Chemistry Studio

An Intelligent Tutoring System: Problem Solving

B.Tech Project

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Objective

- Building a system aimed at helping a student in their learning process
- Generate solutions and explanations in accordance with the interest and knowledge of the student.
- Hint Generation and Problem Generation
- Target Users: High school students (Grade 9 to 12)

Basic Intuition

- Scenario: A professor gives a problem in the domain of Periodic Table to the class.

- Students Response
  - Pre-knowledge of Basic Facts
  - Theorems & Relations
- System Response
  - In-built knowledge of Basic Facts
  - Breaks the complex into smaller problems
  - Builds up explanation (using *rules*)

- System tries to simulate the thinking of the student and is in a better position to guide the student.

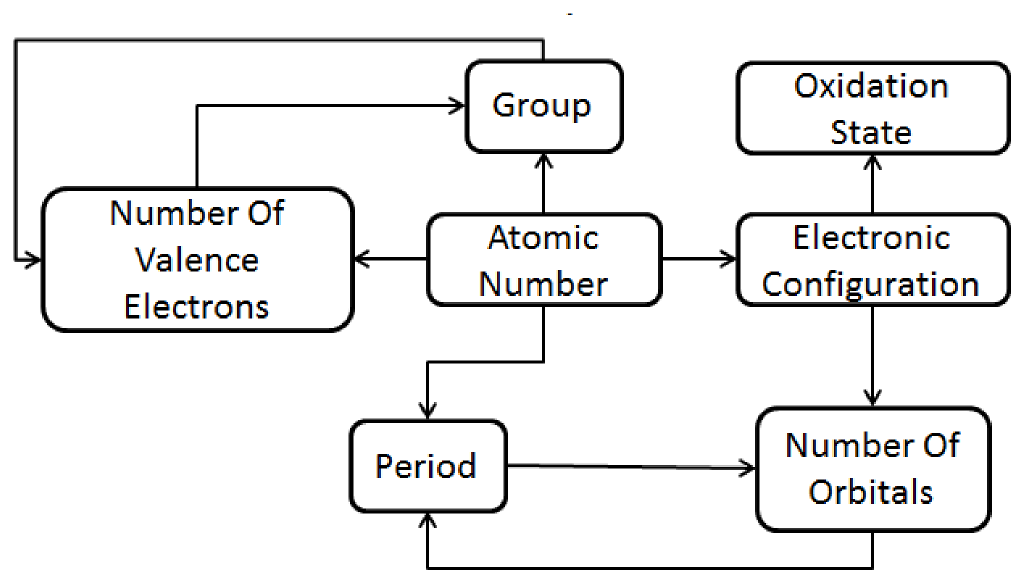
Intermediate Logic Component

- Identification of major entities in the Periodic Table
- Intermediate representation between the NLP and Problem Solving component.
- Terms: Predicates, Functions, Variables

Unary Predicates	Unary Functions
AlkaliMetals	FirstIonizationEnergy
AlkalineEarthMetals	AtomicRadius
Transition Metals	IonicRadius
Metalloids	AtomicNumber
Non-Metals	GroupNumber
Halogens	MetallicCharacter

Prolog Database

- Construct a set of facts and rules in the logic programming language Prolog
- Build a directed dependency graph
  - *Nodes* – Predicates
  - *Edges* – Dependency between predicates



Prolog Database (contd.)

- Basic Facts about each element
- For each predicate, discover its relation with all possible predicates and facts

```
data(atomicNumber, element, groupNumber, period-
Number, atomicMass, FIE, EA)

data(1, 'H', 1, 1, 1.008, 1312, 72)
data(2, 'He', 18, 1, 4.003, 2372, 0)
data(3, 'Li', 1, 2, 6.941, 520, 60)
```

```
1) firstIonizationEnergy(X, Y, '+') :- trendPeriod(X, Y, '='), !,
trendGroup(X, Y, '+'), !.
2) firstIonizationEnergy(X, Y, '+'):- trendGroup(X, Y, '='), trend-
Period(X, Y, '-'), !.
```

Yield Prolog (YP)

- Yield Prolog is an implementation that enables Prolog to be directly embedded into C#.
- Used as an interface to process the input XML file, query the prolog database and outputting the result.
- Advantage: Unifies the power of procedural and declarative programming.
  - No API standing between our code and Yield Prolog
  - Mix Prolog-style predicates with ordinary arrays, file I/O, GUI calls and all your own classes
- Generation of Prolog Database to YP using YP Compiler

Problem Solving Component

- XML File Generation
- Prolog Goal Generation
- Yield Prolog (C#) Goal Generation
- Compile & Execution of Goal Code
- Derivation Tree for Solution

Same/And Query Planning

- Recursive unification of child nodes
- *And* of clauses is represented as a *comma-separated* list in the prolog goal

- Example-
  - Same(Group(Ca), $1)
  - And(And(Same(2, Group($1)), Same(3, Period($1))), (AtomicNumber($1), $2))

Demo: Questions 1-5

Max/Min Query Planning

- Many questions (a *property* & a *domain*)
- Challenge: Extra conditions to be satisfied
- Passed as *Filter* conditions
- Restrict Domain (happens in *Interface*)

Demo: Questions 12-14

ForAll Query Planning

- Trivial Approach
  - Scan all elements of Periodic Table to find binding
- Our Approach
  - Assert the antecedents with new constants
  - Satisfy the goal with consequents containing new constants

<u>Database</u>

$$A(x), A2(x) \rightarrow P(x)$$

$$A1(x), A2(x) \rightarrow R(x)$$

$$R(x) \rightarrow Q(x)$$

$$P(x), Q(x) \rightarrow B(x)$$

<u>Goal</u>

$$\forall x : A(x), A1(x), A2(x) \rightarrow B(x)$$

<u>Assertions</u>

$$A(a),\ A1(a),\ A2(a)$$

<u>New Goal</u>

$$B(a)$$

Demo: Questions 15

Trend Query Planning

- Properties vary along a direction
- Encapsulate directions
  - Basic knowledge which a student has related to a direction
  - Assert that knowledge and retract after solving
- Find the varying trend *or* property *or* direction

```
assertFact(‘down’) :- assertz(trendAtomicNumber(‘p’, ‘q’, ‘-’)), as-
sertz(trendGroup(‘p’, ‘q’, ‘=’)).
assertFact(‘right’) :- assertz(trendAtomicNumber(‘p’, ‘q’, ‘-’)), as-
sertz(trendPeriod(‘p’, ‘q’, ‘=’)).
          ⋮
retractFact(‘down’) :- retract(trendAtomicNumber(‘p’, ‘q’, ‘-’)), re-
tract(trendGroup(‘p’, ‘q’, ‘=’)).
retractFact(‘right’) :- retract(trendAtomicNumber(‘p’, ‘q’, ‘-’)), re-
tract(trendPeriod(‘p’, ‘q’, ‘=’)).
          ⋮
```

Demo: Questions 6-9

Order Querying

- Rearrange the elements w.r.t. the value of a certain property

- Merge Sort

Demo: Questions 10-11

Challenges Faced

- Combining two or more prolog goals to build a more general unified goal
- Understanding the intricacies of the YP compiler
  - Asserted rules and facts treated in separate predicate store as the existing predicates
  - Dynamic passing of predicates in the yield prolog environment not supported
  - Successfully modified the compiler to fix the above bugs
- On the fly compilation of the dynamically generated code from PHP script

Statistical Evaluation

- Evaluation Metric: Number of question solved by the system versus the number of predicate rules defined.

- Solving 70 questions out of the 100 collected questions.
  - Using existing 5 templates and approximately 20 predicate rules
  - Collected Set is not representative of the entire domain

- As the predicate rules and templates increases, the system would be able to achieve higher question solving ability

- In future, proof-length with *ease of understanding* can be used to gauge the efficacy

Derivation Tree

- System emulates the thinking of the student
- At each step of derivation, the logical reasoning for that step can be accumulated to give an overall reasoning.
- Can have multiple successful derivations for a single goal
  - Represent different solutions to a particular problem
  - Important to let the user decide which solution to prefer
- Use the existing knowledge-base of the user to simulate which solutions would be more attractive to the user.
  - For example: Solution using Concept X and Concept Y
  - Give the user the choice to see any of the derivation

Future Work

- Hint Generation
- Efficient Query Planning
- Problem Generation
  - Use the depth of the proof as a heuristic to measure hardness
  - Assigning certain initial predicates a score of hardness
  - Use few basic templates and conjunction operators
- Future Interactive System
  - Modeling the initial knowledge of the student
- Handling Exceptions and Conflicting Rules
- Similarity Metric
  - Variation within an ε-range

Thank you …

Questions ?