OFFICE OF NAVAL RESEARCH (ONR)

CORNELL UNIVERSITY DEPARTMENT OF COMPUTER SCIENCE

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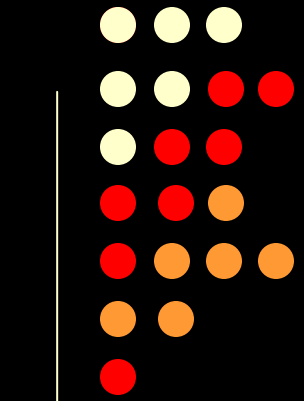
An Interactive Digital Library of Algorithmic Knowledge



and other Information Science projects at Cornell

April 14, 2003 / UC Berkeley

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Topics

- The Office of Naval Research (ONR) Digital Library Project
  - Goals, Design, Implementation
- Other Information Science Projects
  - National Science Digital Library, NSDL
  - Ranking Function
  - Modeling Bursts of Activity on the Web

ONR Digital Library Project

" … to create a digital library of algorithms and constructive mathematics useable for program and software construction."

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ONR Digital Library Project

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Goals

- Semantics-based interactive infrastructure
- Create, collect and organize formal content

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Meaning of Formal

"… having a precise meaning or objective criteria of correctness … ideally computer verifiable, based on syntactic form."

Formalization I

Scheduling Application Formalization

Specify components and behavior
Use mathematical definitions and theorems

Reveals assumptions, increases assurance, and optimizes task assignments.

Doing A then B then A is the same as doing A.


Formalization II

- Halting problem, Alan Turing - informal

  Does a given algorithm ever halt when executed on given arguments?

  – no method to solve it for all inputs

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- Halting problem, Alan Turing - informal

  Does a given algorithm ever halt when executed on given arguments?

  - no method to solve it for all inputs

- Formalization
  - Create formulas to express halting
  - Mechanically prove no method exists for all inputs

$\neg\exists h{:}\bar{A} \rightarrow \text{Bool}.\ \forall n{:}\bar{A}.\ h(n) = \text{true iff } n \text{ halts}$ ✓

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ONR Digital Library Project

" … to create a digital library of algorithms and constructive mathematics useable for program and software construction."

Benefits

- Accelerate discovery
- Access to formal content
- Resource for reliable software and education

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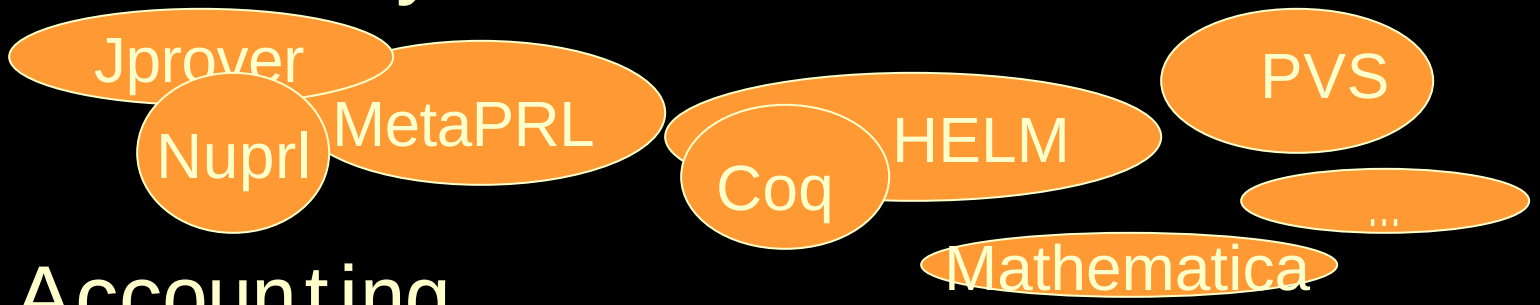
Strategy for Meeting ONR Goals

- Community of contributors



- Accounting
  - differences and limitations amongst systems, different meanings

- Semantics-based library services

Challenges and Problems

- *Small* and disconnected community
- Formal proving is still hard work
  - Large expansion in size
  - Shallow resource base
  - Demanding skill set

Challenge Citation

"PVS is a large and complex system and it takes a long while to learn to use it effectively. You should be prepared to invest six months to become a moderately skilled user (less if you already know other verification systems, more if you need to learn logic or unlearn Z). "

- PVS website at SRI

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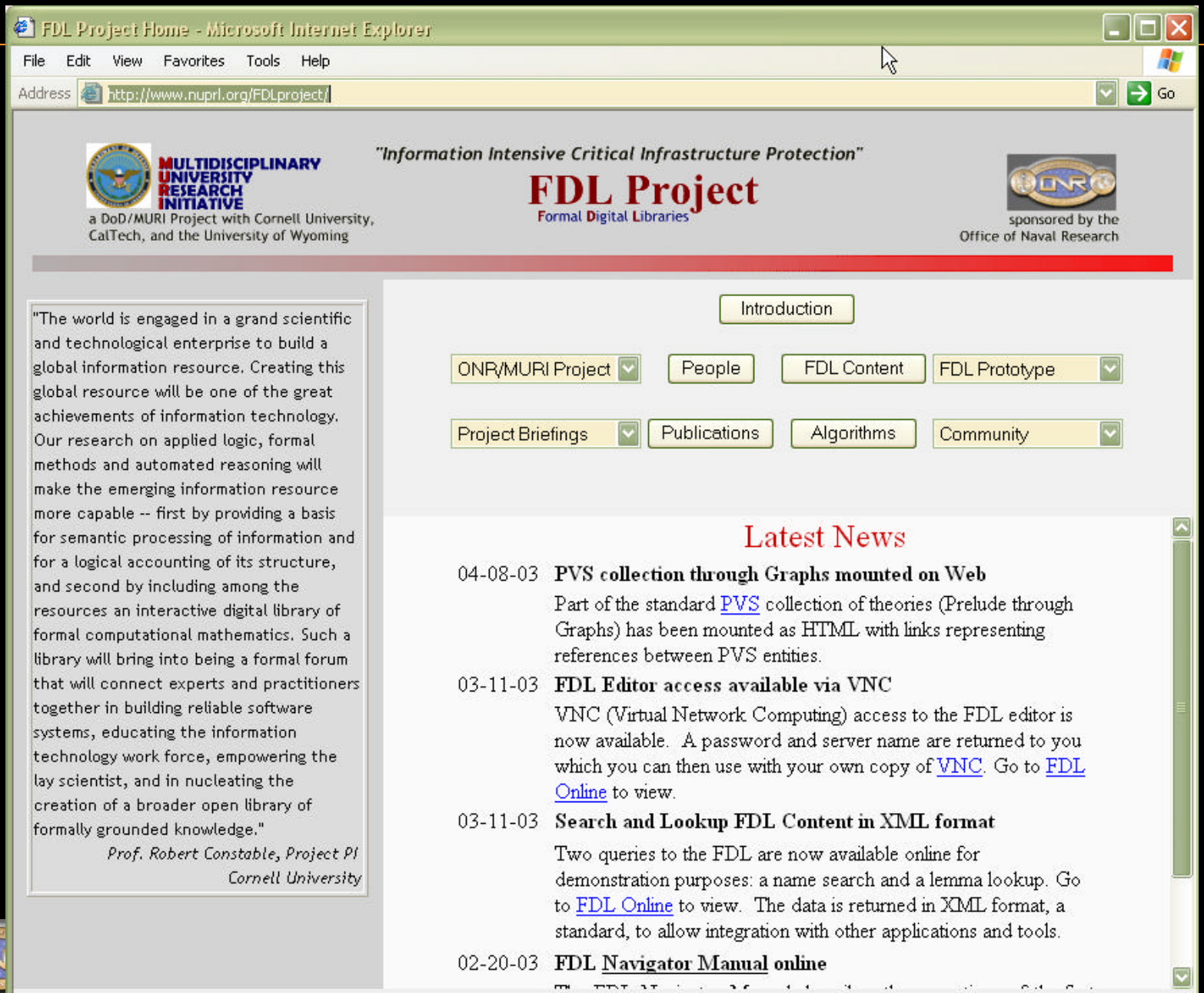
Formal Digital Library (FDL)



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Objects

FORMAL

rules	definitions	algorithms, code
conjectures	theorems	specifications
inferences	certificates	proofs, partial proofs

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Objects

FORMAL	rules	definitions	algorithms, code
	conjectures	theorems	specifications
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INFORMAL	displays	articles	documentation

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Objects

FORMAL

rules	definitions	algorithms, code
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displays	articles	documentation

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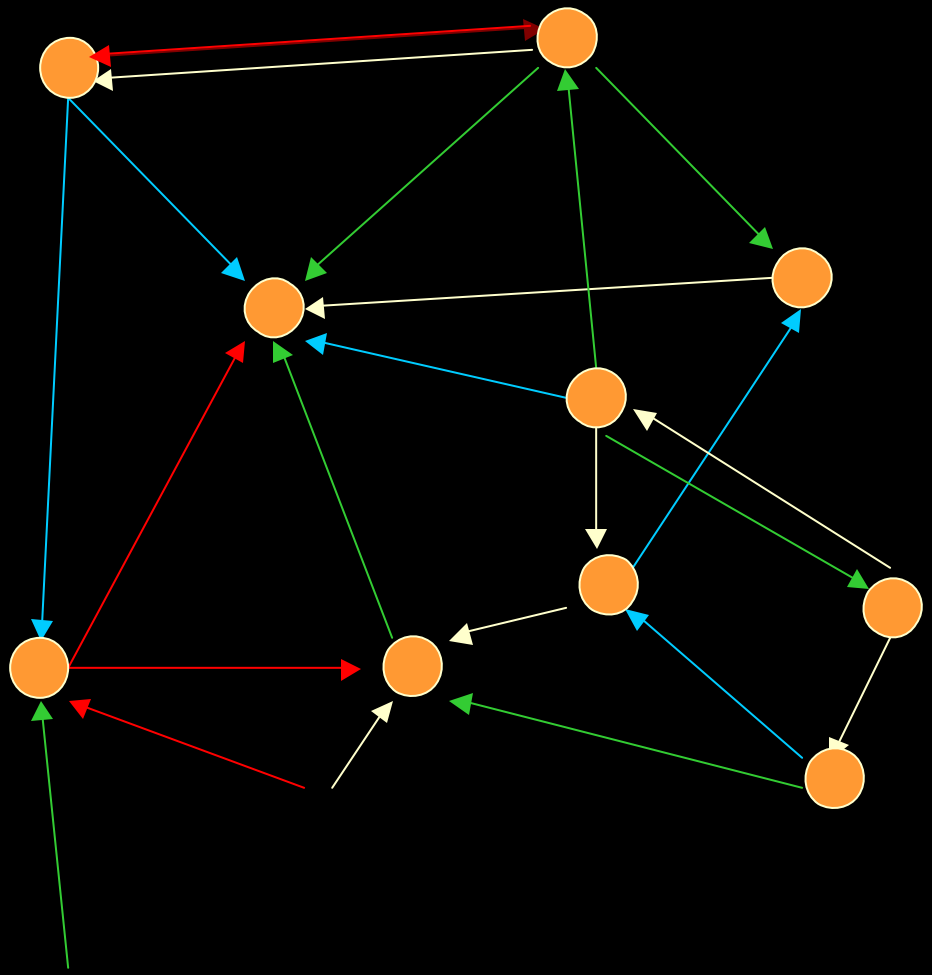
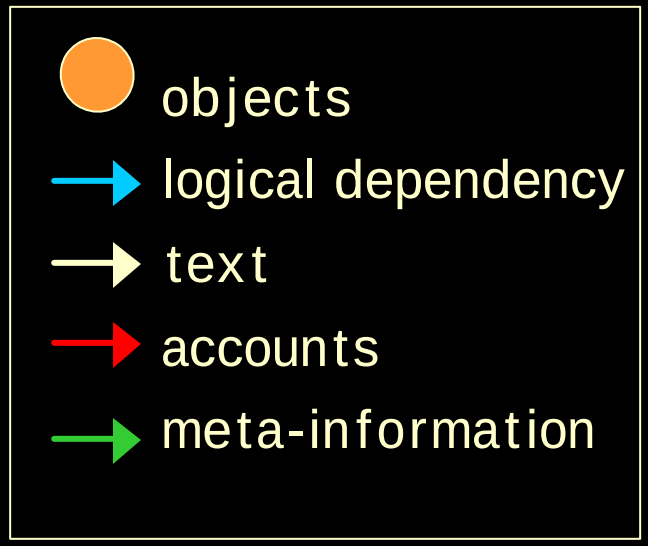
Information Graph of the FDL



Objects have interdependencies and informative links



Proof Example

proof

```
⦿ *- PRF : pos_length @edd.lori_10_13 @nuprl4.cs.corne
* top
∀A:𝕌. ∀l:A List.  ((¬(l = [])) ⇒ (||l|| ≥ 1 ))

BY aux_auto(RepeatMFor 2 (D 0) THENM D 2)

* 1

1. A : 𝕌
⊢ (¬([] = [])) ⇒ (||[]|| ≥ 1 )

BY auto(D 0 THENM D (-1))

* 2

1. A : 𝕌
2. u : A
3. v : A List
⊢ (¬([u / v] = [])) ⇒ (||[u / v]|| ≥ 1 )

BY AbReduce 0 THEN aux_auto(D 0)

* 2 1

4. ¬([u / v] = [])
⊢ (||v|| + 1) ≥ 1

BY InstLemma `non_neg_length` [⌜A⌝;⌜v⌝] THEN Auto
```

article

accounting

theorem

$$\forall A:\mathbb{U}.\ \forall l:A\ \mathrm{List}.\ \ (||l|| \geq 0\ )$$

Accounting Archive

FDL performs archival functions…

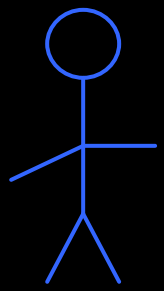
- Automath system Auto QE checked the following formalization of Landau's Grundlagen (February 22, 1974)
- EQP proved the Robbins Conjecture, an open problem for mathematicians since 1933 (October 10, 1996)
- JProver proves "the Butler did not do it" in the this logic-based "who-done-it" problem (October 13, 2000)
- CLI presents a formal model of the Java Virtual Machine (May 13, 1997)
- ACL2 verifies Y2K conversion rules (March 21, 2000)

Basic FDL Operations

- search by name
- lookup object by id
- create an object (empty)
- save
- undo
- “activate” object
- “deactivate” object

Translation Operations

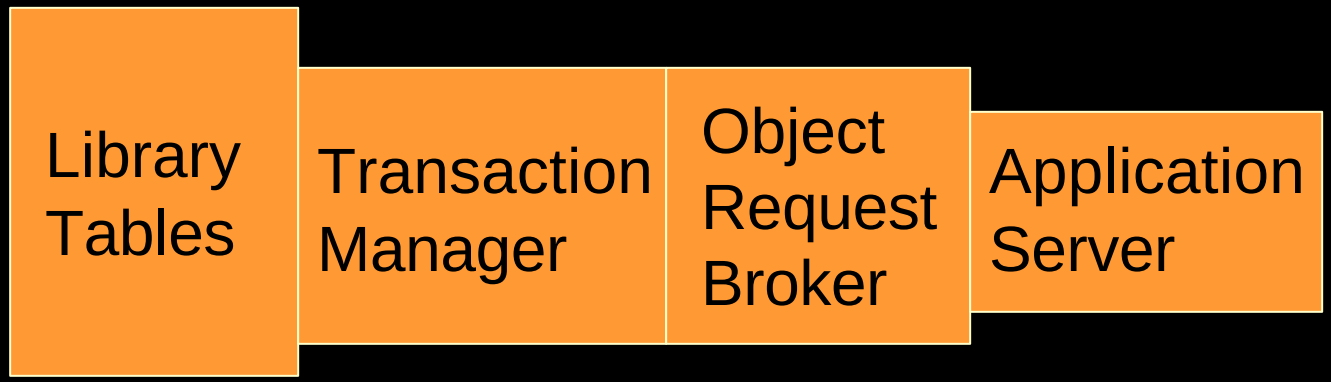
FDL performs translations on collections, or subgraphs.



Give me the smallest *closed* set with respect to logical references of objects that contains the proof of Total Order in Distributed System, D.

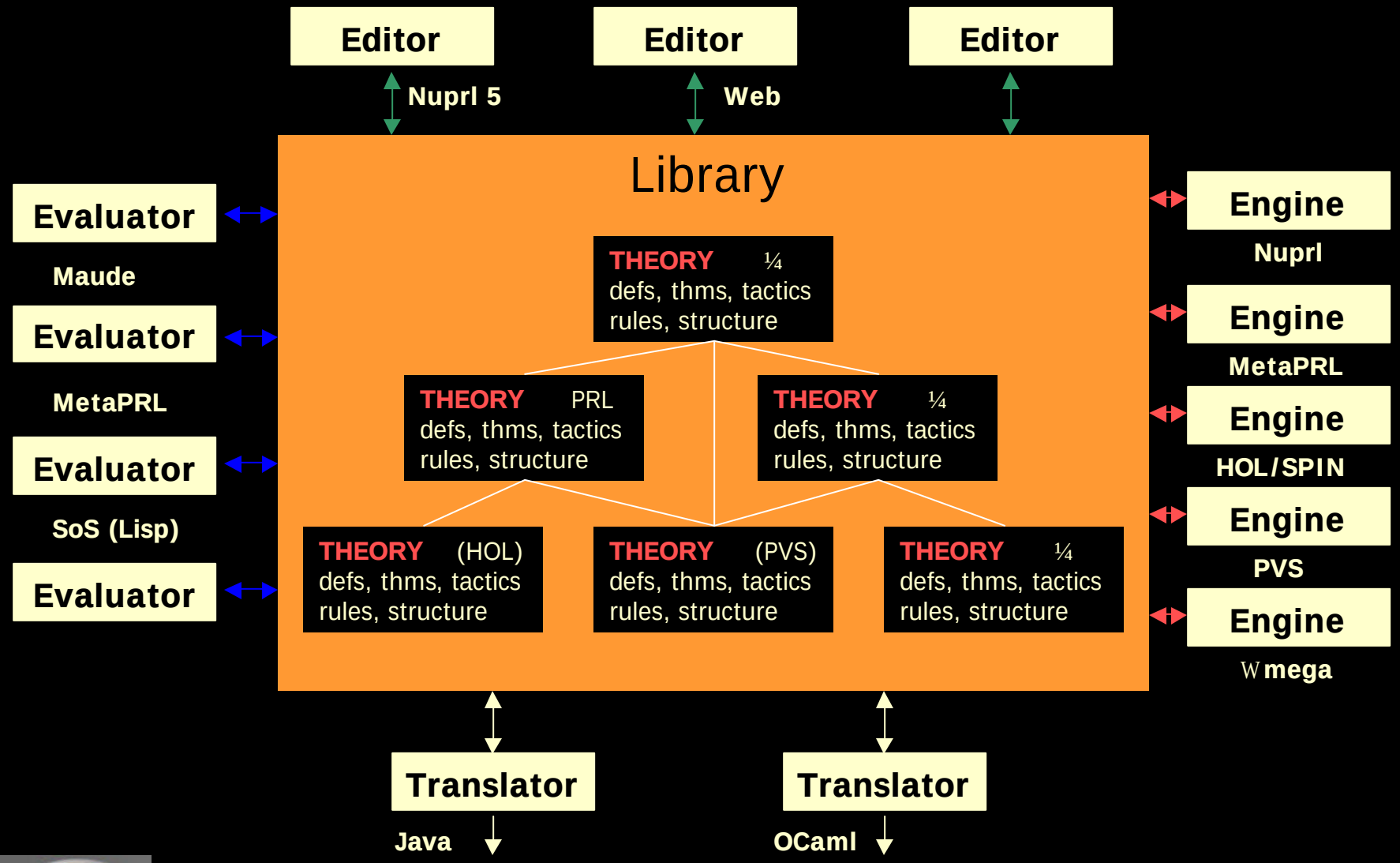
Give me the largest *closed* set with respect to textual links that contain information about prime numbers.

Implementation



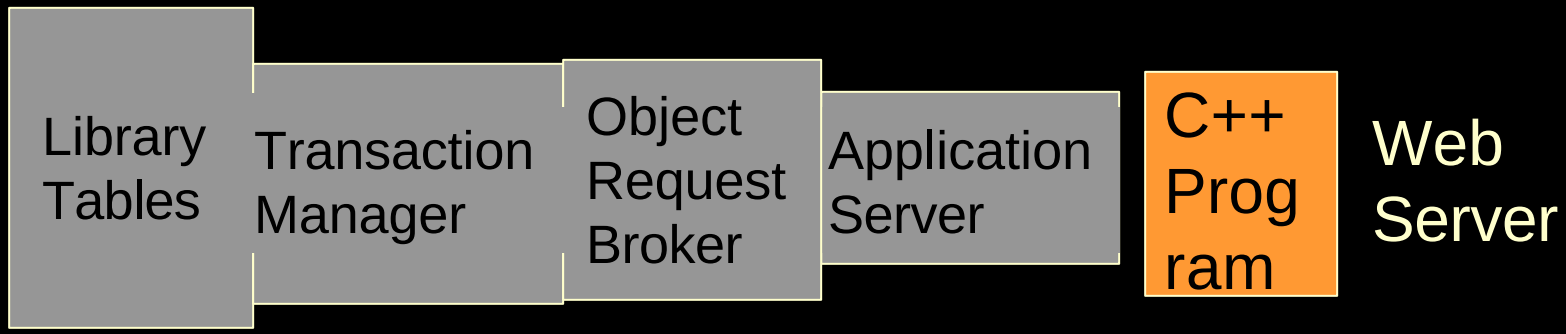
- LISP/ML based system
  - 6,000 functions
  - 62,000 lines code
  - 22,000 lines comments
- Adapted from Logical Programming Environment and Nuprl

Architecture



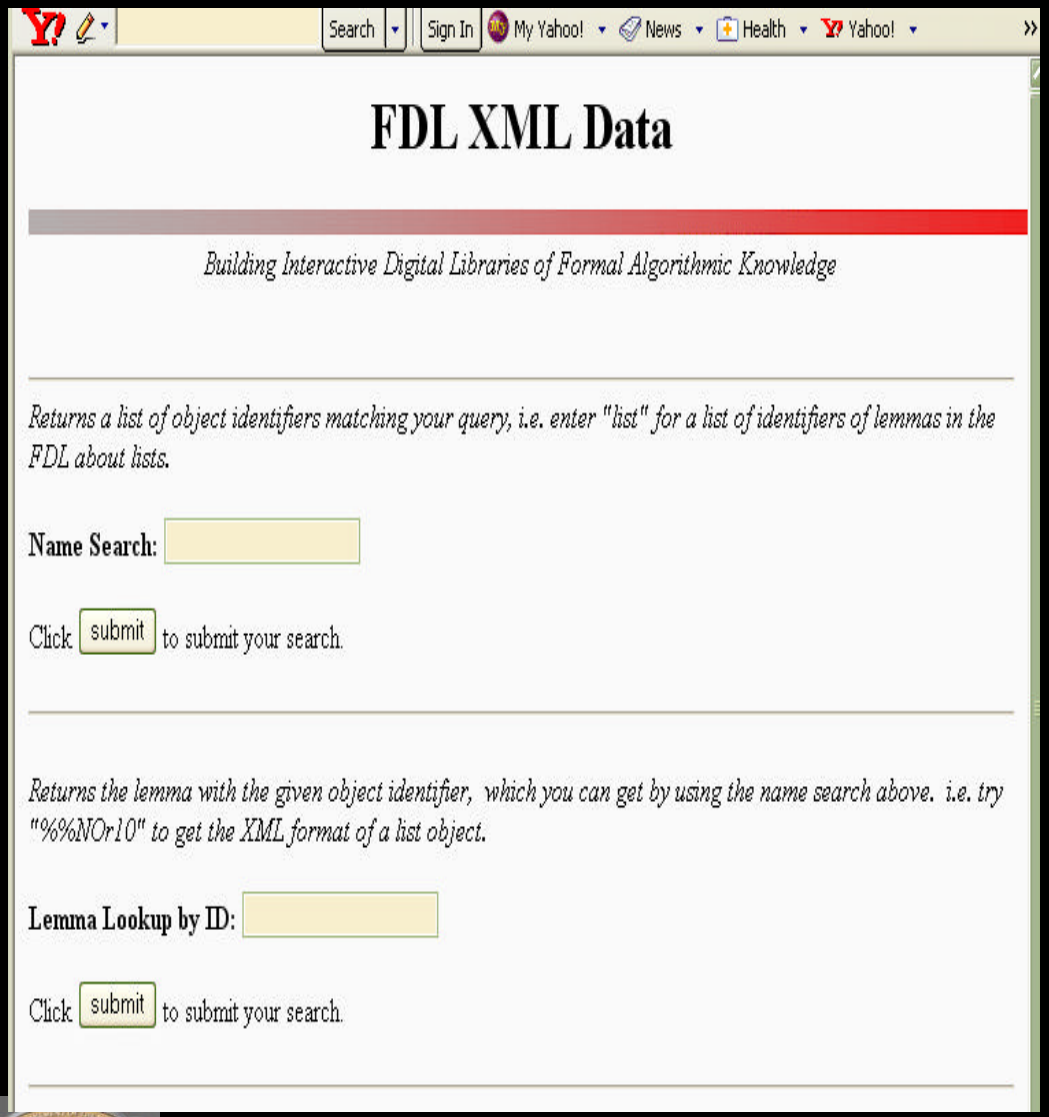
FDL Online Demo

- search by name
- lookup object by id



- vnc into editor

FDL Online Demo




```
<fdl:term>
<fdl:param_list>
  <fdl:param>
    <fdl:paramtype>t</fdl:paramtype>
    <fdl:paramvalue>implies</fdl: …>
  </fdl:param>
</fdl:param_list>
<fdl:term_list>
  <fdl:term>
    <fdl:param_list>
      <fdl:param>
        <fdl:paramtype>t</fdl:paramt
        <fdl:paramvalue>equal</fdl:
      </fdl:param>
    </fdl:param_list>
        …
```

Current Contents

- Nuprl and PVS Content
  - 422 theories (collections)
  - 1699 definitions
  - 7351 theorems
  - 3867 proofs
- MetaPRL (Cal Tech)
- In Progress – import many more in xml and mathml formats

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Is Data Format Sufficient?

- Term: Operator (Op) x Term List
- XML (DTD for HELM)
- OMDoc
- MathBus
- Ascii (compressed and uncompressed)

Op = Opname{params}

op(Term List)
add{}(x;y)
x=natural{1}()
y=mult(z;r)

Contribution Methods

System	Method
Jprover	MathBus
C++ Program	Ascii uncompressed
MetaPRL	MathBus
OMDoc	XSLT
PVS	LISP structures
Larch from ATC	In progress

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Related Work

- HELM (Hypertextual Electronic Library of Mathematics) - http://helm.cs.unibo.it/
- MathWeb - http://www.mathweb.org
- Mathematical Knowledge Management (MKM) - http://imps.mcmaster.ca/na-mkm-2002/presentation
- Wolfram Research MathWorld - http://mathworld.wolfram.com/
- Living Book - http://www.slicing.de/books

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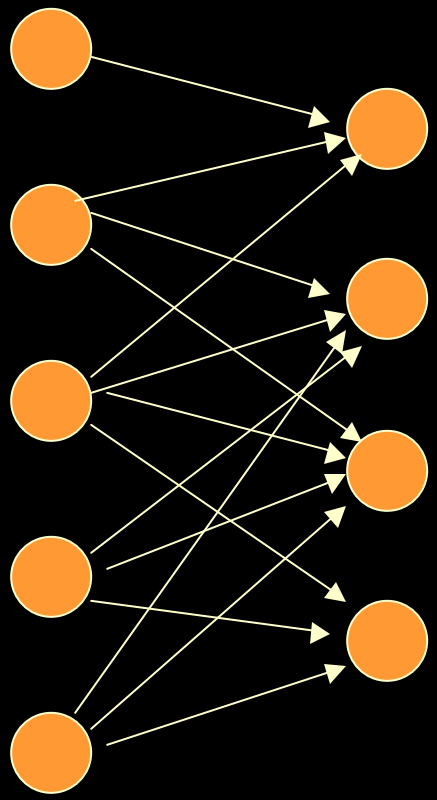
Questions

- What communities to target?
- How to most effectively search?
- Data format justification?

Questions

- What communities to target? Education, Code
- How to most effectively search? dependency
- Data format justification? MathML future?
- What usability studies and evaluations can we perform?
- Can we learn from semantic knowledge?

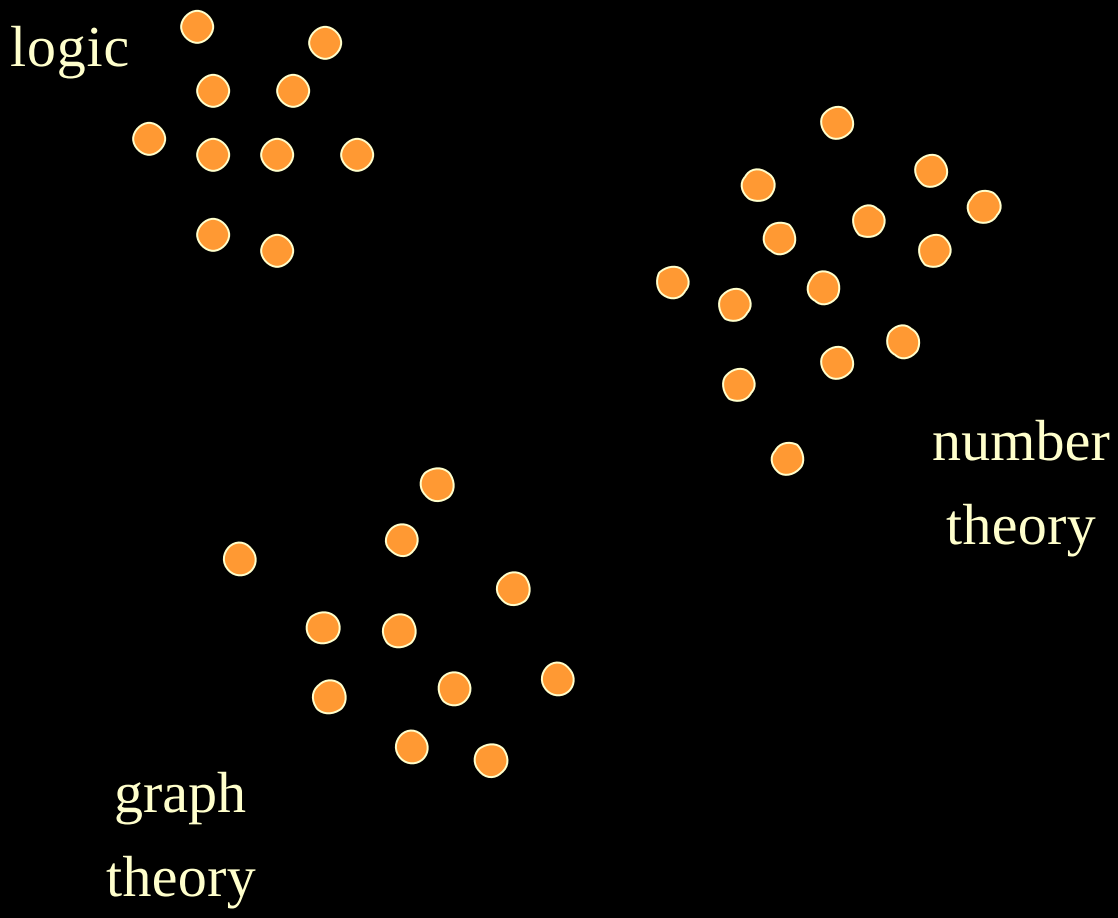
Learning from the Information Graph



hubs

authorities

Classifying by Eigenvectors



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NSF NSDL

digital library: "A managed environment of multimedia materials in digital form, designed for the benefit of its user population, *structured* to facilitate access to its contents, and equipped with aids to navigate the global network ... with users and holdings totally distributed, but *managed as a coherent whole*."

--Mel Collier, *International Symposium on Research,Development, and Practice in Digital Libraries 1997*

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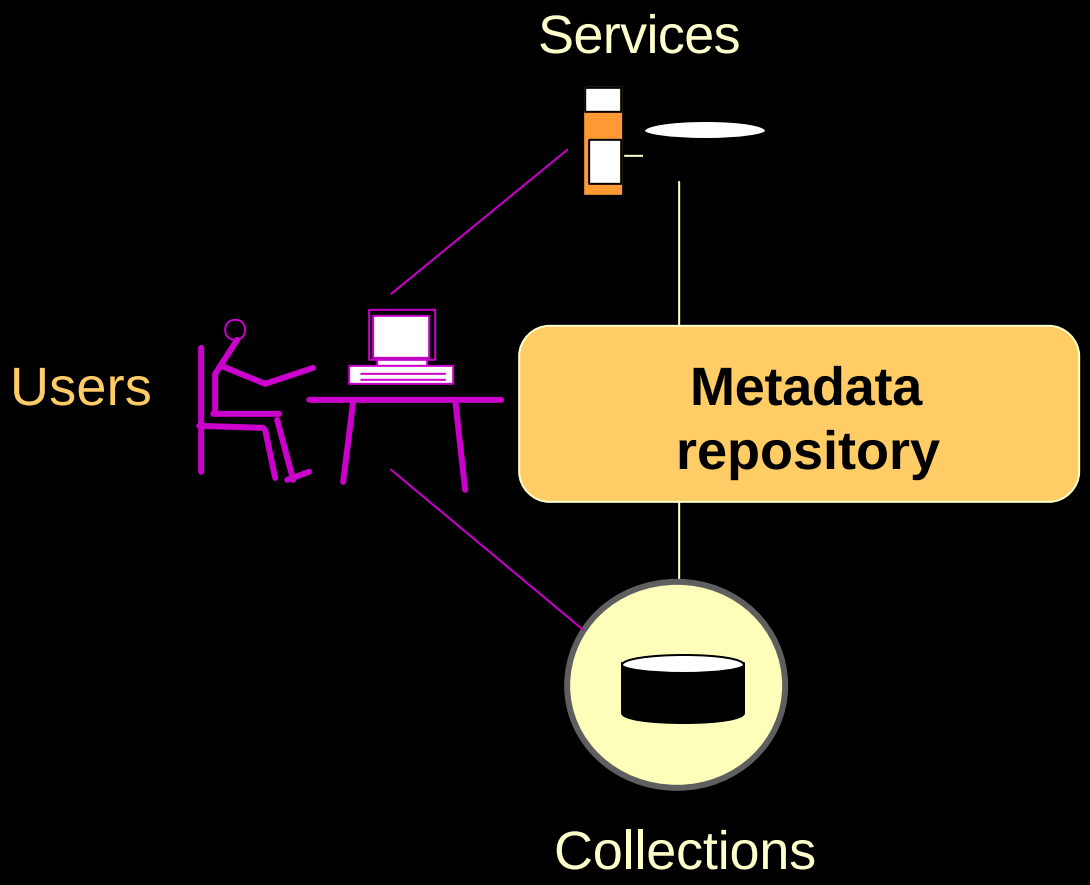
Bill Arms (director), Naomi Dushay, Carl Lagoze, Sandy Payette, Carol Terrizi, Vicky Weissman, <more>

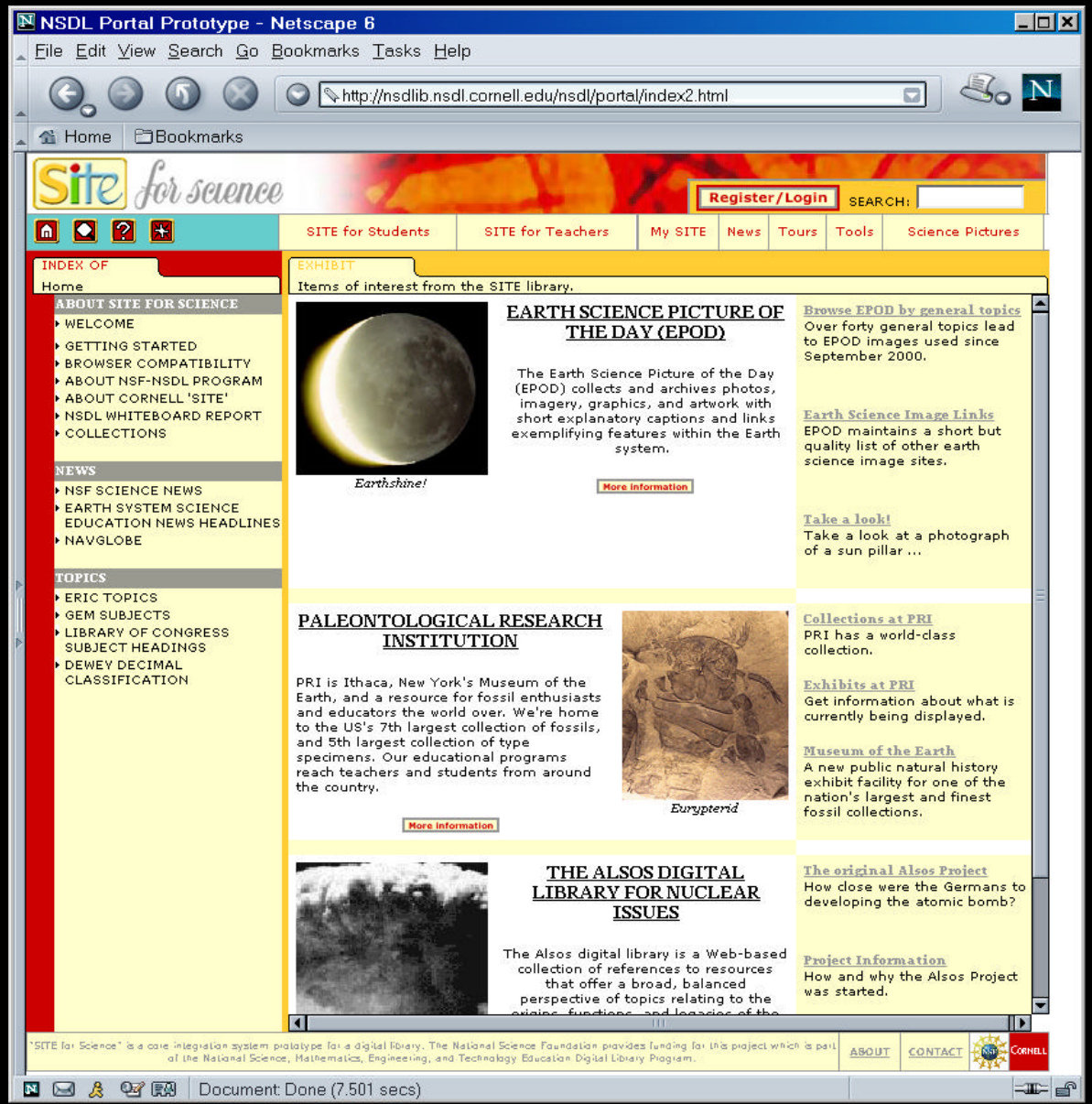
Metadata Repository

The Open Archives Initiative Protocol for Metadata Harvesting: Los Alamos, Nasa, and Cornell



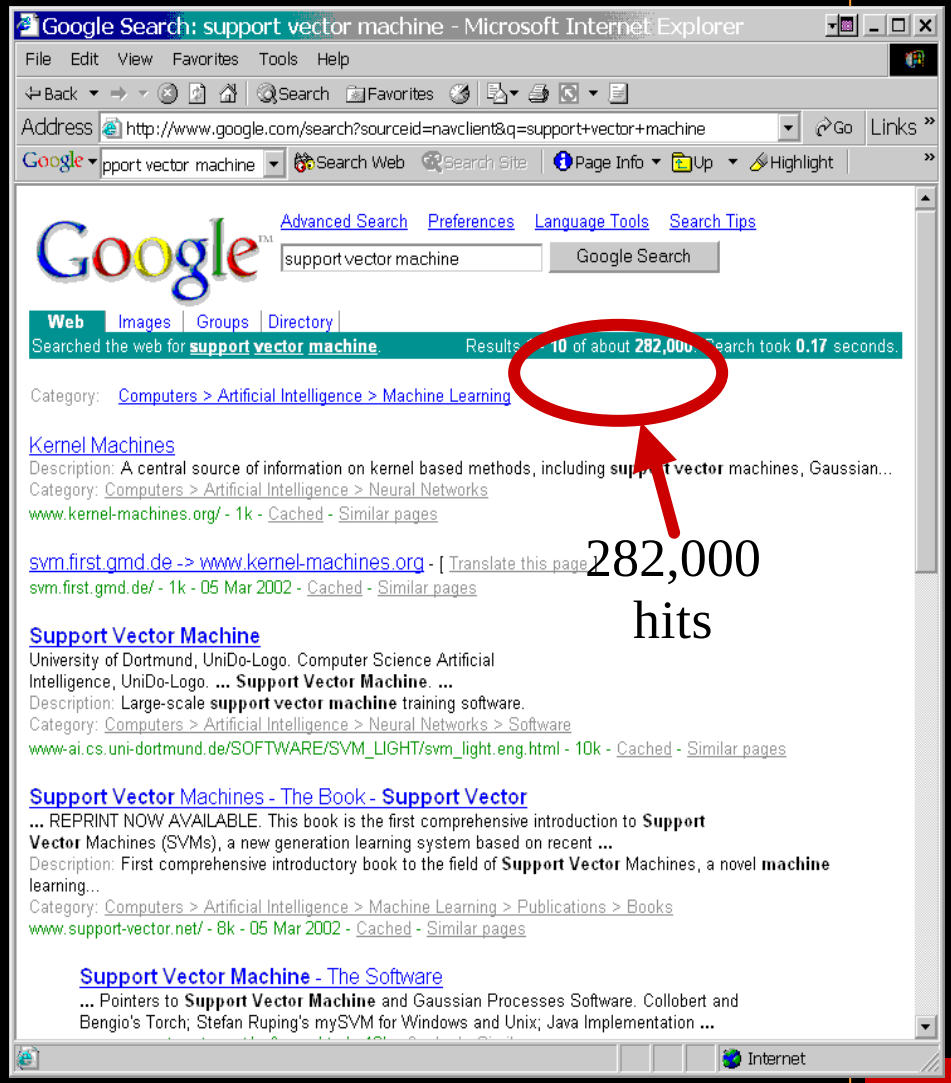
http://www.openarchives.org/OAI/2.0/openarchivesprotocol.htm

Cornell's NSDL Portal



Using Machine Learning in Ranking

- T. Joachims
  - Support Vector Machines
- Classification
  - "A is good", "B is bad"
  - Often not appropriate
- Ranking
  - "A is better than B"
  - Information Retrieval
- Example
  - Improve Search Engine using Machine Learning



Experiment

- Training- 260 queries from 20 users
- Learning- ranking function, *r*
- Comparison- Google, MSN, TopRank
- Results- *r* shows improvement with a 95% significance using two-tailed binomial sign test
  - Google: in 13/88 queries users clicked on more Google links, and in 29, more from *r*

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Modeling Bursty Streams, J. Kleinberg

- What are Bursts of Activity? – sharp rises in frequency of certain features of the stream

Email Messages	Conference Titles	Current Affairs	Web Usage Data

- Bursts are modeled as state transitions in a weighted automaton model

ACM SIGKDD '02

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US Presidential State of the Union Address (1790 to 2002)

Word	Interval of burst
gentlemen	1790 - 1800
whilst	1857 - 1860
emancipation	1862 - 1864
coinage	1877 - 1886
depression	1930 - 1937
war	1942 - 1945
peacetime	1945 - 1947
inflation	1971 - 1980
women	1981 - 1984
college	1995 –
communities	1995 -
america	1996 –

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Computing and Information Science

Cornell University

CIS

Cornell

"studies digital information in its human and social context."
Dean Robert Constable

- *Information systems*
- *Social systems*
- *Human centered systems*

Research Programs
Undergraduate Education
Courses
Concentration/Minor / Major
Graduate Education
Faculty and Researchers
Information Science Building
IS Seminar Series

INFORMATION SCIENCE MAJOR JUST APPROVED

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Reference Cites

- FDL www.nuprl.org/FDLproject
- NSDL www.nsdl.org/
- Rank www.cs.cornell.edu/People/tj/
- Bursts www.cs.cornell.edu/home/kleinber
- Info Science www.cis.cornell.edu/

Thank you!

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