OpenSees

Getting Started With OpenSees

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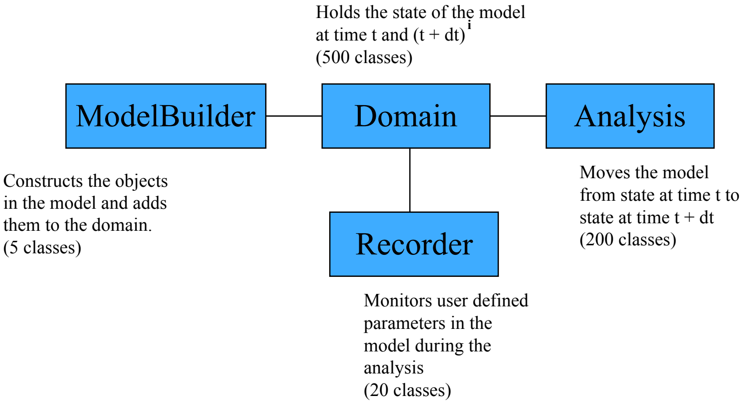
OpenSeesDays 2010

NEES NEEScomm

Remember OpenSees is a Software Framework?

- A framework is **NOT an executable**.
- A ***framework*** IS a set of cooperating software components for building applications in a specific domain.
- The OpenSees framework is written primarily in the object-oriented language C++; though other languages namely C and Fortran are also used.
- The abstract classes in the OpenSees framework define the interface. The concrete subclasses that exist in the framework provide the implementations.
- Other classes can be provided to extend the capabilities of the framework by developers using DLL's or providing the source code to the OpenSees repository.
- Currently over 1000 classes in the OpenSees framework.

Main Abstractions in OpenSees Framework



Holds the state of the model
at time t and (t + dt)
(500 classes)

ModelBuilder

Domain

Analysis

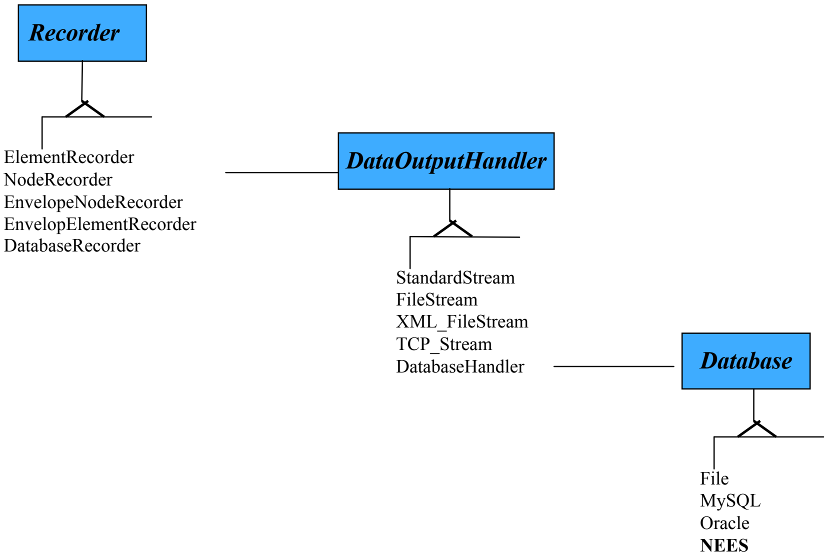
Constructs the objects
in the model and adds
them to the domain.
(5 classes)

Recorder

Moves the model
from state at time t to
state at time t + dt
(200 classes)

Monitors user defined
parameters in the
model during the
analysis
(20 classes)

Recorder Options



Recorder

ElementRecorder
NodeRecorder
EnvelopeNodeRecorder
EnvelopElementRecorder
DatabaseRecorder

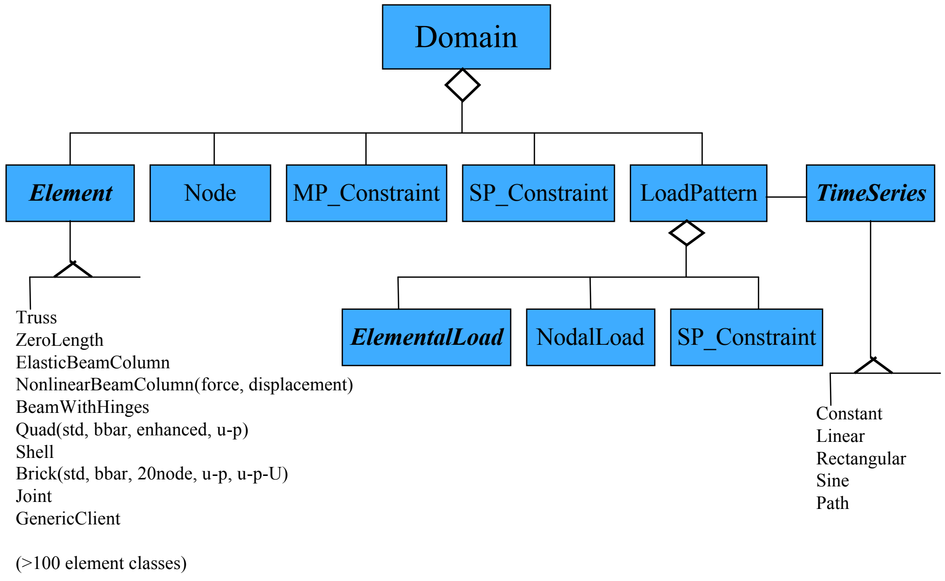
DataOutputHandler

StandardStream
FileStream
XML_FileStream
TCP_Stream
DatabaseHandler

Database

File
MySQL
Oracle
NEES

What is in a Domain?



Domain

Element

Node

MP_Constraint

SP_Constraint

LoadPattern

TimeSeries

ElementalLoad

NodalLoad

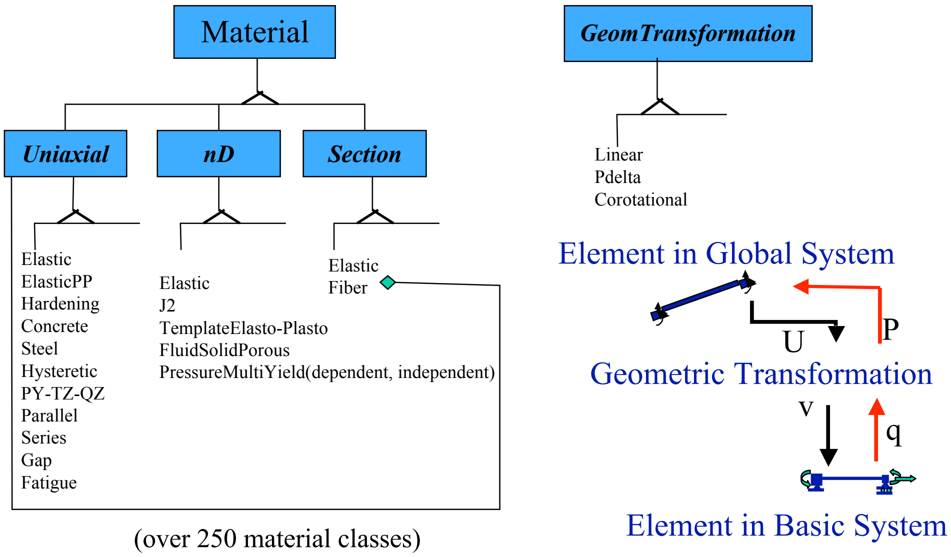
SP_Constraint

Truss
ZeroLength
ElasticBeamColumn
NonlinearBeamColumn(force, displacement)
BeamWithHinges
Quad(std, bbar, enhanced, u-p)
Shell
Brick(std, bbar, 20node, u-p, u-p-U)
Joint
GenericClient

(>100 element classes)

Constant
Linear
Rectangular
Sine
Path

Some Other Classes associated with Elements:



Material

Uniaxial

nD

Section

Elastic
ElasticPP
Hardening
Concrete
Steel
Hysteretic
PY-TZ-QZ
Parallel
Series
Gap
Fatigue

Elastic
J2
TemplateElasto-Plasto
FluidSolidPorous
PressureMultiYield(dependent, independent)

Elastic
Fiber

(over 250 material classes)

GeomTransformation

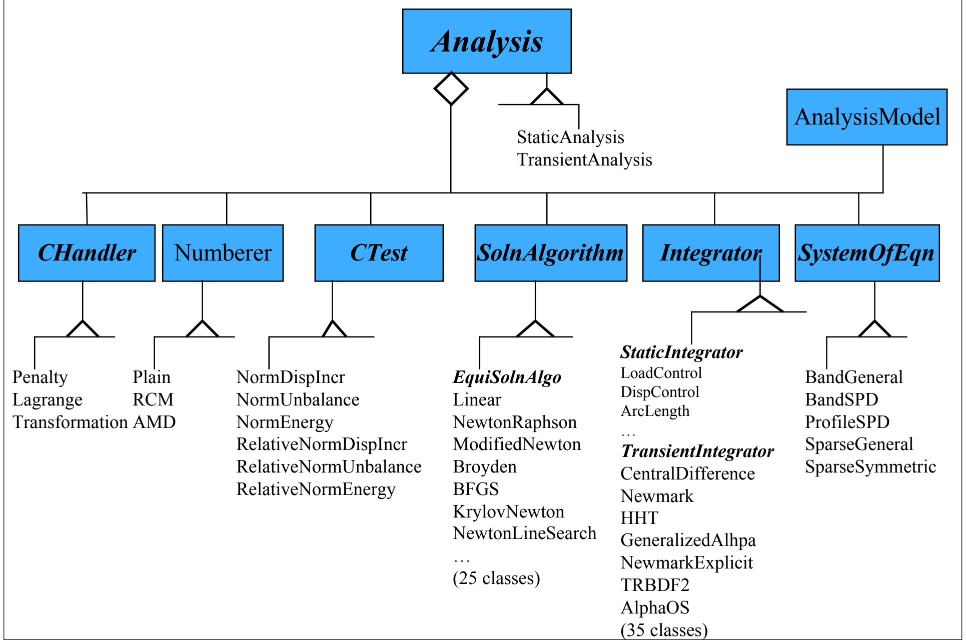
Linear
Pdelta
Corotational

Element in Global System

Geometric Transformation

Element in Basic System

What is an Analysis?



Analysis

StaticAnalysis
TransientAnalysis

AnalysisModel

CHandler

Penalty
Lagrange
Transformation

Numberer

Plain
RCM
AMD

CTest

NormDispIncr
NormUnbalance
NormEnergy
RelativeNormDispIncr
RelativeNormUnbalance
RelativeNormEnergy

SolnAlgorithm

EquiSolnAlgo
Linear
NewtonRaphson
ModifiedNewton
Broyden
BFGS
KrylovNewton
NewtonLineSearch
…
(25 classes)

Integrator

StaticIntegrator
LoadControl
DispControl
ArcLength
…

TransientIntegrator
CentralDifference
Newmark
HHT
GeneralizedAlhpa
NewmarkExplicit
TRBDF2
AlphaOS
(35 classes)

SystemOfEqn

BandGeneral
BandSPD
ProfileSPD
SparseGeneral
SparseSymmetric

How Do People Use OpenSees Framework?

- Provide their own main() function in C++ and link to framework.

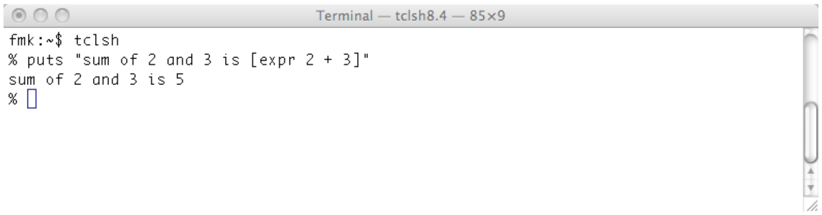
- Use OpenSees interpreterS. These are extensions of the Tcl interpreters, tclsh and wish, for performing finite element analysis.
    1. OpenSees.exe
    2. OpenSeesTk.exe
    3. OpseseesSP.exe
    4. OpenSeesMP.exe

Tcl Interpreters

- **wish** and **tclsh** **are tcl interpreters**.
    - Interpreters (Perl, Matlab, Ruby) are programs that execute programs written in a programming language immediately.
    - There is no separate compilation & linking.
    - An interpreted program runs slower than a compiled one.

puts “sum of 2 and 3 is [expr 2 + 3]”

sum of 2 and 3 is 5



```
fmk:~$ tclsh
% puts "sum of 2 and 3 is [expr 2 + 3]"
sum of 2 and 3 is 5
% 
```

What is Tcl

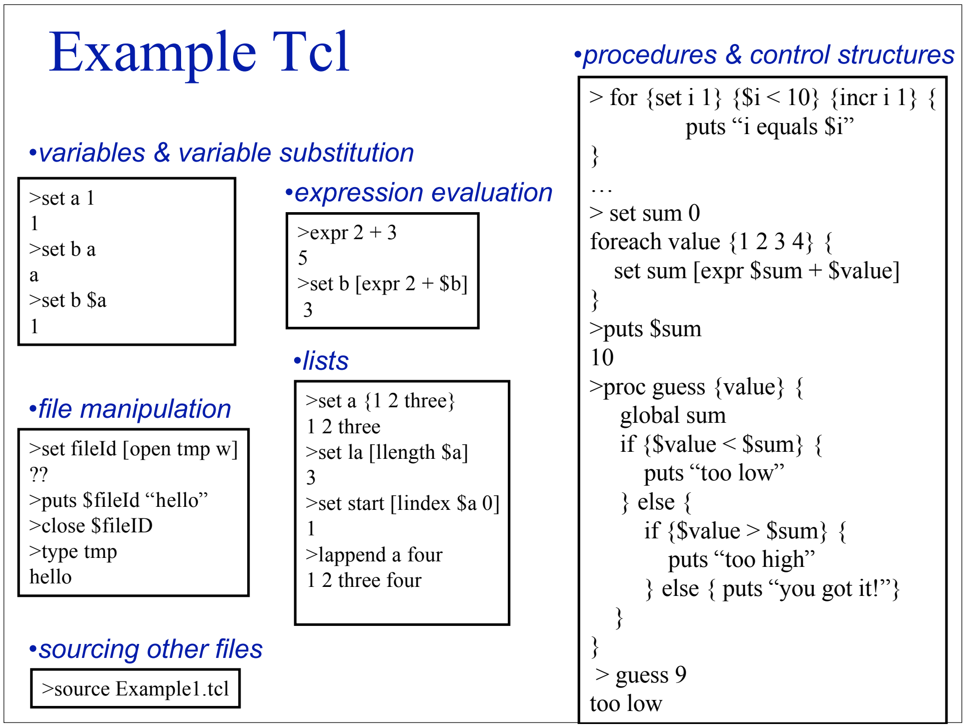
- **Tcl is a dynamic programming language**.
    - It is a string based command language.
    - Variables and variable substitution
    - Expression evaluation
    - Basic control structures (if , while, for, foreach)
    - Procedures
    - File manipulation
    - Sourcing other files.

- Comand syntax:

  command arg1 arg2 …

- Help

1. http://www.tcl.tk/man/tcl8.5/tutorial/tcltutorial.html



Example Tcl

•variables & variable substitution

```
>set a 1
1
>set b a
a
>set b $a
1
```

•expression evaluation

```
>expr 2 + 3
5
>set b [expr 2 + $b]
 3
```

•lists

```
>set a {1 2 three}
1 2 three
>set la [llength $a]
3
>set start [lindex $a 0]
1
>lappend a four
1 2 three four
```

•file manipulation

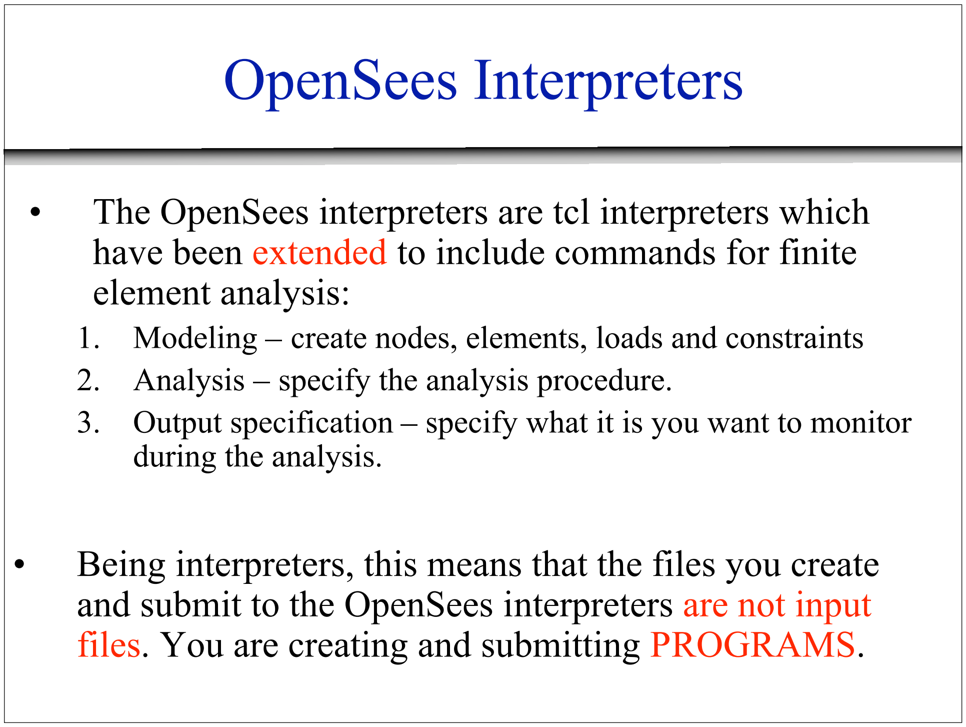
```
>set fileId [open tmp w]
??
>puts $fileId “hello”
>close $fileID
>type tmp
hello
```

•sourcing other files

```
>source Example1.tcl
```

•procedures & control structures

```
> for {set i 1} {$i < 10} {incr i 1} {
            puts “i equals $i”
}
…
> set sum 0
foreach value {1 2 3 4} {
   set sum [expr $sum + $value]
}
>puts $sum
10
>proc guess {value} {
    global sum
    if {$value < $sum} {
        puts “too low”
    } else {
        if {$value > $sum} {
            puts “too high”
        } else { puts “you got it!”}
    }
}
 > guess 9
too low
```



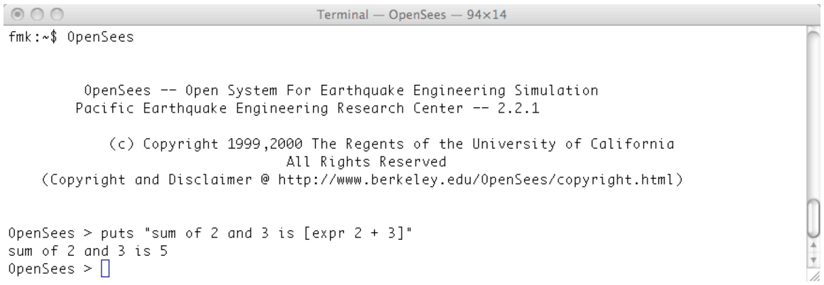
OpenSees Interpreters

- The OpenSees interpreters are tcl interpreters which have been extended to include commands for finite element analysis:
  1. Modeling – create nodes, elements, loads and constraints
  2. Analysis – specify the analysis procedure.
  3. Output specification – specify what it is you want to monitor during the analysis.

- Being interpreters, this means that the files you create and submit to the OpenSees interpreters are not input files. You are creating and submitting PROGRAMS.

OpenSees.exe

•An interpreter that extends tclsh for FE analysis.



```
fmk:~$ OpenSees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OpenSees > puts "sum of 2 and 3 is [expr 2 + 3]"
sum of 2 and 3 is 5
OpenSees > 
```
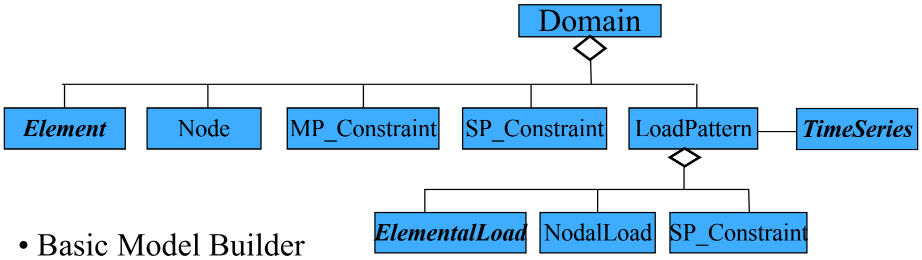

WARNING: There is no GUI!

model Command

*Adds the modeling commands to the interpreter.



- Basic Model Builder

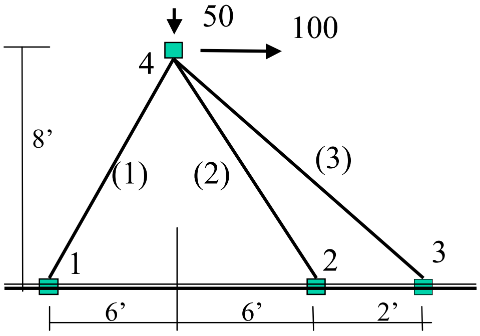
model Basic –ndm ndm? <-ndf ndf?>

This command now adds the following commands to the interpreter:

node element pattern timeSeries eleLoad mass
load sp equalDOF fix fixX fixY fixZ
uniaxialMaterial nDMaterial section geomTransf
fiber layer patch block2D block3D

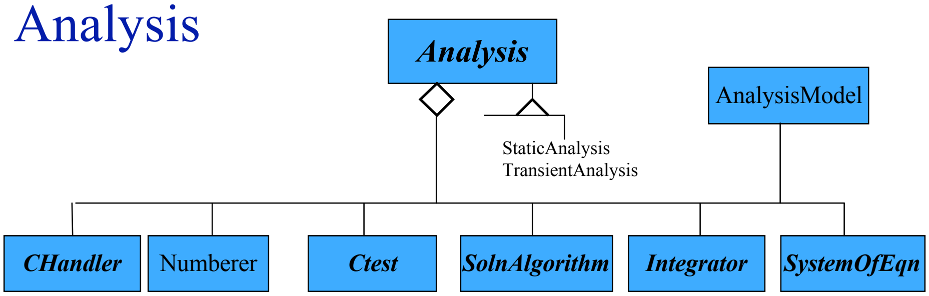
Truss example:

```
model Basic -ndm 2 -ndf 2
node 1 0.0 0.0
node 2 144.0 0.0
node 3 168.0 0.0
node 4 72.0 96.0
fix 1 1 1
fix 2 1 1
fix 3 1 1
uniaxialMaterial Elastic 1 3000.0
element truss 1 1 4 10.0 1
element truss 2 2 4   5.0 1
element truss 3 3 4   5.0 1
timeSeries Linear 1
pattern Plain 1 1 {
  load 4 100.0 -50.0
}
```



	E	A
1	3000	10
2	3000	5
3	3000	5

Analysis



Analysis

AnalysisModel

StaticAnalysis
TransientAnalysis

CHandler Numberer *Ctest* *SolnAlgorithm* *Integrator* *SystemOfEqn*

handler type? args…

numberer type? args…

test type? args…

algorithm type? args…

integrator type? args…

system type? args…

analysis type? args..

analyze args …

Example Analysis:

- Static Nonlinear Analysis with LoadControl

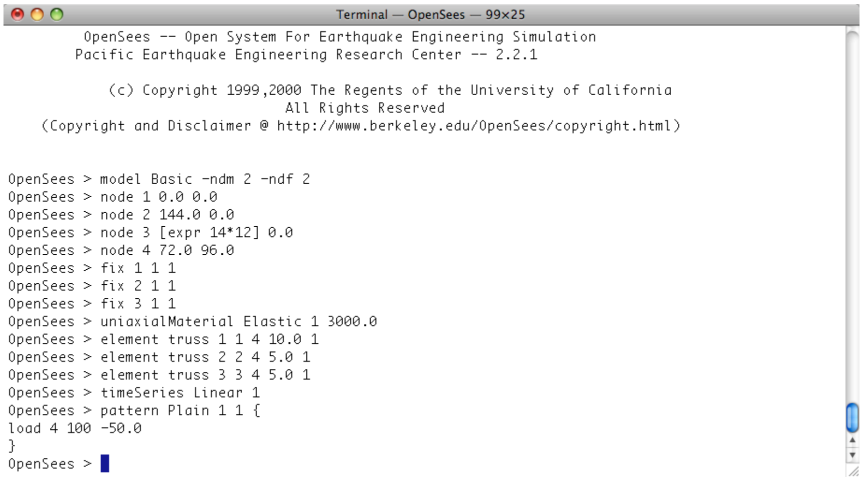
```
constraints Transformation
numberer RCM
system BandGeneral
test NormDispIncr 1.0e-6 6 2
algorithm Newton
integrator LoadControl 0.1
analysis Static
analyze 10
```

- Transient Nonlinear Analysis with Newmark

```
constraints Transformation
numberer RCM
system BandGeneral
test NormDispIncr 1.0e-6 6 2
algorithm Newton
integrator Newmark 0.5 0.25
analysis Transient
analyze 2000 0.01
```

3 Ways to Execute the commands

1. Interactively - the commands as we have shown can be input directly at the prompt



```
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OpenSees > model Basic -ndm 2 -ndf 2
OpenSees > node 1 0.0 0.0
OpenSees > node 2 144.0 0.0
OpenSees > node 3 [expr 14*12] 0.0
OpenSees > node 4 72.0 96.0
OpenSees > fix 1 1 1
OpenSees > fix 2 1 1
OpenSees > fix 3 1 1
OpenSees > uniaxialMaterial Elastic 1 3000.0
OpenSees > element truss 1 1 4 10.0 1
OpenSees > element truss 2 2 4 5.0 1
OpenSees > element truss 3 3 4 5.0 1
OpenSees > timeSeries Linear 1
OpenSees > pattern Plain 1 1 {
load 4 100 -50.0
}
OpenSees > 
```
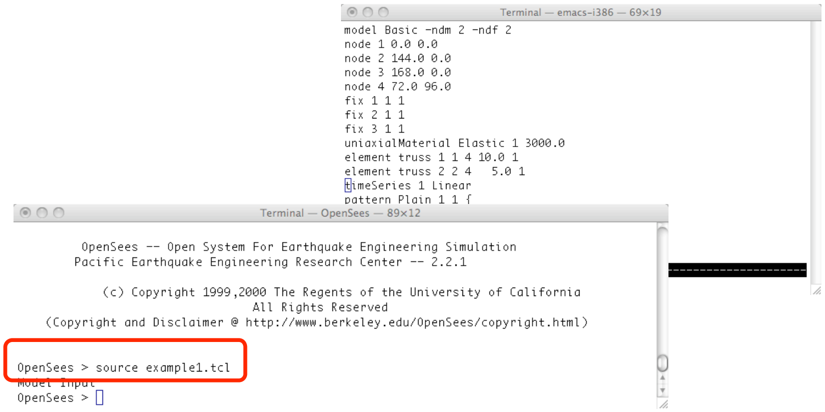

3 Ways to Execute the commands

2. Sourced from File- the commands are placed in a text file which is sourced in



```
model Basic -ndm 2 -ndf 2
node 1 0.0 0.0
node 2 144.0 0.0
node 3 168.0 0.0
node 4 72.0 96.0
fix 1 1 1
fix 2 1 1
fix 3 1 1
uniaxialMaterial Elastic 1 3000.0
element truss 1 1 4 10.0 1
element truss 2 2 4   5.0 1
timeSeries 1 Linear
pattern Plain 1 1 {
```

```
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OpenSees > source example1.tcl
Model Input
OpenSees > 
```
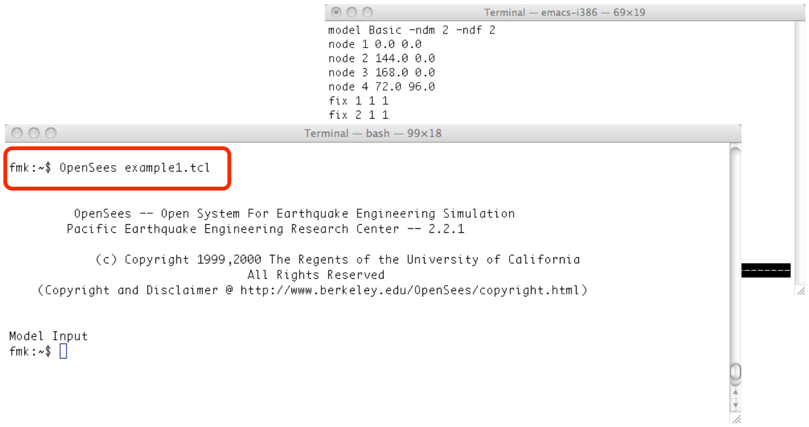

3 Ways to Execute the commands

3. Batch Mode- the commands are placed in a text file which are executed at startup.



```
model Basic -ndm 2 -ndf 2
node 1 0.0 0.0
node 2 144.0 0.0
node 3 168.0 0.0
node 4 72.0 96.0
fix 1 1 1
fix 2 1 1
```

```
fmk:~$ OpenSees example1.tcl


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Model Input
fmk:~$ 
```
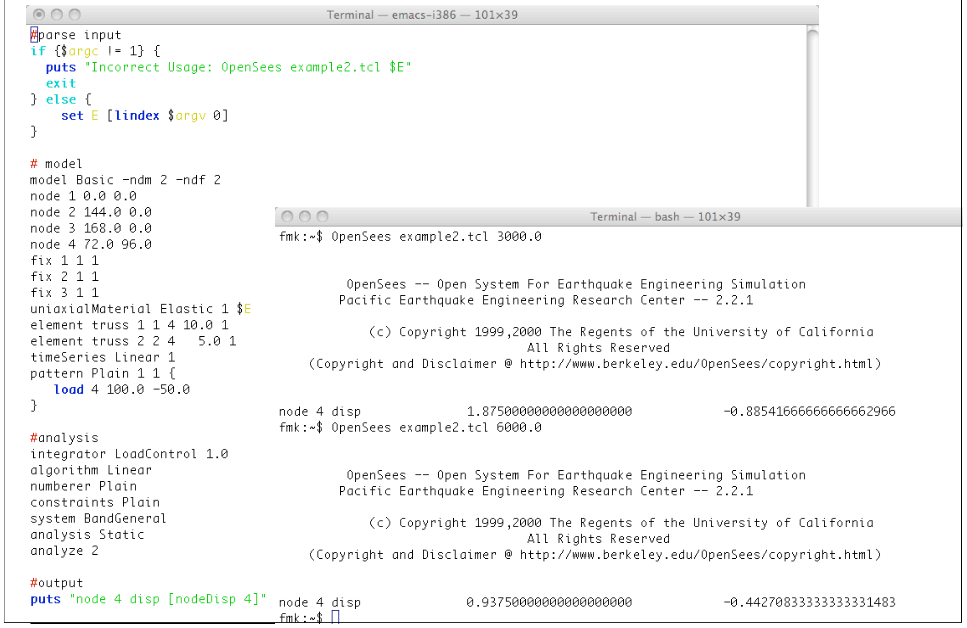

useful default variables: argv & argc



```
#parse input
if {$argc != 1} {
  puts "Incorrect Usage: OpenSees example2.tcl $E"
  exit
} else {
    set E [lindex $argv 0]
}

# model
model Basic -ndm 2 -ndf 2
node 1 0.0 0.0
node 2 144.0 0.0
node 3 168.0 0.0
node 4 72.0 96.0
fix 1 1 1
fix 2 1 1
fix 3 1 1
uniaxialMaterial Elastic 1 $E
element truss 1 1 4 10.0 1
element truss 2 2 4   5.0 1
timeSeries Linear 1
pattern Plain 1 1 {
   load 4 100.0 -50.0
}

#analysis
integrator LoadControl 1.0
algorithm Linear
numberer Plain
constraints Plain
system BandGeneral
analysis Static
analyze 2

#output
puts "node 4 disp [nodeDisp 4]"
```

```
fmk:~$ OpenSees example2.tcl 3000.0


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node 4 disp            1.87500000000000000000          -0.88541666666666662966
fmk:~$ OpenSees example2.tcl 6000.0


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node 4 disp            0.93750000000000000000          -0.44270833333333331483
fmk:~$ 
```
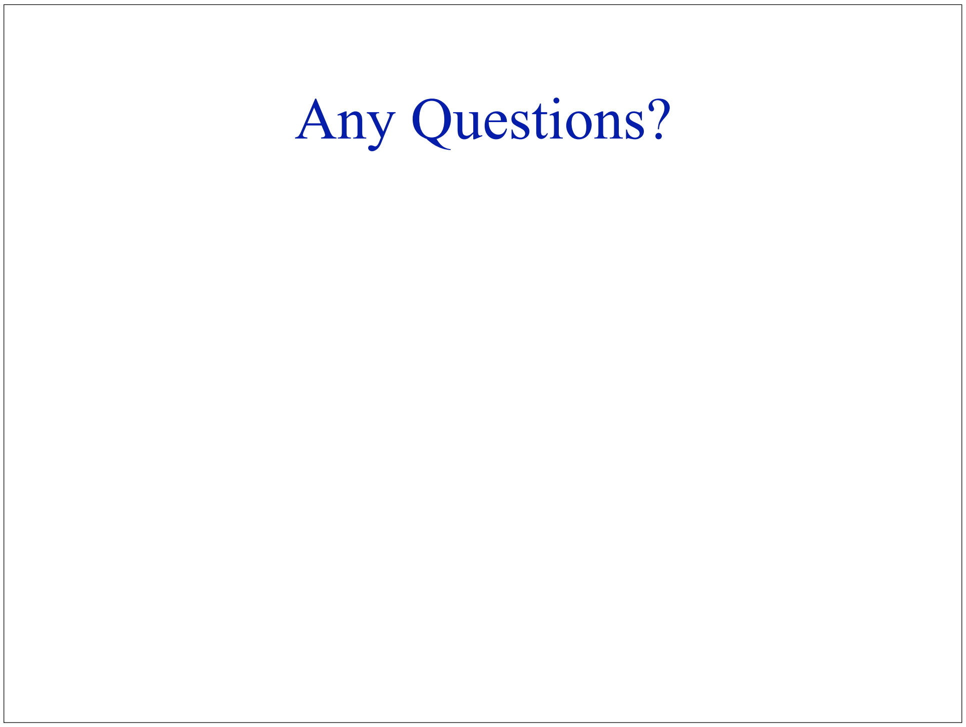

OpenSees Resources
http://opensees.berkeley.edu

- Message Board - **look for answers**, **post questions** and **ANSWERS**
  http://opensees.berkely.edu/community/index.php
- Getting Started Manual - basic how to for getting started
  http://opensees.berkeley.edu/wiki/index.php/Getting_Started
- User Documentation - command documentation & theory!
  http://opensees.berkeley.edu/wiki/index.php/Command_Manual
- User Examples
  http://opensees.berkeley.edu/wiki/index.php/OpenSees_User
  http://opensees.berkeley.edu/wiki/index.php/Examples_Manual
- Developers
  http://opensees.berkeley.edu/wiki/index.php/OpenSees_Developer
  http://opensees.berkeley.edu/cgi-bin/cvsweb2.cgi/OpenSees/SRC/

OpenSeesWiki - Editable by all **(including YOU!)**



Any Questions?