Formalizing Trust-based Decision Making in Electronic Commerce Transactions

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**1st International Workshop on Combining Context with Trust, Security, and Privacy,
Moncton, New Brunswick, Canada
July 30th, 2007**

* Work done while at Georgia Southern University

Agenda

- Observations
- Goal
- Related Work
- Our work - E2T2
- Trust-based Decision-Making in Electronic Commerce Transactions
- Modeling in E2T2
- Examples of E2T2 Use
- Future Work

Observations

- At least two decades of research into trust management for computer systems.
- A growing need for automated tools that enable trust-based interaction.
- A lack of deployed tools/mechanisms based on formal notions in computer science.

Goal

- Examine the decision-making process for Electronic Commerce.
- Extract the key concepts and notions.
- Leverage epistemic, event and temporal logic to create a flexible platform that can be used to enable this decision-making.

Related Work

- Security Modeling
  - Systems that enable distributed access control and/or authorization simplification, e.g. KeyNote, REFEREE
  - Focused on access rights management
  - Not well-defined formal models underpinning them
- Social Modeling
  - Systems that leverage social science notions, e.g. reputation and recommendation, to create online interaction models, e.g. Epinions, Yelp, Ebay
  - Focused on trust-building through human evaluations
  - Limited and simple model for metrics combination

Introduction to E2T2 (Epistemic Event Temporal Trust)

- A formal model based on beliefs, which assumes that:
  - Each party in an online transaction has its own set of beliefs, which evolve over time.
  - Each party's behavior may change over time based on trigger events.
  - Trust is a quantified belief.
- The model takes a modal approach to modeling belief. However, BEL_{str} is defined due to quantifier. A reified approach to temporal reasoning is employed.

E2T2 – The Basics (1/3)

- Syntactic primitives, sentence construction rules and semantics detailed in the paper.
- Core Predicates:
  - BEF(t_1, t_2) – true if t_1 is before t_2.
  - HOLDS(s, t_1, t_2) – true if state s holds between t_1 and t_2.
  - OCCURS(e, t) – true if event e occurs at time t.
  - IMPACTS(e, a, b, e' ,r) - true if the occurrence of the event e impacts the level of trust that a has in b to bring about e' by r, where r is a ratio.*

*The ratio is negatively correlated to the amount of confidence I already have.

E2T2 – The Basics (2/3)

- Core Operators and Functions
  - BEL(a, str, t, p) – agent a believes proposition p with confidence str at time t.
  - CANINDUCE(a, e) – describes the state of agent a being able to bring about event e.
  - REQUEST(a_1, a_2, e) – describes the event of a_1 requesting a_2 to bring about event e.
  - COMMIT(a, e, t) – describes the event of agent a committing itself to being about event e before time t.
  - THRESHOLD(a, b, e, t) – describes the upper bound on a's willingness to take the risk to engage b to perform event e at time t.

E2T2 – The Basics (3/3)

- Core Operators and Functions
  - TPER(a_1, a_2, e, t) – describes the time at which a_1 can reasonably expect a_2 to have delivered on its commitment to being event e.*
  - SECURE(a, e) – describes the state where a is secure with respect to event e.
  - CALC(s1, s2, s3, s4) – a function that calculates the cumulative strength based on input strength values.

*It is assumed that a_2 committed to being about e at time t.

E2T2 – Fundamental Definitions

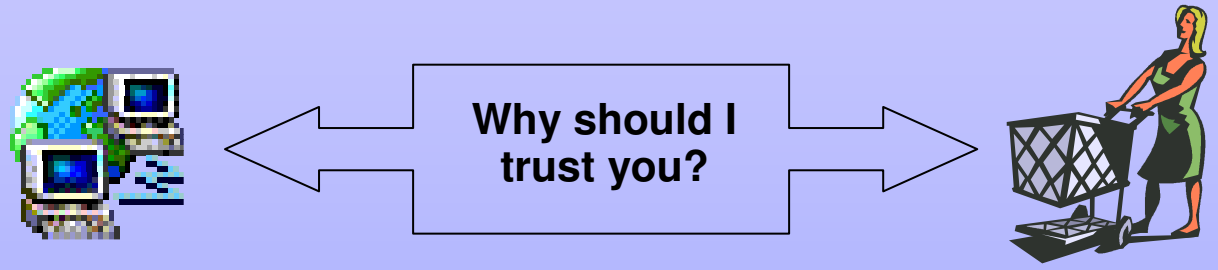
- **Trust** is the quantified belief by a trustor with respect to the competence, honesty, security and dependability of a trustee within a specified context.*

  TRUST(a,str,b,t,e) - a trusts b at trust level str at time t to bring about event e

- **Distrust** is the quantified belief by a trustor that a trustee is incompetent, undependable, not secure and or dishonest with respect to bringing about some event or state of affairs for a specified context.*

* "Trust in E-Services: Technologies, Practices and Challenges". Ronggong Song. IDEA Group 2007

Trust-based Decision-making in Electronic Commerce Transactions



- **System/Entity Considerations**
  - Competence, Honesty, Security, Timeliness and Reliability
- **Business/Social Considerations**
  - Transaction Properties, i.e. value, insurance, loss compensation model, risk.
  - Guarantees on Privacy Compliance.
  - Experience, i.e. your and others.
  - Reputation in the community or industry of interest.
  - A recommendation from a friend.

Modeling Trust in E2T2

TRUST(a, CALC(str1, str2, str3, str4), b, t, e) ↔

a believes that b is capable of bringing about e in a timely manner.

a believes that whenever it requests of b to bring about e, then b will, within a reasonable period of the request being made, form the intention to bring about event e in a timely manner.

a believes that b is secure with respect to e.*

a believes that whenever b has committed to bringing about e before some time, e will indeed occur before that time.

* a does not have to assume that b will be secure with respect to e forever, but merely for the period in which it is reasonable for a to expect b to perform e after a has requested b to perform e.

Modeling Trust Evolution in E2T2

- Observations:
  - Trust relationships evolve as new experiences and new information is added and incorporated.
  - This evolution can be modeled as a change in the trust level.
  - Trust changes based upon changes in beliefs about the competence, dependability, security and honesty of an entity and or at the occurrence of some event.
- Formalism in E2T2:

  $(\forall t{:}T)\ [(TRUST(a, n, b, t, e)\ \&\ OCCURS(e',t)\ \&\ IMPACTS(e',a,b,e,w)) \rightarrow TRUST(a, n*(1+w), b, t+1,e)]$

  - if a trusts b to perform e with trust level n at time t, and at time t some event e' occurs that impacts a's trust in b to bring about e by ratio w, then a's trust level in b to bring about e at the next point in time has changed by ratio w.
- The effects of the concepts of experience, reputation, recommendations, business confidence, diffidence, expectation, reliance and deception can be modeled using the formalism above.

Modeling Risk in E2T2

$$(\forall t{:}T)\ [(\mathrm{TRUST}(a, n, b, t, e) \ \&\ (n > \mathrm{THRESHOLD}(a,b,e,t)\ \&\ \mathrm{OCCURS}(\mathrm{REQUESTS}(a,b,e), t) \rightarrow \mathrm{BEL}(a,(\exists t'{:}T)\ (t' < \mathrm{TPER}(a,b,e,t)\ \&\ \mathrm{OCCURS}(e,t'))]$$

- If a's trust in b to perform e exceeds THRESHOLD(a,b,e,t) then a is willing to engage b to perform e at time t as a is certain that any request for b to perform e will result in e occurring within a reasonable period of the request being made.*
- Risk-averse entities will trust if their thresholds are not exceeded, whereas risk-loving entities do the opposite.

*The important observation here is that confidence levels and risk thresholds are in the same numerical range and can be compared because there is a semantic equivalence.

Single-Party Example of E2T2 Use

- A single user, Abby, states that she trusts an Ebay seller to successfully fulfill a transaction based on the seller's honesty and the risk of the transaction.*

$$\text{TRUST}(\#\text{Abbey.Browser}, \#\text{CurStr}_{\text{ebay}}, \#\text{seller}, \#\text{Now}, \text{fulfill}(\text{Trans}))$$
$$\leftrightarrow$$
$$\text{BEL}(\#\text{Abbey.Browser}, \#\text{CurStr}_{\text{ebay}}, \#\text{Now},$$
$$(\forall x{:}T)(\forall x'{:}T)\,[\text{OCCURS}(\text{COMMIT}(\#\text{seller}, \text{fulfill}(\text{Trans}), x'), \#\text{Now}) \rightarrow (\exists x''{:}T)\,[\text{BEF}(\#\text{Now}, x') \,\&\, \text{BEF}(x', x'') \,\&\, \text{OCCURS}(\text{fulfill}(\text{Trans}), x'')]])$$
$$\&\ \text{risk}(\text{Trans}) \leq \text{THRESHOLD}(\#\text{Abbey.Browser}, \#\text{seller}, \text{fulfill}(\text{Trans}), \#\text{Now})$$

* Assuming the E2T2 trust evolution statements are in effect.

Two-Party Example of E2T2 Use

- Amazon trust business partners who are dependable with regards to honoring orders. Business Partners trust resellers that pay in a timely order after requesting goods.

Amazon

TRUST(#Amazon.Server, #CurStr, #Partner, #Now, fulfill(order)) ↔

BEL(#Amazon.Server, #CurStr, #Now, (∀x:T) [OCCURS (REQUEST (#Amazon.Server, #Partner, fulfill(order), #Now) → (∃x':T) (∃x'':T) [BEF(#Now, x') & BEF(x', TPER(#Amazon.Server, #Partner, REQUEST(#Amazon.Server, #Partner, fulfill(order)),#Now)) & BEF(x', x'') & OCCURS(COMMIT(#Partner, fulfill(order), TPER(#Amazon.Server, #Partner, fulfill(order), #Now)), x'')]])

Business Partner

TRUST(#My.Browser, #CurStr$_{re}$, #reseller, #Now, pay(Trans)) ↔

BEL(#My.Browser, #CurStr$_{re}$, #Now, (∃x':T) (∃x'':T) [BEF(#Now, x') & BEF(x', TPER((#My.Browser, #reseller,REQUEST(#My.Browser, #reseller, pay(Trans)), #Now)) & BEF(x', x'') & OCCURS(COMMIT(#reseller, pay(Trans), TPER(a, #reseller, pay(Trans), #Now)), x'')]])

Future Work

- Model scenarios that require probabilistic measures, e.g. unknown parameters, uncertainty.
- Develop a reasoner for E2T2.
- Develop tooling to enable specification of trust behavior.
- Create distributed infrastructure for E2T2 use.

Conclusion

- The leveraging of epistemic, event and temporal logic is a necessary step forward if we want systems to be built on formal frameworks.
- E2T2 is a first step towards this goal of creating a formal model upon which automated trust-based decision-making technology can be built.
- The ground concepts and notions have been modeled.
- E2T2 is flexible enough to handle new concepts as they emerge.
- Hopefully, this is an interesting area for future academic research.

Thank You

Questions ???

Slides available at: http://www.almaden.ibm.com/cs/people/tgrandison/talks.html

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