Automatically Generating User Interfaces Adapted To Users’ Motor And Vision Capabilities

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and Daniel S. Weld

University of Washington
Computer Science & Engineering
Road Map

- Introduction

- Interface generation as optimization

- Modeling motor capabilities

- Adapting to motor capabilities

- Adapting to vision capabilities

- Adapting to motor and vision capabilities together

- Pilot User Study

- Lessons learned
Automatic Interface Generation

- Manually capture design knowledge as rules
- Automatically apply rules to generate new interfaces
Automatic Interface Generation

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- Automatically apply rules to generate new interfaces
- **Problems:**
Automatic Interface Generation

- Manually capture design knowledge as rules
- Automatically apply rules to generate new interfaces

**Problems:**
- New rule sets necessary for every device type, interaction style or even screen size
Automatic Interface Generation

• Manually capture design knowledge as rules
• Automatically apply rules to generate new interfaces

**Problems:**
• New rule sets necessary for every device type, interaction style or even screen size
• No good way to adapt to individual preferences or needs
Our Approach: User Interface Generation as Optimization

Driven by a “cost function”:

$\ldots$ and constraints

[Gajos and Weld, IUI’05]
Find the interface that minimizes $ without violating constraints

[Gajos and Weld, IUI’05]
Single Algorithm -- Many Devices
Single Algorithm -- Many Devices
Robustly Adapting to Different Screen Sizes
Flatratesex, für nur 14,99 Euro kannst Du Dir einen monat lang über 200 Private Livecams anschauen, dazu noch unzählige Bilder und Videos, ohne 0190 ohne versteckte Kosten. Der absolute Hammer!

http://www.sexania.com

Location: (847.0, 240.0)

Name: Dan
Office: 588
Highly Personalizable!

$\left( \right) = ??$
Adapting to Preferences

$\$(\text{Stereo}) = \text{Preference estimate}$

[Gajos and Weld, UIST’05]
Adapting to Motor Capabilities

\[ \$ (\quad) = \text{Estimated task completion time} \]
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## Participants

<table>
<thead>
<tr>
<th>Motor-impaired</th>
<th>Device used</th>
<th>Impairment</th>
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Elicit a Person’s Motor Abilities Model

Pointing

Dragging
Predicting Movement Time

Actual Data
Predicting Movement Time

Actual Data

Fitts’ Law Prediction
Predicting Movement Time

Actual Data

Fitts’ Law Prediction

Distance to target

Movement time (ms)

size-10

size-15

size-25

size-40

size-60

Distance to target

Movement time (ms)

size 15

size 25

Distance to target

0 100 200 300 400 500 600

0 2000 4000 6000 8000 10000 12000

0 100 200 300 400 500 600

0 100 200 300 400 500 600

Fitts’ Law Prediction
Custom Motor Capability Models

- Supple++
- Automatically selects the best set of features for a custom regression model for each participant from: ID, 1, log(D), log(W), D, 1/W, W
- Trains the models
Predicting Movement Time

Actual Data

Fitts’ Law Prediction

![Graph comparing actual data and Fitts’ Law prediction]
Predicting Movement Time

Actual Data | Fitts’ Law Prediction | Custom Model
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UI Building Blocks

• Widgets
UI Building Blocks

- Widgets
- Layout
UI Building Blocks

• Widgets
• Layout
• Structure (divide into windows, pop-ups, tabs)
UI Building Blocks

- Widgets
- Layout
- Structure (divide into windows, pop-ups, tabs)
- Size of interactors
UI Building Blocks

• Widgets
• Layout
• Structure (divide into windows, pop-ups, tabs)
• Size of interactors
Optimization as Search
Optimization as Search
Optimization as Search
Optimization as Search
Optimization as Search

Light Level: <int, [0,10]>
Power: bool
Light: {  ,  }
Light Bank: {  ,  ,  }
Light ... Light ...
A/V: {  ,  ,  }
A/V:
Input: <string, {data1, data2, video}>
Screen: bool
Power: bool
Screen:
Vent: <int, [0,3]>
Vent:
Projector:
Classroom:
Classroom:
Right Center Left
Optimization as Search

Light Level: \(\langle \text{int}, [0,10]\rangle\)
Power: \(\langle \text{bool}\rangle\)
Light: \(\langle \text{bool}\rangle\)
Light Bank: \(\langle \text{bool}\rangle\)

Light Bank:
Light Level: \(\langle \text{int}, [0,10]\rangle\)
Power: \(\langle \text{bool}\rangle\)

Light ...

Light ...

A/V:
Power: \(\langle \text{bool}\rangle\)
Input: \(\langle \text{string}, \{\text{data1}, \text{data2}, \text{video}\}\rangle\)

Projector:
Power: \(\langle \text{bool}\rangle\)

Screen:

Classroom:
Vent: \(\langle \text{int}, [0,3]\rangle\)
Optimization as Search

Light Level: <int, [0,10]>
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Light: {  ,  }
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Screen: bool
Power: bool
Projector: {  ,  ,  }
A/V: {  ,  ,  }
Classroom: {  ,  ,  }
Optimization as Search
Optimization as Search

- **Light Level**: \( T: \langle \text{int}, [0,10] \rangle \)
- **Power**: \( T: \text{bool} \)
- **Light**: \( T: \{, \} \)
- **Light Bank**: \( T: \{, , \} \)
- **Light ... Light ...**: \( T: \{, , \} \)
- **A/V**: \( T: \{, \} \)
- **Projector**: \( T: \{, \} \)
- **Classroom**: \( T: \{, \} \)
- **Input**: \( T: \langle \text{string, \{data1, data2, video\}} \rangle \)
- **Vent**: \( T: \langle \text{int, [0,3]} \rangle \)
Optimization as Search

Enumerate all the options: ~370 years
Optimization as Search

Enumerate all the options: \(~370\) years

Supple: \(~2\) seconds
Optimization as Search
Optimization as Search

Light Level:
!: <int, [0,10]>

Power:
!: bool

Light:
!: {  ,  }

Light Bank:
!: {  ,  ,  }

A/V:
!: {  ,  }

Projector:
!: {  ,  }

Classroom:
!: {  ,  ,  }

Light...

Light...

A/V...

Projector...

Classroom...

Input:
!: <string, {data1, data2, video}>

Vent:
!: <int, [0,3]>

Screen:
!: bool

Power:
!: bool

Screen:
!: bool
Optimization as Search
Optimization as Search
Optimization as Search

Light Level: \(<\text{int}, [0, 10]\>\)
Power: \(!\) bool
Light: \(!\) \{ , \}
Light Bank: \(!\) \{ , , \}
A/V: \(!\) \{ , \}
Projector: \(!\) \{ , \}
Classroom: \(!\) \{ , \}
Input: \(!\) \(<\text{string}, \{\text{data1, data2, video}\}>\)
Vent: \(!\) \(<\text{int}, [0, 3]\>\)

Light Level: \(<\text{int}, [0, 10]\>\)
Power: \(!\) bool
Screen: \(!\) bool
Screen: \(!\) bool
Input: \(!\) \(<\text{string}, \{\text{data1, data2, video}\}>\)
Optimization as Search

Light Level: \( \langle \text{int}, [0, 10] \rangle \)

Power: \( \langle \text{bool} \rangle \)

Light: \( \langle \text{bool} \rangle \)

Light Bank: \( \langle \text{bool} \rangle \)

A/V: \( \langle \text{bool} \rangle \)

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Input: \( \langle \text{string, \{data1, data2, video\}} \rangle \)

Vent: \( \langle \text{int, [0, 3]} \rangle \)
Optimization as Search

Use Supple to optimize for motor abilities:

hours or days

MT( ) = ?

MT( ) = ?
Supple++

- Novel optimization-based algorithm computes a lower bound on movement time through a layout even before all the widgets are chosen.
Supple++

• Novel optimization-based algorithm computes a lower bound on movement time through a layout even before all the widgets are chosen

Use Supple++ to optimize for motor abilities: seconds or minutes
Results

Font Formatting

<table>
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<tr>
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Underline style: (none)

Effects

- Strikethrough: [ ]
- Double Strikethrough: [ ]
- Superscript: [ ]
- Subscript: [ ]
- Shadow: [ ]
- Outline: [ ]
- Emboss: [ ]
- Engrave: [ ]
- Small Caps: [ ]
- All Caps: [ ]
- Hidden: [ ]

Preview

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Underline style:
- (none)
- Single solid
- Double solid
- Dotted
- Dashed
- Wavy

Effects:
- Strikethrough
- Double Strikethrough
- Superscript
- Subscript
- Shadow
- Outline
- Emboss
- Engrave
- Small Caps
- All Caps
- Hidden

Preview:

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### Underline style
- (none)
- Single solid
- Double solid
- Dotted
- Dashed
- Wavy

### Effects
- Strikethrough
- Double Strikethrough
- Superscript
- Subscript
- Shadow
- Outline
- Emboss
- Small Caps
- All Caps
- Hidden
- Engrave

### Character Spacing
#### Scale
- 200%
- 150%
- 100%
- 90%
- 80%

#### Spacing
- Normal
- Expanded
- Condensed

#### Position
- Normal
- Raised
- Lowered

### Text Effects
#### Animations
- (none)
- Blinking Background
- Las Vegas Lights
- Marching Black Ants
- Marching Red Ants
- Shimmer
- Sparkle Text
Impaired dexterity

Low strength

Able-bodied
Popular OS Solution: “Large Fonts”
Popular OS Solution: 
“Large Fonts”
Supple++ Solution
Supple++ Solution
Supple++ Solution
Our Approach

- User selects desired minimum size for all visual cues
- User interface generation constrained to meet desired visual cue size
- Fast “resize and reflow”
Our Approach

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Our Approach
User selects desired minimum size for all visual cues

User interface generation constrained to meet desired visual cue size

Our Approach

Content arranged in tabs
Road Map

✓ Introduction
✓ Interface generation as optimization
✓ Modeling motor capabilities
✓ Adapting to motor capabilities
✓ Adapting to vision capabilities
Adapting to motor and vision capabilities together
☐ Pilot User Study
☐ Lessons learned
for “typical” users
for “typical” users

impaired dexterity

modified cost function
for “typical” users

modified constraints

modified cost function

impaired dexterity

low vision
for “typical” users

modified constraints

modified cost function

impaired dexterity

low vision

low vision & impaired dexterity
Results of a Pilot Study
Results of a Pilot Study

- Enabled interaction for one participant
Results of a Pilot Study

• Enabled interaction for one participant

• For others, personalized interfaces improved performance by 20%
Results of a Pilot Study

- Enabled interaction for one participant
- For others, personalized interfaces improved performance by 20%

But
Results of a Pilot Study

- Enabled interaction for one participant
- For others, personalized interfaces improved performance by 20%

But

- Large variance
Results of a Pilot Study

- Enabled interaction for one participant
- For others, personalized interfaces improved performance by 20%

**But**

- Large variance
- Better but not best
Problems uncovered

- List selection ≠ drag + point
Problems uncovered

- List selection ≠ drag + point

\[ R^2 = .09 \]
Modeling List Selection Times

direct model: $R^2 = .64$
Since this paper...
Since this paper...

• In the new study, we found that participants with motor impairments were consistently **faster** (by 26%) using interfaces generated by Supple++

• made 73% **fewer errors**

• strongly **preferred** Supple++ interfaces to manufacturers’ baselines
Summary of Contributions
Summary of Contributions

• Supple++ for automatically generating user interfaces adapted to user’s motor and vision capabilities
Summary of Contributions

• **Supple++** for automatically generating user interfaces adapted to user’s motor and vision capabilities

• No expert necessary
Summary of Contributions

- **Supple++** for automatically generating user interfaces adapted to user’s motor and vision capabilities
- No expert necessary
- Custom regression models for individual motor capabilities
Summary of Contributions

• **Supple++** for automatically generating user interfaces adapted to user’s motor and vision capabilities

• No expert necessary

• Custom regression models for individual motor capabilities

• Novel optimization-based algorithm for efficient ability-based GUI generation
Limitations & Future Work
Limitations & Future Work

- Limitations of modeling
Limitations & Future Work

- Limitations of modeling
- Pointer-only interactions
Limitations & Future Work

- Limitations of modeling
- Pointer-only interactions
- Movement time as proxy for performance
Limitations & Future Work

- Limitations of modeling
- Pointer-only interactions
- Movement time as proxy for performance
- How to address other concerns?
Limitations & Future Work

• Limitations of modeling
• Pointer-only interactions
• Movement time as proxy for performance
• How to address other concerns?
• Design tools
More Information

- **SUPPLE:**
  http://supple.cs.washington.edu/
or Google: supple interfaces

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- **Daniel Weld:**
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