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Domain Background

Distribution centers play a crucial role of modern supply chain and logistics operations. These centers are responsible for receiving, storing, and shipping products to retail outlets, customers, or other distribution hubs. Inventory Monitoring is one of the main challenge distribution center faces during these operations which is essential to ensure that products are available for shipment in a timely manner, and that the right quantities are dispatched for customer orders. Inventory Monitoring involves tasks like sorting, tracking, and packaging products into different bins, boxes, or pallets. Performing these tasks manually is time consuming and error prone. We can automate most of tasks using robots, automated systems or ML agents. A critical challenge in such environments is ensuring accurate inventory tracking and verifying that the correct number of items are packed and shipped. This becomes even more complicated when bins contain multiple different objects. Manual counting of items within each bin is inefficient and error-prone, especially when dealing with large volumes of goods.

Other works developed in this domain that led to my motivation for investigating problem in this domain:
Destro, I. R., Staudt, F. H., Somensi, K., & Taboada, C. (2023). The impacts of inventory record inaccuracy and cycle counting on distribution center performance. *Production*, *33*. https://doi.org/10.1590/0103-6513.20220077

Problem Statement

One of the key tasks of inventory monitoring in distribution centers is the accurate counting of objects within bins. Bins may contain a variety of items, and having a precise count of each item is essential for tasks such as inventory tracking, quality control, and ensuring the accuracy of shipping consignments. An error in the number of items could lead to overstocking or understocking of products, delays in order fulfillment, or even customer dissatisfaction.
For example, when preparing a shipment, it is critical that the correct number of products are included in each bin, as discrepancies could lead to incomplete orders or incorrect shipments. Manually counting items inside a bin is labor-intensive and prone to errors, especially when bins contain hundreds or thousands of small items.
To address this issue, a solution is needed that can automatically count the number of objects in each bin during the inventory monitoring distribution center. An automated system that can detect and count the objects within bins will help reduce human error, improve accuracy and performance during inventory monitoring in distribution centers.

Solution

Machine Learning can provide solution to this problem of counting the objects in bin. By training a machine learning model on images or sensor data of bins, it is possible to develop a system that can accurately count the number of objects in each bin. The model can be integrated with the automation systems, allowing it to make real-time inventory

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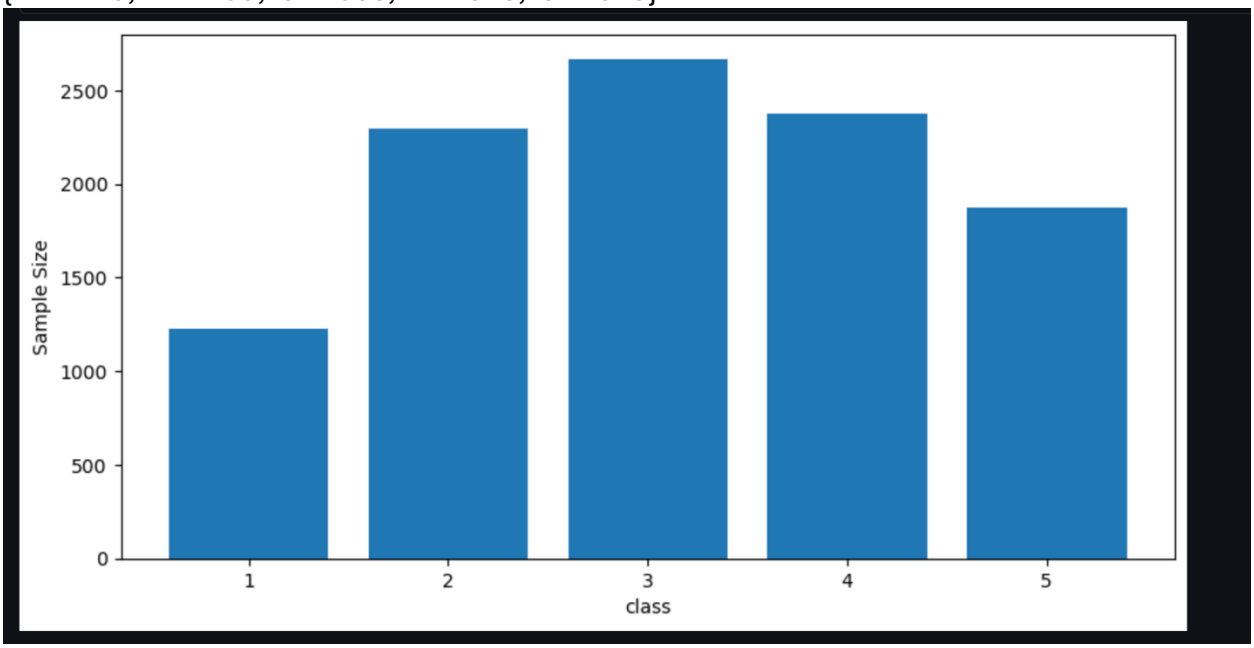
updates which increases the performance in distribution centers ultimately leading to customer satisfaction.
In this project, the goal is to build an object counting model using machine learning techniques, which can process images of bins, analyze the contents, and accurately count the number of items within. The machine learning model will be trained using labeled data that is images of bins with the corresponding object counts and deployed in the distribution center to assist with automated inventory tracking and shipment verification.

Dataset

Amazon is one of leading supply chain and logistics company and has lot of distribution centers. For this project, we will use the Amazon Bin Image Dataset which consists of 500,000 images of bins, each containing one or more objects. These images were captured in various scenarios to reflect real-world conditions that might be encountered in distribution centers. Each image in the dataset contains an assortment of items, ranging from small objects to larger, more complex items. The variety of objects and bin configurations within the dataset is important, as it allows the model to generalize across different types of bins and object arrangements. Since there is lot of data I will be taking a smaller set of the entire data. Below is the bin count and the number of images containing that bin count.
{'1': 1228, '2': 2299, '3': 2666, '4': 2373, '5': 1875}



We have this file file_list.json (https://github.com/udacity/nd009t-capstone-starter/blob/master/starter/file_list.json) which contains the metadata images of all these images. We will this meta data to download the images from the s3 bucket aft-vbi-pds
More info can be found here: https://registry.opendata.aws/amazon-bin-imagery/

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Base Model:

Image Classification Based On CNN will be taken as Base Model. It is CNN model for image classification with good results.
Elngar AA, Arafa M, Fathy A, Moustafa B, Mahmoud O, Shaban M, Fawzy N. Image classification based on CNN: a survey. Journal of Cybersecurity and Information Management. 2021 Apr;6(1):18-50.

Model

To address the challenge of counting objects in bins within a distribution center, I am building an efficient machine learning solution based on a pretrained neural network. Instead of training a model from scratch, which can be computationally expensive and time-consuming, I will leverage the power of transfer learning. By fine-tuning a pretrained model, I can adapt an already trained neural network to our specific problem of object counting, saving significant development time while achieving high accuracy.
The core of this solution involves modifying the architecture of a pretrained neural network by adjusting the layers to better suit the object counting task. Specifically, I will focus on replacing or fine-tuning the final layers of the network to ensure it can output the correct number of objects for each bin. This approach will allow the model to learn not just to recognize individual items, but to estimate the total count of objects present in the bin based on visual features. I will also be focusing on to find the right hyper parameters for the model.
Using this strategy, the model will take input images or data related to the bins, process the information through the modified neural network, and output the predicted object count. By leveraging AWS SageMaker, I will streamline the model training, validation, and deployment process, ensuring an end-to-end solution that is scalable, reliable, and ready for integration into real-world distribution center operations.
This solution demonstrates a practical application of transfer learning and neural network fine-tuning, while also showcasing how pretrained models can be adapted and optimized to solve domain-specific problems in a more efficient and effective manner.

Evaluation Metrics

As this is a Classification Model, we will use Accuracy and Root Mean Squared Error to evaluate this model.
Accuracy=Total number of predictionsNumber of correct predictions

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Formula for RMSE:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}$$

Where:

- n is the number of observations (or test samples).
- y_i is the true count for the i^{th} observation.
- $\hat{y}_i$ is the predicted count for the i^{th} observation.

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Design