TAMING THE WILD BEAST

ENCAPSULATING OPEN-SOURCE SOFTWARE BEHIND DEMOCRATIZATION FRAMEWORK
Agenda

• Definition and distinctives of Democratization
• Issues and benefits of opensource analysis software
• Forklift Bumper model
• Process flow for Open Source
• Process flow for Democratization
• Conclusions and Recommendations
1896
Ford Quadricycle

Industry size in the millions of dollars

Only an expert (i.e., a mechanic) can drive

2015
Ford Focus

Industry size over 1.5 trillion dollars

Anybody (i.e., non-expert) can drive

Democratization: “Makes Technology Vanish”
## Democratization vs Standard Engineering Scripting

<table>
<thead>
<tr>
<th>Democratization of Simulation</th>
<th>Engineering Scripting</th>
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<tbody>
<tr>
<td>(rigorous, validated, standards-based for non-experts)</td>
<td>(ad-hoc, inconsistent, non-maintainable for experts)</td>
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<tr>
<td>Puts simulation <strong>safely in the hands of the non-experts</strong></td>
<td>Improves the efficiency of the experts</td>
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<td>Requires easy-to-use GUI's</td>
<td>A command line interface is “just fine”!</td>
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<tr>
<td>Requires rock-solid, validated, reusable Templates</td>
<td>Often done in an ad-hoc, one-of-a-kind manner</td>
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<td>Encodes and <strong>enforces validated company standards</strong></td>
<td>Often does not adhere to any standards</td>
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<td>Creates non-expert applications that <strong>speak the language of the user</strong>, not the language of simulation</td>
<td>No attempt is made to hide the language of simulation</td>
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<td>Creates applications that have a wide design scope</td>
<td>Often written to solve “today’s problem”, then extended over time in an ad-hoc, non-documentated manner</td>
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<tr>
<td>The best ones <strong>work across a product family</strong></td>
<td></td>
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<tr>
<td>Usually division- or enterprise-wide libraries of applications that are made <strong>consistent and maintainable</strong></td>
<td>Created and maintained in an ad-hoc manner, often with little coordination across divisions</td>
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The Wild Beast - Issues and Benefits of Open Source Analysis Software

- Many open source structural solvers, most compatible with democratization
- We will use Calculix for our example
- Calculix (GPL license)
  - FEA solver noted for partial compatibility with Abaqus and stability

- Open Source Benefits
  - Cost vs commercial codes
    - Big issue for small firms
  - Customization ability
  - Accessibility and Scalability
  - Significant good performing SW
  - Sometimes excellent online documentation and support

- Open Source Issues
  - Lots of deviations from standards
  - Can be buggy with limited error messages
  - Significant missing pieces in the analysis pre-solve-post stack
  - Customer occasionally question Open Source solution integrity
  - Lack of guaranteed support options
  - License legalities may not be usable for your business

- Many open source structural solvers, most compatible with democratization
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Flow Diagram for Democratize Model Development

**NON-EXPERT ACCESS**

Democratized Frontend
Comet Solutions

**SPECIALIZED EXPERT REQUIRED FOR THESE**

Geometry and Meshing
Gmsh
+ Python deck rewrite (conform to calculix)

Solver
Calulix

Post Process
CGX script and Python Script

Geometry + Tags
PROE/SolidWorks/et.al.

Mesher
Comet Solutions

Solver
Calulix

Post Process
Vcollab

OR

We will look at this approach
Rubber Bumper Model

- Forklift striking post with rubber bumper

- Objective: Guide design of new form factors to protect posts and prevent excess rubber deflection

- FEA Calculix transient model
  - Tetrahedron elements
  - Simulated impact velocity

- Metrics of interest
  - Peak VonMises stress of post, bolt, bumper bracket < Yield Stress (30ksi)
  - Deflection of Rubber Bumper < 50% of original height
Gmsh Geometry and Meshing
Cost= 4 days

- GUI and scripting
- Structured and Unstructured mesh
- Parameterization a natural fit
- Meshing advanced- partitions, etc. to avoid negative Jacobians – plan to tweak

Good graphics and most commands pickable – picks appended to script

Setup Parameters

```plaintext
//parameterize post dimensions (assume square), thickness and hgt
pstwidth= 6;       // min= 1, max= 12
pstthk= .25;       // min= .0625, max= (pstwidth - .75)
psthgt= 60.;       // min= 10, max= 120
...
```

Create Geometry and control mesh size

```plaintext
// create post
p1 = newp; Point(p1)= {0, pstwidth/2, 0};
p2 = newp; Point(p2)= {0, -pstwidth/2, 0};
L1 = newl; Line(L1)= {p1,p2};
// Control mesh size around p1, p2
Characteristic Length {p1,p2} = .3;
// Force this line to have only 1 element
Transfinite Line(L1)= 1;
...
```

Some extrusion and Boolean operations

```plaintext
S3 = new s; Plane Surface(S3)= {LL,LL1, LL2, LL3};
//extrude surface to volume
ex = Extrude {0, 0, bmphgt} { Surface{S3};};
...
```

```
// Finally some Mesh Controls
Mesh.Algorithm=1; //1=MeshAdapt, 2=Automatic, 5=Delaunay
Mesh.ElementOrder=1;
...
Mesh 3;
Coherence Mesh; Save “m.inp”;
```

Finally set and launch mesher and save to file
Calculix Structural FEA Solver
Time= 4 days

• Similar to Abaqus data decks
  – Some problems such as 80char/line limit
  – Interconnects and *step control different
  – Fix by hand or custom scripts

• Powerful NL and Linear Solver
  – Multi-proc’s
  – Reliable

Custom Python script - conform Abaqus to Calculix

$ Python mod_inp.py gmsh_mesh.inp

**main_forklift.inp
*include, file="gmsh_mesh.inp"
...
*MATERIAL,NAME=aluminum_inch
...
*STEP,INC=10000, nlgeom=yes
*STATIC
...
*STEP,INC=10000, NLGEOM= yes
*DYNAMIC,ALPHA=-0.2,SOLVER=ITERATIVE CHOLESKY
1.E-4,5.e-3,1.E-12, 1.

Main driver deck for calculix – similar to Abaqus .inp

Command line execution

$ ccx main_forklift

Results in .frd, .dat files
CGX, Calculix, GraphiX, and Python Post Processing

Time = 2 days

- CGX gui limited but reads .frd
  - Can be run batch mode
  - Cryptic scripting but works

- Difficult to find reliable post processors for .frd format
  - Force to do lots of scripting

Calculix Results
- .frd, .dat files

Output files need conversion scripts

$ cgx -b postproc.cgx
- Creates .png’s Fringe plots

$ python readccxdat.py main_forklift.dat
- Custom summary max-min data

$ python frd2vcollab.py main_forklift.frd
- Convert to Comet Solutions/Vcollab
Wild Beast Tamed – SimApp Model Create-Execute

• Non-expert can easily submit this analysis in .5hr

• Time=1 day for specialist to create this SimApp using the EASA low-code platform
Wild Beast Tamed – SimApp Results and Decision Report

- Non-expert can easily understand the RED/GREEN pass fail indicator
  - Primary top level report

- Pass-fail indicator controlled by specialist from backend
  - Specialist responsible for SimApp results

- Easily access Extra detail plots and fringe plots if desired

5MPH – Both metrics pass
Decision = Yes

7.5MPH – Fails deflection metric
Decision = No

http://websimapps.com
etsolutions.com/easa/
Conclusions and Recommendations

- Time for specialist to setup, debug, and conduct this bumper analysis with Open Source
  - 10 days (8 hour/day) ~ 1-2x more time than commercial + 1-2 days SimApp
  - Extra time typically required for open source
  - Often only option for small firms due to cost

- Time for new non-specialist to conduct new analysis on new bumper geometry with democratized SimApp
  - <2 hr
  - No difference in time opensource vs commercial after democratization

- For families of products
  - Order of magnitude savings using democratization
  - Order of magnitude savings using open source if democratized

Recommendations

- For families of products
  - Specialist create model systems, consider open source if business model/customer supports it
  - Specialist democratize model system to SimApp for all future studies and design changes/updates
    - This is savings for commercial and Open Source resourcing
Thank You!

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