Challenges from IsoGeometric Analysis to CAGD – Experiences from the TERRIFIC project

Tor Dokken

SINTEF, Norway

tor.dokken@sintef.no

The work is funded by the European Union
through Factories of the Future
TERRIFIC project (EU Contract 284981)
www.terrific-project.eu

TERRIFIC
Enhancing Interoperability

TERRIFIC -Towards Enhanced Integration of Design and Production in the Factory of the Future through Isogeometric Technologies

SEVENTH FRAMEWORK PROGRAMME

Formal project data for TERRIFIC

- 7th Framework program
- Instrument: STREP
- Start date: September 1, 2011
- End date: August 30, 2014

- Budget: 5 213 450€
- Maximum funding: 3 496 000€

- Effort: 402 person months

TERRIFIC
Enhancing Interoperability

SEVENTH FRAMEWORK PROGRAMME

European collaboration

The partners grouping is a well balanced mix of members coming from the contributing countries

SINTEF

Jotne

SIEMENS

Technische Universität Kaiserslautern

engineering center steyr

Johannes Kepler Universität Linz | JKU

TopSolid

Institut National de Recherche en Informatique et en Automatique | INRIA

AleniaAeronautica

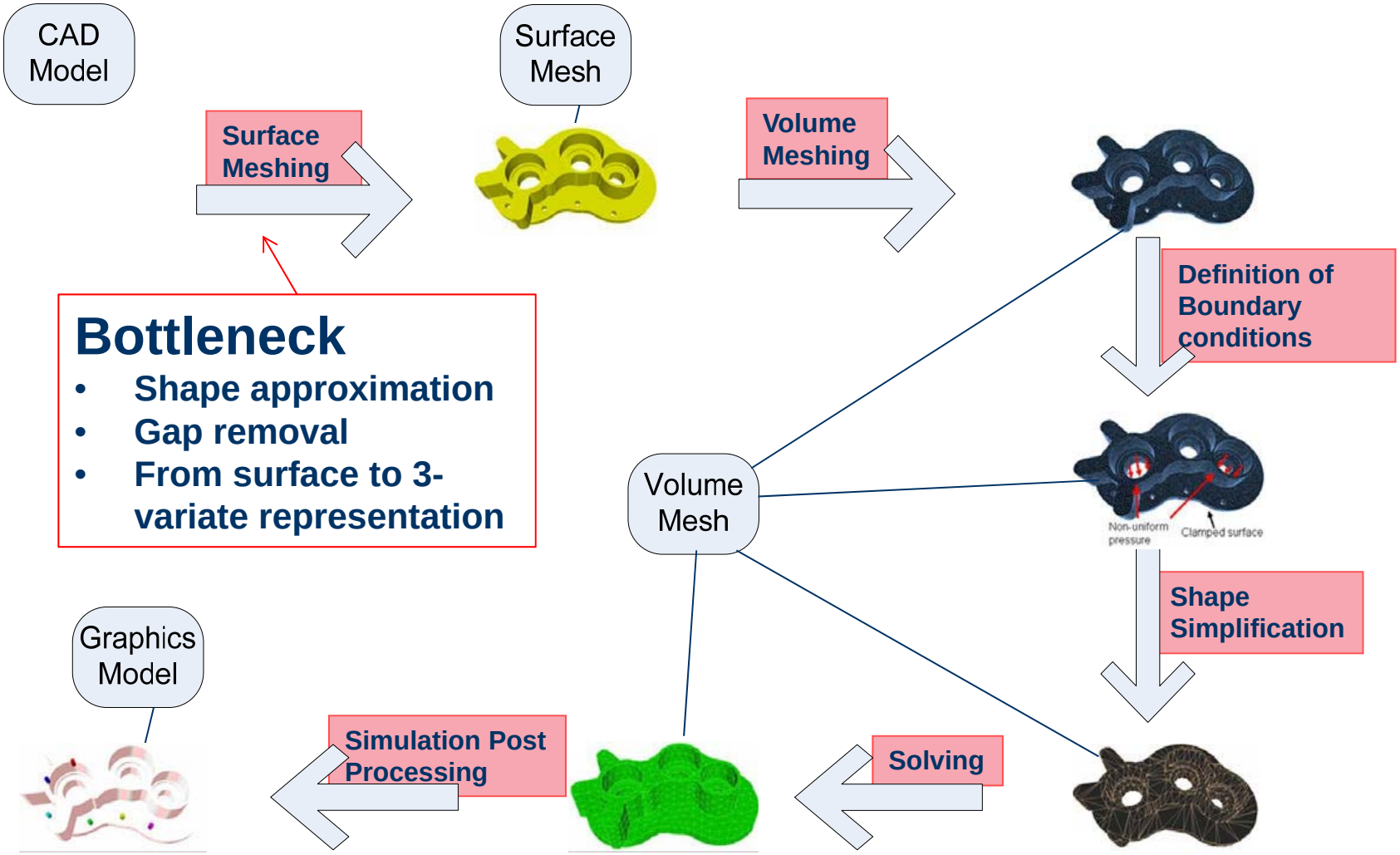
TERRIFIC
Enhancing Interoperability

SEVENTH FRAMEWORK PROGRAMME

Interoperability of 3D digital models

- The representation formats for most 3D digital models are still the same as the formats used before 1990
  - Triangulations
  - NURBS, elementary surface and boundary structures (STEP ISO 10303)
  - Finite Elements
- Limited mathematically and semantically consistency of the different representations poses a major challenge for needed interoperability of models between design, simulation/analysis and manufacturing.
- Currently model conversion and approximation is a major bottleneck in many industrial workflows.

Traditional simulation pipeline

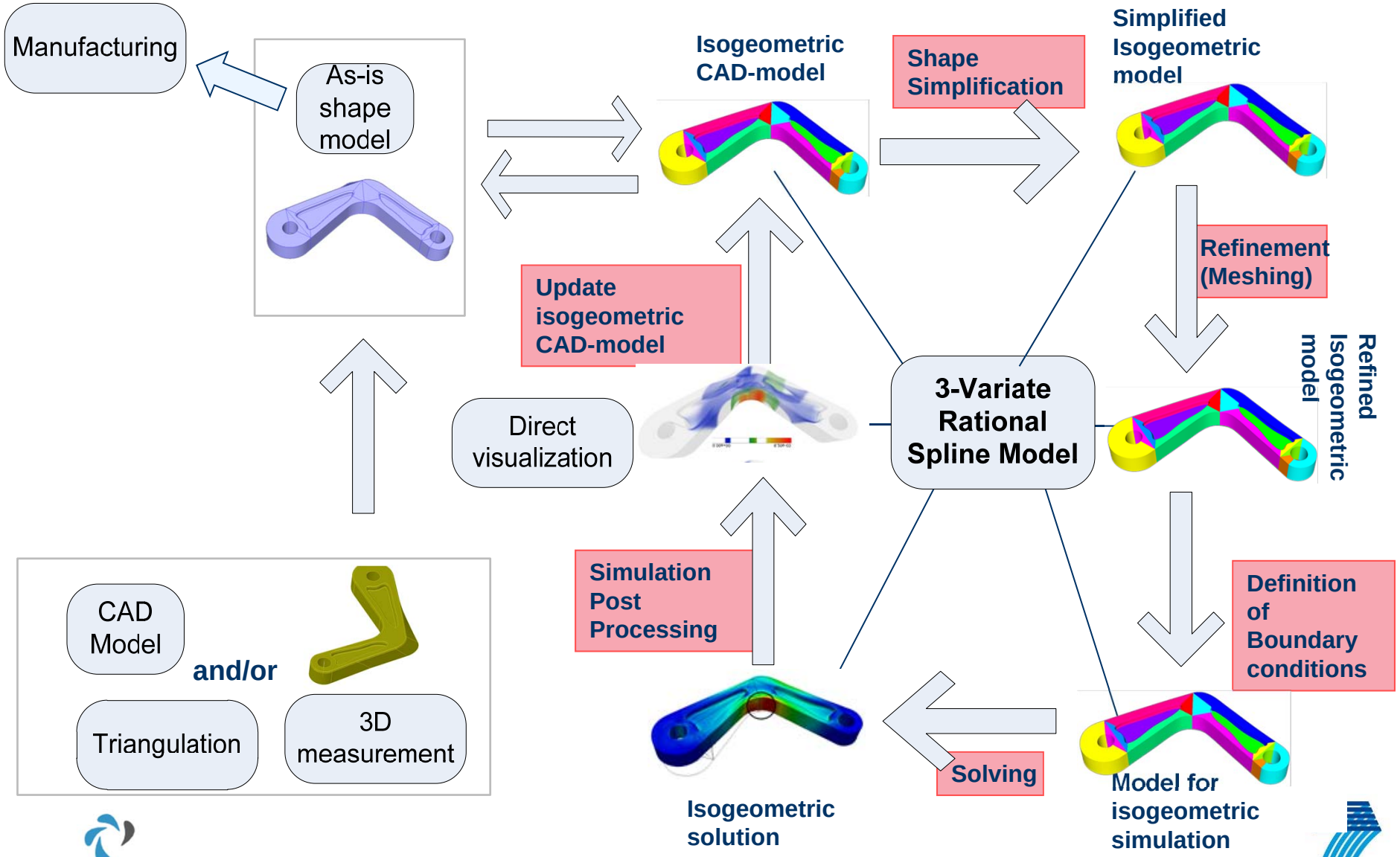


TERRIFIC
Enhancing Interoperability

Limited mathematically and semantically consistency of models

SEVENTH FRAMEWORK PROGRAMME

Isogeometric simulation pipeline

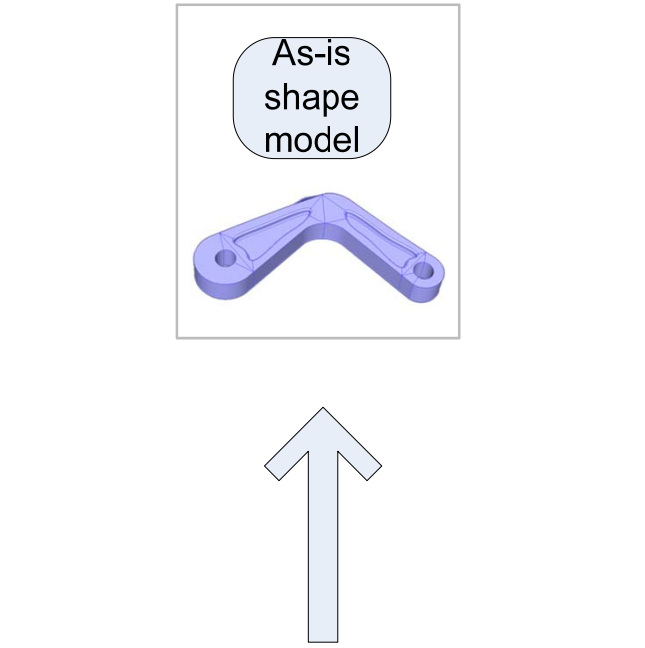


TERRIFIC
Enhancing Interoperability

Mathematically and semantically consistency of models

SEVENTH FRAMEWORK PROGRAMME

Challenge 1: Create “as-is” model



- CAD-models describes the object as planned
  - Combines elementary surfaces (plane, cylinder, cone, sphere, torus and NURBS)
  - CAD-models are not watertight, gaps and unnecessary tangential discontinuities.
- Models aimed at visual purpose most often represent shape by (texture mapped) triangulations
- Laser scanning efficiently produce millions of points on the geometry
  - Extracting information from 3D datasets is complex
  - Using the datasets for validation and updating of 3D models (CAD) is challenging

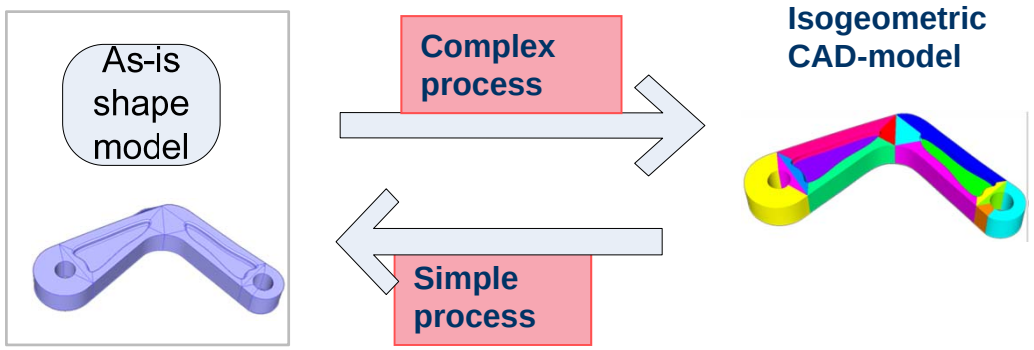
TERRIFIC
Enhancing Interoperability

SEVENTH FRAMEWORK PROGRAMME

Improve as-is model

- Improve shape quality aimed at production addressed by TERRIFIC partners MISSLER and INRIA.

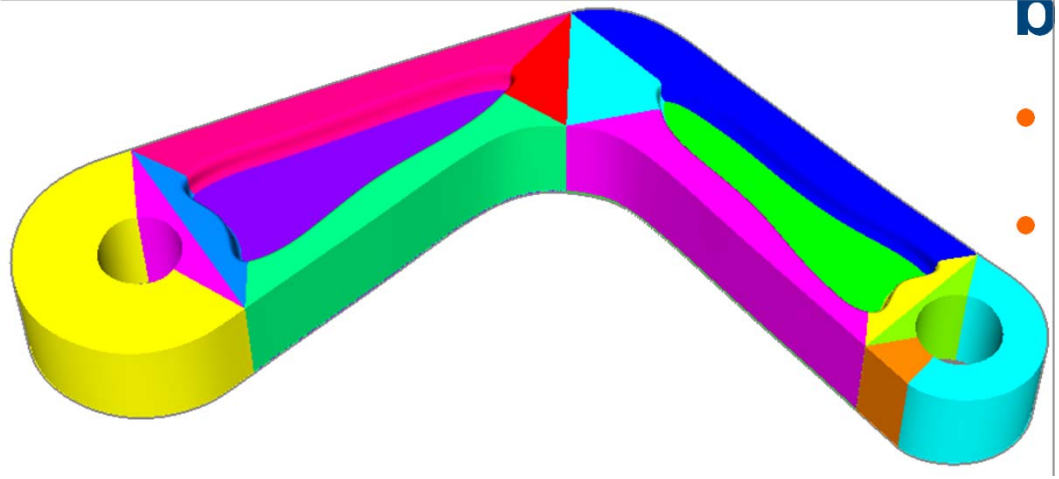
Challenge 2: Create 3-variate isogeometric model



- The “As-is” shape model describes mathematically only the inner and outer hulls (surfaces) of the object using triangulations, elementary surfaces or NURBS surfaces.
- The isogeometric model is analysis/simulation suitable and describes the volumes mathematically by watertight structures of blocks of 3-variate rational splines
- Building an isogeometric model is a challenge:
  - There is a mismatch between the surface patch structure of the “As-is” model, and a suited block structure of an Isogeometric 3-variate rational spline model.
  - Augmented spline technology is needed such as the novel Locally Refined Splines.

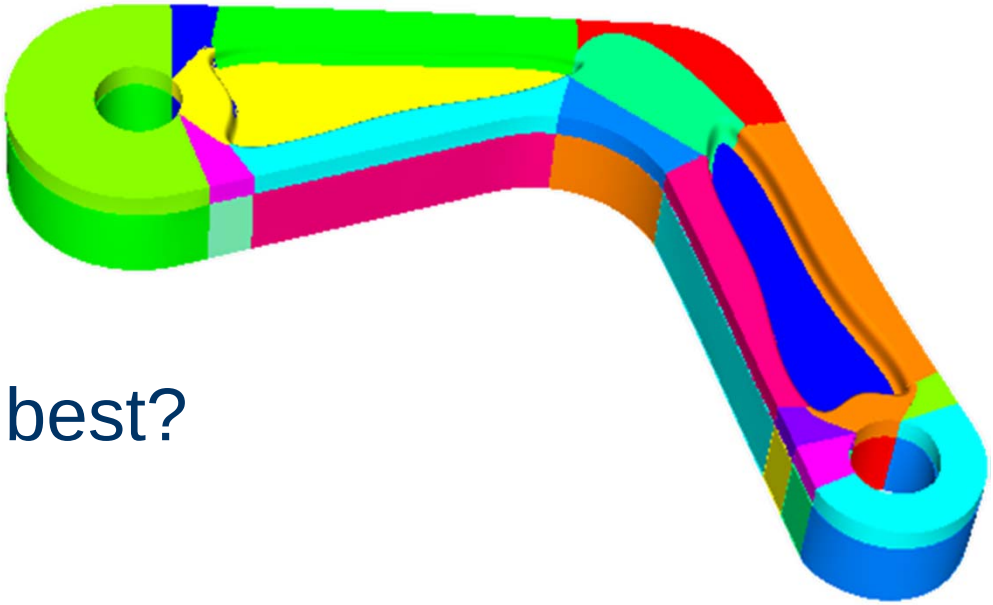
Two approaches for building the isogeometric model in TERRIFIC

- Tessellate the surfaces of the model, build the block structuring based on the triangulated model. Approximate the blocks with NURBS-volumes. An experimental approach (JKU, ECS).
- Isogeometric Toolkit (SINTEF). Build the NURBS directly from the CAD-model. This approach has been used for the demonstrator examples to be discussed.



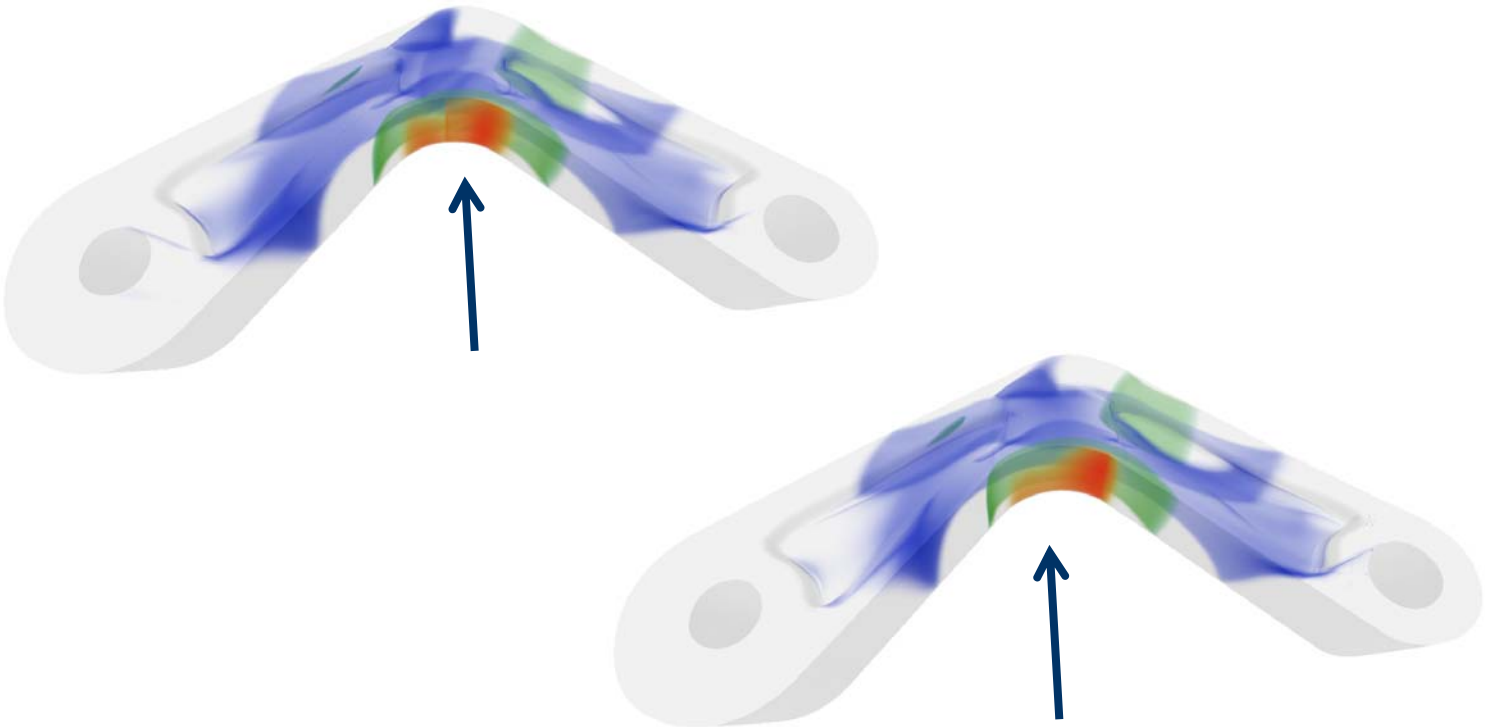
How to make a good block structure?

- Parameterization
- Analysis aspects



Which is best?

Linear elasticity computations, von Misses stresses



TERRIFIC
Enhancing Interoperability

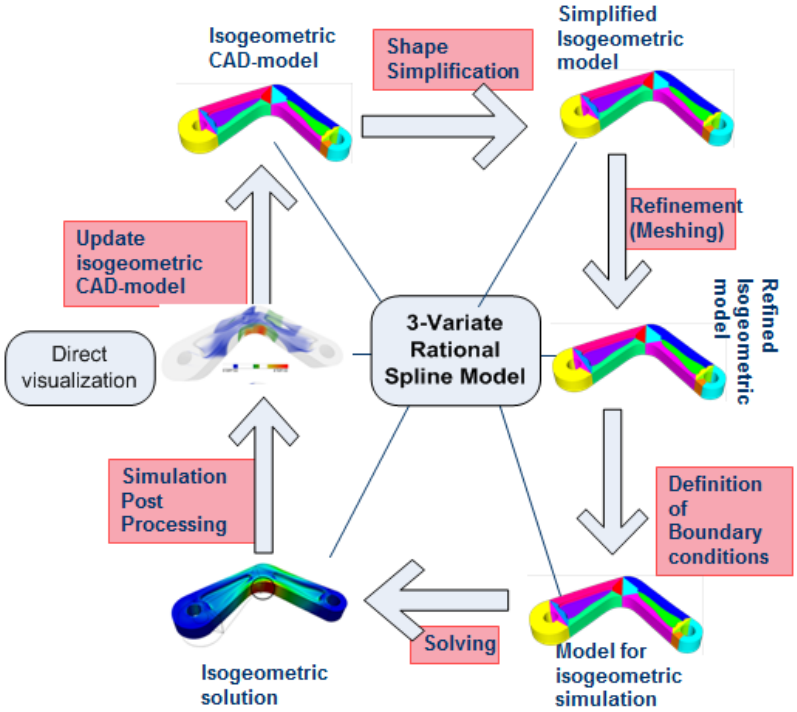
SEVENTH FRAMEWORK PROGRAMME

Challenge 3: Isogeometric analysis itself

First introduced in 2005 by T.J.R. Hughes

- Replace traditional Finite Elements by NURBS - NonUniform Rational B-splines
- Accurate representation of shape
- Allows higher order methods
- Perform much better that traditional Finite Elements on benchmarks
- Refinement of analysis models without remeshing
- Exact coupling of stationary and rotating grids
- Augmented spline technology is needed, e.g., Locally Refined Splines

In terrific addressed by partners SIEMENS, UNIKL, UNIPV and ALENIA

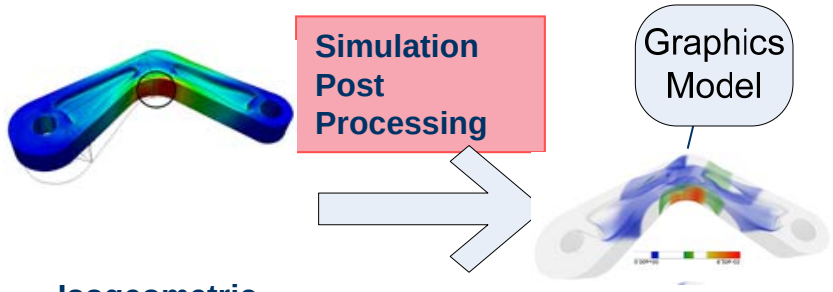


TERRIFIC
Enhancing Interoperability

SEVENTH FRAMEWORK PROGRAMME

Challenge 4: Isogeometric visualization

- Traditional visualization technology is triangle based (tesselation)
  - The isogeometric model has to be approximated with triangles for visualization
  - Results are degraded and information lost
- Need for visualization solutions exploiting the higher degree representations
  - Higher degree representations are more advanced and can better represent singularities in the solution
  - Create view dependent tessellation of splines on the GPU
- Addressed in SINTEF in projects parallel to TERRIFIC



Challenge 5: Local refinement and linear indepence

- Local refinement of the spline based IGA models is essential
  - For stitching the geometry, (water tight CAD-models)
  - For refining the analysis model
- Approaches included in proposed extension of ISO 10303
  - T-splines
  - LR-splines

  Both can easily be represented using STEP type B-splines.
  - LR-splines added to TERRIFIC Isogeometric Toolkit.
- However, both approaches still have open questions

IGA and standards

- The TERRIFIC project is proposing extensions to ISO 10303 - STEP to support IGA and Locally Refined Splines (T-splines and LR B-splines)
- When STEP is extended with IGA support simpler industrial deployment of IGA is facilitated.

Addressed by TERRIFIC Partner JOTNE

The TERRIFIC demonstrator story

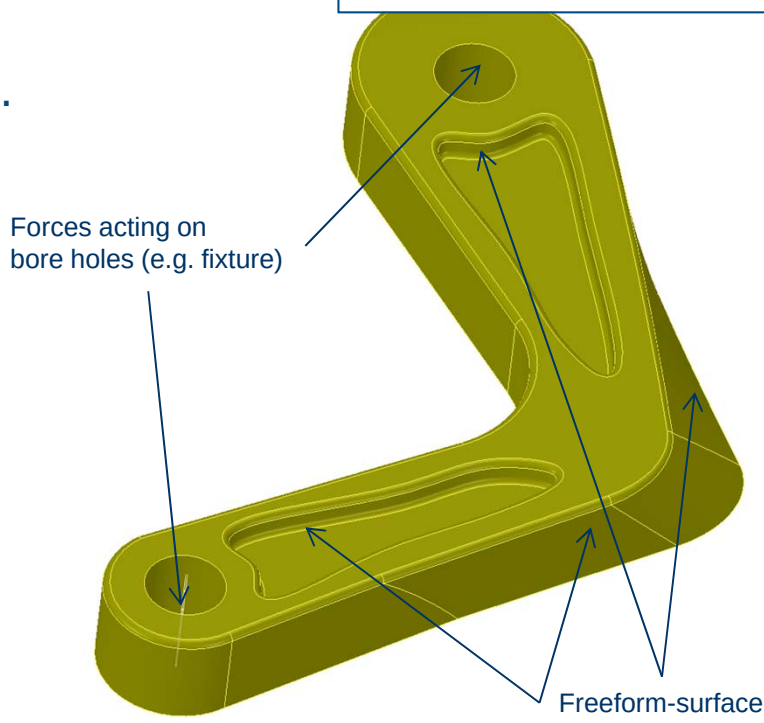
Design:
Stefan Boschert,
Siemens

A new mounting bracket has to be designed fulfilling geometrical space constraints. Further a limit on allowed stress is also given.

The part is designed in CAD (considering guidelines necessary for IGA). Using this CAD-model a volumetric parametrization is done and finally an isogeometric analysis (stress and eigenfrequencies) performed.

The part is then manufactured demonstrating the capabilities of the isoparameterization of patches.

In a last step a dip paint simulation for the final part is performed, showing advanced capabilities of dip-paint simulation software.



General design goal: part has to withstand a given mechanical load under geometrical constraints (available space & weight).

TERRIFIC
Enhancing Interoperability

SEVENTH FRAMEWORK
PROGRAMME

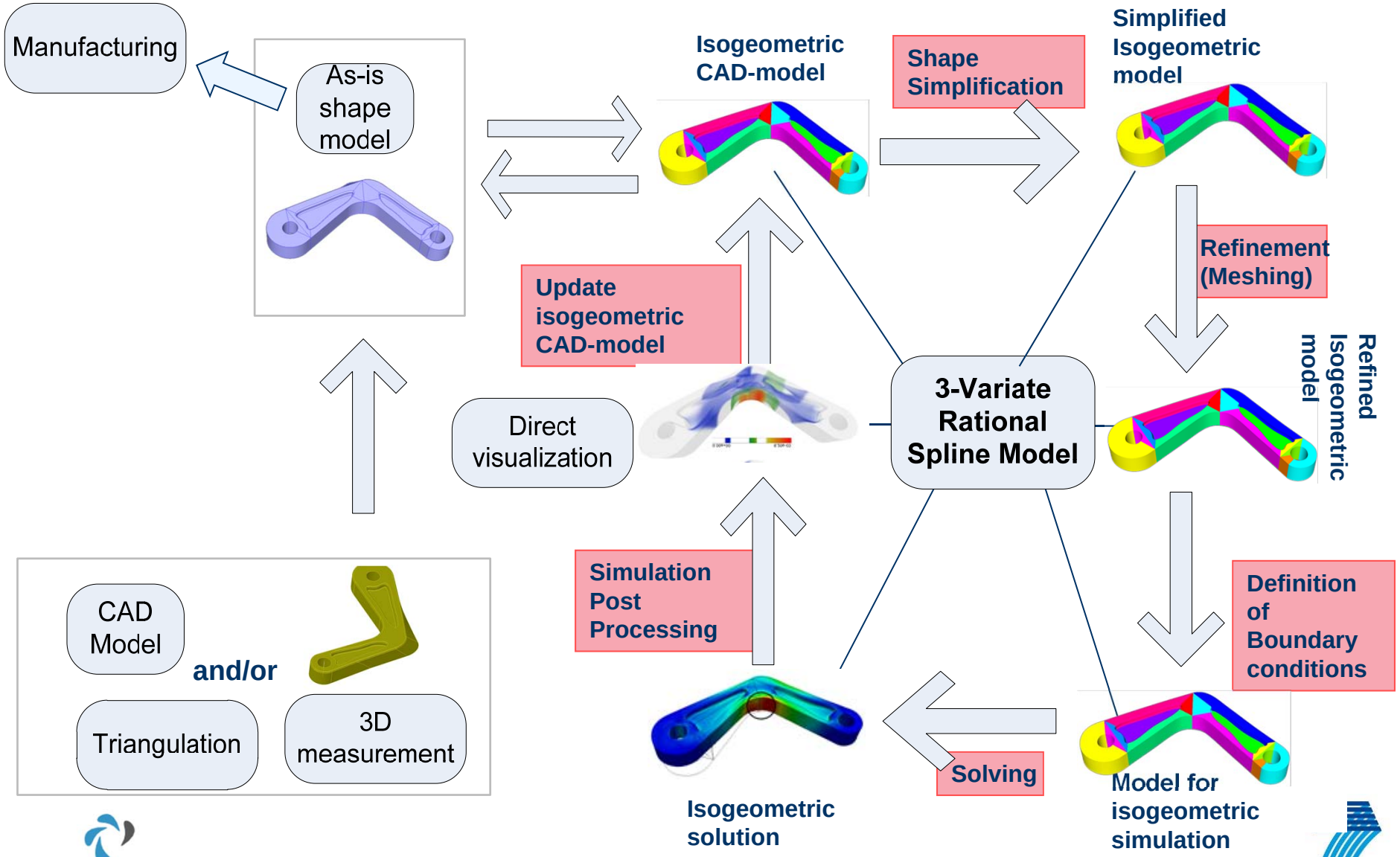
6. Software for IGA

- In TERRIFIC a number of software toolkits for IGA have been addressed:
  - SINTEFs GoTools extended with 3-variate volumes and needed modelling functionality for building 3-variate spline volumes (LR-splines added)
  - Axel from INRIA extended, interfaced to GoTools
  - UNIPV had developed IGATools, interfaced to GoTools
  - UNIKL has developed a set of solvers
- The tools are available both as Open Source and commericallly.

Summing up

- Even with the efforts and achievements of TERRIFIC still many challenges before IGA can be deployed on a broad scale to industry
  1. Building the high quality as-is surface model
  2. Building the 3-variate spline model with a "good block structure" and a "good parameterization"
  3. IGA itself
  4. Visualization of the fields defined over the 3-variate spline volumes
  5. Local refinement
  6. Software tools
  7. We need to present IGA outside the CAGD and IGA community

Isogeometric simulation pipeline



TERRIFIC
Enhancing Interoperability

Mathematically and semantically consistency of models

SEVENTH FRAMEWORK PROGRAMME