

Visualization of “States” in Online Educational Games



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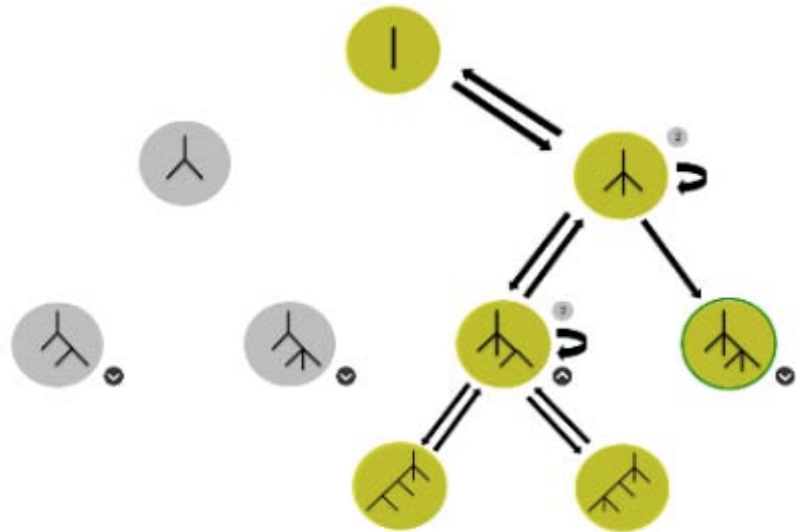
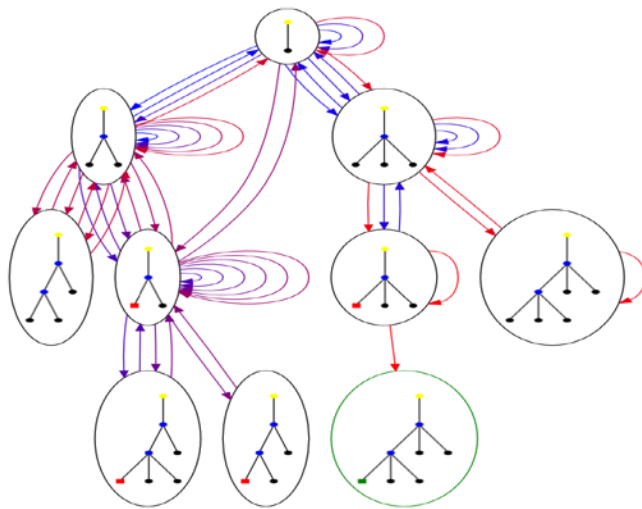


Table of Contents

➤ Introduction

- Mathematics Education
- Educational Games
- What is Refraction?
- Research Questions

➤ Changing Visualizations

- Old Fraction Man
- New Tree-based Structure

➤ Discussion & Future Work

Background: The Need

Mathematics Education

- Mathematics proficiency is critical for success in school
- Algebra as a gateway to high school & college
- Rational numbers are core concept in elementary school mathematics
- Fractions are one of the most challenging areas of mathematics



Educational Games

Electronic Games:

- Routine part of childhood

Educational Games:

- Rising popularity

Design:

- Unstructured environments
- Educational concepts
- Trial and error
- Fun interfaces

Justification:

- Students love games
- Naturally motivated



SCRATCH



➤ What is Refraction?

- Free, online educational game, developed at the Center for Game Science (CGS), University of Washington
- Aimed at developing pre-algebra concepts in elementary and middle school students



Center for Game Science

GAMES

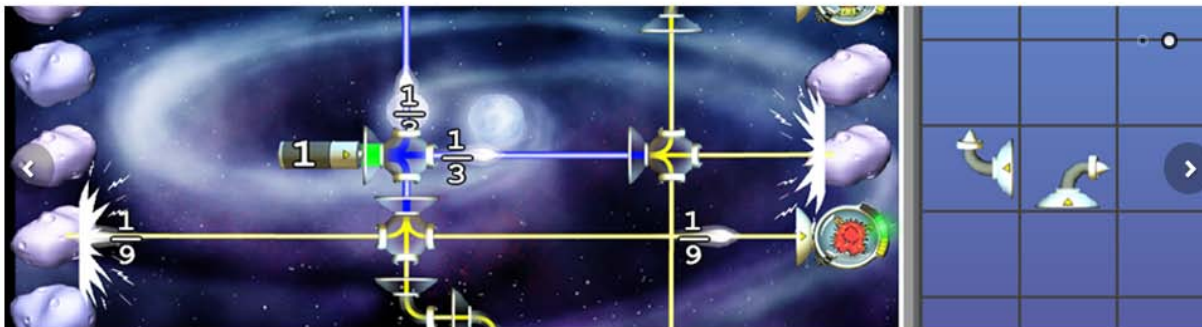
PEOPLE

RESEARCH

Refraction

Refraction focuses on teaching fractions and discovering optimal learning pathways for math education.

[previous](#) / [next](#)



Overview

Refraction is a game in which you bend and split lasers to free animals trapped in space.

[Play Refraction!](#)

[http://centerforgamescience.org/
portfolio/refraction/](http://centerforgamescience.org/portfolio/refraction/)

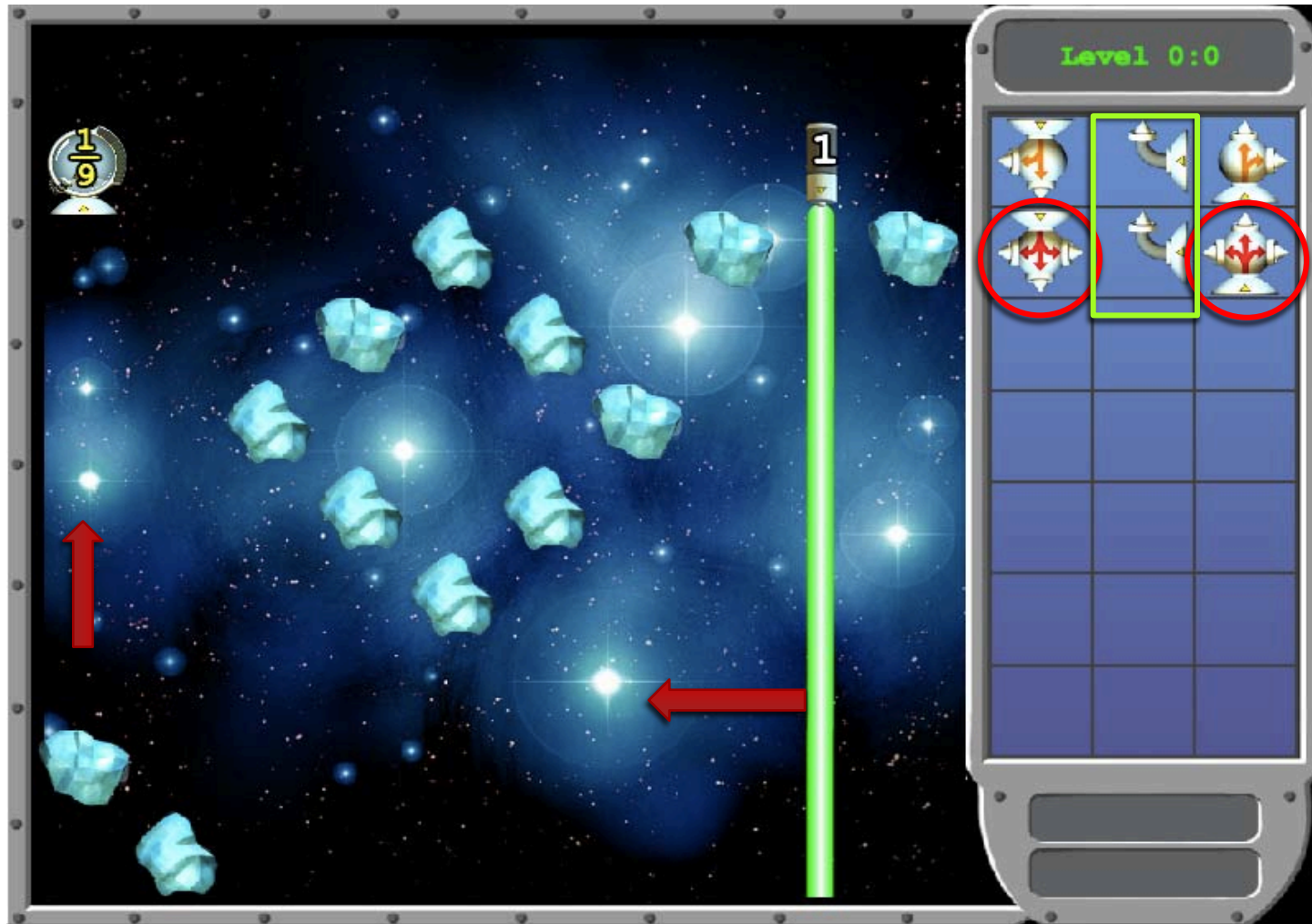
➤ Research Questions

- Discovering optimal pathways for learning early mathematics
- Detecting what it looks like when children learn fractions
- Categorization of ways students learn by playing



Refraction Level 189

<http://centerforgamescience.org/portfolio/refraction/>

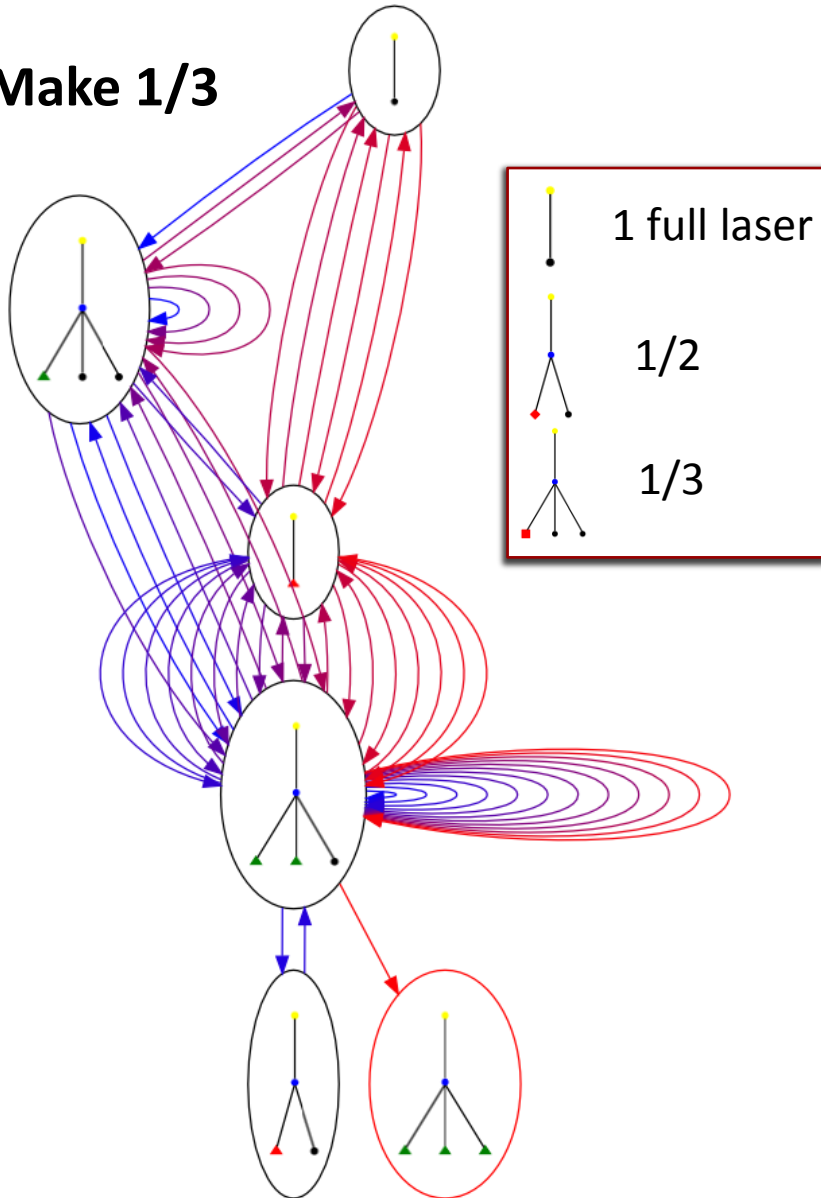


Fraction Man Visualization

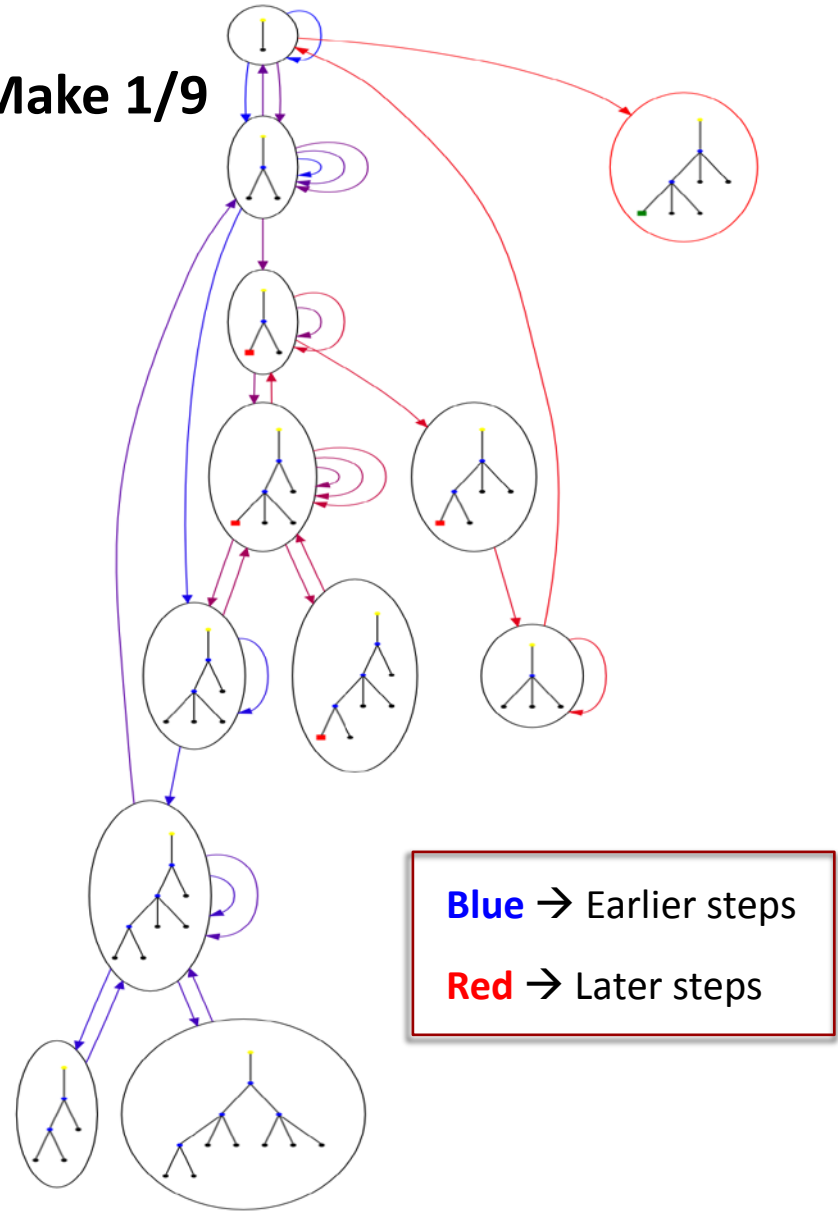
- Motivation: Display gameplay of a student
- “States” & “transitions” of the game shown as directed graph
- State: represented as vertex (ellipse)
- Transition: represented as edge
- Use specific symbols for the splitters
- Addition of benders does not result in a new state
- Sequential blue-red color scheme used to display order of transitions

Fraction Man Visualization

Make $1/3$



Make $1/9$



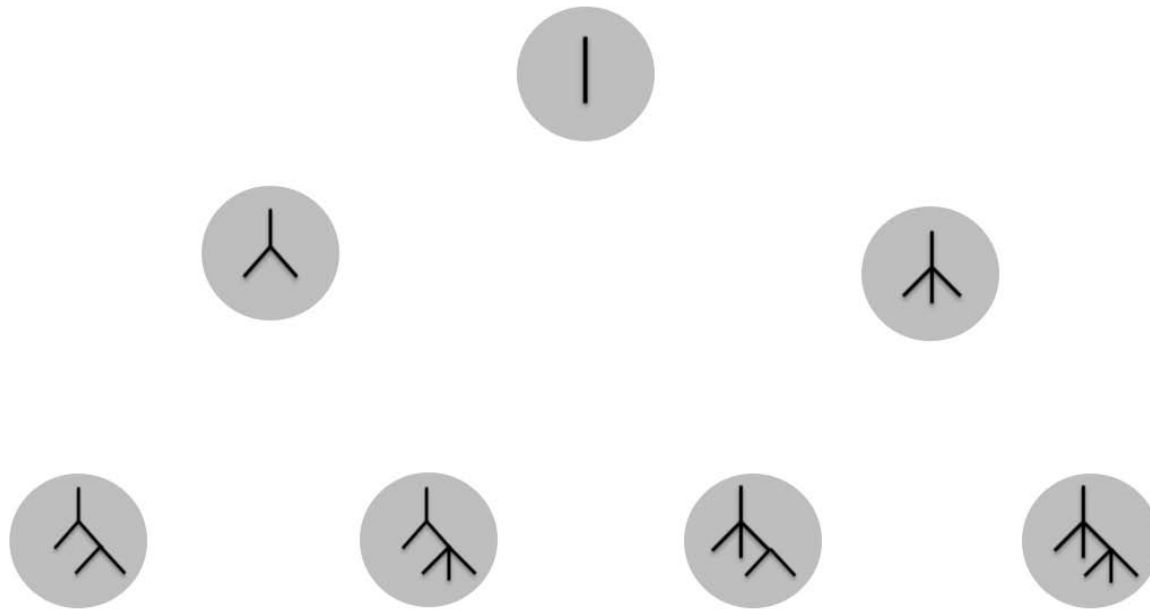
Limitations of Fraction Man Visualization

- Can become crowded and incomprehensible
- Hard to determine exact order of transitions as colors can be hardly distinguished
- Number of states shown on graph often does not match number of mathematical states
- Lack of structure: same state may appear at different locations in the graph when comparing multiple gameplays
- Goal of a level not easy to indentify

Concepts of Tree-based Visualization

- Incorporates ideas of network data visualization
- Based on “small multiples” where each state has a fixed location in the tree => Usable for comparison of gameplays of multiple students
- Identification of final goal via color
- Distinction between states reached and not reached via color
- Addition of a timeline to display order of transitions

Initial "States"



"States": Reached vs. Not Reached




States **reached** by the student




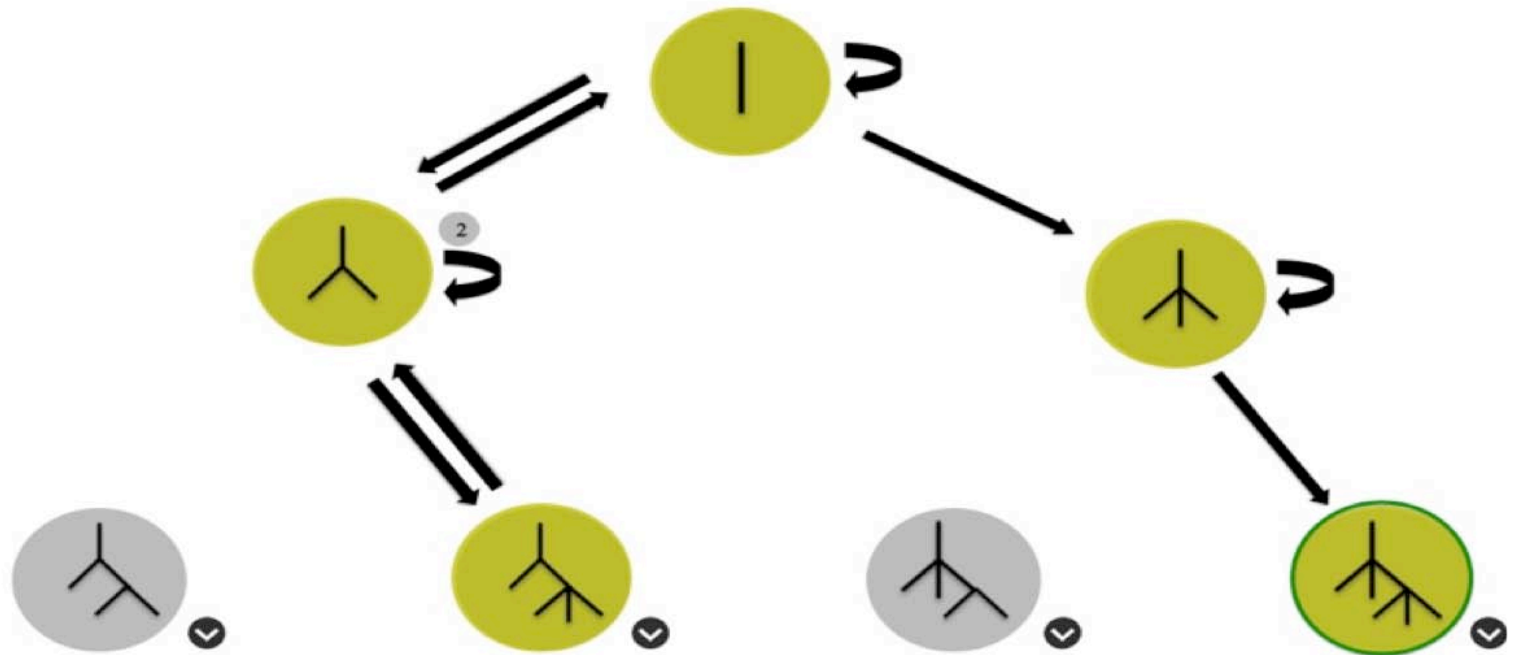
States **never reached** by the student



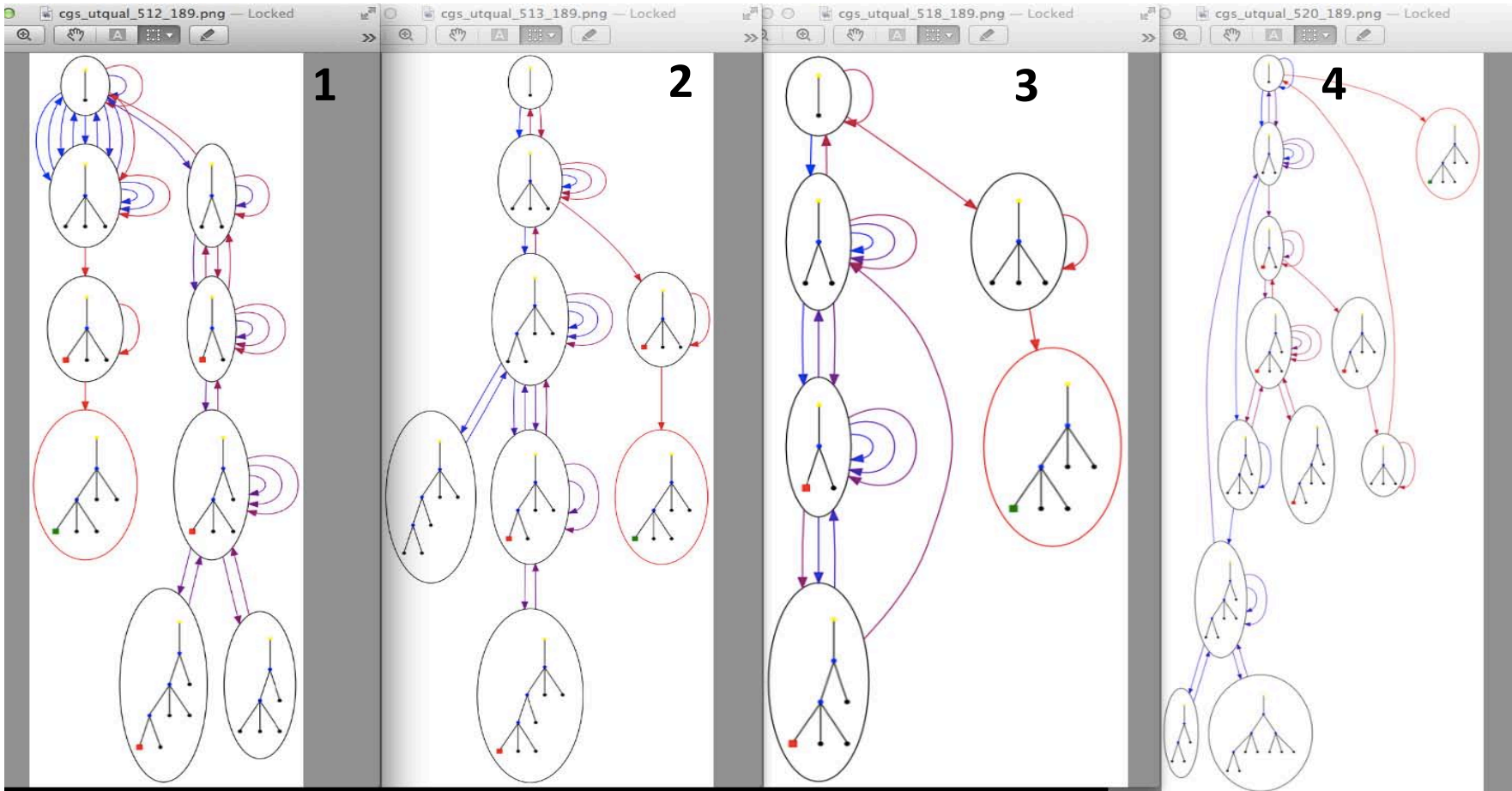
"States" & Transitions

 States **reached** by the student

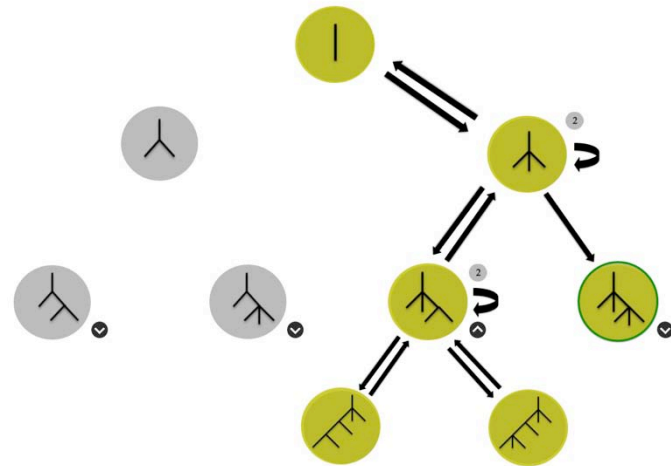
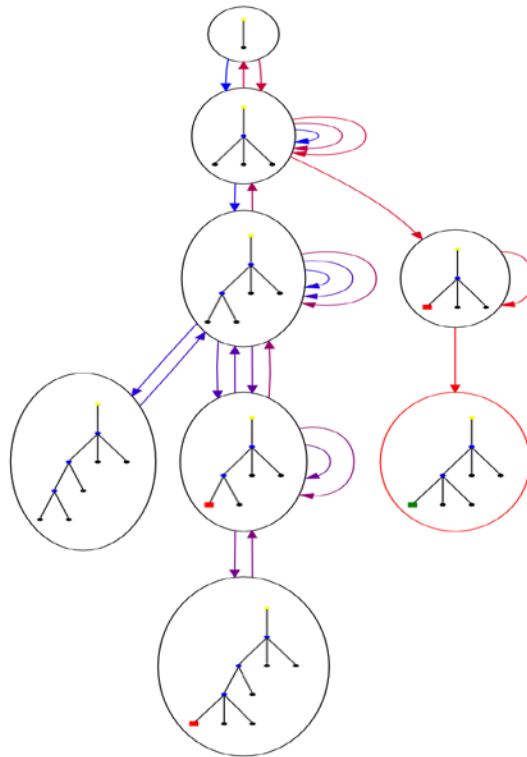
 States **never reached** by the student



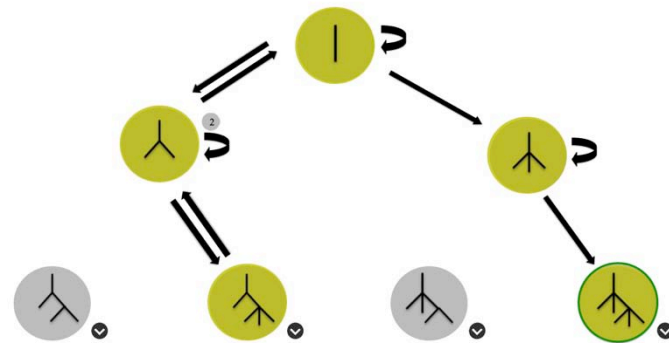
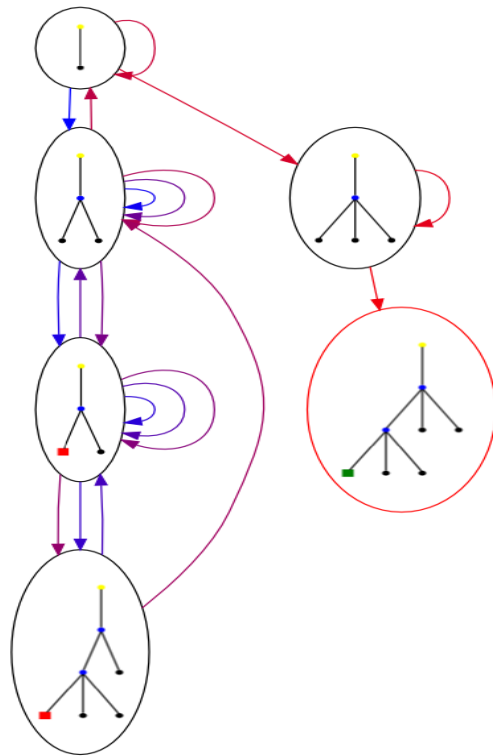
Level 189: Fraction Man Visualization



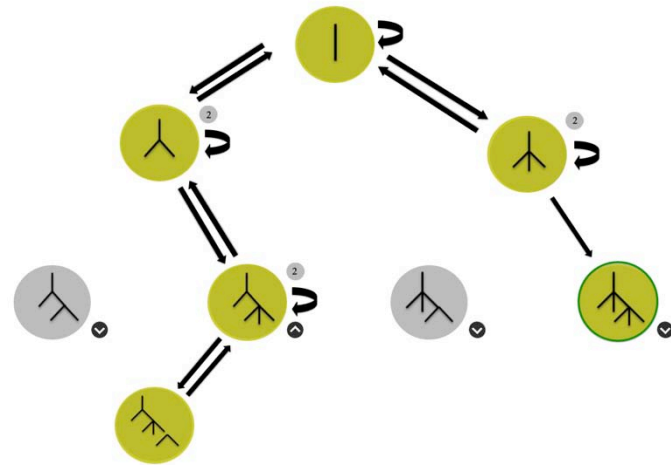
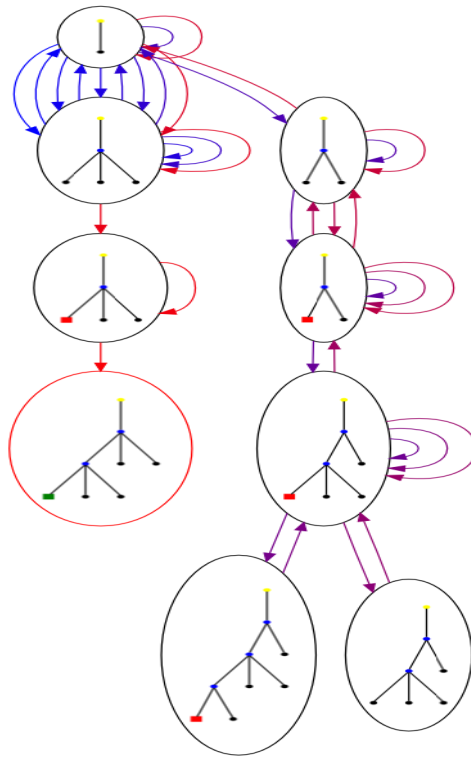
Student 513 Level 189



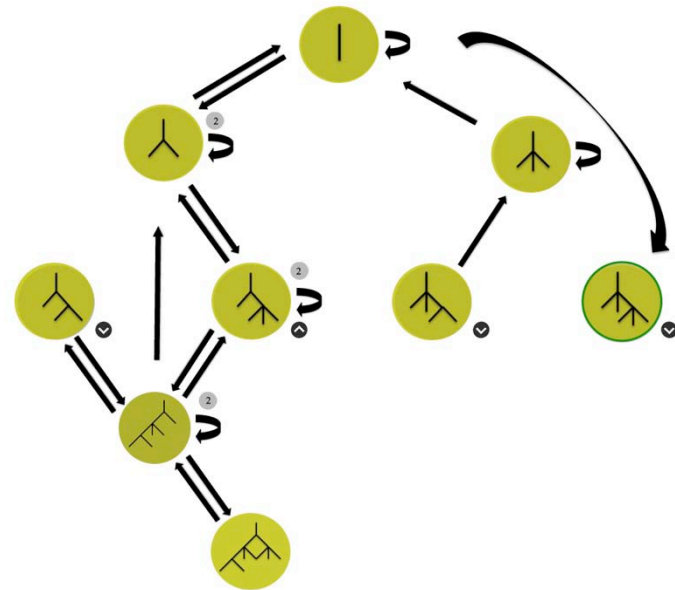
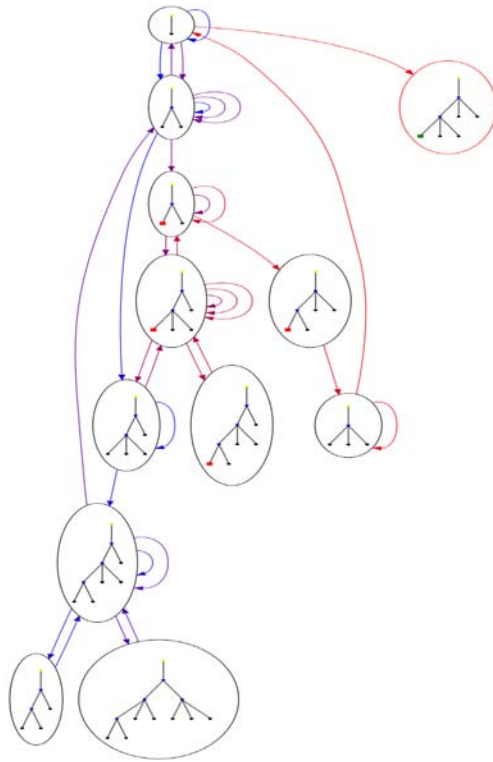
Student 518 Level 189



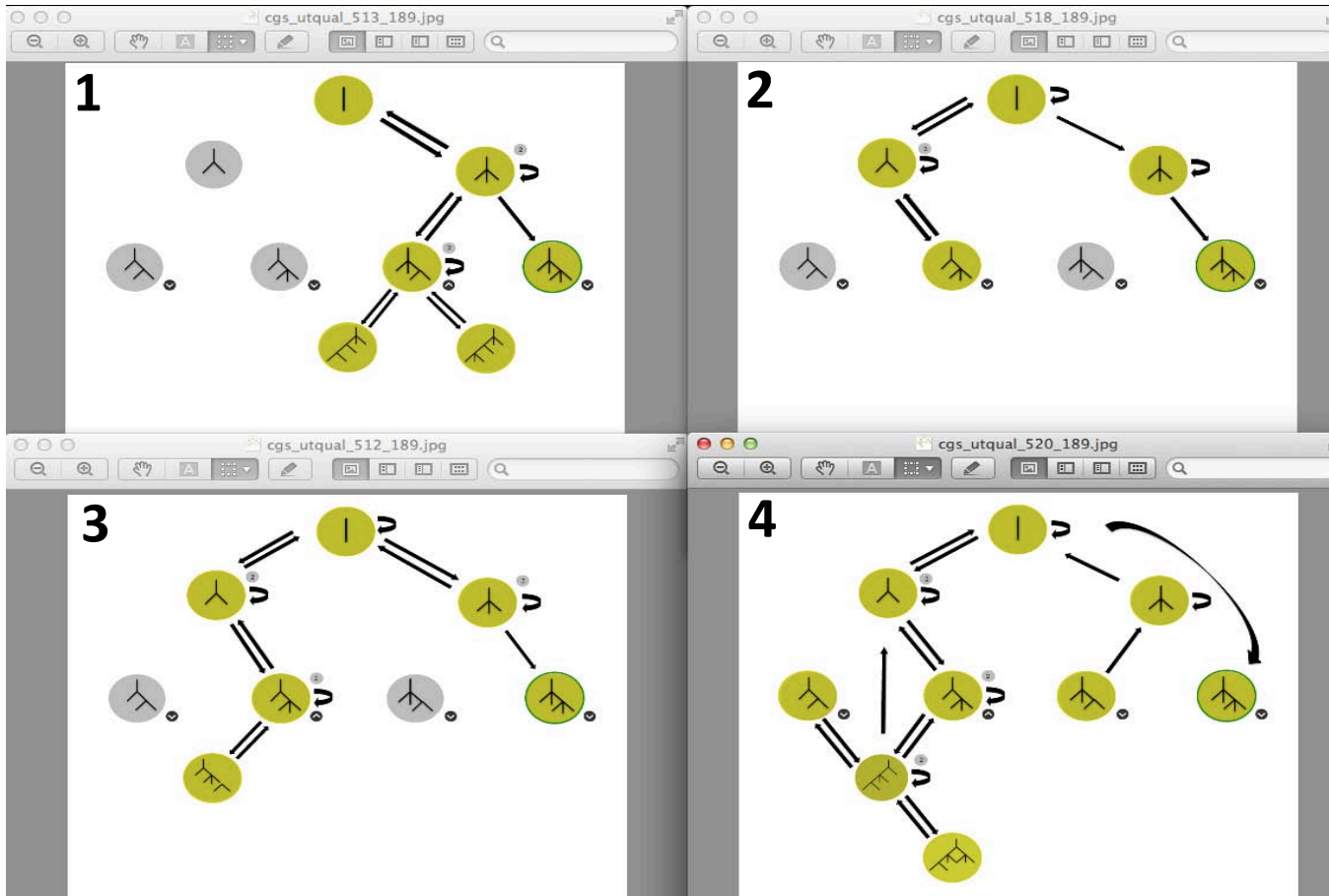
Student 512 Level 189



Student 520 Level 189



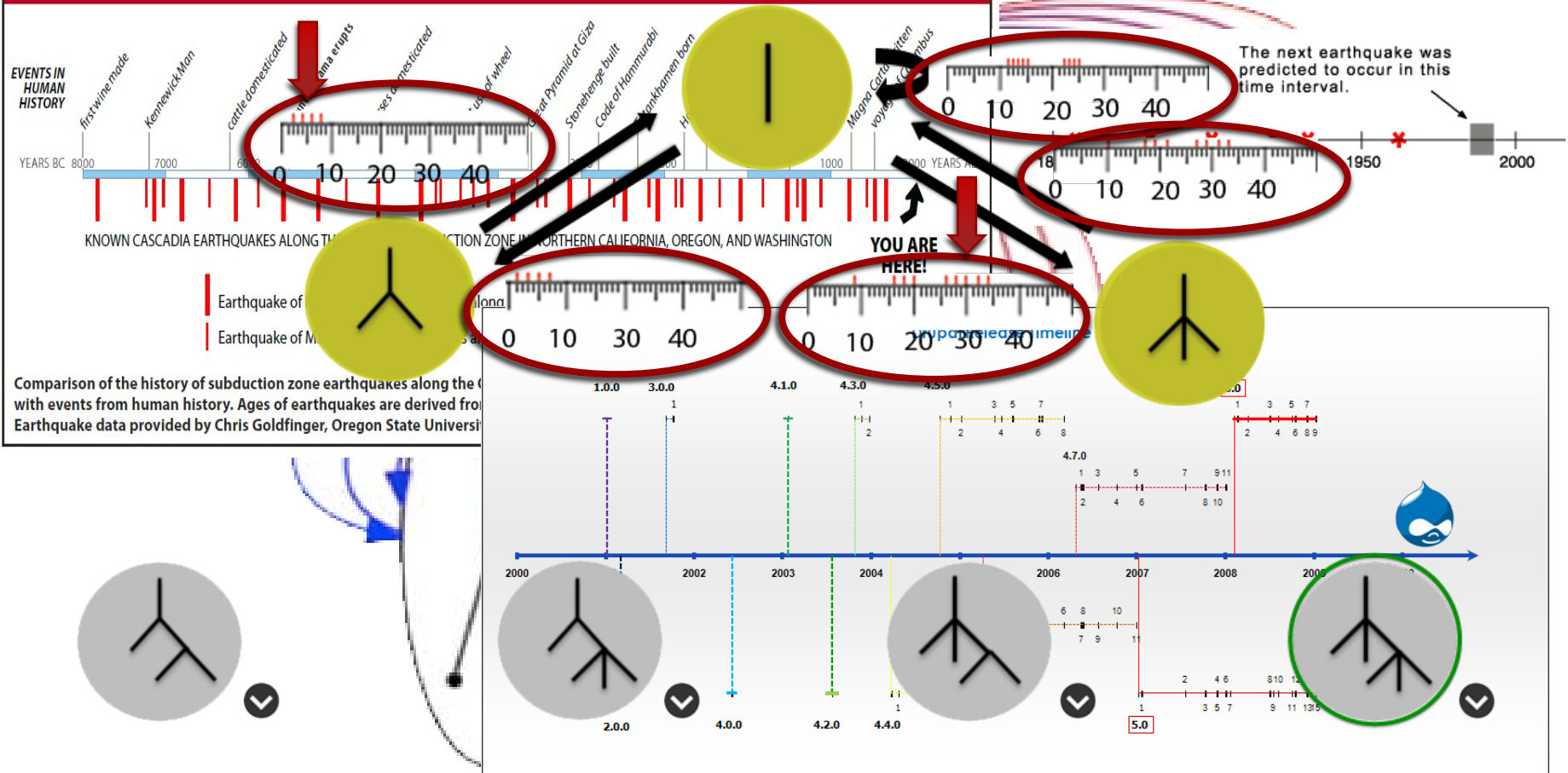
Level 189: New Visualization



● States reached by the student

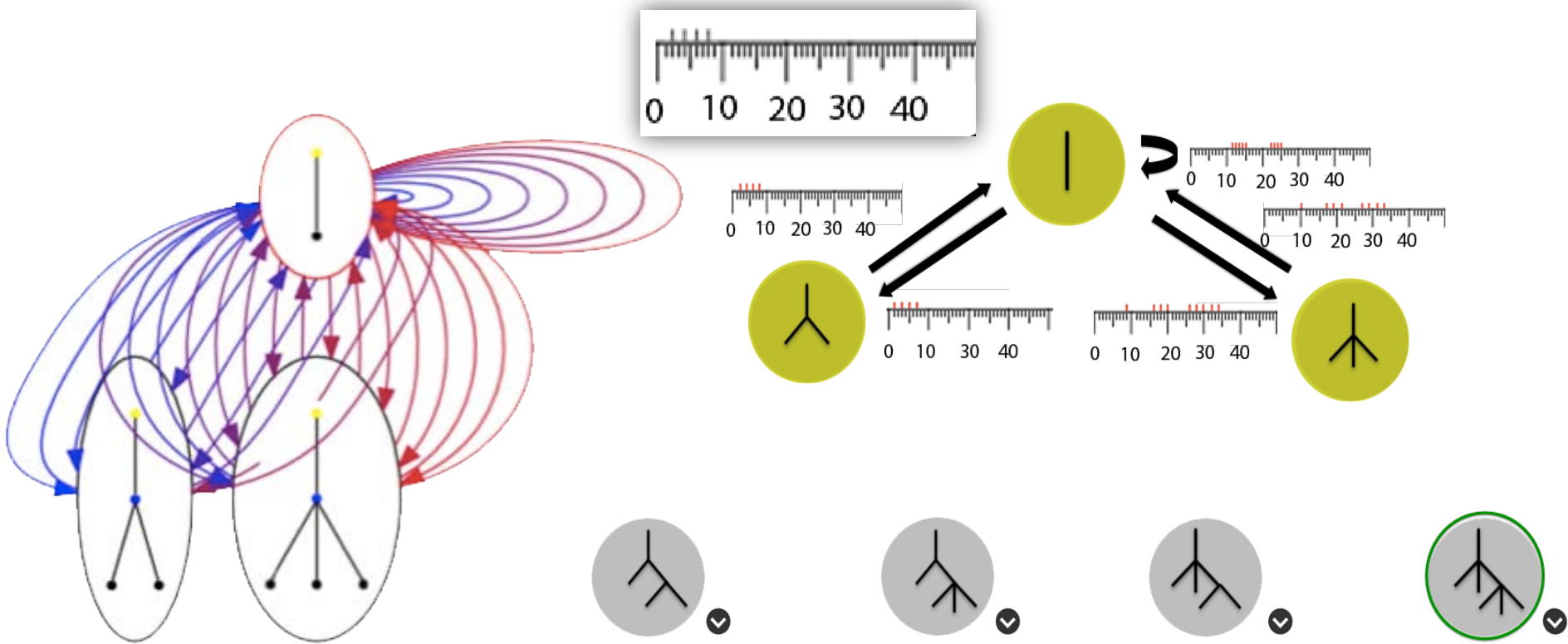
● States never reached by the student

CASCADIA EARTHQUAKE TIME LINE



The Alternative & the Timeline





Comparison

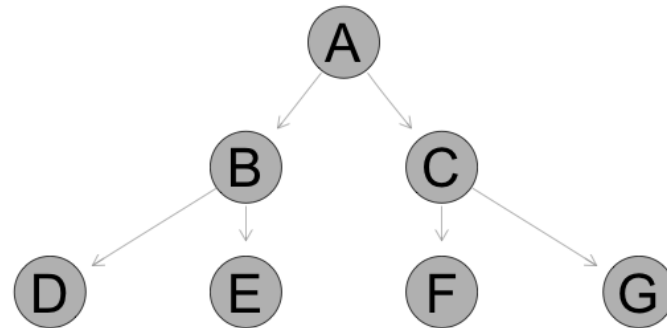
Left: Old visualization

Right: New visualization with timeline



R's Role: Implementation via Rgraphviz

```
1 library("Rgraphviz")
2 # List nodes
3 MyNodes <- c(
4   "A",
5   "B",
6   "C",
7   "D",
8   "E",
9   "F",
10  "G"
11 )
12 # For each node above (and in the same order),
13 # list nodes for which the node is a "child"
14 # (i.e., the nodes to which the node will have an edge pointing)
15 # with an empty list if it is not a "child" for anything.
16 MyEdges <- list(
17   A = list(edges=c("B","C")),
18   B = list(edges=c("D", "E")),
19   C = list(edges=c("F", "G")),
20   D = list(),
21   E = list(),
22   F = list(),
23   G = list()
24 )
25 g <- new("graphNEL",nodes=MyNodes,edgeL=MyEdges,edgemode="directed")
26 plot(g, attrs=list(node=list(label="whatever", fillcolor="grey"),
27   edge=list(color="darkgrey")))
```



Discussion & Future Work (1)

➤ Benefits:

- Structured (small multiples!)
- Easy to compare and contrast students' pathways through the same game level
- Allows teachers/researchers to conduct exploratory analysis of student's pathways

Discussion & Future Work (2)

➤ Future Work:

- Finish basic R implementation
- Add interactive components
- Allow aggregation of data from multiple students to identify student's common problems and mistakes
- Create student profiles (based on multiple levels played) to predict student success and identify struggling students



Questions ???