NutriVision: AI-Powered Food Recognition and Nutritional Analysis

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Our platform combines AI food recognition with personalized dietary guidance.

Dataset Overview

Food-101 Dataset

101,000 images across 101 food categories with balanced, realistic images

USDA FoodData Central

1,841,897 entries with comprehensive nutritional information

Dataset Overview

FOOD 101:

Index	Food Class
1	Apple Pie
2	Baby Back Ribs
3	Baklava
4	Beef Carpaccio
5	Beef Tartare
6	Beet Salad
7	Beignets
8	Bibimbap
9	Bread Pudding
10	Breakfast Burrito

- 101 food categories with 101,000 images (1,000 per class)
- Ranges from desserts (Apple Pie) to protein dishes (Baby Back Ribs)
- Balanced class representation
- Dataset serves as comprehensive training foundation for our classification model

USDA FoodData Central DB:

- USDA FoodData Central database: Contains over 1.8 million entries
- Structured data includes: Unique FDC_ID identifiers, food descriptions, serving sizes, and key nutritional metrics (calories, protein, fat)
- Wide nutritional variation: From high-calorie oils (867 kcal) to low-calorie broths (4 kcal)
- Database enables detailed nutritional analysis for ideally any identified food item

FDC_ID	Description	Serving Size	Calories	Protein	Fat
1105904	WESSON Oil 1 GAL	15 ml	867	0	93.33
1105905	Swanson Beef Broth	240 ml	4	0.83	0
1105906	Clam Chowder Soup	440 g	82	2.45	5.31
1105907	Cheese Broccoli Soup	440 g	82	1.22	6.12
1105908	Swanson Chicken Broth	240 ml	4	0.83	0
1105909	Bean and Ham Soup	412 g	61	3.67	0.61

Exploratory Analysis

Image Preprocessing

- Resizing and normalization
- Data augmentation techniques
- Class distribution visualization

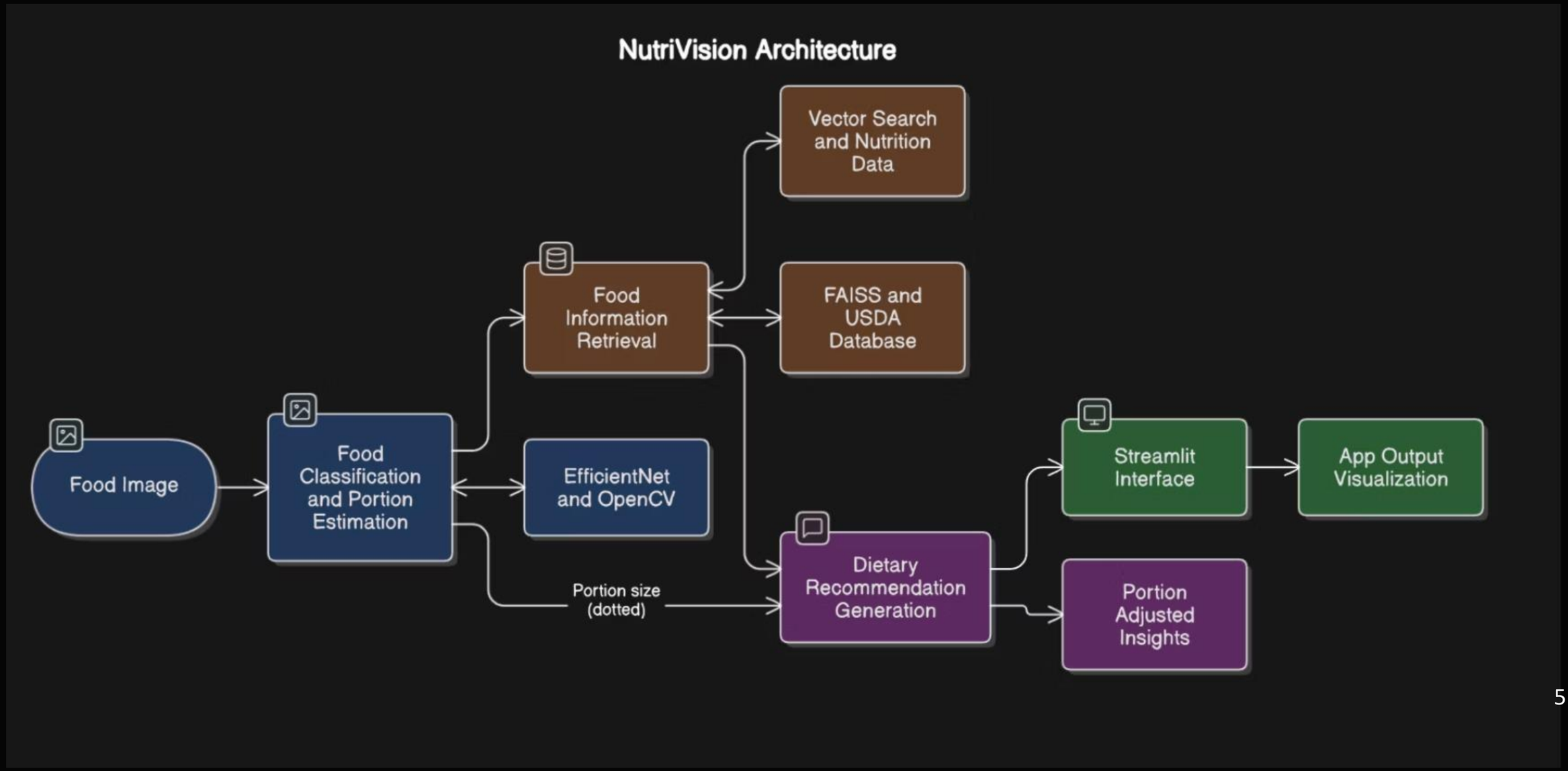
USDA Data Exploration

- Nutritional value distributions
- Food category breakdown
- Missing value handling

Vector Embeddings

- Food description embeddings
- Clustering similar foods

System Architecture



System Architecture

Modular Code Structure

app.py, vector_db.py

Component Interactions

User uploads food image via Streamlit UI

EfflicientNet Model processes image and returns predicted food class

vector_db.py finds semantically similar foods using FAISS

app.py queries USDA database for nutritional information

generates personalized dietary insights using OpenAI/Anthropic APIs

Results displayed to user through Streamlit interface

Key Features

Vector-based RAG implementation

Pre-trained EfficientNet model fine-tuned on Food-101 dataset

FAISS index for efficient similarity search

Integration with generative AI for personalized recommendations

Dependencies

Core ML: Tensorflow, Keras, FAISS

Embedding: Sentence Transformers

Data: Food 101, USDA FoodData Central - UI: Streamlit

AI: OpenAI GPT-4o, Anthropic Claude-3

Data Processing & Feature Engineering Overview:

Multi-Modal Data Pipeline:

- Image preprocessing for food recognition (224×224 RGB normalization)
- Text processing for food descriptions and embeddings
- USDA nutritional database integration (1.8M+ entries)

Food Classification Labels:

- 101 food categories from Food-101 dataset (Apple Pie → Breakfast Burrito)
- Labels mapped to predicted class

Vector Embeddings for Semantic Food Search:

- 384-dimensional semantic representations using SentenceTransformer
- Local FAISS index for efficient similarity search
- Streamlit caching for performance optimization

Computer Vision Portion Size Estimation

How It Works:

Original Food → Processed Binary Image → Contour Detection → Area Calculation

- **Computer Vision Pipeline**: Converts images to grayscale → enhances contrast → creates binary mask → detects food contours
- **Size Calculation**: Compares detected food area to reference database of average portion sizes
- **Nutritional Adjustment**: Automatically scales nutritional values based on detected portion size (1.0-3.0x)

Example: A cheeseburger detected as 1.4x average size → 40% increase in calculated calories, protein, fat, and carbs → more precise dietary guidance

Modelling

EfficientNetB0

Pre-trained on ImageNet, fine-tuned on Food-101

Layer (Type)	Output Shape	Param #
EfficientNetB0 (Functional)	(None, 7, 7, 1280)	4,049,571
GlobalAveragePooling2D	(None, 1280)	0
Dropout	(None, 1280)	0
Dense	(None, 1024)	1,311,744
Dropout	(None, 1024)	0
Dense	(None, 101)	103,525
Total Parameters		8,295,380 (31.64 MB)
Trainable Parameters		1,415,269 (5.40 MB)
Non-Trainable Parameters		4,049,971 (15.45 MB)
Optimizer Parameters		2,830,540 (10.80 MB)

Table 3: Model parameters for the NutriVision EfficientNetB0-based model.

Transfer Learning Strategy

- **Feature Extraction**: EfficientNetB0 without its top layer (include_top=False) serves as a pre-trained feature extractor that already understands visual patterns, textures, and shapes from training on ImageNet.
- **Task-Specific Classification**: The custom classification head (GlobalAveragePooling2D → BatchNormalization → Dropout → Dense) is specifically designed for 101 food classes.

```
base_model = EfficientNetB0(weights="imagenet", include_top=False,
input_shape=(224, 224, 3))
base_model.trainable = True
model = Sequential([
    base_model,
    GlobalAveragePooling2D(),
    BatchNormalization(),
    Dropout(0.3),
    Dense(101, activation="softmax", kernel_regularizer="l2")
])
```

- GlobalAveragePooling2D() flattens EfficientNet's output
- Dense(101, softmax) replaces the original classifier with your 101 food classes

Initial Experimentation

Baseline Model

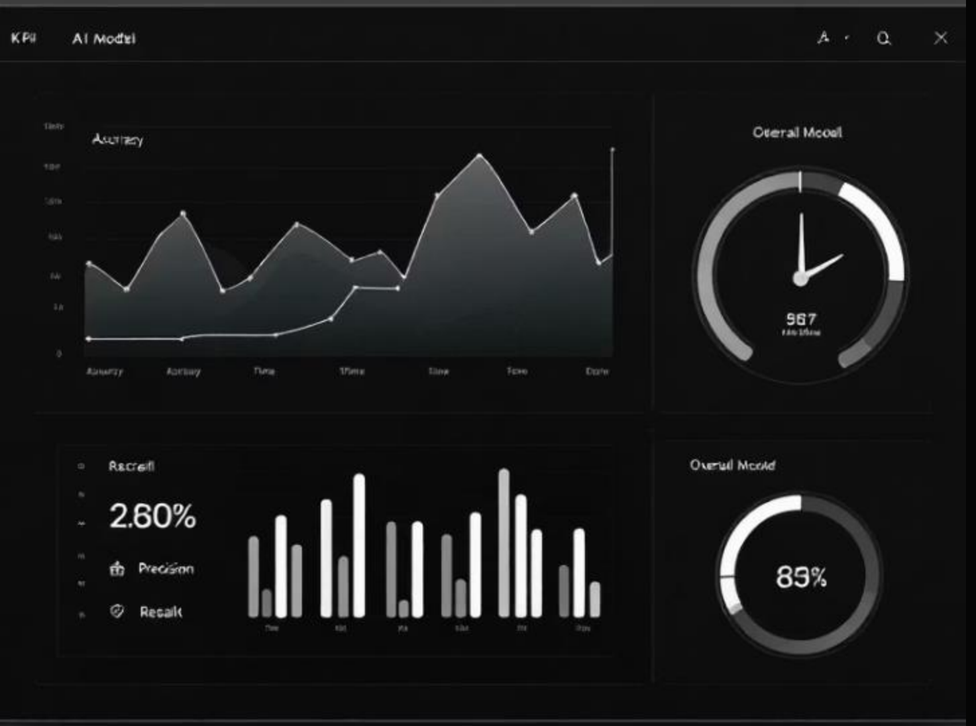
- EfficientNetB0
- Learning rate: 0.0003
- 30 epochs with dropout optimization

Vector Search

- FAISS index
- Simple text embedding approach

Generative AI

- Structured prompt templates
- GPT-4o vs Claude-3 comparison



Model Evaluation

82%

Validation Accuracy

Final classification model performance

84%

Training Accuracy

Model learning effectiveness

Generating AI Insights

AI-Powered Dietary Insights Process:

1. Food classification from image (EfficientNet)
1. Nutritional data retrieval (USDA database)
1. Context formation combining food class & nutritional data
1. Prompt engineering for nutritional guidance
1. AI-generated personalized dietary recommendations

```
def generate_dietary_insight(nutrition_text, model_choice="GPT-4o"):
    """Generate dietary insights using generative AI"""
    try:
        if model_choice == "GPT-4o":
            # Generate with OpenAI GPT-4o
            response = openai.ChatCompletion.create(
                model="gpt-4o",
                messages=[
                    {"role": "system", "content": "You are a helpful nutrition assistant focusing on providing concise, actionable dietary advice."},
                    {"role": "user", "content": f"Based on this data: {nutrition_text}, provide a concise, actionable dietary advice that's personalized and specific."}
                ]
            )
            return response['choices'][0]['message']['content'], "Generated by GPT-4o"
```

Final Results

Improved Classification

EfficientNetB7 with fine-tuned last 50 layers, advanced augmentation, early stopping

Enhanced RAG Implementation

Streamlined vector search with efficient caching

Local FAISS index for fast similarity retrieval

Duplicate removal while preserving result order

Refined AI Prompting

Structured system prompts for personalized dietary recommendations

UI Optimization

Responsive Streamlit layout with progress indicators and error handling

Demo

Setup

Python 3.9+, API keys, sample food images

Image Upload

~0.5 seconds for preprocessing, ~1-2 seconds for inference

Search & Analysis

AI Recommendations

Future Work

Advanced Models

Vision Transformers integration and ensemble approaches

Optimization

Model compression and edge device deployment

New Features

Multi-food detection, meal planning, environmental impact assessment

User Experience

Preferences, dietary restrictions, and history tracking