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Master of Science in
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KEBI: Project Report

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COLOPHON

This thesis was typeset using LaTeX and the `memoir` documentclass. It is based on Aaron Turon's thesis *Understanding and expressing scalable concurrency*[1], itself a mixture of `classicthesis`[2] by André Miede and `tufte-latex`[3], based on Edward Tufte's *Beautiful Evidence*.

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[1] https://people.mpi-sws.org/~turon/turon-thesis.pdf

[2] https://bitbucket.org/amiede/classicthesis/

[3] https://github.com/Tufte-LaTeX/tufte-latex

Declaration

I herewith declare that I have produced this paper under the supervision of Prof. XXXX at the University of Camerino, without the prohibited assistance of third parties and without making use of aids, other than those specified. Notions taken over directly or indirectly from other sources have been identified as such. This paper has not previously been presented in an identical or similar form to any other Italian or foreign examination board.

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2024

* This dissertation is presented in partial fulfillment of the requirements for **Ph.D. degree** in the School of Advanced Studies of University of Camerino.

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Part I

PROLOGUE

1

Introduction

"In the end, it's not the technology that matters, but our ability to use it to improve and enrich the lives of people."
—Tim O'Reilly

In today's digital era, many restaurants have transitioned to digitized menus accessible through QR codes. While this technological advancement offers convenience, it also presents challenges, especially for guests with specific dietary preferences or restrictions. The small screen size of smartphones can make it difficult to get a comprehensive and full view of a menu, and guest often have to shift through numerous options that may not align with their dietary needs.

To address these issues, this project aims to develop a knowledge-based system that tailors menu recommendations based on individual guest preferences. By leveraging knowledge engineering techniques, we can create a system that filters and presents only those meals that match the guest's dietary profile. This enhances the dining experience by providing a more personalized and manageable menu.

Knowledge engineering plays a crucial role in this project, as it involves the creation, representation and utilization of knowledge to solve complex problems. The solutions created in this project include decision tables, Prolog, and knowledge graphs/ontologies, each offering unique advantages for representing and querying knowledge.

In developing our solution, we utilized the menu from the Italian restaurant Nero Balsamico as a case study (`https://www.nerobalsamico.it/`). This real-world example provided a rich dataset of typical Italian meals, including pizzas, pastas, and main dishes, along with detailed information about their ingredients and nutritional content. It surely added complexity rather than mocking a simple and common Menu but we gladly went through with the challenge.

The report is structured as follows:

1. **Introduction**
    - Overview of the project, its objectives, and the importance of knowledge engineering.

2. **Decision Tables and DRD**
   - Explanation of decision tables and Decision Requirements Diagrams (DRD).
   - Creation and implementation of decision tables for menu recommendations.
3. **Prolog Implementation**
   - Introduction to Prolog and its use in knowledge representation.
   - Development of Prolog facts and rules for guest-specific meal recommendations.
4. **Knowledge Graphs and Ontologies**
   - Explanation of knowledge graphs and ontologies.
   - Use of SWRL, SPARQL, and SHACL for meal recommendation queries and rules.
5. **AOAME**
   - Introduction to the AOAME tool.
   - Modeling of our ontology leveraging the power of AOAME.
6. **Evaluation and Conclusions**
   - Evaluation of the system's performance.
   - Discussion of results and potential improvements made by each individual member of the project.

By the end of this report, we will have demonstrated how knowledge-based systems can significantly enhance the dining experience by providing personalized and relevant menu recommendations. This project not only showcases the practical application of knowledge engineering but also highlights the potential for such systems to be integrated into modern restaurant operations. You can view all the project implementation and try it out yourself by checking the following **Github Repository**: (`https://github.com/Meguazy/project_KEBI`).

Part II

DECISION TABLES

2

Decision Tables and DRD

"A decision table is the simplest form of representing the decision logic in a tabular manner, which helps in organizing and ensuring completeness."
—Anonymous

2.1 DRD DESCRIPTION

Decision tables were the first step towards our solutions; they are a powerful tool used in decision-making processes. They provide a structured way to represent decision logic by mapping different conditions to corresponding actions through a tabular representation. We leveraged the power of decision tables to model our system with rules that allowed us to filter the initial ingredients list to ensure we would consider the Guest's dietary needs and allergens. During our solutions, we made extensive use of the FEEL language, which enabled us to create a more dynamic system. We followed a course on Camunda about Decision Tables to deeply understand their advantages and managed to elaborate every single table in our DRD with powerful FEEL expressions.

To have a deep understanding of the solution we provided through the decision tables, we shall start by describing our DRD, a Decision Requirements Diagram, which illustrates the decision-making process for recommending meals based on client-specific dietary information.

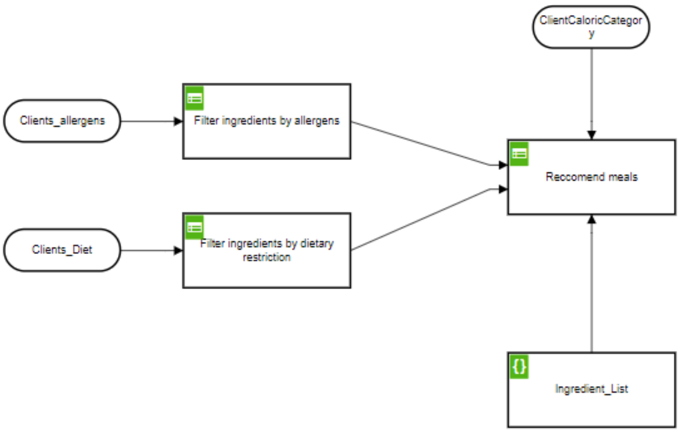

FIGURE 2.1: Decision Requirements Diagram (DRD) for Recommending Meals Based on Dietary Preferences

As we can see from Figure 2.1, this DRD is composed of several elements. We will analyze each element individually and provide an accurate description. The diagram is made up of the following components:

- **Filter Ingredients By Allergens:** This is a decision table that filters out ingredients containing allergens specified by the clients.
  - These allergens are provided as input data by the component **Clients_allergens.**
- **Filter By Dietary Restriction:** This decision table is responsible for filtering out ingredients based on the client's dietary restrictions, such as Vegan, Vegetarian, and Omnivore.
  - The specific diet of the client is given by an input data shape called **Clients_Diet.**
- **Ingredient_List:** This, unlike the others, is a literal expression and represents the comprehensive list of all possible ingredients available for meal preparation, mapped to their kcal values.
- **Recommend Meals:** This central decision node integrates filtered results based on allergens, dietary restrictions, and caloric categories to recommend appropriate meals based on the client's needs. It represents the heart of our DRD and is responsible for collecting and combining information from other decision tables. As we can see from the inputs, it is linked with almost every element. There is also a new element called **ClientsCaloricCategory**, which we will discuss further in the project report.

First and foremost, it is important to note that we initially used a sequential filtering approach. We later concluded that a sequential approach might have some potential problems in the future regarding extensibility and maintainability, as it was very difficult to retrieve information from previous tables that weren't directly linked. The new DRD's modular design allows each decision component (e.g., filtering by allergens, dietary restrictions, and caloric categories) to be developed, tested, and maintained independently. We have a single responsibility where each table has one logical responsibility. This modularity makes it easier to add new decision criteria or modify existing ones without affecting the entire system.

Another significantly improved aspect is the **Scalability**. As new types of dietary requirements or allergens might emerge, additional decision nodes can be incorporated into the DRD without overhauling the entire decision-making process. This ensures the system remains scalable and adaptable to evolving needs. In fact, unlike sequential filtering, where each step depends on the previous one, the DRD allows for parallel processing of decision rules, leading to more efficient data processing as multiple conditions can be evaluated simultaneously.

The DRD also enhances **Maintainability** by making it straightforward to update specific decision rules or add new ones. This flexibility is crucial for adapting to new dietary trends and regulations, ensuring that the system remains relevant and accurate over time.

In summary, the use of DRD in our project significantly improved the system's extensibility, scalability, and maintainability, providing a robust framework for dynamic and personalized meal recommendations.

2.2 DECISION TABLES ANALYSIS

Part III

PROLOG

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Prolog

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Part IV

ONTOLOGY AND KNOWLEDGE GRAPHS

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Ontology & Knowledge Graphs

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Part V

AOAME

5

AOAME Implementation

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Part VI

EPILOGUE

6

Conclusion

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Abbreviations

HTML hypertext markup language

List of Symbols

Latin Letters

l length

Greek Letters

η labeling

Superscripts

$\mathcal{G}$ graph

Subscripts

ρ environment

I would like to thank ...