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?
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%
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Reuse is a proven and successful route to improve quality of software, and increase programmer productivity

- Vast 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
  ⇒ 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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Given a sorted array $A[0] \leq A[1] \leq \ldots \leq A[n-1]$, 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.
Software is forever doomed!

```c
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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Command Parameter Synthesis

Property Models as Multi-way Dataflow Constraint Systems

What was achieved

Experience and Conclusions
Understanding UIs: *Command Parameter Synthesis*

- Dialogs serve to assist the user in selecting values for parameters to some command.
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- Command interested in only a few values
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- Dialog may provide more values than necessary for assistance.
Understanding UIs: *Command Parameter Synthesis*

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![Resize Image dialog](image)

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  - Dialog may provide more values than necessary for assistance.

- After the user edits a value,
  - The dialog is inconsistent.
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- Then it tries to restore consistency
Understanding UIs: *Command Parameter Synthesis*

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![Image of Resize Image dialog with initial settings]

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Understanding UIs: *Command Parameter Synthesis*

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![Image of Resize Image dialog box with initial values 1500, 3000, and 200.0 for Height, Width, and Relative Height, respectively.]

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Experience and Conclusions
Core of the Model: Multi-way Dataflow Constraint System

Variables ...
tied together by constraints ...

Height

Absolute = Height Initial \cdot (Height Relative 100)

each of which can be satisfied by any of a number of methods

a: absolute_height = initial_height \times relative_height / 100;

b: relative_height = (absolute_height / initial_height) \times 100;
Core of the Model: Multi-way Dataflow Constraint System

- **Absolute Height**
- **Absolute Width**
- **Initial Height**
- **Initial Width**
- **Relative Height (%)**
- **Relative Width (%)**

Variables ...

- \[ \text{Absolute Height} = \text{Initial Height} \times \left( \frac{\text{Relative Height}}{100} \right) \]
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Core of the Model: Multi-way Dataflow Constraint System

- Variables ...
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Height Absolute = Height Initial · (Height Relative / 100)
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```
a: absolute_height = initial_height * relative_height / 100;
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Core of the Model: Multi-way Dataflow Constraint System

- Variables ...
- tied together by constraints ...
  - \( \text{Height}_{\text{Absolute}} = \text{Height}_{\text{Initial}} \cdot \left( \frac{\text{Height}_{\text{Relative}}}{100} \right) \)
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Multi-way Dataflow Constraint Systems

- Restoring consistency is now just solving the system
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Solution defines a dataflow.
Multi-way Dataflow Constraint Systems

- Restoring consistency is now just solving the system
- 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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- e.g. a, e → c
Picking the “right” solution

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

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Height</td>
<td>1</td>
</tr>
<tr>
<td>Initial Width</td>
<td>2</td>
</tr>
<tr>
<td>Relative Height</td>
<td>3</td>
</tr>
<tr>
<td>Absolute Height</td>
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</tr>
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  - Stay constraint = does nothing, so its variable stays the same
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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

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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
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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

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;
  }
}
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    }
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Declarative Specification of Command Parameter Synthesis

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  interface:
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    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
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Outline

Motivation

Command Parameter Synthesis

Property Models as Multi-way Dataflow Constraint Systems

What was achieved

Experience and Conclusions
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

[Graph showing the number of bugs reported by AE1, AE2, AE3, and TF over different reporting weeks. The graph has a y-axis labeled 'Bugs Reported' ranging from 0 to 35, and an x-axis labeled 'Reporting Week' ranging from 0 to 16.]
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