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YAP470 – Project Description Report, 13 October 2025

1. Project Description

Our project investigates a challenging problem in multi-domain visual classification: **Can a single neural network learn context-dependent class labels across completely different visual domains?** We aim to train a neural network -potentially convolutional- with two datasets (**MNIST** and **CIFAR10**) which have semantically different but same number of output classes. Our intention is to observe if the model is able to implicitly understand the domain context from the image features alone, without any explicit dataset label. One of our key questions is **"Can a unified classifier with shared class labels learn to distinguish between semantically different concepts from different domains?"**. In this project, we will analyze the performance of this model compared to conventional single-domain baselines and evaluate its ability to generalize across visual domains. We believe that this project could provide valuable insights into how neural networks internally adapt to multiple domains without explicit supervision.

2. Short Literature Review.

- *"A Survey on Multi-Task Learning" (Yu Zhang and Qiang Yang, 2021)-This paper surveys Multi-Task Learning (MTL) methods, categorizing algorithmic approaches, integrations with other paradigms, large-scale adaptations, real-world applications, and theoretical insights*

- *"Universal Representations: The Missing Link between Faces, Text, Planktons, and Cat Breeds" (Mensink et al., 2014)*
  Explores universal visual representations across diverse categories, relevant to understanding if a single network can handle dramatically different visual domains.

- *"Domain-Adversarial Training of Neural Networks" (Ganin et al., 2016)*
  While focused on domain adaptation, provides insights into how networks learn domain-invariant vs. domain-specific features, opposite to what we need but theoretically informative.

- *“A Survey on Mixture of Experts in Large Language Models” (Weilin Cai∗ , Juyong Jiang∗ , Fan Wang∗ , Jing Tang† , Sunghun Kim† , Jiayi Huang†, 2025)-This paper provides a comprehensive survey of Mixture of Experts (MoE) in large language models, covering taxonomy, core designs, implementations, applications, and future research directions.*

- *“Towards a Universal Gating Network for Mixtures of Experts” (Chen Wen Kang, Chua Meng Hong, Tomas Maul, 2020)-This paper introduces data-free methods for combining heterogeneous pre-trained neural networks using gating mechanisms, demonstrating that specialized and universal gating networks achieve the most effective mixtures of experts.*

- *“Multi-domain Sentiment Classification” (Shoushan Li, Chengqing Zong, 2008)-This paper proposes feature-level and classifier-level fusion methods for multi-domain sentiment classification, showing that classifier-level fusion significantly outperforms single-domain models.*

- *“Transfer learning for medical image classification: a literature review” (Hee E. Kim1* , Alejandro Cosa-Linan1 , Nandhini Santhanam1 , Mahboubeh Jannesari1 , Mate E. Maros1† and Thomas Ganslandt1,2†, 2022)-This paper reviews transfer learning in medical image classification, highlighting deep models like ResNet and Inception as efficient and effective feature extractors.*

- *A Comprehensive Survey on Multi-Agent Cooperative Decision-Making:Scenarios, Approaches, Challenges and Perspectives(Weiqiang Jina, Hongyang Dub, Biao Zhaoa,∗, Xingwu Tiana, Bohang Shia, Guang Yangc,d,e,f,∗, 2025)-This paper surveys multi-agent cooperative decision-making, analyzing simulation environments and key approaches and discussing their advantages, challenges, and future directions.*

3. Dataset Information

We are planning to work mostly with MNIST and CIFAR10 but additional datasets might be used if needed for comparison and analysis.

Sources:
All datasets are publicly available through PyTorch Vision Datasets and TensorFlow Datasets.

• MNIST

- **Domain:** Handwritten digit recognition
- **Content:** 70,000 grayscale images of digits (0–9)
- **Image Size:** 28×28 pixels, single channel (grayscale)
- **Classes:** 10

• Fashion-MNIST

- **Domain:** Clothing and fashion item classification
- **Content:** 70,000 grayscale images representing 10 types of clothing (e.g., shirts, shoes, bags)
- **Image Size:** 28×28 pixels, single channel (grayscale)
- **Classes:** 10

• CIFAR-10

- **Domain:** Natural object and scene classification
- **Content:** 60,000 color images from 10 object categories (e.g., airplanes, cats, cars)
- **Image Size:** 32×32 pixels, RGB (3 channels)
- **Classes:** 10

• CIFAR-100

- **Domain:** Fine-grained natural image classification
- **Content:** 60,000 color images from 100 object categories
- **Image Size:** 32×32 pixels, RGB (3 channels)
- **Classes:** 100

• SVHN (Street View House Numbers)

- **Domain:** Real-world digit recognition from street images
- **Content:** Over 600,000 RGB images of digits cropped from house numbers in Google Street View
- **Image Size:** 32×32 pixels, RGB (3 channels)
- **Classes:** 10

4. Tools and Platforms

- **Platform:** Jupyter Notebook
- **Libraries:** PyTorch (torch, torchvision), NumPy, Pandas, Matplotlib, Scikit-learn, Pillow(PIL), Seaborn
- **Frameworks:** PyTorch
- **Hardware:** GPU for faster training (we might use Colab if needed)

5. Planned Division of Tasks

Both team members will collaboratively work on all stages of the project, including model design, dataset preparation, training, and evaluation.