Knowledge Provenance: An Approach to Modeling and Maintaining Evolution and Validity of Knowledge

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Outline

• Problem
• Motivating example
• Static KP Ontology
• Implementation
• Progress
  • Dynamic KP
  • Uncertainty-oriented KP
• Conclusion and future work
Problem to be addressed

- How to determine the validity and origin of Web information
- Why?
  - In general
    - Anyone can publish info on Internet
    - Web info may be true, false, or outdated
    - Need tools to discern difference
  - In the context of enterprise integration
    - Dynamic partnerships
    - Uncertain information flow
    - Knowledge management
Questions KP attempts to answer

- Can this information be believed to be true?
- Who created it?
- Can its creator be trusted?
- What does it depend on?
- Can the information it depends on be believed to be true?
Research Objectives

Goal: to create an approach to determining the validity and origin of knowledge/information on the Web

- Level 1: Static Knowledge Provenance
- Level 2: Dynamic KP
- Level 3: Uncertainty-oriented KP
- Level 4: Judgment-based KP
Relevant Research

- Internet information resource evaluation criteria ([Alexander&Tate99])
  -- Authority, Accuracy, Objectivity, Currency and Coverage
- Trust and Trust Management
  [Marsh94] [Blaze96] [Yu&Singh00][Golbeck02]
  -- formalizing trust
  -- decentralized trust management for web security
  -- trust propagation in social networks
- Social Networks ([Milgram67],[Watts99])
  -- six degrees of separation
- Semantic Web ([Berners-Lee03])
- Technologies from AI/uncertainty logic/Digital Signature
Motivating Scenario

“Arctic sea ice coverage fell from around 6.5 million square kilometres to around 5.5 million square kilometres in 2002.” ---- a news from internet

Is it true?

• Who said this?
  --- NASA

• How can we know the creator is as claimed?
  --- digital signature and digital certification

• Can we trust the creator on this topic?
  --- NASA has authority on the topic
  --- trust relationships
Motivating Scenario (2):
------- Dependent Information

“In 2002, a satellite-based survey [NASA 2003] found that ‘Arctic sea ice coverage fell from around 6.5 million square kilometres to around 5.5 million square kilometres in one year’. The melting sea ice threatens to drive polar bears extinct within 100 years”.

- Quotation
- Derived conclusion
Findings in Scenario

- Basic information unit ---- proposition
- Proposition taxonomy

```
KP_prop
  ----------------
  Asserted_prop
  Dependent_prop
  Equivalent_prop
  Derived_prop
  Composite_prop

  AND_prop
  OR_prop
  NEG_prop
```

- How to determine truth?
  - Information dependencies
  - Trust relationships
Approach

Modeling and maintaining
- information sources
- Information dependencies
- trust relationships
Static KP Ontology(1)

- Motivating scenario
- Informal competency questions/requirements
- Terminology
- Axioms in FOL
Informal competency questions

- Is this proposition true, false, or unknown?
- Who created this proposition?
- What is the digital signature verification status?
- Which knowledge fields does it belong to?
- Can the infor-creator be trusted in the fields?
- Is its truth dependent on other propositions? If so, which ones?
Terminology

- **assigned_truth_value** $(x,v)$:
x has a truth value $v$ assigned by info-creator

- **trusted_truth_value**$(a,x,v)$:
KP agent $a$ trusts: $x$ has truth value $v$.

- **is_dependent_on**$(x, y)$:
Proposition $x$ is dependent on proposition $y$.

- **trusted**$(x, a)$:
x is trusted by $a$

- **trusted_in**$(a, c, f)$:
a trusts information creator $c$ in knowledge field $f$. 
Axioms

- 14 axioms defined in FOL
  - A proposition is "trusted", if:
    - its creator is trusted in the topic
    - digital signature is verified.
  - An asserted-prop is trusted to be true, if:
    - It is trusted
  - An equivalent-prop is trusted to be true, if:
    - has same content as its source
    - its source is trusted to be true.
  - A derived-prop is trusted to be true, if:
    - it is trusted,
    - the propositions it depends on are trusted to be true.
Axiom (2)

**Axiom SKP-12:**

\[ \forall \ (a, x, y, v) \ ((\text{type}(x, \ "\text{derived\_prop}\") \ ^ \ \text{trusted}(x, a) \ ^ \ \text{assigned\_truth\_value}(x, v) \ ^ \ \text{is\_dependent\_on}(x, y) \ ^ \ \text{trusted\_truth\_value}(a, y, \ "\text{True}\")) \rightarrow \text{trusted\_truth\_value}(a, x, v)). \]
Implementation

- Information creators: annotate web info with KP tags (RDFS data)
- Information users (provenance requesters): define trust relationships
- KP reasoner: traces kp tags across web pages and deduce validity of info
  --- has implemented in Prolog
  --- web implementation
Example: annotate web page

<kp:Derived_prop rdf:id="ReduceDelay"
  is_dependent_on = "#ProblemOfDelay"
  in_field = "CRM">
  To reduce response-delay to less than one minute may increase customer loyalty.
</kp:Derived_prop>
Example: KP Process

Trust Relationships:
"Tim Levy" is trusted in "CRM"
"Bill Cox" is trusted in "CRM"

Applying axiom SKP-2&12:
Trusted_truth_value=True

Applying axiom SKP-5:
Trusted_truth_value=True

Applying axiom SKP-1:
Trusted_truth_value=True

Applying axiom SKP-2:
This proposition is trusted

Digital Signature Verification

Yeah, you could believe it! because...

Trust Relationships:
"Tim Levy" is trusted in "CRM"
"Bill Cox" is trusted in "CRM"

 KP software agent

Is it true? Who said?

Yeah, you could believe it! because...

 "Tim Levy" is trusted in "CRM"
 "Bill Cox" is trusted in "CRM"

Trust Relationships:
"Tim Levy" is trusted in "CRM"
"Bill Cox" is trusted in "CRM"
Dynamic KP

- Truth values and trust relationships may change over time
- Dynamic KP extends static KP by attaching an **effective period** to each proposition and each trust relationship
- Dynamic KP determine the validity of a proposition at a give time point
Uncertainty-oriented KP(1)

- Uncertainty in KP
  - uncertain truth values
  - uncertain trust relationships
- Introduce subjective probability to represent uncertain truth values and uncertain trust relationships
Uncertainty-oriented KP(2)

- **Trust Degree:**
  \[ td = Pr(\text{trusted\_in}(a,c,f)) \]
  --- uncertain trust relationship
  --- subject probability for an info user to trust an info-creator

- **Assigned Certainty Degree:**
  \[ acd = Pr(\text{assigned\_truth\_value}(x,"True")) \]
  --- uncertain assigned truth value given by creator
  --- subjective probability of a proposition being true

- **Certainty Degree:**
  \[ cd = Pr(\text{trusted\_truth\_value}(a,x,"True")) \]
  --- uncertain trusted truth value
  --- probability of the trusted truth value being true
Uncertainty-oriented KP(3)

Certainty degree of asserted proposition:

\[ cd = td^*(acd - 0.5) + 0.5 \]
Uncertainty-oriented KP(4)

- Certainty degree of a derived proposition

\[ cd_x = td_x \cdot cd_y \cdot (acd_x - 0.5) + 0.5 \]

- Certainty degree of an equivalent proposition

\[ cd_x = td_x \cdot (cd_y - 0.5) + 0.5 \]

- Certainty degree of an AND proposition

\[ Z = x \land y \]

\[ cd_z = td_z \cdot (Pr(x/y) \cdot cd_y - 0.5) + 0.5 \]
Conclusion

- Formal models of (static, dynamic, uncertain) Knowledge Provenance has been built and implemented in Prolog.
- The KP models could be used to help users to determine the validity and origin of web information annotated with KP metadata.
Future Work

- Level 4: Judgment-based KP:
  Trust propagation and update in social networks
- Web implementation
- Applications
  - E-business
  - Health consulting
Thank You!

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Questions?