

## ✓ Application of Deep Learning on Cancer Images

1000-719bMSB MIM UW, Neo Christopher Chung

In this lab, we make a prediction of lung nodules by a deep learning model and explain that decision making process by attention maps and CDAMs. For the simplicity, we provide a pre-trained model and use an existing medical image dataset. To streamline XAI, we are using a Python library called Obz.

### ➤ Download the obz package

From your venv, clone: `git clone http://github.com/obzai/obz`

If you have never used a virtual environment for Python, consider using uv.

Alternatively, you can download the repo from the website.

Take a note where you clone the obz repo, and set the working directory to that path. The following codes assume that you are in this repo root directory.

[ ] ↴ 1 cell hidden

### ➤ Download the pre-trained ViT model

[ ] ↴ 2 cells hidden

### ➤ Configure the ViT classifier based on DINO backbone

We are adding a binary classification head (see how `torch.nn.Linear`) onto a DINO backbone.

[ ] ↴ 10 cells hidden

### ➤ Extract features for outlier detection

[ ] ↴ 2 cells hidden

## ✓ Explain the AI model

- We first need to choose and set up appropriate XAI tools.

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- Then, we can run the XAI method to our data.

We first apply and visualize attention maps

[ ] ↴ 3 cells hidden

- Generate and visualize CDAM maps

[ ] ↴ 4 cells hidden

## ✓ Homework (for 2 weeks)

Train a Vision Transformer model on any of MedMNIST datasets (except NoduleMNIST), followed by prediction and explanation.

Essentially apply the above steps with a different ViT model trained on one of the MedMNIST datasets.

Double-click (or enter) to edit

```
!pip install torch torchvision timm medmnist matplotlib opencv-python scikit-learn
[?] Requirement already satisfied: requests in /usr/local/lib/python3.11/dist-packages/requests-2.28.1-py3.11.egg
[?] Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.11/dist-packages/markupsafe-2.0.1-py3.11.egg
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.11/dist-packages/pytz-2020.1-py3.11.egg
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[?] Downloading nvidia_cuda_cupti_cu12-12.4.127-py3-none-manylinux2014_x86_64.whl (13.8/13.8 MB 92.5 MB/s eta 0:00)
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207.5/207.5 MB 7.2 MB/s eta 0:0
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21.1/21.1 MB 79.5 MB/s eta 0:00
Downloading medmnist-3.0.2-py3-none-any.whl (25 kB)
Building wheels for collected packages: fire
  Building wheel for fire (setup.py) ... done
    Created wheel for fire: filename=fire-0.7.0-py3-none-any.whl size=114249
      Stored in directory: /root/.cache/pip/wheels/46/54/24/1624fd5b8674eb11886
Successfully built fire
Installing collected packages: nvidia-nvjitlink-cu12, nvidia-curand-cu12, n
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      Successfully uninstalled nvidia-curand-cu12-10.3.6.82
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```

```
!pip install medmnist
```

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Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-p  
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.11
```

```
!git clone https://github.com/obzai/obzai.git
```

```
→ Cloning into 'obzai'...
remote: Enumerating objects: 38, done.
remote: Counting objects: 100% (38/38), done.
remote: Compressing objects: 100% (35/35), done.
remote: Total 38 (delta 6), reused 0 (delta 0), pack-reused 0 (from 0)
Receiving objects: 100% (38/38), 2.19 MiB | 12.59 MiB/s, done.
Resolving deltas: 100% (6/6), done.
```

```
import sys
sys.path.append("/content/obzai/src")
from obzai.data_inspector.extractor import FirstOrderExtractor
from obzai.data_inspector.detector import GMMDetector

import torch
import torch.nn as nn
from torch.utils.data import DataLoader
from torchvision import transforms
from medmnist import PathMNIST, INFO
from transformers import ViTModel, ViTConfig
from tqdm import tqdm

DEVICE = torch.device("cuda" if torch.cuda.is_available() else "cpu")
num_epochs = 1
```

```

from torch.utils.data import Subset
from torchvision import transforms
from medmnist import PathMNIST, INFO

info = INFO['pathmnist']
n_classes = len(info['label'])

transform = transforms.Compose([
    transforms.Resize((224, 224)),
    transforms.ToTensor(),
    transforms.Normalize(mean=[.5], std=[.5])
])

train_dataset = PathMNIST(split='train', transform=transform, download=True)
val_dataset = PathMNIST(split='val', transform=transform, download=True)
test_dataset = PathMNIST(split='test', transform=transform, download=True)

train_loader = DataLoader(train_dataset, batch_size=16, shuffle=True)
val_loader = DataLoader(val_dataset, batch_size=16)
test_loader = DataLoader(test_dataset, batch_size=4, shuffle=False)

class DINO(nn.Module):
    def __init__(self):
        super().__init__()
        config = ViTConfig.from_pretrained('facebook/dino-vits8', attn_implement='attn_gelu')
        self.backbone = ViTModel(config)
        self.head = torch.nn.Linear(384, 9)

    def forward(self, x: torch.Tensor, output_attentions: bool = False):
        out = self.backbone(x, output_attentions=output_attentions)
        x = out["pooler_output"]
        x = self.head(x)
        if output_attentions:
            att = out["attentions"]
            return x, att
        else:
            return x

model = DINO().to(DEVICE)
optimizer = torch.optim.AdamW(model.parameters(), lr=1e-4)
criterion = nn.CrossEntropyLoss()

```

```
def train(model, loader):
    model.train()
    total_loss, correct, total = 0, 0, 0
    for imgs, labels in tqdm(loader, desc="Training"):
        imgs = imgs.to(DEVICE)
        labels = labels.view(-1).long().to(DEVICE)
        optimizer.zero_grad()
        outputs = model(imgs)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()
        total_loss += loss.item()
        preds = outputs.argmax(dim=1)
        correct += (preds == labels).sum().item()
        total += labels.size(0)
    return total_loss / len(loader), correct / total

def evaluate(model, loader):
    model.eval()
    total_loss, correct, total = 0, 0, 0
    with torch.no_grad():
        for imgs, labels in tqdm(loader, desc="Evaluating"):
            imgs = imgs.to(DEVICE)
            labels = labels.view(-1).long().to(DEVICE)
            outputs = model(imgs)
            loss = criterion(outputs, labels)
            total_loss += loss.item()
            preds = outputs.argmax(dim=1)
            correct += (preds == labels).sum().item()
            total += labels.size(0)
    return total_loss / len(loader), correct / total
```

```
import torch
torch.cuda.empty_cache()
for epoch in range(num_epochs):
    train_loss, train_acc = train(model, train_loader)
    val_loss, val_acc = evaluate(model, val_loader)
    print(f"[Epoch {epoch+1}] Train Loss: {train_loss:.4f}, Train Acc: {train_a

# Final test performance
test_loss, test_acc = evaluate(model, test_loader)
print(f"Test Accuracy: {test_acc:.4f}")

# Save model
torch.save(model.state_dict(), "dino_pathmnist.pth")
print("Model saved as dino_pathmnist.pth")

# XAI sample extraction
samples, labels = next(iter(test_loader))
samples = samples[:5].to(DEVICE)
labels = labels[:5].to(DEVICE)

➡️ Training: 100%|██████████| 5625/5625 [1:22:17<00:00, 1.14it/s]
Evaluating: 100%|██████████| 626/626 [03:24<00:00, 3.05it/s]
[Epoch 1] Train Loss: 0.6130, Train Acc: 0.7771 | Val Acc: 0.8400
Evaluating: 100%|██████████| 1795/1795 [02:23<00:00, 12.53it/s]
Test Accuracy: 0.7397
Model saved as dino_pathmnist.pth
```

```
import matplotlib.pyplot as plt
```

```
CLASS_NAMES = {
    0: "background",
    1: "tissue",
    2: "epithelial",
    3: "lymphocyte",
    4: "plasma",
    5: "eosinophil",
    6: "connective",
    7: "muscle",
    8: "nerve"
}
```

```
samples, labels = next(iter(test_loader))
samples = samples[:5].to(DEVICE)
labels = labels[:5].to(DEVICE)

model.eval()
with torch.no_grad():
```

```
with torch.no_grad():
    logits = model(samples)
    predictions = torch.softmax(logits, dim=1)
    predicted_classes = predictions.argmax(dim=1).cpu().numpy()

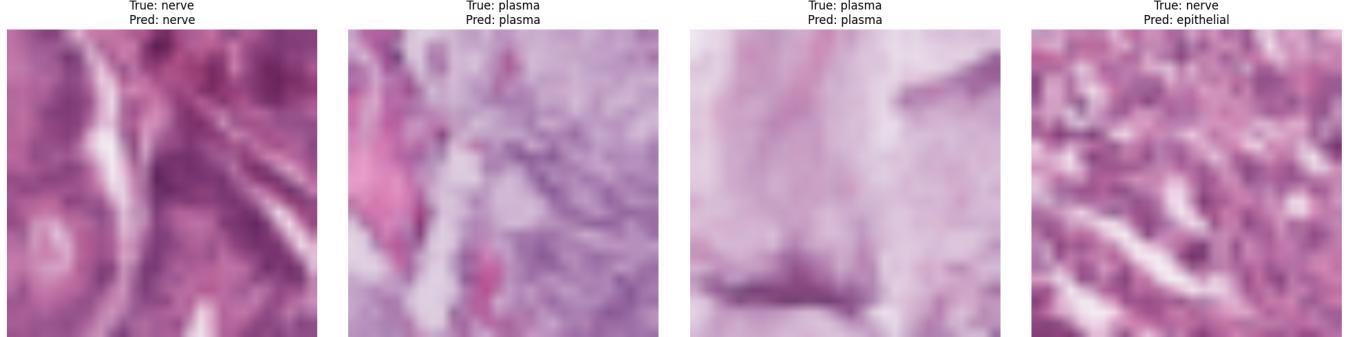
predicted_names = [CLASS_NAMES[int(p)] for p in predicted_classes]
true_names = [CLASS_NAMES[int(l)] for l in labels.cpu().numpy()]

fig, axes = plt.subplots(1, samples.size(0), figsize=(20, 5))

for i in range(samples.size(0)):
    image = samples[i].permute(1, 2, 0).cpu().numpy()
    image = (image * 0.5) + 0.5
    axes[i].imshow(image)
    axes[i].set_title(f"True: {true_names[i]}\nPred: {predicted_names[i]}")
    axes[i].axis('off')

plt.tight_layout()
plt.show()
```

→ <ipython-input-65-4aea588b1f37>:14: DeprecationWarning: Conversion of an array from a NumPy object to a Python scalar is deprecated. Use np.asscalar() or np.item() instead.



```
model.eval()
with torch.no_grad():
    logits = model(samples)
    probs = torch.softmax(logits, dim=1)

print("Predicted classes:", predicted_names)

→ Predicted classes: ['nerve', 'plasma', 'plasma', 'epithelial']

samples = samples[:5].to(DEVICE)
labels = labels[:5].to(DEVICE)

with torch.no_grad():
    logits = model(samples)
    predictions = torch.softmax(logits, dim=1).argmax(dim=1).cpu().numpy()

predicted_classes = [CLASS_NAMES[int(pred)] for pred in predictions]

for i, pred_class in enumerate(predicted_classes):
    print(f"Prediction for Sample {i + 1}: {pred_class}")
```

→ Prediction for Sample 1: nerve  
Prediction for Sample 2: plasma  
Prediction for Sample 3: plasma  
Prediction for Sample 4: epithelial

```
!pip install captum
```

```
→ Requirement already satisfied: captum in /usr/local/lib/python3.11/dist-pac
Requirement already satisfied: matplotlib in /usr/local/lib/python3.11/dist-
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Requirement already satisfied: torch>=1.10 in /usr/local/lib/python3.11/dis
Requirement already satisfied: tqdm in /usr/local/lib/python3.11/dist-packa
Requirement already satisfied: filelock in /usr/local/lib/python3.11/dist-p
Requirement already satisfied: typing-extensions>=4.10.0 in /usr/local/lib/
Requirement already satisfied: networkx in /usr/local/lib/python3.11/dist-p
Requirement already satisfied: jinja2 in /usr/local/lib/python3.11/dist-pac
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Requirement already satisfied: pyparsing>=2.3.1 in /usr/local/lib/python3.1
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Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.11/dist-p
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.11
```

```
from obzai.xai.xai_tool import CDAM, AttentionMap

cdam_tool = CDAM(model=model,
                  mode='vanilla',
                  gradient_type="from_logits",
                  gradient_reduction="average",
                  activation_type="sigmoid")
cdam_tool.create_hooks(layer_name="backbone.encoder.layer.11.layernorm_before")

attention_tool = AttentionMap(model=model,
                               attention_layer_id=-1,
                               head=None)
```

```
attention_maps = attention_tool.explain(samples)

fig, axes = plt.subplots(2, samples.size(0), figsize=(20, 5))

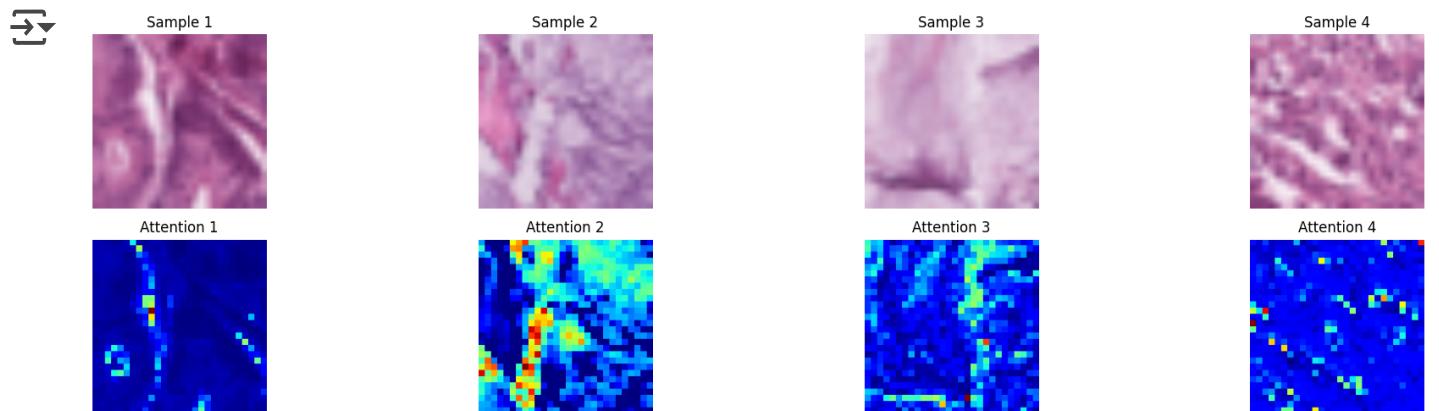
for i in range(samples.size(0)):
    image = samples[i].permute(1, 2, 0).cpu().numpy()
    image = (image * 0.5) + 0.5

    attention_map = attention_maps[i].cpu().numpy()

    axes[0, i].imshow(image)
    axes[0, i].set_title(f"Sample {i + 1}")
    axes[0, i].axis('off')

    axes[1, i].imshow(attention_map, cmap='jet')
    axes[1, i].set_title(f"Attention {i + 1}")
    axes[1, i].axis('off')

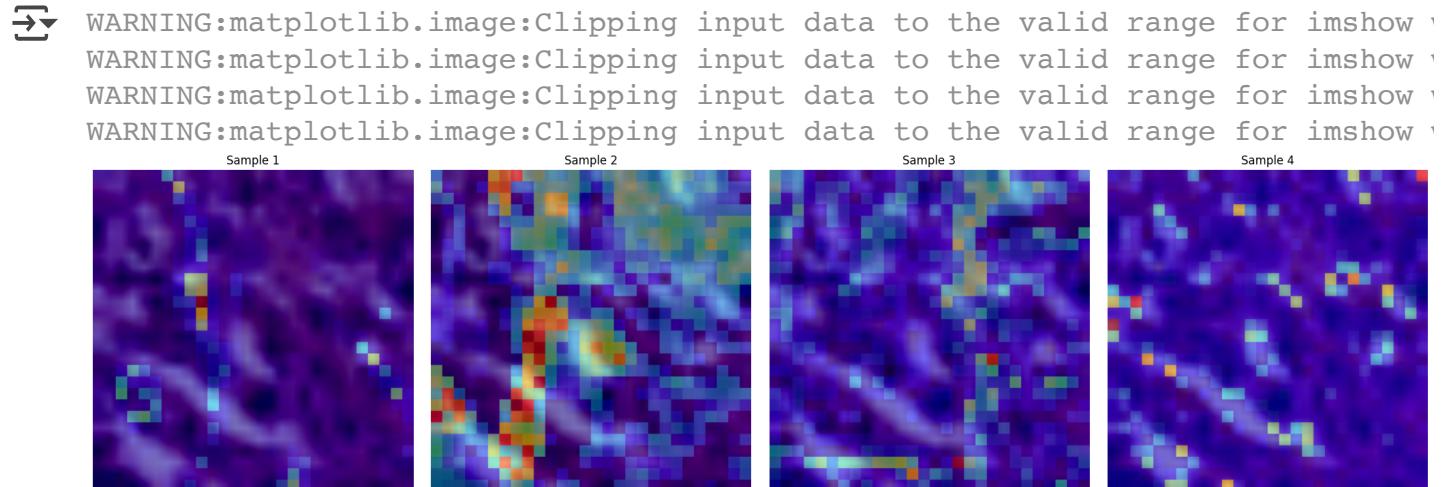
plt.tight_layout()
plt.show()
```



```

fig, axes = plt.subplots(1, samples.size(0), figsize=(20, 5))
for i in range(samples.size(0)):
    image = samples[i].permute(1, 2, 0).cpu().numpy()
    attention_map = attention_maps[i].cpu().numpy()
    axes[i].imshow(original_image, cmap='gray')
    axes[i].imshow(attention_map, cmap='jet', alpha=0.5)
    axes[i].set_title(f"Sample {i + 1}")
    axes[i].axis('off')
plt.tight_layout()
plt.show()

```



```

cdam_maps = cdam_tool.explain(samples, target_idx=predictions.tolist())

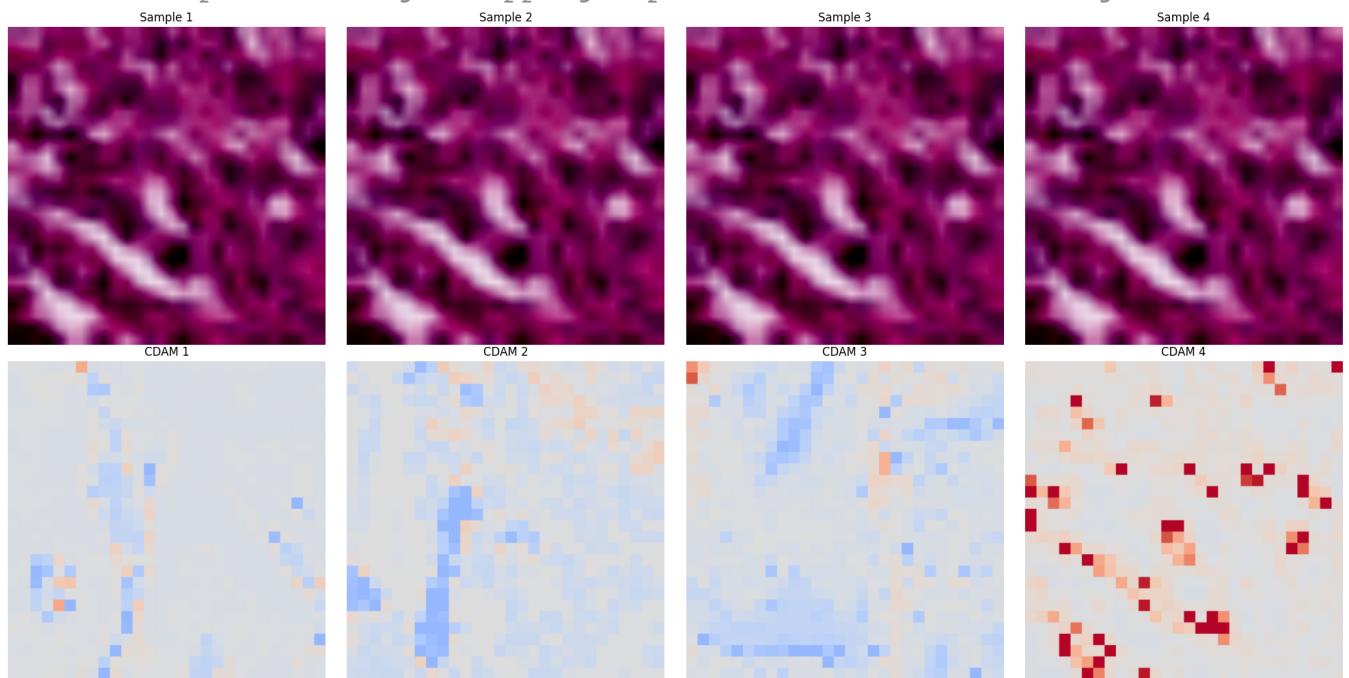
fig, axes = plt.subplots(2, samples.size(0), figsize=(20, 10))
for i in range(samples.size(0)):
    image = samples[i].permute(1, 2, 0).cpu().numpy()
    axes[0, i].imshow(original_image, cmap='gray')
    axes[0, i].set_title(f"Sample {i + 1}")
    axes[0, i].axis('off')

    cdam_map = cdam_maps[i].squeeze().cpu().numpy()
    axes[1, i].imshow(cdam_map, cmap='coolwarm', vmin=-cdam_maps.abs().max(), vmax=cdam_maps.abs().max())
    axes[1, i].set_title(f"CDAM {i + 1}")
    axes[1, i].axis('off')
plt.tight_layout()

```

```
plt.show()
```

→ WARNING:matplotlib.image:Clipping input data to the valid range for imshow  
WARNING:matplotlib.image:Clipping input data to the valid range for imshow  
WARNING:matplotlib.image:Clipping input data to the valid range for imshow  
WARNING:matplotlib.image:Clipping input data to the valid range for imshow



```
fig, axes = plt.subplots(2, samples.size(0), figsize=(20, 10), gridspec_kw={'hei  
for i in range(samples.size(0)):  
    original_image = samples[i].permute(1, 2, 0).cpu().numpy()  
    cdam_map = cdam_maps[i].squeeze().cpu().numpy()  
    axes[0][i].imshow(original_image, cmap='magma')
```

```

axes[0, i].imshow(cdam_map, cmap='coolwarm', alpha=0.5, vmin=-cdam_maps.abs(
axes[0, i].set_title(f"Sample {i + 1}")
axes[0, i].axis('off')

axes[1, i].hist(cdam_map.ravel(), bins=30, color='blue', alpha=0.7)
axes[1, i].set_title(f"Histogram {i + 1}")
axes[1, i].set_xlabel('Value')
axes[1, i].set_ylabel('Frequency')
plt.tight_layout()
plt.show()

```

→ WARNING:matplotlib.image:Clipping input data to the valid range for imshow  
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