Diets in the right way: a machine learning based food macronutrient recognition system

Tammy Tseng

Opportunity evaluation

Obesity and fatal chronic diseases can be contributed by poor diet and lack of physical movements. According to researchers, 42% of the adults and 20% of the children in the United States are currently suffering from obesity or overweight in 2023. Furthermore, around 147 million USD were spent annually for their health conditions. (Source)

Improving the quality and quantity of these patients' diets can be a critical step to support their recovery. There are plenty of dietary strategies which were profoundly proven to increase the efficiency in losing weight in the long term, suggesting higher possibility to recover from obesity. **Controlling the percentages of different macronutrients (also known as "macro-counting") is one of the scientifically approved and popular methods to lose weight. These nutrients include carbohydrate, protein, fat, and fiber.(Source)**

Counting proportions of macronutrients sounds easy in labs or by professional healthcare experts. However, it can be quite difficult to conduct by people without proper education or professional monitoring. (Source)

The problems normal people face when conducting macro-counting ca be:

1. **Lack of knowledge of the portions of each macro-nutrients they should eat for each meal.** For example, patients don't know how much chicken breast, rice, and cauliflower they should put on their dinner plates.
2. **Lack of knowledge in nutrient content in different kinds of food.** For example, patients cannot tell if potatoes are counted as carbs or fiber without googling it or calling their dietitians.
3. **Unawareness of fluctuation of their daily caloric output.** For example, patients might not know that they need to eat more carbs today because they just finished a 5K jog. Female patients might not know that they have different nutrition needs in different phases of their menstrual cycles.

Difficulties in counting-macros for preventing obesity can be quite common among patients, and some of the patients might fight this battle for years. If not treated properly, these pain points can hinder patients' journey toward recovery significantly.

Can Machine Learning (ML) solve these problems in macro-counting to help out obese patients? The answer is yes. Here are the reasons why.

1. **Automation**: ML can replace the tedious and repetitive tasks which were originally provided by healthcare experts (doctors, nurses, and dietitians). These experts' services are expensive, so replacing the services with ML will be a grand costdown
2. **Prediction**: ML is good at identity patterns in great quantities of data. By giving sufficient data regarding macro-counting, ML can predict the best decisions for patients during food choosing.
3. **Customization**: By being fed with sufficient amounts of patient information, ML can learn how to identify and recommend right food choices to individual patients.

Based on the value propositions ML can provide, I will build **a machine learning based food macronutrient recognition system, which can calculate the macro counting by analyzing the pictures of food users upload.** With the macronutrients data coming from the pictures, and other user data, the system can suggest if the food in the plates are appropriate or not for users obese recovery journeys.

The response to the users' picture upload will not be as simple as "Yes" or "No". Based on users' other input, the system can further suggest what food to add in or what to be removed from the plate.

CRISP-DM Business Understanding

The Cross Industry Standard Process for Data Mining (CRISP-DM) is a data mining method which includes six steps: business understanding, data understanding, data preparation, modeling, evaluation and deployment. (Source)

Before I jump into the design planning for this machine learning feature, I want to explore the business understanding of this opportunity first.

1. Define the problem
    a. Target users: Obese patients who have the instructions from healthcare practitioners that using macro-counting as one of the methods to recover. In United States, obesity is defined as when BMI is 30 or higher (Source)
    b. Problem Statement: Macro-counting as a dietary strategy to lose weight for obese patients turns out to be challenging and easy to fail.
    c. Why it matters:
        i. Over 40% of the adults in United States suffer from obesity, which can lead to deadly diseases (Source)
        ii. Successful macro-counting can help obese recovery (Source)
    d. How is it solved today & Why it is not enough
        i. Consult a doctor, nutritionist, or dietitian
            1. A professional can help patients to plan and monitor their macro-counting journey based on patients' medical history and specific needs. Patients can even find professionals who can monitor patients' every meal via sending photos of the food .

        2. Compared to other solutions listed below, this might be the most expensive one even with patients' health insurance.
    ii. Apps and Websites
        1. Many macro-counting and tracking tools are just one Google search away. The most famous ones include: Myfitnesspal, My macros+, and Macros - Calories counter.
        2. These apps feature customized dietary plans and suggestions, but lack precise tracking and counting systems upon what patients' really put on their dinner plates.
    iii. Educational sources
        1. Books, videos, articles, and communities can be found to help patients understand macro nutrients, portion sizes, valuable tips, and science behind these strategies.
        2. Like ii. Apps and Websites, these resources can only give patients semi-customized plans, not real-time suggestions for each individual.
2. Define Success
    a. Quantify the expected business impact
        i. Decrease average time to lose % body weight for obese patients via macro-counting
    b. Identify constraints
        i. This feature require real-time visual identification and customization of what patients need to eat, and if the macro-nutrients on their plates are up to the macro-counting standards
        ii. For patients' safety, this feature should understand what time points to alert healthcare practitioners and have them involved
        iii. Patients' data privacy need to be protect in the machine learning process
    c. Outcome metrics: Reduce average time to lose body weight via macro-counting
    d. Output metrics: MSE of aggregate predictions
    e. Success targets for metrics:
        i. Outcome: Reduce x% of average time to lose body weight via macro-counting
        ii. Output: MSE < xx
3. Define Factors
    a. User related factors
        i. Basic information: Age, gender, demographic, race
        ii. Medical information: height, weight, % body fat, medical history, current usage of medications
        iii. Real-time information: exercise, water intake, heart rate, body temperature, (if a woman) menstrual cycle data points
    b. Photo related factors
        i. Background: Resolution of the photo, size of the plate
        ii. Food: size of the food, macro group of the food, color of the food

ML System design

There are three system design decisions that are presented here. The decisions will mainly be made upon users requirements and constraints.

Users requirements and constraints

The target users for this feature will be obese patients in the USA. The feature I want to build is a machine learning based food macronutrient recognition system, which can calculate the macro counting by analyzing the pictures of food users upload.

Ideally the users should have access to this feature any time in a day, and can use this feature without healthcare practitioners' support, unless the systems detect that the users are somehow in danger. Therefore, **a mobile application will be a good way to present this feature.**

If that is the case, there will be several constraints which need to be considered before we make design decisions.

1. Low latency: The feature should give response within a short time after analyzing the photo users upload.
2. Data Sharing: Healthcare practitioners of the users should have access to users' data.
3. User privacy: Users data should not be shared with other individuals other than their healthcare practitioners.

Three system design decisions

I need to pick one for each of the system design decisions upon their impact on the technologies used for this feature.

1. Cloud vs. Ege
2. Offline learning vs. Online learning
3. Batch predictions vs. Online predictions

Based on users' requirements and constraints, I decided to make this feature **on both Cloud and Edge, with online learning, and with online predictions.** Here are my reasons:

1. Cloud and Ege:
    a. Data needs to be accessed by the healthcare practitioners via Cloud
    b. Low latency via Edge is required for the system to make quick responses to the photo users upload.
2. Online learning: The system needs to make a response for each photo uploaded. Therefore, online learning is better for real-time adoption in the environment.
3. Online predictions: Via online predictions, the predictions (the response) can be created in real-time.

Potential Risks in productions

I listed some of the concerns about how this ML-based feature could have decayed in accuracy.

1. **Training - Serving skew**: One major value this feature provides is its ability in recognizing different food in a photo. However, the conditions given during training and in real life might be different. For example, during training, the system is fed with photos of food in bright light. But in reality, the users might take pictures in bad lighting, suggesting that the system might fail to recognize the food categories and portion sizes incorrectly.
2. **Excessive latency**: It is possible that the feature will take a long time to process the photo and give response, and the users get annoyed by how long it takes. Such situations might occur due to the model we pick, or the volume of data the system needs to process before it gives the response.
3. **Concept drift**: Users in different dietary cultures might create incorrect estimations in the systems. For example, in the photo of the food, there can be a food item the system cannot recognize, or a cooking style that was not used in the training. These culture differences can also lead to bad estimations.