Title:
Towards an Integrated Framework to Support Contract Furniture Industry

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Introduction:
The current worldwide economic crisis pushes all companies, and especially small and medium ones (SMEs), to increase their global competitiveness and capabilities of entering into new, international markets. A promising one is represented by contract furniture [3] that refers to the supply of products and services for large-sized buildings such as hotels, restaurants and retails. From literature overview it appears to be characterized by a multifaceted commitment determined by the agreement among the general contractor, the owner and the architect; short time to market and lead time; iterative design that still remains unstructured and based on traditional methods and supporting tools; participatory design merging product and architectural design issues; complexity of interactions among all involved stakeholders; long negotiation phase; and finally a complex market that is worldwide, involves companies from different countries, addresses diverse target users [6].

Numerous Information and Communication Technologies (ICTs) are used to support market analysis and SMEs promotion, furniture design, data sharing and project management within companies network. However, most of these technologies are general purpose, difficulty meet specific contract furniture needs, are not interoperable, do not offer integral solutions that can be adopted by different-sized companies and do not cover the requirements of each development stage. An extensive overview of related works on the topics of marketing intelligence, collaborative product development, CAD and the Internet, Virtual Prototyping is reported in the paper to demonstrate the main challenges the research proposes [2, 8, 9].

Starting from this complex scenario, this paper proposes the final outcomes of a project, called DesigNET, involving 17 Italian companies operating in contract furniture, whose aim is to develop a Web-based platform providing a decision support system for contract furniture. It provides the description of results achieved during the three-years research that consists in a technological framework, integrating different web-enabling tools, that allows process stakeholders to identify design market trends and new contract opportunities, propose furniture solutions in an appealing way to capture users attention, provide an online furniture configuration system exploiting virtual prototyping techniques, extract the Bill of Material (BOM) of the customized solution and use the developed virtual prototype to assess its impact in real scenes by adopting Augmented Reality techniques.

The paper comprehends the works presented in previous researches [1, 5, 6] that are integrated in the whole framework to show the functionalities offered by the overall implementing platform. What is new are the deep description of two software modules that have never been presented before (i.e. e-marketing intelligence tool and AR-based application integrated with the CAD-based Configurator) and the way data are kept coherent across the platform. In addition, it presents two pilot use cases in

contract furniture that are used to test the platform usability and reliability: the design of a modular service-apartment and a wellness center. Experimental results demonstrate the achieved platform performance, the potential strengths and the identified weaknesses to be improved. Conclusions provide a list of main proposed challenges in contract furniture as well as in web-enabled design tools.

The proposed technological framework:
The research defines a technological framework to overcome the actual limitations of web-based tools for contract furniture in order to support all identified process activities.

The approach adopted to define the general framework is based on the following steps:

- Investigation of the AS-IS contract furniture process by questionnaires and interviews submitted to the involved industrial partners. Structured questionnaires allowed mapping the current process and highlighting the process criticalities and the user needs;
- Elicitation of users requirements by expert analysis: starting from the AS-IS process model and the investigation results, the users requirements are elicited by heuristic evaluation carried out by experts. They define the TO-BE process to overcome the current criticalities and create a list of requirements. After that, requirements are weighted according to a 5-point scale taking into account the users needs' satisfaction;
- Benchmarking of the most suitable technologies by QFD-based correlation: the available technologies are analyzed according to their features and correlated to user requirements by adopting the Quality Functional Deployment (QFD) technique. A correlation matrix is used to evaluate how systems are able to satisfy each requirement and to identify the most suitable technologies. Correlation takes into account also the requirement weighting in order to calculate a relative importance value for each analyzed tool;
- Selection of the most proper technologies according to the user needs and their integration into a unique platform able to enable contract furniture stakeholders in market investigation, furniture design, prototype creation and evaluation in real contexts of use.

The resulting platform is made of four modules that are separately developed and then connected to guarantee a coherent workflow and data sharing (Fig. 1):

- E-marketing intelligence module is a user-friendly Web application to analyze the market trends as well as competitors' offers, and to highlight contract furniture opportunities by detecting and elaborating data from the web;
- Virtual Prototyping-based module to visualize companies' solutions and to configure both each furniture item and the design space;
- Co-design module, to collaborate on 3D models to create custom solutions;
- AR-based module, to support the design evaluation of the configured items and environment by superimposing virtual prototypes and real scenes.

The furniture design process starts with market analysis and target user information gathering by the leading company to support the designer in arranging the interiors, designing the room, identifying provided commonalities and selecting which furniture items should be integrated and in case, customized.

The e-marketing module considers the information about target users' characteristics, needs and actions, and exploits them to carry out an oriented market analysis on Internet sources. Necessary information are retrieved by a semantic-based tool (i.e. Spider) and elaborated by an intelligent tool (i.e. Business Intelligence) in order to identify the market trends and the market opportunities according to the user profile and the configuration options expressed by him/her in the Virtual Prototyping-based Module. The e-marketing module allows companies to easily visualize, identify and analyze geo-referenced information such as:

- Design market trends and competitors' offers regarding a number of products of interest with related aesthetical and functional thanks to the integration of a semantic-based knowledge discovery tool;

- Contract opportunities globally available and/or available in a specific country with further information on the economic situation and tourist trends for a given country (e.g., show contract opportunities, GDP and Tourism Spending in a specific country).
- Users navigation data on the company website to show most viewed products with related aesthetical characteristics associated or terms used in the search form.

The retrieved information is then elaborated by the leading company experts in marketing and design to create a list of requirements for a given hotel room, retail space, serviced-apartment, etc.

The configuration flow starts with the selection of items in the virtual catalogue based on the requirements elaborated from market analysis results. Requirements are translated into tags used to mark items and their possible variants. The virtual catalogue is a web-based market place where the user can navigate across an extensive collection of furniture items and integrated solutions. Available solutions provided with technical documents and their aesthetical and technological variants are modeled and uploaded by manufacturing companies into a specific management tool (i.e. Definer). The users (e.g. mainly designers and architects) can see the companies' offers, search items and create personalized catalogues.

Once identified possible solutions, the designer can open the Configurator module to represent the overall virtual environment and arrange it by inserting products from the marketplace, the personalized catalogues and local databases. The Configurator module is a desktop-based application to be downloaded from the virtual catalogue to create a CAD-based configuration of the contract furniture. It allows the designer, for instance, to create a personal project, import 3D architectural space model (e.g. room, store, hall), populate them with items selected from the Virtual Catalogue and finally configure them according the user needs in terms of aesthetics, performance, functions, etc. Item configuration and positioning into the space follow manufacturers' guidelines and technical constraints. A knowledge-based set of rules are implemented to explicit the relationships among items and the environment [6]. The Configurator and the Virtual Catalogue are continuously synchronized to keep the selected products and integrated solutions ever updated.

In case of need to customize an item due to either particular plant or electrical system specifications or to create a special product variant, the user can ask for a real-time collaboration on 3D models with manufacturers and the other process stakeholders. He/she can access his/her workspace, launch the Co-design module where companies supplying the selected item can be contacted and collaborate with their technicians to define an ad-hoc solution. The module allows the management of real-time collaboration for technical design reviews on many different types of documents: CAD files, images, office files, hypertexts, etc. Once the solution has been defined and modeled, it can be imported into the previously configured environment.

In participatory design, solutions are often validated by the whole project team and by sample final users through an iterative process of test and try on virtual and/or physical prototypes. The fourth module, called AR-based module, directly downloaded from the designer workspace, allows the user to import the resulting virtual space realized by the Configurator into a low-cost AR application. This enables the superimposition of the virtual scene with the real space (e.g. room in construction) to assess the impact it produces on sample users and to validate the decisions taken by the involved stakeholders. The prototypal AR system consists of two components: an AR Interface and a Robot Interface [1]. The AR Interface includes a laptop and an external USB camera installed on a trolley. In this way the AR Interface can be easily moved within the real environment the user aims to furnish with virtual objects. The Robot Interface consists of a mobile robot equipped with a fiducial marker, which is used for tracking purposes. This configuration is used to extend the AR working area. Thanks to these two components, the user can handle the configured virtual items in the real environment by means of a dedicated Graphical User Interface (GUI), which is integrated in the AR Interface. The GUI shows in a preview window all the available virtual items, which are stored in the workspace. The user can select and add a virtual object to the real space: the object is automatically placed in the scene and visualised in front of the camera point of view. Then, the user can change the object position in order to correctly place it in the desired location.

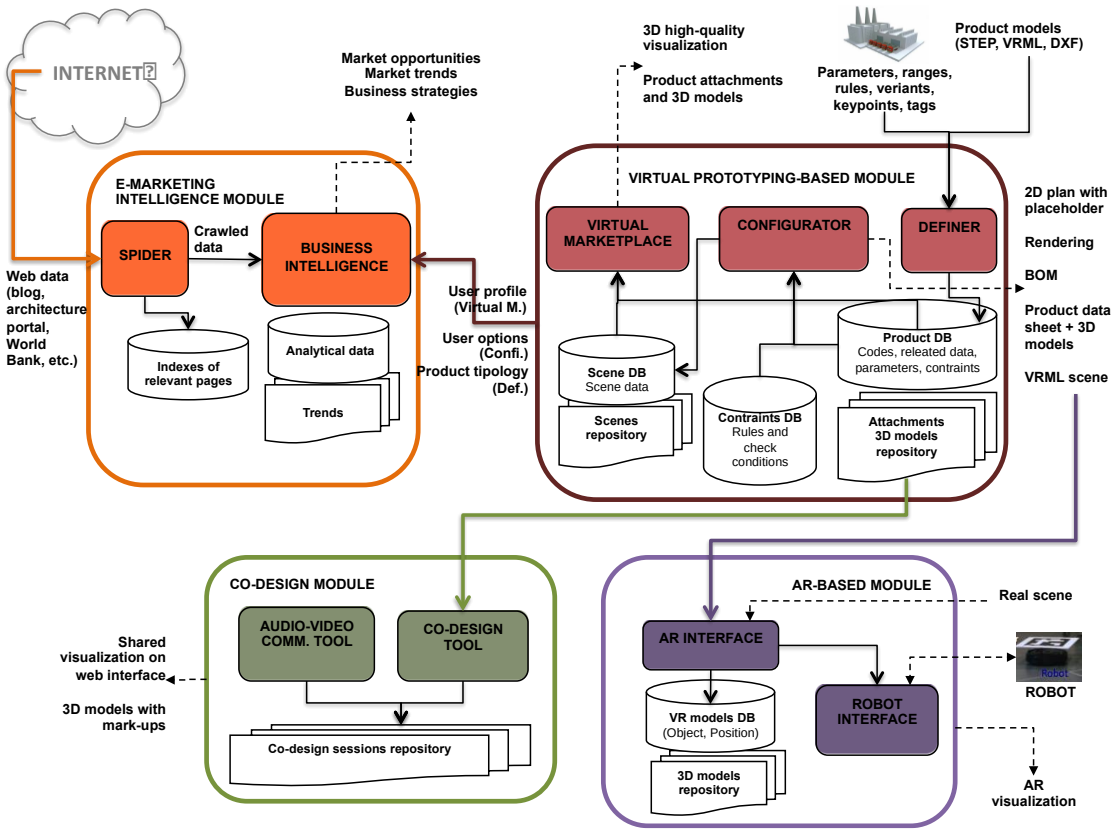

Fig. 1: The technological framework of the whole system platform. The information flow among the modules and external entities are also represented.

Each user can create his/her workspace where to collect the information created and managed (e.g. personalized catalogues, configured projects, co-design sessions, technical documents and 3D models) across the different software applications (Fig. 2).

Experimental results:

The analysis of the achieved platform usability has been carried out into two steps: a preliminary study with five experts in Human-Computer Interaction to detect and correct the main errors of the user interface graphics, semantics and dynamics and a task analysis involving 52 sample users employed in the marketing and technical departments of the project industrial partners. The tasks are defined within two different use scenarios: the design of a serviced-apartment and a wellness center. The adopted evaluation metrics for each task are both subjective and objective. The perceived difficulty, frustration, usefulness, order and pleasantness are measured by post-hoc questionnaires by a 1-5 Lickert Scale. Task completion (%), number of support requests and errors and the execution time are objective metrics assessed by Video Interaction Analysis techniques. Results are arranged in a table according to the three elements of usability (i.e. efficiency, effectiveness and satisfaction). The achieved task completion is about 91%. Designers register a lower percentage for task completion than technicians during the use of the e-marketing intelligence and the co-design modules. Their requests are mainly oriented to deepen the functionalities of the platform and not to ask assistance. This demonstrates the interest they have for a tool supporting their daily work. The Configurator is the more complex tool they perceive as demonstrated by the registered execution time. Globally, the average usability value is 3.6 for companies' employees and 3.34 for designers. The paper will provide

a detail description of the experimental results and some considerations about the system effectiveness to increase market competitiveness.

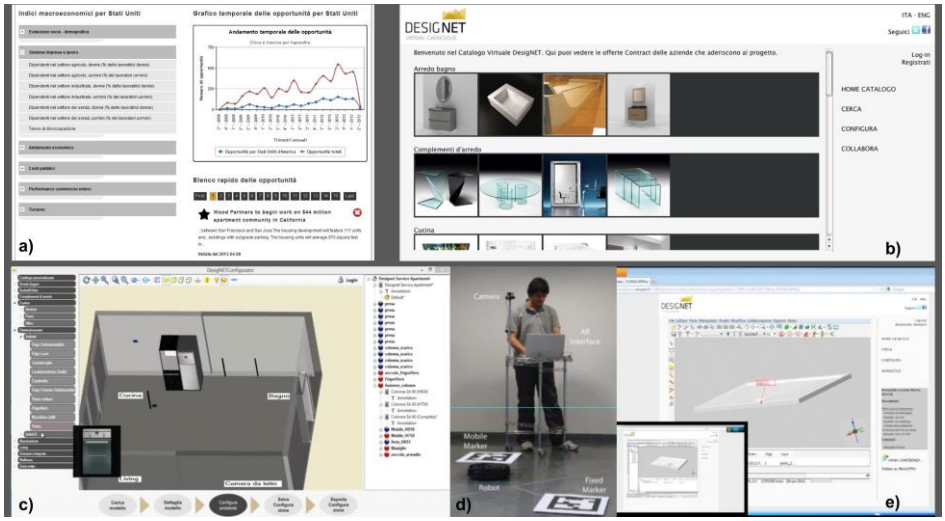

Fig. 2: The user interfaces of the whole platform: a) the e-marketing intelligence module; b) the virtual catalogue to access the different tools and the user personal workspace; c) the CAD-based Configurator; d) the AR-based set-up; e) the co-design environment.

Conclusions:

The research proposes a challenge in supporting tools to address an effective collaboration among all involved stakeholders at the different stages of contract furniture design, identify market trends, reduce delivery times and customize proposed solutions. A technological framework is presented. It integrates different modules for market analysis, web-based virtual prototyping to meet contract furniture requirements. Experimental results demonstrate that the implemented platform is affordable and easy to deploy from non-expert users such as designers, contractors and final consumers.

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