Image Analysis of Plant Based Meat Products

Under the guidance of Prof. Shanmuganathan Raman, IIT Gandhinagar

{badal.chowdhary, hitesh.jain, shanmuga}@iitgn.ac.in

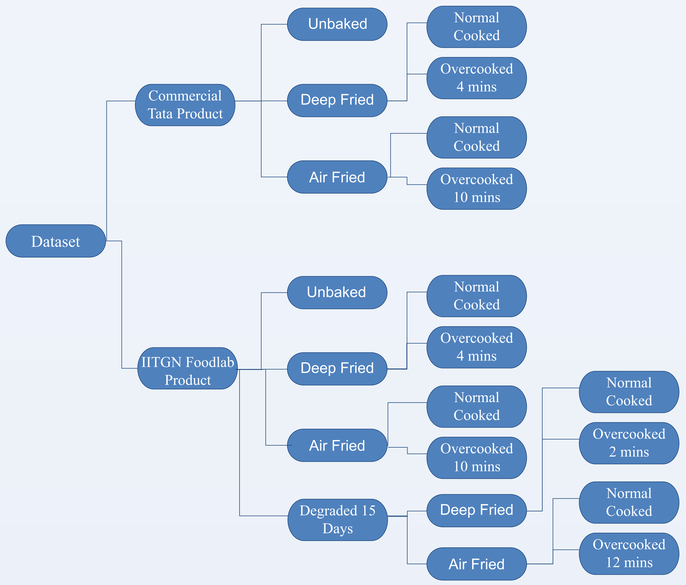
Abstract

1. In the ever-evolving culinary landscape and with changing dietary preferences, plant-based meat products have undoubtedly initiated a revolution in the food industry. These innovative products offer a sustainable and environmentally conscious substitute for conventional meat, catering to the discerning preferences of today's consumers.
2. Traditional texture analysis using spectrometry and microscopy demands costly instruments, limiting routine quality assurance.
3. Developing a model to classify plant-based meat products, differentiating between lab-made and commercial varieties based on specific classes determined by cooking methods and time.

Fig 1. Figures showing plant based meat products of Commercial Tata and IITGN Food lab respectively

Previous Work

The previous research involved creation of a dataset of images with approximately 10,900 images distributed among 14 classes of Plant-based meat products patties, sourced from IITGN FoodLab and Tata commercial product. Two distinct cooking methods namely, air frying and deep frying were used with standardized cooking durations, including instances of overcooking. Ultimately, 14 distinct classes were established as shown below.



Current Work

Zero Shot Inferencing

- Utilized CLIP [1], a state-of-the -art deep learning model created by OpenAI, for zero-shot inference.
- Evaluated classification accuracy for 14 distinct classes and reduced 8 classes using CLIP, results in Tables 1 and 2.
- Defined recall metrics (R1, R3, R5) for image-captioning evaluation. R@K measures top K retrieved captions' relevance, with R1 associating one caption, R3 three, and R5 five.

Dataset Curation

- Dataset initially used two cooking methods; research in [3] showed cooking method has minimal impact on critical parameters. Streamlined to one cooking method, reducing classes from 14 to 8 .
- Challenges: noisy characteristics, diverse backgrounds, misaligned patties. Utilized Grounded-SAM by Idea-Research [2], a state-of-the-art model, to accurately segment and extract images of the patties from the complex background based on the provided prompt. The pipeline is shown in Fig.2.

Training

- Conducted training using the curated dataset on conventional machine learning classification algorithms, incorporating Histogram of Gradients (HoG) as input features to quantify textures. The results are tabulated in Table 3.
- Fine tuned ResNet-50 model trained on Food-101 dataset (shown in Fig.3.) using a robust training pipeline with cross-entropy loss, Adam optimizer, and incorporated strategies such as learning rate scheduling and early stopping to enhance training efficiency and mitigate overfitting.

Results and Observations

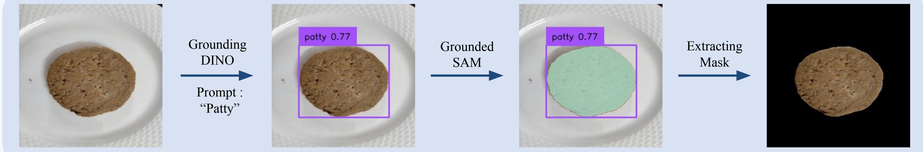


Fig 2. Figures showing dataset curation pipeline using Grounded SAM

Class Name	R@1	R@3	R@5
commercial_air_normal	0.0%	0.5%	16.5%
commercial_air_over	0.0%	2.0%	24.0%
commercial_deep_normal	0.0%	0.5%	56.5%
commercial_deep_over	0.0%	63.0%	76.5%
commercial_unbaked	98.0%	100.0%	100.0%
inhouse_air_normal	0.0%	0.0%	3.0%
inhouse_air_over	0.0%	4.0%	24.0%
inhouse_deep_normal	0.0%	1.0%	11.5%
inhouse_deep_over	0.0%	10.5%	74.5%
inhouse_old_air_normal	0.0%	0.0%	3.5%
inhouse_old_air_over	0.0%	4.5%	15.5%
inhouse_old_deep_normal	0.0%	1.0%	10.5%
inhouse_old_deep_over	0.0%	12.0%	44.0%
inhouse_unbaked	44.5%	98.0%	99.5%

Table 1. Table showing zero shot inference result on 14 classes

Class Name	R@1	R@3	R@5
commercial_deep_normal	0.0%	3.0%	89.5%
commercial_deep_over	0.0%	71.0%	88.5%
commercial_unbaked	98.5%	100.0%	100.0%
inhouse_deep_normal	0.0%	0.5%	15.0%
inhouse_deep_over	0.0%	18.0%	86.0%
inhouse_old_deep_normal	0.0%	2.0%	18.5%
inhouse_old_deep_normal	0.0%	14.5%	53.0%
inhouse_unbaked	40.0%	100%	100%

Table 2. Table showing zero shot inference result on reduced 8 classes

Model	Parameters	Accuracy
Logistic Regression	max_iter = 1000	36.22
SVM	kernel = 'rbf', C= 12.0	35.73
Random Forest	n_estimators = 200, random_state = 42	37.92
KNN	n_neighbours = 32	31.68

Table 3. Table showing accuracy on different classification algorithm using curated dataset

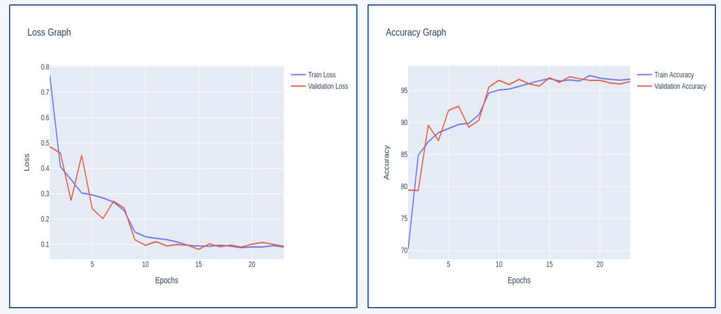


Fig 3. Figure showing training plots for curated dataset trained on ResNet-50 model

Conclusion

1. Traditional models with HoG features yielded low accuracies (30-40%), suggesting mismatched data distribution and suboptimal texture description for varied patty orientations.
2. ResNet-50 trained on the curated dataset demonstrated exceptional performance, achieving a validation accuracy of 96.43% and a training accuracy of 96.77%.
3. When the classes were reduced from 14 to 8, the average R@5 classification accuracy using CLIP showed a significant improvement of 28.85%. Additionally, after curating the dataset with Grounded SAM, the average R@5 accuracy further improved by 3.5%.

Application and Future Aspects

1. Establishing a new dataset for real meat counterparts and employing texture quantification methods can provide valuable insights into the nuanced variations between plant-based and real meat products.
2. Improving dataset quality through standardized conditions, employing Histogram of Gradients (HoG) for nuanced texture analysis, and investigating the potential of Vision Transformers (ViT) for image classification.

References

1. A. Radford, J. W. Kim, C. Hallacy, A. Ramesh, G. Goh, S. Agarwal, G. Sastry, A. Askell, P. Mishkin, J. Clark, G. Krueger, and I. Sutskever, "Learning transferable visual models from natural language supervision," 2021.
2. Y. Zhang, X. Huang, J. Ma, Z. Li, Z. Luo, Y. Xie, Y. Qin, T. Luo, Y. Li, S. Liu, Y. Guo, and L. Zhang, "Recognize anything: A strong image tagging model," 2023.
3. G. Vu, H. Zhou, and D. J. McClements, "Impact of cooking method on properties of beef and plant-based burgers: Appearance, texture, thermal properties, and shrinkage," Journal of Agriculture and Food Research, vol. 9, p. 100355, 2022.

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