Algorithms for User Interfaces

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Outline

- Story of why algorithms matter in programming
- or a promise of never having to write a GUI event handler again

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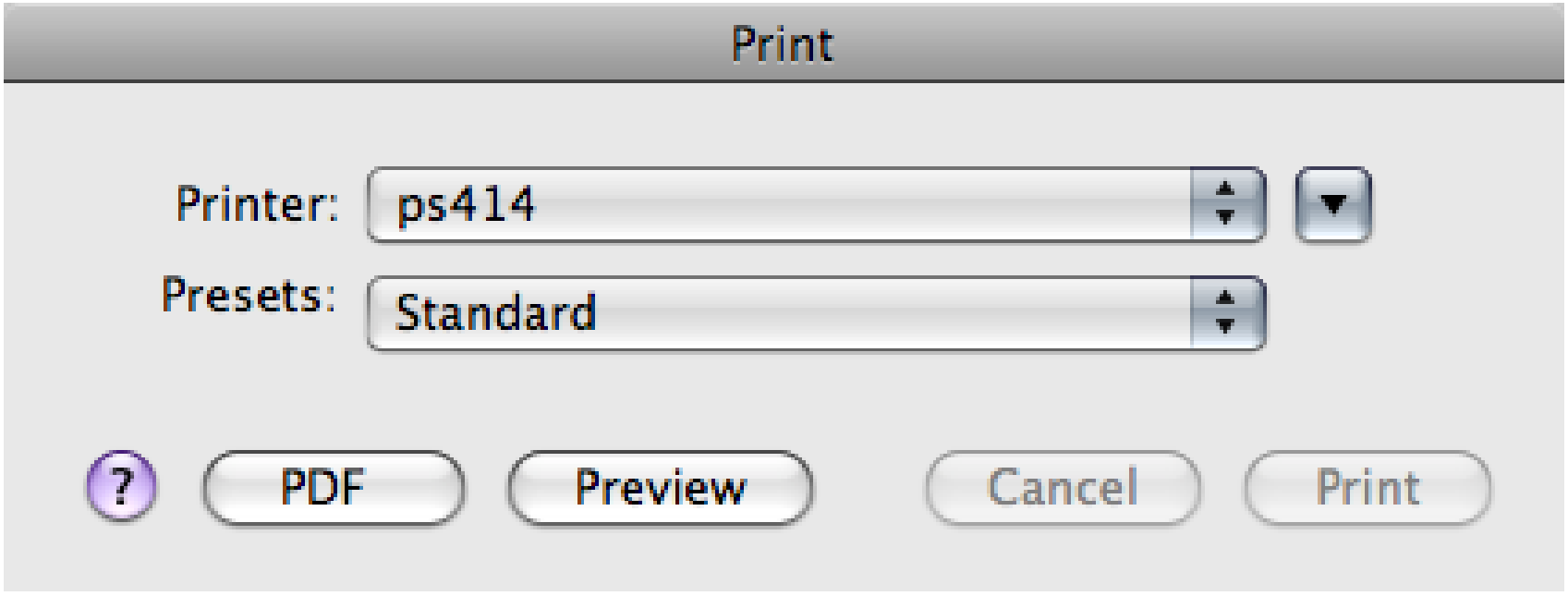
Motivation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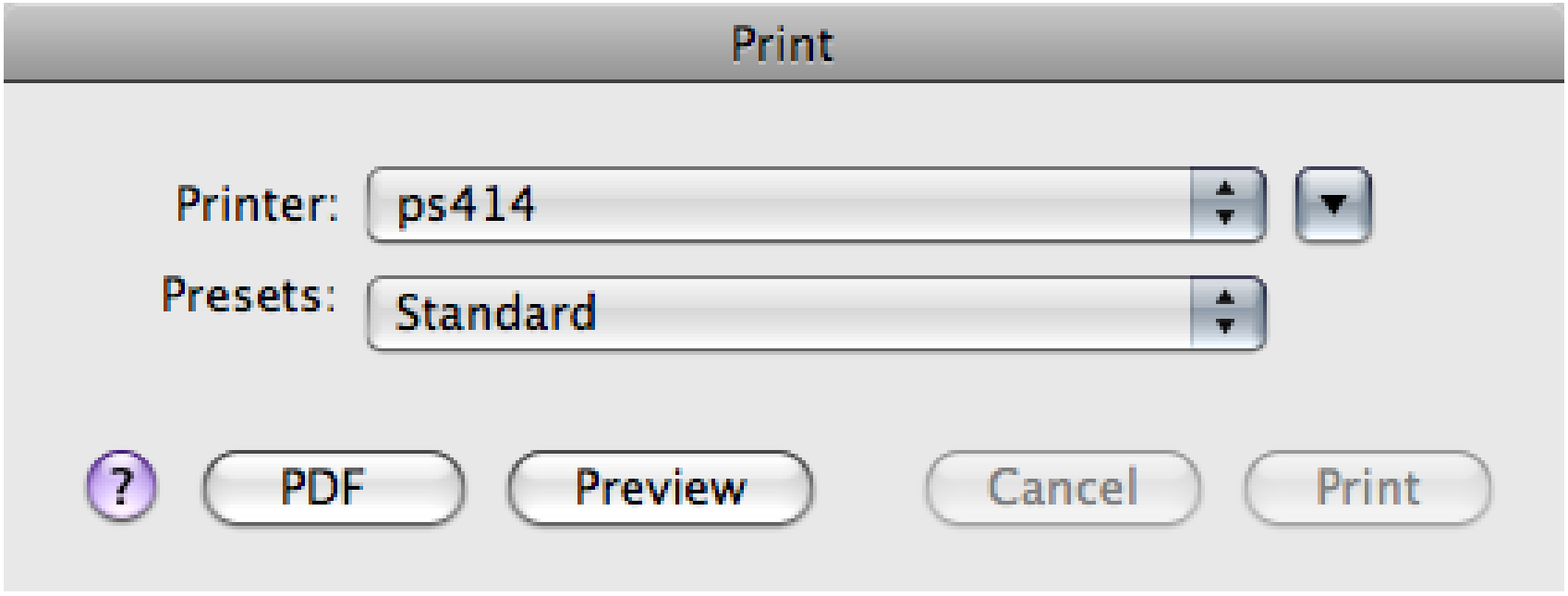
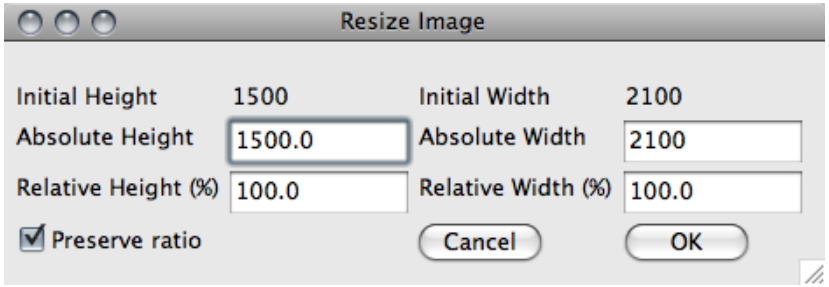
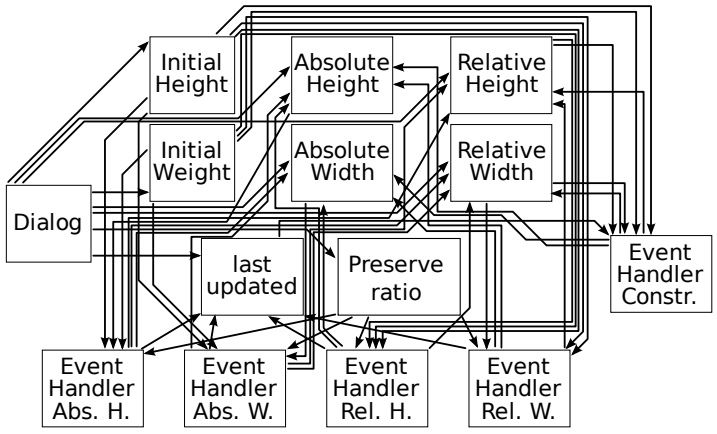


Why is software like this?

Motivation






```
def ChangeCurrentHeightPx(self, event):
    self.LastUpdated = "Height"
    constrained = self.Controls["Constrain"].GetValue()
    # no matter what the percent & current stay bound together
    # get current height, and compute relative height and place new rel. ht
    height = float(self.Controls["AbsolutePx"]["Height"].GetValue())
    pct = height / self.InitialSize[self.Height]
    self.Controls["Relative%"]["Height"].SetValue(str(pct*100))

    if constrained: # update width & width%
        self.Controls["Relative%"]["Width"].SetValue(str(pct*100))
        width = pct * self.InitialSize[self.Width]
        self.Controls["AbsolutePx"]["Width"].SetValue(str(round(width)))

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def ChangeCurrentHeightPct(self, event):
    self.LastUpdated = "Height"
    constrained = self.Controls["Constrain"].GetValue()
    # no matter what the percent & current stay bound together
    # get current rel. ht, and compute absolute height and place new abs. ht
    height = float(self.Controls["Relative%"]["Height"].GetValue())
    cur = height * self.InitialSize[self.Height] / 100
    self.Controls["AbsolutePx"]["Height"].SetValue(str(round(cur)))

    if constrained: # update width & width%
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    if constrained: # update height & height%
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        height = width * self.InitialSize[self.Height] / 100
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def ChangeConstrainState(self, event):
    constrained = self.Controls["Constrain"].GetValue()
    # If the ratio is constrained, determine which dimension
    # was last updated and update the OTHER dimension.
    # For example: if Height was last updated, use Height as
    # Width's new percent, and update Width's absolute value
    if constrained:
        if self.LastUpdated == "Height": # update width px & %
            pct = float(self.Controls["Relative%"]["Height"].GetValue())
            self.Controls["Relative%"]["Width"].SetValue(str(pct))
            width = pct * self.InitialSize[self.Width] / 100
            self.Controls["AbsolutePx"]["Width"].SetValue(str(round(width)))
        else: # update width px & %
            pct = float(self.Controls["Relative%"]["Width"].GetValue())
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            height = pct * self.InitialSize[self.Height] / 100
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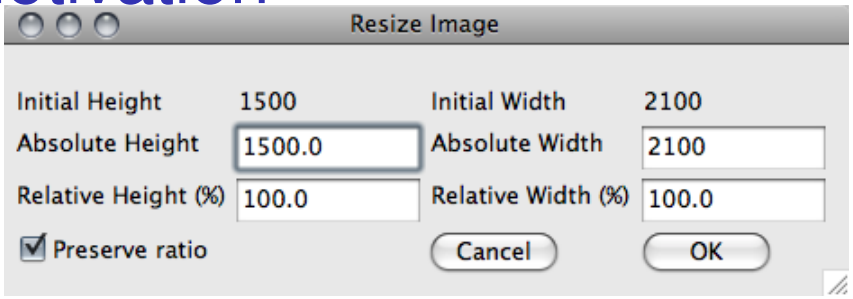

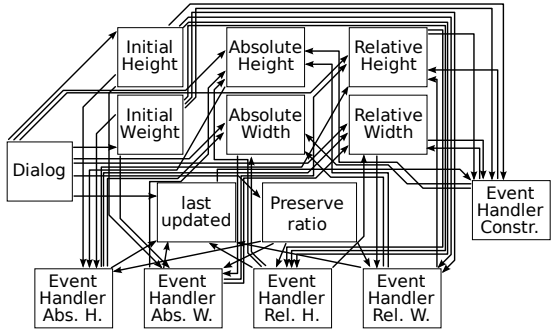

- Reuse is a proven and successful route to improve quality of software, and increase programmer productivity
- Vasts amounts of well tested and proven code routinely reused
  - GUI components, delivering events, rendering, capturing interaction
  - Example: a typical TextBox widget: 100 methods, recognizes $>$ 200 events
- Compositions are not reusable
  - $\Rightarrow$ ad-hoc code, defects, inconsistent behavior, costly development
- Incidental data structures arise from a network of objects
- Incidental algorithms arise from the concert of localized actions
- Minimal requirement for reuse: understandable model
  - Not satisfied by incidental data structures and algorithms

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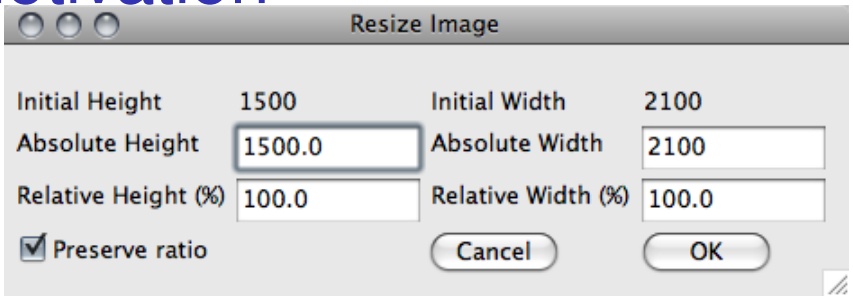

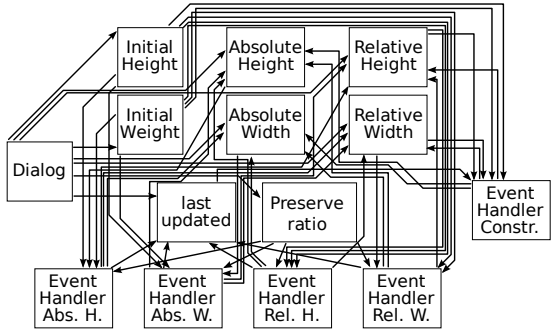

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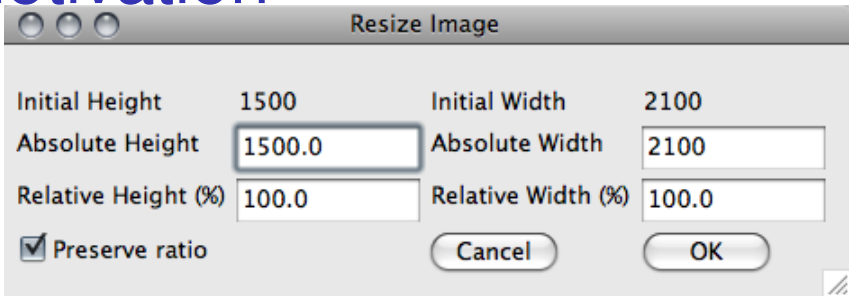

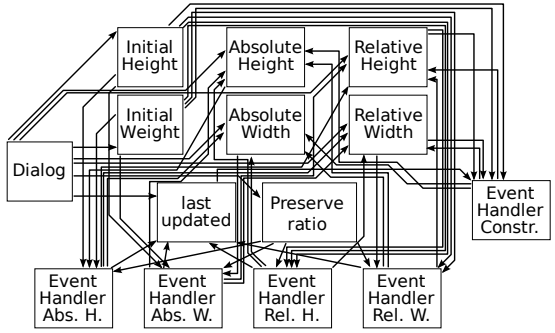

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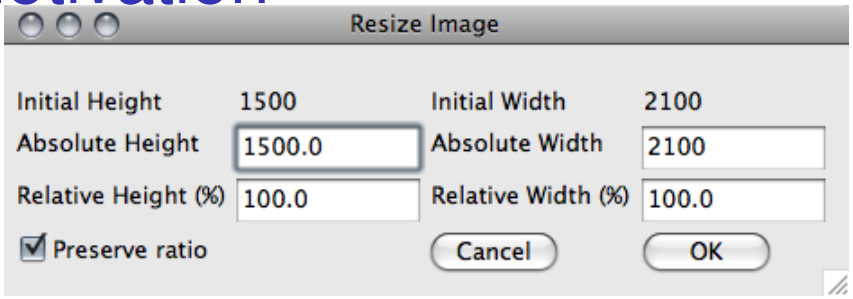

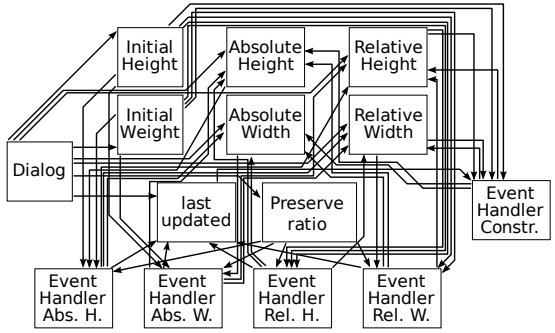

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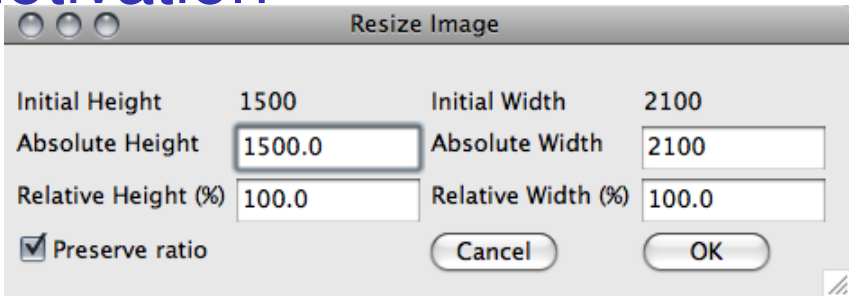

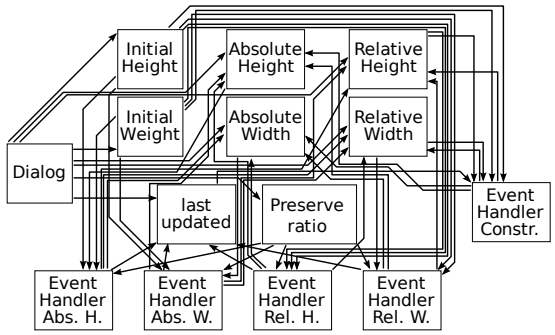

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Software is forever doomed!

Given a sorted array A[0] <= A[1] <=...<= A[n−1], we want to determine if a given element T is in the array. Binary search solves the problem by keeping track of a range within the array in which T must be if it is anywhere in the array. Initially the range is the entire array. The range is shrunk by comparing its middle element to T, and then discarding half the range. The process continues until T is found, or until the range in which it must lie is known to be empty. In an n-element table, the search uses roughly $\log_2(n)$ *comparisons.*

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```
int* binary_search(int* first, int* last, int x) {
   while (first != last) {
      int* middle = first + (last — first) / 2;
      if (*middle < x) first = middle + 1;
      else last = middle;
   }
   return first;
}
```

Cancel that, programming is not forever doomed after all

- The problem: UI related code is
  - bloated and buggy
    - for example, Adobe's desktop applications, event handling is estimated to account for a third of the code and over half of the defects
  - full of incidental data structures and algorithms
- An approach for improving the status quo
  - To understand the commonalities that exist in event-handling code
  - To define a model that captures these commonalities
  - To apply
    - replace incidental data structures with explicit data structures
    - replace incidental algorithms with explicit reusable algorithm
- Result: substantial increase in reuse, programming productivity, software correctness and quality

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Understanding UIs: *Command Parameter Synthesis*

- Dialogs serve to

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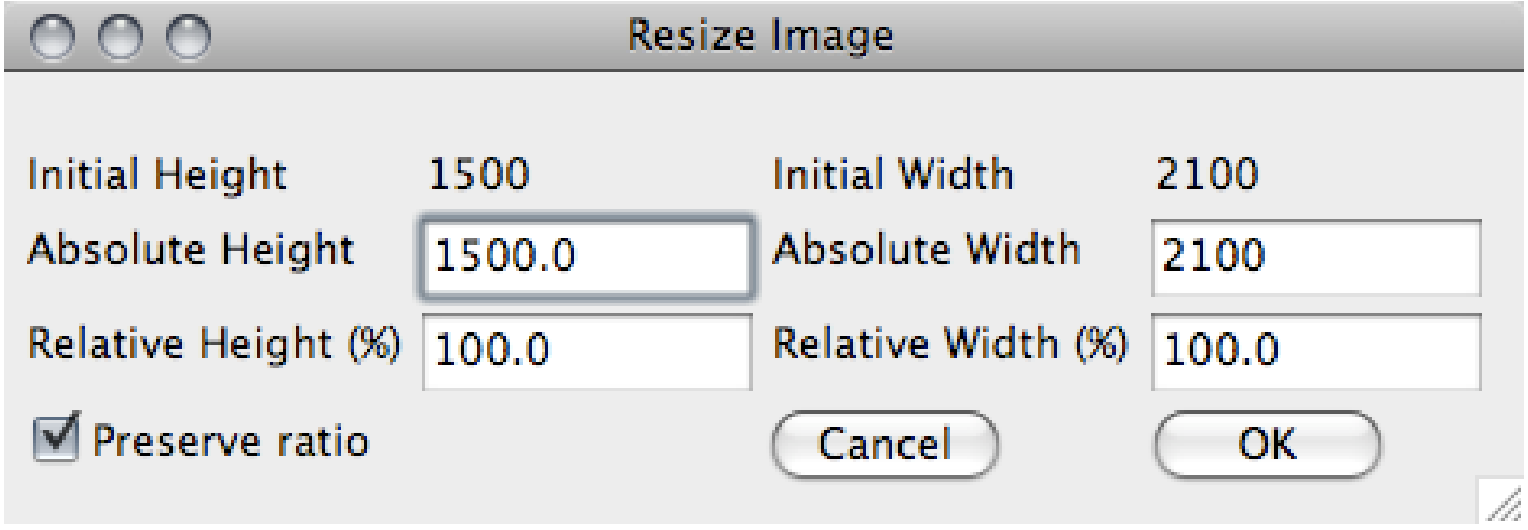

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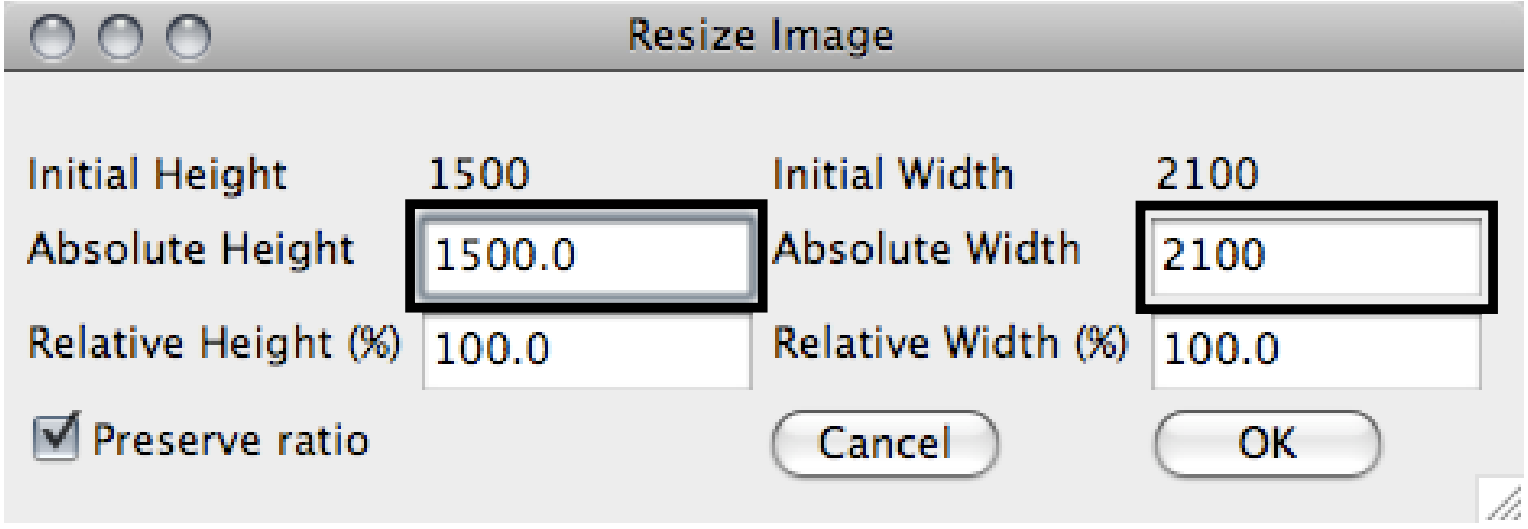

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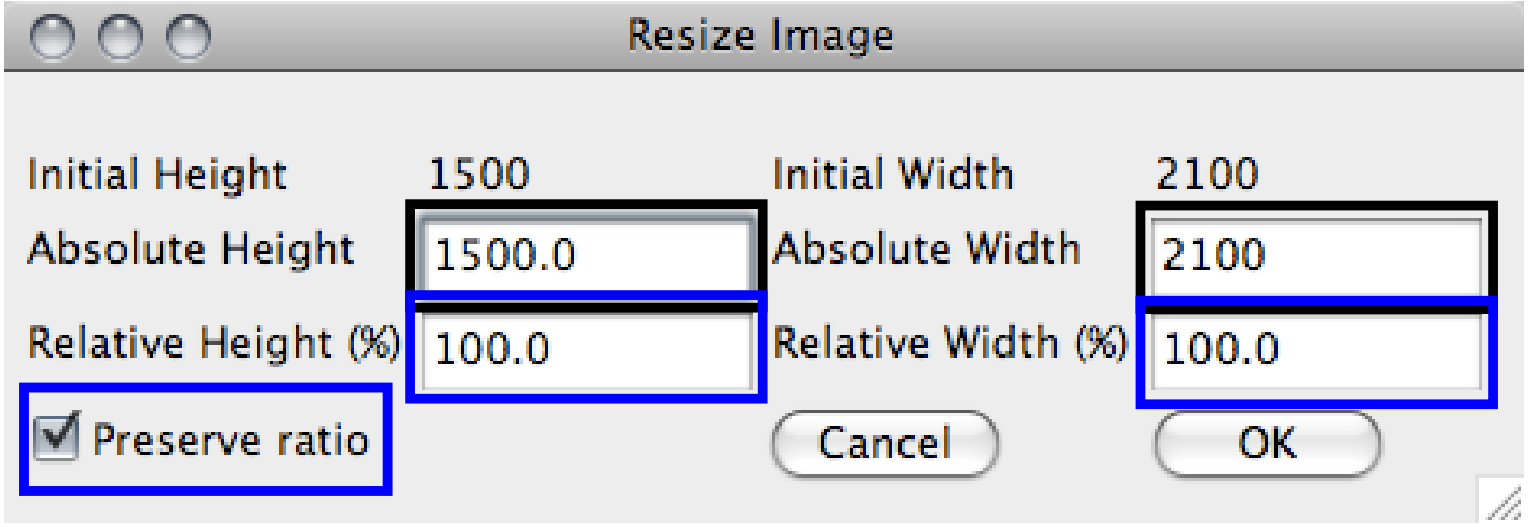

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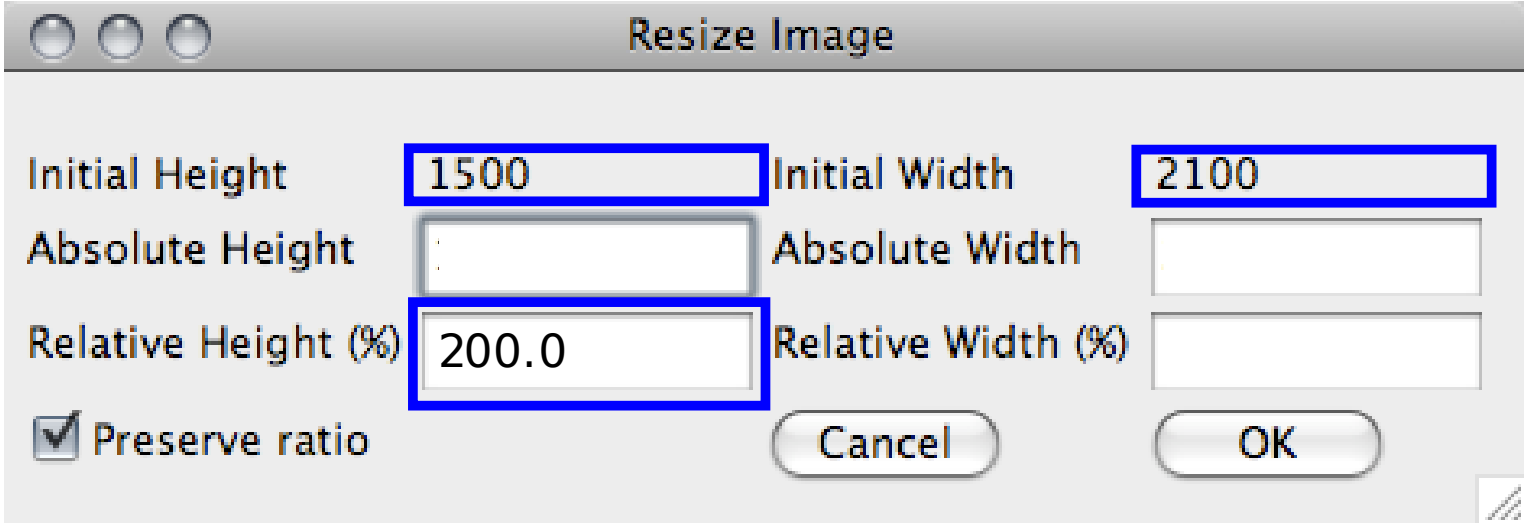

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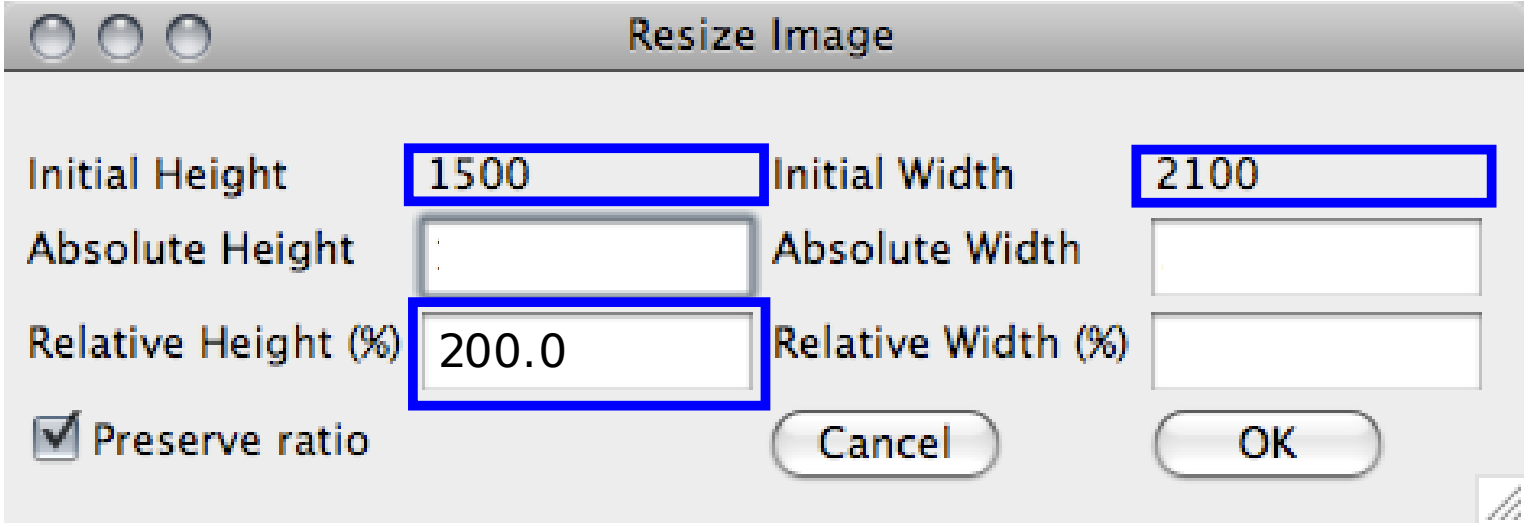

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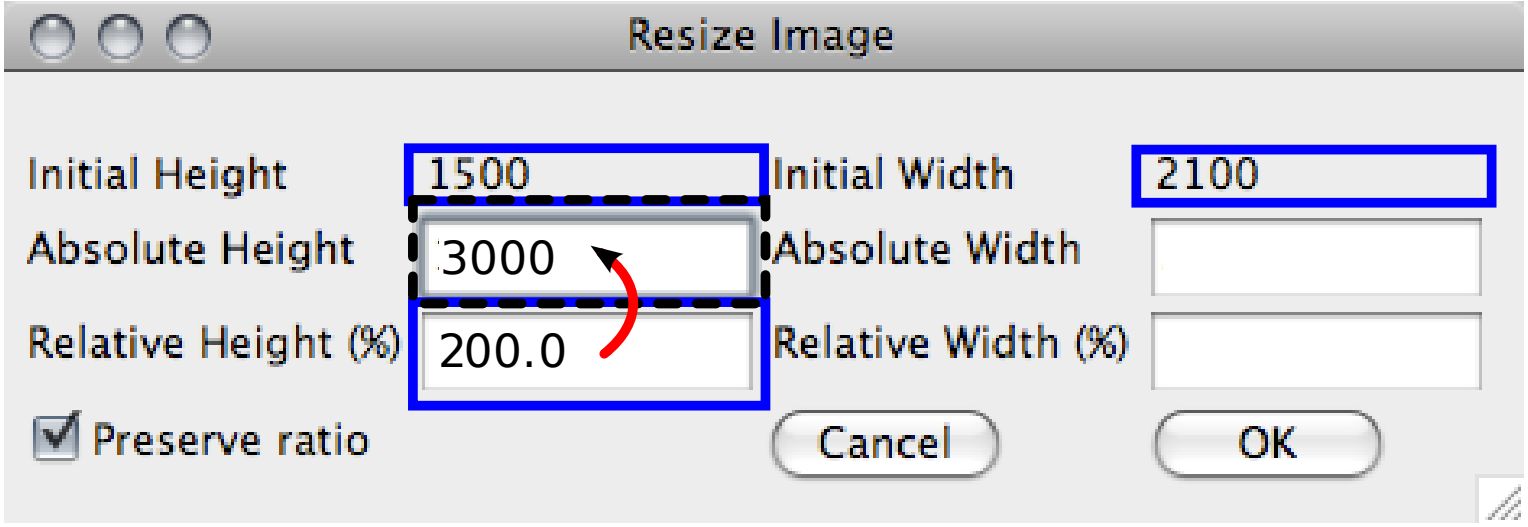

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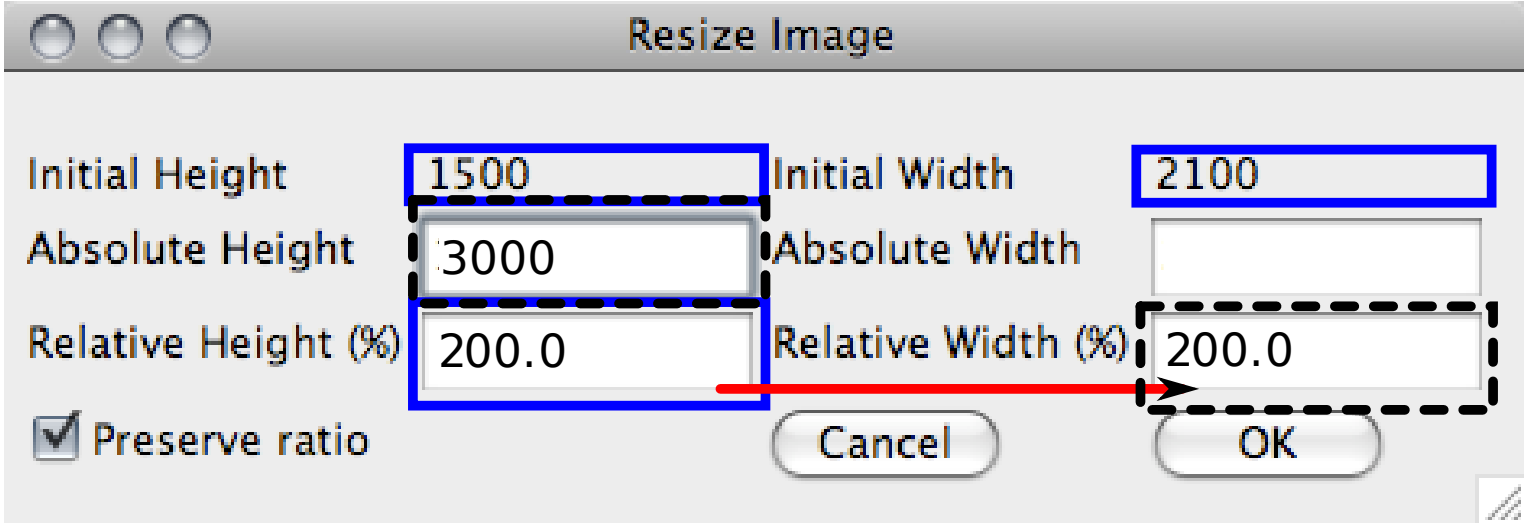

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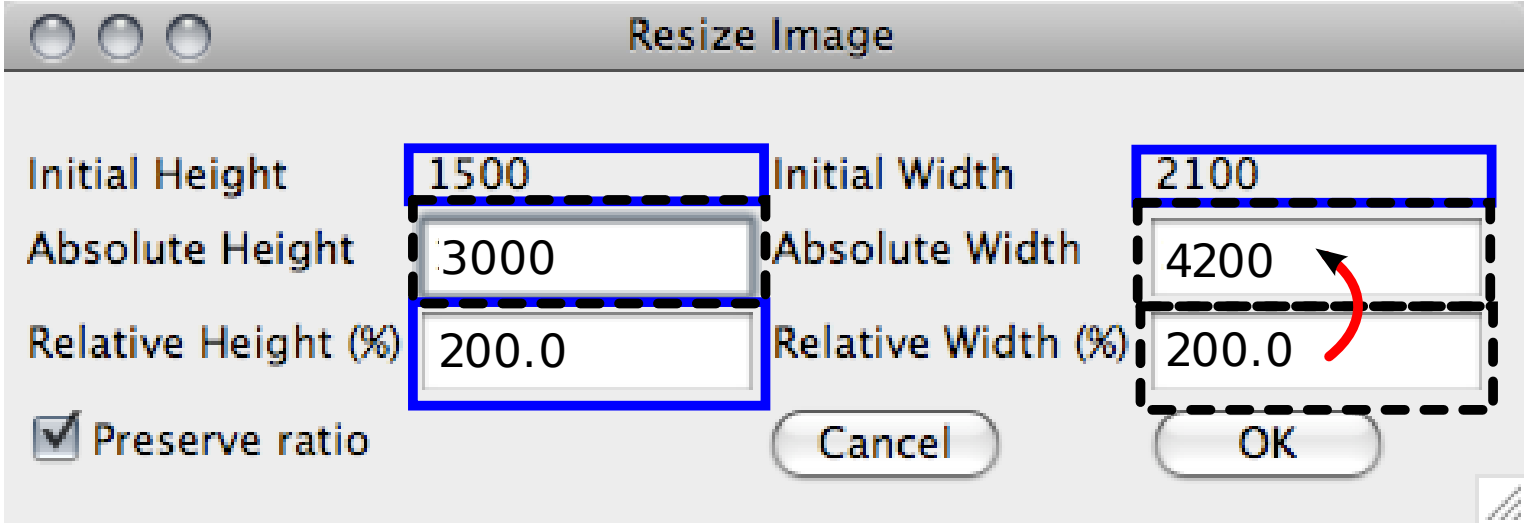

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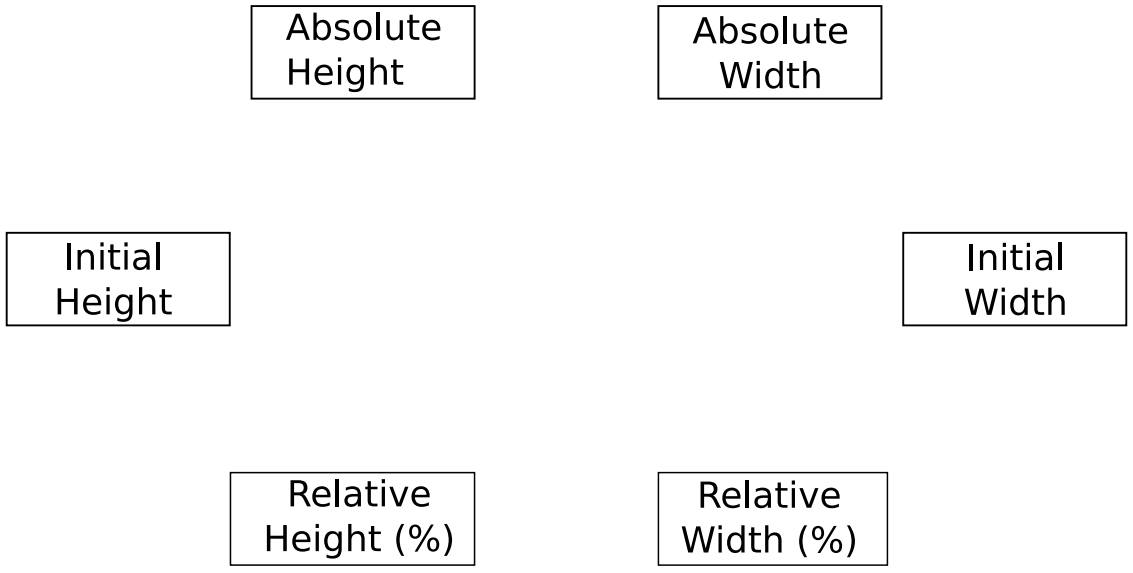
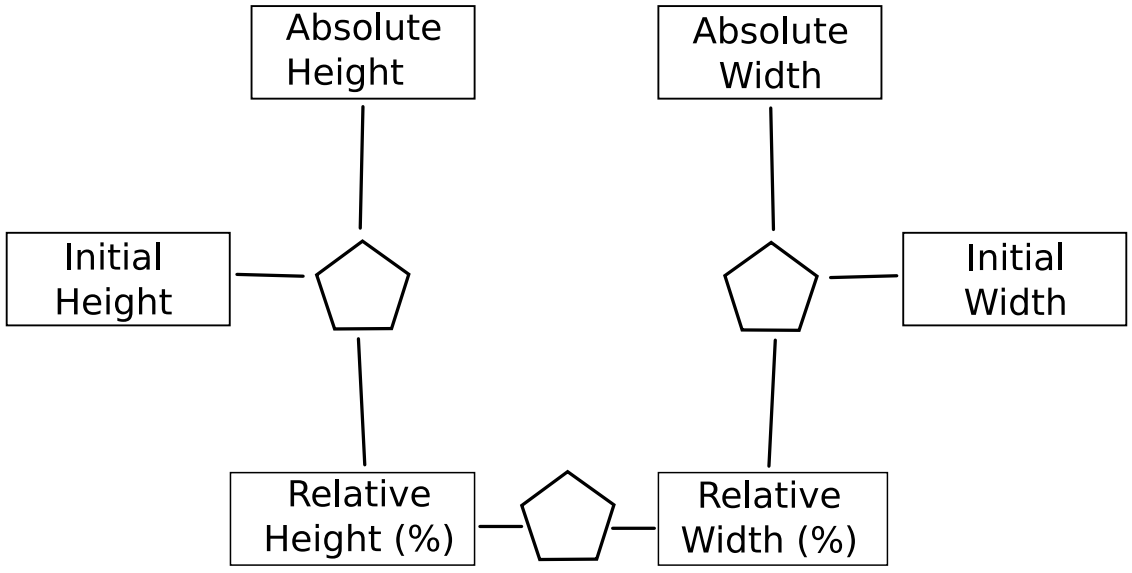


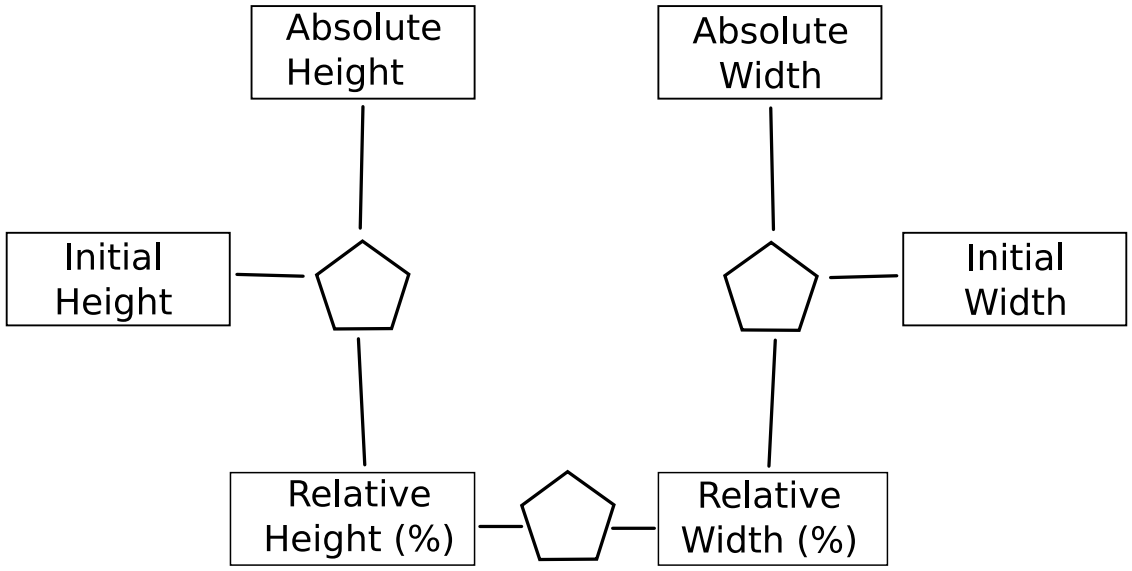
- Variables ...

Core of the Model: Multi-way Dataflow Constraint System



- Variables ...
- tied together by constraints ...

Core of the Model: Multi-way Dataflow Constraint System



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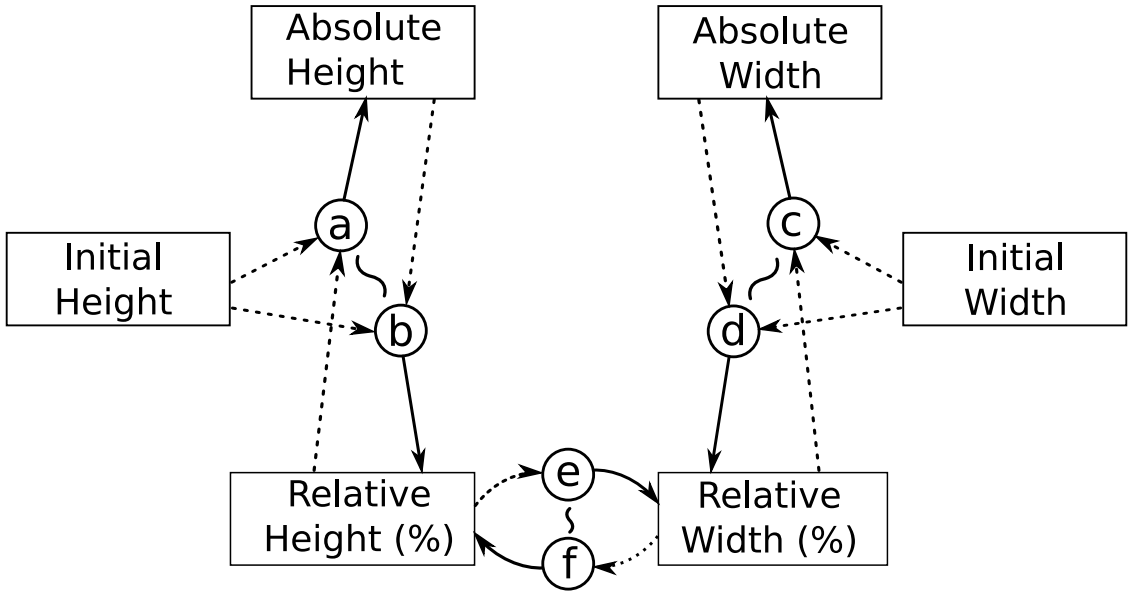

- Variables ...
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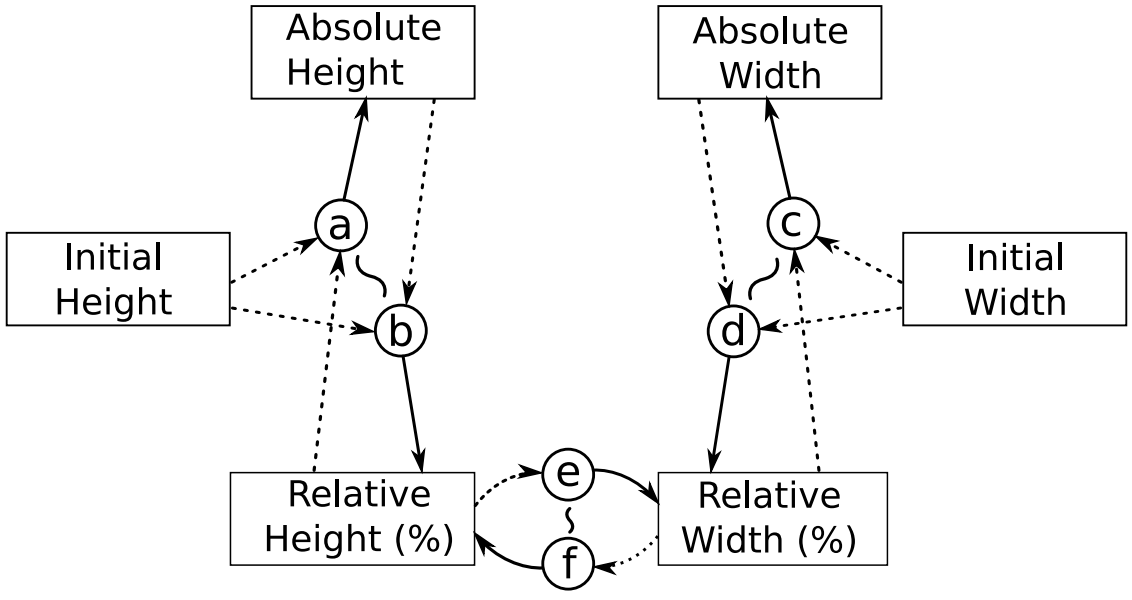

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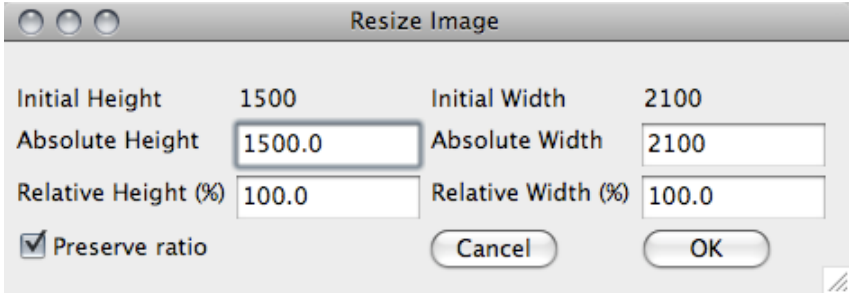
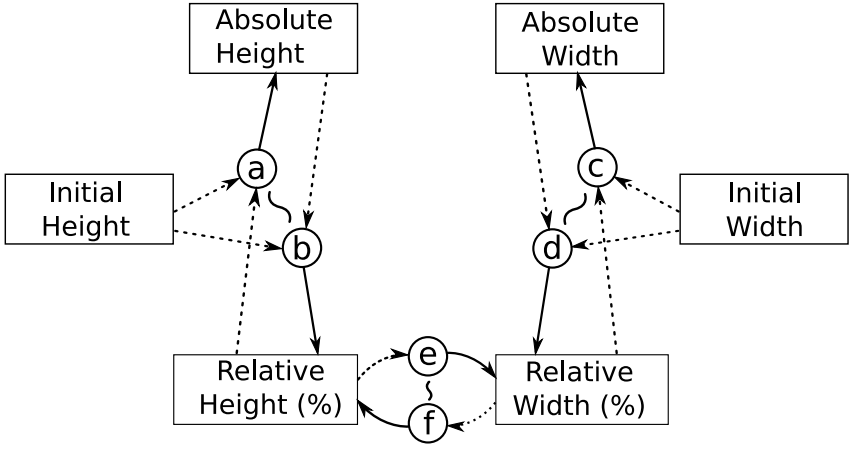
- each of which can be satisfied by any of a number of methods
  - a: *absolute_height = initial_height * relative_height / 100;*
  - b: *relative_height = (absolute_height / initial_height) * 100;*

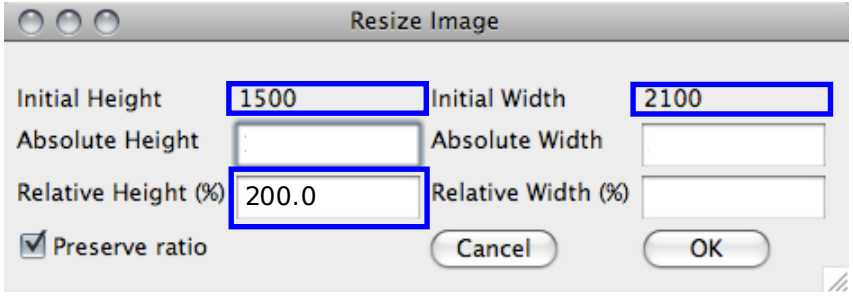
Multi-way Dataflow Constraint Systems

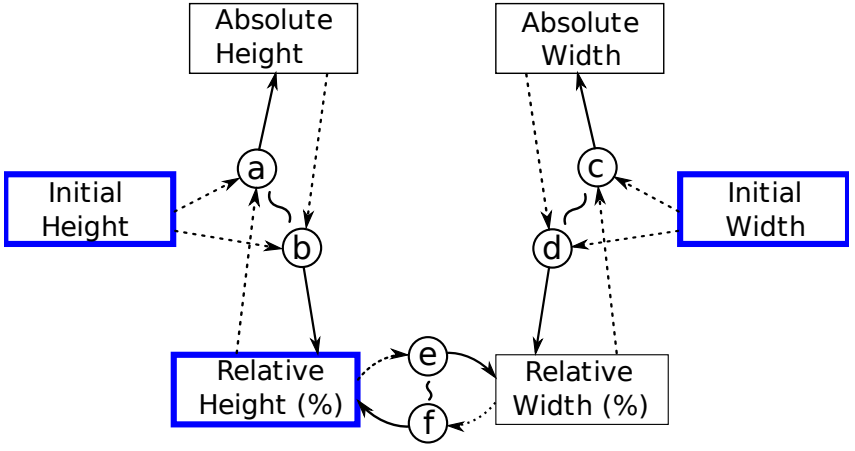




- Restoring consistency is now just solving the system

Multi-way Dataflow Constraint Systems





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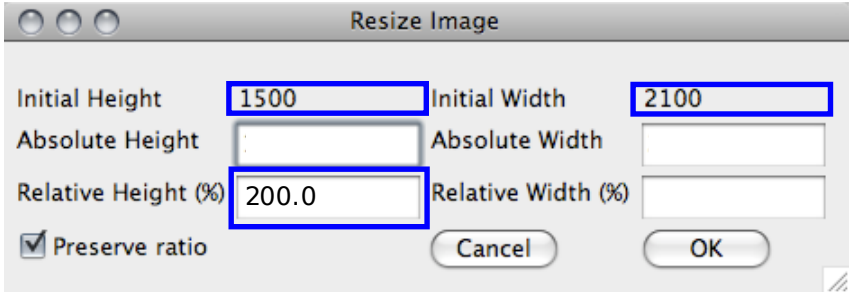

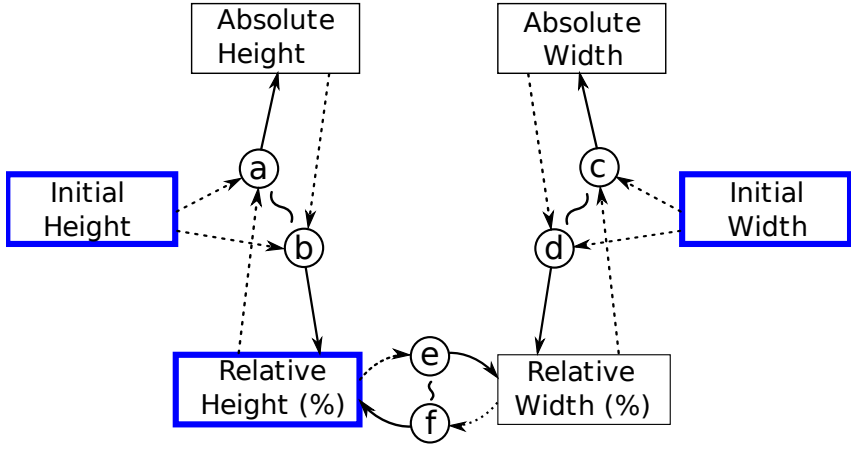

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- Solution defines a dataflow
  - Selection of methods (in order) such that
    - all constraints enforced
    - no two methods output to same variable

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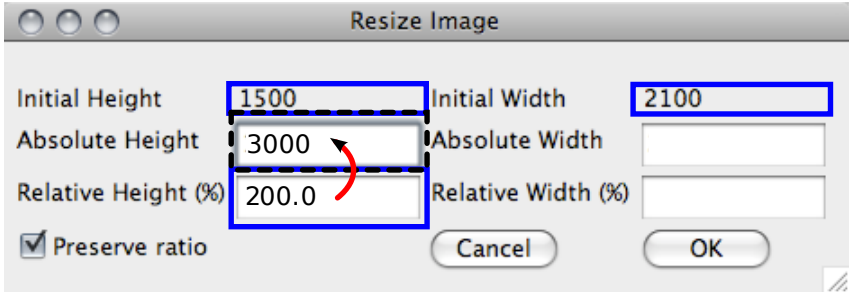

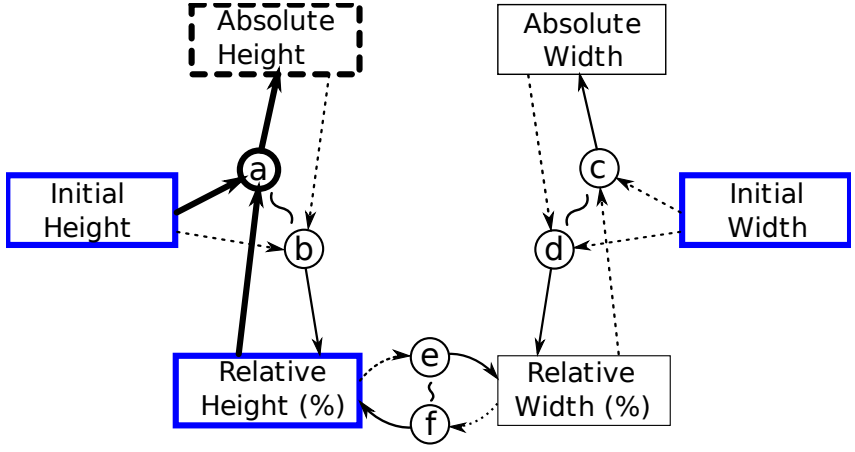

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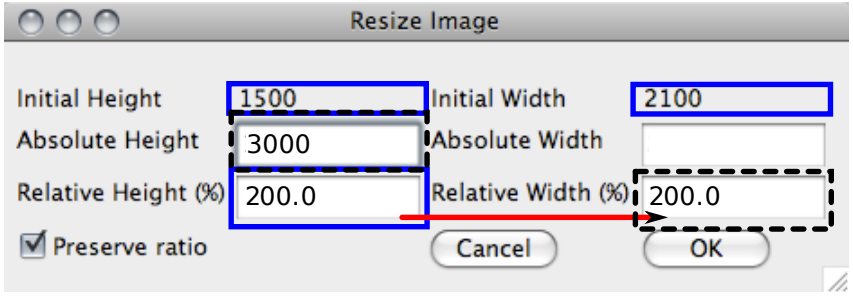
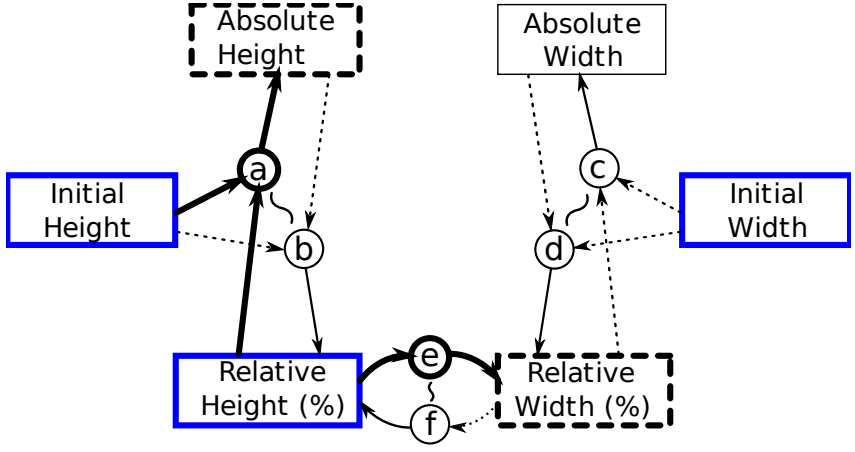
  - Selection of methods (in order) such that
    - all constraints enforced
    - no two methods output to same variable

Multi-way Dataflow Constraint Systems





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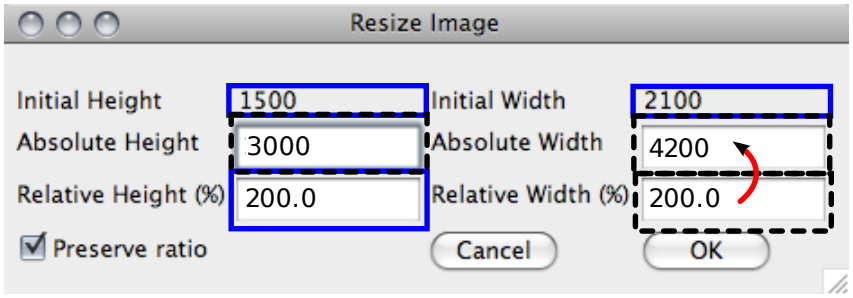

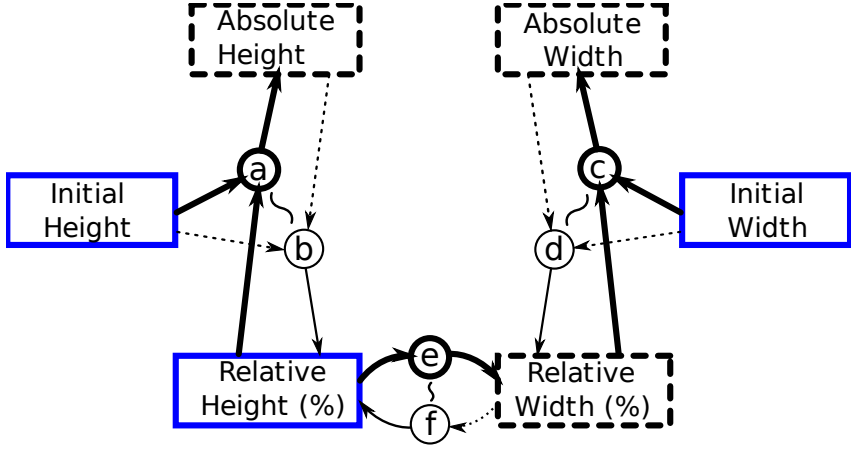

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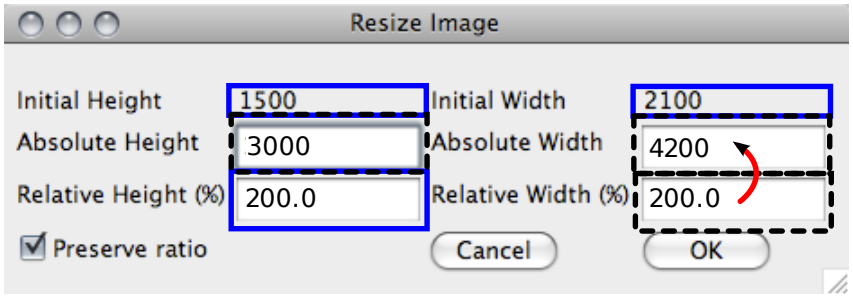

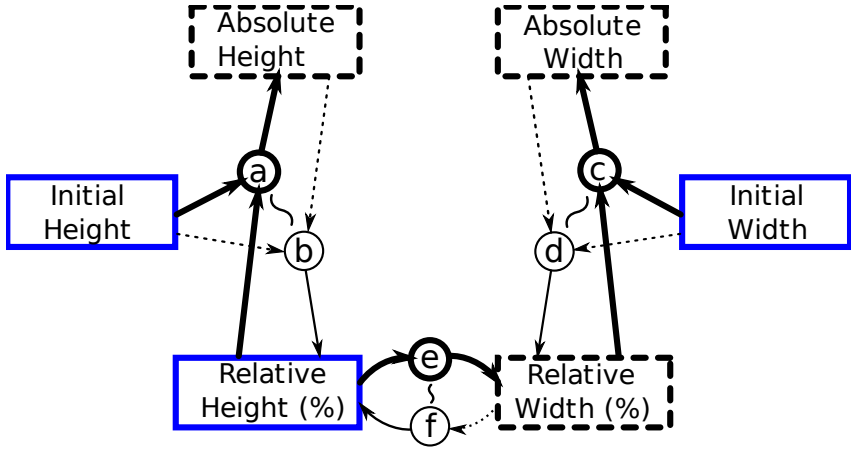

- Restoring consistency is now just solving the system
- Solution defines a dataflow
  - Selection of methods (in order) such that
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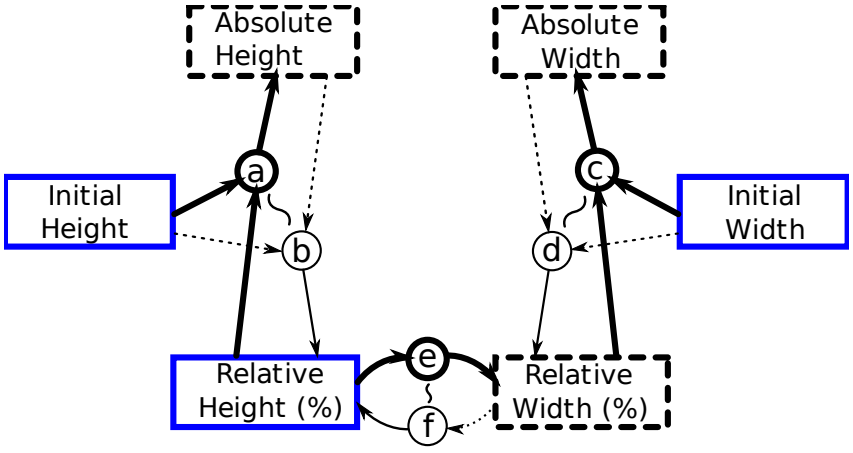
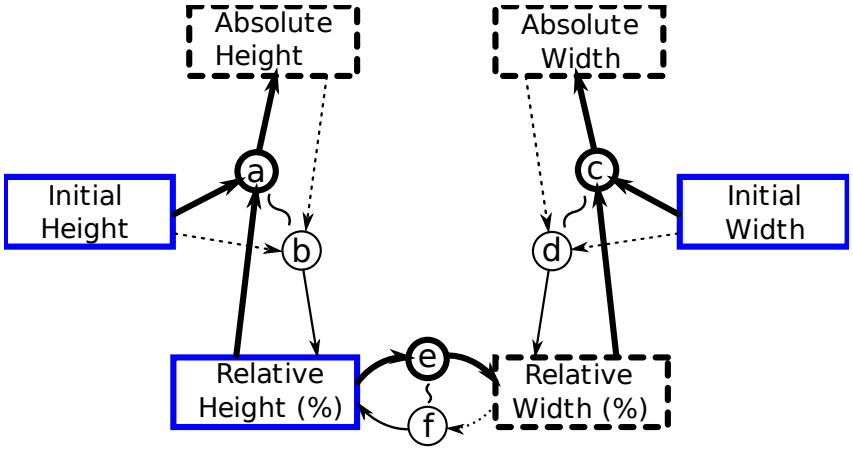
  - e.g. a, e $\longrightarrow$ c

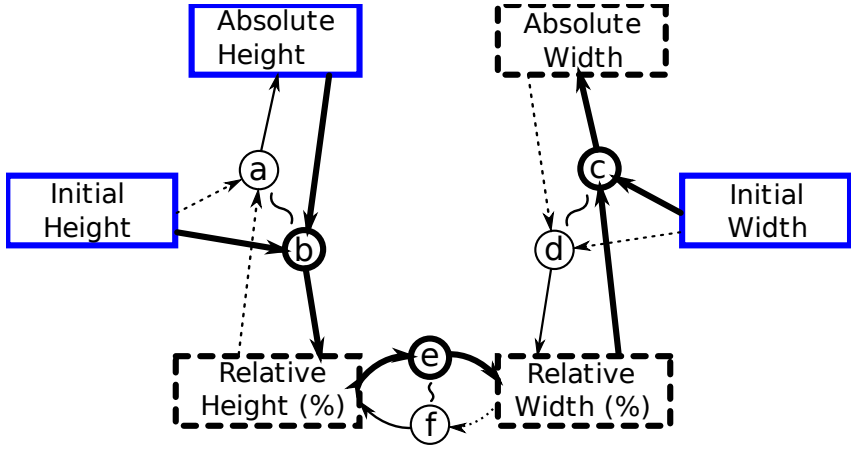
Picking the “right” solution



- Programmer only defines relations and their methods, not which method to execute and when $\Rightarrow$ often multiple solutions

Picking the “right” solution





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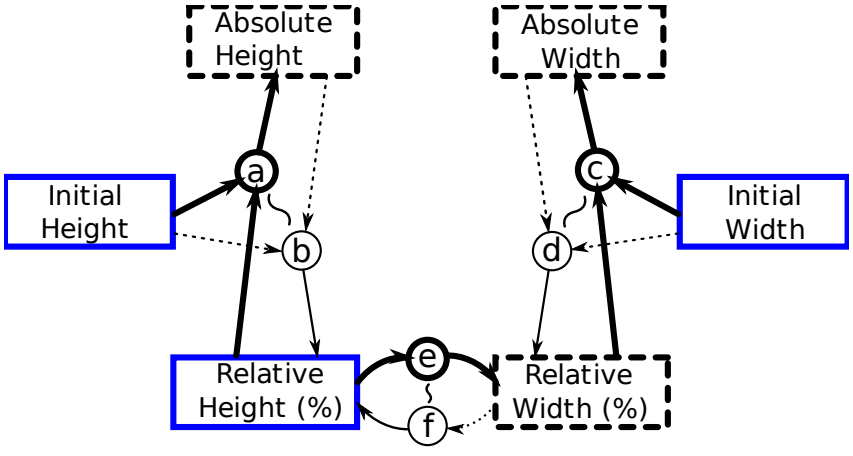

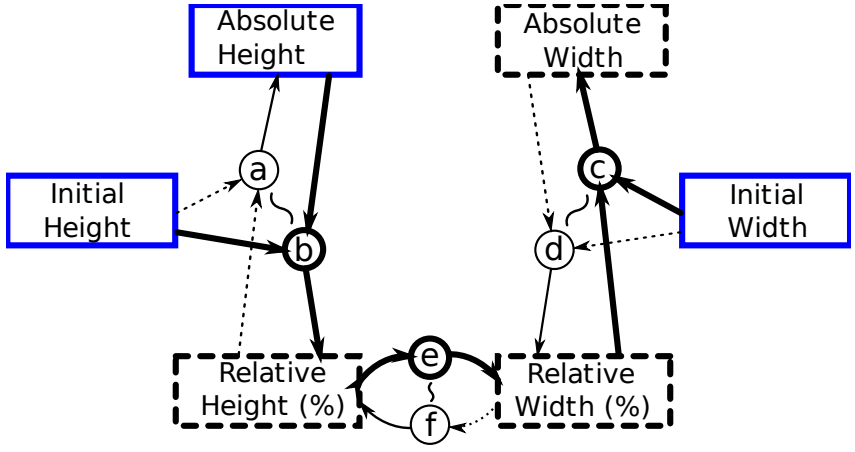

- Programmer only defines relations and their methods, not which method to execute and when $\Rightarrow$ often multiple solutions
  - Need a way to order them

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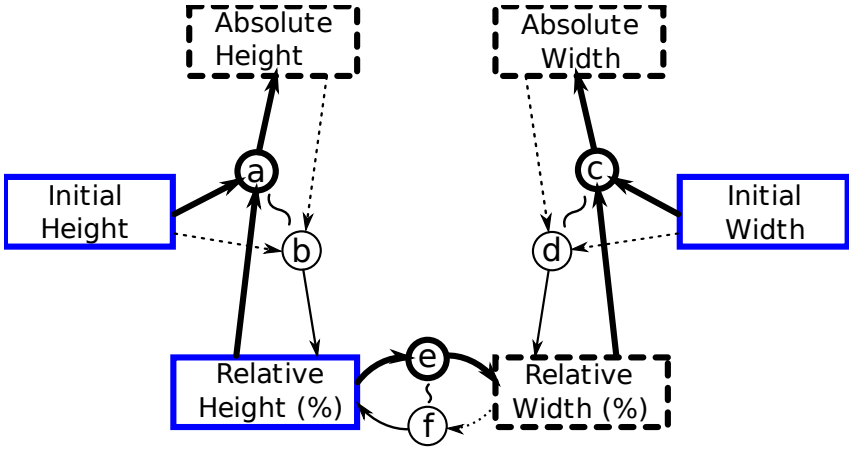
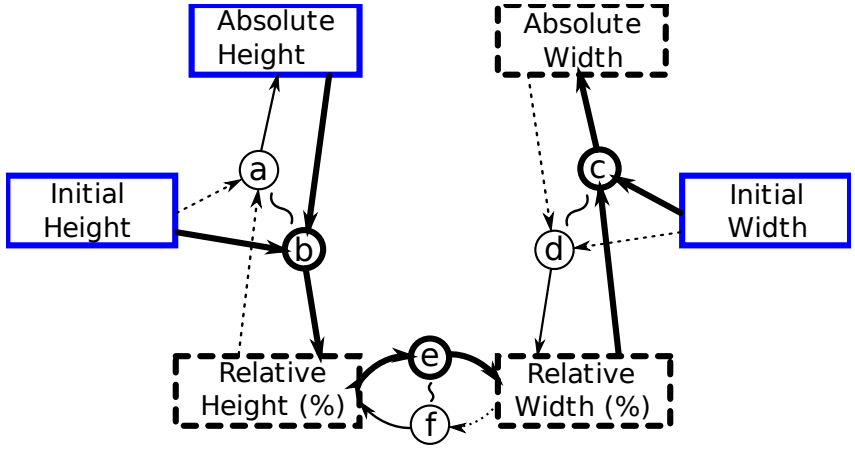
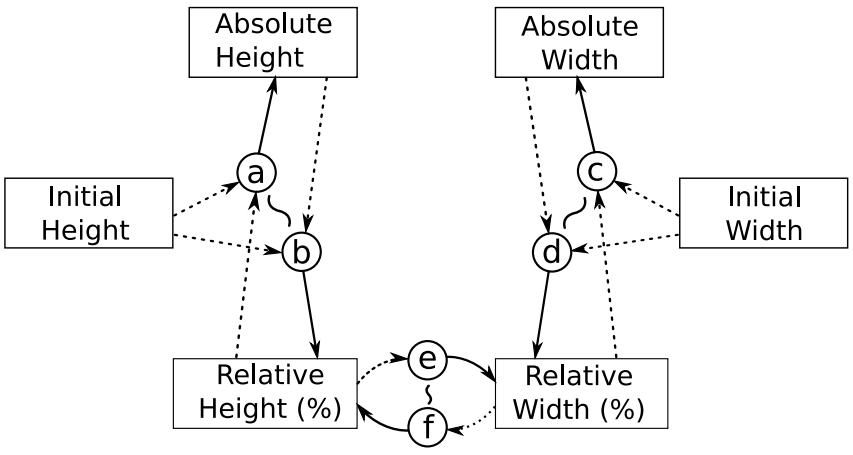




- Programmer only defines relations and their methods, not which method to execute and when $\Rightarrow$ often multiple solutions
  - Need a way to order them
- In general, want to prefer methods that change older values

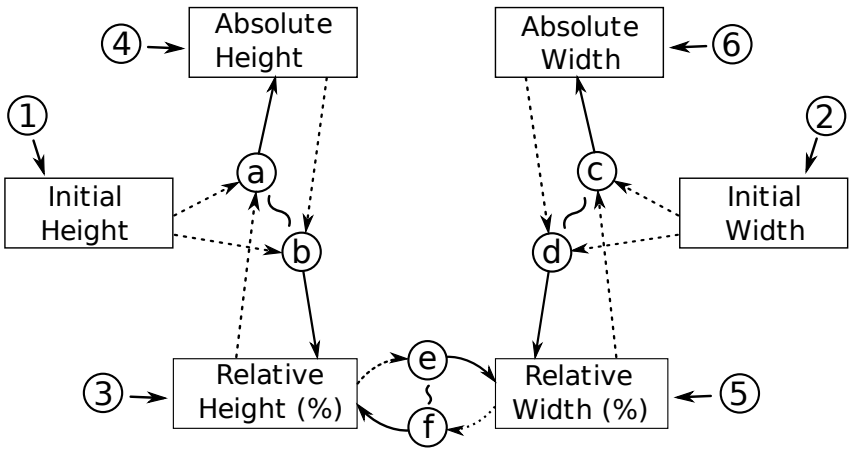
Picking the “right” solution



Initial Height	1
Initial Width	2
Relative Height	3
Absolute Height	4
Relative Width	5
Absolute Width	6

- Programmer only defines relations and their methods, not which method to execute and when $\Rightarrow$ often multiple solutions
  - Need a way to order them
- In general, want to prefer methods that change older values
- Priorities

Picking the “right” solution



Initial Height	1
Initial Width	2
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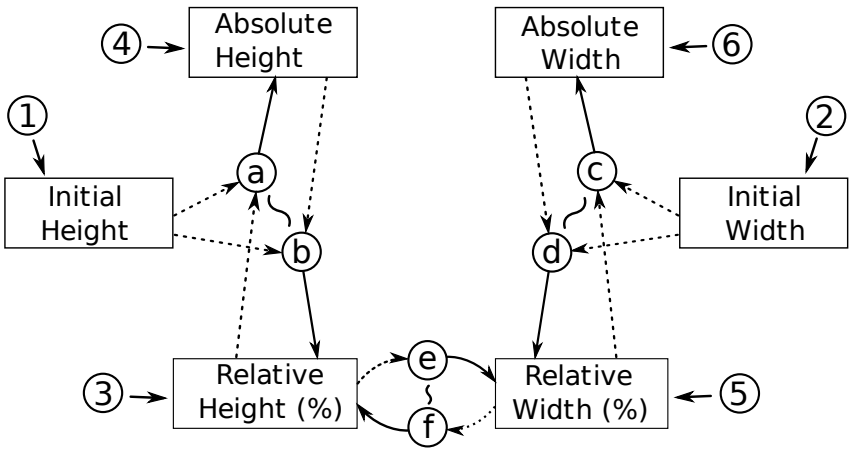
- Programmer only defines relations and their methods, not which method to execute and when $\Rightarrow$ often multiple solutions
  - Need a way to order them
- In general, want to prefer methods that change older values
- Priorities = Hierarchical Stay Constraints

Picking the “right” solution



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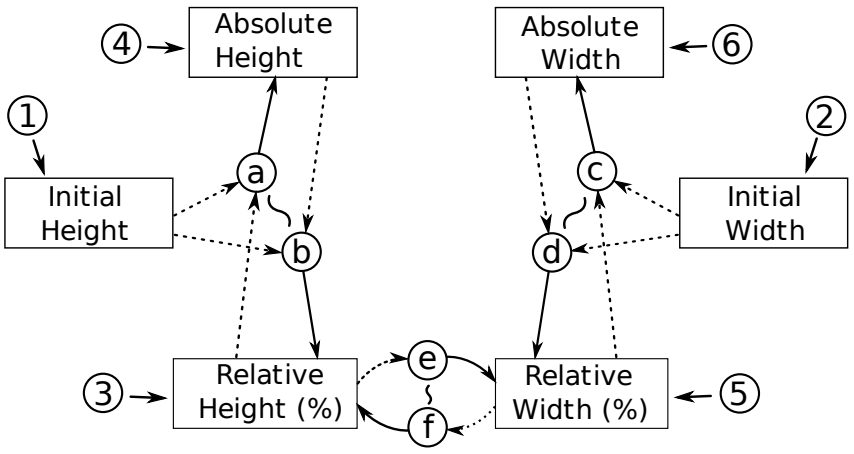
  - Stay constraint = does nothing, so its variable *stays* the same

Picking the “right” solution



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  - Need a way to order them
- In general, want to prefer methods that change older values
- Priorities = Hierarchical Stay Constraints
  - Stay constraint = does nothing, so its variable *stays* the same
  - Hierarchy = groups of constraints with certain strength

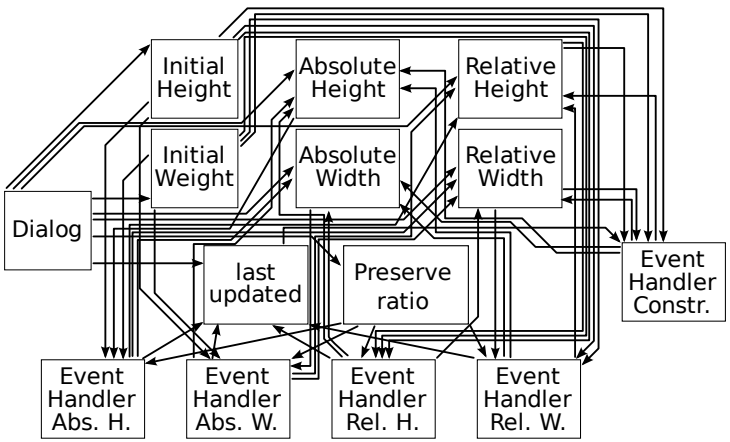
Explicit Algorithm for Command Parameter Synthesis

- Each UI element has a variable in a constraint system
- Event handling code becomes auto-generated boilerplate
  - Value modification generates a request to the constraint system to modify one variable and its priority, and solve
  - At all times, the UI element shows the value of the variable in the constraint system

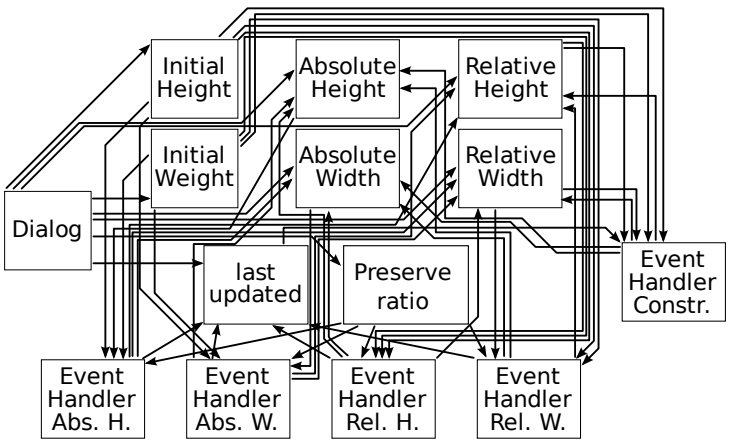
Outline

Incidental Data Structure $\longrightarrow$ Explicit Model

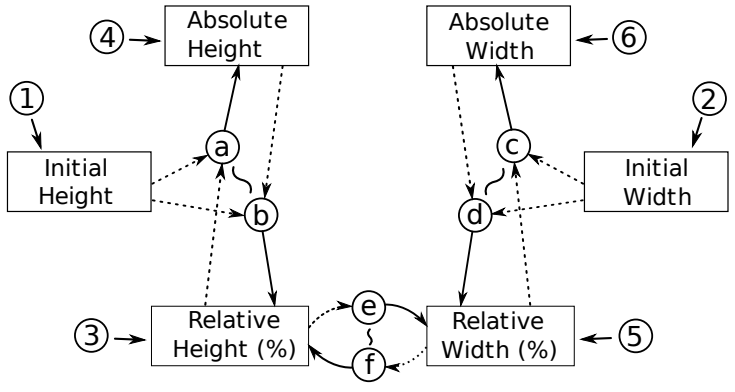
Incidental Data Structure $\longrightarrow$ Explicit Model



Incidental Data Structure $\longrightarrow$ Explicit Model



$\Longrightarrow$



Code of Incidental Algorithm → Model Declaration

```
def ChangeCurrentHeightPx(self, event):
  self.LastUpdated = "Height"
  constrained = self.Controls["Constrain"].GetValue()
  # no matter what the percent & current stay bound together
  # get current height, and compute relative height and place new rel. ht
  height = float(self.Controls["AbsolutePx"]["Height"].GetValue())
  pct = height / self.InitialSize[self.Height]
  self.Controls["Relative%"]["Height"].SetValue(str(pct*100))

  if constrained: # update width & width%
    self.Controls["Relative%"]["Width"].SetValue(str(pct*100))
    width = pct * self.InitialSize[self.Width]
    self.Controls["AbsolutePx"]["Width"].SetValue(str(round(width)))

def ChangeCurrentWidthPx(self, event):
  self.LastUpdated = "Width"
  constrained = self.Controls["Constrain"].GetValue()
  # no matter what the percent & current stay bound together
  # get current width, and compute relative width and place new rel. wd
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  if constrained: # update height & height%
    self.Controls["Relative%"]["Height"].SetValue(str(pct*100))
    height = pct * self.InitialSize[self.Height]
    self.Controls["AbsolutePx"]["Height"].SetValue(str(round(height)))

def ChangeCurrentHeightPct(self, event):
  self.LastUpdated = "Height"
  constrained = self.Controls["Constrain"].GetValue()
  # no matter what the percent & current stay bound together
  # get current rel. ht, and compute absolute height and place new abs. ht
  height = float(self.Controls["Relative%"]["Height"].GetValue())
  cur = height * self.InitialSize[self.Height] / 100
  self.Controls["AbsolutePx"]["Height"].SetValue(str(round(cur)))

  if constrained: # update width & width%
    self.Controls["Relative%"]["Width"].SetValue(str(height))
    width = height * self.InitialSize[self.Width] / 100
    self.Controls["AbsolutePx"]["Width"].SetValue(str(round(width)))

def ChangeCurrentWidthPct(self, event):
  self.LastUpdated = "Width"
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    self.Controls["Relative%"]["Height"].SetValue(str(width))
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def ChangeConstrainState(self, event):
  constrained = self.Controls["Constrain"].GetValue()
  # If the ratio is constrained, determine which dimension
  # was last updated and update the OTHER dimension.
  # For example: if Height was last updated, use Height as
  # Width's new percent, and update Width's absolute value
  if constrained:
    if self.LastUpdated == "Height": # update width px & %
      pct = float(self.Controls["Relative%"]["Height"].GetValue())
      self.Controls["Relative%"]["Width"].SetValue(str(pct))
      width = pct * self.InitialSize[self.Width] / 100
      self.Controls["AbsolutePx"]["Width"].SetValue(str(round(width)))
    else: # update width px & %
      pct = float(self.Controls["Relative%"]["Width"].GetValue())
      self.Controls["Relative%"]["Height"].SetValue(str(pct))
      height = pct * self.InitialSize[self.Height] / 100
      self.Controls["AbsolutePx"]["Height"].SetValue(str(round(height)))
```

Code of Incidental Algorithm ⟶ Model Declaration

```
def ChangeCurrentHeightPx(self, event):
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  constrained = self.Controls["Constrain"].GetValue()
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      height = pct * self.InitialSize[self.Height] / 100
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```

⟹

```
sheet image_resize {
  input:
    initial_width  : 5 * 300;
    initial_height : 7 * 300;
  interface:
    preserve_ratio : true;
    absolute_width  : initial_width;
    absolute_height : initial_height;
    relative_width; relative_height;
  logic:
    relate {
      absolute_height <== relative_height * initial_height / 100;
      relative_height <== absolute_height * 100 / initial_height;
    }
    relate {
      absolute_width <== relative_width * initial_width / 100;
      relative_width <== absolute_width * 100 / initial_width;
    }
    when (preserve_ratio) relate {
      relative_width <== relative_height;
      relative_height <== relative_width;
    }
}
```

Declarative Specification of Command Parameter Synthesis

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sheet image_resize {
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    }
    when (preserve_ratio) relate {
      relative_width <== relative_height;
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}
```

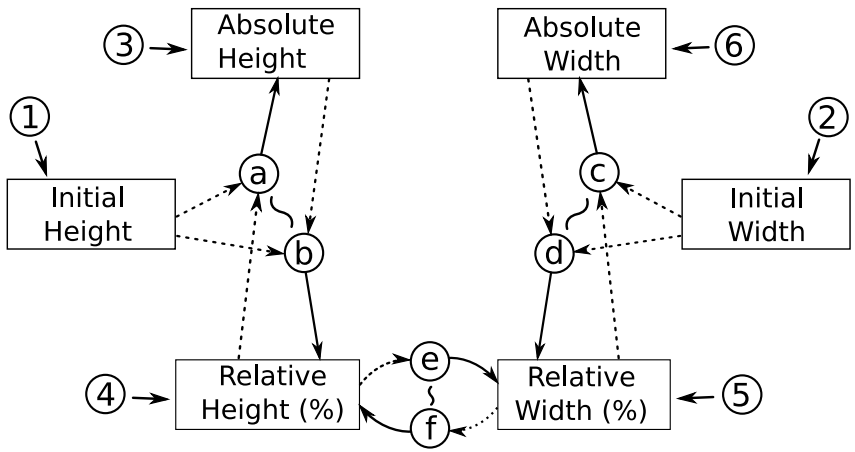

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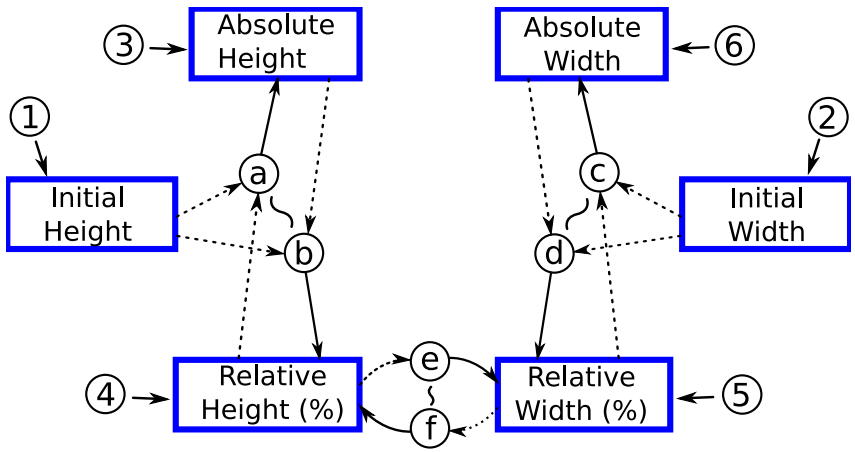
}
```



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    preserve_ratio : true;
    absolute_width  : initial_width;
    absolute_height : initial_height;
    relative_width; relative_height;
  logic:
    relate {
      absolute_height <== relative_height * initial_height / 100; // a
      relative_height <== absolute_height * 100 / initial_height; // b
    }
    relate {
      absolute_width <== relative_width * initial_width / 100; // c
      relative_width <== absolute_width * 100 / initial_width; // d
    }
    when (preserve_ratio) relate {
      relative_width <== relative_height; // e
      relative_height <== relative_width; // f
    }
}
```
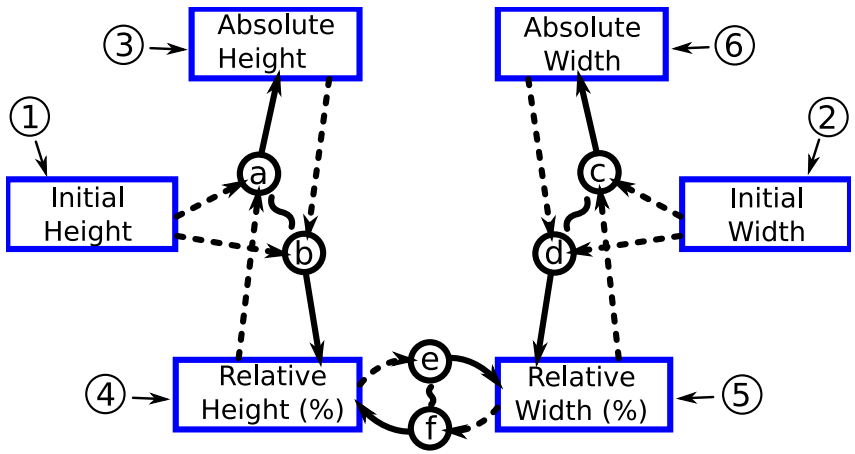
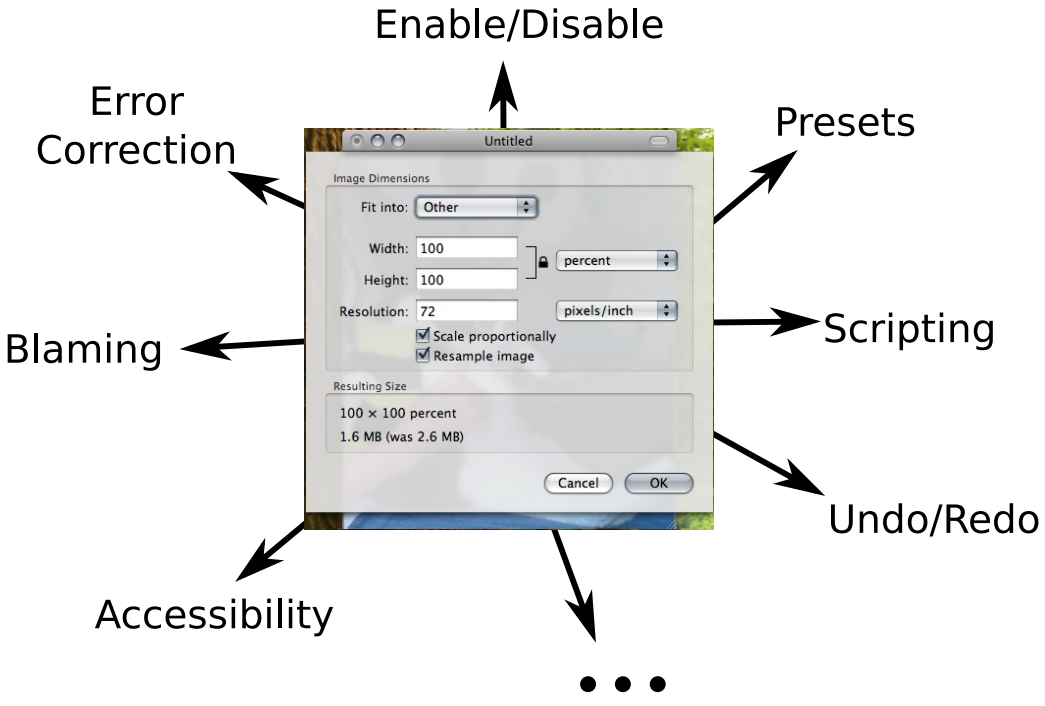



Algorithms for User Interfaces

- Before, every new feature required more spaghetti (incidental) code, specific to each dialog
- Now, each new feature can be defined as a reusable algorithm in a library



Scripting

- A script is a recorded sequence of commands
  - e.g. remove red-eye, skin blemishes, extra weight
- What do we record from our model as part of the script?
- Remember that probably not every value is useful
  - Some are provided by the document
  - Some are provided by the user
- Only want to capture what the user intended

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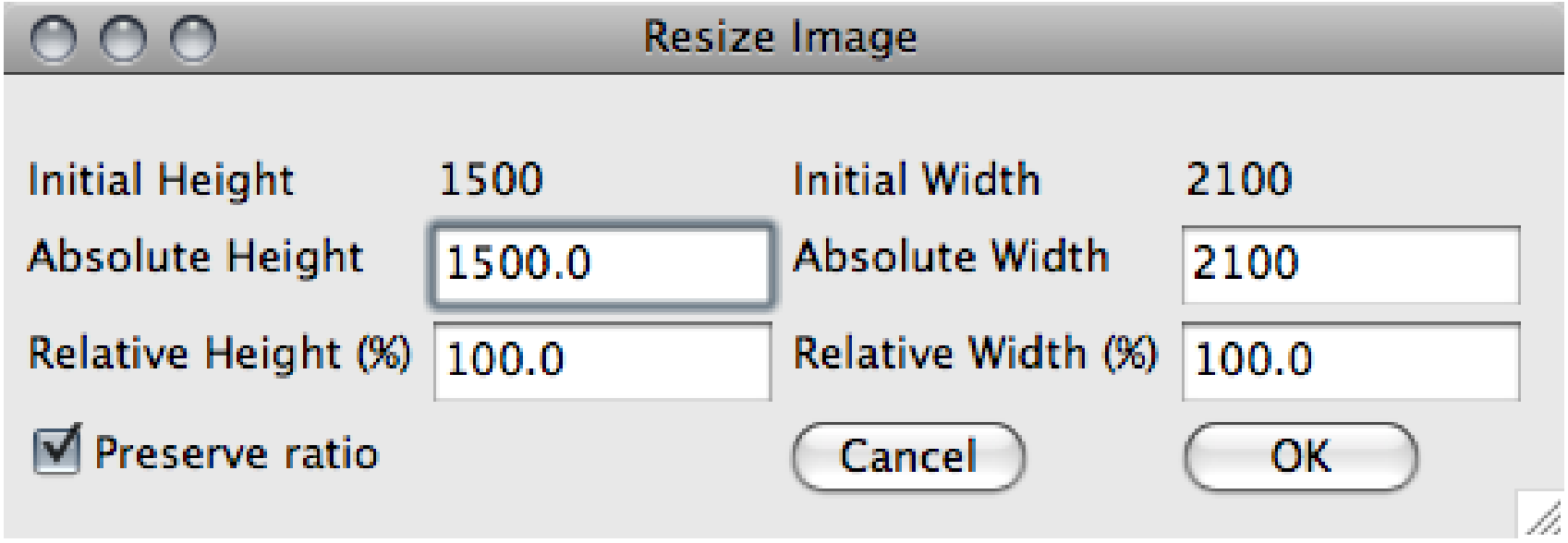
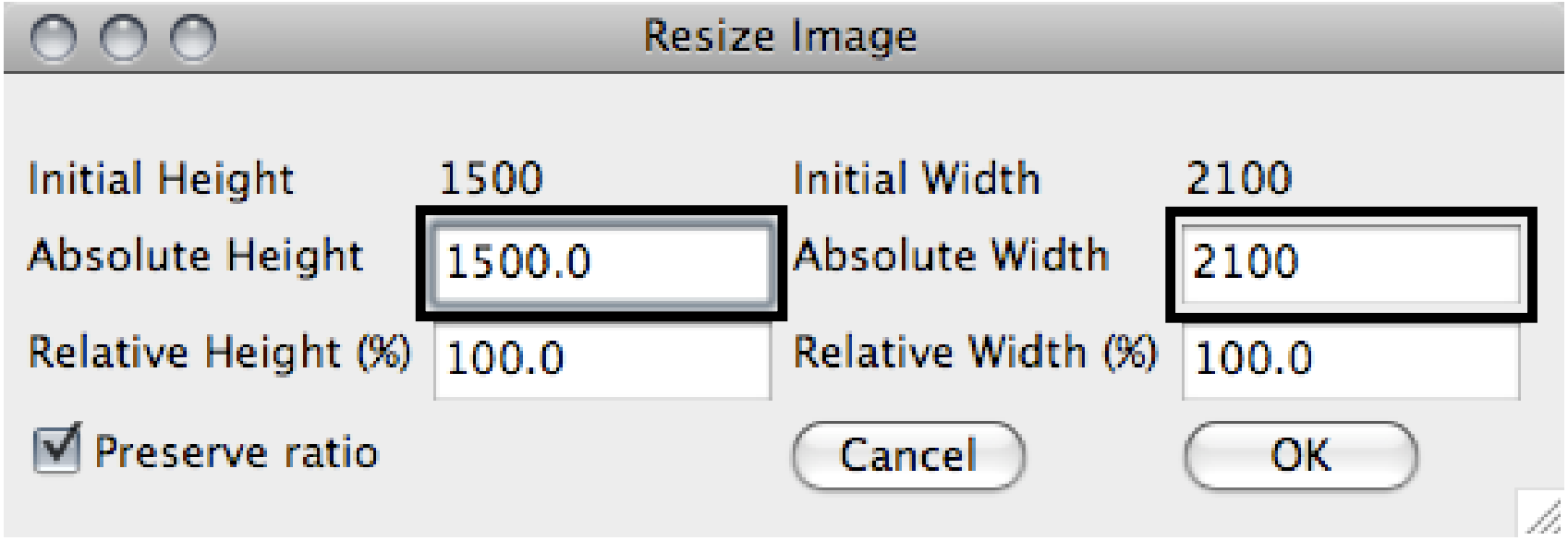
Capturing the User's Intent



- Command looks at Absolute Height, Absolute Width,
- but what we wanted to change is Relative Height

Capturing the User's Intent



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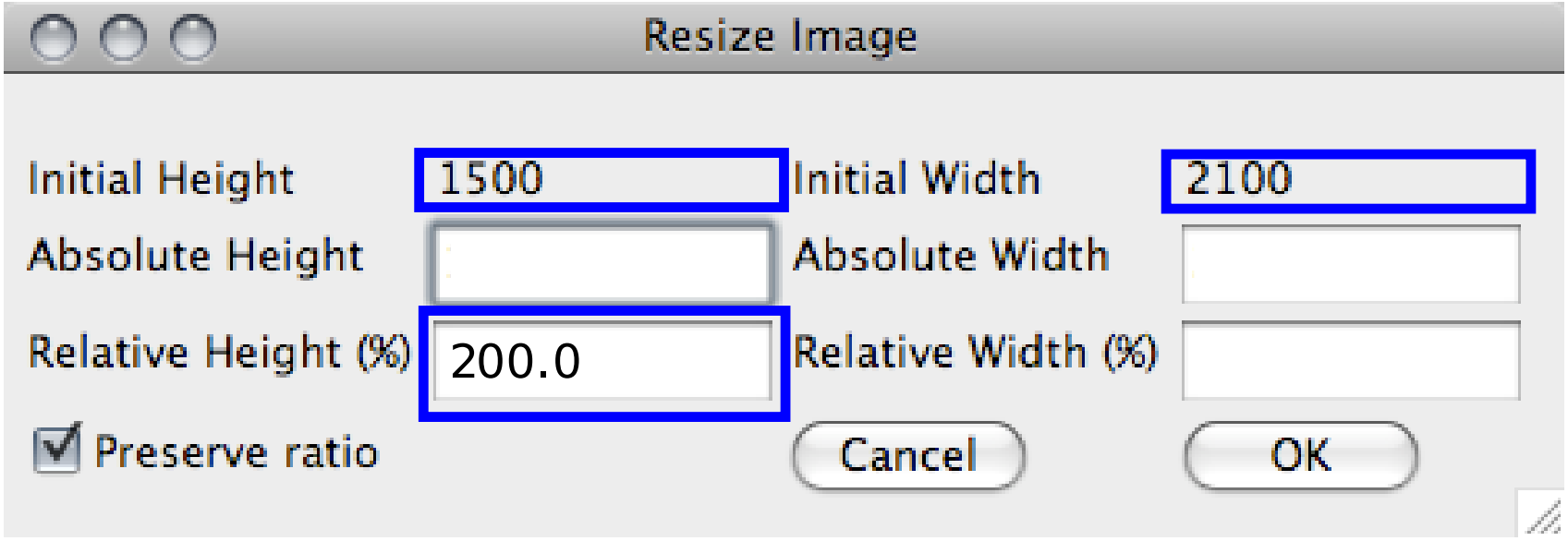
Capturing the User's Intent



- Command looks at Absolute Height, Absolute Width,
- but what we wanted to change is Relative Height

Outline

Experiences

- Early experience deploying our approach for command parameter synthesis at Adobe
  - Code reductions of a factor of 8 to 10
  - Fewer defects
  - Consistency among user interfaces

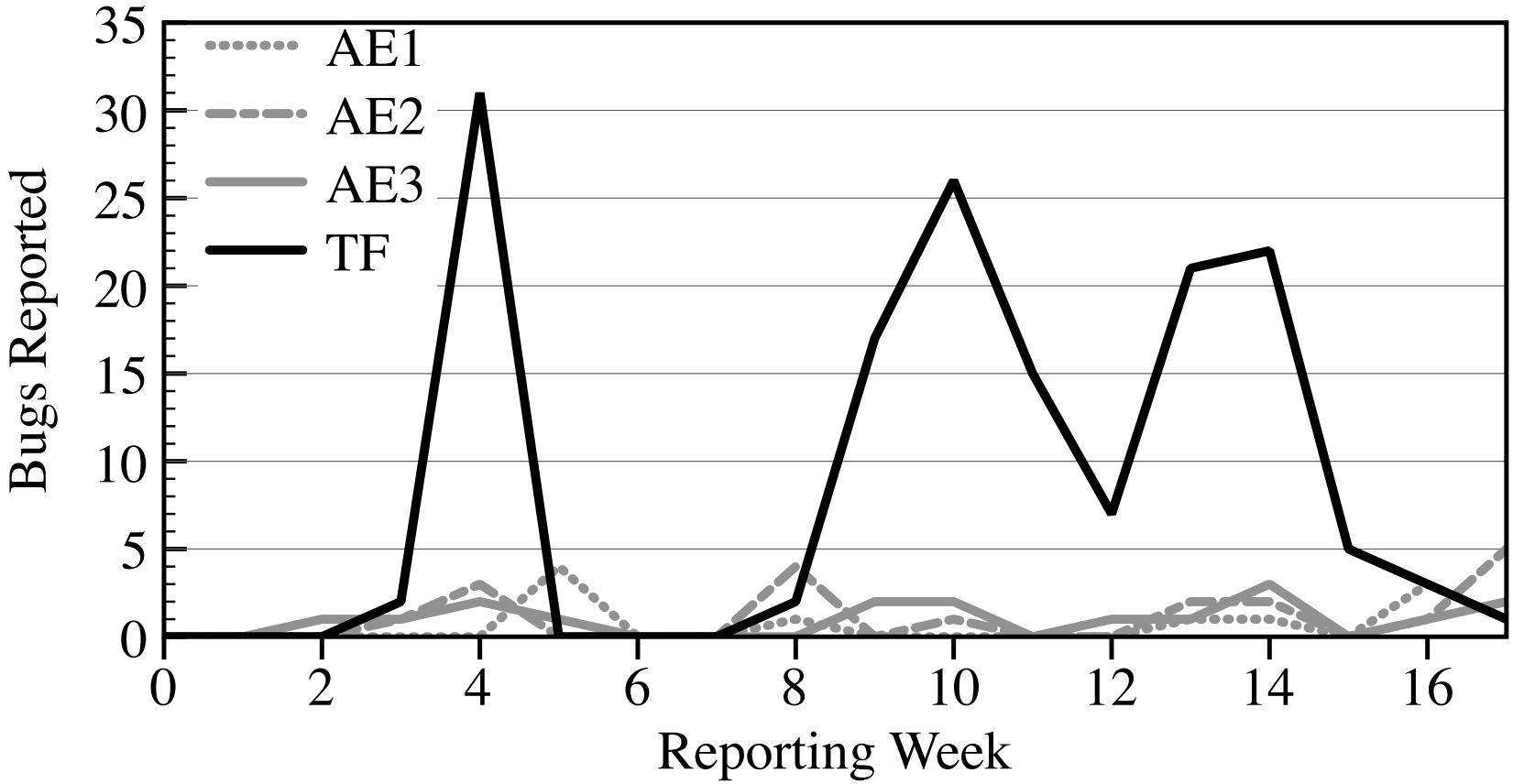
Experiment

- Rewriting user interface code for a major desktop application
- Four teams of roughly three engineers each,
- each tasked with rewriting a large number of dialogs and palettes
- Three teams (AE1–AE3) used the declarative approach, fourth team (TF) a modern vendor-supplied object-oriented UI framework

Results: Productivity

- AE1–AE3 teams combined completed roughly 75 dialogs and palettes, with 50 more underway
- TF team completed fewer than 10 altogether

Results: Defect Count



Future Directions

- Opportunities for user interfaces using property models
  - Recently worked on algorithms for enabling/disabling
  - Presets and defaults will follow
  - Perfecting the model for command parameter synthesis
- Incidental structures present in many areas of software
  - Want to know how the approach generalizes
  - Currently developing ideas about applying the declarative approach/constraint systems to other kinds of document modeling