A Semantic Web Environment for Mobile, Context-Aware Services

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Overall Program Summary

- **Objective:** Open Environments for the creation of Context-Aware Services
  - Re-use, Security & Privacy, Usability
  - Test drive emerging standards and provide input/feedback
  - Initial focus: mobile & pervasive computing
  - Later also: Inter/Intra-Enterprise scenarios

- **Technical Solution Strategy:**
  - Prototype-driven
  - Identify gaps, propose solutions, complement/improve emerging standards

- **Basic Elements of Research**
  - Extensions of OWL to represent rules – ROWL engine & Semantic eWallet
  - Prototype environments, e.g. *MyCampus, InfoBridge, Museum, etc.*
  - Demonstration on DoD-relevant scenarios (SONAT, CoSAR-TS)
  - Participation in SWSA and rules discussion group
  - Public release of tools (2004)
• Rules are critical
  – Capture user preferences – e.g. decision rules, security and privacy
  – **Solution**: Rules in OWL (ROWL): Syntax & XSLT stylesheets for Jess & contribution to SWRL discussions

• Privacy and security are critical
  – **Solution**: Semantic e-Wallet
    • Gatekeeper and clearinghouse to information sources for a user
    • Extension of ROWL for representing privacy rules and service invocation rules – incl. XSLT stylesheets and multi-layer reasoning engine running on top of Jess

• Services are critical
  – **Solution**: Sources of contextual information modeled as web services
    • Integrating eWallet and web service composition

• Usability is Critical
  – **Solution**:
    • Rule Editors
    • Complemented with case-based reasoning
MyCampus

- Campus as “everyday life microcosm”
- Enhance campus life through a growing collection of context-aware agents/applications that users access over the WLAN:
  - Obtain information about users by querying their e-Wallets
    - Automatic identification of available sources of contextual information – modeled as web services
    - Dynamic Service invocation rules
  - Subject to user privacy preferences
    - Access control rules
    - Obfuscation rules
      » Abstraction
      » Modification
    - Including Context-Sensitive Policies
SW Environment for Context-Aware Services

MyCampus: Overall Architecture

Semantic Web-enabled Context Resources
- Calendar
- Location Tracking
- Social Context
- Preferences

User 1

e-Wallet
Personal Resource Directory (incl. Privacy Pref.)

Context-Aware Agents/Services

Internet and Intranet Semantic Web-enabled Services

Contextual Ontologies
Personal Preference Ontologies
Personal Resource Ontologies
Service Ontologies

Semantic Web Service Directory

Wireless LAN

Context-Aware Agents/Services

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• **Semantic e-Wallet:**
  - Unified front end to a set of resources modeled as services
    - e.g. resources of an individual user or an organization
  - Acts as both clearinghouse and gatekeeper to a user’s resources, which are modeled as web services
    - e.g. individual user or an entire organization
  - Relies on:
    - Resource identification rules
    - Security & privacy/confidentiality policies, e.g.:
      - **Access control policies**
        » “Only my colleagues can access my calendar and only on weekdays”
      - **Obfuscation policies**
        » “My classmates can only see the building I am in but not the actual room”
    - Includes policies whose enforcement requires accessing external resources (e.g. context-sensitive policies)
    - Also supports updating & rollback functionality
Example: *Query from John inquiring about Mary’s location*

- the sender of the query is John
- John’s query requires accessing Mary’s location
  1. Is John allowed to see Mary’s location given what we know about the context of the query?
  2. Mary said she only allows colleagues to see her location when she is on campus
  3. John is a colleague of Mary

- Access location tracking functionality or Mary’s calendar
- Is Mary on campus?
- Mary is willing to disclose the building but not the room she is in
- Mary is in Smith Hall
Three-layer architecture: **security through typing**

- **Core knowledge**: static & dynamic knowledge of user
- **Service Layer**: invoke external sources of knowledge: web services and personal resources
- **Privacy layer**: enforce privacy rules on external requests: access control & obfuscation rules
- Backward chaining migration: privacy rules, service rules, static migration rules
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e-Wallet Implementation - II

Ontology in OWL
&
Annotation in OWL
&
Rule in (R)OWL
&
Services in (W)OWL
&
Privacy in (S)OWL
&
Query in (Q)OWL

Ontology stylesheet
&
Annotation stylesheet
&
Rule stylesheet
&
Service stylesheet
&
Privacy stylesheet
&
Query stylesheet

OWL Meta-model in CLIPS

Ontology in CLIPS
&
Annotation in CLIPS
&
Rule in CLIPS
&
Service rule in CLIPS
&
Privacy rule in CLIPS
&
Query rules in CLIPS

XSLT Engine

Result in OWL

JESS

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Rule Editors

Decision rule #1: when giving a talk the screen is public

Body (condition): Add a root element

- Person, ?person
  - activity: Talk, ?talk

Head (conclusion): Add a root element

- Person, ?person
  - has_screen: PublicScreen, aPublicScreen
  - availability: LowAvailability,

Targeted knowledge:

- Person, ?owner
  - location, ?location

Restricting conditions:

- Place, http://www.cmu.edu
  - include, ?location
- EWallet, ?ewallet
  - sender, Variable, Reference, / Instance of
  - ID: owner
- not Query, ?query
  - sender, ?owner

Obfuscation:

- Person, ?owner
  - location, http://www.cmu.edu
Sample Context Aware Applications

• Context-Aware Restaurant Concierge
• Meeting Scheduler with Obfuscation Rules
• People Finder with Privacy Preferences
• Location-Sensitive Services
  – Movies, weather, etc.
• Context-Aware Message Filtering and Delivery
• Remote slide viewing with access control rules
• P2P context-aware poster application
• Context-Aware reminder application
• etc.
• **What technical problems were there and when/how did you overcome them?**
  – Limitations of OWL
    • Rules: **ROWL** and contribution to SWRL discussions
    • Services: Contribution to SWSA
      – Security and Privacy
    • **Semantic e-Wallet** reasoning engine – enforcing context-sensitive policies that require accessing external services
  – Usability
    • **Editing tools** to specify context-sensitive policies

• **Measures of Success**
  – **myCampus:**
    • Anecdotal evidence that MyCampus environment significantly reduces the time it takes to develop new context-aware applications – built a dozen applications
    • User testing – several days at a time/10-20 users
  – **Semantic Web technologies are increasingly viewed as central to:**
    • Pervasive computing, e.g. Wireless World Research Forum
    • Privacy & Security policies, e.g. JRC P3P prototype
    • Future enterprise architectures – different companies we are talking to
  – **Dozens of downloads of ROWL**
  – **Context-aware museum tour guide pilot** seems promising
  – 18 peer-reviewed publications + “best selling” book on Mobile Commerce

• **Did you meet your original or revised programmatic goals?**
  – Absolutely
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Milestones and Accomplishments

• **2002**
  - Semantic Web Demonstrator for mobile, context-aware services – MyCampus
    - Ontologies & initial set of context-aware applications
    - Contribution to Semantic Operational Net Assessment (SONAT) demonstration – context-aware message delivery functionality
  
• **2003**
  - ROWL: Rule extension of OWL
  - Semantic e-Wallet
    - Service invocation rules
    - Privacy/confidentiality rules
      - Access control policies
      - Obfuscation policies
    - Multi-layer reasoning engine for automated service identification and access and for enforcing privacy policies – incl. Context-sensitive policies
    - Support for updates & rollbacks
  - Evaluation on CMU’s campus
    - A dozen context-aware applications & associated ontologies
  - Public release of OWL Semantic Web Engine
  - Context-Aware message delivery functionality used in support of Coalition Search and Rescue – Task Support (CoSAR-TS) - demonstrator developed by AIAI, West Florida, BBN and Sparwar

• **2004**
  - Public release of ROWL and associated reasoning engine
  - Standalone e-Wallet tool
  - Contributions to SWSA discussions and rule discussion group
  - Integration of eWallet and planning functionality
  - Ongoing work with several end-user organizations
    - e.g. Context-aware museum tour guide for national science museum

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Transition/Handoff

• Tools & software released:
  – OWL Semantic Web Reasoning Engine
  – ROWL – Rule Extension of OWL, incl. reasoning engine
  – Semantic e-Wallet (upcoming)

• Influence on specs
  – Contributions to SWSA and rule group discussions

• Publications: 18 peer-reviewed publications & Mobile Commerce book

• Numerous tutorials, keynotes, panels as well as courses

• DoD Contributions: context-aware message filtering application used in SONAT and CoSAR-TS demos

• Additional impact:
  – Context-aware office scenario for the Institute for Information Industry (III)
  – Context-aware museum tour guide – pilot in largest natural science museum in Taiwan (nearly 3M visitors/year)
  – Ongoing negotiations with other prospective end-user organizations
  – Member of Joint Committee
  – DERI advisory board
  – 2004 IBM Best Privacy Faculty Award
## Remaining Issues

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<th>Issue</th>
<th>Remediation</th>
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<tr>
<td>SemWebCentral</td>
<td>-OWL Engine &amp; ROWL: later this month</td>
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<td>-eWallet: early 2005</td>
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Summary

• Demonstrated the relevance of the Semantic Web to mobile and pervasive computing
• Developed and published tools
  – OWL Engine
  – ROWL – Rules in OWL
  – Semantic e-Wallet
    • Privacy & Service identification rules
    • Context-sensitive policies
• Contributed to discussions within:
  – Rules working group
  – SWSA
• Contributed to DoD-relevant demos: SONAT and CoSAR-TS
• Continuing to work with several end-user organizations
  – Mobile &Pervasive Computing
  – Intra- and inter-enterprise solutions
“Well, officer, the coffee pot at home tried to tell my PDA to buy some Colombian beans on the way home, but the car overheard the message and took it as a command to turn for the grocery store right away...”

...Why we need the Semantic Web...