	ARG EXEC_DIR="/opt/executables"
5	ARG DATA_DIR="/data"
6	
7	# Create folders
8	RUN mkdir -p \${EXEC_DIR} \
9	&& mkdir -p \${DATA_DIR}/inputs \
10	&& mkdir \${DATA_DIR}/outputs
11	
12	# Install java 8 jdk
13	RUN apt-get update \
14	&& apt-get install -y openjdk-8-jdk \
15	&& update-alternatives —-set java /usr/lib/jvm/java-8-openjdk-amd64/jre/bin/java
16	
17	# Copy wipp-pyramid-plugin JAR
18	<pre>COPY target/wipp-pyramid-plugin*.jar \${EXEC_DIR}/wipp-pyramid-plugin.jar</pre>
19	
20	# Set working directory
21	WORKDIR \${EXEC_DIR}
22	
23	# Default command. Additional arguments are provided through the command line
24	ENTRYPOINT ["/usr/bin/java", "-jar", "wipp-pyramid-plugin.jar"]

Dynamic Plugin UI: JSON Manifest

```
I "name": "WIPP Pyramid plugin",
"version": "0.0.1",
"title": "WIPP Pyramid building",
I "description": "Pyramid building using NIST accelerated C++ algorithm",
I "creator": "National Institute of Standards and Technology",
I "containerId": "wipp/wipp-pyramid-plugin:0.0.1",
"inputs": [
     {
          "name": "inputImages",
          "type": "collection",
          "options": {
              "format": "tiledtiff"
          },
          "description": "Input Images",
          "required": true
      },
          "name": "inputStitchingVector",
          "type": "stitchingVector",
          "description": "Input Stitching Vector",
          "required": true
      },
          "name": "blending",
          "type": "enum",
          "options": {
              "values": [
                 "overlay",
                  "max"
          },
          "description": "Blending method when assembling tiles",
          "required": false
   ____
"outputs": [
          "name": "output",
          "type": "pyramid",
          "description": "Output pyramid"
11.
```

formation about the plugin: name, version, description Docker image to use

Inputs description - name, type, description

WIPP will use this manifest to generate the job configuration form

Outputs description - name, type, description

Workflow Creation from Algorithmic Plugins

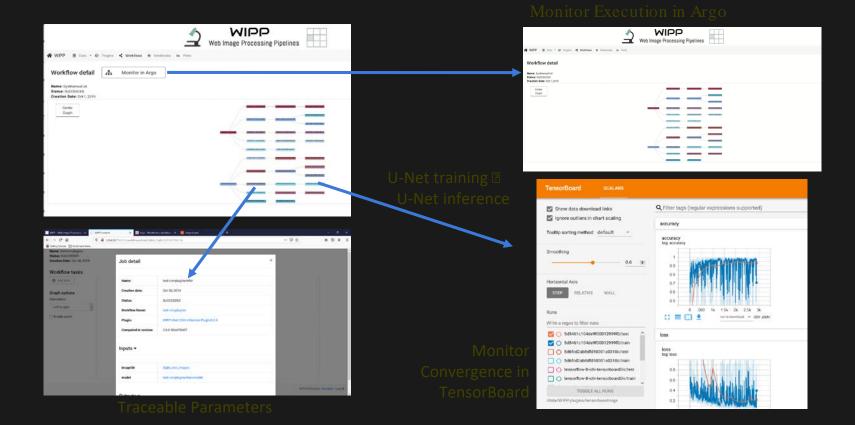
 Interactive workflow creation and visualization

	1	WIPP Web Image Processing Pipelines	٠
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Workflow detail © Submit workflow Name: s12-demo Status: CREATED Creation Date: Oct 2, 2019 Workflow tasks © Add task			

Configure workflow tas ksChain job outputs

WIPP ■ Data • Plugins < Workflows ● Notebooks ten. Plots Workflow defail • Monitor in Argo Name: SynthemasFull Status: SUCCEEPED Creation Date: Oct 1, 2019 • • • • • • • • • • • • •	<u>_</u>	WIPP Web Image Processing Pipelines
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Status SUCCEEDED Creation Date: Oct 1, 2019		
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Workflow Monitoring and Traceability



Interoperable Algorithmic Plugins

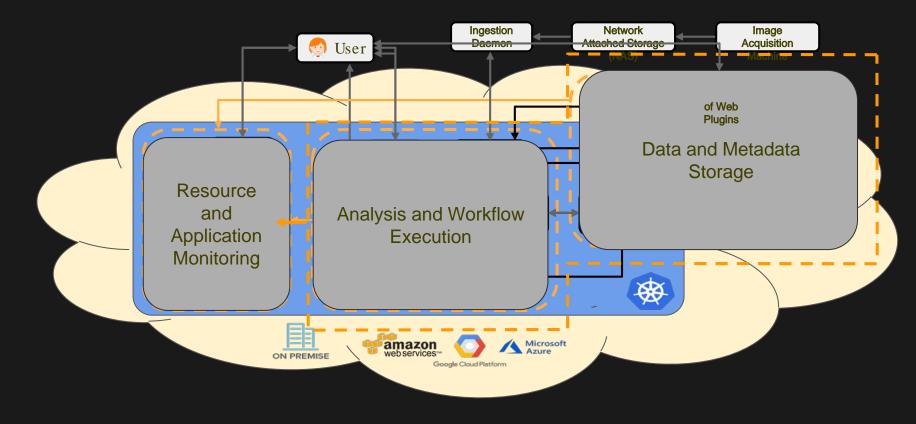
Pros of Container Plugins

- Multi-lingual
 - C++, Python, Java, TensorFlow, etc.
- Containerized
 - Reproducibility of results
 - Compatibility of library dependencies
 - Simplicity of deployment
 - Modularity of analyses
- OSS or Paid
- Interoperable between NIH & NIST





Polus Services: Monitoring, Execution, and Data Storage - Managed Infrastructure!



Plugins and Interaction

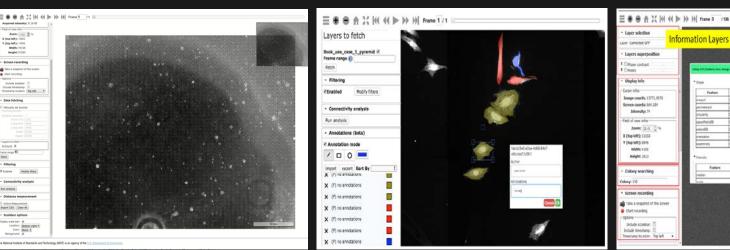
Algorithmic Plugins

- Image stitching (MIST algorithm)
- Image thresholding (ImageJ/Fiji multiple algorithms)
- Pyramid building (accelerated algorithm with low RAM requirements)
- Universal Notebook Execution (Scalably Execute J upyter Notebooks as plugins)



Many Overlapping Microscope Fields of View

Stitched Interactive Image Pyramids



X (hep left): -3042 f (hep left): -3456 WHEN: 76728

Helphi 57285

Screen recording

Start recording

Data fetching

rame range 🚯

Filtering

Enabled

Run analysis

Active Heasurement port CSV Cear All

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Include scalebar:

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Frame Slider

Prototyping Using Jupyter Notebook Interactive Programming

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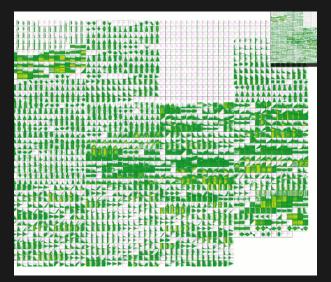
Configurable in-browser Polyglot IDE located where images are stored Collaborative Notebooks using GitHub GUI or terminal Tight Integration with WIPP Jupyterlab Extension

# Prototyping Using Jupyter Notebook Interactive Programming

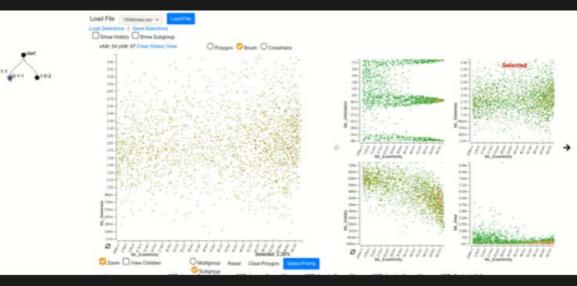
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Configurable in-browser Polyglot IDE located where images are stored Collaborative Notebooks using GitHub GUI or terminal Tight Integration with WIPP Jupyterlab Extension

# Scalable Interactive Visualization of Tabular Data

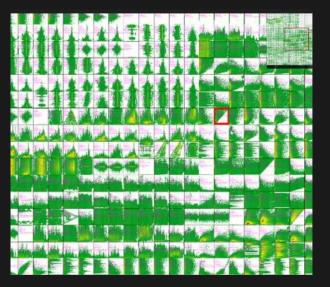


 DeepZoom of all pair-wise feature scatter plots

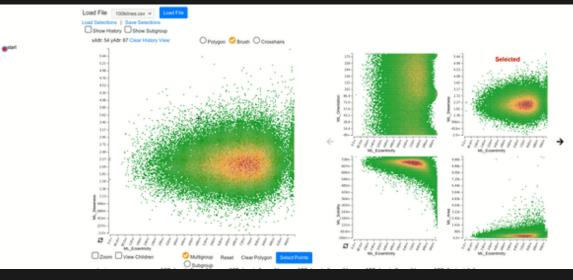


- Interactive data sub-setting across dimensions, zoomed and global views
- Familiar dynamic group selection tools with a history dendrogram and plot view

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 DeepZoom of all pair-wise feature scatter plots



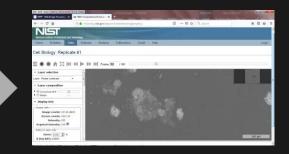
- Interactive data sub-setting across dimensions, zoomed and global views
- Familiar dynamic group selection tools with a history dendrogram and plot view

# Examples of Data Sharing and Dissemination

- Provenance data:hyperlinked computations with all metadata about data and execution configurations
- Large size image data:pyramid representation with Deep Zoom enabled browsing of images
- Image-based measurements: hyperlinked thumbnails and numerical values to persistent image ROIs



Provenance data associated with each computation



Persistent large size image data

# Dissemination (WIPP 3.0 Beta version)

- Source code is in GitHub repositories
  - WIPP (main repo with documentation and deployment instructions) https://github.com/usnistgov/WIPP
  - WIPP-backend (J ava Spring REST API): <u>https://github.com/usnistgobackend</u>
  - WIPP-frontend (Angular 7 app): https://github.com/usnistgov/WIPP-frontence
- Docker containers are in Docker Hub
- We provide single node installation instructions for all platforms
  - Tested on Linux 18.04, Windows 10 Enterprise, and Mac OS10
- WIPP 3.0 installation includes
  - Image processing and AI semantic segmentation plugins
  - Integrated J upyter notebook
    - Prototyping in 13 programming languages
  - Interactive scatter plots
    - Visualization and sub-setting of millions of image-based meas urements.













































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		The g and team

- External NIST BIO/MAT

# Disclaimer

Commercial products are identified in this document in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by NIST, nor is it intended to imply that the products identified are necessarily the best available for the purpose.