Leveraging Ontologies for Handicraft Business Process Modeling: Application for the Pastry-Making Domain

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Keywords: Business Process Model, Ontology, Handicraft, Pastry-Making.

Abstract: The global business environment changes very fast, forcing organizations to seek ways to improve their operational efficiency, cut costs, and enhance their decision-making. Optimizing performance is possible only with a clear understanding of how work gets done. It is here that well-defined business processes become very instrumental. However, for an organization to understand, evaluate, and eventually improve its processes, it is important that they model them in the first place. Traditional modeling techniques, such as BPMN and UML, provide a standard framework of visual and graphical representation for these processes. Most of these methods, however, fall short of capturing domain knowledge. The evolution of semantic web technologies has necessitated ontology-based business process modeling, which provides meaningful representations for business processes through the integration of ontologies. In this paper, an ontology-based business process model (OBPM) of the handicraft domain is presented focusing on the pastry-making field.

1 INTRODUCTION

The dynamic and competitive nature of the modern business environment, including the handicraft sector in the Maghreb region, requires organizations to continuously improve their operational efficiency, reduce costs, increase decision-making capacity, and provide customers with high-quality products and services. To achieve these goals, the concept of business process management has emerged.

Business process management (BPM) system or methodology has been proven to be one of the most effective methodologies to improve the efficiency and performance of organizations (Ongena and Ravesteyn, 2020), (Suša Vugec et al., 2019). It is also defined as a holistic approach providing concepts, methods, and techniques to support the design, administration, configuration, enactment, and analysis of business processes in order to achieve strategic objectives and meet customers' needs (Weske et al., 2007). As a management discipline, BPM emphasizes business processes' importance to achieving the organization's objectives by improving, continuously managing, and governing them (Jeston, 2014).

Central to BPM is Business process modeling (BPMo), which involves creating visual representations of an organization's processes to understand and analyze them, using tools like flowcharts and diagrams. Literature shows that there are many business process modeling standards, techniques, languages, and tools, such as Unified Modelling Language (UML) (Object Management Group, 2017) and Business Process Management Notation (BPMN) (Object Management Group, 2011). However, these techniques have some drawbacks and limitations such as providing graphical elements containing only textual information with no formal semantics (Hepp et al., 2005). To address these limitations, the use of ontologies in business process modeling has emerged as a promising approach.

Through ontologies, a shared conceptualization can be specified formally and explicitly. An ontology defines the concepts, relationships, and rules that govern business processes within an organization, ensuring that all stakeholders and systems share a common understanding of those processes. The use of ontologies enables advanced functionalities like reasoning, knowledge discovery, and semantic interoperability, which are critical for achieving more efficient and effective business operations (Born et al., 2008).

Rennane, F. and Meziane, A.
Leveraging Ontologies for Handicraft Business Process Modeling: Application for the Pastry-Making Domain.
DOI: 10.5220/0012943000003825

In *Proceedings of the 20th International Conference on Web Information Systems and Technologies (WEBIST 2024)*, pages 226-233
ISBN: 978-989-758-718-4; ISSN: 2184-3252

This research focuses on how women engaged in handicrafts in developing or emerging regions make use of modern technology to foster creativity and business initiatives. It is intended to introduce a personalized ontology-based framework facilitating both training and customized organizational solutions for handicraft women (Rennane and Meziane, 2023). The handicraft domain, characterized by the production of unique, handmade goods, presents distinct challenges and opportunities for process optimization. For instance, a specific application of ontology-based modeling within the handicraft domain can be seen in the pastry-making process. By developing an ontology-based pastry-making process model, businesses can achieve a more systematic approach to production, ensuring consistency and quality in the final products. This model not only captures the intricate steps involved in pastry making but also integrates knowledge about ingredients, techniques, and equipment, facilitating better training, process improvement, and innovation in the field.

The remainder of this paper is organized as follows: Section 2 presents a comprehensive review of existing research and studies on business process modeling, as well as ontologies for the handicraft and culinary domains. Section 3 details the ontology development process used in this study. Section 4 outlines the proposed elements of the ontology. Section 5 focuses on the validation phase. Finally, Section 6 concludes the paper and suggests directions for future research.

2 RELATED WORK

A well-defined set of business processes plays a key role in the success of any organization. A business process is defined as a set of logically related and structured activities or tasks that produce a specific product or service for a particular customer or market (Davenport and Short, 1998). These processes serve as the fundamental building blocks that specify how work is done within a company, guaranteeing that tasks are completed effectively and consistently. Modeling these processes is essential for analyzing, simulating, improving, and automating them (Rospocher et al., 2014).

Process modeling is an approach for describing how businesses operate, it includes graphical representations of the activities, events, and instructions composing a business process (Recker et al., 2009). Popular BPMo methodologies include Business Process Model and Notation (BPMN), Unified Modeling Language (UML), and Event-driven Process Chain (EPC) (Weske, 2007). BPMN, in particular, is widely adopted due to its standardization, modeling capabilities, graphical clarity, and strong tool support (Wang et al., 2006).

While traditional business process modeling methods provide initial advantages, they have limitations, particularly regarding semantic precision and interoperability, they typically lack the ability to integrate semantic context and knowledge representation, which are essential for capturing the subtleties of domain-specific processes such as the handicraft domain (Ko et al., 2009).

Given the limitations of traditional BPMo methods, the integration of ontologies into business process modeling has emerged as a beneficial approach in current research. Ontologies, recognized for their structured information management and ability to link concepts, offer sophisticated capabilities for semantic modeling (Gruber, 1995). They enable precise representation of domain knowledge, facilitating detailed and flexible modeling of complex processes.

Research regarding the integration of ontologies in business process modeling has different aspects. Some studies use ontologies to define notations of business process modeling languages (Jenz, 2003) (Di Francescomarino et al., 2009). Koschmider and Oberweis (Koschmider and Oberweis, 2005) define ontologies of Petri nets for business process modeling and automation. Additionally, BPMN Ontology (Natschläger, 2011) and BBO (Annane et al., 2019) aim to formulize BPMN concepts in ontologies to support semantic understanding and interoperability. In addition, some research has been carried out on the development of general business process ontologies such as (Pedrinaci et al., 2008), and PSL (Schlenoff et al., 2000) which provide the primitive concepts that are adequate for describing basic business processes.

Furthermore, significant efforts exist to standardize ontologies for specific business processes across industries. For instance, Industrial Ontologies Foundry (IOF) provides ontologies and data models to improve interoperability among manufacturing systems (Drobnjakovic et al., 2022). The Supply Chain Reference Ontology (SCRO) (Wallace, 2021), and Supply Chain ONTology (SCONTO) (Vegetti et al., 2021) focuses on supply chain processes, providing a detailed representation to improve supply chain management and optimization. These ontologies provide structured representations of both general and domain-specific processes.

On the other hand, the handicraft domain encompasses a rich tapestry of traditional skills and techniques, representing a significant sector in many economies, particularly in developing countries.

Many ontologies have been proposed in the handicraft domain such as Ifugao Weaving Ontology (IWO) (Villafranca et al., 2022), Terengganu brassware ontology (Isa et al., 2020), and Tujia brocade ontology (Zhao et al., 2017). These studies focus on preserving the cultural heritage and serving as a model for designing knowledge bases.

Moreover, in the culinary domain defined as a subset of the handicraft domain, several ontologies have been proposed. For instance, FoodOn ontology (Dooley et al., 2018) provides semantics for a variety of food-related topics, including food production, culinary and chemical ingredients, and processing. While authors in (Markantonatou et al., 2021) modeled the domains of dishes appearing in various diverse menus. Additionally, numerous notable examples of cooking recipe ontologies exist. Villarias (Villarias, 2004) developed an ontology for cooking recipes intended for use with a semantic web querying system, and Batista (Batista et al., 2006) created and implemented an ontology for the cooking domain, encompassing concepts like actions, food, recipes, and utensils. Moreover, authors in (Sam et al., 2014) introduced an ontology for culinary processes defined in recipes. Since there is no consensus on a standard ontology for modeling handicraft business processes, this study aims to contribute to this area by focusing on the domain of pastry-making.

3 THE ONTOLOGY DEVELOPMENT PROCESS

This research work is based on a research project that explores how women involved in handicrafts in the Maghreb region utilize modern technologies to enhance their creativity and business ventures. This study aims to introduce a customized framework utilizing ontology, which supports tailored training and organizational solutions for women in the handicraft industry. Modeling the handicraft business process within this framework offers several benefits. It enables a structured representation of production methods, materials, and artisan techniques. Additionally, the ontology facilitates knowledge capture and transfer within the community, preserving traditional craftsmanship while integrating modern techniques. Moreover, by modeling the business process, the framework can identify areas for innovation, skill development, and business expansion, empowering women artisans to thrive in a competitive market landscape.

This paper focuses on the pastry-making domain as a handicraft business process, where a recipe is organized into phases of the cooking process, each phase consisting of a sequence of ordered tasks. Each task includes an action and details about the necessary and resulting ingredients, along with the duration of each step. Furthermore, recipes are classified and include lists of ingredients and required utensils. Given the rich cultural heritage and regional significance of traditional pastries, it is important to select a representative and notable example. The choice of modeling the Algerian Makrout Louz recipe is significant, as it is ranked in the top three according to the TasteAtlas [1] website (Figure 1), highlighting its cultural and culinary importance in the Maghreb region.

Ontology construction in this paper involved two main stages: knowledge acquisition and ontology construction as depicted in Figure 2.

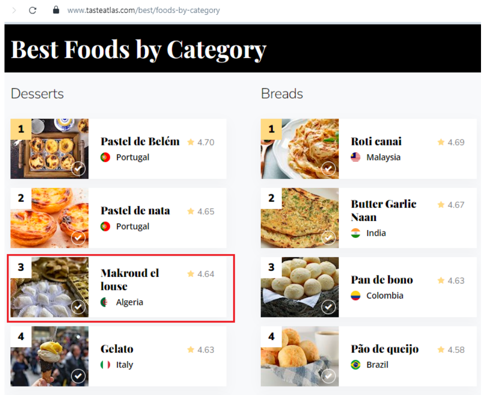

Figure 1: TastAtlas website Food ranking.

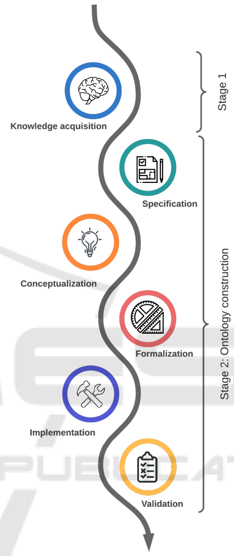

Figure 2: The Ontology building process.

[1] https://www.tasteatlas.com/best/foods-by-category

3.1 Knowledge Acquisition

During the knowledge acquisition phase, crucial information for developing the ontology was collected from various reliable sources, including recent literature and guidelines, as well as interviews with 77 women engaged in handicrafts from different backgrounds coming from both rural and urban areas. These interviews concentrate primarily on gathering socio-demographic information, understanding the nature of craft production, detailing the production process, identifying the tools used for coordination and communication, and uncovering implicit needs.

3.2 Ontology Construction

Different research groups have pursued a variety of approaches to facilitate the process of ontology engineering in the realm of ontology design, leading to the proposal of several different methodologies (Fernández-López et al., 1997) (De Nicola et al., 2009)(Staab et al., 2001), each of which is based on the following steps:

3.2.1 Specification Phase

This phase states the scope and the purpose of building the ontology. The main objective of the proposed ontology is to capture the essential elements within a generic business process, with a particular focus on the production of handicraft items. Within this generic framework, a specialized ontology for the pastry-making business process, specifically focusing on the Algerian Makrout Louz recipe, is integrated to address the detailed nuances of this domain.

3.2.2 Conceptualization

Conceptualization is the process of abstracting and organizing the key concepts and relationships within the domain into a coherent ontology. In this phase, the core elements relevant to the business process are identified and defined, such as materials, tools, artisans, production steps, and skills. Pastry-making processes, such as the Makrout-making process, must indicate ingredients, equipment, and steps.

3.2.3 Formalization

This phase consists of transforming the outcome of the previous action into a formalized model using an appropriate ontology language. Various formalism approaches are available for this purpose, including RDF [2] (Resource Description Framework), which allows for the representation of information about resources on the web, and SKOS [3] (Simple Knowledge Organization System), which is used for linking, merging, and enriching knowledge organization systems. Each of these formalisms provides different levels of expressiveness and flexibility to cater to a variety of modeling needs.

In this study, we use OWL [4] (Web Ontology Language), which is widely accepted as one of the most utilized ontology languages. OWL offers a structured way to represent knowledge and define relationships between entities, making it a robust choice for developing comprehensive and interoperable ontologies.

3.2.4 Implementation

The implementation phase of ontology development requires an appropriate tool that facilitates ontology modeling, editing, visualization, and reasoning. The Protégé [5] framework is used in this paper since it provides a comprehensive set of features and functionalities that assist in developing and managing ontologies.

3.2.5 Validation

The validation of an ontology ensures its correctness, completeness, and compliance with its design. This is achieved by testing the ontology against predefined criteria to detect any inconsistencies, or errors that require correction.

4 THE PROPOSED ONTOLOGY

4.1 The Upper Ontology

The generic ontology illustrated in Figure 3 is an upper-level ontology that captures the fundamental entities for describing a handicraft business process. The proposed ontology focuses on the generic production process for the handicraft product.

4.2 The Ingredient Sub-Ontology

This sub-ontology is a specialized branch of the ingredient ontology focused specifically on substances used in pastry making. It categorizes ingredients commonly found in pastry recipes such as flour, sugar, butter, eggs, and various flavorings like vanilla extract

[2]https://www.w3.org/RDF/

[3]https://www.w3.org/2004/02/skos/

[4]https://www.w3.org/OWL/

[5]https://protege.stanford.edu/

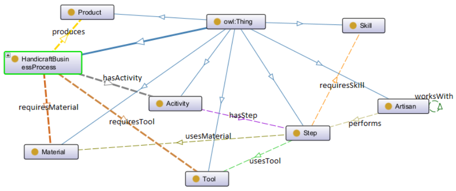

Figure 3: The Handicraft Business Process Ontology.

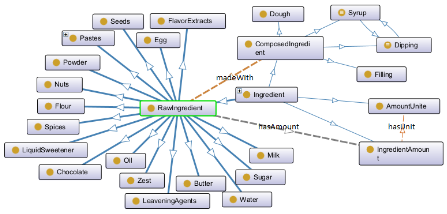

Figure 4: The ingredient Ontology.

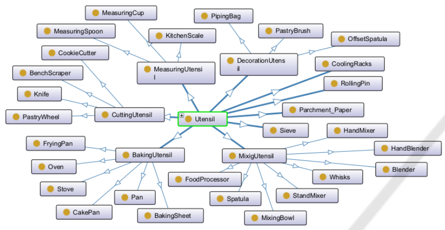

Figure 5: The Utensil Ontology.

or cocoa powder. Each ingredient is defined as an entity with properties describing its characteristics (Figure 4).

4.3 The Utensil Sub-Ontology

The Utensil sub-ontology shown in Figure 5 describes all kitchen tools and equipment necessary for preparing recipes. It encompasses a range of utensils such as knives, pans, mixing bowls, and specialized tools like blenders or pastry brushes. Each utensil is defined as an entity within the ontology, with properties describing its material composition, size, capacity, and specific uses.

4.4 The Recipe Instruction Sub-Ontology

This recipe instruction sub-ontology depicted in Figure 6 represents the steps required in preparing a pastry recipe specifically organized into two major classes: phases and steps. Phases represent broader stages like preparation or baking, while steps are the individual actions within each phase. It specifies attributes like duration and temperature and indicates the order of steps.

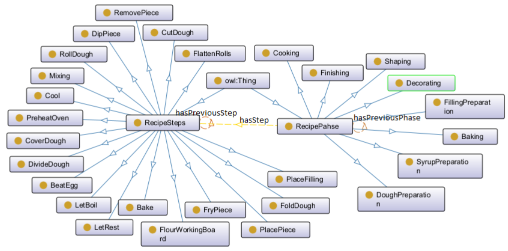

Figure 6: The Recipe instructions Ontology.

4.5 The Pastry-Making Sub-Ontology

This sub-ontology provides a detailed representation of the Makrout Louz recipe instantiation depicted in Figure 7.

5 VALIDATION

The validation stage in the ontology development process is vital for ensuring the ontology's quality, accuracy, and reliability. This step involves various tests and evaluations to assess the ontology against predefined criteria and requirements. This paper focuses on two key validation strategies: consistency checking and rule-based reasoning. These methods help verify that the ontology functions correctly and meets the intended standards.

5.1 Consistency Checking

As part of this strategy, consistency checking is conducted to verify the logical coherence of the ontology. It involves examining the defined axioms to ensure there are no contradictory or inconsistent elements in the ontology's logic. For this purpose, the Pellet reasoner is used (Sirin et al., 2007) as seen in Figure 8. The figure indicates that no inconsistencies were found when the reasoner was applied, confirming the logical coherence of the ontology. The figure also provides a breakdown of the ontology's components, including the number of axioms, classes, object properties, data properties, and individuals.

5.2 Rule-Based Reasoning

In rule-based reasoning, a set of predefined rules is used as a basis for drawing conclusions from facts or assertions. It works by applying a set of predefined rules, often expressed as "if-then" statements, to analyze information and derive new insights. The Semantic Web Rule Language (SWRL) [6] is a crucial formal-

[6]https://www.w3.org/submissions/SWRL/

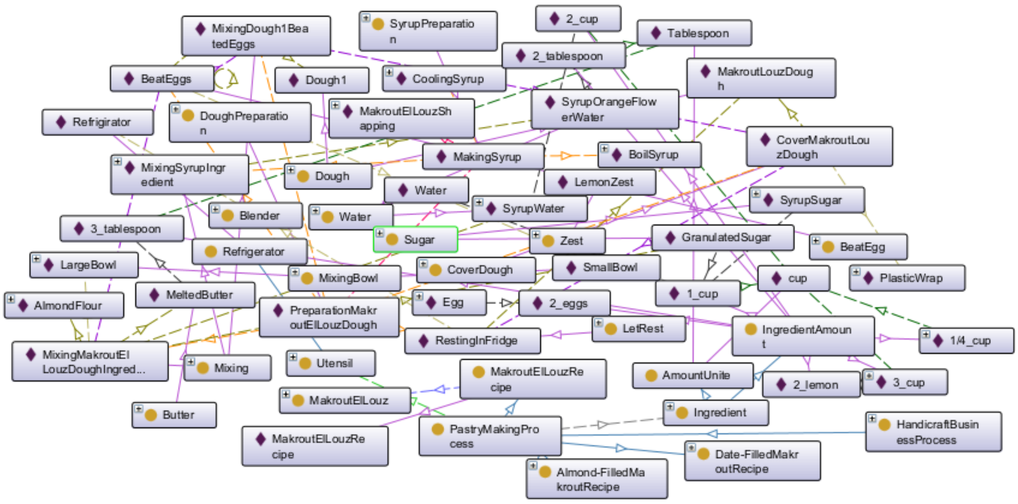

Figure 7: Excerpt of the Makrout Louz Recipe Ontology.

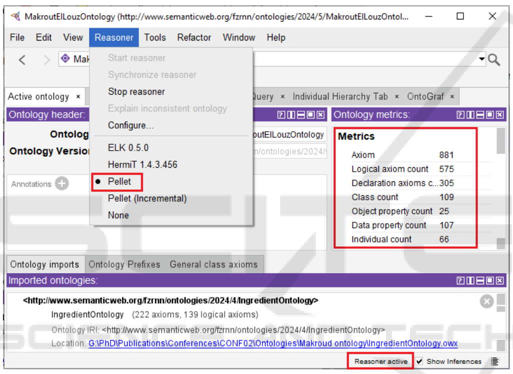

Figure 8: Consistency checking and ontology metrics.

ism for expressing knowledge through rules. SWRL is employed to define inference rules within knowledge models represented in OWL in a semantically consistent manner (Ye et al., 2015). In this study, the ontology model has been enhanced with a set of rules, as shown in Figure 9.

These rules are used to draw additional conclusions, as shown in Figure 10, which depicts the order of steps. They also answer specific competency questions, such as: What ingredients are needed for this recipe? What are the sequential phases involved in the preparation of Makrout El Louz Recipe? What is the sequence of steps for preparing the dough? To illustrate and answer these competency questions, we used the SNAP SPARQL Query plugin in Protégé (Horridge and Musen, 2016). The results are depicted in Figures 11, 12, and 13, respectively.

6 CONCLUSIONS

This paper proposes a handicraft business process ontology, focusing specifically on the Algerian Makrout Louz recipe from the pastry-making domain. This ontology structures and represents all of the intricacies issued from the Makrout Louz recipe, from its ingredients and utensils to the step-by-step process. As future works, there is an evident opportunity for the extension of this ontology to cover a wider variety of recipes and integrate with other handicraft domains. Moreover, it could also integrate with the sociocultural context ontology to provide a grounding able to represent more comprehensively the cultural and social dimensions in the handicraft production process. It could be an ontology that would serve many applications, from recipe recommender systems to cultural-heritage-related use cases.

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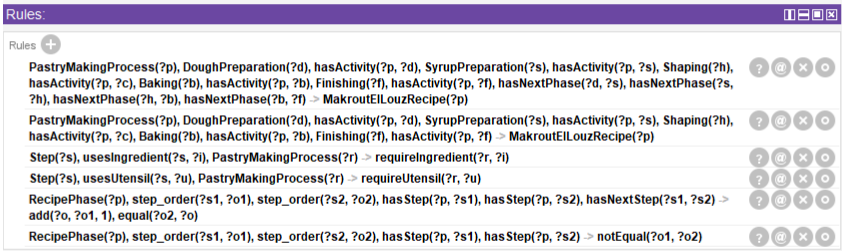

Figure 9: Excerpt of the rules used in the model.

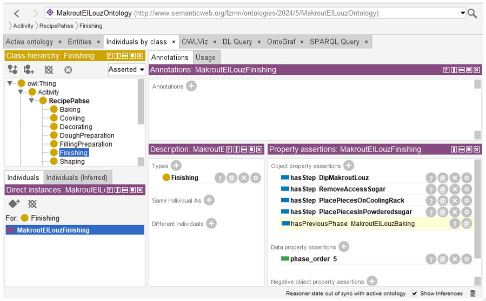

Figure 10: Inference Example.

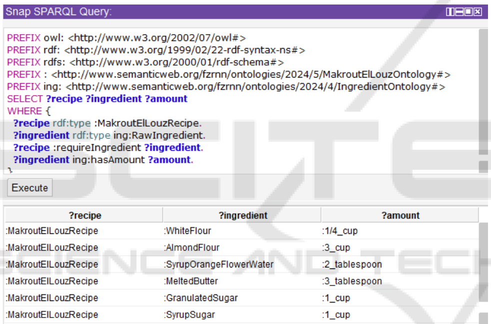

Figure 11: Required Ingredients.

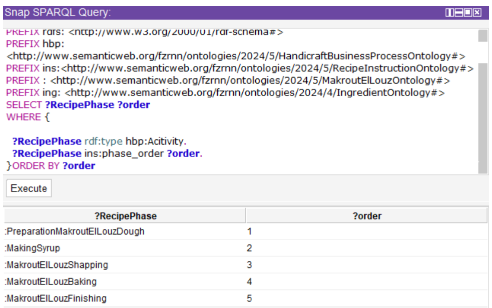

Figure 12: Recipe phases.

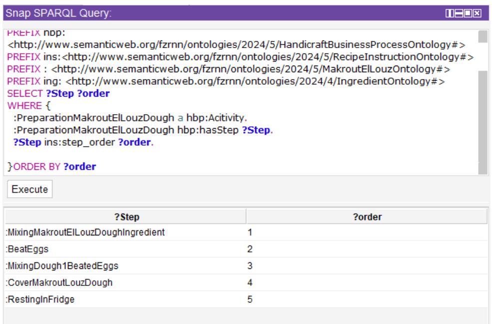

Figure 13: Recipe Steps for preparing the Dough phase.

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