EXPLICIT DYNAMICS IGA: LR B-SPLINE IMPLEMENTATION IN THE RADIOSS SOLVER

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ABSTRACT

Isogeometric analysis has shown to be a very promising tool for an integrated design and analysis process [1]. A challenging task is still to move IGA from a proof of concept to a convenient design tool for industry and this work contributes to this endeavor. This communication deals with the implementation of IGA into Altair's Radioss explicit solver in order to address crash and stamping applications.

To this end, the necessary ingredients to a smooth integration of IGA in a traditional finite element code have been identified and adapted to the existing code architecture. First, a solid NURBS element has been developed in Radioss and then, an existing contact interface has been extended in order to work seamlessly with both NURBS and Lagrange finite elements, using a node to surface formulation. Some academic and simple industrial cases will be presented to show the obtained results and the relevance of the retained solution.

Mesh refinement is the third ingredient added to this integration, as local refinement is needed for solution approximation and computational efficiency. Several existing splines technologies with local refinement were compared in terms of implementation and data management requirements, amongst which Hierarchical B-Splines [2], Truncated Hierarchical B-Splines [3] and Locally Refined B-Splines [4], the latter being implemented into Radioss. The approach is tested on industrial benchmarks such as metal stamping and drop tests, generally used for assessing commercial code performance.

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A COMPARISON OF FOUR ISOGEOMETRIC SHELLS

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ABSTRACT

LS-DYNA® currently has five formulations for isogeometric shells: two Reissner-Mindlin shear-deformable shells, two Kirchhoff thin shells, and a blended shell. In this presentation, we focus on the first four which offer two different shell mechanics formulations and two different approaches to interpolating the fiber mechanics in an effort to understand how the different choices affect the shell element performance in a variety of benchmark problems.

An Octree-based Adaptive Subdivision Algorithm for Slicing Heterogeneous Solid using Trivariate T-splines

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ABSTRACT

Heterogeneous trivariate T-splines greatly facilitate the designing process of arbitrary solid objects with complex geometries and interior heterogeneous materials. This work applies it to additive manufacturing (AM) based on fused deposition modeling (FDM) technology directly.

In this paper, a direct slicing algorithm for heterogeneous trivariate T-splines is proposed. Initially, a harmonic trivariate T-splines is constructed with its radial distribution direction through along the slicing direction. Then, an octree-based adaptive subdivision algorithm is used to directly generate the slicing layers with heterogeneous materials. Finally, for each slicing layer, the interior heterogeneous materials are discretized as finite separate partitions with user-defined boundary conditions, and then boundary contours of each partition are extracted and paired as the rules of CuraEngine to generate the scan paths for FDM machines equipped with multi-nozzles. Experimental results indicate that this algorithm is effective and reliable. The quality of AM can be enhanced at both the designing and slicing stages. This direct slicing algorithm discussed here will be a powerful supplement to maintain the integrity of the model throughout the process from the concept to the final product in AM, especially for solid objects with multiple materials.

Because of the local refinement of T-splines and adaptive structure of T-mesh, the proposed slicing algorithm can naturally follow the radial distribution direction of arbitrary harmonic field. Whereas, how to choose an optimal harmonic field to determine slicing direction automatically is still an open question. For tight integration of Design-Through-Analysis, isogeometric analysis may guide to choose the optimal harmonic field by processing some analysis results based on actual manufacturing situation.

Coreform: commercializing IGA

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ABSTRACT

Isogeometric analysis has been a promising academic field for over a decade. In the past few years, commercial interest in IGA has begun to increase. Coreform LLC (formerly known as Isogeometrx LLC) was formed in 2014 to improve CAD and CAE through commercializing isogeometric analysis technologies.

In this talk, we will share our perspective on the market opportunity for IGA. We will identify which application areas of IGA have the potential to deliver the most immediate value to customers. We will discuss other emerging technologies that also have the potential to disrupt the commercial CAE industry and give our perspective on how IGA efforts can be focused on unique strengths that offer the greatest chance at adoption and differentiation.

While we believe enough has been scientifically proven about the superiority of IGA to warrant commercial efforts, there are still outstanding research questions that if satisfactorily addressed, would provide substantial commercial value. We will give our perspective on the most important open research questions that might positively impact areas of interest to our commercial partners. An integral part of the isogeometric vision is that the same geometry be used to define the CAD as is used in the simulation. We will share our opinion of the most promising ways to push forward CAD authoring tools that generate analysis-suitable geometry. Finally, we will share some updates and results on our own progress towards making a commercial case for IGA.

We hope that this talk will provide a commercial point of view that might give some perspective and motivation to IGA researchers. We also hope this will be informative to commercial attendees who might be considering investigating IGA, to help them understand both the current state and the future potential of IGA applications.

IMMERSOGEOMETRIC METHODS FOR ROTORCRAFT SIMULATION

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ABSTRACT

Immersogeometric Analysis (IMGA) is a recent outgrowth of Isogeometric Analysis (IGA) that directly addresses the issue of rapid simulation of geometrically complex models generated in CAD systems. IMGA foregoes a labor-intensive and, often times, manual process of analysis-suitable model generation. Instead, in IMGA, computational analysis is carried out by immersing the CAD geometry, described in terms of a variety of standard B-rep technologies, directly into a background mesh that does not conform to the object's boundaries and that is simple to generate. IMGA was first developed for medical-device fluid-structure interaction (FSI) simulations, and recently extended to handle applications such as hydraulic arresting gears. Because of the relative simplicity of analysis-suitable model generation, IMGA technology lends itself nicely to design optimization through simulation. However, as a trade-off, the analyst must be aware of the possibly lower quality of the numerical solution near the object's boundaries due to the fact that object cuts through the computational mesh in an arbitrary fashion.

In this work, we illustrate how a recently developed compressible-flow version of IMGA can be applied to efficiently simulate the aerodynamics and FSI of a full-scale military rotorcraft: the H-60, as developed under US Navy STTR N17A-T009 (Prediction of Rotor Loads from Fuselage Sensors for Improved Structural Modeling and Fatigue Life Calculation). The key idea is the observation that the most aerodynamically important surfaces are the rotor blades, which are not so geometrically complex as to present significant challenges to mesh generation. On the other hand, fuselage and landing gear, which are much more challenging to mesh, are not as critical from the aerodynamics standpoint. Using this observation, we illustrate how a multi-domain approach, which utilizes a boundary-fitted methodology for rotor blades and IMGA elsewhere, delivers high accuracy with much greater efficiency relative to traditional simulation approaches.

ISOGEOMETRIC METHODS IN BRIDGE ENGINEERING

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ABSTRACT

Wind actions and aerodynamic stability are amongst the major concerns on long-span bridges. Such effects are traditionally studied in the wind tunnel; however, computational power and technology have made Computational Fluid Dynamics (CFD) and Fluid-Structure Interaction (FSI) methods viable alternatives. We present an investigation of using Isogeometric Analysis (IGA) as the underlying basis for turbulent flow computations on moving domains. With this framework we determine the wind-structure interaction transfer functions for the self-excited- and turbulence-induced forces. Comparisons with wind tunnel experiments show good agreement, and companion finite element analyses prove that IGA outperform the classical finite elements.

LATEST DEVELOPMENTS OF THE ANSA PRE-PROCESSOR FOR IGA APPLICATIONS OF LS-DYNA, IN THE AUTOMOTIVE INDUSTRY.

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ABSTRACT

IsoGeometric analysis (IGA) is maturing to offer adequate benefits for simulation processes and be applied industrially as a solid simulation methodology. Extensively used in the automotive industry for Crash analyses, LS-DYNA is the first solver to provide IGA features to realize these benefits.

In the automotive industry however, the geometric entities of a vehicle's parts, created by CAD systems, are not in a form suitable for IGA. These parts are not watertight, they are modeled as solids, and usually have a very large number of trimmed surfaces. Such issues however, have been long addressed, for the typical FE mesh generation processes, which are established in numerous industries. Moreover, to apply the IGA in already established simulation processes, the mesh generation phase would have to be replaced with the IGA ready geometry generation, while also, the overall pre-processing should be adapted to follow the new paradigm.

To address the above-mentioned issues, BETA CAE Systems and LSTC have joined their efforts to develop all the required tools and workflows to enable analysts to move to the IGA era. These tools, will allow for the creation and analysis of shell structures models consisting of multi patched trimmed surfaces, along with all the necessary functions to apply boundary, and initial conditions for crash load cases. In this presentation these developments are presented.

MACHINE LEARNING FOR DIAGNOSTICS AND PATIENT-SPECIFIC DESIGN OF BIOPROSTHETIC HEART VALVES

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ABSTRACT

Patient-specific diagnostics and customized medical device designs can reduce mortality and morbidity due to cardio-vascular diseases by personalizing the treatment. Predictive biomechanics-based approaches such as isogeometric analysis of heart valves to compute the coaptation area or the effective orifice area for a patient [1, 2] can refine the diagnosis of the heart condition with additional information that is difficult to obtain directly through medical imaging. Such valve performance measures may help reduce surgeries and premature replacement of heart valves. However, such analyses are often computationally intensive and require computational expertise making them inaccessible to surgeons in a clinically viable time frame. Deep learning is an emerging area of research that has proven to be effective in learning complex phenomena with the use of network architecture such as convolutional neural networks [3], autoencoders [4], etc. In this work, we introduce a deep convolutional autoencoder framework (called as DLFEA) to learn the finite element deformation biomechanics of heart valves using a suitable representation of the geometry based on non-uniform rational B-splines (NURBS) surfaces. The DLFEA framework can accelerate the diagnosis by eliminating the time-consuming biomechanics simulations while obtaining the same fidelity in predicting the valve deformations. In addition, a parametric design framework can be built on top of the DLFEA framework that can be used to design patient-specific bioprosthetic heart valves. We present statistical results that demonstrate the robustness of the DLFEA framework and also the applicability of the framework for design optimization. Such a tool can ultimately provide interactive decision support for clinicians and surgeons to aid in diagnosis and surgical planning, thereby improving patient care.

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HYBRID 3D MODELING WITH CGM: A NEW MODELING KERNEL FROM DASSAULT SYSTÈMES SPATIAL CORPORATION

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ABSTRACT

Dassault Systèmes Spatial Corporations's CGM Polyhedra brings a new modeling flexibility by leveraging polygonal models inside CGM Core modeler, a powerful 3D modeler in the heart of Dassault Systèmes 3DEXPERIENCE platform. CGM Polyhedra offers tools for polygonal model repair and cleanup as well as an expanding set of hybrid modeling operations. An overview of existing functionality and sample workflows will be provided along with a brief discussion of current development initiatives and future directions.

NUMERICAL SIMULATION OF MATERIAL TRANSPORT IN COMPLEX NEURONS USING ISOGEOMETRIC ANALYSIS

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ABSTRACT

Neurons exhibit great diversity and complexity in their shapes of neurite networks. However, how their shapes mediate their functions remains a fundamental yet unanswered question. Answering this question is critical to understanding the physiology and disease of neurons. Here, we develop an isogeometric analysis (IGA) based solver to simulate the material transport in complex neurite networks of neurons. The material transport process is described by generalizing a one-dimensional motor-assisted transport model of intracellular particles to three dimensions. We start the modeling and simulation from the single-pipe, bifurcation and simple tree structures, which are the basic structural units of the complex neurite network in neurons. We use a skeleton sweeping method to construct hexahedral meshes for them. To solve the transport equations, we first develop a Navier-Stokes equation solver based on the variational multiscale method (VMS) to obtain the velocity field in neurons. Then, we develop the solver of the motor-assisted transport equations based on the streamline upwind/Petrov-Galerkin method (SU/PG). Finally, specific boundary conditions and initial conditions based on experiments are set to validate the simulations. In summary, our simulation can reliably reproduce the dynamic spatial distribution of cellular particles in neurons.

PENALTY COUPLING OF NON-MATCHING ISOGEOMETRIC KIRCHHOFF–LOVE SHELL PATCHES WITH APPLICATION TO COMPOSITE WIND TURBINE BLADES

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ABSTRACT

Isogeometric analysis (IGA) has been revolutionary in the realm of Kirchhoff–Love thin-shell analysis because the high-order basis functions employed naturally satisfy the requirement of C^1 continuity. Still, engineering models of appreciable complexity, such as wind turbine blades, are typically modeled using multiple surface patches and, often, neither rotational continuity nor conforming discretization can be practically obtained at patch interfaces. A penalty approach for coupling adjacent patches is therefore presented. The proposed method imposes both displacement and rotational continuity and is applicable to either smooth or non-smooth interfaces and either matching or non-matching discretization. The penalty formulations require only a single, dimensionless penalty coefficient for both displacement and rotation coupling terms, eliminating the problem-dependent nature of the penalty parameters. Using this coupling methodology, numerous benchmark problems encapsulating a variety of analysis types, geometrical and material properties, and matching and non-matching interfaces are addressed. The coupling methodology produces consistently accurate results throughout all tests. Further, the suggested penalty coefficient of $\alpha = 10^3$ is shown to be effective for the wide range of problem configurations addressed. Finally, a realistic wind turbine blade model, consisting of 27 patches and 51 coupling interfaces and having a chordwise- and spanwise-variant composite material definition, is subjected to buckling, vibration, and nonlinear deformation analysis using the proposed approach.

PATIENT-SPECIFIC VASCULAR MODELING OF AGEING AORTIC ARTERY USING T-SPLINES

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ABSTRACT

Image-based patient-specific vascular modeling became very popular in the field of cardiovascular biomechanics as a powerful instrument for the detection of aortic diseases. In order to be effective and to be included in the decision time-line of the clinical routine, the image-based patient-specific vascular modeling pipeline, typically involving three steps, i.e. image processing, analysis suitable model generation and analysis, should provide a precise representation of the anatomical district under study and reduced computational costs. These requirements match the key features of Isogeometric Analysis (IgA). Hence, we propose a computational framework, based on IgA and on T-spline technology, to be applied to the study of a large population of patients, stratified by age and characterized by complex branched structures. In particular, we would like to demonstrate how the creation of patient-specific IgA-suitable models of the complete aortic artery can be done quasi automatically and in a short time, by performing a limited number of relatively easy steps. For each patient of each age group, the complete aortic artery is segmented from CT images and post-processed to obtain a quadrangular surface mesh. The corresponding T-spline surface mesh is created by means of the Autodesk T-splines plug-in for Rhino, post-processed and imported in the IgA embedded module of the finite element program FEAP, where it is analyzed as a thin shell body. Structural inflation simulations are performed using a pressure derived from CFD analyses; patient-specific age-based values for shell thickness and circumferential elastic modulus are derived and employed together with Robin boundary conditions to simulate the organs surrounding the aortic artery. The creation of the T-spline surface mesh takes around 20 minutes to complete whereas inflation simulations take about 15 minutes to run. Given these results, we think that the proposed simulation models and analysis settings represent a good compromise between computational time and accuracy and can therefore represent the most adequate starting point for the development of a tool to be used for the study of large population of patients as well as in the daily medical practice.

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PREDICTION OF LOCAL DEFORMATION AND FRACTURE FOR HIGH STRENGTH STEEL MEMBERS USING THE ISOGEOMETRIC ANALYSIS

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ABSTRACT

In order to reduce automobile body weight and improve the crashworthiness of lightweight vehicles, crash simulation has become an indispensable tool in automotive industries. The use of high strength steels in lightweight vehicles leads to dramatic fuel savings and is greatly increasing in the vehicles these years. Meanwhile the high strength steels become less ductile in general. As the results, the fracture of steel material and spot weld failure may occur due to local deformation. Therefore, the accuracy improvement of local deformation to predict the fracture is highly demanded by automotive industries. However, current shell elements of FEM use bilinear shape functions which are difficult to predict a complicated local deformation with high accuracy. To resolve this problem, Isogeometric analysis was considered as a better alternative. We developed a software tool which can convert CAD data to analysis-suitable geometries. Using this tool, local deformations of typical crash verification models were investigated, which were S-frame model, 3-point bending model, L-T model of spot weld and hat-section model. These simulation results based on the Isogeometric analysis correlated well with the experimental tests regarding the local deformation. Next, Cockcroft-Latham fracture criterion[1] and Hill's anisotropic yield condition were incorporated into LS-DYNA to investigate the fracture. And material constants of Cockcroft-Latham fracture criteria were measured by in-plane biaxial stretching test[2]. Finally, 3-point bending model, L-T model of spot weld and v-notch models with third order shape function were calculated to investigate the fracture. It was found that material constants of Cockcroft-Latham fracture criteria were different between bilinear and third order shape function regarding the bending problems.

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PRACTICAL COMPUTER-AIDED TECHNOLOGY ISSUES IN AN ADVANCED MANUFUACTURING ENVIRONMENT

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ABSTRACT

The NNSA's Kansas City National Security Campus, managed and operated by Honeywell Federal Manufacturing & Technologies, is responsible for the manufacture of non-nuclear components for nuclear weapons. To support this mission the KCNSC has a wide assortment of advanced manufacturing and scientific equipment and uses a wide variety of computer-aided technologies (CAx) such as CAD, CAE, and CAM. These tools are used daily by engineers and technicians within production operations as well as for developing solutions for challenging manufacturing problems. However, interoperability issues between these various tools are so ubiquitous that they have become normalized and the core issues have become obscured. As CAx becomes more commonplace, so too are computer-driven manufacturing-related processes, including simulations of complex manufacturing processes (e.g. additive manufacturing, milling, encapsulation, forging, oven-curing) and computer-generated instructions for manufacturing equipment (e.g. G-Code, AM STL-file slicing & hatching). As more manufacturing processes are being driven by analysis and computer-aided design, it is becoming more important than ever that manufacturing processes be integrated into design and analysis. KCNSC is not equipped to develop fundamental solutions to these issues, and is instead reliant on the external development of new algorithms and of vendors' implementation of them within commercially-available software & hardware. We will demonstrate current model-preparation workflows in simulation and manufacturing at KCNSC, discuss existing design considerations for downstream applications, and demonstrate three potential downstream applications workflows: simulation, subtractive manufacturing, and additive manufacturing. We hope that that we may inspire efforts to integrate design, analysis, *and* manufacturing.

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RECENT DEVELOPMENTS OF A PIPELINE TOOL FROM BOUNDARY REPRESENTATIONS TO ANALYSIS-SUITABLE GEOMETRIES

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ABSTRACT

Creating new or converting existing computer-aided design (CAD) models suitable for isogeometric analysis (IGA) is a challenging task that often represents a bottleneck in concurrent engineering design pipelines. To overcome this difficulty, we have developed a software tool that converts CAD designs created by traditional means to analysis-suitable geometries. The initial boundary representations (B-reps) often comprise several hundreds of patches and are non-watertight. Also, the parameterization of the underlying patches is often impractical from the computational analyst perspective.

Our tool is capable of automatically converting B-rep data to four-sided watertight patches using an optimized cross-field generated on the surface.

The software supports conversion to untrimmed as well as trimmed models [1]. Untrimmed designs frequently yield surfaces with many patches to satisfy boundary constraints around holes. Considering trimmed designs, internal boundary constraints are neglected during re-parameterization and the resulting model is reduced to one or just a few surfaces.

In addition, it can generate simple solid data by extruding or sweeping the created analysis suitable (untrimmed) shell data.

Through some illustrative examples, we demonstrate the efficacy of the automatic model generation, discuss current limitations, and highlight ongoing developments to address those.

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MESH GENERATION AS THE BRIDGE BETWEEN DESIGN AND CFD SIMULATION

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ABSTRACT

Mesh generation has been described as the principle bottleneck and dominant cost in the application of computational fluid dynamics (CFD) within the aerospace industry. Complaints about mesh generation have been made since at least the 1980s but have reached a constructive zenith with publication of the NASA CFD Vision 2030 Study [1] (the Study) which recommended several actions by which NASA's CFD capability could achieve the desired level of performance by the year 2030. The Study's recommendations regarding mesh generation cover the gamut of functionality from the relatively poor interoperability of geometry models to the inability to generate a mesh fit for a particular purpose on a complex geometry on the first attempt. In a response to the Study [2] a case is made that mesh generation is the victim of its own success. The ability to generate meshes on complex configurations for use in production-level computational tools within a design environment has been a key enabler that has allowed CFD to change the manner in which aircraft are designed. That success, however, has instilled a bit of process rigidity with respect to the types of meshes that can be used, the manner in which geometry models are handled, and the types of technologies that can be brought to bear on the problem. This presentation will provide a perspective on the current state-of-the-art in CFD mesh generation and a look at technologies that offer the potential to achieve the 2030 vision.

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