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Ph.D. Thesis

Social and Semantic Contexts in Tourist Mobile Applications

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Nessuno che mette mano
all'aratro e poi si volge indietro
è adatto per il regno di Dio.
Luca 9,62

Abstract

The ongoing growth of the World Wide Web along with the increase possibility of access information through a variety of devices in mobility, has definitely changed the way users acquire, create, and personalize information, pushing innovative strategies for annotating and organizing it.

In this scenario, Social Annotation Systems have quickly gained a huge popularity, introducing millions of metadata on different Web resources following a bottom-up approach, generating free and democratic mechanisms of classification, namely folksonomies. Moving away from hierarchical classification schemas, folksonomies represent also a meaningful mean for identifying similarities among users, resources and tags. At any rate, they suffer from several limitations, such as the lack of specialized tools devoted to manage, modify, customize and visualize them as well as the lack of an explicit semantic, making difficult for users to benefit from them effectively. Despite appealing promises of Semantic Web technologies, which were intended to explicitly formalize the knowledge within a particular domain in a top-down manner, in order to perform intelligent integration and reasoning on it, they are still far from reach their objectives, due to difficulties in knowledge acquisition and annotation bottleneck.

The main contribution of this dissertation consists in modeling a novel conceptual framework that exploits both social and semantic contextual dimensions, focusing on the domain of tourism and cultural heritage. The primary aim of our assessment is to evaluate the overall user satisfaction and the perceived quality in use thanks to two concrete case studies. Firstly, we concentrate our attention on contextual information navigation and authoring tool; secondly, we provide a semantic mapping of tags of the system folksonomy, contrasted and compared to the user experts classification, allowing a bridge between social and semantic knowledge according to its constantly mutual growth.

The performed users evaluation analyses results are promising, reporting a high level of agreement on the perceived quality in use of both the applications and of the specific analyzed features, demonstrating that a social-semantic contextual model improves the general users' satisfaction.

Acknowledgments

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The *Cividale del Friuli: Touristic Town* project has been developed with the support of *Comune di Cividale del Friul*i and *Confcommercio - Imprese per l'Italia, Udine*. We would like to thank Marco Lestuzzi and Andrea Urgolo for the implementation of the mobile app; Martina Baldazzi, Matteo Grillo, Francesco La Marra, and Alessandra Zini, students of the Web Technologies course of University of Udine at Gorizia, for a careful revision; Claudia Pitassi, Susi Paulitti of the local tourism office of Cividale del Friuli for information, data and support.
Both the projects have been developed within the SASWeb Research Lab [1].

[1] (http://sasweb.uniud.it)

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Introduction

Nowadays, due to the proliferation of cross-platform integrated touristic services, the design of a Web-based application that provides a usable interface, continuously updated contents, intuitive and memorable interactions in mobility, still remains an open challenge. The creation process of such tourism application demands a significant attention both to the expectations and needs of the *end-users*, and to those of the domain *experts*, who are called to author, maintain and evolve the system by managing heterogeneous and complex data.

Furthermore, the evolution of the Web from information-centric to user-centric in the Social Web, and to machine and interoperability-centric in the Semantic Web, has deeply changed the perspectives of service modeling, offering new opportunities and challenges to tourism organizations.

It is worth of noting that the growth of Social Web applications [KJL10, O'R05] has deeply changed the way users navigate, upload contents, share their preferred items and annotate them. Through freely annotations users have introduced a cooperative classification: for instance, this aspect has deeply influenced user modeling [CCC+07, WZBA10], information retrieval [Pet09] and resources recommendations [DFT12]. Nevertheless, despite a huge amount of available information, applications and recommendation services [KT10, MNI10], users are still lacking personalized spaces.

The main objective of this work is to *model* and *design* a *novel conceptual framework* that exploits *both social and semantic contextual dimensions*, thanks to i) the proposal of a *formal model* based on particular data structures, called *zz-structures*[Nel04], and to ii) *two concrete case study applications.* In particular, we focus our attention on the field of *tourism and cultural heritage*, proposing two cross-platform applications which take into account both the *social knowledge* derived from the tagging activity and the domain *experts knowledge.*

Due to the variety and heterogeneity of all the involved aspects, we require to accomplish with an extensive body of literature. On the one hand, we need to comprehend the basis of information classification systems and in particular, to analyze Social Tagging Systems and *bottom-up* classifications that arise from them: the so-called *folksonomies.* On the other hand, we need to investigate semantic approaches that allow to navigate among heterogeneous data sources. Furthermore, considering the concomitant huge increase of mobile applications, we also have to take into account which are the common contextual elements and features provided by existing tourism and cultural heritage mobile guides. To our extents, we analyze three distinct research areas, but with important points of contact; then, upon on the provided analysis, we propose a novel formal model aimed at answering to previously highlighted limitations. Finally, we provide its application to concrete case studies applications in the field of tourism and cultural heritage. While not a core research contribution, the design and the implementation of such mobile applications lay the foundation for our user evaluation in order to i) validate our proposed model in terms of provided features (i.e. semantic contextual navigation and authoring tools), and ii) to constitute a reusable tool for further investigations. As the result of the performed user evaluations, we show how users can attain a satisfying experience in using such mobile applications, thanks to the provided information classification, the contextual navigation which leverage both social and semantic knowledge, and the available authoring features.

Below we show the outline of this dissertation and the author's contributions.

Outline

In the chapter 1 we begin our dissertation analyzing **information classification** background and **Social Tagging Systems**. We present an overview about categorization and classification methods as well as vocabulary control systems, introducing also *ontologies* and their role along the evolution of the Web, from Social to Semantic. Then, we introduce Social Tagging Systems and, concentrating on the valuable activity of tagging, we focus on the role of folksonomy within Recommender Systems and Information Retrieval.

Stating that limitations of Social Tagging System are largely ascribable to the folksonomy definition, in the chapter 2 after a careful analysis of its definitions, representations and visualization methods, we propose **Folkview**, a novel formal conceptual framework that allows users to manage, visualize and author folkonomies. The proposed model is based on particular graph-centric data structures, the so called *zz-structures*: they have been analyzed as an alternative mean to contextual interconnections among heterogeneous data and exploited in several application fields, primarily due to their potentiality in managing and visualizing multi-dimensional and contextual views.

Then, the chapter 3 overviews critical issues in **mobile guides** for **tourism** and **cultural heritage**. Firstly, we analyze some of the most significant tourist mobile guides developed since the mid-2000s, focusing on contextual elements and provided features; secondly, we focus on **museum mobile guides**, identifying specific analysis parameters such as *user personal spaces*, *personalized content and views*, *authoring tool* and *contextual information and navigation*. Due to this review, we show how despite the large amount of mobile applications existing in this field, they still present significant limitations to the user.

The chapter 4 provides the model and the design of the case study of project **TOGO**, a **contextual tourist mobile guide** dedicated to the town of Gorizia. The formal model is still based upon zz-structures, leveraging the same idea of Folkview: we show the effectiveness in using semantic contextual information thanks to a multi-dimensional navigation; moreover, user evaluation supports our initial aim. In the chapter 5.2 we provide a general overview about *bridge-the-gap* approach between folksonomies and ontologies: focusing on the benefits and limitations that users usually encounter within such systems, we deeply investigate the role of users and typical tasks they are involved in, laying a groundwork for our proposal.

Finally, the chapter 6 proposes **SOSECOM**, a **social and semantic contextual model for tourism mobile application**: compared to Folkview, we propose an extension of the formal model and, leveraging on zz-structure definition, we provide our domain conceptualization. A case study serves as a basis for our framework: we present the contextual tourism mobile application devoted to *Cividale del Friuli: Touristic Town*. In particular we present its architecture, the contextual knowledge conceptualization, the provided tag semantic mapping, and the contextual navigation and authoring tool offered by the system released. Finally, we carry out two user evaluations aimed at analyze the perceived quality in use of the application: the analysis results are strongly encouragingly, highlighting the good usability of both social semantic contextual navigation and authoring tool.

Figure 1 graphically depicts and synthesizes the outline of the dissertation: it also suggests a multi-dimensional interpretation, according to main idea of zz-structures.

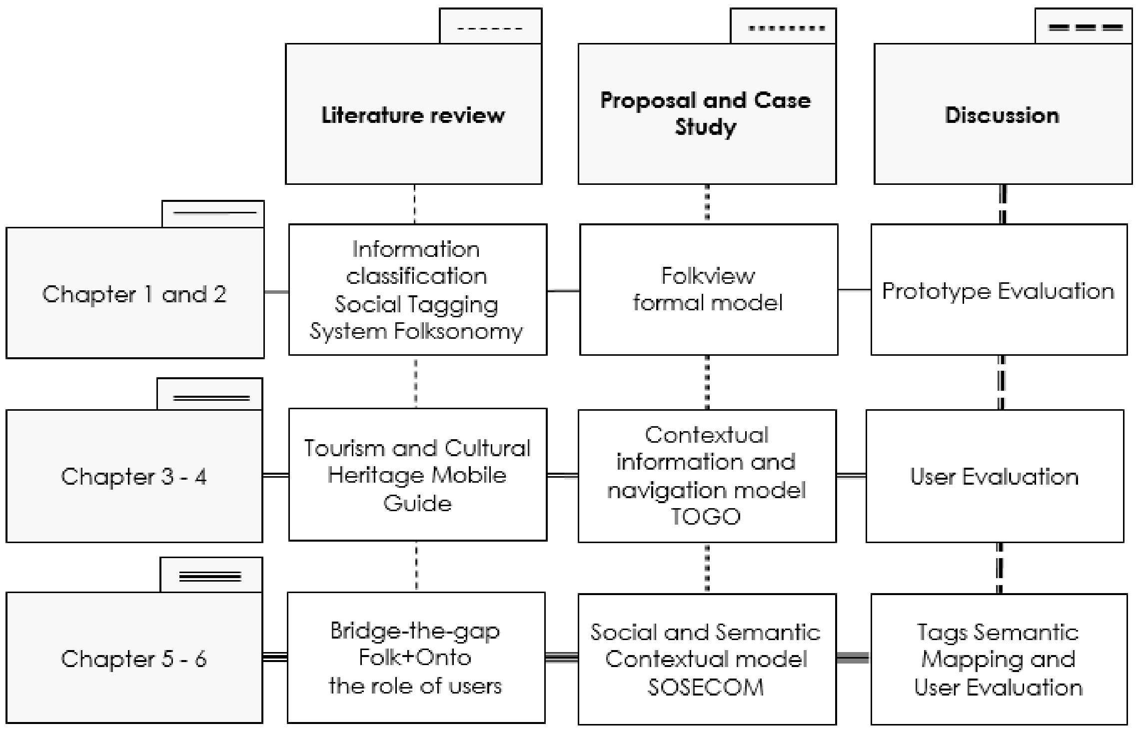


Figure 1: Thesis graphical outline according to *zz-structures* idea

Overview of Author's Contributions

A considerable part of this work has been created during collaboration with the chief and members of the SASWEB Research Lab[2]. This section clarifies the author's contribution relating each publication to its corresponding chapter within this thesis. All other parts of this thesis which are not explicitly mentioned below, are the sole work of the author.

Chapter 1

- Max Chevalier, Antonina Dattolo, Gilles Hubert and Emanuela Pitassi. Information Retrieval and Folksonomies together for Recommender Systems. In: *E-Commerce and Web Technologies, Lecture Notes in Business Information Processing.* vol. 85, p. 172-183, 2011.

Chapter 2

- Antonina Dattolo and Emanuela Pitassi. Folkview: a Multi-Agent System Approach to Modeling Folksonomies. In: *Advances in User Modeling: selected papers from UMAP 2011 workshops.* Lecture Notes in Computer Science 7138, Liliana Ardissono and Tsvika Kuflik (Eds.) vol. 7138, pp. 198-212, 2012.

- Dattolo A, Pitassi E. Visualizing and Managing Folksonomies. In: *Proceedings of International Workshop on Adaptation in Social and Semantic Web (SASWEB 2011)*, vol. 730, p. 1-9, Girona, Spain, July 15, 2011.

Chapter 4

- Antonina Dattolo, Emanuela Pitassi, Alessio Onza, Andrea Urgolo. TOGO: a Contextual Tourist Mobile Guide. In *Proceedings of the 4th International Conference on Information Technologies and Information Society*, Dolenjske Toplice, Slovenia, 7-9 November 2012.

- Antonina Dattolo, Emanuela Pitassi, Alessio Onza, Andrea Urgolo. Contextual Navigation and Authoring in a Museum Mobile Guide. *Frontiers in ICT: towards Web 3.0*, pp. 37-52, Peter Lang (ed), 2014.

[2]Semantic Adaptive Social Web Research Lab - http://sasweb.uniud.it

1

Information Classification and Social Tagging Systems

The advent of the Social Web is characterized by the active participation and interaction of users, which upload, share and freely annotate a huge amount of resources with labels, known as *tags*. Social tagging is a concept referred to the activity of a large number of human readers who associate descriptive terms to Web resources they are reading or searching. In order to maintain the spontaneity and statistically-relevant frequency of use of the terms thought by real people, neither rules nor restrictions are usually offered to readers when generating tags for these resources. Then, these sets of tags are analyzed through statistical tools in order to help other users who are searching the same document, using the same terms. To this extent, a *folksonomy* can be considered as the classification of Web resources emerging from the identification of the statistical prominence of some tags over the others [DDTV10]. Folksonomies have become popular on the Web through the intensive use of several different *social software applications* such as:

- *social bookmarking tools* [FKS+07, HHLS05] such as e.g. del.icio.us[1] [WZB08], CiteULike[2] [CC08, EC07] and Bibsonomy[3] [HJSS06a];

- *file sharing systems* such as Flickr[4] [Cox08, NNY08, VZ07] and YouTube [5] [GB07, GTD09, USKB08];

- *weblogs* [Blo02, Efi09, BWL09] such as Wordpress[6], Movable Type[7] and Typepad[8];

[1]http://delicious.com
[2]http://www.citeulike.org
[3]http://www.bibsonomy.org/
[4]http://www.flickr.com/
[5]http://www.youtube.com
[6]http://wordpress.com/
[7]http://www.movabletype.com/
[8]http://www.typepad.com/

- *social question answering (Q&A) portals* [BLAZ08] such as stackoverflow [9] and Yahoo Answers [10].

Tags reflect personal views upon the Web resources by the users and have been proposed in several works as a lightweight way of classification of information pieces, improving their access through a wide indexing.

As partially surveyed in [Tra09] a *folksonomy* has been analysed from three different point of views: i) as a data structure and its role in information indexing, retrieval and recommendation [DFT10]; ii) as the result of a collaborative process which involves semantic [CDAG08] and cognitive [GH06] aspects of information classification; iii) as part of Social Applications. Starting from a preliminary background about information classification and organization, this section proposes a trail through Social Tagging Systems, the role of a folksonomy with Information Retrieval and Recommender Systems, and an overview of its definitions and representations. This would be an attempt to shed light on the various research contributions about folksonomy and social tagging so far, which still raises challenging questions and open issues.

1.1 Information Classification Background

Descriptive and structured terms used for representing the content of an informational resource are a common approach oriented to organize and manage information on which retrieval operation will be required.

As surveyed in [DDTV10] traditional documents classification methods are based on strict and precise methods: *taxonomies*, *thesauri* and *ontologies* generated by domain human experts, provide construction rules for classifying and representing knowledge explicitly. For instance, experts in library cataloguing assign generally keywords to books in order to describe the content of data source and aggregate documents regarding the same object. To these extent *controlled vocabulary* are used: they describe materials and refer to categorization rules based on specific schemas (*classification systems*). The differences between traditional formal methods of classification and folksonomies concern mainly a different approach in resources description:

- the first ones are based on a *top-down* approach: a vocabulary of a classification system has to be adapted to the resources to describe;
- in the latter case there is a *bottom-up* approach: starting from the resource, the user apply descriptors coming from a non-controlled terms of natural language.

The problem of natural language ambiguity has been long discussed [Kuh13, Rot98, Win72]. Common approaches considered formal subjecting and classification efforts

[9] http://stackoverflow.com/
[10] http://answers.yahoo.com/

in order to produce controlled vocabularies and classification schemes, . These organize terms in structures according to different relationships [Fox00, LR06, Res99]. To define a vocabulary means taking into account different aspects as: the control of *synonyms*, *homonyms* and *homographs* (different forms of the same term); composed or bound words; specific and generic concepts referring to the same content.

Different methods usually utilized in traditional libraries can be divided in two main typologies: i) based upon *categorization and classification*, and ii) based on *controlled vocabulary*. In order to provide the basic foundations underlying the complexity of the topic, a clarification about these methodologies of knowledge organization and classification is needed.

Below an overview of two categorization and classification methods, i.e. *taxonomies* and *faceted classification schemas*, is provided; then two different vocabulary control systems, such as *thesauri* and *ontologies*, are briefly described.

1.1.1 Categorization and Classification Methods

A *taxonomy* is a technique that classify things in categories, and in particular, it represents the classical system of hierarchical categorization. This classification process requires the capability of a breadth and deep information analysis, as well as the consideration of quantitative measurements, completeness and logic [Ric92]. Typically, each term of a taxonomy may share a parent-child relationship (e.g. specialization and generalization), with one or more other elements, and for each element a common restriction consists in having at least only one parent [HFBPL11]. Several influential scientific models have been developed in later centuries and taxonomies exist at least from 1735, when Linnaeus laid the basis for modern biological classification by introducing *Linnean taxonomy* as a mean to classify all life forms. The taxonomy has identified the name of the science of classification, but it has also been used to refer to individual hierarchical classification schemas. The abundance of taxonomic classifications (some of them are surveyed in [HKR09]) suggests that hierarchical structures are highly significant in modelling. In many cases mere hierarchies are not sufficient to describe a domain: as opposed to classical taxonomies, many modern knowledge organization and classification approaches allow objects to belong to more than a single most specific category. Moreover objects may need to be classified based on multiple independent aspects, the so-called *facets*.

An alternative classification to the hierarchical enumerative one consists in the *faceted classification schema* [Bro01]. According to a bottom-up scheme, a subject is divided into concepts and rules are provided to use these concepts in constructing a structured subject. To this extent an element may be described by a combination of criteria rather than by a unique category and any document could be broken down in terms of different facets. Indeed, a faceted approach aims at represent a variety of perspectives that in traditional hierarchical classification may be extremely difficult to convey [Kwa00]. As deeply surveyed in [Her07], this approach to information classification has its origins in the field of library and information science. In 1933, Ranganathan used it to classify books in libraries; later, this approach was developed by the U.K. Research on Classification Group [Ran63][11] for the organization of document collections in scientific fields, as an effective storage method useful for complex and compound subjects retrieval. More recently, faceted classification systems have been exploited to assist automated search and information retrieval also using semantic Web tools [Vic08, Bro06, UJ07].

1.1.2 Vocabulary Control Systems

Thesauri have played an important role in modern information storage and retrieval systems. The standard ISO 2788/1986 [12] defined a set of characterizing elements of a thesaurus as follows: a controlled and consistent terminology, the preferred term to use in describing a concept, the semantic relationships among the terms. Generally, semantic relationships managed by a thesauri are: i) the *equivalence* or synonymic relation; ii) the *hierarchical* relation which defines a tree of terms (*sub/up-ordination* relations and *parents-children* concepts); iii) the *associate* relation which includes cause and effect relations, sequence in time or space, agency and instrument. Some thesauri also differentiate the hierarchical relation in three levels, such as generic, partitive, instance, depending on its granularity [R$^+$98]. As deeply discussed in [SR00], different approaches has been used to publish thesauri on the Web, using both static (e.g. the ASFA Thesaurus[13] and InfoTerm Thesauri[14]) or dynamic format with fully navigable hyperlinks providing advanced visual interfaces (e.g. the OECD macrothesaurus[15], the AGROVOC thesaurus[16], the EuroVoc thesaurus[17] and ERIC Thesaurus on the Web[18]). Recently, the majority of thesauri have moved forward to ontology-based thesaurus management, exploiting Semantic

[11]The Colon Classification (CC) of documents, utilizes five facets as primary categories, called *PMEST*, i.e. *personality*, *matter or property*, *energy*, *space* and *time*.

[12]ISO 2788. Guidelines for establishment and development of monolingual thesauri (2nd edition), 1996.

[13]The Aquatic Sciences and Fisheries Abstracts (ASFA) supports an abstracting and indexing service covering the literature on the science, technology, management, and conservation of aquatic resources and environments, including their socio-economic and legal aspects (`http://www.fao.org/fishery/asfa/en`).

[14]The International Scientific and Technical Dictionaries (InfoTerm) was born under the supervision of UNESCO and ISO in the middle of the XIX century. Interested readers may refer to [Gal] for further details.

[15]`http://bibliotecavirtual.clacso.org.ar/ar/oecd-macroth/`

[16]AGROVOC covers all areas of interest to FAO, such as food, nutrition, agriculture, fisheries, foresty and environment; it is composed of over 30 thousand concepts formalized as RDF/SKOS dataset, accessible through a SPARQL endpoint (`http://www.fao.org/agrovoc/`).

[17]EuroVoc is a multilingual, multidisciplinary thesaurus covering in particular, the activities of the European Parliament. It contains terms in 23 EU languages `http://europa.eu.int/celex/eurovoc`

[18]The Education Resources Information Center (ERIC) contains education-related terms, such as teaching, learning, reading as well as educational administration and policy (`http://eric.ed.gov/`).

Web technologies and languages, especially XML and SKOS/RDF format), conformant to W3C recommendations.

Roughly speaking, an ontology uses a predefined vocabulary of terms to define concepts and explicates the relationships between them for a particular area of interest [HFBPL11]. During the last decade, many definitions of what is an ontology have been given [Fen01], but one that best characterizes its essence, conceives an ontology as a *formal*, *explicit specification* of a *shared conceptualization* [G+93, GOS09]. Ontologies can capture the knowledge domain due to a rich, formal logic-based model: to this extent ontologists can express the semantics behind vocabulary terms, their interactions and context of use. Modelling ontologies with expressive languages, capable to capture all the details of a domain of interest, is a complex task that requires a strong commitment and an high level of know-how.

Actually, Semantic Web utilized a combination of schema languages and ontology language in order to provide the capabilities of vocabularies, taxonomies and ontologies. To this extent, the main objective is not to model a single ontology, but different ontologies aimed at describe portions of reality with a certain degree of consensus among the users of a particular domain. Indeed, an ontology modeled in agreement with a logical formalism enables new knowledge inference thanks to proper reasoners. Designing ontologies means also take into account hierarchical approaches: this has led to the definition of generic *upper* or *top-level ontology* [NP01, Smi03] that describe generic concepts and domain, which in turn should be utilized in more specialized ontologies.

Thanks to the collaborative nature of annotation and information classification of Social Web, new approaches to ontologies definition, evolution and maintenance has rapidly grown, attracting a lot of interest in various research field. All these aspect, will be deepen in the Chapter **??**.

Below, we analyze in short the interactions between Social and Semantic Web across ontologies.

Ontologies, Social and Semantic Web

Social Web has introduced innovative trends and methodologies for creating, sharing and classifying information through enabling platforms, mainly based on *Service Oriented Architectures* [How07, SJ07]. SOA requires the availability of components and software applications as *web services* [Ars04, EAA+04] which, in turn, will be identified, retrieved and utilized through standard protocols in an interoperable manner. In an SOA, software resources are packaged as “services” which are well defined, self-contained modules capable to provide standard functionalities and interfaces allowing the communication with other services, independently from their state [PVDH07]. Several available services have been used increasingly integrating their results, in order to obtain new services: this is the case of *mashups* [YBCD08, ZRN08], i.e. web applications that combine functionalities and data from other services by providing integrated results. Unfortunately, the increase of available information and services increases, rather than reduces, the need for meaningful structured information content spread over the Web [DNDVDSD13, AKTV07].

Despite Social Web technologies and applications have augmented traditional World Wide Web, allowing for easy distributed collaboration, they cannot be considered as the answer to well-known limitations of a Web of documents. Content is mainly suitable for human consumption and it is not machine-accessible: even those contents that are generated automatically from databases usually are presented loosing their original structural information cabled in databases [Ant04].

As envisioned in [BLHL+01], these typical limitations may be considerably overcome introducing *semantic*, intended as the formal interpretation of a computational language. Important goals of the Semantic Web consist in making resources widely accessible, increasing the utility of this knowledge by enabling advanced applications for *searching*, *browsing* and *evaluation* [SHBL06].

Of course, the purpose of the Semantic Web is not to extend the actual Web, but rather to achieve an ideal toward which the Web can evolve over time. Classical Web technologies do not address difficult challenges posed by the main aims of the Semantic Web, and in particular how to model knowledge in a formally specified language and how to reason over it automatically. The importance of standardized languages and protocols, capable to provide Web documents universally accessible on global addressing schemes, has become even greater by approaching the Semantic Web. Semantic Web vision relies on ontologies as its main knowledge structure and W3C indicates them as standard for shared a reusable knowledge [HKR09].

The following section focuses on social tagging applications, taking into account also their limitations and drawbacks.

1.2 Social Tagging Systems

The meaningful power of folksonomy is not simply connected to the creation of tags, but to the act of aggregating them within a social distributed environment such as Social Tagging Systems.

Focusing on the social aspects of tagging, in [MNBD06a, MNBD06b] the authors identify the following characteristic elements the tagging rights (who can tag what); the tagging support (if tags are suggested); the aggregation (duplicate tags for the same resource); the type of object; the source of material; the resource connectivity (links using tags or not); the social connectivity (links between users). Besides, these social systems may stimulate user through both organizational and social motivations, intended as future retrieval, contribution, sharing, competition, opinion expression and self-presentation: such key features may explain the success of these applications. As early defined in [Mat04] social tagging applications allow users to freely associate tags to resources, distributing the task of classifying document over the set of Web 2.0 users. They do not require significant efforts: human classifiers do not have to follow specific rules and may classify only the set of resources they consider interesting. In social tagging applications users both apply tags for personal aims (typically to retrieve the same resource again) and can enjoy the classification applied by other users browse available documents following classifications provided by them [GH06]. Indeed tags contain very useful, social and semantic information, and analyzing the various motivations/goals that lead a user to perform tagging, it is possible to better comprehend their nature. Common purposes can be summarized as follows [DDTV10]:

- *Describe the content.* User may apply tag to summarize the content of the resource (`electionday`, `spread`, ...).
- *Describe the type of the document.* Some users classify a Web resource according to its MIME type or its publication form (`article`, `blog`, `book`, ...).
- *Describe features and qualities.* Adjectives may be used for expressing opinions, emotions or qualitative judges (`interesting`, `good`, `beautiful`, ...).
- *Associate people to documents.* Tags can report the authors of a document or people involved in a particular task or event, defining a relationship between the resources and the tagger (`mycomments`, `mystuff`, ...).
- *Associate events to documents.* Locations, dates, conference acronyms are widely used for associating an event to a document (`ITIS2004`, `Rome`, `9/11`, ...).
- *Associate tasks to documents.* Some tags reveal personal matters or engagements (`mypaper`, `toread`, `jobsearch`, ...).

Other two important factors should be considered to understand the nature of social tagging systems: i) the *heterogeneity* of users and ii) the *changes in time*. Due to users' different level of knowledge of the application domain and different goals in mind, the classification made by some taggers may be not acceptable or comprehensible for others. Moreover different people may use distinct vocabularies to describe the content of a resource, they may have different opinions about a topic or they may have not the adequate knowledge about events, tasks or people associated to a resource by other users. Another aspect to take into account concerns the changeability in time of users knowledge, motivations, and opinions, especially in the case of emotions about a topic tagged in the past.

The freedom of social tagging systems implies that the classification offered by a folksonomy is not rigorous and there are still several issues that arise from the flexibility of these systems. Social tagging does not handle issues that are easily taken into account by classic and well-established classification method previously described, and in particular they suffer from:

- *semantic ambiguity*: social tagging application commonly does not enforce neither propose values from a controlled vocabulary, hence they suffer from the same ambiguity of natural language (homonymy, polysemy, term variations and even misspelled terms);

- *undistinguished concerns*: as described above, having possible different goals in mind during tagging activity, users may introduce for the same resource tags that might be subject descriptors, self-reminders, proper names or remarks;

- *independence of terms*: social tagging does not provide relations capable to connect and relate different terms; each tag is independent from each other and no exploitation of hierarchies of concepts is possible. In fact the well-known problem of *basic level variation* (terms of different levels of *specificity* are used for annotate the same resource) frequently occurs in a folksonomy.

This means that the classification applied through a social tagging application needs to be improved to be useful to the end-users. Technologies like recommender systems, able to overcome the implicit limitations of social tagging and to adapt the available classification to the specific user, are needed. In the section below we provide an overview of interaction among social tagging systems, recommender systems and information retrieval.

1.2.1 Folksonomy and its role with IR and RS

The increasing volume of information on the Web is the main motivation for RS: they support users during their interaction with large information spaces, and direct them toward the information they need. RS model user interests, goals, knowledge, and tastes, by monitoring and modeling the (implicit or explicit) feedbacks provided by the user. A traditional classification [MGT+87] of RS is based on how item suggestions are generated and distinguishes three categories: (a) *CF (Collaborative Filtering)* uses social knowledge to generate recommendations. It may be further differentiated into: Model-based approaches, which build a probabilistic model for predicting the future rating assignments of a user, on the basis of her personal history; Memory-based approaches, which use statistical techniques for identifying the users, called neighbors, with common behavior (user-based approaches) or items evaluated in a similar way by the community (item-based approaches); (b) *CB (Content-based)* analyzes past user activities looking for resources she liked; it models the resources by extracting some features (for example, topics or relevant concepts) from documents. The user profile is then defined describing what features are of interest for the user. The user relevance of a new resource is computed by matching a representation of the resource to the user profile; (c) *HF (Hybrid Filtering)* combines CB and CF approaches.

A more general taxonomy has been proposed in [RBT+08], where current recommendation technologies are discussed considering three dimensions:

1. the **Recommendation Algorithms** dimension includes discussed *CF, CB, HF recommenders*, and also considers *KB (Knowledge-based)* recommenders, which use domain knowledge to generate recommendations.

2. the **User Interaction** dimension includes: (a) *Conversational RS*, which directly interact with the user by asking her to give feedback (Candidate/ Critique systems) or to answer questions (Question/Answer systems); (b) *Single-shot RS* where each interaction is used for suggesting recommendation independently;

3. the **User Models** dimension includes the *Persistent User Model*, which deduces the user interests and preferences from user inputs accumulated over the time, and the *Ephemeral User Model*, which infers the intentions/interests of the user solely on input from the current session. In [KT10], the authors have recently highlighted the centrality of the user model and its specific importance in the e-commerce field, both for Web browsing and purchase recommendation.

Historically, RS and Social Web have been closely interconnected, and the use of folksonomies in RS is widely recognized as a core subject [DFT12]. Nevertheless, another relevant research area has been often associated to RS: *Information Retrieval* (IR). IR and RS appear siblings, share similar objectives, and similar measures (even for evaluation). Both IR and RS are faced with similar filtering and ranking problems. In [Bur07], the author argues, for example, that RS is not clearly separated from IR. The individualized criteria that RS try to achieve probably are the core differences between RS and IR [RRSE11].

Introducing folksonomies as basis for recommendations means that the usual binary relation between users and resources, which is largely employed by traditional RS, changes into a ternary relation between users, resources, and tags, more complex to manage.

Different surveys [KT10, DFT12] analyze the use of social tagging activities for recommendations, focusing their attention in particular on the following aspects:

- **RS improvement thanks to tags:** an interesting overview on social tagging systems and their impact on RS is presented in [MNI10]; while a methodology to improve RS thanks to Web 2.0 systems and particularly to social bookmarking platforms is offered by [SS09]; moreover, the same work [XZL10] provides a recommender system model based on tags.

- **Role of tag recommendation:** the system presented in [RL10] exploits a factorization model to propose personalized tag recommendations, while the work [NDH06] illustrates a strategy used in a Web page recommender system exploiting affinities between users and tags. In addition to these affinities, [DD09] proposes a recommender system exploiting tag popularity and representativeness to recommend web pages.

- **Tags & User modeling:** since RS rely on a user model to generally personalize recommendations, [WZBA10] proposes an original way to enhance modeling to improve tag recommendation. In a general context, [CCC+07] and [Che09] also illustrates how tag activity can improve user modeling.

To conclude, recommender systems contribute in an effective way to better support tagging, browsing, and searching for new resources within social applications, as deeply investigated also in [CDHP11].

1.3 Summary

In this chapter, we described the basic concepts of Information Classification and Social Tagging Systems, mentioning the evolution of World Wide Web into Social and Semantic Web. Considering the importance of *tags*, we focused on folksonomy and its role within IR and RS. We have highlighted some limitations of folksomony, primarily ascribable to the freedom provided by social tagging systems: however, we did not mention how to overcome these limitations.

Due to the definition of folksonomy, social tagging systems present different drawbacks recognizable for instance, i) in the lack of manipulation and authoring tools, and ii) in the absence of personalized views of the annotated resources.

The following chapter provides an overview of the definitions and representations of a folksonomy so far. In particular, we cover in more detail how to visualize, author, navigate and manage a folksonomy starting from a new formal definition, based upon particular data structures, *zz-structure*. We show how they may contribute in overcoming some limitations of the most common folksonomy definitions and of the features provided by social tagging system. Indeed, our proposal is in adding semantic interconnections, providing new modalities of navigation and allowing customizable visualizations chosen by users.

2

Visualizing and Managing Folksonomies: a Novel Approach

In the previous chapter we overviewed information classification systems through the evolution of social and semantic Web, giving particular attention to Social Tagging Systems as a significant mean of information organization and classification. Furthermore, we anticipate the significant role of a folksonomy in the recommendation of web resources as well as in the retrieval of information.

In this chapter, we analyze common capabilities of social tagging systems in supporting users in the management of a folksonomy. Observing limitations of these systems, we point out that they are partly ascribable to the definition of the folksonomy itself. After a detailed overview of common folksonomy definitions and representations, we propose:

- a new formal definition of folksonomy: our proposal is based upon particular data structures, called *zz-structures*. Hereby, we show how they can be exploited in order to model a dynamic folksonomy capable to support user in its management, customized visualization, and authoring;
- a novel conceptual framework capable to help user in manage, visualize and author a folksonomy in terms of dynamic components.

The chapter ends with the evaluation of the proposed prototype, encouraging us in moving forward with the provided model to the wider field of application of tourism mobile guides.

2.1 Limitations of Social Tagging Systems

The collective participation is one of the distinctive specificity of social tagging systems; users upload, share and freely annotate with labels, known as *tags*, a huge amount of resources, explicitly inducing on them personal classifications. Although these systems are widely used and personal annotations represent a democratic, powerful and easy way of classifying resources, they suffer from different issues:

- the lack of general methodologies for extracting semantic information (this topic is widely discussed in the literature, see the survey [DFT10, DFT12]);
- the lack of customizable and dynamic workspaces in which users can *visualize personalized views* of the folksonomy or *apply personal changes*;
- the lack of specialized tools for involving user in the improvement of the folksonomy. The attention is essentially focused on sophisticated methodologies for automatically extracting similarities or recommendations. If a user notes some errors, imprecisions or semantic incongruences, the tagging system does not provide her with appropriate tools for simply transferring her knowledge to the system.

The increasing amount of information scattered across several social applications has strengthened the users' need of customization, manipulation and easy managing of her workspace.

In order to satisfy this need, traditional Web browsers themselves became to offer personal views, so-called *start pages* (see for example the iGoogle[1], NetVibes[2], or My Yahoo[3]). Some extensions of these examples are adaptive bookmarking systems such as PowerBookmarks [LVA+99], Siteseer [RP97] and WebTagger [KWC+97]. Few steps in this direction have been made by social tagging systems. They should deal with these compelling and open challenges, expanding their capabilities and enhancing the visualization and authoring functions, in order to simplify (a) the comprehension of the semantic relations of a folksonomy, (b) the navigation through the involved elements, and (c) the manipulation of existing relations among tags and resources. The folksonomies are generated by the union of a set of personomies. Both are generally visualized as a tag cloud, although, as highligted also in [SCH08], this kind of visualization is not sufficient as the sole means of navigation. Tag clouds are useful for discovering, for example, the number of bookmarks related to a chosen tag or the list of resources annotated with it. However they are not adaptive and not support the user in the generation of customized views, neither in the authoring process.

Let us consider for instance the Figure 2.1 where is shown a portion of workspace offered by delicious[4], , a popular social bookmarking web application.

The user navigates her tag cloud (shown on the left); when she selects a specific tag ("webdesign", in our case), the number of bookmarks related to the chosen tag and the list of resources annotated with it are shown. The navigation may continue by clicking on each resource, tag or user, but

- the tag cloud is not adaptive;

[1] `http://www.google.it/ig`
[2] `http://www.netvibes.com/it`
[3] `http://my.yahoo.com/`
[4] `http://delicious.com/`

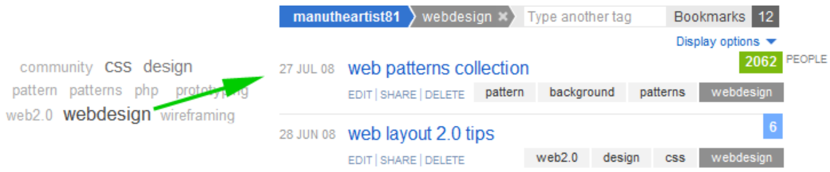


Figure 2.1: A sample view taken from delicious

- personalized views cannot be created;
- it is not possible to simply modify the personomy, or the personal view of the folksonomy (e.g. renaming a tag for a set of resource; merging two or more tags on a unique label).

These limitations are partially ascribable to the static nature attributed in the literature to a folksonomy; in fact, it has been defined in terms of finite sets of *users*, *resources* and *tags* [HJSS06a] and represented as a hyper graph or as a tri-partite graph [CDAG08, CK10]. These definitions do not consider the dynamic aspects, like the personalization and the authoring, as intrinsic features of a folksonomy, although they are. In fact, the role and the importance of a folksonomy are not in the trivial, passive storage and visualization of data, but in the semantics contained in it, in the identification of user features, habits, needs, and in the possibility of inferring recommendations.

2.2 Limitations in Folksonomy Definitions and Representations

Early definitions of folksonomy [Van07, Mat04, Mik05] are related to the user activity of annotating resources with metadata for her own individual aims, and/or for sharing them in a community. In these definitions, only three kind of entities (users, resources and tags) and the relations among them, called *tas* (tag assignments), are considered, instead of any dynamic aspect of visualization and manipulation.

An early formal definition is given in [HJSS06c] where a Folksonomy is described as follows:

$$\mathcal{F} = (U, T, R, Y),\ Y \subseteq U \times T \times R$$

where U, T, R are finite sets respectively of *users*, *tags* and *resources*, ,Y is a ternary relation among them. The same authors add to this definition another element [HJSS06b] and specifically $\mathcal{F} = (U, T, R, Y, \prec)$, where $\prec$ is a user-specific subtag/supertag-relation, i.e., $\prec \subseteq U \times T \times T$, called *is-a* relation.

This formalization, based on a tripartite structure (a simple example is depicted in figure 2.2) for representing the social tagging activity, has been analyzed in several works [Mik05, HRS06, CSB$^+$07, GZacCN09].

An extension to the previous definition is suggested in [Gru07] where the tagging activity is described as a five-place relation *(object, tag, tagger, source, polarity)* where: i) *object*, *tag* and *tagger* correspond to R, T and U in the tripartite model, ii) the *source* is related to the $t$ag space where the user applies the set of tags, iii) the polarity parameter ('+' positive and '-' negative) indicates the goodness or badness of a tag.

Another definition is provided by [AHK08] where the authors present the social application GroupMe!. A *group* is constituted by a set of resources, which can be in turn either a resource or a group. Even if some interesting relations are highlighted in this application, like the relation between tags assigned to different resources of the same group, users are not allowed either to directly manipulate her personomy or to navigate through different and more effective visualizations.
The work [KSB+08a], conceiving a folksonomy as a method for acquiring knowledge from collaborative tagging processes, includes a representation of the collective tagging activities performed by the group of users.

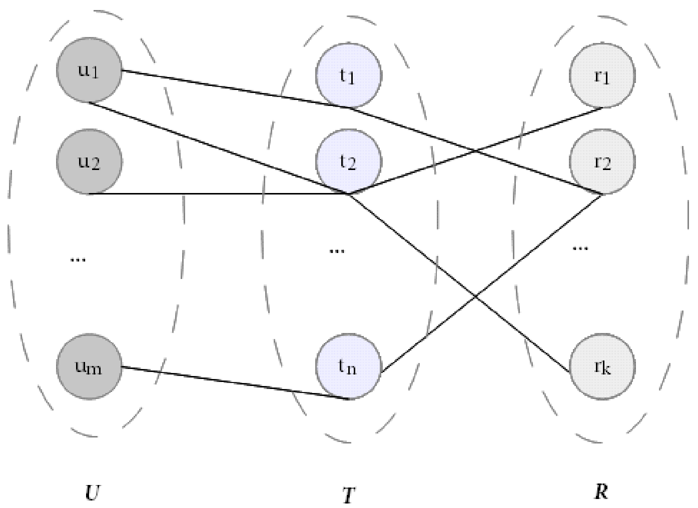


Figure 2.2: A tripartite model representation of a folksonomy

A folksonomy is usually represented by a tripartite graph or network, but this leads to the issue related to the *complexity of the nature of the graph* itself. Various researches have dealt with this problem, projecting a folksonomy on simplified structures. For example, in [LA06], the tri-partite network is first projected on a bipartite network, then on a unipartite one, thanks to the correlations between two nodes of the same kind. In a recent work [DEM11] the authors, starting from the edge-colored multigraph of users, tags, and resources, propose some simplified definitions that maintain some of its properties. Thanks to this mechanism, the information extraction process becomes easier and simplifies the application of a modular and extensible methodology applied for discovering synonyms, homonyms and hierarchical relationships amongst sets of tags.

We specifically concentrate in on the following issues:

i *the folksonomy's navigability*: typically a user has to browse through huge lists of potential interesting resources, before reaching the desired information; In order to simplify the user navigation, in [TKH11] the authors propose tag-resource taxonomies; differently from tag taxonomies, thanks to this approach "*the users not only quickly navigate to related concepts but also to resources from a tagging system*". An alternative methodology aiming at improving the folksonomy navigability, is presented in [HGM06, HST+11] where hierarchical structures are extracted and then exploited as background knowledge for supporting navigation and decentralized searches, and also for evaluating navigational tasks in social tagging systems. These works focused on the creation of taxonomies upon existing folksonomy in order to improve its navigability but they still lack tools for the folksonomy's customization and authoring;

ii *the folksonomy's visualization and managing*: a few research projects have addressed some of them. For instance, in [HMHS07] the authors use a customized cluster maps for visualizing both the overview and the detail of semantic relationships intrinsic in the folksonomy; in [KD09] the authors use information visualization techniques to discover implicit relationships between users, tags and bookmarks and offer end-users different ways to discover content and information that would not have been found through explicit searches. Another project is TagGraph[5], a folksonomy navigator which visualizes the relationships between Flickr tags. User may enter a Flickr username or a tag, and the graph sets out drawing itself automatically; after this early step, she may navigate through related tags or among related images, but could not manipulate her personomy. The mentioned projects are by all means interesting attempts of interactive visualizations of folksonomies; in spite of that, they do not provide neither personalized views nor effective dynamic changes according to the user needs or preferences;

iii *the folksonomy's dynamic authoring*: the aforementioned researches are oriented to provide new ways to visualize a folksonomy or to improve its navigability, nevertheless they do not discuss about possible simple modifications of them. For example, to the best of our knowledge, there are not *dynamic authoring tools* that allow the user to globally change the tag labeled in a certain way within her personomy. The same social tagging applications, such as Bibsonomy, delicious or Flickr, suffer from similar limitations.

In the following section we propose Folkview, a novel approach to conceive folksonomy in terms of particular graph-centric data structures, capable to represent interconnection across multiple semantic dimensions. We show how, thanks to our

[5] http://taggraph.com/

proposal, we can provide to users a novel modality to folksonomy navigability, answering to the issues of folksonomy visualization, managing and authoring.

2.3 Folkview: A Novel Approach to Conceive a Folksonomy

Folkview[DP11, DP12] is a novel approach to conceive a folksonomy: it is a distributed, modular and dynamic system, based on dynamic entities capable to manage its structural and semantic properties, cooperating for obtaining common objectives and for offering personalized and dynamic views. In it, a folksonomy is conceived in terms of a multi-agent system. Each element (tag, user, resource) become an active entity and the folksonomy transforms itself from a traditional passive container of data into a computational agent, provided of a set of procedural and distributed skills.

This section provides the description of the formal model underlying our subsequent case study implementations, and in particular after few preliminary definitions, we provide our definition of a *zz-structure* ZZ [Nel04]. They are non-hierarchical, minimalist, scalable structures for storing, linking and manipulating different kinds of data. From these structures, we inherit many strengths, such as their intrinsic capability to preserve contextual interconnections among different data, thanks to their particular properties. The peculiarity of such structures derives from the relation among their component elements: data is stored into *cells*, that may contain very different types of contents, which are connected with links of the same color into linear sequences called *dimensions*. They have been successfully used in many applications, implemented for different platforms, and due to their flexibility and adaptivity, they have been utilized in different application fields, such as bioinformatic, electronic music, e-learning [DL04], virtual museum tours [DL08, DL09b], etc.

In order to provide our definition of *zz-structure*, below we provide a set of preliminary definitions.

Definition 1. (Multigraph) *A multigraph MG is a triple $MG = (V, E, f_E)$ where V is a finite set of vertices, E a finite set of edges and f a surjective function $f_E : E \to \{\{u, v\} \mid u, v \in V, u \neq v\}$.*

Definition 2. (Degree of a vertex) *Given a multigraph MG, the* degree *of a vertex v, $v \in V$, denoted by $deg(v)$, is the number of edges incident to v.*

Definition 3. (Edge-labeled multigraph) *An* edge-labeled multigraph *is a triple $ELMG = (MG, L, f_L)$ where: $MG = (V, E, f)$ is a multigraph, L is a set of labels, and $f_L : E \to L$ is an assignment of labels to edges of the multigraph.*

Definition 4. (Degree of a vertex in an edge-labeled multigraph) *Given an edge-labeled multigraph $ELMG$, a vertex $v \in V$ and a label $l \in L$, the* degree *of a* *vertex v with respect to label l, denoted by $deg_l(v)$, is the number of edges, labeled l and incident to v.*

Definition 5. (Zz-structure) *A zz-structure ZZ is 3-tuple $ZZ = \{ELMG, C, f_C\}$ where*

- *$ELMG$ is an edge-labeled multigraph (Definition 4) subject to the following constraint: $\forall v \in V, \forall l \in L,\ deg_l(v) = 0, 1, 2$;*
- *C is a set of hypermedia contents;*
- *$f_C : V \to C \cup ZZ$ is an assignment of contents to vertices of $ELMG$.*

In other words, a ZZ is an edge-labeled multigraph where the vertices are either singletons, or are connected in linear paths, or cycles; each vertex is called *zz-cell* and it may be an *atomic zz-cell* if it is associated to an hypermedia content or a *compound zz-cell* if it contains a ZZ; each edge is called *zz-link*, and is identified by a semantic label.

Traditionally, given the sets U, T and R respectively of users, tags and resources, a folksonomy is defined as the set of tas $(u_i, r_j, t_k) \in U \times T \times R$, each of them indicating that user u_i has tagged the resource r_j with t_k. User profiles, functions, metrics or semantic relations among users, tags, resources and tas are not intrinsic properties of the folksonomy they may be (or not) applied by the system which hosts the folksonomy. We indicate this traditional concept of folksonomy as static folksonomy F. In order to define a F, we identify three classes of sets:

- $T_{u_i,r_j} \in T$ is the set of tags used by u_i on r_j;
- $R_{u_i,t_k} \in R$ is the set of resources tagged by u_i with t_k;
- U_{t_k,r_j} is the set of users that tagged r_j with t_k.

Each set represents a structural component of the folksonomy, that we call it *structural*; tags are grouped associating to them a semantic label for identifying their meaning in that dimension.

A graphical example of 6 sets of tags is given in Figure 2.3, on the left. The first three linear paths contain the resources tagged by user u_1, using respectively t_1, t_2 and t_3. So, the labels associated with them are respectively u_1, t_1, u_1, t_2 and u_1, t_3.

Definition 6. *A structural dimension is a connected component*

$$D_{u_i,r_j} = (T_{u_i,r_j}, E, \lambda)$$

where T_{u_i,r_j} is the set of vertices, $E \subseteq T_{u_i,r_j} \times T_{u_i,r_j}$ is the set of edges, $\forall e \in E$, $\lambda(e) = (u_i, r_j)$ is the edge label, and $\forall t_k \in T_{u_i,r_j}$,

$$degree(t_k) = \begin{cases} 0 & \textit{if } |T_{u_i,r_j}| = 1 \\ 1, 2 & \textit{otherwise} \end{cases}$$

Analogously we define D_{u_i,t_k} (resp. D_{t_k,r_j}) as the component constituted by the set of resources R_{u_i,t_k}, labelled with t_k by the user u_i (resp. by the set of users U_{t_k,r_j}, that assigned the tag t_k to the resource r_j).

Definition 7. *A structural folksonomy sF is an edge-labeled multigraph given by the union of three families of structural dimensions.*

$$sF = \bigcup_{i,k} D_{u_i,r_j} \cup \bigcup_{i,j} D_{u_i,t_k} \cup \bigcup_{j,k} D_{t_k,r_j}$$

where $u_i \in U$, $r_j \in R$ and $t_k \in T$.

An example of sF is shown in Figure 2.3 on the right; it is based on the six dimensions visualized on the left.

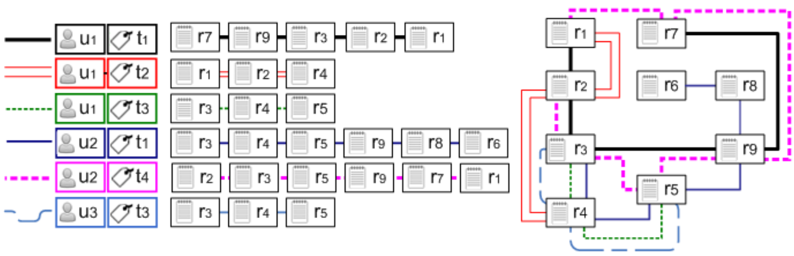


Figure 2.3: 6 structural dimensions (left) and the correspondent folksonomy (right)

This definition is restrictive due to the aforementioned reasons: a folksonomy plays a crucial role in supporting recommendations and suggestions, inferring knowledge about user behaviors, helping in identify similar users, resource and tags. Now, we introduce a formal definition of agent as follows:

Definition 8. *An agent $A = (Ts, En, Re, Ac)$ is a quadruple where:*

- *Ts represents its **topological structure**;*
- *$En = \{\eta_1, \eta_2, \dots\}$ represents its **local environment**;*
- *$Re = \{\rho_1, \rho_2, \dots\}$ is the finite set of incoming **requests**;*
- *$Ac = \{\alpha_1, \alpha_2, \dots\}$ is the discrete, finite set of possible **actions**.*

Ts and En represent the passive components of the agent, while Re and Ac its active part.

Finally, we can introduce the definition of the dimension $\mathcal{D}_{u_i,r_j}$ based on the structural dimension D_{u_i,r_j}.

Definition 9. *A dimension $\mathcal{D}_{u_i,r_j}$ is an agent where:*

- $Ts = D_{u_i,r_j}$;
- $En = \{u_i, r_j, t_1, \ldots, t_n\}$;
- $Re = \{\emptyset\}$ *initially;*
- $Ac = \{$*add-tag, delete-tag, modify-tag,* $\ldots\}$

Analogously, we can define new classes of agent dimension, not only for structural dimensions. New dimensions can be created directly by the user, or computed by the system applying specific metrics, or generated applying ontological models. Furthermore, each dimension (i) is an agent dimension; (ii) can contain other dimensions; (iii) associates a semantics to the set of grouped entities; particular dimensions, called meta-dimensions, are used for managing specific sessions, views, and changes on the folksonomy.

Definition 10. *A folksonomy $\mathcal{F}$ is a multi-agent system formally described as a labeled multigraph of agent entities, organized in semantic contexts, called dimensions.*

$$\mathcal{F} = \bigcup_{i=i}^{n} \mathcal{D}^i$$

All in a folksonomy is a computational agent, equipped with a set of *local variables*, that defines its internal state, and a modular and extensible set of *procedural skills*. So, for example, each user is represented in a folksonomy by an user agent: it knows the resources tagged by the user, and the used tags. Moreover, it contains and manages the user profile, it is able to calculate specific local metrics for her, such as e.g. the average number of tags applied on a single resource, the average time spent on a resource, the tagging date, etc. They can further communicate with the other agents present in the personomy and in the folksonomy, such as the tag agents, or the resource agents, or the same dimension agents.

We identify in Folkview eight classes of agents and its architectural model is based on four layers as follows:

- the *storage layer*: it comprises the three agents $User$, *Resource* and Tag;
- the *semantic layer* that is constituted by *Dimension* agent, primarily devoted to add semantic relation;
- the *social layer* is identified by $Personomy$ and $Folksonomy$ agents;
- the *presentation layer* is represented by $Session$ and $View$.

Figure 2.4 graphically synthesizes Folkview.

We depict an agent as a box containing the name of the agent class, the set of local variables, and the set of methods, as in the next Table 2.1

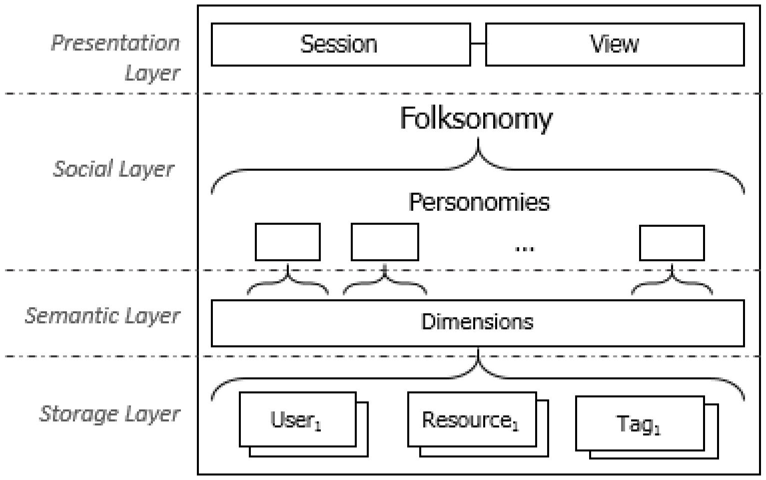


Figure 2.4: A graphical representation of Folkview; from bottom to top: the storage layer, the semantic layer, the social layer and the presentation layer.

2.3.1 The Storage Layer

The three agent classes of the storage layer are shown in Table 2.1.

User Agent u	*Tag Agent t*	*Resource Agent r*
id meta profile settings preferences reputation neighbors ... T^u R^u $T^u_{r_j} R^u_{t_k}$ $\mathcal{D}^u$ $\mathcal{P}^u$ $\mathcal{F}$	id meta label reputation neighbors ... U^t R^t $U^t_{r_j} R^t_{u_i}$ $\mathcal{D}^t$ $\mathcal{F}$	id meta url reputation neighbors ... U^r T^r $U^r_{t_k} T^r_{u_i}$ $\mathcal{D}^r$ $\mathcal{F}$
notify(agent-list, message) update(agent-list,operation) applyMetric(metric) ...	notify(agent-list, message) update(agent-list,operation) applyMetric(metric) ...	notify(agent-list, message) update(agent-list,operation) applyMetric(metric) ...

Table 2.1: The storage layer

The *User Agent u* represents single user; it is uniquely identified by an *id*, and is associated to a set of keywords *meta*; it owns a *profile*, a set of *settings* and *preferences*, a *reputation* and a set of similar users, called *neighbors*. Finally it knows all the tags, resources and semantic connections (=dimension, see next semantic layer) belonging to the user. More in details, T^u and R^u are respectively the set of tags and resources used by u, while $T^u_{r_j}$ and $R^u_{t_k}$ are the set of tags (resp. resources) used by u on a specific resource r_j (on a specific tag t_k). $\mathcal{D}^u$ addresses the list of Dimension Agent belonging to the user, while $\mathcal{P}^u$ and $\mathcal{F}$ address the personomy of u and the folksonomy.

Each *User Agent u* is able to apply a set of methods, such as make aware other agents of an event or a change of internal state - *notify(agent-list, message)*, require an update - *update(agent-list,operation)*, and apply opportune metrics - *applyMetric(metric)*. The other two agents belonging to this layer are similar, as it is possible to argue by Table 2.1. All the instances of these three classes represent the atomic components of Folkview.

2.3.2 The Semantic Layer

The semantic layer is composed by the *Dimension* agents. A dimension is a semantic filter applied to the storage layer: it creates clusters of components, that share a semantic relation (a common meaning, an objective, an interpretation). A dimension can be represented as the union of labeled paths. The label expresses the semantic of the clusters identified. The dimension is the main component of each personomy/folksonomy. *Dimension Agent* $\mathcal{D}$ is shown in Table 2.2.

Dimension Agent $\mathcal{D}$
id meta label type components $\mathcal{F}$ ...
update(agent-list,operation) notify(agent-list,message) applyMetric(metric) ... . . .

Table 2.2: Dimension Agent

It is described by a unique *id*, a set of keywords *meta*, a semantic *label*, a *type*, a list of *components*. We identify three main types of dimensions: *structural*, *computed*, and *user-generated*: the first one regroups all the information contained in a traditional personomy or folksonomy; the second one is automatically computed by the system applying specific metrics, or collapsing edges and applying weighted label to the new edge, or using ontologies. Finally, the third typology of dimension is created directly by the user. We identify two typologies of components: atomic or composite. In the first case, *components* address a list of atomic (storage) agents, while in the second one, it addresses other dimension agents, generating more complex structures.

In order to avoid confusion among sets of items and dimension agents, we use the following notation: we indicate with T_r^u, R_t^u, and U_t^r respectively the set of tags applied by user u to resource r, the set of resources tagged by u with t, and finally the set of users that tagged r with t. Differently, we indicate with $\mathcal{T}_r^u$, $\mathcal{R}_t^u$, and $\mathcal{U}_t^r$ (we use a different font) respectively the **dimension agent** constituted by the set of tags applied from user u with the resource r, by the set of resources tagged by u with t, and finally by the set of users that tagged r with t. For example, consider the personomy related to user u_1 and, in particular, the 14 triples containing u_1 as first component. They can be represented by five linear paths containing the tags applied by user u_1 respectively on resources $r_1, \ldots, r_5$, as shown in Figure 2.5 (left). The five dimensions, on these five topological paths, are indicated respectively by

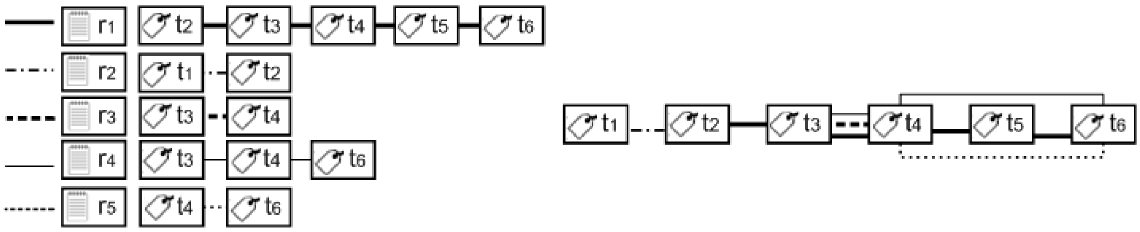


Figure 2.5: Topological representation of the components of 5 dimensions (left) and the corresponding personomy view (right)

$\mathcal{T}_{r_i}^{u_1}$, $i = 1, \ldots, 5$.

Figure 2.5 (right) collapses in a labeled multigraph the five paths/structural dimensions. They are created focusing the attention on tags, and generating relations with the other two components of the storage layer (users and resources). It is simple to argue that three classes of structural dimensions (focused on tags, resources and users) completely describe a static personomy/folksonomy.

Finally, the methods associated to a *Dimension* agent allow it to manage semantic clusters, contacting sending requests, and making aware their components and the same folksonomy.

2.3.3 The Social Layer

The social layer is composed by *Personomy* and *Folksonomy* agents.

Folksnomy $\mathcal{F}$ is unique within the social tagging system; it knows all the $\mathcal{P}$ agents, and contact them for assigning tasks to them; on the other hand, also all the *Personomy* agents know $\mathcal{F}$ and contact it for receiving information or simplify the coordination with other agents.

The social layer is devoted to collaborate with the semantic and the storage layers in order to i) recommend tags and resources, ii) infer knowledge about the user profile, her preferences, needs or skills and iii) identify similar users, resources or tags.

Different types of metrics are evaluated by both $\mathcal{P}$ and $\mathcal{F}$ agents, in order to calculate, for instance the average time spent by user to do a specific task; similarities among users, tag and resources; semantic relations on resource contents.

Table 2.3 contains the two agent classes. The *Personomy* agent manages the social activities of the user u, and knows her tags T^u, her tagged resources R^u, and dimensions $\mathcal{D}^u$. Each $\mathcal{P}$ is able to evaluate specific metrics $evalMetric(data, type)$ and strictly collaborate with other personomies. Each action is coordinated by $\mathcal{F}$. We may note that the social layer strictly interacts with the presentation layer; for this reason, $\mathcal{P}$ and $\mathcal{F}$ address both *Session* S and *View* V agents.

Personomy Agent $\mathcal{P}$	*Folksonomy Agent* $\mathcal{F}$
id meta u T^u R^u $\mathcal{D}^u$ $\mathcal{F}$ ...	id meta personomies ...
update(item,operation) notify(message) getItem(id,type) evalMetric(data,type) ...	update($\mathcal{P}$,operation) notify(message) getPersonomy(id) evalMetric(data,type) ...

Table 2.3: Personomy and Folksonomy Agents

2.3.4 The Presentation Layer

The presentation layer manages the interaction of users with the system, elaborates views on data, supports the authoring process, traces the user sessions. It is composed by two agent classes, *Session* and *View* agents (see Table 2.4).

Session Agent S	*View Agent V*
id meta user history $\mathcal{P}$ $\mathcal{F}$ V ...	id label type session components ...
evalRequest(agent-list,operation) notify(message)...	update(item,operation) notify(message) visualize(...) ...

Table 2.4: Session and View agents

Each session starts with *Session Agent*, instantiated on the specific *user*; it maintains the *history* of the interaction of the user with the system. A fundamental procedural skill is *evaluateRequest*: given a general list of agents and a specific operation the S evaluates it and interacts with the appropriate agents.
There are several operations that $\mathcal{S}$ handles and dispatches:

- apply changes to the structural agents: merge two or more tags, add, modify, delete tags and/or resources, change user personal settings or profile;
- apply changes to the *Dimension* agents: add, modify, delete dimensions;
- select personalized views: interact with the *View Agent V*.

Session Agent knows the personomy $\mathcal{P}$ of user *user* that generates the request, the *Folksonomy Agent* $\mathcal{F}$ and, finally, V.

The *View Agent V* is contacted by specific session agents and provide for them specific views.

Example of *type* are linear, star, m-extended views, discussed more in details in next Section 2.3.5.

Let now consider an example of a simple folksonomy, where $|U| = 3$, $|T| = 6$, and $|R| = 5$, and the *tas*, listed in terms of three personomies, are defined as follows:

- for the user u_1: (u_1, r_1, t_2), (u_1, r_1, t_3), (u_1, r_1, t_4), (u_1, r_1, t_5), (u_1, r_1, t_6), (u_1, r_2, t_1), (u_1, r_2, t_2), (u_1, r_3, t_3), (u_1, r_3, t_4), (u_1, r_4, t_3), (u_1, r_4, t_4), (u_1, r_4, t_6), (u_1, r_5, t_5), (u_1, r_5, t_6);

- for the user u_2: (u_2, r_1, t_1), (u_2, r_1, t_4), (u_2, r_1, t_5), (u_2, r_1, t_6), (u_2, r_2, t_1), (u_2, r_2, t_3), (u_2, r_3, t_4), (u_2, r_3, t_6), (u_2, r_4, t_1), (u_2, r_4, t_2), (u_2, r_4, t_3),(u_2, r_4, t_5), (u_2, r_5, t_4), (u_2, r_5, t_6);

- for the user u_3: (u_3, r_1, t_1), (u_3, r_1, t_2), (u_3, r_2, t_2), (u_3, r_2, t_3), (u_3, r_3, t_3), (u_3, r_3, t_4), (u_3, r_3, t_6), (u_3, r_4, t_2), (u_3, r_4, t_5), (u_3, r_4, t_6), (u_3, r_5, t_4), (u_3, r_5, t_6).

A common graphical representation is the tripartite graph shown in Figure 2.6: this organization of data does not provide the user with simple keys to the reading.

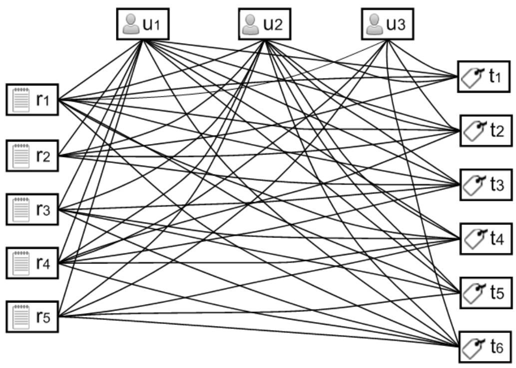


Figure 2.6: The tripartite graph for the folksonomy sample

In Folkview it can be drawn in a number of graphical representations more expressive contrasted with the Figure 2.6. An example of complete view of the whole folksonomy is given in Figure 2.7 where the union of the personomies is shown: this view provides a synthetic and semantic way to visualize a traditional folksonomy.

2.3.5 Visualizing and Authoring

In Figure 2.7 we recognize the labeled multigraph containing a zz-structure. As mentioned in the introduction of the chapter, these structures are particularly interesting to represent, store, link and manipulate different kind of data.

Zz-structures can be visualized in different customizable visualizations called *views*, such as H-view, I-view, star-view, m-extended star view, and also *view spaces*, as canvases, projection spaces, presentational fields and viewing tanks [Nel04]. Now, we show and discuss how a Session Agent may interact with the system in order to manage two different views (*H-view* and *m-extended star view*) and apply a *merge* of two tags into another one.

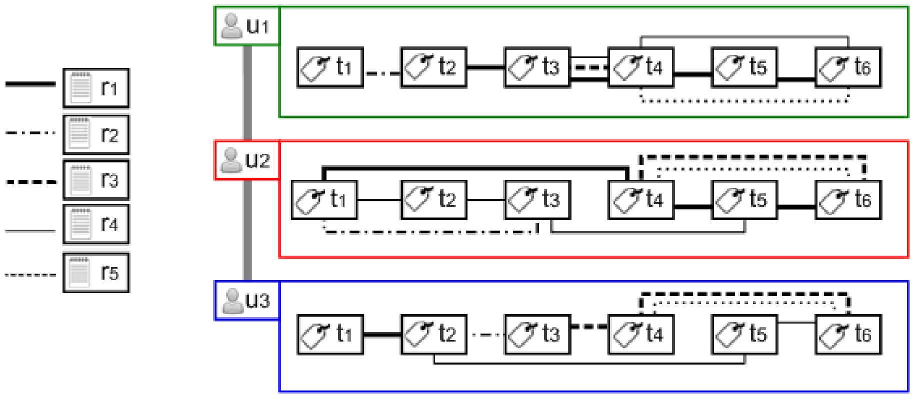


Figure 2.7: A folksonomy view in Folkview.

Suppose that the user u_1 selects a tag and requires the system to visualize a two-dimensional view focused on it and on two specific resources. Let be the tag t_4, the two specific resources r_1 and r_4, and the chosen two-dimensional view a H-view.

This task is managed by the Session agent related to u_1, S^{u_1}: it requires from the personomy $\mathcal{P}^{u_1}$ to contact the user dimensions (where t_4 has been used for tagging the resources r_1 and r_4) in order to obtain from them their components. The sequence of collaboration is the following:

$S^{u_1} \rightarrow \mathcal{P}^{u_1} \rightarrow (\mathcal{T}^{u_1}_{r_1}, \mathcal{T}^{u_1}_{r_4})$

The request is sent to $\mathcal{T}^{u_1}_{r_1}$ and $\mathcal{T}^{u_1}_{r_4}$ in multicast. As successive step, S^{u_1}, received the list of components (if the dimensions exist), sends to V^{u_1} the following request:

$S^{u_1} \rightarrow V^{u_1}$

evalRequest(V^{u_1}, $visualize(t_4, h\text{-}view, ((u_1, r_1)(t_2, t_3, t_4, t_5, t_6)), (u_1, r_4)(t_3, t_4, t_6)))$

In it, S^{u_1} specifies the focus node (t_4), the components (that are from $\mathcal{T}^{u_1}_{r_1}$, {t_2, t_3, t_4, t_5, t_6)} and from $\mathcal{T}^{u_1}_{r_4}$ {t_3, t_4, t_6}), and the type of visualization (h-view).

The result is the visualization shown in Figure 2.8 (left).

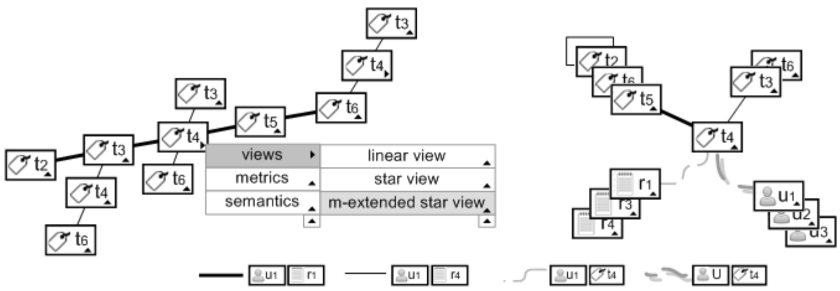


Figure 2.8: A *H-view* (left) and a *m-extended star view* on t_4 (right)

The presence of two black triangle symbols corresponds to the selection of the option (see the triangle used for the option *views*), and to the not selected option (see the other symbol, used for the other options): these triangles are associated to specific methods related to the Session agent, and represent the means to interact with the cell-agents. When selected, the session agent S^{u_1} asks and obtains, through the personomy agent $\mathcal{P}^{u_1}$, the set of methods that can be activated on it. In order to satisfy such a request, t_4 sends a multicast message to all the dimensions in which it is included, and a run-time created contextual menu, organized in three meta-categories (views, metrics and semantics) is shown. The first category is concerning the different kinds of possible *views*. The other two categories of functions are related to the computation of an extensible set of *metrics*, and to the application of opportune *semantic relations and ontologies* in order to generate, for example, specific recommendations on content, tag and user.

Following our example, the user selects the option *views* and then *m-extended star view*. The default value for m is 3, and indicates the maximum number of components visualizable for each different dimension.

The corresponding 3-extended star view is shown in Figure 2.8 (right). Compared to the H-view, the m-extended star view provides a deep insight of the various dimensions: in particular, we can note that the cell t_4 is connected to the following semantic paths (from the top-left corner in a clockwise direction):

- $T_{r_1}^{u_1}$, that it is the set of tags applied by u_1 on the resource r_1;
- $T_{r_4}^{u_1}$, that it is the set of tags applied by u_1 on the resource r_4;
- U_{t_4}, that it is the set of users that used t_4;
- $R_{t_4}^{u_1}$, that it is the set of resources tagged by u_1 with t_4.

Other features, not displayed in Figure 2.8, regard the possibility to dynamically change, at local or global level, the features of each agent, simply clicking directly on the visualized item and applying modifications. To this extent we can highlight that due to the agent-based technology the folksonomy grows and changes according to the user contributes, and then can be shared with the other users. While displaying dynamic views, the user will also be able to personalized her personal workspace, adding or removing dimensions, applying changes to her annotations and so on.

Consider now the situation in which a user, navigating in her workspace, has used two different tags (following our example, t_2=*web2-0*, t_6=*socialWeb*) with the same meaning. Or, equivalently, consider the situation in which the system automatically infers that these two tags are different writings for the same concept, and recommends her to substitute any occurrence of one of them with the other (for example, *socialWeb*) or with a new more popular tag (for example, t'=*social-web*).

If the user accepts to update her tags, then Folkview will manage this task activating a collaborative set of agents. A more general description of this task is the following: the system must merge a set of l tags $t_k^{'}$ $(k = 1, ..., l)$ into one tag $t^{'}$. It could (or could not) be that t'=t_k' for a given k.

It is conceptually equivalent to treat the l substitutions of t_k' with $t^{'}$ in a separate way.

Also in this case, the operations start from the Session Agent S^u and proceed in cascading style for generating the merge: S^u contacts P^u for delegating it of the merging task. In its turn, P^u will contact in multicast all the dimensions that address t'_k, that it is the set $\mathcal{D}^u_{t'_k}$. Received from each of them the list of involved storage agents (t'_k and $R^u_{t'_k}$), P^u directly will contact them for updating. Finally a request of update will be sent to the folksonomy $\mathcal{F}$. We note that the merge of tags is an update local to the user workspace, but the same P^u, ended the task, will require to $\mathcal{F}$ to make aware (=notify, or recommend) the other users of the choice made by u.

In this way, the sequence of collaboration is:
$S^u \rightarrow P^u \rightarrow \mathcal{D}^u_{t'_k}$
$P^u \rightarrow (t'_k\ ,\ R^u_{t'_k})$
$P^u \rightarrow \mathcal{F} \rightarrow \mathcal{P}^U$

Graphically, the topological representation of the personomy components shown in Figure 2.5 becomes that proposed in next Figure 2.9, where the involved tag and structural dimension are highlighted.

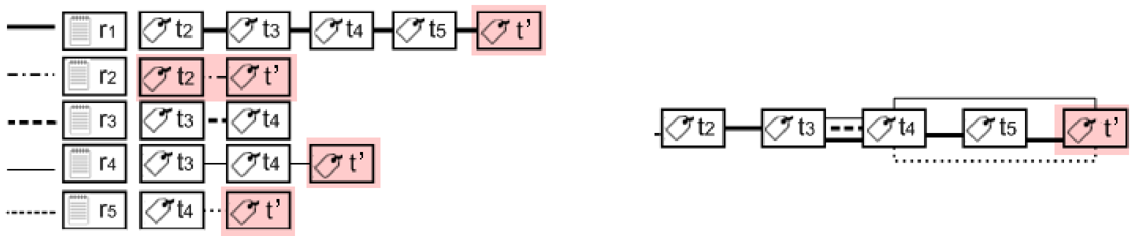


Figure 2.9: New topological representation of the components of 5 dimensions (left) and the corresponding personomy view (right)

The tags t_2=*web2-0* and t_6=*socialWeb* have been merged in t'=*social-web*.

2.4 Evaluation and Discussion

Pointing out that folksonomy definition and representations suffer from several limitations, in this chapter we introduced Folkview, an innovative way to conceive a folksonomy.In particular:

- firstly, we described the formal model through a framework built on different layers,
- secondly, we provided the description of dynamic views highlighting the interaction of the involved agents.

This approach allow us to tackle the issue concerning the traditionally passive definition of a personomy; we also shed light on interesting new modalities in visualizing and managing folksonomy.

Folkview can be used in order to

- simply display customized views;
- create personalized paths;
- modify the semantic associations between tags and resource

We design a simple prototype and we performed an informal participative user based evaluation. The *expected benefits* were:

- identify potentially usability problems before a development stage;
- understand in a deep way users' impressions about the system, with particular attention to the system usability, focusing in particular on the *understandability*, the *ease of use*, the *ease of navigation*.

The *methodology* of the evaluation consists in: a) planning the evaluation, b) running the evaluation session, and b) analyzing the output, as follows:

- *Planning*: we select the most important tasks to evaluate: (i) displaying personalized views and (ii) authoring; then, we select 5 users, considered as representative of the possible target user. They were all students, average age 23, with a medium-to-high experience in utilize web-based application such as delicious, flickr, and other social tagging systems; they already known what is in practice a folksonomy thanks to the typical tag cloud visualization, even if two of them did not know exactly the correct terminology. We produce a simple task scenario: starting from an existing folksonomy sample taken from delicious, we ask them to 1) *display a customized view* and then, 2) to *create a personalized merged tag.*
- *Running session*: after introducing the user to main functionalities of the prototype, having described in more detail what a folksonomy is, we gave them task instructions; we did not give any hints or assistance unless the user was unable to complete the task; we carefully observed the interaction and note any problems encountered. Users were allowed to freely tell their impressions, what they think different components may do, and what they expected as the result of their next action. Each user was also asked to suggest how prototype could be improved.
- *Analyzing the output*: we collected interesting insights about the prototype usability:
  - according to the task 1): in general, users highlighted that the system was pretty innovative and particularly easy to use and easy to navigate; only one user reports minor problems in understanding how interact with the folksonomy displays, and suggest a more evident icon for activate the contextual menu, compared to the proposed little triangle;

- according to the task 2): three users highlighted that the creation of a personalized new merged tag might be very useful along social annotating activities, and if social tagging systems were equipped with this feature, they would use them more frequently; two users report that task appeared quite difficult to accomplish, at the first time, but once it was understood, they felt comfortable with it.

The prototype evaluation reports no significant usability problems, but suggests the need for improvements in the system design, for instance through the design of more intuitive tags' editing and merging mechanisms.

Moreover, we point out that social tagging systems themselves may have too limited boundaries in terms of contents and contextual information. However, additional experiments are needed to validate this claim, which is based on collected user impressions.

Our purpose is to extend our model, based on a novel approach to conceive a folksonomy, and to apply it also to other case studies.

We intend to propose contextual multi-dimensional navigation mechanisms based on semantic interconnections, personalized views and authoring tools exploiting them in the heterogeneous field of mobile applications, considering its concomitant huge increase of that world with social application.

3

Mobile Guides for Tourism and Cultural Heritage

Mobile technologies, especially through the emergence of smartphones and applications, have become more and more relevant in the context of travel and tourism. Thanks to, on the one hand, a broadband Internet access, low cost mobile devices, affordable multi-service telephone rates, large viewing screens and to, on the other hand, increasingly more user friendly and multi-purpose interfaces, mobile applications have been rapidly adopted by the consumer market.

Tourism mobile applications have been initially developed as electronic versions of tourist guides, in order to provide tourists with information about points of interest; then they started to encompass increasingly advanced features aimed at, for instance, support efficiently accessible and personalized recommendations based either on the location of the user, past visited sites or activities of other potentially similar users.

During the last decade, crucial issues such as context-aware and user modelling in ubiquitous environments, attracted a lot the attention of research fields concerning mobile technologies and applications development: the number of dedicated international conferences, special issues and research studies has raised significantly, pushing innovative approaches and prototypes that, in some cases, have become concrete compelling applications, as time goes by.

Particularly, a significant effort has been made in providing tourism mobile guides with i) virtual/augmented reality [ACC+06, BC05, RKD10, Pie12], ii) hybrid recommendation service [VAWVH10, WSA+08, BBC+08], iii) social computing and navigation [CWY08, BFDL08].

Different surveys [BB03, GWP+08, KGE11] has deeply analysed the system of tourist mobile guide, according to different dimensions, as discussed for instance in [WX12]:

- information services, e.g. language assistant, flight manager, online travel agency, resort guide and theme park, food finder, single city destination guide, multiple city destination guide, live camera, entertainment, etc.;

- design features:

  - information models, e.g. personalized content, collaborative filtering, context awareness, etc.;
  - input/output mechanisms, e.g. voice input/output, 3D modeling output, interface design, user-interaction.

- network (thin client, thick client, intelligent client), positioning and mapping.

As a matter of fact, in parallel with the wide diffusion of tablets, smartphones, ipads and iphones, the number of tourist mobile applications has grown rapidly. These provide detailed information and interesting tours concerning towns, museums, shopping, attractions, services and more. Nevertheless, in most cases they do not offer customization or effective user personal workspaces, neither provide a semantic navigation nor allow users to create their own personal journeys (or if they do, this feature is rather limited).

The following sections discuss:

- after introducing *context* and its possible definitions, the analysis of features commonly supported by tourist mobile guides, with main focus on (i) contextual elements provided by the user model and the surrounded environment; (ii) typical features offered to users, highlighting in particular those devoted to personalize views and authoring information;

- the analysis of museum and cultural heritage mobile guides according to the following parameters: i) user personal space; ii) personalized content and views; iii) authoring tool; iv) contextual information and navigation.

3.1 Tourism Mobile Guide Overview

Early tourist guidance systems date back to the mid-2000s: hence they dealt with several limitations, they have to take into account both device (memory capabilities, battery duration, high cost for end-user) and bandwidth issues. Nowadays thanks to current mobile technologies (intended as both software and hardware capabilities) many of these problems have been overcome, but mobile application still suffer from different limitations.

In this section we analyse ten tourist mobile guides in order to provide a framework of the immediate past and current situation in this field, primarily focusing on the provided contextual elements and features.

To this extent, we try to provide a definition of what is meant by context. Indeed, the notion of context has been widely discussed in literature, mostly in the adaptive and mobile computing community research. There is not a unified definition of context though. A seminal work [SAW94] laid the foundations for the definition of context in the field of context-aware computing as a collection of changing and mobile environmental elements that surround the system. In particular, context is described in terms of user location, her/his proximity to resources and her/his social state. Claiming that context is more than a location, in the work [SBG99], it has been extended and modelled following two predominant dimensions: human factors, which are structured into three categories (the user's information, the user's social environment, and the user's tasks), and physical environment, organized into three categories too (location, infrastructure and physical conditions).

To this extent, we can also mention the Contextual Suggestion Track, proposed in the TREC annual framework, since 2012 [HC12]. The main aim of this contest was to search places according to a *given spatial and temporal context* and to personalize search results according to user interests. Leveraging on user profiles, geographic information retrieval, and thanks to the resources offered by the open web, users receive recommendations about interesting places and possible activities to do. In particular, each profile corresponded to a single user, indicating user's preference with respect to a particular attraction. Each *context* corresponded to a particular geotemporal location, including city, day of the week, time of day, and season (in order to simplify the task, the geographical contexts were very coarse-grained, i.e., an entire city). In more recent settings [HCPS+13, CTBD+14], thanks to additional geo-tools and services, as well as improved filtering and ranking processes, contexts encompassed all the available information, such as preferences, popularity, and proximity.

Another definition of context [Dey01] relies on the characterization of an entity, i.e. a person, a place, or an object, that is considered relevant to the interaction between a user and an application, including the user and applications themselves. Focusing on the user's task, this definition allow to consider any piece of information that characterize the situation of a user in an interaction as context.

Below, we propose the analysis of 10 tourist mobile guides, with particular attention to the gathered contextual elements and provided main features.

1) In the middle of 1990s, the pioneer prototype **Cyberguide** [AAH+97] or more precisely, as depicted by the authors, a family of prototypes, proposed an innovative approach for its time, foresaw how computing environments could release the user from desktop's constraints. The authors envisioned effectively possible scenarios for a mobile context-aware application such as, e.g., traveller personal assistant tools and guides, and applications able to support a group interaction on-tour or to enhance accurately recording and composition of a travel diary. They also empathized the role of contextual information in providing a better experience for the ubiquitous user. In particular, they focused on the importance of trace and store either the current location of the user and her past location history, in order to improve the type of services to offer to a tourist, specially compared with a real tour guide. Apart from technical mobile technologies limitations (both in terms of hardware supports and available software) that made this study especially compelling for that time, of considerable significance was the proposed architecture. It broke down into four independent but communicating components: i) a *map component*, ii) an *information component* devoted to provide descriptions about interesting sights and also

about people associated with them, iii) a *position component* responsible for charting and delivering precisely the location and the orientation of the tourist within the physical surroundings, and iv) a *communication component* aimed to deliver a minimalist messenger service among travellers. The iterative approach adopted for the prototyping had always taken into consideration the feedback of the user, thanks to informal surveys, formal questionnaires and field observations: to this extent, it was highlighted how functionalities based on knowledge of the user's physical context were useful, especially to facilitate later access to a rich record of the traveller's experience.

2) Another noticeable project was **GUIDE** [CDM+00], an intelligent electronic tourist guide of the city of Lancaster. Initial key requirements were identified by the authors in i) a *sufficient flexibility* that would allow visitors to explore freely and learn about the city as they wished, ii) the capability of provide users with a *context-sensitive information*, derived from personal and environmental context, iii) the support for *dynamic information* when the appropriate context was available, and iv) the support for *interactive services* in the form of electronic messaging service. The system based on a distributed architecture: user could utilize handheld units (similar to nowadays tablets) and the communication was carried out through a cell-based wireless infrastructure. Of major interest was the proposed built ad-hoc information model, designed by the authors who considered the existing models inadequate for representing all the gathered information. The model took into account geographic information by including special navigation points: each point of interest represented a specific location with several attributes, useful to provide dynamic and updated information. This particular innovative modelling allowed the authors to provide GUIDE with several compelling features for its time. GUIDE interface emulated the one of a browser, with a user-friendly appearance, in order to make the system more approachable to novice users. Once logged in, the user could perform several tasks such as i) *retrieve information* about the area in which she was, the weather, news, and events of the city, ii) *navigate* the city using the map (overview and detail), iii) *create and follow a tour* of the city , and iv) *communicate with other visitors* by sending messages. User evaluation was performed in-depth using two methods, i.e. a session of experts walk-through and an evaluation by field trial. The main objective were to discover problems within the interface, validate and refine the set of requirements against end-users: findings were extremely encouraging, highlighting a high level of acceptability of the system among a wide range of visitors. In no doubt, this work can be consider as a milestone in the research field of context-aware tourism mobile guide, from which several promising challenges have raised.

3) **LoL@** (Local Location Assistant) [PUM02] was a location-based mobile application for UMTS which implemented a tourist guide for users in the city of Vienna. The authors considered carefully both *technical* and *user interaction* constraints: the former were due primarily to low bandwidth of mobile networks, the latter, by the small screen size of mobile devices rather and general environmental constraints.

To this extent, the ambition of LoL@ was to be an efficient application that could meet the requirements of a tourist. The prototype considered three possible scenarios, i.e. *a walk through the city*, *the retrieval of sightseeing information* from a hotel room and *the access to personal and tour information* after the user have finished the tour itself. The location-based system allowed the user to know her position within a map showing the complete tour area and the most important Points of Interest (PoI), which in turn included several sights. Combining automatic user positioning and multi-modal user interaction with the interface (user may click on icons, hypertext links and buttons, select items from a menu and through spoken commands), LoL@ allowed a quite innovative method to determine a route through the PoIs of the city, letting subsequently the user access to her diary. The prototype was developed iteratively, following a semi-formal design and specification methodology that involved also domain experts in the interface design, and was realized by identifying several functional blocks. Interestingly, this approach was chosen in order to gather efficiently both engineers and user requirements and, at the same time, to define an accurate set of a tourist mobile guide specifications.

4) The context-aware tourist information system CATIS [PBAS03], leveraging Web services and XML technologies, provided user with significant adaptation capabilities. Its architecture encompassed several different components, e.g. a specific module that managed the *user's dynamic context* and *user's preferences*, a set of Web services delivering tourist content and, of major interest, a directory of services which provided users with a centralized registry of tourist information. The gathered context information allowed *different types of interface personalization and adaptation*: a location and time-based adaptation, the adaptation of the provided information based on the user's interests and service preferences (expressed explicitly by levels of preference and stored in the user profile), and lastly, depending on the characteristic of the device, such as for instance the content types supported by the client browser, the content was adapted into appropriate representations.

5) The mobile tourist application **COMPASS** [VSPK04] (COntext-aware Mobile Personal ASSistant) proposed the integration of a recommender system with a context-aware application platform. Observing how both context-aware systems and recommender systems are used "to provide users with relevant information and/or services", the authors developed a tourist mobile assistant leveraging mainly the user's location and user's interests. The architecture based on four main components. Firstly, **a set of third-party services** which encompassed: a *Network Services* module devoted to access capabilities (e.g. user identification, messaging, etc.), accessible via Web services and offered by mobile network operators; a *Context Services* module aimed to provide both user's context information, such as location as well as user's schedule, and environmental information, e.g. weather or traffic information service; a *Business Services* module, capable to offer information about Points of Interest (PoI). The second component consisted in the open *WASP platform* that provided generic support services, forwarding user requests to the appropriate underlying module. Particularly significant were the *context manager*, mainly

devoted to retrieve user's context information, aggregate it or derive new context, and the *service registry*, which contained information about third party services and also additional semantic Web, namely OWL, annotations of service elements. The authors highlighted the importance of such annotations in order to enable service providers to formally describe their services and to align them to existing ontologies. Another relevant component was the *matchmaker module*, devoted to manage requests received from the application and to filter out those services that did not match particular criteria (e.g. a certain radius from the location of the user). The third architectural component consisted in the *COMPASS application*. It exploited an *interaction manager* for assisting the interaction of the user on the client side application of the mobile phone, and a *POI retriever* that intermediated recommended items by the recommender service, with the matchmaker module. This component could also access directly to the profile manager which stored all the users' profiles (i.e. users's personal information, interests and ratings). The last fundamental element consisted in the *recommendation engine* which dealt with the prediction of interesting POI to the user, based on contextual factors, such as the last visit that a user made to a POI. In order to evaluate context-aware recommendations, the authors conducted an unsupervised online survey: starting from a given scenario, users were asked to evaluate the usefulness of both location and time-based recommendations. The analysis showed negative results for the perceived usefulness of time-based prediction, and in general empathised how users rather preferred to have more freedom in deciding crucial factors for PoIs' selection and recommendation. 6) **AccessSights** [KKB04] was a multi-modal mobile tourist information system that tried to overcome barriers for blind and visually impaired people. The main focus of this work was to support both blind and sighted users at the same time with the same tourist content, for each user group in their preferred modality. The authors analysed three main phases for tourists during their visit: an *orientation phase*, a *movement phase*, and an *information perception phase*. The project exploited the **Niccimon** platform [BBK+04], which provided several functionalities concerning location-aware services and consisted of several modules offering mobile navigation and orientation support (*GIS module*), a multi-modal interface, and location-based information and services (*Location* and *POI module*). AccessSights highlighted the need for a multi-modal information presentation and adaptation based on the user profile, focusing on the requirements of blindness people. To this extent, a specific auditory framework, namely AIR3DSound, was integrated allowing to present object such as PoIs and dangerous areas within the mobile guide as sound sources, aside from graphical icons. For instance, to distinguish different objects, different types of information were realised by different sounds, creating a virtual auditory environment that augmented the real world. The authors defined content in an independent modality fashion, combining information stored in XML files (user and device profiles), and operating dynamic adaptation through proper transformation languages such as XSLT. In this preliminary work, user evaluation lacked although the authors considered it of the utmost importance for further developments.

7) **MacauMap** [BA04] was a tourism-oriented mobile GIS application for the city of Macau that featured map navigation displaying the user current location. Originally designed for low-performance personal digital assistants and then released for Pocket Pc, it included a map viewing (overview and detail), navigation and searching functions in a bi-lingual (English/Chinese) interface and a set of predefined walking tour . Particularly interesting was the function for calculating optimal bus routes considering the user location and the public bus network and guides. MacauMap also provides sightseeing guides with information about museums, churches, temples, hotels, restaurants and other places of interest, along with their location on the map. This mobile guide included a unique function, called *My Favourite Macau* that allowed users to bookmark their favourite places in Macau which may not already be recorded in the MacauMap database, making it user-extensible.

8) **MultiMundus** [KTJ+07] was a location-aware and multimedia-enhanced Web-based guidance system which supported the visualization of exhibited objects and sights on different types of mobile devices. Content could be encoded in different presentation formats like video, audio, image, and marked-up text. The context of use encompassed a collection of properties describing the current environment of the guide (e.g. the capabilities of the consumer device, its current location, and the user's preferences). In order to increase interoperability both the content adaptation and presentation services were based on standard Web technologies. The guide was fed via a Web-based content management system (CMS) enabling a remote content administration (multi-language content storage and predefined special user profile association), and a statistics module for usage evaluations (complete user session log with daily, weekly, or monthly statistics on e.g., favourite/average content consumption, mainly used languages and profiles, average duration of sessions, and stopover times at certain objects of interest, etc.). As first evaluation, the system was introduced to Minimundus[1], an outdoor theme park in Klagenfurt, in June 2005. Evaluation results pointed out several critical aspects: the system was perceived as a high-end solution for some interested visitors, who want to consume more information than provided by commonly available catalogues and brochures. In addition there were two issues concerned to the use of mobile devices themselves: for instance, the life cycles of the battery were very short and many of the batteries used were completely unusable at the end of the season; moreover, the tourists to which were supplied devices have them sometimes damaged or completely broken. Despite these limitations, Multimundus could be considered an interesting attempt in exploiting multimedia contents, Web technologies and context-awareness.

9) **PSiS Mobile** [ALF10] was the mobile prototype version developed from PSiS [AFL+11], an adaptive tour planning support system based on tourist specific profile and available transportation system between different locations (in a preliminary phase, it has been limited to data from the city of Porto, Portugal). Basically,

[1]Minimundus GmbH, 2006. Die kleine Welt am Wrthersee. `http://www.minimundus.at`

the system was capable to collect knowledge about the tourists profiles, their travel history, and to gather users' feedback on accomplished tours. The objective was to create groups and stereotypes with peculiar interests and then to propose tours accordingly. The PSis Mobile project took into account also the tourist current context and nearby sight context in order to provide context-based recommendations. The system based upon a client-server paradigm: on the Web server all the main information like user profiles, history and similarity values are stored; the client is devoted to the user interaction, who can see a personalized generated route, eventually re-arranged according to her current context, and could also provide feedback about the visited place. In order to reduce the traffic consumption over the network and to allow the application to work without internet connection, this application was occasionally connected (smart client) utilizing a temporary database on the mobile device. To this extent, after requesting a recommendation for a trip, all the necessary data (all the information about nearby PoI) was transferred from the server and stored on the mobile device.

10) **e-Tourist** [JGL+] was a tour guide mobile application about Slovenia tailored to each individual tourist. The application gathered the tourist's main interests such as entertainment, active tourism, gastronomy, cultural and natural heritage, the available time, and any particular user requirement (e.g. mobility impairment). The guide is based on a common architecture: it utilized a Web server, where the application served tourists needs, and a relational database which stores the information about the tourist attractions, automatically converted into speech on the Web server. On the basis of this and other environmental data, e.g. weather, the date and time of visit, a specific touring program was provided to the individual tourists demand. Recommended tours are provided taking into account both similar user behaviours and the user's past preferences. User could comment a sightseeing and rate it, but cannot for instance create a personal path of visits.

Table 3.1 summarizes the provided survey of the ten mobile guides; in particular, we report for the User Model the presence of the following element: User Profile (UP), User History (UH), User Preferences (UPref), User Location (UL); for the environmental contextual elements: Time (T); Device Info (DI), other (Oth). We highlight the following considerations:

- concerning the *contextual elements* in user model: in most cases user model refers to a generic user profile with personal information; 2), 4), 5), 7) and 10) explicitly collect user preferences user interests; guide 3) does not take into account the user model;

- considering *contextual elements* within the environment: except the guide 10), all guides consider the user location as basis for provide content; the half of them (guides 2), 4) 8), 9), 10)) takes into account the current time and only two guides gathered information about the device.

Table 3.1: Comparison of the contextual elements gathered by the surveyed 10 tourism mobile guides.

	Mobile Guide	Contextual Elements						
		User Model			Environment			
		UP	UH	UPref	UL	T	DI	Oth
1)	Cyberguide, 1997 [AAH+97]	✓	✓		✓			
2)	GUIDE, 2000 [CDM+00]	✓		✓	✓	✓		✓
3)	LoL@, 2002 [PUM02]				✓			
4)	CATIS, 2003 [PBAS03]			✓	✓	✓		
5)	COMPASS, 2004 [VSPK04]	✓	✓	✓	✓			
6)	AccessSights, 2004 [KKB04]	✓			✓		✓	
7)	MacauMap, 2004 [BA04]							
8)	MultiMundus, 2007 [KTJ+07]	✓			✓	✓	✓	
9)	PsiS Mobile, 2010 [ALF10]	✓			✓	✓		
10)	e-Turist, 2012 [JGL+]			✓		✓		

Table 3.2: Comparison of the main features provided by the surveyed 10 tourism mobile guides.

	Mobile Guide	Main Features
1)	Cyberguide, 1997 [AAH+97]	People recommendation, later access facilities, messenger
2)	GUIDE, 2000 [CDM+00]	User adaptation, dynamic retrieval, messenger, authoring tool
3)	LoL@, 2002 [PUM02]	Location-based tour, later access facilities, messenger, vocal commands
4)	CATIS, 2003 [PBAS03]	User, location, and device-based adaptation
5)	COMPASS, 2004 [VSPK04]	Location-based services selection, time-based adaptation, PoI's rating
6)	AccessSights, 2004 [KKB04]	User and location-based adaptation, auditory augmented content
7)	MacauMap, 2004 [BA04]	Bus route calculator, new PoI insertion
8)	MultiMundus, 2007 [KTJ+07]	Location and device-based adaptation, multimedia contents
9)	PsiS Mobile, 2010 [ALF10]	Tour recommendations, plans re-arrangement, PoI comments and ratings
10)	e-Turist, 2012 [JGL+]	Personalized tours recommendations, comments, ratings

Table 3.2 summarizes the offered features, which are slightly different. The majority of the guides provide location-based content adaptation; noteworthy, only guides 2) and 7), propose very simple authoring tool.

The following section concentrates on mobile guides dedicated to museum and cultural heritage settings.

3.2 Museum Mobile Guides Overview

Within tourist mobile guides, those dedicated to museums have played a significant role both in research fields (location and context-awareness [RTA05, LC04, HSK09], interactive games [GSS09] augmented-reality [DCB$^+$08, SW05]) and commercial settings.

In spite of the increasing demand by users to create and manage personalized collections, tours and visits in online museums as surveyed in [Mar11], museum mobile guides still remain under-exploited.

According to our primary goals, i.e. enabling users with both personalized spaces and own tours authoring features, we identified the following main issues:

- *User personal space* (**UPS**): within their personal spaces, users may store personal preferences, itineraries and share them among the social Web applications; in particular we considered:
  - *the user's history and preferences*, e.g.: top rated items, top visited elements, list of preferred items, number of sharing per item and/or tour (in presence of social support) etc.;
  - *social support features*, e.g.: possibility to add, and connect with, other "social" accounts, to share an element (object within a collection, event or news) among the list of defined social Web applications, etc.
- *Personalized content and views* (**PV**): profiling the users means to filter the content based on users' behaviour and preferences, and customize views accordingly;
- *Authoring tool* (**AT**): authoring tools enable users to define or create own personal tours, e.g. among items of museum collections, connecting them with special exhibitions or up-to-date events.
- *Contextual information and navigation* (**CIN**): the navigation is often predefined and the users cannot choose alternative and contextual ways of browsing the information. In order to overcome this restriction, it could be interesting to provide each view/object with semantic information able to correlate it with a set of other views/objects.

Considering **USP**, **PV**, **AT** and **CIN**, we analysed museum mobile guides showed in Table **??**. This list has been selected among the 50 top visited museums worldwide[2] according to i) their availability both on Google Play and Apple Store, ii) the number of downloads (more than 1.000), and iii) the average rating (greater than 2, on a scale from 1 to 5 stars, when applicable). Each guide, except those available for Apple products only, has been downloaded and tested on two smartphones (Samsung Galaxy S II with Android 4.1.2 and on iPhone 5 with iOS 7) and on two tablets (Asus Nexus 7' with Android 4.3 and iPad 2 with iOS 6). It is worth noticing that this survey dated to September 2013, and it is a partial extension of the work proposed and published by the author in [DPOU14].

For each guide, we first investigated basic features and provided contents, then we analysed them along **USP**, **PV**, **AT** and **CIN**.

1) **Musée du Louvre Audio Guide** [3]. It provides descriptive information about the museum in general, temporary exhibitions, informative audio explanation about a set of items within the museum collection, and an interactive map that allows users to know where he/she is located within the museum. The guide proposes a predefined tour, e.g. among the so-called "Masterpieces" or "must-sees" (CIN), avoiding the authoring of personal own tour (AT): indeed, the user could only choose among museum elements using a map or a list and then listen to experts' commentaries. Possible tasks are very limited, due to a content presentation lacking of connections to neighbouring elements: the map shows only the position of an element and cannot be accessed from other points in order to allow user to freely navigate through the museum and creating her personal virtual tour. Neither a user personal space (USP) nor user-based personalized views (PV) are provided.

2) **Metropolitan Museum of Art Navigator** [4]. The guide provides general information about the museum, exhibits and collections. The navigation is contextualized to the floor plan as well as the categories witihin exhibitions (CIN). Given an exhibit, user may visualize her position into the map, but any connection with interconnected elements is missing. Moreover, if a user clicked on a specific area on the map, the guide would not link to a related section, as expected. Users may also navigate through the proposed collections though informative descriptions about a single piece of art are quite poor. In general this application does not allow any user personalization (PV) and any support in the creation of a personal space (USP) is lacking completely.

[2]Visitor Figures 2012. Exhibition & museum attendance survey. The Art Newspaper. `http://www.theartnewspaper.com/attfig/attfig12.pdf`. Last accessed: September 2013

[3]Musée du Louvre Audio Guide (Paris, France). `http://www.louvre.fr/en/louvre-audio-guide-app`

[4]Metropolitan Museum of Art (New York, USA). `https://itunes.apple.com/us/app/metropolitan-museum-art-navigator/id646999872?mt=8`

3) **The British Museum Virtual Museum, VUSIEM** [5]. The free available version of this guide offers a set of few basic and informative functionalities about the Ancient Egypt. Here the user could navigate through a list of galleries and visualize a static map for each ground where clickable areas allow to visualize the sculptures presented inside that particular room. Descriptive insights are given for each artefact (CIN) and user can share it through social applications (Facebook and Twitter) and select it as a favourite element (UPS). Despite these attempts in user involvement, a personal space where the user can access and, for instance, revise the list of their favourites, lacks completely. Full version, beyond providing richer information about the complete collection (interactivity maps and interactive views) allow users to create own tours (AT) and to visualize the list of favourite elements. Nonetheless, user-based personalized views (PV) are not provided.

4) **Love Art: National Gallery** [6]. The app contains detailed information about the museum's artworks, including video, audio, zoomable high-resolution images, theme groupings and image galleries The contextual navigation is quite limited (CIN): user may navigate through a simple item list or visualize particular insights of the selected item. There are any personalized views (PV) and a user cannot carry out any other personalization (UPS) or author a personal path (AT).

5) **Vatican Museum** [7]. This application provides rich contents in terms of informative descriptions, high quality images and audio commentaries, nevertheless the user is limited to explore the provided navigation system (not PV) without any possibility of personalization (USP) or authoring feature (AT). The user is introduced to the museum through an interactive map where he/she may choose a specific area to visit: the navigation is contextualized to each museum's area, mapped on a specific colour (CIN).

6) **National Palace Museum** [8]. The application provides several generic information, providing visiting information, opening hours, ticket pricing, guide services, news, film schedule and information on different exhibitions. For each artwork it is possible to see detailed information, and, for some of them, engaging 3d interactive video are provided. User may also learn about history through a timeline, and a learning center, with simple games. Unfortunately, despite these compelling interactive features, user is not allowed to create a

[5] Vusiem British Museum (London, UK). http://www.vusiem.com/apps/vusiemBM.htm

[6] Love Art: National Gallery, (London, UK). https://itunes.apple.com/app/love-art-national-gallery/id314566159?mt=8.

[7] Vatican Museum (Vatican City). http://www.italyguides.it/us/roma/download_audioguide/free_ipod_mp3/vatican-museums-iphone-app.htm.

[8] Taiwan's First Artifact Interactive App (National Palace Museum Taipei, Taiwan). http://www.npm.gov.tw/en/Article.aspx?sNo=03004431.

own tour (AT) and there are no personalized views (PV). A real personal space is missing (USP) even though user may specify her/his preferred items and share them on social networks. User may navigate through the museum's map with exhibition information or experience location-aware navigation on museum campus, at least (CIN).

7) **National Gallery of Art** [9]. The guide provides collection highlights, Kid's tour, events and exhibitions information, and Visitor Information. Starting from the collection highlights, a user may choose among nationality, artist, and theme sub-section following a specific classification criteria. Information and navigation are contextualized to the choose element, (CIN). A user may select an historical period and nationality, and then choose an artwork to discover more detailed information. Unfortunately, clicking on the map, only the position of that item is shown, and not allowing for instance to select other sensitive areas. Moreover the guide does not allow any personalization (PV), user cannot select a list of preferred items or create own paths (AT).

8) **Centre Pompidou** [10]. Users are introduced to current events and may navigate through a simple menu among the current exhibitions or within a selection of the museum's collection providing images, video and audio support. Contextual to each single painting, a user could discover all the connected artists (CIN). Users do not benefit from a personal space (USP) and personalized views are not provided completely (PV): they may share each item on social networks but they are not allowed either to select a favourite item or to create a personal path of visit (AT).

9) **Musée d'Orsay** [11]. The multi-lingual mobile guide of Musée d'Orsay provides users with an up-to-date set of events (exhibitions, guided tours, lectures, music, films in the auditorium, etc), a dedicated page to few videos, the artefact collection and a screen about general information. The guide is very poor both in content (e.g. lacking of a map, descriptive information about objects, etc.), contextual information (CIN) and navigation capabilities (PV). Moreover, users cannot author an own tour (AT) rather than define a set of favourite item or manage a personal space (USP). Noteworthy, what further exacerbates the low quality of the guide is the fact that it always crashes when a specific item of the collection is selected.

10) **National Museum of Korea** [12]. This guide consists of a series of audio commentaries classified according to two main different exhibitions which followed

[9] National Gallery of Art (Washington DC, USA. http://www.nga.gov/content/ngaweb.html.

[10] Centre Pompidou (Paris, France). https://itunes.apple.com/us/app/centre-pompidou/id389191295?mt=8

[11] The Musée d'Orsay application (Paris, France). http://www.musee-orsay.fr/

[12] National Museum Of Korea (Seoul, South Korea). https://play.google.com/store/apps/details?id=dht.national&hl=en

an historical path. Though it presents links to other applications concerning several specific national museum, it is quite poor both in content and navigation. User can only select an item within the floor map and listen to the audio content, but she/he is not allowed to select a preferred item, or share it. User is not able neither to manage a personal space (USP), nor to author a personal tour (AT), and there is not the possibility to personalize views (PV). There is any contextualization to insights or related items but the navigation is limited to the list of artworks proposed within the floor plan (CIN).

11) **State Hermitage Museum** [13]. It provides detailed general information about the museum's history, its events and exhibitions, allowing users located in the city of St. Petersburg to get directions to reach the museum. The user may navigate through the complete catalogue which encompasses rich descriptive content artefacts (there are twelve distinct categories) visualizing an accurate map for each floor of the palace (unfortunately the guide does not support geolocation service). Of major interest, the user has the possibility to add further contents into the catalogue (PV), which can be downloaded for free or bought from the store, such as virtual tours (e.g. panoramas that allow animation and provide dynamic and continuous 360 views), educational courses and thematic excursions. User can create simple own collection of her favourite elements (AT) and share them through social application, creating a limited personal space (USP). Considering contextual information and navigation, users may follow the catalogue classification, select a specific item, and then discover its position within the floor plan (CIN). There he/she may discover to which exhibition area correspond any room of the floor, but unfortunately, there are no explicit interconnections with related items.

12) **MoMa Mobile** [14]. Beyond a calendar of events and generic information about ways to reach the museum, admission, ticketing, and audio commentaries, this guide mainly provides descriptive information about artwork collections and special exhibition. A user may select the element he/she preferred choosing the floor, or may input a number of an exhibited piece of art in order to listen the corresponding audio content. In the former case, the navigation is not personalized completely (PV) and lacking of any contextual navigational support (CIN) (e.g. there is any breadcrumb showing the carried out steps and due to the lack of a map, it is quite difficult to recognize the position of the user among the floor plan); in the latter case, user shall know exactly the number of the artwork whose interested in (otherwise, typing a name of an artist or the title of an artwork, unexpected crash results are caused). This

[13] State Hermitage Museum (St. Petersburg, Russia). `https://play.google.com/store/apps/details?id=org.hermitagemuseum`

[14] Moma Mobile. The Museum of Modern Art (New York, USA). `http://www.moma.org/explore/mobile/index`

mobile guide does not support any personal user space (USP) and a user is not able to author his/her personalized tours (AT): actually, even the possibility of defining favourite elements is not possible.

13) **Museo del Prado** [15]. The official guide to the Museo Nacional del Prado is available in eight languages, exclusively for a fee. It provides visitors with about 400 pieces of artwork, which are organized contextually by artistic school and chronologically within each school. For each item, high-quality images with accurate descriptive information are provided. Users may follow among five contextualized thematic tours (CIN): however, beyond receiving suggestions for preparing a visit, a user has not the possibility to author a new tour (AT), save and share it, and manage a personal space (USP). Users' preferences are not considered for personalized views (PV): a visitor can only select the articles of major interest through a basic "favourites" function.

14) **National Portrait Gallery tour** [16]. Users are introduced to the museum through a navigation menu which provides highlights of the Gallery's Collection, floor plans, and general information about the Gallery (opening hours, information about Gallery's shops, restaurant and caf). The navigation is contextualized (CIN) to proposed themes (Kings and Queens, Science and Discovery, Fames and Celebrity, and Writers): the user may select a portrait, zoom in for a closer look, view detailed information and check its position. Beyond such interaction, users are not allowed to express their preferences (PV), create a own path (AT) or manage a personal space (USP).

15) **Uffizi Touch** [17]. This recent app, which provides particularly high resolution images, allows users to navigate the Uffizi Gallery app following four main sections: masterpieces, periods, rooms and artists. Hereby, the navigation is explicitly contextualized thanks to the Visual Tour, offering users to visualize other pieces of artwork semantically related (e.g. landscapes, jewellery, etc.). Moreover, the interface changes accordingly to the user past behavior (already visited rooms) and her/his position within the museum. (PV). Up to now, user is not allowed to manage a personal space or to create a personal path (AT).

16) **National Museum of Scotland** [18]. The guide allows users to explore the museum through an interactive map, to discover particular details over few collection' elements, as well as providing information about the building and

[15] Museo del Prado (Madrid, Spain). http://www.laguiadelprado.com/EN/index.html

[16] National Portrait Gallery, (London, UK). http://www.npg.org.uk/visit/apps.php

[17] Galleria degli Uffizi (Florence, Italy)https://itunes.apple.com/it/app/uffizi/id365912485

[18] National Museum of Scotland, Highlights (Edinburgh, UK). https://play.google.com/store/apps/details?id=com.xdesign.nmos&hl=en

exhibitions. Users may choose a specific point indicated on the map in order to visualize it and share on social Web (Twitter and Facebook account). Both contents and navigation appear rather limited: for each item, there is only one image, no audio commentaries and few descriptive textual information, and any contextualized information to connected contents is missing (CIN). Moreover, there is not the possibility to author a personal path (AT) or manage a personal space (USP), besides the sharing buttons.

17) **QAGOMA** [19]. This application includes highlights of exhibitions, calendar events, programs, tours and events, general information about the Gallery including hours, floor plans and directions. User may navigate through interactive tours about artworks, including videos, artist interviews, and screencasts. The navigation is contextualized to the selected collection (CIN): once a user choose a specific collection, she/he could visualize details, and then the list of connected artworks. Maps display interactively the locations of the artworks within the Gallery, also for already past exhibitions. Unfortunately, user cannot author a personal path (AT) or manage a personal space (USP), and views are not personalized completely (PV).

18) **Secrets of the Doges Palace of Venice** [20]. This application shows the Doge's Palace in Venice, formerly the Doge's residence and seat of the Republic of Venice. Users may visualize some insights and curiosities on historical information about the Palace or the city of Venice or navigate through a contextualized set of itineraries, mainly based on the intended use of a specific wing of the building (CIN). In-depth descriptions of the must-see rooms within the floors of the Palace, as well as unusual tips, could enrich the visit of the tourist, who has full availability of a geo-location map. Beyond these descriptive features and basic support in the case of an in-place trip, this application does not support in any other form the user (USP), who cannot author an own path of visit (AT), or select a preferred item and share it. Moreover, she/he cannot benefit from any personalization of the proposed views (PV).

19) **Guggenheim Museum** [21]. It provides users with descriptive information on more than 1200 work from the museum collections and accurate audio, video, and photographic documentation for selected exhibitions. The free available version provides a limited user personal space (USP), which takes into account a space for customized favourites and the possibility to share works among the Web using user personal social accounts (e.g. Facebook). Despite the huge amount of data necessary in order to utilize the application correctly

[19] Queensland Art Gallery QAGOMA (Brisbane, Australia) `http://www.qagoma.qld.gov.au/visiting-us/itours`

[20] Secrets of the Doges Palace of Venice (Palazzo Ducale, Venice, Italy). `http://palazzoducale.visitmuve.it/en/il-museo/multimedialita/applications/` (last accessed: September, 2013).

[21] Guggenheim App (New York, USA). `http://www.guggenheim.org/new-york/visit/app`.

(the number of required downloads is about five, and each download demands from 50 to 80 Mb of free space on the device) personalized views are not provided in a very limited way: users could only manage own guides choosing which contents to download. Nevertheless, for each object, related contents and descriptive multimedia insights are provided, enriching the navigability of the application. Noteworthy, navigation and information are contextualized (CIN) to i) the view of the artwork, ii) the artist, iii) the artwork date, and iv) the artwork type. However, only membership account, available for a fee, allow users to have an easy access and manage advanced personalization as personalized tours (AT) and contents.

20) **Kunsthistorisches Museum** [22]. This mobile application allows users to choose favourite objects and learn details about the museums artworks. A variety of features enable users to share (per mail, via social applications, etc.) both objects of the museum and special exhibitions. Despite the possibility to play with the visualization of objects as a matrix, the navigation does not follow a contextualized path (CIN), which remains instead static and without the possibility of any user-based personalization (PV). Unfortunately, the user cannot define an own personal path of visit (AT) and has not a personal space to manage.

The provided survey, gives us interesting insights, useful for our purpose in providing rich contextual navigation and information to tourists. To summarize, concerning general features and contents, we state that:

- all the guides contain information about the museum, such as (i) temporary exhibitions; (ii) up-to-date calendars events; (iii) high-quality images of the art collections; (iv) rich descriptions; (v) informative audio explanations or curator' commentaries;
- guides 5), 6), 9) and 19) contain videos;
- guides 6) 10) and 11) provide users some simple games.

But, considering our parameters, we encountered several limitations as depicted schematically in Table 3.3. In particular:

- guides 9), and 10) do not provide any of our investigated features;
- *UPS*: a total of six guides support user personal spaces in terms of storing preferred items 13); social support 6) and 15); both of them features - social support and preferred items - are provided by guides 3), 6), 19) ;
- *PV*: only guides 11), 16) and 19) partially support personalized content and views through extra down-loadable components, or in a quite limited manner;

[22]Kunsthistorisches Museum (Wien, Austria). `http://www.khm.at/en/explore/media/app/`.

Table 3.3: Comparison of 20 museum mobile guides along the four assessed characteristics (USP, PV, AT, CIN).

	Mobile guide	UPS	PV	AT	CIN
1)	Louvre Audio Guide				✓
2)	Art Navigator				✓
3)	VUSIEM	✓		✓	✓
4)	Love Art				✓
5)	Vatican Museum				✓
6)	Taiwan National Palace Museum	✓			✓
7)	National Gallery of Art (Washington DC)				✓
8)	Centre Pompidou				✓
9)	Muse dOrsay				✓
10)	National Museum of Korea				✓
11)	State Hermitage Museum	✓	✓	✓	✓
12)	MoMa Mobile				
13)	Museo del Prado	✓			✓
14)	National Portrait Gallery				✓
15)	National Museum of Scotland	✓			
16)	Uffizi Touch		✓		✓
17)	GoMA				✓
18)	Secrets of the Doges Palace				✓
19)	Guggenheim	✓	✓	✓	✓
20)	Kunsthistorisches Museum				

- *AT*: three guides, namely 3), 11) and 19) support AT for the creation of personal tours within the museum;

- *CIN*: all the guides but 9), 12), 15), 20), offer differentiate typologies of CIN, as follows: in 1) the user may visualize the so-called masterpieces, discovering their floor position, and following the must-sees tour; in 2), 10), and 11) navigation is contextualized to the floor plan as well as the exhibitions categories. However, any connection with related elements is missing; in 3) and 4) a very limited contextual information is provided by artifact insights; in particular, in 4) the contextual navigation is quite limited to a simple item list rather than particular insights of the selected item. In 5) the navigation is contextualized to each museum area, mapped on a specific color; in 6) navigation is contextualized to the item's position within the floor plan map; user may visualize related information on a historical time-line. In 7) the contextual information is given by the nationality of the artist and the artistic theme: user may select an historical period, nationality or theme, and then choose related artworks. In 8) users can discover all the artists contextualized to each painting; in 13) and 14) users may navigate among a number of predefined contextualized thematic tours. In 16) users benefit from an explicit contextualization of elements, due to a visual tour; an interactive, but limited, collection tour allows user to contextual navigate through the museum in the guide 17). In 18) users navigate through collections, and can select insights or related artworks and related interconnections with other elements; in 19) users can interact by selecting informational tool-tips about a specific exhibition on the museum's map, in order to discover additional information about it, and navigate through a path of multimedia contents.

3.3 Summary

In this chapter we have provided a deep analysis of several different mobile guides in the field of tourism and cultural heritage.

Despite the recently enormous wide diffusion of mobile systems and devices, and of tourist mobile applications in general, even if they provide tourists with rich information about services and events rather than predefined tours within cities, towns, museums, cultural heritage sites, etc. in the majority of the cases, they share the same drawbacks:

- not offering customization neither personalized views;
- not managing dedicated user personal spaces, or in affirmative case, they are rather limited;
- not providing semantic navigation in terms of possible different contextual dimensions;
- not providing authoring tool that enable users to add their preferred tours or to create new travel plans.

As observed, current limitations of both tourist and museum mobile guides, push forward for further investigations and novel solutions, that we discuss in the following chapter, proposing a novel contextual model for a tourism mobile application.

4

TOGO: a Contextual Tourism Mobile Application

Leveraging limitations of current tourist and cultural heritage mobile guide previously discussed, in this chapter we proposes TOGO [DPOU12, DPOU14].

TOGO is a general contextual model for a tourist mobile guide, and a prototype dedicated to Palazzo Coronini Crönberg, the residence of the last count of Gorizia [1], Guglielmo Coronini, and its historical and artistic patrimony put together in the centuries from his family (furnishing, pictures, sculptures, archives, library and collections). We show that TOGO:

- offers contextual and semantic navigation on the data;
- introduces user personal workspaces and manages user profiles;
- enables users to create and share tourist personal paths.

In order to achieve these objectives, special attention is given to identify an advanced model for structuring data, and to maintain the users' navigation history, their contributions, and the evolution of their profiles.

Below we present our framework, describing the structure of the contextual knowledge base and the user model specification. Then, we propose two use cases dedicated to i) user navigation and ii) new personal path authoring. At the end of the chapter, we discuss the analysis results deriving from the user evaluation.

Considering an incremental evolutionary development approach, we develop:

- A first prototype based on Flash technology, Action Script language programming, and XML semi-structured database; its implementation has been important for testing the abstract model and for studying innovative approaches to dynamic paths and authoring in the field of mobile guides. Its implementation represented a test-bed for validating the abstract model and the basis for further work. A first interactive demo has been presented in Gorizia in the occasion of the Researchers Night 2011, an event that occurs annually on the fourth Friday of September all over Europe; a second interactive demo of

[1] TOGO indicate that the model and prototype is dedicated TO the town of GOrizia

the revised prototype has been proposed for user evaluation in May 2012 in Gorizia, in the occasion of èStoria, the 8th international history festival.

- A final version based on HTML 5 and native codes for mobile platforms. The new prototype is a complete tourism guide that compromises all interesting sites of a city (our case of study remains Gorizia), extends the tier-layer of our framework in order to support user recommendation, harvest complex relationships among items, and enhance social aspects.

4.1 The TOGO Architecture

Our framework relies on a client-server architecture; it has been developed following a Model-View-Controller design pattern as shown in Figure 4.1.

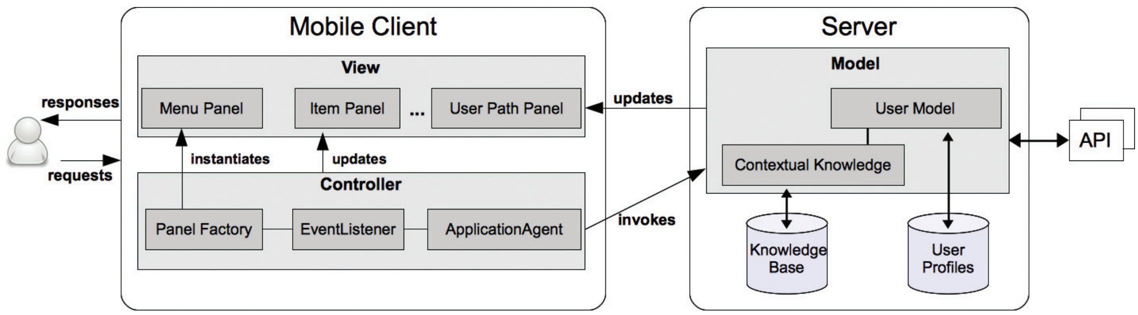


Figure 4.1: The TOGO architecture.

Following the schema depicted in the above figure from left to right, the main components of our architecture, distributed among server and mobile client, are:

- *View*: this component gives a graphical interface to Controller and Model activities. View implements different screen panels, one for each type of content (e. g., Menu Panel, Item Panel, etc.). Particular attention has been given to those panels aimed to create, edit and display users customized views.

- *Controller*: this component mediates between the Model and the View. It has been organized in terms of a multi-agent system (MAS), able to receive the user (and system) requests and manage them in order to carry out the appropriate actions. Whenever the EventListener receives a request, a dedicated class of Coordinator Agent detects the ApplicationAgent able to elaborate it. The result of this process is managed by the PanelFactory that, with the necessary parameters, sends the response to the View. The choice of a MAS guarantees autonomy, local views, ubiquity and distribution.

- *Model*: it contains not only data and knowledge, but mainly a set of methods. Data are organized in two separated datasets, Knowledge Base (KB) and User

Profiles (UP), which collect respectively the items concerning the museum domain collection, and the user profiles (her chronology, her preferences, her features, etc.). This data are properly aggregated and structured by: (a) the Contextual Knowledge (CK) that, using specialized methods and the zz-structures data model, transforms information in semantic knowledge; (b) the User Model (UM) that simplifies the users' navigation, enabling them to create personal paths and manage their workspace. Specific methods allow the Controller to query and retrieve data both from the UP, due to a package devoted to the user management, and from the KB thanks to a set of classes concerning the museum domain collection.

Below, we deepen the discussion on the content of the knowledge base, the semantic organization of the contextual knowledge and on the user model specification. Then we describe two scenarios related to a multi-dimensional navigation and to the authoring of new paths.

4.1.1 The Knowledge Base

The KB contains entries related to historical and artistic patrimony (furnishing, pictures, sculptures, archives, library and collections) of the Coronini Crönberg Palace. These have been carefully modeled working with cultural heritage experts and by extending previous classification at a high level of specification. Though this has been a time-consuming process, it has a twofold advantage: it allowed us to define a customized, proper and effective data structure suitable for manipulation and querying, and to create a structured KB reusable in future extensions and applications. The KB has been stored in a XML semi-structured database, which is conform to a specific DTD definition. In this preliminary phase of study and testing, we chose XML (rather than a standard database) because we privileged the role of meta-data, and the interoperability. The KB contains 14 rooms on two floors, 11 representative cultural heritage categories, for a total of more than 3000 classified objects. The categories are paintings, sculptures, prints, ceramics, coins, miniatures, jewelry, silverware, clocks, fans, laces and weapons. All the items share a common data structure layer which has been depicted by the following attributes: a unique nomenclature, a list of pictures, the room in which they are situated, the position within the room (related to the image plan representative of the floor), a textual description, a historical perspective description, the category to which the items belong and a curiosity description. For each element we have also identified three different kinds of tags, used both for descriptive purposes and for creating connections among the items: the primary tags represent qualifying features of the element (such as the element name, or its category); the secondary tags are extracted by the element description (such as its position, or historical info); the referential tags refer to links to other elements. This annotation schema allows us to have a rich description of the elements useful both for implementing the search algorithm, and for inferring semantic interconnections between different objects.

4.1.2 The Contextual Knowledge

As deeply discussed in previous chapter, generally, cultural heritage virtual tours based on mobile guides, suffer from a rigid navigation. In order to overcoming this issue and provide new, advanced, and contextual navigation, we based the TOGO information and navigation model on zz-structures.

An example of zz-structure is the edge-colored multigraph proposed in Figure 4.2. The nodes, *zz-cells*, represent rooms and objects of the Coronini Museum, and the colored (labelled) edges define semantic relations among rooms and objects. Looking Figure 4.2 from top to bottom, we see the dimensions (the one-color sub-graphs) plan, painting, sculpture, room, furniture, and silverware, that link respectively two floor plans, the paintings present in two rooms (c_1 and c_2), the sculptures, the rooms on the floor, the furniture, and the silverware. The ranks are specific sub-sequences in a dimension: so, for example, all the paintings present in c_1 (the room Atrio/Hall) constitute the rank *painting_of_Atrio* of the dimension painting.

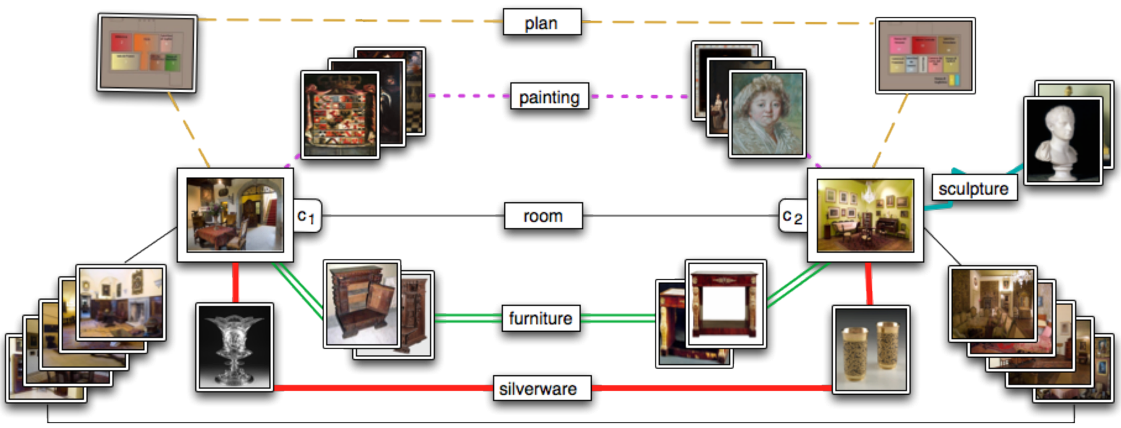


Figure 4.2: A Multiple starview

Alternatively, we can interpret the same picture, focusing our attention on the left part of it; we note that the cell c_1 represents the central node of the so-called *star-view*, which connects this room with all the contextual information related to it. In this way, from c_1 we can simply reach all the semantically connected information; different colors and labels identify it. The users can follow any interesting information on paths created by themselves or by other users. Analogous discussion may be repeated for c_2.

So, each dimension has a specific meaning related to the museum domain: we define a *zz-dimension* for each of all the categories identified (painting, sculpture, print, etc.), for each of the two floors of the museum and for the park. We note that in our application users can create zz-structures in a flexible way: each dimension can contain one or more ranks and the logic mapping of ranks and dimensions can be interchangeably arranged. The semantic of each dimension can be opportunely defined and associated to specific methods of software agents: for example, we defined a meta-dimension, called *view*, that links each cell with its content (description, position on the plan, history, curiosity, semantic connections, etc.).

In our prototype, the instantiation of the zz-structure containing our case of study is made following the flow described in Figure 4.3.

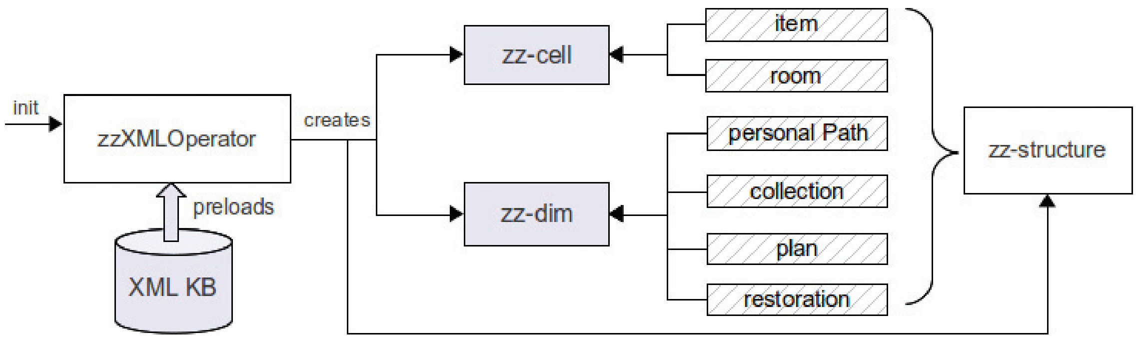


Figure 4.3: The Zz-structure instantiation

The agent `zzXMLOperator` pre-loads the XML Knowledge Base, organized in terms of XML file containing the 'items' and rooms' details (data.xml), on the mobile client. Then, the same agent dynamically defines the `zz − cells` and the interconnections `zz − dim`, inquiring the XML documents containing the collections (`collection.xml`), the plans (`plan.xml`), the personalized paths (`paths.xml`), the predefined tours (`tour.xml`), and the restoration (`restoration.xml`).

4.1.3 User Model Specification

The definition of the user workspace offers an interactive use of the mobile guide; we model the users' profiles, their behaviour, preferences and needs, their chronologies, and personal contributions. The aim is to enable users to create and manipulate customized personal spaces, save the visit paths, generate new ones, annotate information, express votes on items and rooms.

We conceived the User Model (UM) in terms of four different perspectives: personal information, history, workspace, and social features. We gathered such information in order to build, maintain and evolve the UM. The UM initialization is explicitly created during the registration process by a form fulfillment, which contains few mandatory fields about the user's identity and the user's social profile, and optional fields for personal information. The UM updating is captured and updated both implicitly (with the user history in terms of navigation and annotation behavior) and explicitly (tracing the users' direct interaction and their feedback such as ratings, number of shares, searched query, authored paths).

4.2 Use Cases: Navigation and Authoring

The prototype TOGO is based on Flash technology, Action Script language programming, and XML semi-structured database [2]. Up to the time of the design and deploy of this project, the choice of the Flash technology has gained several advantages such as rapid development time and high portability and adaptability to different devices. Although recently Adobe has decided to abandon the Flash technology for Mobile software in favour of developing for HTML 5 support instead, we retain that this experience is significant for testing the mobile interface and the scalability and effectiveness of the model. In this section we show two scenarios of the TOGO prototype, the first related to the navigation on the structure shown in Figure 4.2, and the second related to the creation of a new personal path.

4.2.1 Navigating through Ranks and Dimensions

Figure 4.4 shows a sequence of screens generated during the user navigation. The first screen concerns the view of the cell c1 (the room Atrio/Hall'), already introduced in Figure 4.2.

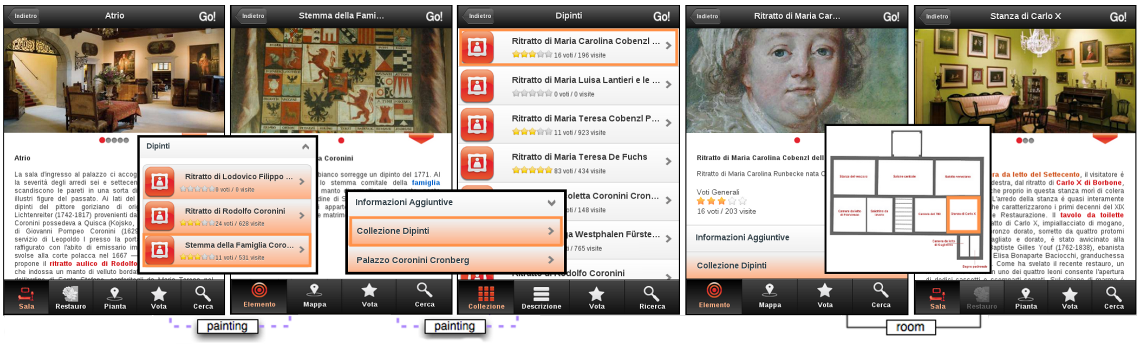


Figure 4.4: Navigation from c_1 to c_2 on different dimensions

The interface shows five possible navigation options in the footer menu: Sala/-Room is the current choice, containing some pictures of the room, its description and the Approfondimenti/Semantic Interconnections section (i.e. the elements contained in a same rank or in a same dimension), which provides a contextual list of all the items semantically connected to the room Atrio. The option Restauro/Restoration contains information and pictures about restoration works; Pianta/Floor plan shows the position of the room within the floor plan; Vota/Vote and 'Cerca/Search' allow users respectively to rate the current item (in a scale from 1 to 5 stars) and search for

[2]Only few third-party APIs have been used such as the IphoneScroller (`http://www.FlepStudio.org`), a library which deals with the scrolling issue within mobile display, and the TweenLite library (`http://www.greensock.com`), a specific set of features devoted to manage screen changes with swipe effect.

items within the application. In our example, the user selected (first screen) in the Approfondimenti/Semantic Interconnections section (that contains four dimensions: Stanze/Room, Dipinti/Painting, Mobili/Furniture, and Argenteria/Silverware), the painting dimension, and then the Stemma della Famiglia Coronini/Family Coat of Arms Coronini (second screen); a similar action (the selection of Approfondimenti/Semantic Interconnections and then of the dimension Dipinti/Painting) shows the list of all the paintings of the museum (third screen); the selection of a specific one (the Ritratto di Maria Carolina/Maria Carolinas portrait) opens the forth screen. Then, visualizing the floor plan and selecting the dimension room, it is visualized the Stanza di Carlo X/Carlo Xs room, in which the Maria Carolina's portrait is exhibited.

4.2.2 Authoring a Personal Path

Starting from any item page, the user can create a personal path (Crea percorso/Create a path) using the interface shown in Figure 4.4.

Figure 4.5: Creating a new path

She chooses the Nome/Name, the Descrizione/Description' and adds all the items/rooms that she prefers (using the + button) to her customized path. In the example depicted in Figure 4.2 the user has already created two personal paths (Mostre/Exhibitions and Storia/History) and is creating the new dimension Miei dipinti/My paintings: in it, he/she inserts four paintings. Then, he/she can choose the order of visit, view the details of each selected items, or remove it. It is interesting to note that for executing this operation, the agent `zzXMLOperator`, applying the script `addPath`, updates the XML data (on the knowledge base) and also adds the instance of the new path into the mobile client.

4.3 User Evaluation

In order to evaluate the perceived quality of TOGO, we conducted a user evaluation in Gorizia, during Storia, the 8th edition of the international history festival; this allowed us to test the application on 89 participants (48 male, 41 female; user age ranged from 16 to 55, averaging at 28.81), both on residents which know Gorizia (62%) and on foreigners (70% from Italy, 25% from Slovenia, and 5% from Austria). Our aim was to determine the quality of information deriving by contextual navigation and the usability of the authoring tool.

In order to achieve this goal, during the interactive demo we firstly presented the interface in general, and then we showed the use of the semantic interconnections and the authoring tool; then we asked participants to navigate freely, using also the semantic interconnections and creating at least a personal path.

Afterwards, the participants were asked to fulfil an evaluation questionnaire of 12 items focused on two constructs, extracted and adapted from [LT04]: information and navigation quality provided using semantic interconnections (SI) and usability of the authoring tool (AT). The questionnaire, originally written in Italian, is reported translated in English in the Table 4.1.

Table 4.1: Questionnaire of the user evaluation assessment

Code	Question	Usability item
AR	The application is reliable	application reliability
SI.1	The application provides reliable information	information reliability
SI.2	The navigation provided by the semantic interconnections it's easy to understand	understandability
SI.3	Using the semantic interconnections functionality the application does not present unnecessary delays.	no delays
SI.4	The application helps in discovering new relations among the artworks of the museum's collection	reliability
SI.5	Semantic interconnections makes me no mistakes	no mistakes
AT.1	The application allow easy orientation while creating a new path	easy orientation
AT.2	Using the authoring tool is satisfactory	satisfactory
AT.3	Creating a new path is easy since the first-time	ease of use
AT.4	The application is easy to navigate	easy navigation
AT.5	Create a new path is not confusing	(not) confusing
AT.6	Once I learned how to creating a new path, I am able to perform it in an efficient way.	efficiency

The levels of agreement were expressed by a 7-point Likert scale (1: completely disagree, 7: strongly agree).

Table4.2 summarizes the average values for each question, discuss below.

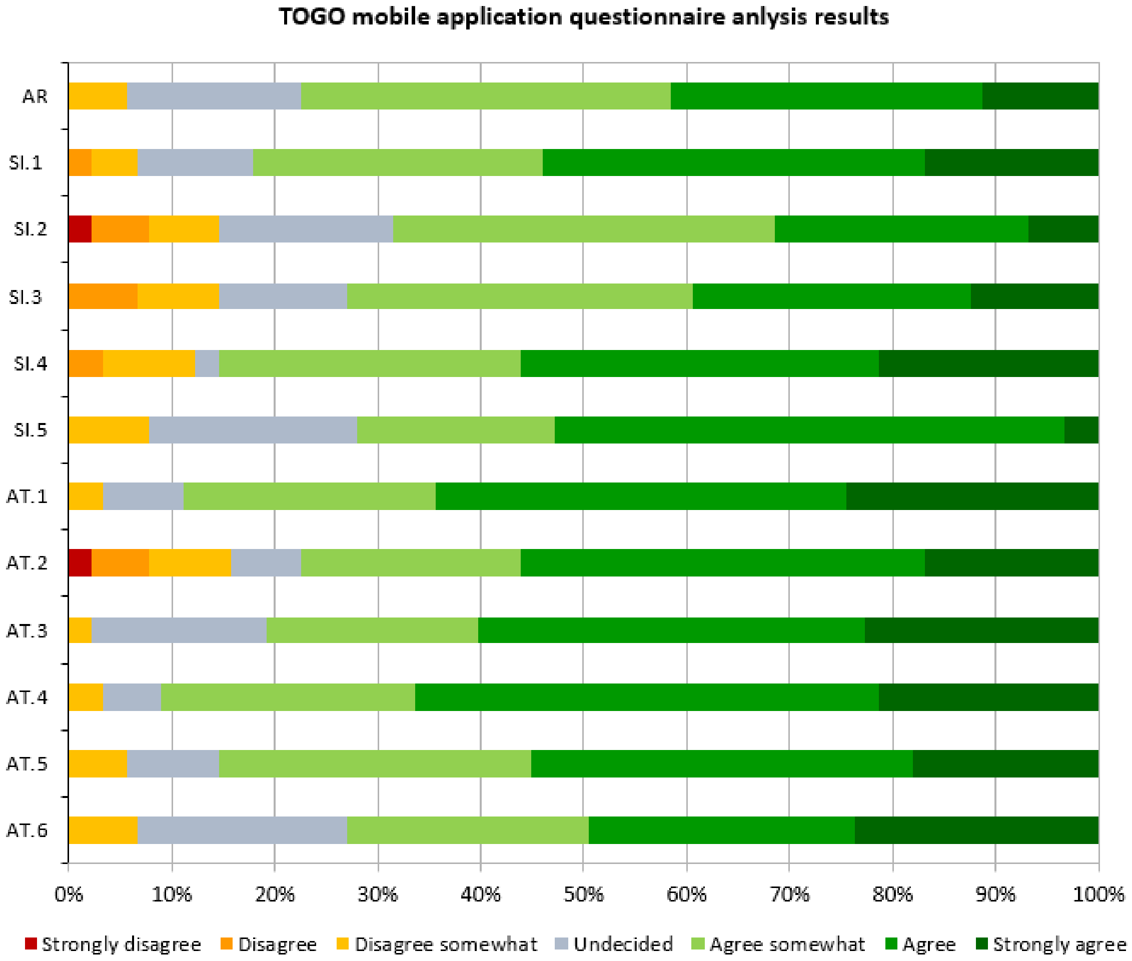


Figure 4.6: TOGO user evaluation questionnaire analysis results

Table 4.2: Average values summary of the TOGO user evaluation

	AR	SI.1	SI.2	SI.3	SI.4	SI.5	AT.1	AT.2	AT.3	AT.4	AT.5	AT.6
mean (μ)	5,25	5,44	4,82	5,03	5,47	5,20	**5,74**	5,25	5,61	5,75	5,53	5,39
std.dev (σ)	1,04	1,16	1,34	1,34	1,29	1,05	1,02	1,50	1,08	0,96	1,06	1,23

The collected ratings are depicted in Figure 4.6, showing a high level of agreement with respect to every usability item, both regarding the SI and the AT.

In particular, the average rating for the perceived reliability of the whole application was 5.25 ($\sigma = 1.04$). Regarding the SI items, users expressed a positive opinion (rate 4 for 82.02%) on information reliability ($\mu = 5.44$ and $\sigma = 1.16$), while 14.61% of users disagreed (rate < 4) on its easy understandability; 73.03% of them agreed on the fact that in SI there are no delays; 85.39% agreed with SI helps to discover new connections and the item SI presents no mistakes achieved the 71.91% of agreement ($\mu = 5.20$, $\sigma = 1.05$).

Regarding the AT items, many participants were significantly attracted by the possibility of authoring personal tours: main reasons cited in favour of AT were its simplicity and the motivation in managing a personal area and storing their favourite elements. In particular, the easy-orientation ($\mu = 5.74$, $\sigma = 1.02$) and the easy-navigation ($\mu = 5.75$, $\sigma = 0.95$) items reached respectively 88.89% and 91.02% of agreement.

Furthermore, AT was considered easy to use by 80.68%, not confusing by 85.39% and efficient by 73.03% of users. The highest percentage of disagreement (15.73%) was achieved by the perceived AT satisfactory. To this extent, considering also general user's feedback, we point out that the users would rather prefer a richer interface than the current one.

4.4 Summary

The design, the modelling, and prototyping of TOGO has represented a preliminary but meaningful experience for testing the contextual navigation interface and the authoring tool.

Evaluation results indicated clearly that SI is reliable and helps users in discovering new relationships among the objects of the museum in an efficient way. The disagreements has encouraged us to improve the implementation of the zz-structures: there emerges the need to to store items and related meta-data, adding a further semantic layer.

Concerning AT evaluation, the results highlighted users' needs for a rich and complete personal workspace space and gave us a boost for further efforts into this direction.

In the following, and final, sections of this dissertation, we discuss how social and semantic knowledge can contribute together in enhancing personal user space, navigation and authoring.

5

Folksonomies and Ontologies Together: the Role of Users

In order to understand how to add a further semantic layer to our model and how user may benefit from it and being involved, we move forward analyzing the role of users within folksonomies and ontologies, and in the so-called *bridging-the-gap* approaches.

In recent times, the issue of bridging folksonomies and ontologies together has drained a significant attention among researchers from different communities. On the one hand, the enormous bunk of information freely accessible across the World Wide Web pushed innovative strategies to annotate and organize it, in a *"bottom-up"* approach trough Social Annotation Systems. These platforms have quickly gained a huge popularity, producing millions of metadata on different Web resources, but carrying with them the disadvantages of uncontrolled vocabularies, making difficult for the end user to benefit effectively from them. On the other hand, despite appealing promises of Semantic Web technologies, which were intended to explicit formalize the knowledge within a particular domain in a *"top-down"* manner, in order to perform intelligent integration and reasoning on it, they are still far from reach their objectives, due to difficulties in knowledge acquisition and annotation bottleneck. Observing advantages and limitations, these two approaches seem to be exactly two sides of the same coin, insomuch as Hotho et al. [HH07, Pas07] suggested to *"bridge the gap"* between the Social and the Semantic Web, in order to combine the best from each other world and overcome with their respective drawbacks.

In this chapter, firstly a general overview on the user issue within folksonomies and ontologies will be presented, focusing on the benefits and limitations that users usually encounter; secondly, the role of users in bridging these two worlds will be discussed deeply, laying a groundwork for our work.

5.1 General Aspects

Although the manual process of classification and organization of knowledge usually reaches high levels of quality for traditional document collections, it does not scale to the huge amount of user-generated resources within the Social Web.

As aforementioned, users generate folksonomies through a "*bottom-up*" consensus based on the considerations about the contents they annotated, moving away from hierarchical authoritative schemes. This freedom in the annotation process introduces ambiguous classification, making difficult to work directly with a folksonomy, although semantic relations among elements may be harness from it.

Conversely, ontologies explicit complex semantic relationships among concepts, which can be processed efficiently to get more elaborated conclusion and to infer new knowledge; ontologies are generally difficult to build and maintain, requiring specialized knowledge and expert users of the domain.

Both approaches present noticeable limitations to users, which could also benefit from their peculiar advantages, as we discuss in the following two subsections.

5.1.1 Users and Folksonomies

As already discussed in chapter 1 and 2, folksonomies are the result of a collaboration in the knowledge classification process: they hold interesting properties from which user may benefit, whenever systems could be capable to catch and manage them properly.

A Folksonomy could be exploited in order to infer knowledge about the user, useful to enhance an existing *user model* or to build it from scratch. Specifically, in the work [CCC+07], a folksonomy has been analysed along three different user dimensions, inferred by the action of tagging: i) the user's interactivity level, ii) the user's organization level and ii) the user's interest in a content. According to a specific classification of tags, these user model dimensions could be matched, providing interesting information about the user's level of knowledge on the content, the participation in the tagging activity, the user's creativity, their trust in the system, and the level of interest in a given content.

More in general, on the one hand, a folksonomy is very easy to create: users do not need any special skills or experience to tag [Mat04]. Users are almost constantly constructing and negotiating shared meaning in collaboration with others by augmenting and evolving a community vocabulary. Morevover, they are able to adapt quite rapidly to new changes in terminologies and domain, tending to stabilize the vocabulary used to tag a resource, as time goes by [Qui05]. When a user assigns a series of tags to a resource, the order in which he does it, is not accidental, e.g. different annotations made by different users, agree more frequently in the first tags that in the last ones [Ben12]. Folksonomies have the potential to scale along the grow of a domain, attracting a large population of users due both to a low cognitive effort and to the immediate feedback on which tags have applied others potentially interesting users [Shi05].

On the other hand, the heterogeneity of users and generally their low support within social annotation systems involve a series of issues concerning both semantic aspects and the effective usefulness of a folksonomy. Users are scarcely supported during the annotation process: the lack of formal and explicit semantic of tags often introduces synonyms, heteronyms or misspelled tags [Ang08, CDAG08, KBH+10].

Another problem, that may adversely affect possible benefits that users can derive from folksonomies, is concerned to different levels of granularity or expertise they have: this lead to basic level variations among tags and an ease add of meta-noise and inaccurate or irrelevant meta-data to the social resources [CCL10, LG08].

Due to the limited navigability of common tag clouds [HMHS06, SCH08, TKH11], many tagged resources are inaccessible from tag clouds, affecting popularity recommendations. Generally, users are scarcely supported in effective browsing, in resource searching and retrieval: the typical flat and non-hierarchical structure of a folksonomy, with unsupervised vocabularies, leads to low search precision and poor resource navigation [HJSS06c, LDZ09].

Lastly, users are not facilitated in share and reuse knowledge due to the lack of a uniform representation among different systems: this issue has drawn a lot of attention by researchers and different surveys analyzed it, proposing different solutions that we will deepen subsequently [GSCAGP12, KSB+08a].

Concluding, we can point out which are main motivations in using, exploiting and analysing folksonomies: apart from the classification useful for index resource and their future retrieval [Che09, HJSS06c, Pet09] rather than recommendation mechanisms [DFT10, DD09, XZL10], the contribution to a wide community sharing and the social promotion have become particularly significant [GH06, SS09]. Besides representing personal opinion expression and self representation through tag assignments, users could benefit from the social interaction by enabling the construction of social networks based on common interests with other potentially similar and interesting users, playing potentially a crucial role in folksonomies managing.

As we will discuss later, these aspects of folksonomies are precisely considered of particular interest into the ontologists' community: the table 5.1 synthesizes these aspects.

5.1.2 Users and Ontologies

The role of users in the definition and evolution of an ontology still results quite arduous.

An ontology, by definition, consists in an explicit, formalized, logic-based representation of a knowledge domain: for this reason, in order to build, maintain and evolve one, users need a deep expertise of the pertinent domain [GCHG10, GZT+11]. In real-world settings, creating and especially maintaining domain-specific ontologies are crucial issues to fulfill users' needs [FT09, ZSdM09]. The distinction between concepts, instances and relations are considerably hard to understand for most users, which should have the capability to handle easily multidimensional relationships such as inheritance, part of, associated with, and many other types, including logical relationships and constraints [HFBPL11].

Table 5.1: Advantages and limitations that impact a user within folksonomies.

Folksonomies and Users	
Advantages	**Limitation**
- Users collaborate in the knowledge classification process - Users can create folksonomies easily: no specialized skills or experience to tag are needed - Users tend to stabilize the vocabulary used to tag a resource as time goes by - Users adapt a folksonomy to new changes in terminologies and domain quite rapidly - Users assign a series of tags to a resource with an order which is not accidental	- Users heterogeneity involves different levels of granularity or expertise, e.g. tags suffer form basic level variations - Users could introduce meta-noise and inaccurate or irrelevant metadata - Users are not facilitated in share and reuse knowledge due to the lack of a uniform representation among different systems - Users are not supported in explicit the semantic of tags, introducing synonyms, heteronyms, etc. - Users are scarcely supported in searching and browsing due to the limited navigability of common tagclouds

The common centralized approach to knowledge management, the need of knowledge experts and the lack in involvement of broader audiences have led the integration and reuse of existing ontologies still challenging to users [DHS07]. One of the major strengths of working with ontologies consists undoubtedly in their encouraging communication capabilities across different applications. The use or the augment of an existing ontology should leverage a well-designed and tested information domain. Nevertheless, users are seldom supported in exploring Semantic Web search engines which do not offer sufficient query facilities to find proper ontologies. In many cases a human user is required to manually download, parse and modify the selected ontology to adapt to her own requirements [BSW+07].

Among the benefits that users could gain from an application that exploits ontologies, we can surely mention the improvement in the retrieval and in the suggestion of appropriate contents as well as the visualization of rich semantic relationships, otherwise discovered with difficulty [LGB+10, LDZ09]. Moreover, resource retrieval performances may be enhanced by effective ontology-based query expansions [Sha09] [1].

[1] Roughly speaking, a ***query expansion*** is a query augmentation realised through the add of new meaningful terms to the initial query: the process can either be manual, automatic or user-assisted. New terms should provide contextual information for the initial query and improve the retrieval results.

Ontologies have been used as a basis for query expansion techniques, as they gathered term suggestions directly from the knowledge they model: e.g. domain specific ontologies should be more suitable in the case of short queries, while general ontologies would be suitable for information broad queries, however an interaction from the user probably is needed.

The interested reader may refer to a landmark survey that covered all these important as-

Table 5.2 summarizes these points. Comparing and contrasting table 5.1 with table 5.2, it is clear that an integrated use of folksonomies and ontologies can allow, on the one hand, the overcoming of both their limits and, on the other hand, the leverage of both their strengths, ensuring the user several benefits.

Table 5.2: Advantages and limitations that impact to the user within ontologies

Ontologies and Users

Advantages	**Limitations**
- Users benefit from a formalized and logic-based representation of knowledge - Users can extract conclusions and new knowledge - Users can extract semantic relationships among data	- Expert users are needed - Users are not supported with sufficient query facilities by the use of Semantic Web search engines - For most users, the distinction between concepts, instances and relations are hard to understand - Creating and maintaining domain-specific ontologies are crucial issues to fulfill the users' needs - For most users the distinction between concepts, instances and relations are hard to understand - In most cases, a human user is required to manually download, parse and modify an ontology to work with

In the following section, the bridging of these two worlds will be discussed thoroughly.

5.2 The role of Users in Bridging Folksonomies and Ontologies Together

To date, bridging these two worlds together has been widely discussed, as demonstrated by several reviews and state-of-the-art surveys [Dot09, GSCAGP12, KSB+08b]. Each of them analysed the problem from different point of views and along different dimensions, placing a number of established methodologies and expected results such as the identification of general processes aimed at extracting semantics from social taxonomies as well as the enhancement of retrieval performances over tagged resources.

pects [BMS07].

Generally, what emerges from these investigations is that the user perspective has been scarcely taken into account. The evaluation of user advantages earned by systems that benefit from the integration of folksonomies and ontologies are still limited or quite restricted, for instance, to specific defined tasks such as browsing resources or getting tag recommendations.

The stimulating growth of research studies in this area induces us to define three different typologies of initiatives, in which encompass our surveyed works, such as:

- *folksonomy supported by ontology*: thanks to several techniques of semantic enrichment, the works belonging to this typology [Sot06, Pas07, Ang08, EACV08, LDZ09, LGB$^+$10, CCLL10, CKJ11, LGBS12] primarily extend a folksonomy into an ontology, or a lightweighted one;
- *ontology supported by folksonomy*: the aim of these works [Mik05, GL06, BSW$^+$07, LG08, GZT$^+$11] is mainly concerned in the expansion of a system ontology enhanced by exploiting folksonomies and collaborative approaches;
- *hybrid approaches*: these works [DHS07, FT09, Sha09, AS13] integrate folksonomy and ontology technologies, combining their advantages and overcoming their well-established limitations in a bi-directional way.

This viewpoint is not new, as shown for instance in [AS13]. Hereby, our intent is to extend this analysis to a wider range of projects and works, focusing our attention mainly on the role of end users. This survey poses several open questions that need further investigations and approaches.

5.2.1 Folksonomy supported by ontology

A number of research projects have discussed folksonomy limitations thoroughly, taking priority over folksonomy semantic enrichment to subsequently exploit it in various settings. Indeed, initial investigations in this direction were mainly concerned on tackling semantic issues that folksonomies carried on typically by the creation or the extension of domain ontologies.

To this extent, in a precursory work [Sot06] Sotomayor proposed the design of a software application called **folk2onto**, mainly devoted to the automated mapping of social tags within del.icio.us bookmarks, into a simple Dublin Core-based ontology. Basically, the folk2onto application, focusing on the extraction of semantic from tags, utilized the semantically annotated lexical database WordNet [2] to filter out semantically poor or redundant social tags (the component of the application deserved to that process was named *tag distiller*). Subsequently the system had to be trained accordingly to the human intervention, and in particular, a user should manually map tags into appropriate ontology categories. The result of this process consisted in a mapping database which stored for each tag several information as

[2]http://wordnet.princeton.edu/

the set of synonyms for that tag, enabling also multiple mappings, e.g. the same tag could be associated to distinct Dublin Core Metadata elements. The training database served to the *Mapper component* as a basis for mapping tags into categories, without user's interventions. Notably, this work limited the role of user exclusively to state whenever a tag belongs to a certain category of Dublin Core, whereas it could be defined in a more incisive way, for instance considering it in a retroactive feedback mechanism, once the entire process had been accomplished.

In one of their preliminary works [Pas07] Passant et al. proposed a method to enrich information retrieval capabilities among blog posts of a corporate blogging. Primary objectives of the work consisted into the removal of tag ambiguity, getting rid of tag variations, and into the inference of related posts, using properties defined in domain ontologies such as Dublin Core[3], SIOC[4] and FOAF[5]. The main idea of the authors was to apply domain ontologies at the top of the existing folksonomy by linking each tag to one or more ontology class or instance. Each post had a RDF representation using the SIOC ontology, which had been created when the user saved his post. Ontology and instances were created and stored in OWL/RDFS and RDF files. A three-store engine was chosen, as it provided support for context in order to keep information about the provenance of each RDF statement. After validating the post and associated tags, users were redirected to a page where they should check and validate relationships between tags and ontology concepts. Concerning the evolution and maintenance of the ontology, the authors assumed that its conceptualization should not evolve a lot during its lifetime. Concerning the instances, the system provided a back-office interface displaying the latest created tags, allowing platform administrators to create new concepts from these tags when needed, and to make needed associations. While this research considered the user interaction as a crucial component, laying the foundation for further investigations especially on collaborative aspects, a systematic analysis of the benefits that users could gain from such a folksonomy enrichment is largely missing.

To this extents, another initial investigation was conducted by Echarte et al.: they proposed the extraction of structured information from folksonomies into an ontology, due to the identification of a group of tags, called **TagGroup**, in order to harvest semantic variations of tags [EACV08]. In particular they developed a generic ontology using OWL[6] capable to model any folksonomy and provided an algorithm in order to integrate all the information contained in it. This project took into account also the ontology evolution in time: meanwhile users were annotating resources, the proposed method stored dynamically the information in the ontology. It is arguable that there is neither a comparison with existing ontologies nor further evaluation of the semantic similarities among tags. Moreover, the user is not considered completely.

[3]http://dublincore.org
[4]http://sioc-project.org
[5]http://www.foaf-project.org/
[6]http://www.eslomas.com/tagontology-1.owl

Concurrently, Angeletou et al. [Ang08] aiming to the definition of a faceted ontology, worked on the **FLOR** (**F**o**L**ksonomy **O**ntology en**R**ichment) project, which was mainly devoted to the semantic enrichment of folksonomies. The authors clearly stated that

> *...the dynamic knowledge provided by folksonomies can be used as a resource for bottom-up knowledge acquisition to support ontology evolution.*

The process started from a tag-set of individual resources or clusters derived by the statistical analysis of folksonomies and subsequently applied a lexical processing (in order to isolate tags that will not be further processed) and a lexical normalisation. Through a semantic expansion and disambiguation they identified all the lexical representations for each tag, including also synonyms and hyperonyms obtained by a combination of thesauri and other semantic knowledge sources. In the final stage of the process, relevant *semantic Web entities* were selected using a semantic relation discovery algorithm. The output of FLOR consisted in groups of highly related tags corresponding to elements in ontologies which could be thought as partial ontologies that conceptualize specific facets of knowledge. From the user point of view some questions arise, such as how richer relations among users could be extracted and how users could effectively benefit from this enrichment.

The work of Lin et al. [LDZ09] stressed the usefulness of the ontological structure extracted from folksonomies in many areas of Collaborative Tagging Systems, such as providing multi-dimensional views, cataloguing and indexing resources, as well as query translation tagging suggestion. The authors combined the knowledge extracted from folksonomies, using data mining techniques with relevant terms from an existing upper-level ontology, namely the WordNet lexicon[7]. The ontological structures obtained in this way could be enriched and deepened using a larger tag dataset, or other semantic relations provided by WordNet, or more specialized semantic lexical resources such as thesauri and subject-specific dictionaries. Notably, a directed involvement of the user lacks completely albeit user evaluation about the so called *jargon tags* (namely non-standard expression used to quickly express users' ideas) could be of major contribution in this semantic enrichment process.

In Limpens et al. [LGB$^+$10] the authors clearly identified two main factors that limit the approaches to semantic enrichment of folksonomies as i) the low accuracy in reflecting the communities knowledge and ii) the scarcely user-friendly interfaces, which lead typically to the user's cognitive overload. The proposed approach consisted of the definition of a folksonomy enrichment life-cycle, based on the analysis of the knowledge exchange practice of online communities, in particular the case study refers to the Ademe community[8]. Starting from flat folksonomy, firstly semantic relationships between tags were retrieved in an automatic way, secondly expert users

[7] http://wordnet.princeton.edu/
[8] http://www.ademe.fr

within the target community of Ademe, contributed to the semantic structuring of the folksonomy, assessing the correctness of semantic relations of the searched tag. Potential conflicts emerging from all user interactions were detected and utilized to help a referent user to maintain a global and consensual point of view. In this work, the user has a predominant role in the creation of the folksonomy-based ontology; conversely the matching and integration with other existing ontologies is not considered. It is worth recalling that the comparison with other semantic repositories, could support the user in searching, browsing and comparing relation among tags, that might not emerge otherwise.

Another interesting attempt in generating ontologies from folksonomies was described by Chen et al. in [CCLL10]. They focused on the detection of basic level concepts from folksonomies, taking cognitive psychology into consideration and then, on the subsequent built of the ontology. The final ontology consisted of a set of concepts related hierarchically, which have been constructed through the extraction of common tags. Basic level categories were characterized due to a particular metric used in psychology, called *category utility.* In order to tackle with differences of tag importance, the authors proposed a weighted category utility: basically the higher the similarity between categories, the higher the value of category utility. At the end, a cognitive basic ontology was generated iteratively. Quantitative and qualitative analyses were performed on three real-world data sets showing the effectiveness of the approach, useful for many immediate applications, such as collaborative tagging, tag aided search and tag recommendation. This method considered only sub-concepts and strictly hierarchical relationships, while more complex relations were not taken into account. Moreover, users' perspective - in the sense of how people define and use concepts - is considered as the basis of the work but an explicit user evaluation on the effectiveness of the proposed tag categorization lacks.

The research discussed by Cantador et al. [CKJ11] concentrated on the limitations of folksonomy-based recommender systems. In particular the authors pointed out their ineffectiveness when recommending items to users, without taking into account the purpose of tags. In more detail, the authors propose an approach to automatically categorise social tags considering four categories of users' intentions such as content-based, context-based, subjective and organisational. The authors' claim that the categorisation of tags based on the users' tagging purpose could help to discard irrelevant tags improving content retrieval process, has been addressed in depth. Tags were collected from Flickr and, after a filtering process, they are mapped to semantic concepts existing in the multi-domain YAGO ontology [SKW08], a Semantic Web knowledge base with structured information extracted from WordNet and DBpedia-Wikipedia. In order to evaluate the accuracy of the proposed categorisation an empirical study was conducted among 30 subjects recruited to evaluate the correctness of about 4.000 tag assignments. The experiment showed that the social tag categorisation approach achieves a high accuracy despite it could be improved by addressing the ambiguity of the tags and more complex semantic aspects. Finally it was showed that considering content- and context-based categorisation of tags, instead of subjective and organisational, performances of the folksonomy based recommender system could be improved considerably. This work is a remarkable example of how user can benefit from a folksonomy expansion via semantic concepts considering co-occurrence similarities, but it questions further considerations about semantic relations between ontology concepts generated from tags, as synonyms and morphological similarities.

Recently, the work of Lezcano et al. [LGBS12] discusses the combination of existing folksonomies with related tag recommendations obtained from ontology relations. This work focused on answering the well-known questions that arise from folksonomies such as polysemy, heteronymy and lack of recall. Its main objective was to provide a hybrid recommendation mechanism that improves tag navigation and browsing. The authors proposed the so called **TagExplorer**, a semantic interface based on the OpenCyc ontology[9], aimed to improve the user experience when navigating across the pages of delicious.com. Firstly, the authors provided a formal model where users explicitly stated mappings between elements in an **Ont ontology** and elements in **Tag** (in the language of the ontology) as a method of *informal semantic interpretation*. Secondly, a family of algorithms was defined in order to derive the relatedness between the tag and the concept of the ontology, allowing the formal ontology to become a basis for the navigational aid in the social tagging system. The TagExplorer was tested on three large datasets: the evaluation was based exclusively on automatic mappings, carried out by matching tags and ontology terms. It demonstrated that the graphs generated from the Delicious folksonomy were much less dense and semantically poorer than those derived from the OpenCyc ontology. The main advantages obtained from the proposed folksonomy-ontology bridging, can be summarized as follows: i) decrease of *dead ends* tags: as TagExplorer recommendations were not based on co-occurrence of tags, but on their semantics, only 3.0% of tags in the TagExplorer graph remain isolated; ii) increase of recall: each cluster of tags contains the conjugations, declensions, abbreviations and acronyms of terms that can act as the cluster root; iii) semantic shortcuts: most of the TagExplorer recommended connections already exist in the Delicious folksonomy, albeit as long paths. Also in this case an evaluation that directly involves final users lacks albeit it would be of greater interest.

Considering the user involvement, beyond the trivial resource annotation task, to be the core dimension of our analysis, the table **??** summarizes the contribution to this dimension of folksonomy supported by ontology research studies discussed hitherto.

5.2.2 Ontology Supported by Folksonomy

The approaches previously described highlighted clearly the evidence for strengthening social classifications throughout ontologies, especially in order to support users

[9] http://www.cyc.com/platform/opencyc

in search, navigation and integration of their published resources on the Web.

Benefits in building and utilizing ontologies have been widely recognized by several foundational works [CJB99, GOS09] as, for instance, the increase of communication between both *people* and *systems*, primarily thanks to the *re-usability* and the *shareable* of ontology components.

Up to date, there is a well-established and considerable amount of work concerning the research field related to ontologies:

- principles, methodologies and technologies for building them [BFGPGP98, CFLGP03, FLGP+02, UG+96];
- the sharing and re-use issues [CdSVR+02, dL09a, GPB99, Gru95] among different settings [PB02, Shi03];
- their evolution and matching [LDKG04, MLR10, SE12];
- their evaluation and validation [EMS+11, TAS10, YTT09].

However, user involvement and collaboration in ontology development, maintenance and evolution processes still remain open issues.

Focusing on the role of users, the aim of this section is to survey research studies and projects that have exploited existing ontologies combined with the ability of folksonomies, in order to encourage users' contributions, useful to overcome with ontology engineering difficulties.

The seminal work of Mika *"Ontologies are Us"* [Mik05] laid the foundations for the extension of traditional bipartite (resource-concept) model of ontologies with the social dimension. The claim was that if *the Semantic Web could be considered as a web for machines, the process to creating and maintaining it was a social one.* First, a tripartite model of ontologies with three different classes of nodes (*actors*, *concepts*, and *instances*) and hyper-edges were formalized. Such edges represented the user agreement in classifying an instance as a specific concept within an ontology. Then, the study proposed an ontology that emerges from a collaborative concept mining, taking into account i) the co-occurrence of tags and ii) the relations extracted from users' similarity. To deal with the difficulties in the evaluation of the outcomes of ontology learning or mapping processes, the involved communities were consulted. What emerged from such evaluation was that the community-based ontology extraction approach, compared to other approaches that utilized general knowledge from search engines, had great potentialities in matching the conceptualization of a particular community. This established research demonstrated that ontologies were inseparable from users in a collaborative and maturing environment, and moreover, the incorporation of a social dimension into ontology model, could only bring benefits in terms of their maintenance and evolution.

The work of Gendarmi et al. [GL06], claiming that Semantic Web tools and social software may take advantage of each other, proposed an approach to collaborative ontology evolution exploiting a community of users. Hereby the primary purpose was to utilize Wikis to edit ontologies, in order to develop a proper **Web Ontology Editor**. They suggested a set of features aimed to support collaborative editing and ontology evolution tracking, as well as expected functionalities useful to the user, like searching and browsing the ontology. Moreover, capitalizing on the wikis capabilities, the author proposal was intended to offer the opportunity to the community to define customized markup tags in a perspective of ontology maturing process. This approach put forward interesting ideas for a collaborative ontology maintenance and evolution, focusing on the role of a user within a community. It is noteworthy that the work was limited to a theoretical proposal without an effective development and, especially, without the definition of how users' contribution could be performed in a precise way and then, subsequently evaluated.

The effort in the maintenance of a specific domain ontology is the major motivation underlying the work of Braun et al. [BSW+07]. On the one hand the authors claimed the need for a more realistic and work-integrated view of how ontologies can be created on a conceptual level, on the other hand they highlighted the lack of tools for supporting ontology engineering activities and the associated social negotiation process. The work proposed a model for involving user to participate on the ontology maturing process: starting from some important observations about ontologies, a model that identifies transitions in a collaboratively development of a shared ontology was defined. In particular the usefulness of a collaborative editing, especially in a multi-lingual environment, was highlighted and analysed deeply thanks to two major case studies. The first case study, **IMAGINATION EU project** [10], focused on the consolidation of image descriptions in communities, where the collaboration allowed the maturing of unstructured tags to commonly accepted concepts. The second case study, called **SOBOLEO** (Social Bookmarking and Lightweight Engineering of Ontologies), grounded on social bookmarking approaches in the domain of informal learning an knowledge management support. Its goal was to support knowledge workers collaborating together in the development of a shared vocabulary and a shared collection of relevant web resources thanks to a lightweight ontology editor and an ontology enabled social bookmarking system. This work put emphasis especially on how users collaboratively could help the evolution of a domain ontology during its maturing process. However, as indicated by the authors too, the work did not present a user evaluation nor a quality assessment on the available concepts.
The work of Liu et al.[LG08] presented a semantic prototype for collaborative investigation and analysis of a system ontology called **CRAFT** (Collaborative Reasoning and Analysis Framework and Toolkit). The main objectives of the prototype were i) to allow users to extend the system ontology in order to capture new concepts as long as their work, encouraging the addition of new classes or relationships, ii) to enable users to share their activities among a social community and iii) with external systems. In order to assess how the extensions made by users affected the evolution of the ontology, a user study was performed. Basically users were asked to

[10] http://www.imagination-project.org

manually enhance an impoverished ontology extended it as needed. They were divided into three groups to evaluate a collaborative use of the prototype. At the end, three different ontologies evolving on different paths from the same starting point were obtained. The authors examined these outcomes taking into account different metrics - such as *relationship* and *inheritance richness* - in order to evaluate the similarity between the three ontologies. Preliminary results were quite encouraging and demonstrated the higher was the user activity in adding new concepts, the higher was the similarity over the three generations of ontologies. Moreover, the evaluation concentrated on the degree of agreement among users in identification of new concepts and relationships: while the former were mostly similar, the latter were more susceptible to variations. However, as observed by the authors themselves, the prototype did not allow to analyse how the changes in the ontology would affect the integration with other external systems, lacking a deeper evaluation of users' involvement.
Claiming that ontology maintenance could be improved by a folksonomy-driven methodology, Gašević et al. [GZT$^+$11] proposed a strategy to improve enhanced ontology in the peculiar case of learning environments. The authors designed an ontology maintenance approach based on the use of collaborative tags provided by learners while they were using learning environments and then, they developed a comprehensive software architecture for evaluate the usability and the effectiveness of the proposed methodology. One of the primary goals identified by the authors was to provide educators with a comprehensible environment in which they can comprehend and intuitively interact with a domain ontology under maintenance. A folksonomy of a community of interest (e.g., a study group) was exploited in order to investigate how collaborative tags could become a source of knowledge evolution and maintenance.

5.2.3 A Mixed Approach

As discussed hitherto, there is a great body of literature which encompasses various approaches in bridging the gap between folksonomies and ontologies in one (from social to formal) or the inverse (from formal to social) direction.

To the best of our knowledge there are few works that combined both directions together: also in these cases, the role of users has not been evaluated deeply, remaining mostly underestimated.

Stemming from the ontology maturing process, the research of Van Damme et al. [DHS07] aimed to propose an innovative way that combine the strengths of collaborative approach to ontology engineering with a mash-up of available social data and semantic resources. This research underlined the need for a semi-automated approach to construct a **FolksOntology** in which, firstly, folksonomies and their associated data, online lexical resources and ontologies and other Semantic Web resources, could be fully exploited for making ontologies. Secondly, all the information extracted from such resources should be validated by a community of users, stimulating the contribution of a collective human intelligence in order to enhance and improve results from previous stages. For instance, users could play a significant role in the discover of information and relations between tags not retrieved directly from the resources. To ease users' activities, the author proposed a set a possible functionalities that a FolksOntology should provide, such as proper visualization techniques as well as implicit and explicit voting mechanism on conceptual choices, in order to grasp the intentions of ontologies concepts. Unfortunately, the work did not present an evaluation framework aimed to validate the collaborative process, albeit it has been suggested to involve users continuously in the form of community approval of the ontology conceptualization.

The model proposed by Freddo et al. [FT09] concentrated primarily on how an ontology, previously generated from a folksonomy, could evolve. The main motivation at the basis of this work was that folksonomies were generally not considered as useful information sources especially during ontology evolution process. This model could be distinguished into two subsequent stages: firstly, the ontology learning from folksonomies and, secondly, the ontology evolution from folksonomies. To demonstrate their approach, a simple case study was presented. Considering a folksonomy related to the tourist domain, the **SCOT tag ontology** based on the Newman's model [NAR05] was populated. After that, the user built an initial ontology taking into account both relations among pairs of tags (e.g. as *instance_of*, *has* and *is_a*) and proper meta-properties. In the second phase of the proposal, new tags from the folksonomy were included and aligned to the concepts contained already by the ontology, according to the highest computed similarity value. This model could be considered at a very initial stage and provided interesting insights, but as observed by the authors, a deeper evaluation largely lacked.

The work of Sharif [Sha09] proposed a simple ontology-of-folksonomy model in order to describe how i) different elements could act in a dynamic space and ii) how implicit relations emerged from implicit complex networks within folksonomies. To this extent, two sub-models were defined, each describing two distinct processes. The first sub-model consisted in an **ontology-based tagging process**, aimed at the knowledge acquisition and representation. It demonstrated how a user can enrich the tagging process through available ontologies. In an initial stage, new tags were suggested by the user to the ontology through both uncontrolled and controlled tagging: hereby, semantic repositories (e.g. Swoogle [11], OntoSearch [12], DAML Ontology Library [13], Protg Ontology Library [14]) came into play with tag/concept recommendation. Then, thanks to an interactive display, user might confirm the candidate tag, or suggest a new one. In such a way user were empowered to extend the ontology with new concepts on demand. At the end an ontology evolution module was defined to map tags into the ontology. The second sub-model was defined as an

[11] http://swoogle.umbc.edu/

[12] http://www.ontosearch.org/

[13] http://www.daml.org/ontologies/

[14] http://protege.stanford.edu/download/ontologies.html

ontology-based folksonomy query expansion model, whose objectives were mainly devoted to knowledge discovery, thanks to proper visualizations and user interactions. To this extent, user could browse an alphabetic list of tags, concepts, actors or groups rather than search a query. From the one hand, ontologies would improve precision and recall, while from the other hand, users envisaged tag space enrichment with semantic relations by exploring online ontologies. Despite the centrality of the role of user was indirectly suggested, a framework for the evaluation of how users could benefit from these two sub-models aimed at checking their validity, was not designed. Moreover, the definition of an enhanced visualization of the folksonomy, especially when it grown, was rather limited. Recently, Alves et al. [AS13] proposed an interesting and still ongoing research study, defining a so-called **Folksonomized Ontology** - FO from now on. This approach put forward the idea of a semantic "travel" in both directions: from folksonomies to ontologies and vice-versa. Basically, the FO allowed to i) enhance tag disambiguation, tag suggestion and semantic similarity driving rich semantic-based matching, categorization and tag suggestion, and to ii) support the review and enhancement of the ontology through contextual data. The initial stages of the proposal followed a trail of common techniques, namely: the information extraction, the semantic enrichment, the tagset-ontology mapping and the ontology evolution. In particular, starting with the meta-data extraction from the folksonomy, tags were filtered and clean in a pre-process phase, in order to define proper tagsets, each of them representing a folksonomic concept. Within the enrichment stage, the latent semantics from the folksonomic tissue was extracted and fused with the ontology. The outcome of the mapping phase consisted in a set of mapping edges: each edge stores the degree of similarity between the tagset and the concept. At the end a fusing phase produced the FO, taking into account enriched relationships among concepts. Again, the user played a predominant role in the ontology evolution and maintenance: thanks to the interaction with a visual tool, the user could support the ontology in its review, analysing data and visualizing the cases in which the collaborative knowledge indicated that the ontology needed for a revision and/or an enhancement. A graphical tool came in support to the user, who could interact with a segment of the FO, analyzing concept and relations among them, and compared them with relations captured from the folksonomy. Unfortunately, at the current stage, the tool has been intended only to suggest modification, with no support to any automatic change or ontology editing. At any rate, this research has advanced a quite complete process that overcome the gap between ontologies and folksonomies, considering the end user a key element in a continuum process of a *folksontology* improvement.

5.2.4 Discussion

To summarize the overview about the analyzed approaches presented in section 5.2, we identify a set of tasks where users play a crucial role within these systems. In particular, table 5.3 indicates, where applicable, the presence of the following tasks:

1. *validation of automated mappings* (Val): users' intervention consists in the validation of a previous, generally automated, mapping of tags into concepts of the ontology;

2. *creation of new concepts from tags* (Cre): the back-end user is able to create new concept and make proper associations;

3. *explicit mapping* (ExMap): users contribute with an explicit concept-to-tag mapping, assign a tag to a concept of an existing ontology;

4. *ontology extension with tags* (Ext): users enrich existing ontology due to their social annotations within a system;

5. *ontology editing and evolution* (EdEv): the user is able to edit and support the evolution of the ontology;

6. *collaborative ontology improvement* (Col): users edit actively the ontology in a collaborative environment.

Table 5.3: Comparison of the bridge-the-gap approaches between folksonomy and ontology considering users' tasks.

	1.Val	2.Cre	3.ExMap	4.Ext	5.EdEv	6.Col
Sotomayor, 2006 [Sot06]	✓					
Passant, 2007 [Pas07]		✓				
Limpsen et al., 2010 [LGB+10]	✓					
Cantador et al., 2011 [CKJ11]	✓					
Lezcano et al., 2012 [LGBS12]			✓			
Mika, 2005 [Mik05]				✓		
Gendarmi and Lanubile, 2006 [GL06]					✓	
Braun et al. 2007 [BSW+07]					✓	
Liu and Gruen,. 2008 [LG08]				✓		
Gašević et al., 2011 [GZT+11]						✓
Van Damme and Siorpaes [VDS]	✓		✓			✓
Freddo and Tacla 2009 [FT09]	✓	✓		✓	✓	
Sharif, 2009 [Sha09]	✓	✓	✓		✓	
Alves and Santanché, 2013 [AS13]	✓	✓			✓	✓

All these approaches limited the analysis and the evaluation of advantages offered both to domain experts, and to end-users, as long as they are utilizing a specific application.

5.3 Summary

In this chapter we have presented the issue of "bridging-the-gap" between folksonomies and ontologies, concentrating our attention on the role of the user, with a special focus on:

- which benefits a user could gain from their peculiar strengths and which weaknesses have to be taken into account;
- to what extent a user is get involved in their creation, maintenance and evolution;
- which are the processes, steps and practices commonly carried out by these' research studies and how the user has contributed to the resulting *folksonomized ontology* or *ontologized folksonomy*;
- which are the major advantages that a user could derive from an application that relies on hybrid and combined approaches.

As showed within our discussion, folksonomies and ontologies worked better together, providing the user with a wide range of features and capabilities that would be difficult to achieve otherwise, without this synergy.

However, we can underline the existence of still critical open issues, for instance the lack in the definition of a general frameworkthat exploits both social and domain's experts knowledge, focused on both user needs and requirements. We can also point out that in the majority of the cases, there is a lack in visualization and authoring tools, capable to ease browsing and searching for tags and resources, rather than potentially similar users. Moreover, both user contextual navigation is scarcely supported.

Concentrating on the role of both *tourists* and *domain-expert* users, and taking into account all the observations and findings gathered so far, in the next and final chapter we:

- propose a novel *bridge-the-gap* approach, based upon zz-structures, that supports the integration of social and semantic knowledge;
- extend the formal model of FOLKVIEW discussed in chapter 2;
- improve and extend the proposed model and the designed framework provided by TOGO case study, analyzed in chapter 4

6

SOSECOM: a Social Semantic Contextual Model for Tourism Application

Our final aim is to provide a *bridge* among *social classification* and *expert knowledge*, taking into account both the role of *domain-expert users* and *end-users*; we leverage on our previous formal definitions proposed in Folkview as well as on the proposed model and the designed framework provided by TOGO.

This chapter proposes a new perspective about the usage and combination of social and experts knowledge focusing on heterogeneous contexts of tourist elements. To this extent, we proposes **SOSECOM**, a **SO**cial **SE**mantic **CO**ntextual **M**odel for tourism and cultural heritage mobile applications; in particular:

- we provide a contextual conceptualization of our knowledge domain in terms of ZZ, partially revisiting and extending our previous definition of *zz-structure* proposed in chapter 2; the domain application is a concrete case study, which allows us to apply our model according to real users' expectations and needs;

- we report the performed semantic mapping of both experts and end-users collected tags to a set of predefined semantic concepts, aimed at describing in a complete and rich manner a touristic Point of Interest (hereinafter, we refer to it with the acronym PoI);

- we propose the definition of our domain ontology, which focuses on i) our case study domain, ii) folksonomy concepts and relations (tags, users, resources, tag assignment), iii) related user actions; furthermore, we provide a set of basic rules primarily aimed at performing the semantic mapping of tags and supporting users with the suggestion of new tags, accordingly to our specific conceptualization;

- we describe the design and the architecture of the system application, highlighting its extensions and implementation improvements compared to TOGO; we also show two use cases, focused on semantic contextual navigation and authoring, briefly discussing also the back-end system which supports expert users;

- we describe the two performed user evaluations aimed at assess the users' perceived quality in use of our mobile application in general and specifically on the provided features; the results are very encouraging, showing a significant high level of agreement with respect to every tested dimension.

Our model, even if applied to a specific touristic case study, allows to be easily extended, providing the addition of further needed contextual information, corresponding features and capabilities.

6.1 The Case Study

The case study refers to the implementation of a tourism mobile application together with an ad-hoc web-based Content Managing System aimed at supporting domain experts, dedicated to the city of Cividale del Friuli[1]. The mobile application is called **Cividale del Friuli - Touristic Town**[2] and it is devoted to the *natural shopping center* of the town.

The domain application of our interest is tourism, intended as a way of promotion of local tradition, cultural heritage, gastronomy, artisan activities, etc. A rich tourism PoI includes not only historical monuments, squares, significant palaces, but also shops with their offered products and services, handcrafted jewelers selling handmade gold creations, old drugstores offering specific services as personalized health analysis and so on.

We focus on the role of users intended as *involved stakeholders* within the field of cultural, historical and commercial tourism. In particular, our research focuses on how tourism stakeholders can benefit from the knowledge that arises from social interaction, combined with semantic information, considering especially the complexity and the richness of contextual elements for each tourist point of interest. We identify two stakeholder groups which may need to interact with our tourist system application, according to their degree of influence within the system application, their claims, ownership, rights, or interests, their past, present, or future interaction activities [Cla95]:

- *internal stakeholders*: they are carriers of a direct interest to the tourist application, or are linked to it from a contractual relationship, i.e. the town municipality who promotes and supports financially the system, owners and

[1]Cividale del Friuli is a town in Northern Italy, that attracts tourist thanks to its medieval center and its particularly significant historical roots. On 25 June 2011 the Langobards part of the historical center of Cividale del Friuli entered the UNESCO heritage list (`http://whc.unesco.org/en/documents/114812`).

[2]The mobile application is literally called "Cividale del Friuli - Città Turistica"

employees of commercial and tourist activities, suppliers, customers and competitors; in our settings we call them *expert users*, *eu*.

- *external stakeholders*: such as tourists, visitors and sightseers: each of them with a set of specific needs, attitudes and expectations; we refer to them as *end-users*, using u according to our previous definition of users within a folksonomy;

In order to emphasize these relevant aspects, since the early stage of the project, we involved our *internal stakeholders* such as local municipality representatives, Tourism Office employee, Museum and Cultural Heritage curators, as well as little artisans, shop managers, restaurants and hotels owners. The aim was twofold:

- define a clear and shared conceptualization of our domain ontology in terms of concepts, properties and relations among them;

- identify how expert tags may help in a better characterization and description of each PoI, according to a *semantic mapping*;

As we will describe in detail, the aim of this mobile application is to represent rich tourist elements, supporting both the stakeholder groups involved.

6.1.1 The Contextual Knowledge Conceptualization

In the early stage of our work, we provided the conceptualization of our tourist mobile app: together with internal stakeholders, we identify nine predominant concepts of tourism PoI.

We called them **categories**; they are the following: (1) Shopping, (2) Where to Sleep, (3) Where to Eat, (4) Services, (5) Events, (6) Promotions, (7) What to See, (8) What to Know, (9) Paths[3]. In Figure 6.1 the homepage of the mobile application is shown: from left to right, from top to bottom, a proper icon represents the specific conceptual category[4] .

Each category represents a particular *concept* with its own properties, to which belong a set of **typologies**. Furthermore, the interaction with internal stakeholders help us in identifying *contextual information* for each typology, which may belong to one ore more categories. In particular, each typology is defined by means of different contextual elements: the majority of them are in common for all the typologies, while other depend on specific peculiarities and characteristics of the typology itself.

All the typologies share the following structure:

[3]In the Italian version of the app they are literally named as follows: (1) Shopping, (2) Dove dormire, (3) Dove mangiare, (4) Servizi, (5) Eventi, (6) Promozioni, (7) Da vedere, (8) Da sapere, (9) Percorsi.

[4]The last icons, Cerca, Entra and Crediti , identify respectively the Search and Login features, and the Credits area.

Figure 6.1: The homepage of the *Cividale del Friuli - Touristic Town* mobile application.

- *Basic*: it represents in a memorable and unique way the PoI itself; it is composed by a i) *Unique Identifier*, a ii) *Description* and a set of iii) *Multimedia* components (they may be photos, audio commentaries, and videos); it also encompasses *Geolocalisation* information, which in turn represents the physical position of the PoI, indeed it is composed by the i) address and by the ii) geo-spatial coordinates;

- *Expert Tags*: expert users freely choose *key-phrases* as descriptors of the PoI according to two levels of granularity and specification: a set of *Generic Tags* devoted to generally describe the PoI (name, brand, general information, etc) and a set of *Specific Tags* such as, for instance, the specific quality of the offered products and services, historical details, etc.;

- *Social*: it represents the social context of each tourism element and it comprises: the *Folksonomy*, the provided *Comments*, and atomic information, such as the *Number of Visits*, the average *Rate*, the number of *Social Sharing*, and so on.

Moreover, (1) Shopping, (2) Where to Sleep, (3) Where to Eat, and (4) Services share another contextual element that represent their *Details*, i.e. a set of detailed information constituted by *Offered Services*, *Offered Products*, and *Further Information* that experts might want to provide to users. The (2) Where to Sleep typology is also characterized by the contextual element *Where To Sleep Details* which contains a set of atomic information giving the particular connotation of the dimension, such as *Room types*, *Spoken languages*, *Facilities*, *Policies*. Similarly, the (3) Where to

Eat dimension comprehend the following *Where To Eat Details*, i.e. *Price*, *Opening Hours*, *Cuisine*, *Reservation*, and *Specialities*.

If we consider this conceptualization in terms of possible *dimensions*, which allow users for a contextual navigation and information, we can now reconsider our previous definition of *zz-structure*, introducing some novel components.

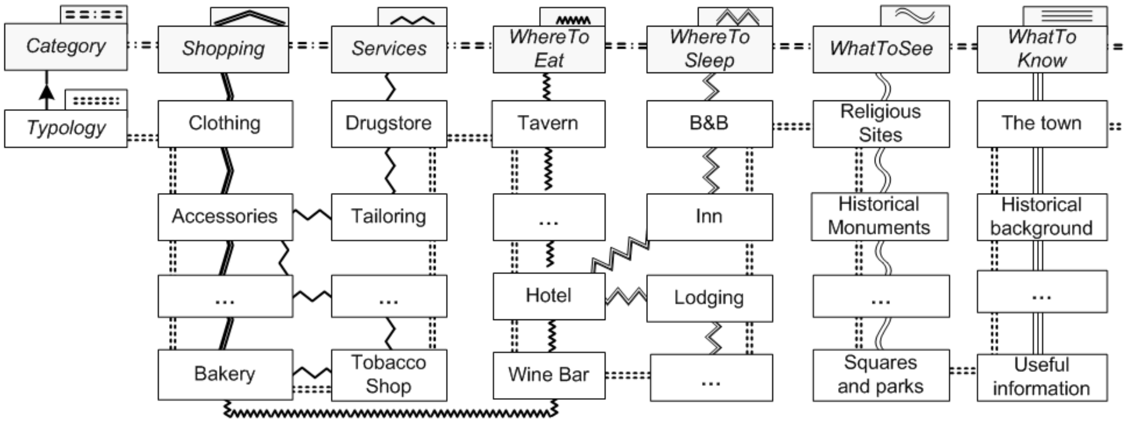


Figure 6.2: An example of zz-structure

Figure 6.2 shows an example of zz-structure representation: here, we represent zz-cells using boxes, zz-links with lines of different styles (thin, dashed, dotted, etc.).

Now, let we focus the attention on a part of Figure 6.2, delimited by the node 'Clothing', in the top-left corner, and 'Useful information' in the bottom-right corner. The zz-cells are represented with boxes, while the different labels are visually represented with different types of lines. So, for example starting from the top-left corner, the zz-cells 'Clothing', 'Accessories', '...', 'Bakery' represent different typologies of commercial activities, associated to the same category 'Shopping' (visualised with a double line); analogously, the other vertical columns represent sets of typologies belonging to (respectively, from left to right) the categories 'Services', 'WhereToEat', 'WhereToSleep', 'WhatToSee', 'WhatToKnow'; finally a double dashed line links all the typologies. Each of these components, connected by a same label (equivalently, type of line), is called *dimension*: it is associated to a specific semantic context.

Special cells In order to simplify the semantic interpretation of a zz-structure, we introduce a special zz-cell, called *main-cell*. It is a zz-cell, positioned as head of a linear path, and has a different conceptual role: it symbolizes the dimension and represents its neighbouring cells. So, considering now the entire Figure 6.2, we recognize as main-cells of the vertical dimensions exactly 'Shopping', 'Services', 'WhereToEat', 'WhereToSleep', 'WhatToSee', 'WhatToKnow'; analogously, 'Category' is the main cell all these categories, while 'Typology' is the main-cell for all the typologies of activities. They are the head (first) zz-cell of a linear path, and their role in the dimension is different from the role of the other cells: they symbolise the dimension, and represent their neighboring cells. Graphically, a main-cell is a box with another small box containing the label representing the dimension (see the cell ‘Category’, for example). The zz-link linking ‘Category’ and ‘Typology’ represents the semantic label ‘is-subclass-of’.

Let we focus now our attention on either of zz-cells contained in Figure 6.2, for example ‘Hotel’. Its content is structured following a precise sequence. In order to represent this content, we introduce the concept of *compound cell*, graphically showed in Figure 6.3.

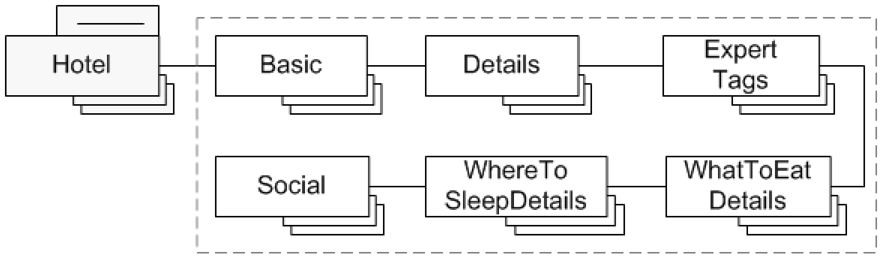


Figure 6.3: Graphical representation of the Typology ‘Hotel’, conceived as a main-cell as well as a compound cell.

The graphical representation of a *compound cell*, compared to that of a *main-cell*, adds three little rectangles in the lower right corner in background: this help us in recognizing it as a zz-cell particularly rich in terms of contents.

According to our case study, each **typology** may be represented by a *compound-cell*, which in turn may be composed by other compound-cells. Each compound-cell may comprehend *dimensions* or *atomic-cells*.

In this representation, ‘Hotel’ is conceived both as a *compound cell* and as a *main-cell*: in the former case, it contains the ZZ for the typology ‘Hotel’, i.e. a set of compound cells that characterizes this typology; in the latter case, following ‘Hotel’ as main-cell, we immediately identify its associated *compound cells*, i.e. Basic, Details, Expert Tags, WhereToEatDetails, WhereToSleepDetails, and Social.
If we look at Figure 6.4, it shows in more detail how each compound cell of ‘Hotel’ is composed. As aforementioned in the case study section 6.1, Hotel is characterized by a set of common dimensions as a typology *per se*, which are namely Basic, Geolocalisation, Details, Expert Tags and Social. These dimensions, completely represent the Shopping category, but Hotel also belongs to the WhereToEat and WhereToSleep categories: thus, from them it inherits also the *WhereToEatDetails* and the *WhereToSleepDetails* dimensions.

Figure 6.4 highlights how each compound cell of Hotel is constituted: comparing this figure to the previous one 6.3, we introduce a dashed box for each compound cell, aiming at graphically containing its components such as atomic zz-cell, e.g. *Unique Identifier*, *Description*, etc., as well as other compound cell, e.g *Multimedia*,

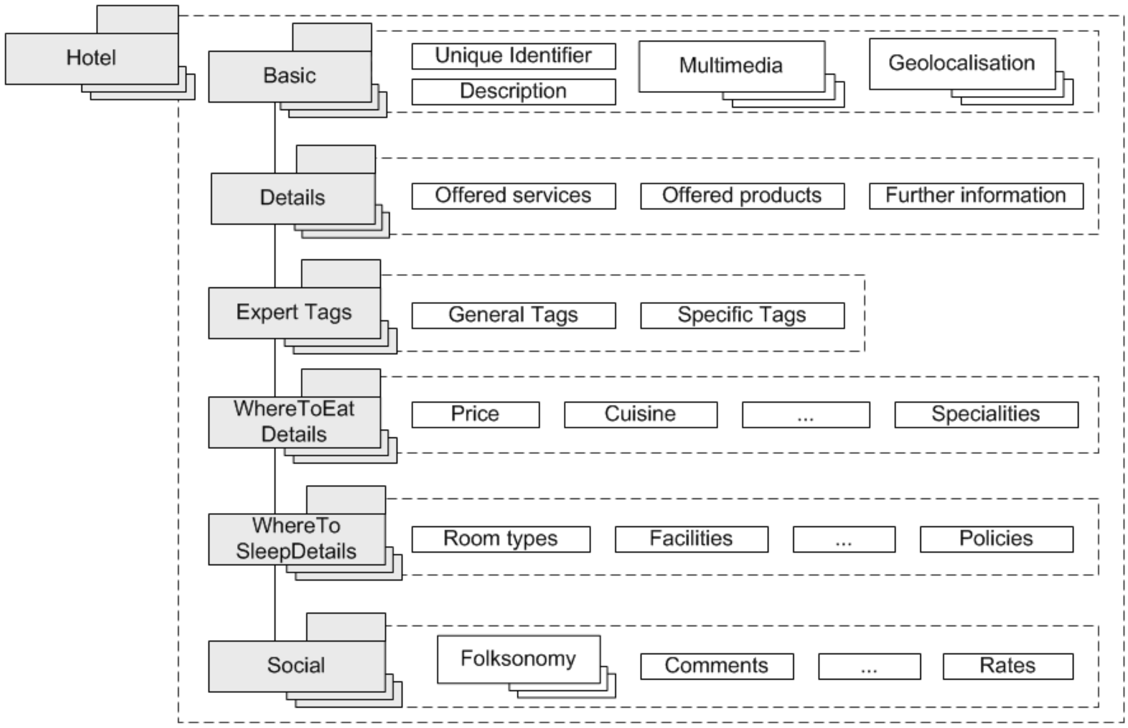


Figure 6.4: Hotel depicted in terms of a set of compound-cells.

Geolocalisation, and *Folksonomy*.

Having introduced these novel components, we now propose a partial extension of the definition of a zz-structure provided in Chapter 2, defining a *zz-app-structure*.

Definition 11. (zz-app-structure) *A zz-app-structure is a zz-structure, where the set of vertices $V = \{R, T, U\}$ is composed by the set of resources R, the set of tags T, and the set of users U and it is conceived to support the description, the visualization, the navigation, and the annotation of a tourist PoI. In particular:*

- R is the set of resources r intended as a tourist PoI, i.e. a resource may represent a shopping activity, a restaurant as well as an historical palace, an event, a touristic path and also a informative content; thus, everything that is not belonging to the set of user U or to the set of tags T is a resource r. According to our previous explanation, each vertex $r \in R$ can be a *compound cell*;

- T is the set of tags used by users u for annotating resources r. More in detail: at the beginning of the content creation and description of each resource, the responsible expert user eu has the possibility to define a set of *general tags* and a set of more *specific tags*. As long as the end-users u freely adds tags to resources, the folksonomy grows. Overall, tags will be mapped to a predefined set of semantic concepts: in this way, expert users will be helped to cover the widest possible range of tags in order to describe the specific resource, receiving proper tag suggestions;

- U is the set of users and in particular, we distinguish among two kinds of users: the expert users, eu, and the set of end-users, u. Both of them may annotate resources with tags, e.g. the eu annotates the resources they are responsible for, as long as the u may freely annotate any available resource.

This definition comprises both contextual and social aspect of a tourist PoI, conceiving it by means of special cells of a ZZ, allowing users to navigate each PoI across a plurality of dimensions, getting detailed and contextual information, participating to the enrichment of each PoI description, thanks to resource' annotation by tags, creating a social and collective knowledge.

Let's take it a step further: in the next section we provide a semantic tag mapping, allowing us the creation of a connection among social and expert knowledge.

6.2 Tag Semantic Mapping

For our purpose in integrating social annotation with expert knowledge, the *Expert Tags* and *Social* dimensions of the *zz-app-structure* are of particular interest.

Expert users where asked to annotate each resource with tags, along they fill in all information for the PoI, meanwhile they utilized the web-based back-end content management system (we will discuss in short the system design and architecture in section 6.3). Also the annotating task made by the end users, contributes to enrich the content provided by the experts: users freely annotate a PoI and they may add a tag both during the visit and after. Moreover, the Social dimension contributes in enhancing the content of the application, representing a valuable tool in understanding both the social reputation of the tourism item (value of the ratings, positive or negative feedback) and the usability of the app itself (if we concentrate our attention to the number of visits, the number of tags, comments and ratings per item). The richness of this dimension could represent a significant tool for the expert user in terms of observation of the end-user behavior. For instance, according to the number of visits, comments, and tags, a tourism items may need a more detailed and precise description.

Now, we concentrate our attention in particular on the collected tags: there were a total amount of **3.079 tags**, **2.030** of them are **unique** tags.

Table 6.1 reports these results highlighting both the number of tags used by expert users and those by the end-users; moreover, the ten most frequent chosen tags for each group of users are reported.

Both the web-based content management system and the mobile application were released in Italian: for this reason all the collected data is in Italian; hereby

Table 6.1: Collected tags analysis report

	Used tags	Unique tags	The 10 most frequent tags
Expert users (*eu*)	1.350	1.041	discount (24), shop (10), clothing (9), women wear (8), path (8), monastery (7), gift (7), De Nordis Palace (6), lunch (6), strucchi (6)
Users (*u*)	1.729	989	Natisone (23), souvenir (20), history (20), friulian cuisine (14), typical cuisine (14), river (14), dinner (13), gift ideas (13), belvedere (12), Devil bridge (12)

we provide the English translation [5]. Figure 6.5 reports the tag cloud representing the most frequent tags as follows: from left to right, the most frequent tags used by experts users *eu* (text color dark blue), the most frequent tags used by both experts and end-users (text color dark grey), and the most frequent tags used by end-users *u* (text color dark green).

Figure 6.5: Tag cloud

We deeply analyzed the collected amount of data and, in particular, for each tag assignment we analyze:

[5]10 most used tags by *eu* are literally: Natisone (21), souvenir (20), storia (20), cucina friulana (14), cucina tipica (14), fiume (14), cena (13), idee regalo (13), belvedere (12), ponte del diavolo (12). 10 most used tags by *u* are literally: sconto (24), negozio (10), abbigliamento (9), abbigliamento donna (8), percorso (8), monastero (7), omaggio (7), Palazzo de Nordis (6), pranzo (6), strucchi (6).

- for the annotated resource, its belonging to *category* and *typology* dimensions: this help us in identifying potential resource that may need further improvements as well as those PoI that might be assigned incorrectly to a specific typology;

- for the analyzed tag, its order in the annotation made by the same user: we trace this kind of information for different reasons, for instance in order to understand how users are influenced by already stored tags and which are first tags they utilize, etc..

In order to achieve our purpose in integrating social and expert knowledge, we perform a *semantic-concept mapping* between each tag and a specific *semantic concept*. After a deep analysis with internal stakeholders, we define a set of *semantic concepts*: in particular we identified *four main classes of concepts*, in order to describe the semantic of a tag, focusing in particular on peculiar characteristics of a commercial or service *activity*, an historical or natural *PoI*, an *event* and the expressed *sentiment*. For each of these class of concepts, we identify different semantic concepts aiming at cover as widely as possible the meaning of a tag, according to the typology of the tagged resource.

The primarily aim of this mapping is to provide an improvement in content quality and accuracy, in terms of chosen tags by the experts. From this basis, we can synthesize the benefits from the resulted mapping, as follows:

- the enrichment of the description of each touristic PoI that may include different facets, some of them may arise from a tag of the folksonomy;

- the improvements in tag suggestion and recommendation for *expert users*, who might did not complete properly their PoI description, with a set of tags enough widely varied;

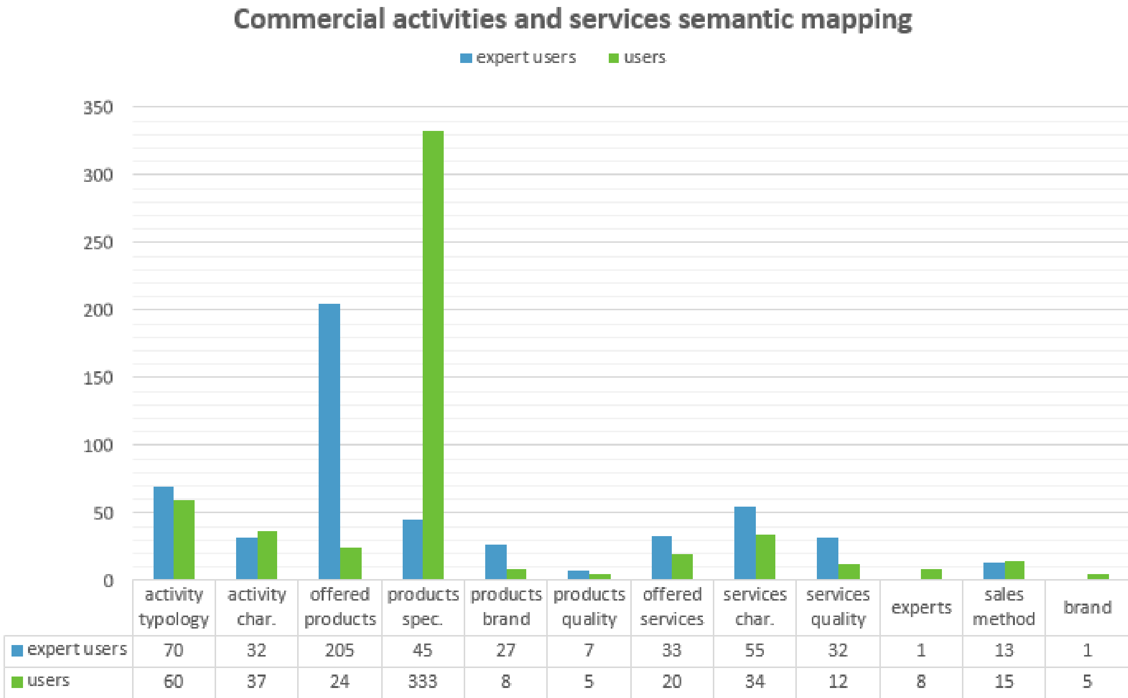
- an incentive for the *end users* of the mobile application in using tags as descriptors of the PoI already visited: starting from a single tag, they may discover similar users, similar PoI, search for a new PoI annotated with that tag, and so on.

Table 6.2 reports exactly the identified semantic concepts, and in particular, it reports for each of them: the number of tags used by the expert users, the number of tags used by end user, and an example of three tags (here, we report them in Italian).
We observe the following results for each class of semantic concepts:

- *commercial activities and services*: the majority of tags fall into this semantic class; in general both expert users and end-users have used tags belonging to these semantic area in a fairly homogeneous and balanced way. We notice a significant amount of tags (333) utilized by end-users that are ascribable

Table 6.2: Expert tags and end-user tags (in Italian) semantic concept mapping in summary.

	eu	*u*	Examples of tags mapped to the semantic concept
Activity typology	70	60	abbigliamento, agriturismo, pasticceria
Activity characteristics	32	37	corsi di cucito creativo, gelateria artigianale, laboratorio orafo artigianale
Offered products	205	24	accessori donna, articoli da regalo, oggettistica
Products specificity.	45	333	abbigliamento taglie forti, artigianato dal mondo, ceramica friulana
Products brand	27	8	Casali, Leon d'oro, Vidussi
Products quality	7	5	specialit friulane, cucina tipica friulana, vino di qualit
Offered services	33	20	degustazione, personalizzazione, sconto
Services characteristics	55	34	cene su prenotazione, creazioni su disegno con oro, gigantografie su tela
Services quality	32	12	wifi gratis, tende su misura, set cortesia
Experts and expertise	1	8	diete personalizzate, medico naturopata, personale amichevole
Sales method	13	15	take away, vendita al dettaglio, vendita on-line
Activity Brand	1	5	Fendi, Gant, Gucci
PoI typology	130	141	piazza, ponte, monumento storico
PoI name	87	12	Piazza Paolo Diacono, ponte del Diavolo, Tempietto Longobardo
PoI general info	89	29	accoglienza turistica, ex-officina, informacitt
How to access	9	0	accesso disabili, animali ammessi, come arrivare
Ownership details	2	0	nobile famiglia Canussio, propriet privata
Access info	10	0	aperto al pubblico in particolari occasioni, chiuso il marted, su appuntamento
PoI characteristics	66	371	contesto naturalistico, immerso nel verde, macigno naturale di appoggio
Building characteristics	33	11	copertura a doppia falda incrociata, loggiato ad archi a sesto acuto, pavimentazione in binderi
PoI quality	1	2	verde, vista panoramica, panorama
PoI decorative properties	34	14	affreschi del '500 nascosti, finestre stile veneziano, muri e mosaici pavimentati
Internal elements of the PoI	27	6	giardino coperto, iscrizione frammentaria, lapide commemorativa
Historic info	48	40	casa XV secolo, altomedievale, antichit
Historic characteristics	47	23	Adelaide Ristori, Antonio Geretti, conte Michel della Torre Valsassina
Historic period	23	9	epoca romana, origine longobarda, seconda met del XV secolo
Geographical info	80	54	accanto al fiume Natisone, a picco sul Natisone, vicino centro storico
Event	0	1	concerti
Event name	10	3	gioco del Truc, Palio, rievocazione storica
Event temporal info	25	7	24 dicembre, quarta domenica del mese, ogni week-end
Event characteristics	188	18	aperitivo, bancarelle, ambientazione medioevale, senza limiti d'et
Sentiment	3	0	mistero, dolcezze, da provare
Positive sentiment	32	139	delizioso, indimenticabile, paesaggio da mozzare il fiato
Negative sentiment	0	1	schifo



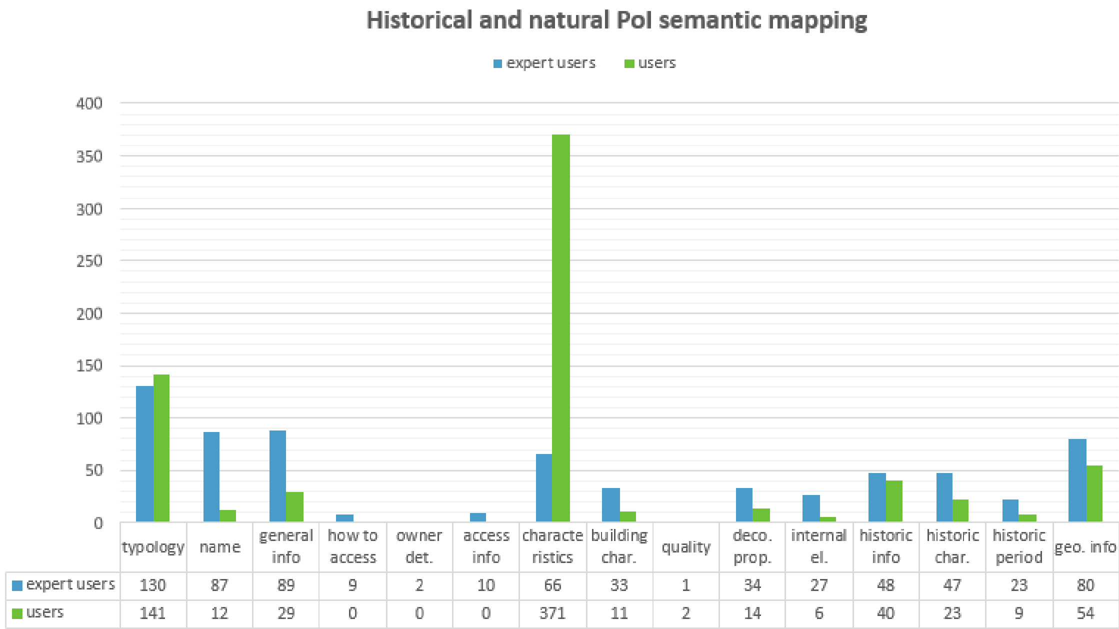
	activity typology	activity char.	offered products	products spec.	products brand	products quality	offered services	services char.	services quality	experts	sales method	brand
expert users	70	32	205	45	27	7	33	55	32	1	13	1
users	60	37	24	333	8	5	20	34	12	8	15	5

Figure 6.6: Tags semantic mapping for the commercial activities and services semantic class

to the semantic sub-class *product specificity* (e.g. friulian pottery, custom jewelry, Christmas fancy goods, etc.)[6]. Surprisingly: only 1 expert assigns a tag (i.e. phytoteraphy expert[7])) mapped as expertise (*expert*, the sub-class of the semantic concept *offered services*); only 1 expert assigns a tag mapped as *brand* of the activity (i.e Vidussi, that is a well recognized shopping center brand). Figure 6.6 graphically depicts the distribution of experts' tags and end-users' tags among the different semantic concepts;

- *historical and natural PoI*: this semantic mapping shows quite balanced choices in annotating resources. However, what emerges is: i) expert users specify tags mapped to semantic concept that end users do not considered completely: it is the case of *how to access*, *ownership details*, *period of access*; ii) end-users use tags mapped to more general semantic concept, as highlighted by the very high amount of tags (371) mapped to the *PoI characteristics* semantic concept. Analogously to the previous class of semantic concepts, Figure 6.7 reports the distribution of experts' tags and end-users' tags mapping for the class of historical and natural PoI;

[6]Literally: ceramica friulana, gioielli personalizzati, oggettistica natalizia
[7]Literally: fitoterapista



	typology	name	general info	how to access	owner det.	access info	caracteristics	building char.	quality	deco. prop.	internal el.	historic info	historic char.	historic period	geo. info
expert users	130	87	89	9	2	10	66	33	1	34	27	48	47	23	80
users	141	12	29	0	0	0	371	11	2	14	6	40	23	9	54

Figure 6.7: Tags semantic mapping for the historical and natural PoI semantic class

- *events*: tags mapped to this semantic concept have been used for the majority of cases, only by expert users; we point out that probably this may be also ascribable to the limited number of events currently available. However, as also discussed later with expert users this gathered information push for enhance the visibility of events, and their descriptive information.

- *sentiment*: particularly significant is the result of this semantic mapping. It is worth of notice that the majority of tags mapped to the concept *expressed sentiment* derive from end-users (to sum up, 140 tags against only 35 tags from experts), and only 1 tag expresses a negative sentiment. Thus, experts may add positive sentiment expressions to their PoI description.

Togheter with the contextual knowledge conceptualization, the described semantic concepts constitute a significant element for our purpose, allowing us to define our ontology.

6.2.1 Defining an ontology

The following definitions stem from the work of Guarino [GOS09].

Definition 12. (Conceptualization, or intensional relational structure) *A conceptualization is a triple* $C = (Di, W, \mathfrak{R})$ *where* Di *is the universe of discourse,* W *the set of possible worlds,* $\mathfrak{R}$ *a set of conceptual relations on the domain space* $< Di, W >$*. In particular:*

- $Di = \{eu_1, eu_2, \ldots, u_1, u_2, \ldots, r_1, r_2, \ldots, t_1, t_2, \ldots, category_1, category_2, \ldots,$ $typology_1,\ typology_2,\ \ldots,\ sem\text{-}concept_1,\ sem\text{-}concept_2,\ \ldots,\ \}$ is the universe of discourse
- $W = \{zz\text{-}app\text{-}structures\}$ is the set of possible *zz-app-structures* evolving in the time;
- $\mathfrak{R}$ is the set of unary and binary relations defined as follows:
  $\mathfrak{R} = \{User^1$, Tag^1, $Resource^1$, $Category^1$, $Typology^1$, $Sem\text{-}concept^1$, $Action^1$, $is\text{-}subclass\text{-}of^2$, $has\text{-}category^2$, $has\text{-}typology^2$,
  $action\text{-}add\text{-}tag^2$, $action\text{-}annotate\text{-}resource^2$, $action\text{-}annotated\text{-}by\text{-}user^2$,
  $action\text{-}define\text{-}sem\text{-}mapping^2$,
  $r\text{-}struct\text{-}dimension^2$, $t\text{-}struct\text{-}dimension^2$, $u\text{-}struct\text{-}dimension^2$,
  $semantically\text{-}describes^2$, $is\text{-}semantic\text{-}mapped\text{-}to^2$,
  $suggested\text{-}tag^2$, $are\text{-}similar\text{-}resources^2, \ldots\}$.

Concerning the set of conceptual relations $\mathfrak{R}$, both structural and semantic relations are explicated; moreover, we assume that $\mathfrak{R}$ may evolve in time, including new conceptual relations, according to the evolution of the considered domain as well as the features provided to both expert users and end-users.

We also assume that these relations do not map the same extensions in every possible zz-app-structure, as they evolve over time. Having *zz-app-structures* that evolve in time $W = \{zz_1,\ \ldots,\ zz_n\}$ is of particular interest for our purposes: zz_1 (the *zz-app-structure* at time 1), may represent a minimal set of resources during the early stage of deployment of a touristic application, probably annotated only by expert users.

Now, we focus on structural conceptualization of our zz-app-structure: let consider the following zz_1: for the sake of simplicity, it represents i) 5 *expert users*, *eu*, each of them ii) manages and feeds two *resources* (let suppose there are ten resources in total), and iii) each of them utilizes 4 *tags* (let suppose that 20 tags have been used in total):
i) $Users^1(zz_1) = \{eu_1,\ e_2,\ \ldots,\ e_{u5}\}$
ii) $Resource^1(zz_1) = \{r_1,\ r_2,\ \ldots,\ r_{10}\}$
iii) $Tag^1(zz_1) = \{t_1,\ t_2, \ldots,\ t_{20}\}$

Now, we proceed with the taxonomic hierarchical classification of the information provided by the zz-app-structure. For instance, let assume that: a) the zz-app-structure contains 4 *categories*, b) there exist only 8 *typologies*, c) each *typology* is assigned only to one *category*, d) each *resource* is assigned only to one *typology*:
a) $Category^1(zz_1) = \{category_1,\ \ldots,\ category_4\}$
b) $Typology^1(zz_1) = \{typology_1,\ \ldots,\ typology_8\}$
c) $has\text{-}category^2(zz_1) = \{(typology_1, category_1),\ (typology_2, category_2)\ \ldots,\ (typology_8,$

category$_4$)}
d) *has-typology*$^2(zz_1)$ = {(r_1,*typology*$_1$), ... (r_5,*typology*$_2$), ..., (r_{10}, *typology*$_8$)}

In order to describe the annotation process that relates a user to a resource with a specific tag, we introduce the unary conceptual relations *Action* that represents each possible user action. So, for each user, and for each annotation activity, we have a unique action (according to the example, we have $5 \times 2 \times 4$ distinct annotation actions):
$Action^1 = \{a_1, a_2, \ldots, a_{40}\}$,
action-add-tag$^2 = \{(a_1, t_1), \ldots (a_{40}, t_{20})\}$,
action-annotate-resource$^2 = \{(a_1, r_1), \ldots (a_{40}, r_{10})\}$,
action-annotated-by-user$^2 = \{(a_1, e_{u1}), \ldots (a_{40}, e_{u5})\}$
We also describe structural dimension defined as follows:
r-struct-dimension$^2(zz_1) = \{(eu_1, t_1) \ldots (eu_1, t_2) \ldots \{(eu_2, t_4) \ldots (eu_2, t_5)\}\}$
t-struct-dimension$^2(zz_1) = \{(eu_1, r_1) \ldots (eu_1, t_2) \ldots (eu_2, r_4) \ldots (eu_2, r_5)\}$
u-struct-dimension$^2(zz_1) = \{(t_1, r_1) \ldots (t_2, r_1)\}$
The above relations explicated within our conceptualization, the structural folkonomy F.

The following step, at the initial stage of the zz-app-structure, consists in adding a *semantic layer* in terms of *tags semantic mapping*: by default, the semantic mapping is carried out by the expert users. We show in the end of this section, how we propose an automatic semantic mapping leveraging tag annotations made by every user.

Let consider that a minimal predefined set of 10 semantic concepts is defined, in order to properly support the description of a resource, during the annotation task, as follows:
sem-concept$^1(zz_1)$ = { *sem-concept*$_1$, ..., *sem-concept*$_{10}$}
action-define-semantic-concept^2 = {(a_1, *sem-concept*$_1$), ... (a_{40}, *sem-concept*$_{10}$)}

Each tag is mapped on a specific semantic concept, according to its meaning that strongly depends on the specific *category* of each resource:
is-semantic-mapped-to$^2(zz_1)$ = {... (t_1,*sem-concept*$_1$), (t_2, *sem-concept*$_1$) ...}

At time n, the zz_n represents the same tourism application, but largely used, with i) a hundred of *end-users* (u) ii) a hundred of *resources*, iii) annotated with new *tags*. So, the conceptual relations map the following extensions:
i) $Users^1(zz_n) = \{eu_1, eu_2, \ldots, eu_{50}, u_1 \ldots, u_{181}\}$
ii) $Resource^1(zz_n) = \{r_1, r_2, \ldots, r_{100}\}$
iii) $Tag^1(zz_n) = \{t_1, t_2, \ldots, t_{2015}\}$

Meanwhile, new experts are added and the *zz-app-structure* evolves also in terms of a) *categories*, b) *typologies*, and c) new relations among them (they may change,

or extend those mapped by the zz_1):
a) $Category^1(zz_n) = \{category_1, \ldots, category_{10}\}$
b) $Typology^1(zz_n) = \{typology_1, \ldots, typology_{40}\}$
c) $has\text{-}category^2(zz_n) = \{(typology_1, category_1), \ldots, (typology_{40}, category_{10})\}$
$has\text{-}typology^2(zz_n) = \{\ldots(r_{25}, typology_{40}), \ldots\}$

Expert users may have changed their initial annotations, according to tag suggestion based on the *end-users* tagging behavior, or according to the tag assignments of other expert users. Indeed, other experts may manage resources belonging to similar typologies and, having complete in a more appropriate manner the resources description, being considered as influencers during the resource annotation process.

Definition 13. (Extensional first-order structure) *Let La be a first-order logical language with vocabulary* Vc *and* $S = (Di, Re)$ *an extensional relation structure, where Di is the universe of discourse and Re the set of relations. An extensional first-order structure (also called model for La) is a tuple* $M = (S, I)$*, where* I *(called extensional interpretation function) is a total function* $I : Vc \to Di \cup Re$ *that maps each vocabulary symbol of* Vc *to either an element of Di or an extensional relation belonging to the set Re.*

A *zz-app-structure* is an extensional first-order structure where $Vc = V \cup L$, $Di = V$, $Re = L$ and the extensional interpretation function maps vertices and labels. So, for example:

$I(Tag) = \{\ldots$typical products, $\ldots$,personalized diets, $\ldots\}$
$I(Category) = \{$Shopping, Services, $\ldots\}$
$I(Typology) = \{$Clothing, Accessories, $\ldots\}$,
$I(is\text{-}subclass\text{-}of) = \{($Typology, Category$), \ldots\}$
$I(has\text{-}category) = \{($Clothes, Shopping$), \ldots\}$

Definition 14. (Ontological commitment, or intensional first-order structure) *Let La be a first-order logical language with vocabulary* Vc *and* C *a conceptualisation. An it ontological commitment for La is a tuple* $K = (C, \mathfrak{I})$ *where* $\mathfrak{I}$ *(called intensional interpretation function) is a total function* $\mathfrak{I} : Vc \to Di \cup \mathfrak{R}$ *that maps each vocabulary symbol in* Vc *to either an element of Di or an intensional relation belonging to the set* $\mathfrak{R}$

In our zz-app-structure, the ontological commitment consists of mapping the relation symbols User, Tag, etc. to the conceptual relations User(w), Tag(w), etc..

Definition 15. (Intended models) *Let* C *a conceptualisation, La a logical language with vocabulary* Vc *and ontological commitment* K*. A model* $M = (S, I)$*, with* $S = (Di, Re)$ *is called intended model of La according to i•*

- *For all constant symbol $c \in Vc$, $I(c) = \Im(c)$;*
- *There exists a world $w \in W$ such that, for each predicative symbol $v \in Vc$, there exists an intentional relation $\bullet \in \Re$ such that $\Im(v) = \bullet$ and $I(v) = \bullet(w)$. The set $I_K(La)$ of all models of La that are compatible with K is called the set of intended models of La according to K.*

In our zz-app-structure, a constant symbol is, for example, Category. For it, we verify that $I(Category) = \Im(Category) = \{$Shopping, Services, $\dots\}$.
Furthermore, considering a predicative symbol, for example User, and I(User), there exists a zz-app-structure ZZ such that $\Im$(User) = User and I(User) = User(ZZ).

Definition 16. (Ontology) *Let C be a conceptualisation, and La a logical language with vocabulary Vc and ontological commitment K. An ontology O_K for C with vocabulary V and ontological commitment K is a logical theory consisting of a set of formulas of La, designed so that the set of its models approximates as well as possible the set of intended models of La according to K.*

In the following we build an ontology O in terms of a set of logical formulae: the universe of discourse is the tourist domain, in particular, we refer to the case study we will depict in the next section 6.1.

We start our formalization specifying the taxonomic information, i.e. the sub-concepts definition:
$O_1 = \{$End-User(x) $\rightarrow$ User(x),
Expert-User(x) $\rightarrow$ User(x),
Typology(x) $\rightarrow$ Category(x)$\}$
Then, we specify the domains and ranges of relations:
$O_2 = O_1 \cup \{$ *has-category*(x,y) $\rightarrow$ Typology(x) $\wedge$ Category(y),
has-typology(x,y) $\rightarrow$ Resource(x) $\wedge$ Typology(y),
action-add-tag(x,y) $\rightarrow$ Action(x) $\wedge$ Tag(y),
action-annotate-resource(x,y) $\rightarrow$ Action(x) $\wedge$ Resource(y),
action-annotated-by-user(x,y) $\rightarrow$ Action(x) $\wedge$ User(y),
action-define-sem-mapping(x,y) $\rightarrow$ Action(x) $\wedge$ Sem-concept(y),
suggested-tag(x,y) $\rightarrow$ Resource(x) $\wedge$ Tag(y)
are-similar-resources(x,y) $\rightarrow$ Resource(x) $\wedge$ Resource(y) $\}$
We also define the symmetric relation:
$O_3 = O_2 \cup \{$ *are-similar-resources*(x,y) $\leftrightarrow$ *are-similar-resources*(y,x) $\}$

Rules Now, we propose a set of rules mainly due to support user expert activity 1) providing the automatic semantic mapping and 2) the suggestion of new tag.

Considering the former case, the following rule specifies that tag t_1 added by the end user u_1 to the resource r_1, is automatically mapped to the semantic concept s_2 due to: it was added by the expert user e_{u2} to another resource r_2, but r_1 and r_2

share the same typology.
$action\text{-}add\text{-}tag(a_1,t_1) \wedge action\text{-}annotated\text{-}by\text{-}user(a_1,u_1) \wedge$
$action\text{-}annotate\text{-}resource(a_1,r_1) \wedge action\text{-}add\text{-}tag(a_2,t_1) \wedge$
$action\text{-}annotated\text{-}by\text{-}user(a_2,e_{u2}) \wedge action\text{-}annotate\text{-}resource(a_2,r_2) \wedge$
$action\text{-}define\text{-}sem\text{-}mapping(a_2,s_2) \wedge$
$\neg(has\text{-}typology(r_1,typology_1) \wedge \neg has\text{-}typology(r_2,typology_1)) \wedge$
$\neg(has\text{-}typology(r_2,typology_2) \wedge \neg has\text{-}typology(r_1,typology_2))$
$\rightarrow action\text{-}define\text{-}sem\text{-}mapping(a_1,s_2)$

For the latter case, first of all we need a rule that states when two resources can be assumed similar. In our settings the following rule specifies that two resources r_1 and r_2, that share at least a tag t_1, with the same semantic concept mapping, are similar r_1 and r_2.
$action\text{-}annotate\text{-}resource(a_1,r_1) \wedge action\text{-}add\text{-}tag(a_1,t_1) \wedge$
$action\text{-}define\text{-}sem\text{-}mapping(a_1,s_1) \wedge action\text{-}annotate\text{-}resource(a_2,r_2) \wedge$
$action\text{-}add\text{-}tag(a_2,t_1) \wedge action\text{-}define\text{-}sem\text{-}mapping(a_2,s_1) \wedge$
$\rightarrow are\text{-}similar\text{-}resources(r_1,r_2)$

The following rule, allows to suggest a new tag to the user (may be expert or end-user); given a resource r_2 the suggestion is based on the similarity with another resource r_1, according to the previous rule. The suggested tag has been annotated to the similar resource r_1 and refers to a semantic concept which is missing instead within the given resource r_2.
$are\text{-}similar\text{-}resources(r_1,r_2) \wedge action\text{-}annotate\text{-}resource(a_1,r_1) \wedge$
$action\text{-}add\text{-}tag(a_1,t_1) \wedge action\text{-}define\text{-}sem\text{-}mapping(a_1,s_1)$
$\neg(action\text{-}annotate\text{-}resource(a_2,r_2) \wedge action\text{-}define\text{-}sem\text{-}mapping(a_2,s_1))$
$\rightarrow suggested\text{-}tag(t_1,r_2)$

Below we describe the system architecture, focusing on the modules that support the formal model described in the previous section.

6.3 The System Architecture

The framework of *Cividale del Friuli - Touristic Town* has been designed building upon the system presented in TOGO, but with considerable advances and improvements. It relies on a client-server architecture and its main components, depicted in Figure 6.8, are the following:

Mobile application: the client side of the mobile application has been implemented both for Android (versions 2.3.3 and up) and for iOS (version 6 and 7); it is based on a model view control design pattern (MVC), and it has been implemented both for Android an IOs. Its main components are:

- The *App Model* interacts with the *View*, manages the data, logic and rules of the client-side, provides specific methods that allow the *Controller* to communicate with the Web services on the server-side. Moreover, it partially stores User Model (UM) in terms of history and some preferences, for instance the personalized visualization on the context-aware map.

- The *Controller* intermediates between the Web server and the other components residing on the mobile client. It receives users' requests and provides the proper actions to carry out them, sending responses to the *View*.
- The *View* provides the graphical interfaces to users implementing different views, one for each screen typology panel, and in particular: the *Grid panel* for displaying the start icons of the app; the *Menu list* panel; the *Search* panel interface; the *PoI panel* interface with its components such as image slider gallery, accordion menus, and so on; the *Context-aware map* interface. Particular attention has been given to User panel screen panel interfaces, i.e. the *User profile* view, the *User preferences* and *setting* interface, the *Social panel* interface that show all the social activity a user has performed.

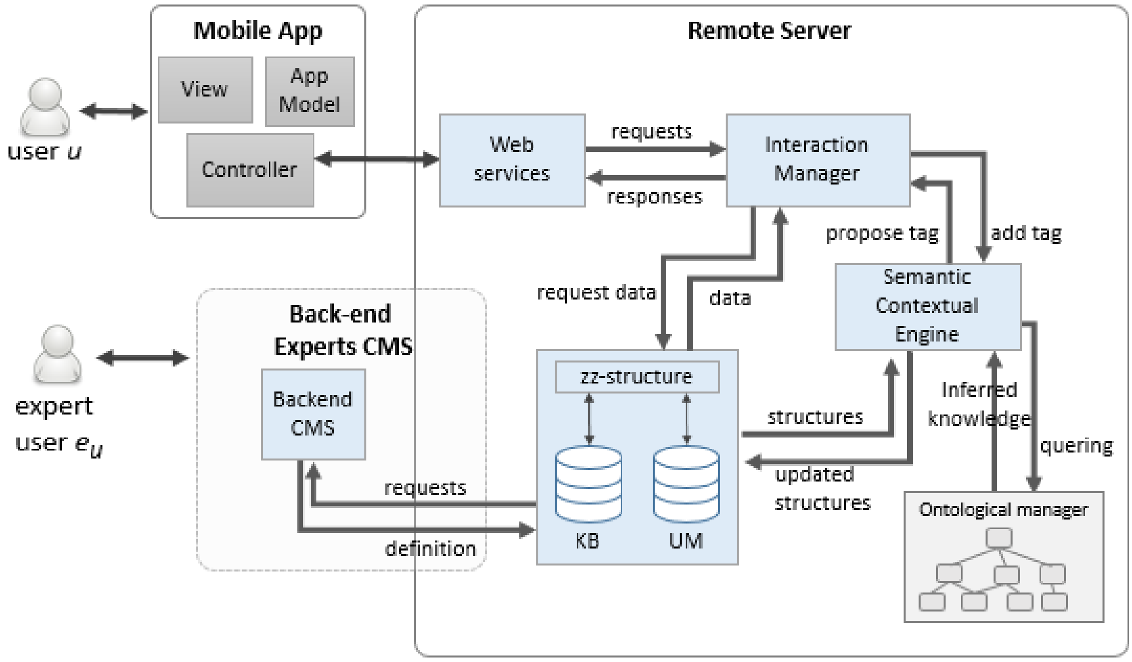


Figure 6.8: *Cividale del Friuli - Touristic Town* overall system architecture

Remote Server: it is the core of the overall architecture; it manages the requests coming from the *end user* who utilizes the mobile app, and also those of *expert users* due to the interaction with the *Back-end Experts CMS*[8]. Following the Figure 6.8 from top to bottom, its main components are:

[8]Literally called "Gestionale Esperti Cividale del Friuli"

- the *Web services* module: it provides a set of features capable to allow the interaction between the Mobile application and the Remote Server itself. It acts as a bridge between the *Controller* of the app, and the *Interaction Manager*. The communication protocol used by web services is based on JSON, and they have been developed to be extensible and reusable.

- the *Interaction Manager*: it deals with performing the requests received from the *Web services* module; it processes these requests, send the proper actions to the *Semantic contextual Engine* module; it also query the *Knowledge Base* and/or the *User Model* to gather the data required by the mobile application.

- the *Semantic Contextual Engine*: it deals with two major functions. The first is to upgrade dynamically the zz-app-structure, let it grownup, according to each user action (e.g. the action of adding a tag); the second consists in interacting with the *Ontological manager* in order to get the needed inferred knowledge. Moreover the engine explicated the role of bridge between social and ontological knowledge, and furthermore, a particularly relevant link between the ontological conceptualization, and its instances, all cabled within the KB.

- the *zz-structure* module: at the very beginning, it instantiates the *zz-app-structure* after having loaded data from the *Knowledge Base* (KB). In particular, all the *zz-cells* (*atomic zz-cells*, *compound zz-cell*) and *special cells* are initialized with the data of the KB. These may evolve in time according to requests coming from the *Interaction Manager* (e.g. the demand for a specific dimension needed for a personalized view). Furthermore, they evolve due to the updates received from the *Semantic Contextual Engine* when, for instance, expert user add new semantic concept mapping. KB, comparing to 4.1.1 is now organized in terms of entity-relations database: this allows us an easy integration with the *Back-end Expert CMS*. The User Model extends the previous design provided in 4.1.3 with a richer *Social* dimension, more advanced preferences and settings.

- the *Ontological* manager: relying on the above formalization, it represents the conceptualization of the domain knowledge in terms of an ontology. It also provides a set of rules for defining interesting associations between concepts or instances (e.g. automatic semantic mapping, tag suggestion). In our settings, for each concept of the domain, the ontology store its conceptual definition, its properties and its conceptual relations, while it does not contain instances, which are stored in the database.

The **Back-end Experts CMS**: it has been developed a customized Content Management System in order to provide expert users with complete content management features. They can create new associations between typology and category, annotate resources with tags, manage, for each resource, the derived social knowledge, having a glare on the folksonomy evolution, social sharing and so on. They can map semantic concepts to new tags, may receive tag suggestions, or decide to remove end-user tags from their own resource. Additionally, a monitor with reporting features is currently under development, but although it is of particular interest, is beyond the scope of this dissertation.

The provided system allows us to provide a novel architectural framework for *bridging the gap* between social semantic knowledge: both of them can constantly growth mutually.

6.3.1 Contextual Navigation and Authoring

Focusing our attention on a sample set of tags, now we show how the possibility to map different semantic concepts to a tag, due to the typology of the resource annotated allows contextual navigation. Conceiving a semantic concept as a dimension, and more in detail as a main cell, helps to discover all the tags that belong to that semantic concept.
Let consider the Figure 6.9: it shows four different semantic concepts (*Product specifity*, *Historical period*, *Experts* and *Services Characteristics*) assigned to 13 tags in different ways.

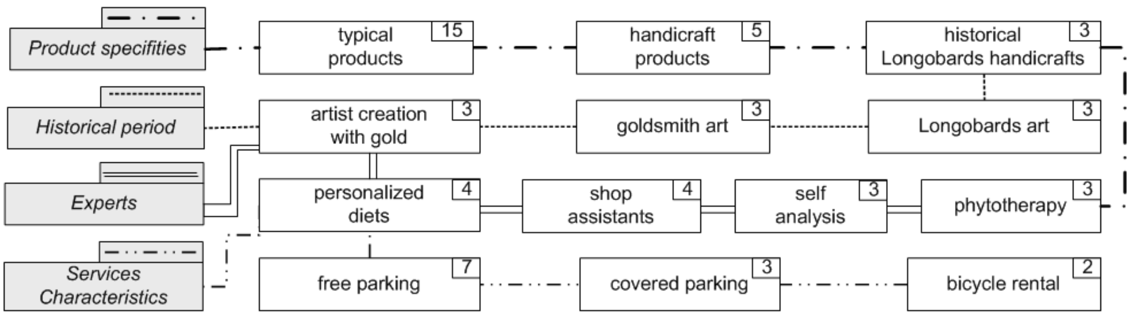


Figure 6.9: Navigate across tags through semantic mapping

Here, we also introduce a new graphical element: a little labeled rectangle in the upper right corner for each zz-cell. It symbolizes the frequency of use of the tag: so, starting from the main cell, the dimension is descending ordered.

For example, the most frequently used tags for the semantic concept *Product specifity* are: *typical products*, *handicraf products*, *historical Longobards handicrafts*, which has also been mapped to the semantic concept *Historical period*, and finally *phytotherapy*, semantically connected to other four tags through the dimension *Experts*[9]. The navigation through these dimensions, enables the discovery of similar

[9]Literally, the Italian version of semantic-concept and tags, from top left corner to bottom right: *Caratteristiche specifiche prodotti*: prodotti tipici, prodotti artigianali, artigianato storico longobardo; *Periodo storico*: creazioni orafe artistiche, oreficeria; *Esperienza*: diete personalizzate,

tags, make possible tags suggestion, and so on.

A slightly different case of contextual navigation is provided by the Figure 6.10, which shows a sequence of panel screens generated and captured during the effective user navigation accross the mobile app.

Similarly to the navigation case study proposed in TOGO 4.2, the picture depicts an example of contextual information, navigation and authoring: hereby, we focus mainly on the role of tags. In particular: we suppose (a) the user displays the list of shopping activity; then (b) the user searches the tag *typical products*: the resulting page provides the list of the different PoI annotated with this tag. They belong to different *typologies* and *categories*; (c) user chooses the element Bosco Romagno: indeed, it offers *typical products*, but it is also a *Where To Eat* and *Where To Sleep* PoI as shown in (d); scrolling down the page, user visualizes the list of tags used by other tourists and adds her personal ones, for instance *comfy place* and *excellent dishes* [10]; then in (f) user visualizes other PoI that share a semantic interconnection with the current visualized PoI. Clearly, user may add a comment, or vote the PoI, store it as preferred item, explore the context-aware map, as well as select a tag, and visualize the list of PoI annotated by that tag.

As aforementioned, the social component may help the expert user in its PoI annotation, and we suppose also in its content curation. To do so, the expert user needs to manage this aspect. Let figure out that the owner of a restaurant wants to analyse the social activity that involves its PoI on the mobile app. We can observe a page example of the Back-end Experts CMS in Figure 6.11. The design of the content management system is minimal and easy to use: from top to bottom, we notice how the list of *categories* appears as the primary navigation bar of the Web page (a). Then, a breadcrumb supports users in identifying her path among the visited pages, from the Homepage. In the example, the current item is highlighted and immediately helps user in recognizing her position: she is visualizing the *Social* (literally Sociale) dimension of her restaurant. The content area of the web page, shows all the social details (b): the list of the comments, and the list of folksonomy tags. The screenshot shows the delete icon for each row of the table containing tags, but in the early future this page will offer expert user more features.

6.4 User Evaluation

The implementation of *"Cividale del Friuli - Touristic Town"* app has followed a user-centered design approach throughout its development cycle: upfront the early stage both stakeholders and end-users were involved in participating to the design Aiming to improve continuously the application itself, three evaluations were performed:

commesse, auto analisi, fitoterapia; *Caratteristiche dei servizi*: parcheggio gratuito, parcheggio coperto, noleggio biciclette

[10]Literally: locale accogliente, and ottimi piatti

Figure 6.10: An example of contextual information and navigation, and authoring.

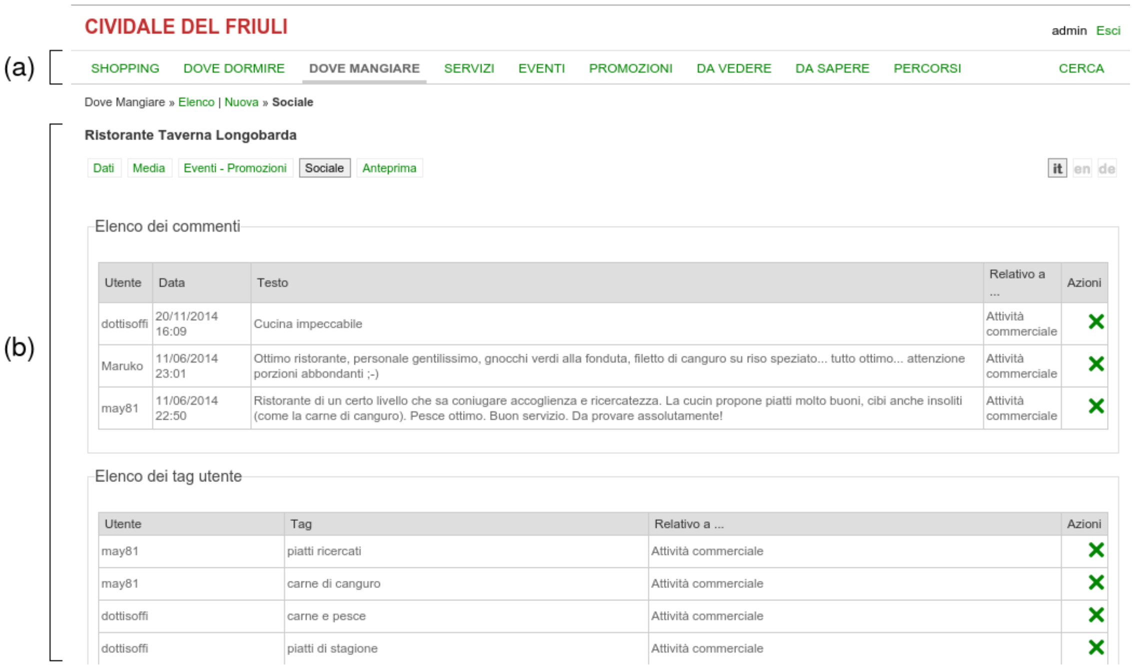


Figure 6.11: A page example of the Web-based Content Management System

- *a small preliminary evaluation* of the early prototype with the participation of few end-users and stakeholders;
- *an extensive and quantitative evaluation* of the first complete release which involved 101 end-users focused on the interface design usability, the contextual information organization, and the usability in performing specific proposed task.

6.4.1 Preliminary Evaluation

The preliminary evaluation was performed immediately after the first implementation of the app. The aim of this evaluation was twofold:

- to identify possible weaknesses and usability problems of the application interface;
- to point out difficulties in performing navigation and available tasks within the personal user work-space, such as adding tags, comments and ratings, etc.

Firstly, we selected 10 stakeholders taking into account the specific type of activity they are involved in (two persons from each of the following activities: a shopping center, a commercial artisan activity, a restaurant service, a news-stand and book-store, an hotel or an inn, and a public utility service). The primary aim of this activity was to check if our prototype met primary stakeholders needs, and if the information architecture as well as the overall presentation provided general features complied with their expectations. They were asked to perform a number of generic tasks such as:

- navigating through the proposed content categories;
- searching for their activity;
- retrieving contextual information;
- analyzing, adding and modifying tags;
- comments and ratings;
- utilizing the location-aware map;

After completing each task, they were asked to fill in a qualitative questionnaire (ten open questions were proposed) aimed at evaluating the *ease of use* of the app, and the intuitiveness of the contextual information provided. Having adopted the *think-aloud* protocol during the assessment has allowed us to harvest free comments and useful suggestions for further improvements.

The results from this early evaluation were particularly significant: all the users appreciated generally the overall presentation and the navigation system. Even if no major usability problems arose, the questionnaire revealed some minor issues though. They primarily referred to i) difficulties in performing the required tasks as adding tags and comments for the first time, ii) the navigation flow through the various items of the application has been sometimes perceived not so intuitive. The majority of the users stated that the navigation was very interesting, primarily due to the possibility to discover interconnections among different items, and to know further rich details. At any rate, they also highlighted few drawbacks, as for instance the fact that these capabilities come to a quite-high cost, in terms of memorability (orientation). We partially redesigned these interface features, answering to the emerged limits and in order to improve few graphical interface problems we have noticed. This leads us to the final prototype, base for the final user evaluation.

6.4.2 Evaluation

In May 2014 a final prototype of "Cividale del Friuli - Touristic Town" was released with 54 activities among *Shopping*, *Where to Sleep*, *Where to Eat*, and *Services*, 16 *Events*, 31 *Promotions*, 35 *What to See*, 6 *What to Know* and 6 *Paths*.

An extensive evaluation test was performed aimed at analyzing the overall perceived quality of the application, and in particular:

- *its general usability*, focusing mainly on the organization of information and contextual navigation;

- *the specific usability* related to user **tasks** such as navigating and browsing information, adding tags, comments, rates.

Before presenting the analysis results, the different steps of the evaluation are described in more detail. We needed to set up the experiment and plan the specification of two scenarios that help users in performing the survey. **101 users** were recruited to perform the evaluation: for the survey we used a free solution, Google Form[11]. We wanted a selection of persons that was as representative as possible: we selected users in the range of 19-40 years old as we expected that our application would fit this range. We had a distribution of 67% female and 33% male respondents [12]

At first, we illustrated objectives and motivations which underpinned the implementation of the app, its main contents, features, and expected task activities (navigation, searching, tagging and interaction within the items). Then two scenarios were described in detail and for each of them a specific task was illustrated, as depicted in Table 6.3.

They were asked to carefully understand the above scenarios and imagine to accomplish the predefined tasks through the app. Before the respondents gave their opinion in our questionnaire, they had to respond to three simple background questions that covered age, gender, and familiarity with mobile devices. A proper version of the app was settled and made available online by both tablets or smartphones. After they had performed required tasks (having at their disposal a time of about one week), they were asked to express their opinion in a questionnaire that presented 16 questions adapted and extended from our previous work [DPOU14].

The questionnaire was written in Italian: an English translation is shown the Table 6.4. The questionnaire items were divided in two parts:

- a **g**eneral evaluation represented by questions from G1 to G7: these questions were aimed at gathering the overall level of acceptance of the application, measured through different usability dimensions [NDA12, HFD13], i.e. the ease of navigation, the ease of orientation, the level of general satisfaction, the effectiveness, the level of confusion;

- a **t**ask-driven evaluation based on the two provided scenarios T1 and T2: questions from T1.1 to T1.4 concerned the first task while questions from T2.1 to T2.5 concerned the second one. Their aim were to measured specifically the level of agreement about the usability of proposed tasks.

Each dimension was measured by means of a 6-point self-anchored scale: this range covers opinion from completely disagree (1) to completely agree (6) without a neutral middle-point. We decided to remove the neutral option to avoid ambiguity as emerged in the preliminary test, rather than adding a *dont'know* option. In order

[11]http://www.google.com/google-d-s/createforms.html

[12]According to Audiweb report, in Italy 54% mobile users range from 18 to 34 years old.

Table 6.3: Two scenarios description with concerning tasks

Scenario	Description	Task to perform
Scenario 1: *planning a funny Saturday in Cividale del Friuli*	I would like to plan the day of tomorrow, Saturday, in Cividale del Friuli, a place I have never been before. I would like to start the morning with a good cup of coffee and then take a walk, visit some monuments particularly representative and learning something more about the history of Cividale. I'd like to know if today there are special events and if there is any sale promotion. For lunch, I would like a quick slice of pizza, and then go shopping in the afternoon. Walking down the streets, I will looking for a book to give to a friend of mine. I have to remember that my niece turns one year old next week, maybe I buy her a gift!	**Task T1 - browsing the app**: navigating through the tabs to display the elements involved, view and save as a favorite the items, marking them with a 5-star rating, that are believed to represent the PoI involved in the proposed scenario.
Scenario 2: *recall a special evening in Cividale del Friuli*	Yesterday, together with friends, I have spent a special evening in Cividale del Friuli. During the sunset, I visited the Belvedere to shoot a couple of memorable photos. For dinner I tried a special restaurant serving local cuisine, where you also have the possibility to bought few souvenirs. Today I want to look over again those sites and leave my own feedback for future visitors.	**Task T2 - Tags, comments, ratings**: identify 10 items which can be considered involved in the proposed scenario. For each of them insert: at least 5 tags, 1 comment, a rating (from 1 to 5 stars).

to assess the internal reliability and consistency between the answers for the items, we measured the Cronbach's alpha which results of 0.88, above then 0.70 threshold for confirmatory research [GSB00].

Collected average values are summarized in Figures 6.12 and 6.13 showing a significant high level of agreement with respect to every tested dimension; furthermore, table 6.5 and table 6.6 report in summary all the average values for each single question.

Regarding the application in general (items from G1 to G7), it is emerged a good average level of agreement with respect of each general usability tested item, further supported by the results from the control question G5. Noteworthy, no user has expressed a strongly disagreement with respect to *ease of navigation* (G1 and G3), *ease of use* (G2), and general *satisfaction* (G7) as well as no user has expressed a completely agreement about the *confusion* in the utilization of the app (G5).

More in detail, about 86% of users expressed a positive opinion on the *ease of navigation* both in the case of searching for specific information (G1: μ = 4,73 and σ = 1,00) and in the case of an overall point of view (G3: μ = 4,73 and σ

Table 6.4: User Evaluation Assessment: the questionnaire

Code	Question	Usability item
G1	Since first using, identifying items that interest to me through the app has been easy.	ease of navigation
G2	Since first using, adding a vote, a tag, a comment through the app has been easy.	ease of use
G3	Navigating through the items of the app is simple.	ease of navigation
G4	The orientation through the items of the app and the information retrieval is simple.	understandability
G5	Utilizing the app is confusing: it was frustrating to waste so much time before I could finally find it.	confusion
G6	Understanding how the application is organized is intuitive.	effectiveness
G7	Using the app is satisfying.	satisfaction
T1.1	The app allows me to identify the elements of interest.	effectiveness
T1.2	The app allows me to identify easily and quickly the elements of interest.	efficiency
T1.3	Navigating through the items of the app has been satisfactory.	satisfaction
T1.4	Navigating the app for identifying the interested items has been difficult and confusing.	confusion
T2.1	The app allows me to manage tags, ratings and/or comments.	effectiveness
T2.2	The app allows me to manage easily and quickly tags, ratings and/or comments.	efficiency
T2.3	Adding tags, ratings and/or comments has been satisfactory.	satisfaction
T2.4	Adding tags, ratings and/or comments has been difficult and confusing	confusion
T2.5	After the first time, I have learned to add tags, comments, ratings and now I am able to do it again rapidly.	learnability

Table 6.5: Questionnaire first part: average values summary

	G1	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**
Min	2	2	2	1	1	2	2
Max	6	6	6	6	5	6	6
Mean	4,73	4,59	4,73	4,62	5,21	4,44	**4,85**
Std. Dev.	1,00	1,25	1,15	1,10	1,00	1,00	1,05

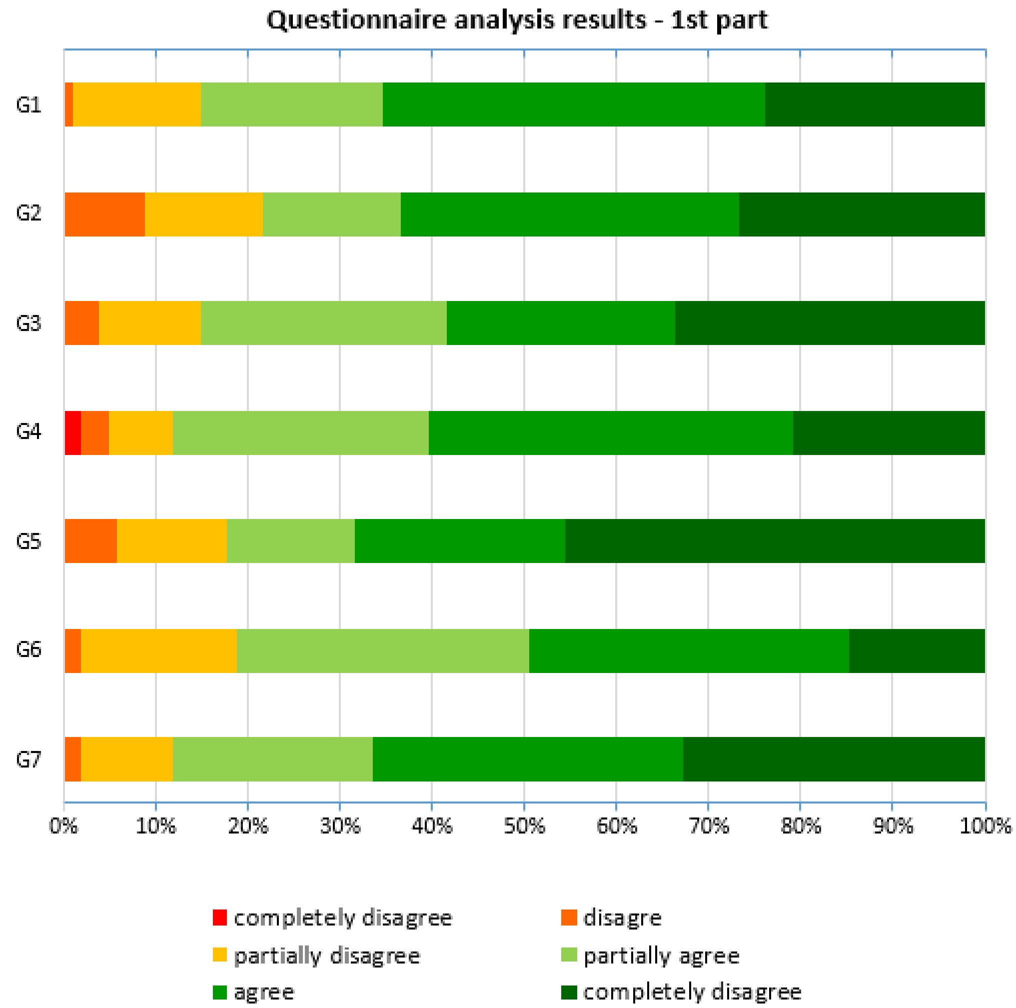


Figure 6.12: Questionnaire analysis results, first part

Table 6.6: Average values summary, questionnaire second part

	T1.1	T1.2	T1.3	T1.4	T2.1	T2.2	T2.3	T2.4	T2.5
Min	2	1	1	1	3	2	1	1	2
Max	6	6	6	6	6	6	6	6	6
Mean	4,70	4,52	4,48	5,04	4,77	4,71	4,59	4,71	**4,90**
Std. Deviation	1,20	1,27	1,22	1,23	0,99	1,04	1,10	1,43	1,26

= 1,15). 78% of users agreed on the *ease of use* (G2: μ = 4,59 and σ = 1,125). Subjects who gave a negative judgment (13% partially disagree and 9% disagree with the item questionnaire) said that adding tag was quite difficult mainly because the interface did not allow user to have complete visibility of the added tag 88% of users agreed on the *ease of understandability* (G4: μ=4,62 and σ = 0,96); only 2% completely disagreed, claiming that they found it difficult to orient themselves; who expressed disagreement (3%) said that they could not stepping back easily to the root of categories, and 11% users did not understand the tab "Categorie affini" (Similar category). 88% of users agreed with a general satisfaction in the utilization of the app.

Considering the task-driven evaluation we highlight the following results: most subjects considered the application effective in order to perform the proposed tasks (respectively T1.1: μ = 4,70 and σ = 1,20, T2.1: μ = 4,77 and σ = 0,99). The 80% of the users agree in considering easy and quick identifying the element of interest (T1.2: μ = 4,52 and σ = 1,27) Slightly lower (78%), but still high, the percentage of agreement in considering satisfying the proposed contextual navigation (T1.3: μ = 4,48 and σ = 1,22).

Both the control questions reinforce the overall positive ratings, showing how the large majority of users do not considered difficult or confusing the provided navigation (87%) and annotation mechanisms(20%) (T1.4: μ = 1,97 and σ = 1,23; T2.4). Adding tags, ratings and comments has been satisfactory for the 84% of users (T2.3: μ = 4,59 and σ = 1,10). And is not surprisingly that 82% of users agree in considering the social annotation tasks as easy to learn (T2.5: μ = 4,59 and σ = 1,10).

We consider these results particularly appreciable and strongly encouraging, pushing for further investigation on other tasks.

6.5 Summary

In this chapter we have presented SOSECOM, a novel conceptual model for bridging social and semantic knowledge and a case study in the field of tourism mobile application.

Focusing on the role of users, the main aim of the proposed application was twofold: i) to provide support to expert users helping them in the content cura-

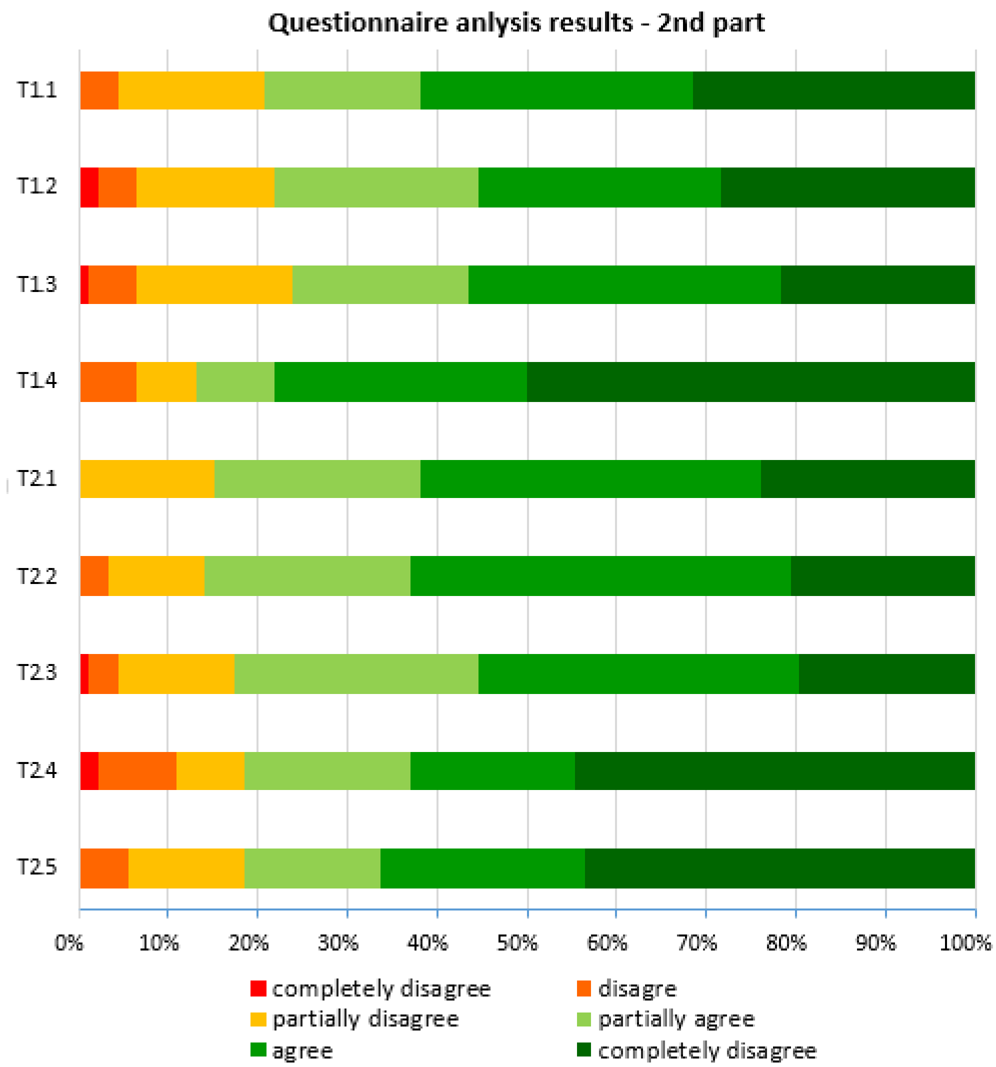


Figure 6.13: Questionnaire analysis results, second part

tion, in managing social knowledge and improving their activity; to i) provide both contextual navigation and authoring tools.

To summarize, we have proposed a novel formal conceptual framework based upon zz-structure, extending previous formal proposal 2 and mobile system application 4, and then, we have provided the ontology definition with a set of logical rules capable to support both expert users and end-users. The case study of the mobile app *Cividale del Friuli - Turistic town* across its design, modeling and prototyping implementation, has allowed us to evaluate our initial proposal. The largely percentage of agreements achieved during the user evaluation of the release prototype highlights the good usability of both social semantic contextual navigation and authoring tool.

Conclusions

In this thesis we have proposed a bridge among social classifications and semantic contextual model, in order to enrich users' personal spaces. We have introduced a model that supports contextual information and navigation, providing customized authoring features, in particular in the field of tourism mobile application.

At the initial stage of our work, we have analyzed limitations of social tagging systems and of folksonomy common definitions and representations. Leveraging on the richness provided by particular data structures, called *zz-structures*, we have proposed **Folkview**. It was conceived as both a novel formal model and a prototype framework, aimed at supporting users with personalized views, contextual navigation by means of semantic dimensions, and authoring tool.

Even if the topic of contextual mobile application has been widely explored in literature, according to different viewpoints, and a huge amount of commercial and research mobile projects already exist, to the best of our knowledge, contextual information navigation that take into account social and semantic knowledge, by means of zz-structure, has never been researched before.

To this extent, we have provided a large overview of tourist and cultural heritage mobile applications, analyze them in terms of user personal spaces, personalized views, authoring tool, contextual information and navigation, showing a set of common different limitations. Concentrating firstly on the two last features, through **TOGO**, we proposed our first contextual tourism mobile application. We have illustrated its underlying conceptual model proposing our definitions of contexts, based on the contextual knowledge; then, on the ground of a case study, we have provided effective use cases of navigation and authoring. The user experimental evaluation aimed at evaluating the quality in use of navigating through semantic interconnections and of the authoring tool. Analysis results have highlighted a high level of agreement on the perceived usability of these features, and have suggested the demand for a further semantic layer as well as possible improvements in the user personal space.

Then, we moved to analyze how social and semantic knowledge have been brought together: the dissertation focused on the role of users in bridging the gap between folksonomies and ontologies. We have shown how, despite the great amount of literature in this field, the user perspective has been scarcely taken into account and, especially, we have shown how in general such systems focused only on one viewpoint (i.e. on the end-user or on the expert one).

The goal of the last chapter is to answer these limitations, taking into account the rest of dissertation. On the one hand, we have re-focused the topic of contextual information and navigation; on the other hand, we have introduced a novel model for bringing together social and semantic knowledge. We proposed **SOSECOM** and a real case study, providing a new formal model that comprises and extends Folkview definitions, and the proposed model and architectural framework provided by TOGO. SOSECOM allows us to provide a bridge between social and semantic knowledge, according to its constantly mutual growth. The results of the user evaluation are significantly promising: both contextual navigation and authoring features gave positive results. Users' ratings were high and almost every subject considered the application usable and useful and foster future experiments.

Future work We plan of improving the framework by introducing a complete set of authoring features for the expert users, continuing the user personal space enhancement; as part of our future work, we will set up a more complex scenario, where all the proposed formal model components will be involved. In particular, according to what we have surveyed in the chapter5 and considering our future research direction, we plan to completely implement and improve the following tasks:

- *validation of the folksonomy*: due to further features of the back-end support system, the expert user will validate social tags, i.e. she may accept or delete them, then tags can be associated to the correspondent ontology concepts; at the time of writing of this dissertation, this feature is almost completely implemented;

- *creation of new semantic concept from tags*: the back-end user will be able to contribute to the ontology conceptualization changing, according to significant behavioral pattern emerging from the social tagging activity, e.g. if a set of identical tags on a tourist item will arise and those tags will be not already present, then the back-end user could add them as characterized tags, enriching the ontology;

- *collaborative ontology improvement*: in our settings the *end-user* may explicitly report special cases to the expert users, for instance, there could be tags which are not properly associated with the PoI, other that could be considered misleading, etc. Expert users will receive a special message, may decide to accept it, and then, they may act accordingly.

Finally, we intend to carry out further improvements of the domain ontology in the field of tourism as well as to extend our model to other case studies.

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