Evaluating Adaptive Generation of Problems in Programming Tutors – Two Studies

Amruth KUMAR

Ramapo College of New Jersey,

Mahwah, NJ 07430, USA

Adaptation in tutors

- Text
- Navigation
- Problem sequence
- Feedback

Adaptive problem generation

- Vector spaces [Kurhila et al ITS 02]
- Learning Spaces [Salton et al 75]

Disadvantages:

- Exhaustive enumeration
- Adding new concepts/problems entails redesign

Associative adaptation

- Identify concepts in a topic
- Build overlay student model in terms of the concepts
  - Maintain proficiency on each concept
- Associate each problem with concept
- For the next problem:
  - Select the concept
  - Select the problem – Round robin algorithm

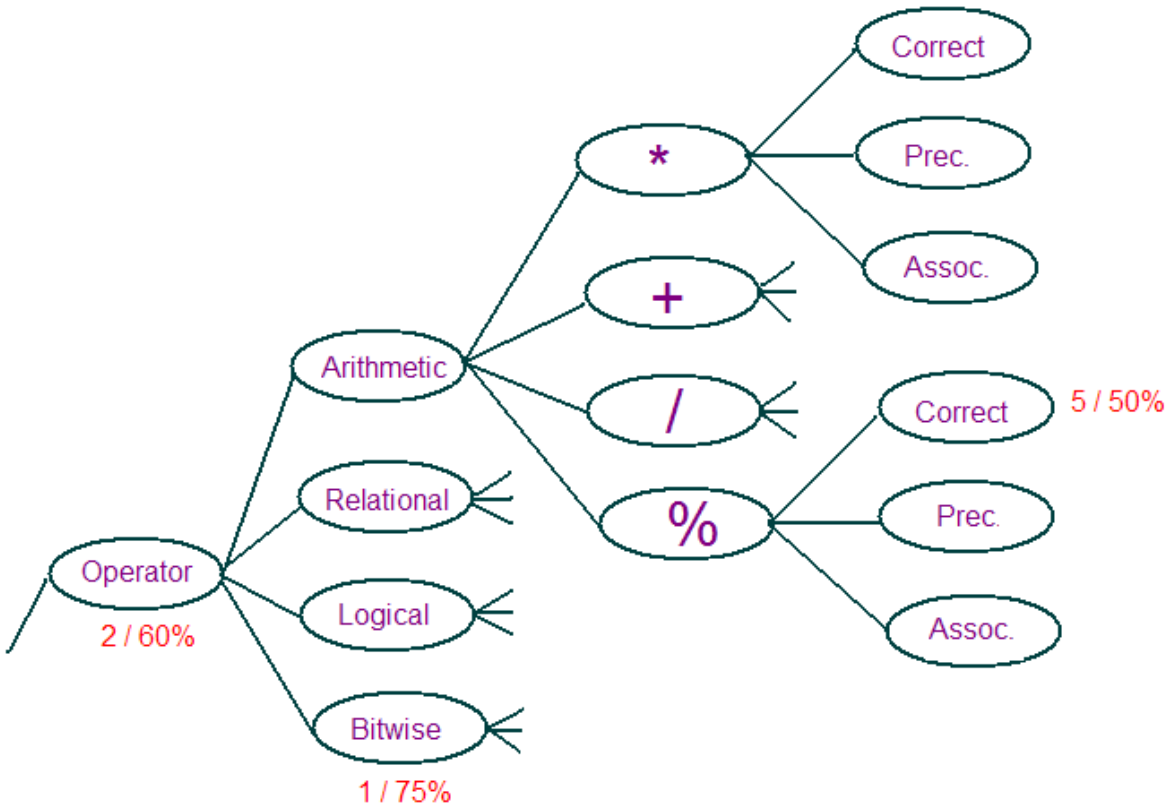
Problets

- Problem-solving tutors for program analysis
- Available for:
  - Expression Evaluation: Arithmetic, Relational
  - Selection
  - Loops – Pretest, Counter-controlled
  - Pointers in C++
- www.problets.org

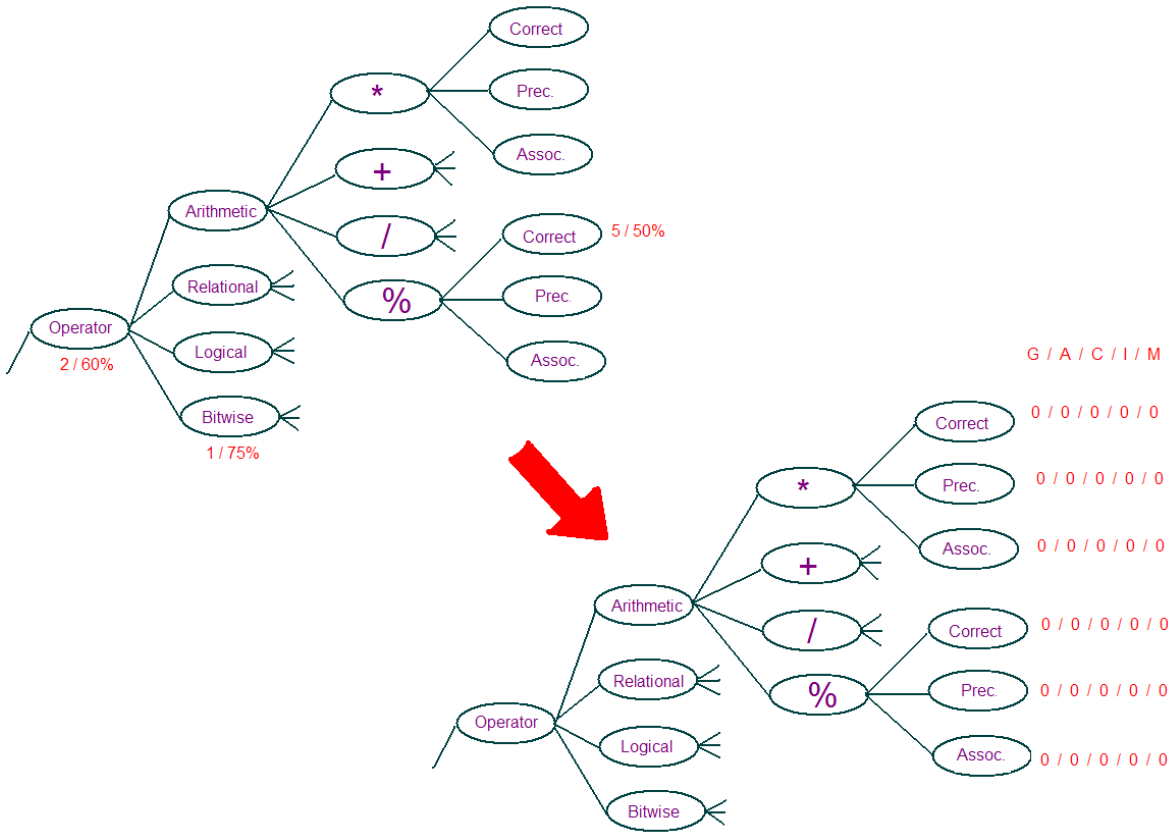
Arithmetic Expression Concepts

- Correct evaluation of +, -, *, / (Integer & Real), %
- Precedence of +, -, *, /, %
- Associativity of +, -, *, /, %
- Coercion in +, -, *, /, %
- Divide by zero error for /, %
- % applied to real operands

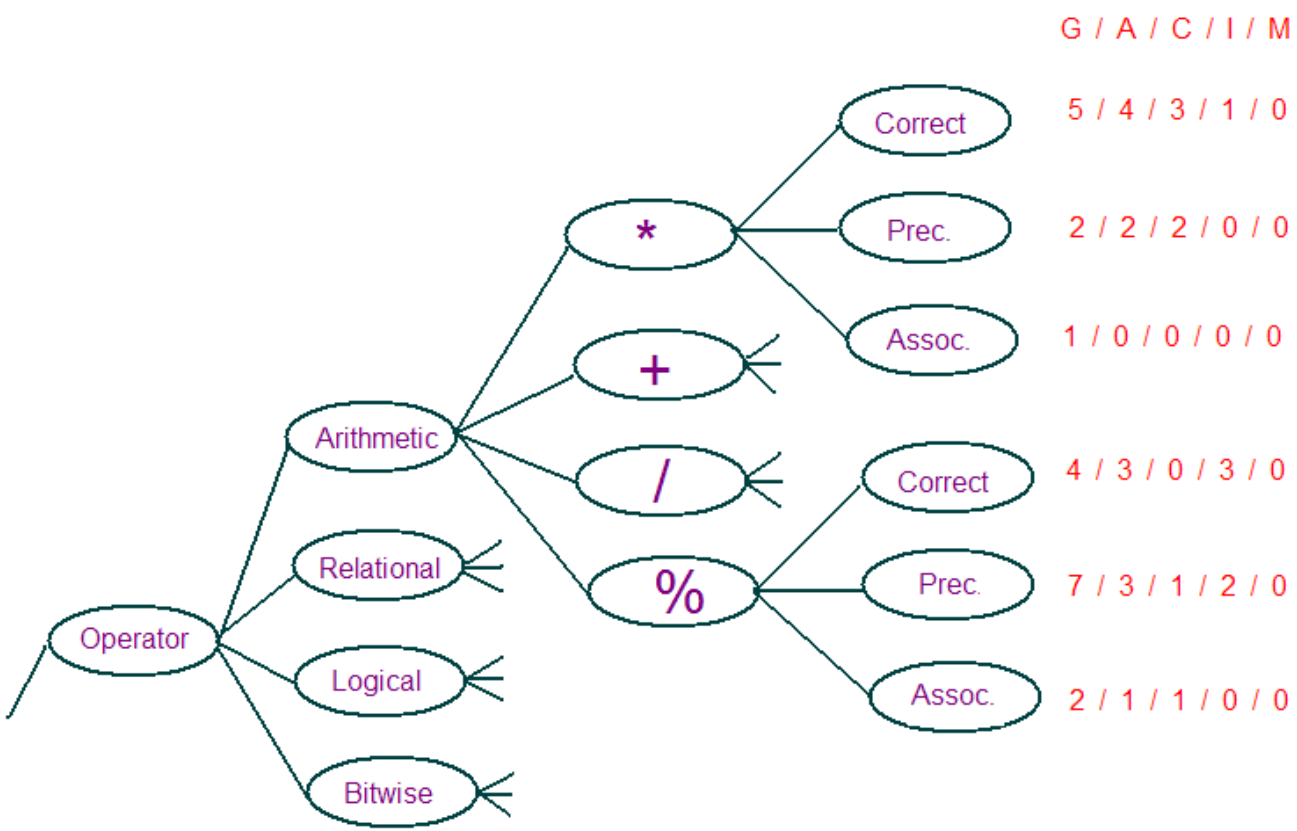
Knowledge Model



Overlay Student Model



Cognitive Student Model



Problem Template

Learning Objective:

Modulus (%) Operator applied to real operands

Template:

<R1#integer;2<=R1<=5;#> % <R2#float;6<=R2<=9;#>

Example:

2 % 6.5

Selecting the concept for the next problem

Given the last concept was Ci:

- If Ci has been mastered, return concept Ci + 1. If i + 1 > n, set i = 1, return C_1
- If p problems already generated back to back on Ci, return Ci + 1. If i + 1 > n, set i = 1, return C1
- Else, return Ci.

Associative adaptation

- Persistence
  - p = 1: rapid context-switch - better for testing
  - p > 3: problems predictable
  - p = 2: better for tutoring

Evaluation Hypothesis - 1

- Targets the concepts less well understood by students.

Principle:

- *Categorize student-concepts, not students into control and test groups*

Tutor on Selection – 05 Protocol

- Pretest – 21 problems, 12 concepts, 8 minutes, no feedback
  - Initialized student model
- Practice – Adaptive, 15 min max
- Post-Test – Similar to Pretest

Classifying concepts

Problems Solved	Pre-Test	Practice	Post-Test
Discarded	0	*	*
Discarded	*	*	0
Known	$A \geq M_1$ & $R / A \geq M_2$	*	*
Control	+	0	+
Test	+	+	+

Control Vs Test Concepts Spring 05 Results

Spring 05	Pre-Test		Practice	Post-Test		*p*-value	
	Prob.	**Ave**	**Problems**	**Prob.**	**Ave**	**Prob.**	**Ave**
Control (N = 56 student-concepts)							
Average	1.02	0.88	0	1.11	0.87	0.02	0.68
Std-Dev	0.13	0.30	0	0.31	0.31		
Test (N = 135 student-concepts)							
Average	1.07	0.46	1.83	1.35	0.68	0.000	0.000
Std-Dev	0.26	0.47	1.14	0.48	0.43		
***p*-value**	0.05	0.000		0.000	0.000		

Control Vs Test Concepts Fall 05 Results

Fall 05	Pre-Test		Practice	Post-Test		*p*-value	
	Prob.	**Ave**	**Problems**	**Prob.**	**Ave**	**Prob.**	**Ave**
Control (N = 26 student-concepts)							
Average	1.15	0.81	0	1.46	0.76	0.002	0.55
Std-Dev	0.37	0.35	0	0.51	0.40		
Test (N = 87 student-concepts)							
Average	1.00	0.61	1.55	1.15	0.86	0.0000	0.0000
Std-Dev	0	0.47	1.20	0.36	0.31		
***p*-value**	0.04	0.02		0.006	0.23		

Pretest Loop/Spring 06

(N=67)	Pre-Test		Post-Test		*p*-value	
	Prob	**Ave**	**Prob**	**Ave**	**Prob**	**Ave**
Unknown Unpractised (N=43 student concepts)						
Ave	1.30	0.00	1.26	0.26	0.622	0.0002
StDev	0.46	0.00	0.54	0.44		
Unknown Practised (N=220 student concepts)						
Ave	1.88	0.04	1.80	0.38	0.144	0.0000
StDev	0.95	0.13	0.93	0.47		
Already Known (N=236 student concepts)						
Ave	1.31	0.99	1.34	0.89		
StDev	0.59	0.04	0.56	0.30		

Counter Loop/Spring 06

(N=66)	Pre-Test		Post-Test		*p*-value	
	Prob	**Ave**	**Prob**	**Ave**	**Prob**	**Ave**
Unknown Unpractised (N=54 student concepts)						
Ave	1.18	0.01	1.04	0.31	0.0585	0.0000
StDev	0.52	0.07	0.19	0.47		
Unknown Practised (N=224 student concepts)						
Ave	1.60	0.07	1.66	0.46	0.2374	0.0000
StDev	0.74	0.18	0.84	0.46		
Already Known (N=161 student concepts)						
Ave	1.24	1.00	1.47	0.86		
StDev	0.51	0.00	0.59	0.33		

Confounds

- Earlier concepts in practice are test, later concepts are control
  - Decreasing order of difficulty – targets harder concepts
  - Increasing order of difficulty – pre-test control average > pre-test test concept average
- More room for improvement on harder concepts – compare for effectiveness:
  - Not control vs test
  - But, pre vs post

Evaluation Hypothesis - 2

- Helps students learn with fewer problems.

Principle:

- Adaptation may be inclusionary or exclusionary
- *Compare:*
  - *Exclusionary adaptation against the worst-case (all-inclusive case);*
  - *Inclusionary adaptation against the best-case (all-exclusive case).*
- Gain of adaptation:
  - Inclusionary adaptation – percentage increase due to adaptation;
  - Exclusionary adaptation – percentage decrease due to adaptation

Arithmetic Expressions Tutor Spring 05 Protocol

- Pre-test: 21 problems, 17 concepts, 7 min, no feedback
- Practice: 15 minutes, p=2, detailed feedback
  - Control group: Non-adaptive tutor
  - Test group: Adaptive tutor
- Post-test: Similar to pre-test

Arithmetic Expressions Tutor Spring 05 Results

Spring 05 Arithmetic	Pre-Test		Practice	Post-Test		*p*-value	
	Prob.	**Ave.**	**Problems**	**Prob.**	**Ave.**	**Prob.**	**Ave.**
Control (N = 21 students)							
Average	10.48	0.46	37.43	14.10	0.61	0.0001	0.0066
Std-Dev	4.21	0.25	19.10	4.95	0.24		
Test (N = 35 students)							
Average	10.11	0.47	25.37	14.23	0.59	0.0000	0.0004
Std-Dev	4.63	0.27	19.39	5.93	0.28		
***p*-value**	0.771	0.927	0.027	0.931	0.851		

Relational Expressions Tutor Spring 05 Protocol

- Pre-test: 17 problems, 17 concepts, 7 min, no feedback
- Practice: 15 minutes, p=1, detailed feedback
  - Control group: Non-adaptive tutor
  - Test group: Adaptive tutor
- Post-test: Similar to pre-test

Relational Expressions Tutor Spring 05 Results

	Pre-Test		Practice	Post-Test		*p*-value	
	Prob.	**Ave.**	**Prob.**	**Prob.**	**Ave.**	**Prob.**	**Ave.**
Control (N = 21 students)							
Ave.	13.90	0.68	45.05	15.00	0.77	0.256	0.020
StdDev	3.13	0.21	19.19	3.39	0.16		
Test (N = 16 students)							
Ave.	14.56	0.73	14.13	15.38	0.82	0.302	0.023
StdDev	3.44	0.22	16.12	2.58	0.16		
***p*-value**	0.554	0.474	0.000	0.705	0.355		

Conclusions

Associative adaptation:

- Targets the concepts less well understood by students.
- Helps students learn with fewer problems.

Associative adaptation - Advantages

- Easier to build
- Supports any learning path
- Scalable
- Domain-independent

Acknowledgments

Partial support for this work was provided by:

- National Science Foundation's Educational Innovation Program under grant CNS-0426021.
- Ramapo Foundation