Summary of a Citywide Meal Planning Service for Kids Based on Logic Programming*

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Abstract. This paper describes an implemented service, and associated mobile app, that has been used for the last five school years to support effective meal planning for kids in Parma, Italy. The service suggests a daily choice of one, two, or three dinner proposals based on what children are expected to eat at the canteens of nurseries, kindergartens, and primary schools. In addition, the service provides proposals for the lunches of non-school days to cover weekends and school holidays. Lunch and dinner proposals are generated by means of a dedicated meal planning service that uses logic programming to solve constraint satisfaction problems associated with meal planning problems. The adopted constraints ensure that the proposals for lunches and dinners are nutritionally balanced throughout the week and that seasonal proposals are preferred to promote the consumption of seasonal vegetables and fruits.

Keywords: NUBI Parma · Meal planning for kids · Constraint satisfaction problems · Logic programming

1 Introduction

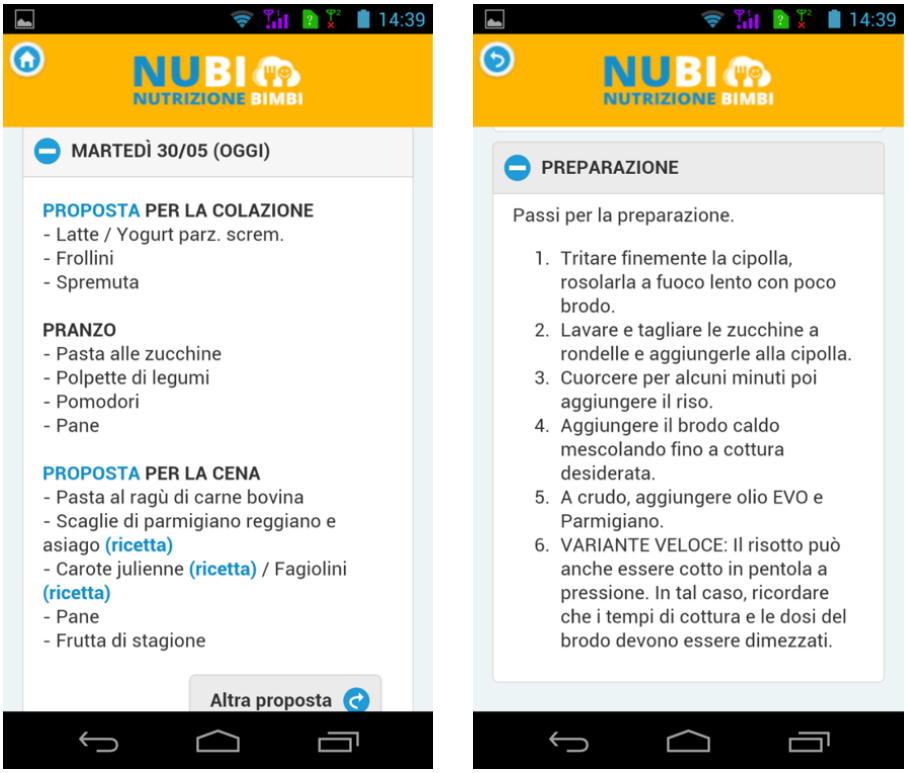
Food is so important in our society that the right to food is accepted in international laws as a legally binding human right that must be guaranteed to all individuals. The right to food is derived from the *International Covenant on Economic, Social and Cultural Rights* (*ICESCR*) [7], which was adopted by the United Nations General Assembly on December 16$^{\text{th}}$, 1966. Basically, the right to food ensures that all individuals can feed themselves in dignity, that they have the means to access food, and that available food adequately meets all dietary needs. The right to food protects the right of all individuals to be free from hunger, food insecurity, and malnutrition. However, many individuals still suffer from various forms of malnutrition despite the age of well-being that we experience today in developed countries.

Malnutrition can be broadly defined as a pathological state that results from inadequate nutrition. Actually, inadequate nutrition can be classified into undernutrition (lack of nutrients), overnutrition (surplus of nutrients), and deficiency of nutrients (e.g., vitamins or minerals). Therefore, malnutrition does not only occur when the quantity of food is insufficient, but, more generally, when the nutritional needs are not met in terms of both the quantity and the quality of food. In the long term, malnutrition can lead to the onset of severe diseases that negatively impact on the quality of life or that can even reduce life expectancy. Moreover, when malnutrition is spread among a significant portion of the population of a country, it can severely reduce the overall perceived quality of the healthcare system of the country.

Nutritionists are working hard to stem malnutrition by proposing various tools designed to instill in individuals, from childhood, a correct diet associated with a healthy lifestyle. One of the several tools proposed to stem malnutrition is meal planning. Meal planning is the task of organizing and scheduling the meals that will be consumed by an individual within a day, a week, or a month. Normally, it is restricted to main meals, i.e., lunches and dinners, but it can also take into account all other meals, which include breakfast and various snacks. One of the most relevant characteristics of an effective meal planning is the ability to nutritionally balance the considered meals, and therefore, to respect the desired distribution of the macronutrients, i.e., carbohydrates, proteins, and lipids, that must be provided through a healthy and balanced diet. In addition, an effective meal planning can also reduce food waste by portioning meals in advance and by controlling the weights of portions. Currently, several software tools are available to help individuals build their meal plans, for themselves and for their families. Such tools are normally implemented as mobile apps that access backend meal planning services. These apps are normally very easy to use, and they sometimes provide recipes and manage shopping lists. Notably, some of the available software tools for meal planning are designed for users that need special meal plans for cultural or health-related reasons.

This paper briefly describes a meal planning service, and the associated mobile app, that is currently in use to support effective meal planning for kids in Parma, Italy. The mobile app is called *NUBI Parma*, from *NUtrizione BImbi* (*childhood nutrition* in Italian), and it is the first mobile app delivered by the NUBI project. The NUBI project is a joint effort of the Artificial Intelligence Laboratory of the University of Parma, of the Department of Food and Drug of the University of Parma, and of Madegus (www.madegus.com), a spin-off company of the University of Parma. The project was conceived to support families in following effective meal plans through dedicated mobile apps and educational services. Currently, the project is running two meal planning services in two neighboring cities in Italy, namely Parma and Reggio Emilia.

NUBI Parma offers to the families living in Parma the opportunity to choose among one, two, or three dinner proposals based on what children are expected to eat at the canteens of nurseries, kindergartens, and primary schools of the municipality of Parma. Also, NUBI Parma provides proposals for non-school day



(a) (b)

Fig. 1. Screenshots of NUBI Parma running on an Android smartphone: (a) the menu of the day, which includes the proposed breakfast, the lunch served at school, and the proposed dinner; (b) the recipe of one of the dishes used to plan the proposals for dinners and non-school day lunches.

lunches to ensure that lunches and dinners are balanced throughout the week and during school holidays. All the proposals suggested by NUBI Parma are seasonal, which ensures that seasonal vegetables and fruits are properly accounted in meals. Often, proposals are matched with recipes to guarantee that dishes are properly cooked at home. NUBI Parma has been constantly used for the last five school years and, in the 2018–2019 school year, the backend meal planning service received 136,034 requests for weekly menus by 5,645 mobile devices. Fig. 1 shows screenshots of NUBI Parma running on an Android smartphone.

The second mobile app delivered by the NUBI project is NUBI Reggio Emilia. NUBI Reggio Emilia is similar to NUBI Parma, but it is intended for the primary schools of Reggio Emilia. NUBI Reggio Emilia has been used for the last three school years to provide dinner proposals in three languages (Italian, English, and Mandarin) to the kids of seventeen schools, including kids that needs to follow, for cultural or health-related reasons, one of the five available special diets.

This paper is organized as follows. Section 2 contains a brief discussion of the meal planning service used by NUBI Parma, to summarize its goals and to concisely present its design. Also, Section 2 discusses how the meal planning service uses constraint satisfaction problems to solve meal planning problems, and it briefly overviews the logic program that actually solves obtained constraint satisfaction problems. Finally, Section 3 concludes the paper with an outlook on planned developments of NUBI Parma and its meal planning service.

2 The NUBI Parma Meal Planning Service

NUBI Parma is a mobile app that provides access to the NUBI Parma meal planning service, which is a dedicated meal planning service designed to provide healthy and balanced proposals for dinners and non-school day lunches. In particular, the meal planning service uses the menus of the canteens of supported institutes, i.e., the nurseries, the kindergartens, and the primary schools of the municipality of Parma, to ensure that the proposed dinners and non-school day lunches are properly balanced. The meal planning service provides proposals based on the recommended food consumption frequencies available in the guidelines of the World Health Organization [9] and of Regione Emilia-Romagna [5]. In addition, the meal planning service takes into account the guidelines for school nutrition adopted by Ministero della Salute [4] and by Ministero dell'Istruzione, dell'Università e della Ricerca [3]. Moreover, the meal planning service considers other reliable guidelines (e.g., [2]) designed to promote healthy and balanced diets. Finally, the meal planning service takes also into account the locality and the seasonality of dishes, as suggested by mentioned guidelines, to promote the consumption of local and seasonal vegetables and fruits. The adoption of mentioned guidelines ensures that the meal planning service promotes healthy and balanced eating behaviors intended to combat overweight, childhood obesity, and other related pathologies.

2.1 Input and output data

The NUBI Parma meal planning service is an offline meal planner that suggests one proposal for every non-school day lunch of the year and one, two, or three proposals for every dinner of the year. It starts from the planned menus of the canteens of supported institutes, and it fills the *meals table* of the database that is consulted whenever a user accesses the service using NUBI Parma.

The principal input sources to the meal planner are the menus of the canteens of supported institutes. Such menus are fed to the planner as three *Comma-Separated Values* (*CSV*) files, one for each type of institute, i.e., nurseries, kindergartens, and primary schools, and the planner uses such files to produce a CSV file that can be immediately used to fill the meals table of the database. Note that, currently, institutes do not provide their menus as CSV files and, therefore, the needed CSV files are produced manually every year by extracting relevant information from the menus of the canteens available on the Web.

The entries in the input CSV files are numeric identifiers that refer to the rows of the *dishes table* of the database, which currently contains 310 dishes used for dinners and for lunches, at canteens and for non-school days. Each dish in the dishes table is described by 37 columns, the most relevant of which are:

- 2 columns to store the numeric identifier and the name of the dish;
- 10 columns that associate each dish with at least 1 of 10 classes, e.g., *for breakfast*, *side dish*, and *vegetable*;
- 7 columns that list the major sources of proteins in each dish, e.g., *white meat*, *fish*, and *legumes*;
- 5 columns that list the major sources of carbohydrates in each dish, e.g., *pasta*, *rice*, and *tubers*; and
- 2 columns that describe the characteristics of each dish when the dish is classified as *vegetable*.

Note that each dish is associated with a category and with a subcategory on the basis of the values in the dishes table. Also note that few dishes are classified in the dishes table as *single* or *semi-single*. A portion of a single dish (e.g., pizza) is sufficient for a full meal, while a portion of a semi-single dish (e.g., gnocchi alla romana) is sufficient for a full meal only when a portion of bread is also given.

Most of the dishes in the dishes table are associated with their respective recipes in the *recipes table* of the database. The recipe of a dish enumerates the ingredients of the dish, with their quantities for kids and adults, and it describes the preparation procedure. Note that the availability of recipes is one of the major reasons why users routinely consult NUBI Parma, and the number of recipes in the database is constantly increasing to respond to users' demands.

The output of the meal planner is used to fill the meals table of the database. The meals table has a row for each day of the year and for each type of institute. For each row, the table contains the menu offered by the canteen of the institute, or a proposal for a non-school day lunch, and one, two, or three dinner proposals. Dinner proposals are compiled using the dishes available in the dishes table, which contains a superset of the dishes offered at canteens. Dinner proposals are compiled taking into account the constraints suggested by the guidelines mentioned at the beginning of this section.

2.2 Constraints from nutritional guidelines

The nutritional guidelines mentioned at the beginning of this section were used to identify a set of constraints that the NUBI Parma meal planner enforces when compiling proposals for dinners and non-school day lunches. Such constraints were divided into three groups. Note that most of the considered constraints are related to the nutritional tradition of the area where the app is used.

The first group of constraints concerns the three types of meals that must appear in a menu according to the considered guidelines. Such types of meals are typical of the Italian tradition, and they are used to compile the proposals for dinners and for non-school day lunches. The three types of meals that the meal

- Regular meal, which consists of:
  1. First dish (carbohydrates);
  2. Second dish (proteins);
  3. Side dish, raw or cooked (all vegetables can be proposed);
  4. Bread;
  5. Fruit.
- Semi-single meal, which consists of:
  1. Semi-single dish;
  2. Semi-single side dish (only some vegetables can be proposed);
  3. Bread;
  4. Fruit.
- Single meal, which consists of:
  1. Single dish;
  2. Single side dish, raw or cooked (only some vegetables can be proposed);
  3. Fruit.

Fig. 2. The three types of meals used by the NUBI Parma meal planning service.

planner currently manages are summarized in Fig. 2. Note that the considered guidelines impose the following restrictions on single and semi-single dishes:

- Dishes that contain carbohydrates and proteins cannot be used when a semi-single dish is proposed; and
- Dishes that contain carbohydrates, proteins, and bread cannot be used when a single dish is proposed.

In addition to the constraints that describe the three types of meals, and how they can be combined, the considered guidelines impose a second group of constraints intended to determine how the three types of meals should be used in a menu. Among such constraints, the most relevant restriction requires that, when three alternative dinner proposals are suggested, two proposals must be regular meals and one proposal must be a single or a semi-single meal. If a single or a semi-single meal cannot be suggested for the shortage of available dishes, three regular meals must be suggested.

Finally, the third group of constraints is imposed by the considered guidelines to restrict the ways in which the various types of dishes can be combined to assemble a weekly menu. Such constraints are expressed in terms of consumption frequencies, as follows:

- Maximum consumption frequency in a week, which is the maximum number of repetitions of a type of dish in a week;
- Maximum consumption frequency in a day, which is the maximum number of repetitions of a type of dish in a day; and
- Maximum consumption frequency in a meal, which is the maximum number of repetitions of a type of dish in a meal.

The most relevant maximum consumption frequencies, as implemented by the NUBI Parma meal planner, are shown in Table 1.

Table 1. Constraints on the consumption frequencies for some types of dishes.

Dish category	Dish subcategory	Weekly maximum	Daily maximum	In-meal maximum
Carbohydrates	Pasta	7	1	1
	Rice	4	1	1
	Tubers	4	1	1
	Soups	4	1	1
	Cereals	6	1	1
Proteins	White meat	2	1	1
	Red and cured meat	2	1	1
	Fish	3	1	1
	Dairy products	3	1	1
	Eggs	2	1	1
	Legumes	4	1	1
	Protein mix	2	1	1
Special dish	Single	7	2	1
	Semi-single	7	2	1
Vegetables	Raw	14	2	1
	Cooked	14	2	1
	For semi-single dishes	14	1	1

2.3 Relaxable constraints

Even if the dishes table of the database contains 310 dishes, it is often the case that the needed proposals for dinners and non-school day lunches cannot be delivered because the dishes in the dishes table are not sufficient to satisfy the constraints on maximum consumption frequencies shown in Table 1. A detailed analysis of the cases in which constraints are too stringent suggested that a few constraints could be relaxed to ensure that the requirements of reference guidelines were met and that the meal planner could actually deliver all needed proposals. Therefore, the current implementation of the NUBI Parma meal planner is allowed to relax the following constraints by increasing the allowed maximum consumption frequencies:

- Maximum consumption frequency in a week of dishes in the subcategory *fish* can be increased from 3 to 4; and
- Maximum consumption frequency in a week of dishes in the subcategory *legumes* can be increased from 4 to 5.

Basically, the current solution to the shortage of dishes in the dishes table of the database is to try to compile menus using all constraints, resorting to relax mentioned constraints only when full menus cannot be completed. Note that, even if mentioned constraints are relaxed, the generated menus do not violate the stringent requirements of the considered guidelines. Also, note that the need of relaxing constraints can be alleviated by adding new dishes to the dishes table. Unfortunately, the dishes in the dishes table are local and seasonal, and the adequate enlargement of the dishes table is definitely not trivial.

2.4 Notes on the implementation of the meal planner

The detailed description of the algorithm used by the NUBI Parma meal planner, and of its current implementation as a logic program, is out of the scope of this paper. The remaining of this section contains a brief description of the coarse-grained architecture of the meal planner and of the most relevant characteristics of its current implementation.

The brief description of the constraints imposed by the adopted nutritional guidelines mentioned at the beginning of this section suggests that meal planning problems can be easily rewritten into related *Constraint Satisfaction Problems* (*CSPs*) over finite domains. Actually, the process of solving a meal planning problem consists of using the set of available dishes to assemble proposals for dinners and non-school day lunches ensuring that constraints from nutritional guidelines are satisfied or properly relaxed. Therefore, the construction of a CSP to solve a given meal planning problem regards identifying a suitable set of variables, a suitable set of domains, and a suitable set of constraints. The NUBI Parma meal planner associates a variable with each dish in a proposal for a dinner or for a non-school day lunch according to the scheme summarized in Fig. 2. Each variable must be associated with the numeric identifier of one of the dishes available in the dishes table of the database. Therefore, all variables share one domain, which is the set of the numeric identifiers of available dishes in the dishes table. Finally, the constraints that the meal planner must satisfy to solve a meal planning problem are described in sufficient detail in the considered nutritional guidelines, as discussed earlier in this section.

The current implementation of the NUBI Parma meal planner uses the approach outlined above to express a given meal planning problem in terms of suitable CSP. A solution to the CSP represents the menu for a year, which is generated, written to a CSV file, and finally stored in the meals table of database. Note that the meal planner splits the construction of the menu by considering the three types of institutes, i.e., nurseries, kindergartens, and primary schools, independently. Moreover, the meal planner splits the year into four periods, which are related to school terms, and it splits each period in weeks. The menus of the weeks in each period are generated independently to ensure that seasonal dishes are properly suggested and that proposals for dinners and non-school day lunches are healthy and balanced throughout each week.

The meal planner is currently implemented as an offline logic program, written in SWI-Prolog [8], that reads input data from the three CSV files mentioned at the beginning of this section to output a CSV file ready to be loaded in the meals table of the database. The meal planner uses the forward checking algorithm (e.g., [1]) to search for the first solution to the considered CSP, and it immediately returns the solution as a satisfactory menu. In particular, the current implementation of the meal planner is based on the implementation of the forward checking algorithm suggested in [6], and it uses the *Minimum Remaining Values* (*MRV*) heuristic to dynamically choose which variable to assign next. If no solutions can be found, the meal planner relaxes the two relaxable constraints mentioned previously, and it tries to solve the new meal planning problem.

Note that the current implementation of the meal planner does not use *Constraint Logic Programming* (*CLP*) because preliminary experiments suggested that no constraints can actually benefit from the use of CLP. Considered constraints are mostly expressed in tabular form, and they are often related to the cardinalities of the sets of variables assigned to related dishes during the search. The use of the tabular form severely limits the expected benefits from current tools for CLP because most of the available tools for CLP are based on algebraic structures and their operations. In addition, the need for set constraints that is inherent to the use of consumption frequencies to express constraints further reduces the viable options for applicable CLP tools.

Finally, note that a brute force approach to the search for the solution to considered CSPs is not feasible because the number of dishes available in the dishes table of the database generates a large search space. On the contrary, the current implementation of the meal planner can produce a monthly menu for one type of institute in less than 100 ms using an ordinary laptop.

3 Conclusion

NUBI Parma has been in constant use by more than 18,193 mobile devices since the end of 2016, receiving more than 558,451 requests for weekly menus. It is now a consolidated tool for the families of the municipality of Parma, and some institutes explicitly instruct families to use the app to consult the menus of canteens and to have suggestions for dinners and non-school day lunches. As such, NUBI Parma and its meal planning service can be considered a relevant application in the landscape of logic programming, at least for the scale of the user base and for its intended casual use.

The short-term development plans for NUBI Parma are based on suggestions received from users. Several users suggested to include the possibility of selecting special diets so that the proposals for dinners and non-school day lunches could be tailored to follow one of the available special diets. Among the plethora of possibilities, users suggested to include in NUBI Parma the same five special diets that are currently supported by NUBI Reggio Emilia, namely, gluten-free, lactose-free, pork-free, nut-free, and vegetarian (no meat and no fish). The mentioned diets are not tailored to the special needs of single users, but they simply introduce new constraints in the yearly planning of meals.

The long-term development plans for NUBI Parma are based on the possibility of quickly planning the meals for a single user so that the service could be extended to provide personalized menus to take into account the preferences and the habits of single users. Such an extension, together with others that are easy to immagine, could give the possibility to stem malnutrition by proposing a tool capable of transparently instilling in each individual, from childhood, a healthy and balanced diet. Actually, an envisaged scientific experiment is intended to measure several nutrition-related values in the population of the municipality of Parma to possibly identify the beneficial effects of the daily use of NUBI Parma for a sufficiently long period of time.

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