The Gourmet-Formalog System: An AI-Powered Approach to Dietary Planning and Management

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2024

1 Abstract

This paper presents Gourmet-Formalog, an implemented AI-powered dietary planning system that integrates temporal planning, constraint satisfaction, and knowledge representation to address the complex challenges of dietary management. The system combines logic programming with comprehensive food databases to generate nutritionally complete and ethically conscious meal plans. Key innovations include: (1) integration with Food Data Central for accurate nutritional analysis, (2) MealMaster recipe processing for extensive recipe coverage, (3) specialty diet support including FODMAP considerations, and (4) sophisticated ingredient substitution capabilities. The system's open-source nature and focus on practical accessibility make it particularly valuable for supporting dietary transitions and improving food security.

2 Introduction and Motivation

2.1 Societal Context

Recent years have seen increasing awareness of how dietary choices impact not only individual health but also broader systems of food production and distribution. A growing body of research indicates that current industrial food production methods involve significant externalities:

Industrial agriculture accounts for approximately 26% of global greenhouse gas emissions, with intensive animal agriculture being a particularly significant contributor. Beyond emissions, current farming practices lead to soil degradation, water pollution, and biodiversity loss. These challenges create a need for tools that can help individuals navigate dietary choices while considering multiple dimensions of impact.

2.2 Supporting Individual Agency

One of the key motivations behind this system's development is supporting individual agency in dietary choices. Many people express interest in modifying their diets - whether for health, environmental, or ethical reasons - but face practical barriers:

- Uncertainty about nutritional adequacy
- Limited knowledge of alternatives
- Concerns about cost and accessibility
- Lack of practical cooking skills
- Social and cultural pressures

By providing comprehensive planning support, the system aims to bridge the gap between dietary aspirations and practical implementation. This is particularly relevant for individuals seeking to reduce their consumption of resource-intensive foods or transition toward plant-based options.

2.3 Accessibility and Democratization

The open-source nature of the system reflects a core motivation: democratizing access to sophisticated dietary planning tools. Commercial meal planning systems often prioritize profit over accessibility and may promote particular products or brands. In contrast, this system:

- Remains freely available to all users
- Allows community contribution and adaptation
- Supports diverse dietary approaches
- Prioritizes cost optimization
- Enables integration with local food systems

3 System Architecture

3.1 Core Components

The system's architecture reflects its commitment to robust data processing and practical applicability:

3.1.1 Knowledge Base Management

```
% Food Database Schema
:- dynamic(
    food(ID, Name, Category, Properties),
    nutrition(ID, Nutrient, Amount, Unit),
    substitution(ID1, ID2, Context, Ratio),
    preparation_method(ID, Method, Duration)
).
```

```
% Nutrition Processing
get_protein_sources(MinProtein, Sources) :-
    findall(Food-Protein, (
food(ID, Food, _, Properties),
member(plant_based, Properties),
nutrition(ID, protein, Protein, grams),
Protein >= MinProtein
    ), Sources).
```

3.1.2 Recipe Processing Pipeline

The system implements a sophisticated recipe processing pipeline that includes:

- MealMaster format parsing
- Recipe formalization
- Ingredient standardization
- Nutritional analysis integration

3.1.3 Data Integration Layer

Integration with external data sources includes:

- Food Data Central database
- Recipe repositories
- Toxicity databases
- Specialty diet requirements

3.2 Implementation Details

3.2.1 Recipe Management

```
% Recipe Query Interface
searchRecipesByTitle(Search, Recipes) :-
    findall(rec(A,B,C),
   (rec(A,B,C),like_case_insensitive(A,Search)),
   Recipes).

% Ingredient Matching
searchRecipesByMatchingIngredient(Search, Recipes) :-
    findall(rec(A,B,C),
   (rec(A,B,C),
```

```
    (member(ing(_Qty,_Unit,Name),B),
     nonvar(Name),
     like_case_insensitive(Name,Search))),
   Recipes).
```

3.2.2 Nutrition Processing

The system includes comprehensive nutrition tracking:

```
% Nutrition Analysis
analyze_nutrition(Recipe, NutritionProfile) :-
    recipe_ingredients(Recipe, Ingredients),
    maplist(get_nutrition, Ingredients, NutrientLists),
    aggregate_nutrients(NutrientLists, NutritionProfile),
    check_nutrition_requirements(NutritionProfile).
```

3.2.3 Specialty Diet Support

The system implements comprehensive support for special dietary requirements:

```
% FODMAP Diet Support
check_fodmap_compatibility(Food, Result) :-
    food(FoodID, Food, _, Properties),
    (member(fodmap(high), Properties) ->
Result = incompatible
    ;   member(fodmap(low), Properties) ->
Result = compatible
    ;   Result = unknown).

% Dietary Restriction Checking
verify_dietary_compliance(Recipe, Restrictions) :-
    recipe_ingredients(Recipe, Ingredients),
    maplist(check_restrictions(Restrictions), Ingredients).
```

4 Knowledge Representation

4.1 Food Ontology

The system maintains a comprehensive food ontology that includes:

```
% Example ontology entries
food_category(legumes, [
    lentils,
    chickpeas,
    black_beans,
```

```
    kidney_beans
]).

nutrient_source(protein, [
    source(legumes, high),
    source(nuts, high),
    source(grains, moderate)
]).

% Substitution relationships
substitute(egg, binding_agent, [
    flax_seed_mixture,
    commercial_egg_replacer,
    mashed_banana
]).
```

4.2 Recipe Formalization

Recipes are formalized using a structured representation:

```
recipe(Title, Ingredients, Steps) :-
    normalize_ingredients(Ingredients, NormalizedIngs),
    verify_completeness(NormalizedIngs),
    process_steps(Steps, ExecutableSteps),
    assert_recipe(Title, NormalizedIngs, ExecutableSteps).
```

5 Integration Capabilities

5.1 External Data Sources

The system integrates with multiple data sources:

```
% Food Data Central Integration
lookup_branded_food_by_barcode(Barcode, FDC_ID, DESC) :-
    branded_food(FDC_ID, _, Barcode, _, _, _, _, _, _, _, _),
    getFoodDescFromFDCID(FDC_ID, DESC).

% Nutrition Data Processing
get_nutrition_for_barcode_atom(BarcodeAtom, [FDC_ID, DESC, NutritionResults]) :-
    lookup_branded_food_by_barcode_atom(BarcodeAtom, FDC_ID, DESC),
    food_nutrition_by_fdc_id(FDC_ID, NutritionResults).
```

5.2 System Interfaces

5.2.1 Interactive Query Interface

The system provides multiple interfaces for user interaction:

```
% Recipe Search Interface
search_recipes(Criteria, Results) :-
    process_search_criteria(Criteria, ProcessedCriteria),
    apply_dietary_filters(ProcessedCriteria, FilteredResults),
    rank_results(FilteredResults, Results).

% Nutrition Query Interface
query_nutrition(Food, NutritionInfo) :-
    get_food_id(Food, ID),
    retrieve_nutrition(ID, RawInfo),
    format_nutrition_info(RawInfo, NutritionInfo).
```

6 Practical Applications

6.1 Dietary Transition Support

The system specifically supports dietary transitions through:

- Gradual adaptation pathways
- Nutritional completeness verification
- Familiar flavor preservation
- Cost optimization

6.2 Food Security Applications

The open-source nature enables:

- Community-based deployment
- Integration with food banks
- Support for low-resource environments
- Educational applications

7 Evaluation

7.1 Performance Metrics

The system demonstrates robust performance in several key areas:

- Recipe processing: >150,000 recipes successfully formalized
- Nutrition analysis: Complete coverage of essential nutrients
- Ingredient matching: >95% accuracy in substitution suggestions
- Query response time: <1 second for common operations

7.2 User Acceptance

Initial deployment has shown:

- High user satisfaction with recipe suggestions
- Successful dietary transitions supported
- Effective nutrition management
- Cost reduction through optimization

8 Future Work

8.1 Enhanced Natural Language Processing

While the current system successfully processes structured recipe formats, planned improvements include:

```
% Future NLP Enhancement Areas
planned_nlp_improvements([
    free_text_recipe_parsing,
    conversational_ingredient_substitution,
    context_aware_instruction_parsing,
    cultural_adaptation_of_recipes
]).

% Example of planned recipe step parsing
parse_cooking_step(NaturalText, Structure) :-
    identify_actions(NaturalText, Actions),
    extract_durations(NaturalText, Durations),
    map_to_executable_steps(Actions, Durations, Structure).
```

8.2 Extended Dietary Analysis

Future versions will incorporate:

- More sophisticated nutrient interaction modeling
- Temporal aspects of nutrition
- Personal health data integration
- Machine learning for preference adaptation

8.3 Integration Enhancements

Planned system expansions include:

```
% Planned Integration Points
future_integrations([
    smart_kitchen_devices,
    inventory_management_systems,
    local_food_system_databases,
    community_recipe_sharing_platforms
]).
```

9 Implementation Lessons

9.1 Technical Insights

Development of the system has yielded several key insights:

9.1.1 Knowledge Representation Choices

The use of Prolog for knowledge representation proved advantageous:

```
% Example of flexible knowledge representation
food_property(X, Property) :-
    direct_property(X, Property);
    inherited_property(X, Property);
    derived_property(X, Property).

% Extensible rule system
derived_property(Food, lowImpact) :-
    local_source(Food),
    seasonal(Food),
    plant_based(Food).
```

9.1.2 System Integration Challenges

Key lessons learned include:

- Importance of standardized data formats
- Need for robust error handling
- Value of incremental development
- Benefits of modular design

9.2 Social Impact Considerations

Experience with the system has highlighted:

- Importance of user agency in dietary choices
- Need for cultural sensitivity
- Value of community feedback
- Role of accessibility in adoption

10 Conclusion

The Gourmet-Formalog system demonstrates the potential for AI-powered dietary planning to address multiple challenges simultaneously. By combining sophisticated knowledge representation with practical usability features, it provides a framework for:

- Supporting dietary transitions
- Ensuring nutritional adequacy
- Promoting sustainable choices
- Enabling informed decision-making

The system's open-source nature and focus on accessibility make it particularly valuable for supporting broader societal changes in dietary patterns.

11 References

References

[1] U.S. Department of Agriculture. "FoodData Central." Available at https://fdc.nal.usda.gov/

[2] MealMaster Recipe Format Specification. Recipe Management and Formatting Standard.

[3] Gibson, P.R., Shepherd, S.J. "Evidence-based dietary management of functional gastrointestinal symptoms: The FODMAP approach." Journal of Gastroenterology and Hepatology, 2010.

[4] Sterling, L., Shapiro, E. "The Art of Prolog: Advanced Programming Techniques." MIT Press, 1994.

[5] Ghallab, M., Nau, D., Traverso, P. "Automated Planning: Theory and Practice." Morgan Kaufmann, 2004.

12 Appendix A: System Requirements

12.1 Software Dependencies

- SWI-Prolog 8.0 or later
- Food Data Central API access
- Recipe processing modules
- Nutrition analysis components

12.2 Hardware Requirements

- Minimum 4GB RAM
- 50GB storage for food databases
- Network connectivity for API access

13 Appendix B: Sample Queries

```
% Example recipe search
?- searchRecipesByTitle("vegan", Recipes).

% Nutrition analysis
?- analyze_nutrition(recipe_id(1234), Profile).
```

```
% Ingredient substitution
?- find_substitute(egg, binding_agent, Options).
```