



*Gecko*

Design for *IGA*-type  
discretization workflows



Funded by the  
European Union



## 1<sup>st</sup> Technical Workshop

---

**DC5 - Large deformation structural elements modelled  
with IBRA, including trimming and multiple coupled  
patches**

**Presenter name: Maram Alkhlaifat**

**Email: [maram.alkhlaifat@tu-braunschweig.de](mailto:maram.alkhlaifat@tu-braunschweig.de)**

**Date: 09.01.2024**

# DC-5

## Project Overview



Focusing on Large deformation structural elements modelled with IBRA, including trimming and multiple coupled patches.

Technische Universität Braunschweig (TU-B), Germany

Supervisors: Prof. Roland Wüchner

Start Date: 01.12.2023



# DC-5

## Project Overview



### Objectives:

1. Develop Precise Structural Elements for large deformations using Isogeometric B-Rep Analysis (IBRA).
2. Address Geometry Challenges along patch boundaries and trimming curves, and work toward achieving high Geometrical Accuracy at critical locations.
3. Enable Direct CAD-Integrated Simulations for industrial relevance, and implement within Kratos-Multiphysics for accessibility and usage.



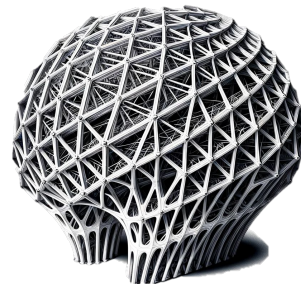
# Early Progress of DC-5



This represents the **foundational phase** in DC5's involvement in the project.

Focuses on acquiring a comprehensive **theoretical understanding**.

Aims to prepare for **practical application modeling** of large deformation structural elements, including beams and shells.



# Early Progress of DC-5

## Literature Review



### Educational trajectory:

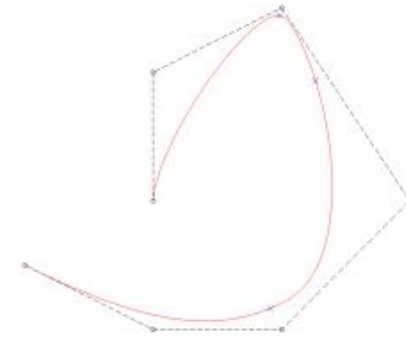
- Introduction to NURBS
- In-depth Study of IGA Fundamentals
- Exploring IBRA Concepts
- Focused Research on IGA Applications in thin-walled structures





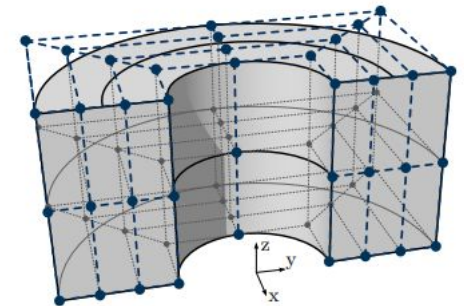
# Early Progress of DC-5

## Literature Review



NURBS curve

- NURBS are uniquely capable of providing **Geometric Flexibility Across Analytic and Free-Form Surfaces.**
- The manipulation of individual control points offers **Localized Shape Control**, while weights allow for broader adjustments without altering the entire structure.
- They are **Standardized for Interoperability** ensuring compatibility across different CAD/CAM systems



NURBS solid



### Reference:

Piegl, Les, and Wayne Tiller. The NURBS book. Springer Science & Business Media, 1996.



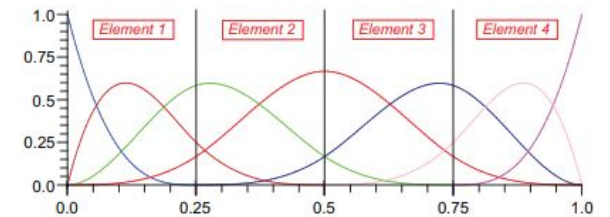
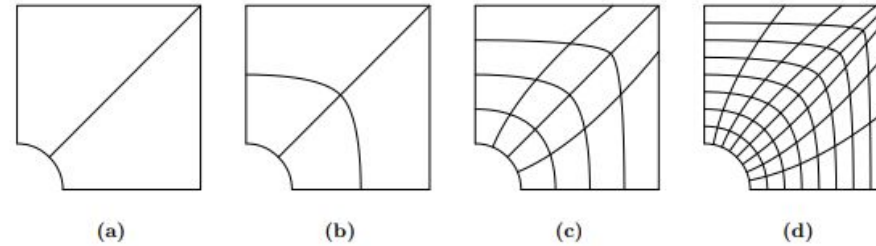
# Early Progress of DC-5

## Literature Review

### In-depth Study of IGA Fundamentals:

- Offering a **Unified Framework** that employs the same NURBS basis functions used in CAD for Finite Element Analysis (FEA).
- **Refinement without Re-meshing** ergo reducing computational workload.
- Provides **Higher-order Continuity Across Elements**, compared to classical FEA that employs  $C_0$  continuity (continuity in displacement only), which may require a finer mesh to achieve similar accuracy.

Different h-refinement for the (a)-(d) classic IGA



Isogeometric elements. The basis functions extend over a series of elements.



Gecko

Design for IGA-type  
discretization workflows

#### Reference:

Hughes, T. J. R., Cottrell, J. A., & Bazilevs, Y. (2009). *Isogeometric Analysis: Toward Integration of CAD and FEA*.

# Early Progress of DC-5

## Literature Review

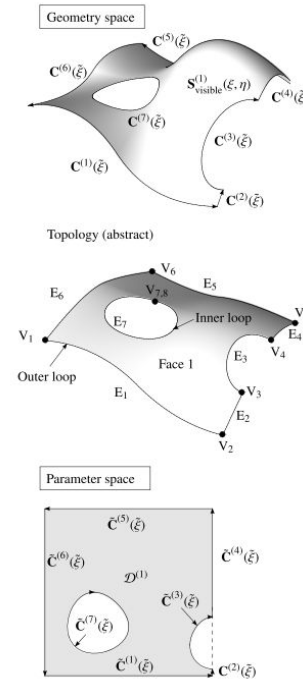


Surface B-Rep model.

V	Vertices
E	Edges (direction is not considered)
C	Space curves
$\tilde{C}$	Trimming curves
S	Surfaces
$\mathcal{D}$	Trimmed domain

### Exploring IBRA Concepts:

- IBRA is based on CAD models comprising trimmed NURBS surfaces, which are industry standard for free-form geometry modeling.
- B-Rep element formulation is introduced that enables the coupling of trimmed multi-patch shells.
- The use of nested Jacobian approach (NEJA) for the numerical integration of trimmed surfaces using NURBS
- Penalty approach formulation to enforce coupling or Dirichlet boundary conditions in the analysis.



Gecko

Design for IGA-type  
discretization workflows

### Reference:

Breitenberger M., Apostolatos A., Philipp B., Wüchner R., Bletzinger K.U.(2014).  
Analysis in computer aided design: Nonlinear isogeometric B-Rep Analysis of shell  
structures.



# Early Progress of DC-5

## Literature Review

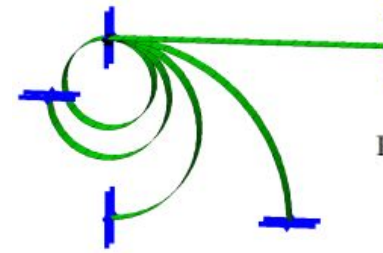
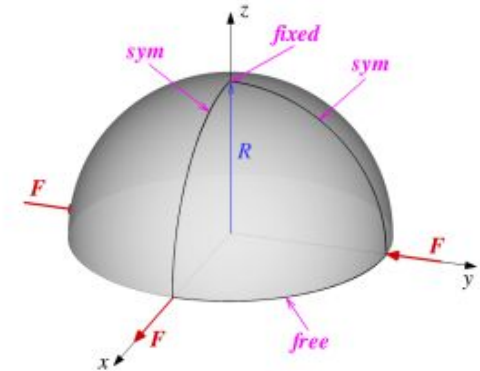


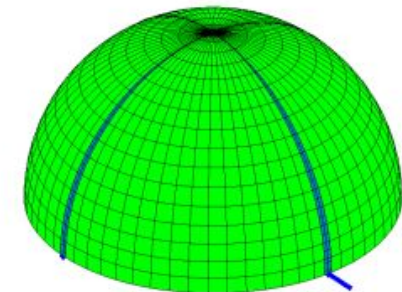
Plate under large deformation.

### Focused Research on IGA Applications in thin-walled structures:

- Non-Uniform Rational B-Splines (NURBS) are utilized as the basis functions for analysis due to their widespread use in CAD modeling, promoting a smooth transition from design to analysis.
- IGA is particularly advantageous for shell structures as their behavior is significantly influenced by their geometry
- The exact description of geometry with NURBS allows for direct evaluation of curvatures on the surface, eliminating the need for rotational degrees of freedom or nodal directors



Hemispherical shell,



*Gecko*

Design for IGA-type  
discretization workflows

#### Reference:

Kiendl, Josef: Isogeometric Analysis and Shape Optimal Design of Shell Structures. Dissertation, 2011.

# Upcoming Focus DC-5



**Delve more into the use of IGA in the context of thin-walled structures**, evaluating improvements in accuracy and computational efficiency.

**Gain proficiency in Kratos software**, and exploring how to integrate these tools with CAD systems for efficient workflow

**Apply the theoretical knowledge of IGA and IBRA in practical scenarios**, starting with basic models to understand the workflow, gradually increasing complexity.

**Run simulations of large deformation structural elements**, focusing on modeling real-world problems or case studies to test the applicability of IGA and IBRA in practical settings.





*Gecko*

Design for *IGA*-type  
discretization workflows



European  
Commission

**Thank you!**

---

**Presenter name: Maram Alkhlaifat**

**Email: [maram.alkhlaifat@tu-braunschweig.de](mailto:maram.alkhlaifat@tu-braunschweig.de)**

**Date: 09.01.2024**