ERCIM "Alain Bensoussan" Fellowship Scientific Report

Fellow: **Ricardo Marroquim**
Visited Location : **Visual Computing Group – CNR of Pisa – Italy**
Duration of Visit: **12 months, 1.11.2008 – 31.10.2009**

I - Scientific activity

The main research focus was related to the mapping of appearance information (color) to 3D geometry. The color information is commonly acquired as photographs while the geometry of the 3D model is obtained with scanning devices, for example. The main problem with previously proposed methods is the assumption of a perfect global alignment of the images with the geometry. However, in real acquisition projects this assumption rarely holds due to a series of issues such as: imprecise calibration of the camera parameters for each photo in relation to the model; distortion and noise introduced by the physical equipments (e.g. camera lenses); low resolution models that do not accurately represent the geometry; lack of geometric or appearance features for alignment; and/or illumination discrepancies between the images. In addition, it is also interesting to have a robust solution able to handle models and photos acquired in different settings and/or by different equipments.

The solution proposed is to correct the misalignments by warping the images locally where they overlap. The technique is also based on various previous works from the host group and integrates with their 3D acquisition pipeline. The method has shown to be robust and is able to handle many difficult cases where previous methods did not render acceptable results. This work not only deals with a challenging research problem, but has also managed to partially solve a practical issue that commonly occurs during scanning campaigns. Moreover, after the correction of the misalignment artifacts, it is possible to produce high quality texture maps or 3D models with color per vertex.

Color per vertex is specially interesting for point based methods, specially when the resolution of the model is very high and memory and performance becomes a issue. This problem is currently being addressed and a point based rendering method developed during my doctorate thesis is being ported to *Meshlab* (a tool developed by the VCG team for geometry processing). Another current research topic is the decimation of very large point clouds guided by the color information acquired from the proposed alignment method. The simplification should take into account not only the geometrical features but also the color details, and in some way propagate the color information of the removed samples to their neighbors. This two topics are the directions of ongoing work and shall be a continuous collaboration between the host group and myself in my future institution back in Brazil.

The other work carried out during my fellow was a continuation of previous collaborations in the area of volumetric visualization and GPU programming. This has resulted in one tutorial and one submitted journal paper.

II- Publication(s) during your fellowship

[1] Ricardo Marroquim, André Maximo, **Introduction to GPU Programming with GLSL**, IEEE Tutorials of Sibgrapi 2009.

Abstract: One of the challenging advents in Computer Science in recent years was the fast evolution of parallel processors, specially the GPU – graphics processing unit. GPUs today play a major role in many computational environments, most notably those regarding real-time graphics applications, such as games. The digital game industry is one of the main driving forces behind GPUs, it persistently elevates the state-of-art in Computer Graphics, pushing outstanding realistic scenes to interactive levels. The evolution of photo realistic scenes consequently demands better graphics cards from the hardware industry. Over the last decade, the hardware has not only become a hundred times more powerful, but has also become increasingly customizable allowing programmers to alter some of previously fixed functionalities. This tutorial is an introduction to GPU programming using the OpenGL Shading Language – GLSL. It comprises an overview of graphics concepts and a walk-through the graphics card rendering pipeline. A thorough understanding of the graphics pipeline is extremely important when designing a program in GPU, known as a shader. Throughout this tutorial, the exposition of the GLSL language and GPU programming details are followed closely by examples ranging from very simple to more practical applications. It is aimed at an audience with no or little knowledge on the subject.

[2] André Maximo, Ricardo Marroquim, Ricardo Farias, **Hardware-Assisted Tetrahedra Projection**, Submitted to IEEE Computer and Graphics Application Journal on 14 September 2009.

Abstract: We present a flexible and highly efficient hardware-assisted volume renderer grounded on the Projected Tetrahedra (PT) method. Unlike recent similar approaches, our method is exclusively based on the rasterization of simple geometric primitives and takes full advantage of graphics hardware. Both vertex and geometry shaders are used to compute the tetrahedra projection, while the volume ray integral is evaluated in fragment shader; hence, volume rendering is performed entirely in GPU within a single pass through the pipeline. We apply a CUDA-based visibility ordering achieving total speed, together with rendering, of over 6 M Tet/s for unstructured datasets. Furthermore, as each tetrahedron is processed independently, we employ a data-parallel solution which is neither bounded by GPU memory size nor does it rely on auxiliary volume information. In addition, iso-surfaces can be readily extracted during the rendering process, and time-varying data are handled without extra burden.

[3] Matteo Dellepiane, Marco Callieri, Ricardo Marroquim, Paolo Cignoni, Roberto Scopigno, **Flow-Based Local Optimization for Image-to-Geometry Projection**, submitted to Eurographics 2010.

Abstract: Multiple photos need to be aligned to 3D geometry in many contexts. Although obtaining a perfect image-to-geometry alignment of a lot of photos (or getting an exact geometry) is possible in theory, it is a very difficult goal to achieve for various (numerical, optical and geometric) reasons. Hence, regardless of the technique used for

blending/merging/combining the overlapping photos, a small misalignment of cameras or a small-scale imprecision of the 3D model leads to blurry details or "ghosting" effects when the images are projected. In this paper we propose a method, based on the computation of Optical Flow between overlapping images, to correct the local misalignment by determining the necessary displacement. The method scales up well with the size of the dataset (both photographic and geometric) and is quite independent of the characteristics of the 3D model (topology cleanliness, parametrization, density). The method is robust and can handle real world cases that have different characteristics: low level geometric details and images that lack enough features for global optimization or manual. It can be applied to different mapping strategies, such as texture or per-vertex attribute encoding.

III -Attended Seminars, Workshops, and Conferences

- **Eurographics 2009**, 30 March – 3 April, Munich, Germany.
- **Sibgrapi 2009**, 11-14 October, Rio de Janeiro, Brazil.
- **Eurographics Italian Chapter**, 22-23 October 2009, Verona, Italy.

IV – Research Exchange Programme (12 month scheme)

1 – INRIA Sophia-Antipolis, 09-13 March 2009
I visited the REVES (Rendering & Virtual Environment with Sound) Group under the leadership of professor George Drettakis. Several members of the group exhibited their works and showed demo application. I also visited the immersive virtual environment and had a meeting with professor Pierre Alliez from the Geometrica Group, and visiting professor Michel van de Panne from British Columbia University. I gave a talk about the research I carried during my doctorate and our first working ideas in Pisa. I also attended a talk given by professor Mikio Shinya from Tokyo University.

2 – ETH Zurich, 5-9 October 2009
I visited the Computer Graphics Lab under the care of professor Markus Gross. I had the opportunity to talk to many pos-doc and PhD students and learn about their works as well as watch four master students thesis defense presentations. It was specially interesting because this lab was one of the pioneers in point based graphics, one of my main research topics. I was given a tour of the Disney Research Center and watched two talks by other invited speakers, one by Bernhard Thomaszewski from Tübingen University and the other by Patrick Ljung from Max Planck Institute. I also had a meeting with professor Renato Pajarola from the University of Zurich.