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| A dissertation submitted to The University of Manchester for the degree of Master of Science in the Faculty of Engineering and Physical Sciences |
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# LIST OF ABBREVIATIONS

|  |  |
| --- | --- |
| AI | Artificial Intelligent |
| API | Application Programming Interface |
| HTTP | Hypertext Transfer Protocol |
| KR | Knowledge Representation |
| OWL | Web Ontology Language |
| RDF | Resource Description Framework |
| UI | User Interface |
| UML | Unified Modeling Language |
| XML | Extensible Markup Language |
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# ABSTRACT

This project is designed to show the benefits of using applications, which are ontology driven, in term of browsing and querying for information. It demonstrates the use of the represented knowledge between machines instead of sharing just raw data. Since, the web full of raw information that could or could not has relevancy with each other, OWL ontology language came to represent the knowledge of domains instead of raw data. OWL simulates the intelligence behind the reasoning process in addition to knowledge representation. By doing this, relations between different objects within a domain are represented as well.

Browsing and querying are two of the main characteristics of a retrieval system. Usually, user tries to figure out the functionalities of a user interface or some instructions are provided to guide the user. As for querying, in conventional querying system that is keywords based rather than the underlying concept, the process of retrieving information depends on recalling specific keywords. This method suffers some issues like the recall of keywords and ambiguity in the search query formation process.

Those issues can be reduced be adopting ontology-based method and faceted-based search mechanism. Representing knowledge within ontologies will drive the interface and take care of guiding the user toward building only valid search queries. The recall problem will be reduced since user does not have to remember keywords and all relevant query elements derived automatically from the ontology. As for ambiguity, faceted-based search is introduced to narrow and personalize the search result.

This project is based on existing application (The Manchester Pizza Finder) that is ontology driven interface. An application is built using the code of Manchester Pizza Finder and adding some new modifications and functionalities. The Manchester Pizza Finder is a tool that display a list of toppings based on pizza ontology. The user query for different pizzas based on included and excluded chosen toppings. This project takes this tool further by adding more functionalities and a number of enhancements such as make it dynamically configured based on the ontology used, and implementing filters to be applied on the constructed query and on the search result. The application has the same basic functionalities with the Manchester Pizza finder and it is called The Manchester Sushi Finder that is a tool to query for sushi based on included and excluded ingredients. Although, the main ontology used is based on a sushi menu restaurant, does not mean only sushi ontology will work. In the contrary, a part of making the tool flexible is to allow it to work with different ontologies and domains.

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# DECLARATION

No portion of the work referred to in the dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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# ACKNOWLEDGMENT

# INTRODUCTION

## Motivation

As the trend nowadays to try making machines more intelligent [1], sharing knowledge of information instead of sharing the raw data in the web is becoming more desirable. Thinking computers that are able to able to understand, sharing knowledge and simulate the reasoning process of human would seems an idea from Artificial Intelligent (AI) fiction movie. Semantic web is helping in converting the current web of information into a web of knowledge. It is all about sharing knowledge, which is understandable for machines, on the web. Knowledge of a concept domain is been captured and represented according to our understanding within a file called ontology. Ontologies are considered the main pillar of the semantic web. Computers do not understand information stored on the web such as Extensible Markup Language (XML) and Hypertext Transfer Protocol (HTML). They are just codes to the machines and they display it to users regardless of what knowledge needed. So, Sematic web came along for machines to make sense of retrieved information. Ontologies are used to represent knowledge and make inferences from that knowledge using machines computational capabilities and some reasoning techniques such as description logics.

An intelligent way of representing knowledge needs an intelligent way of browsing and retrieving it. There are a lot of intelligent browsers that is ontology driven user interfaces such as Transparent Access to Multiple Bioinformatics Information Sources (TAMBIS) [2], Semantic Webs and AgentS in Integrated Economies (SEWASIE) [3], and the Manchester Pizza Finder [4]. Browsing and constructing queries through such user interfaces would be easy and it will save time, due to the fact that the UI acts as an interactive manual. It eases the process of constructing the intended query since the process itself is guided be the UI. In addition, it saves the user time by displaying only what is the system intended to do. The user does not need to have previous knowledge about the domain, because the explicit display of the options of constructing a query. Ideas like manuals and the help menu in the menu bar of a UI would seem absolute comparing to the self-guided UI. Additional technique to make the UI smart is to user faceted browsing. The idea behind faceted browsing is to personalize the search and get more specific results by suggesting some filters. Faceted browsing is very related to ontology driven UI since both provide some information about the query while been constructed [5].

There are some systems, that are ontology driven UI, exist such as TAMBIS and SEWASIE. TAMBIS is a system that gather and analysis bioinformatics information from different sources through one interactive UI. While SEWASIE meant to access multiple sources of data and help user through out constructing the exact needed query.

The idea of ontology driven UI is not new. In this project, will try to build an application on the top of existing tool (the Manchester Pizza Finder) with new functionalities and enhancements. The new tool is called the Manchester Sushi Finder; since it is build mainly for sushi ontology that was previously developed by Ontology Engineering course unit. This does not mean the tool will run only sushi ontology, but it can run ontologies with similar structure, concept domain and have specific configurations.

## Aims

The aim of this project is to investigate and demonstrate the benefits of using OWL ontologies and OWL API within ontology driven UI application as shown in the project page [6]. As well as, making the process of checking and testing ontology easier for students by uploading their ontologies, this will be shown by implementing a configurable and flexible UI. So that most of the configurations will lay in the ontology file, and the UI could browse other ontologies that contain some specific configurations as annotations. The application is called the Manchester Sushi Finder, where a user can construct queries to search for sushi based on included and excluded ingredients defined in conceptual model represented in ontology file.

## Objectives

To achieve the aim of the project, the aim is divided into several of objectives. These objectives are:

* Gather project requirements.
* Increase the reusability of the UI by making it configurable to suite content of other conceptual models.
* Increase the usability of the UI by showing the languages available in the ontology with their percentage and switch between them.
* Increase the accessibility of the system by applying filters on the content of the conceptual model or/and on the result of the search query. By introducing the notion of filters and facets search to access more specific information.
* Increase the accuracy of the system, so users can only construct valid queries and they get the intended results. Making the UI driven by ontology and using the faceted browsing along with will increase the accuracy of what needed to be queried.
* Provide more flexible system by saving most of the configurations as annotations within the ontology itself.
* Represent the constant of the conceptual model with different views such as tree, and list. Users have more one option to view the content of the model.

## Contributions of this Project

This project was undertaken to enhance and add more functionalities to an exiting tool (The Manchester Pizza Finder), which allow users to browse pizza toppings and construct queries to get certain kind of pizza. During constructing query, user chooses included and excluded toppings. As a result, pizza that matches specified criteria will be shown in the result window. This tool can run only one static pizza ontology.

The new tool (The Manchester Sushi Finder) can run ontologies with specific annotations in them as configurations. The new tool can browse the ingredients of any food domain associated with certain annotation properties. The tool has the ability to upload different ontologies during the runtime. Filters decided in the ontology file as annotation and displayed in the tool if they are exist. The tool has the ability to show facets if they were specified in the ontology to be applied on the result. Furthermore, it provides different views (tree view and list view) of the ingredient to ease the process of browsing. It would show languages if the ontology is labeled with different languages and would show also the percentage of the languages according to the ontology.

As part of ontology engineering course unit to develop food domain ontology to demonstrate for student the use and benefit of OWL, this tool would ease the process of check ontologies and might help them to understand the concept faster. Students can see their ontologies running using the tool and can see where are they going to clearly. The tool use annotations heavily, in order for the mentioned functionalities to be working. Finding some limitation in OWL annotation techniques may contribute in considering a fix in newer version of OWL in the future.

## Structure of the Dissertation

## Conclusion

# BACKGROUND

## OWL

OWL is a semantic web language that represents things about the world, group of things, and the relations between them [7]. It is a way to represent knowledge such that it is a representation of the world and our knowledge of it and it is accessible to programs and can be used [8]. It is able to represent explicit and implicit things [7]. The intention behind creating OWL is to be used not only by human but also by applications [9]. OWL can be access from machines because it is based on computational logic so that the machine using some software can reason over them [7]. There are two versions of OWL: OWL and OWL 2 [7]. OWL is a W3C recommendation since 2004, and then OWL 2 was published in 2009, followed with a second edition in 2012 [7, 10]. OWL 2 is just an extension and revision of the original OWL publish in 2004 [7]. OWL has several defined syntaxes including Functional Syntax, RDF/XML, OWL/XML and the Manchester OWL Syntax [7, 10].

The information on the web was described by OWL working group [9] as scattered. This information could mean something for humans but not for machines. So, the semantic web gives explicit meaning for this information. As a result, integrating and processing the information would be easier for machines.

In 2012, OWL 2 has been introduced by OWL working group [11]. It is not different than OWL, it could be seen as an extension of OWL with some additional features. OWL 2 have several syntaxes and semantics, usually a developer needs only one syntax and one semantic. Figure 1 shows the structure of OWL 2.



Figure : The structure of OWL 2 [11]

OWL files or documents are called ontologies, as described in [7]. The purpose of these ontologies is to make it easier of machine to access information in the web and preform reasoning on them. These ontologies can be put into the web or into a local computer depending on the need. One of the advantages of ontologies in the web is that they can be referenced from or reference to other ontologies. Ontologies can be placed in a local computer to be used locally.

### OWLClasses

### OWLObjectProperties

### OWLAnnotationProperties

## OWL API

In Wikipedia [12], Application Programming Interface (API) is described as a set of protocols that make sure the software components interact with each other in the right way, and it could take many forms in different areas. It is used in the web as a set of Hypertext Transfer Protocol (HTTP). Also, it has heavy use as libraries of programming language. API is used in different forms such as libraries of programming languages. For example, Java APIs. In object-oriented languages like java, the API is a set of classes and methods to be accessed and used. Basic examples would be like using the inputting and outputting classes e.g. (BufferedReader and BufferedWriter classes in java). Since this project will be built using java-programming language, the API used is a java API which is called OWL API. OWL API is a set of classes and methods that facilitate the access to Web Ontology Language (OWL) ontologies. It creates objects that represent ontologies objects and manages the interactivity between them and any other program.

OWL API is described in [10] as an Application Programming Interface for the purpose of specifying how to interact with OWL Ontologies. OWL ontologies can be created, manipulated, and reasoned over using OWL API. It has been available since almost the same time of OWL. OWL API went through several revisions following the development of OWL. OWL API has the ability to parse and serialize OWL ontologies to different syntaxes such as Functional Syntax, RDF/XML, OWL/XML and the Manchester OWL Syntax.

OWL API takes out the burden of parsing and serializing OWL ontologies from the developer back, since it has been taken care of in the implementation of it [10]. It has been implanted using java. OWL API comes also with some capabilities such as loading and saving ontologies.

OWL ontologies being accessed using OWL API only through OntologyManager interface [10]. OntologyManager interface manage all changes in ontology as seen in Figure 2 below shows UML diagram of how ontologies would be managed using OWL API.



Figure : UML diagram showing the management of ontologies using OWL API [10]

Inference is applied on the OWL ontologies using OWLReasoner interface [10]. This interface provides some useful check like consistency, checking computation of class and axiom entailments. Since the reasoning functionality is separate, developers either can use the available or can provide their own implementation. There are some already exist implementations of reasoners such as FaCT++, HermiT, and Pellet.

As for query using OWL API, it does not offer much as a query mechanism [10]. Since, it provides some sort of basic querying which is based on entailment checking functionality.

## Conventional Information Retrieval Method

Information retrieval is the method in which some information is retrieved from a source or multiple sources contains needed data. Every retrieval system needs some mechanisms to retrieval relevant needed information. Nowadays, there is more information probably resides on the cloud than it was in the recent years [13]. As the amount of data on the web grows dramatically, the need to find and retrieve relevant information becomes more important. Getting the wanted results is becoming more problematic because of the amount of the data on the web and the technique used. Usually, in a search engine the results range between relevant and irrelevant. It would be nice for a user to query for something and get the most relevant result that meets his/her needs.

There are different methods of retrieving data from the web. Keyword-based search method could be the oldest among the others.

Keyword-based search method use specific words call “Keywords” that are linked with database records [14]. It would be the default and the usual choice to use in search, since it has been used over long time. This method seems easy to use, as it is resemble natural language which could be understandable by humans but not by machines. Because of the human factor that exists in writing the search query, things inevitably could go wrong. Simplicity and ease come with a cost, keyword-based search method suffers from some serious issues. (1) One of these issues is the lack of accuracy and recall because of all of the synonyms and the homonyms which are based on memorizing terms rather than concepts. (2) Another major issue is that using keyword-based search add more ambiguity, when the user want just to browse around to find out what is there or the user does not know the right term used in specific content.

According to [14], there are solutions for both issues. The lack of precision and recall can be treated by ontology-based information retrieval method. The growth in the ambiguity issue, would be solve be using multi-faceted search method which would guide the user during constructing the search query. So, the use of knowledge base and concept base would be more desirable than just providing arbitrary information. In addition, a sense of Artificial Intelligence is also felt since machines can make inferences based on some rules.

In this project, keyword based method won’t be used since it has limitations like recall and ambiguity. As I am trying to overcome these limitations, ontology driven user interface as alternative method will be used.

## Ontology Based User Interface

In general [15], developing user interfaces hindered by the knowledge of the user. Letting the user known what can he ask for and constructing a meaningful search query using the user interface is the major issue. To remedy this issue, solutions have been proposed. Some of those solutions would be making every option in the user interface available to reduce the recall issue. Another solution would be writing manuals to the user to follow. These solutions might be providing more complexity and other problems. The former solution could overwhelm the user with all of the options available whether needed options or not. The latter solution could increase the load on the user to study and spend time on something that needed to be recalled eventually. Ontology driven user interface would be the most suited solution, since ontologies are based on conceptual model rather than just terms [3, 15]. This conceptual model gives a map for the user to follow upon constructing queries [15].

Ontology based user interface is defined by [3, 15], as a user interface that allows the user to construct and manipulate queries based on some domain concept stored in ontology. This domain concept drives the user interface, where there is no need for manuals or shove all available options in the user interface, since the ontology based one which should act as a guide for the user. It depends on recognizing knowledge instead of memorizing keywords. It allows the user to build complex and meaningful queries and return the needed results. In addition, it offers the user the option of browsing around to find out what he/she needs. The user does not have to any thing about the underlying conceptual knowledge. TAMBS give the illusion of retrieving from single source while it read from multiple sources and convert selected options to appropriate query languages that match sources’.

The user interface offers choices and some scenarios for the user, so that the user would be guided toward constructing meaningful queries that return the intended results [3, 15]. Users would not face the no-result status after running queries. Query expressions are Description Logics (DLs) expressions and they are incremental and compositional [3, 15]. DL is a way for knowledge representation used by the conceptual model [16]. It provides hierarchal model based on conceptual model that represent classes of specific domain and the relationships between the instances of those classes [3, 15]. DL model is not easy because of the need knowledge about the DL syntax along with understanding it, so a friendly user interface need to build to separate the user from dealing with DL [15].

According to [15], there are two kind of concepts that the DL model support. The concepts definitions and the assertions made on the concepts definitions, like the subsumption relationship between two classes. In a way, assertions on the original concepts considered as defining new concepts definitions. Compositional concept can be formed using some services provided by DL. Reasoning about the concept definitions is done through the services provided by DL. These services are:

* **Satisfiability**: make sure that the concepts are consistent.
* **Subsumption**: create composite concepts definition from assertion made on the original concepts definition.
* **Classification**: make new classification hierarchy based on the subsumption relationship.
* **Retrieval**: retrieve any individual that is part of concept definition whether it is original or generated from the subsumption relationships.

Ontologies support creating annotation properties within themselves and associate them with entities [17]. These annotations properties consist of the name and the value. Annotations within ontologies play a major role in driving the user interface. Annotations would form some set of rules for the user interface to follow and interact based on. A tool was developed based on some animals ontology and annotations would be a good example of what could annotations do in term of user interface interactivity. This tool allow to brows for Apes’ photos based on some annotated criteria such as the quality of the image and the environment where it been taken.

In this project, I am trying to develop an application to find out different information about sushi. The application is ontology based. Annotations play major role in driving the user interface to make more flexible. This application is based on The Manchester Pizza Finder application, which will be elaborated on a separate section, except this one would have some enhancements.

## Faceted Based Search

Ontology based user interface only provides the taxonomy and conceptual hierarchy and broad search capabilities. With the ontology conceptual hierarchy, user still can get broad search results. Transition from general to more specific results needs some kind of smart retrieval mechanism. Facet-based search along with ontology based user interface would guide the user toward constructing valid search queries and personalizing the search queries to suite the user needs. As using ontology in user interface development eliminates the recall element, using faceted-based search eliminates the ambiguity constructing the query and gets the intended results. So, ontology helps in returning relevant results. But faceted-based search assists in taking those relevant results and returning the most exact results. Ontogator is a system that combines the two methods: ontology driven interface and faceted based search [14]. The intent of Ontogator to search of particular image with specific annotations [14].

Ontology support faceted classification system as it provides a taxonomic order. Taxonomic order allows multiple way of viewing results rather that pre-determined one [14, 18]. Faceted search based on faceted classification system where information element are dimensions called facets [18]. Faceted search is an intelligent and efficient retrieval mechanism that allows the users to filter a collections of information based on some facets [18, 19]. Faceted search is known also as “faceted navigation” or “faceted navigation” [18]. Users can get more accurate and relevant results by applying filters (Facets) [18]. Facets here are derived from the ontology itself based on some annotations as metadata [14].

There are faceted browsing and faceted search. Faceted browsing is constructing search queries by selecting some provided filters (Facets) [14]. In faceted browsing, user is provided with choices to select from to form the valid search query [14]. The query language is hidden from the user, so the burden of knowing the syntax is lifted. On other hand, faceted search is more in personalizing the search result to suit what is needed. Faceted search is used heavily in e-commerce websites like Amazon[[1]](#footnote-1) or eBay[[2]](#footnote-2). Figure 3 shows the use of faceted search in Amazon.



Figure : The use of faceted search in e-commerce website (Amazon)

Faceted search could be applied in two ways, either unidirectional or bidirectional. In unidirectional way, either applies it beforehand on a collection of selection that is browsed to construct the query or on the result of a query so it can be refined more. In the bidirectional way, it is to apply it both beforehand and afterward running the search query. Both serve the same purpose which is to personalized the search and make it easy to suit the user’s needs.

As in [14], facets the filtering process can be represented in more formal way. If C is selected category, where (Ci = 1, .., n) representing all categories selected, and C is also represents . Each category consists of subcategories. For example, in the pizza finder application user may choose Spicy Ingredient to get all pizza that are spicy but the category “Spicy Ingredient” could have subcategories like “Hot Pepper”. Query in DL format would be:

Where is the whole facet and S is the subcategory within that facet. In other words, the S’s are subcategories of “Spicy Ingredient” which they might include Hot Pepper as an S, and the disjunction of the S’s represents the category “Spicy Ingredient”.

Facets bring benefits to applications, some of these benefits are [14]:

* **Guidance**: facets guide the user toward constructing valid search queries.
* **Transparency**: facets give the user idea of what is available and help in browsing the content.
* **Lucidity**: facets help in removing ambiguity caused by synonymous and homonymous query terms.
* **Relevance**: facets help with pre-compute partial results on selecting choices.

## Ontology Visual Querying

The idea of visual querying is constructing a search query visually using drag and drop instead of the traditional way. Same idea can be applied on ontology-based interfaces that would be more powerful because of the benefits of the ontology-based applications. The interface would guide the user to build interactive meaningful queries by using ontologies [3, 5]. In addition, another advantage derived from the benefits of ontology-based applications is constructing only exact queries [3, 5].

According to [5], visual querying is not new. It has been there since almost the beginning of textual query languages. Almost all visual querying languages have two features in common. The two features are: (1) a model to represent the stated query and (2) a way to of constructing the query. Since visual querying languages invented to query from a data structure, it is only natural for its evolution to follow the development of data structure [5, 20]. A simple example of visual querying would in Microsoft Access.

A major benefit from ontology visual querying is the ease of querying, since user only drag and drop what needed to be queried. User does not have to remember or know the vocabulary, since user can survey the domain [3, 5]. As a result, forming queries for naïve users becomes easier [5]. In ontologies, new concept can be defined either directly like defining class or indirectly like making inference of something. Therefore, creating query is the same as creating new concept such as the TAMBIS system and SEWASIE system [2, 3, 5]. Another advantage would be helping users, who not experienced with the system, to create satisfiable queries according to the constraints [5].

## The Manchester Pizza Finder

The Manchester Pizza Finder is an application that finds specific pizza based on some topping choices. User can include and exclude any toppings, and based on that the result would satisfy the query. The use of DL reasoner is present in this application, since it generated the filtering criteria (pizza topping) and their categories in the runtime. It is also make sure that the constructed queries and results are consistent. Based on the choices made the DL reasoner retrieve result that fulfill the input query. This application shows the use of ontologies, OWL API, and the power of building ontology-based interface, and faceted browsing.

## Conclusion

In [4], the Manchester Pizza Finder described as a user interface application that makes use of OWL ontology. It uses pre-defined pizza ontology that represents a domain concept of a pizza restaurant menu. For the application to be able to communicate with the pizza ontology, an API needs to be used. OWL API is an important component as any part of the application if not more important. OWL API manages all the communications between the application and the pizza ontology. OWL API is implemented using Java. So, Pizza finder is developed using Java. This makes the communication between the application and the ontology easier. OWL API have full access to the pizza ontology, it can preform operations on the ontology like make sure it consistent.

Pizza finder is considered ontology-based application, since it is the ontology that derives the interface and provides a conceptual hierarchy of a pizza domain. In ontology-based application, user does not need to recall keyword or know query language on querying for specific pizza. The application itself guides the user toward building only valid queries with the ability of making complex meaningful ones. It has the ability to incrementally compose queries. User can browse around to figure out what specific toppings are needed. It based on the knowledge of pizza domain, not on keywords.

Pizza finder personalizes the query construction process by providing some filters (Facets). As a result, the results would suite the user needs. Pizza finder uses faceted-base in query building, so the user will be guided to construct only valid queries. User does not have to recall what keyword to search for something in the domain. User has the option in querying for broad or specific pizza in the domain based on chosen facet. Figure 4 shows the use of facets in pizza finder, use can query for example for vegetable topping pizzas or can query for more specific thing in vegetable topping category such as Tomato topping.



Figure : Facets are in the left hand side used to specify what is needed exactly as topping [4].

Sushi finder is considered an extension for pizza finder. Some enhancements of pizza finder are to be introduced. In Sushi finder, the application is more flexible than pizza one. The application should be able to work for any given ontology regardless of domain, but should follow some standard annotations. Another enrichment would be the use of annotations to drive the user interface sort of dynamically. Keeping the configurations in the ontology itself make it easier to for the user interface to be flexible. The whole application would be configurable in term of labels and languages being used. It configurable within itself, no need for changing configuration files. Facet search is introduced, user can filter the choosing options based on some configuration done in the ontology as annotations. In addition, user can apply filters on the query results.

# RESEARCH METHODS

## Research Methodology

As mentioned in the objectives section, is to develop a system that will:

1. Find specific sushi based on some ingredients choices. Include and exclude criteria for the ingredients are being used.
2. Students can run the system using an ontology they have developed for their coursework, in condition that they annotate their ontology in some way. The user interface is flexible since all labels can be configured.
3. Users can view the hierarchy of the ingredients in different views like tree and lists.
4. User can filter the hierarchy of the ingredients based on some facets, as well as, filtering the result of the search query. Due to the faceted search, search will be more personalized instead of broad and general one.

To achieve the objectives of this project, it has been divided into five stages.

### Requirements Gathering Stage

Since the project is to develop a system that behaves in a certain way, I have started with the first and important role in software development process which is requirements gathering. The stakeholders of the project are three; the end user who will use the system, the system provider who will provide the tool to the end user and probably does some configurations to the tool, and ontology engineer. Since meeting all of these stakeholders hard, I had to put myself in their shoes. Some of those stakeholders were involved in the requirements gathering process. The main stakeholder was my supervisor as he requested for this system to be develop. Meetings have been setup to discuss the requirements (what exactly should be done?). Some conversations were held with my fallow students, who attended with me the ontology engineering for semantic web course, regarding if they had this system before how it would help them and what functionalities would be needed. All of those meetings and discussions provided more details and helped in understanding some of the requirements. Some were understood later on.

### Background Study Stage

In the second stage, background research and survey of relevant literature was carried out along with exploring techniques to be used in the project. This has been done using journals, articles, publications and existing systems with similar functionalities. A fair amount of time spent reviewing different literatures trying to understand different aspect of the project’s requirements. Reviewing relevant literature really helped in not only having a wider knowledge of the problem domain but it helped also in understanding the requirements of the project. As a result, I have good understanding of the project and approaches taken to handle such systems and it helped me in splitting the project into small tasks.

In this stage, background study is done on OWL ontology, OWL API, ontology-based systems, faceted-based search system, ontology visual querying, and finally study the Manchester Pizza finder a system that I will build my project on.

### Development Stage

In the development stage, first decide in the development tool that is java. Then, refresh myself with java specially swing components, and OWL API. Implementation started in early stage. As the strategy is to divide the development of the system into developing the main functionalities separately then combine them. Although that some functionalities were developed separately from the application itself, the official start of this stage will be after the second semester’s exams. After exams, checking that the functionalities are working probably will be done and combine them.

The development is considered as enhancements of the Manchester Pizza Finder. They involve reading the configurations from the ontology file and act accordingly for more flexibility. Also, different view of the content of the conceptual model and the result of the search query will be considered. As well as, adding a functionality to filter the content of the model based on some criteria saved in the ontology to personalize the search even further to the user.

### Testing Stage

In this stage, testing will be conducted on the application according to some scenarios that are predefined. These scenarios are called users stories which will be elaborated on later on in the report. Since the strategy of doing the project is to develop functionalities alone then combine them, testing is carried out during the development stage on functionalities separately and on the final product after combining them.

### Review and Submission Stage

After success in evaluating the product, the review and submission stage will start. An instruction file will be provided to guide the ontology developer in how to make his ontology to work with the application. The application would act as manual, so there will be no need for a guide for the system. The next step will be finishing the application and finalized the dissertation and then submitting them.

There are five milestones within this project that will guide me through the progress of the project. The milestones are:

1. Initial report.
2. Progress report.
3. Application prototype.
4. Application final product.
5. Dissertation submission.

First milestone was already completed, since initial report was submitted successfully in March. However, submission of second milestone in time was not so successful. So the original plan was altered. The new deadline will be in June 6. The last three milestones would be worked on in parallel due to time restriction. The final product is expected to finish beginning of August. Finally, the submission of the dissertation will be in the first week of September. Gantt chart is included in the next section.

## Project Deliverables

At the end of this project the benefits of using sematic web within applications will be shown. The application will be flexible, as it will run ontology with specific annotations. In addition, it will be fully configurable. It will allow users to query for specific sushi based on some ingredients. There are three main deliverables of this project:

* User stories (scenarios) & acceptance tests.
* Final version of the application.
* Evaluation of the project.

## Project Evaluation Plan

In order to be able to evaluate the whole project, I need some measures to evaluate the project against. Some measures have been recognized to evaluate how good the system is and more importantly measure if the project is consider a success or not. In nutshell measuring the success of the objectives. These measures are:

* **Where the deliverables met?**

A most likely way to measure if the deliverables were met or not according to a timeframe is to check if a deliverable was done within its allocated time or not.

* **Is the system accessible?**

We can think of the system in two ways: one as a project for MSc program that should be accessible for students and lecturers who teach ontology engineering for semantic web, and as real-world application (restaurant menu). Based on that users who should access the system differ. As for the first case, since the application is desktop application and implemented on java this will assure the students and lecturers can access the system easily. In the second case end users can access the system but a web application would be more reasonable. For now it is only a desktop application.

* **Is the system (re)usable?**

As the system designed for end users regardless of what kind of end user students or real-world users, they can determine the usability of the system. There are two concepts here determining the usability and reusability of the system. Therefore, both of them need to be checked as part of project evaluation.

* + **Usability**: as an end user, one can ask several questions that will assure the system is usable. Some of these questions are:

1. How easy to use the system?

The idea behind using ontology-based user interface is to guide the user in how to use it and ease that process. Therefore, the system should be easy to use.

1. How much time spent to figure out the system?

This question can be answered after submitting the project.

1. Does it require experts to use the system?

The system is designed for students who take ontology engineering for sematic web. So, some degree of expertise is needed to configure the ontology to work with the application.

1. How easy to administer the system?

Since most of the configurations are saved within the ontology, administering the system would be a trivial task.

* + **Reusability**: the system is reusable in sense of running different ontologies. This is another goal of the project, making it more flexible. The important question here is how easy it is reuse the system (running different ontologies).
* **Is the system easily configurable?**

As most of the configurations saved in the ontology file, it would be easy to configure the application interface. Ontology developer is the only stakeholder who has to deal with the configurations which are annotations in the ontology file. They are easy to write, as the ontology developer needs to follow some instructions provided with the application. The user interface should be configured automatically using annotations in the owl file.

* **Is the result of the search query narrowed down?**

Stakeholders such as students or real world users, like restaurant customers, will have direct contact with feature. This can be answered after submitting and using the application. Nevertheless, applying a set of filters on the search result will narrow the search for the user, since the system used faceted search method.

These are some questions that can help assessing the project. Most of them can be answered only after using the application by stakeholders. So, evaluation will help in a second version or the final product if it a prototype.

## Project Tools

Since the main part of the project is development, a programming language needs to be chosen. OWL API, which was implemented in java, is used in the project to manage the interactivity between OWL ontology and application. So, choosing java as programming language makes sense. Project is developed using NetBeans 7.4.

## Conclusion

# SYSTEM DESIGN

This chapter provides details about the design process of the ontology used with the tool mentioned in 1.1, and the user stories mentioned in 3.2 as well as the design process of the tool (the user interface). It starts with the design of sushi ontology which is based on sushi menu. Then, it moves to design of user stories and how they have been used to specify system functionalities. Finally, it details the design of the user interface.

## Sushi Ontology Design

In this section, details of designing Sushi Ontology are provided. It shows the class hierarchy, object properties, and annotation properties. Then, it explains semantics used. Finally, it provides some examples of DL queries that are applied on the ontology.

This ontology was developed using Protégé.

### Class Hierarchy



Figure XXX demonstrates the classes’ hierarchy of the sushi ontology. The Thing class is default super class of all other classes. The subclasses of Thing class describe sushi concept domain. Notice that there are two main classes: NamedSushi and SushiIngredient under the generic class Thing. NamedSushi class describes different names of sushi such as AvocadoMaki and BeefNigiri. While SushiIngredient class describe the different ingredients of sushi.

SushiIngredient class classifies the ingredients of sushi from general to specific ingredients. Notice the meat class is general class, while Beef and Duck class demonstrate specific concepts. Seafood class specifies the ingredients furthermore to describe the seafood concepts domain. Notice also equivalent ingredients classes, that are equivalent to some class expressions, like vegetarianIngredients, vegenIngredients, and SpicyIngredients. Any class under sushiIngredient can be used as a filter.

Moreover, this figure also shows the use of value partition patterns such as Spiciness, CookingStyle, Shape and Sweetness classes. Spiciness class partition the spiciness into spicy and nonSpicy, and Sweetness into sweet and nonSweet. These value partitions can be used to specify facets in order to narrow down the result of a search query. For example, spicy class could be use to specify that I want only spicy sushi.

### Properties

There are three types of OWL properties that are being used here. These properties are object properties, data properties, and annotation properties.

Figure XXX illustrates the object properties used within the ontology. Notice there is a default generic object property exists here also. These object properties represent the relations between the classes. hasIngredient object property play an important role since it connects NamedSushi class with SushiIngredients class. The domain of hasIngredients NamedSushi and the range is SushiIngredients. Any specified sushi query use hasIngredients property in constructing it.

The properties hasSpicness and hasSweetness represent test of sushi ingredients. They also represent the relations of SushiIngredients and wither they are spicy, nonSpicy, sweet, or nonSweet. While these object properties show the relations between the sushi ingredients and some their characteristics, other properties represent different thing like hasShape which illustrates the relation between a shape and a NamedSushi.



Figure XXX illustrates the data properties used in the ontology. There are two properties hasCalories that link specific sushi platter and its caloric value. In the other hand, hasPrice link specific sushi platter with its price value. The caloric value and price value both are static value entered by the ontology developer.

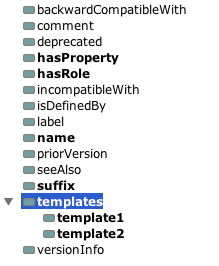


Figure XXX shows the annotations properties that used to annotate the ontology. Annotation properties used to attached metadata to different part of the ontology. Annotation properties are important in this project, since they are being used in specifying filters, facets, and even in driving the UI. User can define new annotation properties such as hasRole, hasProperty. hasRole property is used in identifying the role played by as certain class such as a role of a filter, facet, or ingredient class. suffix property is used to state the suffix used in the class hierarchy if any.

### Expressing Semantics

This subsection illustrates on the semantics used within the sushi ontology. It starts with normal semantics used to represent the relations between classes. Then, it moves to demonstrate the semantics that used to drive the UI, to specify filter, and facets. The semantics of class hierarchy are similar to each other, and the space here is limited. So, the most important semantics are illustrated.

Figure XXX shows the semantics of EggOmlete under SushiIngredient class. This semantics state the taste of EggOmlete is NonSpicy and it is Sweet by using the object property hasSpiciness and hasSweetness.

Figure XXX states the semantics of SpicyIng class. The meaning of this semantics is any SushiIngredinet that is Spicy. The sweet characteristic could be able here also using hasSweetness property and Sweet class to indicate Sweet class.



Figure XXX illustrates the semantics of a NamedSushi class AvocadoMaki. The first one specifies a suitable category for AvocadoMaki that is Maki Category. hasIngredient property is used to specify the ingredients of AvocadoMaki. Notice it uses some to include the ingredients and use only to state that only these ingredients are included.

## User Stories

## User Interface Design

## Conclusion

# IMPLEMENTATION

## Java

## OWL API

## Software Process

## Using Ontology Annotations

## Iterative and Incremental Development

## Limitations

## Conclusion

# TESTING

## Unit Testing

## Integration Testing

## Conclusion

# EVALUATION AND CRITICAL ANALYSIS

## Questionnaire

### Questions

### Participants

### Results

### Hypothesis Acceptance

## Conclusion

# CONCLUSION AND FUTURE WORK

## Summary of Achievements

## Future Work

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