User Interface Optimization using Genetic Programming with an Application to Landing Pages

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The 9th ACM SIGCHI Symposium on Engineering Interactive Computing Systems

June 26-29, 2017 - Lisbon, Portugal

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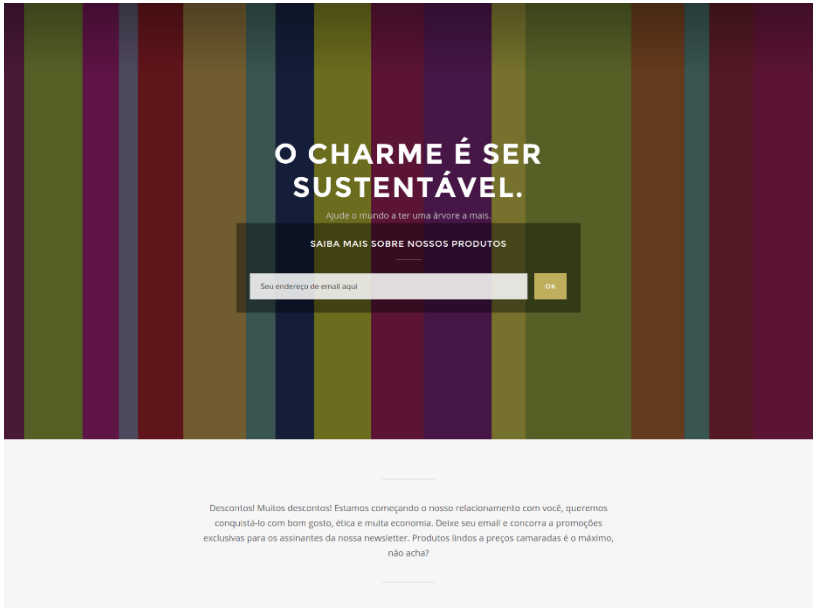
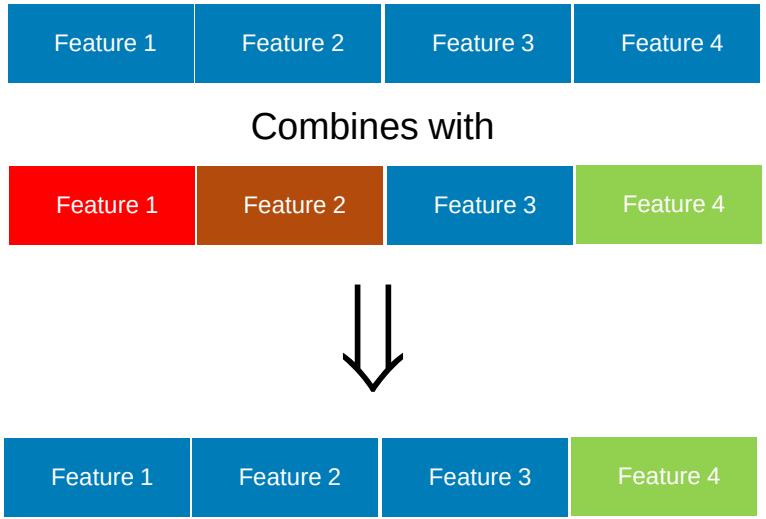
The Problem

- Given some basic **UI elements**, **generate** UIs based on a **specification** that are **optimal** w.r.t. some **performance metric**.
- Elements: texts, images, colors, components, etc.
- Working example: landing pages
  - Users are directed to a special page
  - Users are motivated to take some action (e.g., subscribe to a newsletter)
  - Acquiring users is **costly**, therefore we want to **maximize conversion rates**
  - $conversion\ rate = \frac{actions\ taken}{total\ users}$



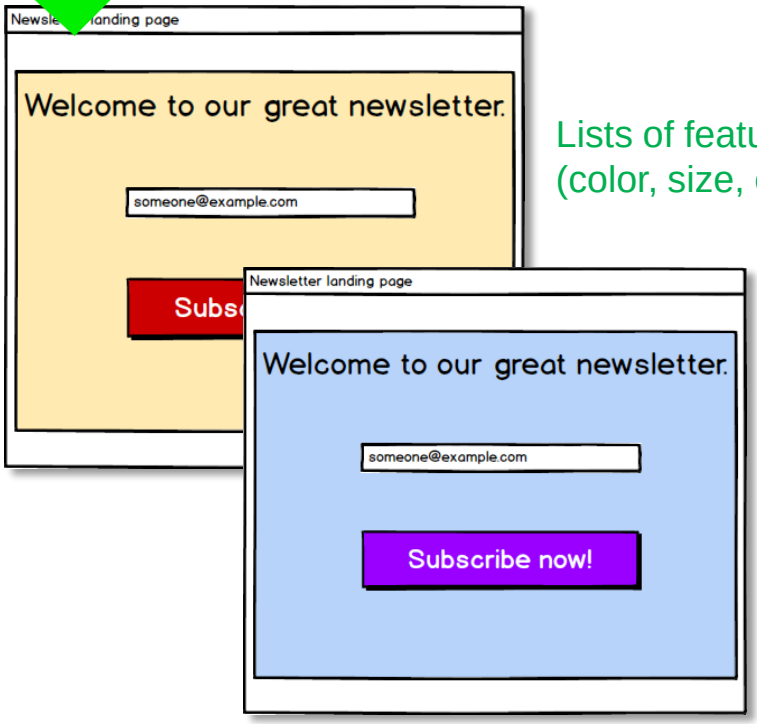
Existing Solutions using Genetic Algorithms

- UIs are **individuals** in a **population**
- Each UI's **genome** is a sequence of features
  - Color of components
  - Images
  - Texts
- By recombining and mutating features, new UIs **evolve**
- Users can **select** their prefered UIs
- Main problem: not general, cannot express arbitrary UIs



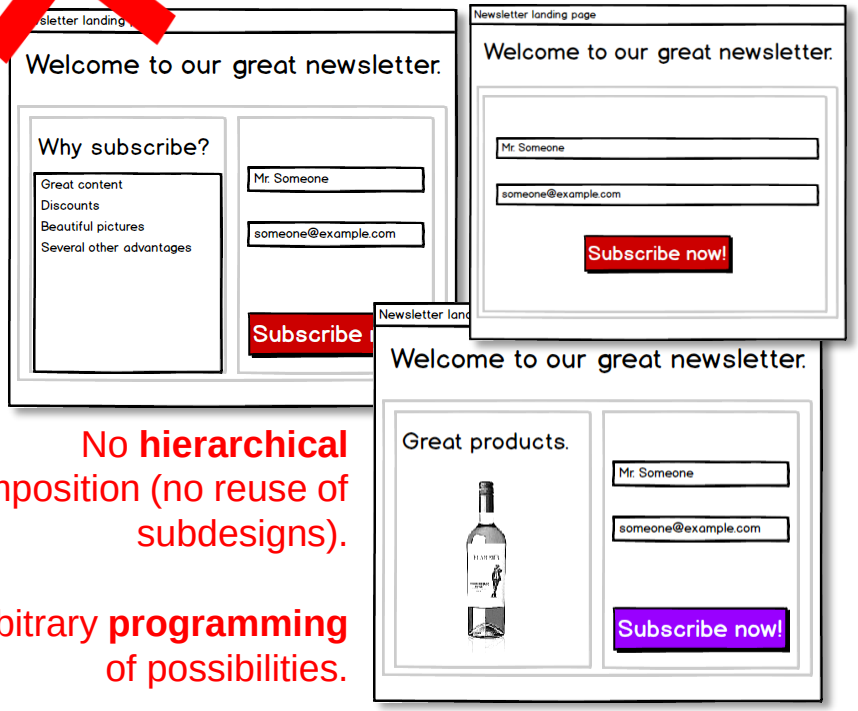
Limitations of Existing Solutions

Can express superficial variations.



Lists of features (color, size, etc.)

Cannot express intrincate UI structural possibilities.



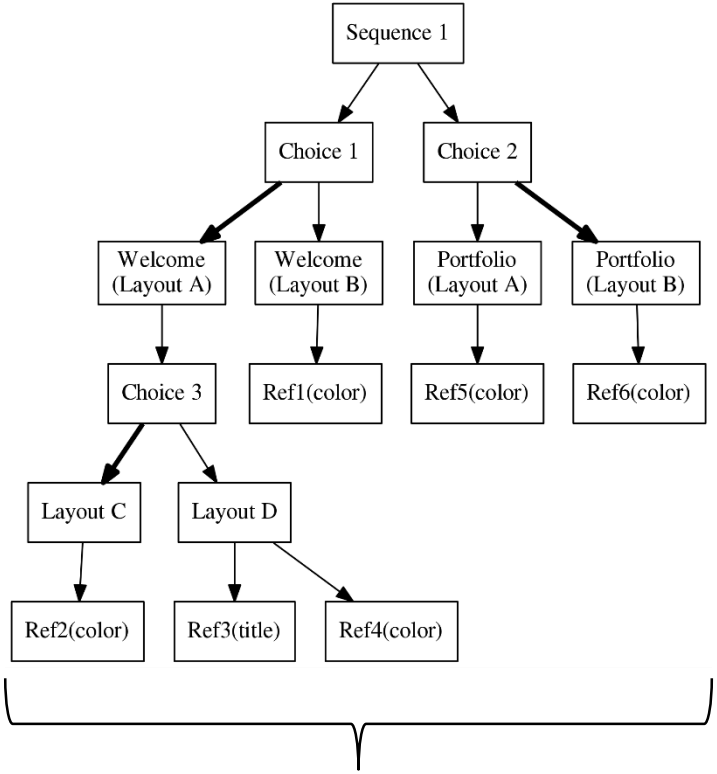
No **hierarchical** composition (no reuse of subdesigns).

No arbitrary **programming** of possibilities.

The Proposed Approach

Genetic Programming

- Programmatic specifications
  - Program expressions instead of features.
- Structured representations
  - Sections, subsections, components, subcomponents, etc.
  - Mimics the structure of the UIs themselves.
- Non-deterministic choices
- Fitness determined by the actions of many concurrent users (i.e., “crowdsourcing”)
- ⇒ **A general way to specify UIs suitable to evolutionary optimization**



possibilities can grow exponentially

UI Specification

Content elements

“This is some headline”
“This is a better headline”
“Some other headline”
Etc.

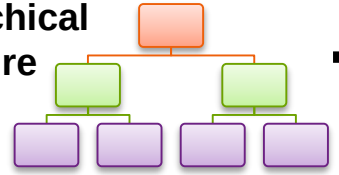
+

Components

Buttons
Input boxes
HTML blocks
Etc.

+

Hierarchical structure



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User actions

Form submission
Clicks
Page scroll
Etc.

Programmatic UI Specification

- Specification given programmatically
- Clear definition of hierarchies and non-deterministic choices
- Domain-Specific Language in Scala

```
Include(LeadGenBlock, variation = 1,
    Sequence(
       Choice(
          Define("opacity", "0.2"),
          Define("opacity", "0.4")
        ),
        ParameterValue("title" ->
                       Reference("title")),
        ParameterValue("tagline" ->
                       Reference("tagline")),
        // (...)
    ))
```

```
<multi-value name="title">
    <text>Recycled furniture and home accessories</text>
    <text>Lovely and recycled furniture</text>
    <text>Taste, recycled</text>
    <text>Learn more about recycling with taste</text>
</multi-value>
```

Can also load content elements from XML:

- Text variations
- Image URLs variations
- Arbitrary HTML variations

Programmatic UI Specification

Program statement	Meaning
`Sequence(a, b)`	The sequential composition of two program statements.
`Choice(a, b)`	The non-deterministic choice among two program statements.
`Define(name, value)`	Defines a variable named *name* with content *value*.
`Reference(name)`	A reference to the value of the variable named *name*.
`Include(blockName, variation, init)`	The rendering of a template named *blockName*.
`ParameterValue(name -> reference)`	Defines that a parameter named *name* has the value specified by *reference*. This must be used within an *Include*'s *init*.
`Div, B, Span, etc`	Primitive rendering operations, which allow the writing of the actual HTML that will be displayed later to the user.

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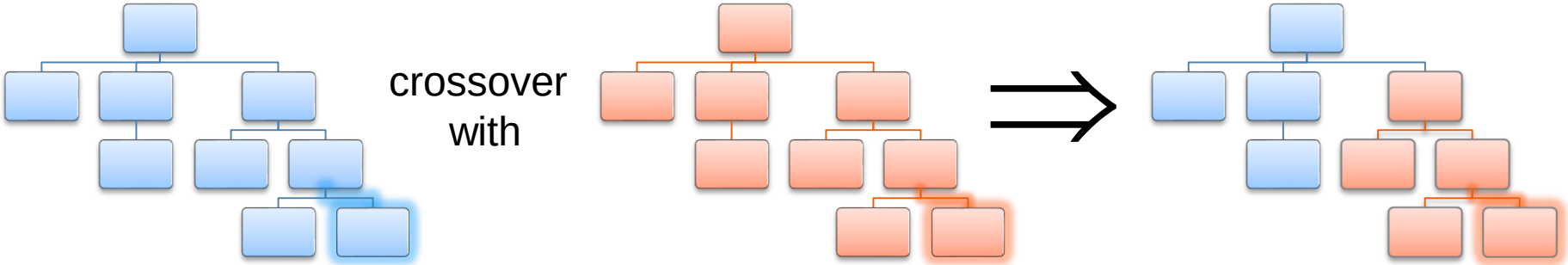
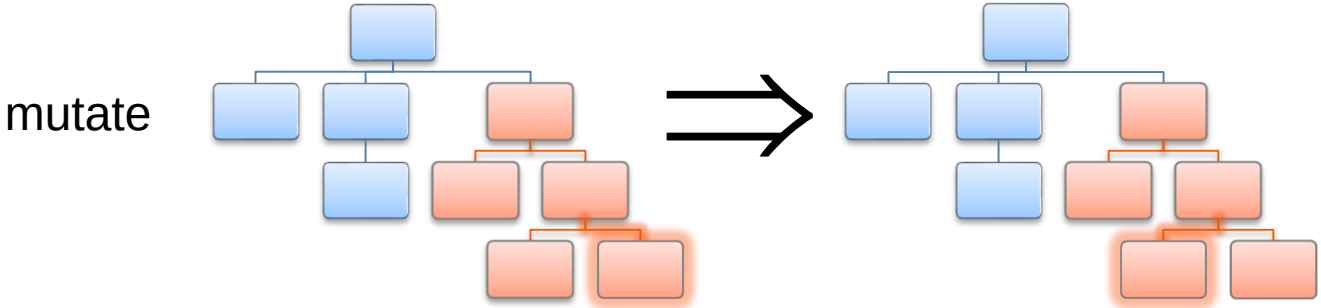
UI Recombination

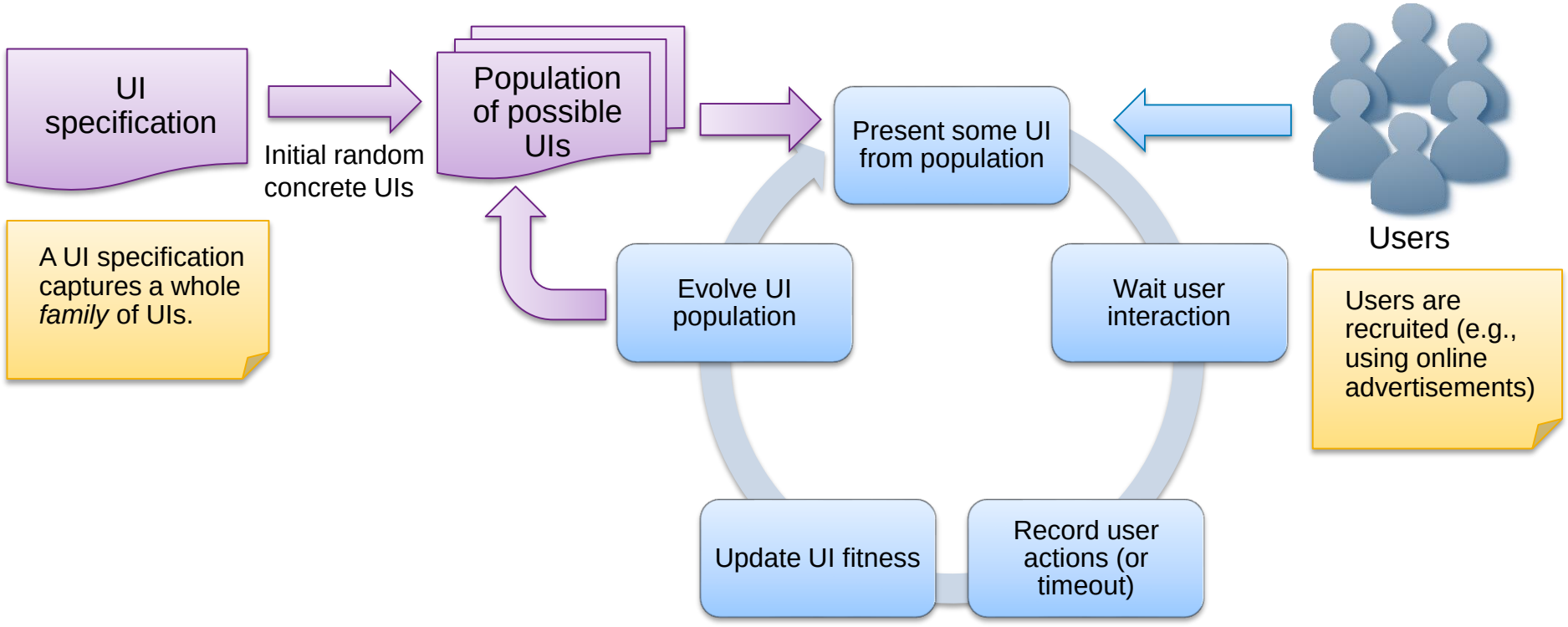
Crossover



Mutation

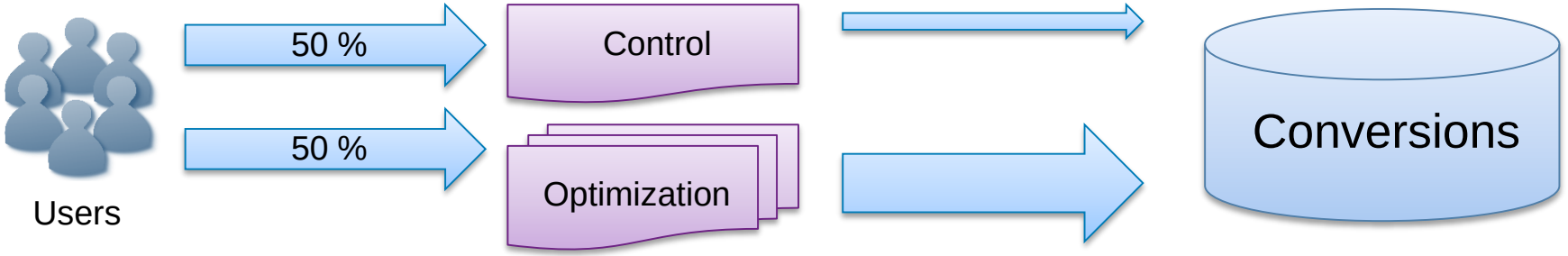


Complete Process

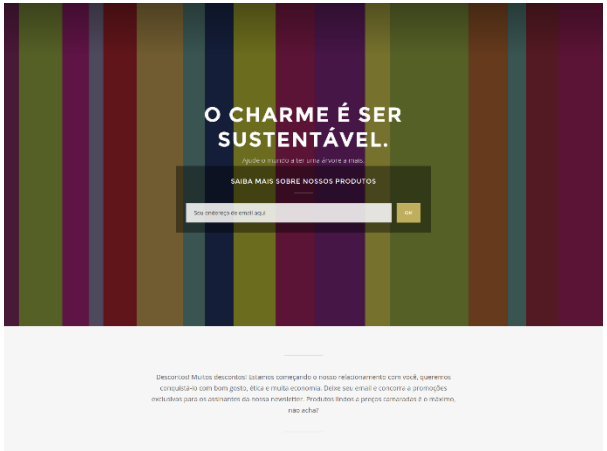


Evaluation

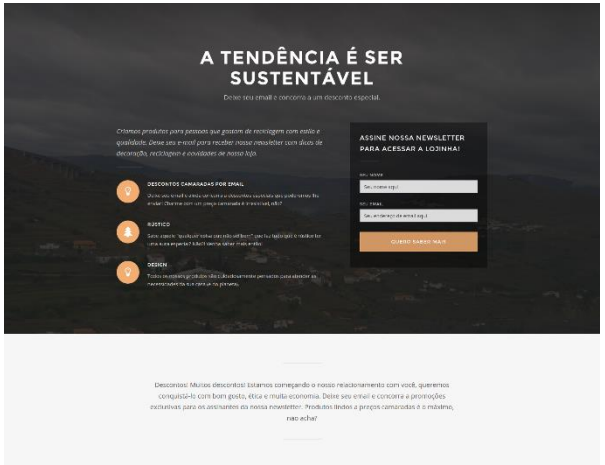
Evaluation



Control page



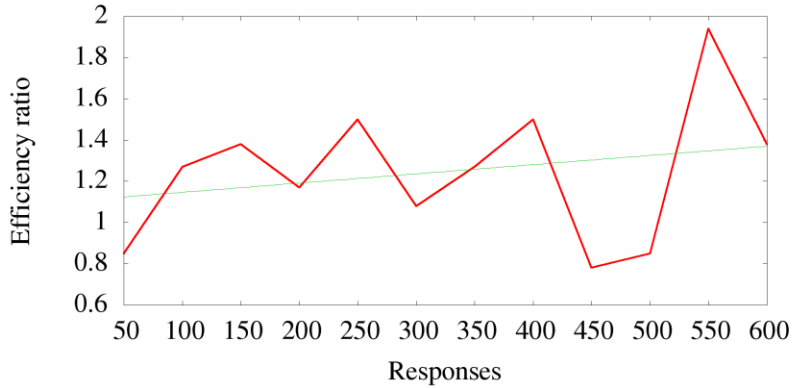
Random initial page



Best page found

Evaluation

- ~ 6^{10} possible concrete UIs
  - Combinatorial explosion
- **5,462 users** were recruited for experiment
- **20%** performance increase
  - Conversion rate (optimized) = 12%
  - Conversion rate (control) = 9.9%
- Non-numerical insights:
  - 8 out of 10 best UIs mentions discounts or monetary savings
  - However, it is not always clear *why* performance improves
- Seasonal effects (i.e., weekends seem to change user behavior).



Efficiency ratio > 1.0 ⇒ optimization performs better than control UI

Conclusion

Future Work

- More experiments, in different domains
- More independent controls, by professional designers
- More programming primitives for UI specification
  - Constraints of various kinds
- More basic UI elements to be composed
- Variations of crossover and mutation operators

Summary

- Designers must think in terms of **UI families** instead of unique UIs.
- **Programmatic**: allows for the specification of arbitrary UI families.
- Foundation for general UI optimization based on Genetic Programming and similar techniques.
- Example uses Web pages, but the approach is general to any UI which:
  - Can be built out of simpler elements
  - Can be instrumented in order to record user actions
  - Has a clear performance metric to be optimized
- Aims at **making designers more productive**, not at substituting them.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