Universidad de Alcalá

Departamento Ciencias de la Computación

Competency-based Learning Object Sequencing: Comparing Two Evolutionary Approaches

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Concepts

- Fields
  - e-Learning
  - Adaptive Hypermedia
  - Natural Computing

Concepts

- e-Learning
  - Learning Object (LO)
    - Reusable Piece of Learning Materials
    - LO = Assets & Metadata (MD)
  - Learning Management Systems (LMS)
  - Standards
    - IEEE Learning Object Metadata (LOM)
    - ADL Shareable Content Object Reference Model (SCORM)

Concepts

- Natural Computing. Kori (2008) taxonomy:
  - Nature as inspiration
    - Classic techniques
      - Cellular automata, neural networks, ALife
    - Evolutionary computation
      - **Genetic Algorithms**, Evolution Strategies, Genetic Programming, Learning Classifier Systems, …
    - Swarm intelligence
      - **Particle Swarm Optimization**, Ant Systems
  - Nature as implementation substrate
  - Nature as computation

Concepts

- Particle Swarm Optimization (PSO)
  - Optimizer originally developed by Eberhart & Kennedy (1995) and intended to work on continuous spaces
    - A set of particles 'flies' through the solution space sharing the information that they gather
  - Every iteration each particle updates its position

$$\vec{V}_{new} = \underbrace{w \times \vec{V}_{old}}_{\text{History}} + \underbrace{c1 \times \mathrm{rand}() \times \left(\vec{P}_{pbest} - \vec{X}\right)}_{\text{Own knowledge}} + \underbrace{c2 \times \mathrm{rand}() \times \left(\vec{P}_{nbest} - \vec{X}\right)}_{\text{Social knowledge}}$$

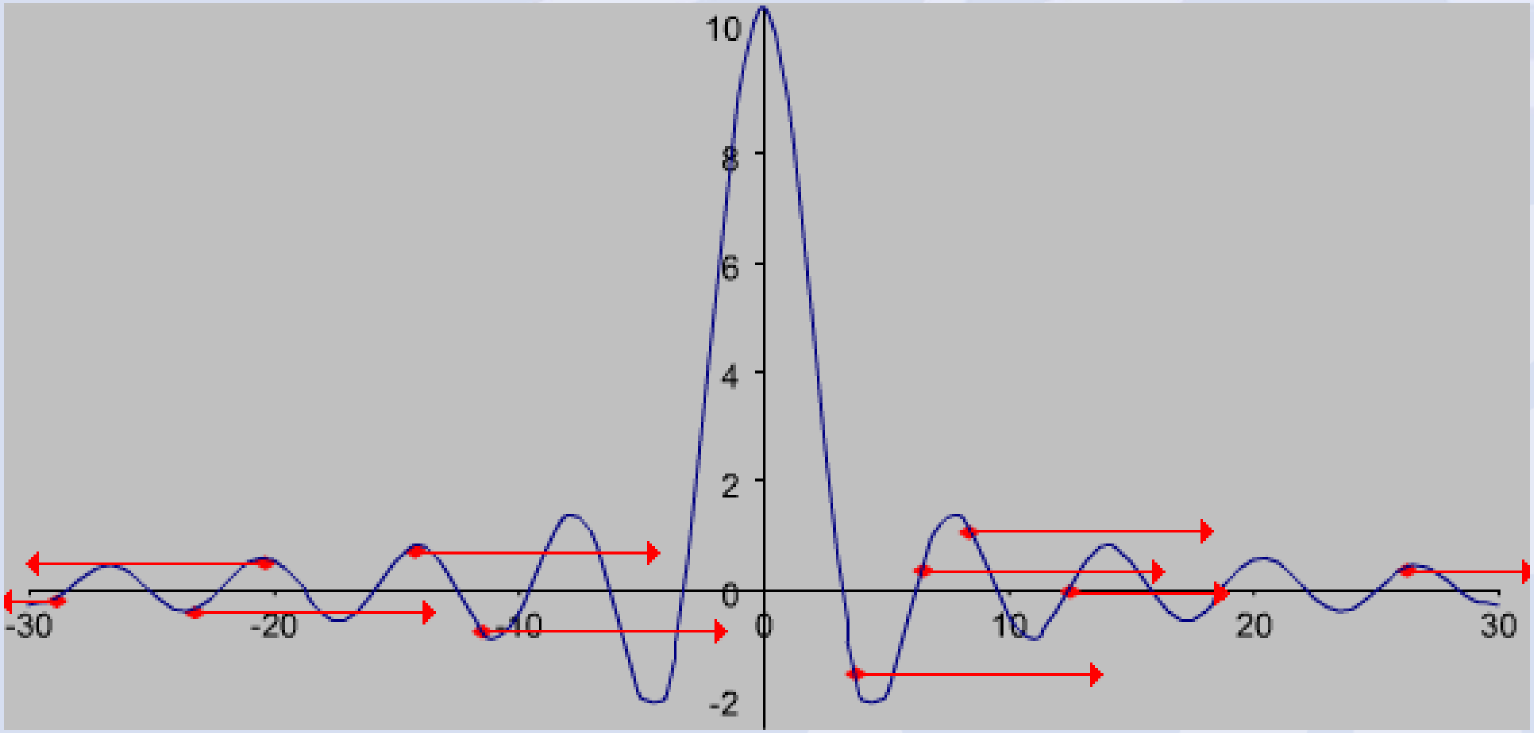
$$\vec{X}_{new} = \vec{X}_{old} + \vec{V}_{new}$$

Concepts

- Particle Swarm Optimization (PSO)

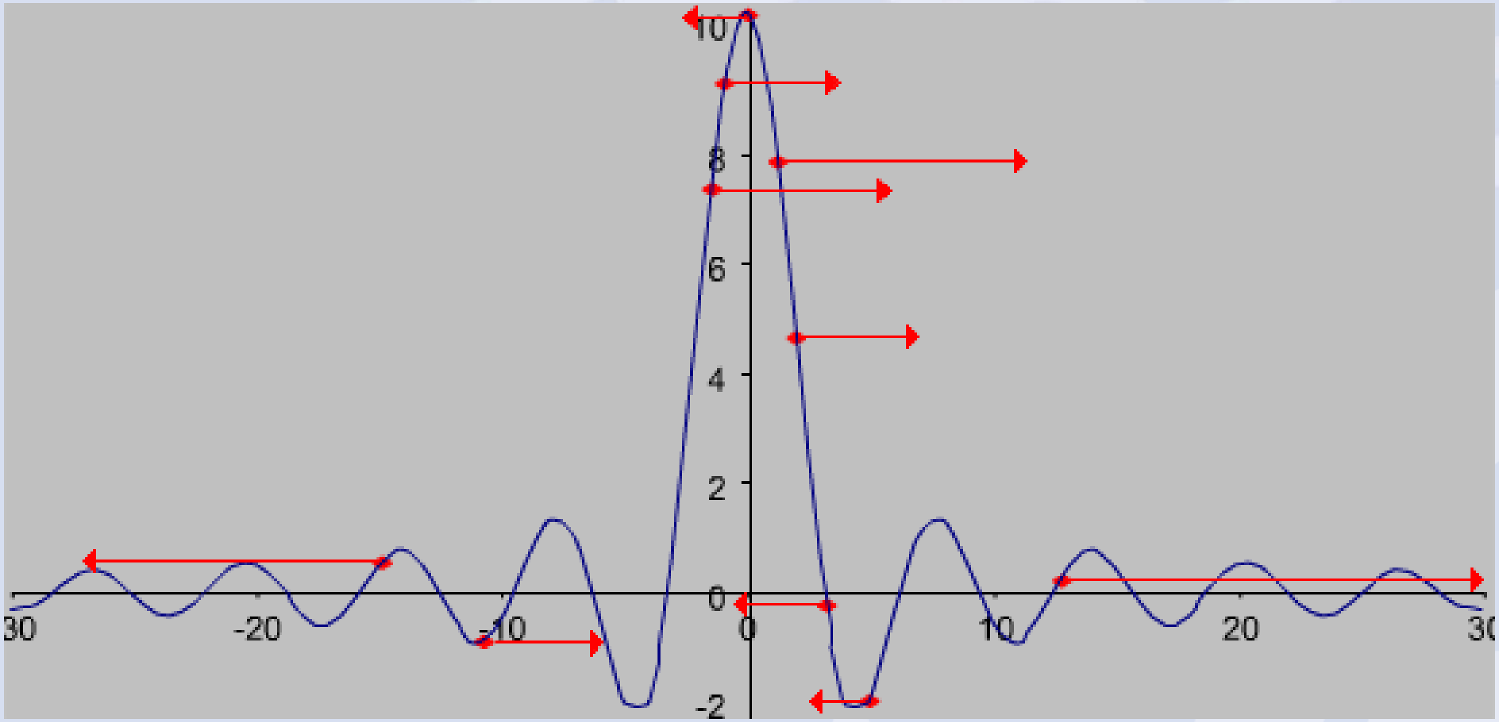
  f(x) = 10 sin (x) / x

  – Iteration 0: Random positions and speeds. 10 particles.



Concepts

- Particle Swarm Optimization (PSO)
  - After 10 iterations



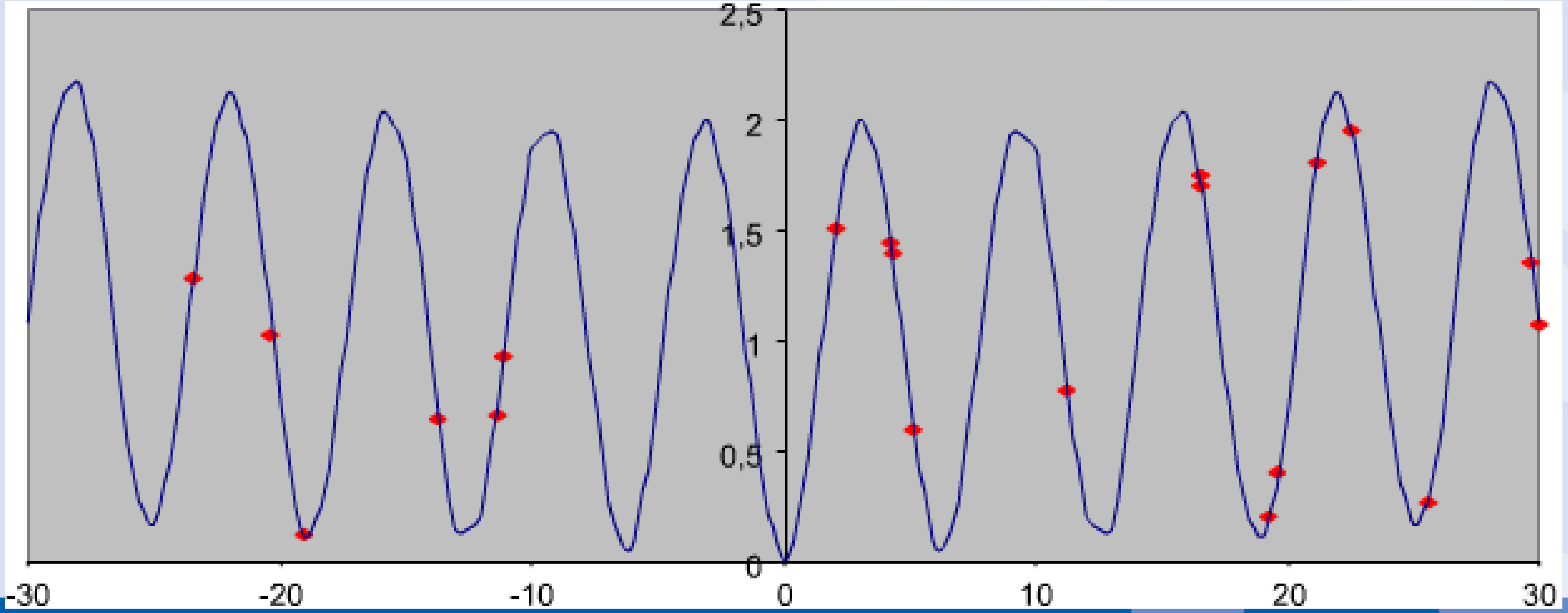
Best solution found x=-0,066, f(x)=9,992. Time 80ms.

Concepts

- Particle Swarm Optimization (PSO)

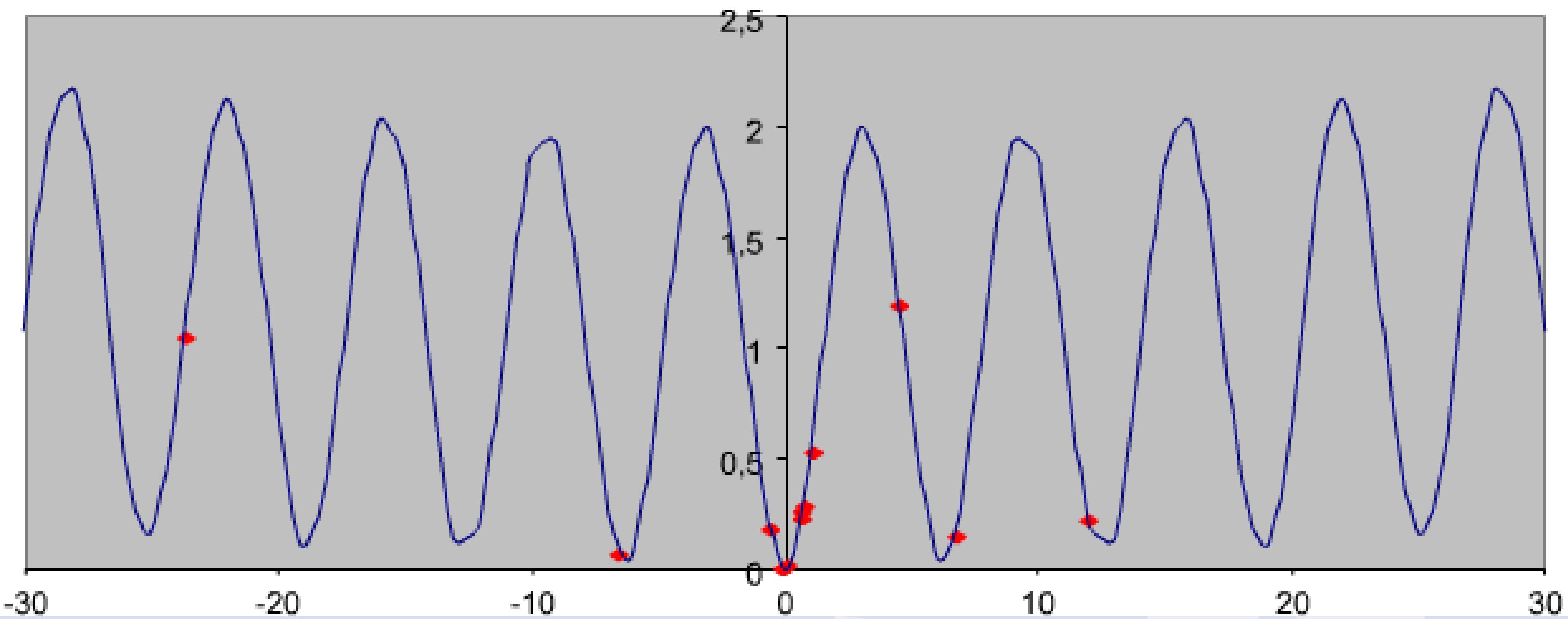
  Griewank Function $$f(x) = \frac{1}{4000}\sum_{i=1}^{N} x_i^2 - \prod_{i=1}^{N}\cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$$

  – Iteration 0: Random positions (and speeds). 20 particles.



Concepts

- Particle Swarm Optimization (PSO)
  - After 50 iterations



Best solution found $x=-4{,}475 \times 10^{-4}$ $f(x)=-1{,}002 \times 10^{-7}$, time 1683ms.

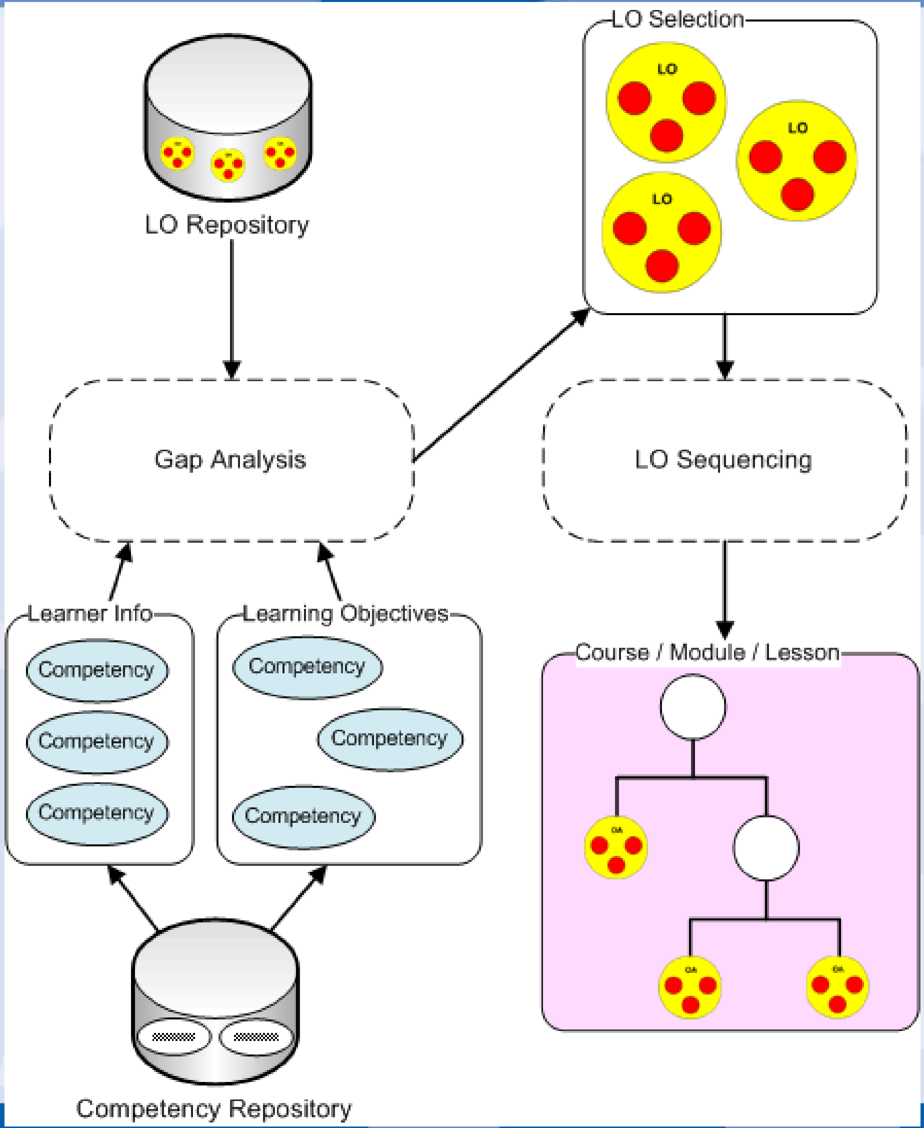
Framework

- Competency-driven content generation model

  -Current model: Instructors create courses targeting generic learner profiles.
  - Tasks: Search, sequence, package

  -Proposal: Automate these tasks to build personalized learning courses

  -Based on:
  - Learning Object (LO) Paradigm (Wiley, 2000)
  - e-Learning Standards and Specifications Conformance
    - SCORM, RDCEO, LOM



Framework

- Competencies for interoperable Learning Object Sequencing
  - Competency views
    - Pedagogic: What learners know, What learners want to know
    - LO: Prerequisites and Learning Outcomes
  - Competency Standards
    - IMS "Reusable Definition of Competency or Educational Objective" (RDCEO) specification
    - IEEE Learning Technology Standards Committee (LTSC) "Standard for Learning Technology - Standard for Reusable Competency Definitions " specification
    - HR-XML Consortium "Competencies (Measurable Characteristics) Recommendation"
    - Objective: Create Reusable Definitions of Competencies (RCDs)

Sequencing

- Curriculum sequencing objective:
  - "to provide the student with the most suitable individually planned sequence of knowledge units to learn and sequence of learning tasks […] to work with" (Brusilovsky, 1999)
- Sequencing Approaches (Gutiérrez & Pardo 2007):
  - UML-based
    - UML-guide (Dolog, 2003), CADMOS-D (Papasalouros, 2004)
  - Graph-based
    - AHA! (de Bra, 2003), Sequencing Graphs and SIT (Gutiérrez, 2004)
  - Stochastic
    - Pedagogical suggestions (Semet, 2003), auxiliary material generation (Huang, 2008)

Sequencing

- Obstacles
  - Standardization issues in actual e-learning systems
    - SCORM Content Aggregation Model (or IMS SS)
    - IEEE LOM

    Real reusability and interoperability are really far
  - Domain dependece vs domain independence
    - Difficulty to build models and they are domain dependent
  - For stochastic approaches
    - Different runs = different results

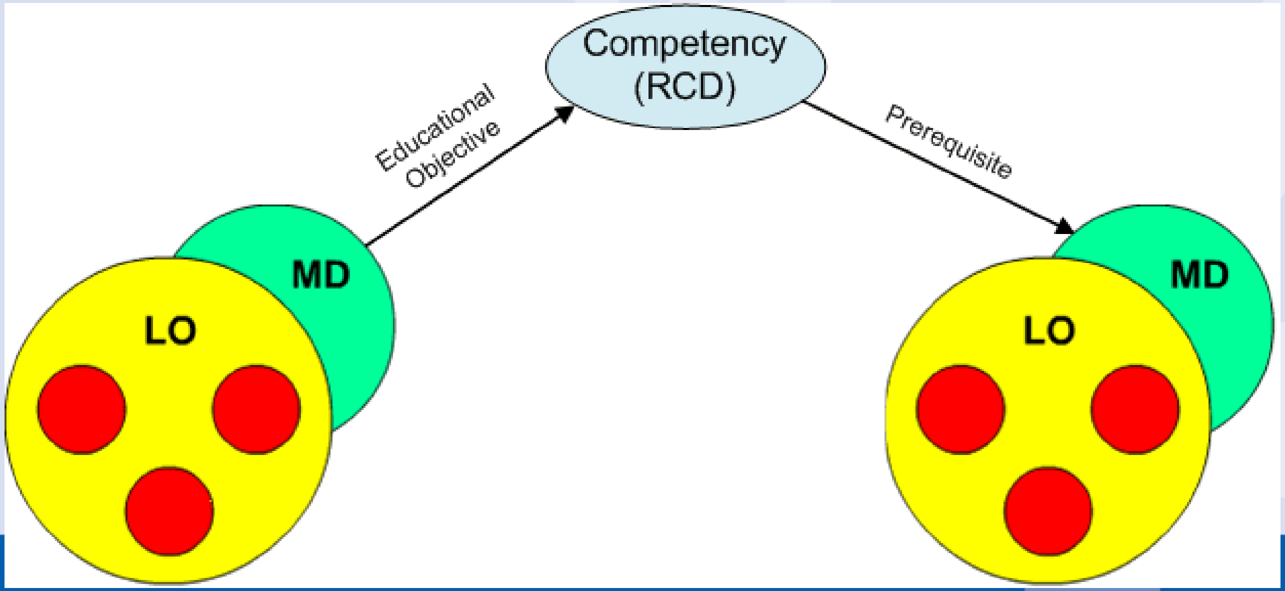
Our Approach

- Objectives
  - Build personalized courses for today e-learning systems
  - Define sequences of learning objects in a interoperable way
  - Create a domain independent sequencing mechanism

- Mechanism
  - Graph approach: to model sequences and its restrictions
  - Stochastic approach: to find feasible sequences

Our Approach

- The Model
  - LO sequencing through competencies
  - LOM records to link learning objects with competencies:
    - LOM element 9, ‘Classification’
      - element 9.1 ‘Purpose’ set to ‘prerequisite’ or ‘educational objective’
      - element 9.2 ‘Taxon Path’ used to reference the competency



Our Approach

- The Problem
  - Given a Random Sequence of Learning Objects find a correct (feasible) sequence
  - Modelled as a Constraint Satisfaction Problem (CSP)
    - Variables: LOs Positions in the Sequence
    - Constraints: Competencies (LOs Relations)
    - Operations: Permutations of LOs within the sequence (PermutCSP)
    - State: Sequence
    - Objective: Find a sequence that satisfies all constraints
    - Fitness function: Standard penalty function

$$\text{fitness}(s) = \sum_{i=0}^{n} s[i].pr_n$$

Our Approach

- The agents (the stochastic part)
  - Problem modelled as a Constraint Satisfaction Problem and two intelligent agents implemented to solve it:
    - Particle Swarm Optimization (PSO): Discrete-PSO (Hu, 2003) with velocity check
    - Genetic Algorithm (Holland, 1975): Order recombination, swap mutation and generational replacement with elitism (*k*-size tournament selection and a duplicate elimination policy)
  - Output: a personalized SCORM package

Our Approach

- PSO Agent Pseudocode

```
SEQUENCING_PSO(input_sequence, w, c1, c2) {
INITIALIZE the swarm
DO {
  FOR EACH particle {
    CALCULATE fitness value
    IF (new fitness < gBest) SET gbest = currentValue
    IF (new fitness < pBest) SET pbest = currentValue
    CALCULATE new velocity as
      V_new = w × V_old+ (c1×rnd()×(pbest-currentValue)) + (c2×rnd()×(gbest-currentValue))
    NORMALIZE Velocity as
      V_norm = V_new/max(V_new)
    CHECK V_norm limit
      FOR EACH v in  V_norm {
        IF(v > length(X)) v = length(X)
      }
    UPDATE particle value
      FOR i = 1 to length(V_norm){
          IF(rand() < V_norm[i]) SWAP currentValue[i] for currentValue[indexOf(currentValue,gBest[i]])
      }
    CHECK Mutation
      IF (currentValue = gBest) swap two  random positions from currentValue
  }
} UNTIL termination criterion is met
}
```

Our Approach

- GA Agent Pseudocode

```
SEQUENCING_AG(input_sequence, μ, k, p, n)
BEGIN
  SET population[0] = input_sequence
  Randomly INITIALIZE the rest of the population μ
  EVALUATE each individual
  SET bests = n individuals with best fitness
  SET n_generations = 0
  REPEAT UNTIL (termination criterion satisfied) {
    SELECT μ/2 couples using k size tournaments
    Perform an ORDERED RECOMBINATION of the μ/2 couples
    Offspring SWAP MUTATION with probability p
    ELIMINATE DUPLICATES
    survivors SELECTION for the next generation {
      PERFORM a generational replacement
      FOR-EACH i in bests
        IF fitness(i) > fitness(best offspring) REPLACE a random offspring with i
      }
      SET bests = n individuals with best fitness
    }
  }
END
```

Results

- Agents implemented and tested in real and simulated scenearios:
  - Real scenario: Sequence of LOs in a MSc Program. Web Engineering Program (23 LOs, 50 Constraints):
    - Basic courses (7) must be taken before any other (course).
      - Restrictions between two basic courses may occur.
    - ‘Itinerary’ courses (5) must be taken in a fixed ordered sequence.
    - Compulsory courses (5). There may be restrictions between two of them
    - Elective courses (6). Additional constraints regarding any other course may be set.

    Search space size: 23! States ($2{,}5 \times 10^{22}$)

    Ratio total solutions / feasible solutions is $8{,}9 \times 10^{12}$ (just an estimation)
  - Simulated scenarios: 5, 10, 20, 30, 40, 50, 60, 75 and 100 LOs with only 1 valid (feasible) sequence (solution)

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Results

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WEB ENGINEERING MASTER PROGRAM

Basic Courses

- Web, Internet & Distr. Syst. Introduction (30h)
- Object Oriented Programming (40h)
- HTML (30h)
- XML (40h)
- Cascade Style Sheets CSS (30h)
- Databases (SQL) (40h)
- Basic JavaScript (30h)

Java track

Java SE (50h) → Java JDBC (40h) → Web Servers (40h) → Java EE (50h) → Web Services in Java (40h) → Project (40h)

.NET track

Basic .NET Programming (50h) → ADO .NET (40h) → Web Servers (40h) → ASP.NET (40h) → Components & Web Services in .NET (50h) → Project (40h)

Compulsory Courses

- Software Engineering (40h)
- Development Methodologies (40h)
- Interface Design and Web Usability (40h)
- Design Patterns (40h)
- Software Testing (40h)

Elective Courses

- Java ME (40h)
- .NET for Mobile Devices (40h)
- Flash (40h)
- ActionScript (40h)
- PHP (50h)
- Advanced JavaScript & DOM (40h)
- UML (40h)

Results

- Agent Execution Example

Input

C1 - Software Engineering
C3 - Interface Design and Web Usability
C5 - Software Testing
E2 - Flash
B6 - Databases (SQL)
I5 - Components and Web Services with .NET
C2 - Development Methodologies
B5 Cascade Style Sheets (CSS)
I4 - ASP .NET
I3 - Web Servers
I2 - ADO .NET
E3 - ActionScript
B4 - XML
B1 - Web, Internet and Distr. Sys. Intr.
E6 - UML
B3 - HTML
E5 - Advanced JavaScript and DOM
B2 - Object Oriented Programing
E4 - PHP
I1 - Basic .NET Programing
E1 - .NET for Mobile Devices
B7 - Basic JavaScript
C4 - Design Patterns

→ Sequencing Agent →

Output

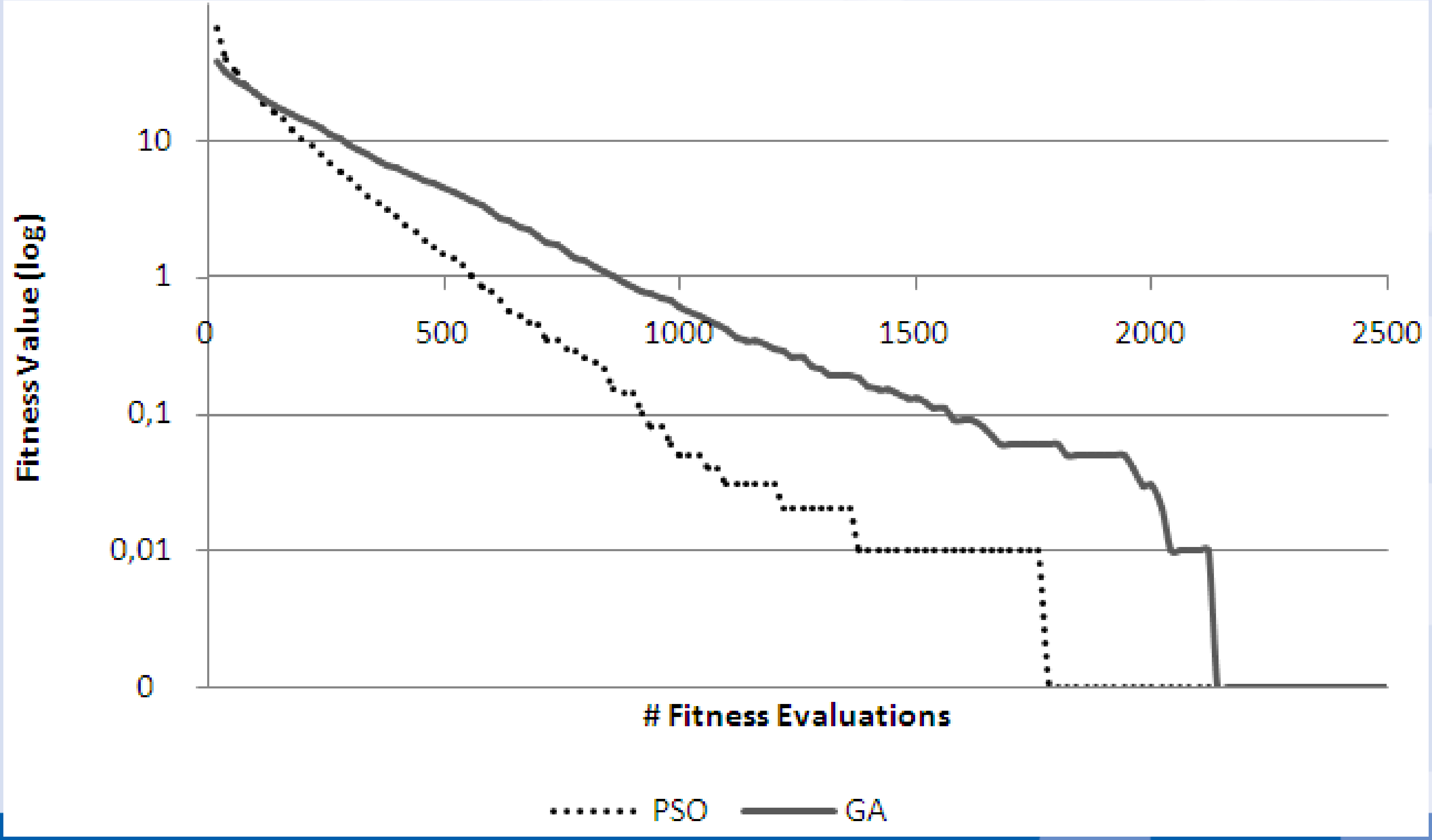
Fitness Function Value: 0
Fitness Funtion Calls: 1102

B1 - Web, Internet and Distr. Sys. Intr.
B3 - HTML
B2 - Object Oriented Programming
B5 Cascade Style Sheets (CSS)
B6 - Databases (SQL)
B7 - Basic JavaScript
B4 - XML
I1 - Basic .NET Programming
I2 - ADO .NET
E1 - .NET for Mobile Devices
E2 - Flash
C1 - Software Engineering
E5 - Advanced JavaScript and DOM
C4 - Design Patterns
I3 - Web Servers
I4 - ASP .NET
C2 - Development Methodologies
C5 - Software Testing
C3 - Interface Design and Web Usability
I5 - Components and Web Services with .NET
E4 - PHP
E3 - ActionScript
E6 - UML

Legend
B = Basic Course
I = Itinerary Course
C = Compulsory Course
E = Elective Course

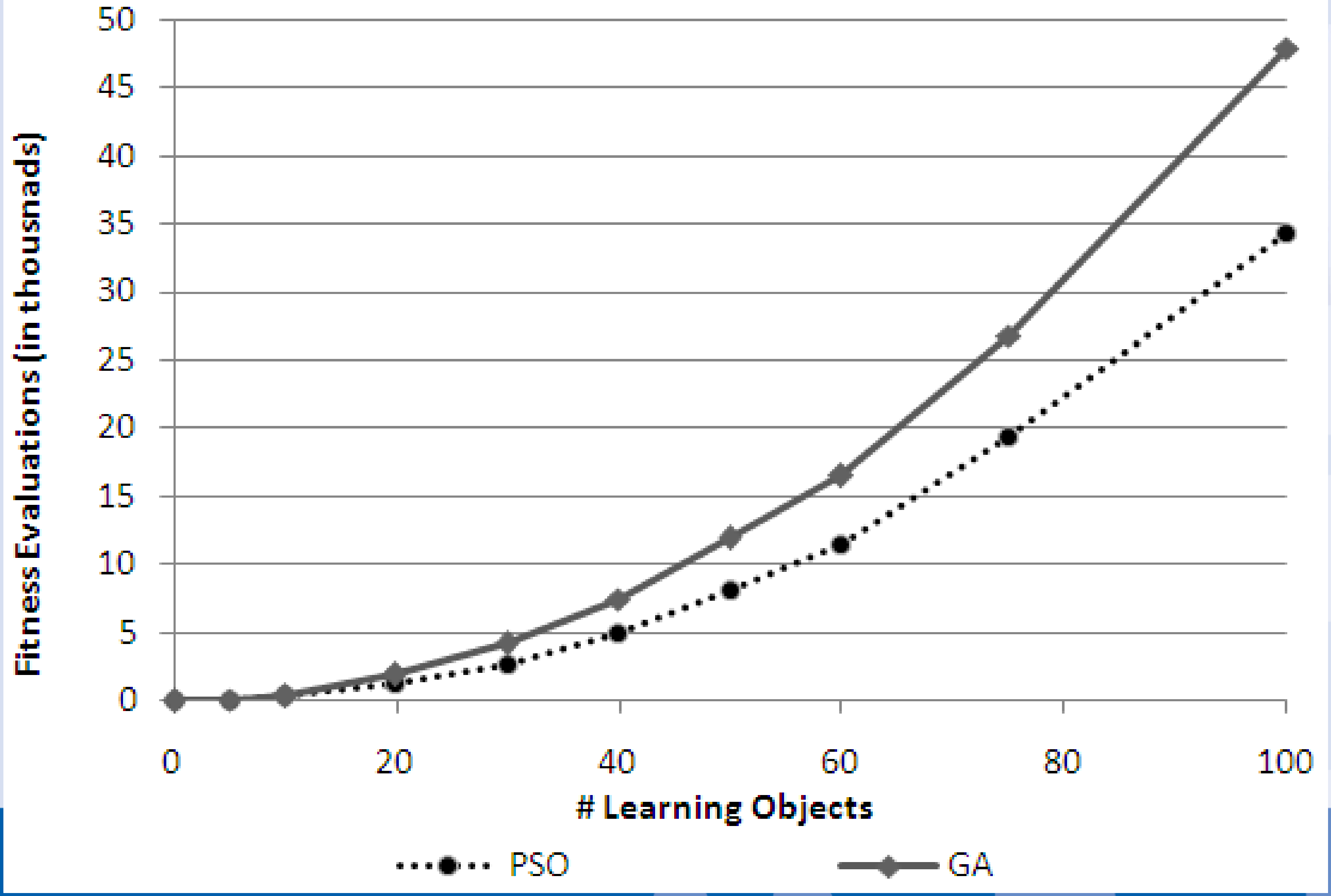
Results

- Agents Comparison



Results

- Scalability



Conclusions

- **Conclusions**
  - It is possible to create personalized courses for wide-use e-Learning systems taken care of standards
  - Learning objects, metadata and competencies can be used to define domain independent sequences
  - An AI approach may be employed to solve the sequencing problem
  - Two evolutionary agents have been designed and implemented
  - Both agents succeed but PSO outperforms GA in all the scenarios

Future Work

- **Future Work**
  - Scalability
    - Exact Techniques
    - Hybrid Techniques
    - Artificial Ants
  - Tree-like courses
    - Genetic Programming
  - Gap Analysis Subprocess
  - Interface
    - Curriculum recommendation to Learners

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Thank you & Questions

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