A Framework for a Sustainable Design and Presentation Process of Furniture Collection

Marco Gaiani[1]*, Silvia Ferioli*[2]*, Pier Carlo Ricci*[3]*, Mirko Barone*[4]*, Michele Agnoletti*[5]
[1,3,5] *University of Bologna Dept. DAPT - Italy,* [2]*B&B Italia - Italy,* [4]*RTTag - Italy,*
[5]*Artificio Digitale - Italy*
[1]*marco.gaiani@unibo.it,* [2]*silvia.ferioli@bebitalia.it,* [3]*pier.carlo.ricci@mail.ing.unibo.it,*
[4]*mirko.barone@rtt.ag,* [5]*m.agnoletti@ravennauta.it*

Abstract. *Design and presentation of new furniture is today a great challenge that requires a large amount of resources: exhibition space, photographic studios, physical prototypes, etc. In this paper we present a new RTR framework RTR-based that allows a more sustainable design and communication process. The framework is addressed to furniture designers, interior designers, furniture companies and presents techniques and methods developed to meet the requirement to ensure predictive rendering quality required by the high level furniture industries. Finally, in order to ensure full functionality a number of tools described in the paper were developed.*
Keywords. *real-time rendering, semantic modeling, virtual furniture design.*

Introduction

Facing a context that changes continuously and significantly - where reaction time in decisional processes is getting faster and faster, time and geographical constraints are no longer an impediment in sourcing information and communicating - furniture design companies are urged by the constant need to change and to know how to be innovative, foreseeing in advance how our own lifestyles, spaces and homes are modifying. On the other hand the current design-development-production-marketing and sales processes in the field of furniture and interior decoration are environmentally and economically very expensive and sometimes unsustainable towards the today social, environmental and economical requirements. In fact, furniture design-to-customer pipeline is very complex and fragmented for dual reasons:

- Intrinsic reasons: i.e. in a single design product different materials and processes are involved from woodwork to upholstery, to metalwork;
- Extrinsic reasons: lack in information communication between furniture suppliers and designers and lack of data interoperability between different departments of the same company.

Besides (oppure Furthermore), in these last years fundamental requirements of the high level furniture marketing have become:

- To suggest the customer not only a single piece of furniture but a whole interior solution with an atmosphere in which its different elements are able to exist together in harmony talking ‘the same language’;
- To offer a large capability of customization of the product (i.e. for a sofa many fabric or leather types and color variants, in terms of finishes and colors).

For these reasons the sale-process requires wide showroom space, many physical prototypes and sophisticated images of furnished settings to evaluate not only functionality but also the style and the quality of the different materials and shape variants of the same object and to show a 'mood' to the customer. Unfortunately photographic sets and physical showrooms are very consuming in terms of cost and space and they do not allow a fast time-to-market. Moreover, it's practically impossible to have in a showroom the full range of each product with all the fabric or leather colors variants (i.e. the swivel sofa AMOENUS in Maxalto furniture collection is feasible in more than 430 variants).

In such a context a first goal is to have a significantly more structured design process, less time, human and economical resources consuming and easier design communication process without the today continuous generation of documents and physical prototypes.

A second goal is to conceive a solution that allows the replacement of the physical space and objects with virtual items able to substitute the physical ones in the simulations along the whole design process and to present to the customers the full range of variants for each furniture in an iconic photorealistic way.

Static high quality renderings are a partial solution, but they don't give a proper solution to the core problem of quality and sustainability of the product design. Another little improvement in the process is the availability of graphic libraries of 2D and 3D models to be used inside commercial CAD or render-er, but most of times these are created just for a general purpose and not for a multi-scale visualization.

Virtual furniture design is a new concept of design method, thinking, and process which reflects the changing requirements and concerns our society in the digital era (Lin and Hsu, 2004). With the aim to give an answer to the issues above described, this paper presents a new framework that makes use of 'virtual furniture' with a new visualization and project management solution developed to support interior and architectural design, and combining virtual modeling with photorealistic visualization. Virtual models of a product are added to the virtual interior, which can be viewed in 3D in a realistic environment. For instance, this framework allows to display different pieces of furniture to the final consumer and to 'virtually' check how they fit in an imaginary or existing environment. The framework is entirely founded on 3D digital models rendered in real-time (RTR) at high quality with the aim to organize, present, and visually navigate 3D interiors scenes. To support our framework we developed a series of specific tools and solutions for typical use case scenarios consisting in process methods, pre-built partial output, guided environments, rendering techniques. For the

Figure 1
Maxalto concept book cover and real-time rendering of the virtual showroom based on concept book design specs.

visualization of the 3D models we used the RTR commercial software RTT Deltagen by Realtime Technology AG [1], the state of the art software for industrial design and automotive. This software house has been involved in the project, giving support in specific features development.

In order to deeply investigate all the processes involved in furnishing design, our system has been developed in collaboration with B&B Italia [2] - a recognized famous leader in the area of modern interior decoration - using as case study the brand Maxalto, a collection totally designed and coordinated by Antonio Citterio (figure 1).

The paper is organized as follows: section 2 illustrates framework characteristics; section 3 describes possible use scenarios; section 4 explains the model semantic organization and model collections management methods. In section 5 techniques and methods developed to meet the requirement of the quality of the predictive rendering typical of the high level furniture industries are presented. New tools to assist the designer are shown in section 6; concluding remarks are reported in section 7.

Framework background and characteristics

The system described in this paper has been established starting from a reasoned review of the sophisticated pipeline of the car design style digital process since it is a mature system allowing close time-to-marked from the concept to the customer communication, and limited use of physical resources. The typical car style design workflow today is a well optimized and closed process, entirely based on real-time visualization of 3D NURBS models, which proceeds without interruptions from design, to review, to final design presentation, using a very limited number of physical prototypes and the same file for the engineering of the new shape and the marketing materials, allowing short time-to-market. We evaluated the differences between car design and furniture processes in order to focus new features required to better support the project in the different phases. Another background of our project has been European FP6 research projects IMPROVE [3] and 'AsIsKnown' [4]. These projects, however, give only partial solutions to our issues.

Our framework is based on RTR photorealistic 3D models as a basic tool to simulate the behavior of the real object both from the point of view of the shape and the function. In this way the system enable 'Direct design' techniques 'perception based' (in contrast to metaphorical design) (Maher et al., 2001). Then, the use of visualization systems in RTR in the field of furniture industry implies: a new weight of the project visualization within the corporate strategies (Gaiani, 2007); the ability to output visualization at different levels of iconicity and using display devices largely scalable from low-level ones like display-totem, DVD, CD, Internet applications, to high-end immersive devices, like immersive rooms, Cadwall, Large Touch screens; finally the use by designer of pre-rendered high quality furniture and interior decoration 3D models showing in real-time many possible variants to the final user.

Synthetic images, configurators, simulators and 3D graphic libraries freely available for interior designers from furniture producers are not new in the interior design field but the quality of rendering lacks in the production of static images, and it is indequate to face the sophisticated quality of the still life photography largely used nowadays.

On the other hand the use of RTR 3D models as communication method is a super-system of the existing communication media (static images, prerecorded animation, web-applications, catalogs, etc.) and in this direction it can be used to generate all possible imaging-based output during the design and communication process:

- Product visualization inside the design process from its concept along all the design steps (Virtual Prototyping);
- Product variants display (Virtual Showroom);
- Sales and marketing phase documentations (i.e. movies, images, etc.);

- Tools to simulate the selected furniture inside an interior project.

Typical new uses of the various outputs are in the following four main fields:

- Project assistance of interior designers;
- Presentations (focus group, marketing, retail, events);
- Sales (promo material, point of sales, web);
- Aftersales (illustrations for handbook).

Our framework, besides, presents several innovations in different areas:

- Modeling for RTR techniques starting from scratch or from engineering data (to give solution to the typical problem of the multiple sources of the 3D data);
- Models semantic organization and model collections management (to easily allow implementations of shape and material variants and model management);
- Shader creation of specific interior design and furniture materials;
- Interior design RTR quality;
- Ambience coordination model and material based guidelines (to drive the interior designer in the design process).

A typical workflow from our framework is illustrated in figure 2. Starting from the 3D model used to conceive the new furniture we have three workbenches to generate single contents and a workbench to generate a specific interior design solution:

1. Model workbench: generation of 3D models for RTR;
2. Shader workbench: generation of 'type', 'detail' and 'color' variants;
3. Ambient workbench: generation of 'matching material table', 'lightning systems', 'product moods', 'sets of furniture components';
4. Final output workbench: generation of specific interior solutions.

To ensure that our framework is consistent, easy and quick to use, each workbench is assisted by specific guidelines, toolkits and pre-generated contents as in figure 2.

Models semantic organization and model collections management

In order to use computer-generated models

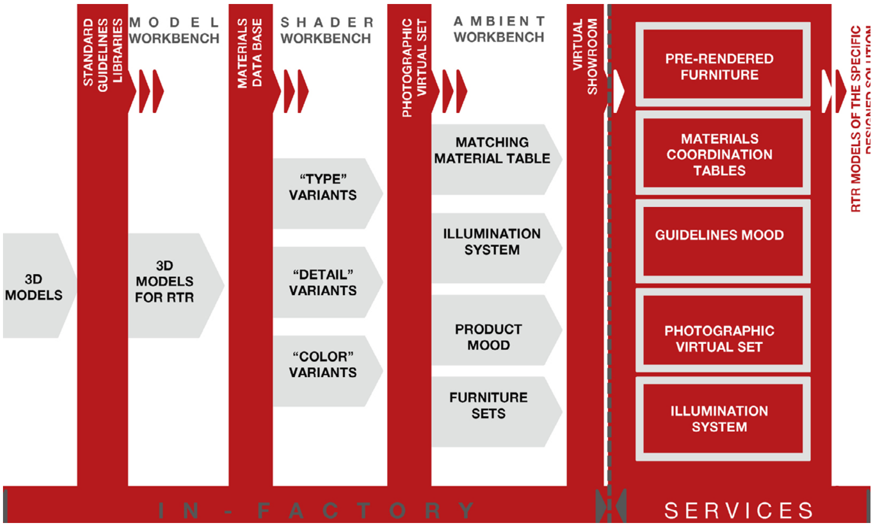

Figure 2
Workflow to generate RTR contents for multiple uses in our framework.

efficiently, data must be must be updated, consistent and transparent throughout the entire product lifecycle. For this reason data must be based on standards and organized in libraries in which each model is continuously maintained and consistently documented. On the other hand the number of sources of models for RTR visualizations is increasing as well: by scratch, by R&DC, by designers externally to the company. Our aim is therefore to improve the retrieval of 3D objects and related information within a repository by annotating each shape not only as a whole, but also in terms of its meaningful subparts, attributes and relationships between them. In this situation a model semantic organization and model and textures collection management is a fundamental requirement.

In order to address these problems, we proposed a solution able to collect and record 3D models of the furnitures, verifying the fidelity with accurate pre-defined quality metric standards and the responsiveness with typical requirements of a 3D RTR model.

From a technical point of view, our system is based on two major components linked through a query modeling and transformation processing layer:

- An efficient storage module for multi–dimensional data;
- A concept–based representation module for the objects identified in the data.

Our 3D modeling methodology follows the shape grammar concept introduced by Stiny and Mitchell (1978), extending the original formulation to 3D shapes and adding a new organization into different sub-elements corresponding to the constructive organization of the furniture (Manferdini et al., 2008). Each single sub-element can be considered as a node, which is linked to a file that can be stored separately from the other ones belonging to the same furniture. All geometry-parts are associated with a semantic meaning (e.g. denoted as structure, upholstery, accessories, etc), and each semantic item is further described with specific attributes. Each part is then connected to series of information created to facilitate the retrieval process in a semantics-based context. Furthermore a semantics driven visualization enhances usability of the model. Semantic structure is then exploited to obtain multi-resolution representations.

The method produces photo-realistic 3D models, classifies them in layers, and associates information to each element beside the already known geometric properties.

Our storage module encodes and manages our different and multiple 2D and 3D data:

- Model Level-of-Detail (LOD) classified according to use. Our system provides 4 LOD;
- Texture LOD (color, normals, pre-calculated GI). Our system provides 3 LOD;
- Furniture components;
- Single model stage visualization (prepared with all the variants of materials);
- A showroom arranged for ‘complex mood’ visualization.

Without needing a 3D file interpretation, the database can rebuild the nodes frame and access to sub-nodes or to the entire 3D model (Figure 3). Through its organization our system also allows:

- Data entry by different operators;
- Qualification of 3D models in relation to the different LODs;
- Quality check of data against the provided technical specifications;
- Fast variants management;
- Availability of high resolution RTR models;
- Direct input into the whole interior project;
- Specific furniture variant manager;
- Ambience variant manager.

Shader materials creation and interior design RTR quality improvements

The goals someone might want to achieve when computing synthetic 3D imagery of interior design scenes for the furniture industry is that the rendered image enables to predict accurately what a virtual scene should look like. This type of image creation is called today predictive rendering, and it is considered as an extension of photography (Wilkie et al., 2009). In order to meet the quality requirement for imagery asked from high-end furniture industries using predictive RTR, we developed new techniques and methods in the areas of shader creation and RTR quality.

The creation of new shaders is due to display complex materials in real-time and to acquire them in an easy way, with the goal to reproduce faithfully the 'look and feel' of materials, regardless of specific physical object that will be applied. A typical case is the surfaces of upholstery. We decomposed the problem in two parts:

1. Mesostructure level (geometric details);
2. Macrostructure level (gross surface geometry).

The ultimate solution to have an accurate digital representation of material mesostructure is multispectral BTF (Bidirectional Texture Functions), a seven-dimensional function that depends on view and illumination directions as well as on planar texture coordinates (Filip et al. 2009). However BTF is typically obtained by measurement of thousands of images covering many combinations of illumination and viewing angles, a hard task that needs expensive and complex instruments, long time, skilled operators and it generates a large size of data, whose use is extremely difficult in any sensible application.

The most popular solution to overcome these problems is to describe the mesostructure with normal mapping techniques (Cignoni et al. 1998). The normal map is usually obtained from color map using tools that transform the depth in X, Y, Z coordinates like the Nvidia NormalMapFilter tool [5]. However this method gives good results only for small bumps and generally fails for fabric where the surface displacements are of the same order of

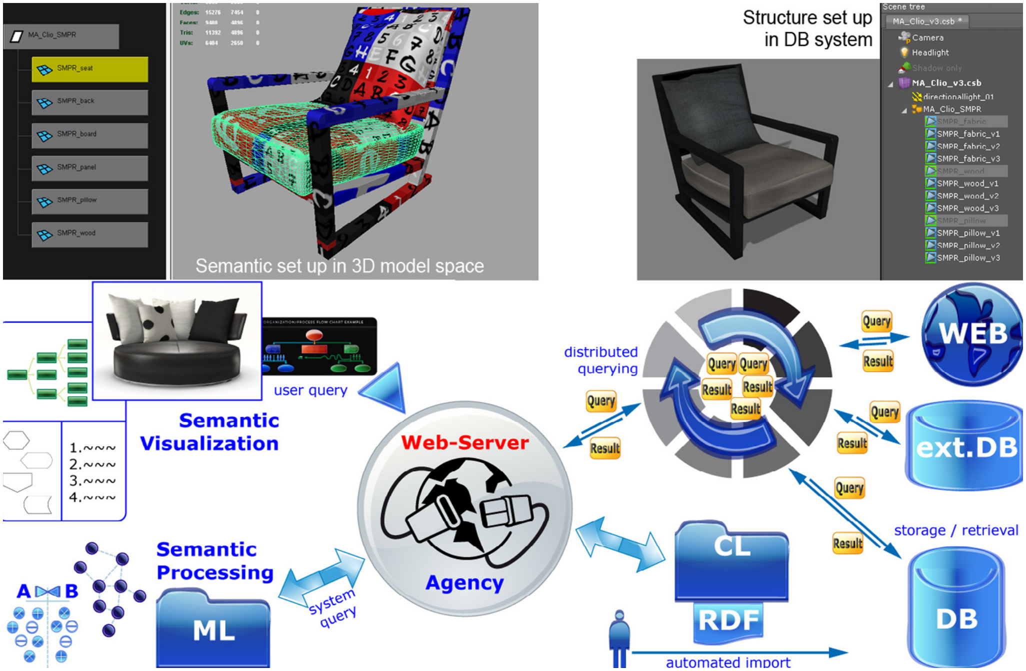

Figure 3
Models semantic organization and model collections management system

magnitude of the plot. Therefore we developed a technique that reconstructs the mesostructure compressing the BTF into an appearance space texture with 3 different maps:

- RGB color map: captured with a flatbed scanner using sRGB color space and color calibration against a reflective IT8.7/2 target;
- Normal map: obtained photographing the fabric four times, enlighten from each of the four cardinal directions and merging them layering, a variant of method described in Rushmeier and Bernardini (1999);
- Heightmap: obtained from the scan image converted in grayscale and blurred using a Gaussian filter.

Finally we obtained our representation of fabric pattern by implementing a variant of parallax occlusion mapping techniques using Nvidia CgFX (Tatarchuck, 2006).

1. The macrostructure reproduction was obtained using multitexture techniques through several steps:
2. UV map creation and texture scaling;
3. Folding addition starting from a pre-generated library of materials;
4. Pre-calculated GI (Global Illumination) layer addition to the texture color of furniture, in order to give real depth on the basis of the light/dark ambient light;
5. Shelf mark seams using 2D image tools and working on hue 'black'.

To improve the RTR quality we worked on chromatic and tone color definition. Besides the open question of how many spectral samples to use, practical barriers to apply full spectral rendering in commercial software are a general dearth of spectral reflectance data, to base spectral simulation on; white balance; 'data mixing problem' (i.e. multiple sources of material characterization data); and computation cost. To overcome these problems we implemented in our RTR system two solutions:

1. Color management throughout the rendering pipeline by working within the context of the final color space in which images can be viewed. Version 9.5 of RTT software allows displaying images through lookup tables (LUTs) and control contrast, exposure, tone mapping, and gamma. We completed these tools with full support as standard profile of the IEC 61966-2-1 sRGB color space. It is a rendered space consistent from data capture to different monitors or videoprojectors visualization well implemented in the OpenGL libraries;
2. Implementation of Ward and Eydelberg-Vileshin (2002) *Picture Perfect RGB Rendering* using the sRGB solution. Ward et al. present the benefit that no modification at all is required for a conventional RGB rendering engine. The spectral pre-filtering is realized performing white-balance against a series of Gretag Macbeth Color Chart placed inside the scene by a fixed approach using the ACR calibrator tools [6] and applying the results of the calibration step through a series of tone mapping algorithm implemented in our software that have a behavior as in Adobe Photoshop. In this way the method is consistent also using HDR images. As suggested in the original paper for the rendering in sRGB space, we performed white balancing ahead of time. Light sources matching the dominant illuminant spectrum were modeled as neutral, while spectrally distinct light sources as having their sRGB color divided by that of the dominant illuminant. Easy to get with RTT as main illuminant source color is well modeled with implementation of std CIE illuminants (D50, D65, etc.).

The implementation of new shaders and RTR chromatic and tone color definition in combination with the use of screen space deferred shading (Dachsbacher and Kautz, 2009) showed excellent results.

New tools to assist the designer

To assist designers in their work we developed a series of specific tools that allow:

- Photorealistic visualization in real-time of the new designed ambience;
- Simplification of the design process for the interior architect;
- Easy comprehension of the new space for the customer;
- Better design quality;
- Great savings in the communication cost for the furniture's producer;
- Less time-to-market avoiding the many misinterpretation of the whole process.

The new tools are addressed essentially to three different operators (furniture designers, communications designers, interior designers) with the aim to have powerful instruments both in conceptual and communication phases. The tools are essentially 3D pre-rendered furniture model and material databases with associated technical datasheet, photo galleries, 2D drawings; 3D interior models to be used in specific tasks; mood guidelines and variant manager to facilitate design solutions creation.

3D models are basically belonging to three families:

- 3D libraries with high quality materials variants, ready to be rendered in a RTR engine at photorealistic level without requiring any additional work;
- Virtual photostudio equipped with a wide collection of presets, scenes, item, HDR images, materials, color patches, lights, environments, virtually copying what is used in the real-world of photography. The lights correctly simulate real light sources by use of standard CIE illuminants;
- Virtual showroom concept space fully textured and with illumination predetermined from physical parameters, allowing virtual furniture testing and showing product variants in the appropriate space inside and outside the company, to the resellers and finally to the customers.

From the software features side, main innovations concern new solutions to drive the interior designer in the design process. The system presents two specific tools:

- Single furniture guided variant manager (figure 4): it allows a constrained design from prearranged libraries of materials and color tables;
- Ambient variant manager (figure 5): it automates the coordination processes of the environment and drives coordinated choices of furniture, materials, finishes and colors in the entire interior.

Another important tool is the Gretag Macbeth Color Checker box that enables color correction of a rendered image in software like Adobe Lightroom allowing typical processes of digital photography for furniture catalogs workflow (figure 6).

Conclusions and future works

In this paper we presented a new framework to improve the efficiency and the sustainability of the furniture design and sales process. The framework is completely new, since founded on RTR techniques and integrates in the same environment different tasks and functions, enabling sharing and reuse of data to multiple operators. The system is supported by various tools and techniques developed that enable the improvement of level of RTR in a field where a predictive quality is a strong request. The framework is pre-validated because built with a world-leading furniture manufacturer, which followed the development process with the purpose of integration in its business process.

References

B&B Italia, Maxalto Concept Book, 2008.

Cignoni, P et al 1998, 'A general method for recovering attribute values on simplifed meshes', *Visualization '98 Conference Proceedings*, ACM Press, pp 59-66.

Dachsbacher, C and Kautz, J 2009, *Real-time global illumination for dynamic scenes*, ACM SIGGRAPH 2009 Courses, ACM Press, New York.

Deering, M et al 1988, 'The triangle processor and normal vector shader: a vlsi system for high perfor-

Figure 4
Material type and color variant manager

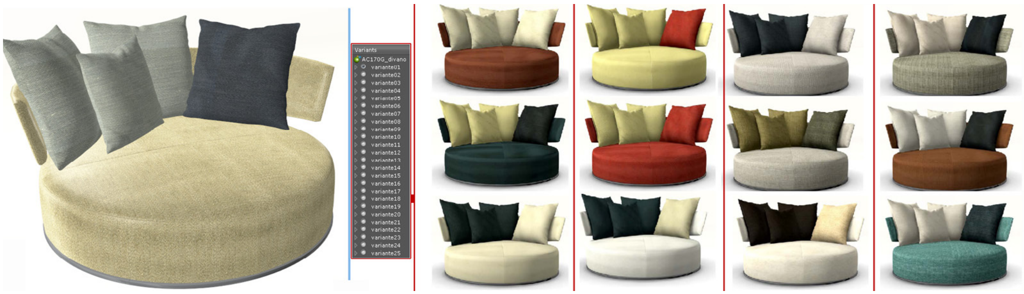

Figure 5
Ambient variant manager

Figure 6
Gretag Macbeth color box inside a scene

mance graphics', *SIGGRAPH 88 Conference proceedings*, ACM Press, New York, pp. 21–30.
Filip, J and Haindl, M 2009, 'Bidirectional Texture Function Modeling: A State of the Art Survey', *IEEE Transactions on PAMI*, 31 (11), pp. 1921-1940.
Gaiani, M 2007, 'Vedere il progetto di Industrial Design', in M. Docci (ed.), *Metodi e tecniche integrate di rilevamento per la realizzazione di modelli virtuali dell'architettura della città*, Gangemi, Roma, pp. 145 - 163.
Lin, CH and Hsu, YL 2004, 'The Influence of Digital Architecture on Virtual Furniture Design', *CAADRIA 2004 Proceedings*, Seoul Korea, pp. 493-504.
Maher, ML, Gu, N and Li, F 2001, 'Visualisation and object design in virtual architecture', *CAADRIA2001 Proceedings*, Sydney, pp. 39-50.
Manferdini, M et al 2008, '3D Modeling and Semantic Classification of Archaeological Finds for Management and Visualization in 3D Archaeological Databases', *VSMM 2008 Proceedings - Project Papers*, ARCHAEOLINGUA, Budapest, pp. 221-228.
Rushmeier, HE and Bernardini, F 1999, 'Computing consistent normals and colors from photometric data', *3DIM99 proceedings*, pp. 99-108.
Stiny, G and Mitchell, WJ 1978, 'The Palladian grammar', *Environment and Planning B: Planning and Design*, 5, pp. 5-18.
Tatarchuk, N 2006, *Practical parallax occlusion mapping with approximate soft shadows for detailed surface rendering*, ACM SIGGRAPH 2006 Courses, ACM Press, New York.
Ward, G and Eydelberg-Vileshin, E 2002, 'Picture perfect RGB rendering using spectral prefiltering and sharp color primaries', *Proceedings of the 13th Eurographics Workshop on Rendering*, ACM Press, New York, pp. 117-124.
Wilkie, A et al 2009, *Predictive Rendering*, ACM SIGGRAPH Asia 2009 Courses, ACM Press, New York.
[1]www.realtime-technology.com/flash/index_eng.php
[2]www.bebitalia.com/
[3]www.improve-eu.info/
[4]www.asisknown.org/
[5]www.developer.nvidia.com/object/photoshop_dds_plugins.html
[6]www.fors.net/chromoholics/