Back to 2nd AD
A VR on-line experience with Virtual Rome Project

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Abstract

The Virtual Rome Project, commissioned by Seat Yellow Pages and the Italian Chamber of Commerce, has developed a VR webGIS application, with front-end and back-end on line solutions, for the interpretation, reconstruction and 3d exploration of archaeological and potential past landscapes of Rome. The purpose is the creation of a three-dimensional open source environment, embedded in a web-browser. The web application has two components: a front end that let the final user interactively explore the reconstructed space and a back end (still in development) that helps researchers to consistently build up the data structures needed to the complex activity of landscape reconstruction. At present the archaeological and ancient landscape of Rome has been reconstructed with variable resolution and accuracy (generally w 10-100 Mt, selected areas near via Flaminia, via Appia and Imperial Fora, with a resolution of 20 cm).
Sites, monuments and archaeological areas are connected with their context and are reconstructed in accordance with real and hypothetical topographies both for the present day and for the past. We will describe the process of contents and software development as well as the methodological approach to ancient landscape reconstruction.
The paper discusses also some problematic aspects that the "Virtual Rome" on line application had to face, both from archaeological and ICT points of view: reliability of reconstructed past landscape; the reconstruction as open and scientific process; large territory dataset on line management (32 GB of high resolution aerial images); different coordinate systems and data resolutions integration; 3d models complexity and dimension (texture and geometry) integration and efficient exploration; vegetation integration; continuous interaction for inter and intra-site browsing and plug-in integration in the browsers most commonly used. We present solutions to further develop the back-end VR webGIS builder, in order to allow a continuous modification of the landscape and the integration of different projects, to realize a 3d cooperative environment and a reference point for virtual communities.

Categories and Subject Descriptors: I.3.7 [Computer Graphics]; H.5 [Information Interfaces and Presentation]; J.5 [Arts and Humanities]

1. Introduction

How did our landscape looks like in the past? Which was the original aspect of that monument, or archaeological site, that today appears so ruined and also so immersed in our crowded built cities? How was its original relation with the surrounding natural environment and also with other sites? How was monument function and how was it used by ancient men?
Landscape reconstruction is one of the most interesting and also complex activities that can involve researchers and attract travellers enquiries about past life and past world [Ren 94, Pes 07].
Landscape reconstruction, for its nature, requires a *multidisciplinary* and an *interactive* approach. In fact it involves disciplines such as archaeology, anthropology, history, architecture, geology, geomorphological, palaeobotany, geoarchaeology, climatology, lithology, agricultural studies, etc. So many disciplines need to maintain continuously a reference with spatial data and

temporal dimension. Therefore researchers need a place to share interactively their knowledge and study, coordinating their work with the common goal of getting to a reliable and scientific result [DOF 96, Ren 94, Pes 08].
On the other side, visitors who wish to explore archaeological landscapes, trying to understand how they should have been in the past, need to have a space to visualize them interactively. Thanks to advanced behaviours, such as the possibility to compare different landscapes switching different terrains, or activating multimedia contents connected to 3d objects, can really help to have a better knowledge [FPP 06, Rou05].
We assumed that the possibility to *compare* different terrains, each one with their ecosystems and models, changing time component, and maintaining the same spatial dimension, can enhance the knowledge and the interest on past landscapes. Moreover we worked on the idea of creating a interactive cooperative on-line environment where scholars, communicators and ICT experts could meet and create dynamically landscape reconstructions and final

on-line visualisations. We choose to follow an open source approach to the project, in order to have the maximum flexibility on behaviours creation, up-datability and further development possibilities. With the same approach we tried also to facilitate an open process in sharing data and scientific results.
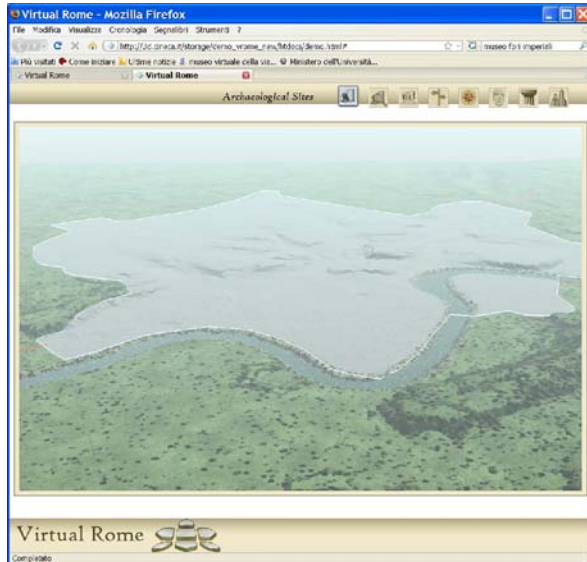

Figure 1. *Virtual Rome Front End interface*

Virtual Rome project started at the end of 2006. It gave the opportunity to start to develop the framework, that is composed by: a *front-end section* and a *back-end section*, used by super-users (programmers, researchers, etc.) to create dynamical landscapes, 3d scenes and to publish data over the web.

Virtual Rome main goal was the creation of an on-line immersive and interactive environment, where users could explore dynamically the archaeological and ancient landscape of Rome and its territory (fig.1).

Virtual Rome is based on a previous work, published in 2004 and 2005, developed for the Appia Project and Esaro Cultural District project [FPP 05, PFC 05].

We started analysing different open source projects and 3d graphic tool-kits such as Virtual Terrain Project, OpenSceneGraph, OpenSG, etc. [USarmy08]. We decided then to base our work on OpenSceneGraph (www.openscenegraph.org), the only one that was offering paging support for terrains and on-line publication capabilities, through the .net plug in [KM 07]. We develop a plug-in, OSG4WEB, actually available for Internet Explorer and Mozilla Firefox.

Virtual Rome project, in fact, had the following requirements:

- paged geospatial dataset support
- coordinate and projection handling (both in input and in output)
- large 3d terrain dataset management
- 3d models integration (modelled with software such as 3D Studio Max)
- natural elements, such as vegetation, integration
- vector layers integration
- on-line 3d data publication and interaction, possibly embedded into a web browser
- Fly and walk navigation tools
- Behaviours integration:
  - terrains, models switching
  - vector information loading
  - models loading
  - picking and loading external pages or multimedia contents
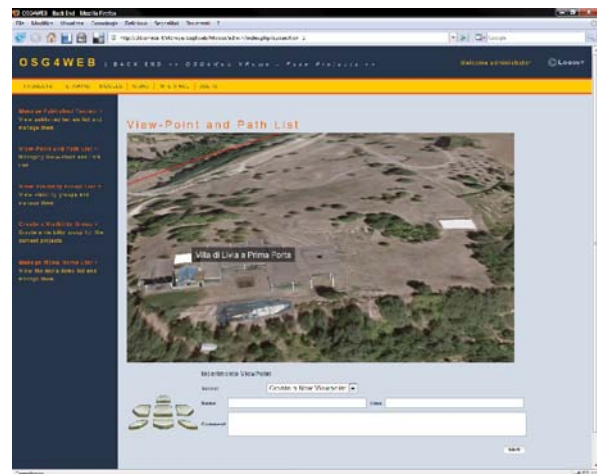 - overview map
  - environment integration

Figure 2. *OSG4WEB back-end section with Path and Viewpoints creation.*

The project required a great effort in two different directions:

    A.   contents development
    B.   software development

Contents were studied and developed in accordance with scientific and archaeological issues and with on-line interactive publication in the virtual reality environment.

A1 – Archaeological and Ancient Potential landscapes reconstruction;

A2 – 3d models creation, optimization and integration in 3d scene;

A3 – Vegetation integration;

A4 – Multimedia Contents integration and connection with 3d contents in the 3d space.

Software development is based on the creation of two different components:

B1 - on line interactive 3d section (*front-end section*) based on the plug-in OSG4WEB (fig.1)

B2 - on line interactive scene creator and project publishing (*back-end section*) (fig.2)

2. Contents

2.1 Landscape reconstruction

A reliable reconstruction requires a precise methodology of study and research: in fact knowledge is the basis for all subsequent processes of interpretation and final communication. Knowing means starting from a first phase of high-level data collection, both basing on the study and collection of texts, archives and images that on technical, physical and material of what we want to reconstruct [VVM 06]. The purpose of the project is to rebuild the archaeological landscape of Rome during Roman times (2nd AD), with geo-located 3D models, accessible via web, along the consular Roman roads Appia and Flaminia, and in the central area of the Imperial Fora.

Therefore, the first phase of work focused on the study both of the landscape and the areas of detail or specific interest, and the various elements of the landscape.

The archaeological landscape is made up of several elements: from the naturalistic to the environmental, from the geological to the historical and anthropic, until the perceptive one. It is the product of different interactions and the result of a long process of transformation.

So, for the virtual reconstruction of archaeological landscape it's necessary to interpret and integrate different elements, taken from many different disciplines. Our work is based on the collection of all relevant data, offering a more complete information about the reconstruction of the landscape, as it was in antiquity. The use of disciplines such as geomorphology, pedology, climatology, hydrography, paleo-botany, together with the study of architecture, archaeology and historical and anthropological area evolutions, gave the possibility to rebuild an archaeological and ancient potential landscape. This method allowed to redesign a landscape on the base of all available data, in a updatable framework.

Figure 3. *Distribution map and a rendering of the reconstructed Roman landscape*

We started with the construction of a GIS project, used mainly for its analytic potentialities, where we create a distribution map of the soils, vegetation and archaeological sites and elements (fig.3). The result of the work is a raster image consisting of different areas, appropriately revised in accordance with specific archaeological and palaeo-environmental knowledge. Each area has a three-

dimensional virtual ecosystems connected to it and each ecosystem has several libraries of plants and models, built in accordance with the specific historical period. For the 2nd AD, in fact, we create a vegetation library with plants available just during Roman times in Rome area [Pes 07, VP 08].

2.1.2 Methodological approach

The concept of ancient landscape reconstruction may be somehow ambiguous without an adequate methodological premise. While the digital reconstruction of an ancient building can be intended as a reproduction of such building in a given stage of its history, it is impossible to deal with the concept of landscape in terms of "reproduction". As a matter of fact, a hill, a wood, a lake, observed year by year, can be very different from their previous conditions. The concept of reconstruction is therefore to be considered in both terms of scientific potentiality and (then) of emotional impact. In order to reach this goal, the process has been focussed on the potentiality of the soils, choosing among the most probable land uses, according to natural features and human presence. Different geomorphological information of this area were acquired from the most updated databases [Arn 03] and related to land uses.

The distribution of Roman ancient villas was also used to draw possible cultivating areas around them, according to the strategy of site catchment analysis, a well-known tool in spatial archaeology [HVF 70], already tested for similar situations [GS 91, CPP 07]. With the processing of these data (soil map, villa's buffers, proximity to rivers, slope and aspect) it is possible to assume the potential aspect of the landscape, in a certain historical period and latitude. A map of potential ecosystems was obtained, it was adapted to the irregularity of geographical situations, and used as starting point for the final digital landscape reconstruction.

Virtual Landscape generation has been achieved, assigning different ecosystems to terrain, based on the colour map (Fig.3). The DEM was then generated, with a resolution of 5 Mt, while information related to natural environment was exported in GeoTIFF format. The software used are ErMapper, GRASS GIS and Visual Nature Studio (VNS).

2.2 Modelling for real time and on line applications

In the last two years the VHLab have been working in two case studies of archaeological landscape reconstruction and architecture modelling. The first one (Via Flaminia project) is developed for application on a local computer, while the second (Virtual Rome project) targets web-based applications. In both cases, the objective is to develop real-time immersive system to visualise 3d models of landscapes and monuments. Both projects led to the reconstruction of the sites and their landscape context. The methodology for the virtual reconstruction is common but the post processing differs depending on the use of data (on-and off-line application). In our case, the on-line VR system required different levels of detail (LOD), therefore three different models in geometry and texture (very simplified, simplified and detailed) were created. We have developed different

optimization approaches based on the same 3d models. Decision on the export file type, weight and polygons number, size of textures and so on usually depends upon final modelling destination. The methodology used for the landscape and architecture reconstruction is unique, but differs in technical aspects, depending on different levels of perception.

The preparation of real time models has required raw models to be optimised, especially in order to reduce the number of polygons and ease the texture management. Two approaches were tested in this respect, to drastically reduce polygon number and textures size, and thus reduce computation time. The first method consist in a 3d Studio Max modifier (MultiRes), which reduces the memory overhead needed to render models by decreasing the number of vertices and polygons. This modifier allows the reduction of the exact percentage or vertex count. The initial model detail allows to generate an accurate decimated model. We divided the model into several parts with the consequence that, after decimation, we were often obliged to sew edges of the divided objects together, vertex by vertex.

The second optimization technique is another modifier of 3d Studio Max: Normal Mapping. After testing both options, we choose to use MultiRes technique as it guarantees the best compromise between graphic quality, number of working hours and the need to manage models in a VR on-line real time systems. In addition, this technique allows to greatly enhance the appearance of a low poly model exploiting a normal map coming from a high resolution model.

Figure 4 – *recontruction of ancient potential landscape*

Level of detail (LOD) approaches increased the efficiency of rendering by decreasing the workload on graphics pipeline stages, usually relying on vertex transformations. The reduced visual quality of the model is often unnoticeable because of the small effect on object appearance when distant or moving fast. Three models of the same monument were produced, with low, middle and high numbers of polygon (fig. 5). The low resolution model is a little more detailed than a bounding box, having the same global dimensions (height, depth and width) than the monument. The final texture for each face will be the rendering computed from corresponding faces most detailed model. This low model is the first to be visible, when the virtual camera is very far (i.e. more than 1.000 meters) the model

resolution in this phase must be very low, because to keep computation speed as the viewport is already full with terrain and vegetation geometry. When the camera moves closer to the monument, the visible terrain and vegetation geometry decrease, so we can thus increase the resolution of the monument switching to the mid-size model. Eventually as the camera gets closer, we can see the full resolution model.

A particular processing was developed for the columns and other instances: each column has a dedicated LOD, so when the camera is moving trough the colonnade the columns nearest to the point of view are at full resolution, while the most distant have a low level of detail. In fact, loading all the columns at full resolution would require up to 343.090 polygons. Another technique was used to visualize the very detailed decorations of Roman façades: the bump shaders, that reduces the polygon number of 3D objects without removing details. The pipeline to produce this shaders is quite complex: First of all we reconstruct the original porch decorations starting from the excavation fragments (fig. 6)
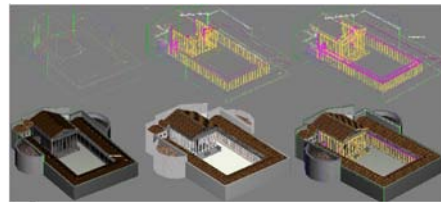

Figure 5

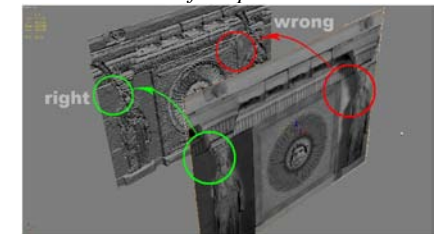**Figure 6**: *reconstruction of the porticos decoration*

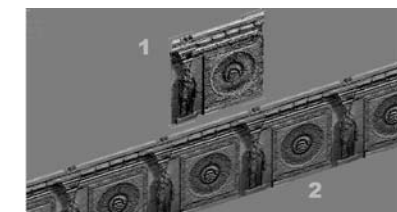**Figure 7**: *displacement maps, shadow/light contrast correction*

Figure 8

Once the final image was obtained, we reduced the light/shadow contrast to avoid wrong bump result on the hi-

res surface (fig. 7). We used previously the displacement maps over a millions-polygon projection-surface, then a normal bump map was baked on a plane made with only two triangles (fig. 8). The result is a very low poly surface with a baked normal bump map, that stores all the detail of the hi-res surface and gives the illusion of a very detailed façade reproduction. Optimized models are finally integrated, through a post-processing tool based on OSG, in the VR.

2.2.1 Modelling post processing

The creation of a 3D-environment usually consist in many stages, the "post-processing" is the stage that follows the "Modelling". In the Modelling stage various expert create all the 3D assets, which are usually released as a set of 3dStudioMax files plus a set of textures. In the PostProcessing all of this data has to be transformed to make it suitable for being streamed over the net.

Among the various technique adopted, the most important are paging and multiresolution. Using this approach the 3d-environment should be represented by a set of small files (the pages) connected each other to form a tree-structure (the pages hierarchy). In this Hierarchy, the root node represents the whole 3D-environment at a very coarse detail, the root children represent different areas of the whole 3D-environment with an increased details and so on, recursively.

This setup allows an optimized navigation of the 3D-environment; our RealTimePlayer will dynamically query the BackEnd for a set of pages chosen by considering the current camera position. The requested pages will cover only the visible area, and the requested level-of-detail will be chosen considering the distance of the area from the camera. This lead to minimize the amount of data to be transferred on the net, reduce the waiting time and increase the quality of the visual experience.

Other optimization that we consider during the post processing are aimed to data-size-reduction: among these, the use of geometry-instancing and various form of texture compression.

In our previous experience, the staff dedicated to the Modelling was not aware of the issues related to production of Models suited for the streaming, so the postprocessing was delegated to a person with skills in OpenSceneGraph programming (the osgProgrammer). This setup proved to have a number of drawbacks: the work of osgProgrammer turned out to be too much creating a bottleneck in the workflow; the streamable 3D environment wasn't testable until the very end of the work.

For the VirtualRome project we were able to develop a PostProcessingTools easy enough to be driven by the Modellers alone, so this activity was spread among the team-members leading many benefits. For example, the Modellers can have an immediate preview of their work, so eventually errors like missing textures, missing parts, misplaced parts, are spotted early, and fixed.

A successful decision was to make the Modellers aware of the LevelOfDetails. We started modelling the Low Level of Details early, and then refining each model by splitting and detailing it. So while in previous work the assets were organized in few huge MaxFiles, now we have an increased set of smaller files. This eased the distribution of the work and encouraged the adoption of a centralized assed manager based on SubVersion.

Modelling the Low LevelOfDetail first, running the PostPropcessor often, and committing all the asset daily, also give the nice property that the whole 3D-Environment can be viewed in its entirely from the early days, giving a good feedback of how the whole work is proceeding.

The Modeller daily activities:
- Choose a particular area to be modelled, and model it using 3DStudio max, starting with the lowest level of detail and increasing the detail subsequently.
- Export each max file in OSG (ascii format) using MaxOsgExporter
- Run our custom PostProcessingTool and supervise the results checking that:
  - All the required parts and textures were found
  - The placement of each model is correct in respect with the model from the other members of the team
  - Fine tune the switching of the various level-of-detail
  - Check that the generated ive-pages satisfy size restriction.
- Committ daily the updated assets on the repository.

Features of the PostProcessingTool:
- Loads a set of osg-ascii files and generate a hierarchy of ive-page-files suitable for the visualization on the web.
- Provide an immediate preview of the result.
- The hierarchy can be composed using nodes coming from different osg-files and it is driven by an easy script provided by the modellers.
- Creation of PagedLOD nodes, with configurable switch settings.
- Correct handling of "geometry instancing". If the same object is reused in many places (like the columns) its geometry is stored only once.
- Configurable processing of the textures. Textures can be converted to a common format, compressed, and stored in the ive-page-files or not
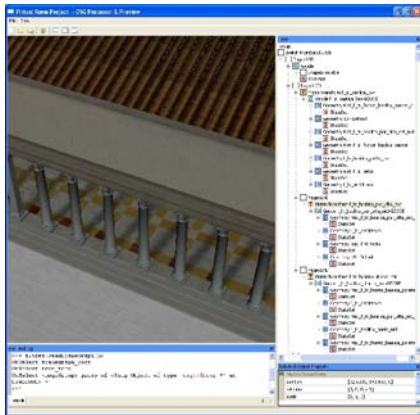- Support for lightmaps.
- Support for bumpmaps.

Figure 9. *The VRome PostProcessing Tool.*

2.3 Vegetation integration

A problematic aspect was the integration and management of 3d vegetation in the 3d scene. We start working with an initial test-case of 30.000 plants. The real time exploration was almost impossible, unless defining a visualisation distance. In order to avoid the disturbing effect of seeing plants popping while moving the scene and trying to achieve a better performance, we then treated them as the terrain. We created a paged version of the vegetation, attaching them to the different hierarchical levels.

3. Software

3.1 OSG4WEB

The main rendering engine, OSG4WEB of the project was developed on the middleware OpenSceneGraph. It allows terrain and 3d models visualisation through a web browser. OSG4WEB is composed by:

1. A *compiled Shell*, that can be easily downloaded by the users (300 kb) as plug-in for Mozilla Firefox or ActiveX for Internet Explorer. It is in charge of the communication between the browser and the 3d scene. It allows also a further automatic download of a second part: the core.
2. A *rendering Core.* The core is downloaded in accordance with a specific project, that has specific requirements. It is compiled referring to what should be visualised. In the case of Virtual Rome project the Shell download the "*fun-core*"

The Core functionalities are:

- paged terrains and paged models loading
- 3d exploration of the hierarchical scene (a master file, the first to be loaded is generated by the back-end section)
- scene switching (each scene switches with precise connection rules between objects, terrains, media files in accordance with reconstructed landscape rules)
- vectors or secondary models loading
- viewpoints and paths camera movements
- models and object interaction
- loading of external multimedia contents linked to the

objects in the rendered scene.
- environment effects integration (fog, sky etc)
- information tool-tip display

The front-end section was developed completely in a dynamic way and programmed in Ajax, that is in charge of server requests and to formatted pages visualisation in the browser (Fig.10).

3.2 Back-end section

A web interface, developed as a CMS, was created in order to edit (create and modify) the 3d scene and the web pages dynamically. The back-end section, with a MySQL database behind, is structured in Projects, that are web publishing projects. Each Project can have different Terrains, Points of View, Models and Interfaces. While in the Model and Terrain libraries can be stored all different resources, in the Interface section of the back-end it is possible to control the final VR application, deciding how many landscapes should be available and switchable, how many models should be attached to a certain terrain, how many icons should be visible with a specific function. The Model section allows to add in a specific position a 3d object and to chose the link a user can activate, clicking on it. It is possible also to create dynamically different viewpoints and paths just storing the camera position while exploring the landscape (fig.2).
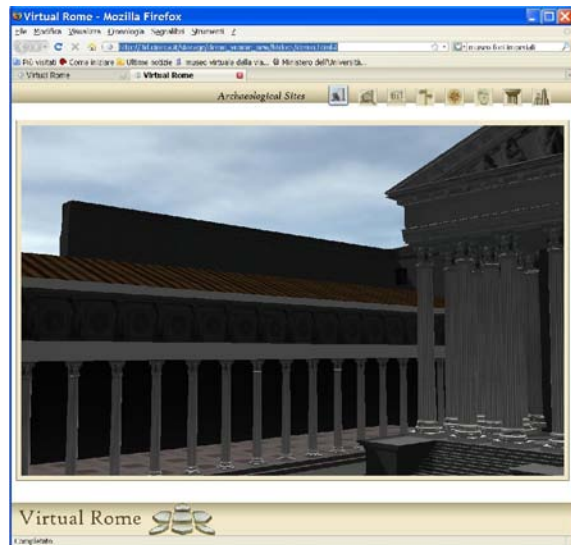

Figure 10 *Virtual Rome exploration of the Imperial Fora*

4. Conclusion

In the next future we would like to expand further the project. The first step would be to integrate a visual way to add 3d models into the landscape, through the back-end section (3d editing tool). Now it is possible to add them just typing geographical coordinates. Part of the work has already been done, but it need to be integrated (fig.11).
While the final installers are actually in progress, the final version of the project will be available at: www.virtualrome.itabc.cnr.it.
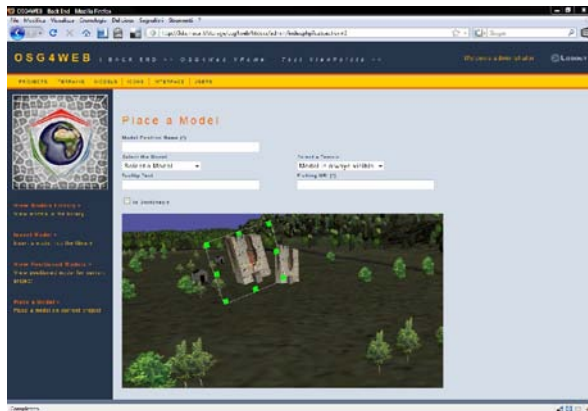
Figure 11 *Future implementation of the 3d editing tool in the back-end*

We would like also to add a Chat section, in order to enable registered users (researchers I.e.) to communicate while reconstructing the landscape or implementing the libraries.

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