Latest advancements for IGA model creation with ANSA

Lambros Rorris[1], Ioannis Chalkidis[2]

[1]BETA CAE Systems AG
[2]BETA CAE Systems SA

1 Introduction

During the last two years, ANSA, the leading preprocessor for crash analysis, has been heavily involved supporting the IGA community, helping create IGA models and Hybrid FE-IGA full vehicle crash models. In doing so we a set a dual target. First, advance and explore all needed technologies which are mainly new and mostly in academic research phase. Second, bring in, industry expertise in making these technologies robust and well suited for production, both in terms of stability and performance, but also in terms of data interoperability and adaptation to the highly automated process flows that characterize current automotive crash procedures.
The cooperation with the ANSYS LST team has been very fruitful and rewarding. These latest developments in the pre-processor side are presented in this presentation.

2 Creating "IGA Ready" geometries

IGA uses the same basis functions as CAD, namely non-uniform rational B-Splines (NURBES). The CAD created automotive parts though, are in a form that is not suitable for IGA. They are not watertight; they are modeled as solid (B-Rep) and contain a very large number of trimmed surfaces. Most of these problems have already been addressed in the past for the classical FE mesh generation. In the already established processes of the industry, robust processes are in place for mid-surfacing (translating the solid B-rep representation to a shell), and geometry clean up. The mesh generation phase that follows must be replaced with the IGA ready geometry generation. This requires the transformation of the CAD part geometry to either single patch surfaces or to parts consisting of few surface patches.

The ANSA IGA creation function does exactly this. Takes as input multiple CAD surface patches, usually representing a part and converts them into a single surface patch representation with parameters suitable for analysis. Our algorithm finds the complexity of the underlying geometry and decides the appropriate knot vectors that will be used to maintain the accuracy while minimizing the memory that will be used. The knot vectors determine the size of the resulted elements. There is the possibility for the user to add specific characteristics and limitations about the resulted elements. For example, the user can request a surface with uniform element size (uniform knot vectors) that are in a specific value range.

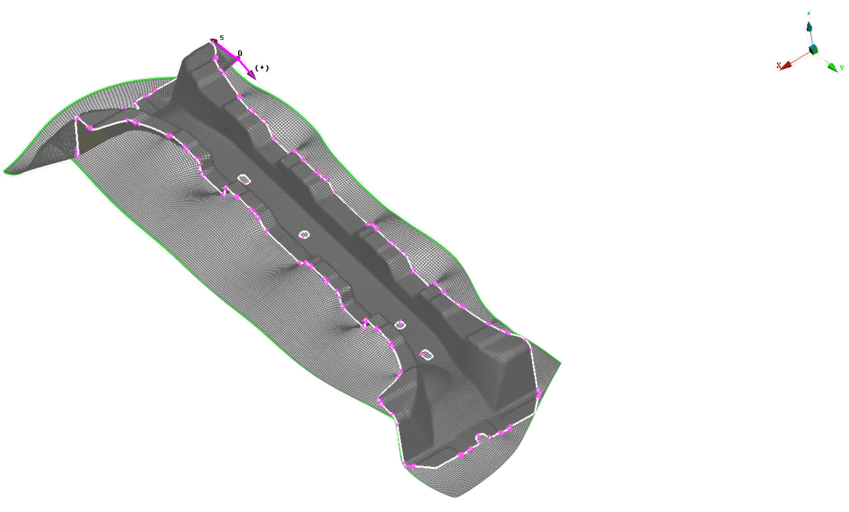

Fig.1: A single surface representation of a complex part

In the newest version of the function the user can also define the desired polynomial degree of the underlying IGA surface. While CAD produces surfaces with very high polynomial degrees up to 13 the IGA creation function can now be set to generate surfaces of polynomial degree of 2,3 or 4 which are suitable for analysis.

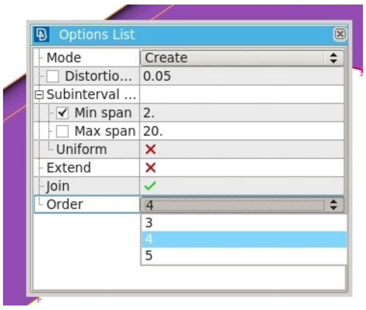

Fig.2: IGA Ready Surface creation parameters (order = polynomial degree +1)

Finally, the surface is validated, and the starting surface representations are replaced by one. During this process there are many small geometric discontinuities originated from the initial dirty translated CAD geometry that might be fixed. The resulting geometry will have a higher order continuity, due to the build-in property of B-spline surfaces which will also be preserved in the solution. After the creation of the IGA ready geometry, the geometric representation is ready to be exported from ANSA to LS-DYNA.

3 The new *IGA Keywords

A recent development first introduced in the latest ANSA v22 version and in LS-DYNA R13 is the new **`*IGA_`** family of keywords. They are designed from the beginning to cover all current and future needs of IGA models. All the needed information of the underlying surfaces and curves can be described in a consistent way, while topology information is also added to describe the connectivity between adjacent patches. Thus, it has inherent support for multi – patched IGA models.

A great example of the new **`*IGA_`** keywords in action and the new possibilities that they give us is the modeling of a T-Joint structure consisting of two surfaces one being perpendicular to the other. The description of this case is purely geometrical where one curve is shared between two surfaces. The curve is a part of the trimming loop for the first surface while it is internal to the other.
This also demonstrates the new possibilities that IGA offers to analysis, moving away from discretization and communicating to the solver the original geometric information in a direct way.

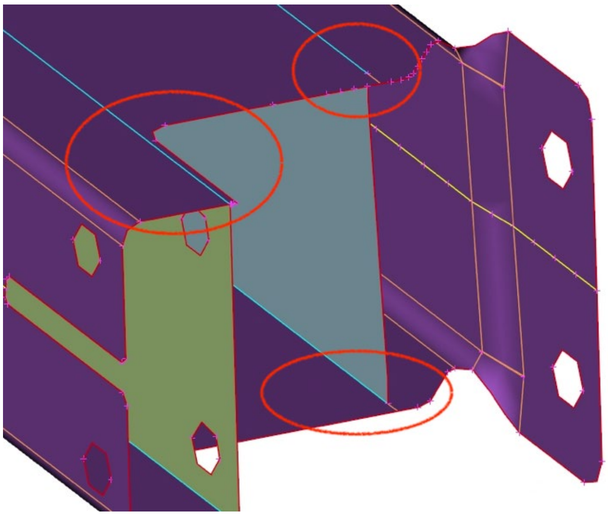

*Fig.3: Blue lines (triple bounds in ANSA), pass through to the solver through the new *IGA_ keywords capability to add topology description*

4 Data exchange, CAD to IGA and BEXT support

Although ANSA can perform the full process, that is, both IGA Ready surface creation and model build up and general pre-processing, there is the need to offer support for other IGA parametrizations. Especially in the academia is very common to try different parametrizations and spline technologies. One could also imagine that direct IGA Ready geometry could be produced by a CAD application if the needed constraints and requirements are set.
For the first case LS-DYNA has already added the `*INCLUDE_BEZIER` keyword to give the opportunity to researchers to feed IGA geometries to the solver in the form of a Bezier Extraction. ANSA will support the BEXT format, so the user can use the pre-processor transparently for the analysis no matter what the choice for the IGA parametrization might be.
For the latter case a direct CAD to IGA function is provided. As CAD is already in trimmed B-Rep representation and ANSA can import CAD data from all major CAD applications and CAD formats a translation will be made from the original CAD format to the new LS-DYNA `*IGA_` keyword format.

5 Model handling and Assembly

Creating an IGA part representation is crucial for analysis, but model build up assembly and load casing is by no means an easy or trivial task if all existing tools are not adapted. It is our goal to make IGA and Hybrid FE/IGA model creation and handling as transparent and easy to the user as possible.

5.1 IGA representation

Since part assembly and handling is done through ANSA's Model Browser, multiple representations of a part can be stored and loaded depending on the analysis. For example, one can have two mesh representations for a part a 2mm and a 4 mm or even a lumped mass representation. Support for IGA representation has been added, so that a user can switch from IGA to FE and do his comparative studies.

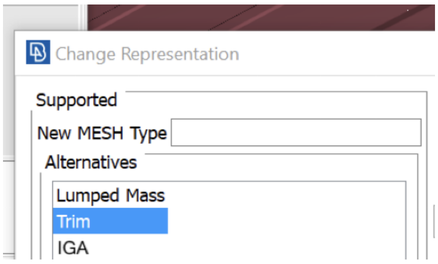

Fig.4: Change representation tool, Possibility to have an IGA part representation

5.2 Spotwelding

Spotwelding and all other types of connections like adhesives etc., can easily be introduced into IGA parts due to their modelling. Since most modern connection representations work through contacts in LS-DYNA, IGA parts can easily be connected if the correct part IDs are added to the respective sets. ANSA is fully aware of the IGA geometries and connection manager can handle them correctly use them for projections and connection creation. The operation is fully transparent to the user.

5.3 Node to Node connections

While working with contacts and parts is easy, when we need node-to-node connectivity with IGA parts there is no trivial way to do it since there are no nodes. The Control Points of the surface are not suitable since they don't lie on the surface anyway. With LS-DYNA new R13 version and the new `*IGA_` family of keywords the `*IGA_POINT_UVW` keyword has been introduced that allow us to tie `*NODEs` to the surface. This is an important solution because it permits us to realize all kind of node-to-node connections especially for hybrid models.

To prove the feasibility of the technology we created a hybrid FE/IGA model based on the public domain Dodge Neon model. This model being old has all the connections modeled with mesh dependant `*CONSTRAINED_SPOTWELD` keywords. Thirty-two parts were replaced with untrimmed IGA representations. The process is straight forward and makes the replacement of FE parts with IGA transparent to the user. The parts were provided by Kendrick Shepherd and Tom Hughes, University of Texas Austin.

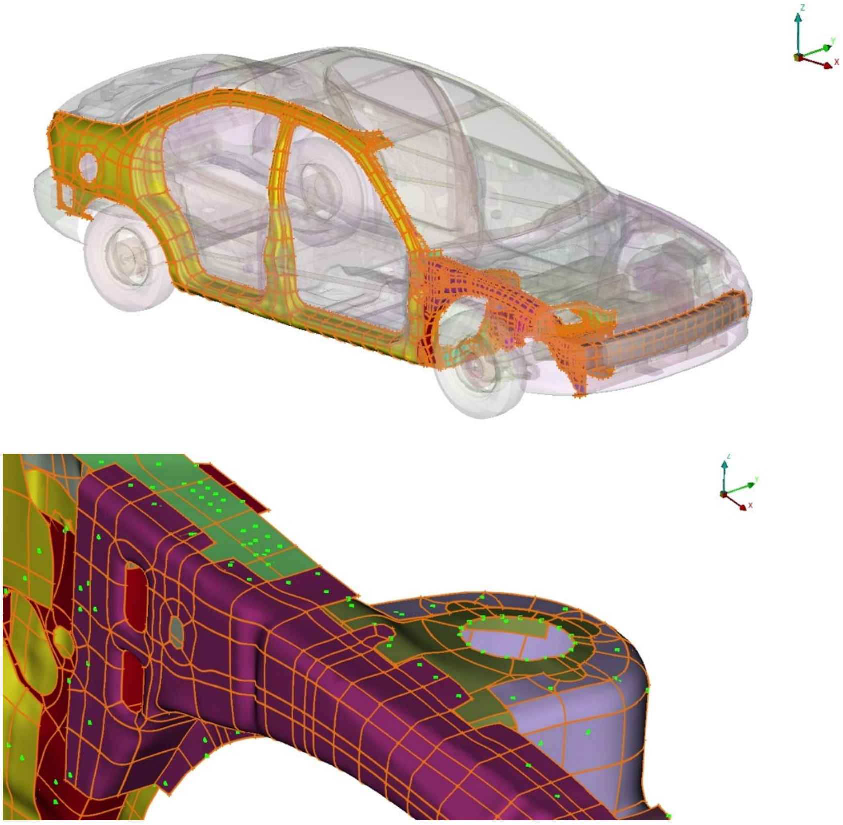

*Fig.5: Replacing all the side panels of the Dodge Neon with IGA parts. Automatic connections via *IGA_POINT_UVW. IGA Parts courtesy of Kendrick Shepherd and Tom Hughes, University of Texas Austin.*

5.4 Assembly points

Assembly points are used to model all kind of connections like Bolts etc. in ANSA. Many realizations need Node-to-Node connectivity. Connection manager is updated to be aware of IGA parts and create any needed IGA_POINT_UVWs to realize the correct node connectivity.

5.5 Boundary Conditions

Another addition in the new keyword families was the option to add to the **`*SET`** keyword geometric entities and thus reference them in BCs and ICs.
This extension of SETs is already available in ANSA v22 and the first keywords supporting the new option are implemented. Soon we expect many more keywords to be used in such a way, directly referencing geometric entities.

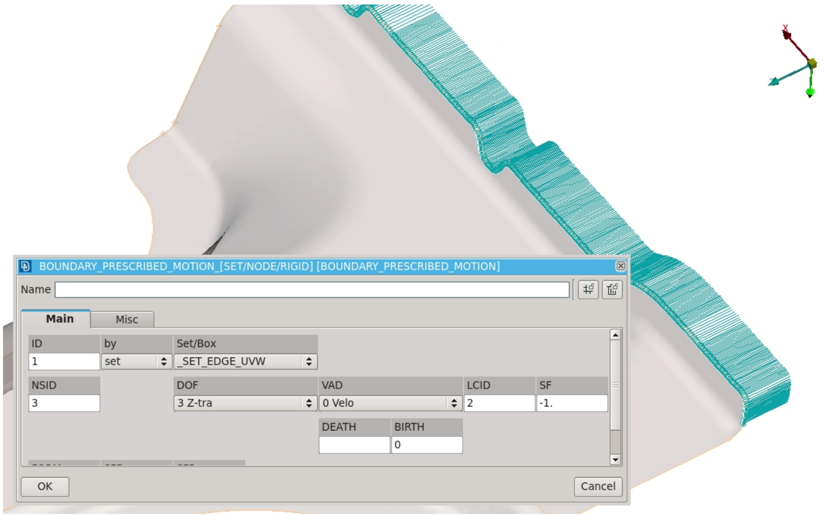

*Fig.6: *BOUNDARY_PRESCRIBED_MOTION created directly on the lower edge of a B-Pillar. "Directly on the lower edge" is written literally since the keyword is referencing a geometric edge.*

6 Morphing

The goal of the analysis is to make better design. Offering tools to alter the current design is need. ANSA already offers various tools to change the geometry, and it's in our plans to make everything IGA aware. Starting with the next version we will be adding the possibility to morph IGA geometries.

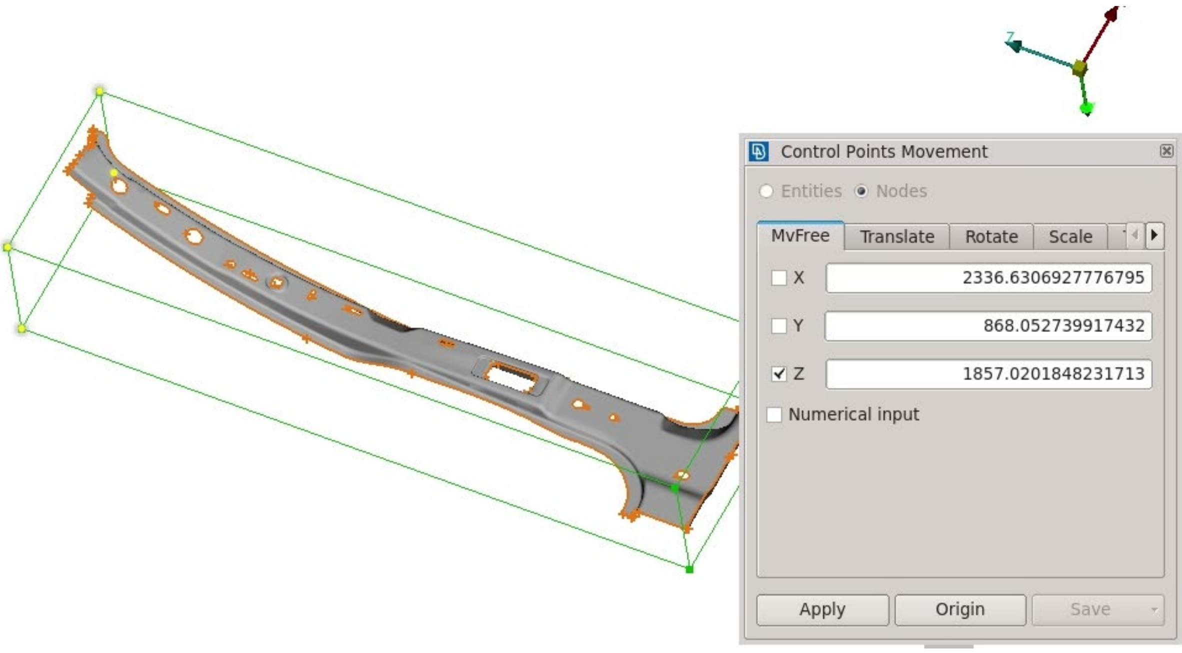

Fig.7: Morphing an IGA B-Pillar

7 Support for Solids

Support for IGA solids is still problematic. The main problem is that 3D NURB representations don't even exist in the CAD world. Cases where a solid can be produced by a swipe of a surface along a curve can only have limited practical applications.
Nevertheless, we follow the same approach of supporting any existing solutions while at the same time researching new areas.

Specifically starting with ANSA version 22 untrimmed 3D NURBs are supported for input (from LS-DYNA files) and general pre-processing. Just as with 2D NURBs various functions of the program will be made 3D IGA aware so the user can build and handle his model.
At the same time, we are working with ANSYS LST on trimmed 3D NURBS and we expect this to be yet another option to model solids and speed up simulation turnaround time.

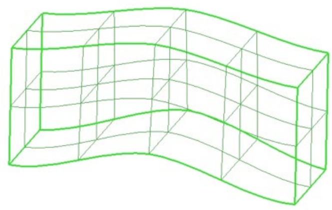

Fig.8: LS-DYNA Untrimmed 3D NURB Solid in ANSA

8 Summary

Isogeometric Analysis (IGA) is maturing and becoming a promising alternative to FE for crash industrial applications. During the last years the capabilities both of LS-DYNA and ANSA in the creation and analysis of IGA crash models have been continuously developed.

Our main focus has been the efficient generation of trimmed NURBS-based multi-patch surfaces that can represent parts of shell structures for the analysis in LS-DYNA. Nevertheless, the IGA community is always pushing the boundaries of the technology, so we are adding pre-processing support for all kind of IGA descriptions both trimmed and untrimmed. We are co-operating with many universities and research groups making sure that the latest technology advancements will be available to the engineers.

The basis for the communication between ANSA and LS-DYNA is the new, *IGA family of keywords including topology information as in B-Rep CAD models. Along with that comes support for better description of Boundary and Initial Conditions and Constraints directly on geometry entities, making modelling more straight forward and transparent from CAD to Analysis.

Continuous integration with existing FE models and easy creation of Hybrid FE – IGA models has been one of our main goals, thus we take all the effort needed, so that both technologies are compatible within the pre-processor and IGA parts can be used interchangeably throughout the whole process from CAD translation to final model assembly.

Our commitment to the technology has proved fruitful during the last two years and we ‘ve seen many examples of successful applications.

9 Literature

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