

Parameters are used both for image undistortion (if required) and for perspective projection. Without intrinsics the calibration pipeline can work assuming images not distorted and using the parallel projection for sphere-based direction estimation.

The next step is undistortion. This can be performed just clicking the "undistort" button. It just apply the OpenCV function undistort and replace the project images with the new one. After the procedure when RTITool re-opens the project it will directly load the undistorted images (as well as the intrinsics).

Light direction estimation

Light direction estimate in H-RTI this is based on reflective spheres put in the scene. The calibration procedure is started selecting the third RTITool tab "Light direction" and the sub-tab "Estimate".

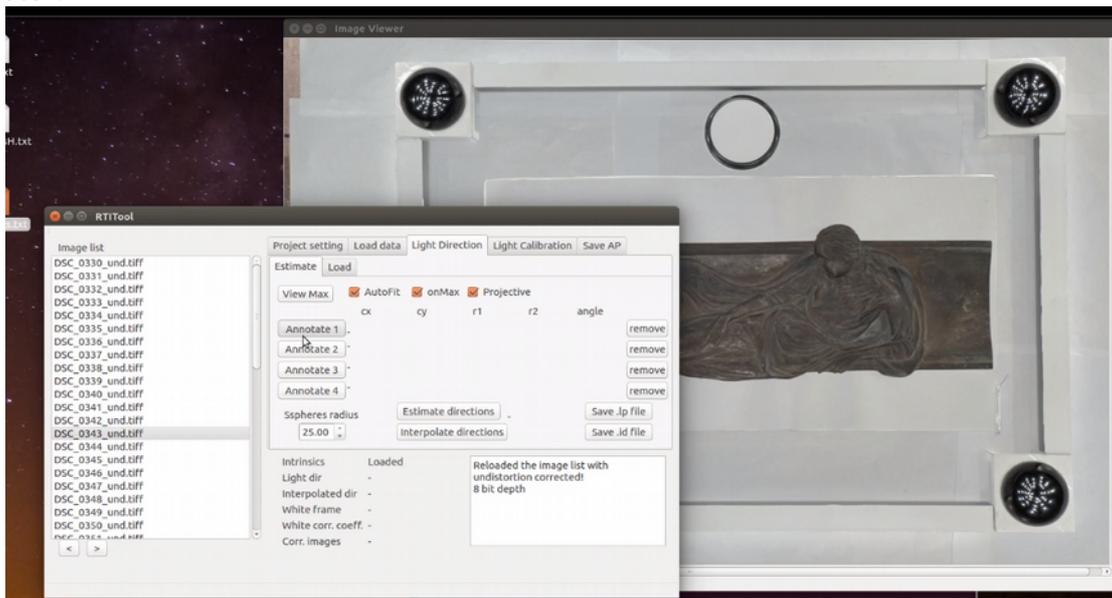


Figure 2 Clicking on the "Annotate" buttons, the detection of the sphere on the maximum image is started



Figure 3 A rectangle around the sphere mask is then drawn

In our pipeline we support up to 4 spheres and we have the possibility of using interpolated directions estimated from 4 spheres at the corner of the images.

Spheres can be annotated assuming perspective projection (elliptical shape) or parallel projection (circular shape). An automatic algorithm should find the contours and curve parameters in both

cases just annotating a rectangle around the sphere. To make the sphere contour detection easier we support processing of the spheres on the maximum image, where shadows are not visible. Visualization of the maximum image can be obtained by pushing the View Max button, while search of contours on maximum image is activated with the related checkbox (default).

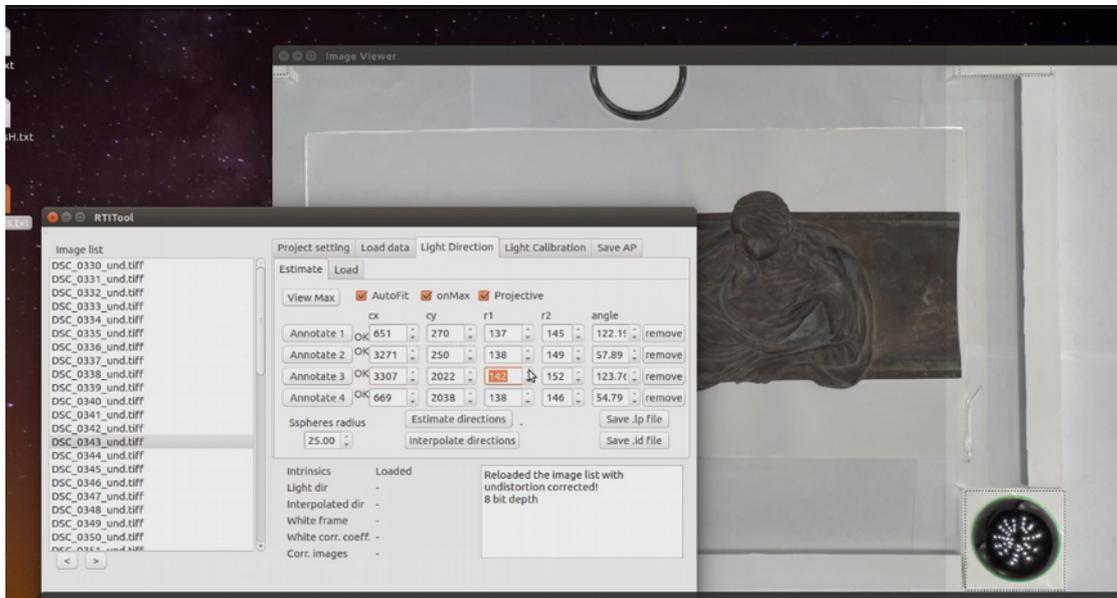


Figure 4 SpinBox buttons can be used to tune manually ellipses parameters to improve segmentation accuracy

To annotate a sphere, click on one of the Annotate 1..4 buttons (see Figure 2), then drag cursor to define the rectangle. The automatic detection will then be performed. If the algorithms does not provide an accurate result, the procedure can be repeated or the circle/ellipse parameters can be manually adjusted with the buttons on the parameters display. To better see the quality of the segmentation, images can be zoomed in (ctrl+ or display window menu).

When the user is happy with the shpere annotation, if the perspective method is chosen (elliptical contours), the size of the spheres should be put in the

he can push "Estimate directions" to estimate the light direction corresponding to all spheres and all images. Information on images annotations and directions can be exported in a .lp file storing image paths, annotations and directions. This is compatible with the format used in RTIBuilder.

If the acquisition has been done with the four sphere configuration it is possible to estimate per-pixel interpolation of the light directions by pushing the "interpolate directions" button.

Light intensity correction

The fourth tab in RTITool is dedicated to the light intensity correction. The correction then creates an image relighted as it was illuminated by a light of constant intensity.

In the H-RTI setup this is obtained as follows: a frame with surface perpendicular to the camera axis is put around the object in the same focusing plane. The frame is covered with a White Lambertian paper. Annotating the regions of the frame that are not shadowed and using a polynomial interpolation, we estimate an image corresponding to a white planar surface put in the object plane and illuminated by the same light of each input image.

This image is not uniform as it should be in case of constant light intensity, and we estimate the correction factor that should be applied to its pixel values in order to have a constant value corresponding to a reference value multiplied bu the cosine of the angle between the ideal object focusing plane and the local light direction. Using the same factor to correct the input images we obtain "corrected" images simulating uniform and known illumination of the input object.

To perform the procedure, select the Light Calibration tab and the Frame subtab. Click on annotate 1...4 and draw rectangles on non shadowed regions. To see non-shadowed regions it is useful to click on "view min" before the procedure in order to visualize the minimum image of the stack. After the annotation, just click on "Estimate Light intensity" to compute coefficients of the white interpolation and "Save corrected images" to save the corrected images. Corrected images are stored in a project subfolder.

The reference white intensity is set to 0.6 of the range as default but can be change from the menu.

Appearance profile export

After the light direction estimation (mandatory) and light intensity calibration (optional), we can finally export our calibrated RTI stacks. Select the final tab



Figure 5 Saving appearance profile files. As multiple files can be created for a single RTI stack, file name is selected with a dedicated dialog.

"Save AP" and choose the desired export options. We support RGB appearance profiles and Intensity appearance profile. In the second case, for each pixel location we don't export all the RGB components for each image, but we export just the intensity values in the AP binary data and an additional image (the median image, exported as "chroma image") that is used to estimate the RGB component ratios. This is the same idea used in the LRGB PTM format, for example. We can select to export light direction information as an interpolated value (coefficients stored in the header file .aph) or single direction (components stored in the header file .aph), using the related checkbox. As the interesting objects are usually placed only in a region of interest, and we could have multiple objects that we want then to process separately, we can select before exporting the APs, the ROI to be included in the AP file. Multiple AP of heterogeneous format can be saved in the same session.

DOME RTI acquisition processing

In case of DOME acquisition processing, we still use RTITool, but we need to create two different projects. One is created to process the direction calibration images, the second is created to process the object acquisition.

Light direction estimation project

To estimate light directions, we acquire images of 4 spheres placed in the acquisition plane. These images are loaded in a RTITool project and undistorted if necessary. Then the spheres are annotated and the interpolated light estimated as in the H-RTI procedure. After this step the project is closed. The lp file included in the project folder can then be used for the light calibration of the following objects acquisitions.

Object acquisition calibration project

To process the object acquisition the procedure is then the following: user must first open a new project with RTITool and import the object images. Then intrinsics are loaded and images undistorted if required.

In the light direction tab, instead of estimating the light directions from spheres, the information must be loaded from the .lp file stored in the direction estimation project. This can be done selecting the "load" sub-tab and selecting the correct file name. Light directions are then imported in memory and interpolated.

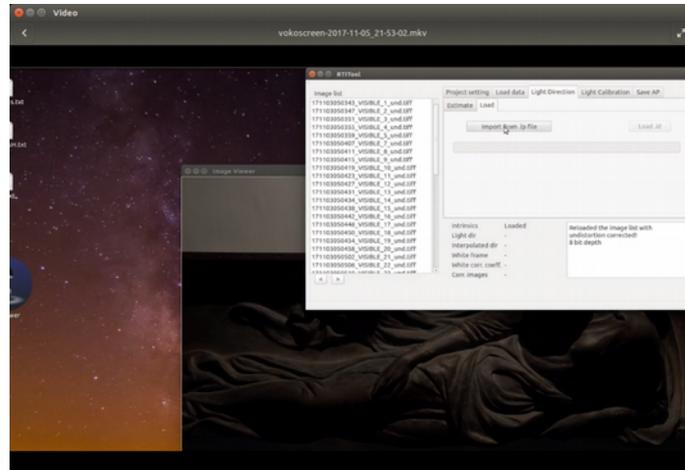


Figure 6 Loading directions from the calibration project

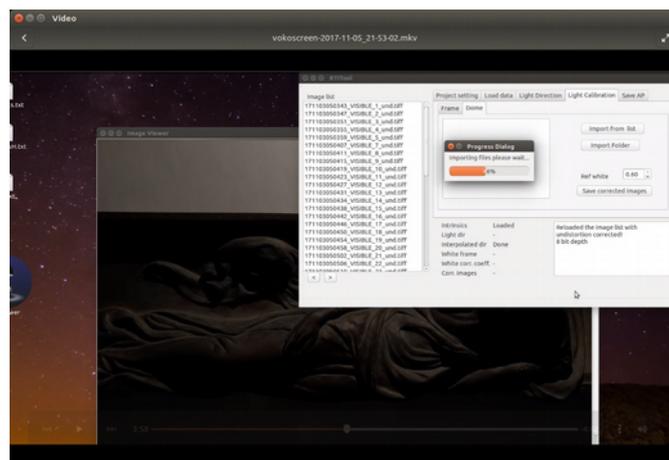


Figure 7 Intensity correction can be performed loading corresponding acquisitions of white Lambertian plane for each image of the stack

To perform the light intensity correction in the DOME processing procedure, instead of using the frame-based approach (still usable in principle, if a white frame around the object is imaged), we can exploit an additional acquisition of a white reference plane at the same distance of the object. If this acquisition is available (and the number and the order of the white images is the same as that of the object acquisition), it is possible to use the white images instead of the interpolated frame values to estimate the intensity correction.

In order to do this, it is necessary to select the "Light Calibration" tab and the "Dome" sub-tab. Clicking on "import from list" it is possible to load the list of the white panel images coupled with the object ones then clicking on the "save corrected images" button it is possible to store the corrected images in the project folder. These images can be used to export the intensity corrected AP structure.