Transformer: A Database-Driven Approach to Generating Forms for Constrained Interaction

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Motivation

• Forms are a common interface for data-entry and querying
  • Ordering food
  • Making appointments
  • Applications
  • Doctor’s office

• Shift from paper to digital

• Smaller screens
Constrained Interaction

• Different devices have different ideal form layouts

• Desktops – Typing is fast

• Touch devices
  • Tablets: imprecision due to lack of physical keyboard
  • Smartphones: small screen

• Incomplete responses and errors, increase user input time
Prior Work

• Manually optimizing forms for every interface can be taxing on the form designer
  • Designers prefer aesthetics to efficiency (Sears, 1995)

• Adaptive form generation – customized to individual user’s ability

• Require interaction data which is not always available

• But every form feeds a database!
Transformer

- Every form field corresponds to a database column
- Leverage prior input data to estimate user effort
- Select form layout that minimizes user’s data entry effort

```
INSERT INTO applications
(lastname, height_feet, date_of_birth)
VALUES (...);
```

Database Cost Function

Original Form

- Data Types, Cardinality, Range
- Data Distribution

Distinct Cardinality of 7

Range of values used to decide widget and widget size

Redesigned Form

- Binary Field
- Data distribution dictates default value

Range of values used to decide widget and widget size
Given a form (and its database), and display dimensions of output device, find the ideal data entry widget for each form field.
Cost Model of Human Effort

• Adaptation of the GOMS Keystroke-level Model (KLM)

• Weighted Sum of 4 Interactions: Tapping, Scrolling, Sliding, Typing

\[ \text{no. of taps} \times w_{\text{tap}} + \text{slider range} \times w_{\text{slide}} + \text{no. of scrolls} \times w_{\text{scroll}} + \text{length of word} \times w_{\text{type}} \]
Leverage Database for Layout Optimizations and Constraints

- Schema based optimizations
  - Referential Integrity

- Datatype based constraints

- Cardinality based optimizations
  - Number of distinct items in a column
Schema Based Optimizations

• One-to-one relationship
  • only one needs to be entered, other can be inferred
    • e.g. Zip code implies City

• One-to-many relationship
  • Can be used to eliminate values of second attribute
    • e.g. Entering State constrains the Cities
Datatype and Cardinality
Constraints

- Range sliders and datepickers are only valid for numeric and date datatypes

- Segmented controller only used when all options fit on one line

- Checkboxes: binary fields grouped by foreign-key
# Database-Driven Cost Estimation

<table>
<thead>
<tr>
<th>Widget</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio</td>
<td>(\frac{\text{count}}{\text{display}} \times w_{\text{scroll}} + w_{\text{tap}})</td>
</tr>
<tr>
<td>Dropdown</td>
<td>(\frac{\text{count}}{\text{display}} \times w_{\text{scroll}} + 2 \times w_{\text{tap}})</td>
</tr>
<tr>
<td>Range slider</td>
<td>((\text{max} - \text{min}) \times w_{\text{slide}})</td>
</tr>
<tr>
<td>Segmented Controller</td>
<td>(w_{\text{tap}})</td>
</tr>
<tr>
<td>Text</td>
<td>(\text{avg length} \times w_{\text{type}})</td>
</tr>
</tbody>
</table>
Grouping Fields

- Pagination vs. Scrolling

- Cost of widget-field combination depends on available page height

- Bottom-up approach: Add each field to page that has minimum cost widget

[Images of questionnaires on whole page and other fields on page]

How do you prefer to study?

- In silence. I find noise distracting when I study.
- In quiet. Soft music or noises don't bother me.
- With noise. I can study almost anywhere.

Do you have a pet that will be living with you here in Boston? If so, what kind/s?

Do you study at home?

- Rarely
- Frequently
- Never
- Occasionally

How do you prefer to study?

- In silence. I find noise distracting when I study.
- In quiet. Soft music or noises don't bother me.
- With noise. I can study almost anywhere.
Algorithm

• For each attribute:
  • For each page:
    • Find minimum cost widget
  • Add attribute to page with minimum cost widget
Evaluation

- Form Completion Time
- Error Rate
- User Rating
## Dataset

- **8 Web forms**
- **Synthetically generated data (from database of names, countries, cities, etc.)**

<table>
<thead>
<tr>
<th>Form</th>
<th>Name</th>
<th>Text</th>
<th>Date</th>
<th>Dropdown</th>
<th>Buttons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Hilton Reservation</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>United Airlines</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>Library Search</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>37</td>
</tr>
<tr>
<td>D</td>
<td>Music Search</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Roommate Matcher</td>
<td>5</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>F</td>
<td>Maintenance Request</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>G</td>
<td>Passport Application</td>
<td>9</td>
<td>6</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>H</td>
<td>Room Reservation</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
Devices and Weights

• iPhone 5s – iOS 9.3.1

• 2 device size configurations
  • Smartphone screen size - 1136px by 640px
  • Simulated watch screen size - 300px by 300px - (no text input)

• Weights
  • Based on prior literature – details in paper
  • Validated with pilot study of 15 users
User Study Setup

• 3 versions of each form: Original, Manually Optimized and Automatically Optimized

• 30 users
  • 15 (7 male, median age 22) for smartphone
  • 15 (7 male, median age 22) for simulated watch

• Within-subject study per device configuration
  • $3 \times 8 = 24$ forms per user

• Order of forms randomized
User Study Procedure

• Pre-study questionnaire on phone usage
  • No significant difference in results based on frequency of phone usage or phone type

• Presented with printed information to be filled in to control for motor memory

• Rate usability on scale of 1-10 at end of each of form
• Upto 50% reduction in form completion time between the original and automated forms
• Most errors stemmed from text entry on phone
• On watch, redesigned forms had errors due to accidental selection due to large widget size
• Average Rating from 1-10 (10 indicated very usable)
• Results on simulated watch are comparable
Summary

• Different screen sizes require different form layouts

• Leverage database to model cost of human input

• Automatically generate form layout for given screen size

• Future Work
  • Semantically group fields
  • Incorporate aesthetics into cost model
Thank you!
Widgets

Segmented controller

Rangeslider

Text

Toggle

Radio button/Checkbox

Datepicker

Dropdown
User Rating - Watch
Weights

- Based on prior literature
- Validated with pilot study of 15 users

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_{slide}$</td>
<td>.5</td>
</tr>
<tr>
<td>$w_{tap}$</td>
<td>1</td>
</tr>
<tr>
<td>$w_{scroll}$</td>
<td>3</td>
</tr>
<tr>
<td>$w_{type}$</td>
<td>7</td>
</tr>
</tbody>
</table>
## Cost Estimation per Widget

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- Sliders can only be used for numerical fields
- Toggle and checkboxes are only compatible with binary fields
Cost Validation

![Graph showing correlation between cost reduction and time reduction with two linear regression lines: one with $R^2 = 0.6$ and another with $R^2 = 0.3$. The graph includes data points labeled A to H and represents Transformer and KLM models.](image-url)
Smartphone Completion Time By Phone Type

- iPhone (9)
- Galaxy (4)
- LG (1)
- Android (1)

Automated Form Completion Time (secs)

Original Form Completion Time (secs)
Smartphone Completion Time By Phone Type

Number of Hours Spent on Phone (sample size)

Automated Form Completion Time (secs)

Original Form Completion Time (secs)

3-4 (7)

1-2 (6)

4+ (2)

500 520 540 560 580 600 620 640 660 680 700

300 350 400 450 500 520 540 560 580 600 620 640 660 680 700
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</tr>
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<td>Range slider</td>
<td>$(\text{max} - \text{min}) \times w_{\text{slide}}$</td>
</tr>
<tr>
<td>Datepicker</td>
<td>$(\text{count}<em>{\text{month}} + \text{count}</em>{\text{year}}) \times w_{\text{tap}} + w_{\text{tap}}$</td>
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