"Computer Graphics and 3D"

A.A. 2016/2017
Prof. Stefano Berretti

1. Course detailed Program (9 CFU)

The course is articulated into two parts:

- **Computer graphics** (6 cfu): This part includes a comprehensive introduction to basic and advanced computer graphics concepts with the most common techniques for 3D modeling, animation and rendering. OpenGL (in C/C++) is used as graphic library to apply the theory in a series on laboratories;
- **And 3D** (3 cfu): this part includes specific aspects related to the acquisition and processing of real 3D data, focusing on practical applications, like 3D retrieval, 3D recognition, 3D biometrics, etc. Practical examples will be given in Matlab.

COMPUTER GRAPHICS - This part can be delivered as 6cfu course

PART I: Getting Started
Linear transformations: Geometric data types; Vectors Geometric Data Types; Vectors, Coordinate Vectors, and Bases; Linear Transformations and 3 by 3 Matrices; Extra Structure; Rotations; Scales. **Affine transformations**: Points and Frames; Affine transformations and Four by Four Matrices; Applying Linear Transformations to Points; Translations; Putting Them Together; Normals. **Respect frame**: The Frame is Important; Multiple Transformations. **Frames in Graphics**: World, Object and Eye Frames; Moving Things Around; Scales; Hierarchy. **OpenGL**: introduction and basics; VBO, VAO, EBO; OpenGL Shaders. **Qt quick start**. **Hello World 3D**: Coordinates and Matrices; Drawing a Shape; The Vertex Shader; What Happens Next; Placing and Moving with Matrices. **Laboratory in OpenGL**.

PART II: Rotations and Interpolation
Quaternions: Interpolation; The Representation; Operations; Power; Code; Putting Back the Translation. **Balls**: Track and Arc; The Interfaces; Properties; Implementation. **Smooth Interpolation**: Cubic Bezier Functions; Catmull-Rom Splines; Quaternion Splining; Other Splines; Curves in Space. **Laboratory in OpenGL**.

PART III: Cameras and Rasterization
Projection: Pinhole Camera; Basic Mathematical Model; Variations; Context. **Depth**: Visibility; Basic Mathematical Model; Near and Far; Code. **From Vertex to Pixel**: Clipping; Backface Culling; Viewport; Rasterization. **Varying Variables**: Motivating The Problem; Rational Linear Interpolation. **Laboratory in OpenGL**.

PART IV: Pixels and Such
Materials: Basic Assumptions; Diffuse; Shiny; Anisotropy. **Texture Mapping**: Basic Texturing; Normal Mapping; Environment Cube Maps; Projector Texture Mapping; Multipass. **Sampling**: Two Models; The Problem; The Solution; Alpha. **Reconstruction**: Constant; Bilinear; Basis functions. **Resampling**: Ideal Resampling; Blow up; Mip Map. **Laboratory in OpenGL**.

PART V: Advanced Topics
Color: Simple Bio-Physical Model; Mathematical Model; Color Matching; Bases; Reflection Modeling; Adaptation; Non Linear Color. **What is Ray Tracing**: Loop Ordering; Intersection; Secondary Rays. **Light**: Units; Reflection: Light Simulation; Sensors; Integration Algorithms; More General Effects. **Geometric Modeling**: Basic Intro; Triangle Soup; Meshes; Implicit Surfaces; Volume; Parametric Patches; Subdivision

Surfaces. **Animation**: Not Even an Introduction; Interpolation; Simulation; Human Locomotion. **Laboratory in OpenGL**.

Specific devices like **Microsoft Kinect**, **Oculus Rift**, **Leap Motion**, will be also introduced to enable the development of Virtual Reality applications.

3D

PART I: 3D Acquisition, basic Processing, and Printing
3D scanning. **Registration**: ICP, ICP variants, CPD. Geometric modeling: triangulation, mesh, implicit/parametric/subdivision surface. 3D mesh loading and visualization, triangulation, ICP and CPD parametric patch surfaces, subdivision surfaces. **3D shape processing**: smoothing, curvature, geodesic distances. **3D printing**. **Laboratory in Matlab**.

PART II: 3D Shape Analysis
3D shape analysis: shape retrieval/recognition problem, shape index and curvedness, shape distributions, mesh-LBP, mesh-DOG/HOG, mesh-SIFT. **Manifold analysis**: mds, non-euclidean, mds, manifold learning. **Laboratory in Matlab**.

2. Books

Most of the lectures on computer graphics will correspond to chapters in the following books:

[1] Steven J. Gortler, "Foundations of 3D Computer Graphics," The MIT Press, 2012.

[2] John F. Hughes et al., "Computer Graphics, Principles and Practice," Wiley and Sons, Third Edition, 2014.

[3] Graham Sellers et al. "OpenGL SUPERBIBLE", Addison Wesley, Seventh Edition, 2015.

The 3D material will be covered mainly by scientific papers.

3. Organization

Teaching is organized in theory and laboratories. Theory will be presented with slides in class. Laboratories will permit weekly to experiment the theory. OpenGL will be mostly used as graphic library (in C/C++) for the computer graphics part; Matlab will be used for the 3D part. Slides, codes and other materials will be made available on the Moodle platform.

4. Evaluation and Exam

Evaluation will be based on: two assignments during the course; Final project; Oral examination. Laboratory assignments will be part of the course and of the evaluation
Assignments: Two assignments during the course. Assigned in a lab and checked off before the next lab.
Final project (individual or group work, expected workload 3-4 weeks): it will be prepared at the end of the course and discussed before or together with the oral examination. The project will be programmed using OpenGL for CG / Matlab for 3D.
Oral examination: will address a subpart of the course program. The subpart will be decided depending on the project subject.
The final grade will combine the three evaluations for laboratory assignments, final project, and oral examination.

5. Scientific Curriculum of the Teacher

Teacher: Prof. Stefano Berretti

Stefano Berretti is an Associate Professor at the Department of Information Engineering (DINFO) of the University of Firenze, Italy, and at the Media Integration and Communication Center (MICC) of the same University. He received the laurea degree in Electronics Engineering and the Ph.D. in Informatics Engineering and Telecommunications from the University of Firenze, in 1997 and 2001, respectively. In

2000, he received the post-laurea degree in "Multimedia Content Design" from the Master in Multimedia of the University of Firenze. From 2001 to 2002 he worked as post-Ph.D. researcher at the Department of Systems and Computer Science of the University of Firenze, where he has been Assistant Professor from 2002 to 2011.

Stefano Berretti teaches "*Fundamentals of Computer Programming*" at the first level graduate program in Computer Engineering, at the School of Engineering of the University of Firenze, and "*Computer Graphics and 3D*" at the second level graduate program (Laurea Magistrale) in Computer Engineering, at the School of Engineering of the University of Firenze.

His current research interests are mainly focused on content modelling, retrieval, and indexing of image and 3D object databases. Recent researches have addressed 3D object retrieval and partitioning, 3D face recognition, 3D facial expression recognition. On this latter research subject, in October-November 2009, Stefano Berretti has been visiting professor at the Institute TELECOM, TELECOM Lille 1, in Lille, France. During spring 2000, he has been also visiting researcher at the Indian Institute of Technology (IIT), in Mumbai, India, working on themes related to image content description and retrieval. In June 2013, he joined the Khalifa University of Science, Technology and Research (KUSTAR), Sharjah campus, United Arab Emirates, as a visiting Professor working on the topic of 3D mesh analysis and representation. Stefano Berretti is author of more than 120 publications appeared in conference proceedings and international journals in the area of pattern recognition, computer vision and multimedia. He is in the program committee of several international conferences and serves as a frequent reviewer of many international journals. He has been co-chair of the Fifth Workshop on Non-Rigid Shape Analysis and Deformable Image Alignment (NORDIA'12), held on October 7, 2012, in conjunction with ECCV 2012, Firenze, Italy. Stefano Berretti will serve as leading guest editor of the special issue on "Representation, Analysis and Recognition of 3D Humans", *ACM Transactions on Multimedia Computing, Communications and Applications* (ACM TOMM), with scheduled publication on late 2017.

Stefano Berretti is member of the Group of Italian Researchers on Pattern Recognition (GIRPR), affiliated to the IAPR, and member of the IEEE.

6. Office hours

Thursday 14:30 -16:30, room 473, second floor, School of Engineering, via Santa Marta 3.