Marie-Curie Initial Training Network
13 PhD studentships: Early Stage Researchers (ESR)
2 Post-Docs: Experienced Researcher (ER)
Integrating Numerical Simulation and Geometric Design Technology (INSIST)

SEVENTH FRAMEWORK PROGRAMME

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYᴅᴅ

Cardiff University School of Engineering
2 PhD studentships/Marie Curie Early Stage Researchers in Computational Mechanics
1 Postdoc/Marie Curie Experienced Researcher in Computational Mechanics

Cardiff University School of Computer Science and Informatics
2 PhD studentships/Marie Curie Early Stage Researchers in Computer Aided Design (CAD)

Salaries: £33138 per annum for PhD fellowships
£50,467 per annum + monthly mobility allowance for Post-Docs

Isogeometric Analysis

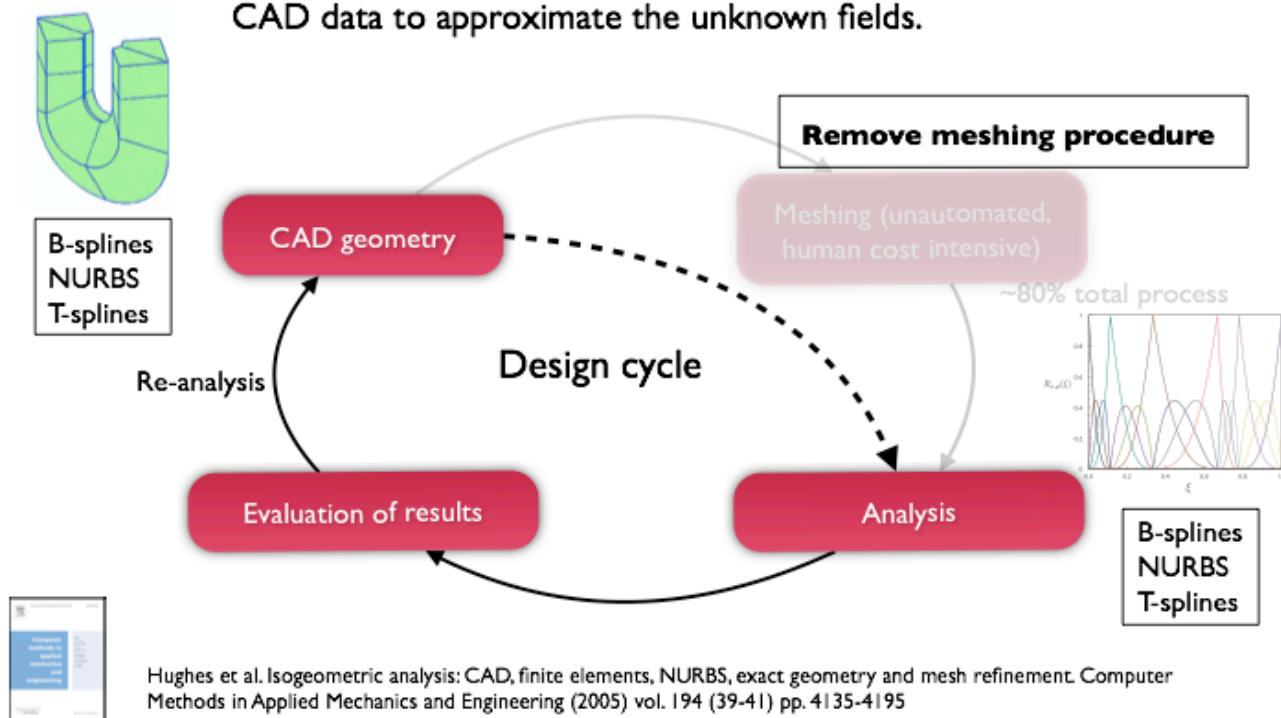**Idea**: use the same functions that are used to approximate CAD data to approximate the unknown fields.

B-splines
NURBS
T-splines

Remove meshing procedure

Meshing (unautomated, human cost intensive)

~80% total process

CAD geometry

Design cycle

Re-analysis

Evaluation of results

Analysis

B-splines
NURBS
T-splines

Hughes et al. Isogeometric analysis: CAD, finite elements, NURBS, exact geometry and mesh refinement. Computer Methods in Applied Mechanics and Engineering (2005) vol. 194 (39-41) pp. 4135-4195

PhD Fellowships and Post-Docs Marie Curie Fellows in Computational Mechanics

Project summary

The objective of our proposed research is the development and implementation of the next generation design/simulation methods. The key outcome of this research is a system/methodology that allows the analysis, simulation and design of engineering products in a more efficient way, reducing costs and offering the unique opportunity for European CAD and CAE companies being ranked in first place. This project aims to extend the IA concept of Hughes and co-workers who focused on the unification of CAD and CAE

whereas we aim to generalize this idea to unify pre-processing (in general) and analysis; in this sense all our methods are isogeometric since they exploit the shape functions to discretize the design model also in the context of numerical analysis (the simulation model). Another main advantage of the proposed generalized isogeometric analysis is its wide applicability. This requires a strong collaboration between universities and companies, which is reflected in the composition of our team. The research programme is structured into 4 main sub-programmes addressing the most urgent issues in the generation and development of efficient design and simulation models:

Programme A: CAD Feature Processing (2 projects).
Programme B: Pre-Processing and Mesh generation (4 projects).
Programme C: Numerical Analysis/CAE (6 projects).
Programme M: Voxel based analysis (1 project).

Specific projects

Fellow: ESR5
Title: Preprocessing for isogeometric and meshless methods
Research Objectives:
• Develop pre-processors for voxel-based data for truly meshless methods
• Develop automatic adaptive refinement and coarsening during pre-processing
• Develop algorithms to automatically detect boundary conditions from the input data
• Analyse the resulting approximation power of the methods.
Description of work (referring to the relevant WPs) and research methodology:
ESR5 deals with the effective pre-processing for meshfree analysis which is the key for an effective MM. The geometric data can be obtained either by CT-scans, surface models, point clouds or other software. MMs do not require any geometric description of an object. However, it has to be ensured that the meshfree shape functions cover sufficiently the geometry. Otherwise, artificial defects are introduced. Therefore, the domain of influence of meshfree shape functions were usually chosen extensively large. Commonly, meshfree shape functions are based on a tensor-product (as in IA) or on radial basis functions. Compu-tationally more effective shape functions employ ellipsoidal domains of influence. However, for optimal pre-processing, adaptive refinement and coarsening procedures (see project C5) are needed in order to ensure that the geometry of the object represented by point clouds is covered properly. Adaptive refinement is particularly simple in MMs because of the absence of a mesh. Moreover, for the imposition of boundary conditions, algorithms that reliably detect the boundaries are needed. The construction of the meshfree shape functions including adaptive refinement and coarsening as well as algorithms for detecting boundaries will be studied in this project. We will use a truly MM that does not require any background mesh.
Deliverables:
• Open Source proto-type codes
• publication in international journals

Fellow: ESR12

Title: Model Order Reduction Methods: towards Rationalised Computational Expense
Research Objectives:
• Development of generalized efficient and robust model order reduction algorithms that can be exploited in MMs, finite element methods and IA (WP3, C5)
• Development of error indicators and novel system approximation techniques if tackling nonlinear problems.
• Development of model order reduction and efficient solvers for Cartesian (X)FEM
• Development of prototype codes
• Collaboration with WP3 and WP4
• Identification and solution of industrially relevant test bed problems.
Description of work (referring to the relevant WPs) and research methodology:
Project C6 concerns the development and implementation of effective model reduction technique. This project is another key ingredient of an efficient numerical method. It is closely linked to all projects in programme C, but its implementation can be done independently. The fundamentals of adaptive model order reduction have been developed by the participants in Cardiff. However, the proposed method lacks reliable error indicators. Indeed, model order reduction can be seen as a further approximation introduced on top of space discretization (FEM, XFEM, MMs, NURBS) and time discretization. In this respect, it is necessary to link the error introduced in the reduced order model to the error introduced by the space and time discreti-zations. The results of this collaboration will benefit all the partners of this program, as the developed model order reduction is applicable to any problem, regardless of the particular discretization techniques used.
Deliverables:
• Open Source proto-type codes
• Publications in international journals

Fellow: ER2
Title: From CAD to Analysis
Research Objectives:
• Development of 3D isogeometric boundary element methods (BEM).
• Coordination of the CAD and CAE work performed by the ESRs.
• Coupling with the model order reduction and reanalysis work to investigate the feasibility of quasi-interactive stress distribution display using isogeometric BEM.
Description of work (referring to the relevant WPs) and research methodology:
A key task of the ERs in project G is to coordinate and support the collaboration and work be - tween the Engineers and Computer Scientists at CU. This task can only be accomplished by an ER until the ESRs have reached a certain maturity.
Isogeometric analysis is a key link between CAD and CAE and the ER will be active in the development of isogeometric boundary element methods in 3D. This work has been started in Cardiff already in collaboration with Weimar (Simpson, Bordas, Kerfriden, Rabczuk) and will be continued.
Coupled with model order reduction, this can offer the perspective to achieve quasi-interactive results where the CAD model is modified and the stress distribution obtained quasi-interactively.
Deliverables:
• Open Source proto-type codes
• Publications in international journals

Candidates

Candidates with experience or interest in **at least one** of the following areas of computational mechanics will be considered:

     - model order reduction (e.g. proper orthogonal decomposition – POD, reduced basis method)
     - advanced discretisation techniques (extended finite element methods/meshless methods)
     - error estimation and adaptivity (if possible in the context of meshless or boundary element methods)

- isogeometric analysis
- boundary elements

Environment The three successful candidates will join the Research Group led by Prof. Stéphane Bordas within the institute of Mechanics and Advanced Materials (iMAM), at Cardiff School of engineering. http://www.engin.cf.ac.uk/research/resInstitute.asp?InstNo=13 This group will be composed in 2012 of at least 5 PhD students and four post-doctoral fellows.

Related projects
The project will be cross-fertilised by ERC Starting Independent Research Grant led by Prof. Bordas and Dr. Pierre Kerfriden in the area of surgical simulation, two ongoing EPSRC Projects on error estimation for cracks using XFEM: http://gow.epsrc.ac.uk/ViewPerson.aspx?PersonId=-160701 and an IRSES (FP7) grant on multiscale fracture.

HOW TO APPLY

Job description PhD Fellowships
http://www.cardiff.ac.uk/jobs/resource/4796.17264.jobDescriptionFile.eng.doc

Application form for PhD Fellowships
http://www.cardiff.ac.uk/jobs/resource/4796.17040.applicationForm.eng.doc

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Application form for Post-Docs/Experienced Researchers
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Links

Professor Bordas' research portfolio: http://www.researcherid.com/rid/A-1858-2009
iMAM webpage: http://www.engin.cf.ac.uk/research/resInstitute.asp?InstNo=13
Professor Bordas' blog on iMechanica for details on the projects and additional research openings: http://imechanica.org/blog/700