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Bridging the Gap Between Simulations and Survey Data: Domain Adaptation for Merging Galaxy Classification

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Leveraging large samples of galaxy mergers from future large-scale surveys will be crucial for furthering our understanding of galaxy evolution and the formation of matter in the universe. Using machine learning models trained on simulated images of merging galaxies and then applying them to newly observed data will help tremendously with these efforts. Unfortunately, training a neural network on a source domain and applying it to a different target domain often results in a detrimental loss in accuracy. In this project, we applied domain adaptation techniques in order to demonstrate their potential to enforce the learning of invariant features across domains for better classification. This was accomplished using two domain adaptation techniques: domain adversarial neural networks (DANNs) which involves adversarial training to confuse a domain classifier, and Maximum Mean Discrepancy (MMD), which minimizes a distance measure of the mean embeddings of the two domain distributions in latent feature space. We also added Fisher loss and entropy minimization as additional losses for both MMD or domain adversarial training in order to enforce in-domain class discriminability. We demonstrated the use of these domain transfer techniques on two examples: between two Illustris-1 simulated datasets of distant merging galaxies, and between Illustris-1 simulated data of nearby merging galaxies and observed data from the Sloan Digital Sky Survey. The application of these techniques increased the accuracy of domain classification in the target domain by up to ~20%. This demonstrates the potential of these techniques to improve the accuracy of neural network models trained on simulation data and applied to detect and study astrophysical objects in current and future large-scale astronomical surveys.

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