Futuro in Ricerca 2013 – Numerical Analysis

Design of Reliable, Exact, and Application-oriented techniques for geometric Modeling and numerical Simulation (DREAMS)

DREAMS Workshop
Dipartimento di Matematica e Informatica "Ulisse Dini"
Viale Morgagni 67/A, 50134 Florence
February 19 - 20, 2015

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Thursday 19, 2015

14,00 - 14,10 DREAMS overview #1

14,10 - 14,50 *Alessandra Sestini* (University of Florence)
14,50 - 15,30 *Cesare Bracco* (University of Florence)
15,30 - 16,10 *Duccio Mugnaini* (University of Insubria)

16,10 - 16,40 Coffee break

16,40 - 17,20 *David Großmann* (MTU Aero Engines AG, Munich)
17,20 - 18,00 *Tadej Kanduc* (Faculty of information studies Novo mesto)

Friday 20, 2015

09,00 - 09,10 DREAMS overview #2

09,10 - 09,50 *Francesco Calabrò* (University of Cassino and Southern Lazio)
09,50 - 10,30 *Francesca Pelosi* (University of Rome "Tor Vergata")

10,30 - 11,00 Coffee break

11,00 - 11,40 *Carlo Garoni* (University of Rome "Tor Vergata")
11,40 - 12,20 *Fabio Roman* (University of Turin)

List of abstracts

Thursday 19, 2015 14,10 - 14,50

Recent advances on PH curves and applications

Alessandra Sestini (University of Florence)

In this talk I will present three recent researches in the field of Pythagorean Hodograph curves and applications. The first two studies are aimed to increase the PH portability, hopefully making them more attractive also for industrial applications. In particular, the first one concerns the derivation of the B–spline representation of a C^2 PH spline and the definition of an algorithm for its local modification. On the other hand, the second study presents a robust strategy for identifying PH curves in the set of general Bézier curves and for obtaining their pre–image. Finally, the third result is a new application of PH curves to surface modelling. Specifically, I will present a new scheme for defining a tensor product patch having a family of isoparametric PH curves and interpolating four assigned boundary curves. Some related open problems will be also outlined during the talk.

Thursday 19, 2015 14,50 - 15,30

Spline spaces for adaptive techniques

Cesare Bracco (University of Florence)

During the last decade, the study of spline spaces allowing local refinements on the underlying topology has been significantly developed. In fact, such a feature makes possible to employ splines in new and more efficient adaptive approximation techniques and in adaptive (and therefore computationally cheaper) algorithms for modelling. In this talk, we will discuss some relevant approximation results concerning different approaches to construct adaptive spline spaces (mainly, we will consider T-spline spaces, spline spaces over T-meshes and hierarchical spline spaces).

Thursday 19, 2015 15,30 - 16,10

Smooth path planning with obstacle avoidance based on PH splines

Duccio Mugnaini (University of Insubria)

Accurate path planning enables autonomous mobile robots to follow an optimal collision free path from a given start position towards a certain goal point without colliding with obstacles in the workspace area. In our work we have developed offline path planning algorithms that allow us to find

a collision–free path in a stationary enviroment. The curvilinear path is constructed in two steps. First, we define a piecewise linear path P by exctracting the shortest path, or a related suitable modification, from the visibility graph or the trapezoidal map associated with the given scenario. Second, we construct the curve by using a G^1 interpolation algorithm based on PH quintic splines. The scheme interpolates the vertices of P and, by using tension parameters, the resulting interpolant can be stretched as much as desired on P. In this context, besides their well known fairness, a significant feature of PH curves is given by the possibility of an easy and exact computation of the arc length, an important feature to properly define a trajectory along the smooth collision–free path.

Thursday 19, 2015 16,40 - 17,20

Geometric modeling in an industrial environment

David Großmann (MTU Aero Engines AG, Munich)

The overall design of modern turbine engines is one of the most challenging tasks in todays engineering world comprising newest technologies in engineering design and simulation, material science and complex manufacturing processes. Within the design process, the capability of fast and robust geometric algorithms for an automatic 3D shape optimization of turbine and compressor blades is a key technology for creating highly efficient engines minimizing flow losses.

After a short introduction on aircraft engines, the talk will give an overview about the currently used geometric modeling framework at MTU Aero Engines combining engine-oriented CAGD algorithms with a commercial CAD kernel, a modern software architecture and a user-friendly interface. Furthermore, we will focus an three different aspects within the engine design process: First, the generation of blending surfaces as an academia 'solved' problem topic which is still challenging in industry. Second, the way of adaptive spline techniques, i.e. truncated hierarchical B-splines (THB-splines), into industry. Third, experiences with isogeometric analysis for the simulation of turbine blades which will clarify to mind the gap between CAD and CAE. Some thoughts on bringing research and industry together in the field of geometric modeling will conclude the talk.

Thursday 19, 2015 17,20 - 18,00

Approximation and interpolation splines on triangulations

Tadej Kanduc (Faculty of information studies Novo mesto)

In the talk I will briefly present research results of my PhD. Firstly, some new results on correctness of polynomial Lagrange interpolation problem on triangles are presented. L. L. Schumaker stated the conjecture that for uniformly distributed domain points on triangle the corresponding collocation matrix has positive principal minors. The conjecture on the minors for polynomial total degree ≤ 17 and for some particular configurations of domain points is confirmed. In the parametric case, two novel constructions solving Hermite interpolation problem (interpolation of points and tangent planes) are proposed. In the first one, a construction of good boundary curves of cubic triangular patches is analysed. The curves minimise an approximate strain energy functional. The remaining free parameters of the spline surface are set in such a way that the patches have small Willmore energy. Next, a generalisation of macro-elements to the parametric case is considered. Hermite interpolation by two types of parametric C^1 macro-elements on triangulations is presented in detail. Cubic triangular splines interpolate points and the corresponding tangent planes at domain vertices and approximate tangent planes at midpoints of domain edges. Quintic splines additionally interpolate normal curvature forms at the vertices. Extensions to G^1 smoothness conditions is also studied. At the end I will present a practical application how splines on triangulations can be used to find the optimal mountain ascent. The main novelty is that we do not use a common linear spline to reconstruct the surface from points but use a smooth spline that better represents the terrain.

Friday 20, 2015 09,10 - 09,50

Reliable, exact or application-oriented quadrature rules

Francesco Calabrò (University of Cassino and Southern Lazio)

In this talk, we will discuss the use of quadrature rules in different settings. Mainly, we will consider cases where the integrals to be calculated have a product structure and one of the terms has some specific feature that has to be explored properly in order to obtain a "good" quadrature rule. This is the case of the two main applications that we will deal with: matrix assembly in Isogeometric Analysis and quadrature with respect to singular measures. Both the theoretical construction involving some application-oriented task and the computational aspects of the application of the quadrature rule will be considered. The tentative aim of this talk is to underline — with some example — how quadrature rules can influence both the kind of approximation and the overall computational cost.

Friday 20, 2015 09,50 - 10,30

Box splines and isogeometric analysis

Francesca Pelosi (University of Rome "Tor Vergata")

In the context of Isogeometric Analysis (IgA) and in the numerical treatment of PDEs in general, efficient local refinement procedures and an easy modeling of complex geometries are crucial ingredients. The tensor-product approach, based on NURBS and their generalization, is not suitable for efficient local refinement, due to its inherent rectangular topology. Moreover, it makes the modeling of "non rectangular" regions a hard task, often accomplished by inserting unnatural singularities in the geometry map.

Splines over triangulations offer the possibility of both efficient local refinement and easy modeling of complex geometries. Nevertheless, dealing with completely general triangulations is quite difficult, because only in few cases suitable bases for the corresponding spline spaces are available. Moreover, their extension to the trivariate setting is computationally prohibitive in practice. On the other hand, splines on regular triangulations are equipped with suitable bases, so-called box splines, which are the natural bivariate generalization of univariate B-splines and can be extended to higher dimensions. Therefore, they can be seen as an intermediate step between tensor-product structures and general triangulations and can provide an interesting alternative to NURBS in IgA.

In this talk we report about our ongoing work concerning the use of bivariate box splines defined on regular three-directional meshes in IgA. A first effort in this direction has been devoted to a proper treatment of the PDE boundary conditions. We also revisit in this perspective standard tensor-product B-splines.

Friday 20, 2015 11,00 - 11,40

Symbol approach in IgA matrix analysis:
from the spectral analysis to the design of fast solvers

Carlo Garoni (University of Rome "Tor Vergata")

Isogeometric Analysis (IgA) is a novel but well established paradigm for solving problems governed by PDEs. The key ingredient in IgA is to use the same basis functions to describe the geometry of the physical domain and to approximate the solution of the differential problem. In its original formulation, IgA is a Galerkin approach based on NURBS, because they are the undisputed standard in CAD systems.

Any discretization of a linear PDE, for some sequence of stepsizes h tending to zero, leads to a sequence of linear systems $A_m x_m = b_m$, where $\dim(A_m)$ increases when h tends to 0. This is what happens also in the IgA case. To properly face the solution of such linear systems, it is important to understand the spectral properties of the matrices A_m. The spectral distribution of a sequence of matrices is a fundamental concept. Roughly speaking, saying that the sequence of matrices A_m has a spectral distribution described by a function f means that the eigenvalues of A_m behave as a sampling of f over an equispaced grid of its domain. In this case, the function f is called the symbol of the sequence of matrices A_m.

In this presentation we discuss the case of stiffness matrices arising from the IgA process. We compute and analyze their symbol by exploiting the properties of cardinal B-splines. We also illustrate how the information contained in the symbol can be applied to design/analyze optimal two-grid and multigrid methods, as well as multi-iterative methods involving the PCG as a smoother in the multigrid procedure.

Friday 20, 2015 11,40 - 12,20

Spectral analysis of matrices in IgA collocation and Galerkin methods with GB-splines

Fabio Roman (University of Turin)

We are interested in the numerical solution of second order elliptic problems. Using either a collocation or a Galerkin approach requires to solve linear systems. Information about the spectral properties of the related matrices (such as non-singularity, conditioning, spectral distribution and clustering of the eigenvalues) is extremely important for the design of fast solvers for these linear systems, in order to pursue an applicative interest. We study such properties in the context of isogeometric analysis based on trigonometric or hyperbolic GB-splines. The main focus is on the Galerkin framework, but we will also show some results in the collocation case.