Trust Domains: An Algebraic, Logical, and Utility-theoretic Approach

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Trust in Multi-Agent Modelling

What is trusted/trustworthy?

- A part of a system that an agent chooses to interact with, in order to achieve its goals.
- A context that enables desired behaviour.

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What is trusted/trustworthy?

- A part of a system that an agent chooses to interact with, in order to achieve its goals.
- A context that enables desired behaviour.

Definition

1. A logical assertion that expresses the properties that must be possessed by any trusted agent.
2. A cost bound that limits the extent to which the system around the agent can be trusted.

That is, the agent will trust only those parts of the system where a desired property can be reached or observed within a given cost expenditure.

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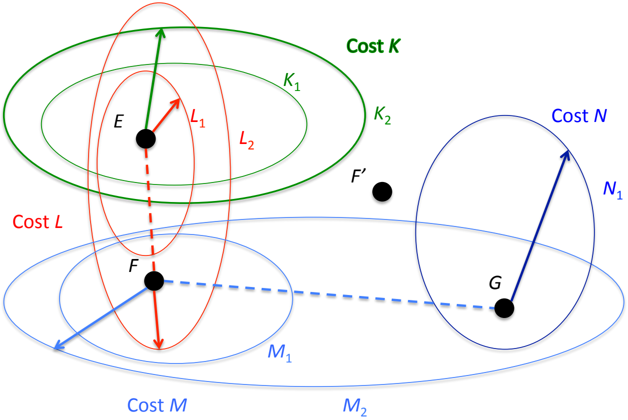
Domains of Trust



Trust Examples

We consider three examples of trust domains

- Contract choices.
- Boundary establishment.
- Information provenance.

These examples are illustrative rather than comprehensive.

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1. Contract choices: risk management trade-offs in a corporate environment
2. Boundary establishment: interaction between different agents with different preferences.
3. Information provenance: determining which resources to rely upon

Contract Choices

- Mergers and acquisitions (M&A) deal team: values companies under consideration.
- Outsources specialised valuations (e.g. real estate).
- Trade offs: cost of valuation vs efficacy of valuation vs risk of data loss.

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Contract Choices

- Supplier A (specialised):
  - Fee cost: 0.6.
  - Valuation utility: 0.5.
  - Data risk loss cost: 0.5.
- Supplier B (generalised):
  - Fee cost: 0.7.
  - Valuation utility: 0.3.
  - Data risk loss cost: 0.1.
- The overall costs are 0.5 for Supplier A and 0.3 for Supplier B.

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Boundary Establishment

- When entering port control is transferred from the ship's captain to a port tug.
- Consider a series of locations, L_1 and L_2.
- The captain would prefer for control to be transferred as soon as possible (insurance reasons):
  - Will take ship as far as L_2 in calm seas, but only to L_1 in rough seas.
- The harbourmaster would prefer for control to be transferred as late as possible, in order to improve throughput.
  - Preferences are dependent on what the captain is willing to do.

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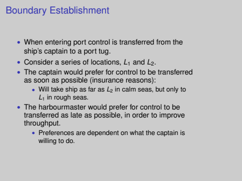

1. L_1 is closest to open sea and L_2 is closest to port
2. less time spent per ship if they don't have to be tugged as far
3. Relate the boundary choirs to security. Different agents making decisions about what they want to do; looking at how implementing agents can interact.

Boundary Establishment

- Captain *C*, at each location, can either choose to go forward or to wait for a tug.

C's costs	Calm Seas	Rough Seas
Forward	0.3	0.7
Wait	0.7	0.3

- Harbourmaster *H*, at each location, can either choose to supply a tug or wait for the ship to come closer.

H's costs	C prefers forward	C prefers wait
Tug	0.5	0.5
Wait	0.3	0.7

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Information Provenance

- When making decisions about data sharing arrangements, the quantity and the quality of the evidence provided is important.
- Smaller quantities of evidence can be mitigated by social or technical mechanisms (e.g. ISO certification or hardened OS's).
- Consider a scenario with two contractors; the first, *A* can leak information in two ways and the second, *D*, can leak it in one way.

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1. makes use of processes that can (but don't necessarily) leak

Information Provenance

- Contractors can show that they use mechanisms that preclude the leaks:
  - Resource e_i denotes evidence that the i'th leak type is precluded.
- The contracting company can't differentiate between the contractors, but can be shown the evidence.
- If it both pieces of evidence the same any one, it will not be able to accurately determine the contractor that has a higher chance of data loss.

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1. i.e. doesn't know that one can fail in multiple ways

Process Models

$$E ::= \mathbf{1} \mid [\,] \mid a : E \mid \sum_{i \in I}{}_{u} E_i \mid E \times E.$$

- Choices take account of agents *around* the agent making the choice.
- Treat contexts as first class objects - processes contain hole tokens [ ].
- Split the semantics in two: cost based and action based.
- We establish the normal bisimulation relation (for resource calculi).

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Action Semantics

$$\frac{}{R, a : E \xrightarrow[C_1]{C_2}{}^{a} \mu(a, R), E}$$

$$\frac{R, E \xrightarrow[C_3]{C_2}{}^{a} R', E' \qquad S, F \xrightarrow[C_4]{C_2}{}^{b} S', F'}{R \circ S, E \times F \xrightarrow[C_1]{C_2}{}^{ab} R' \circ S', E' \times F'}$$

where $C_3 = C_1((S, F(C_2)) \times [\,])$ and $C_4 = C_1((R, E(C_2)) \times [\,])$.

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Cost Semantics

$$\frac{n = u(C_1(R, E_i(C_2)))}{R, \sum_{I}{}_u E_i \overset{C_2}{\underset{C_1}{\Longrightarrow}}{}^{n} R, E_i}$$

$$\frac{R, E \overset{C_2}{\underset{C_3}{\Longrightarrow}}{}^{o} R, E' \qquad S, F \overset{C_2}{\underset{C_4}{\Longrightarrow}}{}^{p} S, F'}{R \circ S, E \times F \overset{C_2}{\underset{C_1}{\Longrightarrow}}{}^{o+p} R \circ S, E' \times F'}$$

where $C_3 = C_1((S, F(C_2)) \times [\,])$ and $C_4 = C_1((R, E(C_2)) \times [\,])$.

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Logic Language and Interpretation

$$\phi ::= \; p \mid \bot \mid \top \mid \neg\phi \mid \phi \wedge \phi \mid \phi \vee \phi \mid \phi \to \phi \mid \langle a \rangle \phi \mid [a]\phi \mid$$
$$I \mid \phi * \phi \mid \phi \mathrel{-\!\!*} \phi \mid \langle \leq n \rangle \phi \mid [\leq n]\phi \mid \langle > n \rangle \phi \mid [> n]\phi$$

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We can establish the customary forward direction of the Hennessy Milner property (the other direction is precluded by the resource and multiplicative logic approach).

Logic Language and Interpretation

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$C_1 \models_{C_2} \langle \leq n \rangle \phi$ iff there are C_1', C_2', m, o such that $C_1 \overset{e,\mathbf{1}}{\underset{C_2}{\Longrightarrow}}{}^{m} C_1'$ and $C_2 \overset{C_1}{\underset{C_\emptyset}{\Longrightarrow}}{}^{o} C_2'$, and $m \leq n$ and $C_1' \models_{C_2'} \phi$.

$C_1 \models_{C_2} [\leq n]\phi$ iff for all C_1', C_2', m, o such that, if $C_1 \overset{e,\mathbf{1}}{\underset{C_2}{\Longrightarrow}}{}^{m} C_1'$ and $C_2 \overset{C_1}{\underset{C_\emptyset}{\Longrightarrow}}{}^{o} C_2'$ and $m \leq n$, then $C_1' \models_{C_2'} \phi$.

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Trust Domains: Definition

$$TD((R, E), \phi, \psi, n) = \{S, F \mid S, F \vDash_{C_\emptyset} \phi \text{ and } R \circ S, E \times F \vDash_{C_\emptyset} \langle \leq n \rangle \psi\},$$

- Definition consists of:
    - An agent R, E.
    - A context S, F.
    - A precondition on the context ϕ.
    - A cost bound n.
    - A desired logical property ψ

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- Definition consists of:
  - An agent R, E.
  - A context S, F.
  - A precondition on the context ϕ.
  - A cost bound n.
  - A desired logical property ψ
- This effectively collates the contexts that make the logical property $\phi \multimap \langle \leq n \rangle \psi$ hold.

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Contributions and Conclusions

- We define an operational semantics and logic for cost and context based transition systems.
- We and establish the expected properties.
- Formally incorporating cost into choice permits us to model interesting risk management scenarios with complex trade-offs.
- A context is considered to be trusted (part of a *trust domain)* if it enables some desire behaviour, within a given cost expenditure.

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Future Work

- Cost determinations require knowledge about the world around a given agent — has game theoretic possibilities.
- Probabilistic modelling would permit us to consider expected rather than absolute costs.
- The cost function can probably be related to the structure of resources and processes in interesting ways — has information flow possibilities.

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