Engineering Sketch Pad (ESP) Training
Session 1: Overview

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Introductions

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Overview

- Background and objectives
- ESP architecture
- Distinguishing features
- BRep terminology
- Overview of training
- ESP Graphical User Interface (GUI)
- Hands-on exercise:
  - bottle
- Muddy cards

Background — 1

- Over the past 40 years, there have been an increasingly-complex (complicated) series of "CAD" systems to support the geometry needs of the manufacturers of mechanical devices
  - CAD = "computer aided drafting"
  - CAD = "computer-aided drawing"
  - CAD = "computer-aided design"
  - CAD = "computer-aided development"
- "CAD" has sometimes been erroneously equated with geometry

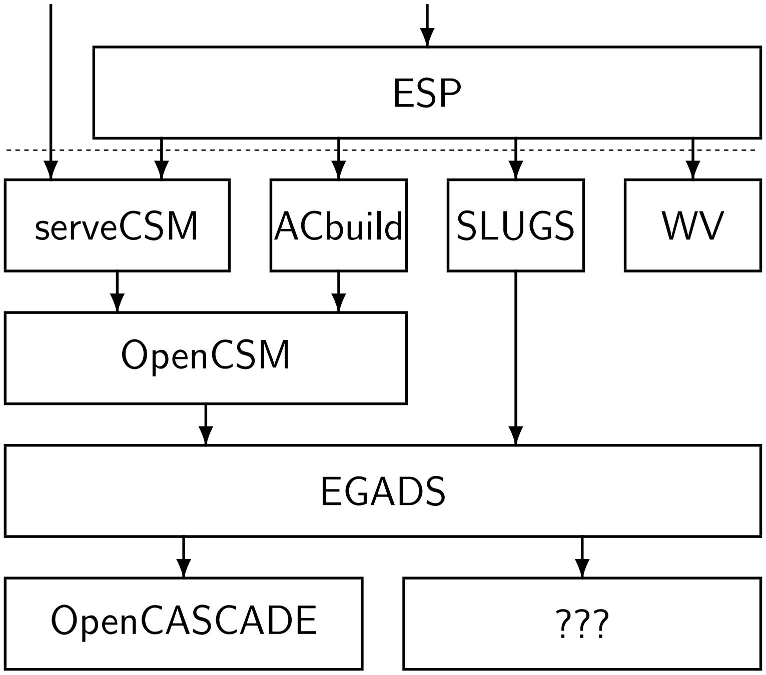
Background — 2

- These systems are built around the notion that the developer of a geometric model should construct the model to be consistent with the manufacturing process (**mCAD**)
- The analytical designer of a system wants to think about the function and performance of the device being generated, often leading to the generation of a separate **aCAD** model
- The modeling techniques supported by **aCAD** and **mCAD** are often so dissimilar that model transfer between them is done by limited translators or by “starting over”
- This one-way path from **aCAD** to **mCAD** leads to a “broken process”

Objective

- ESP is:
  - a geometry creation and manipulation system designed specifically to support the analysis and design of aerospace vehicles
  - can be run stand-alone for the development of models
  - can be embedded into other analysis and design systems to support their geometry needs
- ESP is not:
  - a full-featured computer-aided design (CAD) system designed specifically to support the mechanical design and manufacturing of any complex system
  - a system to be used for creating “drawings”

ESP Architecture



Distinguishing Features — Solid Modeller

- Construction process guarantees that models are realizable solids
  - watertight representation needed for grid generators
  - sheets and wires are supported when needed
- Parametric models are defined in terms of:
  - Feature Tree
    - "recipe" for how to construct the configuration
  - Design Parameters
    - "values" that describe any particular instance of the configuration

Distinguishing Features — Feature-based

- Configurations start with the generation of primitives
  - standard primitives: box, sphere, cone, cylinder, torus
  - grown primitives (from sketches): extrude, rule, blend, revolve, sweep, loft
  - user-defined primitives (UDPs)
- Bodys can be modified
  - transformations: translate, rotate, scale, mirror
  - applications: fillet, chamfer, hollow
- Bodys can be combined
  - Booleans: intersect, subtract, union
  - other: join, connect, extract, combine

Distinguishing Features — Parametric

- ESP models typically contain one or more Design Parameters
- Design Parameters can be single-valued, 1D vectors, or 2D arrays of numbers
- Each Design Parameter has a current value, upper- and lower-bounds, and a current “velocity” (which is used to define sensitivities)
- Design Parameters can be “set” and “get”
  - through ESP’s tree window
  - externally via calls to the Application Programming Interface (API)
- Arguments of all operations can be written as “expressions” that reference Design Parameters

Distinguishing Features — Associative

- ESP maintains a set of global and local attributes on a configuration that are persistent through rebuilds
- Supports the generation of multi-intent models
  - attributes can be used to associate conceptually-similar parts in the various models
- Supports the generation of multi-disciplinary models
  - attributes can be used to associate surface groups which share common loads and displacements
- Supports the "marking" of Faces and Edges with attributes such as nominal grid spacings, material properties, . . .

Distinguishing Features — Differentiated (1)

- ESP allows a user to compute the sensitivity of any part of a configuration with respect to any Design Parameter
- Many of OpenCSM's commands have been analytically "differentiated"
  - efficient, since there is no need to re-generate the configuration
  - accurate, since there is no truncation error associated with "differencing"

Distinguishing Features — Differentiated (2)

- Other commands (currently) require the use of finite-differenced sensitivities
  - less efficient, since it requires the generation of a “perturbed” configuration
  - robust, since a new “mapping” technique guarantees the correct association of points in the baseline and perturbed geometries
  - less accurate, since one needs to carefully select a “perturbation step” that is a balance between truncation and round-off errors

Distinguishing Features — Extensible

- Users can add their own user-defined primitives (UDPs)
  - create a single primitive solid
  - are written in C, C++, or FORTRAN and are compiled
  - can be written either top-down or bottom-up
  - have access to the entire suite of methods provided by `EGADS`
  - are coupled into `ESP` dynamically at run time
- Users can add their own user-defined functions (UDFs)
  - consume one or more Bodys from stack
  - are otherwise similar to UDPs
- Users can add their own user-defined components (UDCs)
  - can be thought of as “macros”
  - create zero or more Bodys
  - are written as `.csm`-type scripts

Distinguishing Features — Deployable

- `ESP`'s back-end (server) runs on a wide variety of modern compute platforms
  - LINUX
  - OSX
  - Windows
- `ESP`'s user-interface (client) runs in most modern web browsers
  - FireFox
  - Google Chrome
  - Safari
  - Note: Internet Explorer is not supported at this time
- `ESP` can be distributed anywhere in the computer environment
  - open-source project (using the LGPL 2.1 license) that is distributed as source

Distinguishing Features — Embeddable

- Models are defined in `.csm` files
  - human readable ASCII
  - stack-like language that is consistent with Feature Tree traversal
  - contains looping via "patterns"
  - contains logical (if/then) constructs
  - contains error recovery via thrown/caught signals
- `OpenCSM` modeling system is defined by an Application Programming Interface (API) that allows it to be embedded into other applications
  - load a Master Model
  - interrogate and/or edit the Master Model
  - execute the Feature Tree and create BRep(s)
  - interrogate the BRep(s)
  - "set" and "get" sensitivities

Boundary Representation – BRep

Top Down ↓

Topological Entity	Geometric Entity	Function
Model		
Body	Solid, Sheet, Wire	
Shell		
Face	**surface**	$(x, y, z) = \mathbf{f}(u, v)$
Loop		
Edge	**curve**	$(x, y, z) = \mathbf{g}(t)$
Node	**point**	

↑ *Bottom Up*

- *Solids* are open at machine precision – tolerances
  - Node points that bound Edges may not be on the curve
  - Edge curves that bound the Faces (through Loops) may not be on the underlying surface

Overview of Training

- The training is divided into a series of sessions that cover the best practices for using ESP
- Each session starts with a lecture in which the basic ideas are discussed
- Each session then contains a series of hands-on exercises, designed to reinforce the basic ideas

Training Sessions

1. ESP Overview
2. Sketching fundamentals
3. Solids fundamentals
4. CSM scripts
5. Using UDPs, UDFs, and UDCs
6. Sensitivities
7. Putting it all together

Launching ESP

- For interactive use, ESP requires both a server (`serveCSM`) and a client/browser (`ESP.html`)
- Technique 1: start browser automatically:

  ```
  setenv ESP_START "open -a /Applications/Firefox.app ../ESP/ESP.html"
  ```

  or

  ```
  export ESP_START="open -a /Applications/Firefox.app ../ESP/ESP.html"
  ```

  or

  ```
  set ESP_START="open -a /Applications/Firefox.app ../ESP/ESP.html"
  ```

  and then

  ```
  serveCSM ../data/tutorial1
  ```

- Technique 2: start browser separately:

  ```
  serveCSM ../data/tutorial1
  ```

  and then open a browser on `ESP.html`

ESP Command Line (1)

- To start `serveCSM`

  `serveCSM [filename[.csm]] [options...]`

  where `[options...]` include:

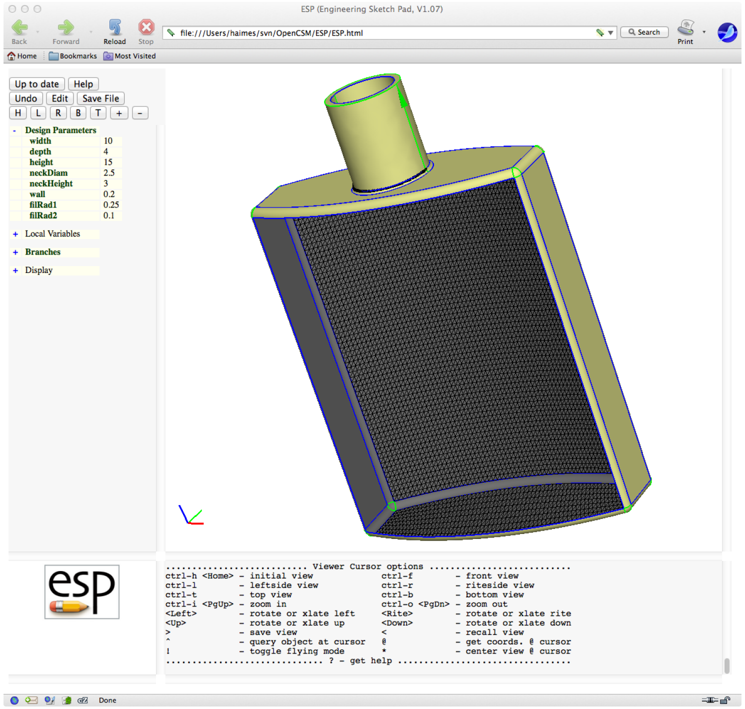
  - `filename` is the name of the `.csm` file that contains the Model
  - `-batch` runs the case but does not attach to a browser
  - `-help` or `-h` prints listing of acceptable options
  - `-jrnl jrnlname` can be used to replay a previous session
    - current session is stored in file `portXXXX.jrnl`
    - file must be renamed to be used for next session
  - `-outLevel n` selects the output level (1 is the default)
  - `--version` or `-version` or `-v` to return version information
  - ...

ESP Command Line (2)

- Other `[options...]` include:
  - `-addVerify` to create `.csm_verify` file that contains verification assertions
  - `-dict dictname` loads constants defined in dictionary file
  - `-egg eggname` uses an external grid generator
  - `-port portnum` selects the port for communication with the browser (7681 is the default)
  - `-printBreps` prints BRep info to server window
  - `-sensTess` to produce configuration sensitivity (instead of tessellation sensitivity) output
  - `-tessFact factor` to adjust default tessellation parameters
  - `-verify` to execute `ASSERT` statements that contain `verify=1`

ESP Screen Layout

- Graphics window
  - 3D image
  - 2D sketcher
  - forms
- Tree window
  - Design Parameters
  - Local Variables
  - Branches
  - Display
- Key window
  - color key
- Messages window



-	Design Parameters	
	width	10
	depth	4
	height	15
	neckDiam	2.5
	neckHeight	3
	wall	0.2
	filRad1	0.25
	filRad2	0.1

+ Local Variables

+ Branches

+ Display

```
............................ Viewer Cursor options ...........................
ctrl-h <Home> - initial view            ctrl-f        - front view
ctrl-l        - leftside view           ctrl-r        - riteside view
ctrl-t        - top view                ctrl-b        - bottom view
ctrl-i <PgUp> - zoom in                 ctrl-o <PgDn> - zoom out
<Left>        - rotate or xlate left    <Rite>        - rotate or xlate rite
<Up>          - rotate or xlate up      <Down>        - rotate or xlate down
>             - save view               <             - recall view
^             - query object at cursor  @             - get coords. @ cursor
!             - toggle flying mode      *             - center view @ cursor
.............................. ? - get help ..................................
```

Image Manipulation via the Mouse

- Translation
  - press and drag any mouse button
- Rotation
  - hold down **Ctrl** and drag any mouse button
  - hold down **Alt** and drag any mouse button
- Zoom
  - hold down **Shift** and drag any mouse button
  - scrolling the middle mouse button also scrolls in/out
- Flying mode
  - press **!** in Graphics window to toggle mode
  - image continues moving image until mouse is released

Image Manipulation via Key Presses (1)

"flying-mode" is off by default

Key-press	"flying-mode" off	"flying-mode" on
←	rotate left 30°	translate left
→	rotate right 30°	translate right
↑	rotate up 30°	translate up
↓	rotate down 30°	translate down
+	zoom in	zoom in
-	zoom out	zoom out
PgUp	zoom in	zoom in
PgDn	zoom out	zoom out
Home	home view	home view

Note: holding **Shift** reduces the increment

Image Manipulation by Key Presses (2)

Key-press	orientation	note
Ctrl-h	home view	y vs x
Ctrl-f	front view	y vs x
Ctrl-l	left side view	y vs z
Ctrl-r	right side view	y vs $-z$
Ctrl-b	bottom view	z vs x
Ctrl-t	top view	$-z$ vs x
Ctrl-i	zoom in	
Ctrl-o	zoom out	

Image Manipulation via Buttons

Button press	orientation	note
H	home view	y vs x
L	left side view	y vs z
R	right side view	y vs $-z$
B	bottom view	z vs x
T	top view	$-z$ vs x
+	zoom in	
-	zoom out	

Button are near top of Tree window

Image Manipulation via the Tree Window

- In the Tree window, **Display** contains an entry for each Body
- If the **Body** is expanded (the + on the left is pressed), then entries appear for **Faces** and **Edges**
- If the **Faces** and/or **Edges** are expanded, the names of all Faces and/or Edges are listed
- **Viz** toggles the visibility of the associated Body(s), Face(s), or Edge(s)
- **Grd** toggles the visibility of the grid of the associated Body(s), Face(s), or Edge(e)
- **Trn** toggles the pseudo-transparency of the the associated Face(s)
- **Ori** toggles the orientation vectors of the associated Edge(s)
- Toggling at a “group” level effects the setting of its children

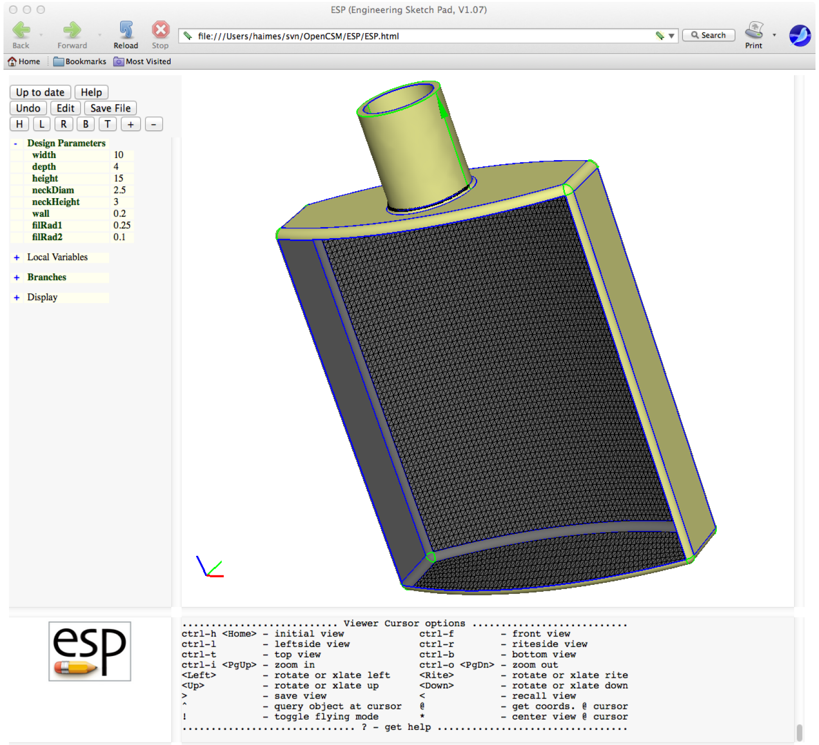
Image Inquiry

- Re-center the image at the current location and set a new “rotation center”
  - *
- Find the location of the cursor (in 3D space) and report it in the Messages window
  - **@**
- Identify the object (Edge or Face) and list all its attributes in the Messages window
  - $\wedge$
- List the key-press options in the Messages window
  - **?**
- Orientation of image in Graphics window
  - red axis in x-direction
  - green axis in y-direction
  - blue axis in z-direction

Hands-on exercise

1. Start `serveCSM` using the file `bottle.csm`
2. Explore the various image manipulation tools
3. See if you can get the image on the next page

bottle After Image Manipulations



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Muddy Cards

- Opportunity to provide immediate “feedback”
- Any questions about presentation material, critique of sample problems, . . .
- Questions will be answered at next session