Interacting With Social Networks of Intelligent Things and People in the World of Gastronomy

Published version:

DOI:10.1145/2448116.2448120

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DOI: 10.1145/2448116.2448120

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The work presented in this paper was partially supported by Regione Piemonte, ICT Converging Technologies, project PIEMONTE (People Interaction with Enhanced Multimedia Objects for a New Region Experience). Special thanks to Adriano Design (www. adrianodesign.it) for the name *WantEat* and its logo and to many other colleagues for helpful discussions.
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DOI 10.1145/0000000.0000000 http://doi.acm.org/10.1145/0000000.0000000

This article introduces a framework for creating rich augmented environments based on a social web of intelligent things and people. We target outdoor environments, aiming to transform a region into a smart environment that can share its cultural heritage with people, promoting itself and its special qualities. Using the applications developed in the framework, people can interact with things, listen to the stories that these things tell them, and make their own contributions. The things are intelligent in the sense that they aggregate information provided by users and behave in a socially active way. They can autonomously establish social relationships on the basis of their properties and their interaction with users. Hence when a user gets in touch with a thing, they are also introduced to its social network consisting of other things and of users; they can navigate this network to discover and explore the world around the thing itself. Thus the system supports serendipitous navigation in a network of things and people that evolves according to the behavior of users. An innovative interaction model was defined that allows users to interact with objects in a natural, playful way using smartphones without the need for a specially created infrastructure.

The framework was instantiated into a suite of applications called *WantEat*, in which objects from the domain of tourism and gastronomy (such as cheese wheels or bottles of wine) are taken as testimonials of the cultural roots of a region. *WantEat* includes an application that allows the definition and registration of things, a mobile application that allows users to interact with things, and an application that supports stakeholders in getting feedback about the things that they have registered in the system. *WantEat* was developed and tested in a real-world context which involved a region and gastronomy-related items from it (such as products, shops, restaurants, and recipes), through an early evaluation with stakeholders and a final evaluation with hundreds of users.

Additional Key Words and Phrases: Social Web of Things, Smart Objects, Playful Interaction, Social Intelligence, Social Networking, Preserving Cultural Heritage and Keeping it Alive, Gastronomy, Mobile Intelligent Applications. Real world testing.

ACM Reference Format:
The Piemonte Team: WantEat: interacting with social networks of intelligent things and people in the world of gastronomy. ACM Trans. Interact. Intell. Syst. V, N, Article A (January YYYY), 34 pages.
DOI = 10.1145/0000000.0000000 http://doi.acm.org/10.1145/0000000.0000000

1. INTRODUCTION

The research described in this paper presents a framework for creating rich augmented environments based upon a social web of intelligent things and people. We have been motivated by the problem of developing innovative approaches for (i) promoting a region, its cultural heritage and its special features; and (ii) involving people living in or visiting the region in an engaging experience. The research stems from the idea that things (we prefer this term to “objects”), or more precisely *smart* things, can play the role of gateways, allowing the interaction between people and a region with its cultural heritage to be enhanced. The idea is that, if things such as everyday objects, artifacts, products, etc. could interact with people, they would be able to tell us about the world around them, its history and traditions, and also about the people they got in touch with, their experiences and emotions.

Things are silent protagonists and witnesses to the history of a region and of a community at the same time. If they could remember what happened to them and around them and could tell stories about that, then the possibility of interacting with things could give people a significantly enhanced experience. Things could introduce people to their world, which is made of people, other things and relationships among them and which evolves over time due to the mutual interaction between people and things.

In our approach, in order to be smart, a thing should have two basic abilities: (i) the capability to manage information and knowledge about itself and its world, including user-generated content; (ii) the capability to manage relationships with other things and people. Thus, a smart thing is a social entity capable of having “social interaction” with other entities. By “social interaction” we mean the ability to exchange information and knowledge with others (people and things) and the ability to manage relations (e.g. friendship) with others (people and things). We refer to a thing with these abilities as an **Enhanced Intelligent Thing**. When a person interacts with such a thing, then, the thing itself should be able to exchange information with the person and should be able to introduce its network of “social relationships” to him/her. By allowing people to get in touch with its “friends”, a thing would enable them to navigate networks of things and get in touch with potentially interesting ones. This characterizes the idea of a **social web of intelligent things** [Console et al. 2011]. We further developed this idea into a **social web of intelligent things *and* people**, where both things and people are social entities, able to manage and share knowledge and to establish relations with other things and people.

A key feature of this approach is that interaction with things is not merely a way for people to obtain information or share comments and experiences with a community of users, as they commonly do on classical thematic social networks, but is also an opportunity for them to get in touch with all the world behind a certain thing and with a network of people and other things related to it. In this way the social network entities play the role of *hubs*, from where one can "depart" for different destinations and discoveries. The access and navigation of these networks is the added value with which that we provide users.

An enhanced intelligent thing should be able to perform these tasks in an adaptive and personalized way so as to offer true enhancement and not distract or sidetrack the user. Moreover, interaction should be as natural as possible, giving users the impression of continuity with the physical world they are experiencing, and enhancing the specific context in which they find themselves. Another key point for users is the perception of seamless integration between the physical and the virtual environment: the experience the user gets of the real thing (interacting with the physical object or place) and on the web (interacting with the thing avatar) should be as similar as possible, at least for those interactions that are meaningful in both environments.

The *WantEat* suite of applications was designed to experiment with enhanced intelligent things and with the "social web of intelligent things and people" paradigm.

More specifically, *WantEat* is based on three main ideas:

(i) enhancing the user experience by supporting playful interaction with a web of things,
(ii) embedding social intelligence in things,
(iii) extending the notion of social networking from people to things.

The domain of application of WantEat is gastronomy, as a way of getting in touch with a region's traditions and cultural heritage. Things include not only food products, market stalls, restaurants, shops and recipes, but also geographic places and actors such as cooks, producers, shop owners, etc. Interacting with a certain food product (e.g. a bottle of wine) is a way of getting in touch with the cultural heritage behind it, made up of stories and traditions, as well as with the social network of its friends, made up of grapes, producers, and shops, in addition to people who have talked about it, tasted and liked it, recipes that go well with it, or other products (e.g. a cheese traditionally served with that wine). This is in line with the Slow Food[1] philosophy advocating a new model of sustainable gastronomy, where food is *good, clean and fair* and where people are aware of the region they live in or visit, of its resources, history, traditions and of the actors and the processes in the chain [Petrini 2007]. A sustainable gastronomy relies on preserving the biodiversity of a region, promoting and supporting its quality food, making consumers aware of that quality, creating networks of actors sharing experiences and shortening the supply chain. In this approach, consumers become co-producers, as their choices have a direct impact on the production chain.

This paper describes *WantEat*, the suite of applications we designed and developed to test the ideas discussed above. We first introduce a scenario (Section 2) to help clarify our goals. Following this, Section 3 discusses the framework and the individual applications, while Section 4 describes the architecture at the basis of our framework, providing details of the software architecture we studied and designed, that support our view of a social web of intelligent things and people. Section 5 presents a field trial of *WantEat* and the results of the evaluations we performed. Section 6 provides a comparison with related work, while Section 7 concludes the paper.

[1] http://www.slowfood.com

2. THE CONSEQUENCES OF A HIKE: A SCENARIO

Premise: the community of Val Sangone (a valley near Torino and close to the mountains) decided to adopt WantEat *to promote its region and in particular its quality food. The local tourist board registers into the system and uploads information about the villages, their attractions and cultural heritage. Local producers register their quality products. For example, Claudio Lussino, a renowned producer of Cevrin di Coazze, a local traditional goats cheese, uploads information about his product.*

Early May. Antonio is on a journey through Val Sangone; during a hike, he discovers a pasture land where goats graze. They belong to Claudio Lussino. Antonio visits Mr. Lussino's shop, tastes the cheese, and decides to share his experience with WantEat*. He takes a picture of the cheese label with his smartphone. Lussino's cheese is recognized as a smart thing in* WantEat *network and Antonio is put in contact with its virtual avatar. Antonio reads further information about the cheese, about Val Sangone and its history and traditions. In particular, he discovers that there is an interesting ethnographic museum nearby where he can learn how people used to live in the mountain valley and how they traditionally produced cheese, infuses and liquors with herbs. Before going to the museum, he bookmarks and tags the cheese, and uploads a comment in which he mentions an exceptional white wine (Erbaluce) he just drank together with it. "A perfect matching!" Antonio says.*

Later in July, Lisa walks through the Giaveno farmers' market, Val Sangone's main town. Lisa is a tourist, and is interested in local food and wine. Her user model in WantEat *says that she loves goats cheese, and that her personal tastes are indeed similar to Antonio's. Although the two of them have never spoken to each other, their interaction with the system and the things in it suggests that they may like the same kinds of products. On her smartphone, Lisa has the application turned on, hence as she gets close to Mr. Lussino's market stall she comes into contact with the Cevrin cheese. Lisa is presented with a short story of how Cevrin production had been slowly disappearing before a number of producers decided to save it. In addition, she is presented with some interesting things people did or said about the cheese, in particular the people that have a profile similar to hers. Lisa is then shown the Lussino's Cevrin's social network including Mr. Lussino himself, Val Sangone, a restaurant called "La Stufa" where the cheese can be tasted together with other local products, a recipe of a salad made with the cheese, and the Erbaluce wine that Antonio and many other people found perfect to drink with the cheese. After tasting and liking Lussino's cheese, Lisa follows the link to Erbaluce and in the wine's network she discovers a nearby wine shop where she can buy it. Following the link from the cheese to"Val Sangone", she learns about the dialect spoken in the valley and how it derives from the fact that, in the past, the valley was part of different kingdoms and served as a border between them. Lisa reads a summary of the comments by other people regarding the Val Sangone dialect and discovers that it is actually a dialect of the Franco-Provençal language.*

Moreover, Lisa is interested in the cheese salad recipe: she remembers her grandmother preparing it, so she connects to the recipe page, and discovers that it is a traditional dish prepared in spring to welcome the new season. Lisa bookmarks the recipe because she wants to find it easily once she is home. That same evening, when using the system again to search for a good restaurant, she discovers that the restaurant La Stufa is highlighted because it serves the salad whose recipe she had bookmarked earlier, and that other users have recommended the dish.

Once home, Lisa tastes the wine she bought and finds out she likes it a lot, she agrees with the comments that suggested it to complement the Cevrin. She connects to our application on the Web and finds the virtual transposition of the market stall adding a positive evaluation to the cheese-wine match.

After some days Mr. Lussino connects to WantEat Back-shop *on the web and reads about the comments on his farm and cheese. He discovers the connection with Erbaluce and also the shops and restaurant selling and serving his cheese; in this way he discovers the profile of people who appreciate his cheese and can establish direct links with his customers.*

Table I highlights some of the activities performed in the scenario. A label identifies each action, which involves an actor (a person or a thing or the WantEat system) and possibly an object on which the action is performed (again a person or a thing).

Table I. Key activities performed in the scenario.

Label	Actor	Action	Object
A0	Mr. Lussino	registers	his farm and his products
A1	Antonio	takes a picture of	Lussino's Cevrin
A2	Lussino's Cevrin	shows its social network	
A3	Antonio	bookmarks	Lussino's Cevrin
A4	Antonio	tags	Lussino's Cevrin
B0	WantEat	connects	Lisa and Lussino's Cevrin
B1	Lussino's Cevrin	presents its story	
B2	Lussino's Cevrin	shows other people's comments on itself	
B3	Lussino's Cevrin	shows its social network	
B4	Lisa	follows the link to	Erbaluce wine
B5	Lisa	asks for	a restaurant recommendation
C1	Mr. Lussino	gets feedback on	his farm and products

The project's core ideas are the key players in this story. Let us better define them with Antonio and Lisa's help.

The first key idea is the one of **enhanced intelligent things**. Things are enhanced in their capability to interact with people *and* other things. They display intelligent behavior: they *know and remember* facts about the people who interact with them, thereby adapting their behavior; they collect facts and user comments about themselves, and use them to build their own knowledge base, their social relations and their own public image. Lussino's Cevrin knows who Lisa is and what to tell her about itself. For example, it knows that Lisa might like the salad recipe. Things know about the world around them and can play the role of gateways allowing users to get in touch with the cultural heritage of the region they are linked to. Antonio discovers about the traditions of the valley and the ethnographic museum; Lisa learns about the valley's dialect and its roots. This is not necessarily "static" information associated with the thing. For example, the link from the cheese to the ethnographic museum may be inferred by the cheese itself from the interaction with people who mentioned the museum to the cheese. This stems from the fact that things have *knowledge* about themselves and the places they are in.

Things also have social behavior. This introduces the second key element, that of **mixed social networks**. Rather than having social networks of users who discuss and express opinions on things, we propose the use of social networks that combine people *and* things. These social networks can include things such as Lussino's Cevrin, the Erbaluce wine, the recipe for a cheese salad, Val Sangone, as well as actors in the domain such as Mr. Lussino and users like Antonio and Lisa. The networks can be created in different ways, exploiting knowledge about the domain and taking into account users' behavior, as will be discussed later. In particular, things have an active social role in these networks and can establish social relationships among themselves and with people: for example, Lussino's Cevrin becomes a friend of Erbaluce.

It is important to notice at this point that in *WantEat* we are interested in **generic things** (such as Lussino's cheese or Erbaluce wine) and not in individual instances (a specific bottle of wine or a specific cheese wheel). We are interested in the concept of Lussino's Cevrin, in its relations with other products, in the content people share with it, and in what the thing itself can share with people. In this way all the interactions with wheels of Lussino's Cevrin are interactions with the same concept: Lussino's Cevrin itself. This depends on the goals of our application, i.e., sharing cultural heritage via the interaction with things and knowing the world and traditions behind things. Our aim it not to discuss individual wheels or bottles of wines and to track them[2].

The third important issue is **natural personalized interaction**. *WantEat* exploits natural forms of human computer interaction in order to make the interaction between users and enhanced things a recreational (playful) and pleasant experience. The user does not perceive the use of the system as something that distracts him/her from the real-life experience, but rather perceives it as its enhancement. Examples of this are the possibility to access the system by just taking a picture, as Antonio does with the cheese label, as well as recording comments, rather than typing them. Secondly, interaction must be tailored to each individual user. Lisa's and Antonio's interests are tracked and the interaction with each one of them is personalized, taking their interests and preferences into account and possibly creating links between users based on the similarities in their profiles. Natural personalized interaction is an important issue for things to display intelligent behavior.

The fourth key ingredient is the **integration of physical and virtual environments**. All the elements of our social network - people and things - exist as physical entities *and* web avatars at the same time. In a traditional approach, users would access them at separate times, since they are unable to access the functions of a physical thing (e.g. tasting a cheese) and those of its avatar (e.g. tagging or commenting the cheese) simultaneously. In *WantEat* these functions are accessible at the same time without the user perceiving a "context jump" (see Antonio's interaction with the cheese); this is particularly important, especially in our context where sensory experience is at the center of the enjoyment of the whole experience. It is worth mentioning that the user is able to recall his or her interactions when using the Web (see Lisa's behavior at home), like a suitcase of experiences that follows him/her around in both the physical and the virtual world.

A further ingredient of the scenario is the fact that it exploits a **lightweight infrastructure**. Lisa can get in touch with the market stall and Lussino's Cevrin without adding sensors or electronics to the objects. Things are *recognizable* so that the user can get in touch with them using a smartphone. Finally, paradigms of augmented reality are adopted to make the interaction natural and playful; Antonio takes a picture with the smartphone camera and a contact with the recognized cheese is established. "Push" and "pull" interaction between the system and the user must be possible and the system is able to localize users and (some of the) things.

A final ingredient of the scenario is the fact that **stakeholders can get feedback** from the system. Mr Lussino can read the comments on his cheese and farm and can establish direct links with his customers. Intelligent objects can thus report what happened to them, the friendships they established with their "owners", i.e., the stakeholders who registered them on the system. On the one hand this is a way of *keeping cultural heritage alive* with contributions from a community of people. On the other hand, it is a way of supporting direct links between stakeholders and consumers *in the direction of shorter and more sustainable food chains*.

In the next section, we discuss *WantEat* in more detail, introducing the applications we designed to make the above scenario possible and the technology behind them. In particular, we first introduce the applications for end users and stakeholders and then we present the server side, which implements the things' social intelligence. Social intelligence was implemented on an application server and was achieved by combining in a particular way different technologies, including ontologies, techniques for knowledge integration and for processing user generated contents, techniques for user modeling, adaptation and recommendation, techniques for data analysis and learning from data, techniques for managing social networks. The application server consists of a number of modules that put these different technologies together. The applications behave as clients that connect, via a module that manages interaction, to the application server where most of the activities are performed (e.g., label recognition, integration of knowledge associated with a thing, social networking, etc.). This allowed us to avoid providing infra-structures for things, which do not carry any sensor or electronics on board.

[2]It is worth noticing that our framework could be adapted to this goal, which, however, was outside the scope of our project.

3. WANTEAT: THE APPLICATIONS AND THEIR DESIGN

In this section we discuss the applications we designed. A user centered design process was adopted and thus, before going into detail, we discuss how the requirements for the applications have been elicited from experts and stakeholders.

Promoting cultural heritage around quality gastronomy and supporting a sustainable gastronomy is the main objective of Slow Food and the main area of research of Università degli Studi di Scienze Gastronomiche and Slow Food. Therefore, in the early stages of the project we discussed and brainstormed with experts in these partner organizations and with representatives of local governments interested in promoting their region. In particular, we focused on how advanced ICT could be exploited to support local communities in this process. We came to the idea that interacting with things, and especially food things, could be an appealing way of achieving these goals. Given this initial design idea, we started investigating it in detail with stakeholders.

3.1. Requirement elicitation and analysis with stakeholders

As the first step of the requirement elicitation process we decided to perform a structured study involving some of our stakeholders, namely, food producers (we did not involve end users since we target generic end users and not specific classes of users). The objectives of this study were manifold: (i) understanding the state of the art, in particular regarding the methods currently used to promote their products and their region and (ii) getting early feedback from them about the possibility of using the innovative approach proposed by the project and (iii) asking them which information and services concerning themselves and their region they would like to offer users interacting with their products and which type of feedback they would like to receive.

Two well-defined geographic and cultural areas in Piemonte which can act as representatives of the agricultural, dairying and wine traditions of the whole region were selected: (i) the *Langhe*, situated in the province of Cuneo which is well known worldwide for its wines (such as Barolo and Barbaresco) and (ii) a less well known but emerging area in the province of Asti. An interview was prepared and then fine-tuned by performing a pilot study with three producers (see http://www.piemonte.di.unito.it/interview/interview.html for a complete description of the interview).

Twelve producers (three small cheese producers, three medium cheese producers, three small wine producers and three medium wine producers, all from different parts of the chosen areas) were selected. These producers were visited in Summer 2009 and interviewed (for about 2 hours) by members of our research group with specific experience in ethnographic and qualitative studies. During the interviews, the producers were asked about their work, their customers, the way they keep in contact with customers, the way they promote themselves in conjunction with their region, if and how they use information technologies and what they lack in terms of support for promotion. Two storyboards similar to the scenario in the previous section were presented to the producers in order to explain to them what our project could do for them. In the former a customer getting in touch with their products at a market was considered while in the latter, we showed how the customer could get information about the region and how the producers could receive feedback from the customer's comments.

From all the producers, independently of the area and of the product, we elicited the need for tools to promote their products and region, the need to be supported in the direct contact with consumers (both end ones and professional ones, such as shop owners and restaurants), the need to promote their products as part of the region's cultural heritage, and the need to provide customers with detailed information about the quality of their products. Moreover, the producers would really like visitors to the region to be able to find them and also be more closely integrated with the region's tourism offers. Their promotion is currently based mainly on word-of-mouth and on participation in markets and fairs, which however has a high cost. We did not notice a significant difference between cheese and wine producers, while some differences emerged between small and medium producers (see Table II). The table illustrates the main requirements elicited from all the producers (first column) and from small and medium ones (second and third columns).

Table II. Requirements elicited from producers

All	Small	Medium
Guaranteeing quality Direct contact with customers Knowing the customers Providing information about their products Stronger link with region No interest in e-commerce Supporting word-of-mouth for promotion Improving customer loyalty Need for help to use the Web	Promotion Preserving tradition in production Being localized	Monitoring the market Getting feedback on products

The need for a connection with the region was stronger in the emerging area in the Asti province, where producers expressed the need to develop shared policies with local governments to increase the region's tourism offers (this is not a strong need in the Langhe where tourism is already well developed). Many of the producers (9 out of 12) are connected to Internet but are not interested in e-commerce and feel that Internet could do more for them. Thus, they would like to have support in the areas of exploiting it for promotion and creating and maintaining links with the region and their customers. They liked the idea of a social network which involves the region and perceived it as a way of being found, similar to when they participate in markets and fairs in the region. In this sense they were very supportive of our ideas and contributed to the definition of the requirements we used for the design of *WantEat* and the applications for stakeholders.

After the analysis of the requirements, the design of the applications in the *WantEat* framework was started:

— *WantEat Mobile*: an application for smartphones that allows people to get in touch with things, interact with them and navigate their social networks of other things or people.
— *WantEat Back-shop*: a Web application that supports the registration of things in the system and provides a number of administrative and analysis tools. This application is meant for the stakeholders (e.g. producers, restaurant or shop owners, etc.) to insert their things into the social network, and follow them analyzing what users say and do on them.
— *WantEat Web*: a Web application that allows people to browse things and their networks on the web. It is a companion to *WantEat Mobile*, sharing a similar interface and philosophy in order to support a continuous experience when moving from the physical to the virtual world.

In the following subsections the applications and the choices we made, given the goals and the requirements from the domain, the experts and the stakeholders, are presented.

3.2. WantEat Mobile

WantEat Mobile has been developed for touch screen smartphones and introduces a new and unique interaction model that supports user interaction with social networks of intelligent things. This interaction consists of three main phases: (i) getting in touch with the thing, (ii) exchanging information with it, and (iii) exploring its social network.

3.2.1. Getting in touch. A basic assumption made in this project is that the infrastructure of the environment must be minimized. The aim is to support the interaction with everyday things, with no embedded electronics or sensors and with no ad-hoc tags (as for example RFID or QR codes) attached to them. These technologies, in fact, would not be acceptable to small producers of quality products (e.g., a cheese producer in the mountains). For this reason, the following ways of creating a contact between a user and a thing were developed:

(a) (b)

Fig. 1. Getting in touch with the iPhone. (a) Framing a label and taking a picture. (b) Geopositioning: things are shown as markers on a map or in an augmented camera image.

- **Taking a picture**. The user frames a recognizable element of the thing (it can be the product label, the sign of a shop or restaurant, a town's coat of arms) with the camera. The picture is recognized as the symbol of the thing, and a contact between the user and the thing is created (figure 1(a)).
- **Geopositioning**. The user can see which things (e.g., shops, restaurants, market stalls) are the closest to him/her and get in touch with them directly. Figure 1(b), shows an example: the user is positioned on a map (green mark on the small map in the bottom right corner of the screen) with close interesting things (red marks). When the phone is kept vertical (as in the figure) the camera image is augmented with a label corresponding to the direction for getting to a thing in the map. The labels in the augmented image and the markers in the map are clickable to get in touch with the corresponding things. Geographical locations (towns, significant landmarks, etc.) can participate directly in the social network; for them, geo-positioning is the most natural point of contact.
- **"Surprise"/"Recommend"**. The user can ask the system to be put in touch with a random thing; *WantEat* chooses one thing that is close to the user position (i.e., in the region the user is visiting). As we shall see, the application keeps a model of each user, describing her/his interests and preferences. In this way the system can recommend things to the user based on her/his model, her/his position and/or the user's social network.
- **Bookmark**. The user can create a list of "preferred" things and can start the navigation from one of them. In other words, the user can have a list of friends including both people and things and can at any time get in touch with one of these friends.
- **Search**. The user can directly search for things by name.
- **Push**. A thing can "call" the user, in a push modality. Shops, market stalls, restaurants, etc., communicate their position to the system which also has information on the products they sell/serve.

Whenever a user has the application turned on and gets close to a thing that the recommender considers relevant for him/her, the thing can call the user.

3.2.2. Interacting with the thing and its world: the wheel. Once a contact with a thing has been established, the user can interact with it and access its social network. Since we aim at using things as hubs to access the cultural heritage of a region, an interaction model which allows users to explore the world starting from the contacted thing was designed. More specifically, our interaction model should allow users to learn basic information about the things in which they are interested, to discover things that are related in some way, which may be of different types (e.g. products, recipes, restaurants, regions or users), and to understand the nature of the relationships between pairs of things. Navigation should not be rigidly structured, allowing users to interact with things rather than with an abstract hierarchy of categories; however, some sort of spatial organization should be provided in order to allow users to distinguish different types of things and different types of relations quickly. Moreover, if users are interested in one of the new things they have discovered, our interaction model should allow them to make it the new focus of their exploration and to continue in a snowball-like fashion, freely proceeding from one interesting thing to another. Navigation should therefore support discovery and serendipity rather than goal-oriented search of some specific items users have in mind.

Thus, our interaction model can be intended as a sort of “village square”, where users can informally interact with things, exchange information and knowledge with one of them, explore its neighbors and friends. Finally, natural and immediate interaction modalities should be provided to allow users to select things, express their interest in them or make them the starting point of their exploration.

After the definition of the requirements we started high-level prototyping a number of alternatives for the interaction model. The following ideas were proposed:

— *Cells model*. Things are visualized as differently colored cells which move on the screen. When a cell is selected, it generates “baby cells” which correspond to related things. Users can hide irrelevant cells.
— *Map model*. Different types of things (e.g. products and shops) are represented as regions in a map, specific things are represented as points and relationships among things are suggested by means of point proximity.
— *Multi-faceted sphere model*. Each facet in the sphere stands for a thing. When a facet is selected, facets which identify related things are highlighted.
— *Wheel model*. A specific thing the user is interested in is visualized as the center of a wheel, while related things are grouped in wheel sectors which can be expanded and browsed at will. Related things can be brought to the wheel center in order to continue navigation.

Paper-prototyping tests, involving a small number of colleagues and friends, were conducted. The wheel model was selected as the most promising one, since it satisfied all our requirements and was preferred to the other concepts due to its visual appearance and user interaction. In particular, in the wheel model there is a clearer focus on the thing the user is currently interested in (compared to all the other models); it is easier to identify related things (e.g. with respect to the map model); navigation is easier since sectors provide some hint of the type of related things they group (e.g. with respect to the sphere model); and there is no need for users to actively hide irrelevant things (e.g. in comparison to the cells model).

Starting from these concepts, the wheel model in figure 2(a) was developed. The thing the user is interacting with is at the center of the wheel. The user can get in touch with it simply by touching it, which is an appealing and natural way of performing selective actions with a touch sensitive interface [Vogel and Balakrishnan 2005]. The selected thing tells the user about itself, providing both general knowledge and information synthesized from the interaction with other people (including tags, comments, ratings) (figure 2(b)). The user can, in turn, tell the thing something: in particular, he/she can add his/her tags, comments and ratings or can add the thing to his/her list of friends by

Fig. 2. Example of the wheel on the iPhone. (a) The wheel with the thing in focus in the center and the four sectors (“Persons”, “Products”, ”Cousine”, “Region”). (b) Getting details about the thing in focus. (c) Exploring one of the sectors of the wheel; the friends of the thing in focus are shown displayed as small circles in a ring. (d) Selecting one item from the sector and dragging and dropping it to the center of the wheel (shown as an icon in the bottom right corner). This leads to a new wheel (e) with the selected item in the center. (f) User’s possible actions on the things in focus (“Vote”, “Tag”, “Comment”, “(Add To/Remove From) favorites”, “Explore”).

bookmarking it (figure 2(f)). These actions contribute to (i) adding the information to the thing in focus and (ii) influencing the social relations between things, as discussed in section 4.1.5.

The thing in focus is surrounded by the social network of its friends (figure 2(a)), which contains both people (including users) and other things. Each friend belongs to one of four sectors; the division into sectors depends on the thing in the center. In the example in figure 2(a), the thing in focus is a food product; the first sector “Territorio” (Region) contains the friends related to the region, the production and supply chain (e.g. producers, shops, production places, etc.). The sector “Persone” (People) gives people who are friends of the thing in focus (e.g. people who bookmarked it or who wrote a comment on it); the sector “Prodotti” (Products) shows other food products that are friends of the thing in focus (e.g. a wine that goes well with a cheese); the sector “Cucina” (Cuisine) contains entities related to cuisine, such as cooks, restaurants, recipes, and so on.

Each sector can be expanded by touching it; the expanded sector fills the screen and the items in the sector are displayed as small circles in a ring (see figure 2(c), where the “Territorio” sector is expanded), similar to the dialer in an old style telephone. The items are ordered based on their type and the user model (maintaining items of different types and preferring those more suitable for the user). The items can be explored by rotating the ring, in the same way as dialing on the old style telephone. The items are enlarged one at a time and the relationship between it and the thing in the center is explained in a small box; see again figure 2(c), which shows that the thing in the center of the wheel (minimized in the bottom right corner of the screen) is produced in (“prodotto in”) the place (“Valle di Lanzo”, i.e. Lanzo valley) enlarged in the sector. Information about the enlarged item can be displayed by touching it.

The user can continue exploration by changing the thing in focus. This can be done by simply dragging the enlarged item toward the wheel miniature in one of the corners (figure 2(d)). At this point the whole wheel is recomputed and displayed to the user. In the example, “Valli di Lanzo” would become the center of the wheel and all the wheel and sectors would be rearranged (see, figure 2(e) which shows the wheel for “Valle di Lanzo”).

In this way, using the metaphor of the wheel representing a village square, the user can explore the region via the social network of the intelligent things she/he meets; users can exchange contents and stories with these things and explore the networks of their friends. Further details of this interaction metaphor can be found in [Biamino et al. 2011; Chiabrando et al. 2011].

A video introducing the application and showing an interaction can be found in the project Web site: http://piemonte.di.unito.it/applications.html.

The users’ evaluation of the model will be further analyzed in Section 5.

3.3. WantEat Back-shop

WantEat Back-shop is an application we designed for stakeholders in the gastronomy and cultural heritage domain. It provides two groups of functions: registration of things in the system and behavior analysis of the registered things.

3.3.1. Registration. This module allows the stakeholders to register themselves and their things as members of our system. For example, a producer can register herself/himself and the cheeses she/he produces, providing information about them. The type of information to be provided depends on the type of stakeholder and on the type of thing to be registered. For example, a location is required for a production site, whereas a label, some pictures and the type are required for a cheese.

The system classifies the things that are registered, exploiting its knowledge base (see Section 4.1.1). Thus, whenever a thing/person is registered, it is immediately inserted in the social networks of things and people based on its properties, those provided by the registrant and those inferred by the system.

3.3.2. Behavior analysis. This second module of *WantEat Back-shop* is a web application that allows stakeholders to follow and analyze the behavior of the things they registered in the system and get feedback on the users’ behavior. The system is organized as a dashboard, with two types of tools:

— Exploring details. A stakeholder can inspect the specific annotations (comments, votes, tags) associated with a thing and its social network, discovering who its friends are, accessing the public information about these items (friends include both people and things) and discovering how the friendships were established. The stakeholder can also get information about the people who got in touch with the thing, the stories they told the thing (and the tags and ratings), the events it was involved in, and can analyze how the thing aggregated and synthesized such information to tell people stories in turn. Finally he/she can discover how other stakeholders made use of the thing. For example, a producer may get the information about the shops where his/her product is sold or the recipes in which it is used or the restaurants which served the thing. This is an important instrument to establish direct links between producers and consumers (or restaurants and shops) and can be a powerful tool to shorten supply chains and give quality producers the opportunity to promote and market their products. It is indeed a way to support sustainable high quality gastronomy.
  For example, figure 3 shows, once again using the wheel metaphor (although with slightly different functionalities and design, due to the different usage context), the social network of one of the things registered by the user, which is in the center of the wheel and is surrounded by its friends. The wheel has the same sectors as the mobile version, and gives producers the possibility to explore the friends of the thing at the center of the wheel, by clicking on it with the mouse. The "Persone" (People) sector, for example, contains all the people that commented on, tagged or bookmarked the thing, while the "Territorio" (Region) sector contains information on shops that sell the thing or places where the thing has been encountered by users. The distance from the center is used to visually represent different types of relations (e.g. in the "Persone" sector the people who bookmarked the thing are the closest to the center, followed by those who commented, tagged and voted. The specific comment/tag/vote can be obtained by clicking on the user's icon.
  It is worth noticing that in this case the wheel is static; it cannot be rotated or re-organized moving items since the goal is to only show items related to the one in the center of the wheel. Different wheels are generated for each one of the items registered by a user.
— Statistics about the thing's performance, i.e. the actions involving the thing, such as number of contacts, comments, tags, the average rating. These data are grouped in different ways, depending on the profiles of the users, the location, the time and so on. Comparisons between the behaviors of several things can also be made. For example, a producer can obtain statistics about where and when his/her products are served or sold and about the people who liked them, as well as comparing the performance of his/her product with those of a competitor or with the average of the performance of the things belonging to the same class (or to similar classes) in the domain ontology. This is an important set of tools to get feedback and subsequently to learn how to improve production/relationships with consumers.
  For example, figure 4 shows the statistics on the tags associated with one of the things registered by the producer. The figure shows a dashboard with four items in which the tags associated by users to a product are grouped according to the users' age (upper left box), gender (upper right box), if they are SlowFood members (lower left box), and the location where the tagging was performed (provinces of Piedmont, lower right box).

The above examples concern producers. Similar sets of tools are available for other types of stakeholders as well. For example, local administrators of a region can get statistical information about the people who got in touch or visited the region. In this way they can profile tourists in the region and thus use our system as a source of information for promotion.

3.4. ***WantEat Web***

WantEat Web implements functions similar to those of *WantEat Mobile*. The user can, of course, get in touch with things by searching for them or retrieving them from the bookmarks, or by exploiting the recommender. On the other hand, each thing can provide more information and tell more

Fig. 3. WantEat Back-shop - Exploring the social network of a registered product. In the example a producer (Elsa) explores the friends of one of her products (“Toma di Lanzo di Elsa” - Elsa’s Toma di Lanzo), which are displayed using the wheel metaphor again. She discovers (i) the people that got in touch with the product (sector “Persone” - People on the top right) and their comments, tags or votes; (ii) the other products that became friends of her product, given users’ action (in the “Prodotti” - Products - sector); (iii) the shops that sell her product (in the “Territorio” - Region - sector); (iv) the restaurants that use it and their recipes (in the “Cucina” - cousine - sector).

complex stories. For example, while only the name and a few lines of description are provided for a recipe in the mobile version, full details of the ingredients and cooking instructions are given in the web version. Moreover, links to external sites may be available in the Web application, for example in the description of places or restaurants.

WantEat Web is thus designed to provide a continuum of experience to users, who should be able to switch freely from one application to the other, without losing or having trouble finding the information they provide or bookmark. They could use the Web application before visiting a region and bookmark interesting places or products, and then use the mobile application during the visit, and finally use the Web application again after the visit to get further details about the things with which they got in touch. Users can also obtain a history of their activity and interactions with things in the Web application.

For example, Figure 5 shows how a user can navigate on the *WantEat Web* the history of the actions performed using *WantEat mobile* during a visit to a region. The upper part of the screen contains a time line, which can be zoomed in or out. In the example the user zoomed in on a specific day and the timeline gives the time. The actions performed by the user are displayed on the timeline. When a specific action is selected, information about it is displayed in the bottom part of the screen, including the object on which it was performed (“Cevrin di Coazze”), the thing’s “wheel” (lower left part of the screen) and details about the selected thing (lower right part). Also in this case we use a wheel-shaped control to display information about the selected item.

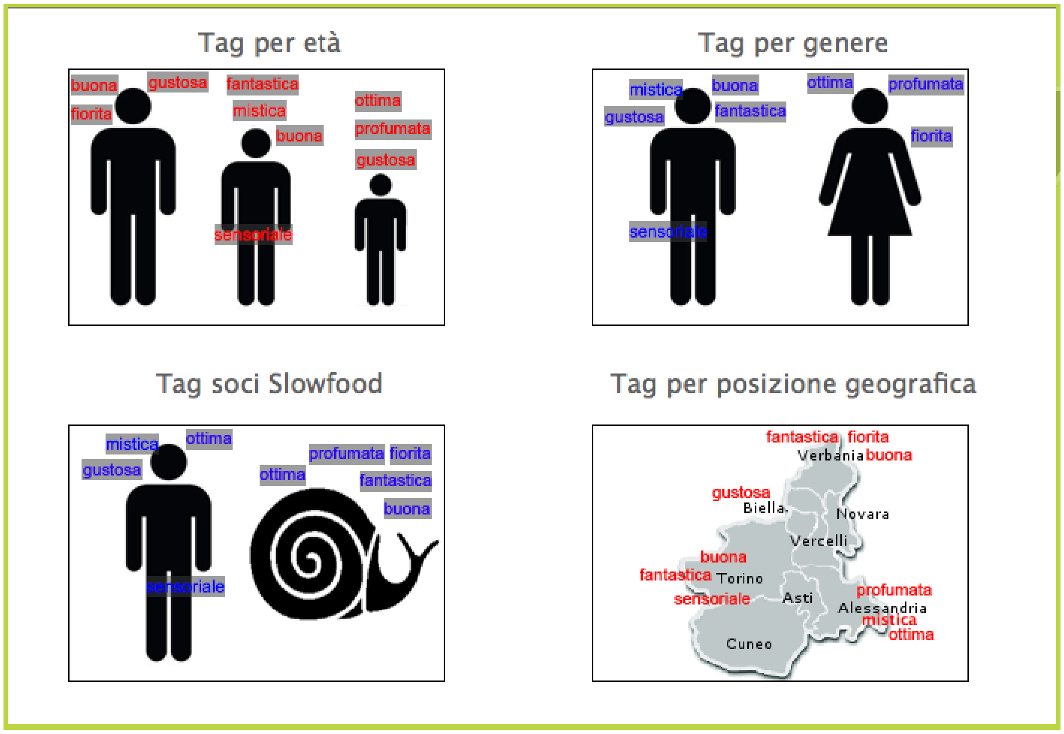

Fig. 4. WantEat Back-shop - Getting statistics about a registered product. In this example the producer Elsa can read statistics about the tags associated with her "Toma di Lanzo di Elsa" (Elsa's Toma di Lanzo). The tags are grouped by age (top left), gender (top right), whether the users who tagged the product are members of the Slow Food association (bottom left), and the province of Piemonte where the tagging was performed. These are only examples of the groupings that can be generated by the system.

4. ARCHITECTURE OF THE FRAMEWORK

In this section we sketch the architecture of the framework and applications that have been developed, focusing on the modules that support the functions described above. The framework has been designed as partially distributed. The following elements can be identified within it: (i) a **"server side"** in charge of the creation and management of the network of things and people, containing the logic for creating intelligent adaptive behavior; (ii) the **"client side"**, available on mobile smartphones (we are currently using Apple iPhone) and on the Web, which manages the interaction between people and things and networks; (iii) the **infrastructure** for the interaction with things.

Figure 6 provides a description of the architecture, including the modules in the "server side" (in grey boxes), those used by the mobile application (and the Web one, solid boxes and lines) and those used by the Back-shop application (dashed boxes and lines). The modules will be described in further detail in the following sections.

4.1. Server Side

This section briefly describes the main logical modules on the server side, explaining how the functions discussed in the previous sections are achieved.

Some preliminary remarks are necessary at this point. The modules on the server side could, in principle, be implemented on an application server or could be distributed on things, if the on-board computational power allows this solution. In *WantEat* we opted for modules on application servers since we assumed that things are not infra-structured with embedded electronics.

Fig. 5. Navigating History in WantEat Web. A user is retrieving his experience during a visit to Val Sangone. The actions he performed using *WantEat mobile* are displayed on a time line in the upper part of the screen. At 14:00 he bookmarked "Cevrin di Coazze". When this action is selected on the time line, the bottom part of the screen shows details about "Cevrin di Coazze," which was the object of the action. The wheel of "Cevrin di Coazze" is displayed (bottom left part of the screen). Whenever an item is selected in the wheel, details about it (a person who voted "Cevrin di Coazze" in this case) are displayed (bottom right part of the screen).

4.1.1. Ontology and DataBase manager. First of all, we decided to represent the knowledge in the system by means of ontologies. This is motivated by the fact that an ontological representation of the enhanced things in the project domain allows for representing both similarities and differences among domain items (food and people involved) as well as generic items and very specific ones. Ontologies also include relations among things and allow for inferences to extract implicit information.

Since the domain is very complex and heterogeneous, we developed a set of light-weight specific ontologies, imported by a more general upper ontology. The upper ontology aims at representing the application domain, and defines all the concepts in the domain and the relations among them[3]. The upper ontology includes the ontology of gastronomical products (e.g. different types of cheeses with different properties such as the type of milk and production techniques) and links such products to the ontology of the actors (producers or market stall owners), to the ontology of geographical places, to the ontology of the recipes involving the use of the products. Particular attention is paid to production philosophy (e.g. organic, traditional, etc), represented by a different ontology.

A set of SWRL (Semantic Web Rule Language) rules[4] for defining interesting associations between classes of things (or individual things) has also been included. Rules may define associations between products or recipes and wines based on the product, recipe and wine properties and characteristics. For example, a rule like:

Cheese(?x) ∧ has_hardness(?x,Soft) ∧ has_aging(?x,Medium) ∧

[3]The ontologies have been derived from books and guides of the Slow Food association, guides and web site of Provincia di Torino and have been evaluated and approved by Slow Food and by University of Gastronomic Sciences domain experts.
[4]http://www.w3.org/Submission/SWRL

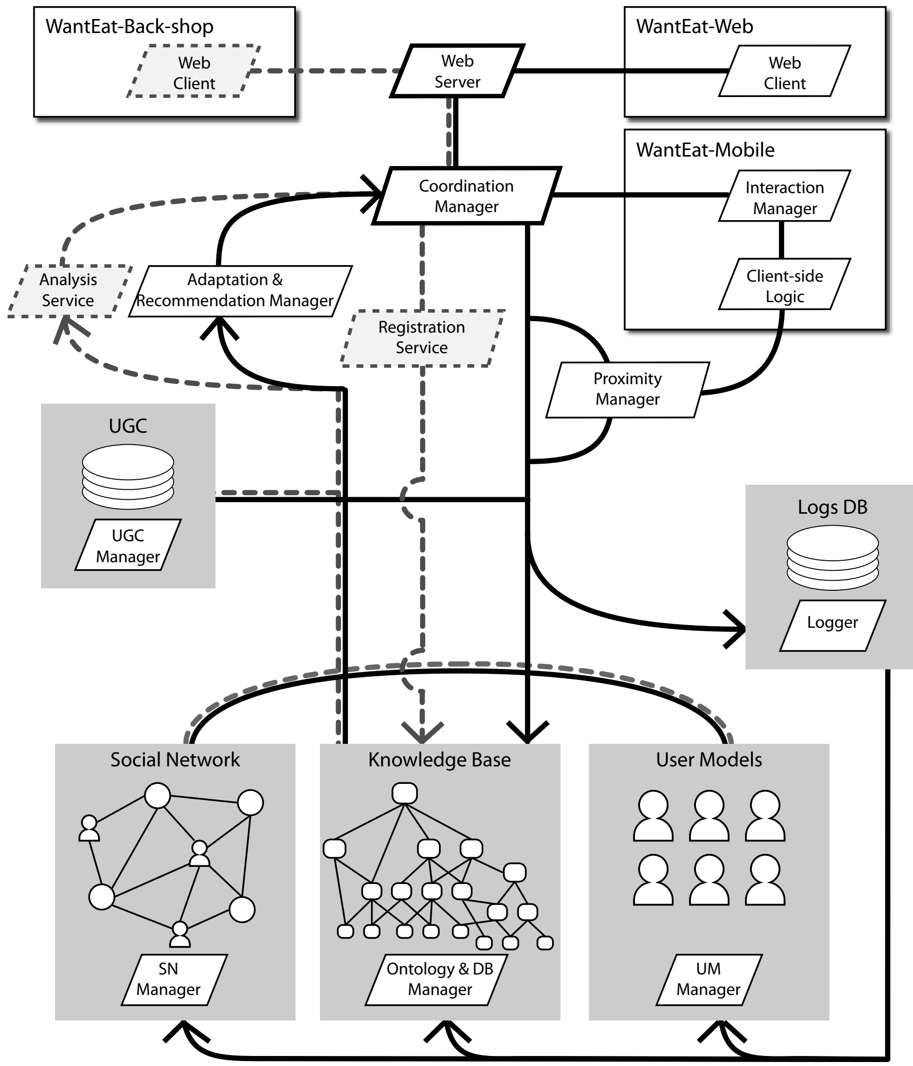

Fig. 6. *WantEat* architecture and its modules. The core server-side modules are in grey-shaded boxes in the bottom part of the scheme. The client-side modules correspond to the boxes in the upper part. Solid arrows indicate the interactions and flows generated by the end-user clients (*WantEat mobile* and *WantEat Web*) that connect to the core via a Coordination manager and receive information back via an Adaptation and Recommendation Manager. Dashed arrows represent the flows generated by the stakeholder applications (*WantEat Back-shop* that connect to the core via the coordination manager (and possibly a registration service) and via an analysis service.

$$\begin{array}{l}\text{wine(?v)} \wedge \text{has\_color(?v,White)} \wedge \text{has\_aging(?v,?y)} \wedge \\ \text{swrlb:greaterThan(?y, 2)} \wedge \text{has\_flavor(?v,Flowery)} \wedge \\ \text{has\_taste(?v,WellEquilibrated)} \rightarrow \text{pairs\_with(?x, ?v)}\end{array}$$

specifies that a flowery white wine is perfect with medium goats cheeses.

Inferences on the ontologies allow the system to: (i) associate inferred properties to things, which, in turn, can be shared by things with interested users; (ii) create links between things. In fact, one way to create a link between two things is to deduce it from some property they share in the domain ontology (such as cheeses made with the same type of milk or wines made with the same type of grapes) or by exploiting the other ontologies (such as the things originating from the same place or being produced in similar ways or responding to the same production philosophy). Other links may be created by rules. For example, given the Erbaluce wine, we can associate with it all the properties of that wine, including where it comes from, wines that are similar to it (e.g. they use the same type of grapes), the vineyards used by its producer, the producers themselves but also other food products from the same area. Moreover, rules can create further links, e.g. between Erbaluce and dishes. For example, the link between the goat cheese salad and Erbaluce wine may be inferred because Erbaluce is a flowery white wine and these wines are ideal for salads with medium-aged cheese (thanks to the above rule).

For each of the relevant things, the system also keeps track of other types of information such as pictures, including a picture of its label to be used by the recognition algorithms, or links to external resources containing cultural information (for places).

Part of the information concerning each thing is stored in the ontology, by defining the corresponding properties in the class to which the thing belongs (e.g. the Cheese class in the ontology has a *type of milk* property to specify the type of milk of each specific cheese type). Another part of such information (e.g. long textual products descriptions, producers' contact information), is stored in the database. Therefore, each thing is both an instance in the ontology and a row in the database table; the link between these two "identities" is provided by the D2RQ tool [Bizer and Seaborne 2004]. This tool allows to view (part of) a relational database as a collection of OWL individuals (rows) belonging to OWL classes (tables) and having properties (columns). Moreover, these individuals can be linked to instances already present in the OWL ontology, so that the information in the database is actually seen as an extension of the information in the ontology. When querying the ontology, the presence of the D2RQ layer guarantees that, if necessary, properties that are described in the database are taken into consideration as well.

In order to experiment the system we developed and populated ontologies with information about the Italian Piemonte region, and in particular its wines and food. We focused on the products of the *Paniere dei Prodotti della Provincia di Torino*[5], which identifies the 32 most distinguished food products (ranging from vegetables to cheeses, wines and cold cuts) of the area. These products (and their product categories) have been modeled as classes in the domain ontology with their properties, including links to the geographic ontology of Piemonte and to the ontology of production philosophies. Since cheeses and cold cuts (14 products out of 32 fall in these categories) are the main excellence of the region, we decided to add more specific information about them. Thus the sub-ontologies of cheeses and cold cuts were detailed in more depth, to capture the distinguishing features of each variety, and for each of the 14 specific classes describing the "Paniere" cheeses and cold cuts, we included information about producers (about 200 in total), shops and restaurants where they can be bought or tasted (about 80 places) and recipes where they can be used (about 50). The resulting ontologies which constitute the knowlelge and data base for the experimentation contain 98622 triples and 53 rules associating products (mainly cheese-wine associations).

4.1.2. User-Generated Content Manager. Information can be associated by users to things in the form of ratings, tags, comments. The system stores such information in a database, also tracking the identities of the users who provided the information and the time of interaction. These pieces of information are used in different ways. First of all, the system aggregates and synthesizes the tags and ratings associated with each thing; it can merge the comments based on the profile of the users who made them. For example, when user X asks a thing to tell him/her about itself, the thing may include recently-made comments by users with a profile similar to X in the synthesis to be

[5]Literally *A basket of Turin region products* (http://www.provincia.torino.it/agrimont/sapori/tipici/).

presented. Secondly, the information provided by the users is exploited by both the user modeling and social networking modules.

More complex forms of digital storytelling are being explored. In particular, we designed an ontology-based language for representing and storing simple narrative fragments. People can use it to share simple "facts" concerning their interaction with one or more things within the system (e.g. "Lisa bought Lussino's Cevrin in Giaveno"). Similarly, the *WantEat* system can use it to store the information on what users did with its applications (e.g. "Lisa tagged Erbaluce while in Giaveno"). The language is simple enough for users to build fragments by simply dragging icons or names of things and people. However, the language structure allows the system to make inferences on the narrative fragments, presenting users with "stories" of what has happened in the system that may be of interest to them [Likavec et al. 2010].

Whether information provided by users should be moderated or not was a source of lengthy debate. It was finally decided to have no moderation for the prototype because this is more in line with the social nature of the system and the philosophy of social networks on gastronomy. However, the notion of "filter" was added to the system. The user can select the filters she/he wants to activate and only some of the user-generated contents are taken into account for each filter. In Figure 2(a) filters appear as icons in the bottom part of the screen. The snail icon filter only offers those contents that are provided by members of the Slow Food organization. Consequently, comments provided by other users are not displayed, and neither are the relations generated using these comments. Similarly, other filters can be implemented. Therefore, users can choose whether to consider all user generated content or focus their attention on contents provided only by trusted users. Finer grained forms of moderation are currently not implemented but we plan to return to this decision after a field trial of the system (we shall return to this point in the conclusions).

4.1.3. User model manager. The system designed is **adaptive** and provides information and services tailored to the specific user and context of usage [Brusilovsky et al. 2007]. The **user modeling** module keeps a model of each user. The model is an overlay on the domain ontology and describes the user's interests/preferences with respect to the concepts in the domain ontology and his/her opinion about the different philosophies represented in the ontology. It may also include preferences for specific things. A user model is represented as a set of "concept/value" pairs, where the concept is a class of the domain ontology, and the value is the level of the user's interest for such concept. At the beginning of the interaction, the initial model is empty; the system logs all the actions performed by each user and the user's model is updated periodically by performing log analysis and inducing preferences from his/her behavior. The approach we use to update the model in time is similar to the one used in other adaptive systems such as ICity [Carmagnola et al. 2008]: we periodically analyze the actions performed by a user and ascribe them to concepts in the domain ontology; in this way the actions give evidence of the user's interest in that concept. Different actions have different strengths in this induction process. For example, bookmarking a thing is a strong indication of the user's interest in the thing and in its class, while mere interaction with the same thing provides a weaker evidence. Tagging is an example of an intermediate strength action with respect to those mentioned above. The information about the user's interest obtained from this analysis is then combined with the existing user model, which is revised based on the interest deduced from the user's action. The more a user model is consolidated along time, the less it is affected by the update (see [Carmagnola et al. 2008] for the mathematic details of the computation).

The user model is the basis for computing similarities between users as the distance between their models. This is a more fine-grained approach with respect to basic collaborative filtering ones which simply consider two users to be similar if the ratings they provided on things are similar (see once again the approach used in [Carmagnola et al. 2008]). Such similarities are exploited throughout the whole systems in different ways. Whenever a user explores the comments and tags associated with a thing, he/she can filter them focusing on those provided by similar users. Moreover, similarity can be exploited to provide a sort of word-of-mouth recommendations: things that belong to a user's bookmarks can be suggested to other users with a similar model. The fact that Lisa is contacted by the market stall is an example of this type of recommendation: she is similar to Antonio and Antonio bookmarked Lussino's Cevrin.

4.1.4. Adaptation and Recommendation manager. Our system includes a **recommender** which exploits the user models and the domain ontology, taking into account the context of user interaction (e.g. the location and time of the interaction provided by the mobile terminal). The recommender can rank a set of things (and people) based on an estimate of how much the user may be interested in each one of them. Thus, when several items have to be shown to the user (e.g. when displaying the social network of a thing or a person), the recommender can order them according to such parameters. This is particularly relevant when items have to be displayed on a mobile device. Actual ranking for recommendation is not only based on the user model. Other criteria taken into account are the ratings associated to things by users, geographic locations (preferring those closer to the user), how much a thing is "cool" or "trendy" (based on the recent interactions with it). The ranking is a combination of all these factors though the user can select the most important factor for him/her.

4.1.5. Social network manager. This module manages **social networks** of things and people. We consider different ways of creating links in these networks:

— *User-to-user links*. Links between users are either created explicitly by the users (e.g., the network of each user's friends) or by the system based on the analysis of user behavior. In the former case we consider friendship relations as is common in other social networks and interoperability with widely used social networks such as Facebook, e.g. importing links between friends, is also being considered. The latter case includes links between similar users (based on their user models, see above), the links between users who are in the same location at a given time, the links between users who are fond of (bookmarked) a specific thing or a class of things. Notice that some links may depend on the context of interaction (e.g. time or place).
— *Thing-to-thing links*. These links are created by the system based on the analysis of the users' behavior and interaction with things (notice that things also include actors such as producers or cooks). Thing X may be linked to another thing Y in the case that, for example, X has been mentioned as a tag or in a comment on Y, X and Y frequently appear together in the bookmarks of several users, X and Y have been visited frequently on the same occasion by several users. In order to create these links log files (where actions performed by the users are tracked) are analyzed, and significant correlations between things are searched for. In the data analysis we may adopt filters in order to consider only the actions performed by specific groups or classes of users. Consequently, on the one hand links are created based on the behavior of certain classes of users (e.g. users who are recognized as "experts" in the field); on the other hand links can be personalized (a link is visible to a user only if it is created based on the behavior of his/her friends or similar users) or can depend on the context of interaction. Thing-to-thing links can also be established as a consequence of ontology-based inference (e.g. X is the value of a property in Y); these links are established when the thing is registered in the system and updated when its description changes. They are of a more stable nature than "emergent" links, that may disappear as time passes if users behavior does not reinforce them.
— *User-to-thing links* These links are mainly based on the user's actions, i.e., a user is linked to the things he/she bookmarked/commented/tagged/rated positively/visited. Further links between users and things can also be created using the same techniques discussed in the previous item, i.e., whenever a user name is frequently associated by other users to a thing (or vice-versa).

4.1.6. Coordination manager. The coordination manager is in charge of the interaction with the user clients. It processes client requests and dispatches them to the other modules. Moreover, it adapts the interaction to the user's specific preferences, device and interaction context. It is strictly connected to a **log service**: all the requests and actions performed by the users are logged; the logs are then used by both the social networking manager to maintain the social networks and the user modeling module to update the user models based on user behavior.

4.1.7. Proximity manager. The proximity manager tracks the position of users and selected things. In particular, we assume that the position of things such as shops, restaurants, markets is known, while the position of other items (such as food products) is not known in order to avoid adding sensors to them. The user's position can be obtained from the GPS in her/his smartphone. This module can also trigger the interaction between a thing and the user, when they are close to each other (e.g., when Lisa gets close to the market stall). However, the user must agree to being tracked when registering to the service.

4.1.8. Registration service. This service supports the registration of a stakeholder and his/her things in the system. It exploits the domain ontology and a stakeholder must classify himself/herself as one of the types of actors in the domain (e.g., producer, shop owner, cook). After that the stakeholder can register his/her products and associate each one of them to a class in the ontology. The service has been designed in such a way that the user has to provide little information, as this information is mostly inferred by the system given the association to a class in the ontology. This facilitates the work of users that are not familiar with technology. At present the extension of the ontology with the creation of new classes of products is allowed only to super-users.

4.1.9. Analysis service. This service supports *WantEat Back-shop*. It provides a registered user with the data and statistics concerning the thing(s) he/she registered within the system. It exploits other services in order to provide the information on the social network of a thing and on the users that have a strong link with it. Moreover, it uses the logging service to compute up-to-date statistics about the interaction with each thing.

4.2. Client side

The client side of the mobile application has been implemented on Apple iPhone. It consists of an Interaction Manager, which is in charge of (i) managing the interaction between a user and things and (ii) creating the interaction environment discussed in the previous sections (the "wheel"), sending requests to the server (coordination manager) and processing the answers in order to generate the appropriate way of presenting them.

The Interaction Manager adopts an identification service, as taking a picture is the main method for users to get in touch with things. We experimented both a client side recognition algorithm, running on Apple iPhone, and server side algorithms.

The client side algorithm needs the logo of a product to be bordered by a black frame. This restriction allows for quick recognition and accurate pose estimation of the marker. This algorithm uses ARToolKitPlus [Wagner and Schmalstieg 2007], a library for augmented reality, optimized for use on mobile devices such as smartphones and PDAs. In this way the algorithm supports a form of augmented reality: after the logo is recognized, its picture is overlaid in the right position on the display. For more details on marker recognition see [Grillo et al. 2011].

The server side algorithm does not require any restriction and so can also recognize logos without any borders. Moreover, it can recognize logos even if they are only partially visible. It is a proprietary algorithm by Telecom Italia which is also used in other applications. However it requires the image to be sent to the server and this may cause some delay if no 3G network is available.

The user experience is the same with both algorithms; the server side algorithm allows us to achieve the goal of requiring no infra-structuring at all as it recognizes the labels as they are and have been in the past. The client side algorithm, on the other hand, can support forms of augmented reality and more direct interaction with things.

The interaction manager uses the GPS to monitor the user's position and, if the user selects a push option, it periodically sends this position to the server in order to allow things to get in touch with the user based on his/her position.

The other two clients (i.e. WantEat Web and Back-shop) have been implemented as Web applications. They both use a Web server interacting with the coordination manager, providing a Web interface to expose the server side functionalities. It is the coordination manager's responsibility to dispatch queries to the different modules within the system in order to reply; it runs the proper flow of operations depending on whether a query comes from the *WantEat Web* or the *WantEat Back-shop* client.

4.3. Privacy issues

Privacy policies are a relevant issue in *WantEat* and were the focus of lengthy debates with partners and stakeholders. Broadly speaking, in the domain of gastronomy people tend to be quite liberal about privacy. In guides and sites about restaurants, for example, usually users' comments and recommendations are visible to the whole community and in many cases the identity of the commenter is disclosed. In *WantEat*, each individual user can decide which pieces of information can be made public (e.g., his/her profile, localization, bookmarks, comments, tags or ratings) and to whom. In particular, information may be private or visible to all or even only to selected users such as his/her friends. Thus, each user is in control of the information about him/her exploitable by the system and made available to other users.

4.4. Infrastructure and implementation

Having a lightweight infrastructure is an important goal of the project. For this reason, the image recognition approach is the main way to establish a contact between a user and a thing, since it does not require any physical hardware to be integrated in the things or in their environment. In particular, with the server-side algorithm, we can recognize any label or image, without any constraints and thus stakeholders are free to attach any label to a product when registering it. Hence, stakeholders do not need to use any extra tag on their things; this is very important given our target of small quality producers.

Regarding GPS localization, we assume that the geographical position of the places such as shops or restaurants is known to the system, while the user's position is available thanks to the GPS included in Apple iPhone. Regarding the implementation of the framework, we decided to centralize the core of the system. This choice has been driven by the fact that we aim at interacting with concepts, via their instances (see the discussion above) and we are not interested in tracking or interacting with individuals.

4.5. Implementation of the Initial Scenario

In this section we briefly revisit the key activities performed by the different actors in our initial scenario (see Section 2, table I). The goal is to show how the modules in the above described architecture (see Figure 6) cooperate to make the activity possible. A full description including figures of the interaction steps is available on the Web at: http://www.piemonte.di.unito.it/applications/storyboard.html.

— *A0 - Mr. Lussino registers his farm and his products.* Mr. Lussino uses *WantEat Back-shop* to carry out the registration. He registers both his farm and his products. The Registration Manager queries the Ontology & DB Manager to show Mr. Lussino the product categories, so that the products are placed in the proper classes and they inherit the relevant properties from the class. Each product becomes an instance of the ontology class it belongs to; the Registration Manager also inserts a matching DB entry, mapped to the ontology instance using an ontology URI. The DB entry contains the information such as the address and the phone number of the farm, or the textual description and pictures of the products.
— *A1 - Antonio takes a picture of Lussino's Cevrin* In this case the key role is played by the Recognition Service, that matches the image framed in Antonio's phone camera with a product. In the prototype this task is performed by the Interaction Manager, and the name of the identified product is sent to the server for retrieval. If the Recognition Service is on the server, the whole image is sent to the server's Coordination Manager, which then dispatches it to the Recognition Service and consequently retrieves the information about the recognized product.
— *A2 - Lussino's Cevrin shows Antonio its social network on WantEat mobile* Upon receiving the name of the recognized product, the Coordination Manager sets up a process where the Ontology

& DB Manager provides the information about Lussino's Cevrin, the Social Network Manager gives the social network of the cheese, the UGC Manager provides user generated content for Lussino's Cevrin, and the User Model Manager provides Antonio's user model. The Adaptation and Recommendation Manager then intervenes to properly merge and present the information to Antonio, taking advantage of his user model. For example, the ratings for Lussino's Cevrin may be averaged considering only people that Antonio considers experts. Or, the elements in the social network may be ranked according to Antonio's preferences.

— *A3 - Antonio bookmarks Lussino's Cevrin.* Bookmarks are part of the user-generated content, so the UGC Manager is responsible for storing Lussino's Cevrin in Antonio's bookmarks. This action is recorded by the Logger in the Logs DB, and both the Social Network Manager and the User Model Manager will take it into account when updating the information in their care.
— *A4 - Antonio tags Lussino's Cevrin.* These activities take place in the same way as A3.
— *B0 -* WantEat *connects Lisa and Lussino's Cevrin.* Lisa has the application turned on in push mode, so the system knows her GPS-tracked position, and determines a set of products that may be of interest to her, through the Adaptation and Recommendation Manager. The Proximity Manager recognizes a proximity between Lisa and one of these potentially interesting products, Lussino's Cevrin, and pushes the information to the Client-Side Logic.
— *B1, B2, B3 - Lussino's Cevrin presents various types of information about itself on WantEat mobile.* The execution flow of this activity is analogous to that of A2. What we want to remark here is that the link to the Erbaluce wine is present because the Social Network Manager inferred a friendship between Lussino's Cevrin and Erbaluce using food-wine matching rules.
— *B4 - Lisa follows the link to Erbaluce.* Lisa "follows the link" by bringing a new element to the center of the Wheel. The request sent to the Coordination Manager is then the same as in activity A2; only the name of the product is determined in a different way (it is chosen by Lisa and not found by the Recognition Service).
— *B5 - Lisa asks for a restaurant recommendation.* Here Lisa is using the "Recommend" function on the client, with a filter that only shows restaurants. The Coordination Manager then activates the following process: the Ontology & DB Manager provides a list of restaurants that are close to Lisa (by using the Proximity Manager). The UM Manager provides Lisa's user model. The Adaptation & Recommendation Manager then ranks the list according to Lisa's user model, where her recent activity shows that she bookmarked the salad recipe and could therefore be interested in tasting it.
— *C1 - Mr. Lussino gets feedback on his farm and products.* Mr. Lussino connects to the Back-shop Website, which uses functions from the Analysis services to provide statistics about his cheese and details about the people that got in touch with it and the shops and restaurant selling or serving it.

As this example shows, most of the activities require a cooperation of several, if not all, server side modules.

5. EVALUATION

We adopted a user-centered approach in the design of *WantEat* and its interaction models. In section 3.1 we discussed how we involved stakeholders in the early design phase. In this section we discuss the evaluation of the applications with users. In particular, three phases were performed:

— In the preliminary phase, a small-scale user evaluation with end users was carried out. This was to evaluate the first interface design with the wheel metaphor, with a special focus on usability issues.
— In a second phase, an evaluation of the performance of the prototype has been performed
— In the final phase, an extensive quantitative user evaluation on the first complete prototype of *WantEat Mobile* application with end users was carried out. The first complete prototype of *WantEat Back-shop* was presented to stakeholders and informal comments were collected.

5.1. Preliminary evaluation

The preliminary evaluation was performed after a first *WantEat* wheel interface software prototype was implemented. The aim of this evaluation was to check the usability of the interface and to point out problems in the use of the wheel interaction paradigm. In this and the subsequent final evaluation we decided to divide users in four groups based on:

— *Age.* Users were considered "Young" if younger than 35 years and "Old" if older. Our studies based on *ad hoc* market research and official statistics from the Italian Institute of Statistics[6] have shown that 35 is the age in which the Italian population has a real change in personal lifestyle (a solid economic independence, marriage, children, etc.).
— *Attitude toward new communication technologies.* Users were considered "Soft" if they used up to 4 technologies from a 9-item list (touch-based devices, Internet navigation for more than 15 hours per week, GPS and navigation, last generation console for videogames, Pay TV, MP3 player, peer-to-peer, social networking such as Facebook, and micro-blogging websites such Twitter). They were considered "Hard users" if they used 5 or more of the listed technologies.

We selected 12 users, 3 for each one of the four possible subgroups (Young/Soft, Young/Hard, Old/Soft, Old/Hard).

The aim was to evaluate different aspects of the interface such as navigation, access to the detailed description of items, the wheel idea and access to a sector, the rotation of the items in a sector, the reconfiguration of the wheel paying attention to information architecture and to the affordance of the labels and icons.

Users were asked to perform a number of tasks such as: searching for information on a product, writing comments on products, recognizing a product label and retrieving information about the area where it is produced, reading comments by other users on a product. After each task they had to fill in a questionnaire aimed at evaluating (using a 5 level Lickert scale) if the actions to be performed were intuitive and easy and if the interface was clear. At the end the users were also asked to answer some general questions about the service provided by the system, whether they found it useful or not and whether they would use it and in which contexts.

The results from this evaluation were very positive: in fact, all users liked the service and appreciated the interaction model; no major usability problems arose. However, some minor usability issues were highlighted and fixed in the following re-design phase, leading to the final prototype. User appreciated the idea of the wheel and considered it a very intuitive navigation paradigm. Average ratings were 4 or higher for almost all questions and groups. The service was perceived to be very useful, pleasant and interesting. Users stated the service was very interesting especially to discover new products, to obtain information on places they are visiting, and where products can be found. Users also provided interesting ideas about the possible scenarios where *WantEat* applications could prove useful. The majority (10) said they would use it while visiting a certain area or while visiting a market for discovering products; 9 of them would use it at a fair, 6 at the supermarket.

5.2. Prototype evaluation

In July 2010 the prototype with the knowledge and data base covering the Piemonte region and discussed in Section 4.1.1 was released and an internal test was performed before introducing the applications to potential real users. This test had two main goals: checking the stability and efficiency of the server and validating the consistency of the entered data. *WantEat* performed well in both respects. The system is hosted by an internal server at the University and could serve up to 100 users in parallel, assuming a request every 10 seconds from each user. Most importantly, given the goals of our experimentation, the server never crashed, its answers were never delayed, and no answers that was not compatible with the clients' protocols were provided during a stress test with 20 simulated clients sending a total of 200 requests per minute for a full day. Regarding the consistency

[6]ISTAT, http://www.istat.it/en

Fig. 7. Market stalls in the Provincia di Torino area and users testing *WantEat*

of the knowledge bases, the answers given by the server were checked manually, and the support of gastronomy experts was also requested, who approved the associations between food products computed using the *WantEat* ontologies.

5.3. Evaluation at Salone Internazionale del Gusto

In October 2010 *WantEat* was introduced to and tested by a wide public at a gastronomic fair, the Salone Internazionale del Gusto[7] of Turin. The Salone Internazionale del Gusto is a huge fair dedicated to the culture of quality food from all over the world. It is organized by Slow Food in Turin every two years, with over 200,000 visitors. Thus, the 2010 edition of the Salone provided an ideal context to test our application, since the visitors are our target users as they are interested in quality gastronomy and in the cultural aspects related to gastronomy. As visitors are required to pay an entrance fee, they definitely have a positive attitude toward gastronomy and a certain level of interest in high-quality food. Therefore, we decided to perform a large scale test of our application at the Salone del Gusto.

The Salone del Gusto was set up as a set of squares, one for each region (Italian as well as foreign regions were represented). Each square held a number of stalls presenting the region's products and, in most cases, a stall with tourist and cultural information about the region. The stall of the products in the Provincia di Torino square were equipped with the *WantEat* logo and big product labels were added to the stalls selling the products of the Paniere dei Prodotti della Provincia di Torino in order for them to be recognized (see figure 7; the logo was added to the stalls since such stalls were overcrowded and it would have been very difficult for users to get close to the product labels in order to recognize them).

[7]http://www.salonedelgusto.it

Table III. Average values for the four dimensions indicating the level of acceptance of *WantEat Mobile* application

<table>
<tr><th rowspan="2">Dimension</th><th rowspan="2">Young/Hard</th><th rowspan="2">Old/Hard</th><th rowspan="2">Young/Soft</th><th rowspan="2">Old/Soft</th><th colspan="2">Total Sample</th></tr>
<tr><th>avg.</th><th>s.e.</th></tr>
<tr><td>Ease of use</td><td>3.49</td><td>3.57</td><td>3.44</td><td>3.24</td><td>3.42</td><td>0.03</td></tr>
<tr><td>Comprehensibility</td><td>3.5</td><td>3.64</td><td>3.43</td><td>3.32</td><td>3.46</td><td>0.03</td></tr>
<tr><td>Pleasantness</td><td>3.42</td><td>3.49</td><td>3.44</td><td>3.38</td><td>3.43</td><td>0.03</td></tr>
<tr><td>Usefulness</td><td>3.01</td><td>3.30</td><td>3.13</td><td>3.09</td><td>3.12</td><td>0.03</td></tr>
</table>

Table IV. Frequency distribution for the four dimensions indicating the level of acceptance of *WantEat Mobile* application.

Dimension	1	2	3	4
Ease of use	1%	7%	39%	53%
Comprehensibility	0%	8%	38%	54%
Pleasantness	1%	7%	37%	55%
Usefulness	4%	17%	41%	38%

Users could borrow an iPhone from our position at the stall of the Provincia di Torino and, assisted by a student, test the system (figure 7 shows a tester using the iPhone to recognize a product label). Users were asked to perform simple tasks: select a product, recognize its label, read what the product said about itself, then navigate to discover its origin, its producers, other people's comments, and finally comment or tag or vote a product. Following this, they used the application for a few minutes and were asked to fill in a short questionnaire. The entire task, including the interview, lasted 15 minutes at most, to avoid overly distracting users from their visit. Students supported users and acted as experimenters and interviewers so that they could take notes of what the users did and said during the test.

The subjects for our study were selected at random from the Salone del Gusto visitors. There were 684 selected subjects in total. In accordance with the selection criteria we adopted for the small-scale user evaluation, we segmented the final sample in the same 4 sub-groups based on the dimensions of age and attitude toward new communication technologies. Such subgroups were composed as follows:

— Young/Hard Users: 228;
— Old/Hard Users: 114;
— Young/Soft Users: 175;
— Old/Soft Users: 167.

The structured interview was divided in two parts: "basic statistics" and "evaluation". The statistics part was aimed at gathering socio-demographical information (e.g. age, place of residence, etc.) and at determining the user's attitude toward new communication technologies.

The evaluation part was aimed at gathering the overall level of acceptance of the application, measured through four different dimensions: ease of use, comprehensibility, the pleasantness and usefulness. Each dimension was measured by means of a 4-point self-anchored scale, where 1 means "not at all" and 4 means "very much". When subjects selected a negative answer with respect to a certain dimension (points 1 and 2), the interviewer also asked them to give their reasons for such a judgment, selecting one or more options among a set of multiple answers. Finally, at the end of the interview users were asked to indicate possible application scenarios for *WantEat Mobile*, as well as new features that could be implemented in the future (the interview template is available on the Web at: http://www.piemonte.di.unito.it/interview/interview.html).

The results of the evaluation, summarized in tables III and IV, show a very high level of acceptance with respect to every tested dimension.

More specifically, the average for *ease of use* was 3.42. Most subjects considered the application very or quite easy to use. Subjects who gave a negative judgment (8.% of the total sample) said that they did not feel in control of the application (40%), that navigation was not intuitive (34%), that it was difficult to remember all the commands (25%), and that the commands themselves were inaccurate (22%).

The average for *comprehensibility* was 3.46. A few subjects who expressed a negative opinion (9% of the total sample) claimed that they found it difficult to orient themselves (41%), that the icons were not clear (39%), and that it was difficult to find the specific items they had in mind (38%). For 28% of the users, the meaning of some features was unclear; 16% of the users stated the labels were not very understandable and 15% of the dissatisfied subjects believed that the information provided in response to an explicit user request was not the expected one.

The average for *pleasantness* dimension was 3.43. Only 8% of the total sample expressed a negative opinion. Of these, the majority considered the application not pleasant on the whole (37%), or unsatisfactory concerning the design of the interface (37%), whereas 23% of the users did not like the animations and 12% of the users did not like the colors.

The average for *usefulness* was 3.12. Among the few subjects that have had a negative opinion (21% of the total sample), the majority (36%) believed that the whole application is not very useful, while 28% of the users thought that the possibility to share their opinions with friends or to express opinions about products and places is not so useful (17%). Finally, some users did not find the in-depth descriptions of the products (15%) or the relationships between products (12%) to be useful.

76% of the whole sample answered affirmatively to the question if they personally would *use the application in their daily lives*. In addition, 88% of the users answered positively to the question if they would *recommend the application* to friends and relatives.

At the end of the interview, subjects told the interviewer in which *context of their everyday life they would use the application* (a set of multiple answers was proposed, from which subjects could choose one or more options): 49% of the users answered during a trip, 46% of the users would use it at a market or at a fair, 39% of the users would use it at the supermarket, 20% of the users would use it at home and 19% of the users at the restaurant. Finally, the most valued possible new features were: the possibility to compare the prices of different products (70%); the possibility to compare the products themselves (45%); the possibility to buy the products through the application (36%) and to book hotels and restaurants through the application (35%). Only 25% of the interviewed users were interested in watching videos related to the products. Also in this case, users could choose multiple options from a set of answers.

In summary, the evaluation was very positive and supported the planning of further steps for organizing a field trial of the system. However, the evaluation was performed in an artificial context and some of the aspects of the system could not be taken into account. For example, the possibility of using localization and using it for providing recommendation was disabled. The system's social aspects were not the main focus of the evaluation; the users could see social annotations and recommendations and indeed the networks of things evolved as the result of the users' behavior. However, users did not have the opportunity to use the system for a longer period of time and explore the evolution of the networks. The cycle starting from a stakeholders' registration of a product to the behavior of end users and to stakeholders getting feedbacks was evaluated only qualitatively and not in a real context, which would involve all the actors, resources and services in a region.

To overcome some of these limits and to test all the aspects of our framework in a real context we have planned a field-trial of the framework that will start in the coming months and will involve all the stakeholders in a specific area of Piemonte (from local tourist boards to local communities and producers, shop owners, restaurant, hotels, tourist attractions) promoting the use of the applications to people either visiting or planning to visit the region. Besides allowing us to test the application in a real environment the field trial will also allow us to analyze other important technical issues such as the scalability of the approach with respect to the dimensions of the knowledge and data bases and the number of users. In particular, we will test the approaches we developed for integrating ontologies and databases which exploit caching of the inferences for efficient retrieval of the relations between things. In the current prototype we did not include any application for modifying ontologies. Ontologies have to be modified manually. Indeed in the prototype evaluation this was not a problem; the trial we will be useful to test the coverage of our ontologies. A support desk will be set up in case stakeholders have problems in registering their things.

5.4. Evaluation of WantEat Back-shop

WantEat Back-shop was presented to the producers of the products involved in the experiment (none of them were involved in the early interviews for requirement analysis). During the five days of the Salone del Gusto, they had the opportunity to assess the testers' feedback. All of them were positively impressed by the system and in particular by the possibility of analyzing the performance of their products, relations of their products with other products and, most particularly, of discovering the shops and restaurants selling or serving their products.

After the Salone, we visited twelve of the producers (representatives of most types of products) to show them the functions and the interface of the Back-shop application in detail. We let them use the application and see the feedback from the users at the Salone del Gusto and then the producers were interviewed in order to receive qualitative feedback from them. The aim was to (i) obtain feedback about the interface, its usability and level of comprehension, (ii) discuss with them the usefulness of the feedback, and (iii) receive further requirements, if any, for other types of feedback they would be interested in receiving from WantEat Back-shop.

The interface was evaluated very positively by all of them, even if only half of them were familiar with the use of Internet and the Web. Almost all of them said that they would definitely use the application and that they would benefit from (i) the comments and statistics, and (ii) the possibility of contacting consumers, shop owners and restaurants directly, using the system as a support to shorten the supply chain. They all appreciated the possibility of networking with other stakeholders but, conversely, but did not like the possibility of a comparison being made between their products and other products. Most of them stated that in order to use the application and in order for it to be useful, support from the local government and especially the local community is pivotal. In this way information about their product can be integrated with local and tourist information. A more thorough evaluation of the Back-shop will be performed during the planned field trial.

6. RELATED WORK

Our project carries out innovative research aimed at providing users with an immersive experience where they can interact with objects as living entities and access a range of information in an easy and natural way. For this purpose, the project merges recent research from different promising areas like embodied and natural human-computer interaction, mixed reality, ambient intelligence, augmented memories and location based systems.

It is related to the concept of *embodied interaction*, according to the definition proposed by Dourish in the early 2000s: "*an interaction with computer systems that occupy our world, a world of physical and social reality, and that exploit this fact in how they interact with us*" [Dourish 2001]. In Dourish's vision, *tangible computing* is a central concept that refers to the augmentation of the everyday world with computational power. While we do not try to move human-computer interaction completely off the screen, we take his idea to design interaction with everyday objects as a way to enrich and augment users' experiences, providing a number of services based on this interaction. The concepts behind tangible computing have inspired two categories of systems: *natural interfaces* and *smart spaces*, which are more directly related to our work. Natural interfaces refer to user interfaces that are invisible, or become invisible with successive learned interactions, to their users. Examples of natural interfaces are: the *digital desk* [Wellner 1993], a computationally enhanced desktop supporting interaction with both paper and electronic documents; the *Stanford Interactive Workspaces* project[8], which focuses on augmenting a dedicated meeting space with technology such as large displays, wireless/multimodal I/O devices and seamless integration of mobile devices; the

[8]http://iwork.stanford.edu/

MIT's *Intelligent Room*[9], a highly interactive environment that recognizes human activities, users' actions and emotional states; *ReachMedia* [Feldman et al. 2005], a system supporting on-the-move interaction with objects by means of a gesture interface; *Physical Mobile Interaction Framework (PMIF)* [Rukzio et al. 2005] for the communication between a device (e.g. smartphone) and objects in the environment.

Smart spaces refer to environments instrumented with smart objects [Kallmann and Thalmann 1998; Kortuem et al. 2010], i.e., objects modeled with their interaction features and having distributed reasoning capabilities that can help and support users in different ways when they perform tasks in the environment. Smart objects are able to communicate with each other in order to reach common goals and to elaborate the information perceived from their surroundings. This gives rise to the *Internet of Things* paradigm [Atzori et al. 2010], where "Internet stands for World Wide network of interconnected computer networks based on TCP/IP communication protocol" and "Things represent undefined physical objects." It therefore means a network of interconnected smart and context-aware objects uniquely addressable and based on standard communication protocols. A wide range of applications dealing with smart spaces have been deployed in several domains, for example in the transportation and logistics domain [Broll et al. 2009; Karpischek et al. 2009], in the healthcare domain [Niyato et al. 2009], in the personal and social domain [Welbourne et al. 2009] and in everyday living domain, such as smart meeting rooms [Johanson et al. 2002] and city-wide infrastructures [Filipponi et al. 2010]. In all these systems, in order to make objects identifiable, proper technologies must be allowed, such as identification and communication technologies.

Our idea has similarities with research on smart spaces and with natural interaction, since we aim at allowing novel natural forms of interactions with the objects in the environment. However, there are many differences between our work and those mentioned above. A first main difference is the fact that we aim at creating a smart environment without infra-structuring everyday objects. Second, we aimed at embedding social intelligence into the objects in the spaces so that mixed social networks of things and people evolve. This provides a further type of interaction where an object introduces users to the network of its friends and users can navigate this network.

We exploit ideas from *mixed and augmented reality*, which propose to overlay the real-world environment with digital objects. For example, *Magic Book* [Billinghurst et al. 2001] visualizes virtual 3D models on the page of a physical book, which acts as a handle: moving the book, models can be moved and observed from different points of view. Other interesting applications of augmented reality can guide visitors inside a building [Reitmayr and Schmalstieg 2003] or guide tourists in a city [Feiner et al. 1997]. The latter is an early example of mobile augmented reality that, due to the recent advances in capabilities of handheld platforms, is gaining significant interest. In this area, a relevant application is *Wikireality* [Gray et al. 2009], a system exploiting GPS data and live camera to query Wikipedia through photos of the surrounding landscape. We borrowed some ideas from augmented reality; the main difference is again related to the fact that the things we are interacting with are socially intelligent and provide users with more complex forms of information and interactions.

Research on *ambient intelligence* [Weber et al. 2005] aims at adding intelligence into the real world to help humans manage tasks by delegating their execution to intelligent computing units in an unobtrusive, personalized and adaptive manner. For example, [Emiliani and Stephanidis 2005] examines the requirements of ambient intelligence spaces that should help the elderly and the disabled. In our project the challenge is how enhanced objects can attract and direct human attention in a natural way.

Our project can be seen as an evolution of *augmented memories* systems, which enrich the human capabilities in recording and organizing experiences. *SharedLife* [Wahlster et al. 2006] shows how the sharing of personal, augmented memories automatically built from context information may support users in different situations. Our approach focuses on the interaction with intelligent objects

[9]http://aire.csail.mit.edu/

that record experiences and non-linear stories explicitly added by users, and on the social communication that can be stimulated by similar experiences. *Semprom* [Kröner et al. 2009] presents an approach to collect knowledge about a physical object during its lifecycle via smart labels. The vast amount of heterogeneous information stored by these digital product memories and possibly taken from the web is presented to the user considering his current status and goal (e.g. a shopping situation). We share some goals with this project, such as exploiting ontologies to semantically organize the knowledge and using the real object as a means of interaction. But we differ in the choice of avoiding all types of infrastructuring, both to collect physical data and to manage the object/user interaction. Moreover, in our project knowledge about an object can arise from the user's actions, such as tagging, rating and commenting. Finally, and most notably, we introduce the idea of social intelligence, i.e., the ability of objects to actively participate in mixed networks of people and things.

Wikicity [Calabrese et al. 2007] is an example of *location-based services*. It is a real time system which monitors a city with sensors and the cellular network during specific events or emergency conditions. Differently from these systems, where people are passive, the user in our project is directly involved in the process of content creation. Moreover, the real experience is transposed into the virtual world where it can be recalled, enriched and shared with other users.

The project is related to *adaptive systems exploiting user models* [Brusilovsky et al. 2007], providing a new area of application for these systems. It also elaborates on the notion of social networking, extending it in different ways with respect to the *social applications* that are attracting growing attention in the literature. We are innovative with respect to the literature in that we create mixed networks that involve people *and* objects (of different nature) and thus objects assume an active role in establishing the relationships in the network. The approach we adopt for managing the user model and for social recommendation has similarities with the one in [Carmagnola et al. 2008]. However, we integrate ontologies more deeply in the processes. Ontologies, moreover play an important role in the creation of the networks of things and people which are one basis for a sort of word-of-mouth recommendation.

Ontologies have also been proved as valuable instruments to augment things' intelligence: in this sense our work has similarities with those that exploit Semantic Web in order to represent the objects' knowledge. However, the overall goal is different as we aim at managing a web of things, while other projects such as SOFIA [Liuha et al. 2009] or [Gruninger et al. 2010] exploit ontologies to create context aware smart objects.

As far as providing users with uniform access to heterogeneous ontological data is concerned, we can compare our project to SEWASIE project[10]. In [Catarci et al. 2003] the basics of an intelligent user interface for querying such data is described. On the other hand, we want to provide users with an opportunity to navigate a vast amount of information in a playful and natural way. Mobile devices can be used to access ontologically organized data, as in SMARTWEB project,[11] where a context-aware, multi-modal mobile application for the Semantic Web is developed [Wahlster 2004]. One more framework for ontology navigation is described in [Franconi et al. 2010], where users can freely explore the ontology or query the information system, without having knowledge about the data organization and vocabulary used to describe the domain. Although in our framework ontologies play a central role in the domain representation, the ontological knowledge is enriched by knowledge from other sources and offered to the user by means of a Resource Oriented Architecture. The work described in [Guinard et al. 2011] presents a resource oriented approach to the Web of Things context. Similar considerations to the one provided in this work about the knowledge representation can be made in our work, the resources being seen as avatars of physical things that tell the users about their properties and relations.

Finally, many mobile applications and websites concentrate on gastronomy, allowing people to provide information and comments or to create social networks about food. A significant one, for

[10]http://www.sewasie.org/
[11]http://www.smartweb-project.de/

example, is *WikiFood* [12], a volunteer network of food product users who provide lists of products' ingredients that may be of interest for the community of allergy patients and consumers. Moreover, producers interested in food security can deliver information about their products to the WikiFood community. *WantEat* shares the application domain with *WikiFood* and people participate in providing the content, but there are no other aspects in common because in the latter system no intelligence is associated with things and no interaction with them is allowed.

7. CONCLUSIONS

This paper introduced an innovative framework and applications that allow people to get in touch with the cultural heritage of a region. The basic idea of the approach is that this can be obtained by (i) associating different forms of intelligence and social awareness to things and (ii) allowing people to interact in a natural and playful way with things, exchanging information with them and exploring their social networks which consist of other objects and people. The approach has been put in practice in *WantEat*.

WantEat includes:

(i) an application for smartphones based on an innovative interaction model, which supports users while interacting with things, allowing both push and pull interaction, without requiring the infra-structuring of the involved things;
(ii) a Web application for users, whose aim is to create a seamless continuum between physical and virtual interaction with things;
(iii) an application for stakeholders allowing them to register things in the system, and to analyze how they behave, how they interact with people and how they establish relations with other things and/or people.

The specific application domain of *WantEat* is gastronomy and thus things include food products, shops, restaurants, food producers, cooks, recipes etc. Gastronomy is a way to get in touch with the deep cultural heritage and traditions of a region and to preserve them. This is considered a very important leverage to achieve sustainability, making people aware of the resources of the region in which they live in or visit. Using *WantEat* they can discover quality products from the region, can get in touch with quality producers and can be part of the production chain, following Carlo Petrini's philosophy that "*eating is the first agricultural act*" [Petrini 2007].

WantEat can also contribute to the shortening of supply and distribution chains creating direct links between producers and consumers, producers and transformers (e.g., restaurants) or producers and sellers. This is one of the aims of *WantEat Back-shop*, which supports stakeholders in discovering these links. In this regard the social dimension of *WantEat* is particularly important and, more specifically, the idea of creating mixed networks of people and things is the basis for making this possible. The social dimension is important for users as well, supporting word-of-mouth recommendation and allowing users to benefit from the experiences of others (friends or users with similar interests and similar profiles).

WantEat has been designed adopting a user centered approach. Stakeholders have been involved in the definition of requirements while users have been involved in the design of the prototypes in several phases. The final prototype evaluation with users provided a very positive feedback on the usefulness and acceptability of the application. Moreover, it confirmed that the choices made in the interaction model design pointed in the right direction. We are currently examining in further detail the free comments from users after answering the questionnaire and the suggestions that emerged from the discussions with stakeholders that can be very helpful in the development of further applications (currently under design) in the *WantEat* suite.

In summary, we would like to point out that, even if our evaluations showed very positive results, if it was subject to some limitations. First of all, the preliminary evaluation suffers from the classical

[12] http://www.wikifood.lu

problems of usability test described in [Tohidi et al. 2006], especially regarding the post-experiment questionnaire, since it is well-known that usability tests were vulnerable to overly positive results. Second, the prototype evaluation (the most important one) was performed in an artificial context and it covered only some of the aspects of the system, since it has been mainly devoted to assess the accuracy of the interaction paradigm and the acceptance of the application by users. We did not measure in this evaluation the architecture performance and the ontology accuracy in covering the domain, as well as all the social aspects. To overcome these limits and to test all the aspects of our framework in a real context, as we remarked at the end of the evaluation section, we have planned a field-trial of the framework in the coming months, in order to assess the architecture performance, to investigates the behaviour of human in such mixed social network of people and objects (how they explore the content, how much they participate, etc). We expect further interesting insights to emerge from this trial, concerning both application and technical issues.

Finally, although we focused on gastronomy as a way to promote the cultural heritage of a region, the approach we propose could be generalized to other domains and contexts of application. Thanks to the modular nature of the framework, in order to apply it to other domains only the knowledge models need to be changed, importing the specific domain ontologies, and setting the service logic to deal with them. We believe that the idea of using smart objects as hubs to support exploration and discovery can be useful in many other situations and believe our experience can contribute to stimulating research in this direction. For example: the products of a store can be smart objects and can support users in shopping activities; the objects in a house can support users in everyday life; the objects in an office can support people in their work; and so on.

To conclude, the following considerations emerge from our work:

— Setting up a heavy infrastructure is not necessary to endow things with intelligence. A sensor infrastructure can help but in many cases it can be avoided and this can significantly facilitate the application of the approach and its acceptance by stakeholders in the application domain.
— The application goals and context led us to make choices. For example, we chose to consider classes of things rather than individuals, and to centralize intelligence on an application server. Different applications of the framework we propose could require different choices, without affecting the general idea we propose. For example, it would be easy to modify our framework to deal with individuals (provided that they can be identified and recognized). Similarly, we chose to avoid endowing things with sensors, while in some domains this may be more natural as things already have on-board electronics.
— The involvement of stakeholders from the early phases of the project has been a key factor of the success of the prototype. The stakeholders did not experience the technology we proposed as something out of their control or imposed from above, and they could participate in various phases of the design and experimentation affecting many of the choices we took. Their active participation will continue throughout the field trial. As a related issue, one of the keys of the success of our project was the diversity of competencies among the partners, ranging from anthropology and ethnography to different branches of computer science and human computer interaction.
— Research in many directions is important in order to strengthen and go beyond the technologies we used. For example, more intelligence and autonomy could be embedded into smart things, making them more active also from the social point of view; more sophisticated forms of knowledge aggregation and storytelling could be investigated. Interaction is an open research theme and innovative forms of natural interaction with things (including tangible interaction) are a very interesting direction for further investigation.
— Smart objects could become not only a hub of knowledge but also a hub for services. In fact, they can provide people with a deep integration of services coming from the objects networks. In this way, services could share and exchange information through the network of objects and people, in order to adapt themselves in an optimized way according to the specific needs of the users.

A final remark on our application domain, namely gastronomy, and its relations with information and communication technologies: we believe that ICT can do a lot to support the efforts in preserving biodiversity on the one hand and traditional local culture (which is tightly connected to the world of food) on the other. Our project is a first step to provide a contribution to sustainability. Also, our project can bring economic benefits to the local small food farms producing valuable high-quality products, supporting them in promoting their products and in the creation of new relationships with stakeholders and other producers, and providing tools to obtain direct feedback from consumers about their products.

More generally, the positive results of the evaluations encourage us to continue the study on the social web of smart things and to look also for other areas of application. We claim, in fact, that the approach can be beneficial in areas where sharing knowledge and networking via a natural interaction with a smart environment can provide interesting innovative services and opportunities for all the actors involved in the environment (end users, stakeholders). In particular, the approach can provide support to the participation and inclusion of all actors and to the sustainability of the environment.

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