Parallel Webpage Layout

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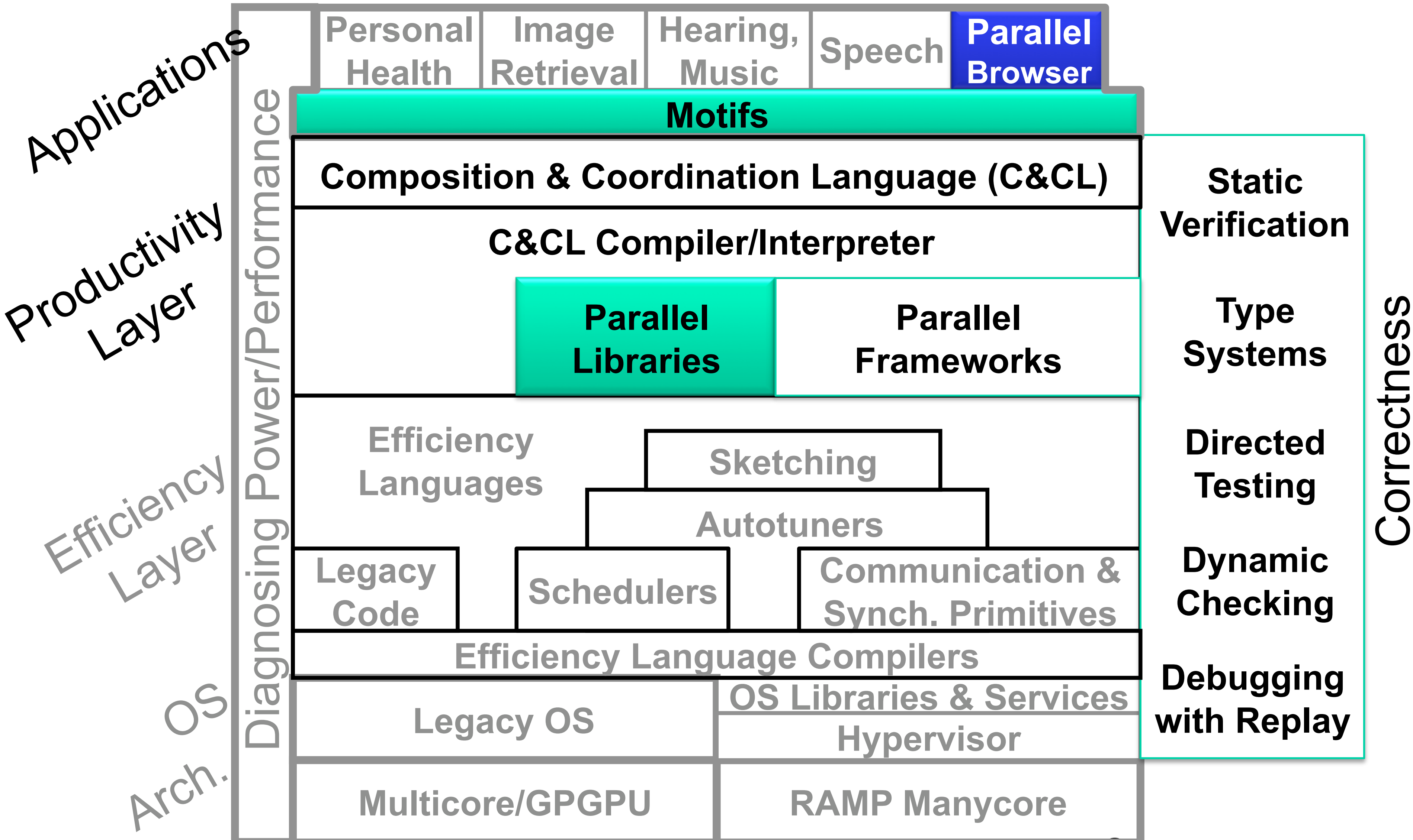
UC Berkeley

Par Lab Research Overview



Parallel Web Browser

Why the browser?

- an important application platform
- browser wars again: competing on performance (latency)
- how important? handheld pageload is tens of CPU seconds

Why a parallel browser?

- soon in your phone? 4 cores x 2 threads x 8-wide SIMD = 64
- parallelism is more energy efficient

Technical challenge

- Parallelize the browser to run with 100-way parallelism

This Talk: Parallelize Single Page Layout

- Page layout (HTML+CSS) is the LaTeX of the Web
  - latex takes seconds to format a document
  - but pageload should be 20-100ms
  - pageload is a bottleneck : 51% of CPU time on IE8
- Page layout is a challenging "*desktop*" application
  - not parallelized before
  - specifications: often ambiguous and sequential
  - low-latency: problems are short-running
  - less understood motif: tree computation
- Knuth: "Multiprocessors are no help to T_EX"

Our Contributions

1. Analyzed browser performance
   - layout is a bottleneck; we identified its critical motifs
2. Distilled essential CSS and wrote a declarative spec for it
   - crucial step for exposing parallelism hidden by today's spec
3. Developed first parallel page layout algorithms

   (1) matching: task parallel, 20x speedup, strongly scales to 16

   (2) solving: task parallel, 4x speedup, strongly scales to 3 cores
4. Future steps – components and algorithms

Overall Page Layout Problem

What the browser does

```
<body>
  hello
  <img  src="http:...”>
  <p><b>world</b>
     ok ok ok ok ok
```

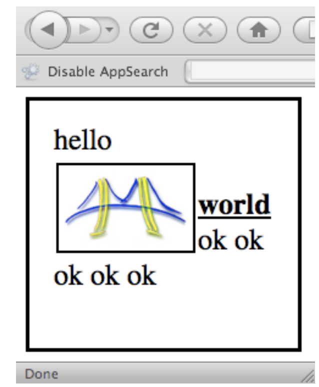
HTML

\+

```
p     { width: 100% }
img   { width: 100px;
        float: left   }
p img { width: 10pt   }
```

CSS styling rules

→

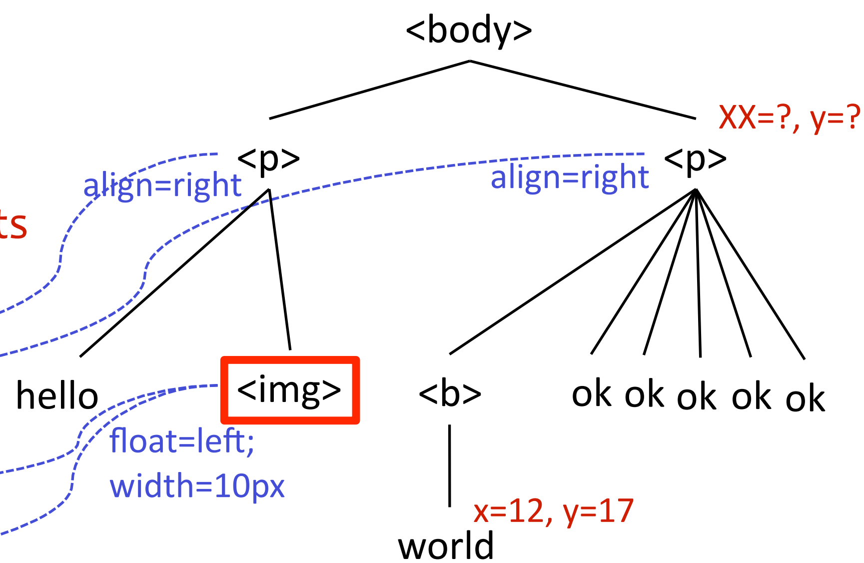


Our page layout subproblem

Input: document tree + CSS rules
Output: sizes and positions of tree nodes
Steps: determine styling rules; solve constraints

25% 25%

p	width=100%
img	width=100px float=left
p img	width=10px

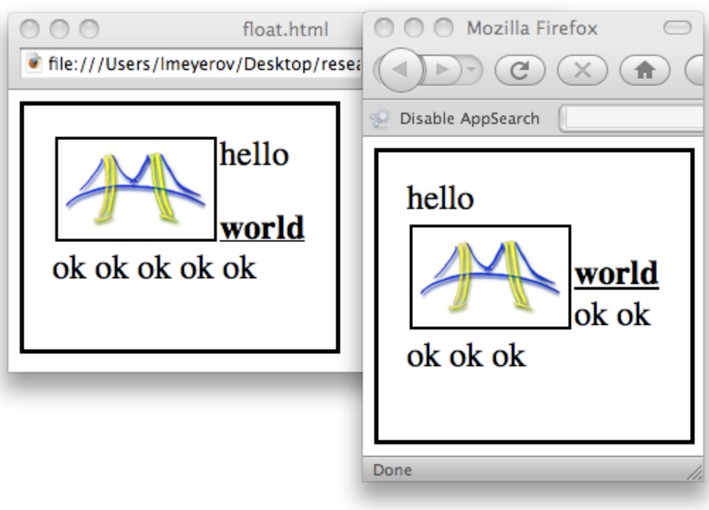


The layout spec is confusing

Example of spec:

- "In general, the left edge of a line box touches the left edge of its containing block… However, floating boxes may come between [them]."

Hard to implement correctly, even sequentially.



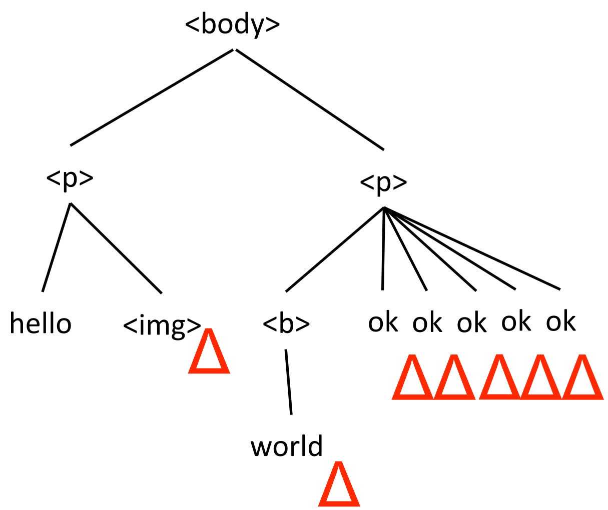
Safari Firefox

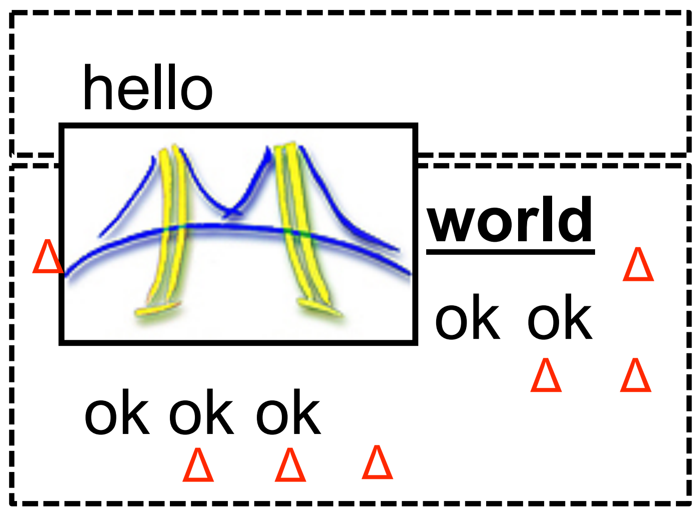
Flow: sequential layout in today's browsers

simplest way to implement the spec seems to be to (mostly) flow the elements sequentially in order

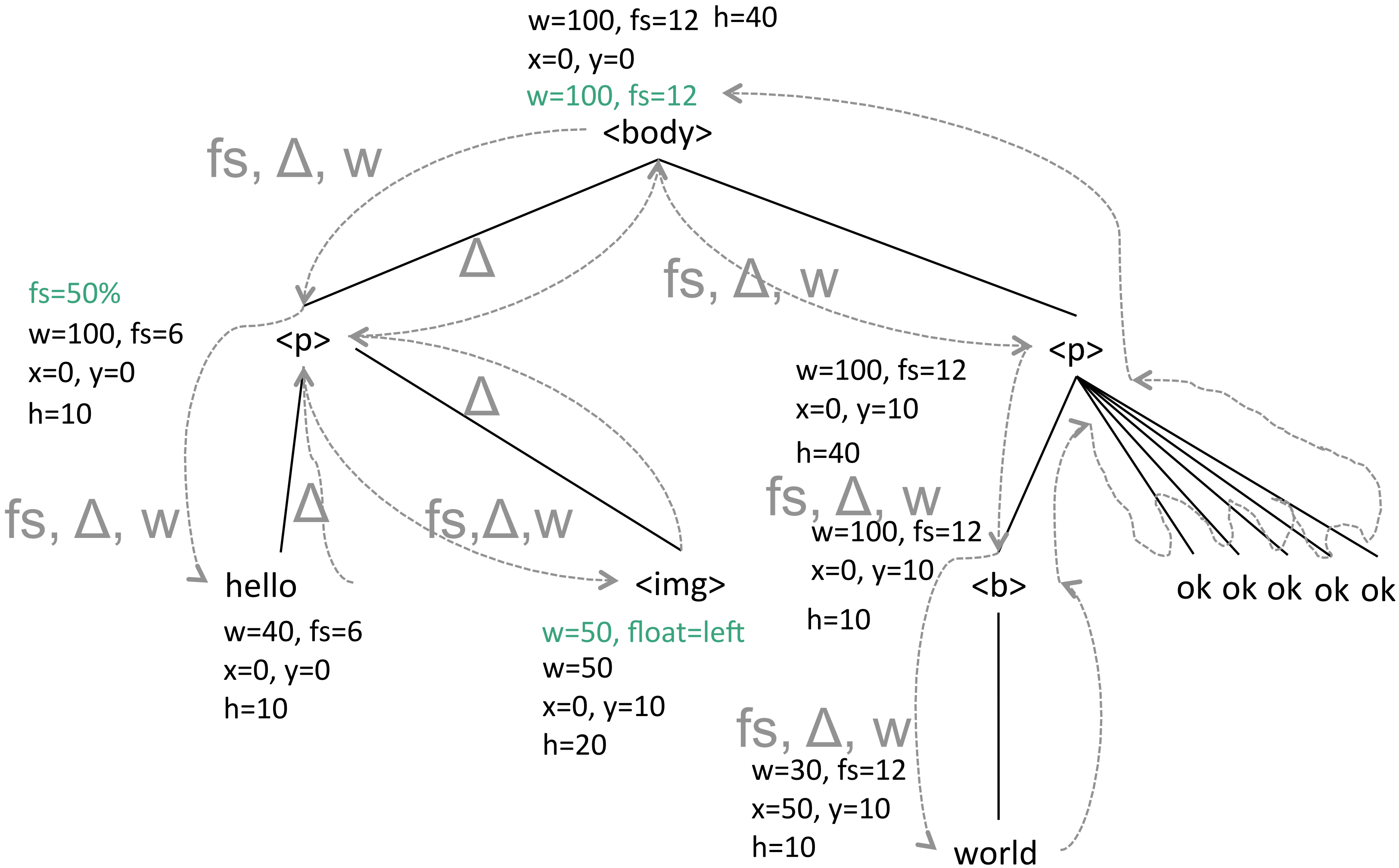
Flow is guided by a cursor

Cursor Δ points to where next element goes



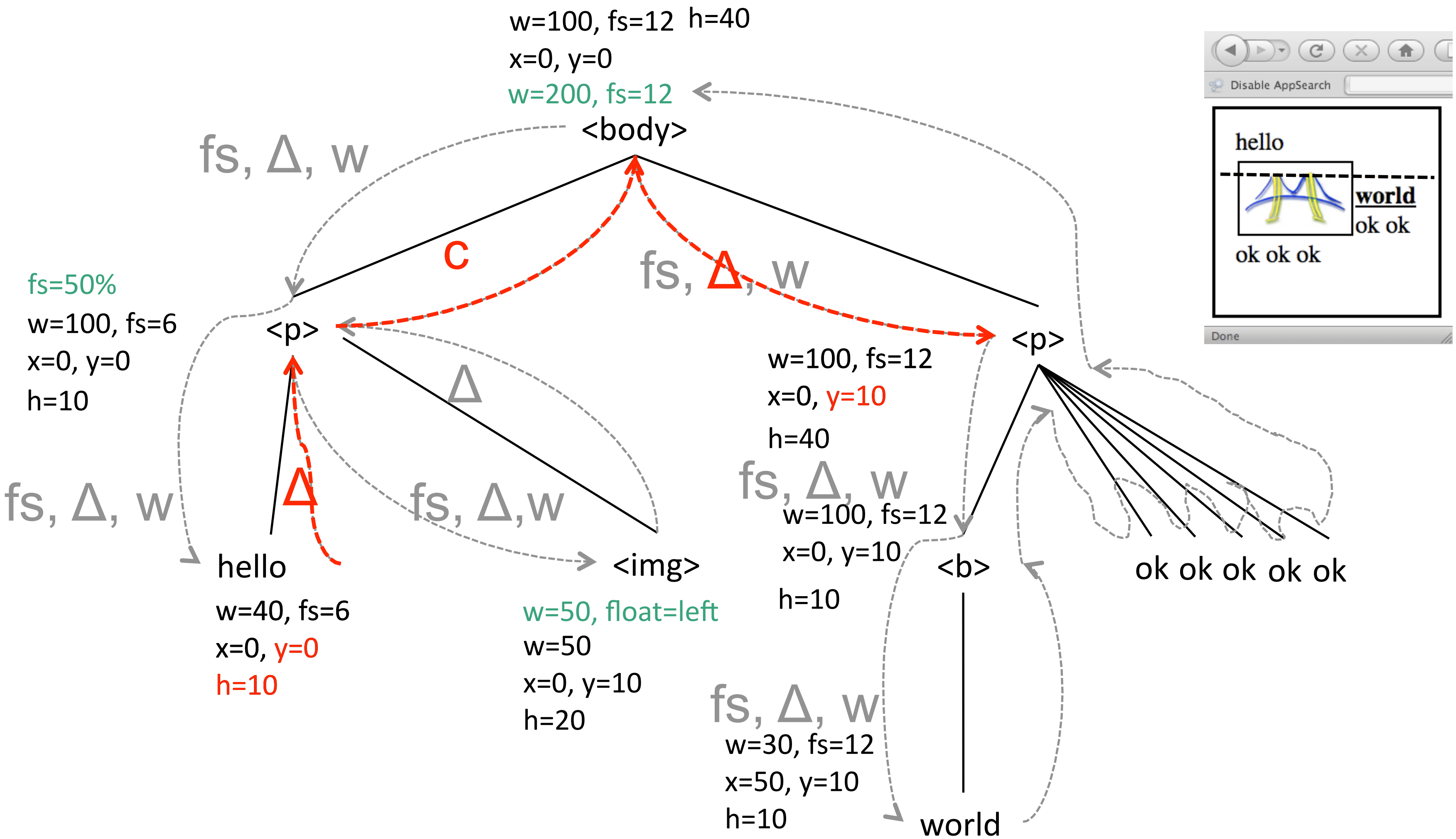


Flow’s dependences

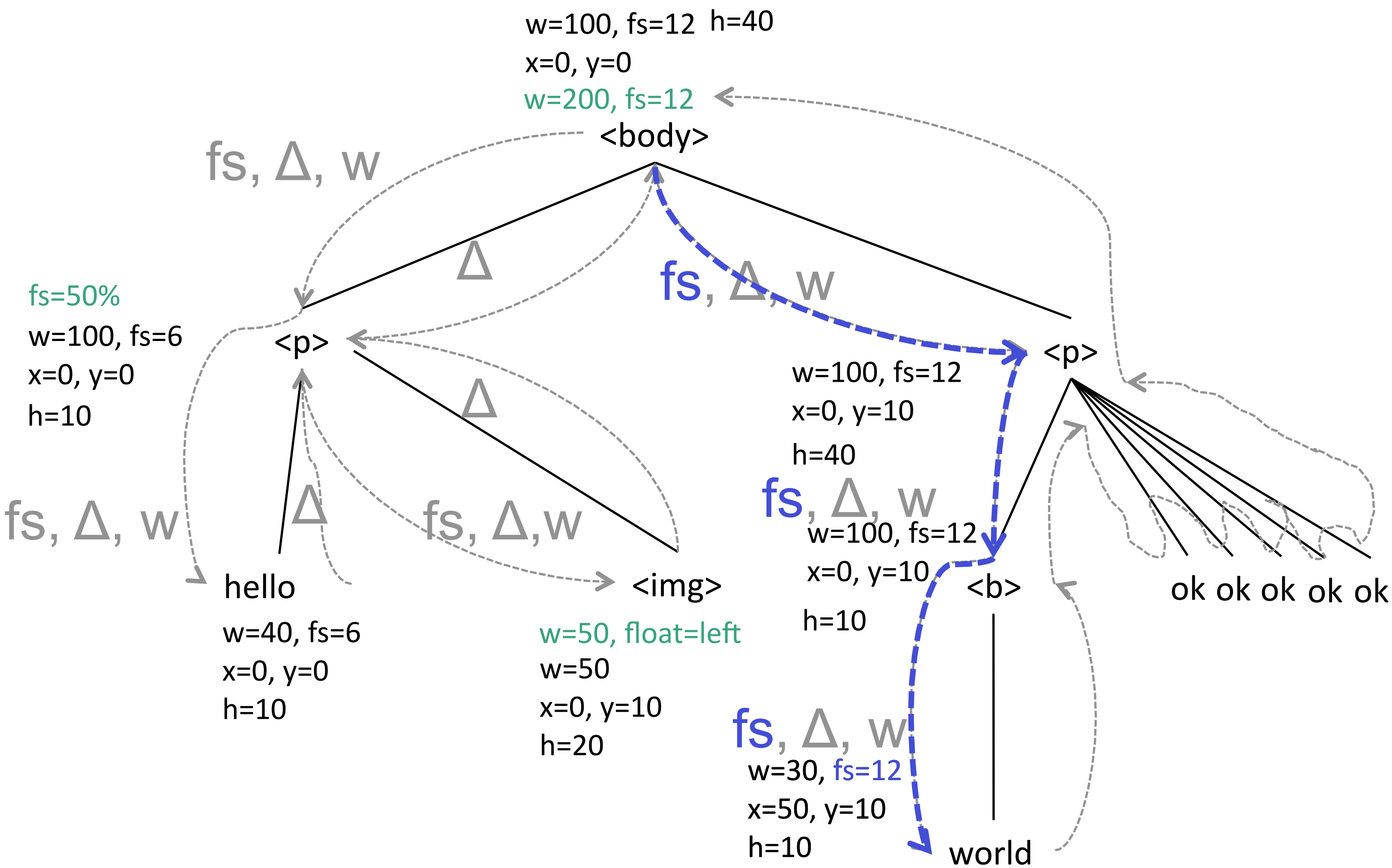


constraints not specified if equality (e.g., inherited) or intrinsic (e.g., default image size or aspect ratio)

Dependencies prevent parallelism



Enable parallelism by doing part of work



Parallel Layout Solving: Five Phases

Extensive analysis led us to five phases

These enable parallelism

↓ 1. font size, tentative widths

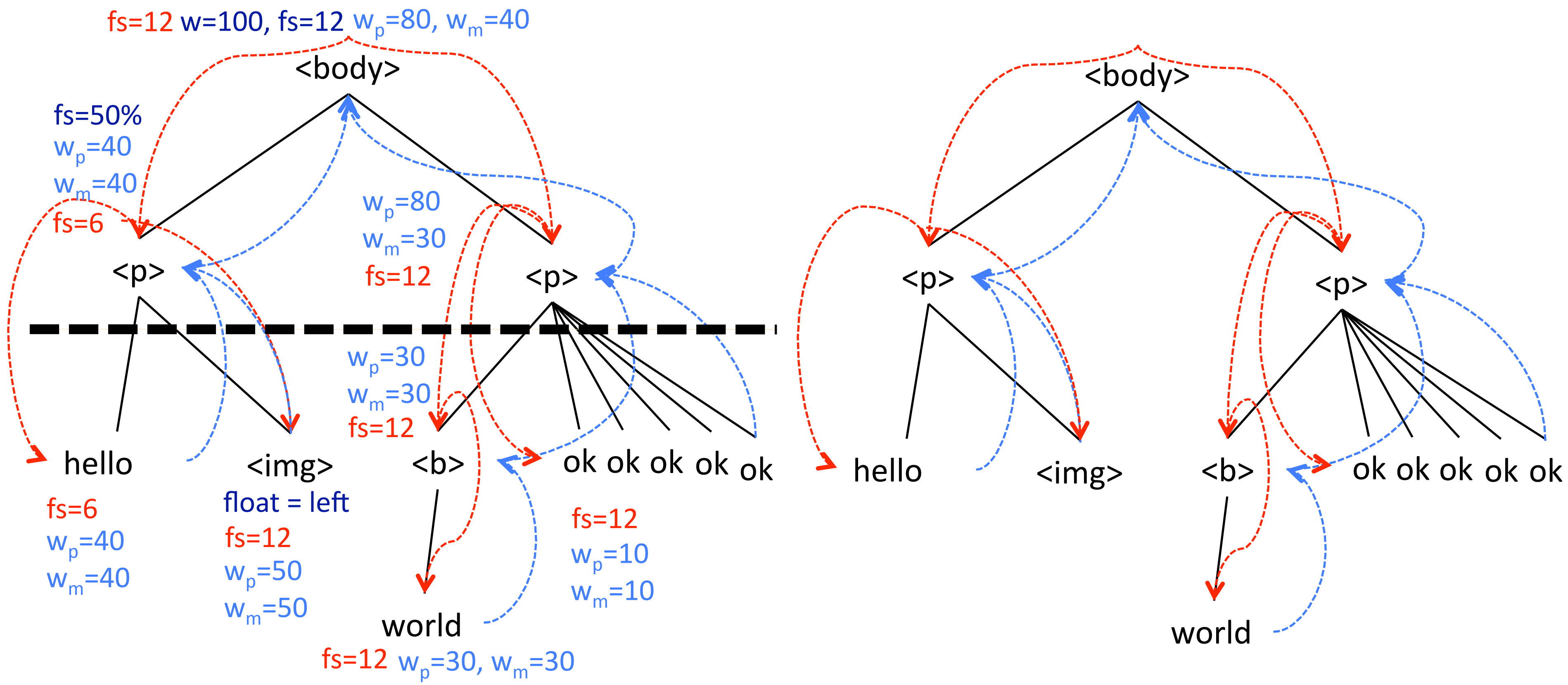
↑ 2. preferred widths: max, min

↓ 3. final widths: break cycles by over-specifying CSS

↑ 4. heights, relative x/y positions

↓ 5. absolute x/y positions

Each Phase Exhibits Tree Parallelism



Phase 1: font size, temporary width

Phase 2: preferred max & min width

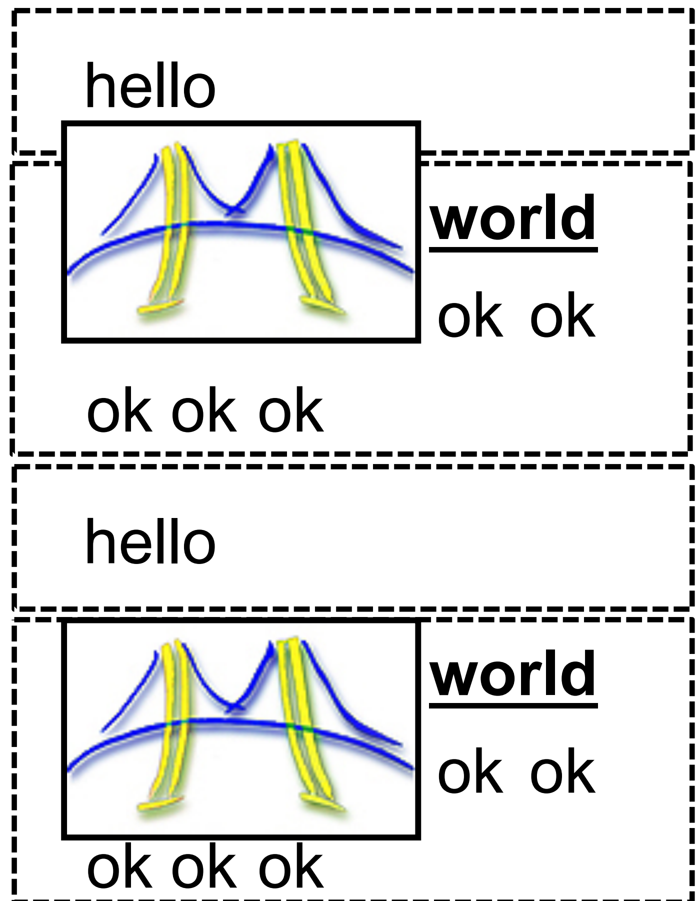
Phase 3: width

Phase 4: height, relative x/y position

Phase 5: absolute x/y position

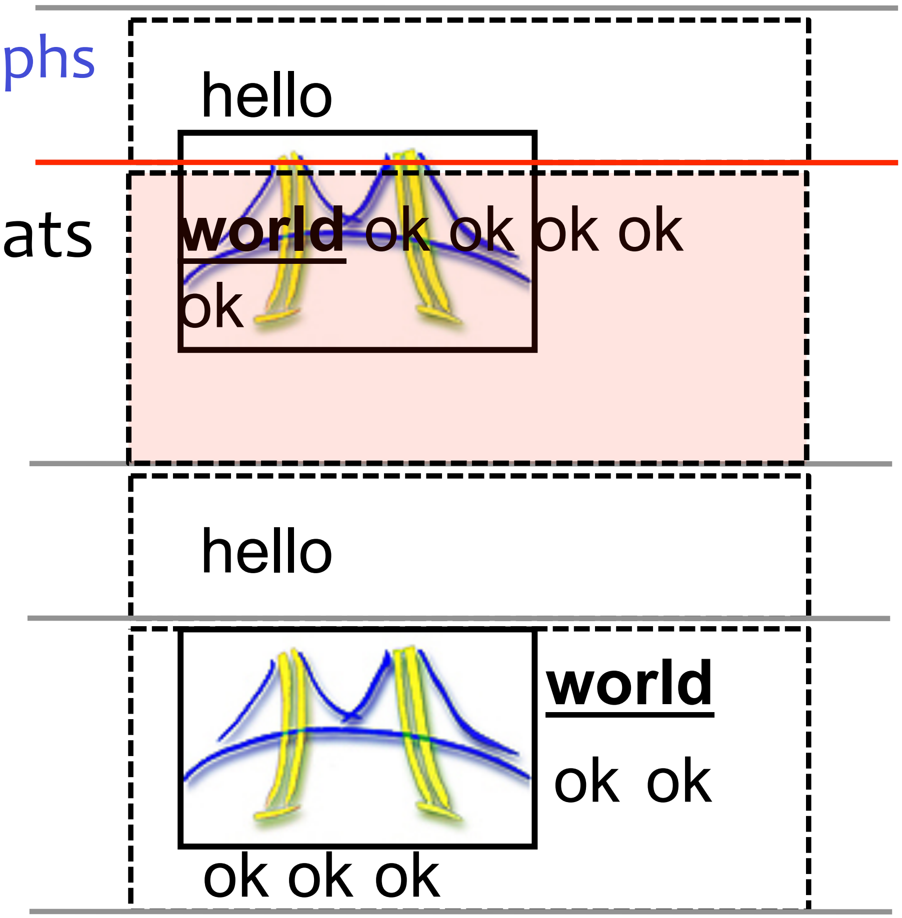
Parallel Layout: Speculative Evaluation

- Did not break dependencies for floats
  - might stick out of paragraphs



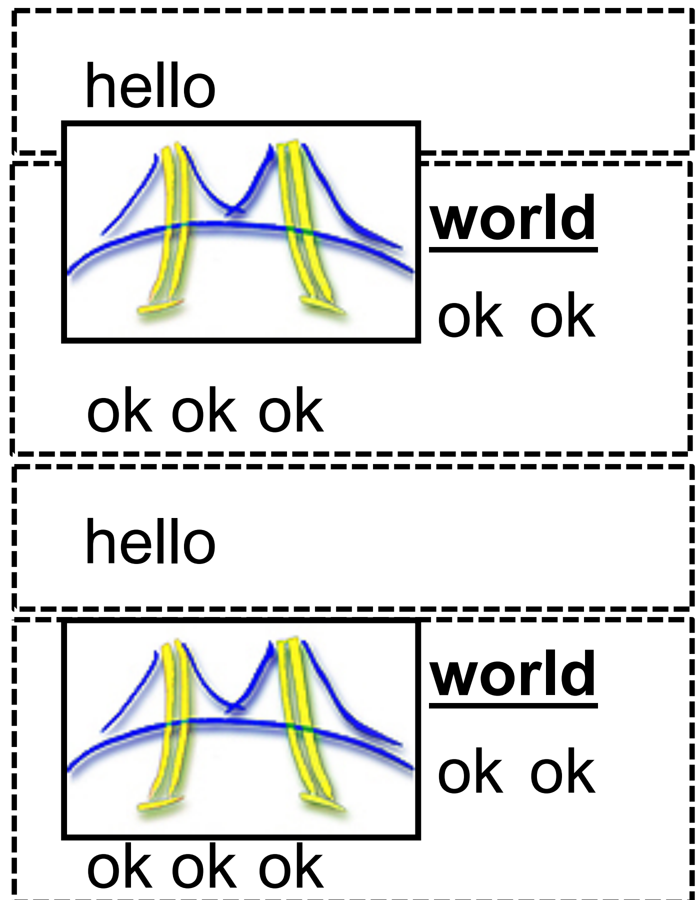
Parallel Layout: Speculative Evaluation

- Did not break dependencies for floats
  - might stick out of paragraphs
- Speculate: assume no floats
- Check
- Patch up as needed



Parallel Layout: Speculative Evaluation

- Did not break dependencies for floats
  - might stick out of paragraph
- Speculate: assume no floats
- Check
- Patch up as needed
  - floats rare
  - *We believe* overflow is minimal



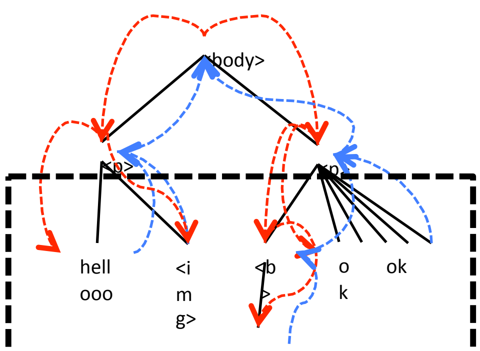
Berkeley Style Sheet Layout Language

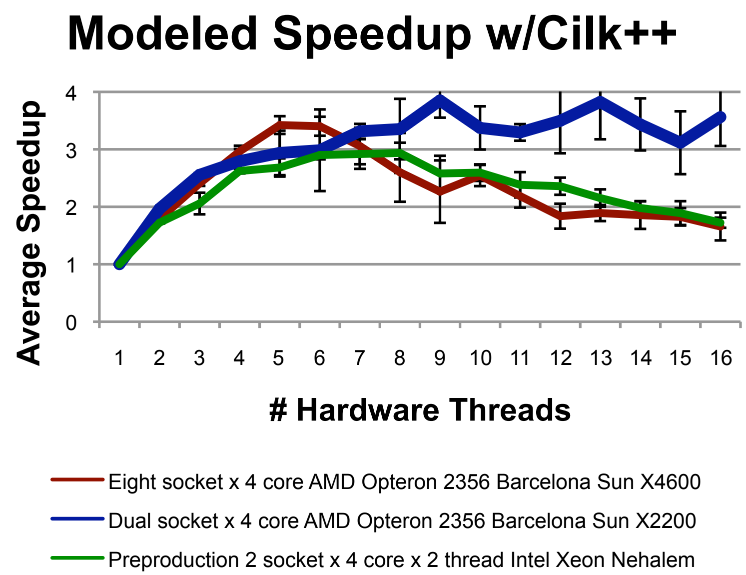
- Can compile essential CSS into it
- Refactored CSS to separate features
- Simplifies: correctness, parallelization, use

$$
\begin{aligned}
&V \rightarrow \\
&\quad \{y_{acc} \hookleftarrow 0\} \\
&\quad (\{\$1.x = 0; \\
&\quad\quad \$1.w = \phi(\$0.w,\ \$1.tempw,\ \$1.m,\ \$1.p)\} \\
&\quad\quad\quad\quad (V \mid H) \\
&\quad\quad\quad\quad \{\$1.y = y_{acc}; \\
&\quad\quad\quad\quad\ y_{acc} \hookleftarrow y_{acc} + \$1.h\})^{*} \\
&\quad \{\$0.h = \$0.temph \bowtie y_{acc}\}
\end{aligned}
$$

Analysis

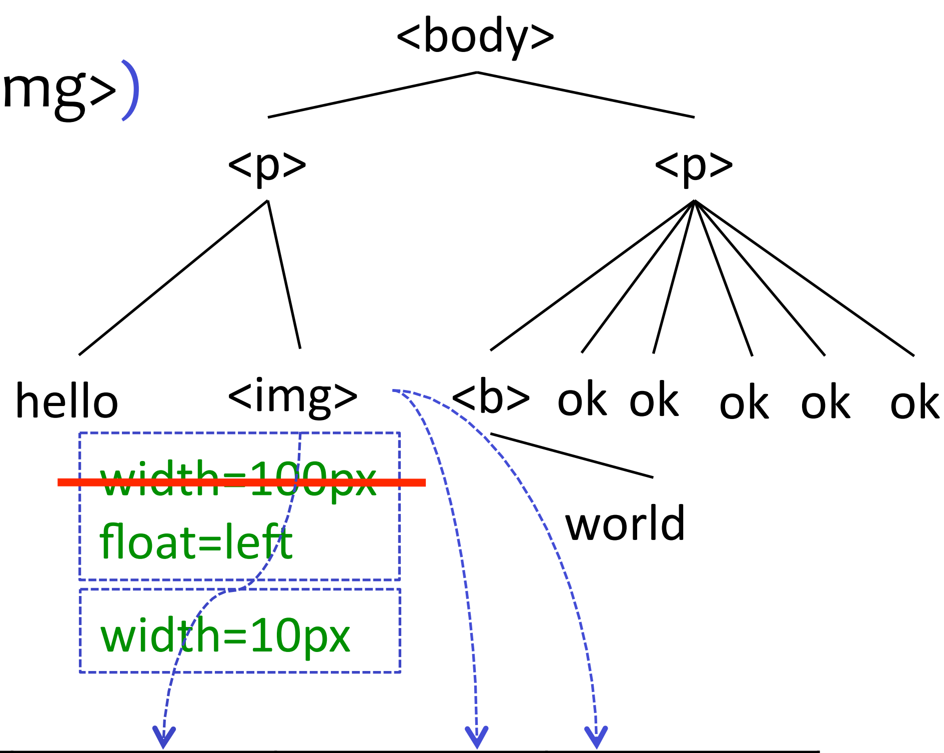
- Model: sequential speed ~= Firefox speed
- Cilk++: 4x speedup, scales to 3 cores
- Need to SIMDize leaves





Rule Matching: Problem Statement

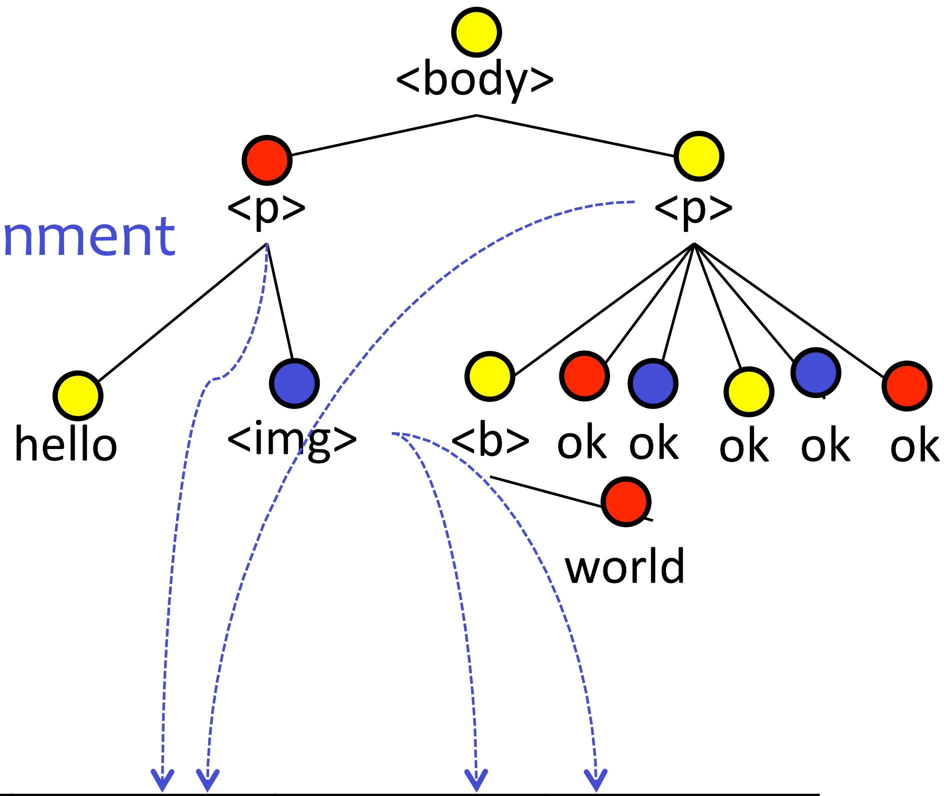
- Matching
  - Tag path (img: <body> <p> <img>)
  - Rule Selectors
  - For each tag path: which selectors are ~substrings?
- Rule resolution
  - Prioritize properties by rule order: lower overrides



selectors	p	img	p img
properties	width=100%	width=100px float=left	width=100px

Rule Matching: Parallelization

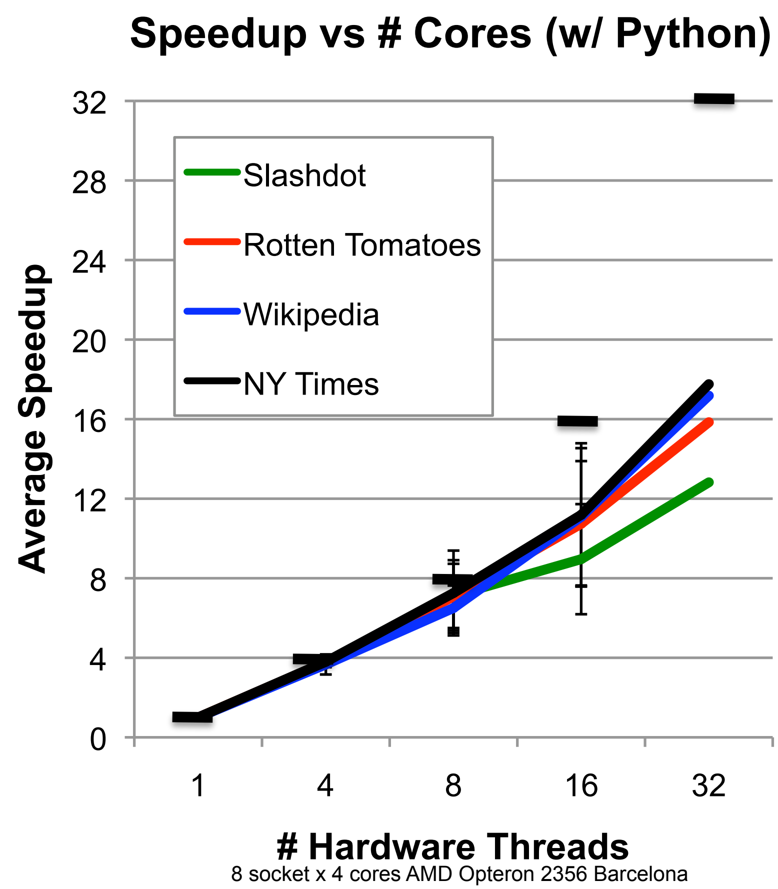
- ~600 nodes, 1000s rules
- Assign nodes to cores
  - load balancing: random assignment
- SIMDizable?



selectors	p	img	p img
properties	width=100%	width=100px float=left	width=100px

Analysis

- Results
  - perfect scaling: up to 10 cores
  - 20x speedup on 32 cores
  - … but with python
    - interp. overhead (seq.)
    - procs., not threads
- Future
  - C++ implementation
  - SIMD rule matching



Takeaways

- Artifacts
  - BSS/CSS specification & dependency decomposition
  - 4x solving speedup (untuned), 20x matching (in python)
- Lessons
  - 4x << 100x → SIMDize low-level libraries (e.g., fonts)
  - motifs: low latency tree ops, vectors, pixel blending
  - attribute grammars helped
- Next steps
  - tune tasks, SIMD kernels, bigger scope of model
  - implications for concurrent scripts using layout?

(questions?)