Efficient, Parallel Mobile Web Browser

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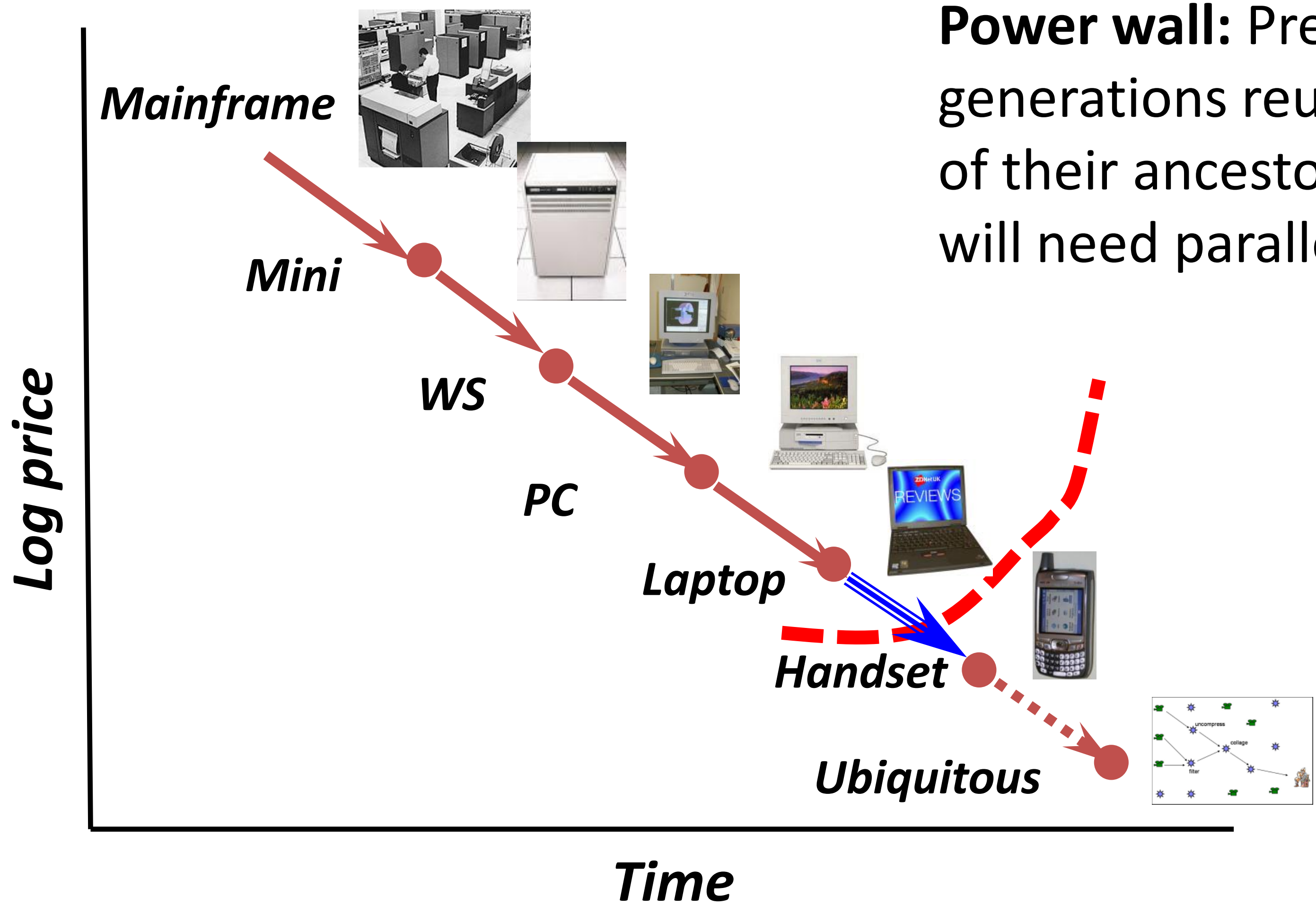
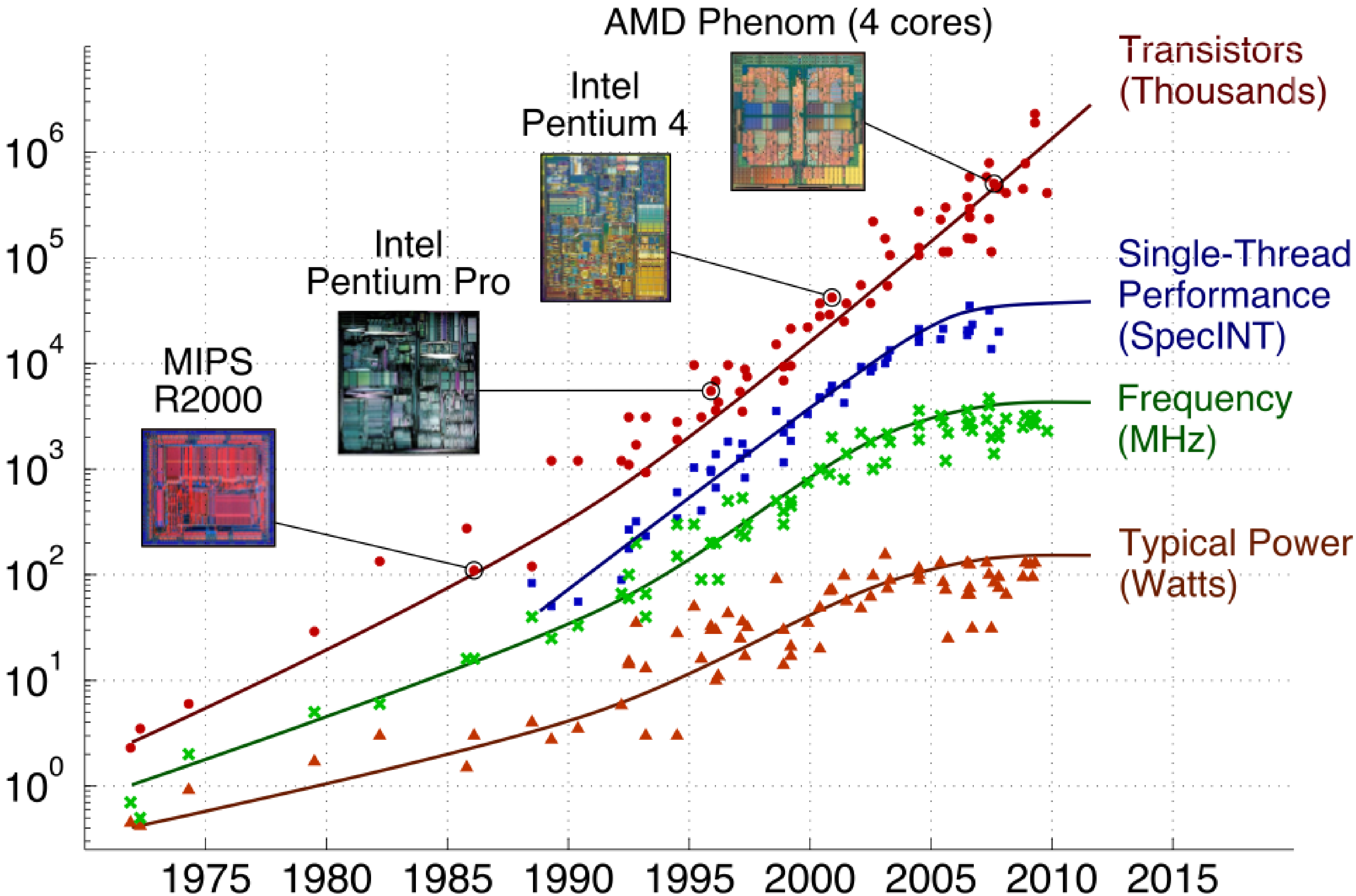
The Transition to Handhelds



Power wall: Previous generations reused software of their ancestors. Mobiles will need parallel software.

Soon on mobile: 4-cores x 2-threads x 8-SIMD = 64-way parallelism

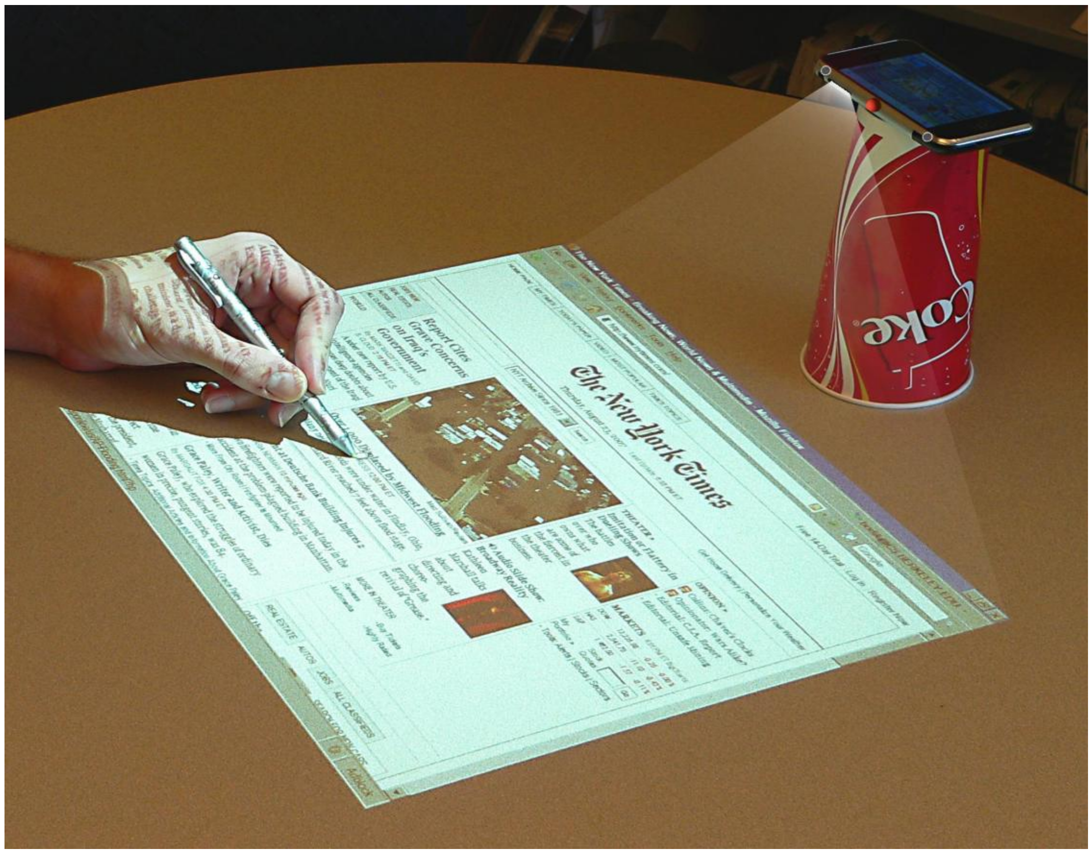
Problem: Power Wall for Individual Threads



(C. Batten, M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond)

Handhelds may soon replace laptops

A guy walks into a bar, asks for a cup, and starts his browser.



Let's see why this "tablet phone" may actually appear soon...

Can handhelds make laptops unnecessary?

Hypothesis: laptops become largely unnecessary if handhelds can provide *laptop-quality web browser*

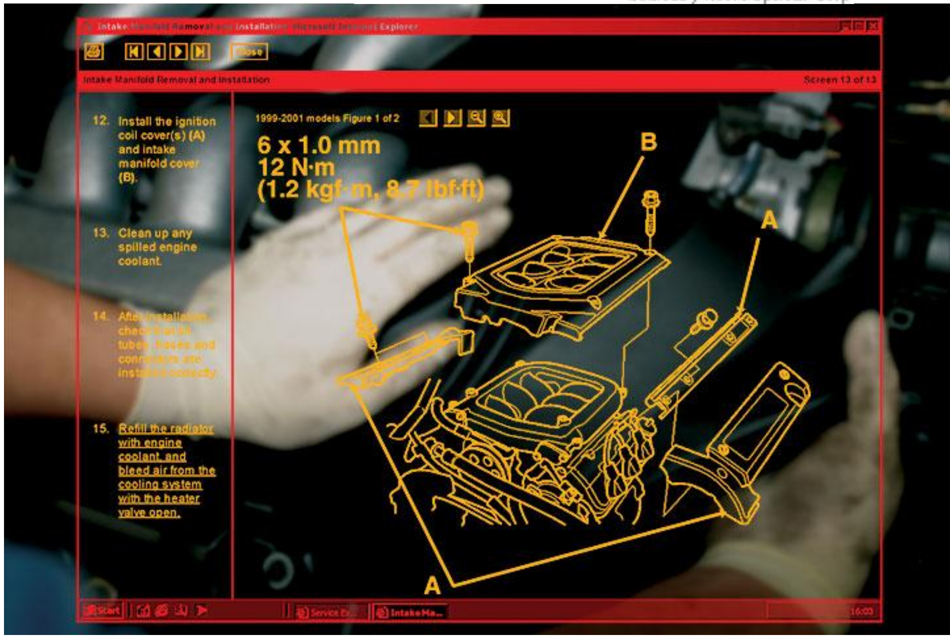
For that, we need

- **network:** 50Mbps
- **display:** at least 1024x768
- **input:** keyboard-like rate

All three are forthcoming …

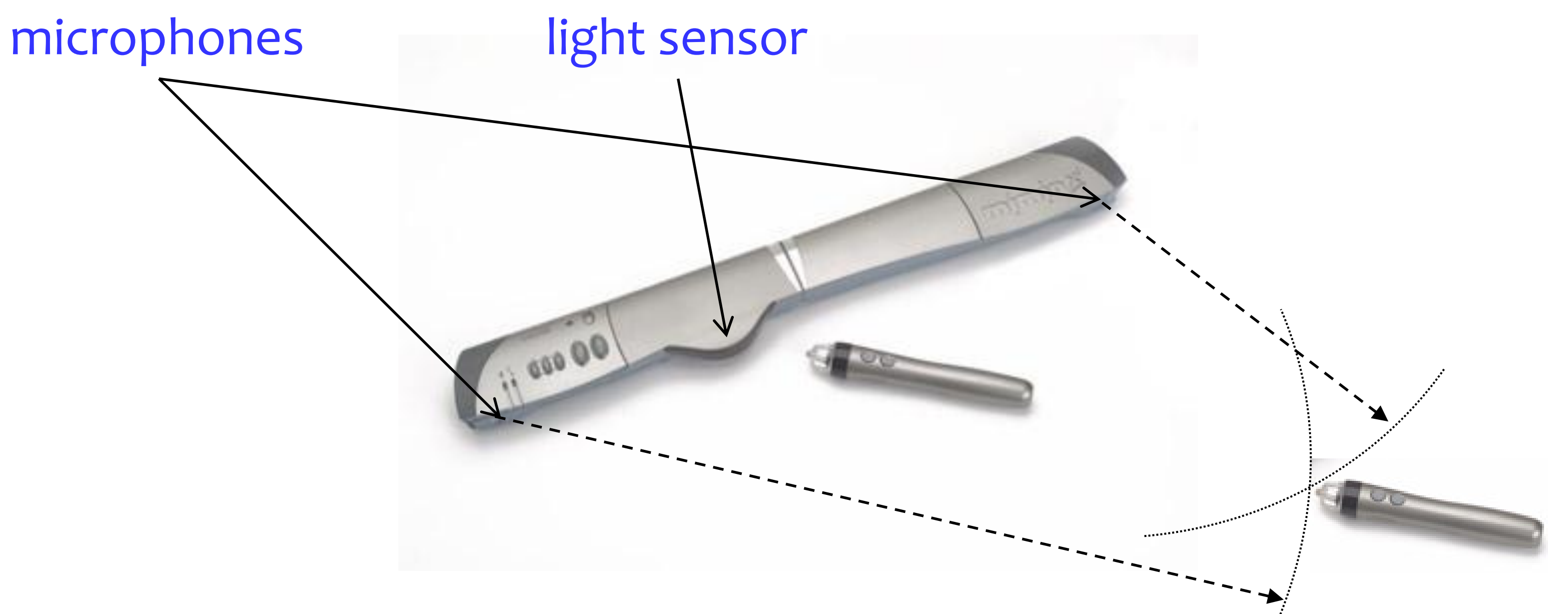
Output Alternatives


Courtesy MicroOptical Corp



Input: idea for tablet input for a handheld

Inspiration: mimio, a whiteboard recorder (mimio.com)



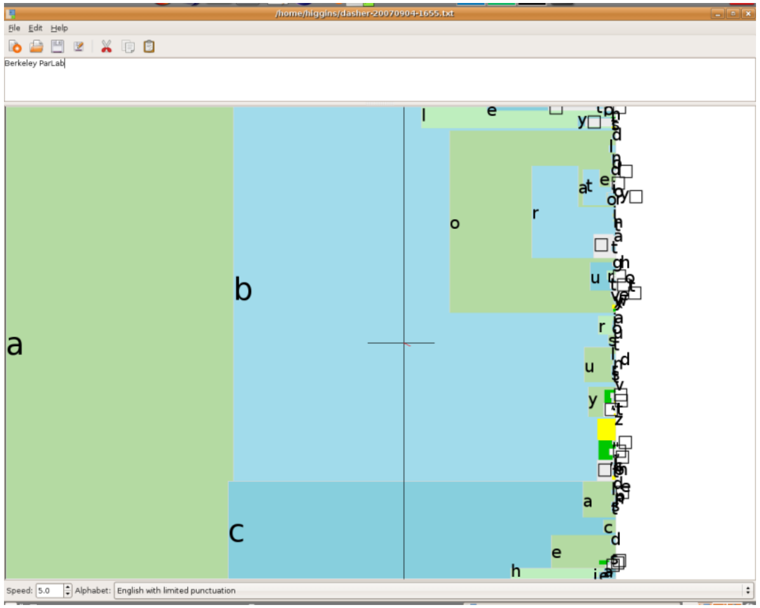
How mimio works:
triangulates in the same way that one measures lightning distance

1. marker simulates a lightning strike: simultaneously emits light and sound signals;
2. capture bar measures sound travel time: yields marker distance to each mic;
3. the two distances determine marker location on the whiteboard; goto step 1

Dasher + picomimio = keyboard-rate input

Dasher: replacement for traditional keyboards

- Input rates up to ~30 words/minute
- Only needs 1 input axis (up/down) to work
  - can be controlled by picomimio, eyes, tilt sensor, …



See http://www.inference.phy.cam.ac.uk/dasher/ for more info, online demo

Why Parallelize a Browser?

Dominant application platform

- easy deployment: apps downloaded, JS portable
- productive programming: scripting, layout

… but not on handhelds

- slow: for Slashdot, Laptop: 3s => iPhone: 21s
- native frameworks for: iPhone, Google Android

Parallel browser may need new architecture

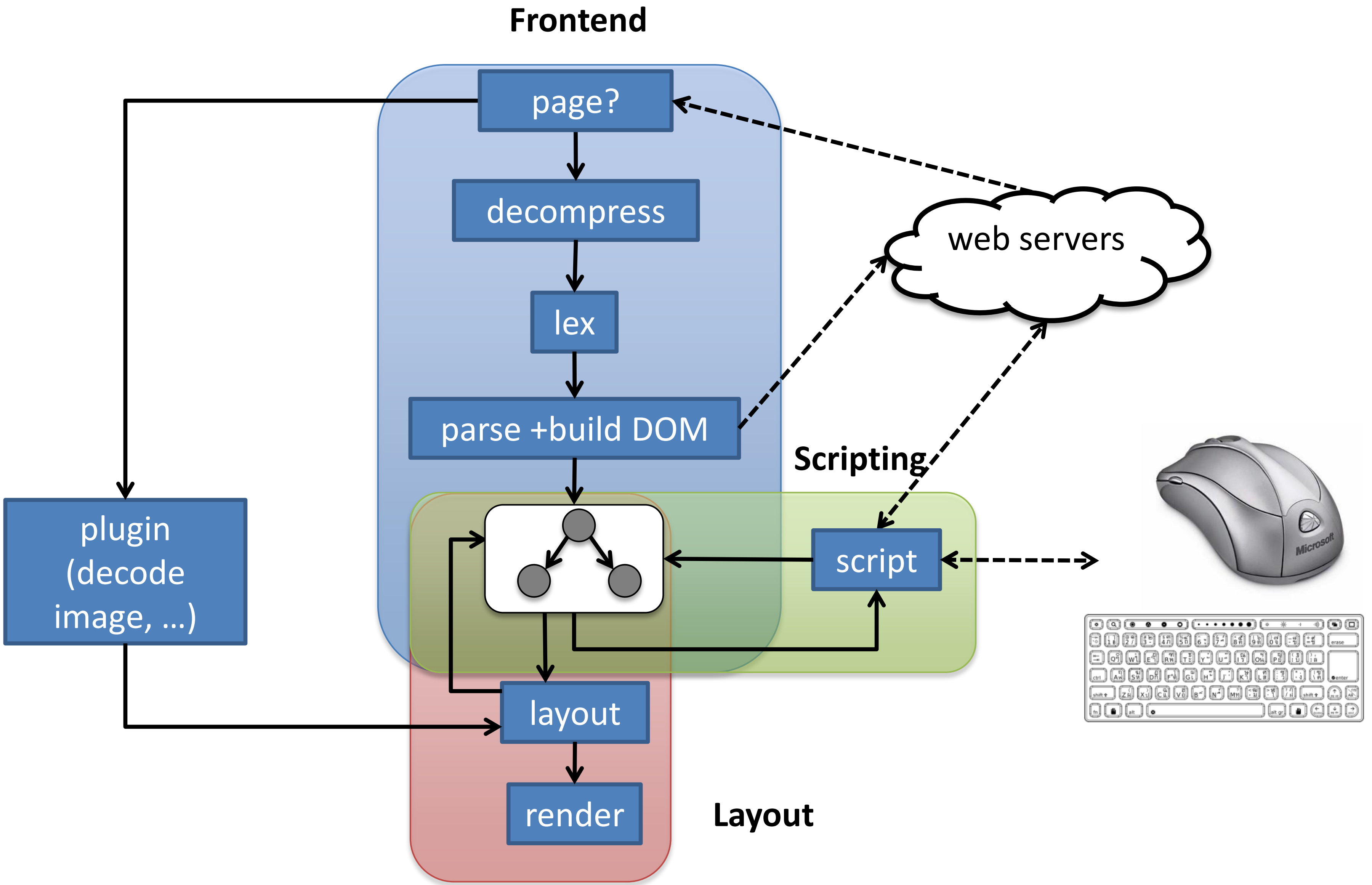
- ex: JavaScript relies on "gotos", is too serial

Run Browser on Server ?

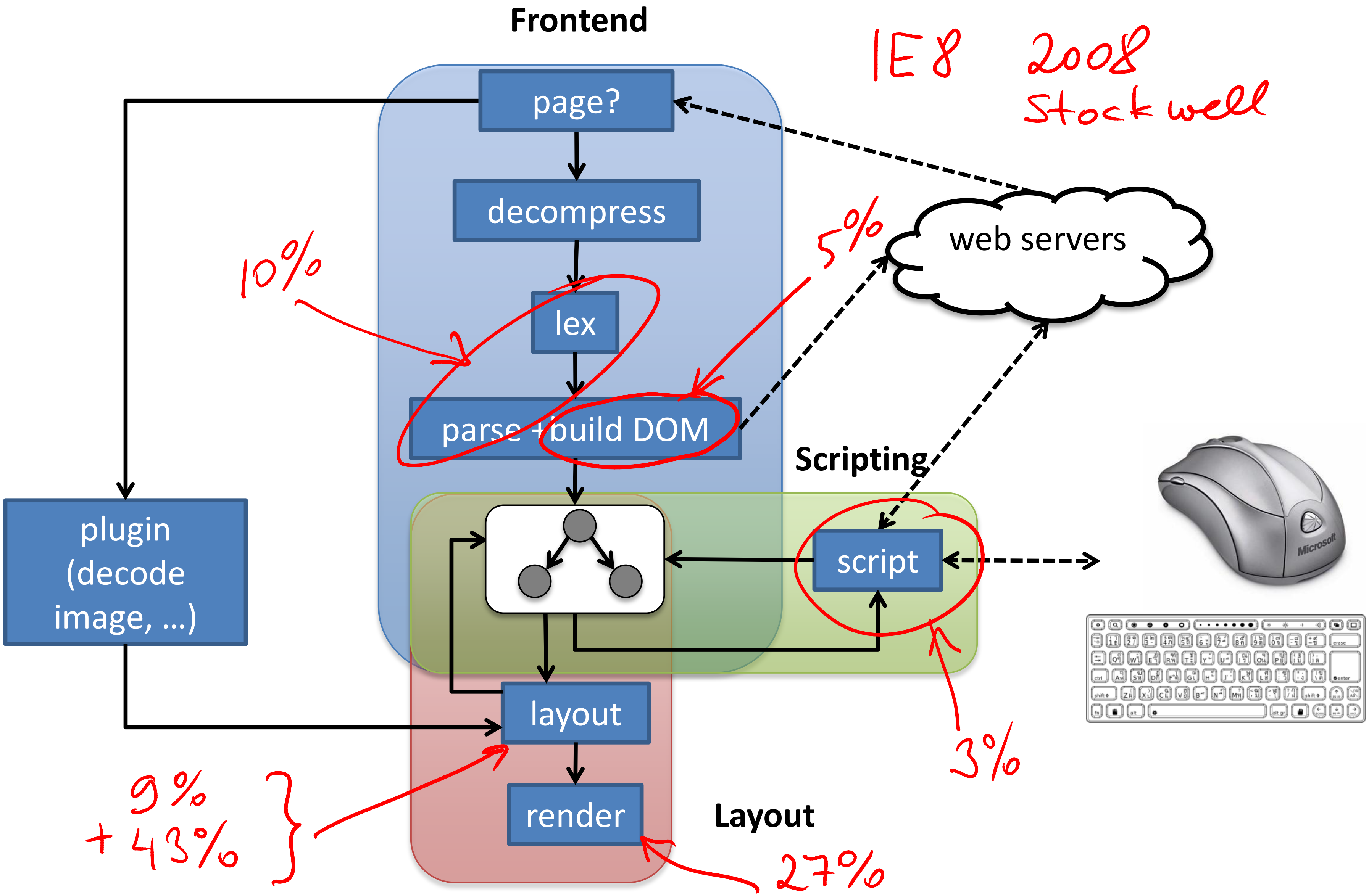
On the cloud or on nearby devices

- bandwidth: must support *all* users
- connectivity
- latency
- … *short-term* solution?

Anatomy of a Browser



Anatomy of a Browser



Project Status

Parallel algorithms for

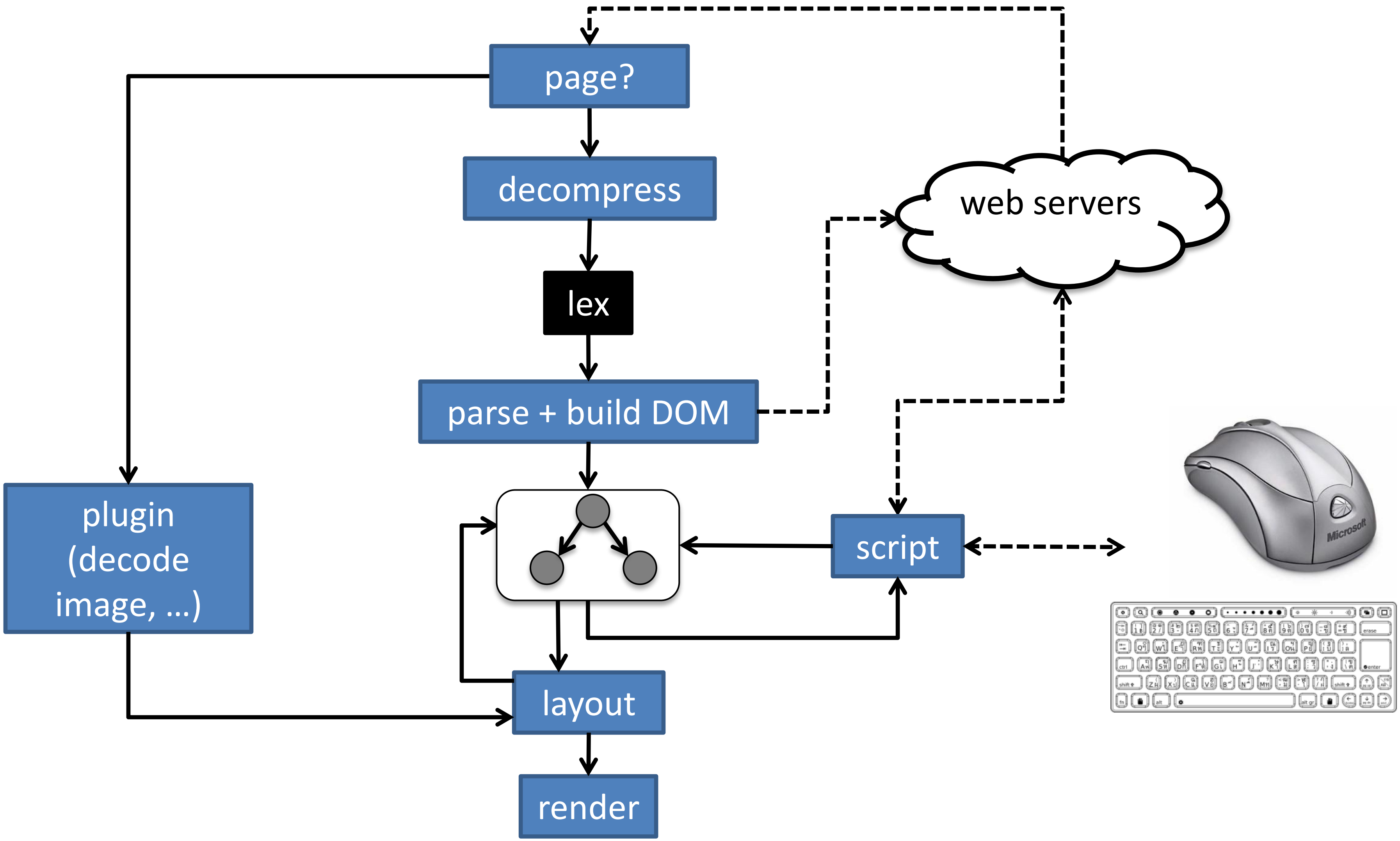
- *CSS rule matching:* parallel-map with a tiling optimization
- *Page layout*: break up tree traversal into five parallel ones
- *Lexing:* speculation to break sequential dependencies
- *Parsing*: parallel version of the popular packrat

work-efficient : no more work than sequential algo.

Designed a new scripting language

- *programmer productivity*: from callbacks to actors to constraints
- *performance*: adding structure to detect dependences

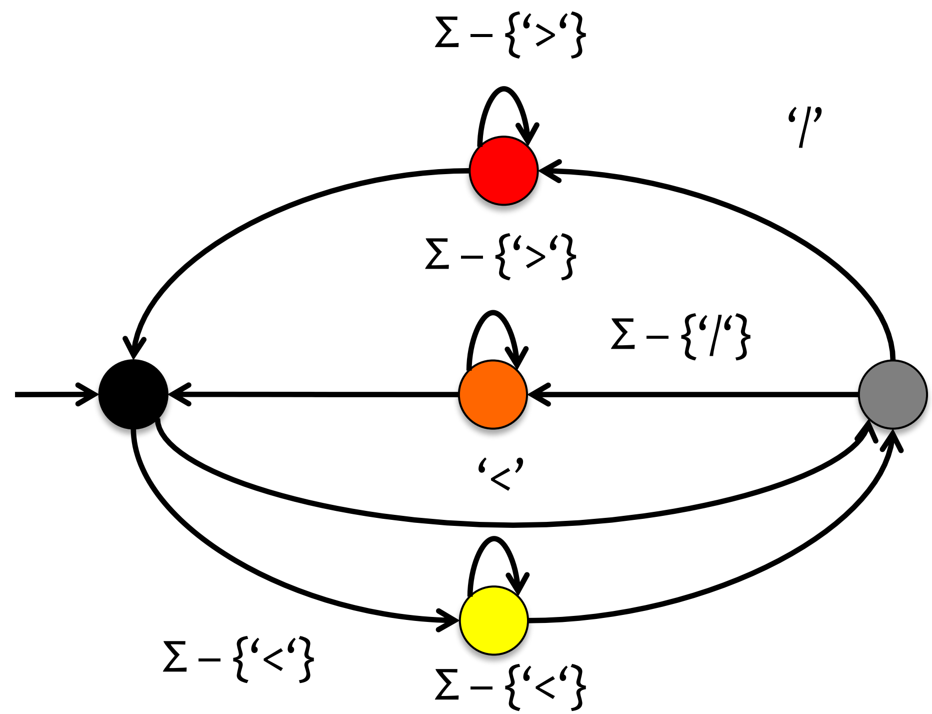
Frontend: Lexing



Lexing, from 10,000 feet

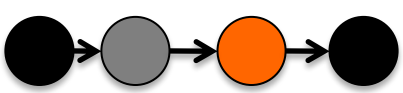
Goal: given lexical spec and input, find lexemes

```
STag    ::= <[^>]*>
Content ::= [^<]+
ETag    ::= </[^>]*>
```



STag

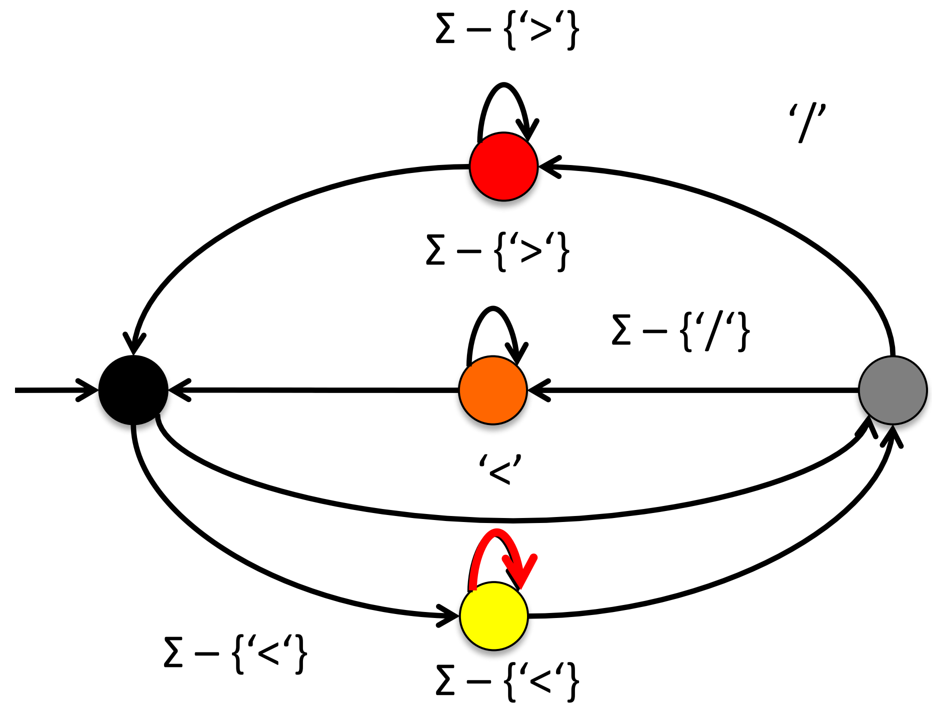
<	b	>	B	e	r	k	e	l	e	y	!	<	/	b	>

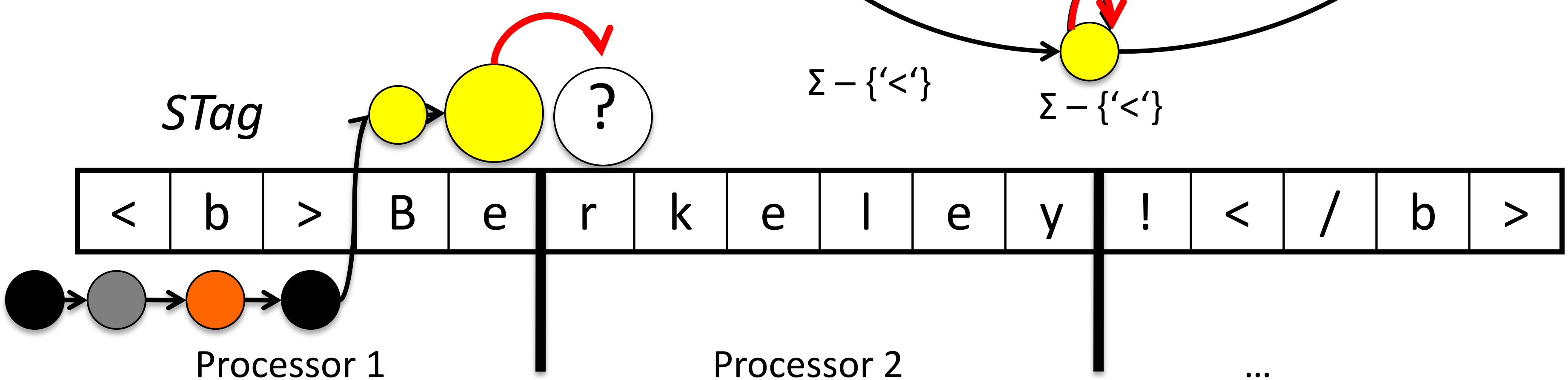


(label each character with its state)

Inherently Sequential?

```
STag    ::= <[^>]*>
Content ::= [^<]+
ETag    ::= </[^>]*>
```



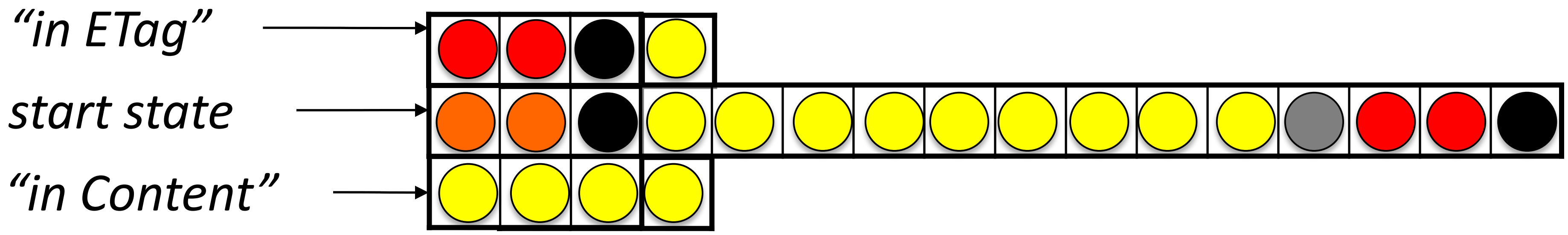


An observation

In lexing, almost regardless of where DFA starts, it converges to a *stable, recurring* state

Lexing:

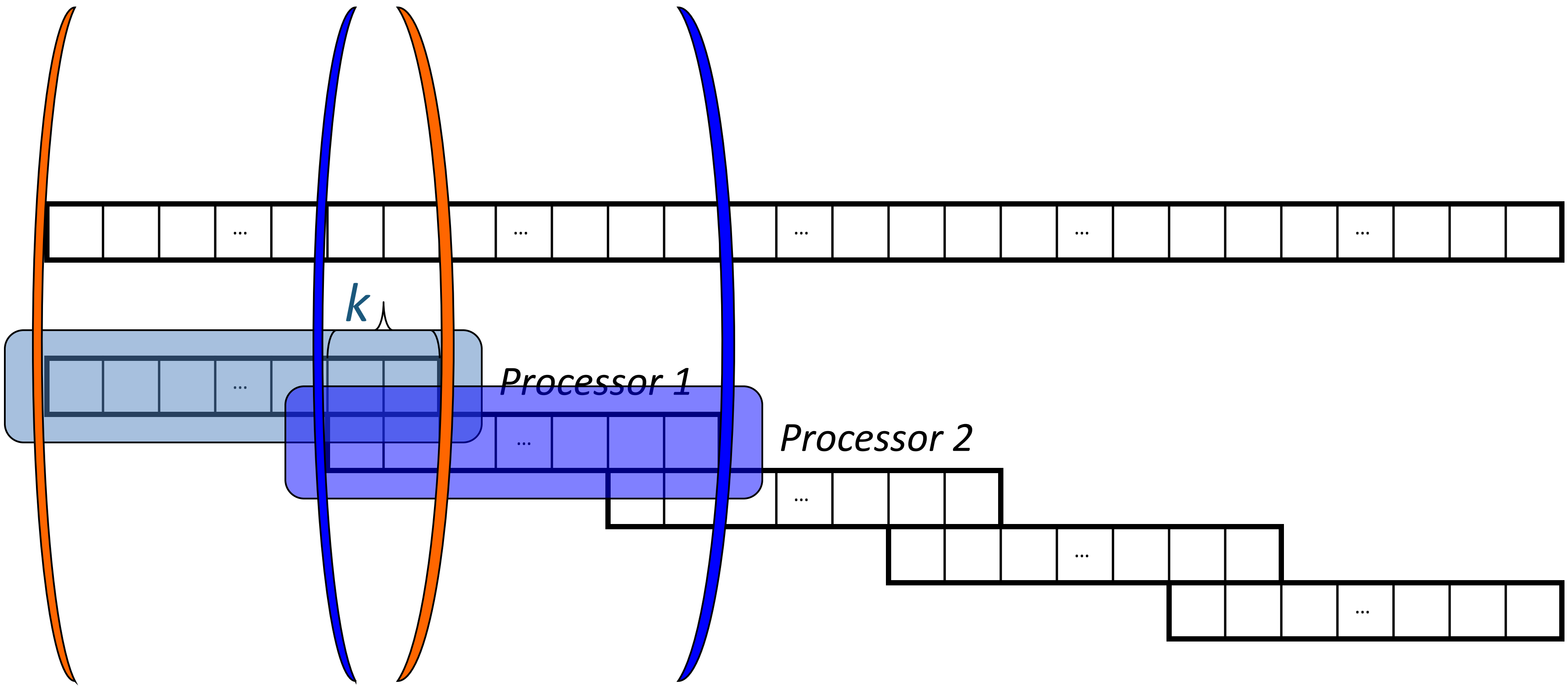
<	b	>	B	e	r	k	e	l	e	y	!	<	/	b	>



Parallel scans thus need not scan from all possible states, just one, yielding a work-efficient algorithm.

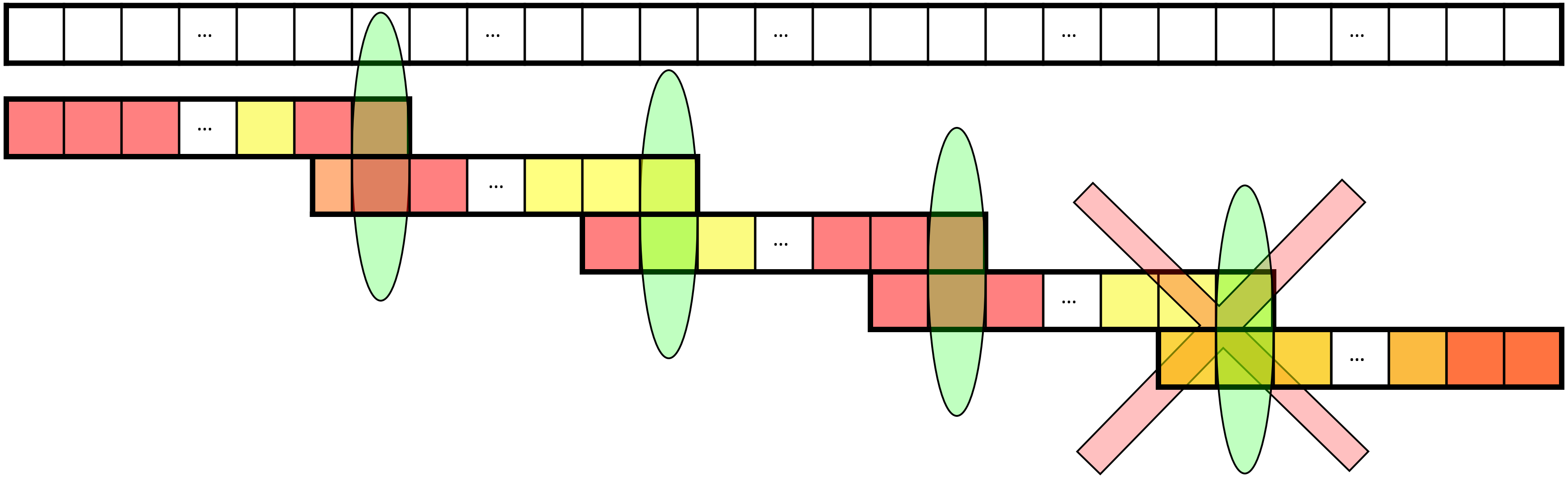
Our solution (1/2): Partition

- split input into blocks with *k*-character overlap
- scan in parallel; start block from a *tolerant* state

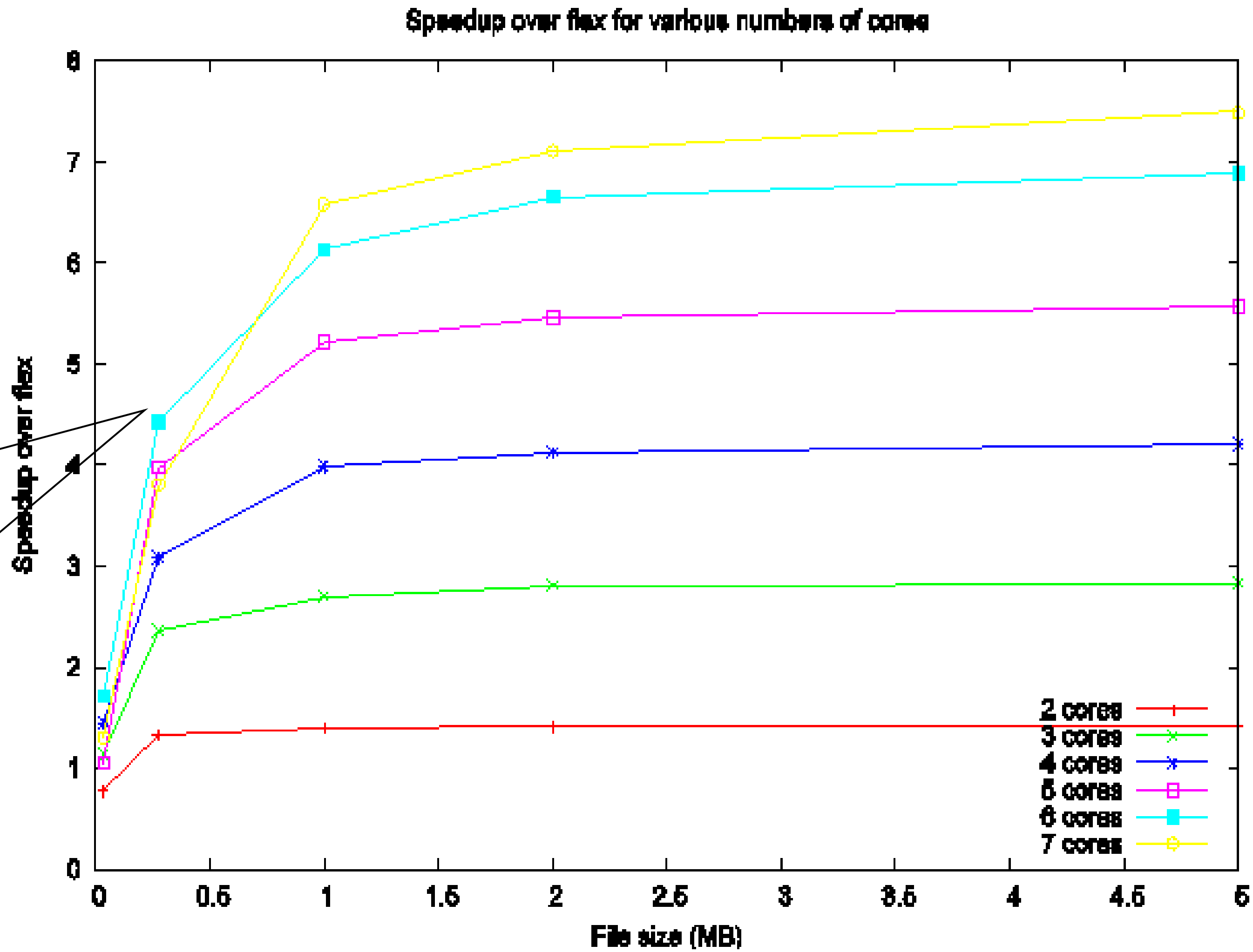


Our solution (2/2): Speculate

- split input into blocks with *k*-character overlap
- scan in parallel; start block from a *tolerant* state
- check if blocks converge: expected in *k*-overlap
- speculation may fail; if so, block is rescanned



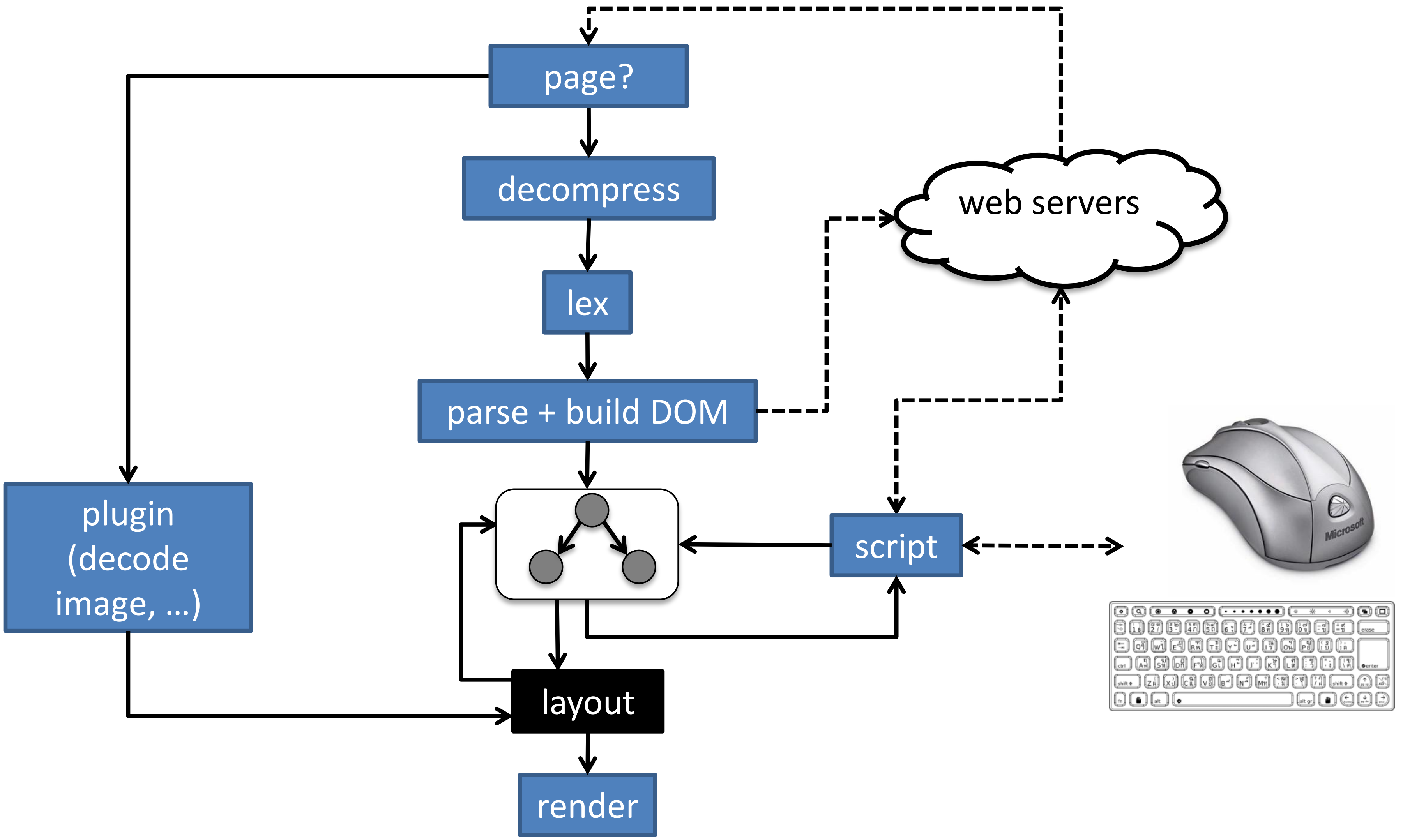
Speedup: Flex vs Cell



today's page sizes*: 5 cores are 4.5x faster than flex*

baseline: (sequential) flex on the CELL main CPU

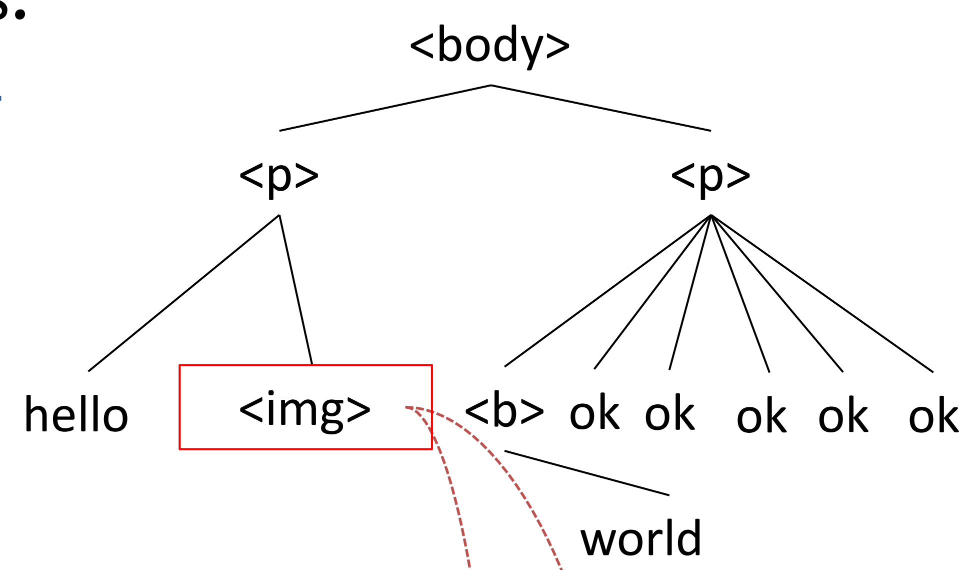
Layout Solving (1/2)



Rule Matching

Goal: Match rules with nodes:

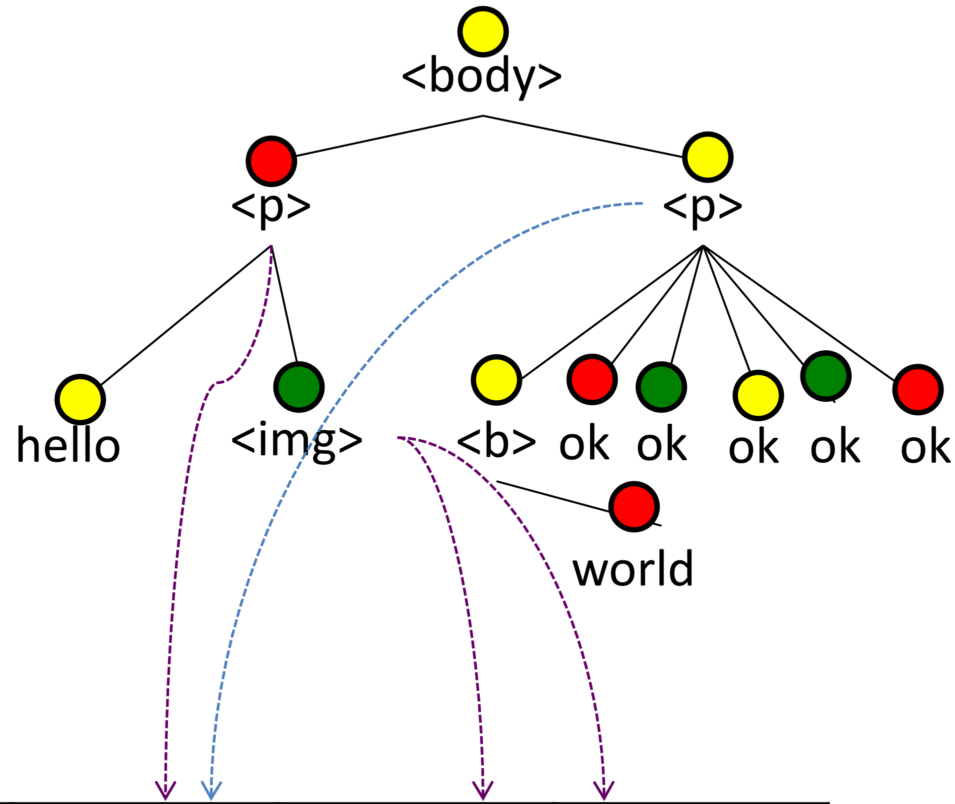
- a rule: p img { fontsize: 7px}
- rule-to-path matching:
  - rule is a substring of path
  - ends with same node



selectors	p	img	p img
properties	height=83%	width=100px float=left	fontsize=7px

Parallelization

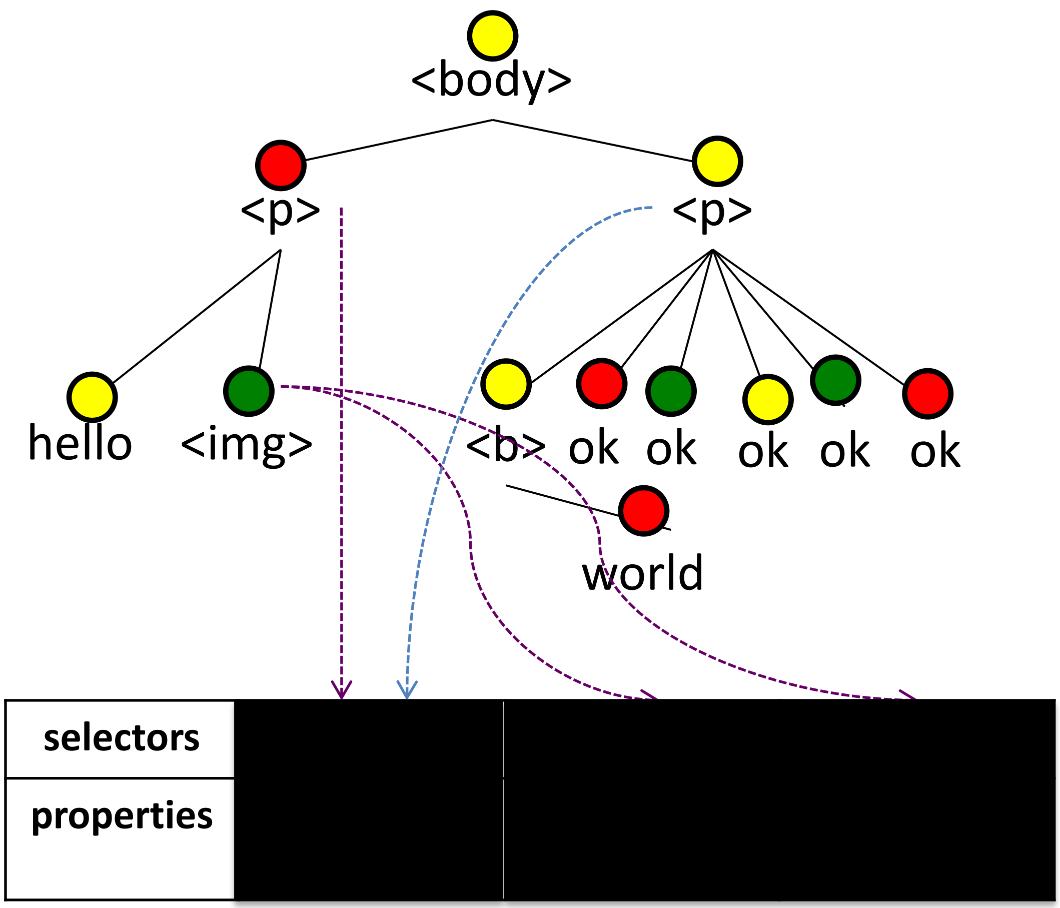
- 1000s nodes, 1000s rules
- assign nodes to cores



selectors	p	img	p img
properties	height=83%	width=100px float=left	fontsize=7px

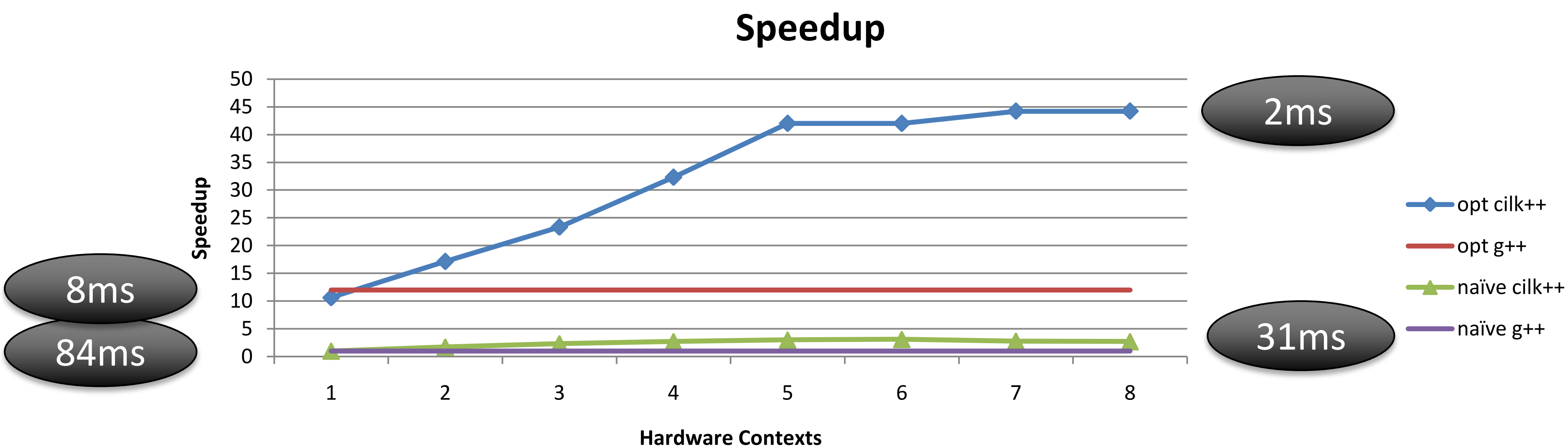
Tiling for Caches

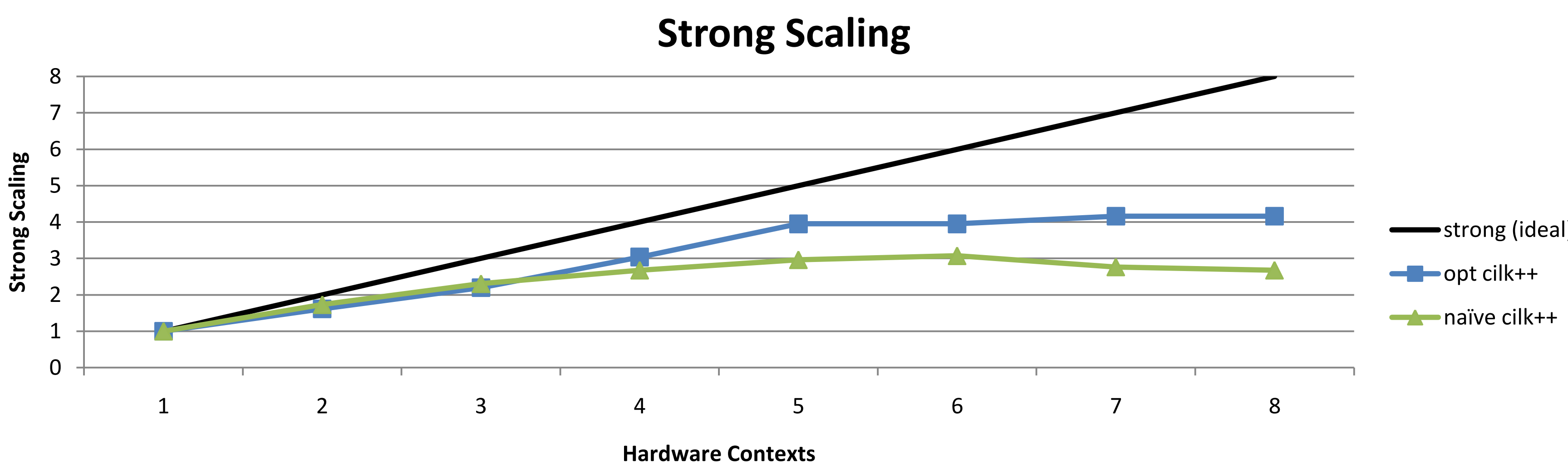
Problem: all the nodes + selectors might not fit in cache!



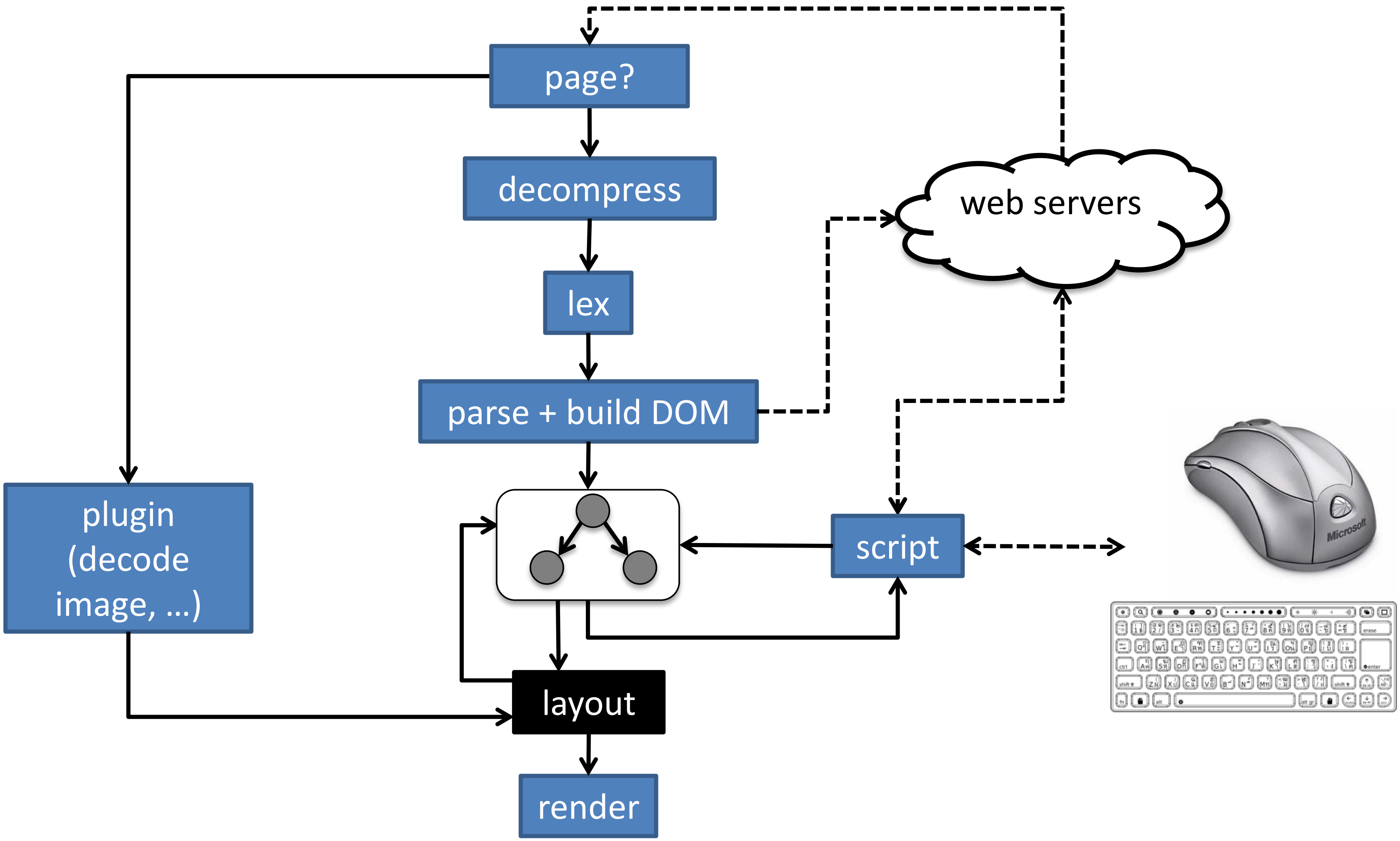
Performance: Slashdot

4 cores x 2 thread (2.66 GHz, 256KB L2, 8MB L3)

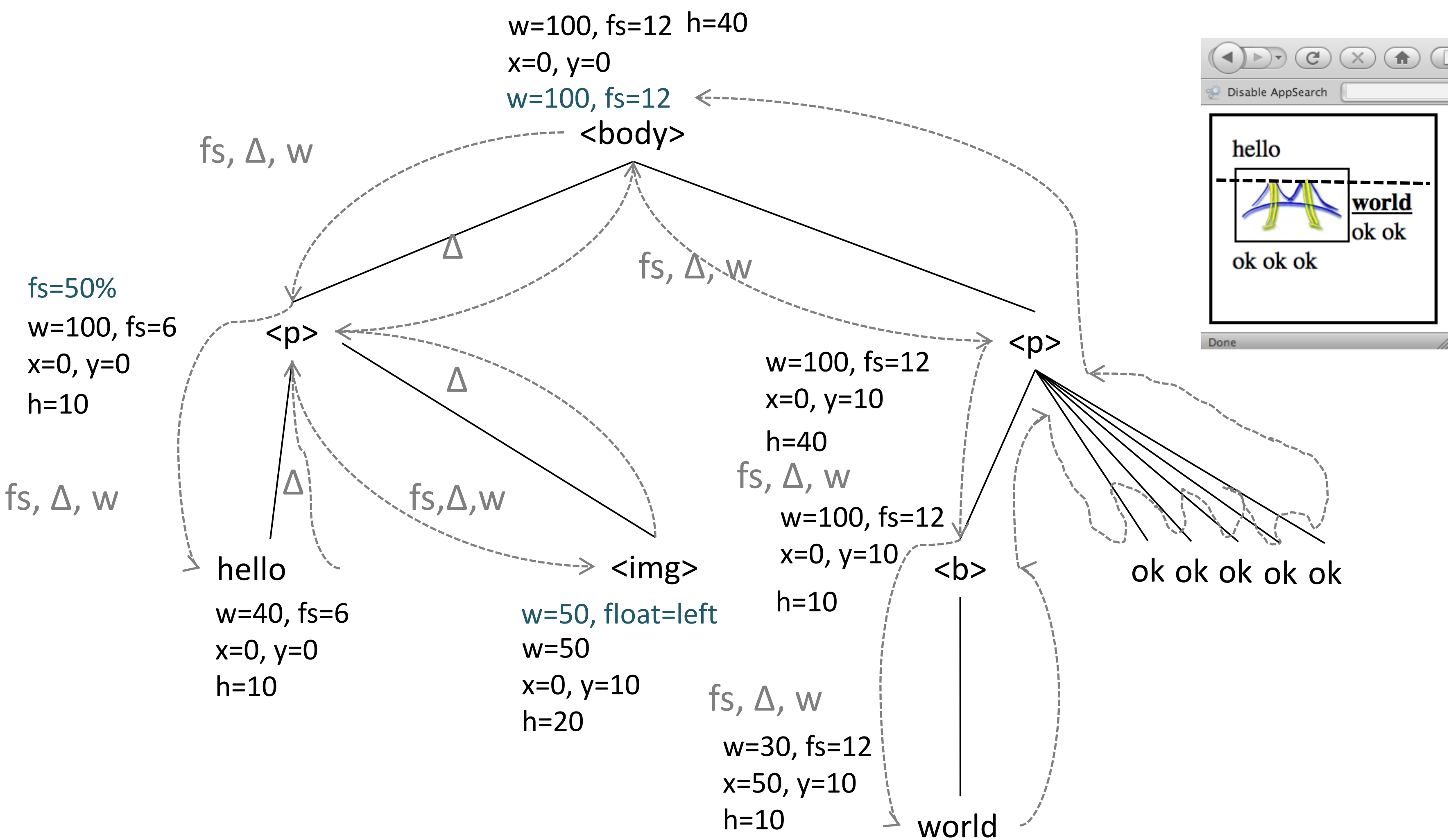




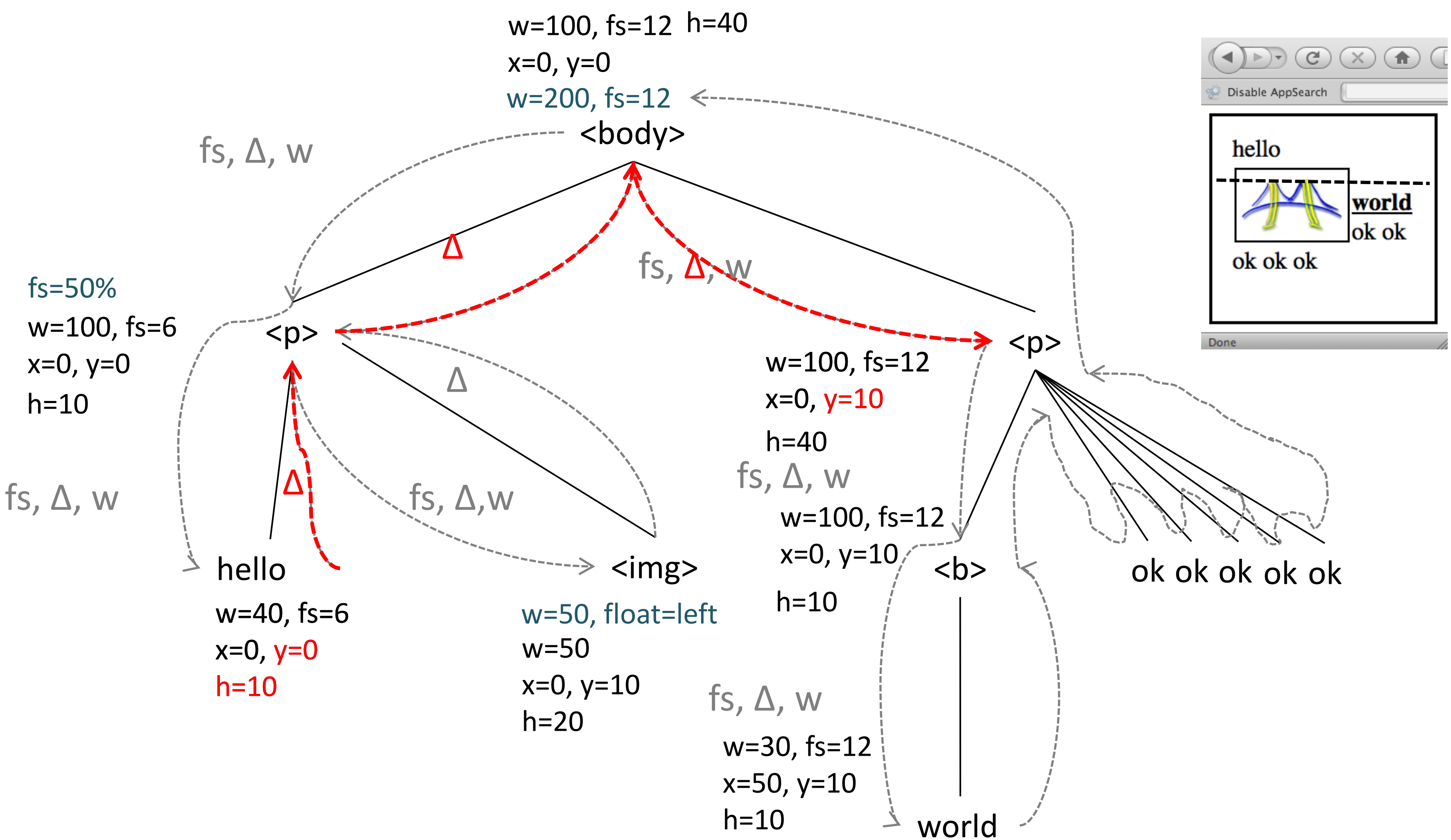
Layout Solving (2/2)



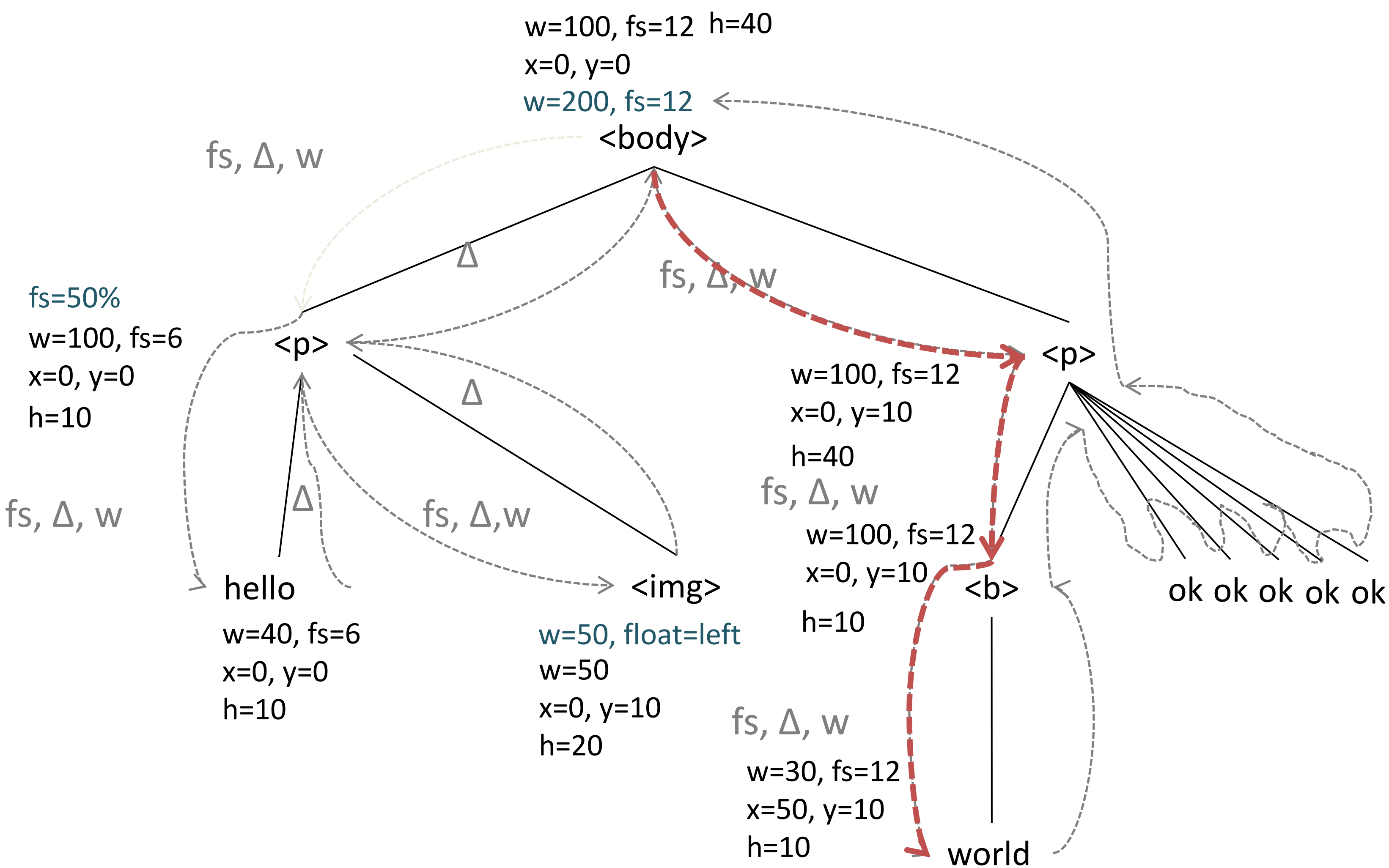
Problem: Layout a Page



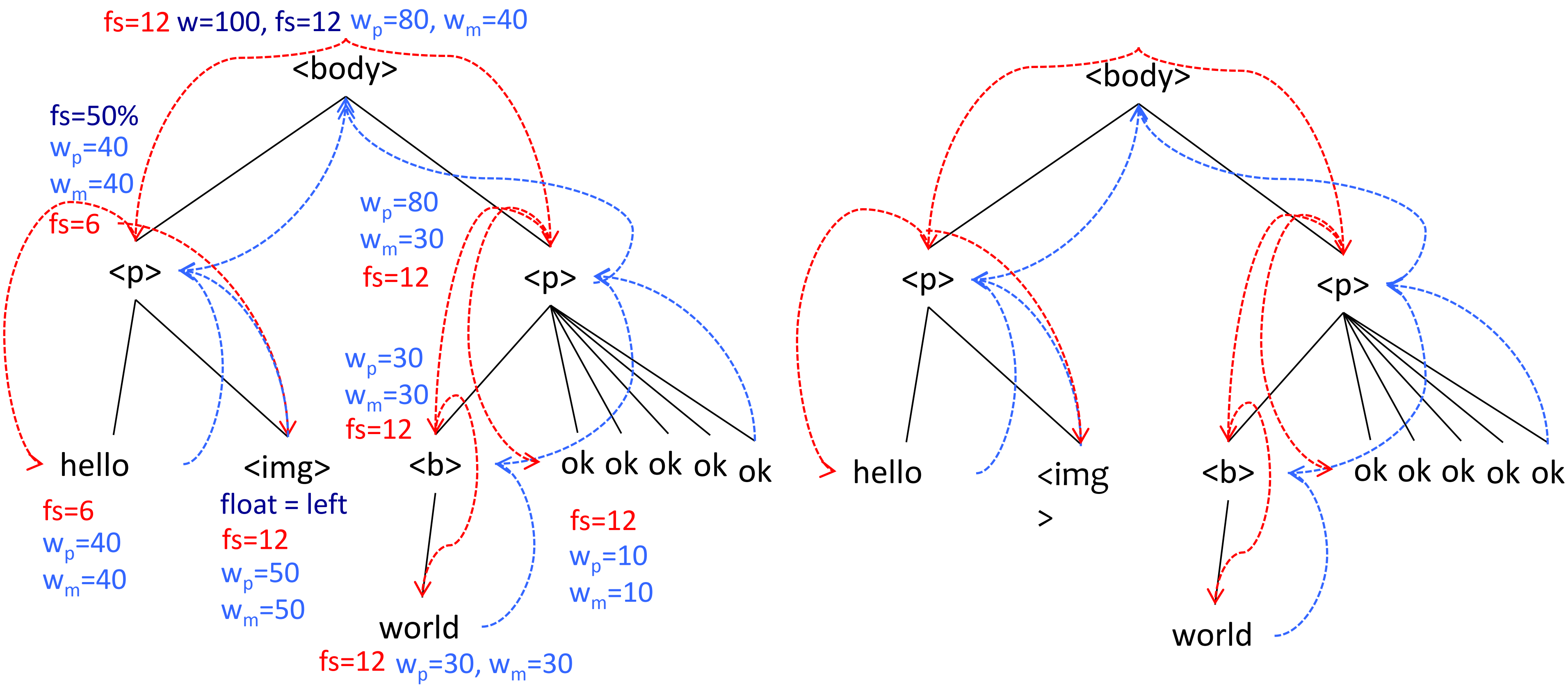
It looks rather sequential..



But not entirely



5 Phases: Each Exhibits Tree Parallelism



Phase 1: font size, temporary width

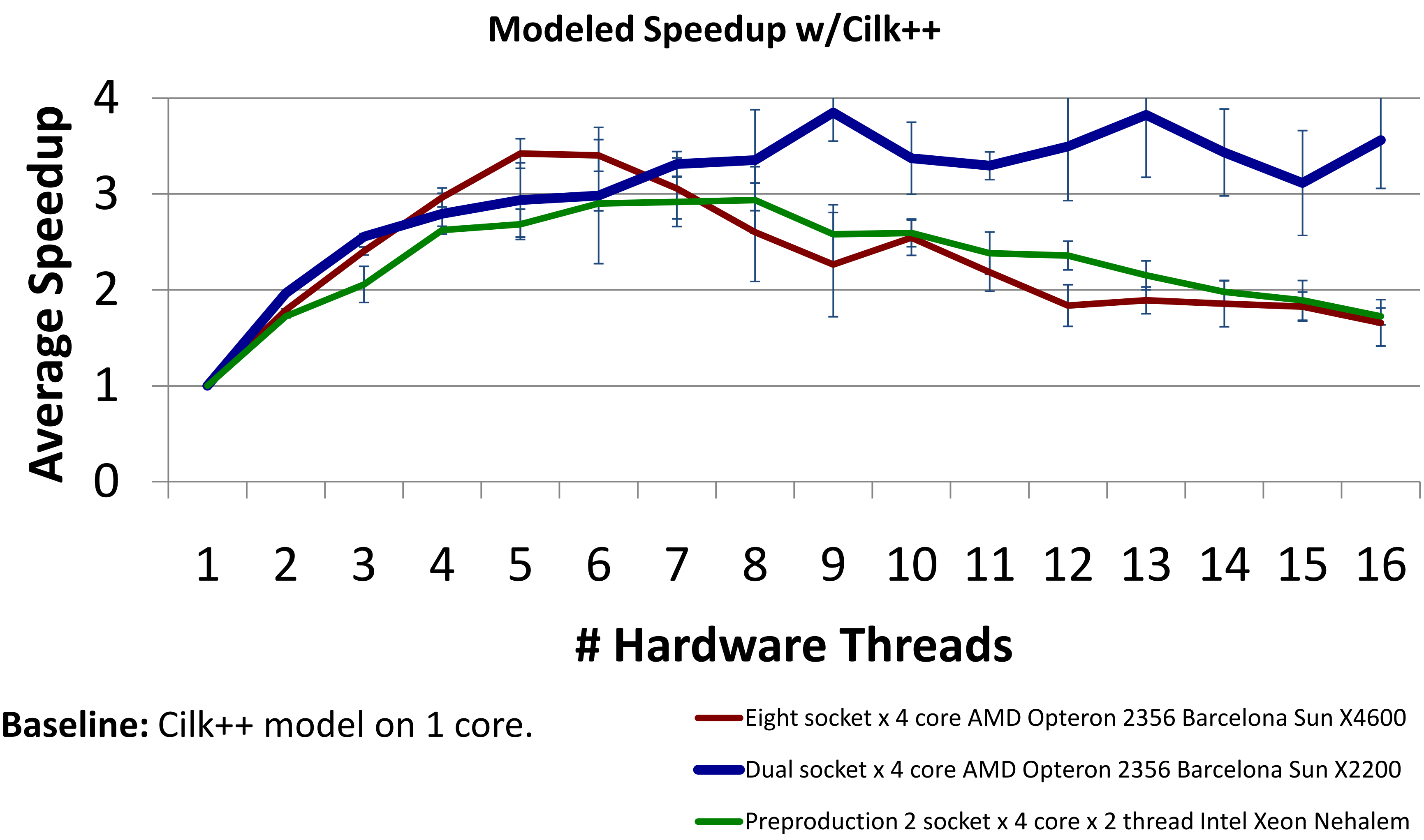
Phase 2: preferred max & min width

Phase 3: solved width

Phase 4: height, relative x/y position

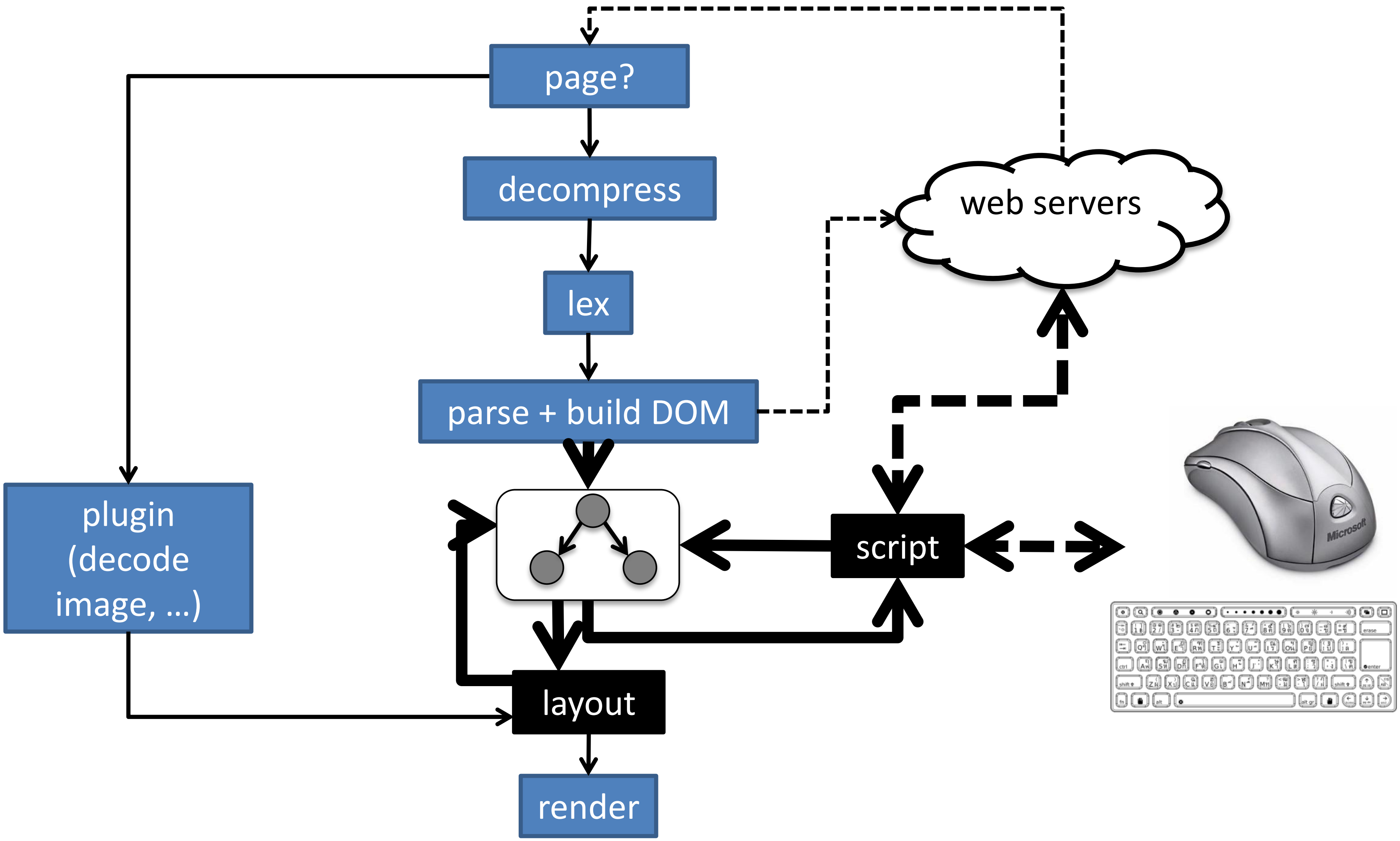
Phase 5: absolute x/y position

Results: layout (*modeled*)

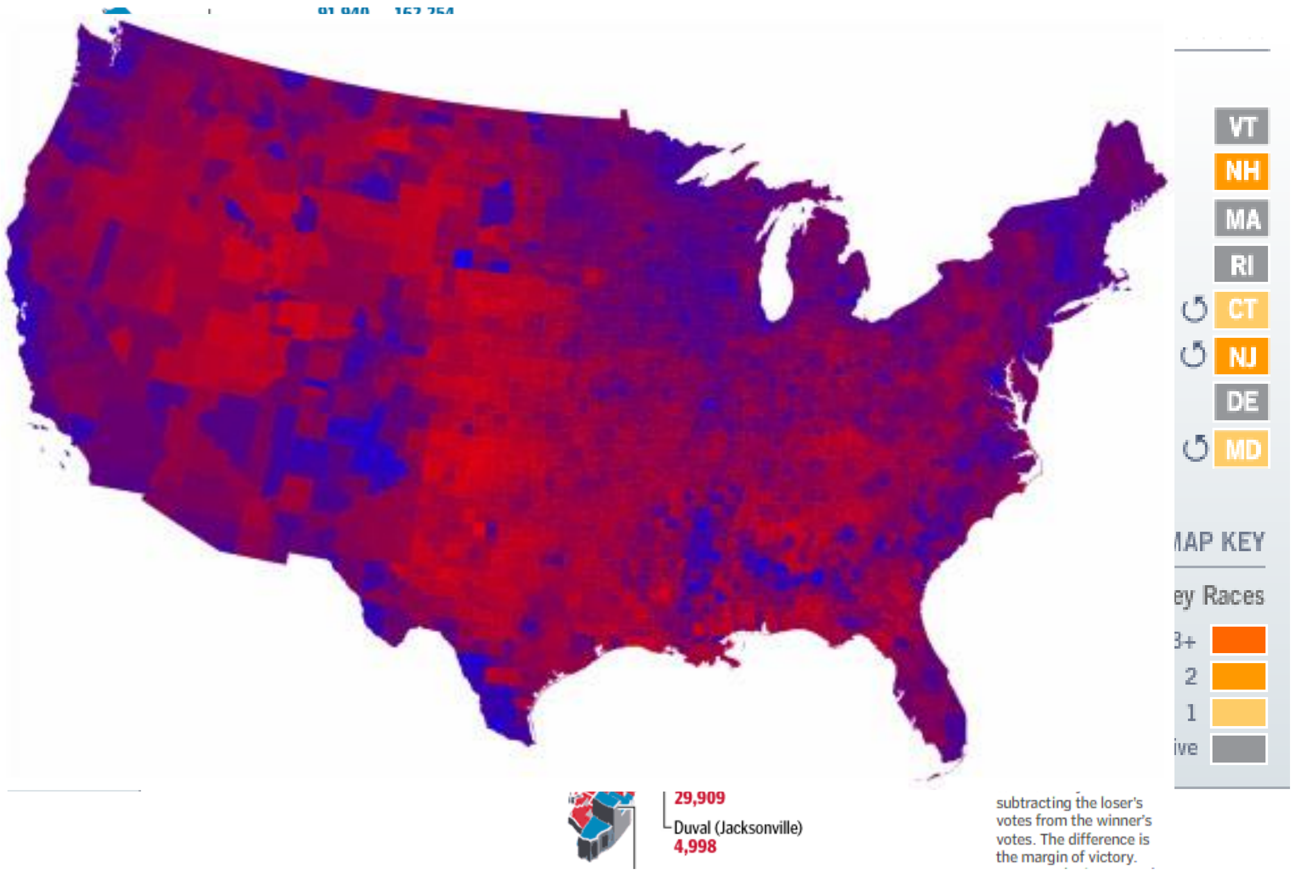


Baseline: Cilk++ model on 1 core.

Scripting


page?
decompress
lex
parse + build DOM
web servers
plugin (decode image, …)
script
layout
render

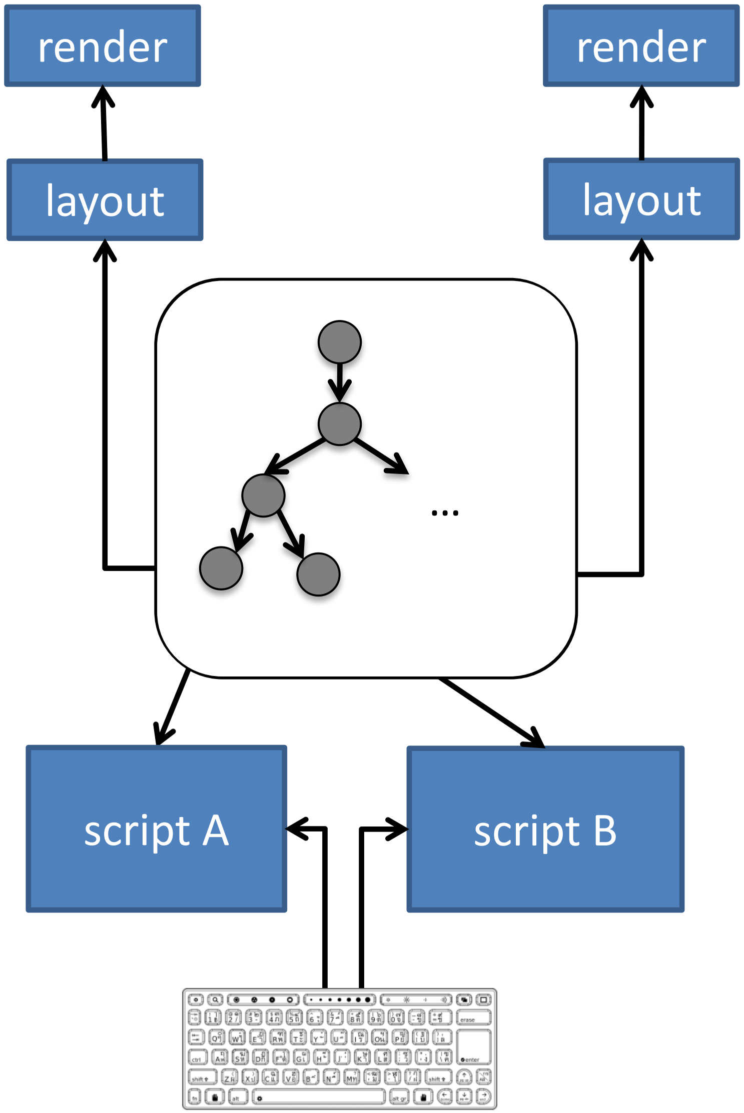
Why parallelize scripting (example)



Example: animate between different views

- each transition: recolor, resize each state or county
- animation rate 30fps => 33ms for 1000s of nodes

The browser programming model



- Nonpreemptive event model
- Handlers respond to events
- Handlers execute atomically
  - document changes cause relayout
  - style changes cause relayout

- To parallelize, must understand how the document is shared
  - document-carried dependencies:
    handler A:california.x =100;
    handler B:varz = california.x;
  - layout-carried dependencies:
    handler A:america.w = 200%;
    layout: california.w = 200%;
    handler B:varz = california.w;

Concurrency bugs

1. GUI animations and interactions
   – several animations modifying an object simultaneously
2. Server interactions
   – responses to requests may be delayed, reordered
3. Eager script loading
   – executing a script on a document before done loading

“Gotos” in JavaScript

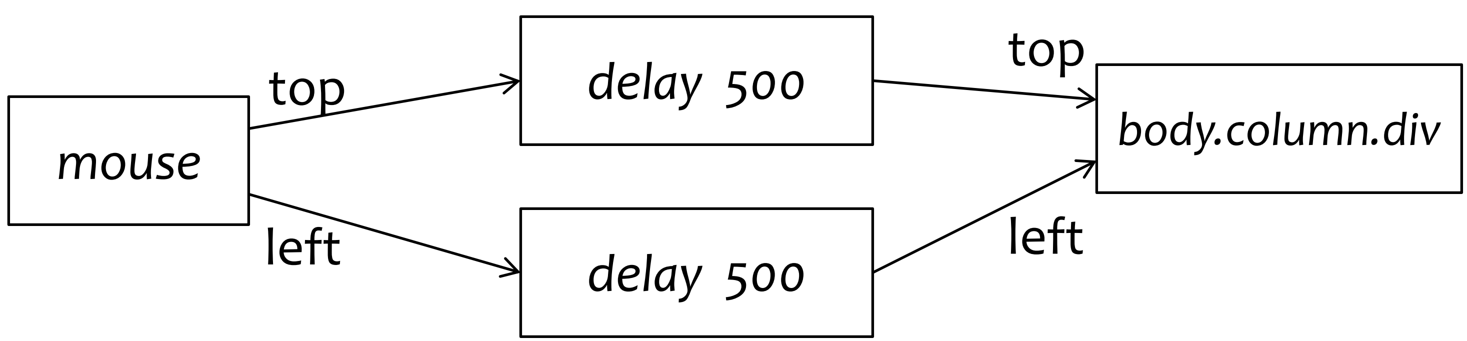
```
<div id="box" style="position:absolute; background: yellow;”>
  My box
</div>

<script>
document.addEventListener (
    'mousemove',
    function (e) {
        var left = e.pageX;
        var top = e.pageY;
        setTimeout(function() {
            document.getElementById("box").style.top = top;
            document.getElementById("box").style.left = left;
        } , 500);
    }, false);
</script>
```

Dataflow language (version 1)

Program structure is clearer when data and control is explicit

- in dataflow version: **changing mouse coordinates are streams**
- coordinate streams adjust box position after they are delayed
- **structured names** of document element allow analysis



Summary

1. **Developed *work-efficient* algorithms**
   - *Rule matching:* parallel-map with a tiling optimization
   - *Layout*: break up tree traversal into five parallel ones
   - *Lexing:* speculation to break sequential dependencies
2. **Reexamining the scripting programming model**
   - *programmer productivity*: from callbacks toactors
     - influenced by Flapjax, Ptolemy, Max/MSP, LabVIEW
   - *performance*: adding structure to detect dependences
     - current browsers: JIT compilation, font vectorization, task parallelism eg for image rendering – all these are useful, too.