Augmented Reality for the Documentation of Villa Adriana in Tivoli, Rome

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Abstract: During the annual survey campaigns of Villa Adriana in Tivoli (Rome), in collaboration with the Superintendence for Archaeological Heritage of Lazio, a fruitful scientific collaboration for the study of the whole complex emerged that could become the field of sperimentation of the latest techniques of Digital Survey, whose outputs can be configured as photorealistic 3D models navigable and searchable.
The applications and scientific results accrued through years of experiments conducted by the Laboratory of Survey of Department of Architecture of University of Florence have allowed to develop applications of the most advanced digital technologies in the field of survey for the digital documentation of architectural and archaeological heritage thanks to augmented reality.
The campaign involved the Palace Area, the first nucleus of the imperial residence built where there was a pre-existing republican villa.
The first part of the work led to the generation of a three dimensional point cloud of the area generated with the use of laser scanners; later was created a photogrammetric model of the entire complex, scaled and oriented through the cloud of points itself. The generated model was finally put online and was created a planimetry, which can be read by any mobile device with a camera and internet connection, which acts as a key to access to the view of the virtual model in augmented reality.
The construction of such project conceived on a larger scale would allow to make available the information for different levels of users and, could be aimed to both technical experts and a wider audience, highlighting thematic routes also for tourism; the activities of systematizing the information and data by creating cognitive structures that, resubmitting the complexity of reality, make it possible to develop experiments and development forecasts congruous with the Management Plan of the site.

Keywords: Augmented Reality, Villa Adriana, photogrammetry, Digital survey, point cloud

Villa Adriana in Tivoli

Preface

Nowadays, new media and digital tools offer us the possibility to experience, as visitors, travellers or even as residents, 3D virtually rebuilt historic sites. Many critics have identified different issues that often inhibit widespread distribution and use of virtual heritage. This paper through some examples referring to an UNESCO World Heritage archaeological site – Villa Adriana in Tivoli (Rome) – attempts to introduce and analyse, even critically, some of the different methodologies and investigation strategies now available for the construction of equipment documentaries and surveys also aimed to the virtual reconstruction of the archaeological heritage. The possibilities offered by media allow users to select different levels of detail, to customise paths of knowledge, to foster dialogue with contemporary contexts in the rest of the world, thus breaking down geographical, cultural and linguistic barriers. In practice, this is achieved by designing content and related communication strategies that identify the languages and the most appropriate tools to meet different information requirements, and interact with any type of audience.

Archaeological sites, museums and heritage sites are to be considered as spaces or learning and interaction, not "just" cultural institutions founded on functions of conservation. This also adds a "socially inclusive" dimension, able to offer a museological project with paths that might have different keys of interpretation and cognitive expectations.

In order to satisfy the request addressed to heritage sites by the globalized tourism, it is essential that professionals acknowledge the question of cross-cultural communication and make a conscious effort to overcome these problems. Globalized heritage communication strategies should consider the archaeological areas and open air museums as "sensible systems" where cultural differences may help conservators and institutions to create several different visitors' interpretations.

New technologies have become a global challenge reality all over the world, irrespective of their economic contexts. However, the question of the accessible interface with these new tools and their cultural impacts has not been yet completely addressed.

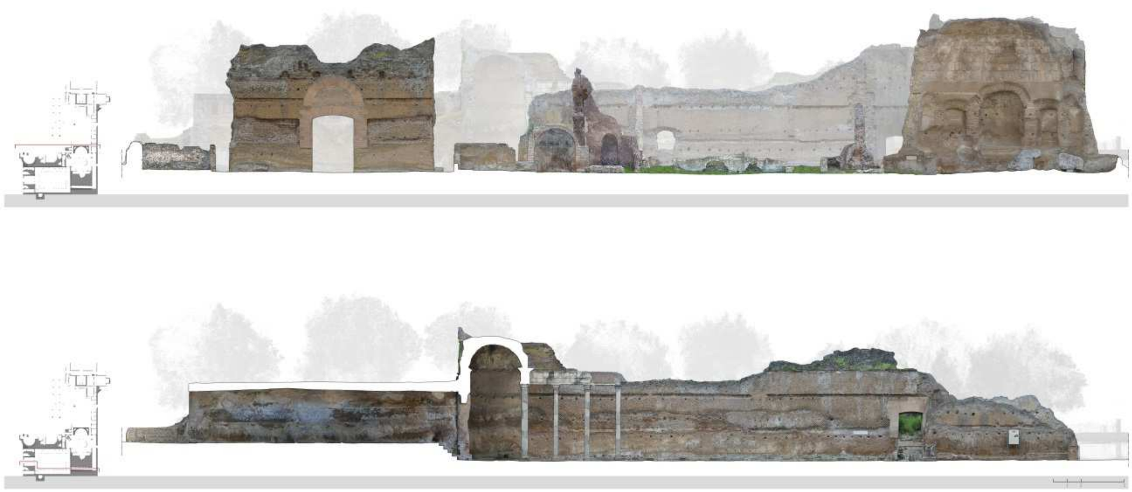

Fig. 0 – environmental sections

Villa Adriana in Tivoli

The project "Documentation of Villa Adriana in Tivoli: digital survey to the conservation and enhancement of archaeological sites" which presents some survey campaigns conducted by the Department of Architecture of the University of Florence could be considered as a starting point. Survey campaigns carried out on Villa Adriana, a site near Tivoli (Rome), built between 118 and 138 C.E. by Emperor Hadrian over an area of 120 hectares and declared a World Heritage Site by UNESCO in 1999, focused on three areas of the great Imperial mansion: the so-called "Area di Palazzo", the Courtyard of the Libraries and the Maritime Theatre. Topographic and 3D laser scanner devices, together with photo modelling applications based on *Structure*

From Motion, provided to the research team a framework for the documentation of the archaeological area of the villa at different levels of detail. The project started in 2010 and involved three universities: Florence, Pavia and Bologna, in collaboration with the Superintendence for Archaeological Heritage of Lazio, with the aim to digitalize the documentation of Villa Adriana archaeological site. The purposes of this collaboration are to create a comprehensive digital documentation of the existing site, indeed, as you can see in fig. 1, much of the villa has been detected to contribute to the drafting of the UNESCO management plan and to create a database that will serve as a base cultural resource management tool for further historic preservation, conservation and restoration activities.

In this extract it was decided not to create a unique model to maintain a high level of detail; creating a single model would have greatly decimated the mesh. All the models were then classified within groups, environments and construction bodies, always referring to the classification identified by Guidobaldi (GUIDOBALDI, F., et al., 1994, ADEMBRI B., 2000). The mesh models have been optimized with a software of reverse modeling and they have been remapped into the photogrammetric software. A major part of the model is in fact devoid of texture because it was generated directly from the laser scanner as free as RGB. Such models were imported into a software of rendering where we added lighting. For verification, we compared the individual macro-photogrammetric products with the corresponding models from laser scanner data and we got a standard deviation of 2.2 cm verifying the high reliability of the product.

In order to provide useful information on the web to view this area of Villa Adriana, it has been suggested a platform where any user, visitor or researcher has the possibility to view all the work produced, according to their interest.

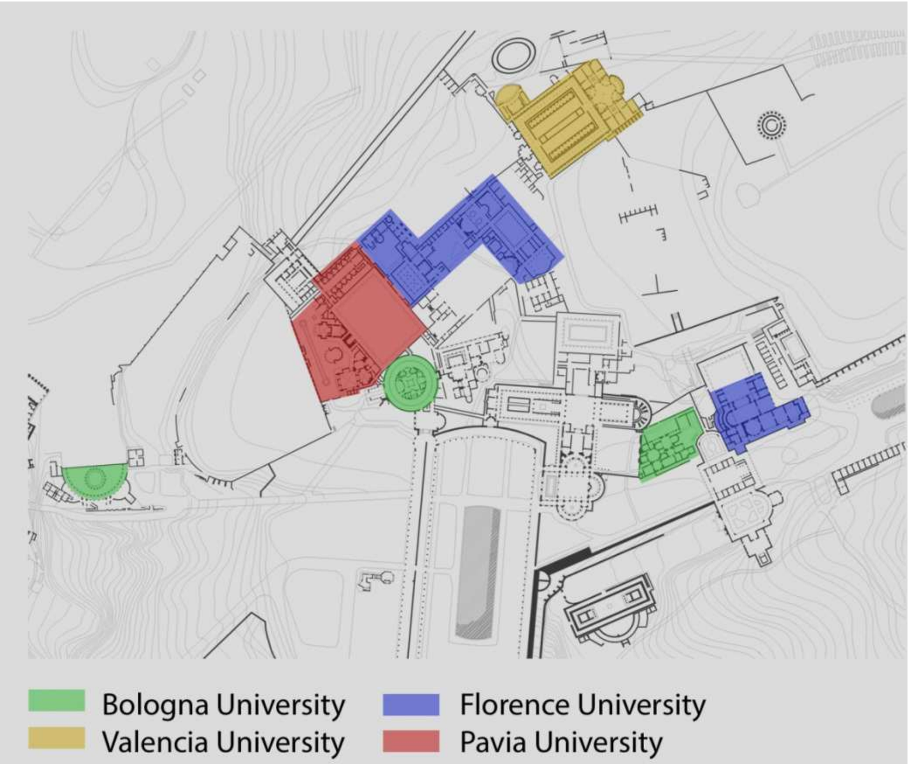

Fig. 1 – surveys made by universities

"Area di Palazzo", the digital survey

Data acquisition

The laser scanning survey campaign in the Palace lasts from February 2013.

Here, the Nymph Palace, the Hall of Doric Pillars, the so-called "Throne Room" and the southern part of the courtyards were scanned. In October, the remaining area of the Palace, the upper level was scanned. Both campaigns have been planned for the registration of the point cloud by targets. This methodology is more accurate but requires a major project activity with a higher level of detail. In April 2014 the survey of cryptoporticus started and the entire thickness masonry towards the Piazza d'Oro was scanned to complete the whole area. This campaign was carried out with the registration of the point cloud through morphological points. Around 69 scans were performed using the laser scanner Z + F 5006 h (fig. 2).

Before you can analyse the data of the individual scan station it was necessary to filter the data acquired by the laser scanner errors and afterwards to turn every single scan from the format Z + F to the PTX format for the Leica Geosystem Cyclone software.

At this point it was possible to register the data with Leica Geosystem Cyclone; the result of this operation was a new cloud of points detailing the entire area that was then used as a reference system for photogrammetric models.

For Photogrammetry around 6500 photos were taken.

All photos were taken in JPEG mode + nef, in such a way that you are able to correct and to balance white. A good photogrammetrical survey is possible dividing the entire project into several parts. This operation is important in order to create more manageable chunk (so called PhotoScan projects), with no more than 300 to 350 photos. This follows the cataloguing system made by Guidobaldi in 1994 in his work "The sectilia Paving Villa Adriana".

Post processing elaboration

For photogrammetric processing Agisoft PhotoScan has been used, a program of photogrammetry able to generate point clouds processing simple photographs. This technology is based on SFM (Structure-from-Motion), a technique that, as primary purpose, has the automation of the entire process of creating a dense point cloud which then turns into a mesh model which finally combines a UV Map.

The cloud created by PhotoScan must be scaled and oriented in 3D space. To do this it was necessary to find the coordinates of at least three well known points within each chunk. We can use, in this case, some of the points produced by the laser scanner, in order to identify the coordinate system and assign it to the PhotoScan chunk (fig. 3).

Fig. 2 – Reference point cloud

Fig. 3 – Reference point between point cloud and photogrammetry model

For the creation of the mesh models it was decided to use 3DSystem Geomagic Studio, a powerful program of reverse modeling, because it is more suitable for processing of large point clouds.

Once the point cloud has been imported from Agisoft Photoscan, “delete noise” command has been used in order to compensate the noise of the cloud moving single points into more physically correct positions, creating a more linear disposition of points. After that, a mesh was created using “wrap” command that allows to define the number of polygons.

The command “Mesh Doctor” automatically repairs imperfections in a mesh.

The models obtained were finally imported in Agisoft PhotoScan in order to to create an associated UVMap.

A total of 33 photogrammetric models was created (fig. 4). It was decided not to create a unique model to maintain a high level of detail; in fact to create a single model would be necessary to significantly decimate the mesh. All models were then grouped into broad groups always using the classification made by Guidobaldi.

Union of single models to create the four macromodels has been done using “Union” command. This allows to combine models avoiding loss of data and, above all, eliminating overlapping of models. Then, all the final models have been optimized again and re-imported in Agisoft Photoscan in order to create a new associated UVmap.

Fig. 4 – One of the 33 photogrammetric model

Quality of survey

After the modeling phase it was necessary to verify the quality of the survey. First of all an analysis on single models has been done. It highlighted that the sum of all the polygons has been decimated by 35% and that the mean standard deviation in the alignment in agisoft photoscan weren’t higher than 2.5 cm.

To further verify the errors of the models, an analysis on the deformation mesh is subjected to, during optimisation and decimation steps in 3DSystem geomagic, has been done.This involved an analysis of the standard deviation for each macro model created with photogrammetry compared with models generated from the point cloud, considered reliable with an error of circa 2mm. With this type of analysis Geomegic reports the distance existing between every single face of the macromodel and the respective one.

The standard deviation analysis was performed in 3DSystem Geomagic Studio obtaining an average of 0.022 meters.

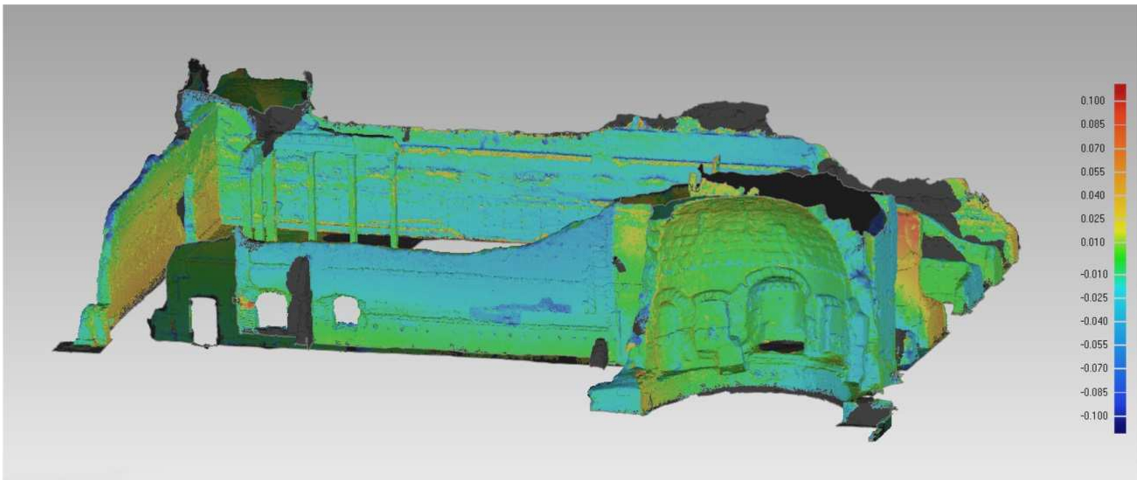

Fig. 5 – The standard deviation between the laser scanner model and the photogrammetry one

The augmented reality

Augmented reality model of “Area di Palazzo”

“Augmented reality” refers to the enrichment of human sensory perception through electronic manipulation of information which otherwise would not be perceived with human five senses. For this instance, an augmented reality model was created in order to show the entire area analysed by photogrammetry, using files downloaded from the web platform.

Several software platforms have been used to create the augmented reality model: Toolbox, which allows to acquire the reference system; Metaio Creator, which allows to manage the connection between reference system and the virtual model; Junaio, which opens the possibility to view the augmented reality model directly on your smartphone.

In order to use this technology, it was necessary to create a reference system easily replicable, so we created a site plan, where was placed a QRcode that works as a reference center for the positioning of all the macro-models to lock models on the horizontal axis. The vertical axis to lock models, instead, was created a model in 3d printing of the entrance door to the nymphaeum with the same scale as the floor plan (fig. 6).

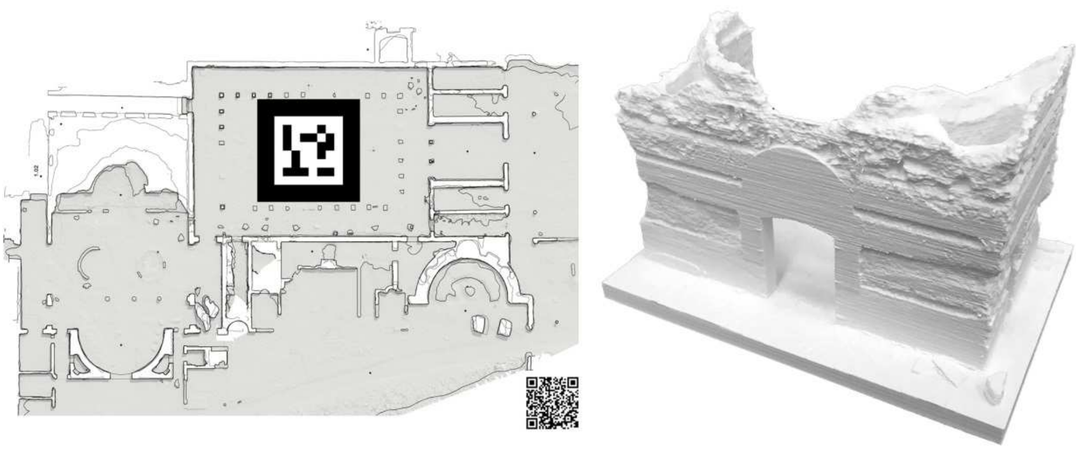

Fig. 6 – The reference site plan and the 3d printed model for the augmented reality model

The reference system was created using a smartphone equipped with a camera, a cloud of points in which to place the virtual model.
Imported the cloud into Metaio Creator is possible to import a macro model (decimated and optimized properly), to orient and climb it on the plan. After all models are loaded and placed on server, the software saves the results and generates a QRcode that, framed by any device with an internet connection, allows download and view the model in augmented reality on the reference system.

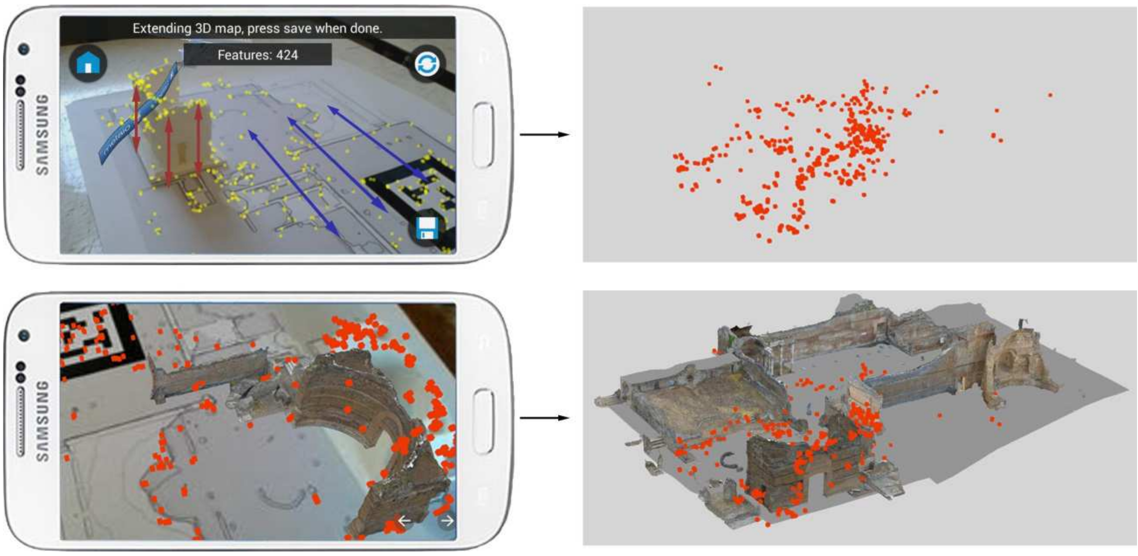

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Fig. 7 – Creation of the reference point cloud for augmented reality

Metaio Creator offers unlimited possibilities. We could see a reconstruction of the area, perhaps by loading on line the various assumptions made by archaeologists over the years. Another interesting feature is the possibility to insert panoramic photos, so as to "navigate" in those, taking advantage of the smartphone gyro sensors so that it seems to be within the area.

Web platform

In order to spread the knowledge of this area of Villa Adriana, a web platform was hypothesised, which allows users to view the model in augmented reality and all the work produced as well was hypothesised. It is possible also to acquire scientific data of the area discharging plans and sections, to explore area with the panoramic tour and to understand better all the complex area of building viewing the virtual tour.
The augmented reality model is achieved with a link that allows you to download the site plan in jpeg and obj files, to be printed at any printing lab the 3d model. The union of these products, together with QRcode always present in the site, allows to display in a physical way the entire area affected by the survey (fig. 9). In this way, any user in the world can play the model of augmented reality, showing the area to others or using it for his own research.

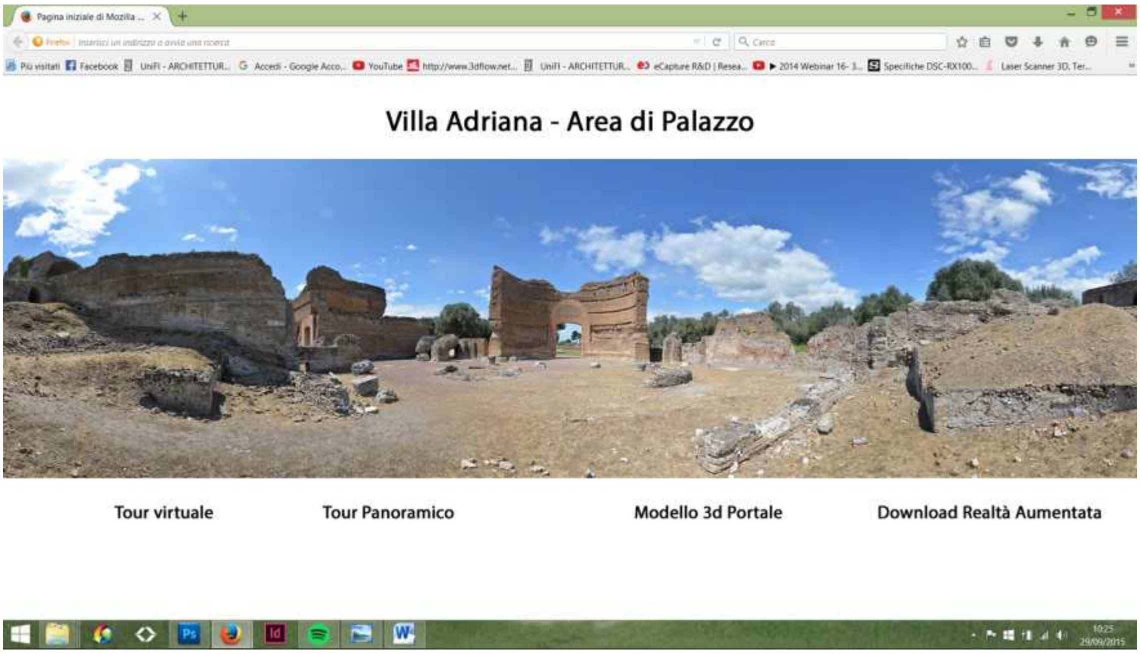

Fig. 8 – Website homepage

Fig. 9 – Augmented reality model

Conlusion

The continuous evolution of techniques for surveying and 3D modeling based on the sensors and the development of ever more efficient systems for displaying digital data highlighted the added value from the use of these methods in the context of architectural and archaeological documentation.

The technological solutions available nowadays at disposal of the architectural survey offer numerous opportunities for conducting documentation projects in the field of Cultural Heritage, both as regards the time of primary survey, or rather the phase of metric data acquisition, and as regards the question of representations for objects of archaeological, artistic and architectural interest.

It is an integrated and multi-disciplinary approach of techniques and technologies that make up many others different approaches to determine the multi-scale surveys, which place a phenomenon in relation with its context, where all the data and results of a survey converge into a single and well defined reference system.

The digital techniques and technologies offer the possibility of obtaining new products not only from survey activities, but also in the representation and in the visual field; with the purpose of having a accurate metric description of the architecture, structures and artefacts they constitute powerful instruments for the analysis of objects in support to the conservation and restoration.

The acquisition and the processing of data must be made following appropriate methods, taking into consideration the characteristics of each technique both in terms of inherent capabilities, such as accuracy and format of the data, and for the purpose of mutual integration, with the aim to incorporate all the products in a common database, useful for many applications.

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