Tutorial: MONAI Core

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Solutions Architect, Higher Education & Research

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@ University of Florida

Agenda

- What is MONAI?
- What is MONAI Core & Why use it?
- MONAI Core local success story
- How to use MONAI Core on HiperGator? +demo
- Resources
- Data analytics: CuPy, RAPIDS

WHAT IS MONAI?

Medical Open Network for AI

Project MONAI

- a collaborative open-source initiative
- founded at MICCAI 2019
- establish and standardize the best practices for deep learning in healthcare imaging to accelerate the pace of innovation.

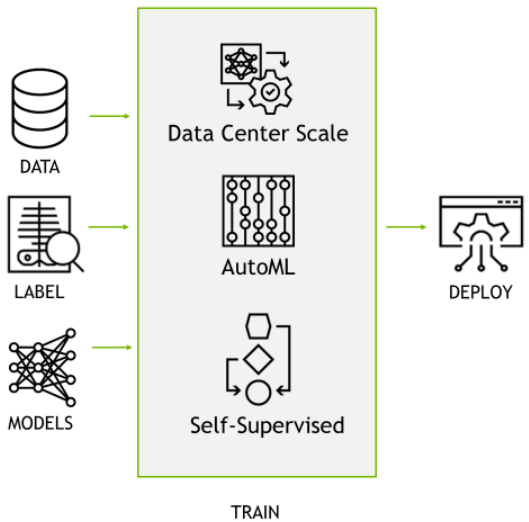
MONAI

World's Most Advanced Framework for Medical AI

428,000 Downloads of MONAI Core

STATE-OF-THE-ART AI

From Data to Deployment Dev Tools



GLOBAL ECOSYSTEM

Community Lead | Accessibility

World Leading Contributors

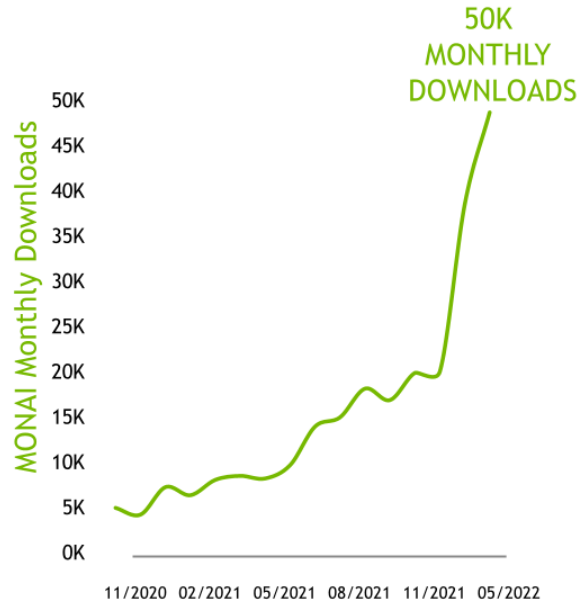
AI CENTRE for Value Based Healthcare · dkfz. German Cancer Research Center · Frederick National Laboratory for Cancer Research · IOWA · King's College London · kitware · Mayo Clinic · Mass General Brigham · Guy's and St Thomas' NHS Foundation Trust · NVIDIA · Technische Universität München · UCSF · ci² center for intelligent imaging · Universitätsklinikum Essen · Vanderbilt University · Warwick

Integration Partners

Amazon SageMaker · Microsoft · Google Cloud Platform · mlflow · 3DSlicer · Open Health Imaging Foundation · Answer · quantiphi Solving What Matters

EXPONENTIAL GROWTH

Accelerating Open Research



R&D MOMENTUM

Publishing to Production

Top 30+

Research Medical Centers
Published over 138 Papers

AI CENTRE for Value Based Healthcare — **AIDE: A NEW OPERATING SYSTEM FOR THE HOSPITAL**

MAYO CLINIC — **EXPERIENCES WITH ALGORITHM DEPLOYMENT IN HEALTHCARE SETTINGS**

aws — **ACCELERATE YOUR MEDICAL IMAGING RESEARCH WITH MONAI ON AWS**

WHAT IS MONAI?

Accelerate Pace of Research Innovation With a Common Foundation

AI-assisted image labeling tool

MONAI Label v0.4

deep learning training

MONAI Core v0.9

create applications from models
in minutes

MONAI Deploy App SDK v0.3

Coming Soon!

MONAI Stream

MONAI Core

Medical-imaging PyTorch.

MONAI Core

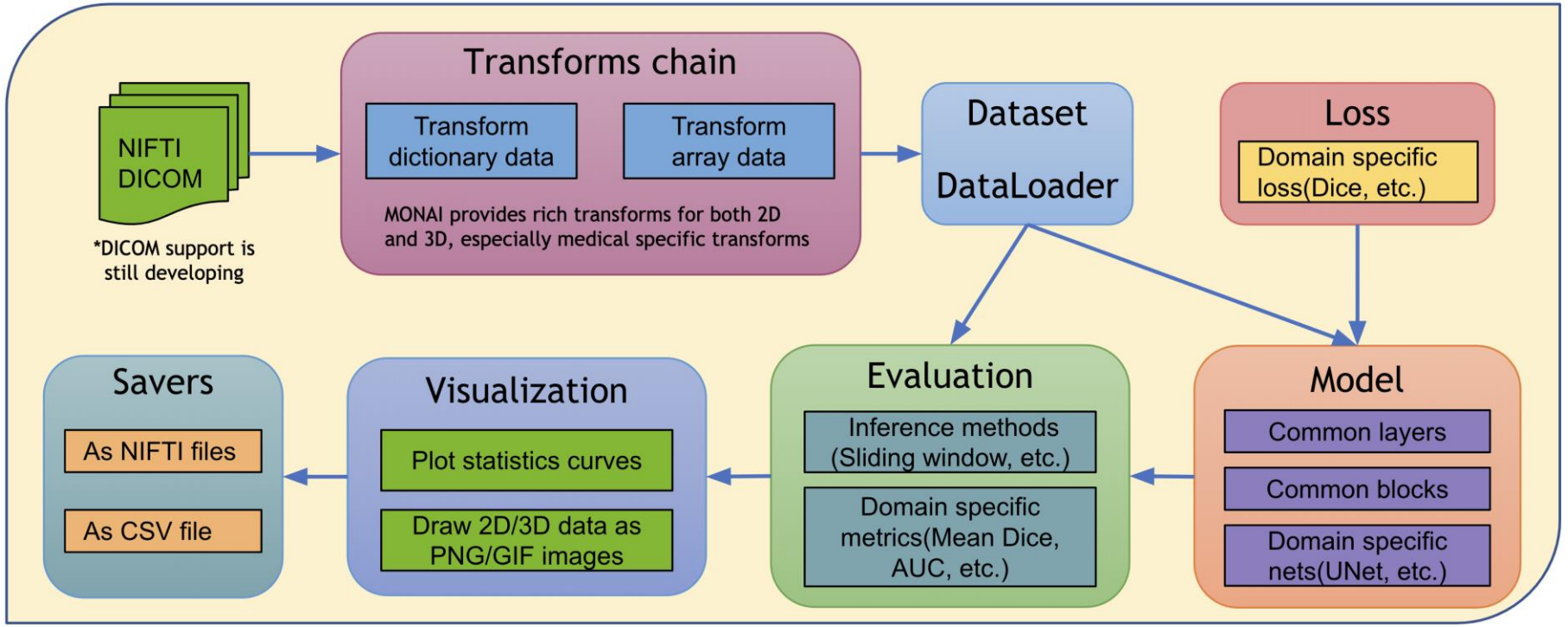
1. Medical-imaging-specific AI framework

2. Superior performance

3. Friendly community

MONAI Core

1. Medical imaging specific AI framework – ***comprehensive & flexible***
2. Superior performance
3. Friendly community



MONAI website https://monai.io/

MONAI Core

1. Medical imaging specific AI framework – ***comprehensive & flexible***

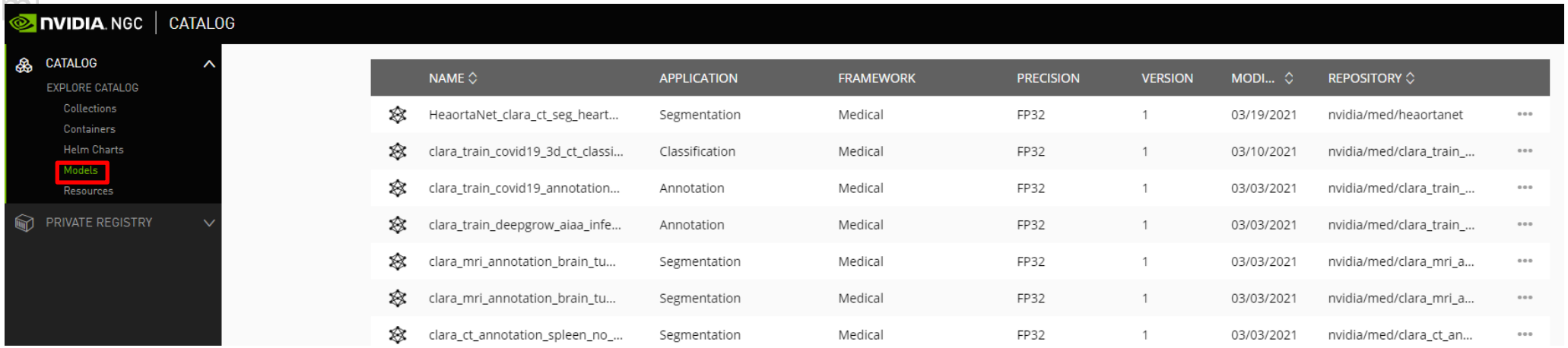
PRE-TRAINED models

2. Superior performance

Download from NGC 20+ Pre-Trained Models: CT, MRI, X-Ray, Digital Pathology

https://catalog.ngc.nvidia.com/ go to CATALOG/Models, then search `clara`

3. Friendly comm



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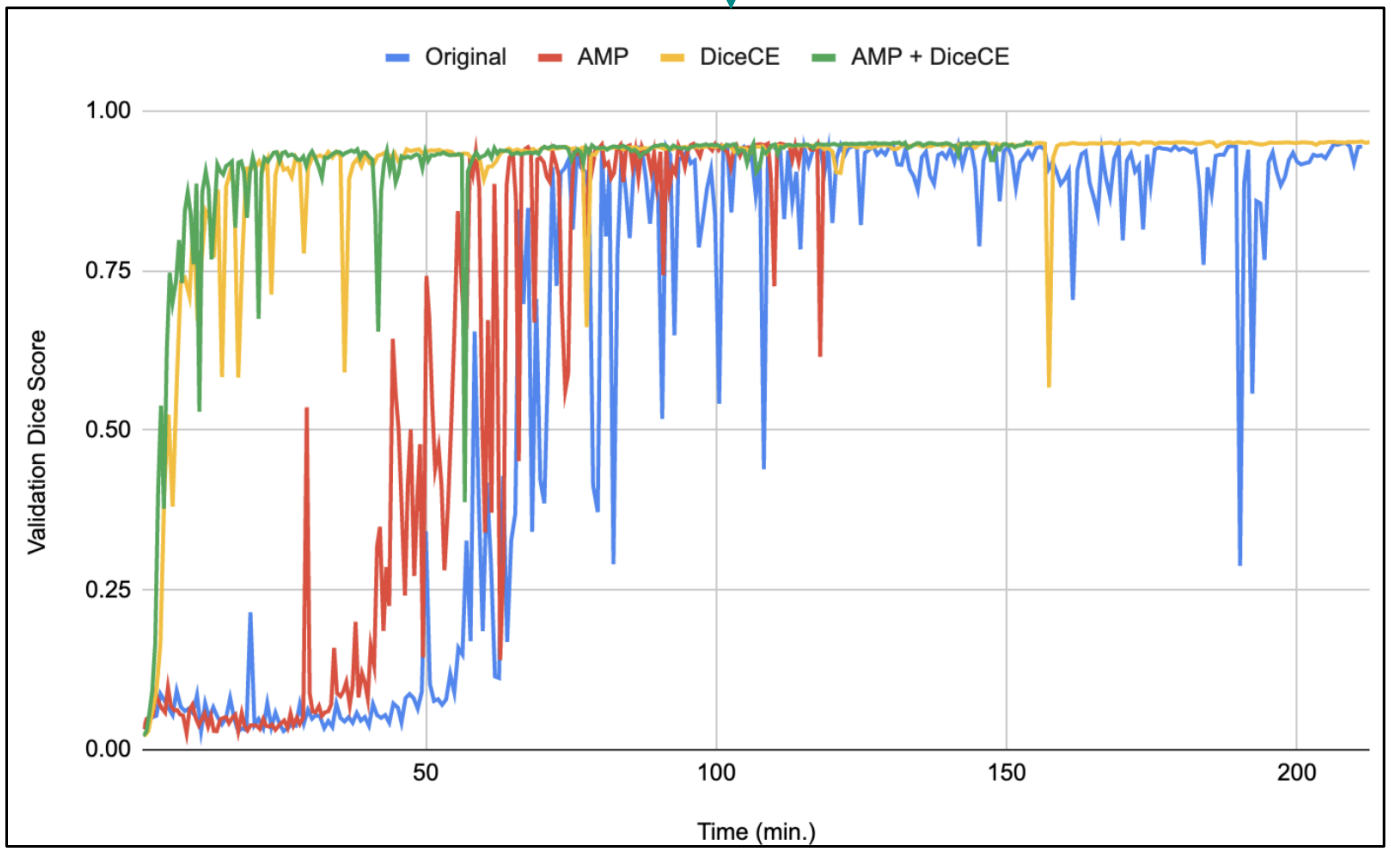
Improve AI algorithms

- *Network architecture - UNETR*, Swin UNETR …*
- *Optimizer - Novograd …*
- *Loss function - DiceCELoss …*

- Self-supervised pretraining
- ranked 1st on the public test leaderboards of both MSD and BTCV datasets



* *Hatamizadeh et al., UNETR: Transformers for 3D Medical Image Segmentation*

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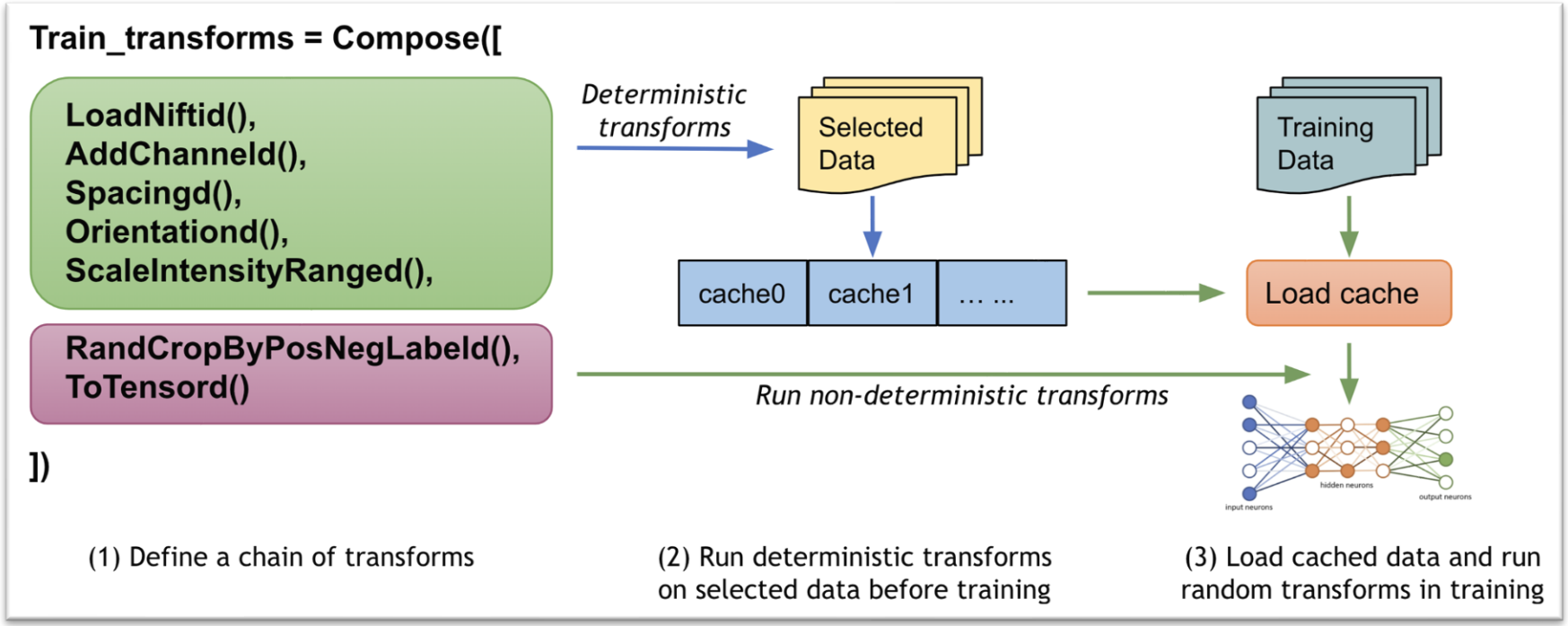
Optimize data loading

Dataset Caching - 10X speed up



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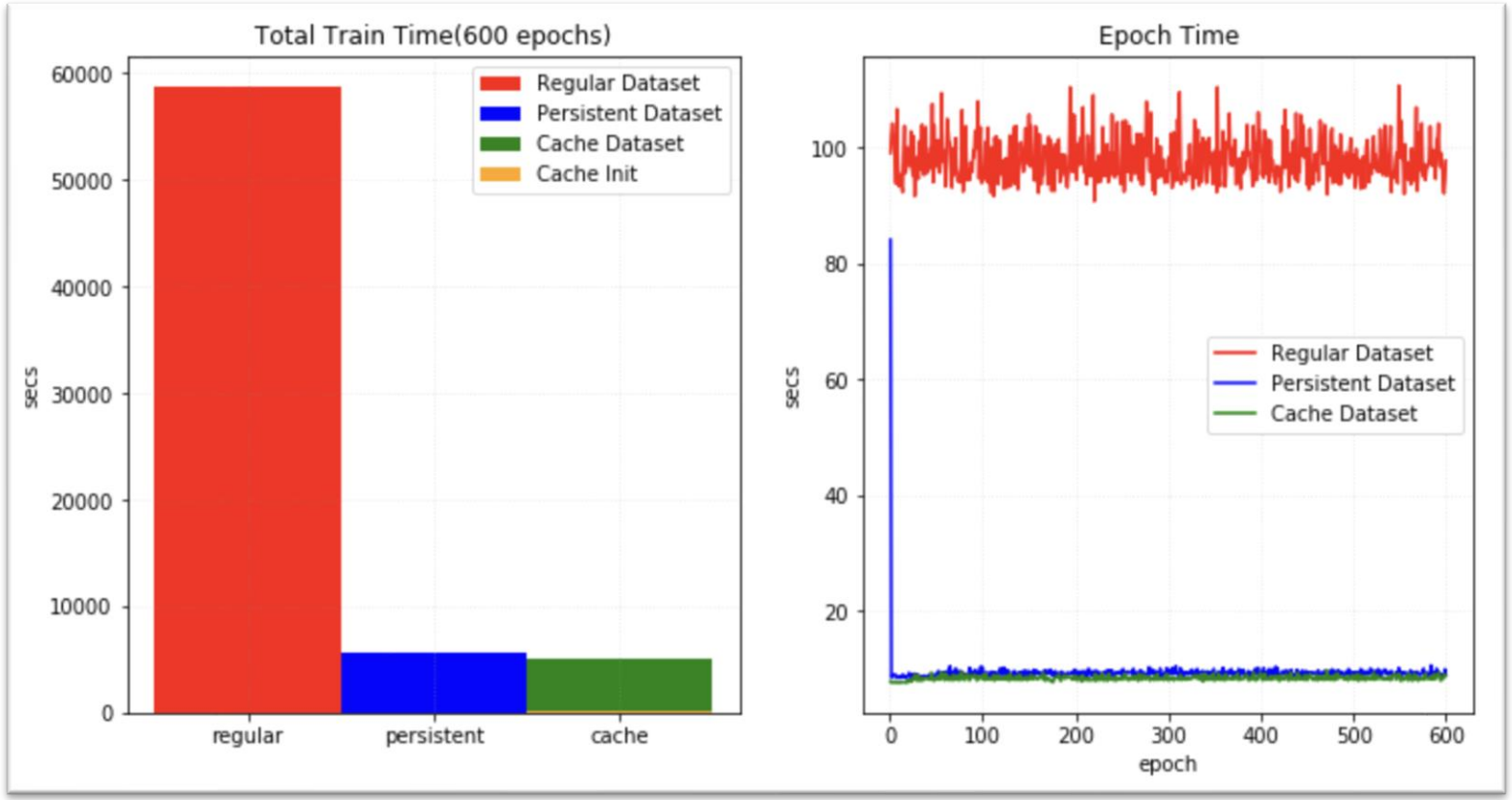
Optimize data loading

Dataset Caching - 10X speed up

e.g. CacheDataset, PersistentDataset, SmartCacheDataset



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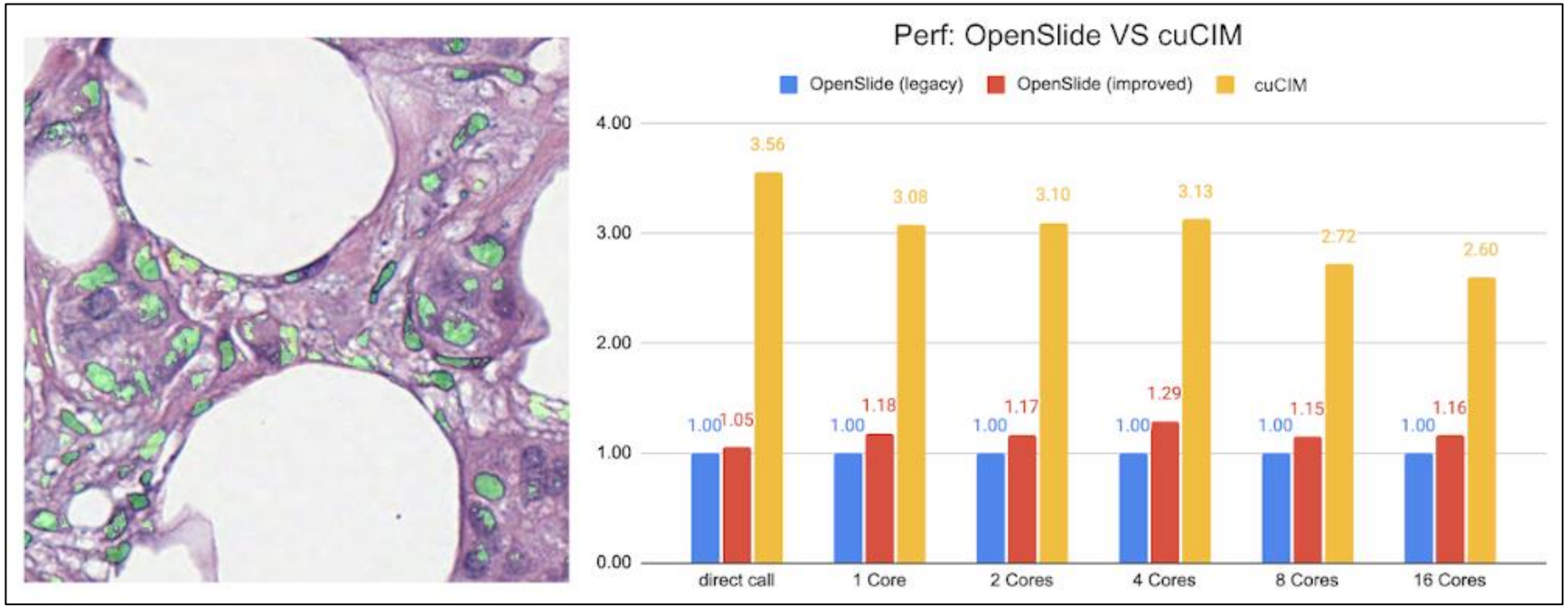
Optimize data loading

cuCIM – Whole Slide Imaging (digital pathology)



cuCIM - a toolkit within RAPIDS

MONAI Core

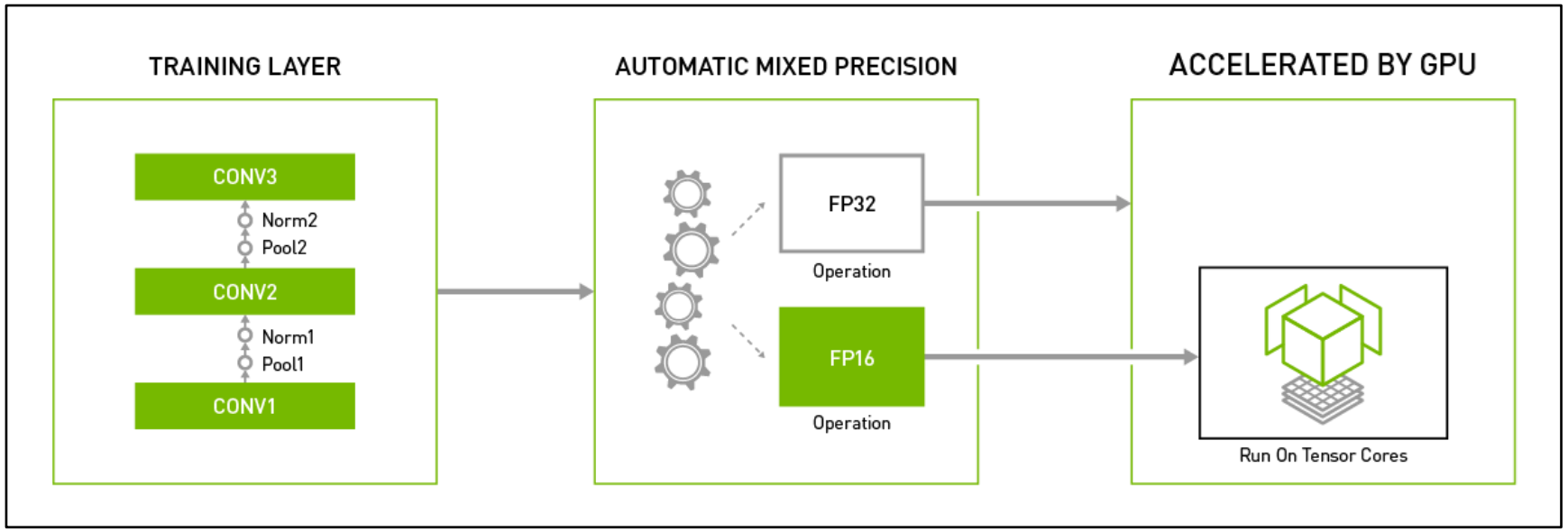
Optimize GPU utilization

AMP (Automatic Mixed Precision) - 2X speed up

1. Medical imaging specif

2. Superior performance

3. Friendly community



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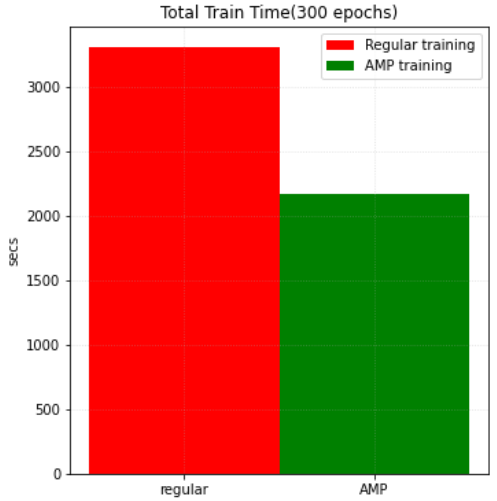
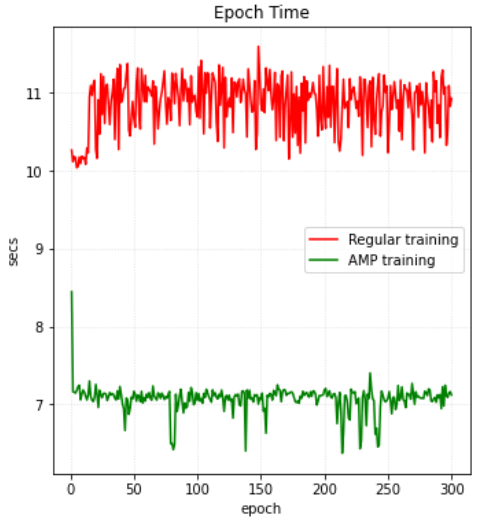
Optimize GPU utilization

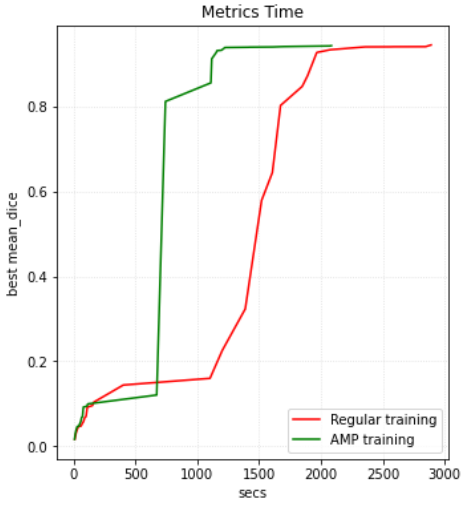
AMP (Automatic Mixed Precision) - 2X speed up

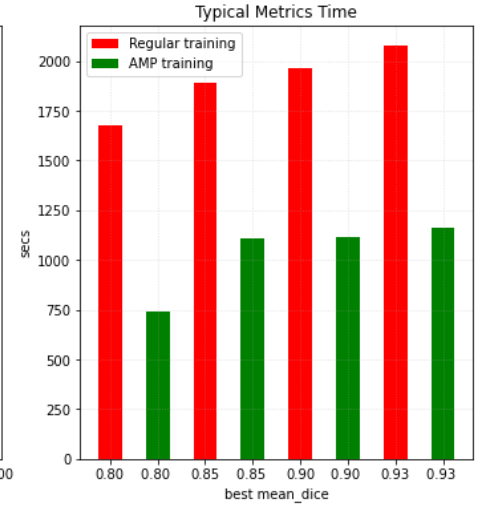
V100

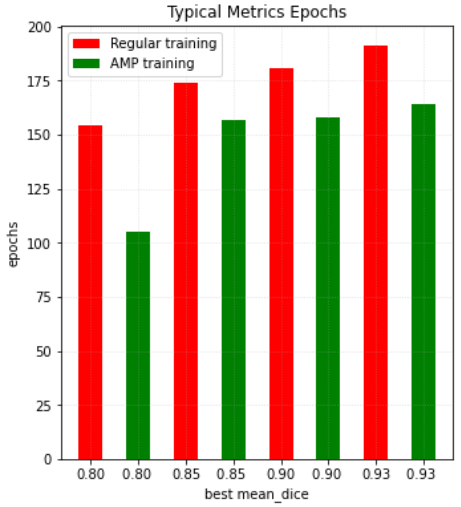
*A100 - **another 2X***











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Optimize GPU utilization

AMP (Automatic Mixed Precision) - 2X speed up

Easy to enable in MONAI workflow

```
trainer = SupervisedTrainer(
    device=device,
    max_epochs=100,
    train_data_loader=train_loader,
    network=net,
    optimizer=opt,
    loss_function=loss,
    inferer=SimpleInferer(),
    post_transform=train_post_transforms,
    key_train_metric={"train_acc": Accuracy()},
    train_handlers=train_handlers,
    amp=True,
)

evaluator = SupervisedEvaluator(
    device=device,
    val_data_loader=val_loader,
    network=net,
    inferer=SlidingWindowInferer(),
    post_transform=val_post_transforms,
    key_val_metric={"val_mean_dice": MeanDice()},
    additional_metrics={"val_acc": Accuracy()},
    val_handlers=val_handlers,
    amp=True,
)
```

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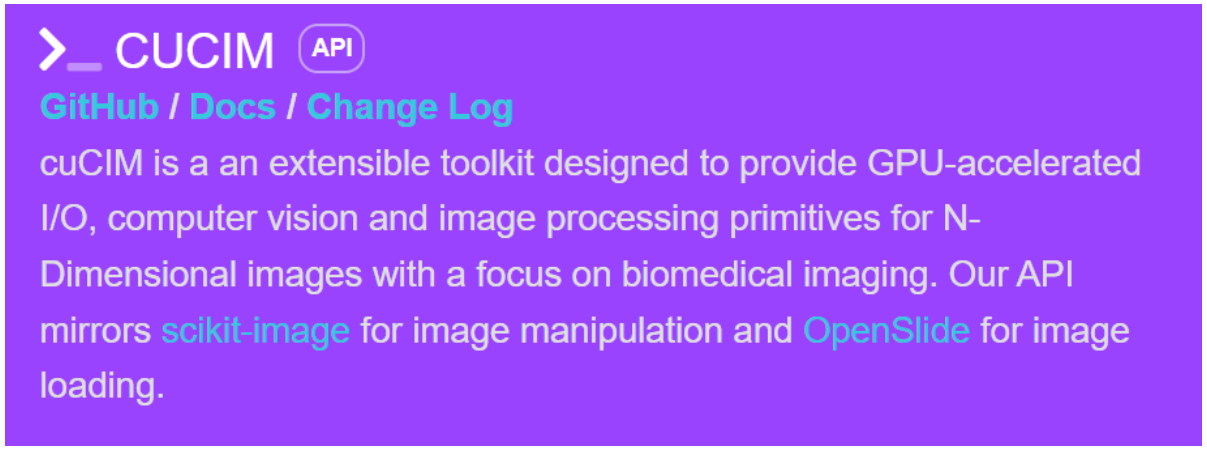
Optimize GPU utilization

Do transforms on GPU

cuCIM -> common transforms in digital pathology



https://rapids.ai/

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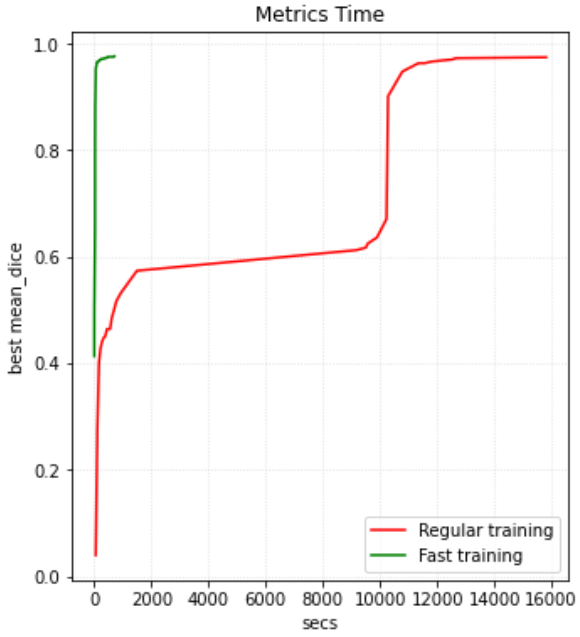
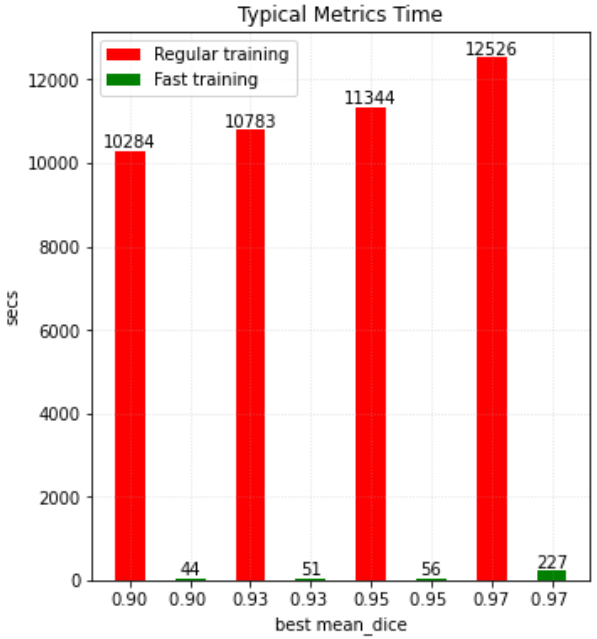
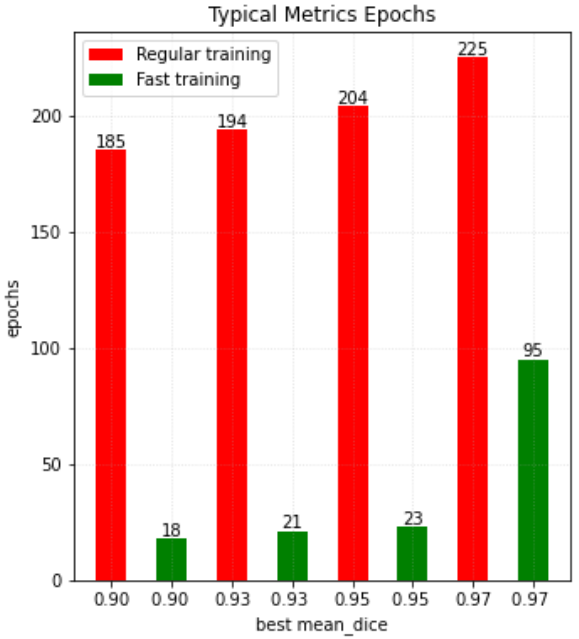
Combine previous techniques: 3D spleen segmentation

Novograd optimizer + DiceCELoss + CacheDataset + ThreadDataLoader + AMP

*A100 - **200X** native PyTorch*







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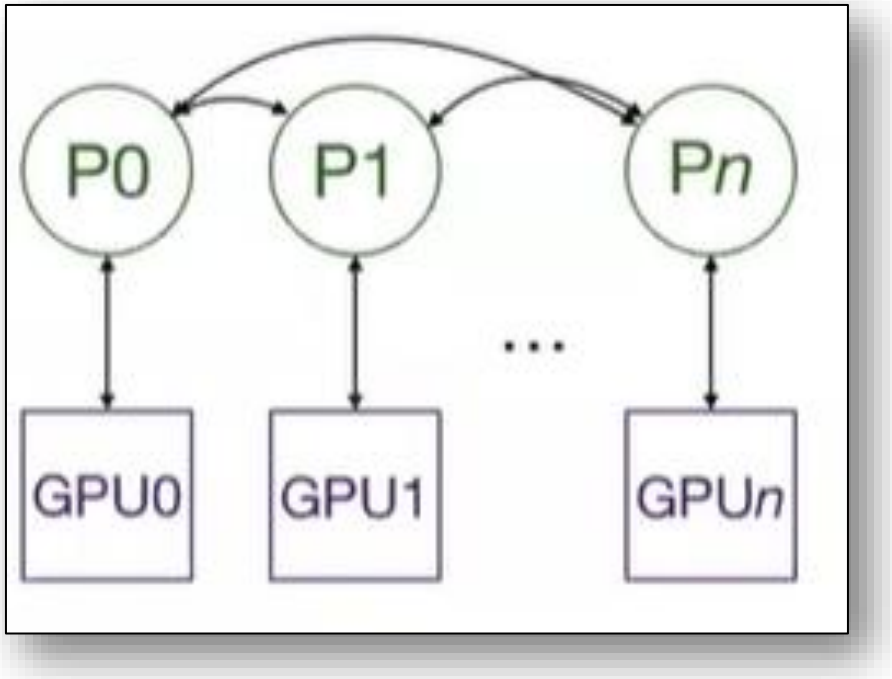
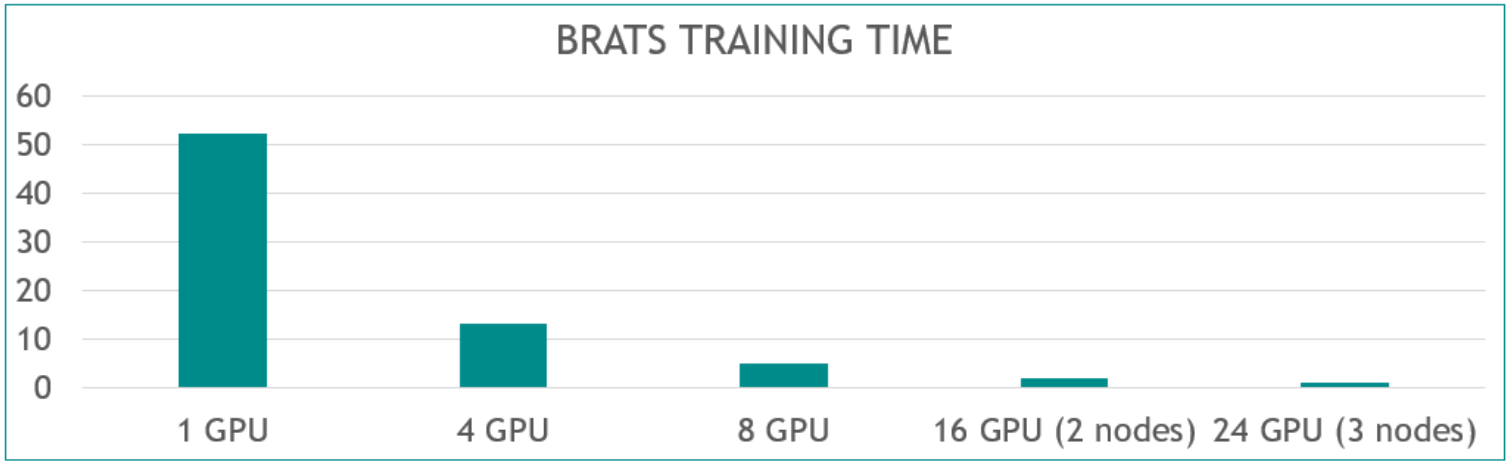
Leverage multi-GPU multi-node training

DDP (Distributed Data Parallel)

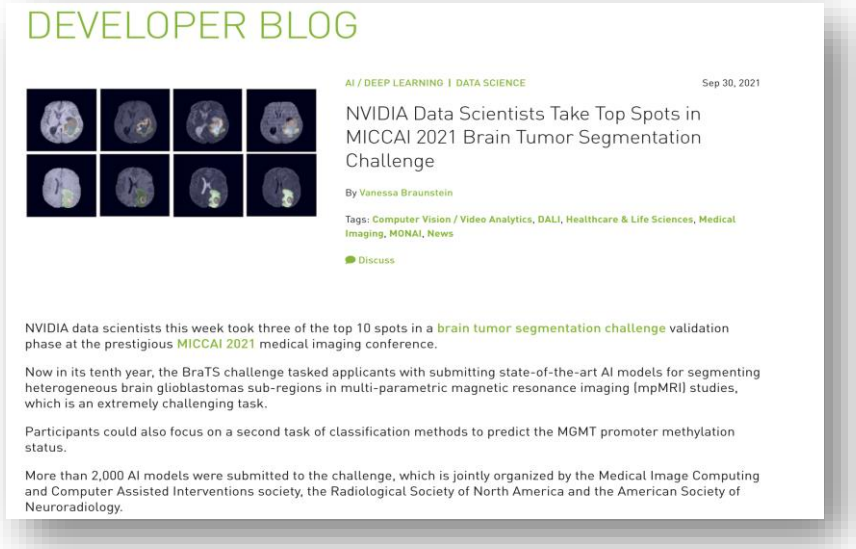


RSNA-ASNR-MICCAI BRAIN TUMOR SEGMENTATION (BRATS) CHALLENGE 2021

3 / top10 models were built by MONAI Core



BRATS'21 workloads executed on DGX A100 320GB systems.



DEVELOPER BLOG

AI / DEEP LEARNING | DATA SCIENCE Sep 30, 2021

NVIDIA Data Scientists Take Top Spots in MICCAI 2021 Brain Tumor Segmentation Challenge

By Vanessa Braunstein

Tags: Computer Vision / Video Analytics, DALI, Healthcare & Life Sciences, Medical Imaging, MONAI, News

Discuss

NVIDIA data scientists this week took three of the top 10 spots in a brain tumor segmentation challenge validation phase at the prestigious MICCAI 2021 medical imaging conference.

Now in its tenth year, the BraTS challenge tasked applicants with submitting state-of-the-art AI models for segmenting heterogeneous brain glioblastomas sub-regions in multi-parametric magnetic resonance imaging (mpMRI) studies, which is an extremely challenging task.

Participants could also focus on a second task of classification methods to predict the MGMT promoter methylation status.

More than 2,000 AI models were submitted to the challenge, which is jointly organized by the Medical Image Computing and Computer Assisted Interventions society, the Radiological Society of North America and the American Society of Neuroradiology.

link

MONAI Core

1. Medical imaging specific AI framework

2. Superior performance

Learn more [Tutorial: Fast Model Training Guide]

3. Friendly community

MONAI Core

1. Medical imaging specific AI framework

2. Superior performance

3. Friendly community – ***learn***, ***ask***, ***contribute***, ***guide***

MONAI Core

1. Medical imaging specific AI framework – ***comprehensive & flexible***

2. Superior performance – ***improve algorithms, optimize data loading & GPU utilization, multi-GPU***

3. Friendly community – ***learn, ask, contribute, guide***

MONAI Core for High-Fidelity Head Image Segmentation for Precision Intervention in Cognitive Aging

UF BME

UF College of Public Health & Health Professions UNIVERSITY of FLORIDA

UF Center for Cognitive Aging and Memory Clinical Translational Research
EVELYN F. AND WILLIAM L. MCKNIGHT BRAIN INSTITUTE


Dr. Ruogu Fang, Ph.D.


Skylar Stolte


Dr. Adam Woods Ph.D.


Dr. Aprinda Indahlastari, Ph.D.

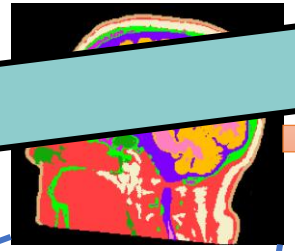

Alejandro Albizu

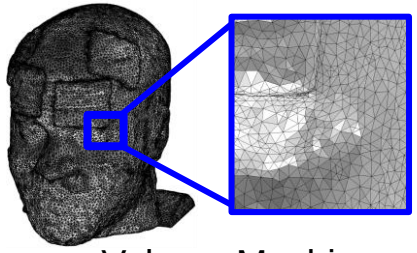
- **MONAI** offers **modular**, **open-source**, and **state-of-the-art** deep learning frameworks for versatile medical image analysis applications.
- MONAI Core accelerates our investigation and development of a **high-** **image se** structural MRI images.
- This tool potentiates a **fully-automatic, high-precision, and personalized intervention** system using non-invasive brain stimulation to remediate cognitive aging and prevent dementia.
- **Next steps:** Build an interactive app using MONAI Label and package using MONAI Deploy where researchers can obtain fast high-fidelity head image segmentation and improve the model using direct interaction.

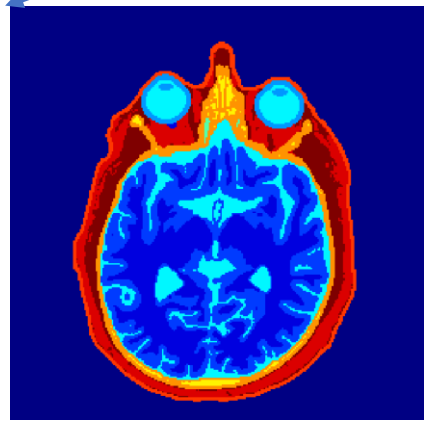
Training 27hr → 5 hr

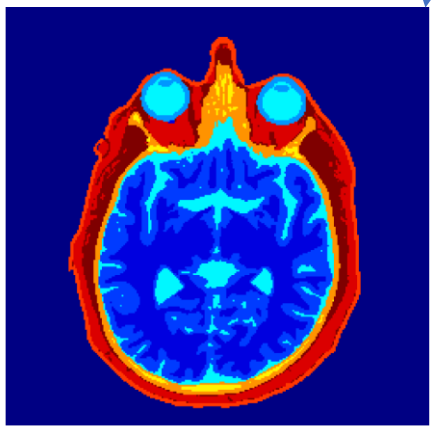

tDCS Stimulation

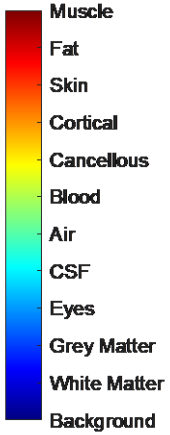

T1 MRI

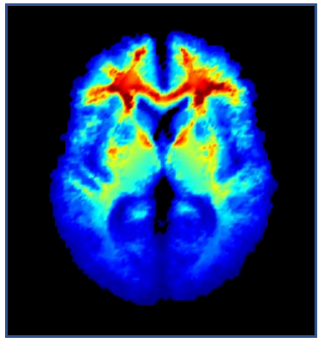

Head tissue segmentation


Volume Meshing


Ground Truth Manual Segmentation (~20 hours)


MONAI-Enabled Auto-Segmentation (3 s)




Electrical Current Map

How to use MONAI Core on HiperGator?

Demo

https://github.com/hw-ju/monai_uf_tutorials

Resources

HiperGator

- Become a HiperGator user (request HiperGator accounts, trials, submit purchase forms, etc)
https://www.rc.ufl.edu/get-started/hipergator/

- How to use HiperGator?
  - UFRC wiki https://help.rc.ufl.edu/doc/UFRC_Help_and_Documentation
  - Open OnDemand https://help.rc.ufl.edu/doc/Open_OnDemand

- MONAI wiki page https://help.rc.ufl.edu/doc/Monai

- Need more help?
  - Submit a ticket https://support.rc.ufl.edu
  - Doc on getting help https://help.rc.ufl.edu/doc/Get_Help

Resources

MONAI sessions @GTC 2022

- AI-assisted Annotation for Continuous Learning with MONAI Label [DLIT2098]
- Developing for the AI Medical Project Life Cycle: MONAI Community Developer Meetup [SE2174]
- Accelerate your research with MONAI on AWS [S42397]
- Design, Train, and Evaluate Domain-specialized Health-care Imaging AI Models with MONAI [DLIT2097]
- Creating Inference Applications for the Medical AI Project Life Cycle using MONAI Deploy [DLIT2099]
- HCLS Dev Summit: Building an Open-source Foundation to Fuel R&D Innovation [S42639]
- Experiences in Algorithm Deployment in Large Healthcare Settings and Continuous Learning [S41923] Mayo Clinic
- Scientific Process of Building AI Models (Presented by Quantiphi, Inc.) [S42426] Quantiphi, Inc.
- AI Building Blocks for Industry 4.0 (Presented by Supermicro) [S42564] Super Micro Computer, Inc.

Resources

MONAI

1. **Get Started with MONAI**

- Homepage (Doc & Github links on top right) https://github.com/Project-MONAI
- YouTube Channel https://www.youtube.com/c/Project-MONAI
- MONAI Bootcamp 2021 at MICCAI
  - GitHub https://github.com/Project-MONAI/MONAIBootcamp2021
  - Bootcamp Recording Playlist (sessions for MONAI Label, MONAI Core, MONAI Deploy, MONAI Federated Learning) https://www.youtube.com/playlist?list=PLtoSVSQ2XzyCobzE6NvwjNpITsQyPUtfs
- MONAI Bootcamp 2020
  - Github https://github.com/Project-MONAI/MONAIBootcamp2020
- MONAI Label – Annotate datasets & interactively create AI models for annotation
  - Github https://github.com/Project-MONAI/MONAILabel
  - Doc (please explore the top menu bar What's New, Installation, Quickstart [step-by-step tutorials], Modules Overview, Application Deployment, API Reference) https://docs.monai.io/projects/label/en/latest/whatsnew.html
  - Recording from MONAI Bootcamp 2021 (please try to repeat the two demos, see attached *demos_monailabel.docx* for steps used in the demos) https://www.youtube.com/watch?v=o8HipCgSZIw&list=PLtoSVSQ2XzyCobzE6NvwjNpITsQyPUtfs&index=11&t=1819s
  - To learn more about 3D Slicer basics, see Getting Started section in its doc https://slicer.readthedocs.io/en/latest/user_guide/getting_started.html
- MONAI Core - Create AI models
  - Tutorials (for almost all common tasks) https://github.com/Project-MONAI/tutorials
  - Fast Model Training Guide https://github.com/Project-MONAI/tutorials/blob/4735dd0387db0aa8c37729ec7b6261ba1b52b6a2/acceleration/fast_model_training_guide.md
  - Github https://github.com/Project-MONAI/MONAI
  - Doc (please explore the top menu bar What's New, Installation, etc) https://docs.monai.io/en/stable/whatsnew.html
  - Recordings from MONAI Bootcamp 2021 (many sessions in the playlist below) https://www.youtube.com/playlist?list=PLtoSVSQ2XzyCobzE6NvwjNpITsQyPUtfs
  - End-to-End MONAI Core Workflow Google Colab jupyter notebook from MONAI Bootcamp 2020 https://colab.research.google.com/github/Project-MONAI/MONAIBootcamp2020/blob/master/day1notebooks/lab2_end_to_end.ipynb

Resources

MONAI

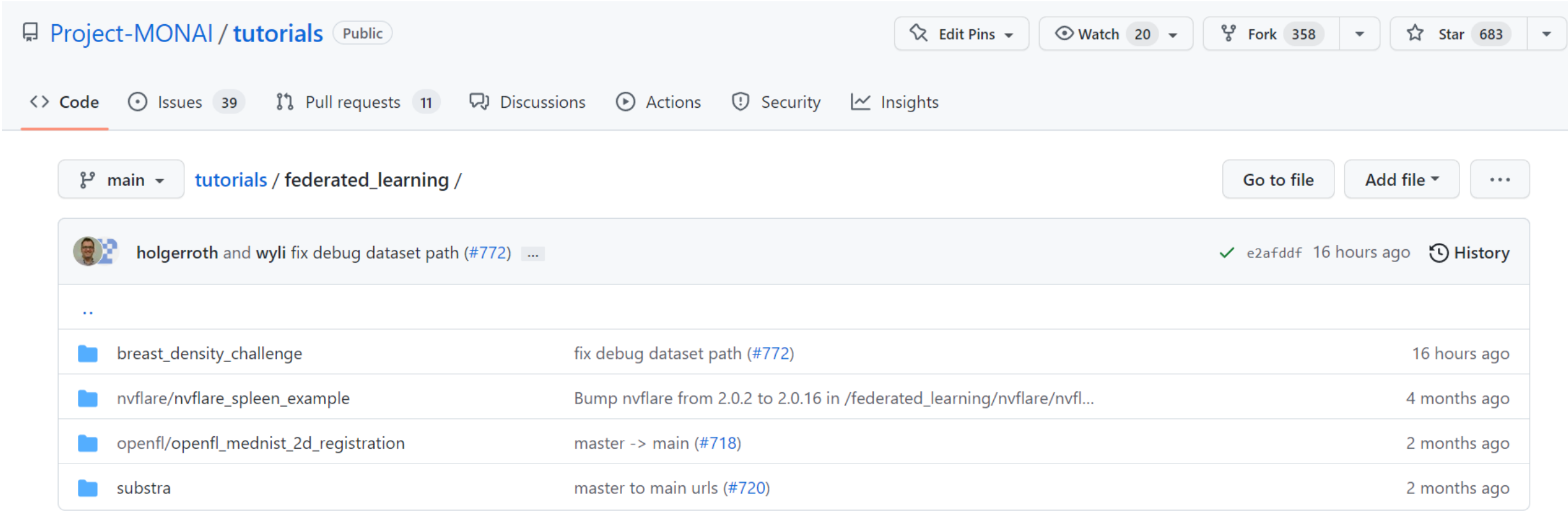
- MONAI Deploy - Create an application from an AI model
  - Github https://github.com/Project-MONAI/monai-deploy-app-sdk
  - Doc (please explore the top menu bar, the Getting Start tab has multiple tutorials) https://docs.monai.io/projects/monai-deploy-app-sdk/en/latest/release_notes/index.html
  - Recording from MONAI Bootcamp 2021 (please try to repeat the demos, step-by-step tutorials for the demos are within the Getting Start tab of the Doc listed above) https://www.youtube.com/watch?v=pS68i8ShoOk&list=PLtoSVSQ2XzyCobzE6NvwjNpITsQyPUtfs&index=12
- MONAI Federated Learning – use MONAI within NVIDIA Flare
  - Tutorials https://github.com/Project-MONAI/tutorials/tree/master/federated_learning
- Report bugs\ask questions\request new features\provide any feedback: Issues & Discussion tabs within each repo (they always reply promptly). E.g., for MONAI Core
  - Issues tab https://github.com/Project-MONAI/MONAI/issues
  - Discussion tab https://github.com/Project-MONAI/MONAI/discussions
- **Digital Pathology** (please do more thorough exploration by yourself, search `pathology` within Doc &Project-MONAI Github repo should be helpful)
  - Tutorials https://github.com/Project-MONAI/tutorials/tree/master/pathology
  - From the doc
    https://docs.monai.io/en/stable/whatsnew_0_5.html?highlight=pathology#lesion-detection-in-digital-pathology
    https://docs.monai.io/en/stable/whatsnew_0_8.html?highlight=pathology#multiple-instance-learning-for-digital-pathology-wsi-analysis
    https://docs.monai.io/en/stable/highlights.html?highlight=pathology#integrate-third-party-transforms

2. Contribute to MONAI

- GitHub
  - Community Guide: https://github.com/Project-MONAI/MONAI#community
  - Contributing Guide: https://github.com/Project-MONAI/MONAI#contributing
- Join the Slack Channel. Fill out the Google Form here https://forms.gle/QTxJq3hFictp31UM9

Federated Learning using MONAI Core

Based on NVIDIA Flare (open-source SDK)
https://nvidia.github.io/NVFlare/



https://github.com/Project-MONAI/tutorials/tree/master/federated_learning

TOWARDS MULTI-OMICS / MULTIMODAL DATA

```
class CSVDataset(Dataset):
    """
    Dataset to load data from CSV files and generate a list of dictionaries,
    every dictionary maps to a row of the CSV file, and the keys of dictionary
    map to the column names of the CSV file.
```

patient_id	age	sex	kg	image	video	letter
Subject_01	34	M	75	./imgs/01.nii.gz	./vid/01.mp4	./letters/01.doc
Subject_02	62	F	84	./imgs/02.nii.gz	./vid/02.mp4	./letters/02.doc
Subject_03	57	M	112	./imgs/03.nii.gz	./vid/03.mp4	./letters/03.doc
…						

EHR | Image | Video | Letter

```
batch = {'ehr': ...,
         'image': ...,
         'video': ...,
         'letter': ...
        }
```

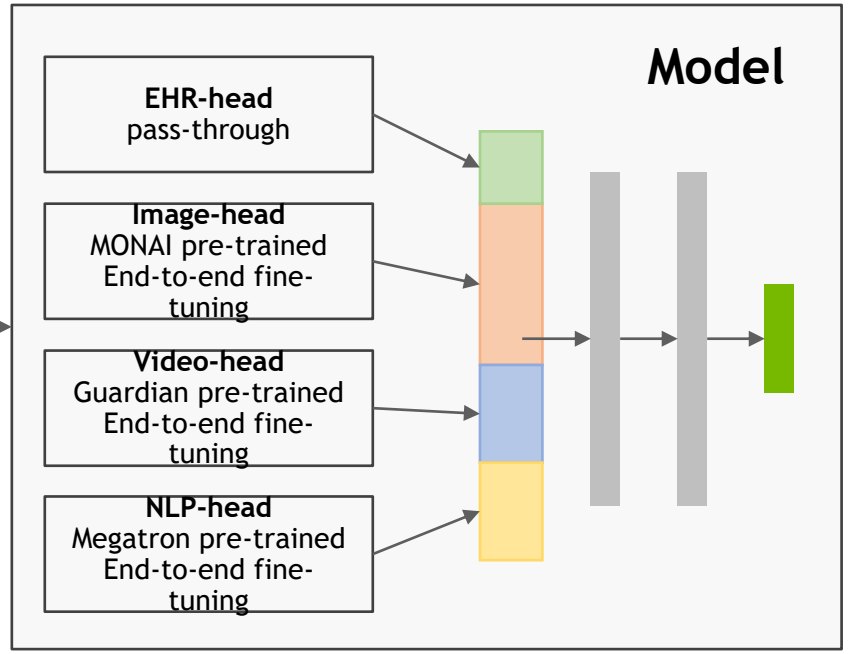
Modality-specific transforms

Tutorial notebook:

- CSVDataset and HuggingFaceTransform: [notebook]
- Multimodal transformer model TransCheX: [notebook]

Classes:

- CSVDataset
- TransCheX



Data Analytics: CuPy

Drop-in replacement for Numpy

CUPY

A NumPy like interface to GPU-acceleration ND-Array operations

BEFORE

```
import numpy as np

size = 4096
A = np.random.randn(size,size)

Q, R = np.lingalg.qr(A)
```

AFTER

```
import cupy as cp

size = 4096
A = cp.random.randn(size,size)

Q, R = cp.lingalg.qr(A)
```

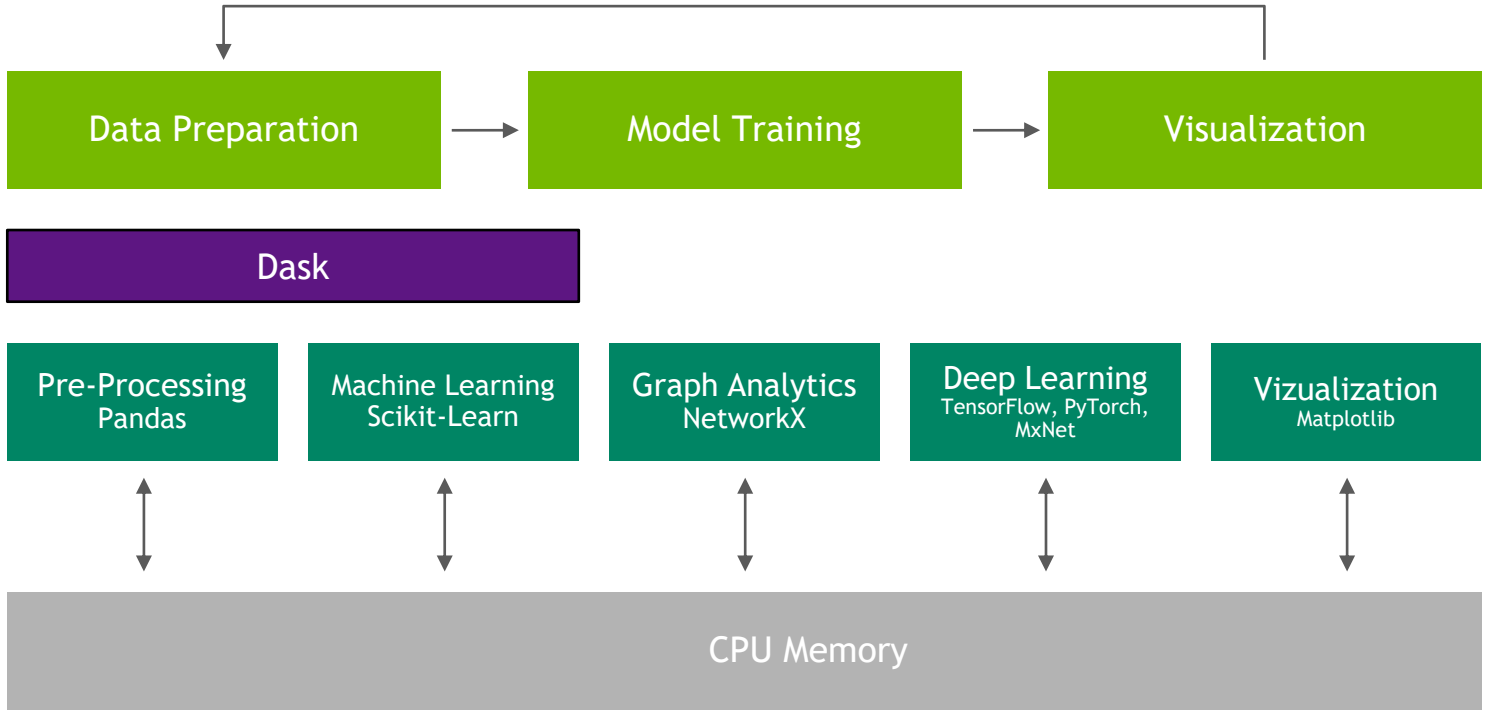
52x Speedup!

CuPy

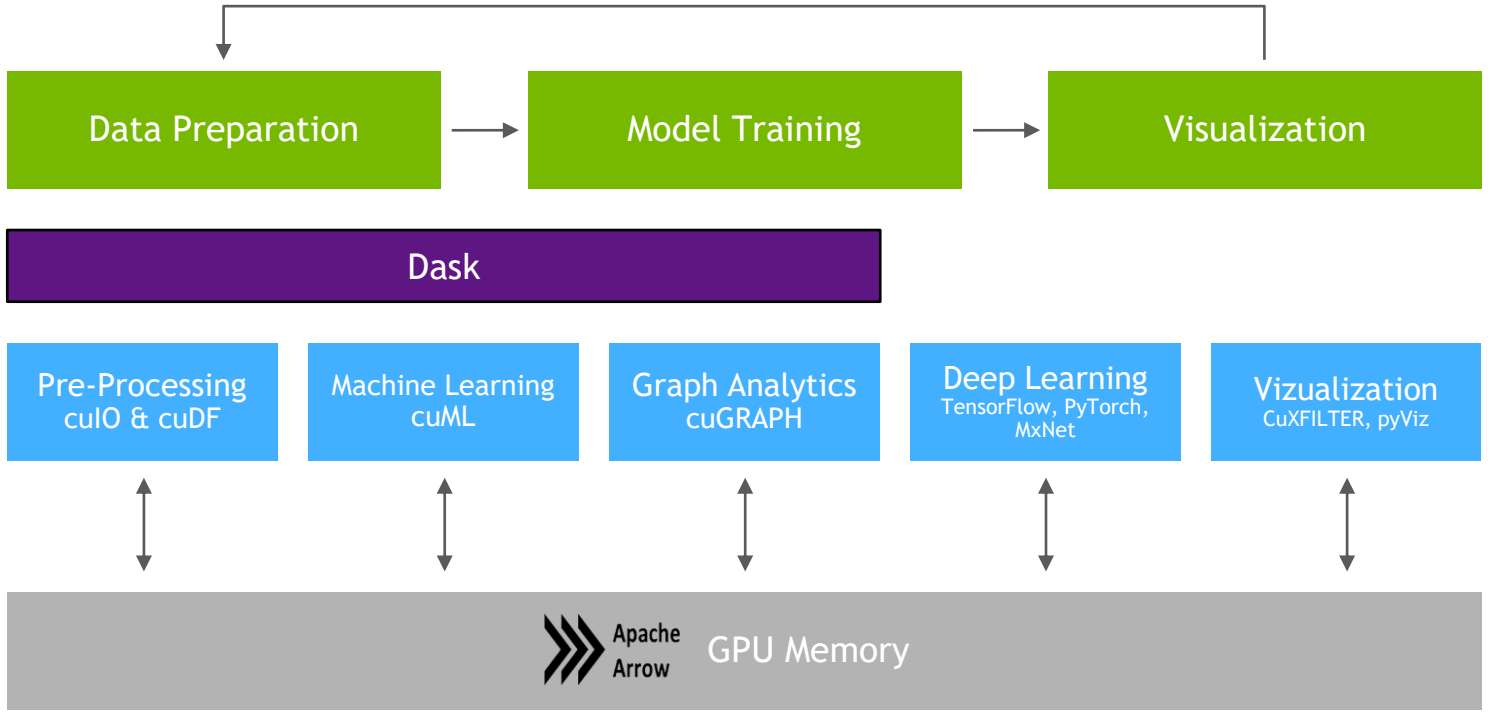
Data Analytics: RAPIDS

GPU-accelerated data science with API alignment

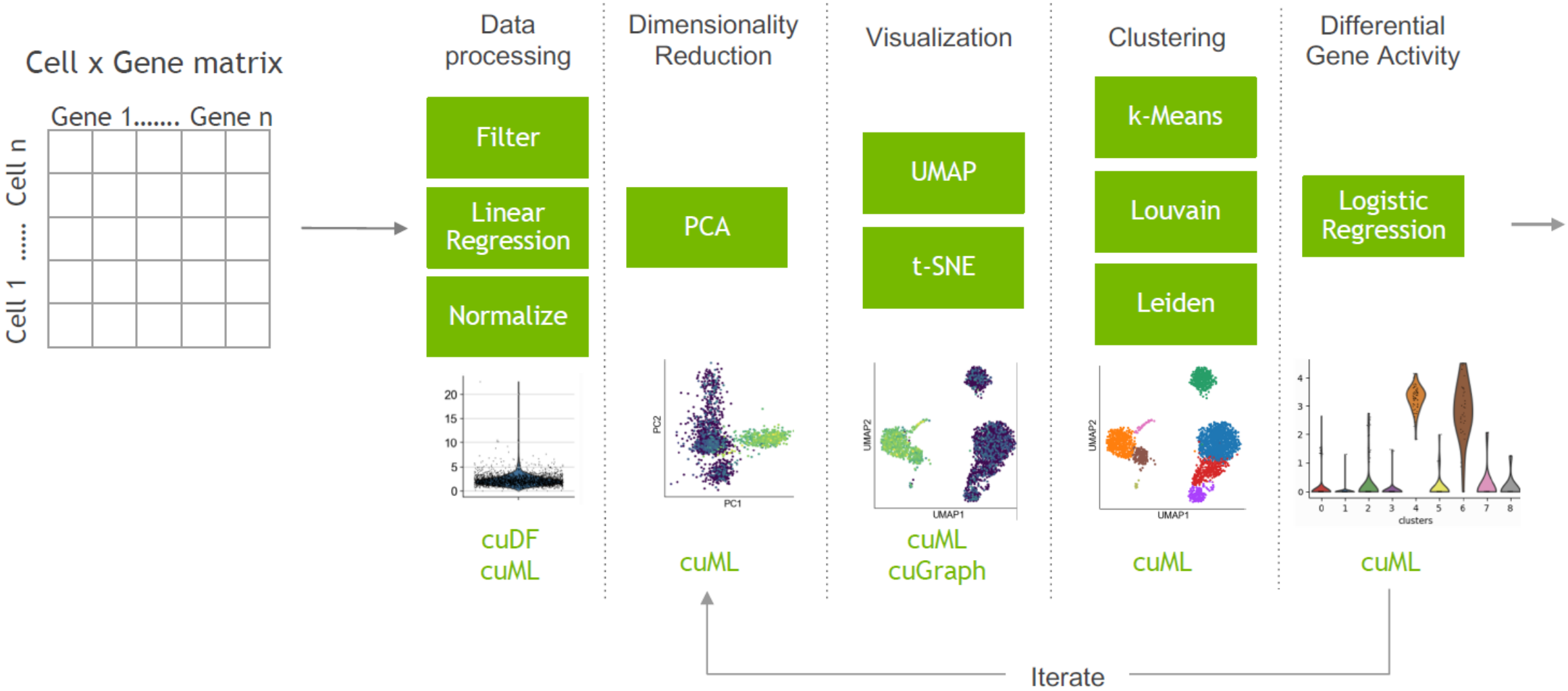
TRADITIONAL DATA SCIENCE APPLICATIONS



RAPIDS: GPU-ACCELERATED DATA SCIENCE
WITH API ALIGNMENT



SINGLE-CELL RNA-SEQ ANALYSIS USING RAPIDS

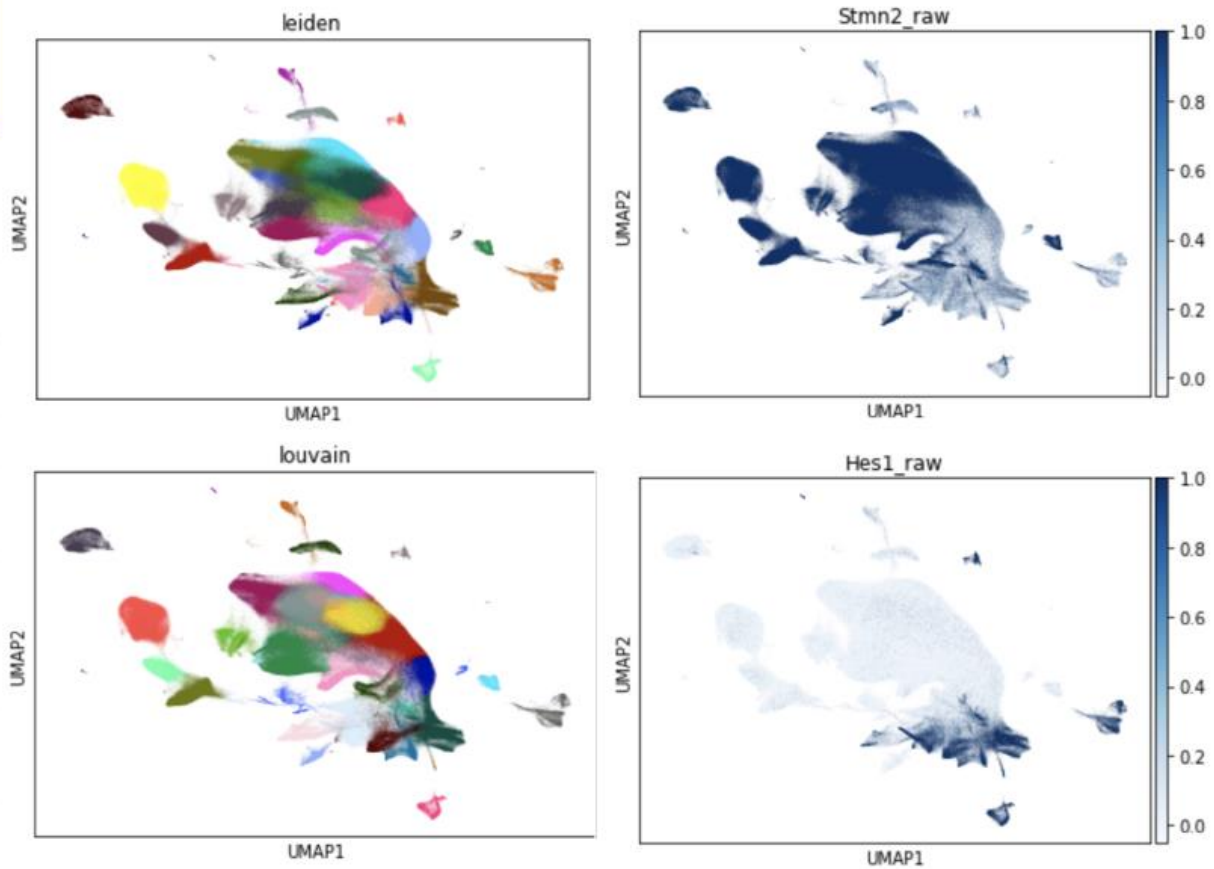


Rapids single cell jupyter notebooks

GPU ANALYSIS OF 1 MILLION CELLS

From 3.5 hours to 8 minutes

	CPU Runtime n1-highmem-32 32 vCPUs	GPU runtime a2-highgpu-1g Tesla A100 40GB GPU	GPU acceleration
Preprocessing	28m35s	3m21s	9x
PCA	29.2s	11.4s	2.6x
t-SNE	1hr23m10s	28s	178x
KNN	3m5s	46s	4x
UMAP	21m47s	13.4s	98x
k-means clustering	2m6s	1.9s	66x
Louvain clustering	15m5s	1.9s	476x
Leiden clustering	51m1s	1.4s	2186x
End-to-end runtime	3hr31m48s	8m22s	25x
End-to-end cost	$6.682	$0.553	



Rapids single cell jupyter notebooks

Thanks

Q&A

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