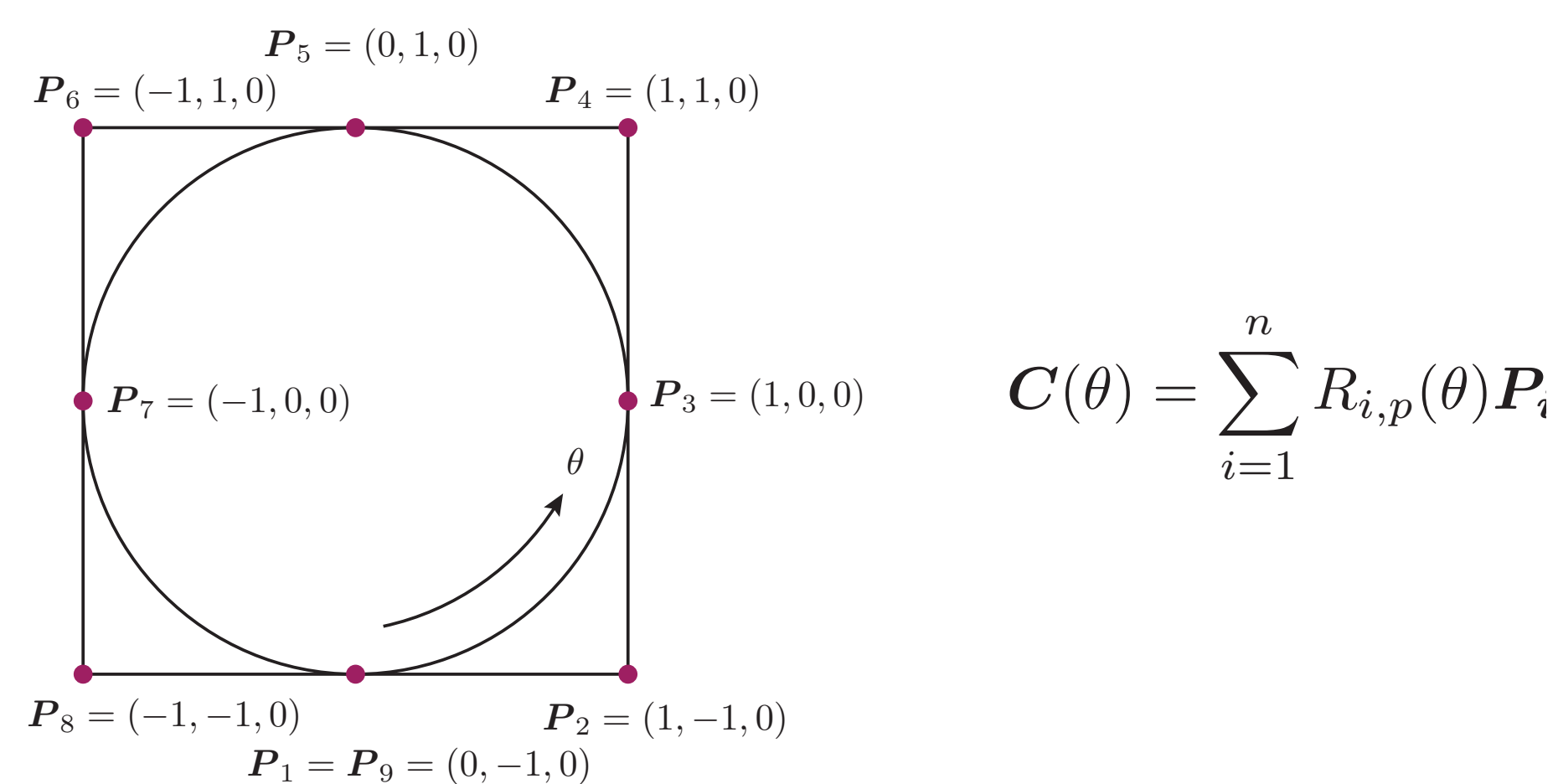


# NURBS-based Approaches in Fluid-Flow

## NURBS



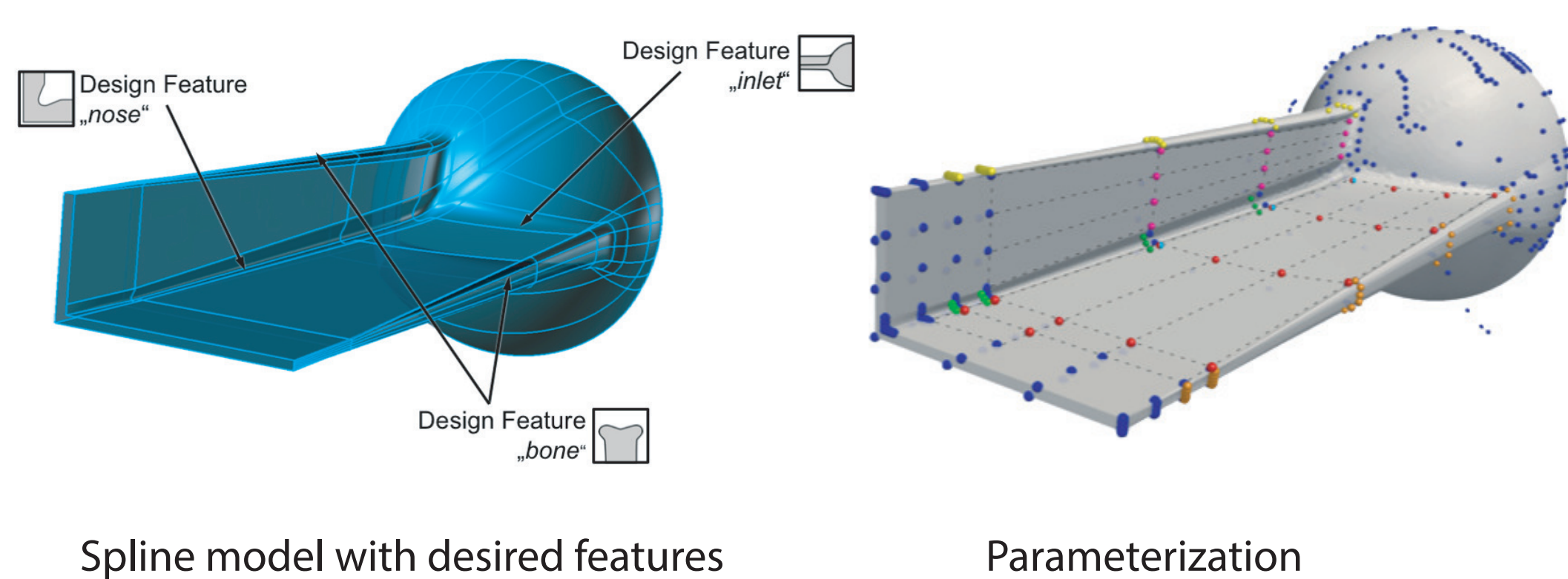
Important **specifications** during the historical development of **NURBS** were to generate a curve:

- whose smoothness is completely under user control,
- which occupies a predefined space,
- which allows for local shape control, and
- which is able to represent both free-forms and analytical shapes.

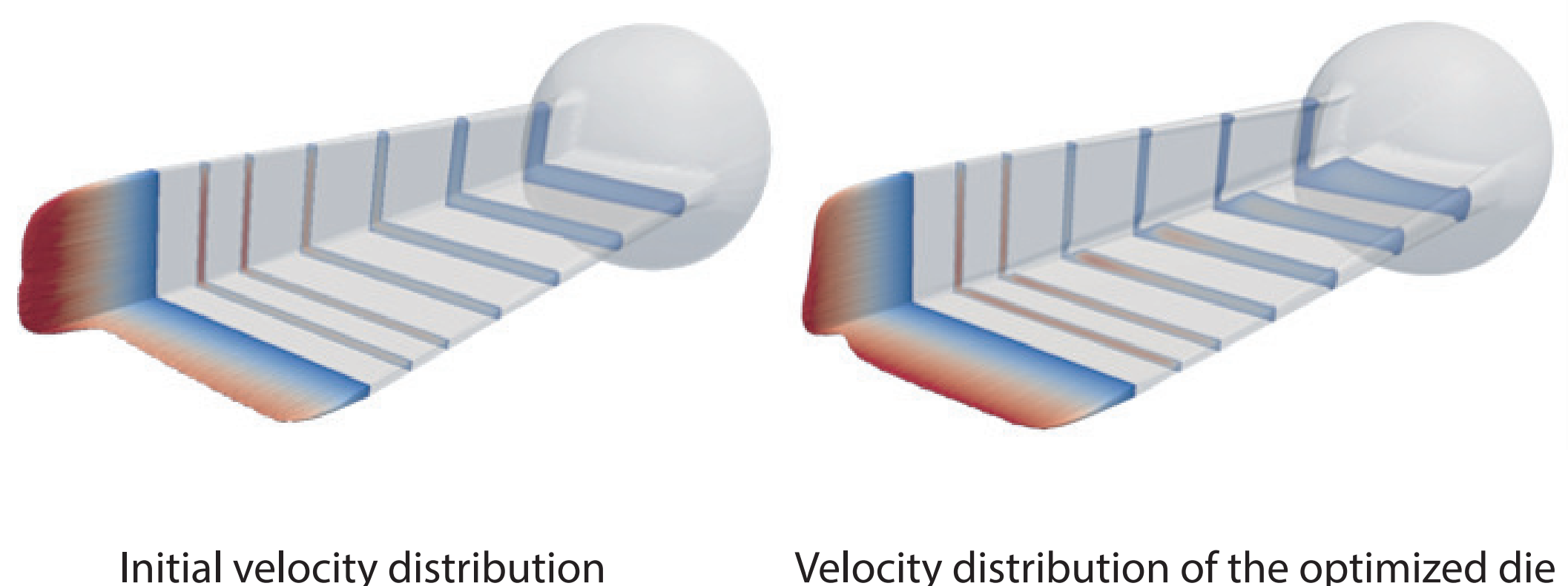
Splines as an aid in analysis

- Geometric information is computed from a NURBS representing the boundary
- NURBS-enhanced finite element method (Huerta et al.)
- Isogeometric Analysis (Hughes et al.)

## NURBS in Shape Optimization

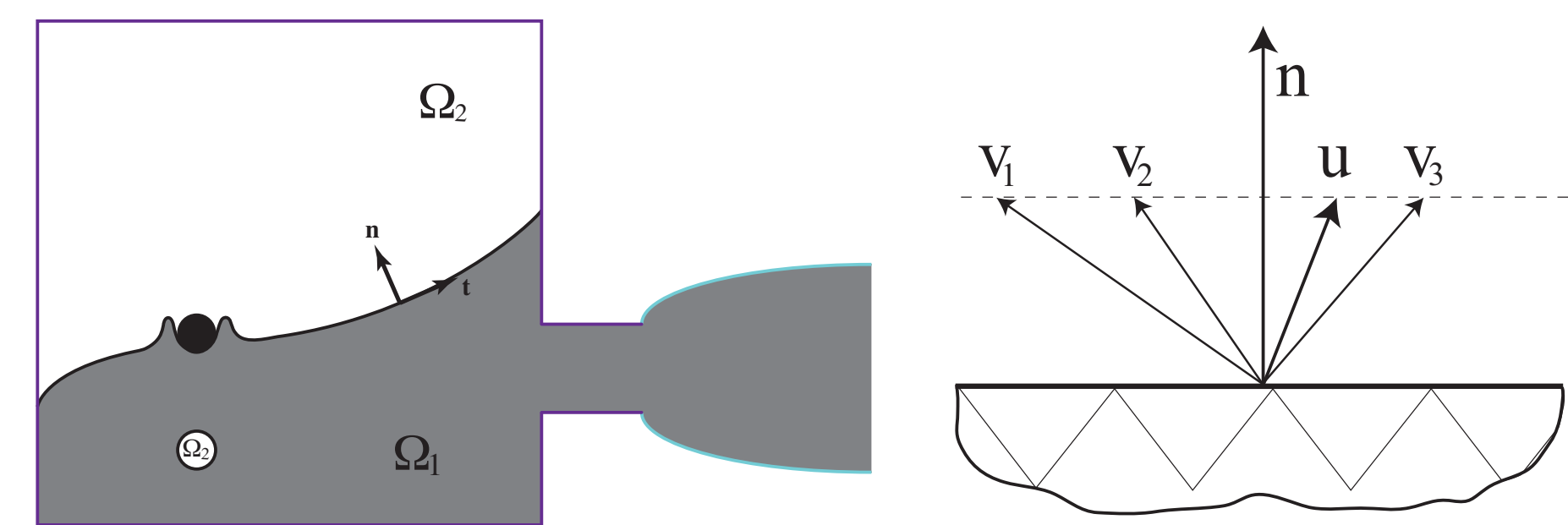


- Every point on the boundary of the finite element mesh is connected to a corresponding point on the NURBS surface.
- Control points serve as design vector.

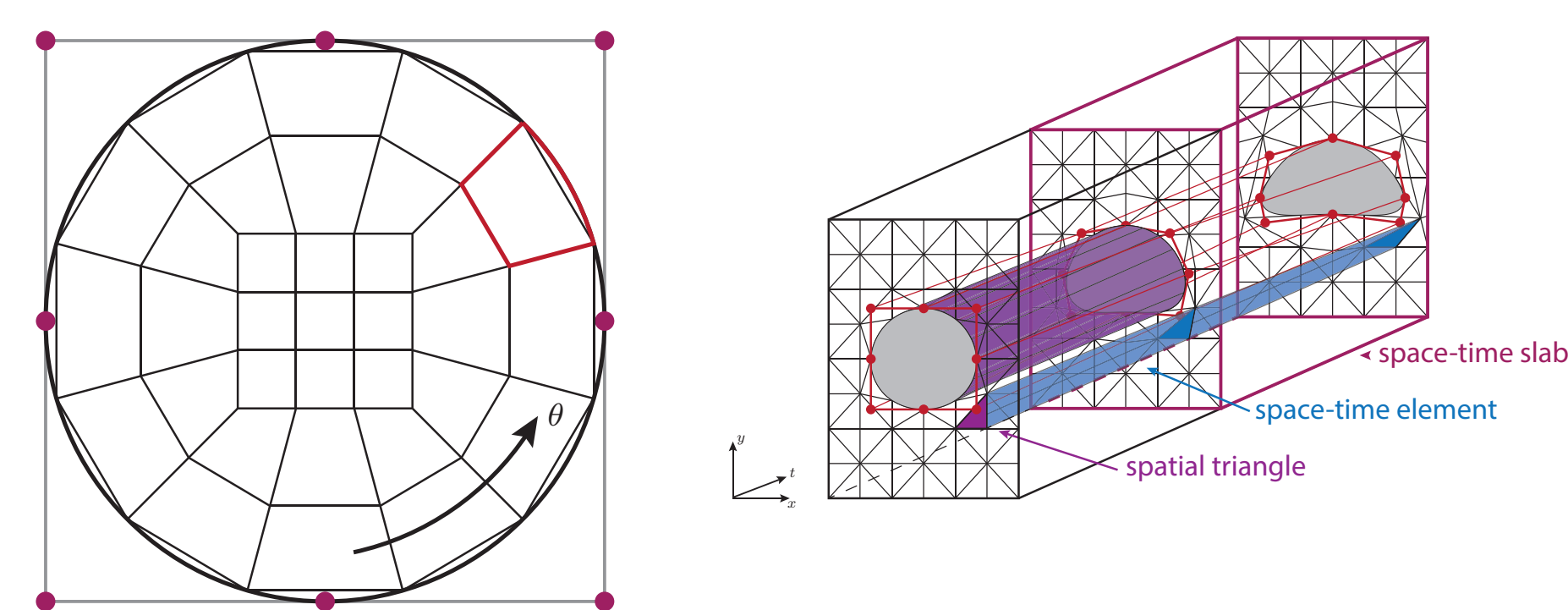


## NURBS in FEA

- Free-surface flows



- **Free-boundary problem:**  
along with the flow solution, the domain shape is also unknown
- Governing equations of **fluid flow** are **coupled** with a **domain deformation approach**
- As the free-surface evolves, the mesh deformation is connected to the flow solution by the **no-penetration** boundary condition  
 $\mathbf{v}(\mathbf{x}) \cdot \mathbf{n}(\mathbf{x}) = \mathbf{u}(\mathbf{x}) \cdot \mathbf{n}(\mathbf{x})$

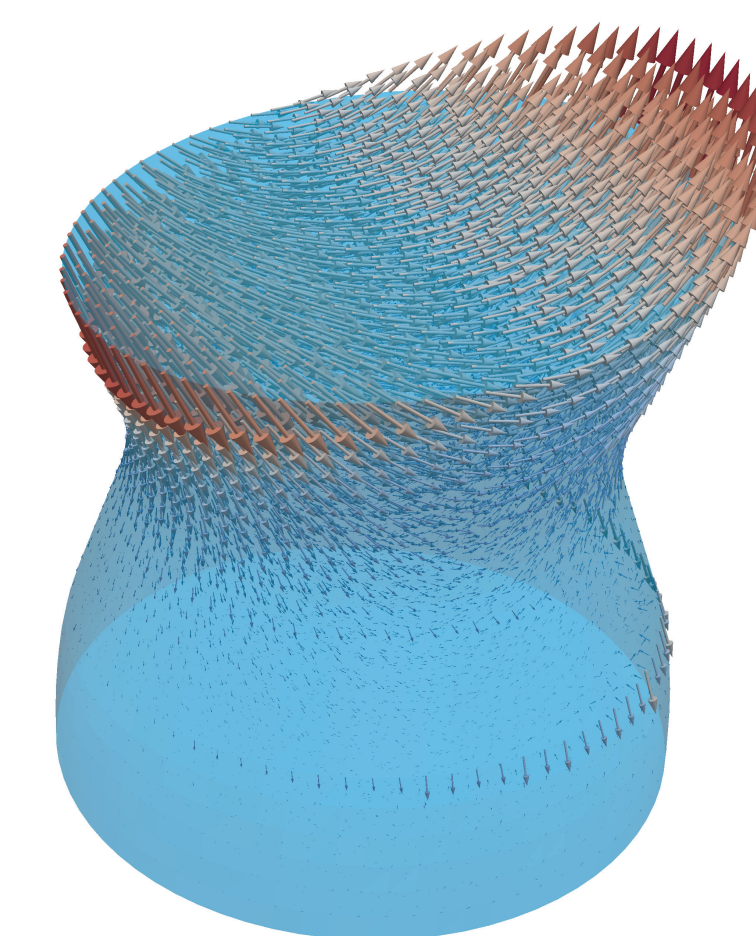


- The elements, which do not touch a NURBS boundary, are treated as standard finite elements.
- The elements on the NURBS boundary represent the exact geometry.

- Fluid-structure interaction

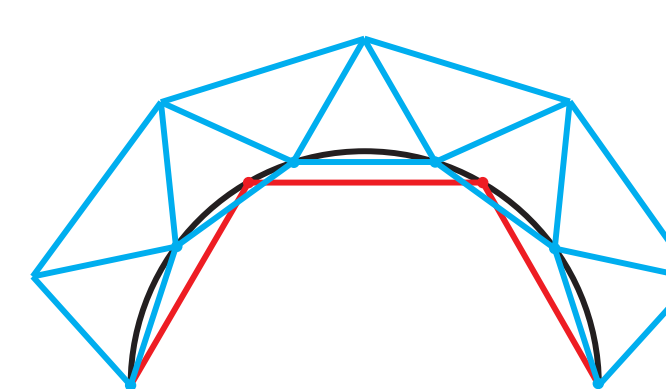
### Requirements

- free-surface flow
- deformable domain with arbitrary wall shapes
- deformable structure

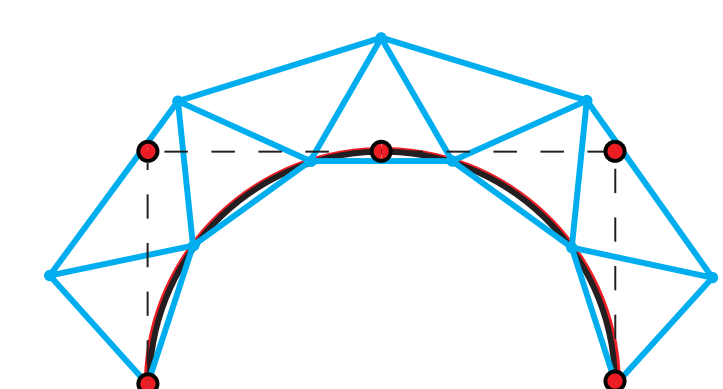


### Methods

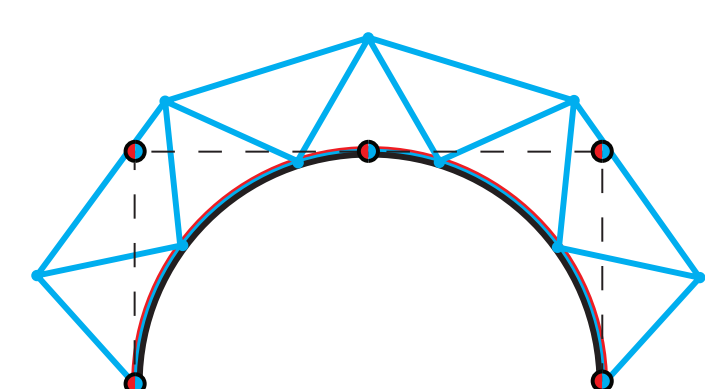
- interface tracking
- NURBS-enhanced finite elements
- arbitrary boundary description through NURBS
- Isogeometric Analysis for elastodynamics



Standard FE



IGA + Standard FE



IGA + NEFEM



### Stefanie Elgeti

- Scientific vita:
  - Diploma and PhD in mechanical engineering
  - Chief engineer at RWTH Aachen University
- Research interests
  - Numerical design of engineering components
  - Free-surface and two-phase flows
  - Spline based space-time finite element methods