

Making Web Applications More Energy Efficient for OLED Smartphones

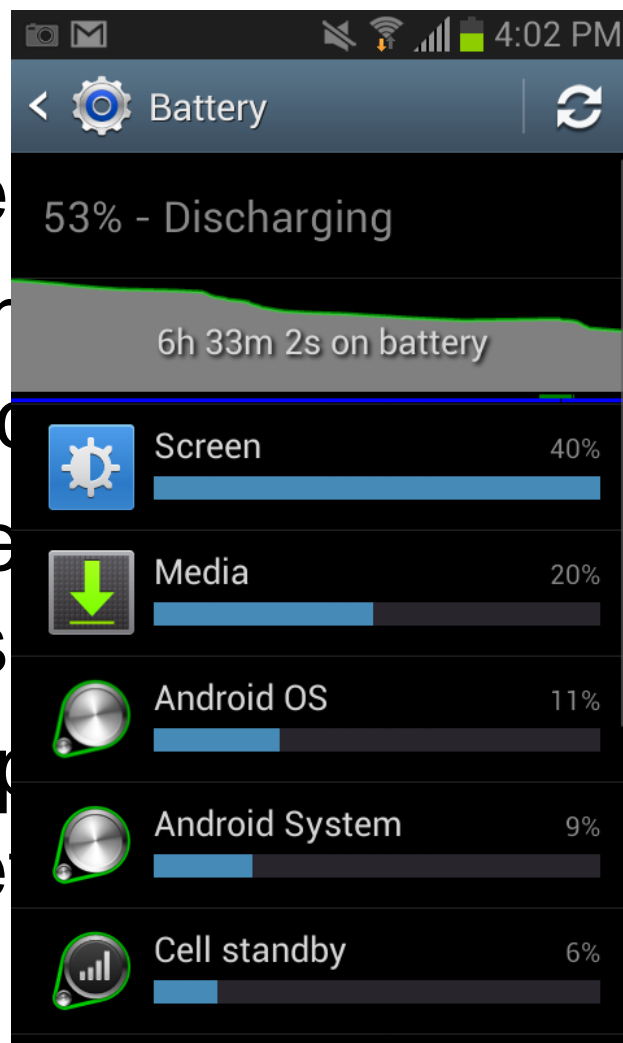
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Motivation



- Energy is a constraint for smartphones
- Screen is one of the most energy consuming components
- Smartphone applications access web resources
- Most web applications are not designed to be energy efficient



Other Techniques

- Dim the display
 - Good start, but more can be done
- Invert colors:
 - 
- Chameleon:
 - Requires customized browser
 - Needs additional server infrastructure
 - Color schemes are manually generated

OLED Screens



High



low energy

- Popular technology for smartphone displays
- More energy efficient than prior technologies
- Different energy consumption patterns

Goal

Automatically transform the implementation of a web application so that the web pages it generates consume less energy when displayed on an OLED smartphone.

Challenges

1. Identifying

- Need to be able to

2. Detecting web

- Important

3. Translating

- Main

```

1 public void print_html()
2 {
3   print("<body bgcolor=\"white\" style=\"color:black;\">");
4   println("<table><tr>");
5   int a=1;
6   if(a==0){
7     println("<td>hi</td>");
8   }
9   else{
10    println("<td style=\"background-color:red; color:yellow;\">ha</td>");
11  }
12  for(int i=0;i<2;i++){
13    println("<td style=\"background-color:green; color:blue;\">usc</td>");
14  }
15  println("</tr></table>");
16  println("</body>");
17 }

```

application

that can

in the

are

scheme

esthetics)

Approach Overview

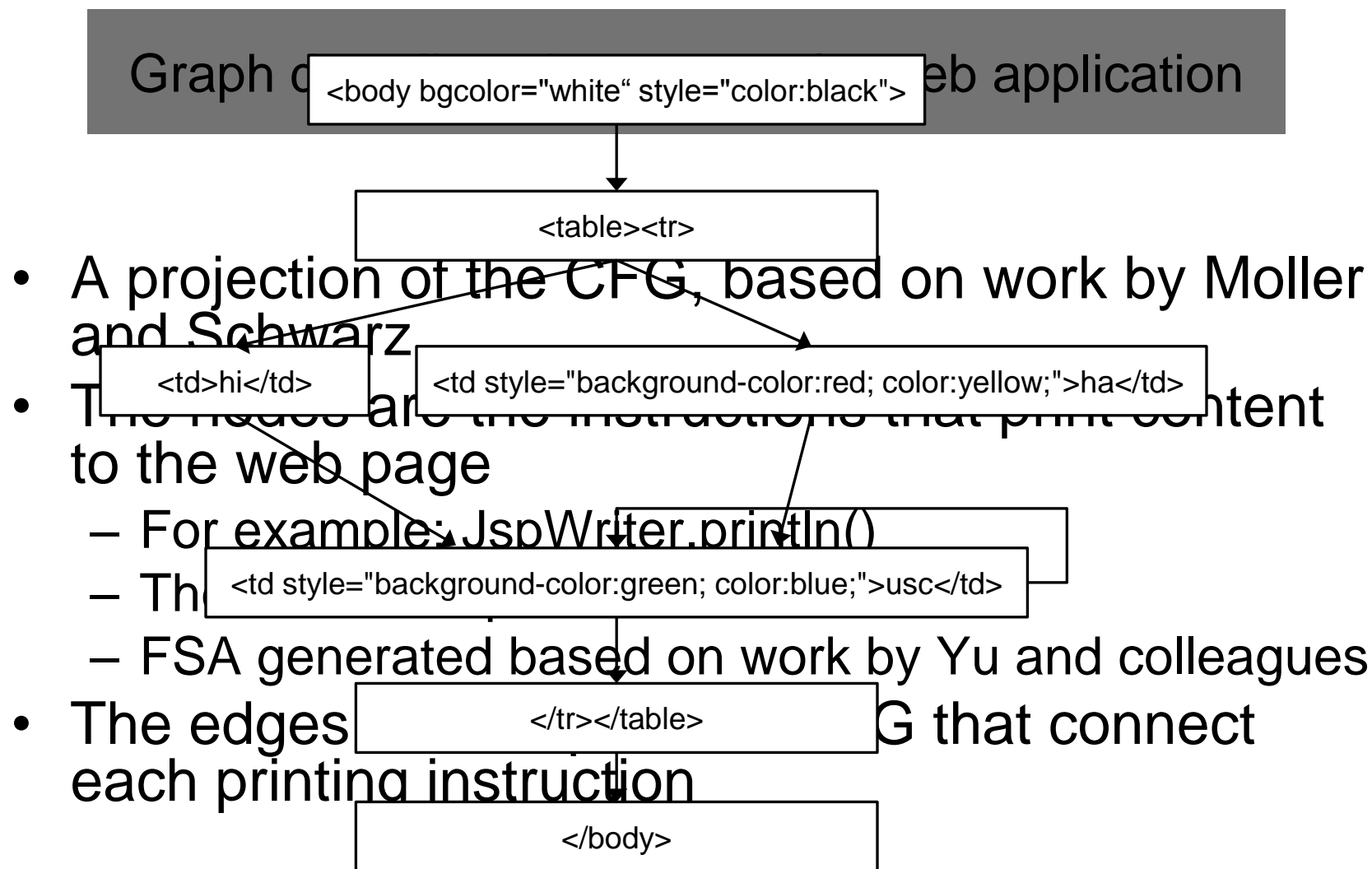
1. Compute the set of generated HTML pages
2. Determine visual relationships in pages
 - Example: adjacent and contained
3. Identify colors that have visual relationships
4. Solve for a new color scheme
 - Is more energy efficient
 - Maintains similar color differences
5. Rewrite application to use new color scheme

Phase 1**Phase 2****Phase 3**

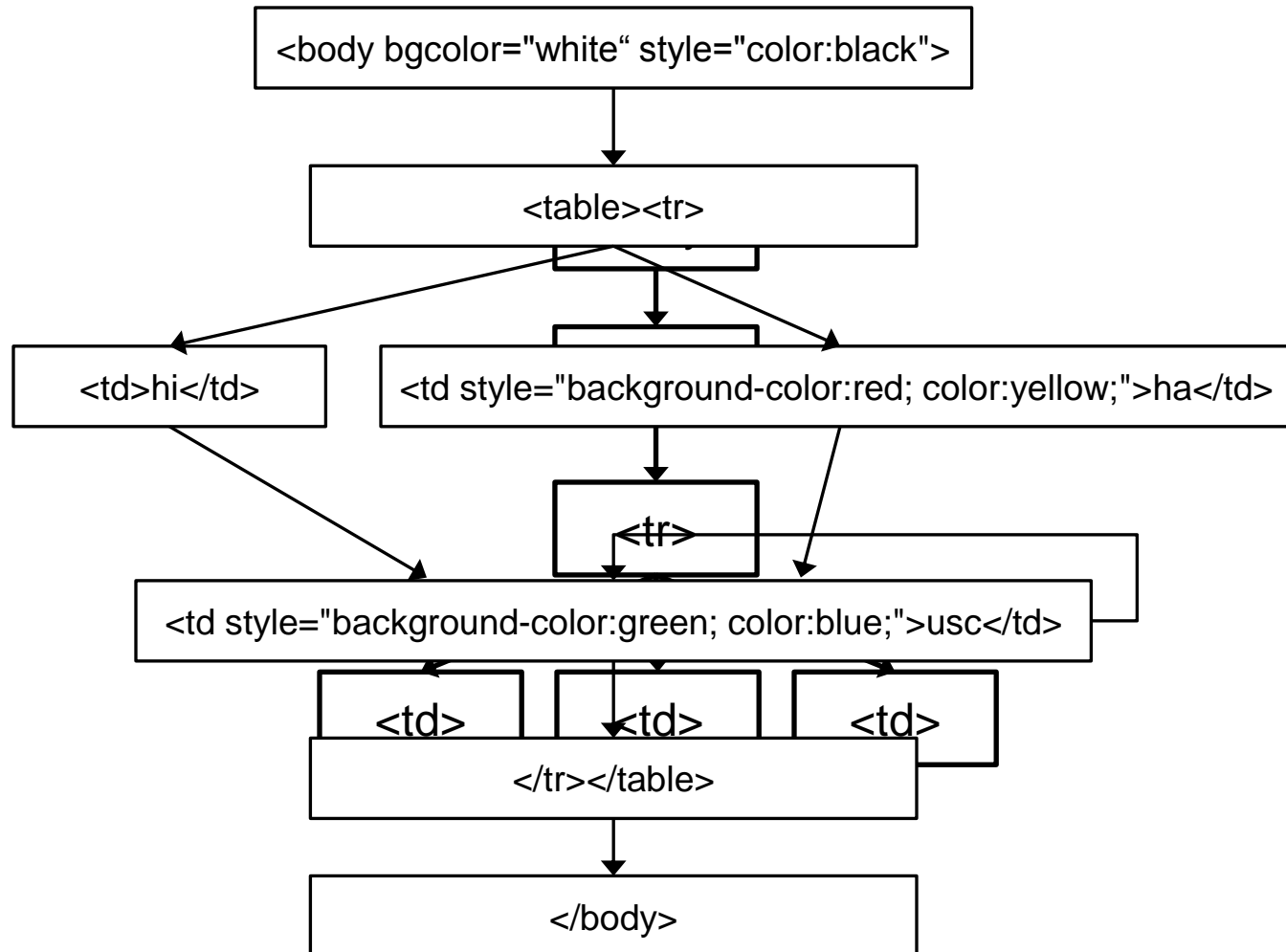
Phase 1: HTML Output Analysis

- A. Compute the set of HTML pages that could be generated by the application at runtime
- B. Determine visual relationships among HTML elements in the pages
 - Example: adjacent and contained

Phase 1A: HTML Output Graph



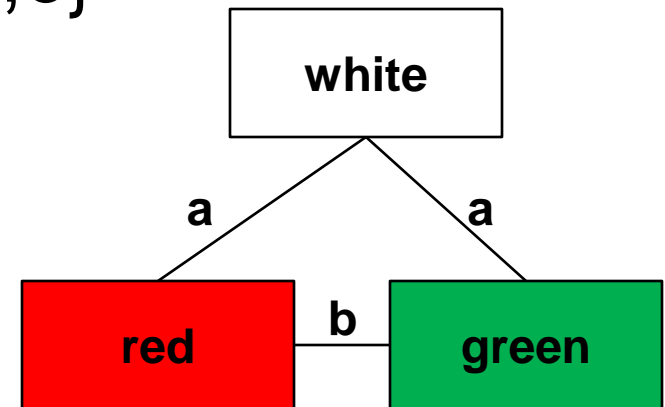
Phase 1B: Visual Relationship Graph



2: Color Transformation

Color Conflict Graph (CCG)

- Shows visual relationships of colors in a page
- BCCG: weights are in $\{a,b,c\}$
 - $a > b > c > 0$
 - a: parent-child
 - b: siblings
 - c: everything else

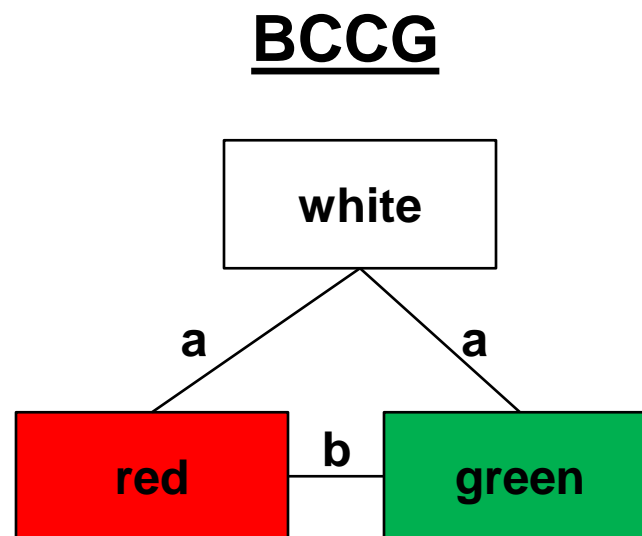
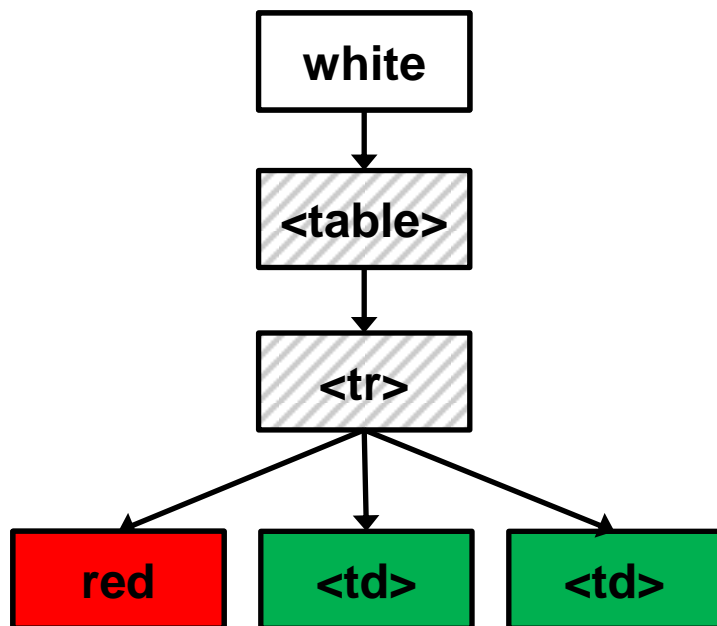


2: Color Transformation

Building the Color Conflict Graph

1. Basic unit is color definition (CD)
 - CSS based
 - HTML based
2. Perform reachability analysis over visual relationship graph
3. “Reaching CDs” define edges in CCG

2: Color Transformation



BCCG: weights are in $\{a,b,c\}$, $a > b > c > 0$

a: parent-child

b: siblings

c: everything else

2: Color Transformation

Generate the color transformation scheme (CTS)

1. Let $S = \langle C_0, C_1, C_2, \dots, C_k \rangle$ nodes of the CCG
2. Let S' be the new coloring, where $C_0 = \text{black}$
3. Compute S' that results in similar color differences as in S , i.e. minimize:

$$\sum_{i=0}^k \sum_{j=0}^k w_{ij} |Dist(C_i, C_j) - Dist(C_i', C_j')|$$

4. Optimization problem is NP-Hard, use simulated annealing to approximate optimal solution

Phase 3: Output Modification

1. Dynamically generated HTML pages
 - Insert instrumentation to replace HTML printing instructions
 - Replace original colors with new colors
2. Template based frameworks
 - Use CSS parser to identify entries to be replaced
 - Replace entries by rewriting CSS and HTML

Evaluation

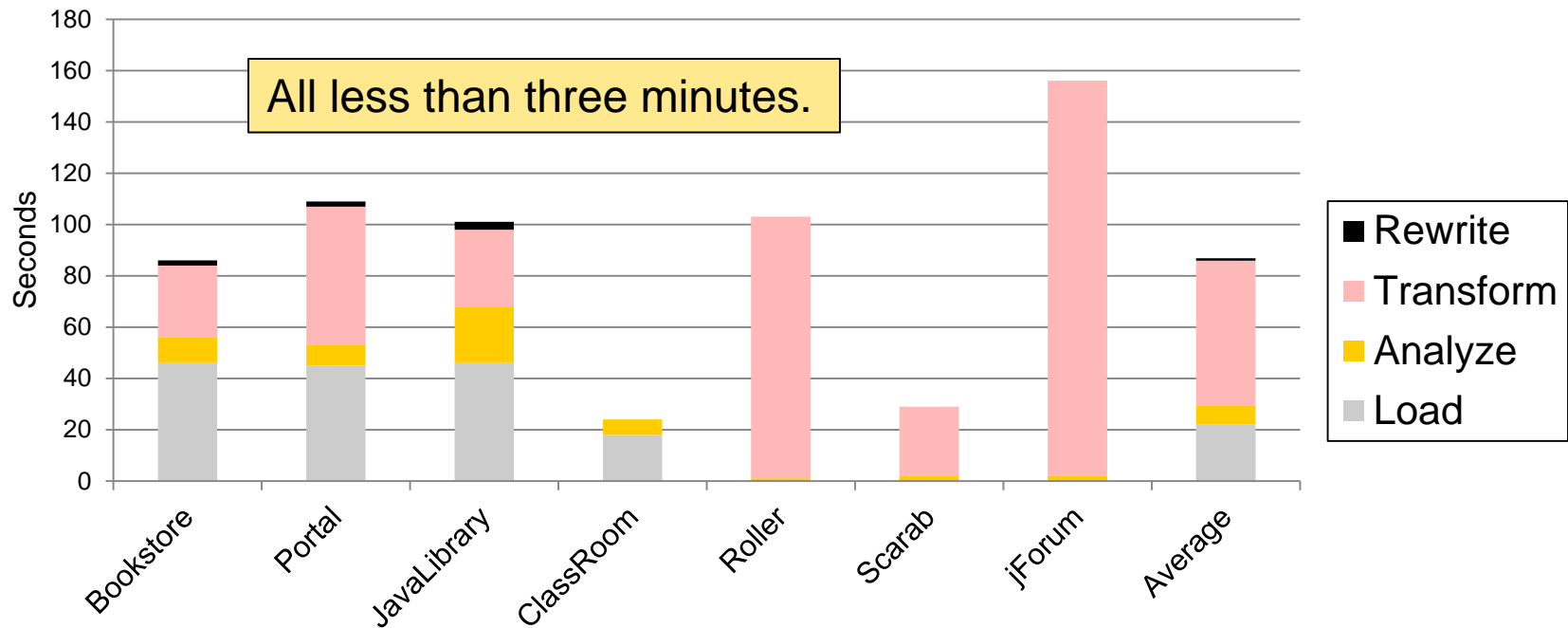
- **RQ 1:** How much time does it take to generate the new color scheme?
- **RQ 2:** How much energy is saved by the transformed web pages?
- **RQ 3:** To what degree do users accept the appearance of the transformed web pages?

Subject Applications

Name	Framework	SLOC
Bookstore	JSP	24,305
Portal	JSP	21,393
JavaLibrary	JSP & Servlet	73,468
ClassRoom	JSP	5,127
Roller	JSP & Struts	154,065
Scarab	Velocity & Turbine	145,435
jForum	Velocity	31,841

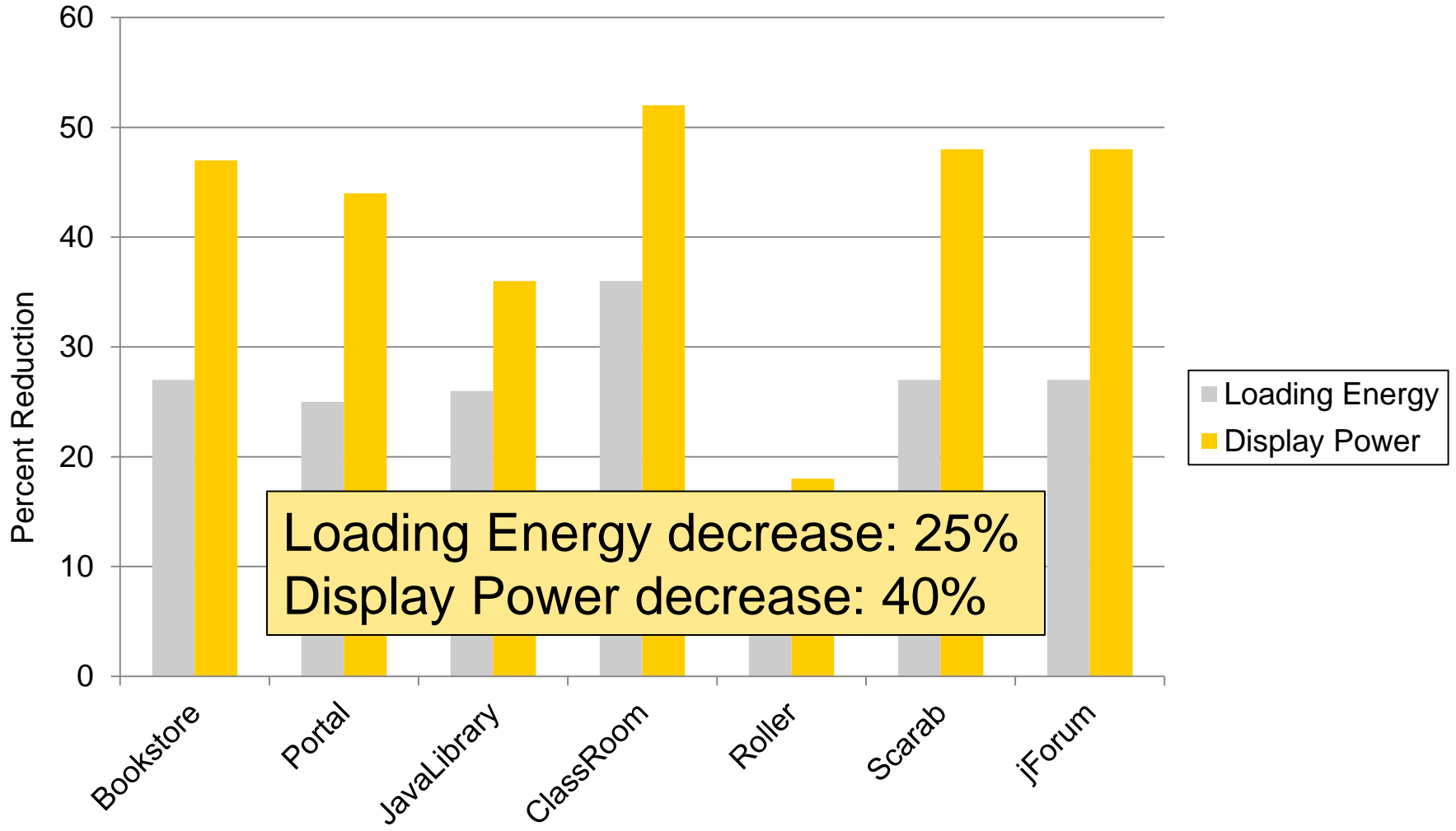
- Four embed color information in HTML, three use CSS
- Three heavily use JavaScript in the user interface
- Three use Model-View-Controller style

RQ1: Time Cost



- Most of the load time was Soot processing
- Load times varies because some apps use templates
- Transform time varies based on complexity of HTML page structure

RQ2: Energy Savings



RQ3: User Acceptance

- Users asked to rate before/after color transformation produced by our approach
- Subject pool: 20 graduate level students
 - 17 responses received
 - Students unaware of project goal
 - No incentives offered
 - Anonymous

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Jim Buyens

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A Sharp Combination
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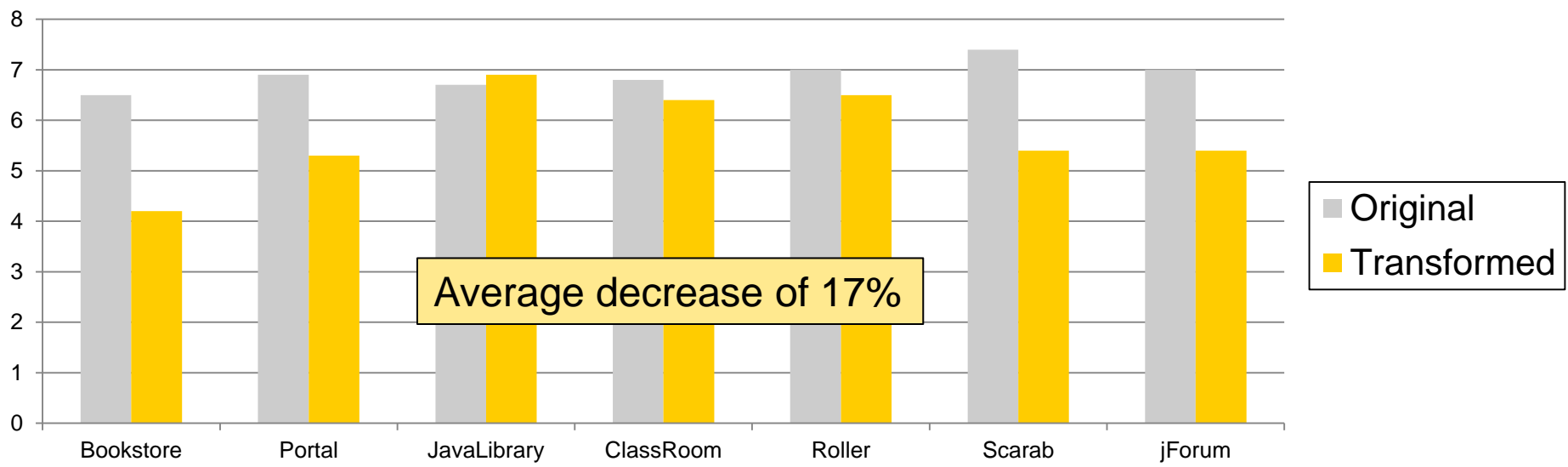
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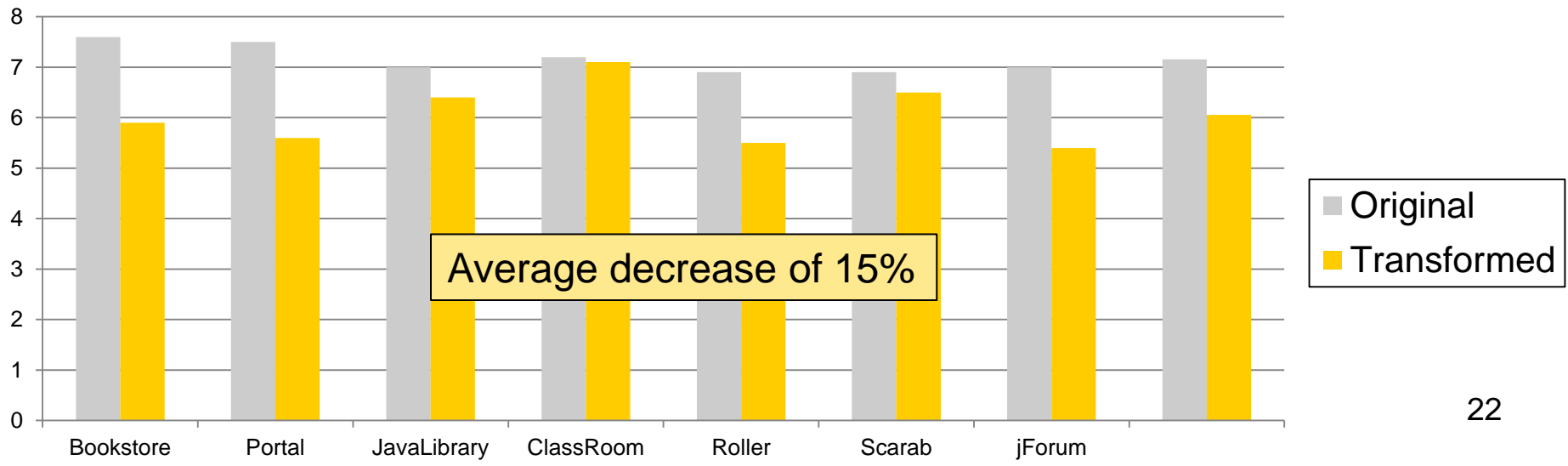
1. How do you rate the readability?
2. How do you rate the appearance?
3. If the version on the right could save you X% of the energy, at what battery level would you choose to use it?
 - a) Always – regardless of battery level
 - b) Most of the time
 - c) Only when the battery level is low
 - d) Only when the battery level is critical
 - e) Never

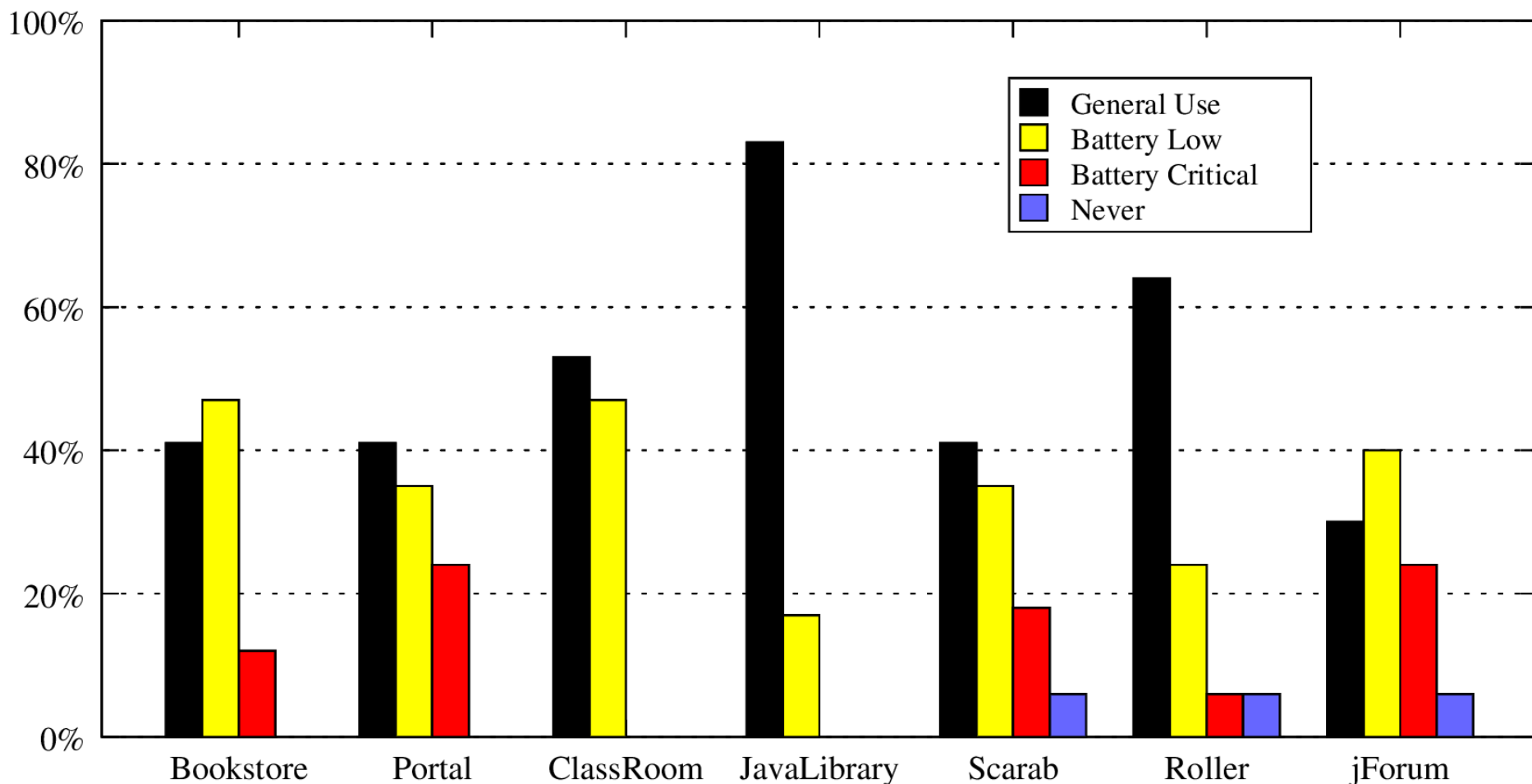
arning (or just jumping into) animations, music tracks, sign, try the Flash 4 Magic. sentations, and a CD.

Attractiveness



Readability





- 60% choose transformed app for general usage
- 97% choose transformed app for battery critical

Summary

- **Goal:** make web pages more energy efficient for display on OLED phones
- **Mechanism:** static analysis and transformation of the app implementation
- **Results:**
 1. Analysis takes less than 3min
 2. Energy savings average 40%
 3. 60-97% of users choose transformed version when energy tradeoff is known

The End

Thank you

Approach Implementation

- Built fully automated tool: **Nyx**
- Soot: for call graphs and control-flow
- BRICS Automaton library: for string FSAs
- SAC CSS Parser: for identifying colors of HTML elements
- BCEL & Perl: for modifying the web apps
- Implemented for HTML 4 and CSS 2

RQ: Runtime Overhead

