Novel models and methods for structured light 3D Scanners

The work made during the PhD course in Information Engineering, was focused on the possibility to find out novel techniques for the quick calibration of a cheap 3D Scanner. It is based on a simple camera and a commercial projector, in order to develop low-cost devices with high reliability capable of acquiring large areas quickly.

Many systems based on this configuration exist, those devices have benefits and disadvantages. They can acquire objects with large surface in a few seconds and with an adequate accuracy. On the other hand, they need a lengthy calibration and they are very sensitive to the noise due to the flicker of the light source. Considering these problems, I tried to find new robust calibration techniques in order to reduce the sensitivity to noise, and, in this way, to have high-performance low-cost 3D scanners with short-time calibration and reconfiguration.

There are many calibration techniques available for these systems.
First, it is necessary to calibrate the camera and then the overall system for projecting analog encoded patterns, typically sinusoidal or digital, such as Gray codes. These techniques are very time-consuming because they require a prior camera calibration phase separate from the calibration of the whole system and also disturbing factors are introduced by the ambient light noise. Indeed, a lot of projection patterns, used to map the calibration volume, are required to be projected.

In order to achieve our goal, different types of structured light scanner have been studied and implemented, according to the schemes proposed in literature. For example, there exist scanners based on sinusoidal patterns and others based on digital patterns, which also allowed the implementation in real time mode. On these systems classical techniques of calibration were implemented and performance were evaluated as a compromise between time and accuracy of the system.

Classical calibration involves the acquisition of phase maps in the volume calibration following a pre-calibration of the camera. At the beginning, an algorithm that allows calibration through the acquisition of only two views has been implemented, including camera calibration, modeled by pin-hole model, in the calibration algorithm. To do this, we have assumed a geometric model for the projector which has been verified by the evaluation of experimental data. The projector is then modeled as a second camera, also using the pin-hole model, and we proceeded with the calibration of camera-projector pair as a pair of stereo cameras, using a *DLT* calibration. Thanks to the acquisition of two views of the target volume in the calibration, it is possible to extract the parameters of the two devices through which the projected pattern can be generated, and the acquisition by the camera can be done, eliminating the problem of noise due to ambient light.
This system is a good compromise between the reduction in calibration time, which passed from half an hour to a couple of minutes, with a reduction in term of uncertainty in order of one percentage point of calibration volumes that was chosen of a depth of 10 centimeters.

The percentage errors could be reduced by considering the lens distortion. During the period in visit at the Machine Vision Group of Oulu in Finland, under the supervision of Prof. J. Heikkilä, problems related to the change of parameters of distortion in a pin-hole model as a function of distance between target and camera have been studied. After several experimental tests, first in simulation and later on real images, it has been concluded that the parameter variations can be justified with the use of a simple model such as pin-hole. The use of advanced geometric models like Axis model and subsequently the Generic model, can incorporate these variables within the model itself, to make the camera and projector calibration more accurate in extended to a greater volume range.

Finally, Self-Calibration for Stereo system has been used for the 3D scanner system in order to reconfigure on-site, i.e. outside the laboratory, a scanner previously calibrated in the laboratory.