Distributed Information Processing

22nd Lecture

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Outline

Information Transmission and Use
- Convergent Networks
- Introduction to the Semantic Web
- A Portrait of the Semantic Web in Action

Performance Evaluation

Dynamic Adaptation

Q&A
A programmable network switch that can process the signaling for all types of packet protocols.
Future of Search Technology [Brewer02]

- Integration of Textual Search and Database Technologies
- Distributed Repositories
- Context
- Integration with the Physical World
- Novel User Interface
  - To Avoid Information Overload
- Personalization
- Bias
Semantic Web Basics
[Gruninger02]

- Ontology
  - Formal Explicit Specification of a Shared Conceptualization
    - Conceptualization: how people think about things in a particular subject area
    - Explicit Specification: concepts and relationships of the abstract model given explicit terms and definitions
Semantic Web Basics (Cont’d)

**Ontology Uses**

<table>
<thead>
<tr>
<th>Uses of Ontology (customized from the uses of ontology identified at the KRSL kickoff meeting 1994).</th>
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<tbody>
<tr>
<td><strong>For communication</strong></td>
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<tr>
<td>between implemented computational systems.</td>
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<tr>
<td>between humans.</td>
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<tr>
<td>between humans and implemented computational systems.</td>
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<tr>
<td><strong>For computational inference</strong></td>
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<tr>
<td>for internally representing and manipulating plans and planning information.</td>
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<tr>
<td>for analyzing the internal structures, algorithms, inputs and outputs of implemented systems in theoretical and conceptual terms.</td>
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<tr>
<td><strong>For reuse (and organization) of knowledge</strong></td>
</tr>
<tr>
<td>for structuring or organizing libraries or repositories of plans and planning and domain information.</td>
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XML vs Ontologies [Kim02]

Commonality

- Means of Explicitly Representing Information Applied So That a Reader Interprets Shared Data As Intended by the Data Author

Differences

- Need for the Same Understanding
  - XML requires it while ontology does not
    - E.g., `<foo>7</foo>`

- Complexity
  - Semantics are not represented with XML use

- Efficiency vs Interpretability
  - Reducing Complexity vs Reducing Uncertainty
Using Ontologies for Uncertainty Reduction [Kim02]

- Case Where Ontology Is Appropriate
Example CS Department Ontology

Name: cs-dept-ontology
Version: 1.0

Extended Ontology
Base Ontology (base-ontology, version 1.0)
ISA Hierarchy (Taxonomy)

Person
  Worker
  Faculty
    Professor
  Assistant
  AdministrativeStaff

Student
Organization
Publication
Schedule

Relationships

Relation  Arg1  Arg2

==========================================
PublicationAuthor  Publication  Person

Inferences
Suborganizations are transitive
Affiliations are invertible
Membership transfers through suborganizations

For the Semantic Web, an Ontology Must Be Expressed in a Formal Language So That a Given Ontology Expression Can Be Interpreted and Processed Unambiguously by a Machine
Ontology Issues [Kim02]

- Designing an Ontology Development Tool
  - Useful and Usable to a Knowledge Worker
- Developing of Decentralized and Adaptive Ontologies
  - To Be Used in Combination with Other Ontologies
- Use of Ontologies for Software Specification
Performance Evaluation

- Exploiting Parallelism with the Distributed System (Compiler or Library)
  - Autoparallelization
    - Heterogeneity
    - Variable latencies
  - Manual Computation Decomposition and Load Balancing (Distributed Memory)
    - Architecture independence
  - Data Allocation (Distributed Memory)
    - Maximizing locality
    - Minimizing communication

Data Parallelism
Performance Evaluation (Cont’d)

- Parallel Execution of Components
  - Load matching
  - Communication optimization

- Overlap of Communication with Computation (Distributed Memory)
  - Large and variable latencies

- Reuse of More Data in Local Memories (Distributed Memory)

- Spreading Computation Evenly across Processors (Distributed Memory)
  - Minimizing communication

- Task Parallelism
- Latency Hiding
- Latency Reduction
- Load balancing
Performance Evaluation (Cont’d)

Performance Tools

- **Goal**
  - User’s identifying and overcoming performance bottlenecks

- **Functionalities**
  - Measurement
  - Analysis
  - Visualization
  - Engineering/Tuning
  - Estimation/Prediction

Via Instrumentation
To Identify Bottlenecks
Critical Path
- Longest Path through the DAG
  - Corresponding to the longest path

Critical Path of a Program
- Longest CPU or Communication Weighted Path of the PAG

Program Activity Graph
- A Graph Consisting of Nodes Representing Significant Events, and Arcs Indicating the Ordering of Events within a Process or Synch Dependencies between Events

Improving This Procedure May Not Improve the Program’s Execution Time

\( \text{val}(\text{CP}) = 8 \)
Dynamic Adaptation

Adaptivity

- Adaptation of Applications to Changes in Their Execution Environment
  - Changes in computational load
  - Changes in network performance

Application-Specific Framework

- Working Cooperatively with:
  - Measurement and monitoring
  - Alternative evaluation and selection
  - Performance-driven scheduling

Support at Different Levels

Prior Identification or Provisioning

Resource Reservation
Dynamic Adaptation (Cont’d)

- Changes in Computational Load
  - Obtaining Additional Resources
  - Asking Other Components to Adapt for Improvement
  - Relocating Computation
  - Reducing Requirements in Areas of Little Interest
Introduction (Cont’d)

- Changes in Network Performance
  - Controlling Error
  - Making a Bandwidth Reservation
  - Making Other Links Ask for More Bandwidth
  - Relocating Communication
  - Applying Compression
Dynamic Adaptation (Cont’d)

Adapting Applications

- Bandwidth Adaptation Approaches
  - Resource reservation (problematic)
    - Consumption of large memory for storing flowspecs
    - Low utilization for guaranteed services
    - Not being supported by nonswitched Ethernet & wireless LANs
    - Need for deploying policy control, security, and charging mechanisms
  - Adaptation of applications’ requirements

- Bandwidth Adaptation Requirements
  - QoS Measurements
    - E.g., RTCP (Control Protocol) in RTP for continuous media
Dynamic Adaptation (Cont’d)

- Delay Adaptation
  - Goal of Using Large Playout Buffers
    - Conversion of a variable delay into a fixed delay
    - Starvation prevention
  - Support for Using Large Playout Buffers
    - Variable buffer requirement estimation
    - Fixed Buffer

- Loss Adaptation
  - Retransmission (Limited by Delay Tolerance)
  - Redundant Transmission
  - Interleaving
  - Forward Error Correction (for Perfect Reconstruction with Redundant Parity Packets)
Application Adaptation

Goal

- Performance Contract
  - Quantified expectations between application performance demands and resource service capabilities

Techniques

- Contract Monitoring
  - Verifying, detecting when, and diagnosing why

- Adaptive Control
  - Adapting to a new resource regime

As a Form of Service-Level Agreements

C.f., Migrating to Other Resources vs Adjusting Contract Parameters Dynamically
Resource and Performance Variability

Sources of Variability in Performance and Availability
- Contention
- No Support for Reservation
- Failure and Preemption

Adapting the Execution for High Performance in a Shared Environment
- Relocating Resources
- Changing Application Behavior
Variability (Cont’d)

- Problem of “Static” Performance Models
  - Working Only under Ideal Conditions
    - Computational speeds
    - Network latency and bandwidth
    - I/O speed
  - Not Working under Dynamic Conditions

- Adapting Dynamically to Changing Conditions
  - Acquiring New Resources
  - Reducing Solution Resolutions
  - Switching to Alternatives
Instrumentation and Metrics

**Instrumentation**
- Automatic
- Minimizing Perturbation and Intrusion
- To Be Inserted at the Proper Level

**Metrics**
- To Be Selected Appropriately
- Considering Measurement Uncertainty and Temporal Variability
  - Tradeoff between the length of measurement interval and adaptability

E.g., for Contract Verification and Validation
Adaptive Control Example

Real-Time (Runtime) Monitoring

- Instrumentation
  - E.g., inserting “sensors”

- Periodic Transmission of Sensor Data

- Analysis of the Data
  - E.g., evaluation of the rule base with the data, and detection of contract violation

- Notification of the Result
  - E.g., distributing the result via the sensors

Issues: e.g., Assessing Temporal Variability and Contract Violation
Adaptive Control Example (Cont’d)

- Remediation
  - Halting the Execution
  - Migrating the Workload
    - At different levels
    - Comparing the benefit & cost
  - Restarting the Application

- Requiring Control Stability and Rescheduling Mechanisms

- Requiring the Support Such as Checkpointing
References


References (Cont’d)
