3D Reconstruction of Free-Form Objets from Range Images Acquired by Laser Scanning

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Abstract

A current challenge is the construction of three-dimensional models digitized with precision enough to be used in manufacturing systems or numerical simulation of the performance of machines and components in operation, as turbines and flows in non-circular ducts, when the geometric model is not available. The 3D reconstruction of objects or scenes from range images, also known as depth maps, is preferable than using intensity images or stereoscopy. These maps represent information of distances measured from an observer (optical sensor or camera) to the scene in a rectangular grid. Therefore, the 3D information is explicit and will not need to be recovered as in the case of intensity images. The reconstruction process presents three stages. The first one is sampling of the real world in depth maps. The second stage is the alignment of several views within the same coordinate system, known as image registration. The third stage is the integration of the views for the generation of surface representation. In this poster an implementation to create 3D models by the alignment of multiple range images acquired by laser scanning is presented. The research has for focus the second stage of the reconstruction: the registration or alignment of range images.

1. The 3D Reconstruction

3D Reconstruction are an essential resource for several areas. One can cite, among others: *manufature*: for creation and improvement of prototypes. *Robotic guidance*: to mapping the environment in 3D coordinates. *Industry of entertainment*: to get realistic virtual creatures and objects in movies and 3D games.

Many times, for an engineer, it is a crucial step to have a computer 3D model of a free-shape solid object in some projects. A situation is when old machines need to be modernized or are due to maintenance but the original design drawings are not available, which implies in re-engineering solutions. Or when, in the design step, several numerical simulations are necessary, such as in the case of hydrodynamics of fluid flows inside turbines. So, there are several examples of engineering problems where a computer object model is necessary, and 3D Reconstruction techniques can be of high interest.

The traditional approach for 3D modeling is first to construct a prototype model of the product in CAD software (Computer Aided Design). Second, the model is exported to CAM software (Computer Aided Manufacturing) such that the product can be manufactured by some specific manufacturing process, such as rapid prototyping, for example.

Reverse Engineering works in the opposite way. The real product already exists and it is necessary to build up its computer model [2], [5]. The priority of 3D Reconstruction in Reverse Engineering is the precision of the obtained models.

Figure 1: Reverse engineering for building a CAD model of a turbine rotor - GRACO/UnB. In the left, a vertical section of a Kaplan turbine. To the center, a single-blade turbine mockup. To the right, the computer model of the turbine rotor obtained from a contact profile digitizer.

The reconstruction process presents the following stages, [3], [4], [6]:
i) data acquisition from multiple viewpoints: multiple range images are acquired using preferentially optic 3D

digitizers using several view points in order to sweep all the object surface. 3D shape digitizers known as rangefinders record surface or even volume data of objects. In many projects it is necessary to construct a specific rangefinder, such as in the acquisition setup showed in Figure 2.

(a) (b)

Figure 2: Setup for range images acquisition - GRACO/UnB: Photograph of the experimental setup, showing camera, diodes and laser light planes on a (a) plain object and a (b) reduced turbine model.

ii) *registration of range images*: the multiple range images are acquired centered in the sensor coordinate system. It is necessary that they are aligned. Aligning images is to bring them togheter to the same coordinate frame centered in the object. This can be turned possible when recovering the rigid transformations between the images.

iii) *Integration of views:* since the range images are aligned they need to be integrated to shape a monolithic model of the sensed object. The Integration step consists in the generation of surface representations from the aligned data.

The goal of this research is the implementation of specific algorithms to create 3D models through the alignment of multiple scanned range images. The focus is the second step of the reconstruction: the registration of range images. The basic algorithm used here to align range images is the popularly known ICP algorithm (Iterative Closest Point). The main objective is to evaluate the algorithm precision to align several image view points from real objects. The main parameter is exactness, since the models are to be used with Reverse Engineering aplications.

2. The ICP Algorithm

Introduced by Besl and McKay, [1], the ICP algorithm is an iterative and fast approach to align 3D data points. The ICP has several steps to which heuristics can be adjusted for turning it to be faster or more accurate, giving rise to a family of algorithms. The ICP algorithm carries out 3D least-square regressions of rigid objects motions exploring redundant points in the images to calculate the motion parameters and to approximate the views. That means, it is assumed that the images overlap. Another requirement is to supply an initial alignment estimation such that the algorithm refines it iteratively.

3. Results and conclusions

This poster presents the description of steps and methods of 3D recosntruction and the implementation of the ICP algorithm for the alignment of multiple range images. The geometric modeling is oriented to reverse engineering of CAD models, where precision is the most important requirement. Experimental results had demonstrated that the most important drawback of the ICP algorithm is not to guarantee convergence, which depends on many factors such as: quality of the initial alignment, methods of choice and matching of points, methods of cost function minimization and methods to recover 3D motion. To increase the algorithm precision, heuristics are being adjusted to prevent false correspondences, or alternatively, a more robust estimator for the metric of error.

4. References

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