Interactive Simulation Driven Design Using Adaptive FEM

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Simulation = Geometry + Physics + Data

- Understanding of physical systems, cars, cell phones, the heart, transport of drugs in the body etc can be gained using computer modeling
- Computer modeling
  - more and more reliable
  - more complex systems can be studied
- Physical systems are described by a combination of
  - Geometry (shape)
  - Physics, eg. solid or fluid mechanics
  - Data, material properties etc
  - Examples: Car, Cell phone, engine, heart, human bone …
- **Simulation** builds on the combination of **geometry, physics,** and **data** in a computer

Problem

- Simulation today is a labour intensive activity carried out by trained experts
- The tools are based on early FEM technology developed in the 70:s
- The crucial link between CAD and FEM is missing
- The simulation results are not reliable since computations are generally done only using one mesh
- Simulations are generally done too late in the design cycle leading to high costs for design changes
- Simulation used at an early stage can be used to guide and optimize the design !

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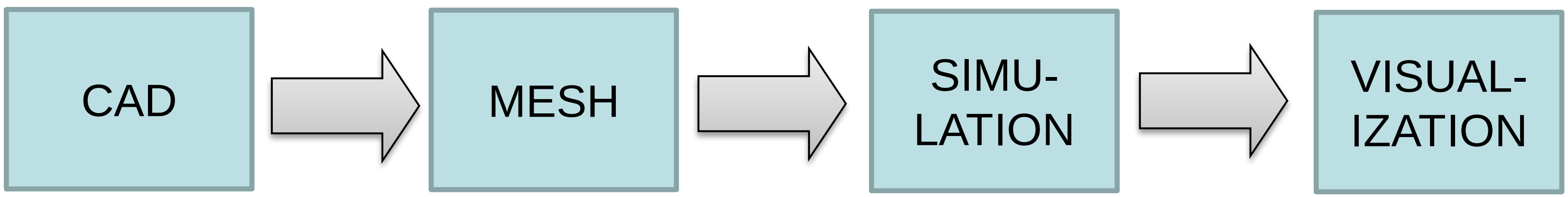
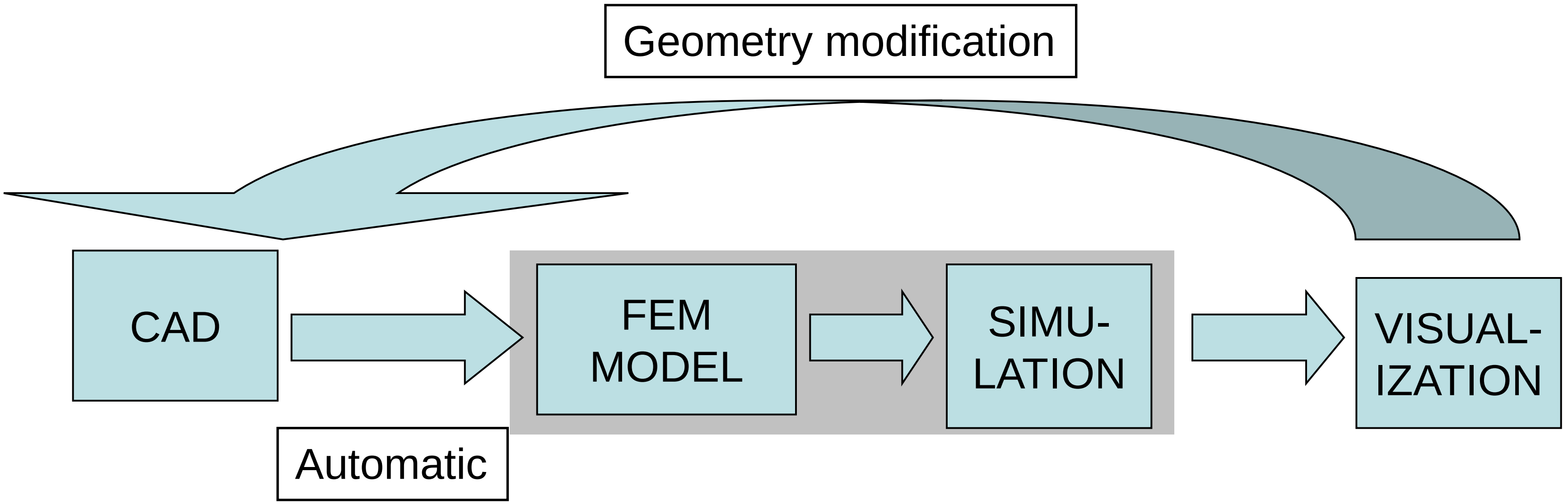
The Traditional Way



- Meshing step is, in general, time consuming, not automatic.
- Only one mesh created, prevents adaptive methods.
- Mesh has no information about the CAD geometry.
- CAD is often simplified to enable meshing with coarse elements
- Simulation software is general purpose which need a mesh of good quality (difficult to achieve in practice).
- Change in geometry leads to remeshing (not automatic).
- Local refinement done by remeshing (not automatic). May not respect CAD.

The New Way



New technology enables:

- Automatic generation of multilevel computational mesh.
- Automatic adaptive mesh generation.
- Automatic set up and solution of finite element simulation.
- Interactive simulation of design changes done in CAD.

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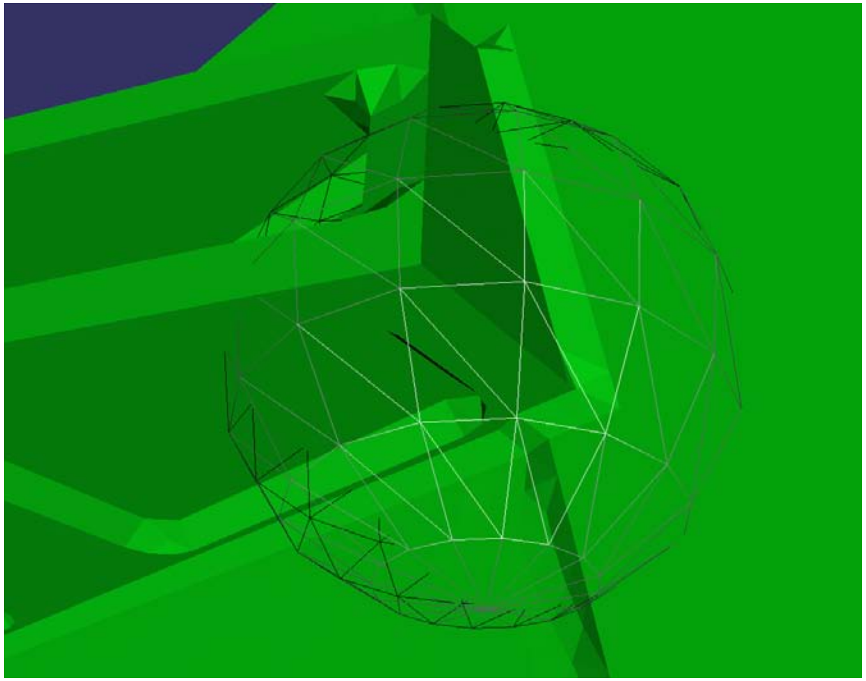
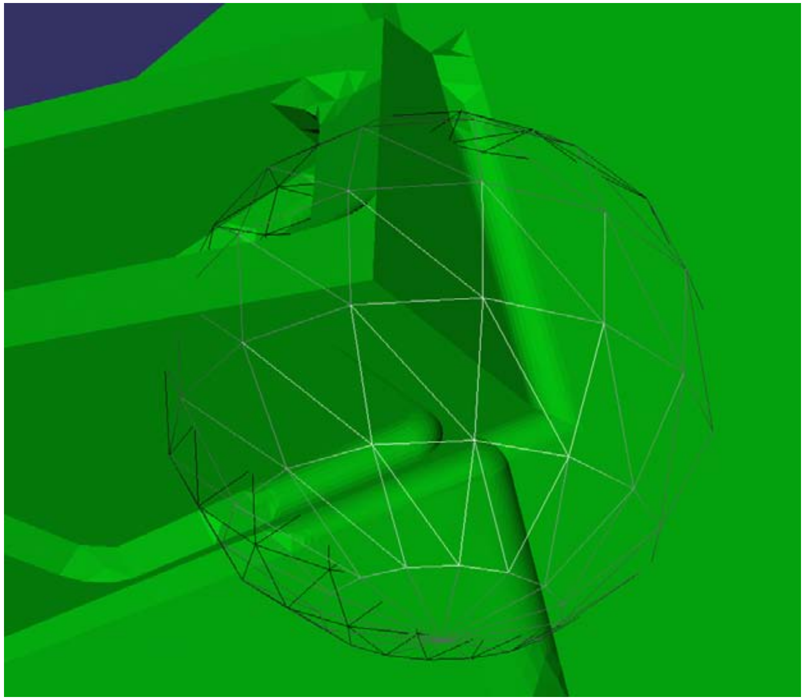
Key Elements

- Discrete geometry object holds multilevel representation of geometry and computational mesh.
- Connection to CAD model.
- Automatic creation of discrete geometry object from CAD and other types of data.
- Fast FE-solver on the same data structure.
- Geometric adaptivity resolves local geometric features.
- Solution adaptivity resolves local solution behavior.
- Adaptivity is based on mathematical theories and guarantees reliable simulation results.

Adaptive Mesh Refinement



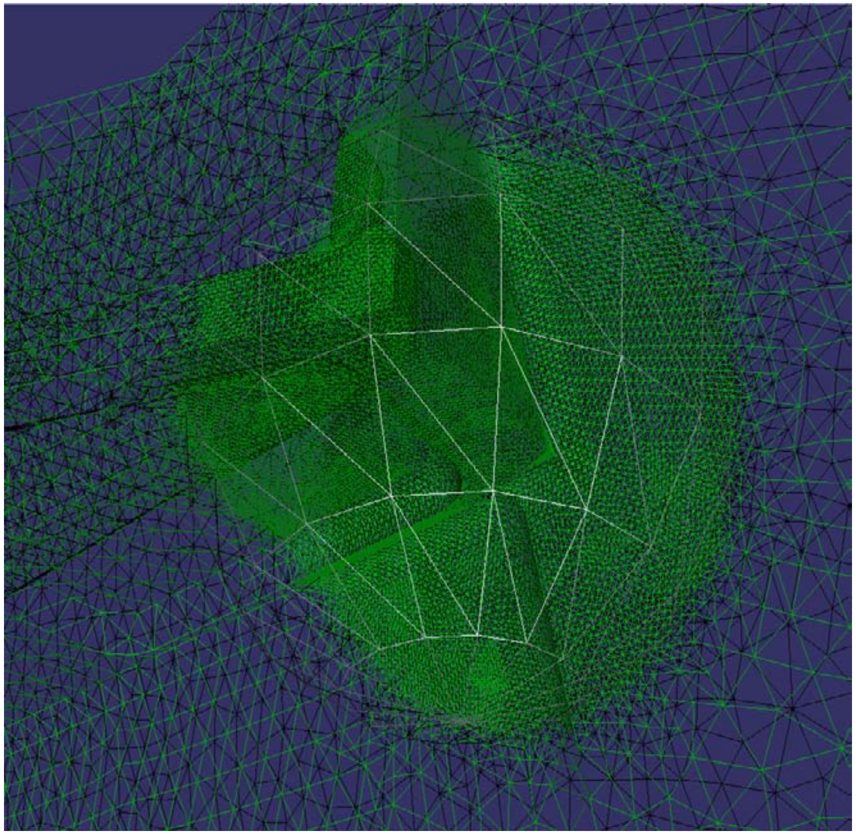
Coarse mesh does not resolve small geometric details (fillets)



Fine mesh resolves all fillets in interactively defined region of interest (inside sphere).

Adaptive Mesh

- Local fine mesh automatically created in a few seconds
- Local fine mesh resolves true CAD geometry
- CAD-Mesh communication necessary. **Not** a standard feature.
- Local fine mesh guarantees sufficient accuracy
- Large elements outside of region of interest



The resulting locally refined mesh. Note small elements in region of interest and large outside.

Estimation of Errors

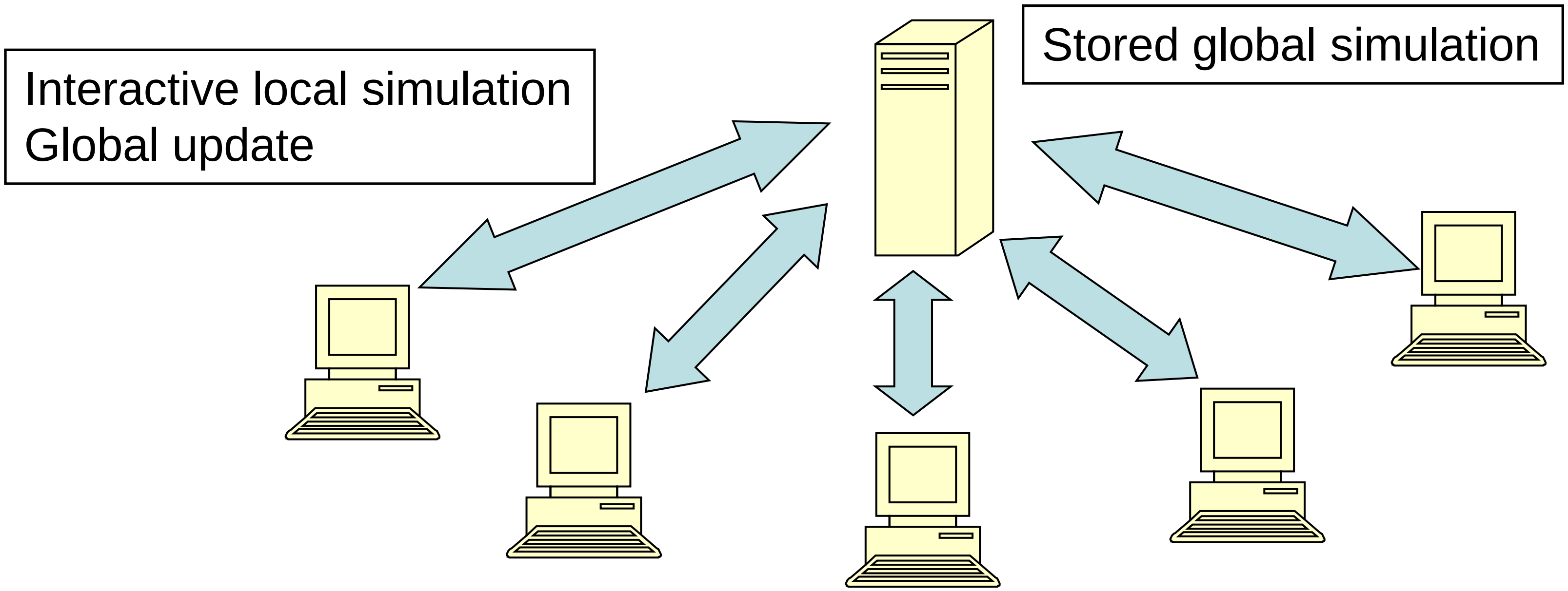
- Reliability of simulation results is key when important decisions are made based on the results
- Using a mathematical technology called a posteriori error estimates we can estimate the errors due to
  - Discretization
  - Choice of models
  - Uncertainty in parameters

  in user specified quantities of interest.
- Example: stress in a specified area used in a durability analysis
- Example: lift and drag of an automobile.

Distributed Computations

Example: Interactive local simulations

- Global simulation of the entire model (stored in database).
- Interactive detailed local simulations on work station.
- Update of global model from local modifications.



Enmesh Component Designer

- Interactive coupling with CAD software
- Boundary conditions set at a first coarse design sketch and are kept throughout the design procedure
- Simulations are done during the design procedure and can be used to guide the design changes
- Thermoelasticity
- First release coupled with SpaceClaim