Real-Time Collaborative environment for interior design based on Semantics,Web3D and WebRTC

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***Abstract*— In this paper, we present a web-based framework for the interior decoration, which successfully merges Real-Time Communication, Web3D and Semantic Web technologies. The interior design concepts of the system are based on an OWL ontology which is hosted by Apache Jena Semantic Framework, while a SPARQL questionnaire with specific number of questions regarding to various parameters of the room space is filled by the users. The display of the appropriate decoration solutions was succeeded with the assistance of WebRTC protocol as the real-time communication mean and an X3DOM scene as the graphical layout according to their ontological descriptors. Moreover, the implemented GUI not only supports an automatic visual reconstruction of a design scheme in users' browser, but it also allows them to modify the scene according to their desires. Also, we implement our own MCU server for multi-party video call, which is written in JavaScript language. Our approach enables WebRTC-based video and audio conferencing.**

Keywords—WebRTC, Node.js, socket.io, X3DOM, Semantic Web, OWL-DL, SPARQL, HTTPS, Multiple conference, real-time communication

I. Introduction

Today, web applications' field is dominated by various technologies that come with convenient cross-platform capabilities. Amongst them the most commonly used is no other than HTML5 -a markup language for the presentation of multimedia-rich content in the Web- whereas the last few years X3DOM framework and WebRTC were stand out from the remaining. X3DOM is an open-source JavaScript framework is capable of integrating 3D content into any webpage without the use of plugins, while WebRTC is an innovative technology that allows Real-Time Communication through several JavaScript APIs. Furthermore, web applications incorporate key elements of Semantic Web vision, a series of technologies that help computers and humans to understand and process the data in the Web. Semantic Web aims to transform these data by integrating human concepts and their relations to improve organization and boost search capabilities. Our vision to combine the previous technologies into a single real-time web-based collaboration application led us to the espousal of WebRTC. This technology allows interconnected users of a specific website to create groups in order to interact with each other. Our application enhances this interaction by providing video streams, text messages and the sharing of a common 3D design space between the participating users.

In the following sections we present the motivation and the theoretic background about the technologies and standards used for the creation of our interior design collaborative environment. Section III describes the underline semantical framework used for the attribution of ontological concepts to the decoration domain, while in section IV is presented our own MCU server which manages and emits the messages received from-and- to connected users. Finally, section V concludes the paper.

II. Background and Motivation

Seeking efficient decoration and interior design solutions for the needs of our application, we carried out a thorough research of programs and tools dealing with such domains. The conducted research pointed out that the majority of these applications provide visual representation and customization capabilities according to user's desires. However, despite the fact that their visualization motive can be easily understood by the users and can be enriched with specific content and attributes (furniture, materials, colors, etc.), their overall functionality requires the installation of a custom-made browser plugin or additional software programs, as IKEA Home Planner tool [1]. Other applications found online like Autodesk HomeStyles [2], Roomsketcher [3], Planner 5D [4] give the possibility of 2D and 3D representations, providing the option to view and change materials and colors. The negative point of these applications is that their rendering procedure is based in Flash Player, which should be preinstalled on user's computer. However, we all know that Adobe Flash is no longer considered by the browser as a standard plug-in. The Planner 5D [4] also provides the ability to store the designed interior space but in JSON-like format, but it does not allow its further deployment in external applications. Finally, a more target-oriented application named Roomstyler [5] enabled a 2D representation of an interior space with the ability to "screenshot" in three dimensions (3D). The three-dimensional visualization of a product is definitely a crucial advantage of any e-commerce application compared to its plain image or 2D representation, since the user is able to imagine it inside its own room space. Recent works in [6] showed that Web3D applications keep gaining ground compared to their 2D or pseudo-3D alternative solutions. "Caidou" was one of the first Web3D applications that allowed customers to configure and view their personal portal on the Web with the ability of exported to a PDF document in PDF3D format.

The ontologies and ontology-based systems appear as the nodal point for the development of potent and profitable Internet commerce solutions. The first electronic shops utilizing ontologies and visualization capabilities have already made their appearance. Amongst them, a Configurable Electronic Shop Platform in the form of a web-based application is presented in papers [7],[8].

However, the most important part of information retrieval and usability design in Semantic Web applications is their query formulation process. A Web-based graphical tools NITELIGHT [9],is a JavaScript written tool which merges various features for the creation of semantic queries in client side. These features included the browsing of an ontology in column view and an interactive graphical interface. Also, an automated reasoning system named SMART [10] it stands for Semantic web information Management with Automated Reasoning Tool, and it was designed to synthesize and validate semantic queries, represent them through a useful graphical interface and map DL queries to SPARQL language.

Furthermore, World Wide Web is able to provide Real-Time Communication (RTC) services between users' browsers all around the Web thanks to WebRTC. With the passage of time, there were applications that integrated WebRTC capabilities within three-dimensional virtual worlds for educational purposes. The majority of them dealt with the composition of a 3D collaborative environment for educational gaming that supported video calls, text messaging and the capability to select, insert, and manipulate 3D objects in an X3D scene using the Data Channel of WebRTC. Such a unification of Communication and Graphics fields is evident in paper [11], where X3DOM framework was merged with WebRTC technologies in order to constitute a virtual 3D collaborative environment for the real-time cooperation of web peers, while at the same time, these peers were able to manipulate the three-dimensional scene without the use of plugins.

In our work we extend the capabilities of the room designer or planner to a fully interactive, customizable and real time environment. Moreover we enhance our designer with a recommendation system supported by a semantic triple-store repository of designs pre-stored by experts and retrieved by a SPARQL queries. Finally we build this designing environment on top of a web conferencing infrastructure we customized with WEBRTC in HTML5 browsers. Thus we present a unique designing environment with advanced features like web plug-in free, multi-point conferencing, real-time, fully web, fully interactive, high compatibility to standard applications (autocad, etc)

III. Previous work

Our collaborative environment borrows its semantics from DEC-O project [12] that aimed to organize all aspects of an interior space into a usable structure. This framework merge Web3D technologies with SVG graphics and Semantic Web ontologies. Its core rested upon an OWL-DL language that described various interior design concepts, from the structural elements of a room space down to the color of a 3D object (e.g.furniture, wall, etc). Each object incorporated a 2D representation in SVG format, followed by its on-the-fly X3D representation thanks to an XSLT transformation algorithm. All these technologies were combined with a SWRL recommender system for the automated implication of the best fitting room space, according to a predefined set of interior design rules and the needs of the end user. Such data were collected by two separate wizards, with the first one to correspond to platform's content providers and the second one to platform's consumers. The managers were able to modify the ontology through Jena Framework with the assistance of dynamically generated drop-down menus, add new individuals, modify existing ones, or add new statements to the current instance of the ontology (see Fig.1).

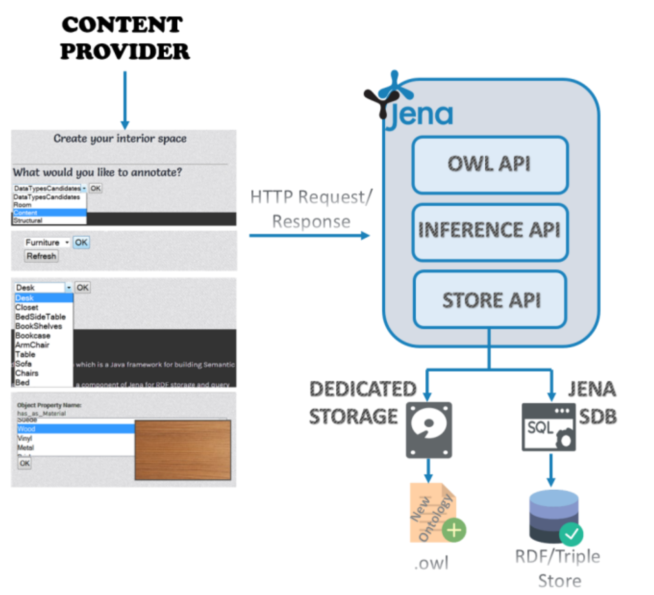

Fig. 1.- Storing an ontology from a content provider's UI

On the other hand, consumers were able to query and search all the ontologies through an easy-to-answer questionnaire backed by an SDB Triple Store mechanism. Reasoning capabilities for interior design domain have been previously presented in [13], where a room space was annotated based on various parameters that come from a questionnaire. Its answers were broadcasted to the server in the form of HTTP requests

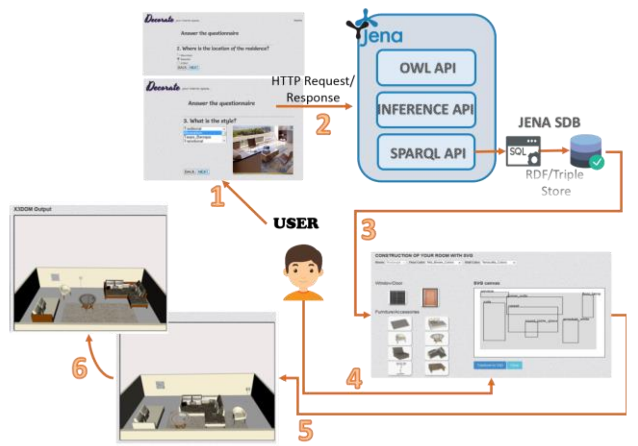

Fig. 2 - DEC-O user interface & SPARQL engine

that ultimately were synthesized into a single SPARQL query. The results of this query were then sent back to the user as the potential decoration solutions that match their needs. The execution of queries was feasible thanks to the adoption of the SPARQL API which was served by the Jena Model interface. The last one was responsible for performing queries directly upon the OWL knowledge base, allowing in that way the retrieval of any information from OWL-DL ontologies. Consecutively, Jena was further used to reason with the existing ontologies of the implemented semantical system (see Fig. 2).

However, for the purposes of this work and concerning frameworks' integration to our collaborative environment, a couple of features were deemed unnecessary. In order to provide friendlier UI experience to the end users of our system SVG and XSLT mechanisms were abandoned and replaced by an automatic operation that involved the real-time generation of 3D content via API statements of X3DOM framework. Moreover, SWRL recommender system was left aside due to its heavy impact on performance with any reasoning services taking place by the previously mentioned SPARQL API. The rest of DEC-O capabilities remained unchanged, were successfully integrated to the collaborative environment and contributed to the node.js and socket.io functionalities

IV. DECO COLLABORATIVE FRAMEWORK

Despite of the numerous capabilities that are shipped with DEC-O, an efficient communication mechanism between its users was totally absent. Moreover, the development of any collaborative environment is based on the establishment of a stable and secure communication protocol, implementing at the same time, all the necessary functionalities that its users may fulfil as subjects of the underlying domain. In the following subsections are described the chosen communication technologies and the stages involved into a commonly used process flow from the perspective of an end-user.

A. Addressing communication problems

In order to address the above-mentioned matters WebRTC was found to be the most lightweight and suitable protocol for the exchange of information. Our WebRTC approach is written in JavaScript language, allowing a wide range of devices (laptop with any operating system, smartphones, tablets with internet connection, etc.) to take advantage of our web application. The application ensures data integrity through a secure channel of communication via HTTPS protocol and guarantees the connectivity under different networks with the collaboration of a STUN server. More specifically, Session Traversal Utilities for NAT (STUN server) allows an end host to expose its public IP address when it is located behind Network Address Translation (NAT) in various complicated conditions (e.g. with or without firewall). This ability enables the Interactive Connectivity Establishment (ICE) technique and helps devices to connect to each other under different networks. The authored application not only enables peer-to-peer communication, but also supports WebRTC-based multi-party video calls and chat messaging services. While it's technically possible to make a point-to-point video call without anything other than a network between the two clients, it becomes difficult to create multi-party video calls without a hardware or software mean between the endpoints. This is where a Multipoint Conferencing Unit or Multi-Point Control Unit (MCU) comes into play. An MCU is a bridge that offers the ability to connect multiple users/participants to a single voice or video session. It makes use of a mixing architecture, where every participant sends its video or/and audio to a central server, while at the same time, it retrieves this server's mixed media stream of the other previously received participants. For the purposes of this work we have developed our own MCU for the streaming of messages through the server, reducing in this way the overall traffic of the communication. Moreover, it makes use of the same signaling server (socket.io) under node.js for signaling messages, chat messages and video call messages. Besides the aforementioned technologies, no other device or API was used for the creation of our MCU.

In addition, the scope of the implemented system does not simply lie to the provision of a real-time communication service between its users. It comes with several registration roles (e.g. decorator, content provider, and simple user) uncovering different access control methodologies for those users that participate in the same session. Relying on DEC-O framework, the set of Semantic Web solutions mentioned in the previous Section has been also applied to the decoration component of the newly designed collaborative environment. In this way, any kind of users are free to modify the depicted room-space alongside with its 3D objects, rather than just look at a non-interactive and poor 3D representation of a house blueprint.

B. A typical process flow

Upon entering application, user comes confront with the very first page of the system, which is none other than the Login/Registration page. At this point, user has the ability to log in with its credentials in order to join an available "session" and make use of the capabilities provided by the 3D collaborative environment. The available roles have been reduced to decorators and simple users, two basic components of the system that come with different functionalities in each session. A session is nothing more than the synonym of "group" that points to a room occupied by a decorator at a given time, enabling its appearance and availability to user's dashboard. The whole process is based on the frequent update of a MySQL database with the execution of the corresponding statements via Java Servlets. In order to make sure that all signed users are able to communicate with each other, a couple of functions initiate the signaling process with the creation of a new RTCPeerConnection object for each user who signed in. A list of the connected peers is kept on our MCU server, which detects and manages the "offer", "answer" and "ice candidate" events coming from these peers to enable video call services.

Leaving aside the simple user of the system, decorators are provided with a semantic web questionnaire, which is forwarded in the form of questions by the decorator himself via a video call or chat message. User's responses lead to a finite number of recommended room-spaces, which are displayed to decorator's dashboard in order to select the closest related space according to user's needs. Ultimately, a 3D representation of the chosen room is immediately shown in the webpage of all participants without the use of any plugin or additional software. The supported functionalities involve the resizing, rescaling, relocation of physical objects and spaces, and the ability to include a desired X3D object in the presented room-space. In Fig.

3 below is displayed the flowchart of the communication between each user and the server. For example, when the user selects a 3D item from the scene and clicks it, the color button from the X3DOM editor's menu and a color picker pops-up with a variety of colors. As soon as he chooses the color he likes, a message is emitted from this user to node.js server and a socket.io event is generated. Finally, the server broadcasts the initially received data to the rest of users encoded with JSON format.

Summarizing, we have developed a web-based communication architecture with a 3D modeling environment for the purposes of a collaborative design management tool. The whole application is running under Apache Tomcat Server in cooperation with node.js server and socket.io module for the real-time communication part of our application. The users of the same session share and work together upon the same web page and 3D scene, possessing the ability to change the scene and directly transmit the update to other users. Even though that the implemented application is in its primary steps and can be of use for non-professional customers/users, it can be further enhanced with extra functionalities and real-time recording capabilities for content providers and interior design companies.

V. Conclusions

Our previous avocation with ontologies and Semantic Web gave birth to an innovative environment that successfully integrated the visual representation and semantic layers with a real-time communication layer between its users. In this way, it was created a standalone product which can be used as the basis for decoration and interior design purposes from decorators and companies. Taking into consideration modern era's capabilities and technologies along with the continuous increment of users navigated to Internet via their mobile devices (e.g. smartphones, tablets, etc.), our work also involved state-of-the-art technologies that are independent of plugins or additional software. Moreover, the Responsive Web Design was applied throughout our application in order to ensure its ease of use and accessibility from any kind of device and platform.

The security of the communication was ensured through the HTTPS protocol, while its integrity and stability were guaranteed with the assistance of a carefully custom-made Multi-Point Control Unit. Finally, the target groups of the implemented application do not limit to decorators and interior design companies, but simple users are able to create their own room space according to their likes and interact with a manufacturer or a domain expert to finalize their initial architectural pattern.

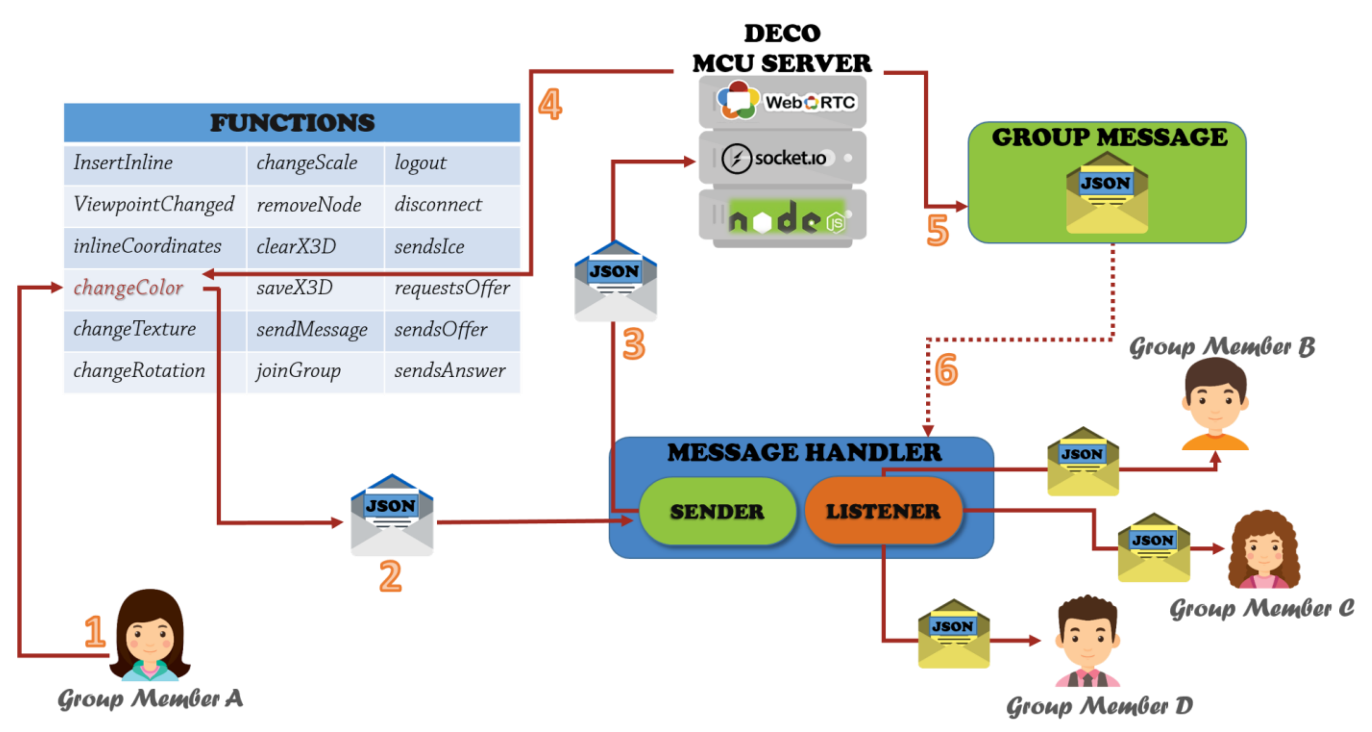

Fig. 3 – Flowchart of the communication between users with DECO MCU server

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