Dent.py: Training Dental Models from Zero to Hero

Part 1 of 5

Planning for the Future

Objectives

- Pipeline Overview
  - Understand the purpose of building a pipeline and identifying its inputs and outputs.
  - Define a pipeline and its modular components.
- Pipeline Components
  - Examine the stages (building blocks) of a pipeline.
- Input and Output Specifications
  - Inputs: Discuss modalities and Dimensionality.
  - Outputs: Define tasks.

Pipelining AI Tasks

What is a Pipeline?

Pipeline is a structured sequence of processes or steps

- Transforms raw data into meaningful insights or outputs

Multistep

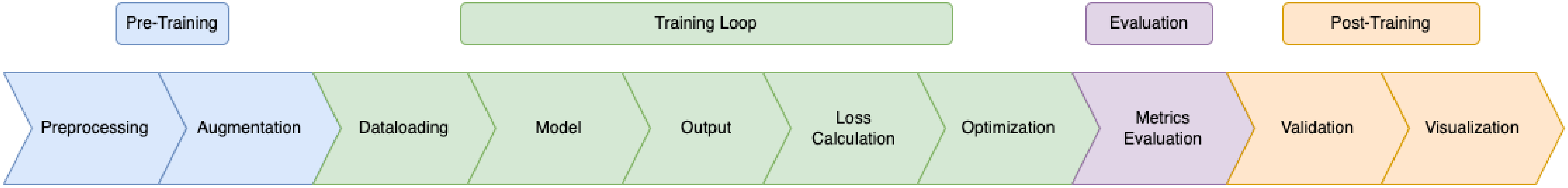
Modular

- Step can be customized or replaced

Adaptable

- Different tasks
- Different data types

Pipeline Stages

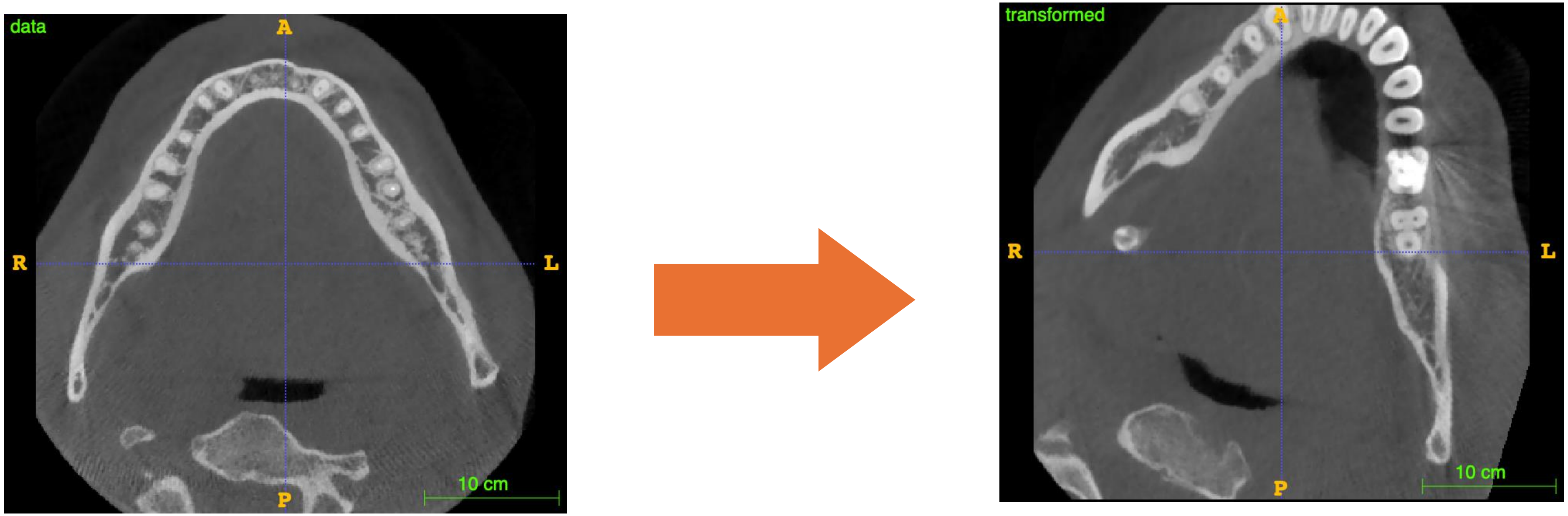


Pre-Training

- **Preprocessing**
    - Transform raw data into a clean, structured format suitable for model input

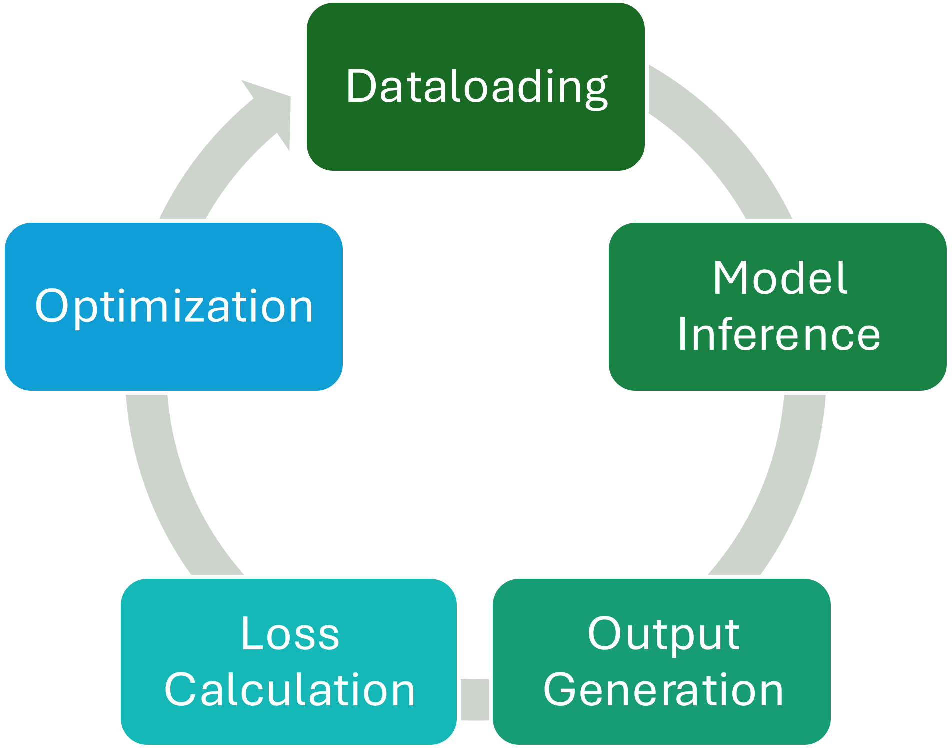
Pre-Training

- **Augmentation**
  - Enhance data by applying transformations to create diverse, robust samples for training



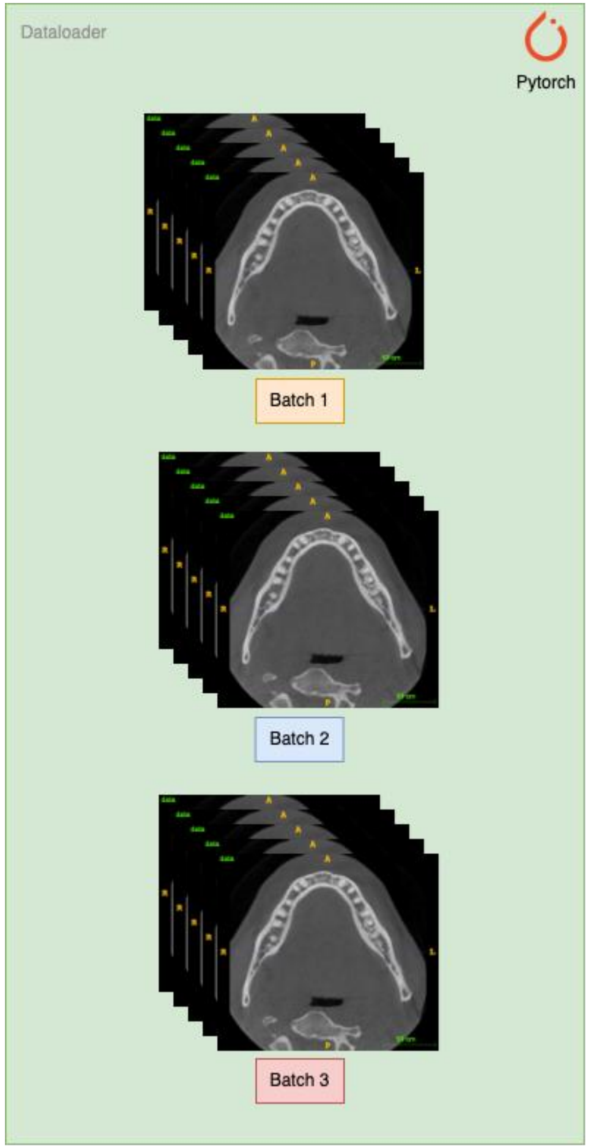
Training Loop

- **Iterative**
  - Consists of multiple iterations called epochs
- Epoch consists of multiple activities
  1. Dataloading
  2. Model Inference
  3. Output Generation
  4. Loss calculation
  5. Optimization



Training Loop

- **Dataloading**
  - Efficiently load and batch data to feed into the model during training and evaluation.



Training Loop

Model Inferencing

Use the trained model to make predictions on new or unseen data.

Output Generation

Generate predictions or classifications as the final model result.

Training Loop

Loss Calculation

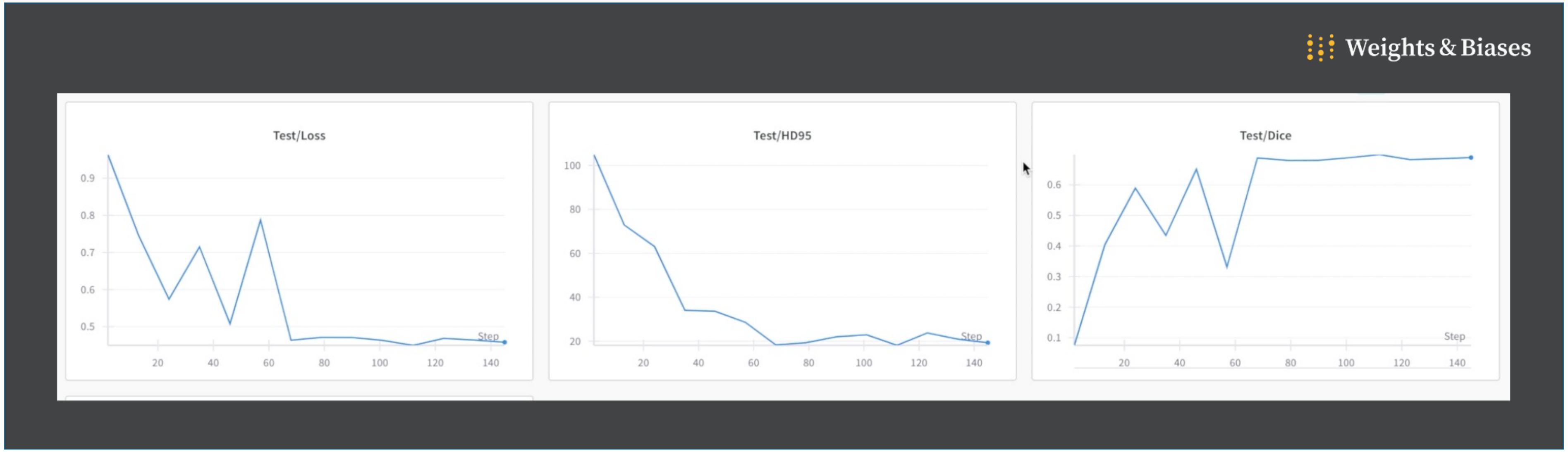
Measure the difference between predicted and true values to guide model improvements.

Optimization

Adjust model parameters to minimize the loss and improve accuracy.

Evaluation

- **Metrics Evaluation**
  - Assess model performance using quantitative metrics to ensure it meets the objectives.



Post-Training

Validation

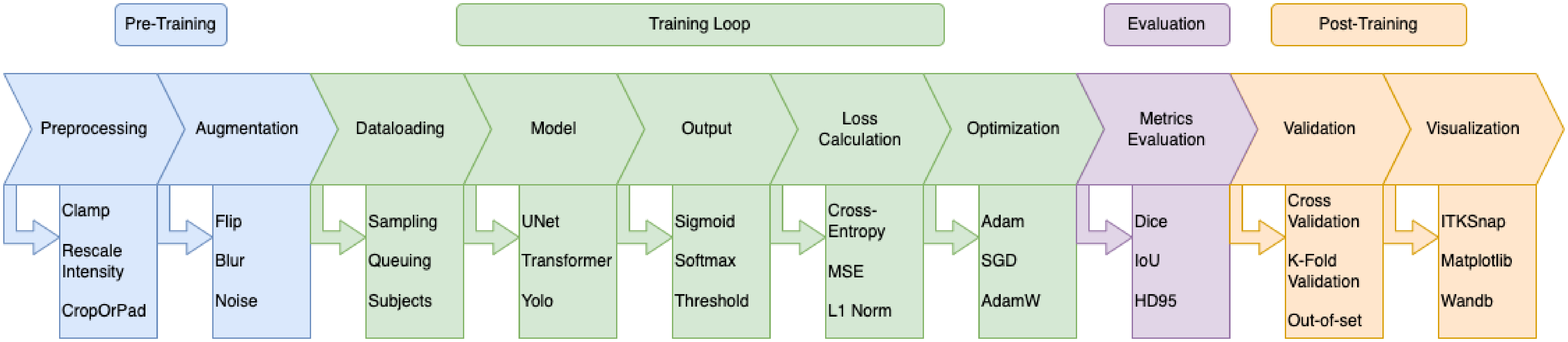
Test the model on a separate dataset to check generalization and avoid overfitting.

Visualization

Present data, model performance, or results in graphical formats to aid interpretation and analysis.

Pipeline Flexibility

Flexibility allows for interchangeable steps



Knowing your I/Os

I/Os

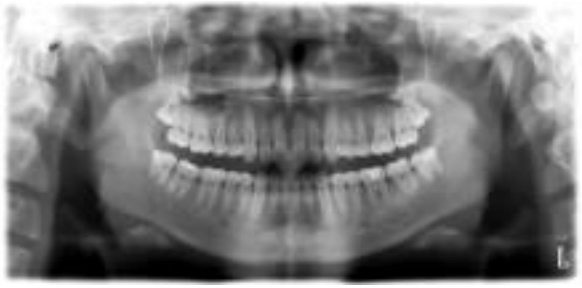
- I/O refers to **inputs** and **outputs**
- Understanding your pipeline's inputs and outputs is crucial for:
  - Model performance and architecture
  - Task accuracy
  - Evaluation decisions

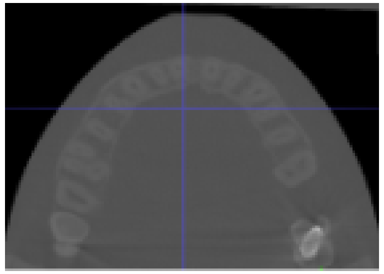
Input: Modality

- Modality refers to the type of data or sensory input used by a model or system

Input: Modality

- Modality come in the form of
  - Images / Medical Images (CT, CBCT, Panorama)
  - Videos
  - Text (Reports)
  - Audio





Input: Modality

- Models can be
  - Uni-Modal
    - Using only a single modality as Input
  - Multi-Modal
    - Using more than one modality of same form (ex: CBCT + Panorama)
    - Using more than one modality of different forms (ex: CBCT + Text Reports)

Input: Dimensionality

- Dimensionality often corresponds to the spatial, spectral, and temporal dimensions of the data.

Input: Dimensionality

Spatial Dimensions:

- Medical images typically have two or three spatial dimensions, represented as height, width (2D), and sometimes depth (3D) → CT, CBCT

Spectral Dimensions:

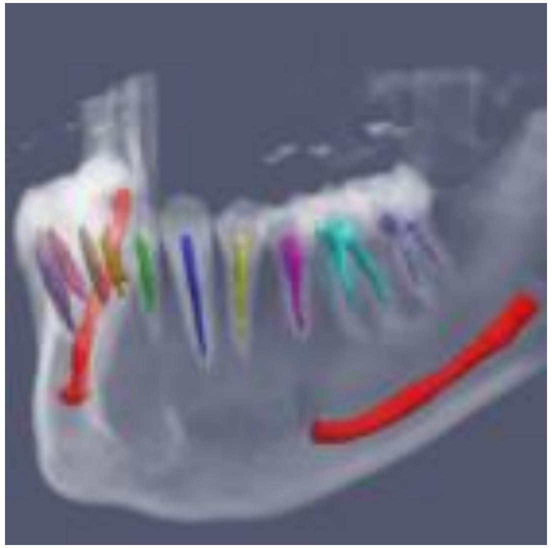
- Capture data across different wavelengths or functional responses → Functional MRI (fMRI) or multi-spectral CT

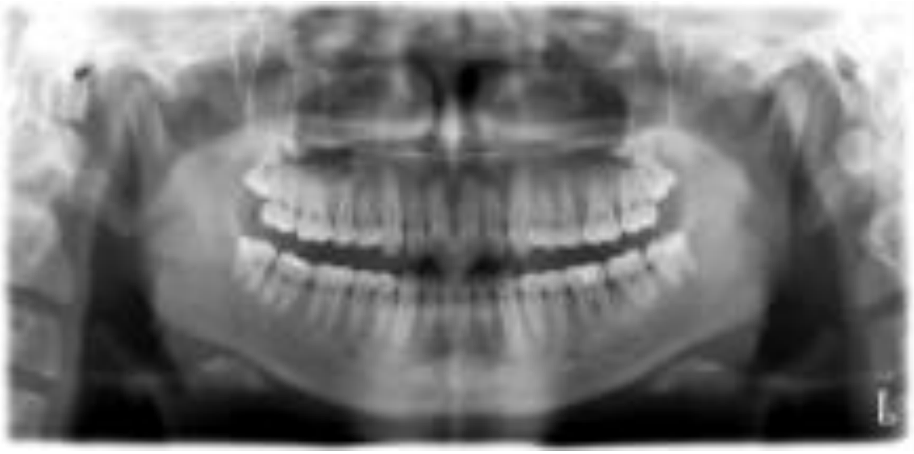
Temporal Dimensions:

- Temporal dimension is added, capturing changes over time → 4D CT or real-time ultrasound

Input: Dimensionality

- We are more interested in Spatial Dimensionality
  - 2D
    - Panoramic scans
    - Intraoral Images
  - 3D
    - CT / CBCT Volumes
  - Sliced 2D
    - CT / CBCT Planar slices across (Axial, Coronal, Saggital)



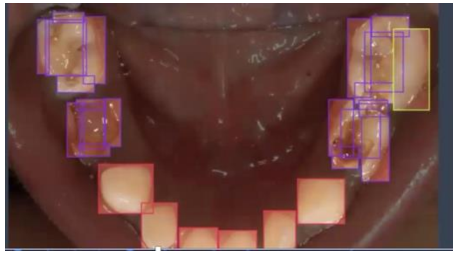


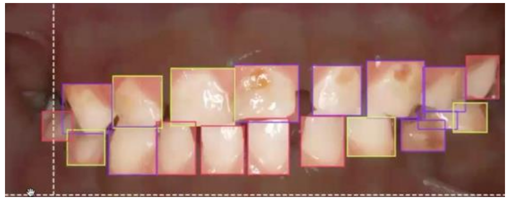
Output: Task Definition

- The number of outputs constitues the task defintion

Classification

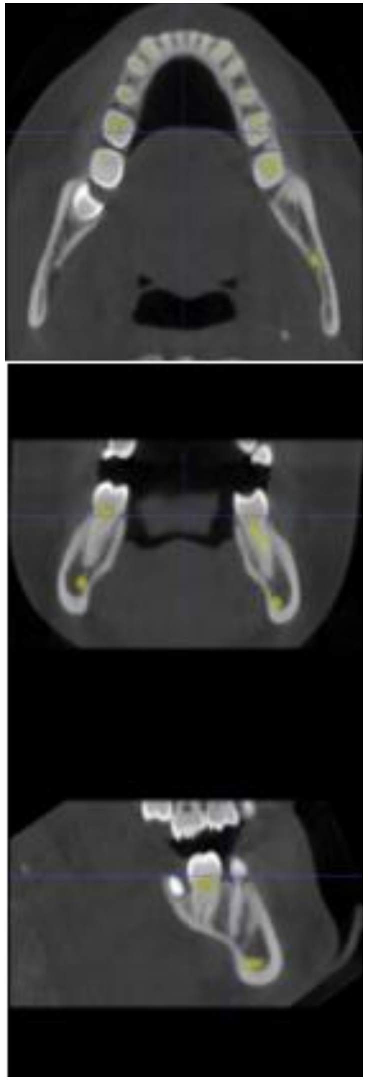
- Involve categorizing medical images or specific regions within them into predefined classes or labels
- Examples
  - Caries Detection
  - Lesion Classification
- Task Definition
  - Single Output ➔ Yes or No
    - Does this image contian caries?
  - Multiple Outputs ➔ Mild, Moderate, Severe
    - What is the level of severity of caries in these images?





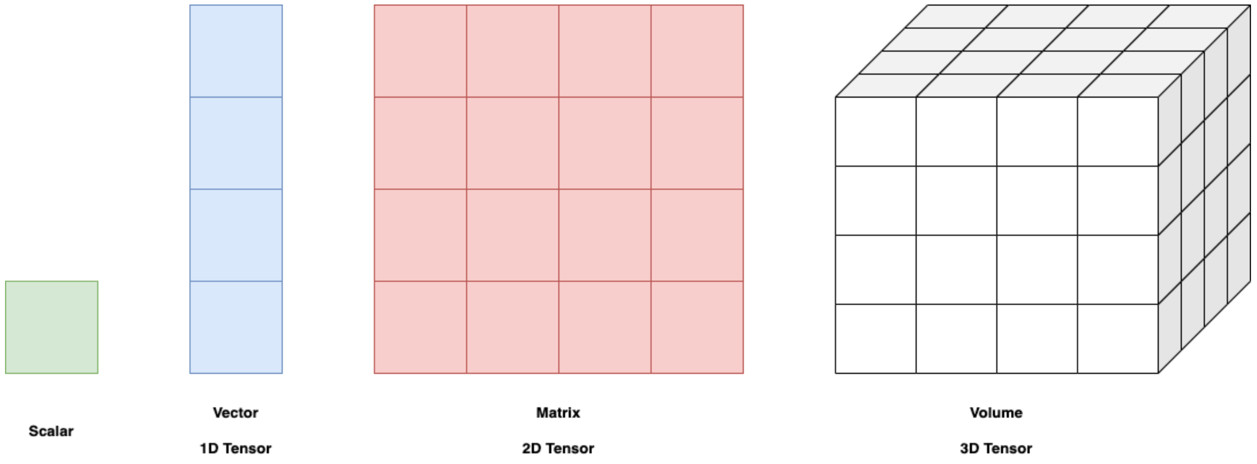
Segmentation

- Involve partitioning an image into distinct regions or structures
- Examples:
  - Hard Tissue Segmentation
  - Pulp Instance Segmentation
- Task Definition
  - Single Output → Matches input size (Semantic)
    - Detect all lesions in the mouth
  - Multiple Outputs → Matches input size (Instance)
    - Detect all lesions in the mouth with their types respectively



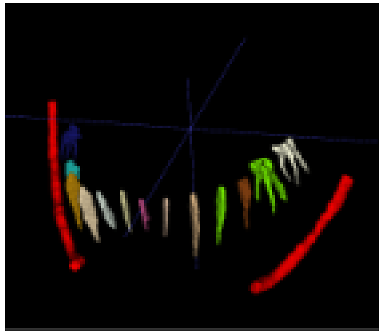
I/O Representation

- I/O are represented as **tensors**
- Tensors can have varying **ranks** (or dimensions)
  - each rank represents a level of data complexity



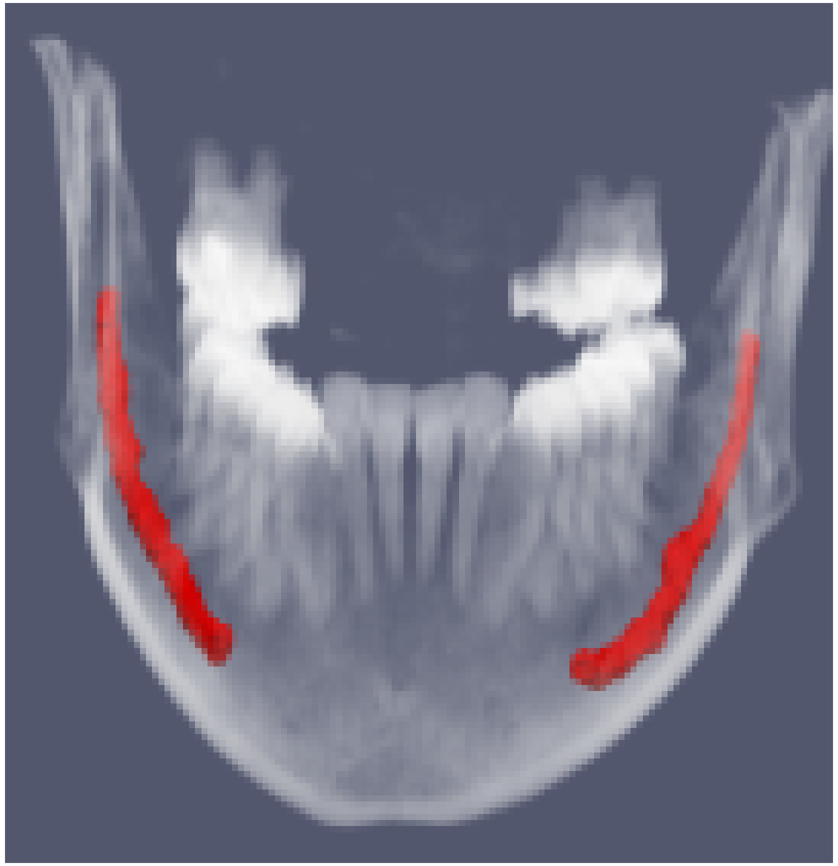
I/O Representation

- **Higher-Rank Tensors** (Rank 3 or more):
  - 3D tensor for a color image
    - (height × width × color channels)
  - 4D tensor for a batch of 3D volumes
    - (batch size × height × width × depth)
  - 5D tensor for a batch of 3D volumes each predicting a class label
    - (# of classes x batch size × height × width × depth)
    - That's what we used to get this →



Use Case: IAN Segmentation

- Through this workshop we will dive into segmenting the IAN
  - First, perform some data exploration
  - Second, create a pipeline
  - Third, train and evaluate the model
- What to expect
  - A pipeline ready to be used for most common deeplearning tasks



Questions?

Workshop Activity

- Notebooks Link
  - https://github.com/KnightsLab/EMRA-Workshop