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Semi-Supervised Sorting via Deep Feature Extraction and Density-Based Clustering with User Feedback

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Abstract

Precise and efficient data sorting without prior knowledge of their characteristics or appearance is crucial in various industries like logistics, recycling, and manufacturing. However, this task remains challenging, particularly when objects are not represented in the original dataset used to train deep neural networks. Furthermore, humans may cluster objects differently than a machine due to the nuanced incorporation of contextual information and subjective perspectives which is a well-known problem of unsupervised learning.

In this paper, we introduce an innovative semi-supervised algorithm that combines deep feature extraction and density-based clustering, augmented by user feedback, to address this complexity. We use a pretrained deep feature extractor trained on a wide-ranging dataset enabling the model to learn high-level representations and abstract features. Subsequently, we employ dimensionality reduction techniques like PCA and t-SNE to get refined features and remove noise, enhancing the performance of hierarchical density-based clustering. We introduce the clustering results to the user, who provides feedback through a limited number of sophisticated queries, aiding in cluster refinement. These help to split or merge clusters as well as to assign outliers. A considerable amount of work has been dedicated to crafting a user interface that enables semi-supervised clustering in a very intuitive and efficient manner. We've prioritized minimizing user interactions by formulating inquiries that yield the most significant knowledge advancement, thereby guiding the labeling process. Based on the resulting labels a multi-class support vector machine is trained in the original feature space.

We showcase our algorithm's potential for advancing semi-supervised clustering by applying it to a screw sorting demonstrator. The screws traverse a conveyor belt while an overhead camera captures high-resolution images, feeding them into a deep feature extractor. After a considerable number of screws have been recorded, the process of feature reduction and clustering is launched. The user is presented with some queries and has the option to manually drag and drop objects in a simplified point cloud representation. With the resulting labels, a multi-class support vector machine is trained in the original feature space.

Upon the second pass, a precise robotic arm swiftly allocates each screw to its respective bin. Notably, our system adeptly classifies previously unseen objects, highlighting its adaptability and efficacy in real-world scenarios. Our semi-supervised sorting algorithm, complemented by its intuitive user interface, can be applied to diverse image datasets spanning multiple domains and use cases.