Software Architecture for Identifying and Updating Parameters

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Structural Engineering

Applications Requiring Parameterization

- Structural reliability
- Optimization
- System identification
- Design/Response sensitivity
- Parametric studies (Tcl scripts)
- Graphical user interfaces

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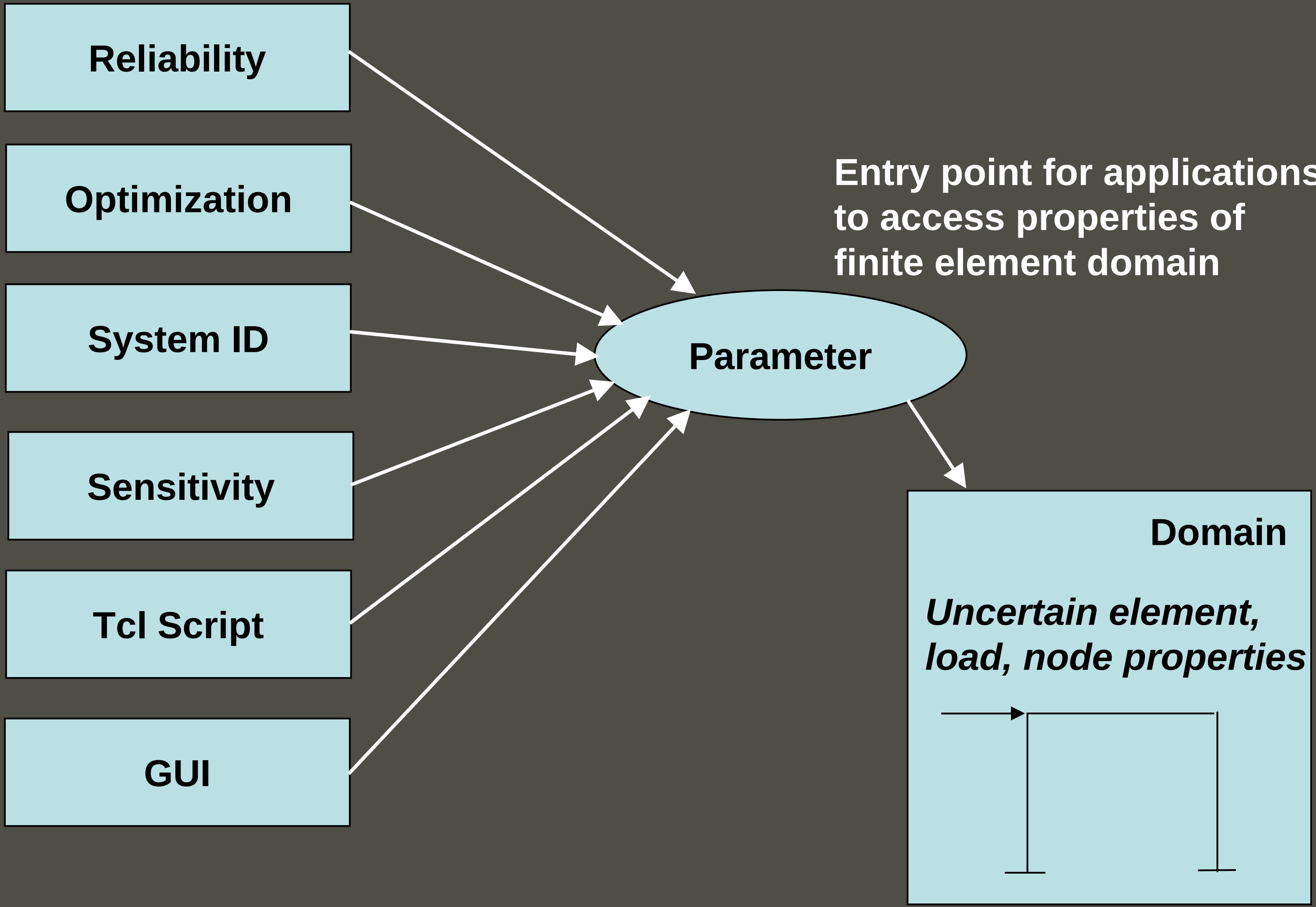
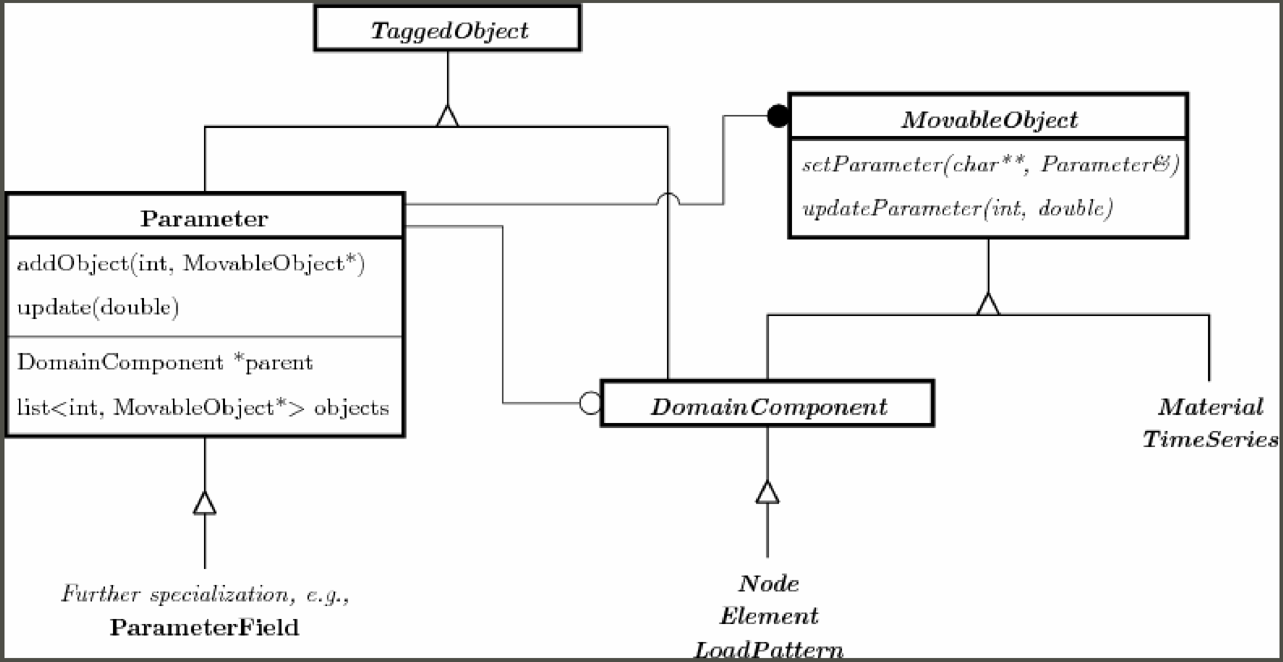
Parameter Class



Entry point for applications to access properties of finite element domain

Parameter Class Diagram


TaggedObject
MovableObject
setParameter(char**, Parameter&)
updateParameter(int, double)
Parameter
addObject(int, MovableObject*)
update(double)
DomainComponent *parent
list<int, MovableObject*> objects
DomainComponent
Material
TimeSeries
Further specialization, e.g.,
ParameterField
Node
Element
LoadPattern

- Parameter contains pointers to MovableObjects (base class for most everything in OpenSees)
- Parameter::addObject adds a MovableOjbect to list

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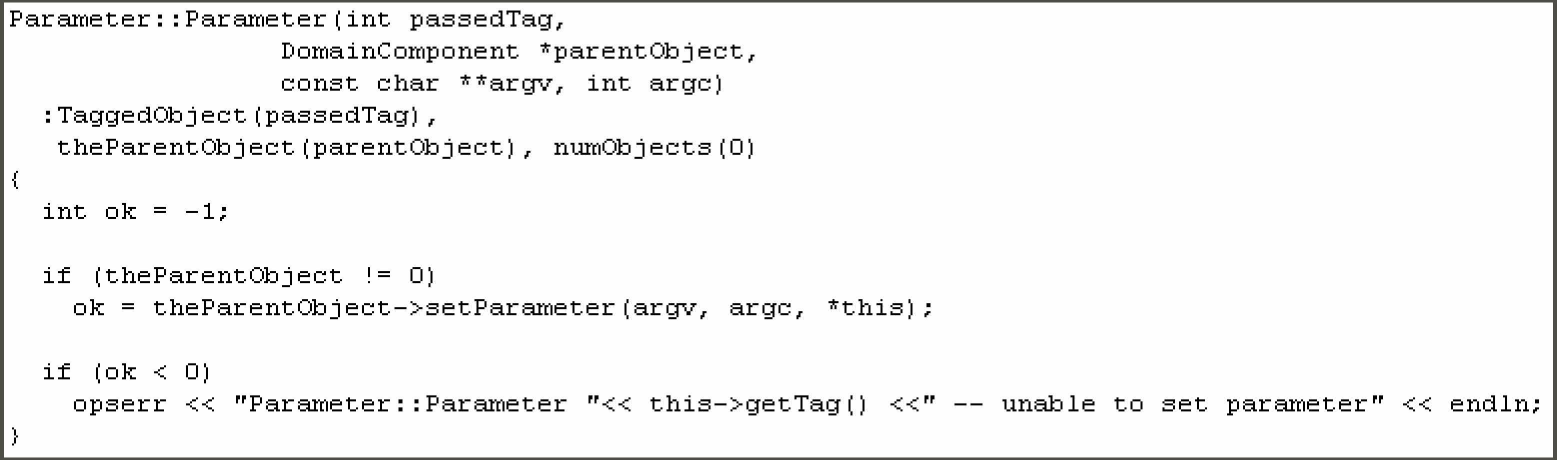
Parameter Class Constructor

- Invoke setParameter on a DomainComponent
- “Chain of Responsibility” software pattern



```
Parameter::Parameter(int passedTag,
                     DomainComponent *parentObject,
                     const char **argv, int argc)
  :TaggedObject(passedTag),
   theParentObject(parentObject), numObjects(0)
{
  int ok = -1;

  if (theParentObject != 0)
    ok = theParentObject->setParameter(argv, argc, *this);

  if (ok < 0)
    opserr << "Parameter::Parameter "<< this->getTag() <<" -- unable to set parameter" << endln;
}
```

Example of Truss Elements with Elastic UniaxialMaterial

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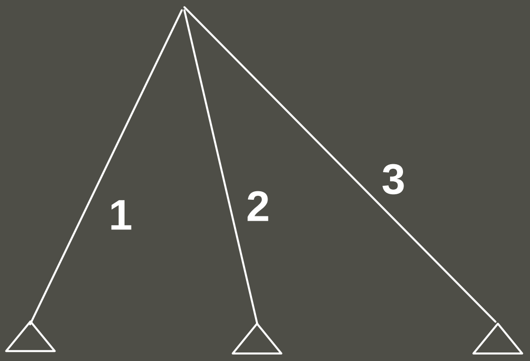
Tcl commands in OpenSees

Model Building

```
uniaxialMaterial Elastic 1 29000.0
element truss 1 1 2  4.0 1
element truss 2 1 3  4.0 1
element truss 3 1 4  4.0 1
```



Parameter identification

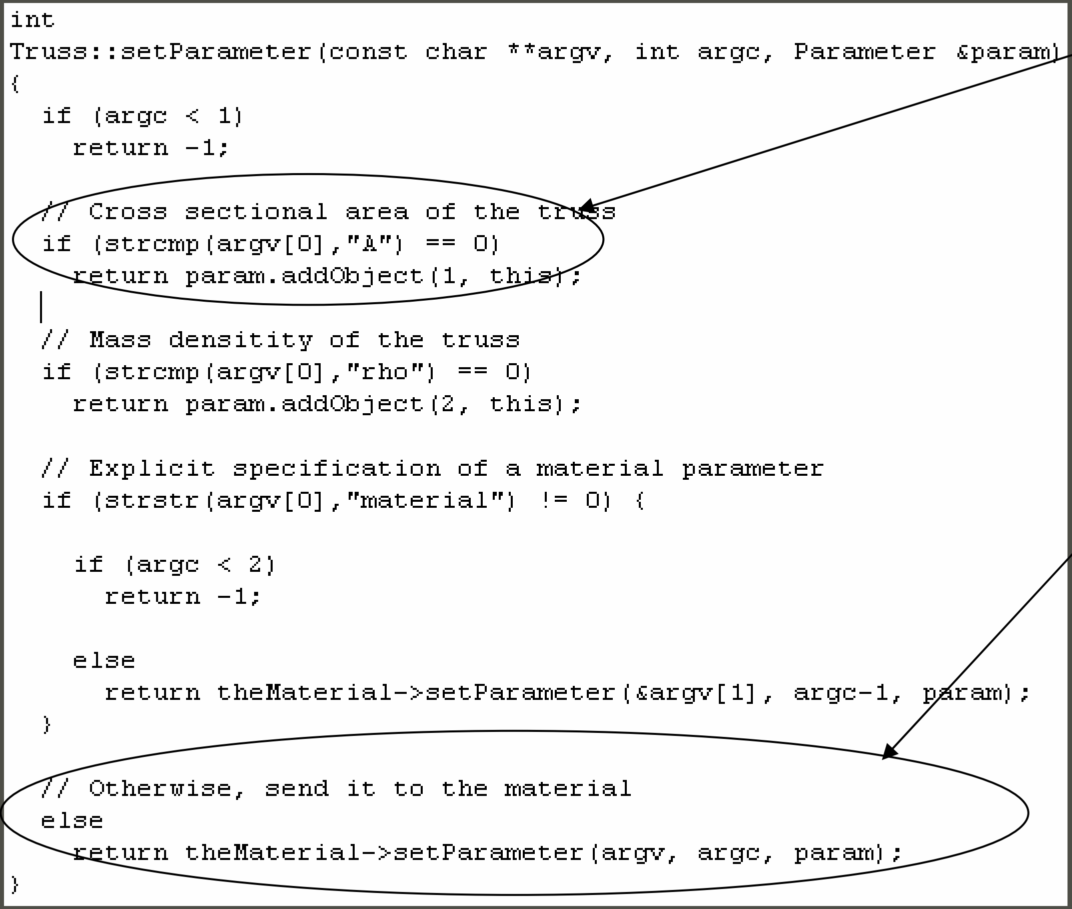
```
parameter 1 element 1 A
parameter 2 eleRange 1 3 E
```

Parameter update

```
updateParameter 1 5.0
updateParameter 2 30000.0
```

Code for parameter identification in element

parameter 1 element 1 A



```
int
Truss::setParameter(const char **argv, int argc, Parameter &param)
{
  if (argc < 1)
    return -1;

  // Cross sectional area of the truss
  if (strcmp(argv[0],"A") == 0)
    return param.addObject(1, this);

  // Mass densitity of the truss
  if (strcmp(argv[0],"rho") == 0)
    return param.addObject(2, this);

  // Explicit specification of a material parameter
  if (strstr(argv[0],"material") != 0) {

    if (argc < 2)
      return -1;

    else
      return theMaterial->setParameter(&argv[1], argc-1, param);
  }

  // Otherwise, send it to the material
  else
    return theMaterial->setParameter(argv, argc, param);
}
```

Add id and pointer to self to Parameter object

Forward request to UniaxialMaterial object if no parameters found

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Code for parameter identification in material

parameter 2 eleRange 1 3 E

```
int
ElasticMaterial::setParameter(const char **argv, int argc, Parameter &param)
{
  if (argc < 1)
    return -1;

  if (strcmp(argv[0],"E") == 0)
    return param.addObject(1, this);

  else if (strcmp(argv[0],"eta") == 0)
    return param.addObject(2, this);

  else
    return -1;
}
```

Add self to Parameter object

Else parameter not found (end of chain)

- Association of id to parameter is encapsulated by each class
- Developer decides what is a parameter and which id values to use

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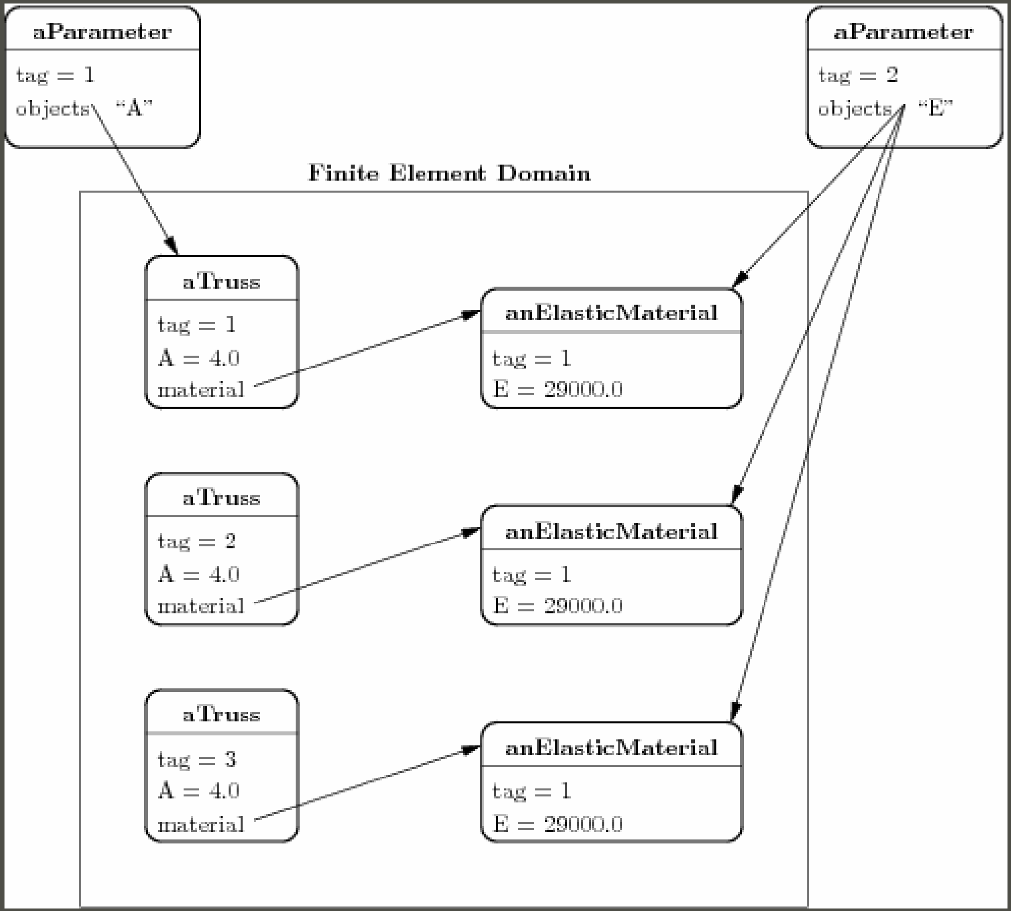
Object Diagram After Parameters Identified

parameter 1 element 1 A
parameter 2 eleRange 1 3 E



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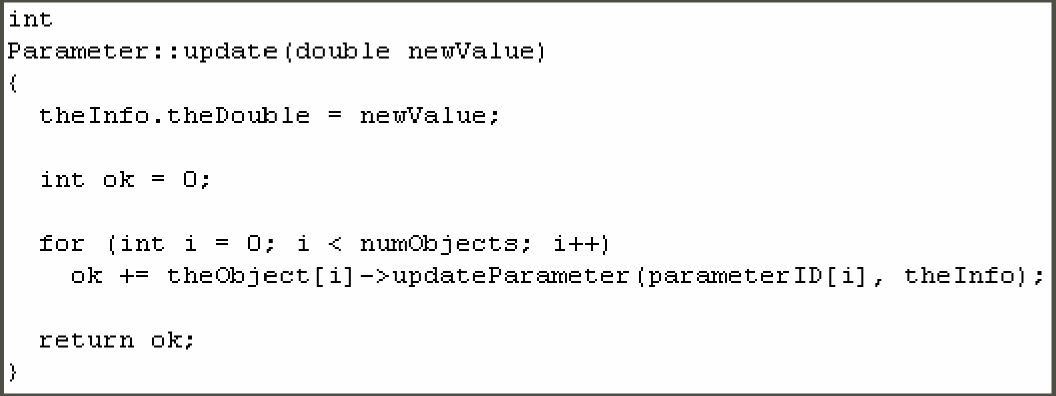
Code to update parameter values

updateParameter 1 5.0
updateParameter 2 30000.0



```
int
Parameter::update(double newValue)
{
  theInfo.theDouble = newValue;

  int ok = 0;

  for (int i = 0; i < numObjects; i++)
    ok += theObject[i]->updateParameter(parameterID[i], theInfo);

  return ok;
}
```

- Iterate over MovableObjects and invoke updateParameter with new parameter value and id number

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updateParameter Methods

updateParameter 1 5.0

```
int
Truss::updateParameter (int parameterID, Information &info)
{
  switch (parameterID) {
  case 1:
    A = info.theDouble;
    return 0;
  case 2:
    rho = info.theDouble;
    return 0;
  default:
    return -1;
  }
}
```

match the id, then update the parameter

updateParameter 2 30000.0

```
int
ElasticMaterial::updateParameter(int parameterID, Information &info)
{
  switch(parameterID) {
  case 1:
    E = info.theDouble;
    return 0;
  case 2:
    eta = info.theDouble;
    return 0;
  default:
    return -1;
  }
}
```

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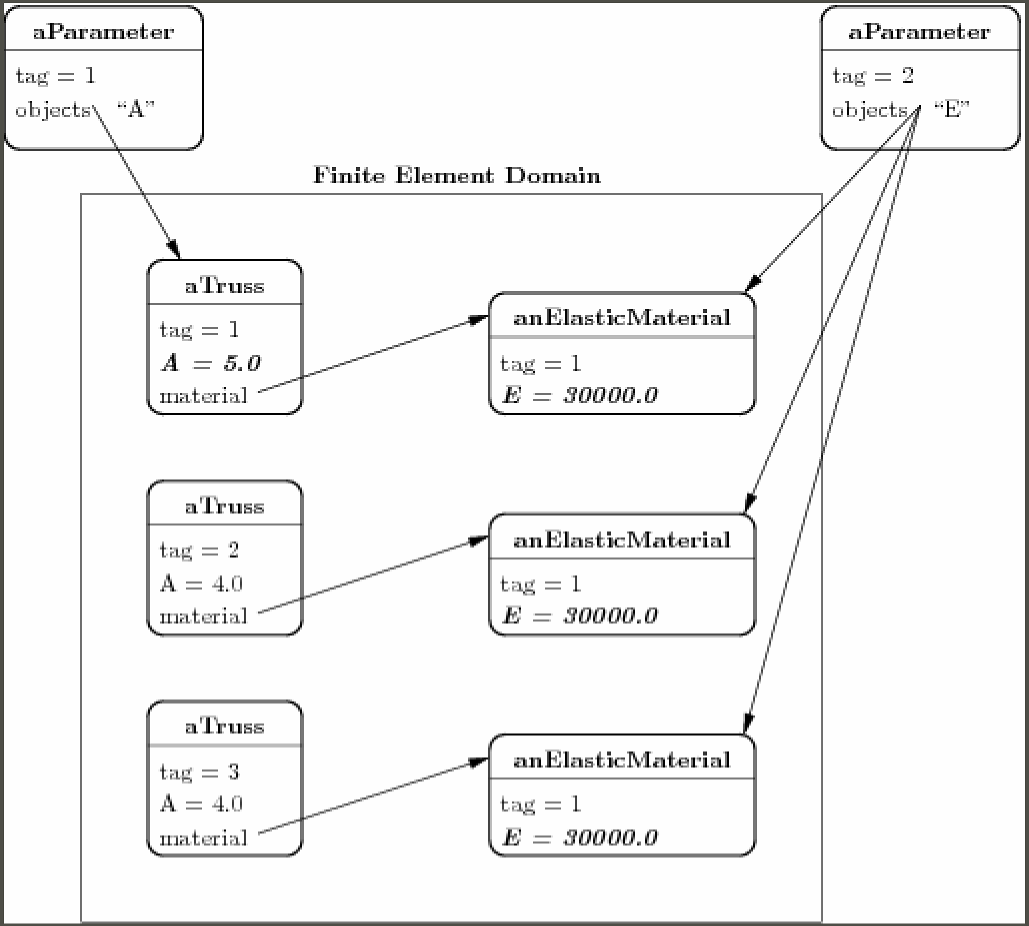
Object Diagram After Parameters Updated

updateParameter 1 5.0
updateParameter 2 30000.0



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Extensible Parameterization Framework

- Solid and beam-column elements
  - constitutive model at each integration point
- Fiber-discretized cross sections
- Nodal coordinates
- Nodal and element loads
- Any MovableObject…

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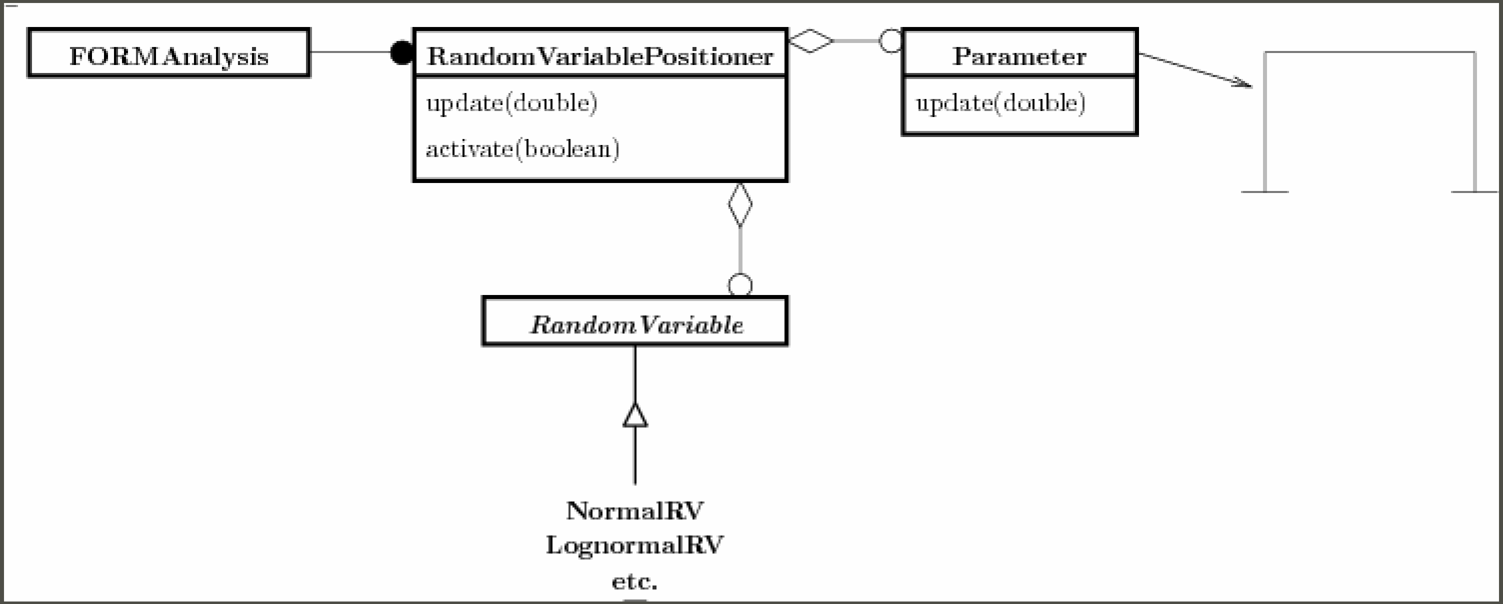
Random Variables in a Reliability Analysis



- RandomVariablePositioner aggregates a RandomVariable with a Parameter in order to model uncertain properties in the finite element domain (Terje Haukaas, UBC)
- Additional methods required to compute response sensitivity with respect to each parameter

Questions/Comments?

- Reference:

  Scott, M.H., Fenves, G.L., McKenna, F.T., and Filippou, F.C. "Software Patterns for Nonlinear Beam-Column Models" *Journal of Structural Engineering*, Under review, Submitted July 2006.

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