3DEXPERIENCE®

Kings, Star Wars, and Uri Geller

Element Selection in a Nutshell

Axel REICHERT

Overview

- Problems
  - With our Library
  - With our Customers
  - With Ourselves
- Solutions
  - The Rationale
  - The Recipe
- Example
- Summary

Problems

With our Library

AC1D2 AC1D3 AC2D3 AC2D4 AC2D4R AC2D6 AC2D8 AC3D10 AC3D15 AC3D20 AC3D4 AC3D5 AC3D6 AC3D8 AC3D8R ACAX3 ACAX4 ACAX4R ACAX6 ACAX8
ACIN2D2 ACIN2D3 ACIN3D3 ACIN3D4 ACIN3D6 ACIN3D8 ACINAX2 ACINAX3 ASI1 ASI2 ASI2A ASI2D2 ASI2D3 ASI3 ASI3A ASI3D3 ASI3D4 ASI3D6
ASI3D8 ASI4 ASI8 ASIAX2 ASIAX3 B21 B21H B22 B22H B23 B23H B31 B31H B31OS B31OSH B32 B32H B32OS B32OSH B33 B33H C3D10 C3D10E
C3D10H C3D10HS C3D10HT C3D10M C3D10MH C3D10MHT C3D10MP C3D10MPH C3D10MPT C3D10MT C3D10P C3D10PH C3D10PHT C3D10PT C3D10T C3D15
C3D15E C3D15H C3D15V C3D15VH C3D20 C3D20E C3D20H C3D20HT C3D20P C3D20PH C3D20R C3D20RE C3D20RH C3D20RHT C3D20RP C3D20RPH C3D20RT
C3D20T C3D27 C3D27H C3D27R C3D27RH C3D4 C3D4A C3D4E C3D4H C3D4P C3D4PH C3D4PHT C3D4PT C3D4T C3D5 C3D5H C3D6 C3D6A C3D6E C3D6H
C3D6HT C3D6P C3D6PH C3D6PHT C3D6PT C3D6T C3D8 C3D8A C3D8E C3D8H C3D8HS C3D8HT C3D8I C3D8IH C3D8P C3D8PH C3D8PHT C3D8PT C3D8R
C3D8RH C3D8RHT C3D8RP C3D8RPH C3D8RPHT C3D8RPT C3D8RT C3D8S C3D8T CAX3 CAX3E CAX3H CAX3T CAX4 CAX4E CAX4H CAX4HT CAX4I CAX4IH
CAX4P CAX4PH CAX4PT CAX4R CAX4RH CAX4RHT CAX4RP CAX4RPH CAX4RPHT CAX4RPT CAX4RT CAX4T CAX6 CAX6E CAX6H CAX6M CAX6MH CAX6MHT
CAX6MP CAX6MPH CAX6MT CAX8 CAX8E CAX8H CAX8HT CAX8P CAX8PH CAX8R CAX8RE CAX8RH CAX8RHT CAX8RP CAX8RPH CAX8RT CAX8T CAXA4HN
CAXA4N CAXA4RHN CAXA4RN CAXA8HN CAXA8N CAXA8PN CAXA8RHN CAXA8RN CAXA8RPN CCL12 CCL12H CCL18 CCL18H CCL24 CCL24H CCL24R CCL24RH
CCL9 CCL9H CGAX3 CGAX3H CGAX3HT CGAX3T CGAX4 CGAX4H CGAX4HT CGAX4R CGAX4RH CGAX4RHT CGAX4RT CGAX4T CGAX6 CGAX6H CGAX6M CGAX6MH
CGAX6MHT CGAX6MT CGAX8 CGAX8H CGAX8HT CGAX8R CGAX8RH CGAX8RHT CGAX8RT CGAX8T CIN3D12R CIN3D18R CIN3D8 CINAX4 CINAX5R CINPE4
CINPE5R CINPS4 CINPS5R COD2D4P COD3D6P COD3D8P CODAX4P COH2D4 COH2D4P COH3D6 COH3D6P COH3D8 COH3D8P COHAX4 COHAX4P CONN2D2
CONN3D2 CPE3 CPE3E CPE3H CPE3T CPE4 CPE4E CPE4H CPE4HT CPE4I CPE4IH CPE4P CPE4PH CPE4R CPE4RH CPE4RHT CPE4RP CPE4RPH CPE4RT
CPE4T CPE6 CPE6E CPE6H CPE6M CPE6MH CPE6MHT CPE6MP CPE6MPH CPE6MT CPE8 CPE8E CPE8H CPE8HT CPE8P CPE8PH CPE8R CPE8RE CPE8RH
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CPEG4RT CPEG4T CPEG6 CPEG6H CPEG6M CPEG6MH CPEG6MHT CPEG6MT CPEG8 CPEG8H CPEG8HT CPEG8R CPEG8RH CPEG8RHT CPEG8T CPS3 CPS3E CPS3T
CPS4 CPS4E CPS4I CPS4R CPS4RT CPS4T CPS6 CPS6E CPS6M CPS6MT CPS8 CPS8E CPS8R CPS8RE CPS8RT CPS8T CSS8 DASHPOT1 DASHPOT2 DASHPOTA
DC1D2 DC1D2E DC1D3 DC1D3E DC2D3 DC2D3E DC2D4 DC2D4E DC2D6 DC2D6E DC2D8 DC2D8E DC3D10 DC3D10E DC3D15 DC3D15E DC3D20 DC3D20E DC3D4
DC3D4E DC3D6 DC3D6E DC3D8 DC3D8E DC3D8R DCAX3 DCAX3E DCAX4 DCAX4E DCAX6 DCAX6E DCAX8 DCAX8E DCC1D2 DCC1D2D DCC2D4 DCC2D4D DCC3D8
DCC3D8D DCCAX2 DCCAX2D DCCAX4 DCCAX4D DCOUP2D DCOUP3D DGAP DRAG2D DRAG3D DS3 DS4 DS6 DS8 DSAX1 DSAX2 EC3D8R EC3D8RT ELBOW31
ELBOW31B ELBOW31C ELBOW32 EMC2D3 EMC2D4 EMC3D4 EMC3D6 EMC3D8 FP2D2 FP3D2 FPC2D2 FPC3D2 FRAME2D FRAME3D GAPCYL GAPSPHER GAPUNI
GAPUNIT GK2D2 GK2D2N GK3D12M GK3D12MN GK3D18 GK3D18N GK3D2 GK3D2N GK3D4L GK3D4LN GK3D6 GK3D6L GK3D6LN GK3D6N GK3D6T GK3D6TN
GK3D8 GK3D8N GK3D8T GK3D8TN GKAX2 GKAX2N GKAX4 GKAX4N GKAX6 GKAX6N GKPE4 GKPE6 GKPS4 GKPS4N GKPS6 GKPS6N HEATCAP IRS21A IRS22A
ISL21A ISL22A ITSCYL ITSUNI ITT21 ITT31 JOINT2D JOINT3D JOINTC LS3S LS6 M3D3 M3D4 M3D4R M3D6 M3D8 M3D8R M3D9 M3D9R MASS MAX1
MAX2 MCL6 MCL9 MGAX1 MGAX2 PC3D PD3D PIPE21 PIPE21H PIPE22 PIPE22H PIPE31 PIPE31H PIPE32 PIPE32H PSI24 PSI26 PSI34 PSI36 Q3D10M
Q3D10MH Q3D20 Q3D20H Q3D20R Q3D20RH Q3D4 Q3D6 Q3D8 Q3D8H Q3D8R Q3D8RH R2D2 R3D3 R3D4 RAX2 RB2D2 RB3D2 ROTARYI S3 S3R S3RS S3RT
S3T S4 S4R S4R5 S4RS S4RSW S4RT S4T S8R S8R5 S8RT S9R5 SAX1 SAX2 SAX2T SAXA1N SAXA2N SC6R SC6RT SC8R SC8RT SFM3D3 SFM3D4 SFM3D4R
SFM3D6 SFM3D8 SFM3D8R SFMAX1 SFMAX2 SFMCL6 SFMCL9 SFMGAX1 SFMGAX2 SPRING1 SPRING2 SPRINGA STRI3 STRI65 T2D2 T2D2E T2D2H T2D2T
T2D3 T2D3E T2D3H T2D3T T3D2 T3D2E T3D2H T3D2T T3D3 T3D3E T3D3H T3D3T WARP2D3 WARP2D4

Problems

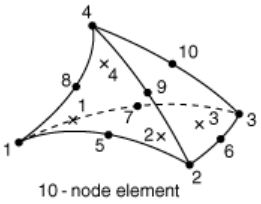
With our Library

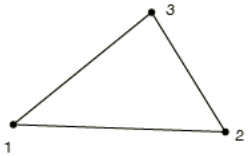
- 577 different element types in Abaqus
  - 485 unique to Abaqus/Standard
  - 10 unique to Abaqus/Explicit
  - 82 common to both codes
- Spoilt for choice
- However, only 20 element types cover already 50 percent of our example database (almost 50000 `*ELEMENT` options)

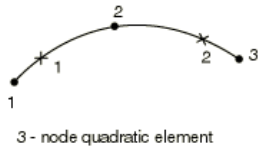
Problems

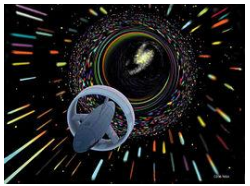
With our Library

- `R2D2` (rigid beam, as can be seen from the cross-sectional area)
- `R3D3` (successor model, different designer)
- No `C3PO` (had too much contact chatting)
- `B32` (good for most applications, two integration points)
- No `B52` (good for military applications, many disintegration points)
- `DS3`, `DS4` (popular in France)
- `HEATCAP` (popular with propeller heads)
- `MAX1`, `MAX2` (“royal” elements popular in Bavaria)
- `PSI` elements (vanish without `*MODEL CHANGE`)
- `WARP` elements (converge extremely fast)
- `C3D10MPH` (popular in America)
- No `C3D10KMH` (due to “unit imperialism”)









Problems

With our Customers

- Not knowing the name of the element
  - Customer: “I am getting an error for my ‘HEX8’ element.”
  - Support engineer: “Use one of the 46 hexahedrons with 8 nodes available in Abaqus.”

Problems

With our Customers

- Not knowing the properties of the element
  - Customer: “I am getting wrong buckling loads for my Euler column.”
  - Support engineer: “Use `C3D8I`, not one layer of `C3D8` or `C3D8R`.”

Problems

With our Customers

- Not knowing the assumptions underlying the element
  - Customer: “I am getting zero compression stress for my shell structure.”
  - Support engineer: “Use a solid element, not a plane stress formulation.”

Problems

With our Customers

- Not knowing the documentation for the element
  - Customer: “I am getting only little bending for my `C3D4` with 179.84° interior angle.”
  - Support engineer: “Search the Guides for ‘should be avoided as much as possible’.”

Problems

With our Customers

- Not knowing the theory behind the element
  - Serendipity/Lagrange
    - Persian fairy tale/Italian mathematician
  - Incompatible modes
    - Work on both Linux and Windows machines
  - Assumed/parasitic strains
    - “To be(nd), or not to be(nd)”
  - Hourglass control
    - Check old-fashioned time-measuring devices
  - Volumetric locking/selectively reduced integration
    - Save the “H” for last

Problems

With Ourselves

- Assuming you know the theory
- Assuming you want to know the theory
- Assuming you delight in unnecessary complexity as much as we do
  - Offering a 2-day seminar with 378 slides: `CAXA8n`, `CPEG4IH`, `CCL24RH`, and `CINPS5R`
  - Covering the white board with equations: “Every engineer needs to know this!”

Solutions

The Rationale

Solutions

The Rationale

- KISS: “Keep It Simple, Stupid”
- William of Ockham: Law of Parsimony (“Occam’s Razor”)
- What customers like
  - Black box thinking
  - Robust recommendations
  - Rules of thumb
  - If-then-else decision trees

Solutions

The Recipe

- Covers Abaqus/Standard and Abaqus/Explicit
- Covers 3D structural mechanics
- Suggests element choices that are
  - “Satisficing” (Herbert A. Simon)
  - Reasonably accurate and fast
  - Avoiding gross modeling mistakes
  - Less numerous, but more general

Solutions

The Recipe

- 1D elements
  - ▷ `B33` cannot be used for large strains, is missing in Abaqus/Explicit
  - ▷ `B32` should not be used for contact
  - ⇒`B31`
- 2D elements
  - ▷ Few types can be used for thick *and* thin shell behavior *and* large strains
  - ▷ Quadrilaterals are better than triangles
  - ▷ `S4` cannot be used for hyperelasticity, is expensive in Abaqus/Explicit
  - ⇒`S4R` (stacked `SC8R` for detailed analysis of transverse shear stresses)

Solutions

The Recipe

- 3D hexahedral elements
  - ▷ C3D8 should not be used for bending, is expensive in Abaqus/Explicit
  - ▷ C3D8I is very sensitive to element quality
  - ⇒C3D8R if you might be using Abaqus/Explicit
  - ▷ C3D20 should not be used for nearly incompressible materials
  - ⇒C3D20R if you will not be using Abaqus/Explicit (CSS8 for compression of thin structures)
- 3D tetrahedral elements
  - ▷ C3D10M is no true 2nd-order element, needs considerable mass scaling in Abaqus/Explicit
  - ▷ C3D10HS is quite expensive, is missing in Abaqus/Explicit
  - ⇒C3D10

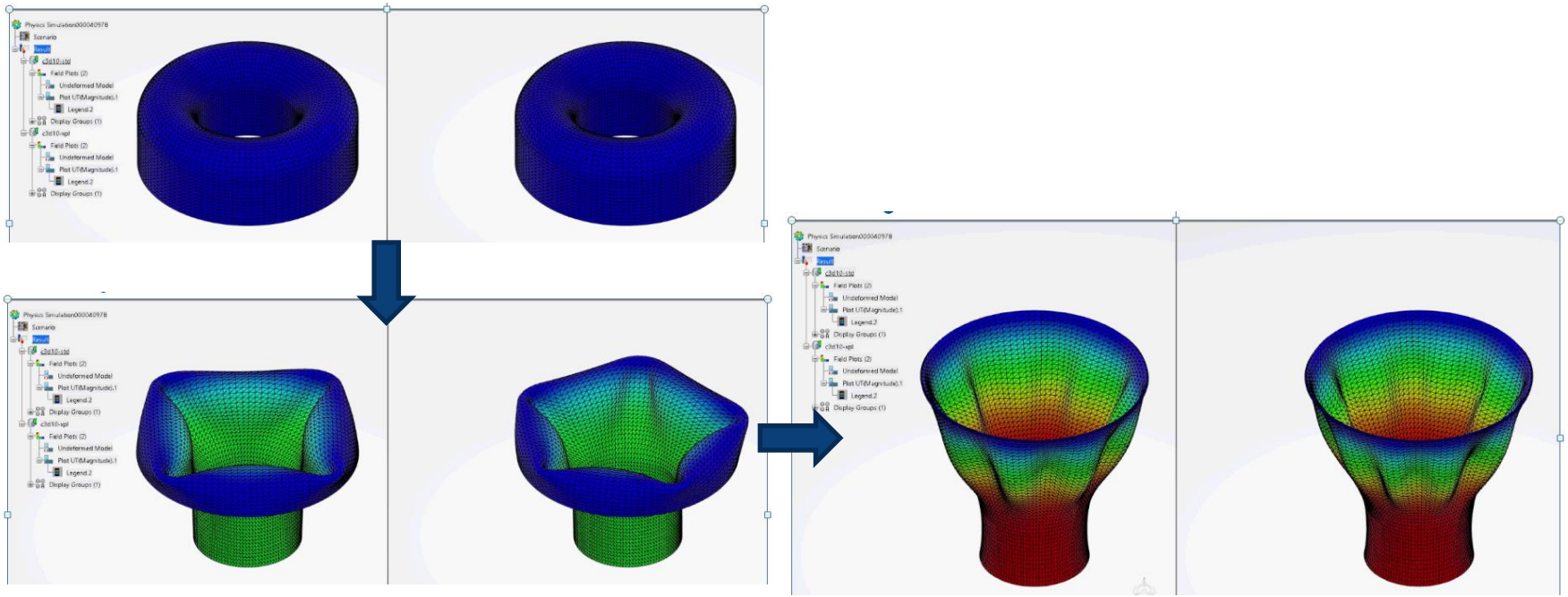
Solutions

The Recipe

- Miscellaneous
  - Prefer `*RIGID BODY` for deformable (solid) elements over “skin modeling” with `R3D4`, `SFM3D4R`, `M3D4R`, or `S4R`
    - No fiddling with density, thickness, or offset: Mass is automatically calculated correctly.
    - No snagging in contact analysis: Nodes are automatically pushed outside.
  - Prefer `CONN3D2` over spring and dashpot elements
    - Abaqus had connector elements since 2001. They offer much more functionality.
  - For fully incompressible materials, append an “`H`” to the 3D element name
    - Abaqus had hybrids decades before the advent of electromobility.

Example

Turning a rubber tube inside out



Example

Model details

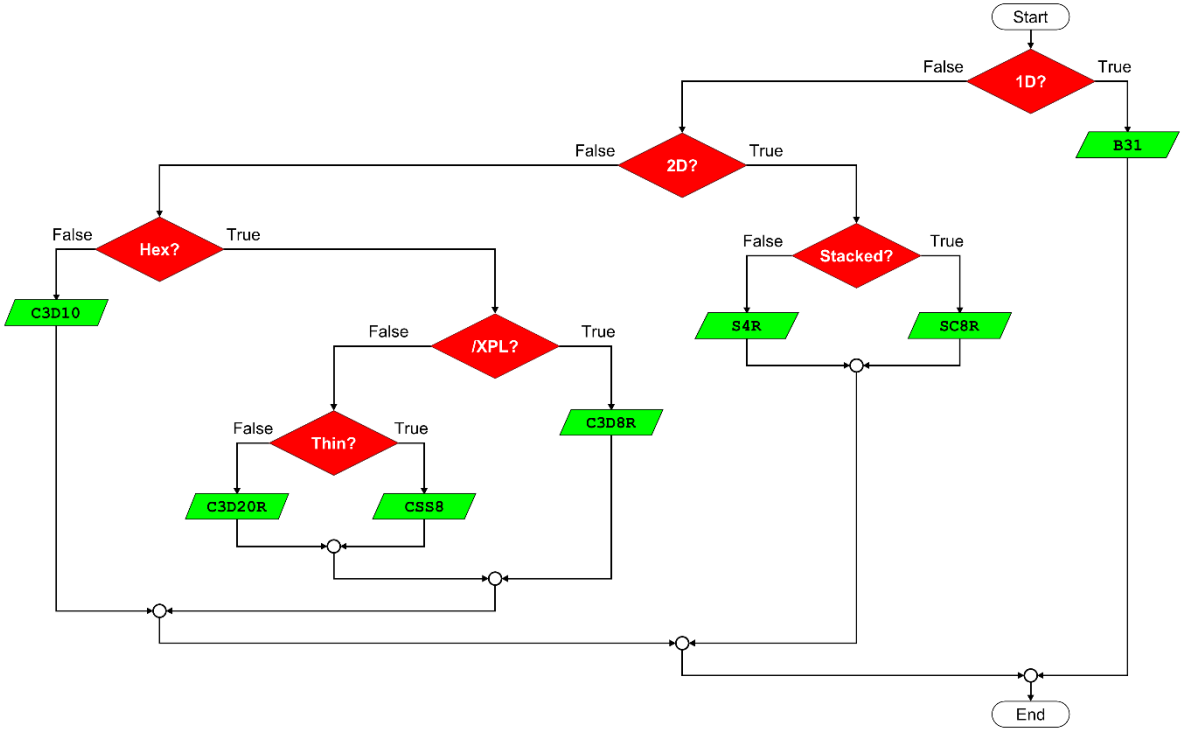
- One `C3D10` element over thickness
- Almost incompressible neo-Hooke
- Outer edge pinned
- Inner face displaced
- Smooth step amplitude
- Frictional self-contact

Example

Comparison of the implicit and explicit versions

- Qonvergence Quartet with:
  - “Quasi-static” type for implicit
  - Variable mass scaling for explicit
- No *CONTROLS
- No stabilization
- Abaqus/Standard took took 16 hours on 3 cores.
- Abaqus/Explicit was factor 8 faster.

Summary



Sources

- "R2-D2": https://en.Wikipedia.org/wiki/R2-D2#/media/File:R2-D2_Droid.png
- "C-3PO": https://en.Wikipedia.org/wiki/C-3PO#/media/File:C-3PO_droid.png
- "2010 Citroën DS3 (MY10) 1.6 VTI DStyle Plus 3-door hatchback. Photographed in Singapore": By EurovisionNim under CC BY-SA 4.0
- "Citroën DS4 SoChic": By M_93 under CC BY-SA 3.0 de
- "A propeller hat, also known as a propeller beanie": By Nemosandman under CC BY-SA 3.0
- "Denkmal für König Maximilian II. Joseph (1811-1864) sog. Max II Denkmal": By Maximilian Dörrbecker (Chumwa) under CC BY-SA 3.0
- "Fork bent by James Randi": By Bubba73 (Jud McCranie) under CC BY-SA 3.0
- "Kiss at Hellfest in Clisson, France, 2013": By Llann Wé² under CC BY-SA 3.0
- "William of Ockham, from stained glass window at a church in Surrey": By Moscarlop under CC BY-SA 3.0
- "French razor with horn scales": By CoffeeAddict under CC BY-SA 3.0

… stop teaching you on $\bar{B}$,
you can have one more beer at the bar.