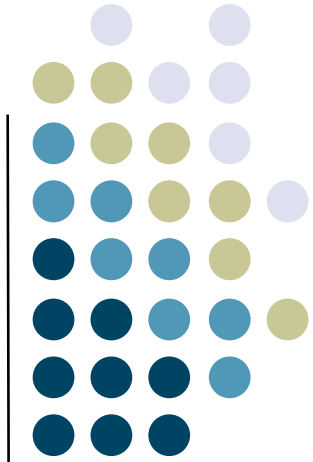
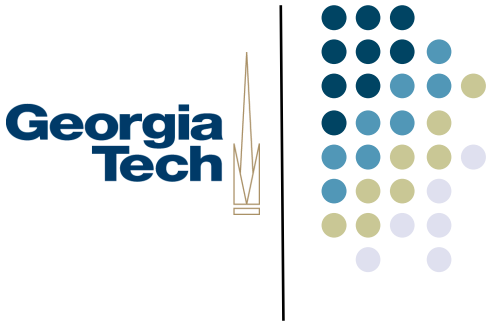
Damage Management & Layout



Georgia Tech

Damage management

- Need to keep track of parts of the screen that need update
  - interactor has changed appearance, moved, appeared, disappeared, etc.
  - done by "declaring damage"
    - each object responsible for telling system when part of its appearance needs update



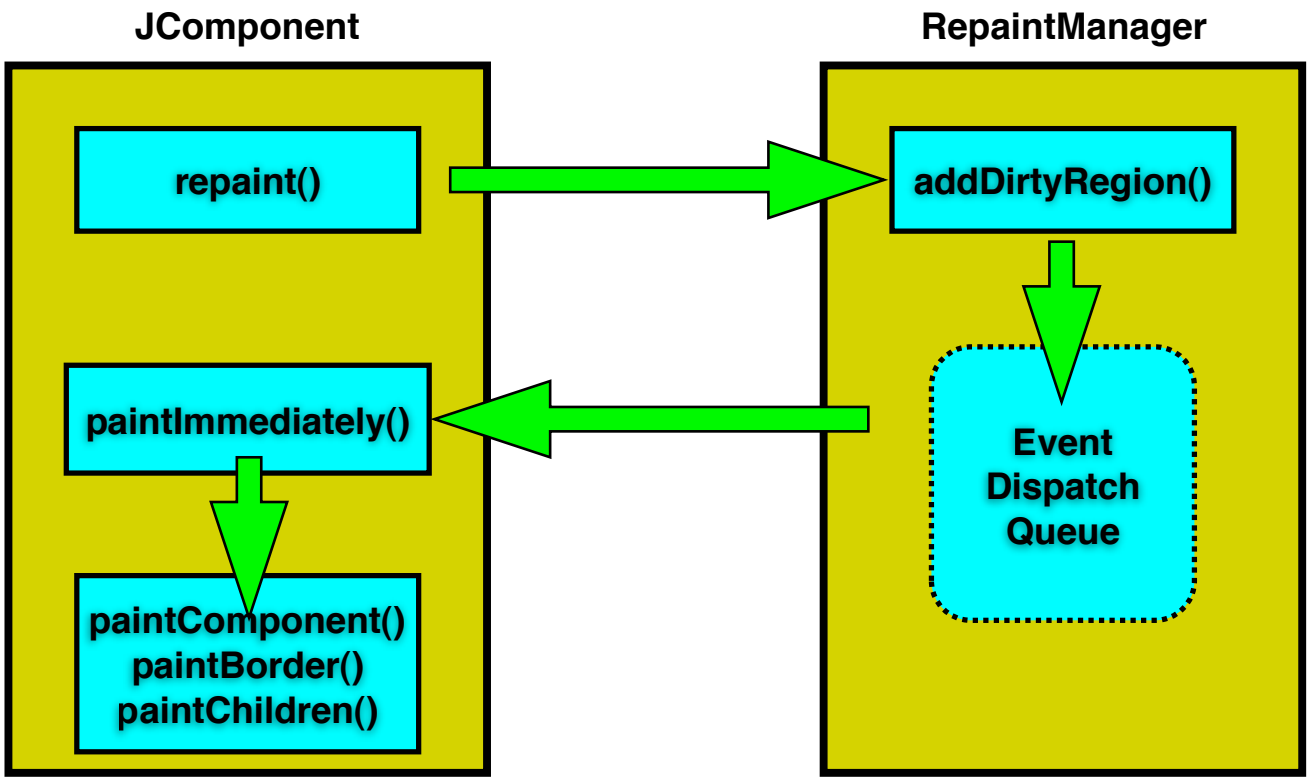
Damage management

- Example: in Swing done via a call to repaint()
  - takes a rectangle parameter
  - Adds the specified region to the RepaintManager's *dirty list*
    - list of regions that need to be redrawn
    - RepaintManager schedules repaints for later, can collapse multiple dirty regions into a few larger ones to optimize
  - When scheduled repaint comes up, RepaintManager calls component's paintImmediately() method, which calls paintComponent(), paintChildren(), paintBorders()
    - You generally never want to call this yourself
    - Generally, seldom need to work with RepaintManager directly

Damage Management

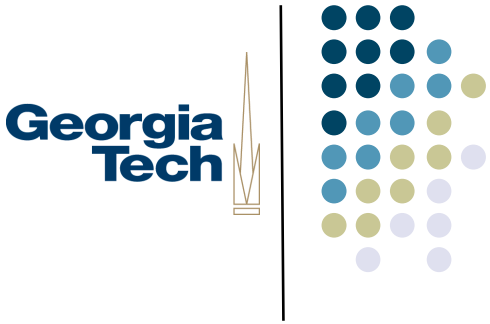
- Can optimize somewhat
  - Multiple rectangles of damage
  - Knowing about opaque objects
- But typically not worth the effort

Damage Management in Swing



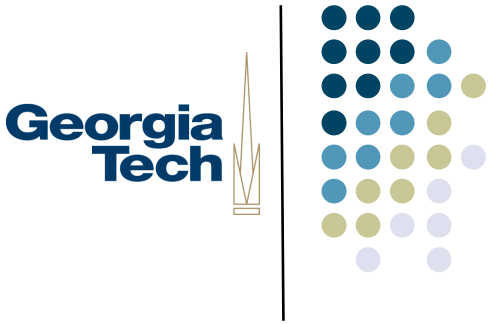
Typical overall "processing cycle"

```
loop forever
  wait for event then dispatch it
    ➡causes actions to be invoked
      and/or update interactor
      state
    ➡typically causes damage
  if (damaged_somewhere)
    layout
    redraw
```



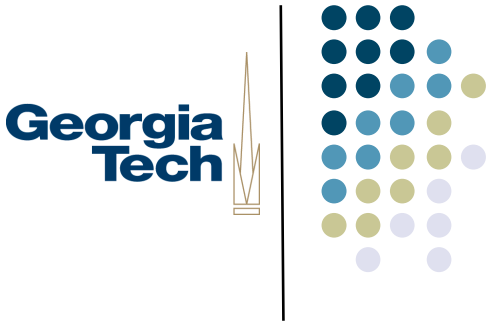
Layout

- Deciding size and placement of every object
  - easiest version: static layout
    - objects don't move or change size
    - easy but very limiting
      - hard to do dynamic content
  - only good enough for simplest cases



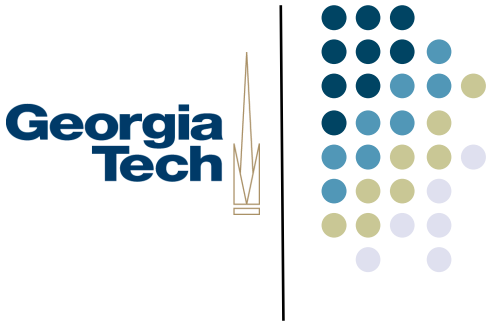
Dynamic layout

- Change layout on the fly to reflect the current situation
- Need to do layout before redraw
  - Can't be done e.g., in paintComponent()
  - Why?



Dynamic layout

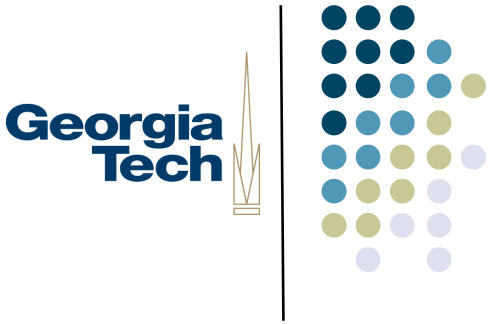
- Change layout on the fly to reflect the current situation
- Need to do layout before redraw
  - Can't be done e.g., in paintComponent()
  - Because you have to draw in strict order, but layout (esp. position) may depend on size/position of things not in order (drawn after you!)



Layout in Swing

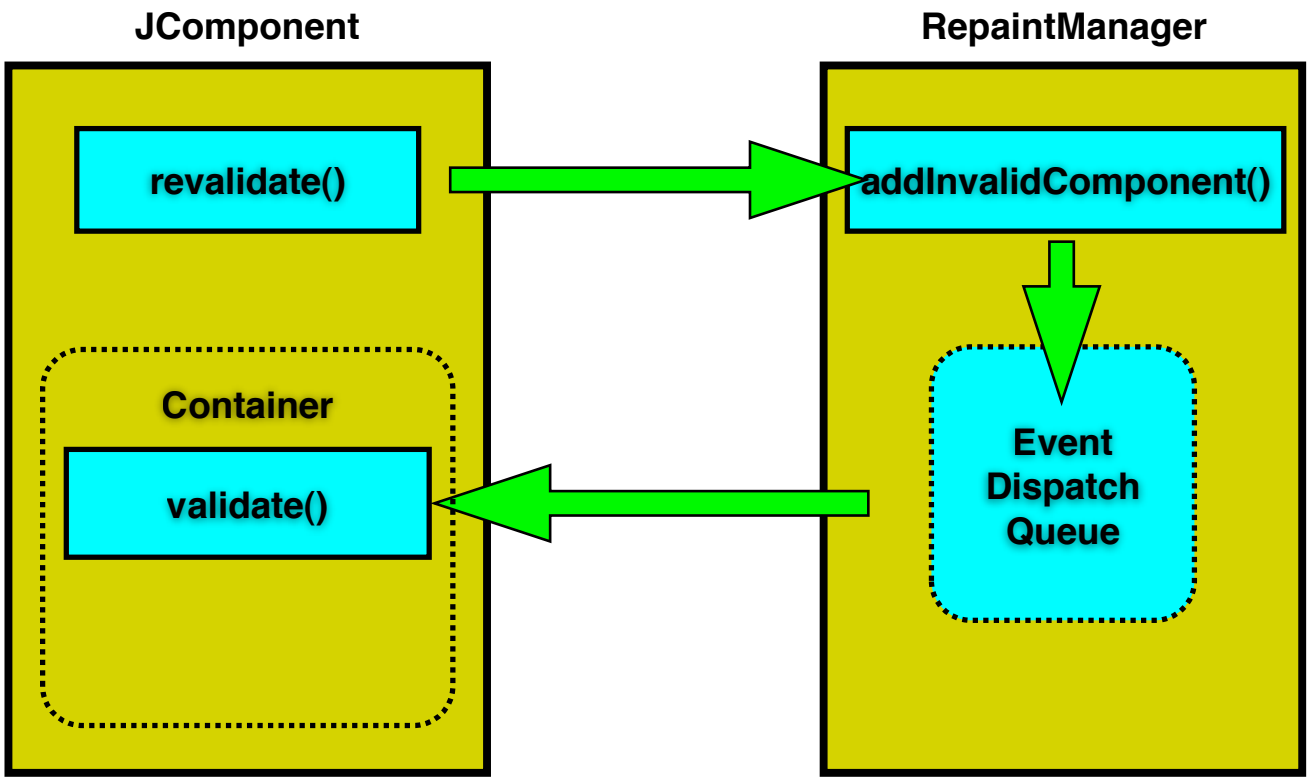
- invalidate() method
  - Called on a container to indicate that its children need to be laid out
  - Called on a component to indicate that something about it has changed that may change the overall layout (change in size, for example)
- validate() method
  - Starts the process that makes an invalid layout valid--recomputes sizes and positions to get correct layout

"Issues" with Swing validation



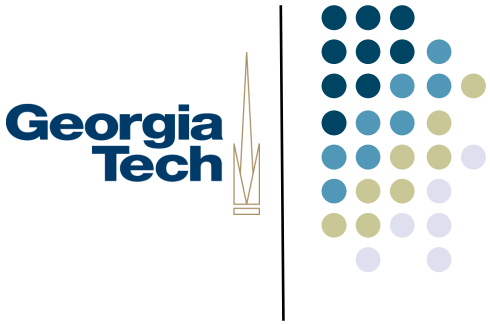
- invalidate() is often called automatically
  - e.g., in response to changes to components' state
- ... but not always
  - e.g., if a JButton's font or label changes, no automatic call to invalidate()
  - Mark the button as changed by calling invalidate() on it
  - Tell the container to redo layout by calling validate() on it
- In older versions of Swing you had to do this by hand
- Newer versions (post 1.2) add a shortcut: revalidate()
  - Invalidates the component you call it on
  - Begins the process of validating the layout, starting from the appropriate parent container
- Validation *also* uses the RepaintManager

Layout Validation in Swing



Layout with containers

- Containers (parent components) can control size/position of children
  - example: rows & columns
  - Two basic strategies
    - Top-down (AKA outside-in)
    - Bottom-up (AKA inside-out)

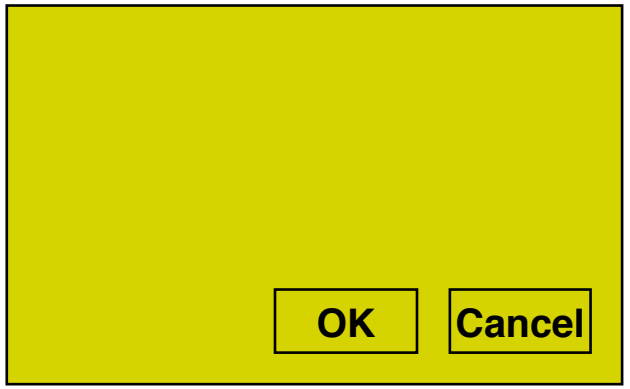


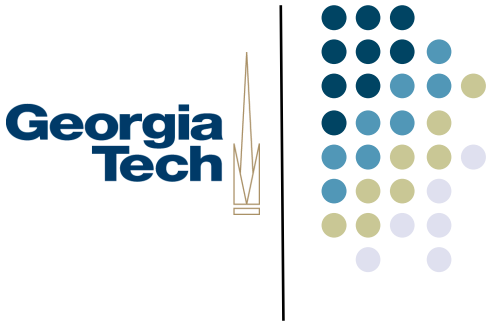
Top-down or outside-in layout

- Parent determines layout of children
  - **Typically used for position**, but sometimes size
  - Example?

Top-down or outside-in layout

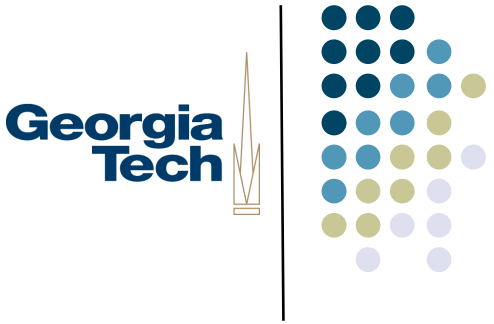
- Parent determines layout of children
  - **Typically used for position**, but sometimes size
  - Dialog box OK / Cancel buttons
    - stays at lower left





Bottom-up or inside-out layout

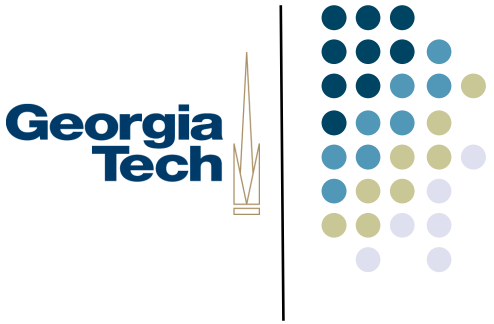
- Children determine layout of parent
  - **Typically just size**
  - Example?



Bottom-up or inside-out layout

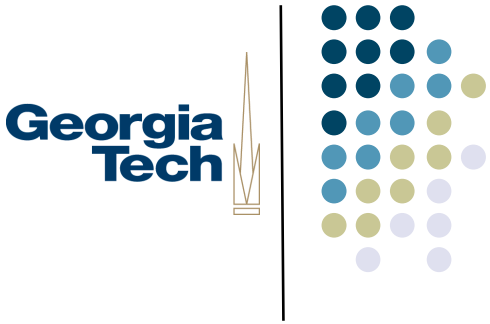
- Children determine layout of parent
  - **Typically just size**
  - Shrink-wrap container
    - parent just big enough to hold all children
    - e.g., pack() method on JWindow and JFrame
      - Resizes container to just big enough to accommodate contents' preferredSizes

Which one is better?



Neither one is sufficient

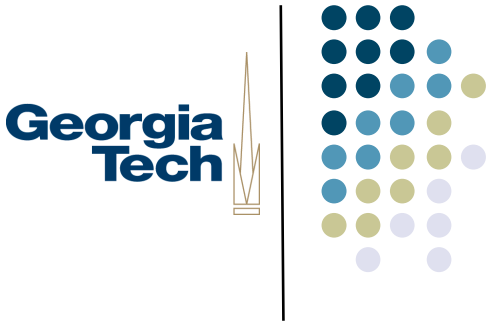
- Need both
- May even need both in same object
  - horizontal vs. vertical
  - size vs. position (these interact!)
- Need more general strategies



Layout Policies in Swing

- Swing layout policies are (generally) customizable
- Some containers come with a "built-in" layout policy
  - JSplitPane, JScrollPane, JTabbedPane
- Others support "pluggable" policies through *LayoutManagers*
  - LayoutManagers installed in Containers via setLayout()
  - Two interfaces (from AWT): LayoutManager and LayoutManager2
  - Determines position and size of each component within a container
  - Looks at components inside container:
    - Uses getMinimumSize(), getPreferredSize(), getMaximumSize()
    - ... but is free to ignore these
- Example LayoutManagers:
  - FlowLayout, BorderLayout, GridLayout, BoxLayout, ...

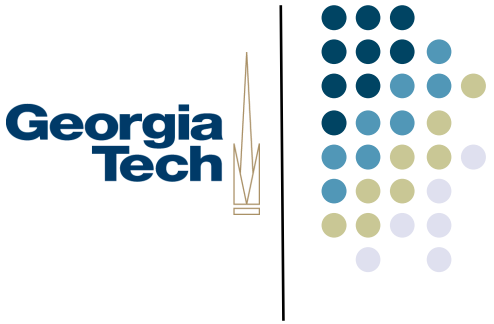
Layout Policies in Swing



- Each LayoutManager is free to do what it wants when layout out componens
  - Can ignore components' min/preferred/max sizes
  - Can ignore (not display) components at all
- Generally, most will look at children's requests and then:
  - Size the parent component appropriately
  - Position the children within that component
- So, top-down with input from child components

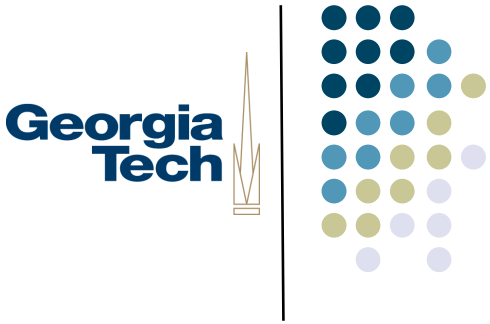
More general layout strategies

- Boxes and glue model
- Springs and struts model
- Constraints



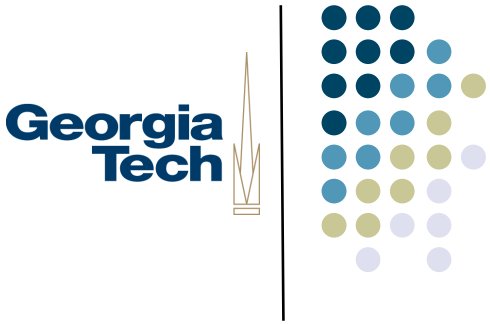
Boxes and glue layout model

- Comes from the TeX document processing system
  - Brought to UI work in Interviews toolkit (C++ under X-windows)
  - Tiled composition (no overlap)
    - toolkit has other mechanisms for handling overlap
    - glue between components (boxes)



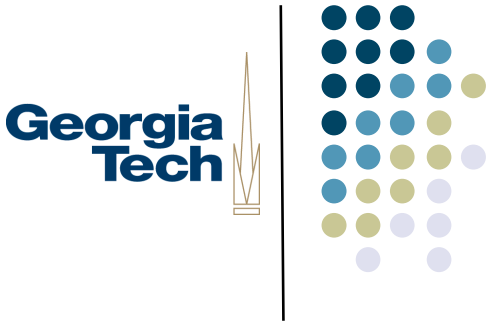
Boxes and glue layout model

- 2 kinds of boxes: hbox & vbox
  - do horiz and vert layout separately
    - at separate levels of hierarchy
- Each component has
  - natural size
  - min size
  - max size



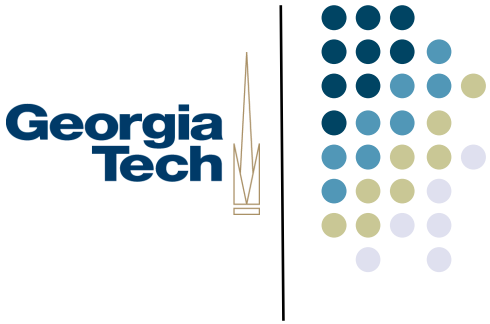
Box sizes

- Natural size
  - the size the object would normally like to be
    - e.g., button: title string + border
- Min size
  - minimum size that makes sense
    - e.g. button may be same as natural
- Max size ...



Boxes and glue layout model

- Each piece of glue has:
  - natural size
  - min size (always 0)
  - max size (often "infinite")
  - stretchability factor (0 or "infinite" ok)
- Stretchability factor controls how much this glue stretches compared with other glue

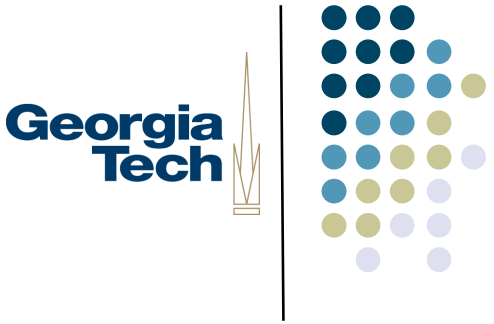


Example (Paper: p13, fig 4&5)

- Two level composition
  - vbox
    - middle glue twice as stretchable as top and bottom
  - hbox at top
    - right glue is infinitely stretchable
  - hbox at bottom
    - left is infinitely stretchable

How boxes and glue works

- Boxes (components) try to stay at natural size
  - expand or shrink glue first
  - if we can't fit just changing glue, only then expand or shrink boxes
- Glue stretches / shrinks in proportion to stetchability factor



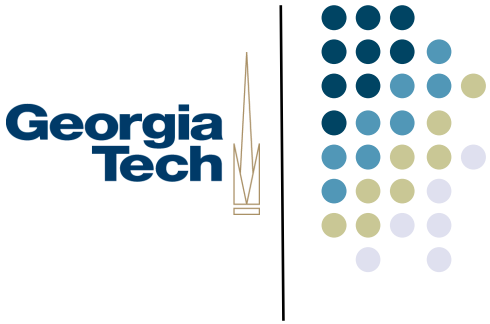
Computing boxes and glue layout

- Two passes:
  - bottom up then top down
- Bottom up pass:
  - compute natural, min, and max sizes of parent from natural, min, and max of children
  - natural = sum of children's natural
  - min = sum of children's min
  - max = sum of children's max

Computing boxes and glue layout

- Top down pass:
  - window size fixed at top
  - at each level in tree determine space overrun (shortfall)
  - make up this overrun (shortfall) by shrinking (stretching)
    - glue shrunk (stretched) first
    - if reaches min (max) only then shrink (stretch components)

Top down pass (cont)



- Glue is changed proportionally to stretchability factor
  - example: 30 units to stretch
    - glue_1 has factor 100
    - glue_2 has factor 200

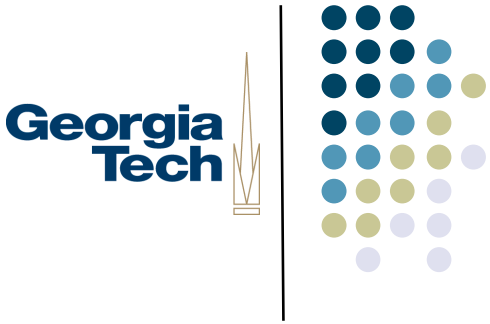
    - stretch glue_1 by 10
    - stretch glue_2 by 20
- Boxes changed evenly (within min, max)

What if it doesn't fit?

- Layout breaks
  - negative glue
  - leads to overlap

Springs and struts model

- Developed independently, but can be seen a simplification of boxes and glue model
  - more intuitive (has physical model)
- Has struts, springs, and boxes
  - struts are 0 stretchable glue
  - springs are infinitely stretchable glue



Springs and struts model

- Struts
  - specify a fixed offset
- Springs
  - specify area that is to take up slack
  - equal stretchability
- Components (boxes)
  - not stretchable (min = natural = max)

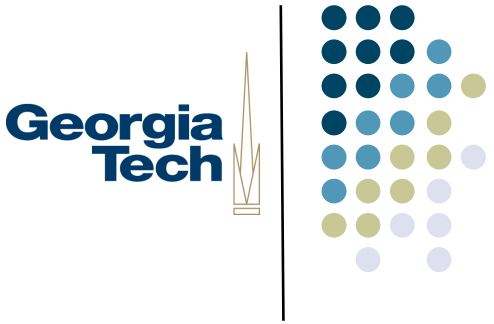
Constraints

- A more general approach
- General mechanism for establishing and maintaining relationships between things
  - layout is one use
  - several other uses in UI
    - deriving appearance from data
    - multiple view of same data
    - automated semantic feedback

General form: declare relationships

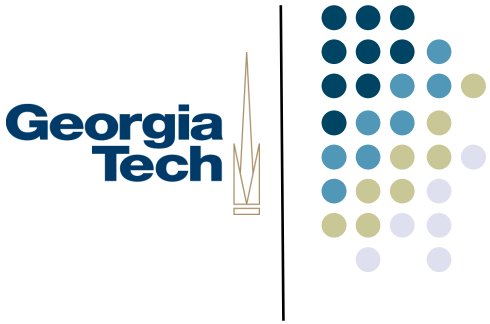
- Declare "what" should hold
  - this should be centered in that
  - this should be 12 pixels to the right of that
  - parent should be 5 pixels larger than its children
- System automatically maintains relationships under change
  - system provides the "how"

You say what
System figures out how



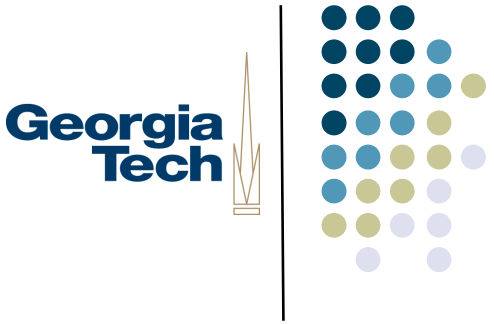
- A very good deal
- But sounds too good to be true

You say what
System figures out how



- A very good deal
- But sounds too good to be true
  - It is: can't do this for arbitrary things (unsolvable problem)
- Good news: this can be done if you limit form of constraints
  - limits are reasonable
  - can be done very efficiently

Form of constraints

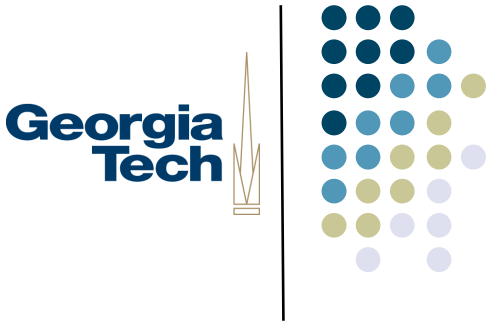


- For UI work, typically express in form of equations
  - this.x = that.x + that.w + 5

    5 pixels to the right
  - this.x = that.x + that.w/2 - this.w/2

    centered
  - this.w = 10 + max child[i].x + child[i].w

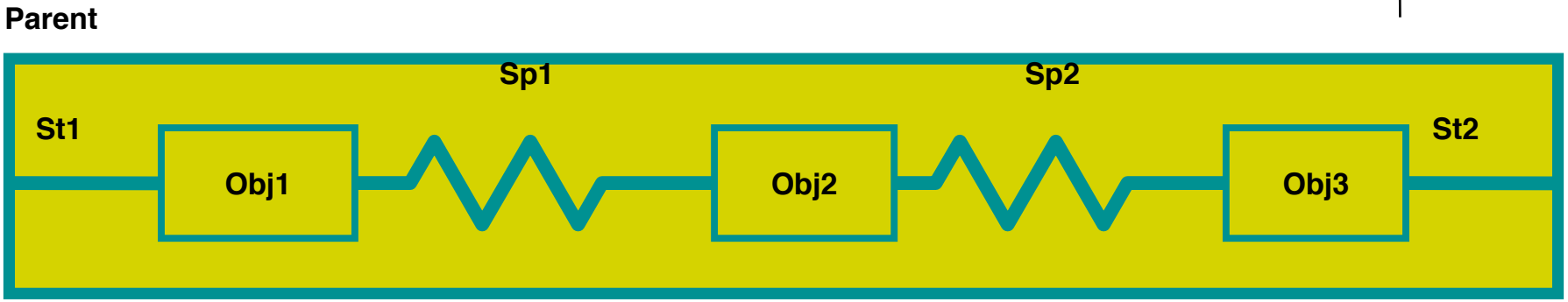
    10 larger than children



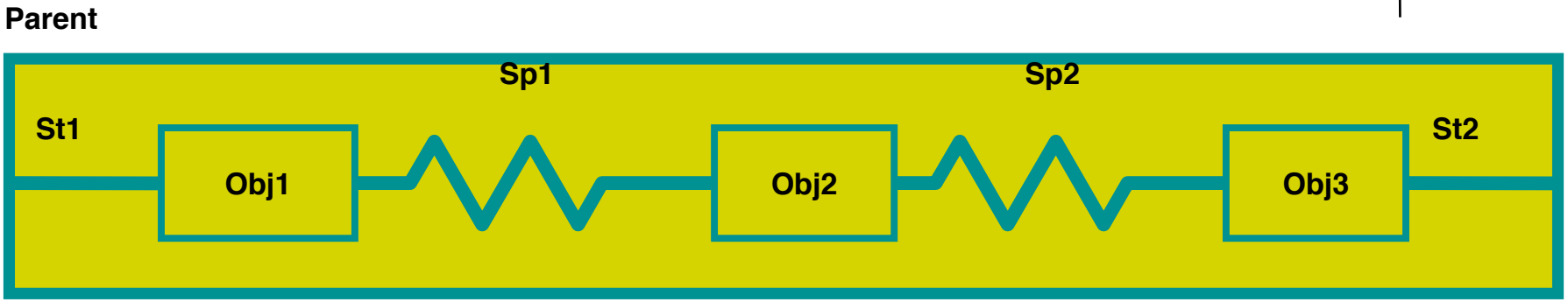
The Power of Constraints

- this.x = that.x + that.w/2 - this.w/2
  - What's so cool about this?
- Power comes from *dynamic computation of result*
  - Value isn't just computed immediately
  - Instead, saves references to objects involved in calculation
  - When any operand changes, result value is automatically recomputed
- *Express relationships declaratively*
- *Systems updates as necessary to preserve the constraints you've specified*

Example: doing springs and struts with constraints

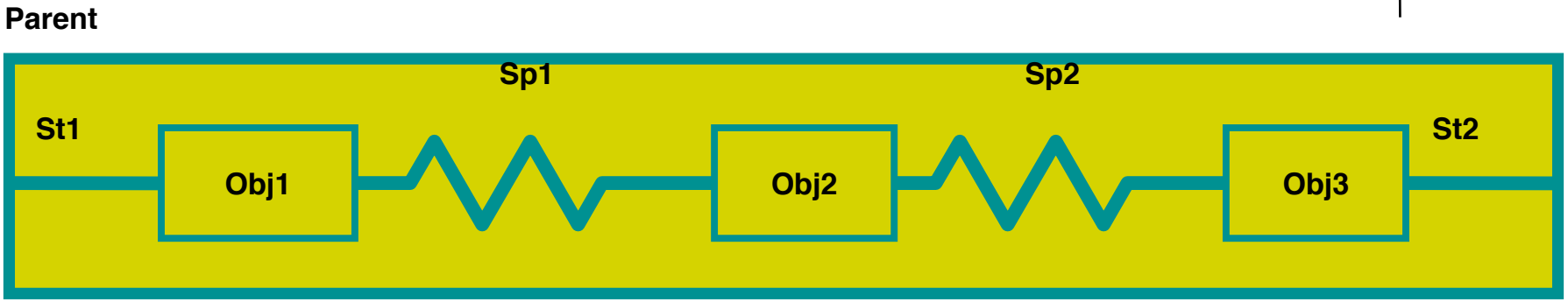


Example: doing springs and struts with constraints



- First, what does this do?
  - Obj1 and obj3 stay fixed distance from left and right edges
  - Obj2 centered between them

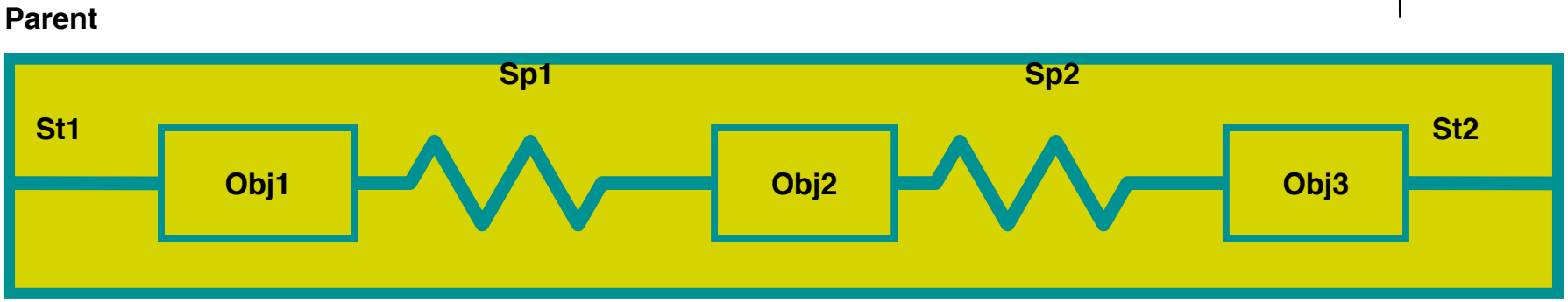
Example: doing springs and struts with constraints



- Compute how much space is left

  parent.slack = obj1.w + obj2.w + obj3.w + st1.w + st2.w - parent.w

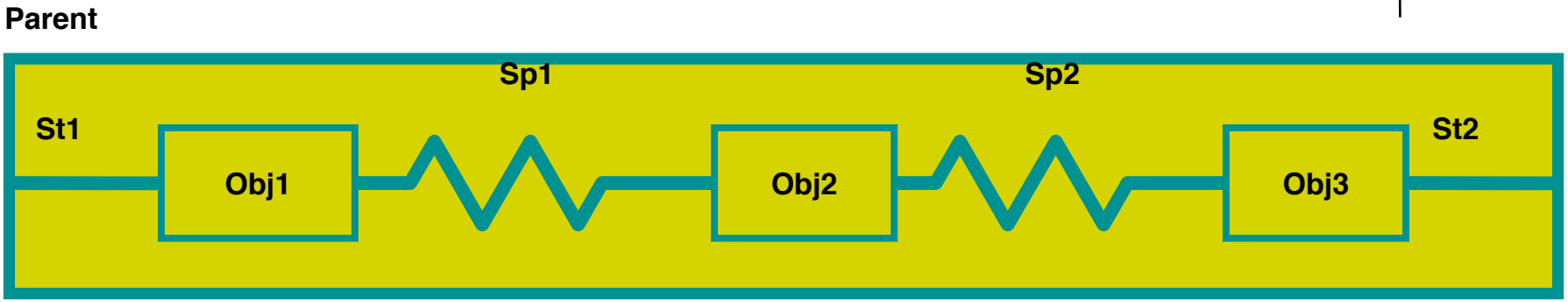
Example: doing springs and struts with constraints



- Space for each spring

  parent.sp_len = parent.slack / 2

Example: doing springs and struts with constraints

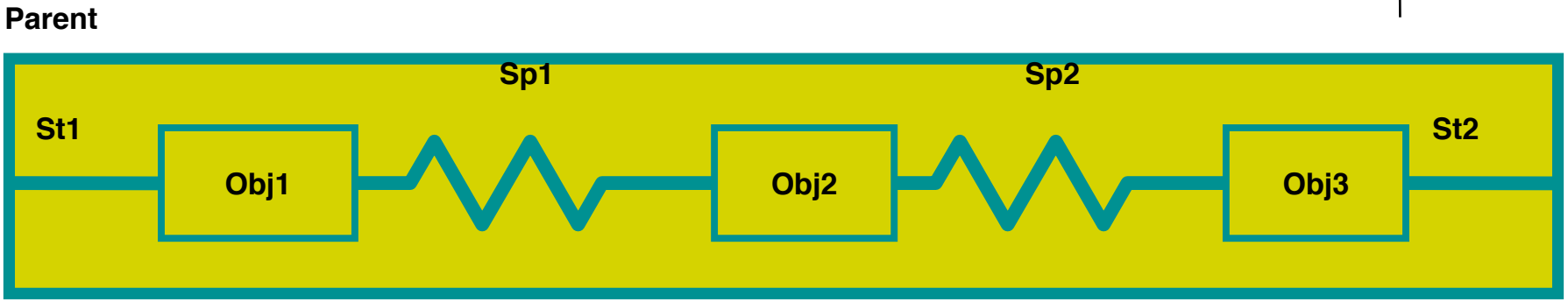


- A little better version

  parent.num_sp = 2

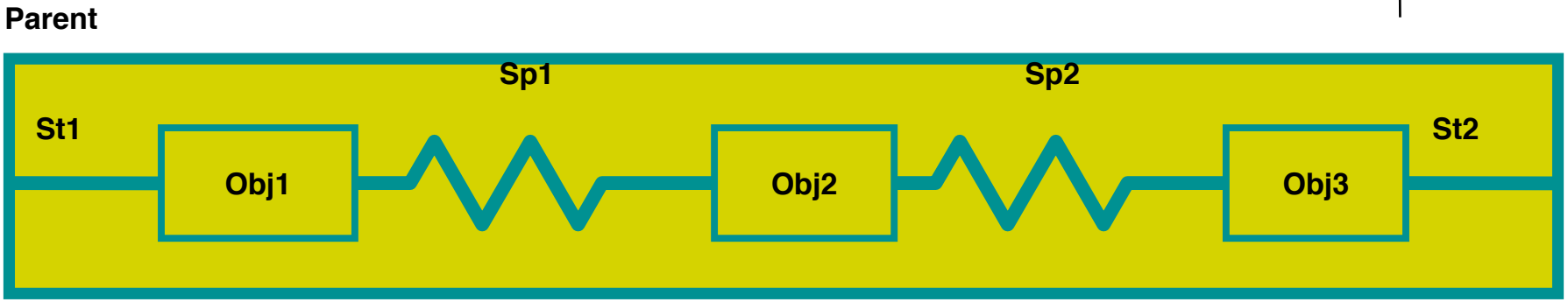
  parent.sp_len = if parent.num_sp != 0 then parent.slack / parent.num_sp
  else 0

Example: doing springs and struts with constraints



- Now assign spring sizes
  sp1.w = parent.sp_len
  sp2.w = parent.sp_len

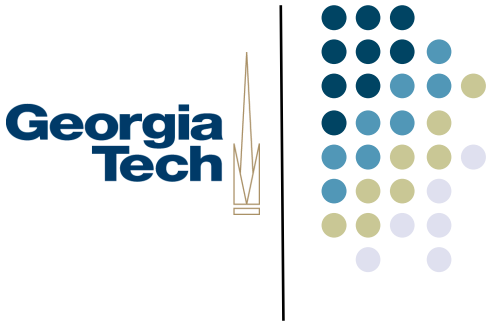
Example: doing springs and struts with constraints



- Now do positions left to right
  st1.x= 0
  obj1.x = st1.x + st1.w
  sp1.x = obj1.x + obj1.w
  ...

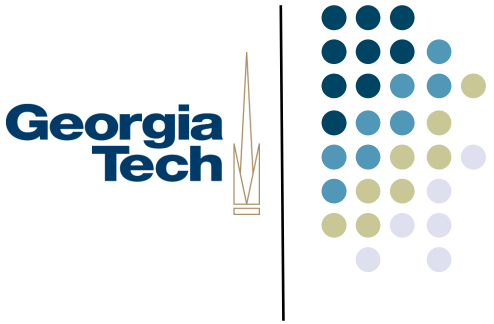
Power of constraints

- If size of some component changes, system can determine new sizes for springs, etc.
  - automatically
  - just change the size that has to change, the rest "just happens"
    - very nice property



Bigger example

- Suppose we didn't want to fix number of children, etc. in advance
  - don't want to write new constraints for every layout
  - instead put constraints in object classes (has to be a more general)
  - in terms of siblings & first/last child



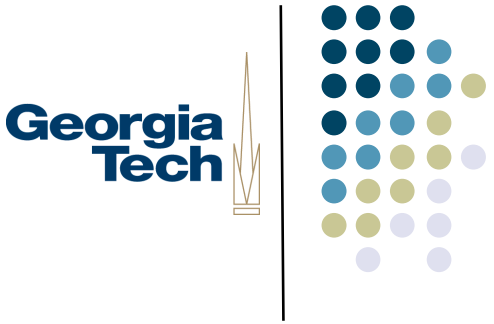
Bigger (generalized) example

- First compute slack across arbitrary children
- Each strut, spring, and object:

  obj.sl_before = if prev_sibling != null

  then prev_sibling.sl_after

  else parent.w



Bigger (generalized) example

- For struts and objects:

  obj.sl_after = obj.sl_before - obj.w

- For springs:
  - spr.sl_after = spr.sl_before

Example of a "chained" computation

- Compute my value based on previous value
  - Special case at beginning
  - This now works for any number of children
    - adding a new child dynamically not a problem
- Very common pattern

Now compute number of springs

- For springs use:

  spr.num_sp = if prev_sibling != null
  then prev_sibling.num_sp + 1
  else 1

- For struts and objects use:

  obj.num_sp = if prev_sibling != null
  then prev_sibling.num_sp
  else 0

Carry values to parent

parent.num_sp = last_child.num_sp

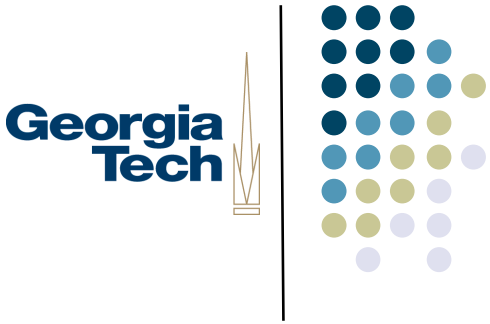
parent.slack = last_child.sl_after

- Again, don't need to know how many children
  - Correct value always at last one

Compute spring lengths

parent.sp_len = if parent.num_sp != 0
then parent.slack / parent.num_sp
else 0

Set sizes of springs & do positions



- For springs use:

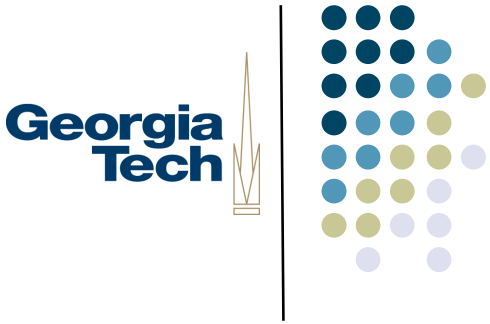
  spr.w = parent.sp_len

- For all use:

  obj.x = if prev_sibling != null

  then prev_sibling.x + prev_sibling.w

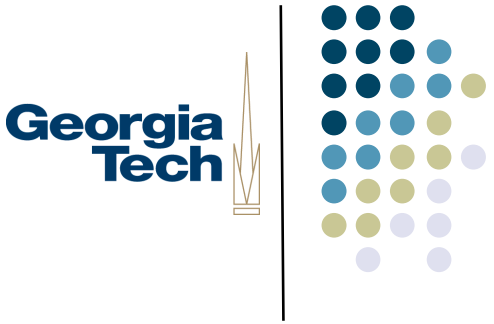
  else 0



More complex, but...

- Only have to write it once
  - put it in various superclasses
  - this is basically all we have to do for springs and struts layout (if we have constraints)
  - can also do boxes and glue (slightly more complex, but not unreasonable)
  - can write other kinds of layout and mix and match using constraints

Springs 'n' Struts in Swing



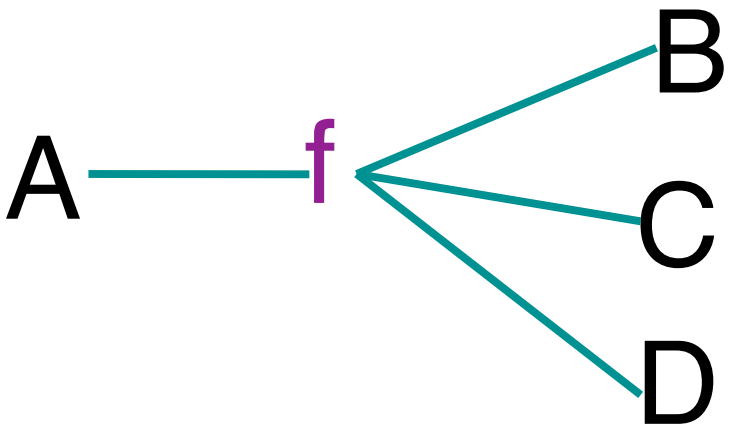
- Swing provides a basic constraint-based Springs'n'struts LayoutManager
  - javax.swing.SpringLayout
- Allows simple arithmetic computation of constraints

Dependency graphs

- Useful to look at a system of constraints as a "dependency graph"
  - graph showing what depends on what
  - two kinds of nodes (bipartite graph)
    - variables (values to be constrained)
    - constraints (equations that relate)

Dependency graphs

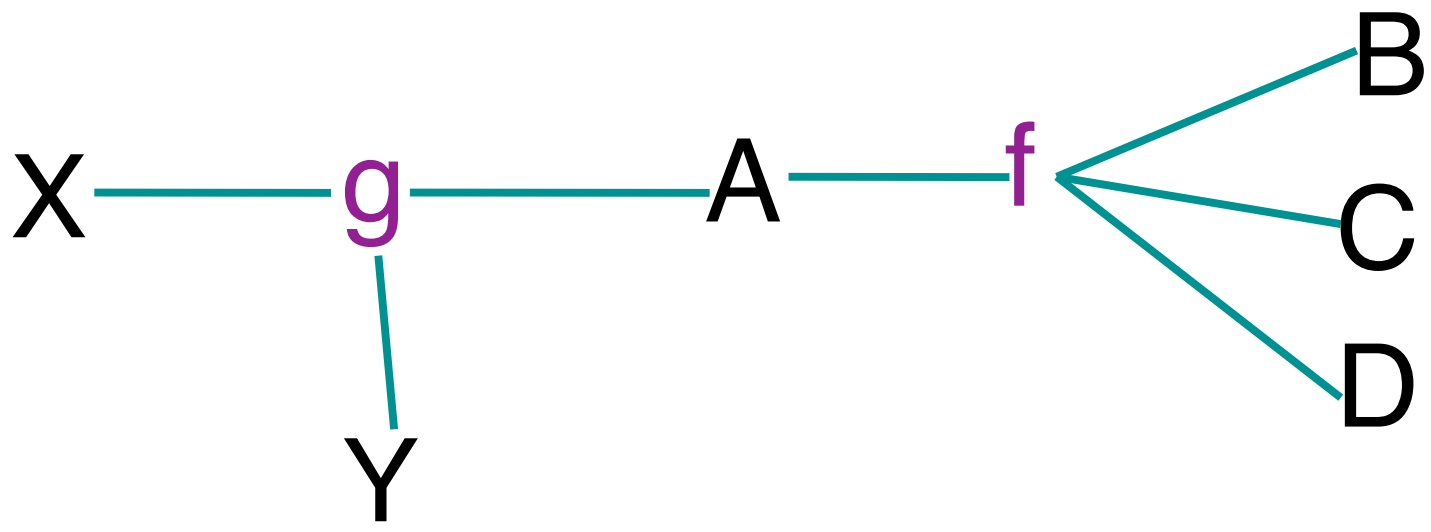
- Example: A = f(B, C, D)



- Edges are dependencies

Dependency graphs

- Dependency graphs chain together: X = g(A, Y)

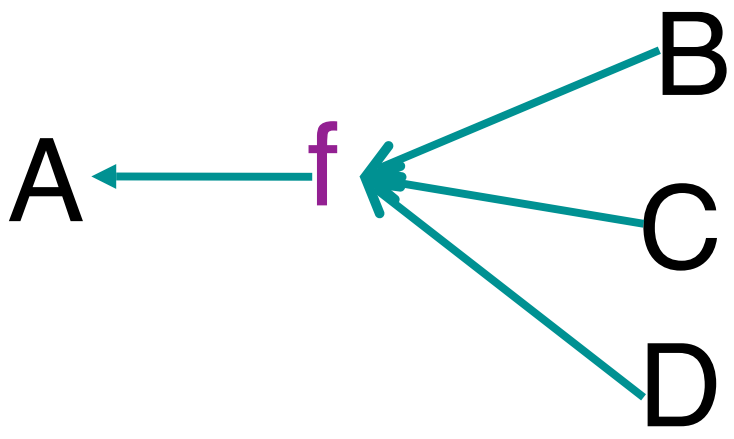


Kinds of constraint systems

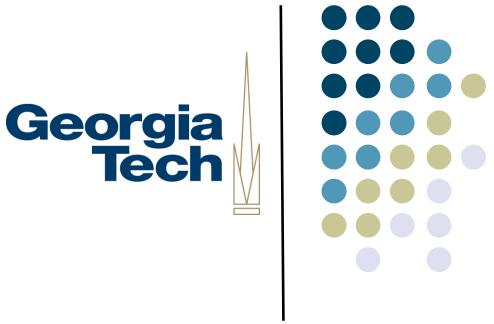
- Actually lots of kinds, but 2 major varieties used in UI work
  - reflect kinds of limitations imposed
- One-Way constraints
  - must have a single variable on LHS
  - information only flows to that variable
    - can change B,C,D system will find A
    - can't do reverse (change A …)

One-Way constraints

- Results in a directed dependency graph:
  - A = f(B,C,D)



- Normally require dependency graph to be acyclic
  - cyclic graph means cyclic definition



One-Way constraints

- Problem with one-way: introduces an asymmetry

  this.x = that.x + that.w + 5

  - can move (change x) "that", but not "this"

Multi-way constraints

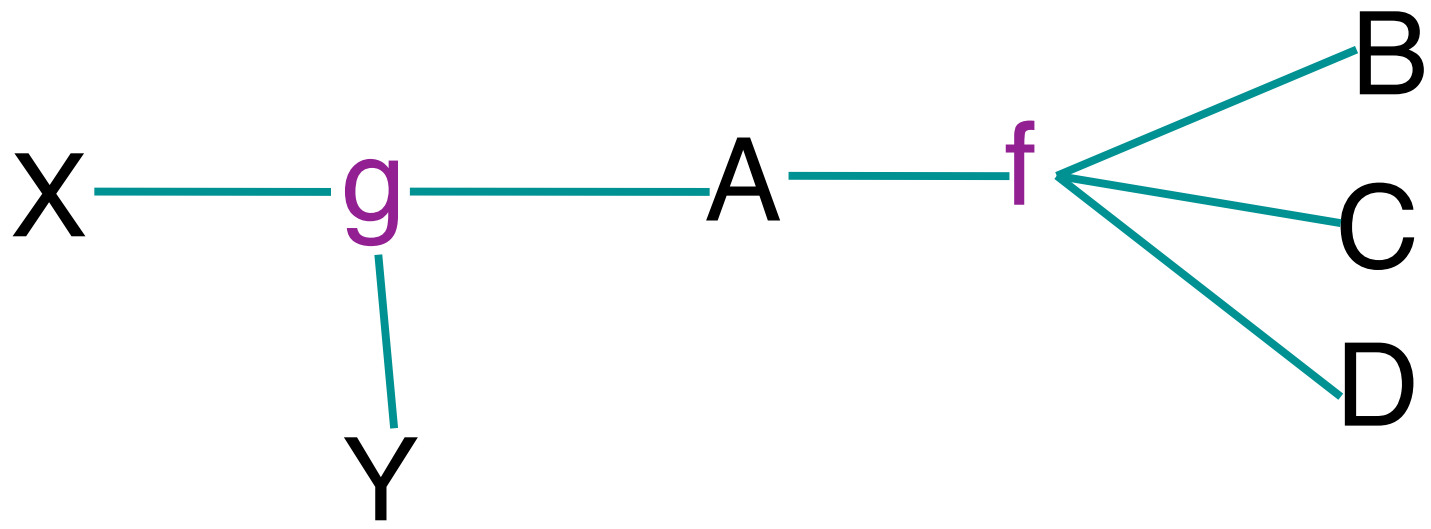
- Don't require info flow only to the left in equation
  - can change A and have system find B,C,D
- Not as hard as it might seem
  - most systems require you to explicitly factor the equations for them
    - provide B = g(A,C,D), etc.

Multi-way constraints

- Modeled as an undirected dependency graph
- No longer have asymmetry

Multi-way constraints

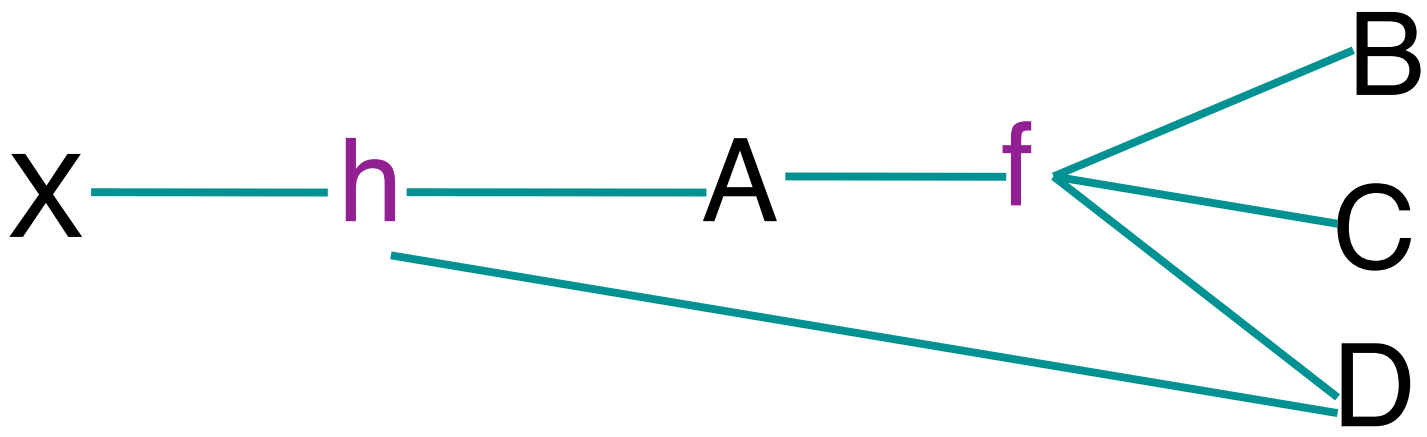
- But all is not rosy
  - most efficient algorithms require that dependency graph be a tree (acyclic undirected graph)



OK

Multi-way constraints

- But: A = f(B,C,D) & X = h(D,A)



Not OK because it has a cycle (not a tree)

Another important issue

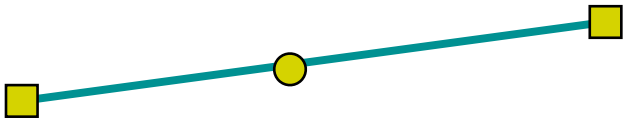
- A set of constraints can be:
  - Over-constrained
    - No valid solution that meets all constraints
  - Under-constrained
    - More than one solution
      - sometimes infinite numbers

Over- and under-constrained

- Over-constrained systems
  - solver will fail
  - isn't nice to do this in interactive systems
  - typically need to avoid this
    - need at least a "fallback" solution

Over- and under-constrained

- Under-constrained
  - many solutions
  - system has to pick one
  - may not be the one you expect
  - example: constraint: point stays at midpoint of line segment
    - move end point, then?



Over- and under-constrained

- Under-constrained
  - example: constraint: point stays at midpoint of line segment
    - move end point, then?
    - Lots of valid solutions
      - move other end point
      - collapse to one point
      - etc.

Over- and under-constrained

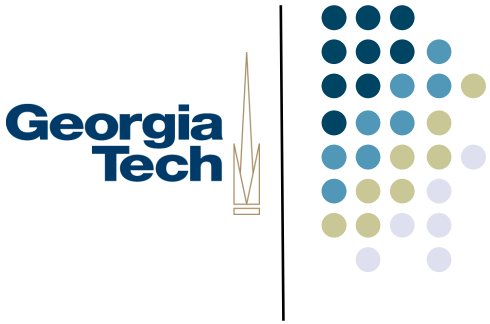
- Good news is that one-way is never over- or under-constrained (assuming acyclic)
  - system makes no arbitrary choices
  - pretty easy to understand

Over- and under-constrained

- Multi-way can be either over- or under-constrained
  - have to pay for extra power somewhere
  - typical approach is to over-constrain, but have a mechanism for breaking / loosening constraints in priority order
    - one way: "constraint hierarchies"

Over- and under-constrained

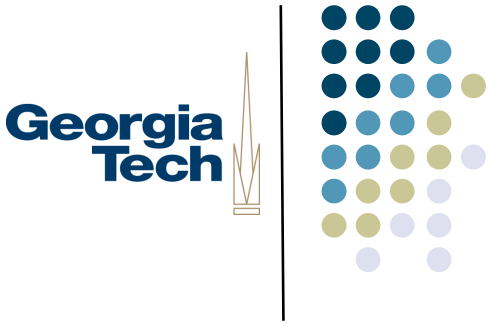
- Multi-way can be either over- or under-constrained
  - unfortunately system still has to make arbitrary choices
  - generally harder to understand and control



Implementing constraints

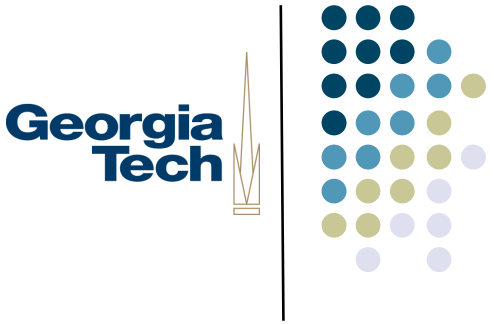
- Simple algorithm for one-way
  - Need bookkeeping for variables
  - For each keep:
    - value- the value of the var
    - eqn - code to eval constraint
    - dep - list of vars we depend on
    - done- boolean "mark" for alg

Simple algorithm for one-way



- After any change:

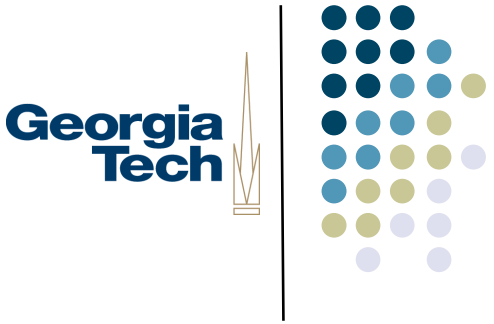
```
// reset all the marks
for each variable V do
   V.done = false;

// make each var up-to-date
for each variable V do
   evaluate(V);
```



Simple algorithm for one-way

```
evaluate(V):
  if (!V.done)
  |  V.done = true;
  |  Parms = empty;
  |  for each DepVar in V.dep do
  |  |  Parms += evaluate(DepVar)
  |  V.value = V.eqn(Parms)
  return V.value
```

Approach for multi-way implementation



- Use a "planner" algorithm to assign a direction to each undirected edge of dependency graph
- Now have a one-way problem

Better algorithms

- "Incremental" algorithms exist for both one-way and multi-way
  - don't recompute every variable after every (small) change
  - (small) partial changes require (small) partial updates