

TreeJuxtaposer: Scalable Tree Comparison using Focus+Context with Guaranteed Visibility

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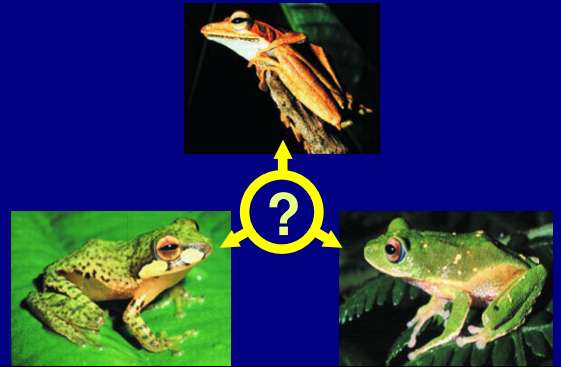
1

Tree comparison

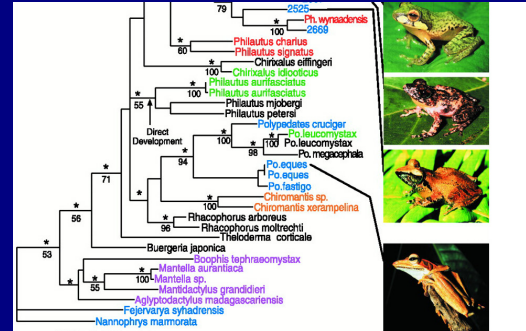
- Active area: hierarchy visualization
 - previous work: browsing
 - comparison still open problem
- Bioinformatics application
 - phylogenetic trees reconstructed from DNA

2

Inferring species relationships



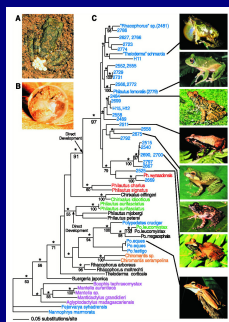
Phylogenetic tree



M Meegaskumbura et al., Science 298:379 (2002)

4

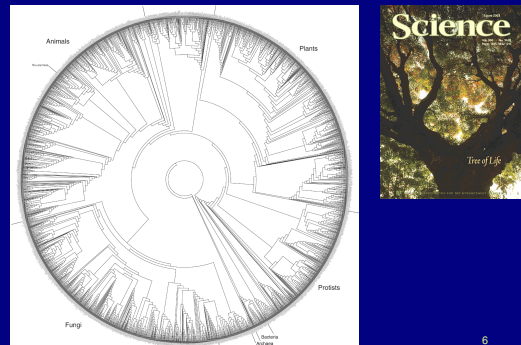
Phylogenetic tree



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5

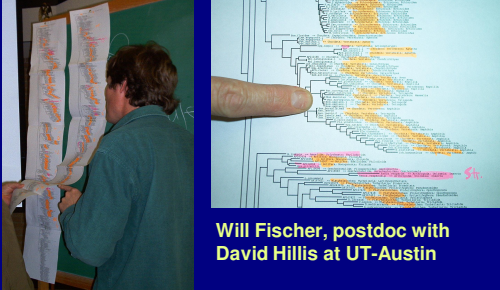
Tree of Life: 10M species



David Hillis, Science 300:1687 (2003)

6

Comparing trees: current practice



Will Fischer, postdoc with David Hillis at UT-Austin

7

Biologists' requirements

- Reliable detection of structural differences
 - rapid identification of interesting spots
- Analysis of differences in context
 - mostly side by side comparison
- Manipulation of increasingly larger trees

- Support for multiple platforms

8

TreeJuxtaposer contributions

- Interactive tree comparison system
 - automatic detection of structural differences
 - sub-quadratic preprocessing
 - efficient Focus+Context navigation and layout
 - merge overview and detail in single view
 - guaranteed visibility under extreme distortion
- Scalable
 - dataset size: handles 280K – 500K nodes
 - display size: handles 3800x2400 display

9

TreeJuxtaposer video

- Platforms shown
 - java 1.4, GL4Java 2.7 bindings for OpenGL
 - Windows
 - 2.4 GHz P3, nVidia Quadro4 700XGL
 - 1.1GB java heap
 - window sizes 1280x1024, 3800x2400
 - Linux
 - 3.1 GHz P4, nVidia GeForce FX 5800 Ultra
 - 1.7GB java heap
 - window size 800x600

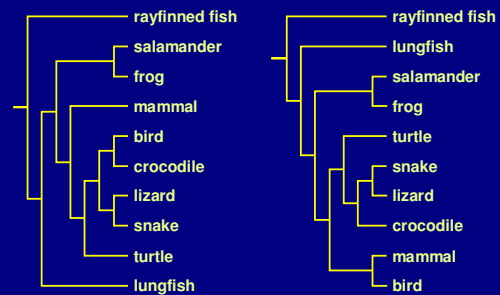
10

Outline

- Application domain: evolutionary trees
- Demonstration
- Computing structural differences
- Guaranteed visibility of marked areas
- Results and conclusions

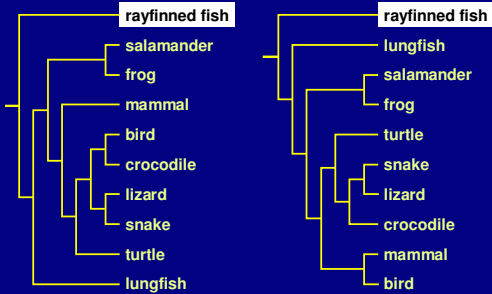
11

Comparing tree



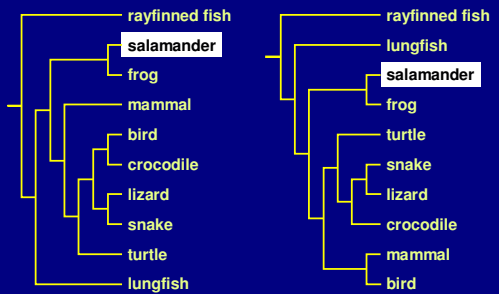
12

Matching leaf nodes



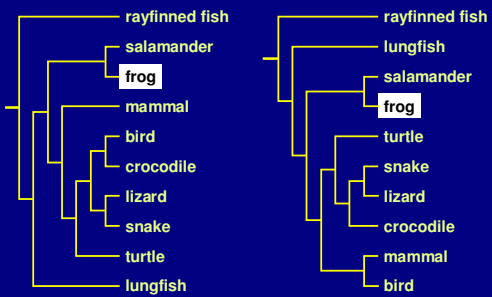
13

Matching leaf nodes



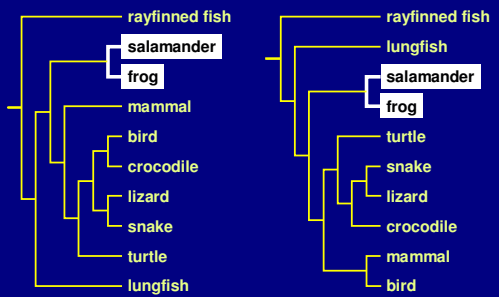
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Matching leaf nodes



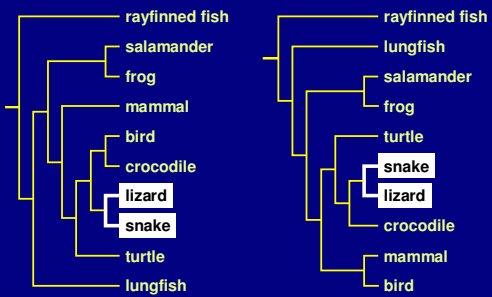
15

Matching interior nodes



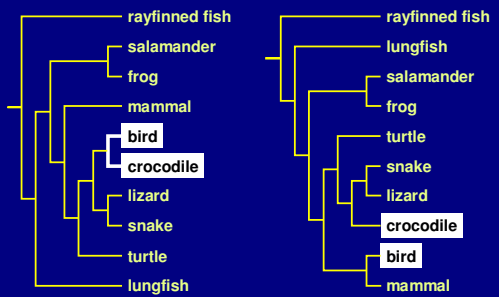
16

Matching interior nodes



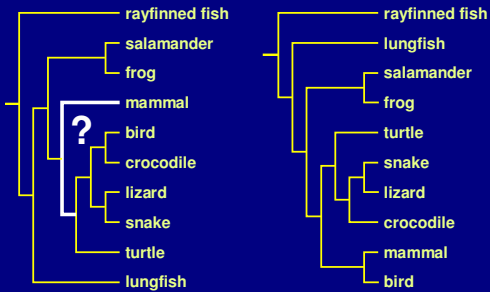
17

Matching interior nodes



18

Matching interior nodes



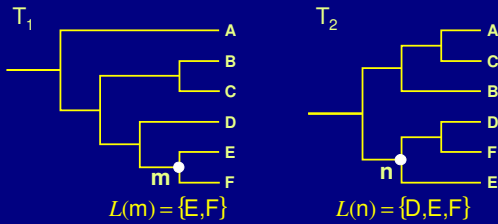
19

Previous work

- Tree comparison
 - RF distance [Robinson and Foulds 81]
 - perfect node matching [Day 85]
 - creation/deletion [Chi and Card 99]
 - leaves only [Graham and Kennedy 01]

20

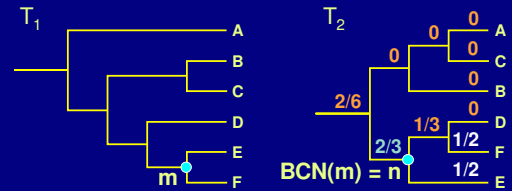
Similarity score: $S(m,n)$



$$S(m,n) = \frac{|L(m) \cap L(n)|}{|L(m) \cup L(n)|} = \frac{|{E,F}|}{|{D,E,F}|} = \frac{2}{3}$$

21

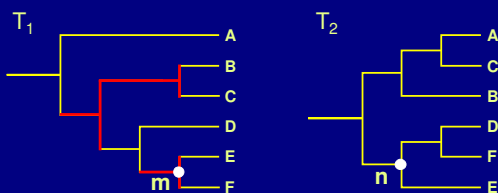
Best corresponding node



- $BCN(m) = \operatorname{argmax}_{v \in T_2} (S(m,v))$
 - computable in $O(n \log^2 n)$
 - linked highlighting

22

Marking structural differences



- Nodes for which $S(v, BCN(v)) \neq 1$
 - Matches intuition

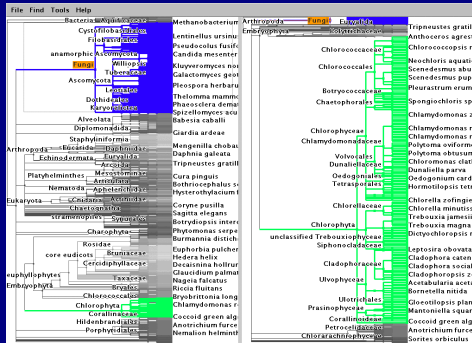
23

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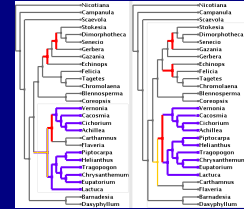
24

Guaranteed mark visibility



Marks

- Region of interest shown with color highlight
 - structural difference
 - search results
 - user-specified
- Purpose
 - guide navigation
 - provide landmarks
 - subtree contiguity check



26

Guaranteed visibility of marks

- How can a mark disappear?

27

Guaranteed visibility of marks

- How can a mark disappear?
 - moving outside the frustum

28

Guaranteed visibility of marks

- How can a mark disappear?
 - moving outside the frustum
- Solutions
 - choose global Focus+Context navigation
 - “tacked down” borders

29

Focus+Context previous work

- combine overview and detail into single view
- Focus+Context
 - large tree browsing
 - Cone Trees [Robertson et al 91]
 - Hyperbolic Trees [Lamping et al], H3 [Munzner 97]
 - SpaceTree [Plaisant et al 02]
 - DOI Trees [Card and Nation 02]
 - global
 - Document Lens [Robertson and Mackinlay 93]
 - Rubber Sheets [Sarkar et al 93]
- our contribution
 - scalability, guaranteed visibility

30

Guaranteed visibility of marks

- How can a mark disappear?
 - moving outside the frustum
- Solutions
 - choose global Focus+Context navigation
 - “tacked down” borders

31

Guaranteed visibility of marks

- How can a mark disappear?
 - moving outside the frustum
 - occlusion
- Solutions
 - choose global Focus+Context navigation
 - “tacked down” borders

32

Guaranteed visibility of marks

- How can a mark disappear?
 - moving outside the frustum
 - occlusion
- Solutions
 - choose global Focus+Context navigation
 - “tacked down” borders
 - choose 2D layout

33

Guaranteed visibility of marks

- How can a mark disappear?
 - moving outside the frustum
 - occlusion
 - culling at subpixel sizes
- Solutions
 - choose global Focus+Context navigation
 - “tacked down” borders
 - choose 2D layout

34

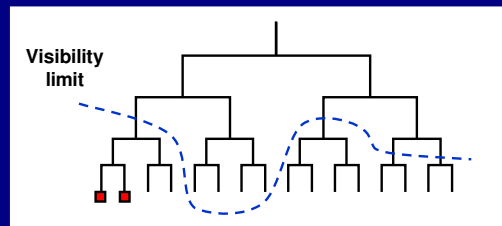
Guaranteed visibility of marks

- How can a mark disappear?
 - moving outside the frustum
 - occlusion
 - culling at subpixel sizes
- Solutions
 - choose global Focus+Context navigation
 - “tacked down” borders
 - choose 2D layout
 - develop efficient check for marks when culling

35

Preserving marks while culling

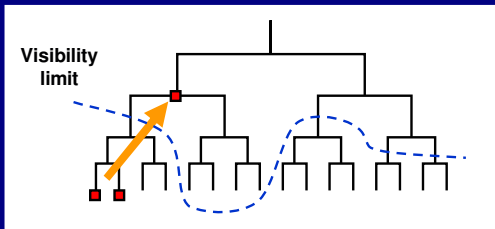
- Show mark at unculled node



36

Preserving marks while culling

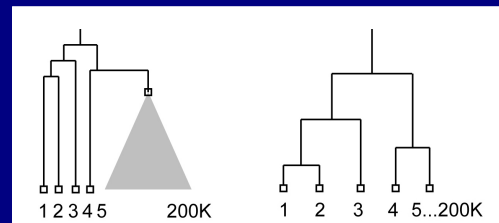
- Show mark at unculled node



37

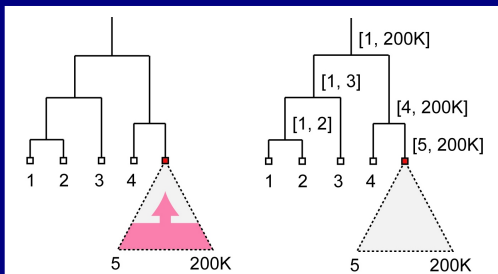
Mark preservation strategies

- Compress large subtree to small spatial area



User selects nodes [135,19995]

- Propagation : cost depends on total nodes
- Precomputation: cost depends visible nodes



40

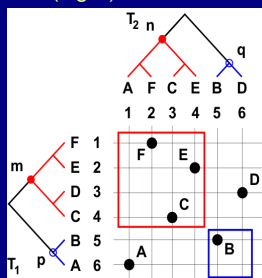
Marks and linked highlighting

- Also check for linked marks from other tree

- check if best match for node is marked
 - up to $O(n)$ to look up each node in range
- intersect node ranges between trees
 - reduces to point in polygon test, $O(\log^2 n)$

Efficient marking detection

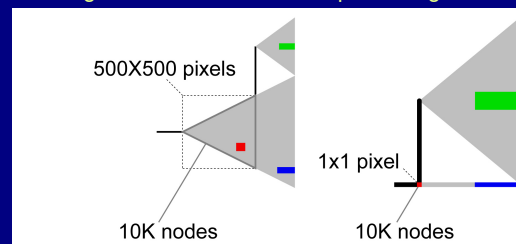
- Intersecting ranges between trees
 - Query in $O(\log^2 n)$



41

Storing topological ranges

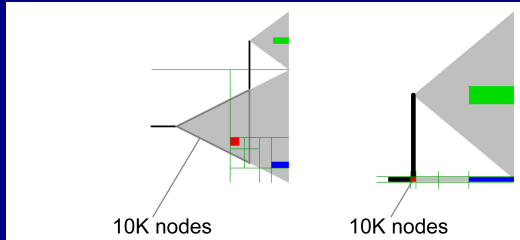
- At each node, store range of subtree beneath
 - range stored doesn't match spatial range needed



42

Storing spatial ranges

- At each box, store range of objects inside



43

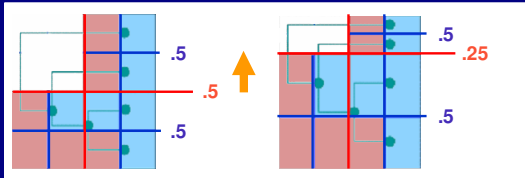
Spatial range solution

- Recursive spatial subdivision
 - quadtree
 - store range of objects enclosed for each cell
 - quick check: spatial range vs. selection range
- Extending quadtrees to Focus+Context
 - quadtree cells also “painted on rubber sheet”
 - efficient $O(\log n)$ update when stretch/shrink
 - details in paper

44

Rendering infrastructure

- Focus+Context QuadTree
 - Fixed mapping between nodes and quad cell
 - Sparse cell instantiation
 - Split boundary relative to the node parent
 - Hierarchical propagation of deformation



46

Guaranteed visibility previous work

- Visibility of abstract information
 - Effective view navigation [Furnas 97]
 - Critical zones [Jul and Furnas 98]

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47

Difference computation

- Powerful and totally automatic
 - leads users to important locations
 - efficient algorithms: 7s for 2x140K nodes
 - matches intuition
 - UT-Austin Biology Lab, several others
- Challenges
 - memory footprint
 - handling weighted edges

48

Guaranteed visibility

- Relief from exhaustive exploration
 - missed marks lead to false conclusions
 - hard to determine completion
 - tedious, error-prone
- Compelling reason for Focus+Context
 - controversy: does distortion help or hurt?
 - strong rationale for comparison

49

Guaranteed visibility challenges

- Integration with progressive rendering
 - might lose context during motion
 - need several seeds for rendering queue
 - focus point
 - marked items
 - up to empirical cutoff, no guarantees
- Constraint to fit everything in frustum
 - instead could show indirectly

50

Future Work

- Adoption
 - open-source release
 - tighter integration with biology tools
 - broad range of application domains
- Detectability vs. visibility
 - display resolution, surrounding colors
- Extend difference computation
 - weighted trees
 - graphs

51

Conclusion

- First interactive tree comparison system
 - automatic structural difference computation
 - guaranteed visibility of marked areas
- Scalable to large datasets
 - 250,000 to 500,000 total nodes
 - all preprocessing subquadratic
 - all realtime rendering sublinear
- Techniques broadly applicable
 - not limited to biological trees

52

Acknowledgments

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 - David Hillis, Bob Jensen, Will Fischer, Derrick Zwickl
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53