Optimized 3D modeling of virtual retail environments

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ABSTRACT
The article shows a methodology developed for surveying, 3D modeling, texture mapping, and real-time virtual navigating large commercial environment (200 to 2000 square meters). Its purpose is to define a process for generating a digital model of a commercial environment and all the products contained in it. Such model allows to interactively design the display areas, verifying the relationship between the building and the furniture, and the location of products on the shelves, through a realistic perception of the virtualized Point of Sale (POS). This approach allows to compress the timing of testing, evaluation and physical implementation of such kind of projects. The consequently reduced time-to-market involves a significant advantage on the competitors for the companies and retailers involved.

Categories and Subject Descriptors
J.7 [**Computer Application**]: Real time

General Terms
Measurement, Experimentation.

Keywords
3D acquisition, 3D modeling, virtual reality, shop layout evaluation, virtual retail.

1. INTRODUCTION
In the current landscape of instruments and services for commerce, 2D and 3D visualization are nowadays more widely used for supporting strategic choices for management, logistics and purchase [1] [2] . Different tools are dedicated to the POS management thought the shelf layout definition. The planogram management system become the interface between inputs, such as financial and management data, and different outputs like graphic and alphanumeric display schemas. The most advanced applications are based on the 3D virtual replica of the real environment, in this way the visualization of display areas and goods becomes closer to the real experience, and allows therefore a better space management thanks to the simulation of the actual buyer point of view.

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Some other kind of tools are developed for market research in order to know in advance which will be the consumers behaviors and reduce investments risks. Since 2000 a few companies have proposed software and services for creating 3D environments capable to be navigated in real-time by consumers panels. Acting in such simulated retail environment, these test users generate useful information both for each producer and the retailer, for defining the offer based on the actual preferred items.

The web has been used until now to access to catalogs of information. Lately, thanks to the availability of virtual platforms and a growing bandwidth, Internet is going to become a global immersive environment offering several experiential levels.

Thanks to these virtual worlds, applications in different areas related for example to chemistry, surgery, industry, military and games, have been proposed for simulating real world situations in a controlled environment.

This paper is centered on porting such technologies to commercial environments, where 3D modeling and immersive visualization might become a possible instrument for cooperation between the involved stakeholders (i.e. good producers, retailers and end-users) [3][4][5]. An example of this cooperation concerns the definition of a POS layout according to specific strategies (e.g. highlight some good categories or specific brands among others in the shop display).

Digital 3D models usable in a VR environment, especially when displayed at their actual scale, allow to show different design proposals and their variants in real-time. This operating approach allows to accelerate the decisional processes and to reduce the time-to-market.

According to the digital reproduction of existing physical items, several project proposals can be implemented and verified in terms of spatial positioning and aesthetic feeling without any physical intervention on the actual POS.

Virtual reality application might be definitely positive but, despite this, there are potentialities still unexploited. One of the main reasons it is that the truthful digital reproduction of a commercial environment involve the generation of an huge number of models concerning architecture, shelves and some thousand of displayed products.

This may involve long production times and therefore costs not always sustainable by a commercial company. In this paper an application of 3D modeling and Virtual Reality (VR) for interactively redesigning commercial areas is described. It was proposed a semi-automated modeling pipeline in order to obtain a reduced time to generate the single product and the whole environment.

2. ESPERIMENTS AND RESULTS

The development of the method has been experimented within a cooperation between: the Reverse Modeling and Virtual Prototyping group at Politecnico di Milano, with previous experiences of massive 3D acquisition and modeling for Virtual Reality [6]; the Italian branch of Beierdorf SpA (BDF), owner of famous brands like Nivea or Eucerin, that created the "Retail-Lab" in 2007 for facilitating the rapid design of new POSs; the Seac02 company, that develops and produces software for managing shops layout in VR, capable to manage libraries of 3D furniture and objects suitable to be selectively inserted on the 3D scene.

These players faced the reconstruction from physical reality of large selling environments, characterized by the presence of thousands of 3D elements (an average supermarket contains roughly 50000 items), with the common goal of identifying a workflow capable to make feasible and repeatable the project of a selling space based on 3D digital models, with development times compliant with those typical for the industrial and commercial environments.

The experimentation has been made on two different typologies of POS:

a) single shops such as for example a pharmacy, whose size is below 400 square meters, characterized by an autonomous management of the selling space, based only on the choices of the shop owner;

b) large supermarkets whose dimensions are above the 400 square meters, with a cosmetic or pharmaceutical section, characterized by a management of their space standardized by the owning chain according to specific rules.

The proposed process has been set-up based on the experimentation developed on two supermarkets and two pharmacies.

2.1 Critical issues

The survey of a POS involves the architectural and display structures, and all the products included. It has to catch both the geometrical and the iconographic aspect of such elements in order to allow the proper modeling and texturing of the final 3D digital model. The problems arising are related mainly to three aspects: dimensions of the spaces involved, time limitations for completing the job, accessibility of the space during the surveying work. In the experiments conducted we have found two different size orders: on the one hand the large size of the whole environment that may vary from hundreds to many thousands of square meters depending on the type of shop (single pharmacy vs. supermarket); on the other hand the small size of each single product on the shelf, whose size might be few cubed centimeters.

Another problem was related to the survey time. Since the place to be 3D acquired is a commercial site, the data acquisition has to be made possibly in time slots when the shop is closed to the common public. When such periods are not planned by the shop management such activity has to be performed just in the shortest possible time, in order to avoid potential interference with the normal commercial activities both for the shop customers and the personnel. In addition, if the surveys are executed during the opening time, often some data can be compromised by the presence on the scene of people occluding some areas (e.g. during acquisition of digital images). Finally, a problem of space accessibility may emerge, because in a commercial area every available surface is heavily exploited and, for this reasons, different zones are occluded to each others. Or again, if a typical area like a supermarket aisle has to be surveyed, whose shape is narrow in one direction and very long in the other one, the photographic or photogrammetric acquisition needs a large number of frontal shots even with a wide-angle, due to the mandatory limited distance between camera location and target area.

The digital reproduction of the acquired environments has necessarily to be rapid and realistic. It has to be rapid in order to stay in the limited time frame of the highly competitive commercial environment. If for a 3D model in the Cultural Heritage field it is possible to spend months or even years, due to the uniqueness of the artifact, and the intrinsic value of a detailed 3D documentation [7], for the digital reproduction of a commercial area times have to be limited to few weeks.

Considering that a company can launch one or more new products each year for which different specific display solutions could be potentially be arranged, it's clear that a longer development time would make the result nearly useless. On the other hand the 3D digital reproduction has to be sufficiently realistic to allow a virtual immersion in the environment for a proper evaluation of project variants. This means that, although expeditious, the digital reconstruction of the POS building has to return a digital model capable to guarantee a proper perceptive feeling. Each model has therefore to represent the specific geometry and texture mapping of the place. Even if the building has a standardized shape (as for some supermarket chains) the work of "personalization" is still not negligible for the need of digitally reconstruct the "mood" of the specific place at the time of the survey.

A different consideration can be done for the display racks and the products. The display furniture has to be specifically evaluated in each project since different cases can occur, like for example:

- Supermarkets display furniture, that generally are represented by standard modules with few formal variants that can be used also in other supermarkets, sometimes even belonging to different chains;
- Shops display furniture that in general represent characterizing elements of a specific POS, but that may present a certain level of modularity inside that particular shop;
- Brand personalized display furniture, generally more complex by the formal point of view, having a low probability of repetition both inside the same POS or between different POS.

Another important aspect is the 3D digital reproduction of products. In this case the element might be geometrically more or less complex, but for sure they are present several times in the same POS or in different projects of POS reproduction.

One of the critical points of this kind of work is the time necessary to reproduce all the displayed products. We estimate that to 'populate' a cosmetic department of a medium-size supermarkets almost 2000 different models are needed, that means nearly 60 working days of a single operator.

Although single models are relatively easy to be produced, they have a large variety of shape and graphic finishing. A so large number of items involve a potentially huge amount of manual modeling and data entry.

Especially in this phase of the process the number of polygons of each model has to be constantly kept under control. The purpose was to obtain the best compromise between shape fidelity and low number of polygons. This was because the large repetition of a single model in the virtual scene involves the multiplication of its

polygons with an increase in the computation effort that could compromise real-time performances.

2.2 Survey

For the survey of the different 3D components of the scene, from the architecture to the products, an integrated approach has been used, ranging from direct measurements with the help of documental sources, close range digital photogrammetry, and when necessary, laser scanning. The main principle was to generate the maximum level of geometrical information in the minimum time, approximating each part of the model according to the level of interest. For example in each project the beauty care areas have been documented in detail, while for the others we limited the detail in order to save time, leaving anyway the volumetric reproduction of the different elements.

The same approach has been employed for the products. Those related to the beauty care department have been precisely measured with a caliper, with 3D scanning, or with high resolution digital images. A portable photographic set, specifically defined for this project, was equipped with a color calibrated chart for the color correction and a metric reference for dimensional characterization [8]. For the environment texture mapping and the reproduction of lighting conditions, a panoramic HDR image of the POS has always been realized in each project [9]. The image has been quickly created orienting toward the ceiling a digital reflex camera equipped with a fisheye lens capable to acquire an angle of 180°. In this way with a single photogram, repeated at 7 exposure levels (-3 -2 -1 0 +1 +2 +3) stops, a good HDR image can be created in a very short acquisition and processing time. Such image allows to faithfully simulating the actual illuminating conditions in the environment with no need of modeling separately each illuminating source.

2.3 Modeling and texture mapping

According to different element types that we need to model we adopted different approaches. The architectural environments where modeled faithfully, according to the 3D survey data, or previously available technical documents such as drawings and planimetries.

The single shop architectural model is not usable in other works, and it is amortizable only if there are several POS arrangements (the content) on the same architectural model (the container). Regarding the display racks, the approach can be different if located in supermarkets or shops. In the first case, the results of an investigation showed that most supermarkets, even if belonging to different chains, use the same standard shelves. These elements are characterized by a modular and parametric structure whose variables usually are: width, depth, height and shelf number. The first step was to do a typological analysis of the display configurations, followed by the generation of the consequent three-dimensional models.

A different situation is the reconstruction of display furniture of small pharmacies, because in these cases the furniture is generally customized and not replicated in other shops. In this case the furniture needs a specific survey to identify possible repetitions. If these conditions are verified, a parametric modeling approach can be used, otherwise each one has to be modeled individually. Another case is represented by brand customized displays, which can be located both in supermarkets and in pharmacies. This kind of objects is usually strongly characterized both in terms of shape and iconographic appearance. For these reasons such 3D model need to be separately generated implementing an higher level of detail.

Both for architectural and display furniture models, single color textures were mapped on the surface. This choice allow, independently of the model file format conversion, to keep the same color characteristic defined from the texture rather than a color associated to a shader, much more software-prone. Besides, if there are objects with transparent parts, like for example blisters or shelves with metallic grids, we used texture with transparence mapping. Using this system we can make some really simple objects and give them a complexity appearance just with transparence mapping. In this way it's possible to strongly reduce the number of polygons of the whole scene in order to increase the performance of the virtual reality application.

Another important subject matter is related to the modeling and texture mapping of the displayed objects. The products positioned in areas of secondary interest were modeled in approximate way, creating box or volume shaped in accordance with the outline of group of products. The realistic appearance was given thanks to the application of planar textures arranged *ad hoc* with the pictures took in the physical POS.

2.3.1 An automated approach for modeling and texturing products

According to the aforementioned critical issues, we developed an optimized automation process for survey, modeling and texturing.

The first activity carried out was a detailed formal analysis of the products of interest, almost 2000 samples of the BDF case-study. It revealed that about 80% of them have many common geometrical features, even transversally between different brands, having differences only in size and texture. Four main typological family were identified: box; tube; linear extrusion surface and curvilinear shape. A large number of products belonging to these families were analyzed in detail, finding more characterization criteria's. As result of this work a cataloguing of 31 shape typologies were defined. Here each element is characterized by the same pre-defined set of curves and surfaces, with differences only in the actual numerical values defining their shape (e.g. a curvature radius) rather than in their combination.

The main idea is that products can be modeled with the aid of modeling systems based on pre-defined geometrical rules, allowing a quick model generation. In order to obtain this result the 3D modeling process was analyzed to define a set of repetitive operations that could be automated. For example:

- Create new model file;
- Environment set-up (units of measurement, reference system, etc);
- Positioning in space of reference points and curves;
- Surface modeling
- Conversion of math model to polygons;
- Optimization of polygon numbers;
- Topologic check;
- Texture mapping with planar projection;
- Polygonal model export.

The listed steps must be carried out for the generation of every 3D model with an indication of the specific variables related to formal archetypes and the measurements of each product. To increase the automation process, different approaches has been taken into account, in addition to the procedural and parametric

ones [10]. As solution a normal surface modeler it was chosen, capable to implement custom process trough a scripting language.

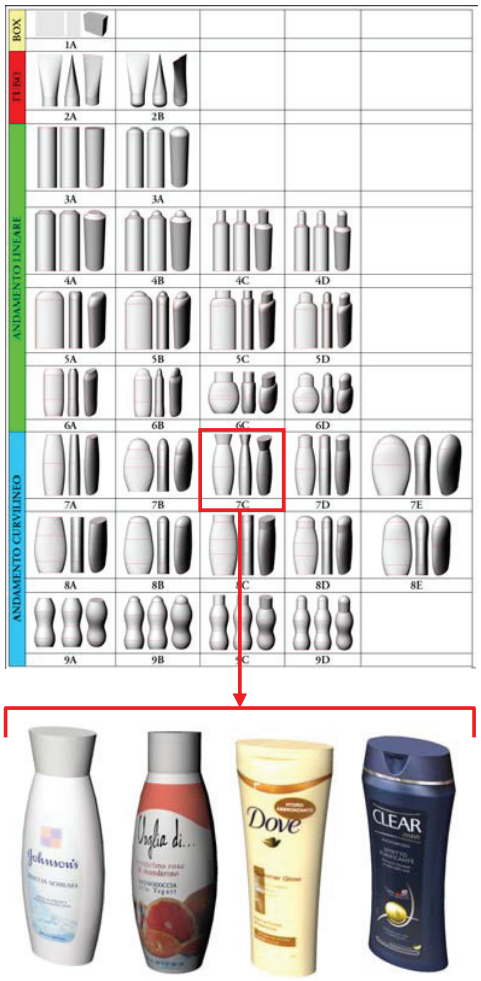

Figure 3. Semi-automatic modeling and texturing system based on products analysis: typologies catalog; product models belonging to one typology family.

For the implementation of the system, the commercial modeling environment Rhinoceros (Mc Neel, USA) has been chosen, for its advantage in user-friendliness and low-cost. In addition the Rhino system contains a powerful scripting language compliant with Visual Basic, suitable for implementing the meta-scripts mentioned above.

In this way an average user, even non expert in 3D modeling, can just specify a few parameters (type selection, model size, texture path, etc) activating an automation based on modeling scripts that generates the final 3D model used in the virtual simulation in a much shorter time respect to a standard 3D modeling approach. Furthermore, the system guarantee that all models are realized whit uniform logic a standard quality. Using these semi-automatic techniques the digital model is generated in almost 1 minute time, faced to the 5-30 minutes necessary with the traditional process.

2.4 Real-time scene visualization and 3D models database

When all the 3D textured models are completed (products, shelves and architectural environment) these have to be assembled all together in a single scene for the real-time exploration. To carry out this phase of work we used the software DisplayDesigner, produced by Seac02. This is a realtime rendering system developed for the management of commercial POS simulation. Using this software a database of products, shelves (empty or filled), POS environments with their collision map, it was created. Once the elements of the entire system were defined, the whole virtual POS for real-time navigation was reproduced: the planimetry was generated and populated with the products and the shelves textured models. Different project variations on the same scene were pre-loaded, ready to be visualized in the project revision phase. The navigation of the POS occurs through two windows. In the first one of this the operator visualizes the shop map with the possibility to define view- path and visual attributes such as: camera pitch, camera height and camera field of view (FOV). In the second one the corresponding real-time rendered scene is displayed, possibly in a virtual theatre.

3. CONCLUSION AND FUTURE WORKS

The 3D virtual model of a Point of Sale for real-time application allows to make interactive project review of display racks configurations, with immediate evaluation of possible project solutions and layout configurations. The tested experiences have shown that the proposed method allows to have a better control on the whole process and to reduce the corresponding decisional time with a consequent time-to-market reduction of the shop set-up.

Thanks to the scripting system it is possible to generate an high number of products in a limited time, equal to 1/5 of the time needed with the traditional modeling approach. Despite this system makes much easier the generation of each digital model, some general problems still hold, as for example the need to input manually the starting data in each script, or the huge amount of data and files needed for implementing the process.

In order to solve the latter critical aspects we are developing a data base system capable to manage univocally the products data, suitable for managing the user interactions with the different scripts.

Besides in the shown commercial field the method presented in this paper can be used also in other application with similar characteristics: architectural environment, furniture elements and a large number of objects that needs to be visualized all together in a real-time virtual reality to evaluate project proposals. The systematic and prompt use of this process method could allows to the players project to reduce the decision time and to income the profits thanks to the virtual reality techniques.

The process shown is currently set to obtain models for high quality applications of immersive virtual reality. However, the methodology has been designed to generate models with a variable number of polygons, in order to generate also lighter models possibly usable through the web.

Figure 2 – Virtual reality model of a Pharmacy shop

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