Systems Engineering Analysis for Cooking Recipes from the Perspective of Work Instructions

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Abstract. In this paper, we focus on the labour-intensive human cooking process and analyze cooking recipes using systems engineering techniques. The purpose of this is paper to help analyze the impact of specifying cooking recipes from the perspective of work instructions on the reproducibility and development of food. Specifically, we use as an example the recipe for "Fuhafuha Tofu," which appears in number 21 of the cookbook "Tofu Hyakuchin" published in the Edo period between 1603 and 1868 in Japan. We focus on the ambiguity of the description method in this cooking recipe. First, we extract expressions that are described as explicit textual information in the cooking recipe. Next, we analyze the information containing the ambiguity described in the cooking recipe and the information that is not directly described. These are assumed to be information containing ambiguities that can be inferred from the context even without being instructed when the operator performs the cooking task. We will take the specifications of modern cooking recipes and compare and analyze how they are written from the perspective of work instructions.

Keywords: cooking recipe, systems engineering, work instruction, gastronomic sciences, food

1   Introduction

A recipe is defined as a method of preparing a dish. A recipe describes the necessary information on ingredients and the cooking process, and the cook attempts to reproduce the described dish based on the information obtained from the recipe. In addition to paper, recipes can be passed on orally through hearsay in the community or region or memorized implicitly in the mind without being directly written on a medium. In recent years, research has been conducted on recommending dishes based on lifestyle and preferences [1]-[3], recognizing food images and using deep learning to estimate cooking recipes and information such as nutrients contained in them [4], and businesses utilizing recipe data.

Salvador et al. have proposed an Inverse cooking system that generates cooking recipes from food images [5]. The information generated is the name of the dish, the ingredients, and a description of the cooking method (Instruction). The system

comprehensively determines the ingredients that make up the dish from the image and generates a cooking recipe by estimating the transformation processes such as slicing, stirring, and mixing with other ingredients as interactions between the image and the ingredients. Here, we focus on the process of estimating the cooking method in the reverse direction, using the cooking image as the final form. The given cooking image shows the finished state of the dish. In other words, the process is oriented toward reproduction.

However, in general, when a person cooks based on the information in a cooking recipe, the degree of fidelity to the recipe is left to the discretion of the cook. It is not uncommon for the cook to change the seasoning or heat level, or substitute ingredients within the range of available ingredients, depending on the preferences of the family or the cook. When cooking recipes are considered as work instructions, they can be used in a variety of ways according to the cook's purpose of cooking, unlike the conventional work instructions that standardize and describe the work to improve productivity and quality. Therefore, in this paper, we focus on the labour-intensive manual cooking process and analyze the influence of the cooking recipe on the reproducibility and development of the dish. In this paper, we focus on the labour-intensive manual cooking process, and analyze the effect of the cooking recipe on the reproducibility and development of the dish. We also analyze the cooking recipe using the system engineering method, in order to examine how the method of information presentation and work instructions in the cooking recipe stimulates the creativity and ideas of the cook or worker, and which tasks should be left as human tasks, and which should be automated or robotized in the future. In this paper, we analyze cooking recipes using the system engineering method. Specifically, the ambiguity of the description method will be analyzed using "Tofu Hyakuchin" (Tofu Hyakuchin), a cookbook published in the Edo period (1782), as a case study. The characteristics of the recipes will also be discussed by comparing them with modern cooking recipes.

2   Systems engineering analysis of cooking recipes

In this section, we analyze "Tofu Hyakuchin", a cookbook published in the Edo period. The ambiguity of the description in the recipe is analyzed using "Fuhafuha Tofu," which is described in number 21 of the book, as a case study. We extract the expressions that are explicitly described as textual information in the recipe and sort out the content of the explicit description and the ambiguous information when executing the cooking process.

First, the textual information described in "Fuhafuha Tofu" shown in Fig. 1 is translated into modern Japanese. In this analysis, we focus on the textual information. The following steps are used to analyze the text information translated into modern Japanese.

- **STEP1:** Extraction of information explicitly described in cooking recipes
  Extract character strings that are explicitly described in the cooking recipe and divide them into morphemes. These include noun phrases for ingredients and verb phrases for processes.

- **STEP2:** Process description
  Describe the process diagram using the extracted morphemes (Figure 2). Noun phrases are written as squares, verb phrases as circles, and other words as text.
- **STEP3:** Identifying non-unique information for cooking reproduction
  Organize the information that is not uniquely determined when attempting to reproduce the cooking based on the described process diagram. These include the specific amount of food, the amount of heat and mixing, and adverbial expressions such as frequency and degree for verb phrases.
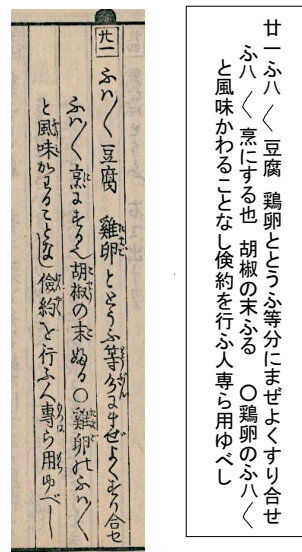- **STEP4:** Estimation from ambiguous information

Figure.1 Left: "Tofu Hyakuchin" (National Diet Library website (Japan)), Right: reprint result

In Step 3, information that is not uniquely determined in the cooking reproduction is defined as ambiguous information in this paper. This can be interpreted as inducing a state in which the cook cannot specify the specific cooking process when he or she sees the cooking recipe as a work instruction. The cook is required to proceed with the cooking by inferring the ambiguous information from the information before and after the explicit description in the cooking recipe and the context of the dish or supplement the information with the cook's own ideas and devices.

The following is an example of applying the steps described above to Fuhafuha Tofu. The explanation follows the steps from the left of the process diagram (Figure 2). The original recipe, translated into English, is described as follows.

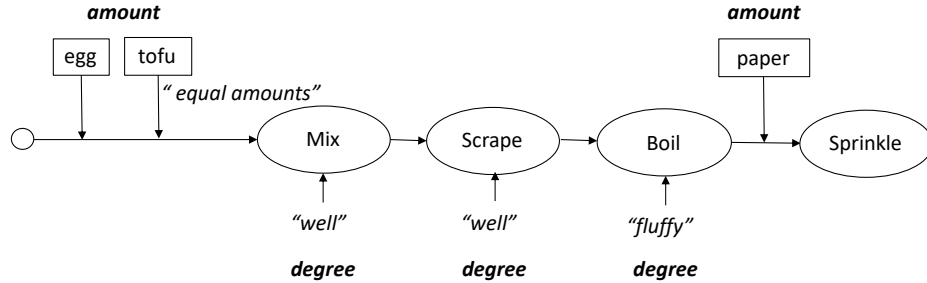1. Mix equal amounts of chicken egg and tofu and scrape well.

Figure.2 Process description diagram for "Fuhafuha Tofu".

    2. Boil it fluffy

    3. Sprinkle with pepper

    Note: The egg fluffy and flavor will not change. Therefore, thrifty one uses tofu instead of eggs.

    Ingredient: Tofu, egg, pepper

The first step is to mix equal amounts of egg and tofu. However, no specific amount is given here. In the section on mixing well and boiling to a fluffy consistency, the expressions "well" and "fluffy" are ambiguous as to the specific level of detail. The cook cannot uniquely identify the cooking process because there is no detailed description as in modern cooking recipes, such as mixing with a whisk until the mixture becomes angular or until the egg is no longer sticky, and no image information is given to confirm the process. The final step is to sprinkle pepper. The cook is required to imagine the cooking process based on the context associated with the name of the dish and the information before and after the cooking process, because the process of adding liquid such as broth or water to the boiling process is not described.

3   Estimation of ambiguous information

When cooking a cooking recipe that contains ambiguous information, the cook needs to estimate the task from the context and the context before and after as shown in the previous section. In this section, as one of the estimation approaches, we consider the cooking recipe as an optimal design problem.

First, the objective variable is set based on the information described explicitly in Step 1. The objective variable is set by assuming the goal that the recipe is intended to achieve from the explicitly described recipe information. It is possible to estimate multiple optimal design problems from a single recipe, and objective variable settings can be defined for each problem. For example, in the case of "Fuhafuha Tofu," for the description of "Fuhafuha" in the name of the dish, the objective is how to make the finished dish into a Fuhafuha state, which is assumed to be a maximization problem of the Fuhafuha state. In Japanese, "fluffy" means very soft and fluffy. In other words, it can be regarded as a problem of maximizing softness and fluffiness. Next, in STEP 3, ambiguous information that is not

Figure.3 Cooking results of "Fuhafuha Tofu".

uniquely determined is set as explanatory variables. In the estimation of explanatory variables, we focus on the following two perspectives. One is the existence of a quantitative expression for the foodstuff. Quantitative amount for a foodstuff can be set as an explanatory variable, if the required input of the foodstuff is not specifically specified. The second is the presence or absence of degree expressions for the cooking and processing operations. We focus on the time required for the cooking and processing operations, and the amount and intensity of the operations. For example, the heating time and heat level in the heating process, and the degree of force and stirring time in the stirring process. Here, we add that even if the specific amount and degree of manipulation are not described as quantitative expressions, the state of change of the food after the cooking and processing operation can be described specifically. For example, whipping cream until it becomes cubed, or continuing heating until the surface of the food becomes white, such descriptions can be interpreted as unambiguous expressions. In this example of "Fuhafuha Tofu", we set the degree of mixing in "well-mixed" and the degree of heat and heating time in "simmering". In this example, the degree of mixing in "well-mixed" and the degree of heat and heating time in "simmering" were set as explanatory variables.

The information that is not explicitly described in the cooking recipe, such as the process and the amount of ingredients, was regarded as incomplete information and was considered as design variables. As a result of cooking with multiple combinations of these design variables as different conditions, the finished products varied depending on the combination of conditions. The different features of appearance in finished products and nutritional components differed depending on the combination of different conditions were observed, i.e., cooking process and ingredients. For example, the different appearances observed in the cooking results of "Fuhafuha Tofu" were like scrambled eggs and pancakes. (Figure 3). Near-infrared spectroscopy NIRS analysis showed

that the nutritional components also differed due to the effects of cooking wear and tear caused by the different cooking processes.

In recent years, many recipes have been published using videos and photographs. The information given to cooks by video recipe representation is discussed in order to compare it with the recipe containing ambiguous information analyzed in this study. In a video recipe, the cook can check the condition of the ingredients and the degree of processing from the images at each time in a series of snapshots. It is possible to determine from the image information how much heat should be added and when the condition of the food should be changed to the next step. Therefore, video recipes can be said that a suitable way for faithfully reproducing recipes. On the other hand, the recipe analyzed in this paper contains ambiguous information. It is possible that recipe descriptions containing ambiguous information were created due to the fact that the measurement technology for describing quantitative expressions was not yet developed at that time. Therefore, the cook has the discretion to reflect environmental constraints and/or regional and personal preferences within the range of information that is not uniquely defined in the cooking process. Cooks can add various interpretations and imaginations for targeted ambiguous information. The accumulation of such actions may have led to the development and diversity of home tastes and local cuisine.

4   Conclusions

In this paper, we considered cooking recipes as work instructions and conducted systems engineering analysis focusing on ambiguity. It is future work to analyze the effect of ambiguity on the cook's ingenuity and the development and variability of the dish.

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