

SimStudent: Building a Cognitive Tutor by Teaching a Simulated Student



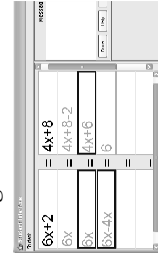
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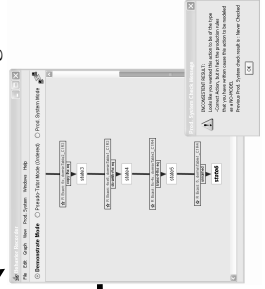
Next Generation Authoring

Build a tutor GUI

Teaching a solution



SimSt. learning



Production Rules

```

Rule simplify-LHS:
IF
    Is-equation( Eq ),
    Is-lhs( Eq, Lhs ),
    polynomial( Lhs ),
    all-var-terms( Lhs ),
    simplify( Lhs, S-lhs ),
Then
    enter( S-lhs )
    
```

CTAT: Cognitive Tutor Authoring Tools

- *Example-Tracing Tutor* with zero programming
 - A cognitive model specific to a particular problem
 - Some generalization by modifying a behavior graph
- *Model-Tracing Tutor* requires a cognitive model
 - Cognitive task analysis is challenging
 - Writing production rules is even more challenging
 - *Performing the task* is much easier...

SimStudent

- Machine learning agent
 - Learns problem-solving steps by ...
 - Observes model solutions / solving problems, and ...
 - Outputs a set of production rules
- Fundamental technology
 - Programming by Demonstration
 - Inductive Logic Programming

Lau, T. A., & Weld, D. S. (1998). Programming by demonstration
Blessing, S. B. (1997). A programming by demonstration authoring tool for model-tracing tutors

Authoring Strategies

- Authoring by demonstration
 - Learning from worked-out examples
 - Demonstrate whole solutions
 - Learning by generalizing examples (when it can't "self-explain")
- Authoring by tutoring
 - Learning by doing (with tutor feedback)
 - Interactively tutor with immediate feedback and hint
 - Learning by generalizing hint with taking feedback into account

5

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Demo!

6

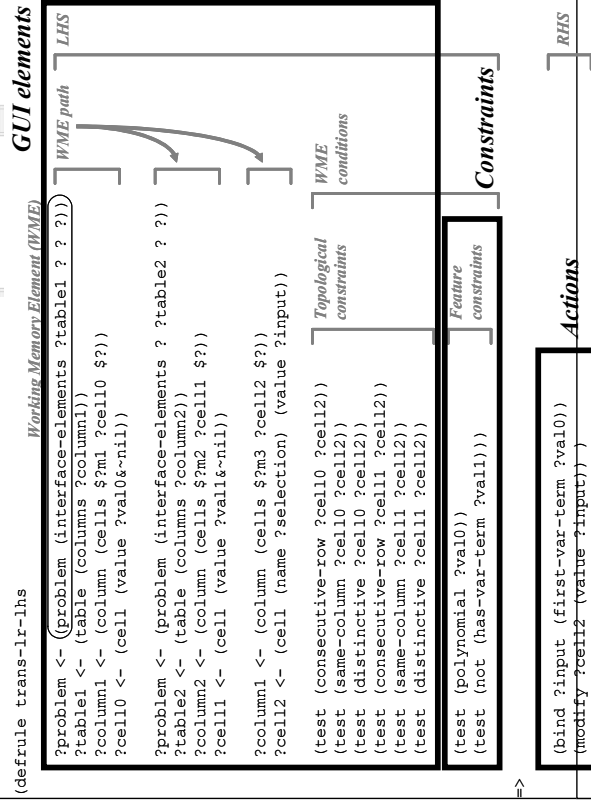
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Learning Production Rules in 3 parts: What-When-How

If
such and such *constraints* hold
When
among this and that *GUI elements*
What
Then
do *actions* with the GUI elements
How

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Production Rule in JESS



Background Knowledge

- Domain concepts to “explain” demonstrations
 - Operators
 - Feature predicates

- External Jess function written in Java

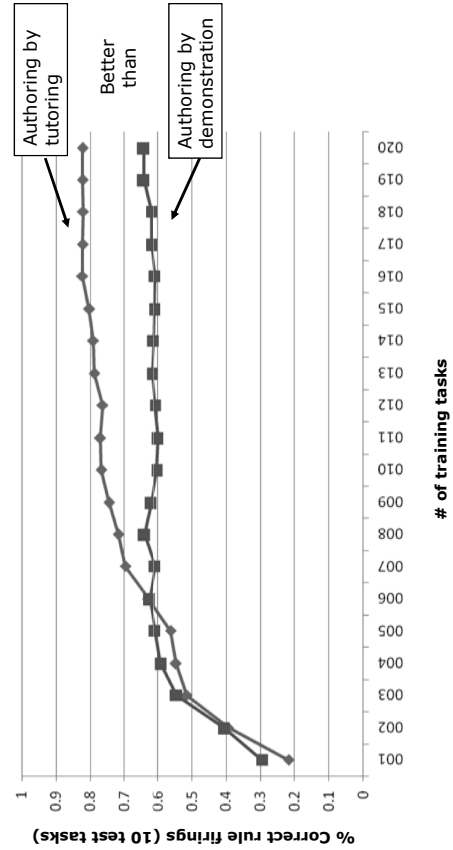
```
(defrule multi-lhs
...
?var22140 <- (column (cells ? ?var22143 ? ? ? ?))
?var22143 <- (cell (value ?val0&~nil))
(test (fraction-term ?val0 ))
=>
(bind ?val2 (denominator ?val0))
(bind ?input (mul-term-by ?val0 ?val2))
...
)
```

9

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Learning Results

$$StepScore = \begin{cases} 0, & \text{if } C = 0 \\ \frac{C}{C + I} & \end{cases}$$



11

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Example : Algebra domain

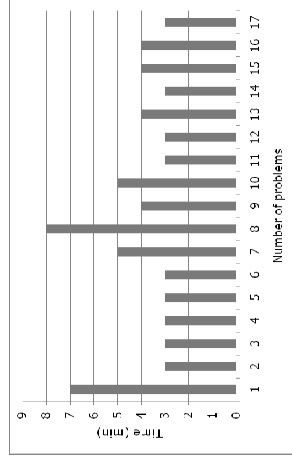
- 16 Feature predicates & 28 operators

Feature Predicates for LHS conditions	Operators for RHS actions
HasCoefficient	LastVarTerm
HasConstTerm	MulTerm
HasVarTerm	MulTermBy
Homogeneous	Numerator
IsFractionTerm	ReverseSign
IsConstant	RipCoefficient
IsDenominatorOf	SkillAdd
IsNumeratorOf	SkillClt
IsPolynomial	SkillDivide
Monomial	SkillMultiply
NotNull	SkillIRf
VarTerm	SkillMt
IsSkillAdd	SkillSubtract
IsSkillSubtract	VarName
IsSkillDivide	
IsSkillMultiply	
	AddTerm
	AddTermBy
	Coefficient
	CopyTerm
	Denominator
	DivTerm
	DivTermBy
	EvalArithmetic
	FirstTerm
	FirstVarTerm
	GetOperand
	InverseTerm
	LastConstTerm
	LastTerm

10

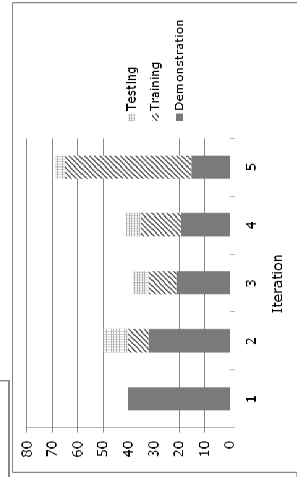
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Authoring Time



Authoring by Tutoring

- Authoring by tutoring took 86 minutes
- Authoring by demonstration took 238 minutes
- A 2.8x speed-up!



Authoring by Demonstration

12

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