Gexcel

JRC 3D Reconstructor

CAMERA CALIBRATION & ORIENTATION
In this tutorial you will learn how to...

- Include in the project external digital pictures of the scene you are modeling

- Calculate the original position and parameters of the digital cameras that captured your scene (camera calibration and orientation)

- Add digital pictures to the project, as camera items
These tools are useful for...

1. Adding photorealistic color to your 3D point clouds

2. Inserting calibrated and oriented images (cameras) in JRC 3D Reconstructor than can be re-projected in real time (see Camera Reprojection tutorial) and used for texture mapping (see Texture Mapping tutorial)

3. Analyzing your model from where the pictures were taken, and perform virtual scans using the calibrated cameras
Introduction

JRC 3D Reconstructor allows to add color information to point clouds or meshes, using pictures from any digital camera (thermo camera included).

The procedure is divided in 3 main steps:
1. Camera calibration and orientation: to calculate the camera’s internal parameters and orientation using range scans, 3D points or calibration frames. This results in calibrated and oriented images (camera items).

2. Camera re-projection on 3D objects in real time: to re-project the calibrate and oriented images (cameras) onto point or meshes in real time.

3. Texture mapping: to apply several cameras over one mesh model blending together the cameras’ images.
Any picture can be “calibrated” on the model.
Camera calibration means:
1. Determining position and orientation of the camera
2. Determining the camera’s internal parameters (optical centre, focal lengths, etc.)
Camera parameters in detail

Camera calibration and orientation consists in determining several parameters:

- **6 extrinsic parameters (orientation)** to determine the camera’s pose:
  - 3 for the 3D position
  - 3 for the rotation

- At least 4 **intrinsic parameters (calibration)** to determine the camera’s internal features:
  - 2 for the coordinates of the optical centre
  - 2 for horizontal and vertical focal lengths
  - other parameters may be considered, e.g. for radial and tangential distortions

These parameters give sufficient knowledge about the camera to correctly project the picture on the 3D model.
Two workflows

1. Based on a grid point cloud
2. Based on a list of 3D coordinates

JRC 3D Reconstructor offers also the possibility to calculate only the calibration (intrinsic) based on a calibration frame.
Workflow n.1 | **Range scan orientation**

1. Select a picture and a grid point cloud to calibrate the picture onto.

2. Select at least 11 correspondencies between image points and 3D points.

3. JRC 3D Reconstructor calculates the camera extrinsic and intrinsic parameters (this is not a deterministic process!)

4. JRC 3D Reconstructor reprojects the specified 3D points on the picture and outputs the mean reprojection error.

```
Mean reprojection error of selected points = 1.2401 pixels, 0.0352302% of image size
```

**Reprojection error satisfies user?**

No → back to step 3
Yes → creation of camera item in JRC 3D Reconstructor project
Camera calibration interface
Camera calibration procedure

1. The interface for calibration shown in the former slide can be opened by clicking on the Camera calibration toolbar button, or via Tools → Color tools → Image-grid homologies...
2. The user can select a picture and a grid point cloud via A and B
3. The user then selects 11 points on the image (left panel) and corresponding 11 in the point cloud (right panel)
   - To interact with the picture and point cloud panels see Navigation tutorial, about navigation functions for all 2D views
   - More interaction functions are given in the table below

<table>
<thead>
<tr>
<th>Keyboard/mouse event</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMB double click (on main panel or zoom view)</td>
<td>Set a marker</td>
</tr>
<tr>
<td>Mouse wheel rotation</td>
<td>Zoom in and out</td>
</tr>
<tr>
<td>Ctrl + move mouse on image or grid panel</td>
<td>Viewport of small zoom windows moves with mouse pointer</td>
</tr>
<tr>
<td>RMB click on a marker</td>
<td>Marker is deleted</td>
</tr>
<tr>
<td>Key ‘z’</td>
<td>Toggles the zoom windows G and H</td>
</tr>
<tr>
<td>Alt + CMB</td>
<td>Image resizes to fit the window</td>
</tr>
<tr>
<td>LMB click on a marker + move mouse</td>
<td>Move marker around</td>
</tr>
<tr>
<td>Spacebar</td>
<td>Rotates image 90°clockwise</td>
</tr>
</tbody>
</table>
At least 11 pairs of photo points and 3D points must be selected. Chosen points are listed in the table \( F \) in the interface. If more than 11 points are selected, the solution is more robust with respect to eventual noise.

4. The user presses the *Calibrate* button \( C \). Reconstructor selects the best 11 point pairs out of the ones provided by the user, through a non-deterministic procedure called *RANSAC*. The camera calibration is then calculated.

5. JRC 3D Reconstructor outputs the calibration result in the bottom-left panel of the interface.

Ex:

```
Calibration for C:/Models/FARO_Arch_Schaff/REC2/Images/untitled_1.bmp:

Resolution 2016 x 2112 pixels
points within reprojection threshold = 11
Mean reprojection error of selected points = 1.2401 pixels, 0.0352302% of image size
FOVX = 49.288 deg, FOVY = 37.7792 deg
Principal point of centering [50.1903, 34.7771] pixels, [1.78253, 1.64665]% of image size

Distortion coefficients \([k_1, k_2, k_3, p_1, p_2] = [-0.339541, 2.32037, -5.28779, -0.00152892, 0.00288369]\)
Focal lengths \([f_x, f_y] = [3069.11, 3086.15]\) pixels
Principal point \([c_x, c_y] = [1458.15, 1690.78]\) pixels
```

If the mean reprojection error is too large, the calibration can be repeated > go back to step 4.
6. When the calibration is fine, the *Save calibration* (D) can be pressed. The dialog below opens, to save a .cal file with all the calibration information.

If *Add to project* is checked, then a *camera* item is added to the project tree. Right-click on it → *Load projector* will project the picture on the 3D model according to the calculated calibration parameters.
The **RANSAC procedure** is used to select the 11 best point pairs out of the set specified by the user. It is not deterministic, and its parameters can be set via the panel E in the interface. It selects a random set of 11 point pairs out of the original set, then it iterates checking if it can find a better set (the *consensus set*) by adding some of the pairs left out. The threshold *Reprojection tolerance* determines how easily a pair can be included in a better set.

- The user can choose to perform **Full** or **External** calibration via the buttons I. When **External** is selected, only the extrinsic parameters will be calculated. The system will need in this case only 7 point pairs.

- Two calibration algorithms can be selected: **OpenCV** or **Tsai J**. They are based on two different camera models. The OpenCV model includes more intrinsic parameters for modeling the radial distortion, therefore it is more suited for fisheye cameras.

- The user may need to do **camera calibration on multiple scans**: he/she can indicate point correspondences among the picture and many point clouds, but the *global coordinates* checkbox on the top-right corner of the interface must be checked.
Reprojection. After having calibrated a picture, the user can obtain a *reprojection* of the picture on the grid point cloud, by pressing *Make reprojection K*.

*JRC 3D* Reconstructor will create an image representing the grid point cloud coloured with the projected picture.

An example of reprojection is the image below.
Camera calibration result

The camera item gives color to your 3D objects.

The projection of the picture on the 3D model can be turned on or off.

The picture that the camera projects can be set to another, or edited.
Workflow n.2 | 3D points

The idea
While the first workflow always starts from an image and a grid point cloud, the second allows more possibilities, accepting as input 3D points that come in principle from anywhere.

The rest is the same as before
- At least 11 homologies must be indicated between the image and the 3D world
- Then the calibration procedure is the same as points 4 and following of Workflow n. 1
Click on menu item *Tools* → *Color tools* → *Image-World homologies*...

The interface below appears

1. Load the image to be calibrated, clicking on **M**

2. Load at least 11 image points in text format, clicking on **N**. They can come from a former save, done e.g. with **L** in the former interface

3. Load the 3D points in homology to the image points, clicking on **O**
3D points are loaded in text format and can come from multiple sources:

- JRC 3D Reconstructor’s point list window, filled by Alt+double click on 3D points
- Total station
- Etc.
If you need some more **information**, please contact our **Gexcel Sales Team** writing to **sales@gexcel.it**

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