150 Digit. Integrating 3D visit and social functions into a Web 3.0 learning-oriented approach.

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Abstract—This paper is about the 150 Digit project, a web 2.0 portal designed for the publicity and dissemination of the exhibitions set up for the celebration of the 150 years of Italian unity. Targeted at schools, 150 Digit encourages the active participation of the users to the classification (in terms of tagging) of the exhibition contents and to the creation of new contents. The social components of the portal are leveraged by a semantic layer, which recommends the users with new tags, thus inducing new connections over the exhibits. Content items are recommended as well using both the same semantic strategy and collaborative filtering approaches. As part of the user involvement, 150 Digit features a 3D visit of the exhibitions, where the users can navigate the reconstruction of the exhibitions through a specifically developed web-plugin.

Keywords—Web 3.0, recommender systems, web 3D, elearning.

I. INTRODUCTION

This paper is about the 150 Digit project, a web portal designed to promote the exhibitions set up for the celebration of the 150 years of Italian unity (http://www.150digit.it). Targeted at schools, 150 Digit encourages the active participation of the users (students, teachers, registered users) in different ways: by tagging and commenting, with their own words, the exhibition contents, by expressing their likes and dislikes through votes, by creating new contents.

These social components are leveraged by two innovative elements: a semantic layer and a 3D component, in a 3.0 perspective. Web 3.0 sites, in fact, exploit semantic representation to provide innovative services, such as semantic search, personalization, etc. A broader definition of Web 3.0 also encompasses 3D data and augmented reality. These features are encompassed by the definition of Web 3.0 provided by W.L. Hosch as the "executable web". In the analogy to file system permissions, Web 1.0 was "read-only", Web 2.0 is "read-write", and Web 3.0 will be "read-write-execute".

This paper is structured as follows. Section II provides a general description of the project. The semantic component is described in Section III, while Section IV describes the 3D visit, its implementation and design. The user-centered design and the evaluation are described in Section V. Conclusions end the paper.

II. PORTAL DESCRIPTION

The goal of 150 Digit is to implement an open environment where students can visit the exhibitions online and access a wide repository of media items related with the subject of the Unity of Italy, a process achieved 150 years ago, in 1861. The repository contains both institutional contents, taken from the exhibitions, and user-generated contents. Contents can be tagged and annotated by the users, thus inducing new connections over the exhibits, and can be accessed via tags. User preferences and tags are used to

generate recommendations and promote the exploration of contents in a “bottom-up” perspective, in parallel with the institutional classification of the exhibits enforced by the architecture of the site.

The site relies on the metaphor of the ‘visit’ to structure the information. The user can visit the four exhibitions through a 3D tour, a standard hypertext-based visit, or by searching tags. Moreover, he/she can switch from one modality to another, and remain in the same (virtual) location.

The project encompasses three user profiles: the editor, who is in charge of editing and publishing the institutional contents provided by the curators, and validating the contents uploaded by the students; the student/teacher, who can visit the exhibitions, add tags and comments to the exhibits, vote them, and upload new items; the registered user, who can visit the exhibitions, vote and tag the exhibits and create her/his own playlist in a private area. Given these profiles, the portal has three main functions: content classification and publication; content editing; navigation and visualization.

The portal relies on a semantic layer to improve content description and recommendation, and features a plugin, tested on major browser, for navigating the exhibitions in a 3D environment, with the aim of making the access to the exhibits more compelling and less mediated by text. This approach borrows from entertainment (and videogames in particular) to offer students with a modality of access they are familiar with. The standard visit of the exhibitions, structured along a hierarchical classification of the exhibits (including user-generated contents), is accompanied by two alternative modalities of visit: the 3D visit of the exhibitions and the tag-based visit (see Figure 1).

150 Digit has been developed by a multi-disciplinary team, involving AI, computer graphics, interaction design and media experts, and with the participation of the target users along all the phases of the project, from design to prototyping, according to an iterative design methodology. The resulting portal integrates different components in a seamless interface that overcomes the challenges posed by the software integration issues and the content production process.

III. SEMANTIC FRAMEWORK

The tags contributed by the users represent one of the main asset of Web 2.0 sites: in the case of 150 Digit, the folksonomy is intended to integrate the description and classification superimposed to the site contents by the curators’ work. The recommendation function exploits the folksonomy and the preferences expressed by the user to help the users find interesting contents. In 150 Digit, light semantic tools have been employed (WordNet and WordNet domains) to support prototyping, development and production within a tight time schedule. Suggesting tags to users aims at overcoming the well known trend by which a site folksonomy, after a while, stops or slows its growth because the users start to use the same tags, and do not introduce new tags anymore [1]. At the same time, given the educational goals of 150 Digit, the tag recommendation function serves the purpose of supporting the teachers’ work on the linguistic description of the art objects, documents and historical facts implied by the site.

Differently from other approaches, where the recommendation of tags is aimed at finding the most relevant tags given the intrinsic properties of an item, in 150 Digit this goal is accompanied by the purpose of achieving ‘serendipity’ in the exploration of the linguistic and conceptual implications of a certain item. Given the historical, cultural and artistic nature of the featured contents, each item is likely to gather multiple meanings, including controversial and contradictory readings. In order to support the standpoint of different users (studentship, citizenship, etc.), the tag recommendation mechanism is rather a constrained expansion of the meaning of existing tags than a relevance-driven search for specific tags [2].

The content recommendation function mixes a collaborative filtering approach [3] with a semantics-based approach to the selection of recommended items, so as to take advantage of both the preferences expressed by the user
through votes and the expansion of the folksonomy through the users’ tagging.

The applicative perspective that characterizes 150 Digit has determined the choice to rely on ‘light’ semantic tools to leverage the social functions of the portal, such as the incorporation of tags, comments and contents by the community of users. The use of a semantic representation describes in a formal language the contents of a site, thus improving the access to contents by the users: formal representations, being machine-readable, allow a web site to “reason” on content description and similarities, opening the way to the implementation of advanced search and recommendation functions.

A. Tag Recommendation

The recommendation of tags in 150 Digit is accomplished in an interactive fashion (see Fig. 2). When the user inputs one or more tags in the system, an auto-completion function shows the possible words given the letters inserted so far; then, the user can ask the system to propose new, related tags. The quantity of recommended tags is regulated by a slider: the user can move the slider from the “less tags” position (where it is initially situated) to the “more tags” position, through intermediate positions. Recommended tags are presented to the user in the form of a tag cloud, where the font size corresponds to the tag frequency in the folksonomy and the frequency in the language use. The user can accept one or more of the recommended tags by clicking on them.

The recommendation of tags exploits the meaning relations incorporated in WordNet [4] to expand the user tags, offering the user with a selection of semantically related tags. In WordNet, words are gathered into sets of synonyms (terms having the same meaning), called synsets; synsets are linked according to meaning relations, such as hyperonymy (a term having a more general meaning than another) and hyponymy (a term having a more specific meaning than another). In 150 Digit, we use MultiWordNet [4], that includes the Italian language and is aligned to WordNet 1.6.

In detail, the tag recommendation algorithm is the following:

1) For each user tag, get the corresponding lexical entry from the lemmatizer;
2) Given the lemma, get the synsets from MultiWordNet in which it appears;
3) For each synset found, get all the lemmas it contains;
4) Merge the obtained synsets by deleting the repeated entries.

The tag expansion works in the following way:

1) For each user tag, get the corresponding lexical entry from the lemmatizer;
2) Given the lemma, get the synsets from MultiWordNet in which it appears;
3) For each synset, get the related synsets by following the hyperonymy and hyponymy relations.
4) Merge the obtained synsets by deleting the repeated entries.

The user tags can be expanded also by getting the correlated terms (terms that have a direct hyperonym in common with the given tags).

The simple tag expansion mechanism described above, however, does not guarantee that the recommended tags are actually related to the user tags, due to the polysemy of natural language. Moreover, the presence of hyponyms and hyperonyms can be sufficient to disorientate the user, since their introduction in the set of recommended tags may not obvious to the user. In order to overcome this problem, we resorted to a tag cloud to present the recommended tags. Tag clouds, in fact, are an object users are familiar with and of which they know the properties, including their random nature. The use of the tag cloud, here, prepares the user to the possible presence of unexpected tags. In addition, word frequency (taken from “Corpus e Lessico di Frequenza dell’Italiano Scritto”, CoLFIS [5]) is exploited to weigh the size of the tags in the cloud, so that more unusual terms are likely to be less visible in the final cloud.

1) Disambiguation in Tag Recommendation: In 150 Digit, the disambiguation relies both on ‘syntactic’ knowledge provided by the context of other tags and on the ‘semantic’ knowledge provided by a light ontology. The context-based disambiguation, a technique widely employed in natural language processing, is accomplished by a simple synonymy criterion: for each proposed tag, if it is co-occurs
in the same synset with one of context tags (i.e., is a synonym of one of the tags that have already been added to the exhibit), it is included in the recommended tags; otherwise it is discarded.

In WordNet, each synset is associated with one or more semantic domains, organized in a hierarchy of about 200 nodes, called WordNet Domains [6]. This hierarchy is structured along three levels; a special domain Factotum, gathers the terms that do not have a domain-specific meaning. For each exhibition in 150 Digit, each category has been associated, in cooperation with the curators, with one of more domains. The domain associated with a category describes its semantic context. Each exhibit inherits the domain labels associated with the category it belongs to (each exhibit belongs to only one category, in parallel with the actual arrangement of the exhibition) and of the exhibition itself. These domains provide the context against which the proposed tags are filtered out to eliminate the non relevant tags.

After testing various combinations of the tag expansion and disambiguation strategies, the final implementation of the recommendation slider has been determined by the need to make the set of recommendations grow monotonically, so: i) the semantic relations that have been introduced for the expansion are not removed ii) disambiguation mechanisms are gradually removed. The final configuration of the slider is represented in Figure 3.

2) Architecture of the Tag Recommendation System: The architecture of the tag recommendation system includes the following components:

- **Lemmatizer**: it performs the morphological analysis of the user tag, returning its non flexed form, needed to access the lexical knowledge. For example: “persone” (people), the plural form of “persona” (person) is converted into the singular form. Since most tags are nouns, we chose to consider only the plural to singular conversion. The latter is achieved by using a data base of forms, implemented in mySql.
- **The Expansion Module**: written in PHP, implements the expansion of the user tags along the semantic relations incorporated in MultiWordNet, as described above. Again, MultiWordNet is stored in a mySql data base and is accessed by a set of PHP APIs.
- **The Disambiguation Module** (also written in PHP)

implies the context-base and the semantic-based disambiguation strategies. This module interacts with the site CMS to get the set of tags that have already been added to the item and the domain labels that are associated with it.

- The **Tag Cloud Generator** determines the size of the tags in the generated cloud based on the frequency of tags in the folksonomy and in the lexicon.

**B. Item Recommendation**

The item recommendation system exploits both the description of the items given by the tags and the preferences expressed by the community of the users.

The semantic-based recommendation exploits the tags associated with the items to select items that share the same tags. Items are ranked according to the number of tags they have in common with the given item.

The social recommendation is based on the preferences expressed by the community of the users, according to the technique of collaborative filtering [2], [7]:

1) Given the current content, select its highest vote;
2) Select all the users who have given the same vote to that item;
3) For each of these users, select the items to which the user has given the same (or higher) vote; If the set is empty, set the vote to vote – 1;
4) Rank the selected items by their highest votes;
5) Select the first n contents;

Figure 5. Content recommendation in 150 Digit. On the left, the tag-based recommendations; on the right, the preference-based recommendations.
Figure 6. A snapshot of the 3D visit of the exhibition “Fare gli Italiani”.

The user is presented with the two sets of recommendations (tag–based and preference–based); the difference between the two is communicated by different labelings, “150 Digit recommends you” and “Other schools recommend you” respectively. In case the same item appears in the two sets, the duplication is eliminated.

IV. 3D VISIT

The 3D visit of the 150digit portal was conceived as a constrained spatial navigation that allows the access to a selection of the exhibition items [8]. The visit is partially constrained to some fixed positions, in a sequential order, where the visitor is “transported” through a stepwise flight simulation.

The curators of the exhibitions have classified the items according to a number of categories, that are listed in the accessible visit. A Java applet provides access to a 3D model of the exhibition space, where models of the items are exposed according to the layout of the real exhibition.

A. 3D Visit: Interaction Design

An initial camera motion provides an overview of the exhibition and gets the user to the first group (category) of exhibits. Each group is represented by a 3D text with the label of the group; this label hovers over the actual position of the items (see Figure 6).

In front of each label, there are three signs (see Fig. 7):

1) an arrow oriented to the NEXT group (in case of the last group, a special arrow marked START points to the first group);
2) an arrow oriented to the PREVIOUS group (in the case of the first group, a special arrow marked END points to the last group);
3) a hand-shaped icon that points to the label itself.

By clicking the arrows, the visitor is transported to another group label; by clicking the hand, the visitor descends to the items, and is positioned in front of the first item. Again, the system of the three signs allows the visitor to get to the next item of the group (NEXT arrow), the previous item of the group (PREV arrow), the information about the item itself (hand-shape icon). These signs allow a kind of direct guidance [9], an adaptive navigation technique that proposes to users a strict linear order through the navigation space.

Each click causes a transportation to another fixed location and a callback to the web server to load a page related to the destination of the transportation. So, the web site is constantly updated with information aligned with the 3D visit. When the user gets to a single item, the callback triggers the loading of the information related to the item itself and the possibility to launch the player of the item, namely audio or video streaming, PDF opening, image display.

Finally, we some keys have been programmed to control the camera orientation and motion. These keys are the standard PC keyboard associations for videogame interactions (W going ahead, S going back, ); so, expert visitors can take advantage of such recreational possibilities.

B. 3D Visit: Development and Editing

MESH (Mise-en-scène Helper) is a software platform for authoring environments in computer graphics.² The MESH architecture relies upon a number of opensource libraries that account for the major modules of realtime computer graphics, from the rendering engine to the simulation of rigid body physics. The architecture allows for the import of scenes and characters from a number of authoring tools, including

²http://www.edu.vrmmp.it/mesh/
Google SketchUp. The MESH software architecture consists in a core platform, called Enthusiasm\(^3\), that includes the high-level graphic framework Tarta4D, the Sound Manager, and the graphic interface Director Studio, with the associates Control Score Player.

The core of the scene rendering is the Tarta4D Framework, a rendering library and 3D engine that offers high-level functionalities: Graphics (import of 3D objects authored with the most popular 3D authoring tools, realtime 3D rendering, 3D objects animation, automated animation blending); audio (spatialized 3D audio, playback of pre-loaded samples or in streaming mode); physics; multiplatform support (Windows, Linux, MacOS X); simplified scene management; multi-thread support, C++ and Java APIs and Effortless integration in Java AWT/Swing interfaces.

The Tarta4D API (Application Programming Interface) exposes a simplified scenetree approach. A scene is defined as a tree of objects, cameras and lights. All the technical details about the reuse of resources (materials, geometries, skeletons, and the like) is completely automatized and hidden to the end user. A 3D Object in Tarta4D is a complex entity associated to a visual aspect, able to emit sounds, and responsive to gravity and collisions. A Scene is a container of objects characterized by light condition (sun light and ambient light) and a Root Object. Starting from the Root, the Objects are organized as a hierarchical tree. Scenes can be saved to and loaded from files, in an XML format.

Thanks to its Java wrapper, the Tarta4D library can be easily used to deploy an applet running into a web page. This is done by tacking advantage of an Ogre3D feature which allows the programmer to specify the surface that can be used for the 3D rendering. A rendering surface can be a window, or a portion of it, that has been already allocated by the operating system. This binding, which has been implemented on the Window and MacOS X platforms, allowed to easily create an applet by simply instantiating a Tarta4DCanvas inside our player (EnthusiasmStandalone-Player), which extends the Applet class. The deployment of the applet has been done using the Java Web Start technology\(^4\), which provides all the facilities to transfer the required native libraries to the client machine. With respect to the development of ad-hoc plugins for specific browsers, our approach has the great advantage that the applet works on any browser supporting Java applets. The applet has been successfully tested on Explorer, Firefox, Opera and Chrome on WindowsXP, Vista and 7, and on Safari, Firefox and Chrome on the Mac OS X platform.

From an authoring point of view the interaction between the applet and its surrounding web page is performed through javascript callbacks. Each time a "callback" is raised by the 3D content (for example, after the user clicked on an object), a corresponding "callback" javascript is called, carrying a generic string parameter. This allows the web page developers to execute the appropriate action, such as updating page sections or showing a pop-up, according to the string parameter content. The Director Studio (see Fig. 8) is a set of windows that allows the author to control the initial layout and the dynamic behavior of all the elements of a scene, namely object instances, cameras, lights, animated characters, paths for the displacement of

\(^3\)enthusiasm.sourceforge.net

\(^4\)http://download.oracle.com/javase/6/docs/technotes/guides/javaws/
cameras and characters. As for the majority of authoring tools, the elements are arranged onto a hierarchy, with the possibility of represent the composition of complex objects in an analytic way. A MESH project consists of many scenes, each associated with a layout and a number of control scores. The graphic interface is organized in three panes: assets, scene layout, and control scores. The asset pane allows for the selection of a scene of the project and the setting of an environmental/sun light.

V. Evaluation

We designed the web interfaces of 150 Digit following a user centered approach. Since the first design choices, we involved final users as primary and secondary school teachers.

As proposed in Gena and Weibelzahl [10], we carried out different evaluations at different stages of development: the requirement phase, the preliminary evaluation phase, and the final evaluation phase.

A. Requirement Phase

The requirement phase is usually the first phase in the system design process. After having designed a set of basic static interfaces showing the main system functionalities, we carried out a focus group involving 5 users, 4 males and 1 females, 40-62 aged. Three of them were secondary school teachers, two of which were teachers of technical education, while one was a music teacher. The remaining two were primary school teachers. All of them were in charge of the school computer room and of computer science classes. We showed them a set of 15 scenario based interfaces and we discussed with them for 3 hours about the main systems functionalities, labeling and layout. The main findings/changes emerged from the focus group, and included in project, were the following:

- changing some label (e.g., favourites instead of playlist, etc.);
- adding new functionalities: i) new collaboration tools for sharing contents between users, specifically educational users; ii) the possibility of creating a virtual class, wherein educational users, namely students, can discuss the artworks and with comments that are visible only within the virtual class. The super-user (the teacher) can then aggregate, modify and publish the class comments;
- modifying existing functionalities: teachers suggested to show tag recommendation only on request. They observed that students are generally lazy, and having tag recommendations may inhibit their efforts and creativity.

In general this group of teachers highlighted the need of having textual contents associated with the artworks, and dedicated tools for contents creation. They really appreciated the proposed interfaces/functionalities, and they considered them as valid tools for classroom work and students involvement.

B. Preliminary Evaluation Phase

The preliminary evaluation phase occurs during the system development. The interface design of 150 Digit has been inspired to usability heuristics and usability guidelines, as well as to information architecture principles. Moreover the web pages has been implemented in respect to the Italian accessibility law (Stanca Act). An usability expert followed the interface design together with the web designers and reported heuristics and guidelines that have guided the design decision process.

During the preliminary evaluation phase of 150 Digit we carried out an evaluation of a static prototype, namely interface screenshots, and of a vertical prototype, namely the tool for tags recommendation. The main goals of this evaluation were to empirically verify the following points: i) the understanding of the proposed labelling, ii) the effectiveness of the different ways of going back home, iii) the understanding of the functionalities offered to educational users for generating new contents, iv) the correct exploitation of breadcrumbs, recommendations, tags and tagging, v) some different graphics proposals. 5 users completed the test, 3 males and 2 females, 25-55 aged. Two of them were secondary school teachers, one of which was a technical education teacher, while the other one was a music teacher. The remaining three were educators. Except the oldest user, the remaining ones were frequent Internet users. We showed users the static scenario-based prototypes and we discussed with them the proposed solution, following the aforementioned goals. Then we asked them to accomplish a set of tasks with the vertical prototype. The main findings emerged from this evaluation, included in the re-design, were the following ones:

- we changed some confusing labels (i.e., regarding the label of the category grouping the set of actions for generating educational contents, we changed the verb “work— to “contribute”, since users did not understand the meaning of the label);
- we removed the “social share” buttons, since most users of the system (teacher and student working in classroom) do not have group accounts for social networks;
- we added the possibility of increasing the size of artworks, a functionality especially useful when artworks are seen in the smart board modality;
- we added explanations and tooltips for explaining the meaning and the usage of tags. Especially less frequent Internet users did not know the concepts of ‘tags’ and tagging related actions;

C. Final Evaluation Phase

The final evaluation phase occurs at the end of the system development and it is aimed at evaluating the overall quality
of a system with users performing real tasks. We decided to test the system with real users performing real tasks in a usability test. Users were also asked to report any kinds of problems they experienced while using the system.

5 users performed the test, 1 males and 4 females, 46-58 aged. They were all primary school teachers. Three of them were frequent Internet users, while the remaining two use the web 2/3 days per week. Users were asked to perform a set of tasks, then they had to complete a post-test questionnaire, and finally they were interviewed by the tester. The questionnaire contained 9 questions, with single Likert scales choices ranging from 1 to 5.\footnote{A Likert scale is a type of survey question where users are asked to evaluate the level at which they agree or disagree with a given sentence [11].}

The analysis of results showed that visitors were quite satisfied with the system. From the analysis of post test questions we found the following average scores (scale 1 to 5): easiness in finding information: 3.6; understanding of link labeling 3.8; quality of information 4.4; completeness of information 4.4; pleasantness of interfaces 4; quality of language 3.6; easiness of reading 4; quality of interactive experience 4; global grading of the web site 4.4.

After having analysed the users tasks and their comments, we redesigned the system and in particular:

- we changed/removed some confusing label (i.e., the label “Home” in the logged in version has been changed in “My 150 digit”. The label “150 Digit tag cloud” has been removed since it was not understood by users, etc);
- we changed the ordering of items in the chronology section, showing the most recent items at the beginning;
- we moved some links to important functionality (e.g., how to join the Museum Laboratory) in the global navigation menu;
- the items in “My tool” box were grouped by meaning/functionality and alphabetically ordered accordingly to avoid user disorientation;
- we lighted up the green colour used to highlight the users current section.

VI. Conclusions

In this paper, we described the 150 Digit project, i.e., the design, implementation and testing of a Web 3.0 portal concerning the exhibitions set up in Turin for the celebration of the Unity of Italy.

Developed by a multi-disciplinary team, 150 Digit integrates social and immersive functions in a coordinated environment where students and teachers can actively participate in the construction of the site contents, thus enriching the historical and cultural framework provided by the exhibition curators.

The evaluation shows that the development methodology, based on iterative design and user involvement, has assured satisfactory results in the final evaluation of the site.

As future work, we envisage the evaluation of the quality of the recommendations (content and tag) and of the 3D navigation systems against a larger set of user data.

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