



POLO TERRITORIALE DI COMO

Master of Science in
Computer Engineering

Virtual Museum: recreate the reality.

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Abstract

This thesis is about new technology that intends to recreate reality in the best way. I will talk about virtual tour or 3D panoramas that give an illusion of presence and help you to visit place you can't visit on some reasons.

Virtual tour is photos stuck together in the flat 2D panorama and then recreate 3D sphere panorama. The main idea is to take enough photos of the object you want to recreate (hotel room, museum, supermarket etc.) and then to join photos in the proper way using several software to get 3D panorama.

That is I will talk about in my thesis – from the very beginning – how to make proper photos to the very end – how to use 3D panorama on the web site to attract visitors.

Index

1. Background	4
1.1 Technical background	4
1.2 Applications	12
2. Goals and Motivations	15
3. Design	17
3.1 Overview	17
3.2 Data Model	19
3.3 Hypertext model	
3.4 Presentational model	
4. Implementation	4
4.1 Overview of the system	4
4.2 First step. Shot images	4
4.3 Second step. Create panorama	4
4.4 Website. Backend part	4
4.5 Website. Frontend part	4
5. Conclusions	4
6. Bibliography	4

1. Background

1.1. Technical

What is virtual tour?

A **virtual tour** is a simulation of an existing location, composed of a sequence of still images. Such virtual tours are made up of a number of shots taken from a single vantage point using special technology and then stitching together using special software. Photos are taken and then stitched in such way to recreate reality in the best way. So, for example virtual tour of museum allows you to go through all rooms, see pictures, and enjoy museum sitting at home.

What equipment was used to create virtual tour?

Creating virtual tour is rather exacting from the technical point of view, thus it requires a lot of instruments. Below there is a list of all photo technique I used while doing this job.

1. Of course, it is obvious that I need a **camera**. I have single lens reflex (SLR) camera Canon EOS 1100D (CMOS imaging sensor size 22.2 x 14.7 mm, 12.2 Mp). Frankly speaking, it is one of the cheapest single lens reflex cameras. Matrix of my camera is cropped, this means that its size is less than common "full-frame" matrix size 35*24 mm.

2. One of the things that influence on the quality of the virtual tours is **fish-eye lens**.

I have Sigma 10mm 1:2.8 lens for cropped matrix.

A **fish-eye lens** is an ultra wide-angle lens that produces strong visual distortion intended to create a wide panoramic or hemispherical image¹.



Pic 1.1.1

On the *picture 1.1.1* you can see how my fish lens looks like.

Fish-eye lens helps you to make panorama much faster as you need to shoot less pictures and also you achieve better results.

On the two pictures below you can see how photos shot with fisheye lens differ from photos shot using normal lens. Picture 1.1.2 was shot using normal lens with focal length 17mm and picture 1.1.3. was shot using fisheye lens with focal length 10mm. Both pictures were taken from the same distance and with the same focal point, but as you can see on the second one we captured much more scene along both axis (horizontally and vertically) - this is due to the ultra wide angle of view of the fisheye lens.

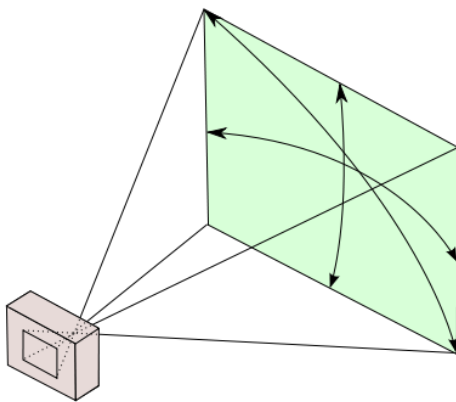


Pic 1.1.2



Pic 1.1.3

It is worth to mention another very specific feature of the fisheye lens - distortions in the images. Distortion is a deviation from rectilinear projection, a projection in which straight lines in a scene remain straight in an image. On the picture took with normal length (pic 1.1.2) we have straight lines - this is rectilinear projection, whilst on the picture took with fisheye lens all straight lines are curve due to the distortion. The manner of distortion is referred to as their mapping function of the fisheye lens, whilst the most common is equisolid angle. Distortion increases with the objects alienation from the focal point.



Pic 1.1.4

Each lens has such parameter as angle of view. Angle of view (or more generally field of view) describes angular extent that will be captured by camera (see pic. 1.1.4). Normal lens with focal length around 17mm have horizontal FOV 64 degrees, whilst

fisheye lens can have up to 180 degrees of horizontal FOV.

For example, when taking pictures with fisheye I should do 14 pictures of the scene I want to make panorama. On the other side when using common lens (for example 17mm Sigma) I should create 47 pictures.

Furthermore, software usually had problems while stitching together so many pictures or even refuse to stitch them.



Pic 1.1.5

3. **Panoramic head** is “must have” thing if you want to create professional virtual tours. It allows you to accurately position your camera so that when you turn it you are turning it about the no-parallax-point of your lens, eliminating parallax error.

On the picture 1.1.5 you can see my photo camera on the tripod with panoramic head. As you can see photo camera is placed not directly on the tripod but using panoramic head to avoid parallax. Red vertical line shows the axis around which camera is rotated – it is chosen in such way that it goes through no-parallax point.

Parallax is a displacement or difference in the apparent position of an object viewed along two

different lines of sight, and is measured by the angle or semi-angle of inclination between those two lines¹.

More simply, parallax is shifting of foreground in relations to the background, when shooting the same scene from a slightly different point of view.

You can easily understand effect of parallax of doing such simple experiment:

Hold up your index finger in front of you. Close one eye and line up your finger with something further away such as a door. Now try to fix your finger without moving it, turn your head left, then right. Your finger will seem to move slightly as you turn your head - this is the effect of parallax, as large as life.

No-parallax-point is the center of the lens's entrance pupil. If you rotate your camera around some randomly chosen point, your images may show parallax and be difficult to stitch. With most lenses, there is one special point around which you can rotate your camera and get no parallax - no-parallax-point.

Three pictures below (pic 1.1.6) show how parallax looks like. First and second pictures were shot by rotating camera around some randomly chosen point. Blue and red line are drawn to show that distance differs between red building which is far away and black post that is in the front. The difference in distance between these two objects is parallax, which results in error while stitching photos. The result of stitching you can see on the right image – the post is truncated in the middle.



Pic 1.1.6

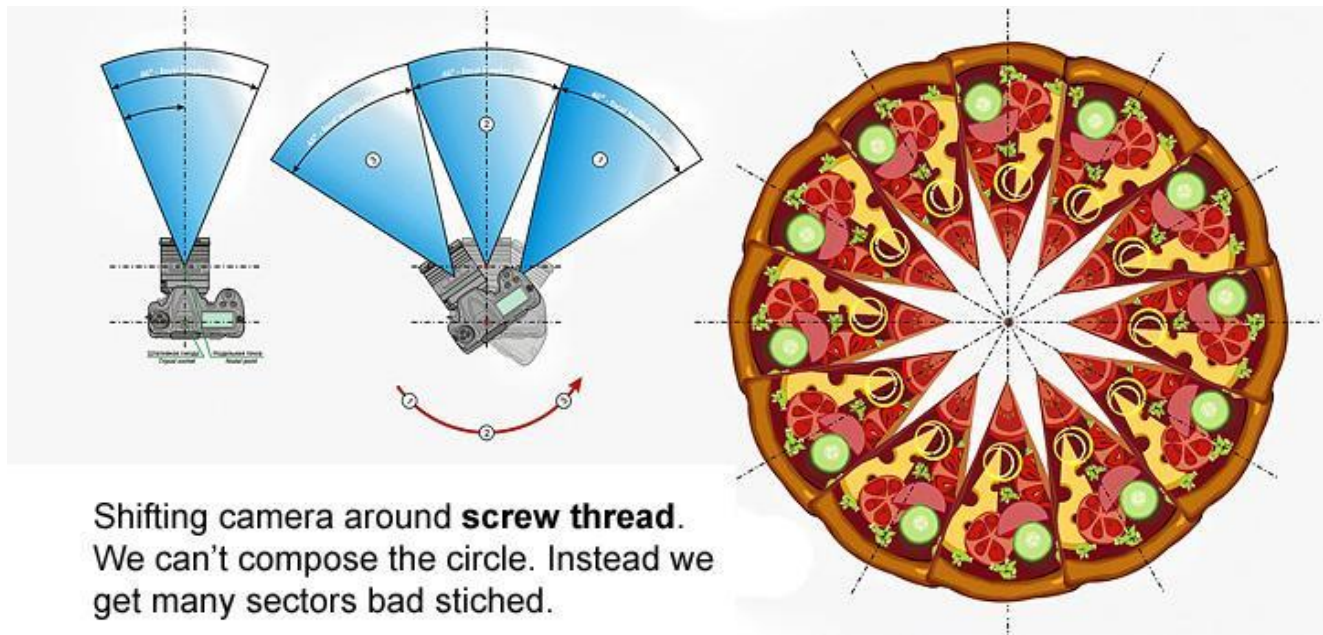
Next three pictures (pic 1.1.7) will show you the same photos but without parallax. First and second pictures on the left were shot by rotating camera around nodal point of the lens. You can see that in this case distances between objects remain the same, and due to this we have good quality stitched photo (on the right) without any defects.



Pic 1.1.7

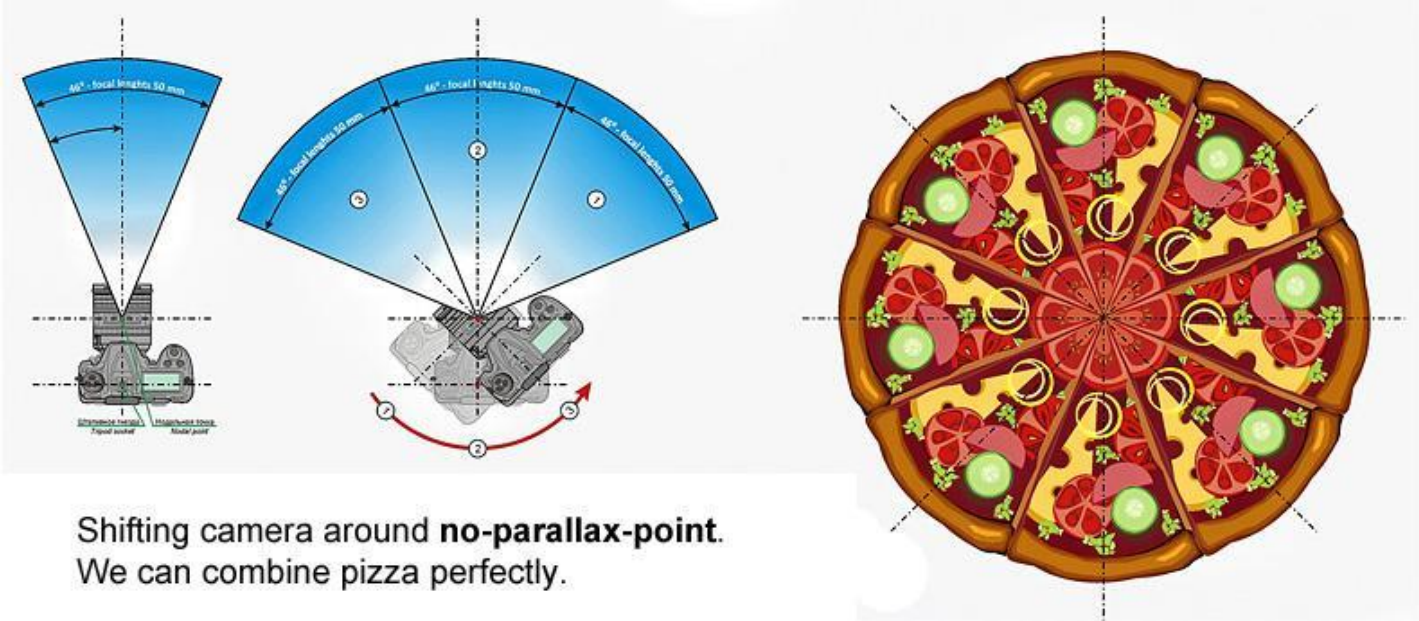
When taking pictures for panorama with parallax you will have problems to stitch them together. Parallax causes ghosting, blurring, or even prevent stitching software from being able to join all pictures in one panorama.

Two pictures below illustrate how parallax influences on the stitching. On the picture 1.1.8 photo camera is rotated around screw thread of the tripod. It is rather clear from the picture that we can't compose perfect circle – instead we get bad stitched sectors.



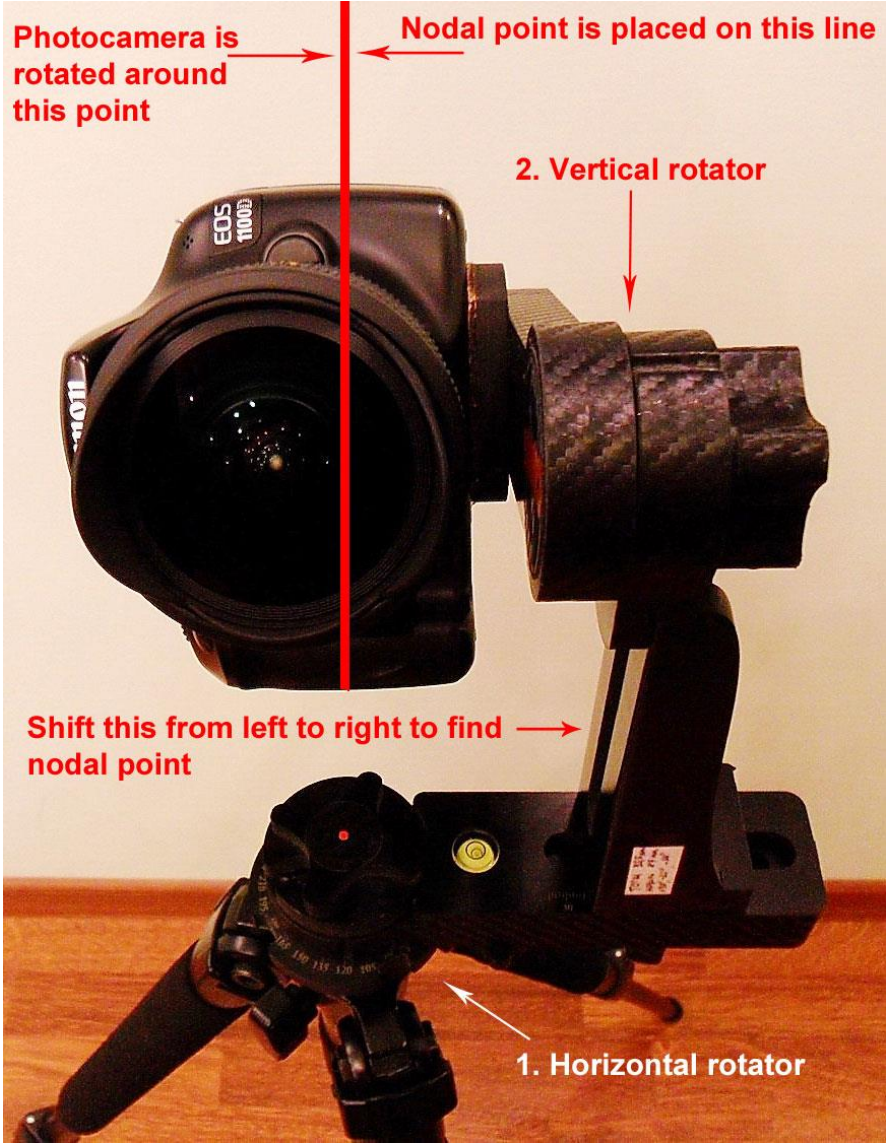
Pic 1.1.8

On the picture 1.1.9 we rotate camera around no-parallax point, as a result we can compose sectors all together in the perfect circle.



Pic 1.1.9

On the picture below (Pic 1.1.10) you can see mine panoramic head and photo camera. I want to show you how it works. The first spinner allows you to rotate camera horizontally. It has convenient scale from 0 to 360 degrees so you can easily manipulate it. The second spinner has also scale with degrees and allows rotating camera vertically – from zero to 180 degrees.



Pic 1.1. 10

To find no-parallax point of the camera you should shift the installation with camera from left to right.

To recreate the whole room I should capture it 360 degrees horizontally and 180 degrees vertically – so when shooting I fasten photo camera in one vertical position and then rotate it horizontally making one “layer” of the photos (for example top layer with ceil and top half of the room).

Then I rotate camera vertically and again fasten it, rotating on 360 degrees horizontally I create another layer – bottom one with bottom half of the room and floor.

Later I will show you this photo “layers” in details.

Above I described the most common and important equipment that you need to create panorama. Besides, I usually use remote camera controller. It helps to get more sharp pictures and reduce blurring.

1.2. Applications

What software is used to create virtual tours?

1. Photomatix Pro 4.1.4

Photomatix is a software that allows to make one HDR picture from multiple pictures and convert HDR picture to LDR picture.

Cameras take pictures at one exposure level with a limited contrast range, this result in the loss of details in bright or dark areas of a picture. I am sure that everybody faced with the problem when for example taking pictures in the sunny day in the room. Usually you get as a result either picture with normal

brightness in the room and very bright window (from where sun comes) or window with normal brightness and dark room. This means that your camera can't catch the whole exposure range.

When doing panoramas you will have such problem very often because usually you should shoot inside the buildings. That's why we should solve this problem. We can solve it using HDR method of taking pictures.

The main idea of HDR method is taking multiple pictures instead of one (usually 3-5 pictures is enough) of the particular scene. This multiple pictures should be shot at different exposure levels (for example -1, 0 and +1 level of exposure). As a result you will have the whole information about the light in this scene, and after stitching together you will have a much better result. Let's again have a look on that example of dark room and very bright window described above.

Picture made on the -1 exposure level will be much darker - with dark room and nice window. Picture made on the +1 exposure level will have very bright window and good looking room. Picture with 0 exposure level will be in the middle between pictures described above. So what Photomatix does is merging these three pictures into the one - with good looking both window and room.

Everything seems too good and simple yeah? But there is one small issue when you come up to this. Indeed, as a result of merging Photomatix produces high dynamic range image which can't be represented on the monitors and paper. What we need to do is to tone map that HDR image. Tone mapping is simply changing image from HDR to LDR (limited dynamic range). There

are a lot of algorithm and methods but it can be challenging sometimes to create good looking LDR picture.

2. PTGui

PTGui is software that stitches all images together⁴. It provides rather friendly-user interface. A big advantage of PTGui is that it works with HDR images. It means that it stitches HDR images in one HDR panorama that is much easier to convert to LDR image than converting each HDR image separately.

There are two modes of creating panorama in PTGui - simple and advanced. I use advanced as I need some more features available in this mode as optimizer, crop, mask, etc.

You should specify lens that was used for shooting images (focal length and lens type - in my case lens is fish eye and focal length is 10 mm) and either you have cropped matrix or not. If you have cropped matrix you should specify crop factor - how much your matrix is less than full frame, in my case crop factor equals to 1.583.

Using these parameters PTGui will stitch images all together. If you are not satisfied how PTGui stitch your images (and believe me you will!) you can tune the results by working with masking, exposure and control points. Usually if images were shot without parallax you won't waste too much time to get perfect result.

3. Pano2VR

Pano2VR³ is an application that converts spherical or cylindrical 2D panoramic images into 3D panoramas (usually as flash movies) that you can easily integrate into the website.

Pano2VR has a lot of settings that you should use to customize your panorama.

Later, I will explain how to work with all these software in more details.

2. Goals and Motivations

The main goal of this project is to provide society with comfortable, intuitive and friendly way to explore reality. In my case I will create virtual tour for museum, but it could be any place you want – shopping mall, hotel, restaurant, etc. Most museums for now have very static information on their websites. It is enough to get practical information - location, prices, but it is not enough to attract more visitors and to explore museum as you are in it.

3D panorama is a new unique way to represent reality, which is gaining popularity. Unlike photography, 3D panorama creates the illusion of presence. The two main advantages of 3D panorama - is interactivity and informativeness.

Interactivity is that unlike traditional photos while viewing the panorama you are an active looker; using the mouse or the keyboard you can independently rotate the panorama in any direction as if you were in that place exploring it with your eyes.

Informativeness is characterized by the possibility of detailed examination of the whole room and in your own pace.

The unique feature of the 3D panorama to create illusion of presence can be very useful for those who can't visit your museum due to the different reasons. Using 3D panorama you can give the user much more information in very light intuitive way.

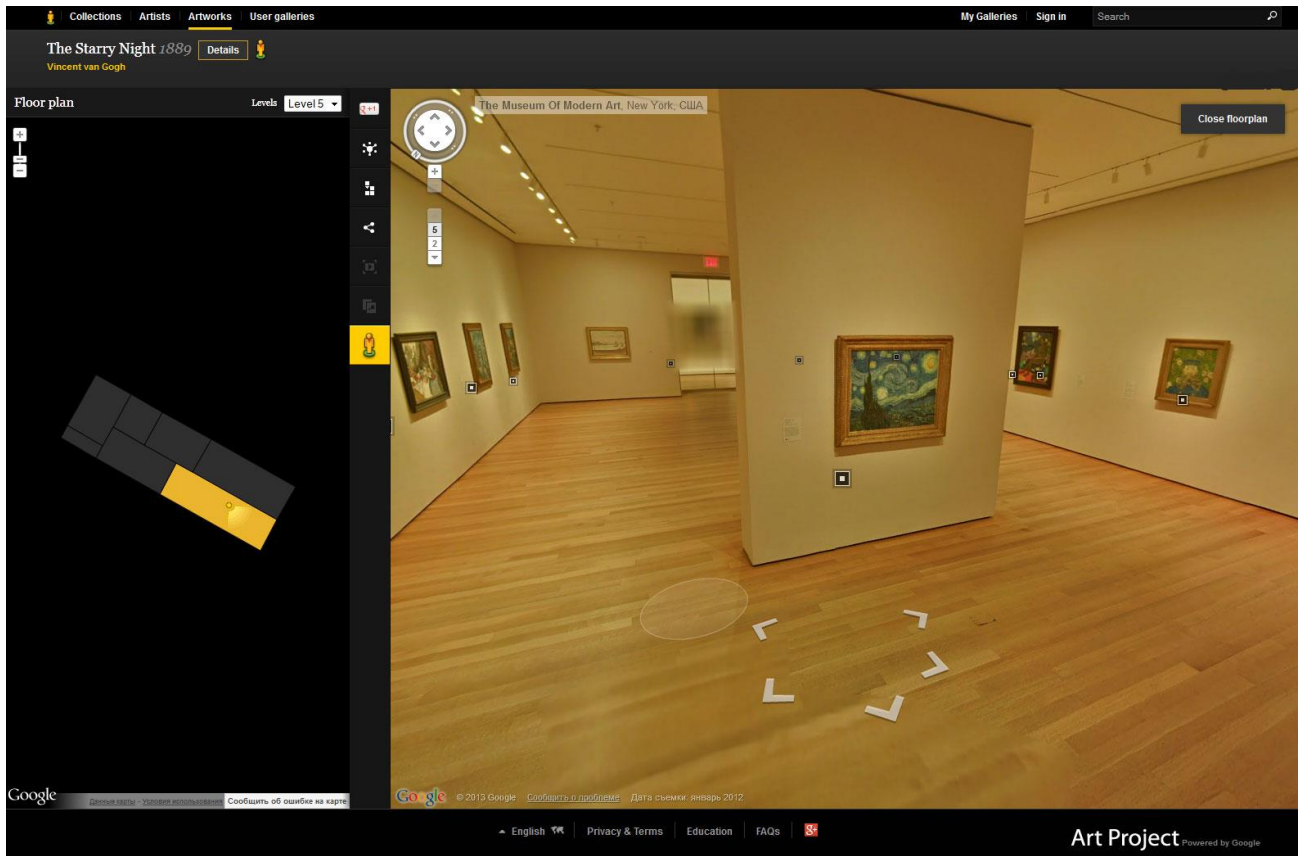
Such intuitive and native way of presenting museum helps to attract more visitors as they will understand much better how interesting your museum are.

The best example of virtual museums is project powered by Google called Art Project¹⁸.

Google Art Project¹⁷ is an online platform through which the public can access high-resolution images of artworks housed in the initiative's partner museums. The platform enables users to virtually tour partner museums' galleries, explore physical and contextual information about artworks, and compile their own virtual collection. The "walk-through" feature of the project uses Google's Street View technology.

On the screenshot (Pic 2.1) below you can see how Art Project looks like. This is the Museum of Modern Art in New York and the famous painting of Vincent van Gogh "The Starry Night" in the center.

In general, Art Project is the magnificent idea. Of course there are many errors such as bad stitched part of panorama – but this is due to the fully automated process of creating panoramas.



Pic 2. 1

3. Design

3.1. Overview

The main goal of my thesis work is to create panoramas, but to make a complete job I will create a web site for the museum to show how panoramas can be used in web applications.

To create a web site first we should design or model it, that is what this chapter tells about.

Models represent a solid starting point for the implementation of a Web application taking into account static and dynamic aspects of the content, hypertext, and presentation levels of a Web application. A systematic approach and a specification of the Web application to be built in the form of visual models are recommended if we need to develop complex Web applications. Modeling is aimed at providing a specification of a system to be built in a degree of detail sufficient for that system's implementation. The result of a modeling process is models representing the relevant aspects of the system in a simplified and – ideally – comprehensible manner.

Unified Modeling Language (UML) is a standardized general-purpose modeling language in the field of object-oriented software engineering. The Unified Modeling Language includes a set of graphic notation techniques to create visual models of object-oriented software-intensive systems. Unified Modeling Language is used to specify, visualize, modify, construct and document the artifacts of an object-oriented software-intensive system under development.

Unified Modeling Language (UML) combines techniques from data modeling (entity relationship diagrams), business modeling (work flows), object modeling, and component modeling. It can be used with all processes, throughout the software development life cycle, and across different implementation technologies.

The tools of the trade in Web application modeling are basically not new, however, methods to model traditional applications are not expressive enough for specific characteristics of web applications. For example, traditional modeling languages (such as UML) do not provide appropriate concepts for the specification of hyperlinks. This was the reason why special modeling approaches for Web applications have been developed during the past few years.

WebML⁵ (**Web Modeling Language**) provides graphical, yet formal, specifications, embodied in a complete design process, using visual design tools.

The main aims of the WebML design process are:

1. expressing the structure of a Web application with a high-level description, which can be used for querying, evolution, and maintenance
2. providing multiple views of the same content
3. separating the information content from its composition into pages, navigation, and presentation, which can be defined and evolved independently;
4. storing the meta-information collected during the design process within a repository, which can be used during the lifetime of the application for dynamically generating Web pages
5. modeling users and communities explicitly in the repository, to permit the specification of personalization policies and one-to-

one applications;

6. enabling the specification of data manipulation operations for updating the site content or interacting with arbitrary external services.

WebML⁶ enables designers to express the core features of a site at a high level, without committing to detailed architectural details. WebML concepts are associated with an intuitive graphic representation, which can be easily supported by CASE tools and effectively communicated to the non-technical members of the site development team.

The specification of a site in WebML consists of four orthogonal perspectives:

- 1 **Data Model:** it expresses the data content of the site, in terms of the relevant entities and relationships.
- 2 **Hypertext Model:** it specifies composition and navigation of the site.
- 3 **Presentation Model:** it expresses the layout and graphic appearance of pages, independently of the output device and of the rendition language, by means of an abstract XML syntax.
- 4 **Personalization Model:** users and user groups are explicitly modeled in the structure schema in the form of predefined entities called User and Group. The features of these entities can be used for storing group-specific or individual content, like shopping suggestions, list of favorites, and resources for graphic customization.

3.2. Data Model

The WebML data model is a suitable adaptation of conceptual models for data design, as already in use in other disciplines, such as database design, software engineering, and knowledge representation. It is compatible with the Entity-Relationship data model, used in conceptual database design, and with UML class diagrams, used in object-oriented modeling. The fundamental elements of data models are entities, defined as containers of data elements, and relationships, defined as semantic connections between entities. Entities have named properties, called attributes, with an associated type. Entities can be organized in generalization hierarchies and relationships can be restricted by means of cardinality constraints. Instances of entities are considered individually addressable by means of a unique identifier (OID). WebML OIDs are abstract concepts, which can be implemented in alternative ways in the underlying storage manager, e.g., primary keys in a relational data store or XML ID attributes in a XML data source.

Entities

An entity represents a description of the common features of set of objects of the real world. An entity has a population, which is the set of objects that are described by the entity. These objects are also called the instances of the entity. Entities are denoted by means of rectangles, with the entity name at the top, followed by the list of attributes (properties of the objects).

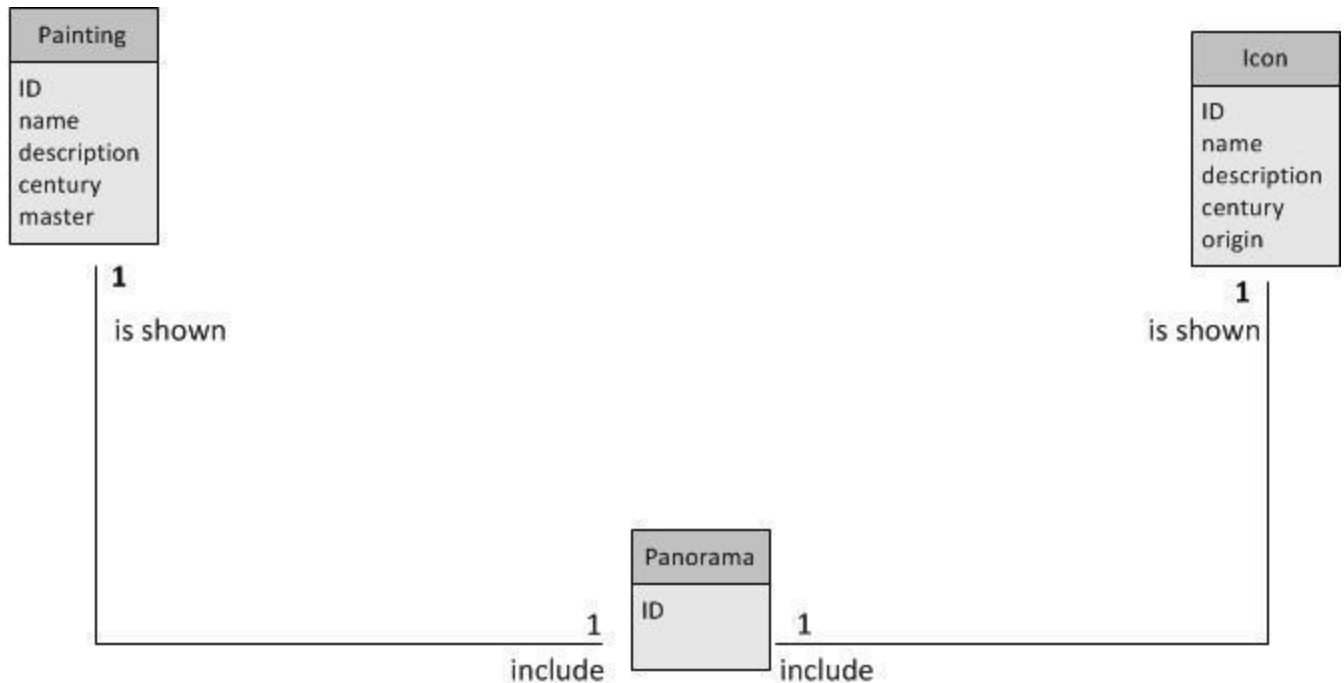
Relationships

Relationships represent semantic connections between entities. The meaning of the association is conveyed by the relationship's name, which is established by the designer.

The simplest form of relationship is the binary relationship, which connects two entities. Relationships involving more than two entities, called N-ary relationships, are allowed; however, the use of N-ary relationships is discouraged, because they can be equivalently expressed by means of multiple binary relationships. Each binary relationship is characterized by two relationship roles, each one expressing the function that one of the participating entities plays in the relationship.

Relationship roles can be annotated with minimum and maximum cardinality constraints, respectively denoting the minimum and maximum number of objects of the destination entity to which any object of the source entity can be related.

On the schema below (pic 3.2.1) there is data model for the future website for the virtual museum. Data model is rather simple in this case, because we have only three entities related with each other.



Pic 3.2.1

Entities:

- Painting has its unique ID. It is described with name, century when it was created and master who create this painting. Painting may have description.
- Icon has its unique ID. It is described with name, century when it was created and country, region where it was created. Icon may have description.
- Panorama has its unique ID.

Relationships:

- Painting-Panorama describes that painting is shown in the panorama. Each painting can be shown on the only one panorama, that's why cardinality is 1:1.
- Icon-Panorama describes that icon is shown in the panorama. Each icon can be shown on the only one panorama, that's why cardinality is 1:1.

3.3 Hypertext model

Hypertext model describes one or more hypertexts that can be published in the site. Each different hypertext defines a so-called site view. Site view descriptions in turn consist of two sub-models.

Composition Model: it specifies which pages compose the hypertext, and which content units make up a page. The pages of the Web site are the containers of information actually delivered to the reader.

Units are atomic content elements used to publish the information described in the data model. Seven types of units are predefined in WebML to compose pages: data, multi-data, index (and its variants multi choice and hierarchical), entry, scroller. Each unit is associated to one underlying entity, from which the content of the unit is computed. The specification of the underlying entity dictates the object type from which the content of a unit is derived (e.g., albums, artists,...). When appropriate, units may be optionally associated to a selector, i.e., the specification of a set of restrictions that determine the actual instances of the underlying entity to be used as the content of the unit at runtime.

Navigation Model: it expresses how pages and content units are linked to form the hypertext. Links are either non-contextual, when they connect semantically independent pages (e.g., the page of an artist to the home page of the site), or contextual, when the content of the destination unit of the link depends on the content of the source unit.

Navigation of the site is specified through links. Links can be defined between the units inside a single page, between units placed in different pages, and between pages. The information carried along a link is called navigation context, or simply context. Links that carry context information are called contextual links, whereas links that have no associated context information are called non-contextual links. Context information is typically necessary to ensure the computability of units.

In the schema below (pic 3.3.1) there is a hypertext model of my project, which consists of:

- **Home Page**: main page of the website. Home page has non-contextual links to the other pages, such as Panoramas Page, Search Page, etc.
- **Search Page**: page for searching items. It consists of one Entry Unit. Entry Unit is unit which represents a form for collecting users input values. Search Page is connected with Home Page by non-contextual link and with Search Page Result by contextual link, which represent searching value - thus what items to show to the user.
- **Search Result Page**: page with result of the search consists of two multidata units - one for representing list of icons that correspond to searching value; another to represent list of paintings that correspond to searching value. Searching value is sent by contextual link from Search Page.
- **Panoramas Page**: page consists of one multidata unit which represents a list of all panoramas. It can be reached from Home Page via non-contextual link. It has contextual links to Panorama Page.
- **Panorama Page** consists of one Data unit which represents the concrete panorama. This page can be reached from Panoramas

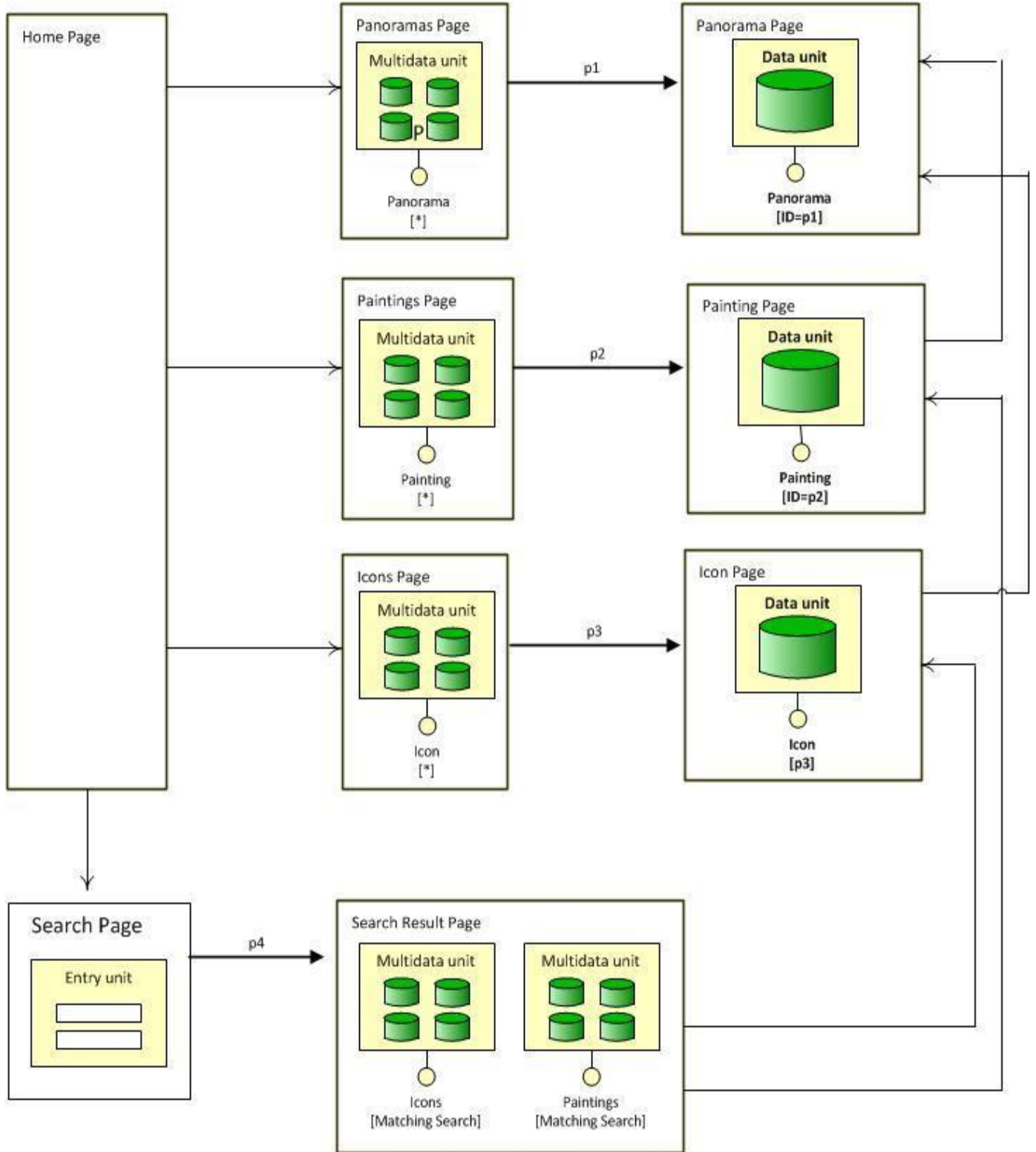
Page by contextual link, which transfer ID of the concrete panorama.

- **Paintings Page**: page consists of one multidata unit which represents a list of all paintings. It can be reached from Home Page via non-contextual link. It has contextual links to Painting Page.

- **Painting Page** consists of one Data unit which represents the concrete painting. This page can be reached from Paintings Page by contextual link, which transfer ID of the concrete painting.

- **Icons Page**: page consists of one multidata unit which represents a list of all icons. It can be reached from Home Page via non-contextual link. It has contextual links to Icon Page.

- **Icon Page** consists of one Data unit which represents the concrete icon. This page can be reached from Icons Page by contextual link, which transfer ID of the concrete icon.



Pic 3.3.1

3.4 Presentation Model

Presentation modeling is aimed at designing the structure and behavior of the user interface to ensure that interaction with the Web application is simple and self-explanatory. In addition, the communication and representation task of the Web application are taken into account.

Presentation modeling generates a two-fold result: First, it produces a uniform presentation concept by modeling recurring elements on the pages, e.g., headers and footers. It should ideally show the composition of each page and the design of the fields, texts, images, forms, etc., included in these pages. Second, in addition to the structure of the pages, the presentation model describes the behavior-oriented aspects of the user interface, e.g., which button to click to activate a function of the application logic. Due to the wide variety of navigation options and the inherent risk of getting lost, care should be taken to give users appropriate orientation help on the presentation level. This can be achieved, for example, by displaying the current navigation path, or pages visited during the active session.

WebML does not include a specific model for expressing presentation at the conceptual level, but leverages standard approaches, more familiar to graphic and communication experts. Since WebML specifications can be represented using XML, presentation is considered like a document transformation mapping the WebML specification of a page into a page written in a concrete implementation language like JSP or ASP.NET. Consequently, presentation is addressed in WebML by attaching XSL style sheets to site views, pages, units and unit sub-

elements. XSL style sheets take in input WebML specifications, coded as XML documents conforming to the WebML Document Type Definition, and output page templates embodying the required mark-up code and data access queries. An implementation of WebML may include several pre-defined presentation style sheets and the server-side components supporting the data access queries needed to populate the content of the page templates produced by the XSL style sheets.

4. Implementation

4.1. Overview of the system

Panoramas were created for the real museum located in Kiev. Website was done as an example for the thesis work to show how panoramas can be used. The main idea of this project was to create website for the museum that will be informative enough, friendly-usable, using modern technologies.

The created system is able to collect information about museum's paintings and icons and show them for users. But the website created during this work has one marvelous difference from other websites. This website has panoramas of the museum which give visitors full illusion of presence, and in such way help to attract more visitors.

4.2 First step. Shot images.

As virtual tour is stitching of the still images, I need photos of the museum. I went to the museum with all my equipment I was talking about in the chapter "Background" to shot photos of the museum.

Equipment that I used to create panoramas:

1. SLR camera Canon EOS 1100D with APS matrix 22.2 × 14.7 mm (*Kropfactor* = 1,58)
2. Fish-eye lens Sigma⁸ with focal length equal to 10mm and f-number equals to 2.8
3. Panoramic head "Sfera"⁹ (made in Ukraine. Professional panoramic head from well-known manufacturers are very expensive... So I decided to buy Ukrainian one.)
4. Tripod Slik
5. Cable for remote triggering of camera. It is better to use such cable, than to push the button on the camera, as it decrease camera's shaking and thus pictures are not blurred.

Museum is 7th floor building - so it takes several days to take photos of all its halls.

How much pictures I have to take to create panorama of one "room"?

To understand this we need to calculate the field of view of my camera with this specific lens.

The field of view of a lens (sometimes called the angle of coverage or angle of view) is defined as the angle (in object space) over which objects are recorded on the film or sensor in a camera. It depends on two factors, the focal length of the lens and the physical size of the film or sensor. Since it depends on

the film/sensor size it's not a fixed characteristic of a lens and it can only be stated if the size of the film or sensor it will be used with is known. For a lens used to form a rectangular frame, three fields of view are often given; the horizontal FOV, the vertical FOV and the diagonal FOV.

We can't use the general formula to calculate FOV of fisheye lens, as fisheye lens is an ultra wide-angle lens that produces strong visual distortion. Formula for calculating FOV depends of what kind of "mapping equations" or "projections" has your lens. Lens that I used has equisolid angle projection. This means that every pixel subtends an equal solid angle, or an equal area on the unit sphere. Formula to calculate FoV for fisheye lens with equisolid mapping:

$$\text{FOV (equisolid)} = 4 * \arcsin (\text{frame size}/(\text{focal length} * 4))$$

Using this formula I calculated vertical, horizontal and diagonal FoV for my fisheye lens:

$$\text{vFOV} = 4 * \arcsin(14.7 / (10*4)) = 86.2 \text{ (degrees)}$$

$$\text{hFOV} = 4 * \arcsin(22.2 / (10*4)) = 135 \text{ (degrees)}$$

$$\text{dFOV} = 4 * \arcsin(26.6 / (10*4)) = 167 \text{ (degrees)}$$

We need to capture 180 degrees vertically and 360 degrees horizontally to reconstruct panorama. Here we should mention that fact that in my case photo camera is placed "vertically" on the panoramic head, rotated by 90 degrees. That is why vFoV = hFov=135 and hFoV=vFov=86.2.

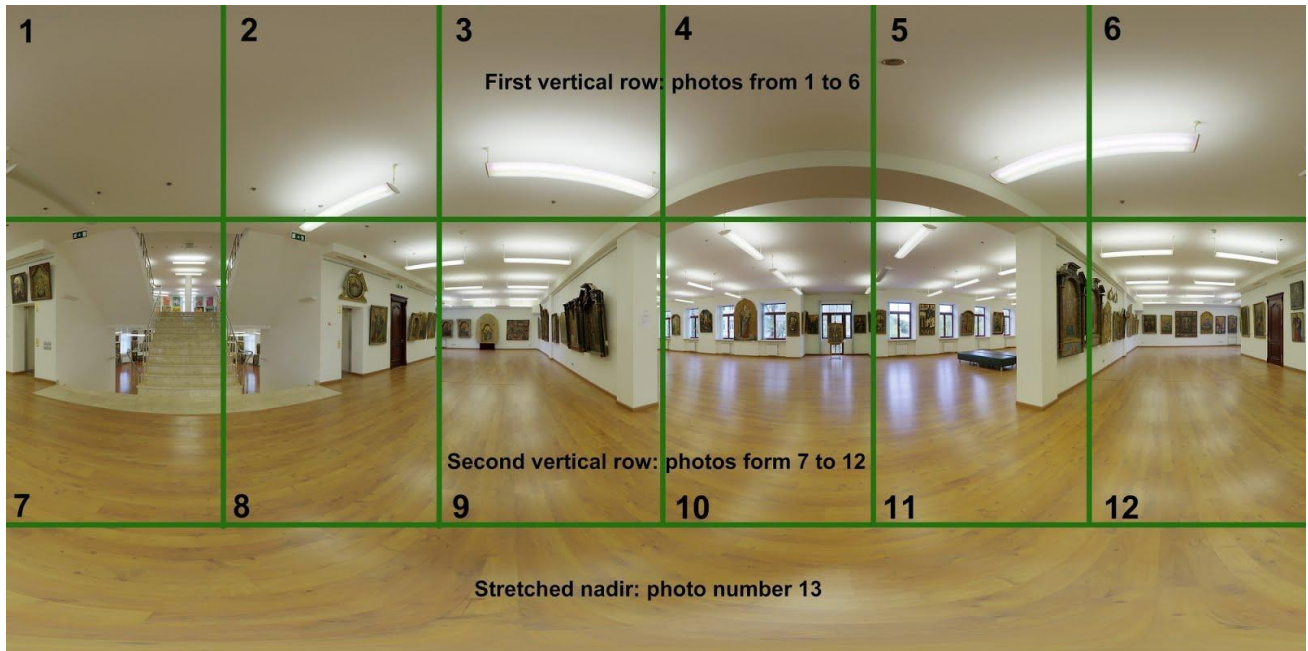
So, in theory, we need to take $180/135 = 1.33$ frames vertically and $360/86.2=4.17$ frames horizontally. But such calculations don't take into account that fact that we must have at least 15% of overlapping between images to perfectly reconstruct panorama

without any visible "seams". So in practice, by taking a lot of experiments I decided in favor of taking 2 frames vertically and 6 frames horizontally, that is not so much far away from theoretical calculations.

So, vertically we need to take two rows of photos and horizontally we need to take 6 photos. Also I should take picture of the floor separately - without this photo I will have legs of tripod on the floor. This last photo is the most hard to take - because I need to bend tripod - as a result photo can be blurred. Some people consider we also need one separate photo for ceilings - but my numerous experiments confirm that it is more than enough to take top row of photos to get ceiling in the resulted panorama. There were some cases when I indeed have to take ceiling separately. One of the case was when I shot panorama of Villa Olmo's hall. Ceiling here is too high and there is very beautiful chandelier in the center. But due to the lack of the light chandelier was not as beautiful in the panorama as it should be without that last photo of the ceiling...

Let's see how it works in the picture below (Pic 4.2.1).

There is an example of panorama in equidistant projection - to receive it we cut the sphere and lay it on the plane, stretching top and bottom (zenith and nadir) for a rectangular image.



Pic 4.2.1

So, as it was said above we need to take only 13 pictures that will reconstruct the whole room.

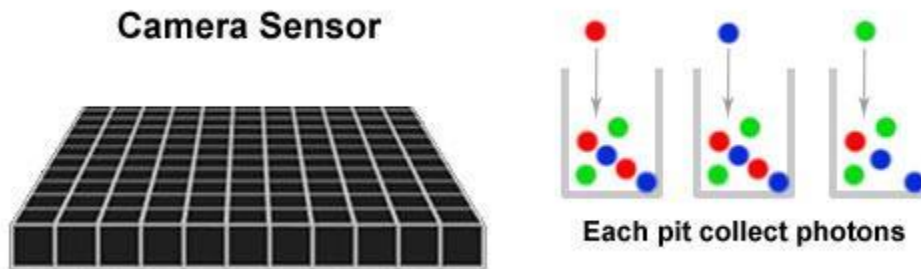
But, there is still one very important issue that was talked about in the chapter "Background".

Why we should use High Dynamic Range Images to create excellent 3D panorama?

Let's first recall how **digital camera's sensor** is designed and how it works.

A digital camera uses an array of millions of tiny light pits or "photosites" to record an image. When you press your camera's shutter button and the exposure begins, each of these pits is uncovered to collect and store photons. Once the exposure finishes, the camera closes each of these photosites, and then tries to assess how many photons fell into each pit. The relative quantity of photons in each photosite are then sorted into various

intensity levels, whose precision is determined by bit depth (0 - 255 for an 8-bit image).



Pic 4.2.2

Photosites or pits can be thought of as buckets which hold photons as if they were water (see pic 4.2.2). Therefore, if the bucket becomes too full, it will overflow. A photosite which overflows is said to have become saturated, and is therefore unable to discern between additional incoming photons — thereby defining the camera's white level. Once buckets are full, they overflow, what flows over gets lost, and the values of these buckets all become 255, while they actually should have been different. In other words, detail is lost.

For an ideal camera, its contrast ratio would therefore be just the number of photons it could contain within each photosite, divided by the darkest measurable light intensity (one photon). If each held 1000 photons, then the contrast ratio would be 1000:1.

Since larger photosites can contain a greater range of photons, dynamic range is generally higher for digital SLR cameras compared to compact cameras (due to larger pixel sizes).

The dynamic range of a digital camera can therefore be described as the ratio of maximum light intensity measurable (at pixel saturation), to minimum light intensity measurable. Or in other

words the dynamic range of a sensor is defined by the largest possible signal divided by the smallest possible signal it can generate.

The most commonly used unit for measuring dynamic range in digital cameras is the f-stop, which describes total light range by powers of 2. A contrast ratio of 1024:1 could therefore also be described as having a dynamic range of 10 f-stops (since $2^{10} = 1024$).

The human eye can actually perceive a greater dynamic range than is ordinarily possible with a camera. If we were to consider situations where our pupil opens and closes for varying light, our eyes can see over a range of nearly 24 f-stops.

On the other hand, for accurate comparisons with a single photo (at constant aperture, shutter and ISO), we can only consider the instantaneous dynamic range (where our pupil opening is unchanged). This would be similar to looking at one region within a scene, letting our eyes adjust, and not looking anywhere else. For this scenario there is much disagreement, because our eye's sensitivity and dynamic range actually change depending on brightness and contrast. Most estimate anywhere from 10-14 f-stops.

The problem with these numbers is that our eyes are extremely adaptable. For situations of extreme low-light star viewing (where our eyes have adjusted to use rod cells for night vision), our eyes approach even higher instantaneous dynamic ranges.

When we take a picture it usually becomes challenging. In an instance of great dynamic range, more than our camera is

capable of, we usually have to make a choice. Expose for the highlights or brightest part of the scene and therefore most likely plunging the darker areas into pure black or the noise floor of our cameras.

As a result, if shooting room - we will have either dark room with naturally-lighted window, or naturally lighted room and overexposed window. To avoid such situation and create panoramas as realistic as possible (as human eyes see) we should use technology called **High Dynamic Range Imaging (HDR)**.

Simply speaking these methods of HDR helps to “expand” dynamic range of image.

To implement HDR we first should make three images instead of one for one scene. Number of images shot for one scene can vary, some photographers take 5 or even 7 images, but in my case three images are more than enough.

It is better to use tripod when you want to create HRD image to avoid shifting, blurring etc – thus images should be equal as much as possible for better result (though almost all popular software to create HDR images is able to reduce noise, blurring and shifting).

One more thing worth mentioning - it is much more better to take photos in the **RAW**¹¹ format rather than in the jpg.

A camera raw image file contains minimally processed data from the image sensor. Raw files are so named because they are not yet processed and therefore are not ready to be printed or edited with a bitmap graphics editor. Like a photographic negative, a

raw digital image may have a wider dynamic range or color gamut than the eventual final image format, and it preserves most of the information of the captured image. The purpose of raw image formats is to save, with minimum loss of information, data obtained from the sensor, and the conditions surrounding the capturing of the image.

When shooting in JPEG, the rather contrast tonal curves applied by the camera may clip shadow and highlight detail which was present in the RAW data. RAW images preserve the dynamic range of the sensor and allow you to compress the dynamic range and tonal range by applying a proper tonal curve so that the whole dynamic range is represented on a monitor or print in a way that is pleasing to the eye.

Auto-exposure bracketing mode – is a mode, which allows taking a series of images with an interval of exposure. One picture is taken with a normal exposure, one or more are underexposed and one or more are overexposure.

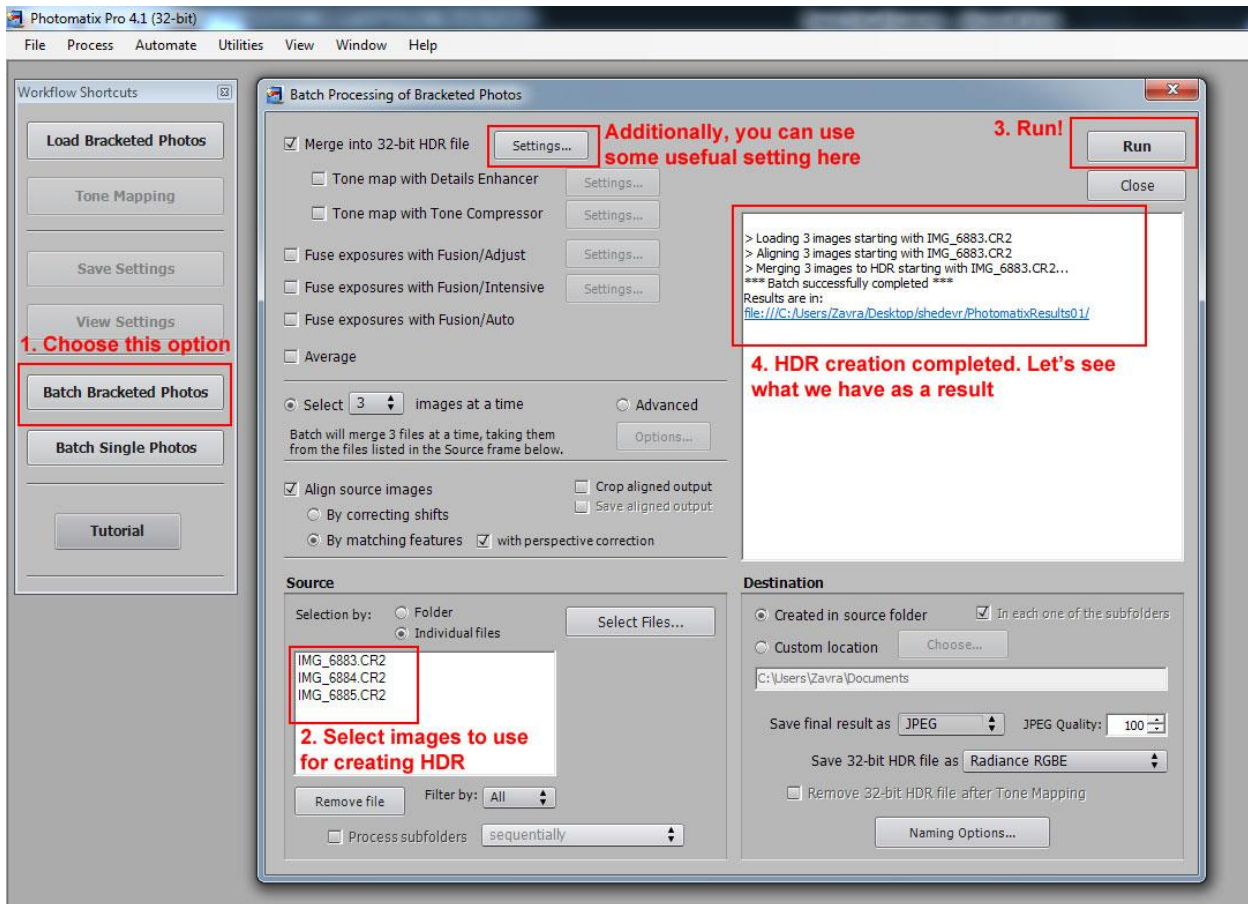
Using auto-exposure bracketing mode in my camera I took these three images (see pic 4.2.3):



Pic 4.2.3

EV – is exposure value, which describes all combination of camera shutter speed and relative aperture that give the same exposure. In my case it is important to have aperture always the same (f-number is equal to 10, for example - this is because I need all elements in scene in focus, thus I need high depth of field). If we assume that aperture is the same – we have only one parameters tuned to change EV – shutter speed. By the way, one more reason why it is more than advisable to use tripod when shooting images for HDR – usually shutter speed increases a lot when you shoot +2 EV – and images will be blurred.

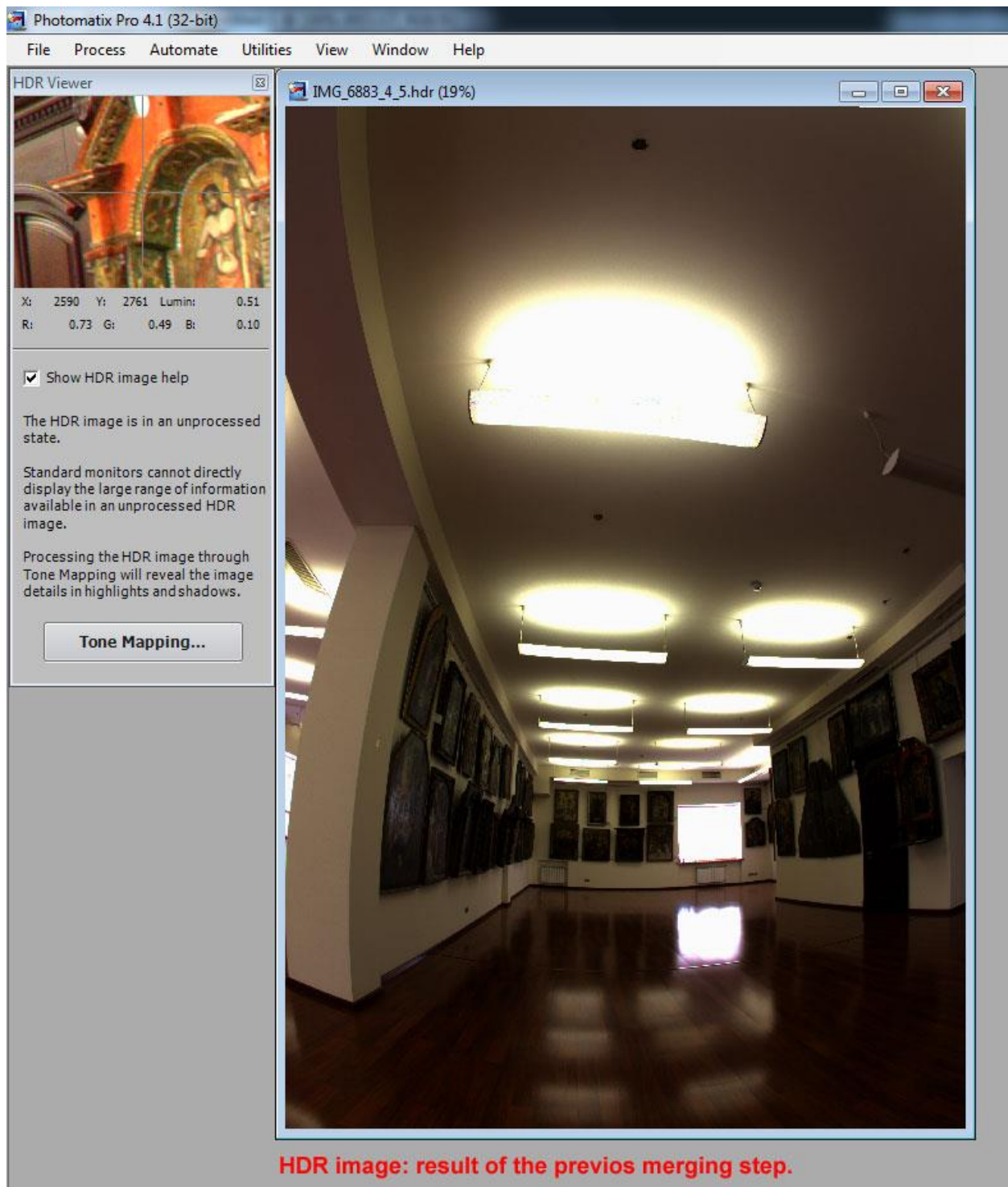
After all, we combine these images using program Photomatix Pro 4.1 which was described in the "Background section".



Pic 4.2.4

Note: as you can see on the screenshot above (Pic 4.2.4) I used files with extension CR2 for merging – this is RAW images.

In the next screenshot (Pic 4.2.5) I open the result of merging – HDR image:



Pic 4.2.5

This is how HDR image looks like on the LCD monitor, which can't reproduce HDR images, just as print-outs and CRT monitors.

Photomatix warns you about this:

"The HDR image is in an unprocessed state. Standard monitors cannot directly display the large range of information available in an unprocessed HDR image. Processing the HDR image through Tone Mapping will reveal the image details in highlights and shadows."

Tone mapping¹⁰ is a technique used in image processing to map one set of colors to another in order to approximate the appearance of high dynamic range images in a medium that has a more limited dynamic range.

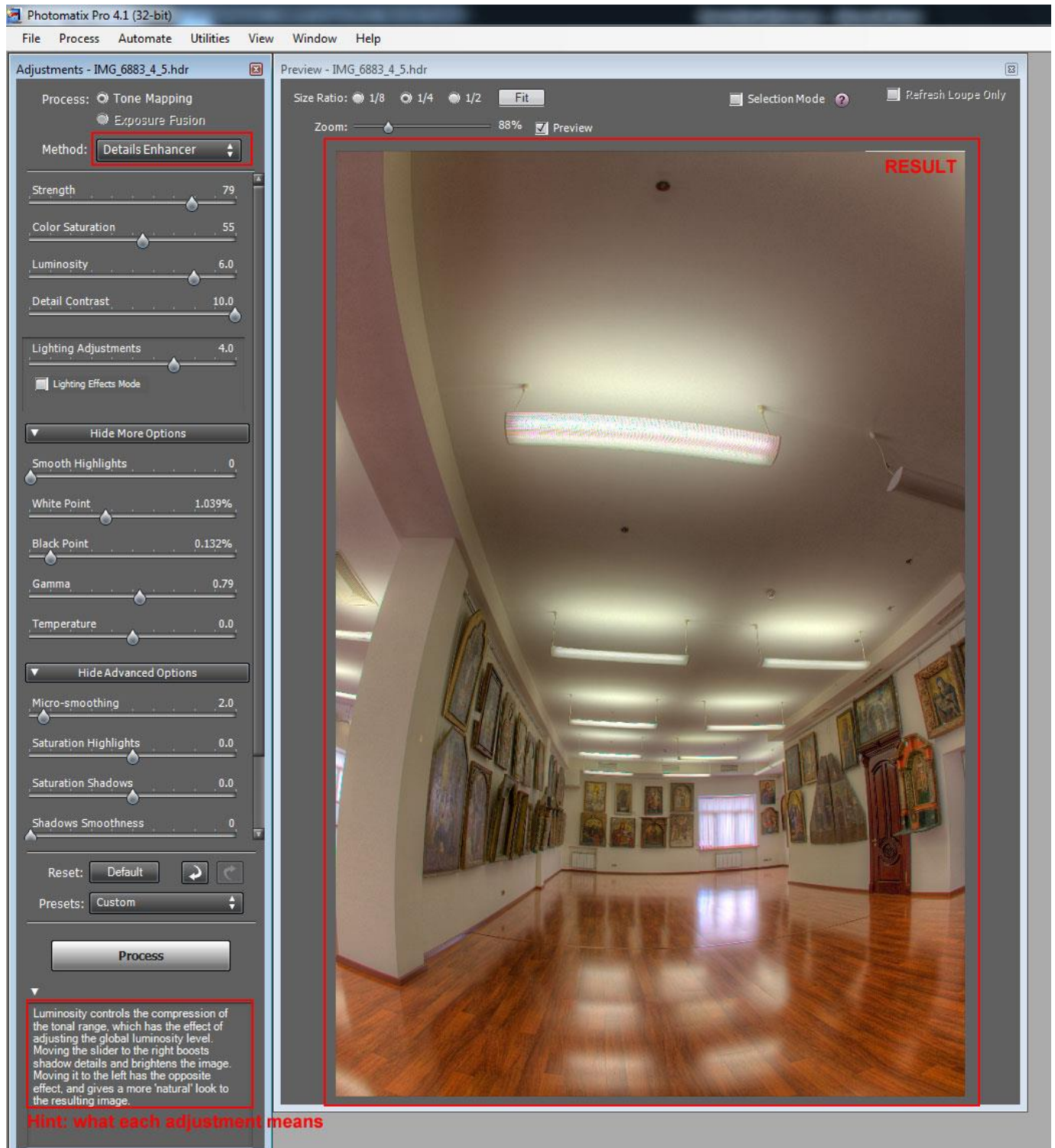
Photomatix provides two methods for tone mapping: Details Enhancer and Tone Compressor.

The Tone Compressor acts like a global contrast adjustment whereas the Details Enhancer acts like a local contrast adjustment. You can get much more "natural" looking images using the Tone Compressor; however you don't get the range in shadow/highlights that Details Enhancer gives.

As for me, I prefer Tone Compressor, but sometimes the Details Enhancer method really gives better result.

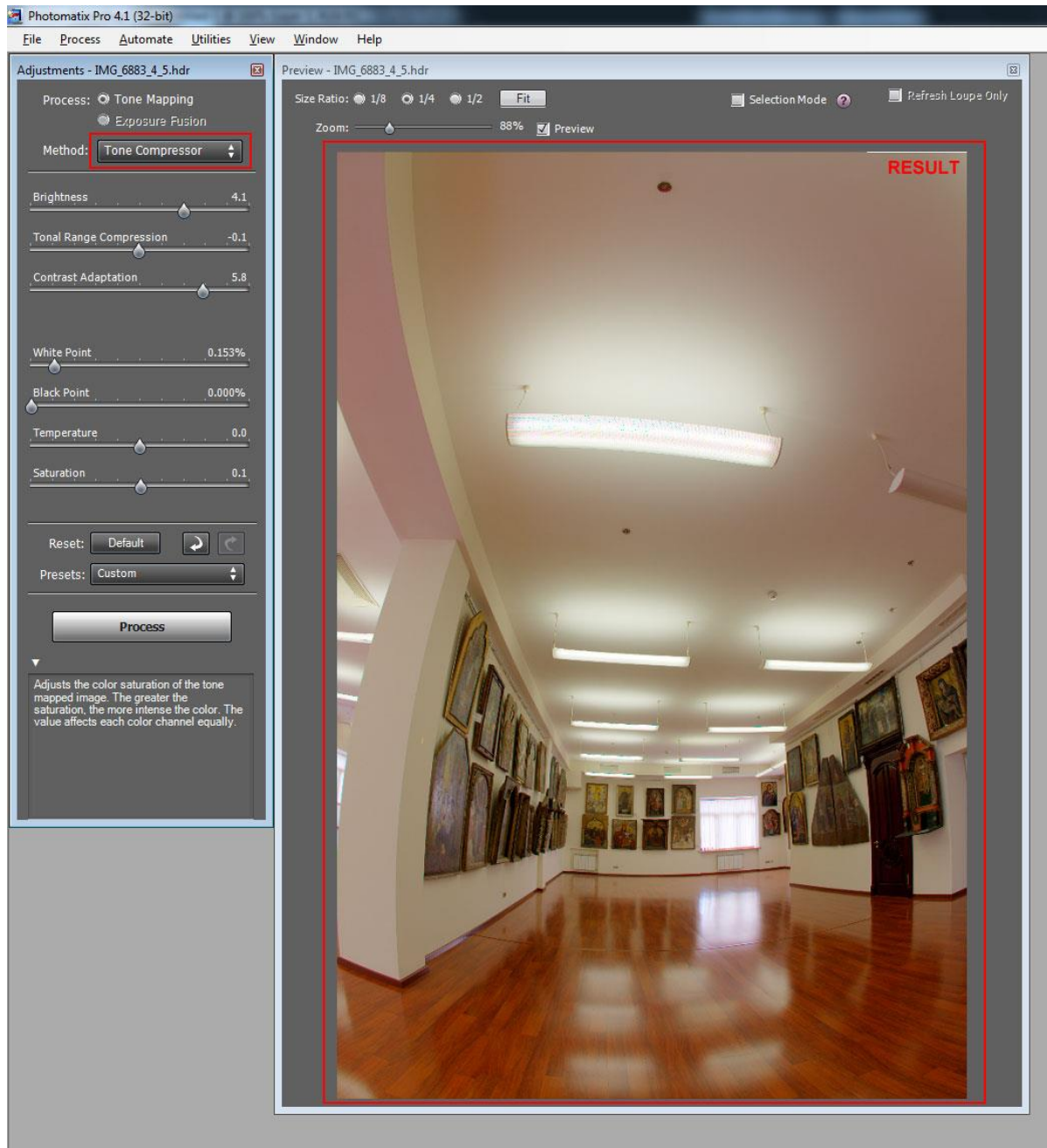
The Details Enhancer method takes into account the local context, mapping a pixel differently depending on whether it is located in a bright or dark area.

Screenshot below (Pic 4.2.6) gives you an idea how The Details Enhancer looks like in the Photomatix and what tuning it has.



Pic 4.2.6

The Tone Compressor method adjusts the image without taking into account the local context. This makes the result free from noise and halo artifacts, but lacking local details and contrast. Screenshot below (Pic 4.2.7) gives you an idea how The Details Enhancer looks like in the Photomatix and what tuning it has.



Pic 4.2.7

To conclude, we see that to create high quality panorama we have to use HDR method. So we will shoot 13(pictures to capture the whole room) * 3 (for each picture shot three instead of one to use HDR method). So in general we will shot 39 pictures for one room.

4.3 Second step. Create panorama.

So, we have 39 images in the RAW format. Let's continue. First, we will reduce the number of images to 13, by applying HDR method to them, using Photomatix (as was described above). After Photomatix merge each three imaged in one, we will have 13 images in the .hdr format.

Luckily, software that stitches images all together in one panorama, PTGui supports files with .hdr extension. That's why we don't need to tone map each of the thirteen images. We will tone map only resulted panorama.

Screenshot below(Pic 4.3.1) shows how PTGui looks like. First we load images, than we align them automatically. We can check the result in the Panorama Editor.

I have algorithm (list of actions that I usually perform to create panorama). There is no sense to describe it here in details. I just want to give you an idea how PTGui works and what does he do.

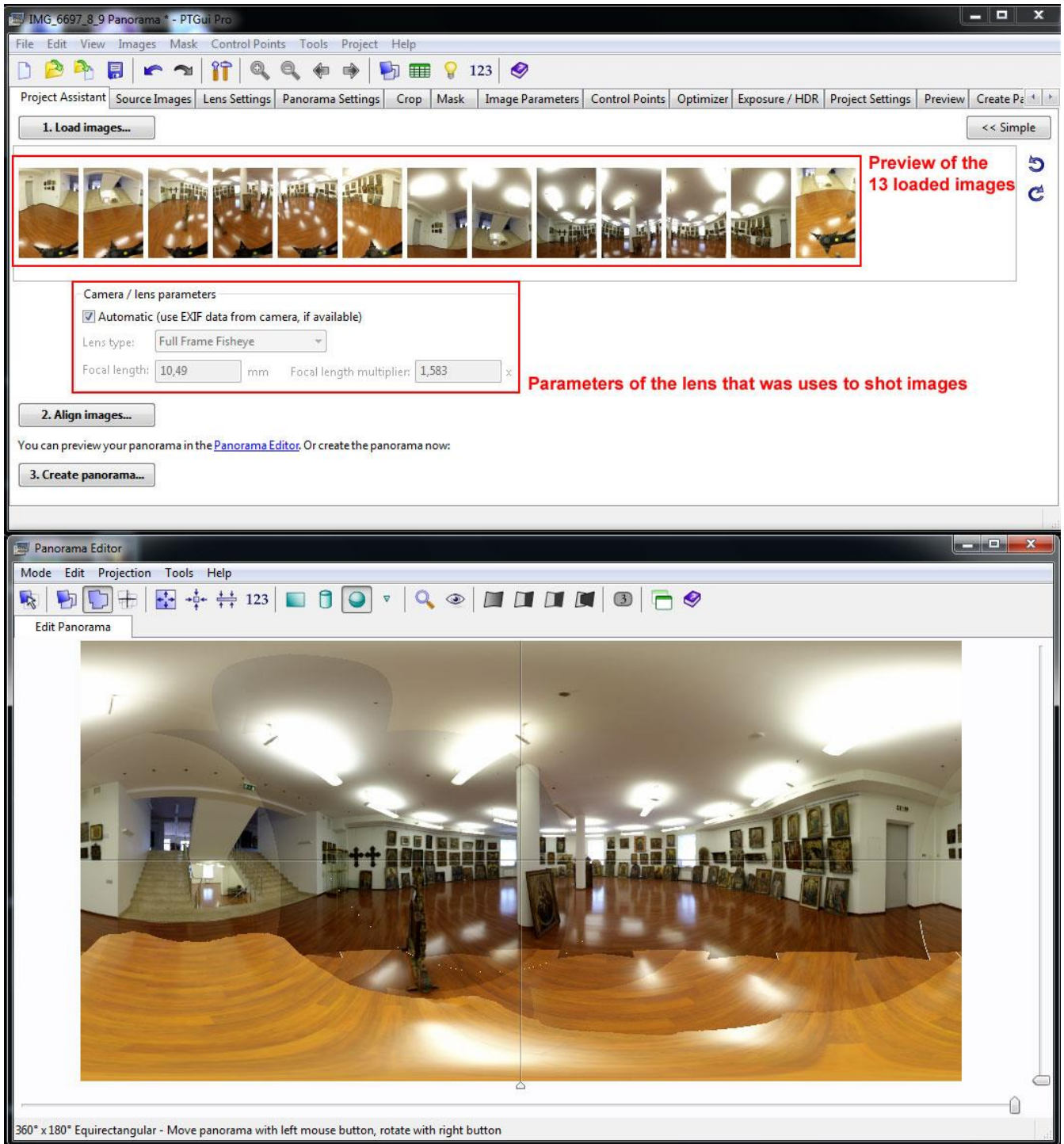
The greatest problem is to stitch the floor to other images without any visible artifacts.

As it was said above we should replace floor with tripod with floor without tripod. To do this we should take picture from not the same nodal point, from which all 12 pictures were shoot.

(Recall here: One of the basic and fundamental moments is that we have to rotate the camera around the so-called nodal point of the lens. Without going into the terms, the nodal point is a point in the camera lens, where the rays of light intersect reaching the film or sensor. And the remarkable thing of this point is that if perform rotation of the camera around this point there will be no parallax objects.)

Simply speaking, to replace floor with tripod we should shot floor from another point of view, shifting both tripod and camera to reveal that piece of floor from tripod.

This makes hard to stitch this 13 image to another twelve. But following some rules and summoning up patience we can reach perfect result.

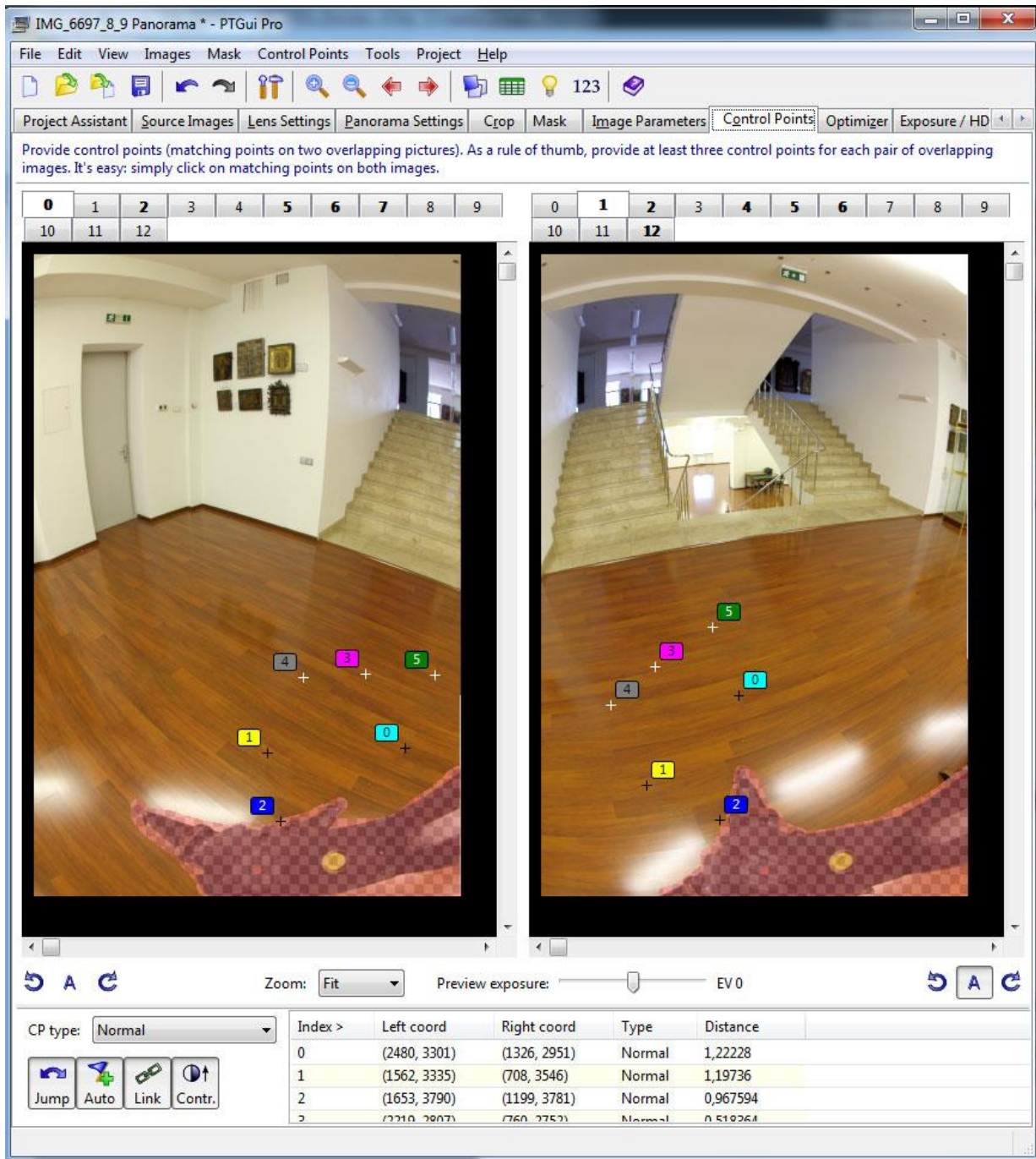


Pic 4.3.1

When the result in the Panorama Editor will satisfy you can press on the button create panorama, where you can chose dimensions of the future panorama. Panorama in the .hdr extension will be created.

Sometimes it can be rather challenging to stitch all images perfectly; in such case we will manually set control points.

On the screenshot below (Pic 4.3.2) we can see two images: number 0 on the left and number 1 on the right. They have common "points". Some control points PTGui finds automatically - they are shown on the images in different colors and enumerated. Sometimes PTGui finds too little control points or they are not correctly placed. So to create perfectly stitched panorama we should be able to correct control points and place new one.



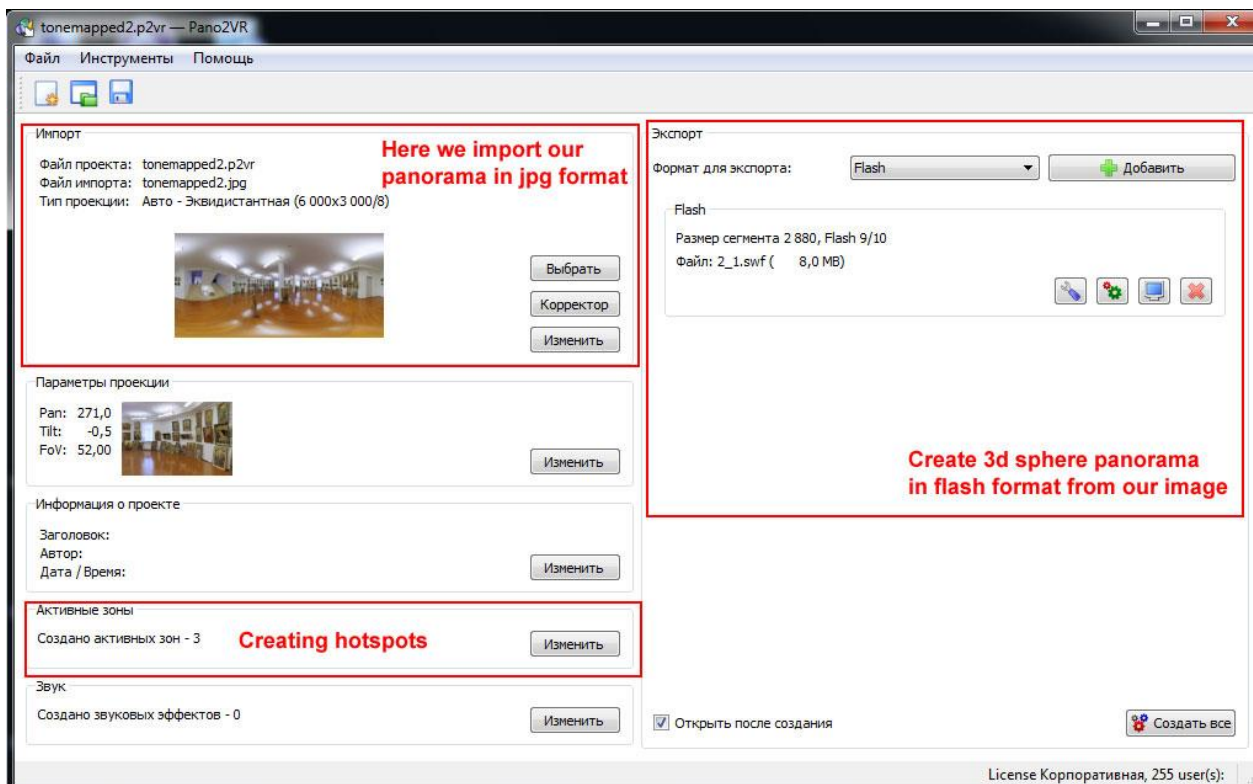
Pic 4.3. 2

So, PTGui help us to stitch all images together. It is worth to recall that PTGui worked with hdr images while creating panorama, thus as a result we will have panorama in hdr format.

We should tone map it to the sdr (standard dynamic range) format using Photomatix and steps discussed above.

Now, when we applied tone mapping we receive 2D panorama in the sdr format – it's time for magic – our flat equidistant panorama will turn in to the 3D spherical panorama. To do this I will use another software, Pano2VR.

On the screenshot (Pic 4.3.3) below you can see how Pano2VR looks like. This is a main window. First, you should import your 2D panorama, that you want to transform to 3D panorama. Pano2VR supports flat, cylindrical, spherical (equirectangular) as input formats. Supported file formats are jpeg, png, tiff, psd.



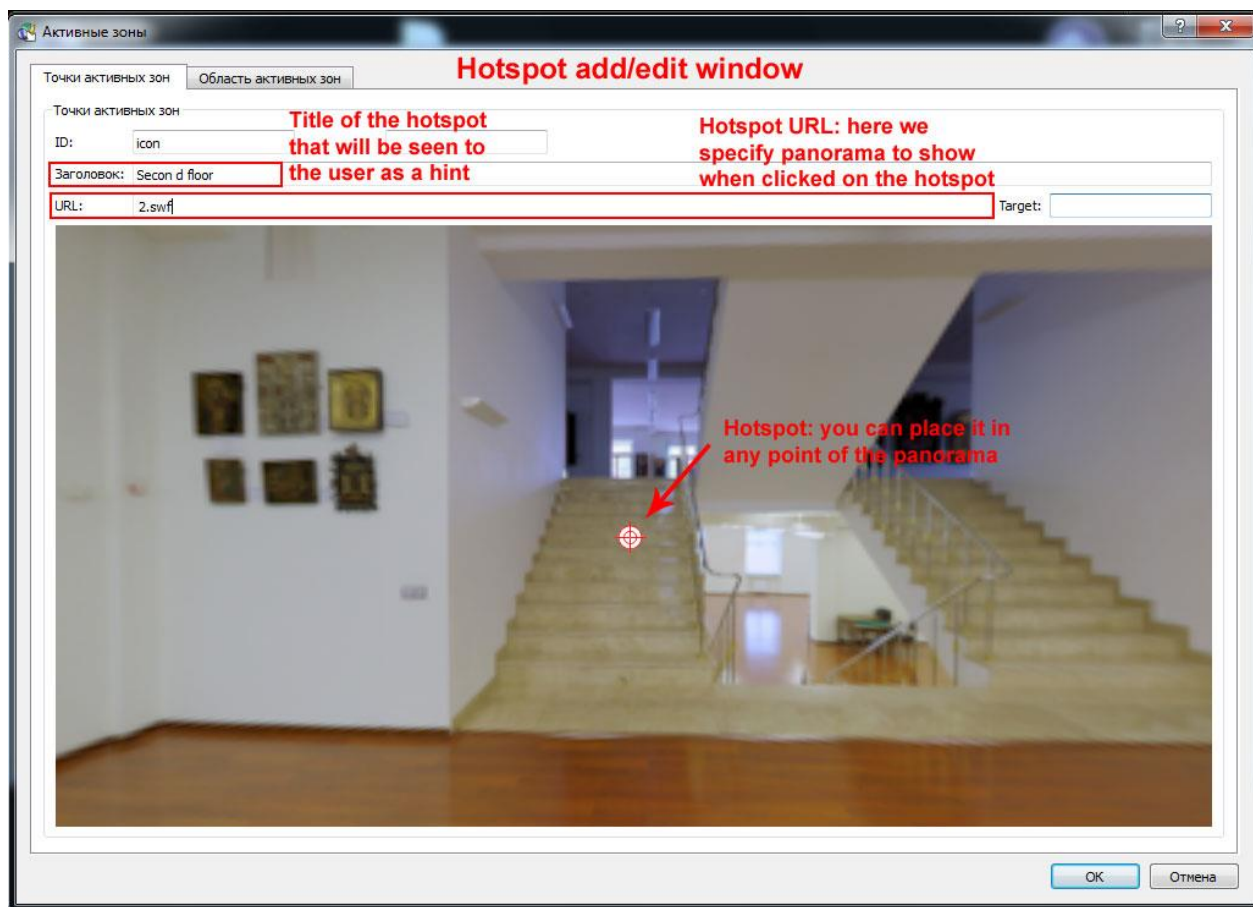
Pic 4.3. 3

The main advantages and features of the Pano2VR are:

1. Hotspots

You can **add hotspots** to your panorama. Hotspot is spot of interactivity on your panorama, this means that when watching panorama you created user can use these spots to do something –for example to go to another panorama or to the webpage. There are two kinds of hotspots – point hotspot and area hotspot.

On the next screenshot you can see Hotspot Window for adding and editing hotspots. Here you see point hotspot.



Pic 4.3. 4

When creating hotspot you should specify URL. You can add a web URL or if you would like to open another panorama, place the file name of the panorama here. When the user clicks on the hotspot they will be directed to the site or panorama specified.

In the example above (Pic 4.3.4) I specify path to another panorama (2.swf) – this means that when user will click on the hotspot he will be redirected to the new panorama. This is very useful feature of the Pano2VR thus it allows recreating Virtual Museum by transferring user from one room to another.

In the field target you can specify where to open the website (or panorama) – it stand for html attribute 'target' of the tag '<a>'. Tag <a> is used to create links in the HTML document. If you write something like this:

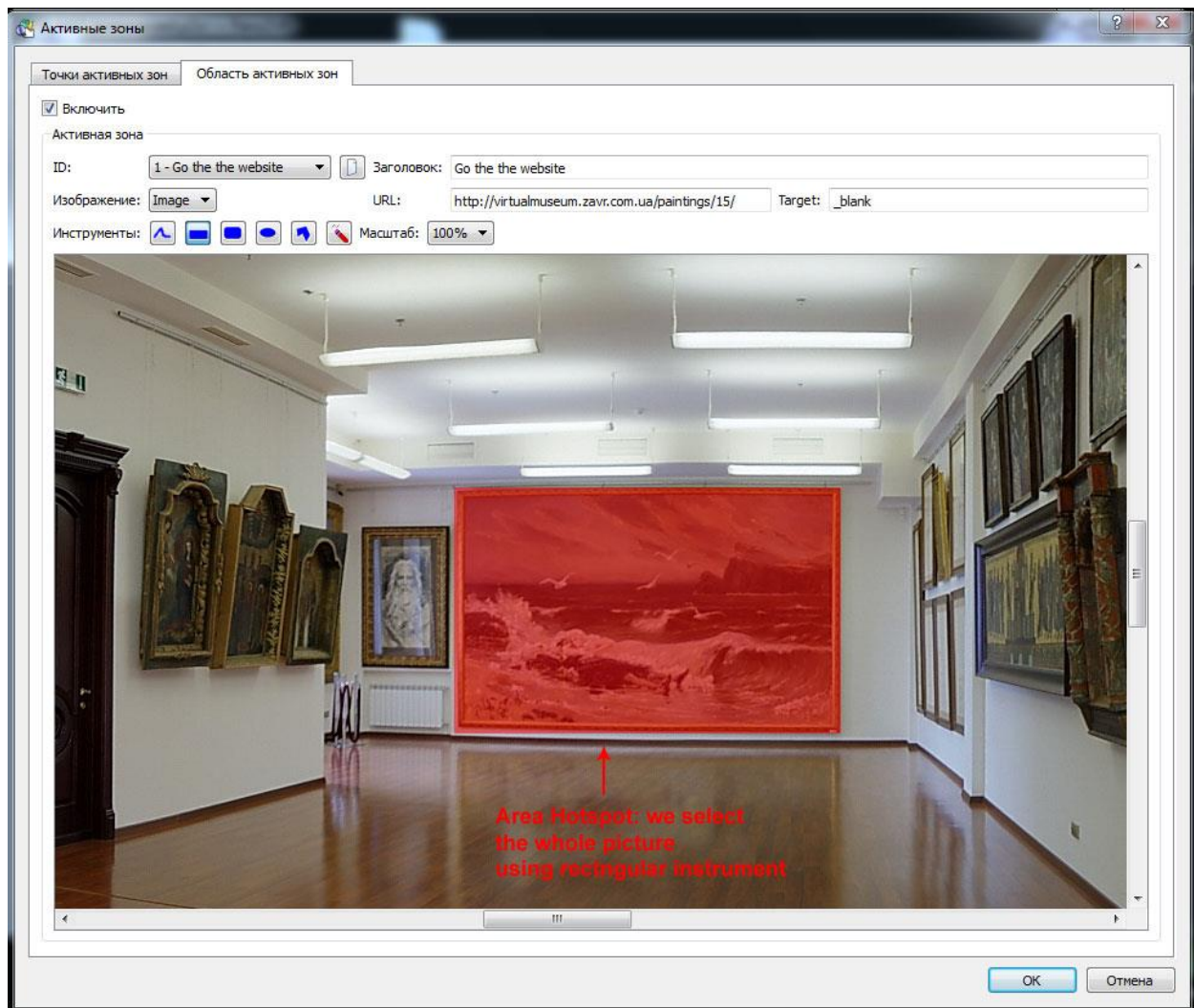
```
<a href="http://www.google.com" target="_blank">Visit  
Google</a>
```

You will create link to the Google page which will be opened in the new window or tab (as target="_blank").

In the field ID you should name your hotspot to be able to call her later on this name.

In the field Title you should specify title of the hotspot – it will be visible to user when he hover hotspot. Title should be informative and short, for instance "Go to the next hall".

On the screenshot (Pic 4.3.5) below you can see another type of hotspots – area hotspot.



Pic 4.3.5

All fields are the same as in the previous case: so I filled fields URL, Title, Target. The main difference is how this hotspot is created. In previous case I simply took hotspot pointer and placed it in any place in the panorama.

In this case you can see the panel with different tools: rectangular, rectangular with rounded corners, ellipse, polygon, pencil to create any form you want and eraser. Using any of these tools you create area highlighted in red color on the screenshot below. In the panorama you won't see this red rectangular – it just marks the area when user hover mouse on it - your title appears and when clicking on this area you will be redirected to URL.

2. Skin Editor

The Skin Editor allows you to design your own look and feel for your panorama player. You can add your own buttons and graphics, design hotspots, build maps for a virtual tour. You can also add animations and sound effects to the skin to help the user interact with your panoramic images.

To make my panorama looks better than default one I of course used skin editor. On the screenshot (Pic 4.3.6) below you can see the window of skin editor.

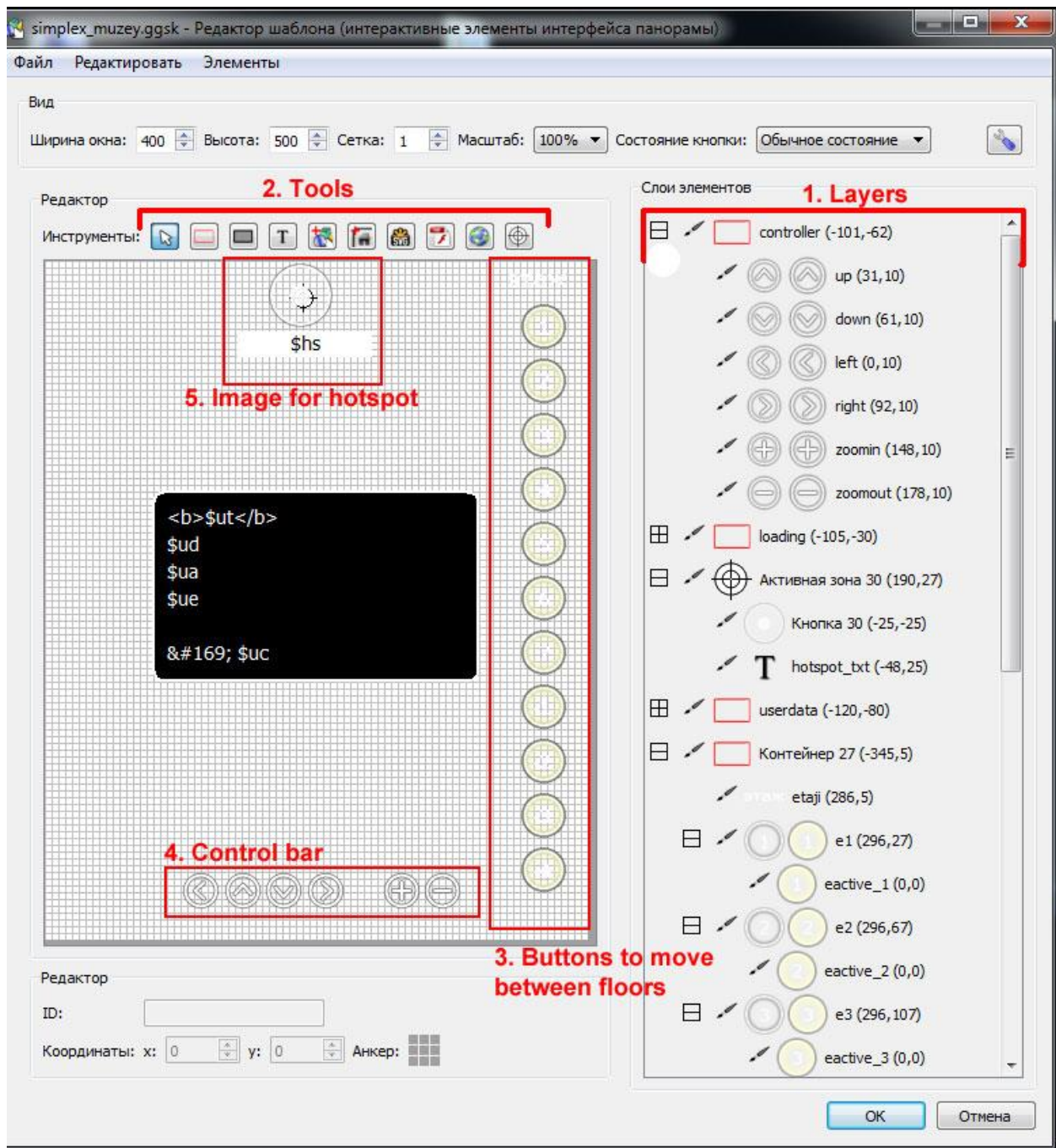


Рис 4.3. 6

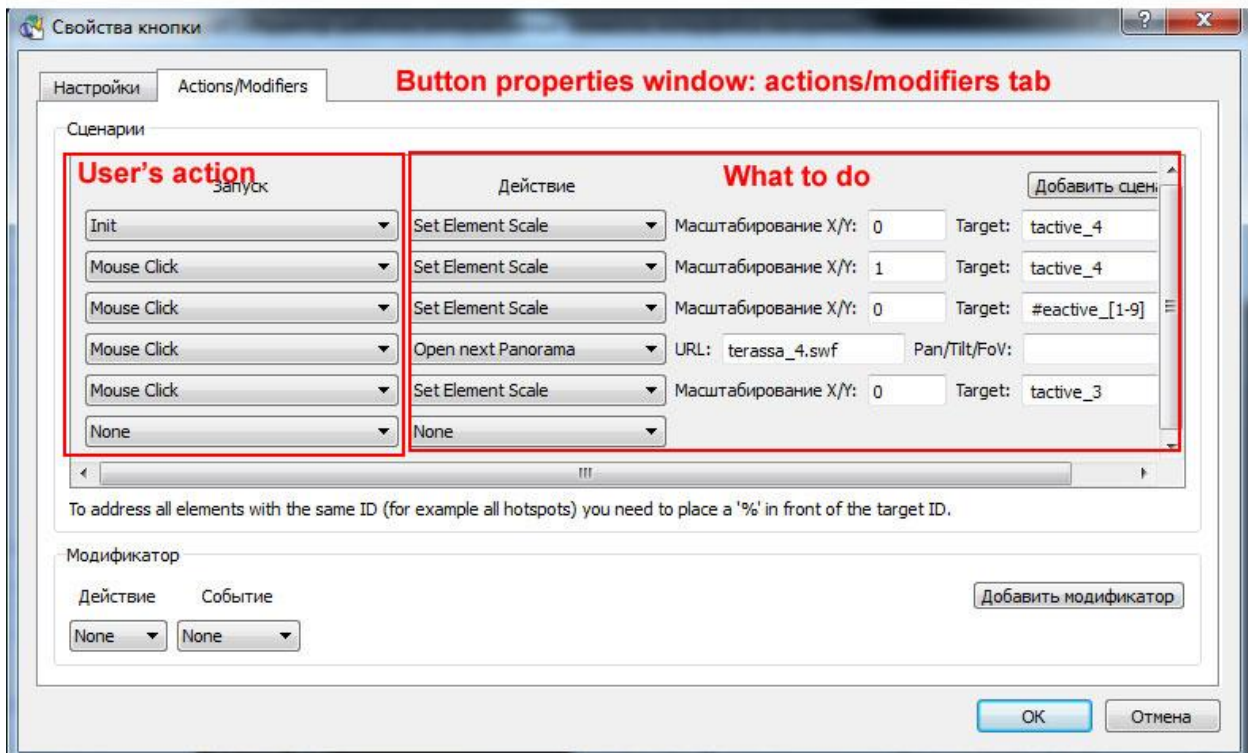
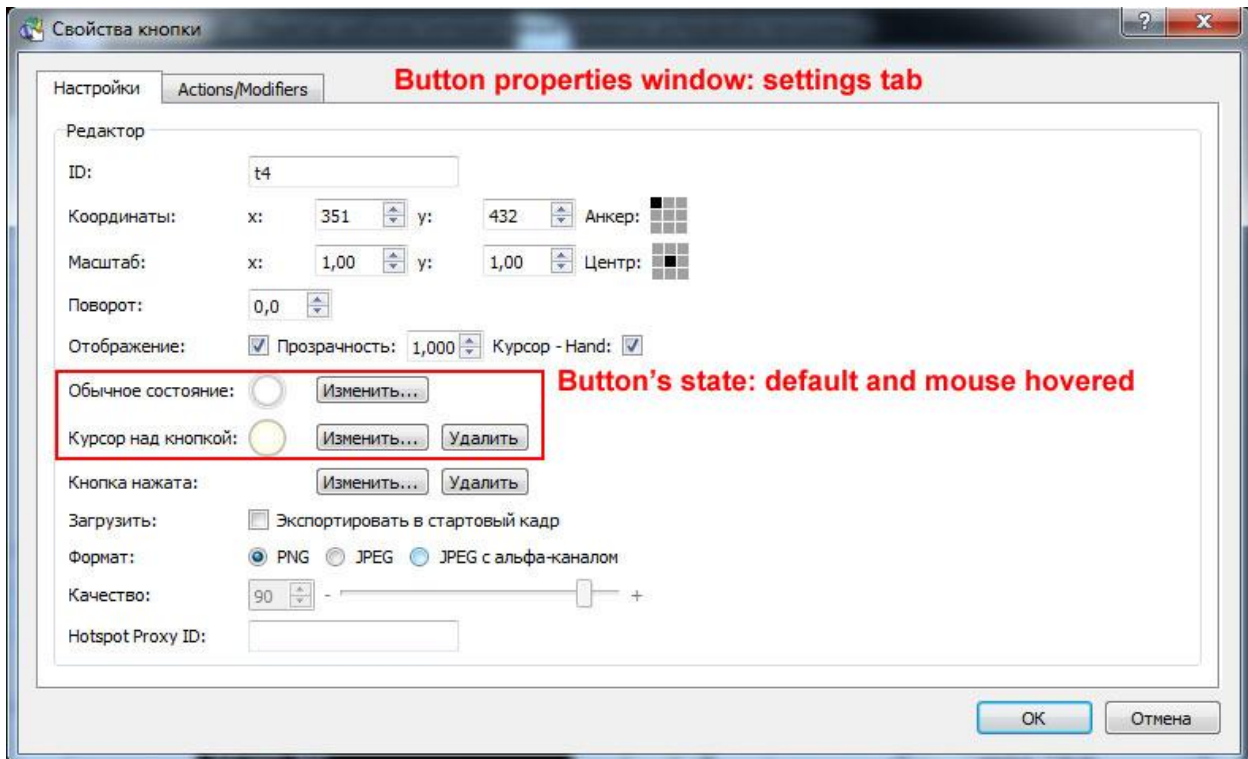
On the right you can see Layers of the elements. Each element is a part of specific group. For example, there is a group called "controller" for buttons of control bar. At the top there are tools: for creating hotspots, adding images of different format, adding

buttons, adding text or creating new group (container) of elements.

For better navigation between panoramas I created buttons that you can see on the right of check field (number 3). This buttons helped you to move through different floors. Later I show you how they look like on the panorama, but now I want to tell you how they were done, in few words - to show that Pano2VR is rather powerful instrument for creating panoramas.

First of all I used button tool to create button. Each floor is represented by separate button with number. When button was added, it will be seen in the Layers. Now it is possible to modify created button and add actions as you need.

On the screenshot (Pic 4.3.7) below you can see button properties window. Here are two tabs – settings tab and action/modifiers tab. In the setting tab we should change button appearance on mouse hover. The main magic for these buttons is made in another tab, action/modifiers tab. We have changed button appearance on mouse hover, but we should change button appearance on mouse click as well. Also we should show proper panorama by clicking on the floor button. The main idea is to hide default button by setting zoom to zero and show active button that was added before, by setting zoom to 1. Here was a little ruse – we have to hide all other active buttons that were activated before, if not we will have two or more active buttons show simultaneously after first click. This trick was done by using pattern: `#eactive_[1-9]`. This means that we hide all elements which id is from `eactive_1` to `eactive_9`.



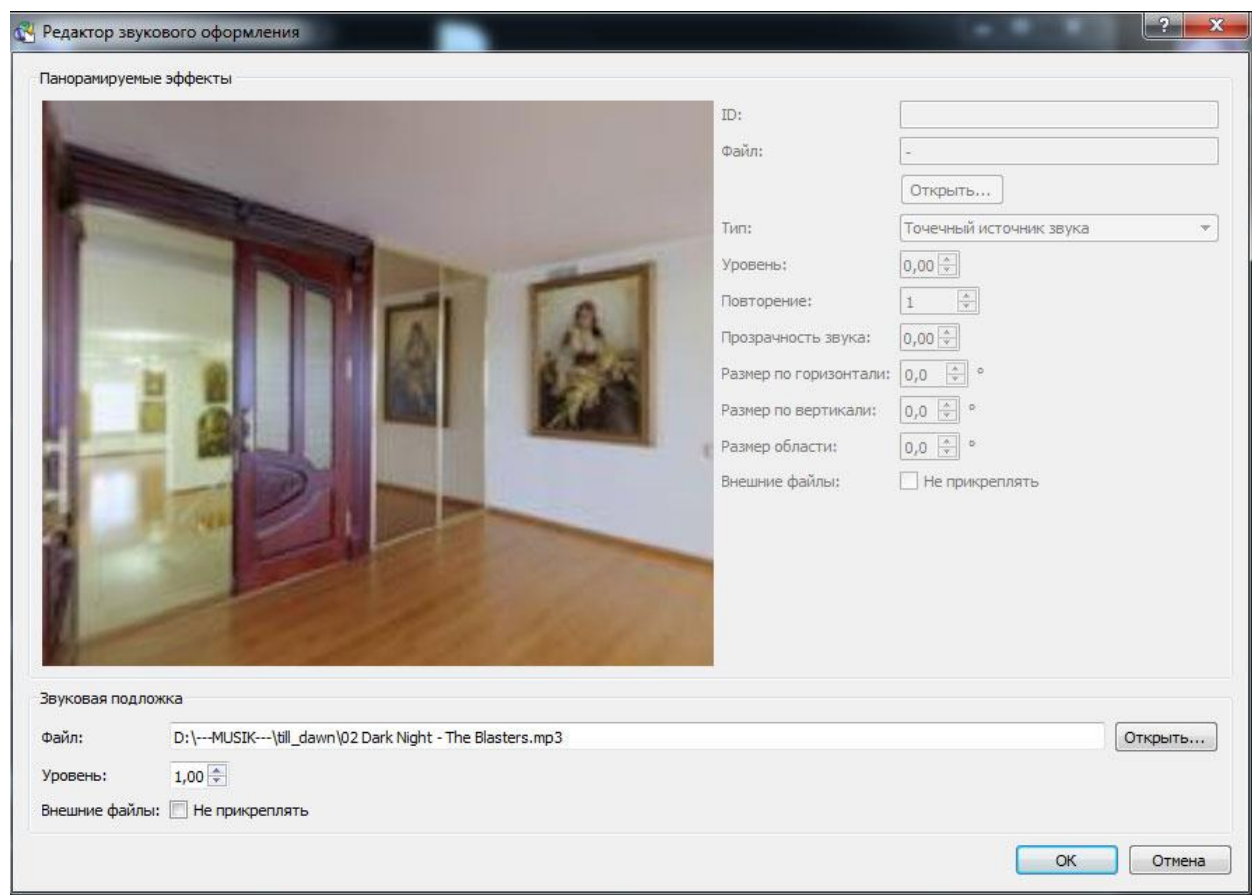
Pic 4.3. 7

3. Sound Effect

With the Sound Editor you can add various sounds to your panorama. You can add a simple background sound or define directional sound sources within the 3D space.

You can choose between different sound field shapes, change the size of the direct and indirect sound field and select a maximum and ambient level to design your own soundscape.

I didn't use sound effects in my panorama. But on the screenshot (Pic 4.3.8) below you can see how sound effect window looks like.



Pic 4.3. 8

4. Flash/HTML5 Export

Pano2VR exports the panorama including all graphical elements as a single SWF file in the Flash 10 format. This allows greater control over the download behavior and makes it easier to distribute the panorama to clients, add it to content management systems or post it on a blog.

Cylindrical as well as cubical panoramas can rotate automatically with selectable direction, speed and delay. Panoramas can contain hotspots as well as pre-defined or fully customizable skins. The integrated skin editor also allows you to add maps, links, logos and other information to the panorama in a user-friendly way.

The HTML5 output uses WebGL or CSS3 3D transformations to allow playback of panoramas on devices and browsers that do not support Flash, like Apple's mobile devices. Scalable vector graphics, point hotspots and skins are also supported in the HTML5 output.

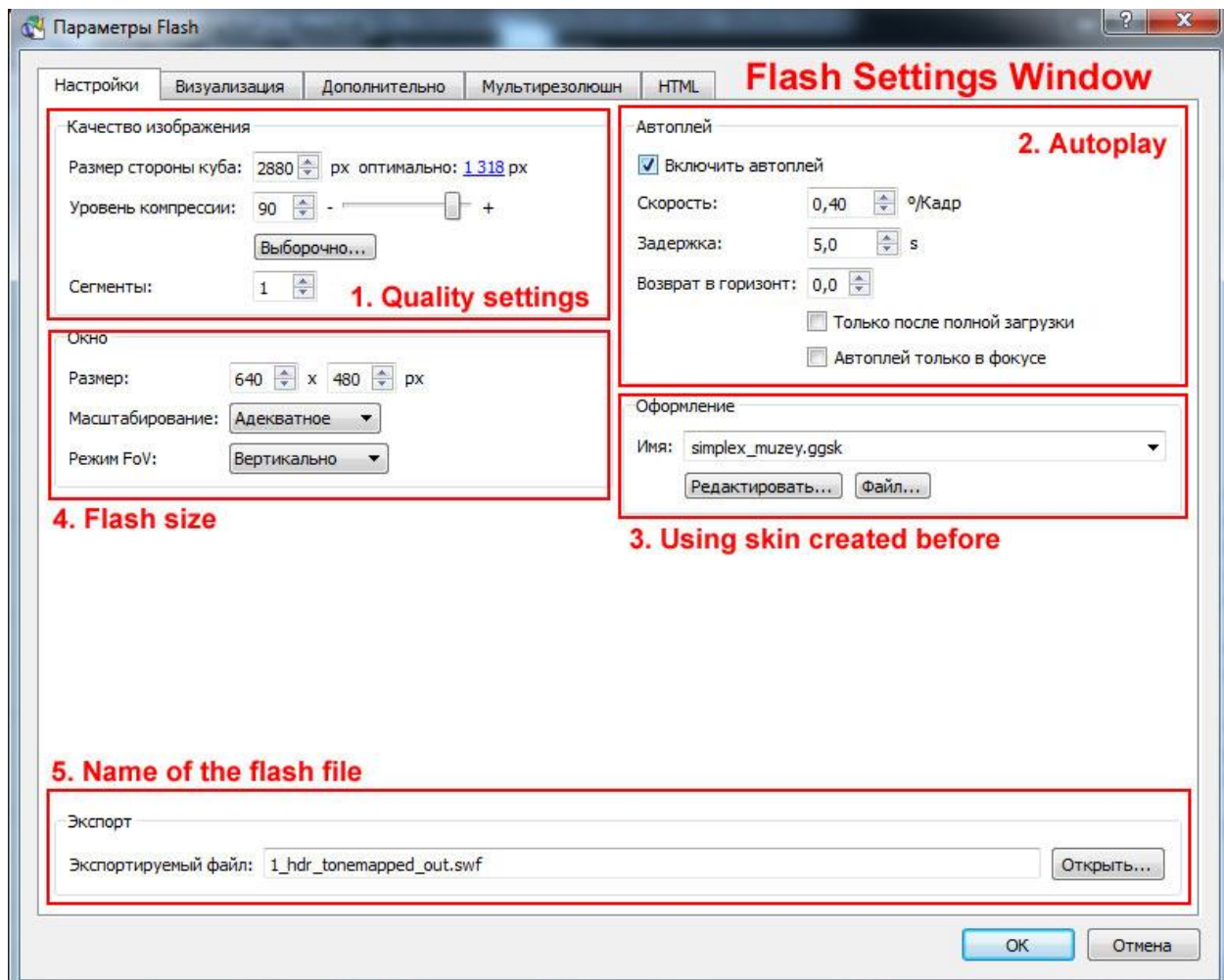
On the screenshot (Pic 4.3.9) below you can see how Flash Setting Window looks like. There are many tabs, but I used only first one. Here we can tune quality of the panorama, flash size.

Autoplay setting allows the panorama to move (rotate) automatically when the window is opened/loaded or when triggered by the mouse. We can set here

- Pan speed: pan speed refers to how fast the movie will rotate from left to right (positive number) or right to left (negative number).

- Delay: The time it takes for the panorama to begin to rotate (in seconds) again after it has been manually moved by the user.
- Start after fully loaded: Enable this option if you want the movie to start rotating only after it has been fully loaded. If left disabled, the movie will rotate while it is being downloaded.

We can also choose either one of the pre-installed skins or choose one that we have created.



Pic 4.3. 9

At the moment, I've discussed more or less the main features of the Pano2VR – software that helps me to create 3D panoramas. When all panoramas were created it was time to create a website.

4.4 Website. Backend Part

Backend part of the system is intended for managers of the museum who will fulfill website with new painting and icons.

As a backend part I used CMS (Content Management System) created by myself. This system was the core of all websites created by myself before. It is written using PHP language and Smarty.

PHP¹⁶ is a widely-used general-purpose scripting language that is especially suited for Web development and can be embedded into HTML.

Smarty¹⁵ is a template engine for PHP, facilitating the separation of presentation (HTML/CSS) from application logic. This implies that PHP code is application logic, and is separated from the presentation.

Speaking, simply, PHP stands for functionality, while templates, written on HTML and Smarty, stand for how page should look like. Smarty is great because we can separate view of the website (HTML templates) from functionality of the web site. Due to such approach code is easy reading, functionality doesn't depend on view.

Backend part of the system is intended for managers of the museum who will fulfill website with new painting and icons. Simple intuitive interface of the backend part allows everybody to add new item, photos and description. After adding in the backend part, item will be shown on the website immediately.

On the screenshot (Pic 4.4.1) below you can see main page of my backend system.

First, you should login as administrator, then you will see home page of the backend part. From here you can add, edit or enter different backend part settings.

As you can see there are two main types: icons and paintings. If click on the green link 'add' – you will create new icon/painting; if click on the type name you will see list of all items.

From the main menu you can enter different useful options:

- Users: you can create/edit/delete users here. Users can be either users of the website or administrators. Administrators may have different level of admission. For example, you can be the only administrator who has the biggest privilege, this means you can do everything and have access everywhere. While your managers can only add or edit items, but not delete them and even don't have access to some options of the backend.
- Database structure: this section is mainly for me as a developer of the system; here I can change structure of the tables.
- Data types: this section is also usually hidden from the managers. Here I can create/edit different types (e.g. icons, paintings), set up their fields (properties), etc.

- Translated phrases: as site can be multilingual we may need some common phrases, as “Log in” for example. This section allow to create such common phrases
- Mail settings: used for “contact us” form, where you can set email for receiving emails.

Site Administration System
virtualmuseum.zavr.com.ua/
ver: 18.02.2012

You logged in as qerty [Log out](#)

ru ukr eng

[Home](#) [Users](#) [Database structure](#) [Data types](#) [Translated phrases](#) [Mail settings](#)

aboutus [edit](#)
icons [add](#)
main_foto [add](#)
paintings [add](#)

Website can be multilingual

Main types of the website.

2. Home page

1. Login Window

Система администрирования сайта
virtualmuseum.zavr.com.ua/

Добрый день!
Для начала работы с системой
введите свой логин и пароль.

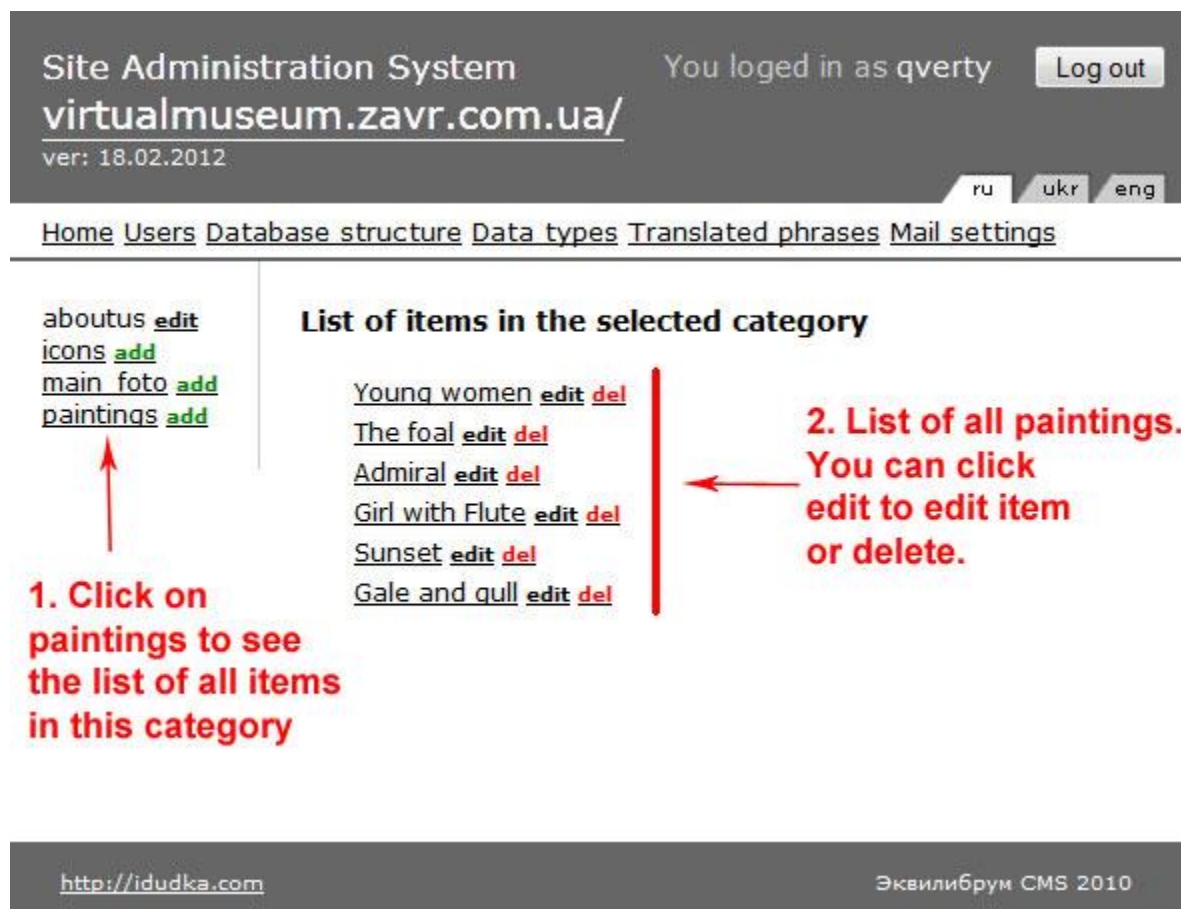
Логин:

Пароль:

http://idudka.com Эквилибрум CMS 2010

Pic 4.4. 1

On the screenshot (Pic 4.4.2) below you can see how page with list of items looks like. First, you should change the category you are interested in and click on it. After this you will see list of all items in this category – you can edit each item or delete it.



Pic 4.4. 2

On the screenshot (Pic 4.4.3) below you can see the Edit page for the painting item. Here all information is filled for item – photos, description, century, master.

[aboutus](#) [edit](#)
[icons](#) [add](#)
[main foto](#) [add](#)
[paintings](#) [add](#)

Edit selected item

Title:

Short description:

Rich text editor toolbar with options: Источник, Стиль, Форматирование, Шрифт, Размер, Bold, Italic, Underline, Text color, Background color, Bulleted list, Numbered list, Indent, Outdent, Undo, Redo, Link, Unlink, Table, Table of contents, Print, Refresh, Home.

1885 oil on canvas; 135x92, bottom right «Franciszek Ejsmond. Munchen. 1885»

Full description:

Rich text editor toolbar with options: Источник, Стиль, Форматирование, Шрифт, Размер, Bold, Italic, Underline, Text color, Background color, Bulleted list, Numbered list, Indent, Outdent, Undo, Redo, Link, Unlink, Table, Table of contents, Print, Refresh, Home.

The famous Polish artist, painter. Born in Krogulova Polish-Russian province of Radom. He studied at the Warsaw School of Drawing in B. Gerson. Since 1880 exhibited at art exhibitions in Krakow, Berlin and Vienna, the pictures on the theme of the Polish national life. Author beautiful portraits. For a time he lived and worked in Germany (1880-1890's). After returning home continued to work on genre scenes, for which received numerous medals at numerous exhibitions in Warsaw, Krakow and Lviv. The works are in many museum and private collections, including the National Museum in Warsaw.

century:
master:
number of panorama:

Photos :



Delete foto

Add foto:

4.5 Website. Frontend part

Frontend part as well as backend one is designed using PHP language and Smarty template engine.

Below you can see the home page (Pic 4.5.1)

about us contacts


SHEDEVVR
virtual museum

[paintings](#) [icons](#) [virtual museum](#)


6th floor


Welcome to the site of the SHEDEVVR museum!


search

 Counterpoint of contrasting textures, and this is especially true with Charlie Parker and John Coltrane, change. Cluster vibrato mezzo forte is the tetrachord, and if in one voice or musical fabric layers works are still ongoing structural and compositional processes of the previous section, in others - is the formation of new ones.

[read more about museum](#)

 ~300 [Icons](#)

 ~130 [Paintings](#)

 [Total](#) ~450

© Virtual Museum "Shedevr" 2012

Made in Ukraine

Pic 4.5. 1

Below is a screenshot (Pic 4.5.2) for the paintings page.

Here you can see the list of all paintings in the museum with short description, small picture and link to the panorama.

In the menu on the top of the page link paintings became green and not clickable – to show user where he is.

Name of each painting is clickable and link to the page of this special painting.


Short description helps you to understand the main idea about the painting. And link below the description lead you to the virtual tour.

Once you click the link “See this picture in the virtual museum ” you will be redirected to the one of the panorama in the virtual museum with exactly this painting.

This was done to help user to feel the atmosphere in the museum, to see how these paintings look in the reality – and to raise interest and desire in the potential client to visit museum in reality.

I hope that such navigation is very friendly and intuitively once you are interested in the painting (or icon) you can read some information on it and see it in the museum at once.

The same is the page with all icons in the museum.




You visit paintings page

[paintings](#) [icons](#) [virtual museum](#)

[about us](#) [contacts](#)

Small image



«Young women»

The famous Polish artist, painter. Born in Krogulova Polish-Russian province of Radom. He studied at the Warsaw School of Drawing in B. Gerson. Since 1880 exhibited at art exhibitions in Krakow, Berlin...


[See this picture in the virtual museum](#)



«The foal»

Born September 11, 1946 in Yagotin. First textbook on painting Anatolia became faded prewar book with lessons in drawing, which he found in the library Yagotin. [1] In 1976 he graduated from the Painting...


[See this picture in the virtual museum](#)



«Admiral»

Admiral is the rank, or part of the name of the ranks, of the highest naval officers. The rank usually refers to the position of full admiral (equivalent to full general) and above vice admiral...


[See this picture in the virtual museum](#)



«Girl with Flute»

The flute is a musical instrument of the woodwind family. Unlike woodwind instruments with reeds, a flute is an aerophone or reedless wind instrument that produces its sound from the flow of air across...


[See this picture in the virtual museum](#)



«Sunset»

Sunset is distinct from dusk, which is the moment at which darkness falls, which occurs when the Sun is approximately eighteen degrees below the horizon. The period between sunset and dusk is called...

[See this picture in the virtual museum](#)



«Gate and gull»

They are more adept walking on land than most other seabirds, and the smaller gulls tend to be more manoeuvrable while walking. The walking gait of gulls includes a slight side to side motion, something...

[See this picture in the virtual museum](#)

1. Name of the painting. Click here to go to this painting's page

2. Short description

3. Click here to see panorama with this picture

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Pic 4.5. 2

Once visitor click on the name of the painting he is interested in he will redirected to the page shown below on the screenshot (Pic 4.5.3). Here visitor can read all information about this painting and again here is a link to the panorama with this painting in the museum.


SHEDEVR
virtual museum

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Name of the painting, century and master
«*Young women*» XIX century, Ejsmond Franz
1885 oil on canvas; 135x92, bottom right «Franciszek Ejsmond. Munchen. 1885»

Short description

Full description



The famous Polish artist, painter. Born in Krogulova Polish-Russian province of Radom. He studied at the Warsaw School of Drawing in B. Gerson. Since 1880 exhibited at art exhibitions in Krakow, Berlin and Vienna, the pictures on the theme of the Polish national life. Author beautiful portraits. For a time he lived and worked in Germany (1880-1890's). After returning home continued to work on genre scenes, for which received numerous medals at numerous exhibitions in Warsaw, Krakow and Lviv. The works are in many museum and private collections, including the National Museum in Warsaw.

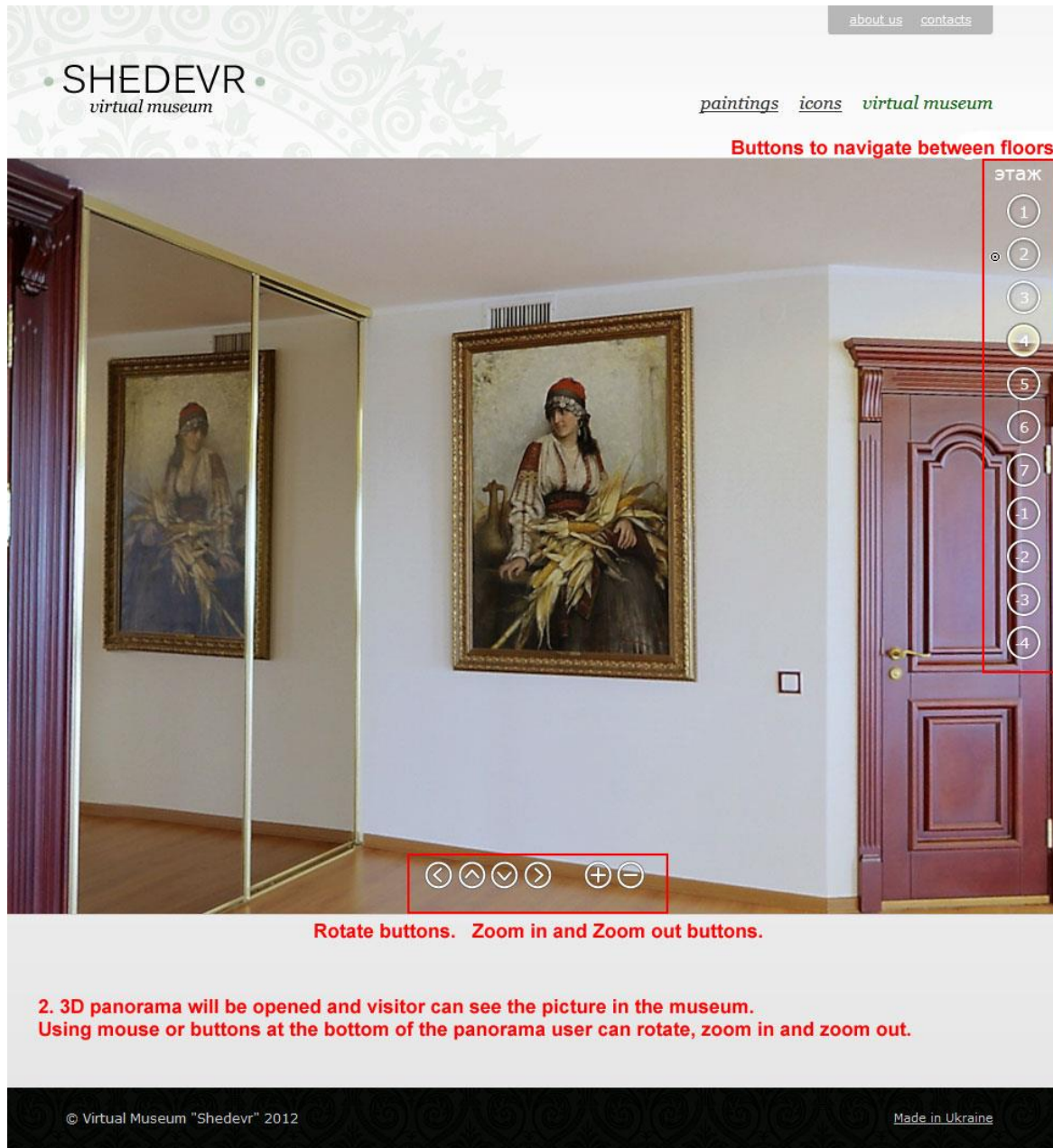
 [See this picture in the virtual museum](#)

1. Visitor click on the image he is interested in in the list of paintings. He is redirected to the page of this painting with all information and big photo. He can see this image in the museum by clicking the link to the panorama.

© Virtual Museum "Shedevr" 2012 Made in Ukraine

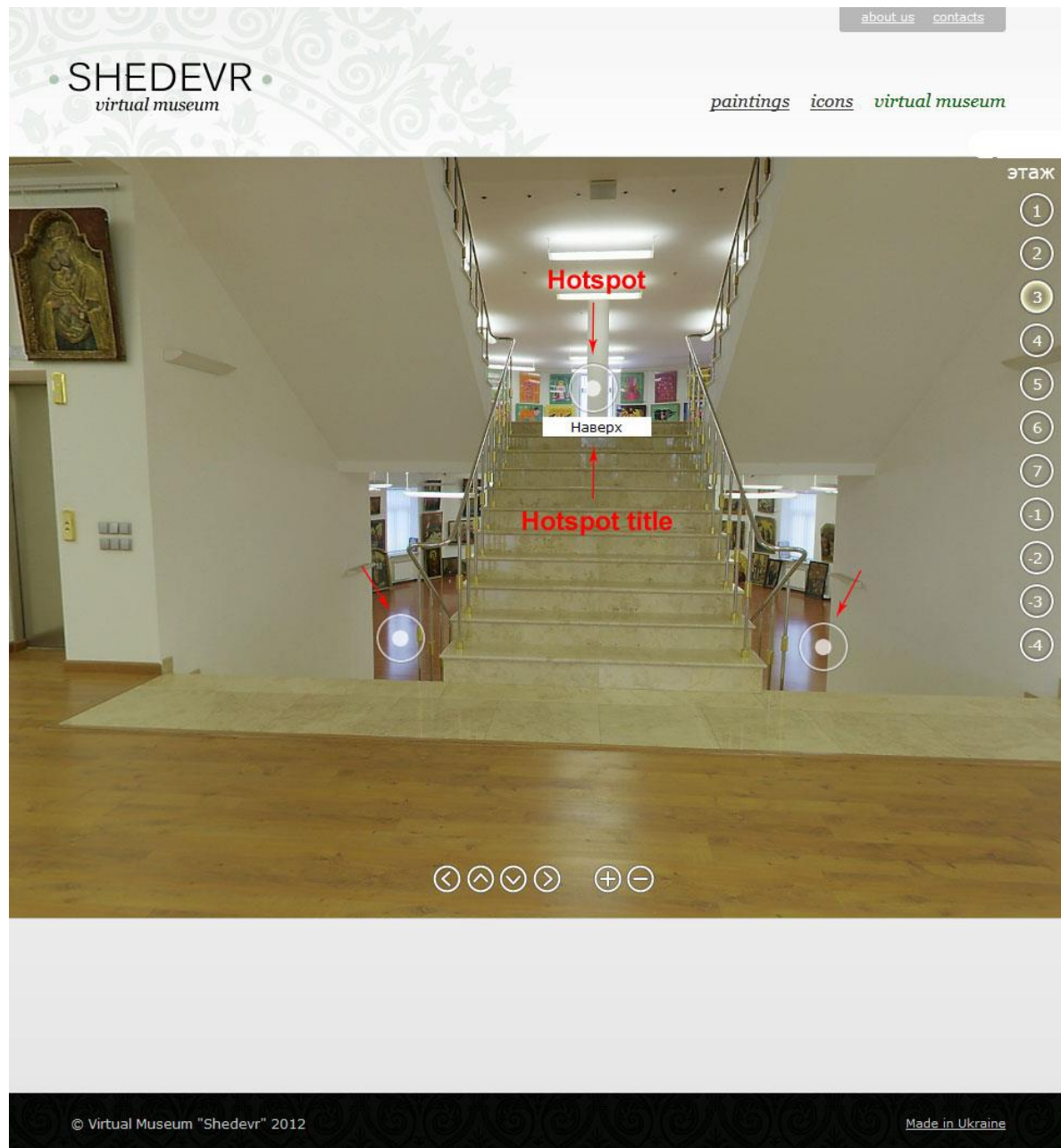
Pic 4.5. 3

On the screenshot (Pic 4.5.4) below you see part of the 3D panorama. User is redirected to this page when clicking on the link "See this picture in the virtual museum". Buttons on the bottom of the 3D panorama are used to rotate panorama and to zoom in/zoom out panorama. The same you can do with mouse.



Pic 4.5. 4

Buttons on the right are used to navigate between floors. As museum is 7th floor building we need simple friendly interface to move between floors – thus I thought up such buttons. I think they are good enough as they don't strike the eye and don't take much place, but at the same time they are intuitively clear. The floor you are in is highlighted with yellow color (as you can see on the screenshot Pic 4.5.4 4th floor is highlighted).



Pic 4.5. 5

On the screenshot (Pic 4.5.5) above you can see point hotspots that were talked about in the chapter Implementation -> Second step. Create panorama ->Hotspots. That is how hotspots look like in the panorama.

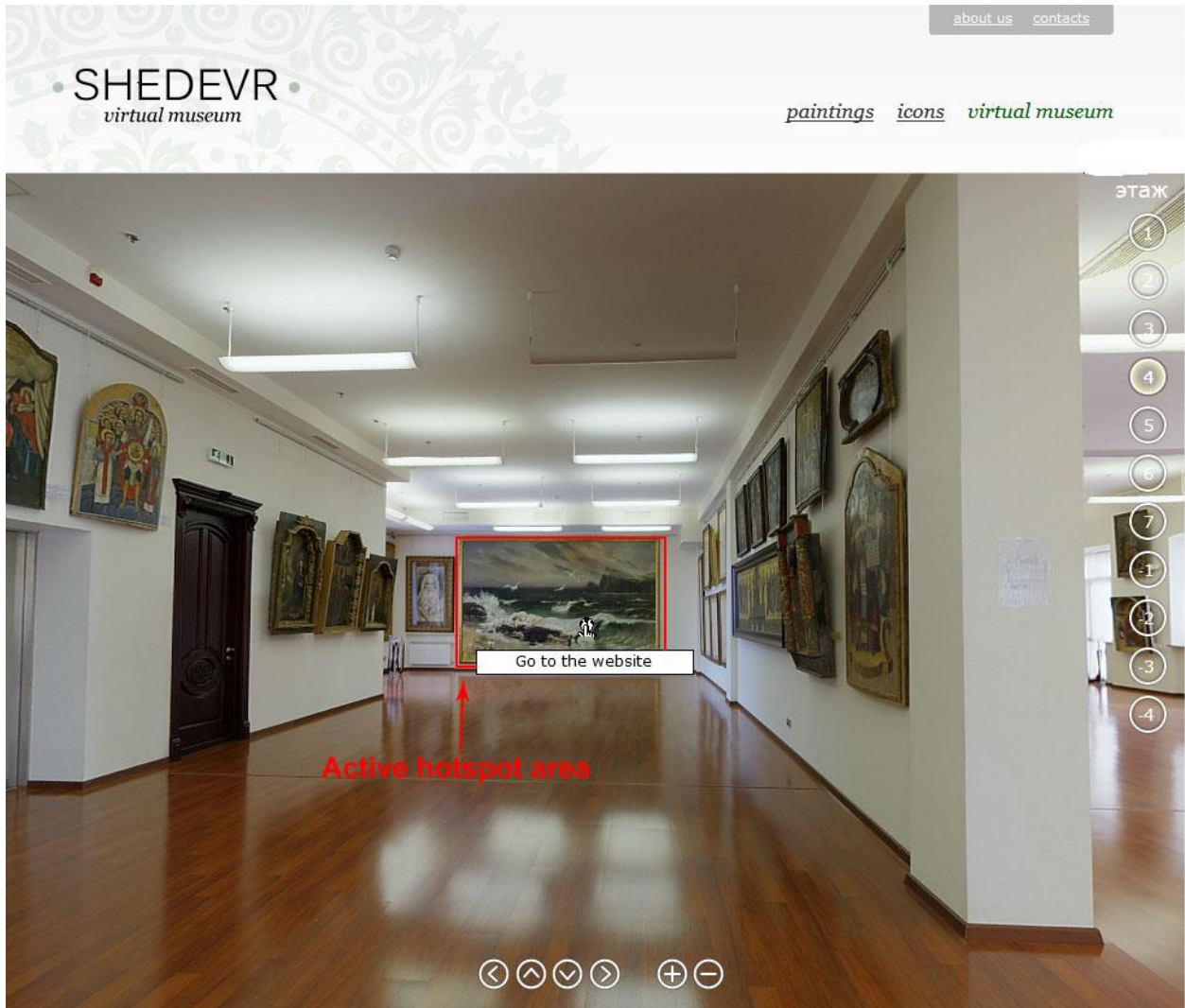
As it was said using software Pano2VR we can substitute any png image to visualize hotspot. In my case hotspot is big white circle that combines well with navigation buttons. On mouse hover hotspot title is shown to help user understand the destination. By clicking on hotspot a new panorama will be shown.

Such concept helps to recreate reality in the best way – as person is walking around museum, going up and down – by simple clicking on the hotspots.

As it was said before person can also move between floors using buttons with numbers on the right.

On the screenshot (Pic 4.5.6) below you can see how area hotspot looks like.

Active area is highlighted in red (only in the screenshot of course). When visitor hover mouse on this area he will see hotspot title as a hint. In this case if user click on the hotspot area he will be redirected to the page of this painting. This concept is also very convenient as it helps visitor to read in one click information about painting he is interested in.



Pic 4.5. 6

Conclusions

I think this thesis can be very interesting for everybody because 3D panorama, or virtual tour is great new method to show and explore reality without going out from home.

I tried to explain in details how to create your own 3D panorama, so this thesis will be a good manual for those who are also interesting in virtual tours but don't know how to begin with.

Doing this thesis was very helpful for me because now I understand what I am interesting in and what I want to be occupied with.

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