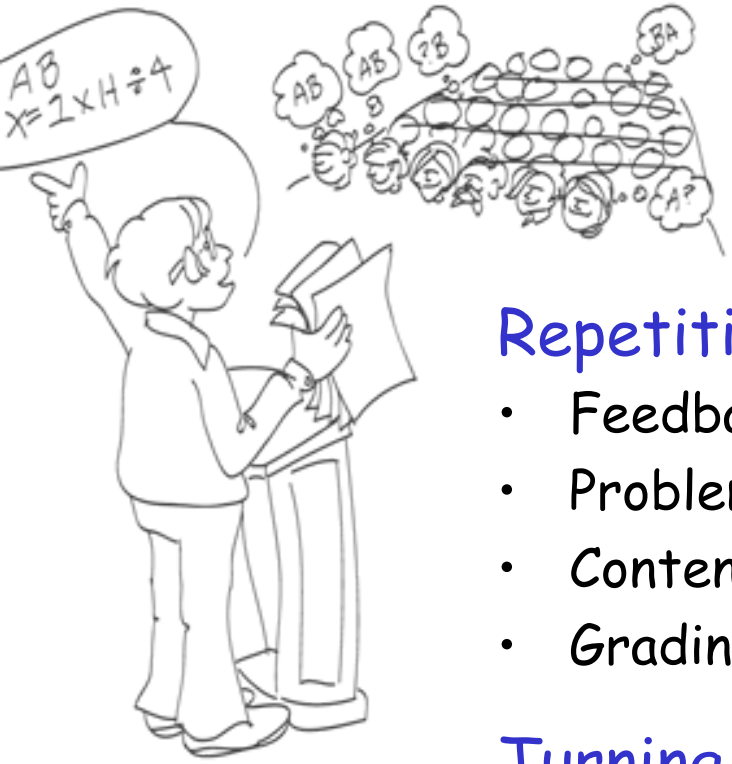
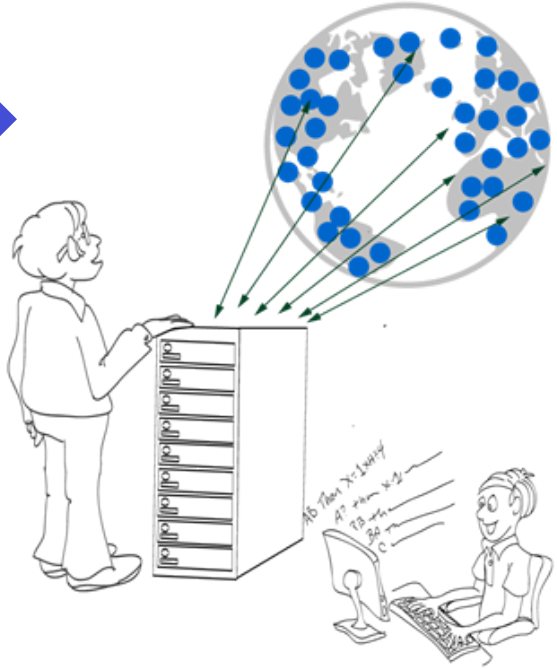
Tasks Amenable to Computational Techniques





Repetitive/tedious tasks

- Feedback Generation
- Problem Generation
- Content Authoring
- Grading

Turning data into knowledge

- Learning Analytics

A range of subject domains

- Math, Logic, STEM
- Automata, Programming
- Languages

[CACM 2014] "*Example-based Learning in Computer-aided STEM Education*"

Feedback Generation

Motivation

- Make teachers more effective
  - Save time
  - Provide immediate insights on where students are struggling/succeeding
- Enable rich, interactive experience for students
  - Generate hints
  - Pointers to simpler problems depending on kind of mistake

A few ideas

- Counterexamples
- Nearest correct solution
- Strategy-level feedback
- Nearest problem description (corresponding to student solution)

Problem Generation

Motivation

- Generate problems similar to a given problem
  - Avoid copyright issues
  - Prevent cheating in MOOCs (Unsynchronized instruction)
- Problems of a given difficulty level and concept usage
  - Generate progressions
  - Generate personalized workflows

A few ideas

- Test input generation techniques
- Template-based generalization
- Reverse of solution generation

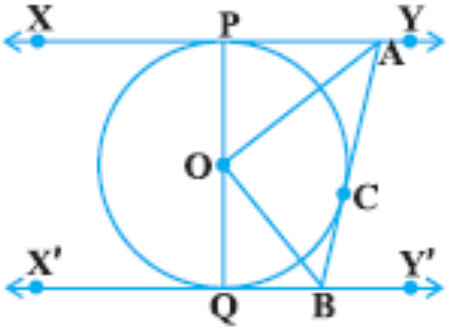
Content Authoring

Motivation: Make it easy to create and edit

- Equations
- Drawings

A few ideas

- Allow multi-modal NUIs such as ink, speech, touch
- Prediction $\sqrt{1+\cos A}/1-\cos A$ ← $\sqrt{1+\cos A}/1-\cos A$
- Error correction



Grading

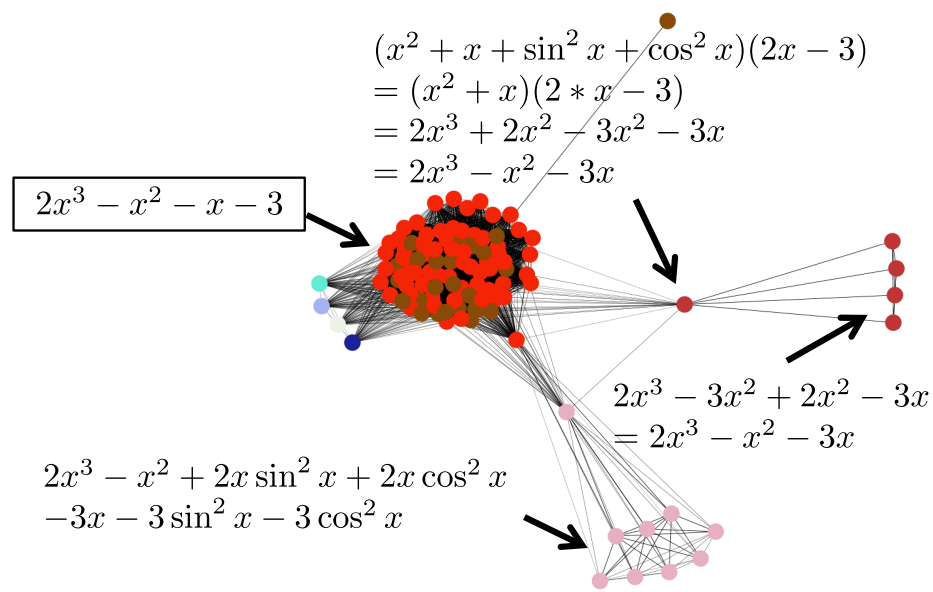
Motivation: Scale up grading and feedback of open-response solutions (beyond multiple choice)

A few ideas

- Peer grading systems
  - Statistical tools to fuse crowd-sourced peer grades
- Clustering similar solutions
  - Computer programs
  - Logical math proofs
  - Mathematical calculations
  - Essays

Q: Simplify:

$$(x^2 + x + \sin^2 x + \cos^2 x)(2x - 3)$$



"Mathematical Language Processing"
[Lan, Vats, Waters, Baraniuk, L@S 2015]

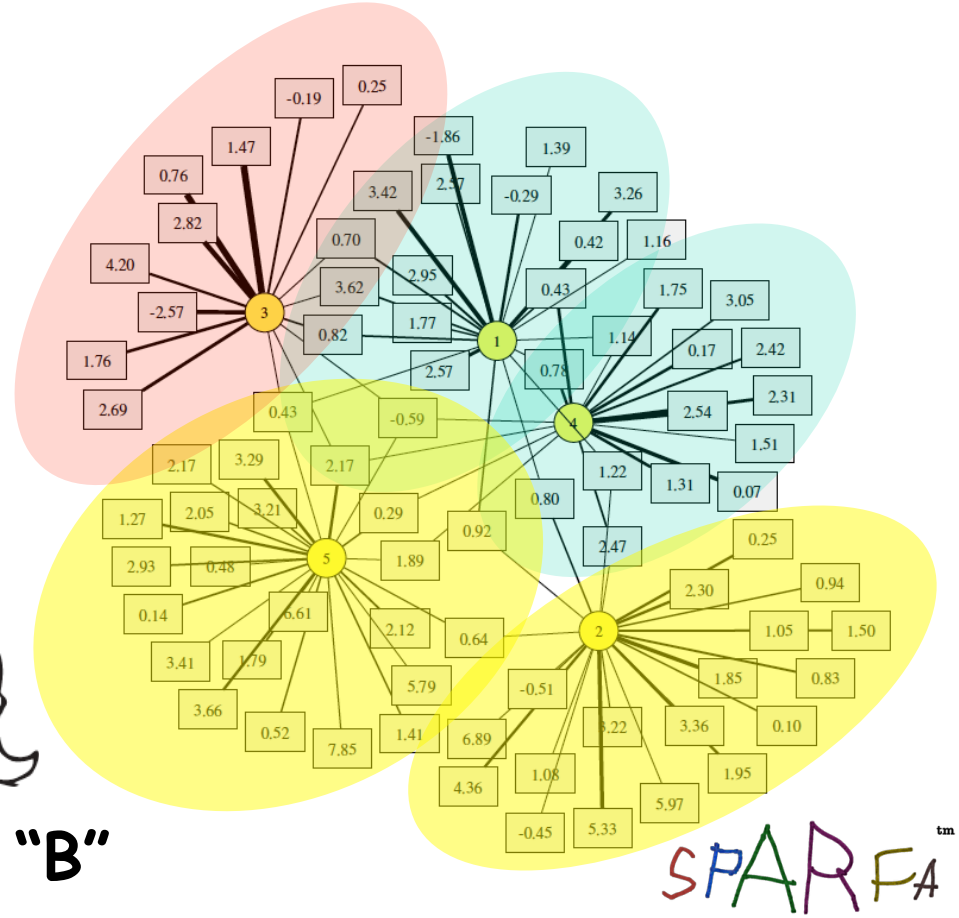
Learning and Content Analytics

Motivation:

- Assess and track student learning progress
- Infer relationships among items of learning content

A few ideas

- Leverage the rich psychometrics literature
- Knowledge tracing
- Factor analysis to disentangle student and content



Susan "B"

SPARFA™

Cross-Disciplinary Effort Needed

- Formal methods
  - Logical reasoning, search
- Machine learning
  - Leverage large amounts of student data for sample solutions, common mistakes, learning pathways
- Natural language processing
  - Word problems, language learning, conversational interaction
- Crowdsourcing
  - Leverage large populations of students and teachers for peer grading, tutoring, problem generation
- Cognitive Psychology
  - Build into tools the latest results on how people learn

Evaluating Impact

- Student learning outcomes
  - Faster, better, happier?
  - How to measure? Randomized trials?

- Data data data
  - More data => better tools, stronger conclusions
  - Machine learning algorithms require large training data sets
  - Progress with Khan Academy, edX, Coursera, OpenStax, DataShop, …

- Cost of developing a personalized learning system
  - Aim for general frameworks that reduce the development cost of domain-specific content and tools

Panelists

- **Mihaela van der Schaar**, UCLA
- **Jerry Zhu**, Wisconsin
- **Zoran Popovic**, Washington
- **Sanjit Seshia**, UC-Berkeley
- **Philip Guo**, Rochester
- **Kathi Fisler**, WPI






Panel

- ✓ Panel Introduction
- 5 minute position piece from each panelist
- Questions and Discussion