A Novel Approach for Test Problem Assessment Using Course Ontology

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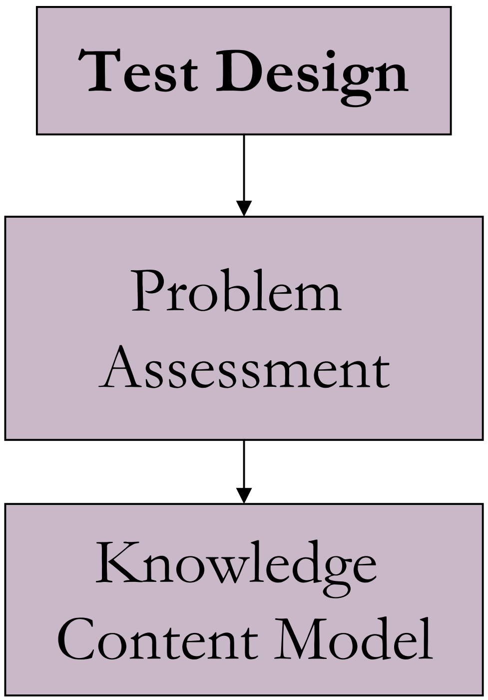
Objective



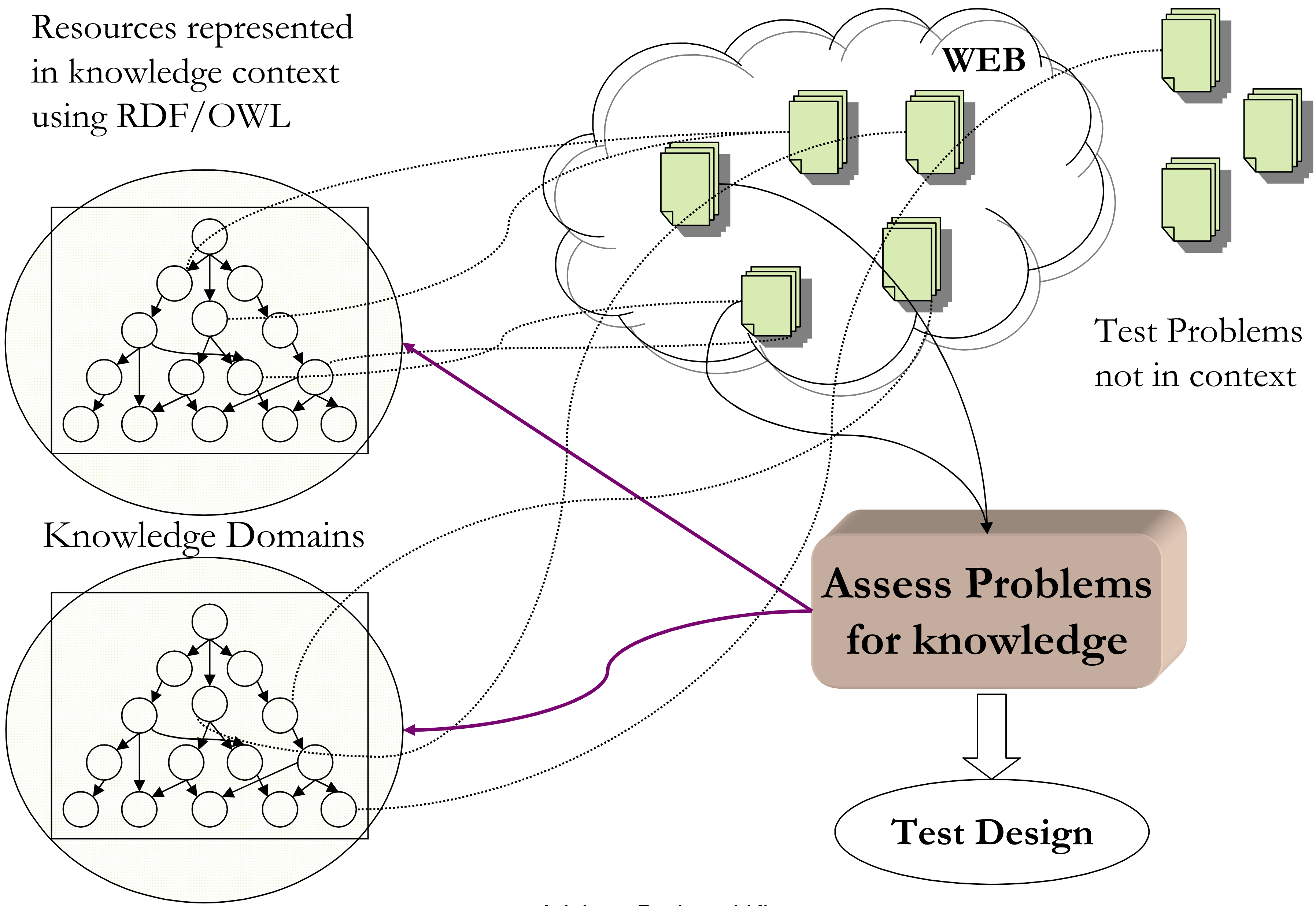
Design is useful for reengineering and reuse

Basic unit of test, is a problem

To answer a problem, knowledge is required

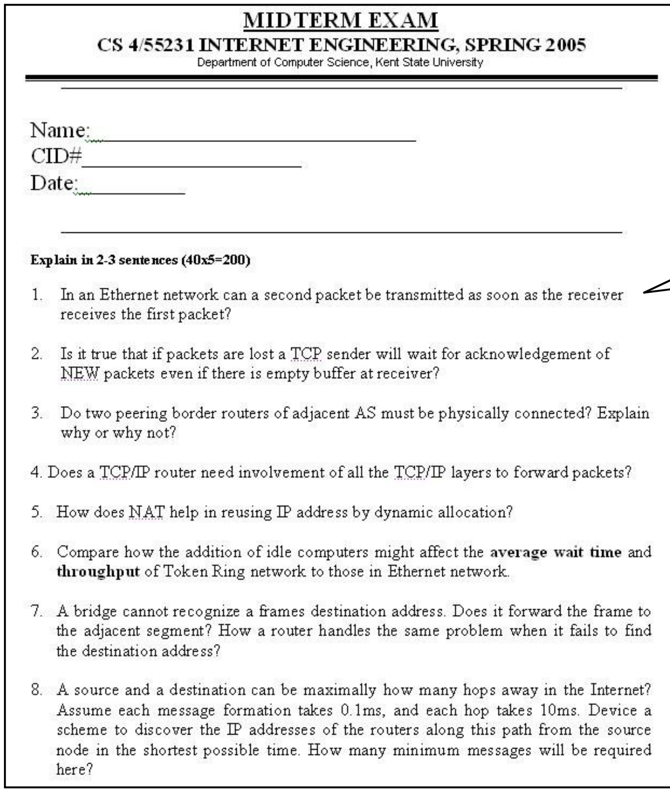
Background

- Web is scattered with online educational resources
- Mostly un-organised, but some in organised fashion as well [OCW, Universia, ACM, NSDL, CORE]
- **Not represented in context**
- Looses reusability, reengineering not possible, not machine interpretable
- Semantic representation standards
  - RDF (http://www.w3.org/RDF/) (2002)
  - OWL (http://www.w3.org/TR/owl-features/) (2004)
  - LOM (http://ltsc.ieee.org/wg12/) (2004)
- **Contextual representation of problems is important**



Resources represented
in knowledge context
using RDF/OWL
WEB
Test Problems
not in context
Knowledge Domains
Assess Problems
for knowledge
Test Design

Birds eye view of the process


MIDTERM EXAM

CS 4/55231 INTERNET ENGINEERING, SPRING 2005

Department of Computer Science, Kent State University

Name:_____________________________

CID#_______________________

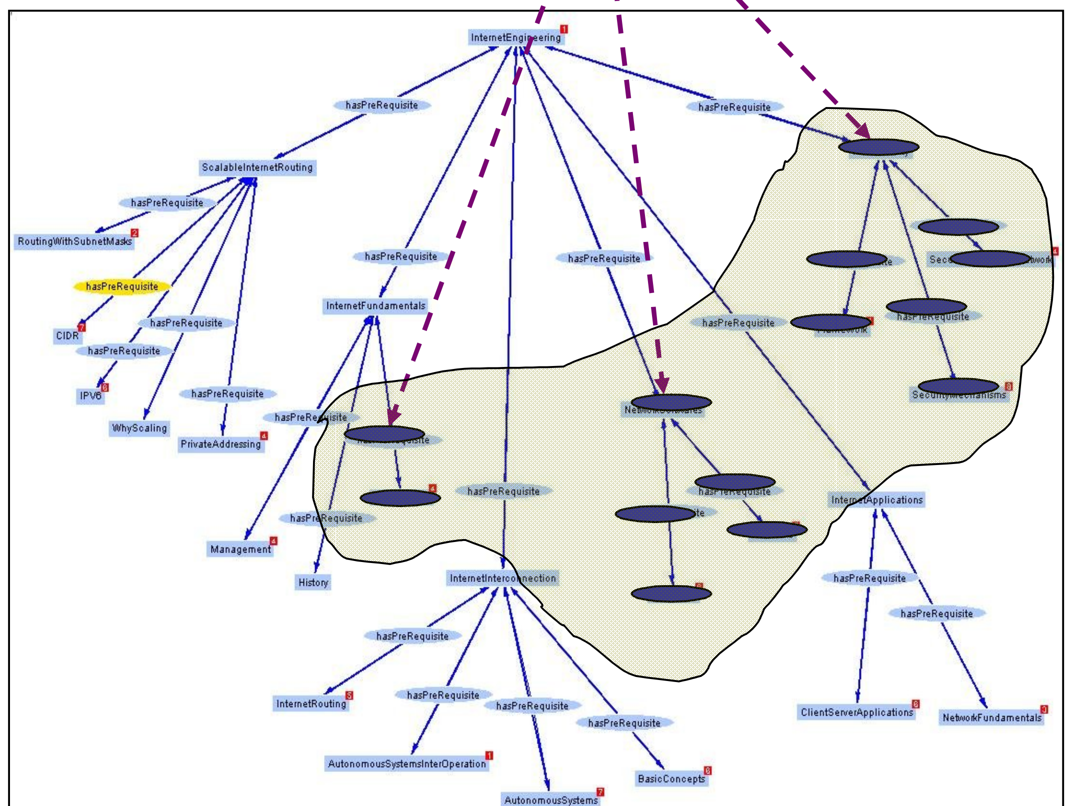
Date:__________

Explain in 2-3 sentences (40x5=200)

1. In an Ethernet network can a second packet be transmitted as soon as the receiver receives the first packet?
2. Is it true that if packets are lost a TCP sender will wait for acknowledgement of NEW packets even if there is empty buffer at receiver?
3. Do two peering border routers of adjacent AS must be physically connected? Explain why or why not?
4. Does a TCP/IP router need involvement of all the TCP/IP layers to forward packets?
5. How does NAT help in reusing IP address by dynamic allocation?
6. Compare how the addition of idle computers might affect the **average wait time** and **throughput** of Token Ring network to those in Ethernet network.
7. A bridge cannot recognize a frames destination address. Does it forward the frame to the adjacent segment? How a router handles the same problem when it fails to find the destination address?
8. A source and a destination can be maximally how many hops away in the Internet? Assume each message formation takes 0.1ms, and each hop takes 10ms. Device a scheme to discover the IP addresses of the routers along this path from the source node in the shortest possible time. How many minimum messages will be required here?

In an Ethernet network can a second packet be transmitted as soon as the receiver receives the first packet?

problem-concept mapping



Objectives

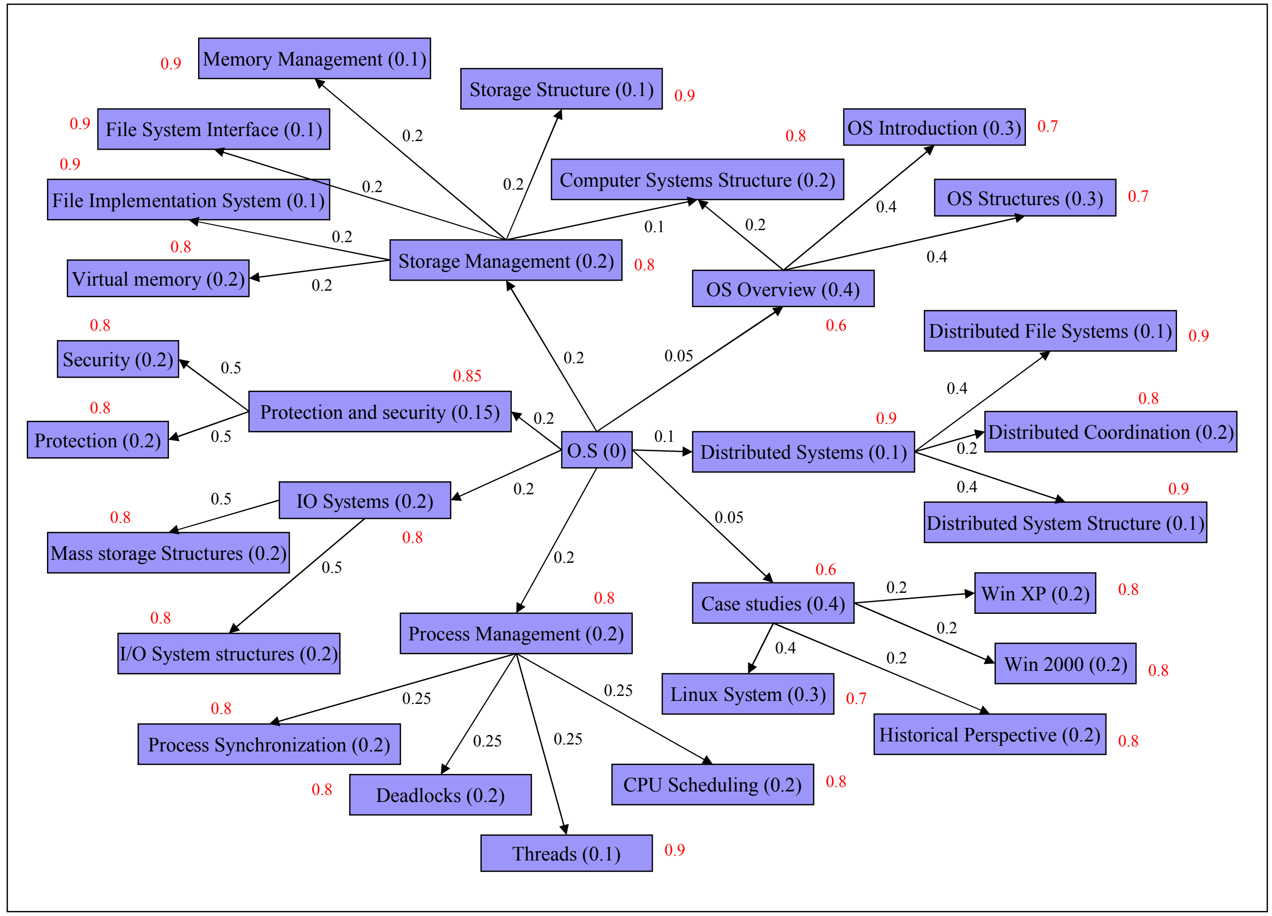
- map concept knowledge
- assess test problems
- analyze the methodology

Scope of this talk

- Course Knowledge Representation
- Problem Assessment
- Results

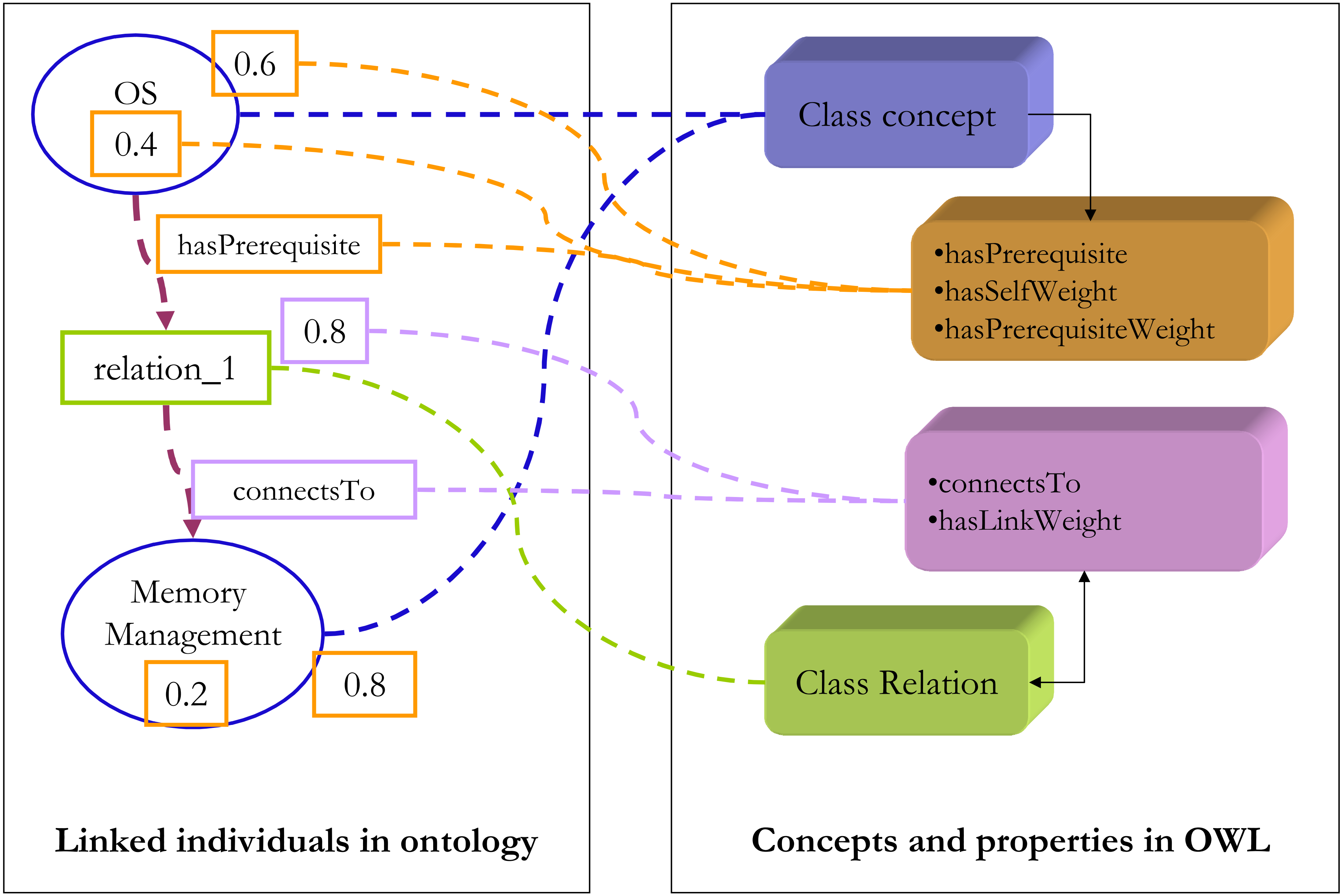
CSG (concept space graph)

- **Course Knowledge is represented using Concept Space Graph called as a "Course Ontology"**
- Course ontology → hierarchical representation of concepts taught in a course linked by "has-prerequisite" relationships.
- Each link → has prerequisite, link weight
- Each node → Self-weight, prerequisite-weight
- Expressive
- Computable



Course Ontology Description Language (CODL)

- Written in Web Ontology Language (OWL)
- Mostly OWL Lite with few extensions on data type properties
- Can represent any course ontology
- Basic Elements on Course Ontology OWL document are
    - Ontology Header
    - Class descriptions
    - Property descriptions
    - individuals


OS
0.6
0.4
hasPrerequisite
relation_1
0.8
connectsTo
Memory Management
0.2
0.8
Linked individuals in ontology
Class concept
•hasPrerequisite
•hasSelfWeight
•hasPrerequisiteWeight
•connectsTo
•hasLinkWeight
Class Relation
Concepts and properties in OWL

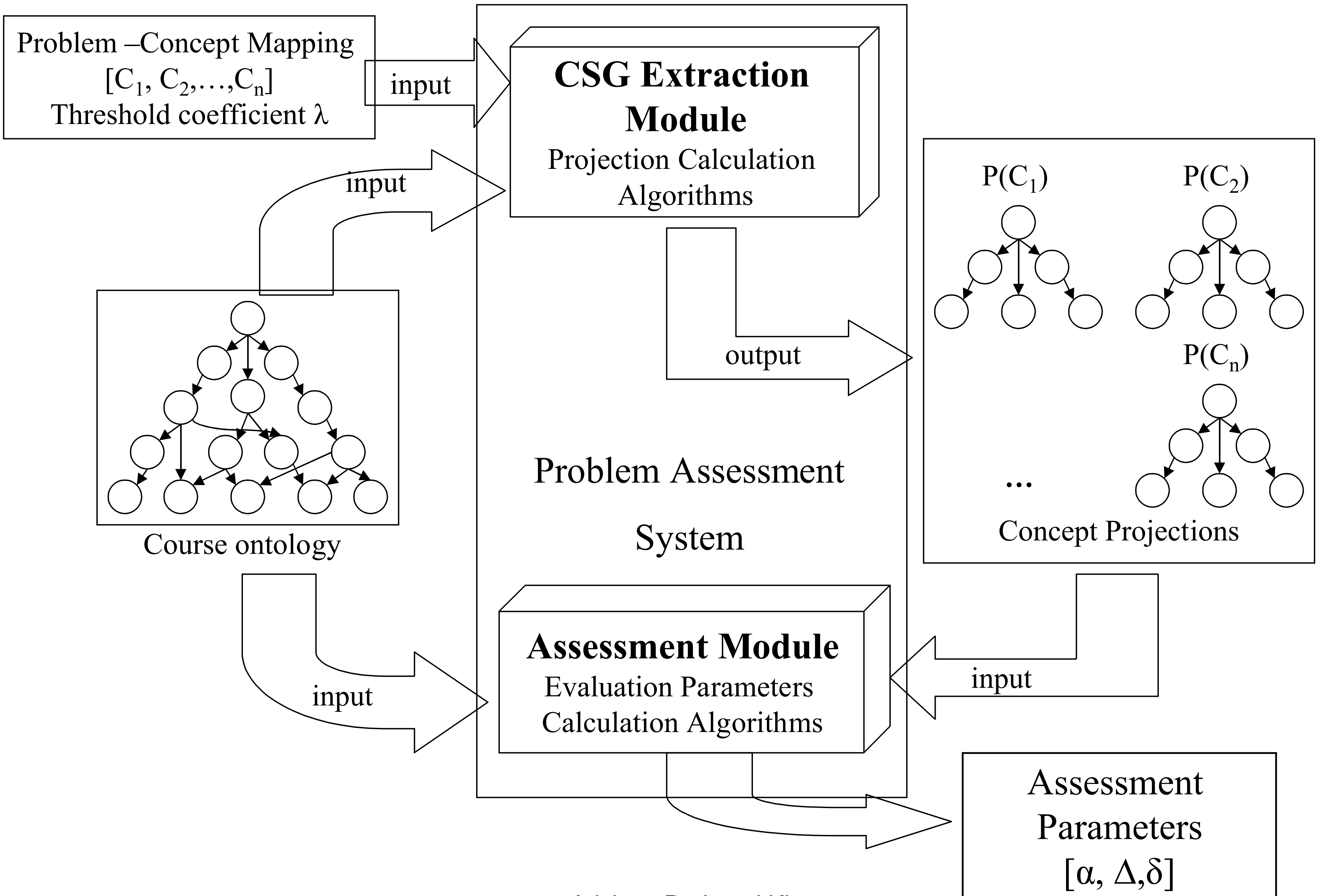
CODL individuals

```
Individuals

<Concept rdf:ID="MemoryManagement"/>

<Concept rdf:ID="OS">
         <hasPrerequisite>
                  <Relation rdf:ID="relation_1">
                           <connectsTo rdf:resource="#MemoryManagement"/>
                           <hasLinkWeight rdf:resource="#0.2"/>
                  </Relation>
         </hasPrerequisite>
         <hasSelfWeight rdf:resource="0.39"/>
         <hasPrerequisiteWeight rdf:resource="0.61"/>
</Concept>
```

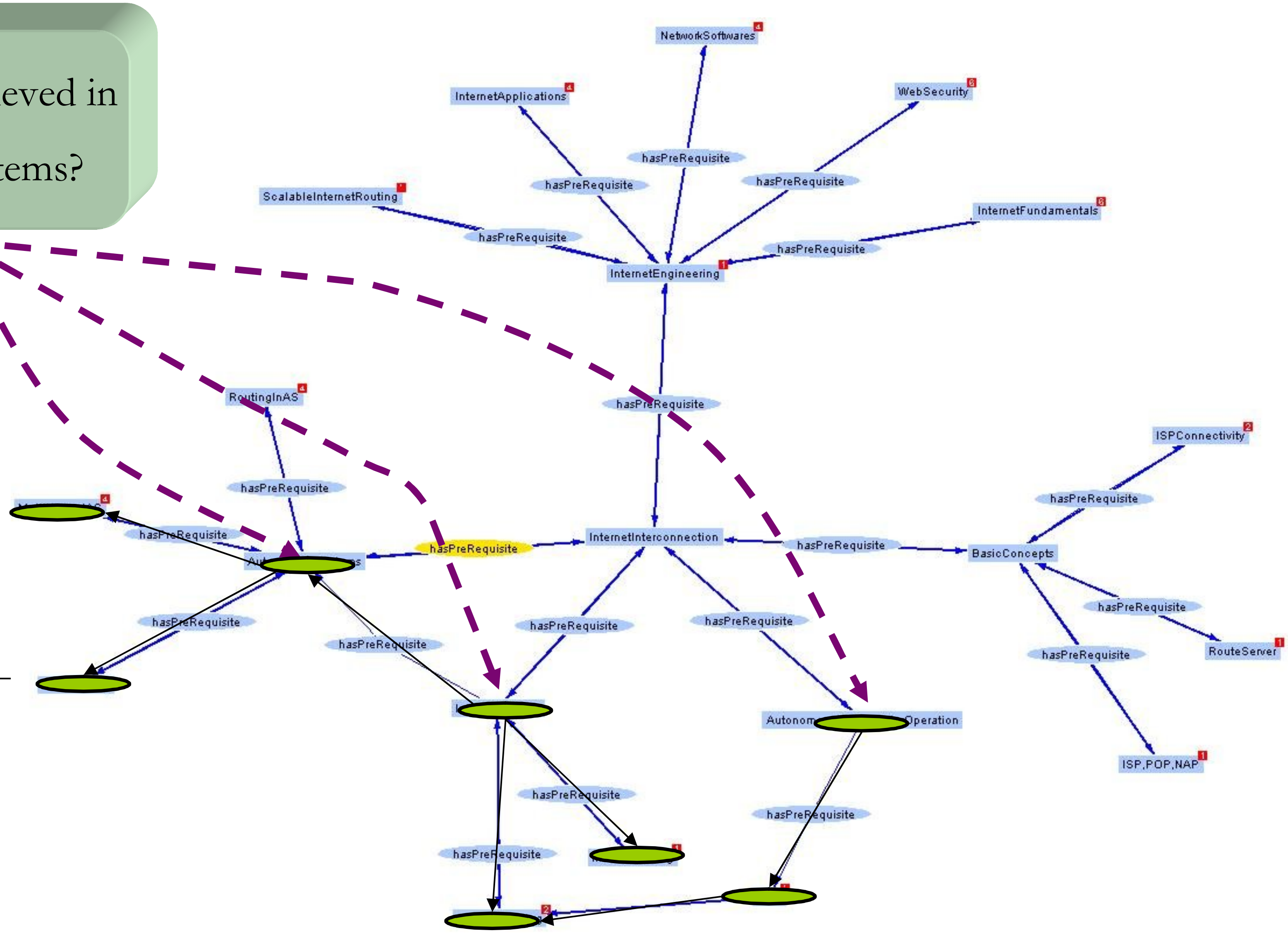
Problem Assessment Methodology


Problem –Concept Mapping
[C_1, C_2,…,C_n]
Threshold coefficient λ
input
CSG Extraction Module
Projection Calculation Algorithms
input
Course ontology
output
P(C_1)
P(C_2)
P(C_n)
…
Concept Projections
Problem Assessment System
input
Assessment Module
Evaluation Parameters Calculation Algorithms
input
Assessment Parameters
[α, Δ,δ]

CSG extraction

- Why?
  - CSG is very big
    - WordNet 50,000 word
    - CYC (over a million assertions)
    - Medical/Clinical Ontology (LinKBase 1 million concepts)
  - Selection of relevant portion of ontology to maintain computability
- How ?
  - Projection Graph
  - Projection Threshold Coefficient (λ)
    - Prunes CSG
    - Desired semantic depth

How is routing achieved in Autonomous Systems?



Prerequisite effect of one node over another

- **Node Path Weight:** *When two concepts x_0 and x_t are connected through a path p consisting of nodes given by the set* $[x_0, x_1 \ldots, x_m, x_{m+1}, \ldots, x_t]$ *then the node path weight between these two nodes is given by:*

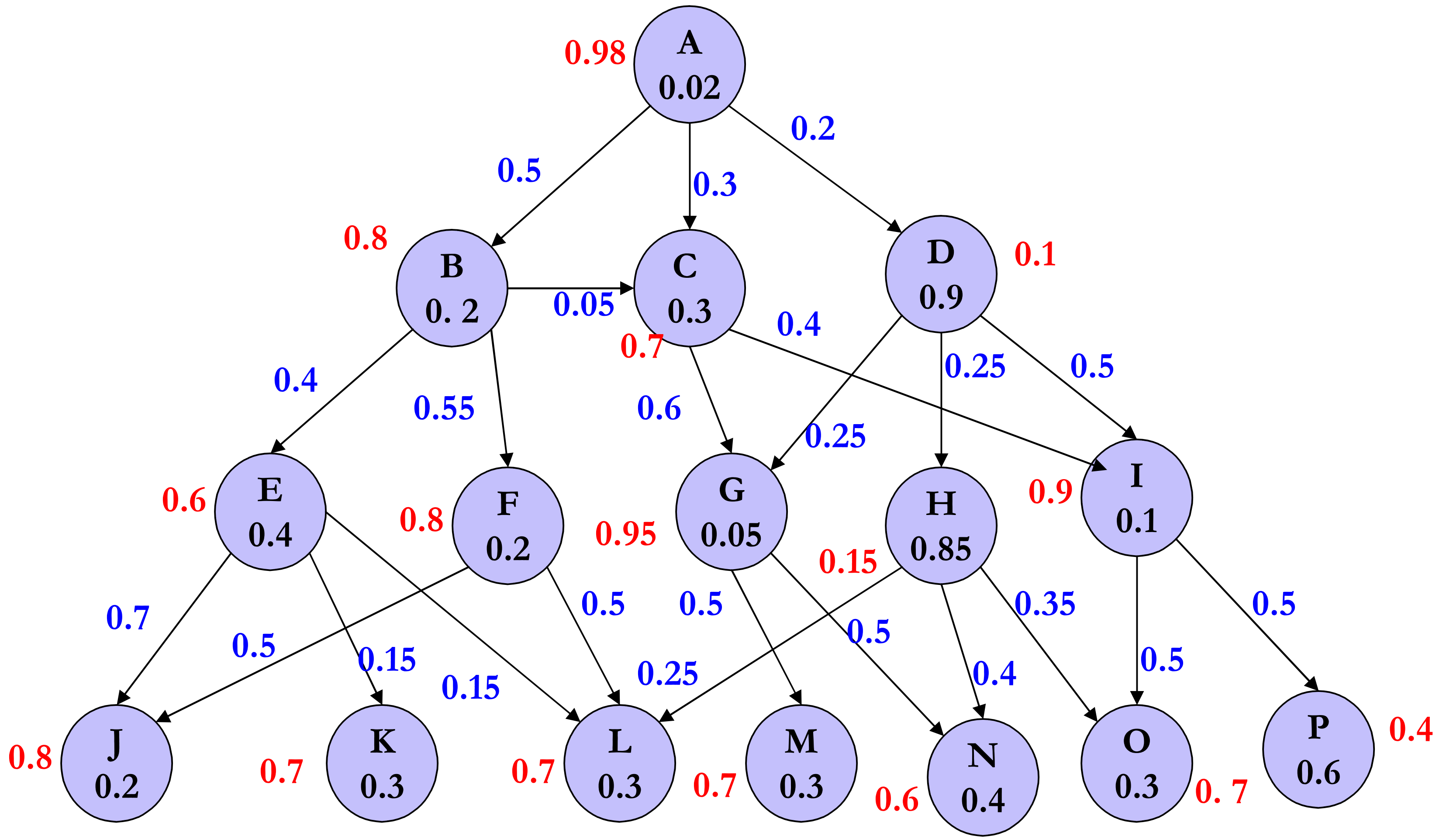
$$\eta(x_0, x_t) = W_s(x_t) \prod_{m=t}^{1} \left[l(x_{m-1}, x_m) * W_p(x_{m-1}) \right]$$

The node path weight for a node to itself is its self weight : $\eta(x_1, x_1) = W_s(x_1)$

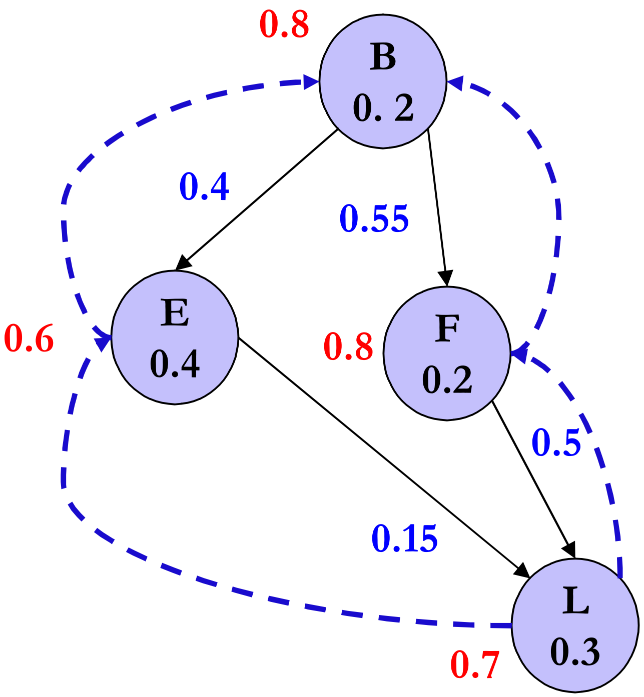
- **Incident Path Weight:** It is the "*the absolute prerequisite cost required to reach the root node from a subject node.*" Incident path weight is same as node path weight without the factor of self weight of the subject node.

$$\gamma(x_0, x_n) = \frac{\eta(x_0, x_n)}{W_s(x_n)} = \frac{\eta(x_0, x_n)}{\eta(x_n, x_n)}$$

Example CSG(A)



Node path weight, Incident Path Weight calculations



$$\eta(B,L)=W_s(L)\prod\left[l(F,L)*W_p(F)*l(B,F)*W_p(B)\right]$$

$$\eta(B,L)=0.3*0.5*0.8*0.55*0.8=0.0528$$

$$\gamma(B,L)=\eta(B,L)/W_s=0.0528/0.3=0.176$$

$$\eta(B,L)=W_s(L)\prod\left[l(E,L)*W_p(E)*l(B,E)*W_p(B)\right]$$

$$\eta(B,L)=0.3*0.15*0.6*0.4*0.8=0.00864$$

$$\gamma(B,L)=\eta(B,L)/W_s=0.00864/0.3=0.0288$$

Projection graph

- *Given a root concept x_0 and a projection threshold coefficient λ, and CSG, T(C, L), a projection graph P (x_0, λ) is defined as a sub graph of T with root x_0 and all nodes x_t where there is at least one path from x_0 to x_t in T such that node path weights satisfies the condition:* $\eta(x_0, x_t) \geq \lambda$

  The projection set consisting of nodes $[x_0, x_1, x_2 \ldots x_n]$ for a root concept x_0 is represented as, $P(x_0, \lambda) = P^{x_0} = [x_0^{x_0}, x_1^{x_0}, x_2^{x_0} \ldots x_n^{x_0}]$
  Where x_i^j represents the i^{th} element of the projection set of node *j*.

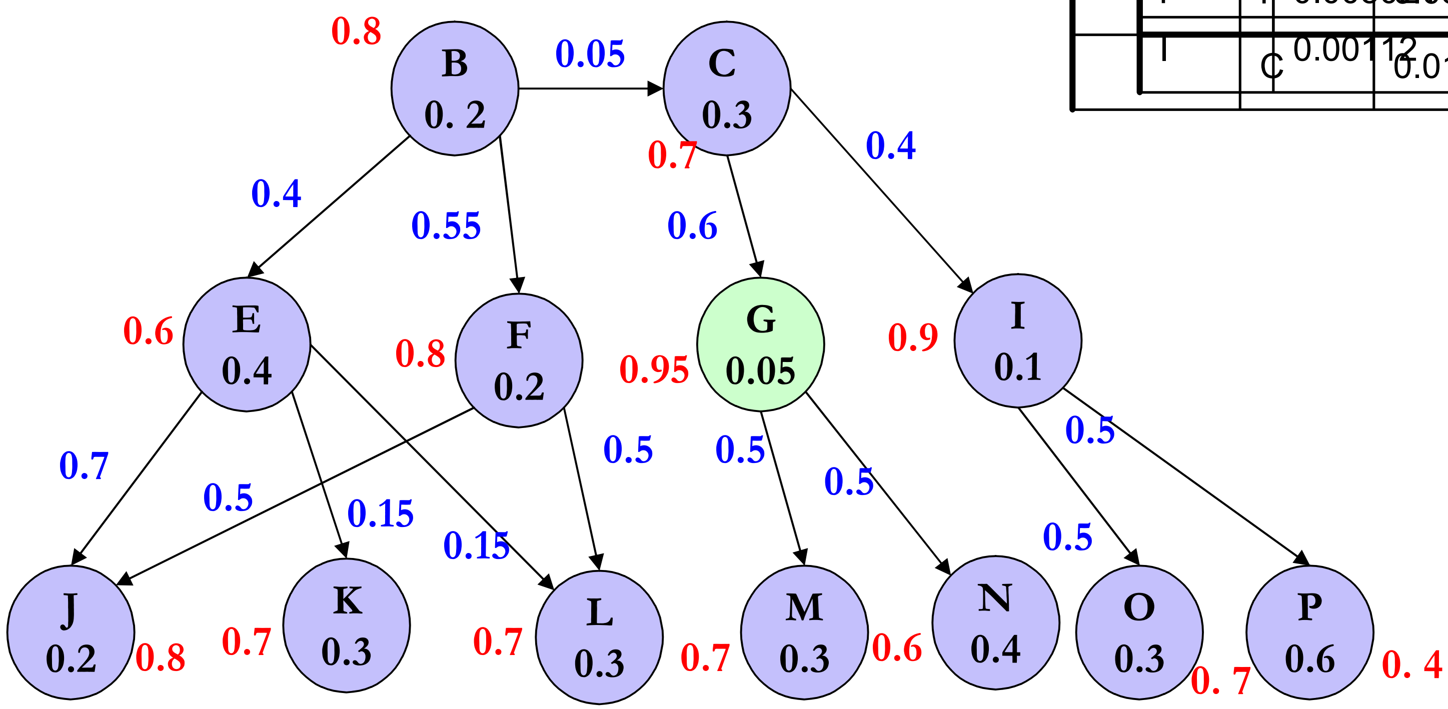
Projection Calculation Example

Calculate the projection graph for Concept B, for λ=0.001.

$P(B, \lambda = 0.001)$

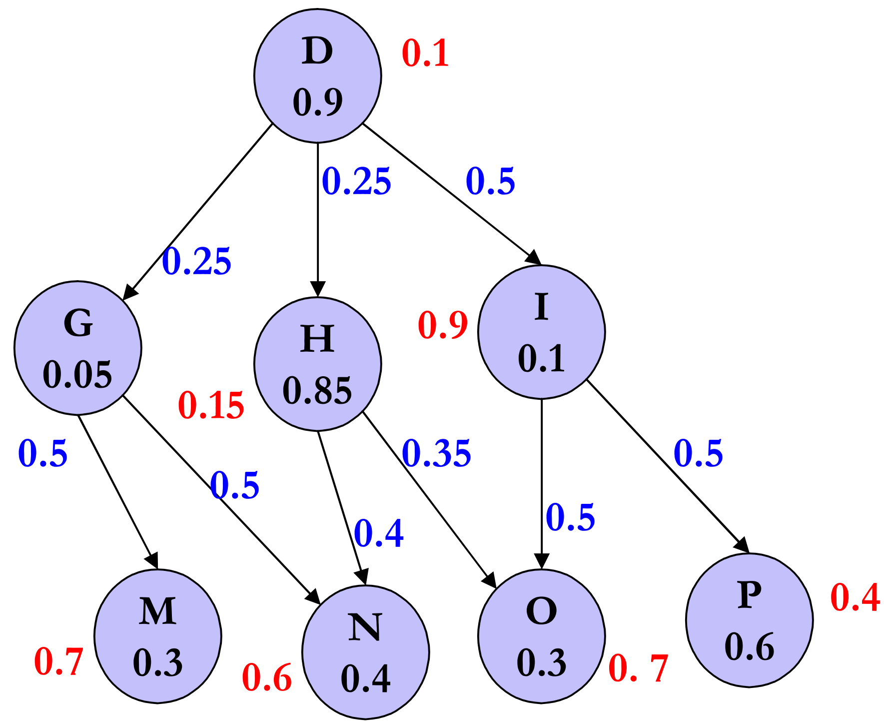
Local root "r"	Node "n"	$\eta(r,n)$	$\eta(r,n) \geq \lambda$?
B	E	0.128	✓
	F	0.088	✓
	C	0.012	✓

J	0.027[illegible]0.035	✓
M	0.0024	✓
K	0.00864	✓
N	0.003192	✓
L	0.0086/0.053	✓
O	0.0015	✓
G	0.00084	✗
P	0.003024	✓
I	0.00112	✓



Projection Calculation

$P(D, \lambda = 0.001)$			
Local root "r"	Node "n"	$\eta(r,n)$	$\eta(r,n) \geq \lambda$?
D	G	0.00125	✓
	H	0.02125	✓
	I	0.005	✓
	M	0.00357	✓
	N	0.00475	✓
	L	0.00028	×
	O	0.00034 (H) 0.00675 (I)	× ✓
	P	0.0135	✓



Problem Assessment Parameters

Coverage

- **Knowledge required**

  - ***Coverage of a node x_0 with respect to the root node r is defined as the product of the sum of the node path weights of all nodes in the projection set $P(x_0, \lambda)$ for the concept x_0 and the self weight of x_0 and the incident projection path weight γ (r, x_0) from the root r.***

If the projection set for concept node x_0, $P(x_0, \lambda)$ is given by $[x_0, x_1, x_2 ... x_n]$ then the coverage for node x_0 about the root r is defined as,

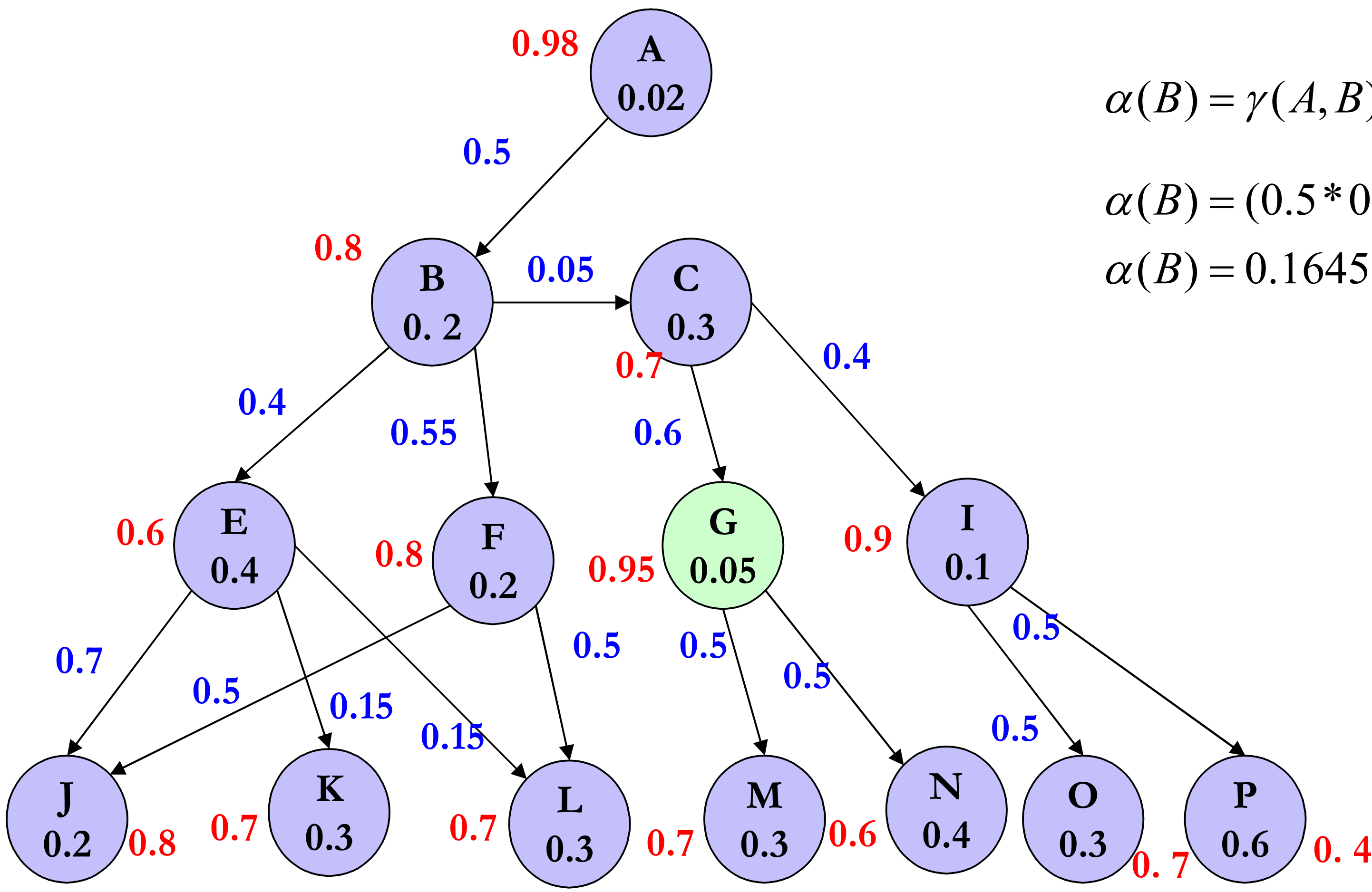
$$\alpha(x_0) = \gamma(r, x_0) * \sum_{m=0}^{n} \eta(x_0, x_m)$$

Total coverage of multiple concepts in a problem given by set $[C_0, C_1, C_2 ... C_n]$ is,

$$\alpha(T) = \alpha(C_1) + \alpha(C_2) + ... + \alpha(C_n)$$

Coverage Calculation

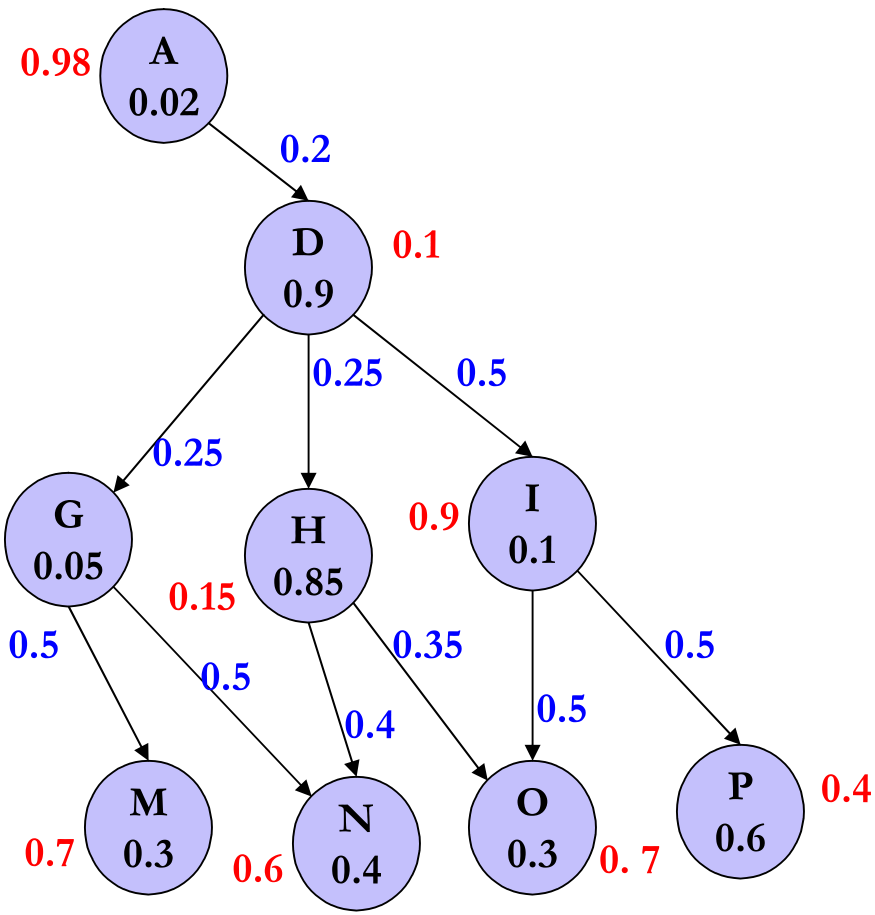
A question connects to concepts B and D from the ontology. Find its coverage.



$$\alpha(B) = \gamma(A,B) * \sum_i \eta(B, P_i^B)$$

$$\alpha(B) = (0.5*0.98)*(0.335882)$$

$$\alpha(B) = 0.16458218$$



$$\alpha(D) = \gamma(A,D) * \sum_i \eta(D, P_i^D)$$
$$\alpha(D) = (0.2 * 0.98) * (0.0560625)$$
$$\alpha(D) = 0.01098825$$

$$\alpha(total) = \alpha(B) + \alpha(D)$$
$$\alpha(total) = 0.16458218 + 0.01098825$$
$$\alpha(total) = 0.17557043$$

Diversity

- **The breadth of knowledge domain**
- **Opposite of similarity**

  - ***The ratio of summation of node path weights of all nodes in the non-overlapping set to their respective roots, and the sum of the summation of node path weights of all nodes in the overlap set and summation of node path weights of all nodes in the non-overlap set.***

Diversity,

$$\Delta = \frac{\sum_{m=1}^{p} \eta\left(i, N_m^i\right)}{\sum_{m=1}^{q} \eta\left(j, O_m^j\right) + \sum_{m=1}^{p} \eta\left(i, N_m^i\right)} \quad \textit{where } \forall \;\; i, j \in C$$

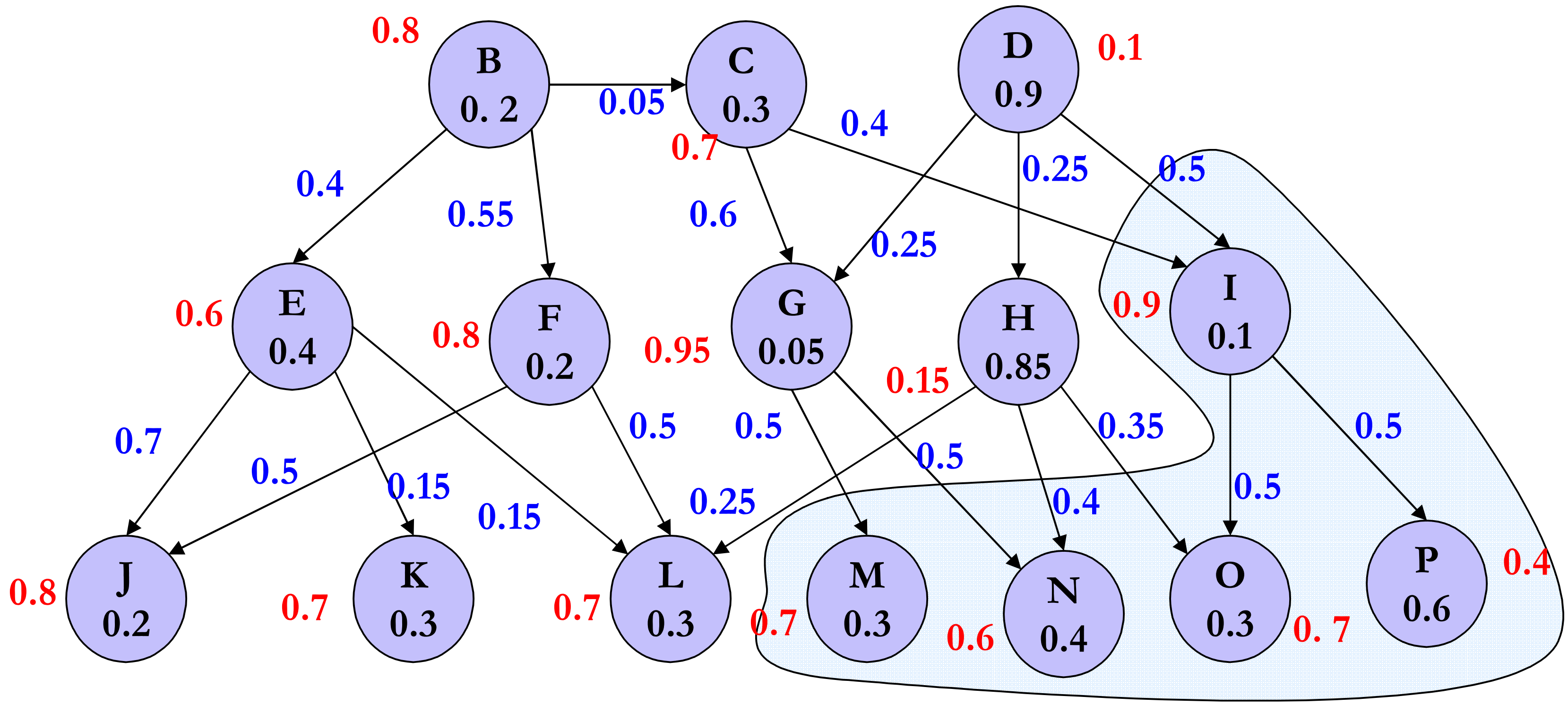
Where, Concept set, $C = \left[C_0, C_1, C_2 \ldots C_n\right]$

Projection sets, $P(C_0, \lambda) = [x_1^{C_0}, x_2^{C_0}, \ldots, x_a^{C_0}]$, $P(C_1, \lambda) = [x_1^{C_1}, x_2^{C_1}, \ldots, x_b^{C_1}]$ $\ldots$
$P(C_n, \lambda) = [x_1^{C_n}, x_2^{C_n}, \ldots, x_c^{C_n}]$

Overlap set, $O = \left[O_0, O_1, O_2 \ldots O_q\right]^j$

Non-overlap set, $N = \left[N_0, N_1, N_2 \ldots N_p\right]^i$

Diversity Calculation



$$N = [B, C, D, E, F, G, H, J, K, L]$$

$$O = [I, M, N, O, P]$$

$$\Delta = \frac{\sum \eta(n, N^e)}{\sum \eta(n, O^e) + \sum \eta(n, N^e)} \qquad n = B \mid D; \quad x^e = element\ of\ set\ x$$

$$\Delta = \frac{1.44714}{0.0448045 + 1.44714} = 0.97$$

Conceptual Distance

- **Measures similarity between concepts i.e. distance from ontology root.**

  - ***It is defined as the log of inverse of the minimum value of incident path weight (maximum value of threshold coefficient) which is required to encompass all the concepts from the root concept.***

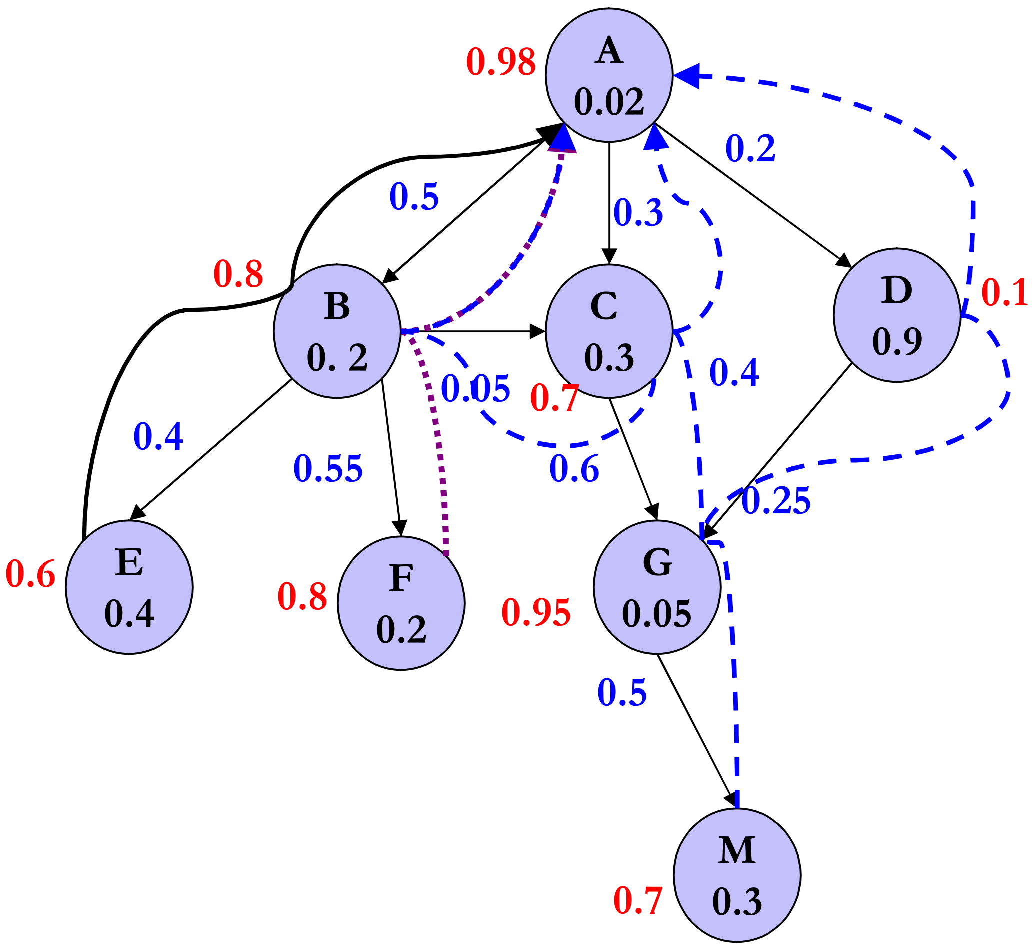
If question asks concept set $C = [C_0, C_1, C_2 \ldots C_n]$ then the conceptual distance from the root concept r is given by,

$$\delta(C_0, C_1 \ldots C_n) = \log_2\left(\frac{1}{\min[\gamma(r, C_0), \gamma(r, C_1) \ldots \gamma(r, C_n)]}\right)$$

  - Greater the distance between the concepts, more is the semantic depth.

Conceptual Distance Calculation

Calculate conceptual distance between (E, F, M)



$$\delta(E,F,M) = \log_2\left(\frac{1}{\min\{\gamma(A,E),\gamma(A,F),\gamma(A,M)\}}\right)$$

$$\delta(E,F,M) = \log_2\left(\frac{1}{\min\{0.1568, 0.2156, 0.0023275\}}\right)$$

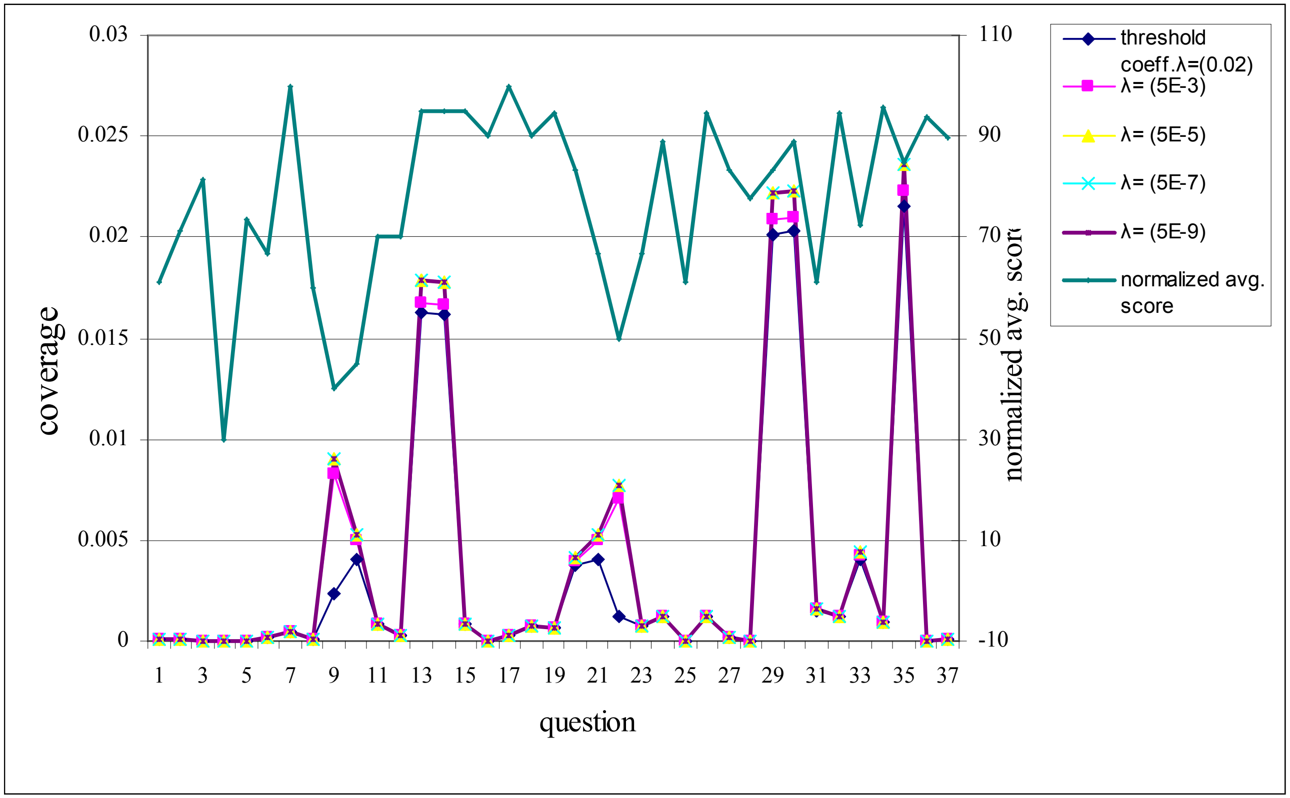
$$\delta(E,F,M) = \log_2(429.65)$$

$$\delta(E,F,M) = 2.63$$

Results and Parameter Performance Analysis

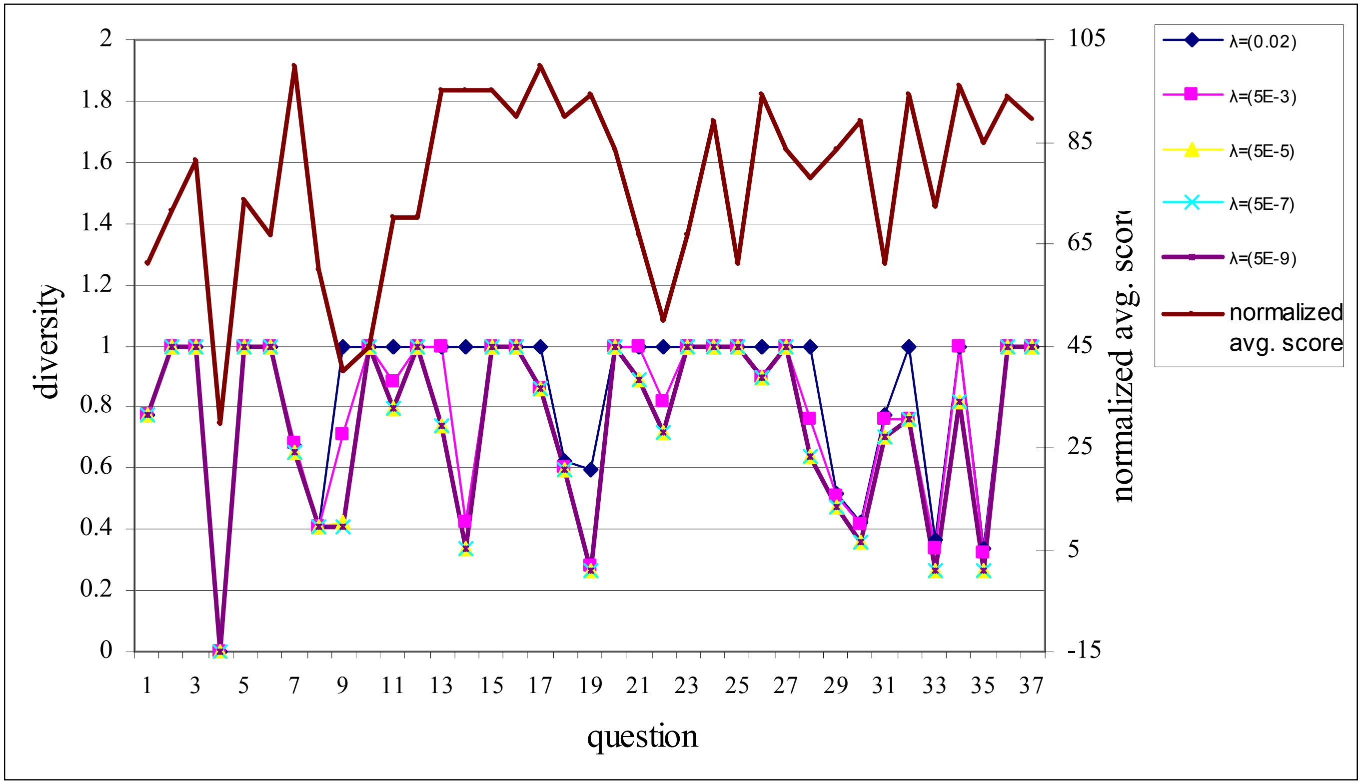
- Setting
  - Operating system course ontology created using prescribed text books
  - OSOnto (>1350 concepts)
  - XML and OWL
- 4 quizzes , 38 questions composed using concepts selected from OS Ontology
- Tests administered by at least 25 graduate and undergraduate students
- Scoring done by at least 2 graders per question and average score taken.
- Do the parameters provide any insight into the perceived difficulty/complexity of the question?
- Performance analysis = Plotting average score/parameter values

coverage vs. average score



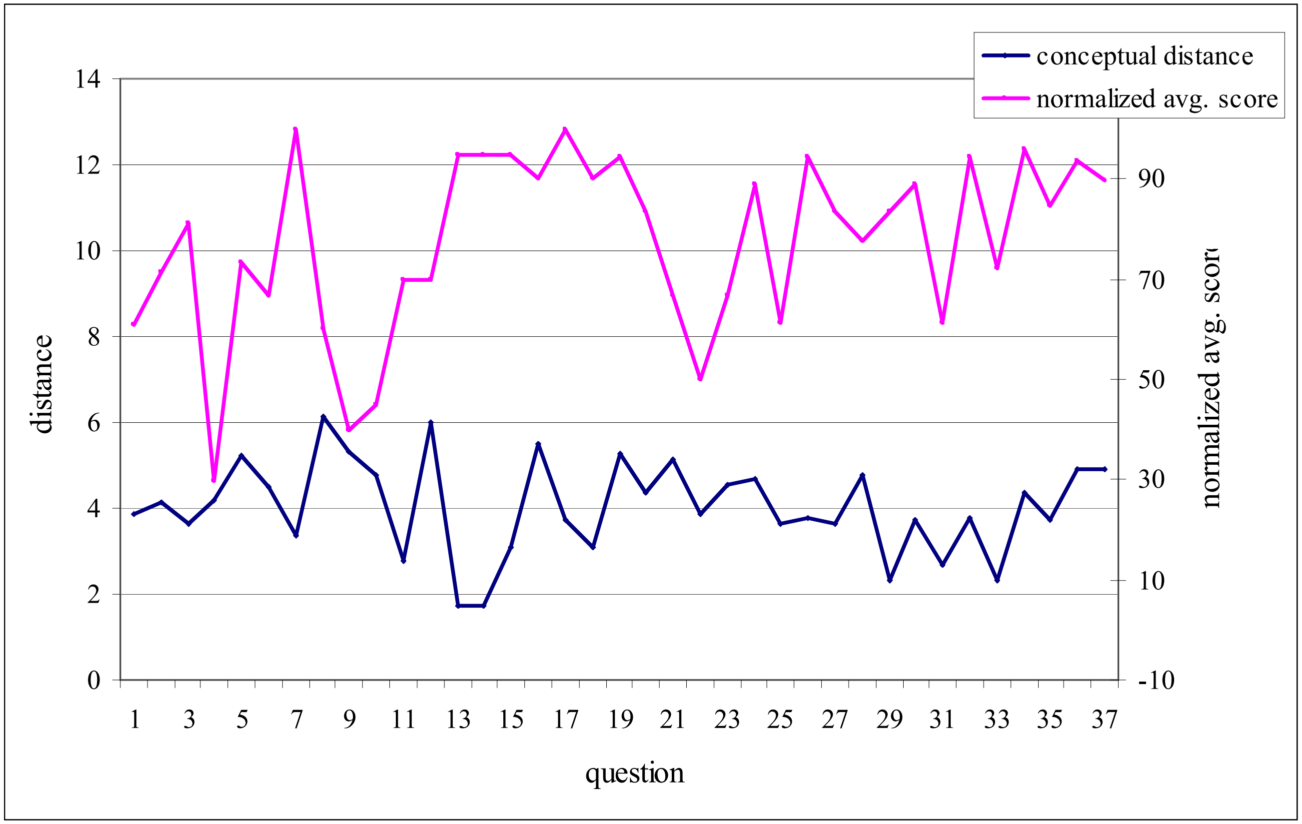
- coverage and average score inversely correlated
- behavior constant for changing threshold coefficient

Diversity vs. average score



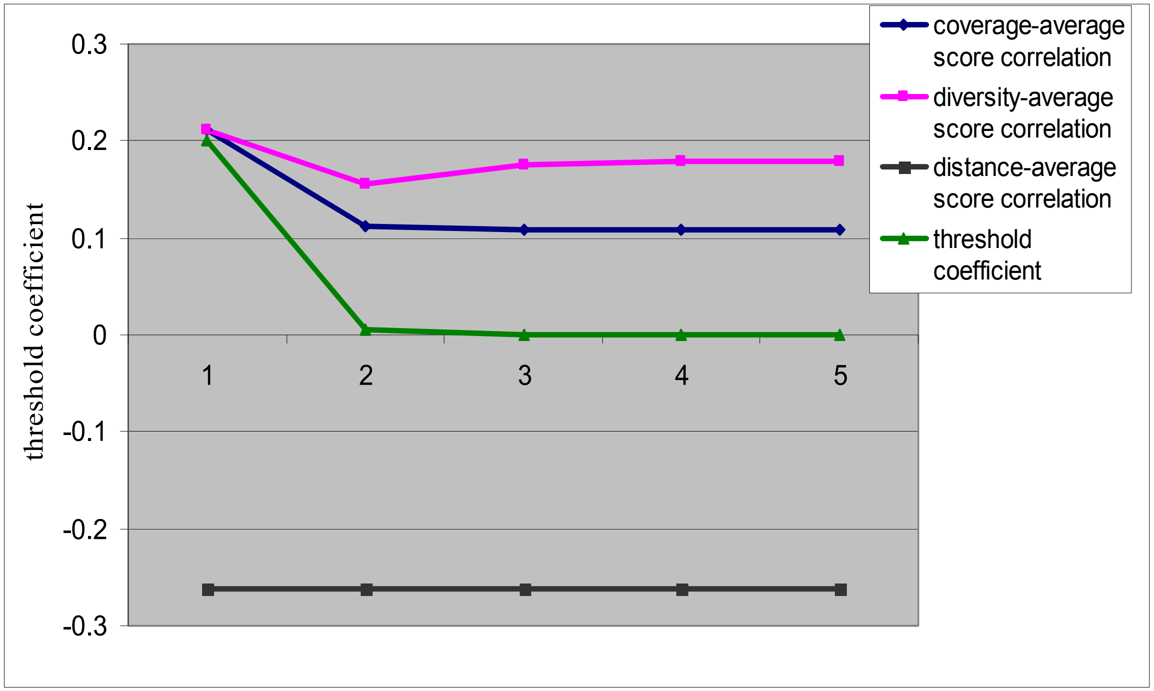
- diversity and average score inversely correlated
- behavior constant for changing threshold coefficient

Conceptual distance vs. average score



- conceptual distance and average score inversely correlated
- distance does not vary with threshold coefficient

Correlation study



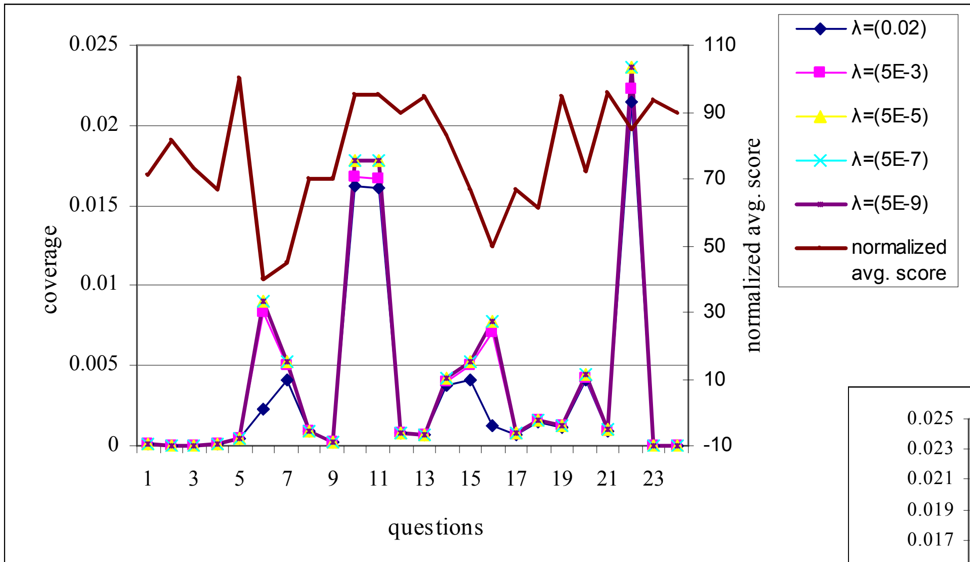
- coverage-avg. score correlation decreases with threshold coefficient
- diversity-avg. score correlation decreases with threshold coefficient

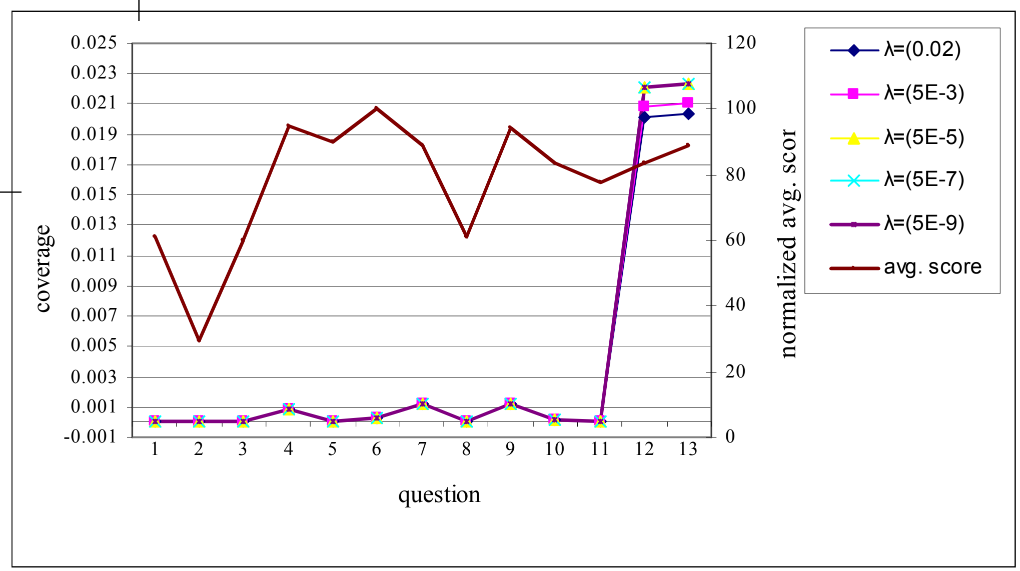
Observations and Inferences

- (Coverage, diversity and conceptual distance) α (1/Average score)
  - Indicates perceived difficulty
  - Coverage gives the knowledge required
  - Diversity indicates the scope and the breadth of knowledge domain
  - Distance gives the relationship of the concepts with the ontology root and a pseudo similarity measure
- Threshold coefficient plays important role
  - Coverage and diversity values change according to threshold coefficient
  - Threshold coefficient changes the projection graph to desired semantic significance
- Conceptual Distance behavior is same for changing threshold coefficient values as it is independent of the projection graph.
  - Gives an inverse similarity measure for subject concepts with respect to ontology root (rather than local root, for which definition can be easily extended).

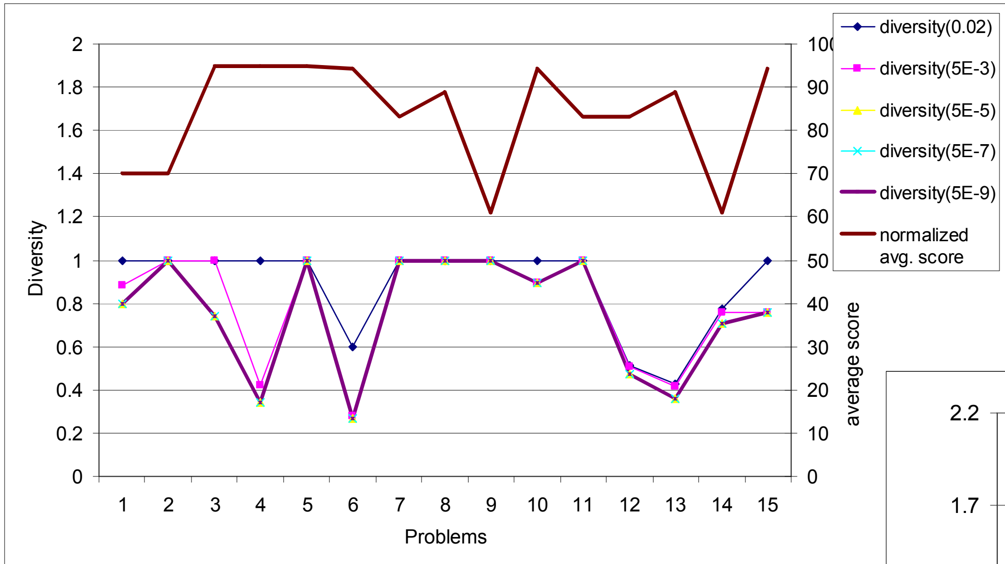
Qualitative Data Analysis

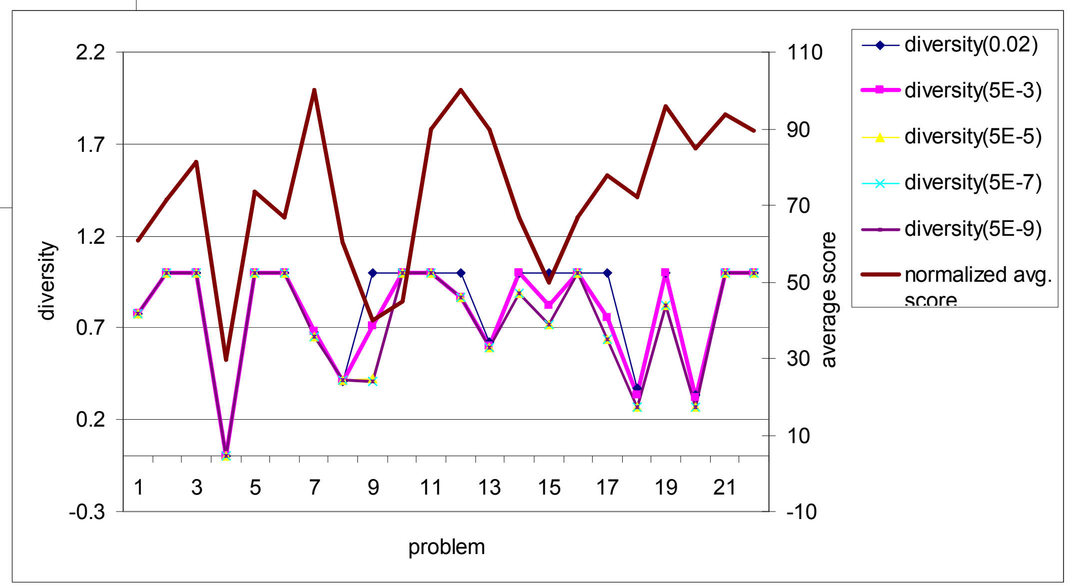
- Questions are sorted according to those with high inverse correlation and those with lower inverse correlation between coverage-average score.



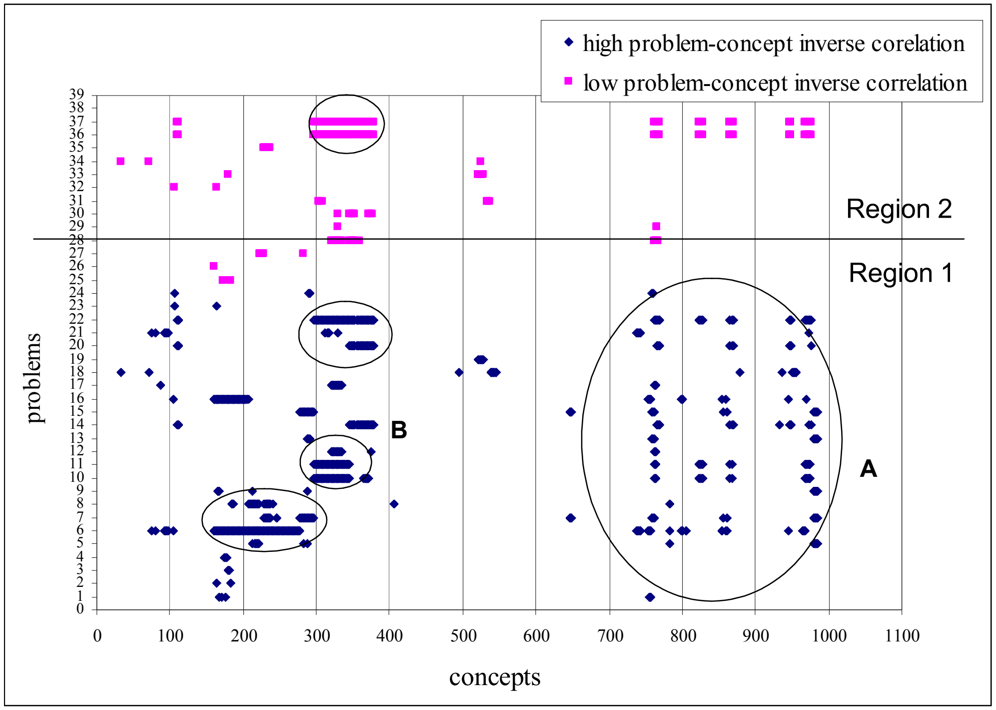


Questions sorted according to diversity



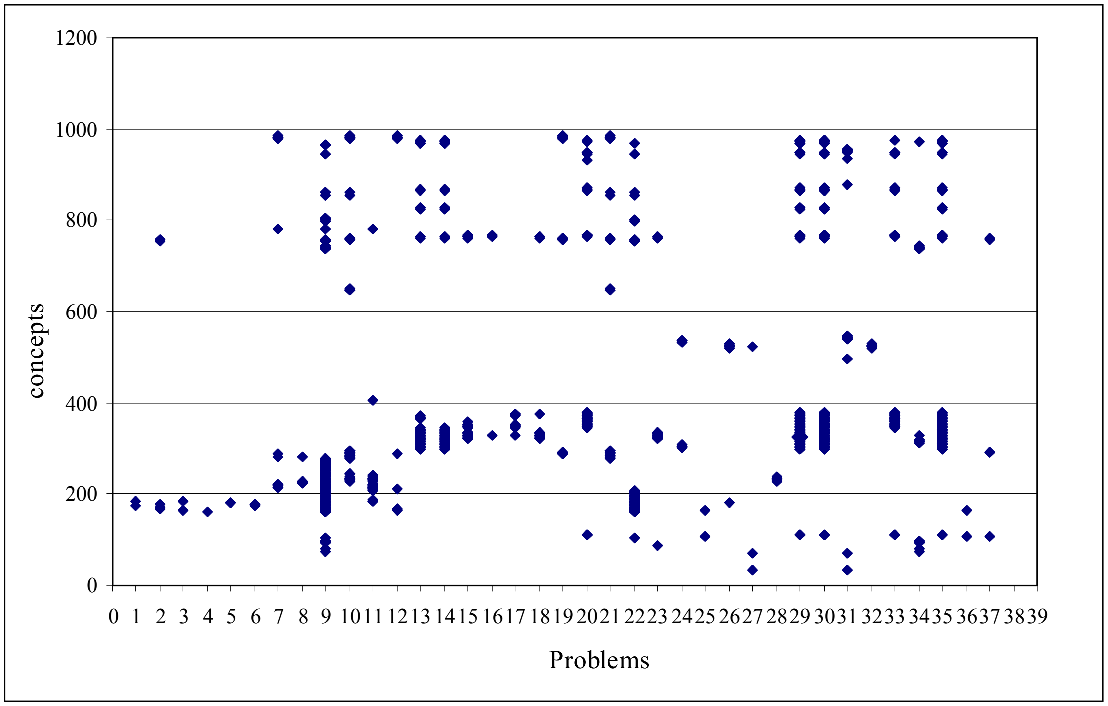


Correlation based analysis



- •Large clustering (big circle)
- •Dispersed concepts distribution and Diversity.
- •Small Clustering
- •Quiz based concepts distribution (200-400 and 750-1000)
- •…more

Test based analysis



- most problems contain concepts in and around 200-400 and 700-1000
- concepts in problems go on increasing
- clustering denote projections of mapped concepts

Conclusions:

- For an automatic test design system and assessment framework is a must.
- To make course ware resources reusable and machine interpretable they have to represented in context. Semantic representation standards like RDF and OWL are used to represent this context.
- A representation language schema for course knowledge representation using ontology is given. The language is in OWL Lite and is expressible and computable.
- Problem complexity and knowledge content can be computed by applying synthetic parameters to course ontology having known the concept mapping. It is observed that the parameters are pretty good indicators of problem complexity.
- Assessment system can be intuitively be applied to automatic test design.

Related Work

- Problem assessment
  - Li, Sambasivam – Static knowledge structure
  - Rita Kuo et. al. – Information objects of simple questions

- Cognitive
  - Lee, Heyworth – Difficulty factors (perceived steps, students degree of familiarity, operations and expression in a problem)
  - Koedinger, Heffernan et.al. – number of symbols, ambiguous language

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Thank you.

Questions???