Trust and Reputation Model for Agent-Based Systems

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Dealing with the issue of uncertainty of agent interactions.
- Agents exist in open and dynamic environments.
- Their behaviour is difficult to predict.
Solution with Trust and Reputation

- **Trust**
  - Measure of the level of risk associated with cooperating with other agents.
  - Derived from direct interactions and reputation.

- **Reputation**
  - Built from information received by third-parties about an agent’s behaviour.
Figure: Agent interactions and terminology used
Proposed Model

- A trust and reputation model that allows agents to quickly adapt to their dynamic environment.
- Approach combines components from several existing models.
- Builds upon aspects of multi-dimensionality of trust and reputation, recency of information and dynamic selection of recommendation providers.
- Includes the use of both direct and indirect recommendations for witness reputation.
Marsh’s Formalism \(^1\)

- Formalism of trust from direct interactions, divided into 3 types:
  - Basic trust
  - General trust
  - Situational trust

- Our approach:
  - uses the 3 types of trust for direct interactions.
  - Witness reputation complements direct trust to achieve greater accuracy when predicting agent behaviour.

\(^1\)Marsh 1994
ReGreT

- ReGreT is a modular trust and reputation model with 3 dimensions of information:
  - Individual dimension
  - Social dimension
  - Ontological dimension

- Our approach:
  - uses the trust of witnesses and an estimation of the accuracy and relevance of their information
  - uses a weighted product model to combine reputation aspects

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\(^2\)Sabater 2002, 2003
FIRE

Modular approach that integrates 4 types of trust and reputation information sources:

- Interaction trust
- Role-based trust
- Witness reputation
- Certified reputation

Our approach:

- considers the interaction trust and witness reputation components.
- uses trust in multiple dimensions as a estimator for the provision of recommendations.

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3Huyhn 2006
Ntropi ⁴

- Trust and reputation model in which trust and the outcome of experiences are represented in levels.
  - Direct trust is used: basic and situational.
  - Models reputation.
  - Recommender trust is used to assess witness credibility.

- In our model:
  - Trust is stored as continuous values, while levels are only used to compare similar values.
  - We use direct trust and recommender trust in multiple dimensions.
  - Witnesses are selected according to accuracy and relevance of recommendations

⁴Abdul-Rahman 2000, 2005
MDT-R $^5$

- Mechanism of multi-dimensional trust and recommendations:
  - Agents model trustworthiness according to various criteria important to them, such as timeliness, cost.
  - Trust values are numerical but trust is stratified into levels for ease of comparison.
  - Sharing of information is done through interaction summaries of past interactions.

$^5$Griffiths 2006
Proposed Model Overview

- Our model is broadly based on MDT-R with extensions to include information on recency and the experience of witnesses when sharing interaction summaries.
- We also consider the relevance of recommendations to better select witnesses and give them appropriate weights when calculating reputation.
- We use indirect recommendations as an additional source of trust information to direct trust and direct recommendations.
Sources of Trust

- Direct trust from direct interactions.
- Witness reputation as recommendations from third parties.
- The 2 types of trust information are used in different situations; witness reputation being used especially when the evaluator has insufficient direct experience.
- Witness reputation is built from both direct and indirect recommendations from third parties.
Direct Trust: Multiple Dimensions

- The separation into several dimensions preserves information about specific service characteristics.
- Sharing of multi-dimensional trust information decreases subjectivity.
- Any number of dimensions can be used, for purposes of illustration, 4 dimensions are modelled: success ($T^s_{\alpha\beta}$), timeliness ($T^t_{\alpha\beta}$), cost ($T^c_{\alpha\beta}$), and quality ($T^q_{\alpha\beta}$).
Direct Trust: Situational and General

- Situational trust is a function of the history of interactions of evaluator $\alpha$ with target $\beta$:

$$ST_{\alpha\beta K}^d = \frac{I_{\alpha\beta K}^{d+} - I_{\alpha\beta K}^{d-}}{I_{\alpha\beta K}^{d+} + I_{\alpha\beta K}^{d-}}$$  \hspace{1cm} (1)$$

- General trust in a target applies regardless of the service provided:

$$GT_{\alpha\beta} = \sum_{k=1}^{allK} ST_{\alpha\beta K}^s$$ \hspace{1cm} \frac{allK}{allK}$$  \hspace{1cm} (2)$$
Direct Trust: Decay and Confidence

- Trust decay occurs when trust values become outdated due to lack of fresh interactions. Trust decays towards the initial trust value.
- Confidence refers to the number of interactions between the evaluator and the target, in each dimension.
Witness Reputation: Witness Selection

- Recommendations involve the selection of witnesses.
- Recommendation trust estimates the accuracy and relevance of the witness recommendation:
  - Accuracy measures similarity of experiences.
  - Relevance relates to the usefulness of the recommendation, based on recency, witness experience and trustworthiness of witness.
- Witnesses are selected from the evaluator’s most trusted interaction partners.
- The evaluator combines different recommendations by applying weights according to their relevance.
Recommendations: Evaluator’s View

- The evaluator does not distinguish between direct and indirect recommendations.
- Recommendation trust represents the trustworthiness of the witness to provide any type of recommendation.
- Future work will look into potential benefits of having different recommendation trust values for direct and indirect recommendations.
Example: Direct Recommendations

Figure: Interactions between the Evaluator and the Witness
Recommendations: Principal Recommender’s View

- An evaluator requests information about a target from the principal recommender.
- The principal recommender first considers its own direct interactions with the target.
- In cases of insufficient or no direct interactions, the principal recommender asks the opinion of its most trusted recommender.
- We use one level of indirection in this version of our model.
- Future work will look into how to apply an efficient way of obtaining indirect opinions along a recommendation chain.
The secondary recommender provides direct task interaction information to the principal recommender.

If it has had interactions about different task types than requested, it shares its recommendation about the target’s general trust.
Example: Indirect Recommendations

Figure: Interactions between the Evaluator, Principal and Secondary Witnesses
Witness Reputation: Calculation

The witness reputation $WR$ of target $\beta$’s task type $K$ in the dimension $d$ is a function of the opinions received from witnesses and their respective weights:

$$WR^d_{\alpha\beta K} = \sum_{i=\gamma}^{\epsilon} \left( \frac{l_{i\beta K}^{d+} - l_{i\beta K}^{d-}}{l_{i\beta K}^{d+} + l_{i\beta K}^{d-}} \right) \times \omega_{WRR_{i\beta}}$$  \hspace{1cm} (3)

$\omega_{WRR_{i\beta}}$ is the weight of the witness reputation relevance $WRR$ of witness $i$ in providing a recommendation for target $\beta$. 
Aggregation of Trust Sources

The evaluator $\alpha$ uses direct trust and witness reputation to assessing the trustworthiness of several potential providers for a task, and selects the best provider by comparing each provider's performance value:

$$PV(\beta) = \prod_{i=1}^{n} (f_{\beta_i})^{\mu_i}$$

(4)

where there are $n$ factors and $f_{\beta_i}$ is the value for agent $\beta$ in terms of the $i'$th factor and $\mu_i$ is the weighting given to the $i'$th factor in the selection of the agent’s preferences.
Conclusion and Future Work

- We have presented our trust and reputation model based on a number of trust sources: direct interactions, direct and indirect recommendations.
- Initial experiments on our model show that trust and trust with reputation for selecting providers gives mostly better results than using service characteristics only.
- Further experimentation on the added benefits of indirect recommendations for the assessment of trust.
- Future work will focus on how to balance the potentially conflicting features that an evaluator needs to consider.
- We will also look into how the decay function for trust relates to the interaction history size.
- Collusion among agents adds to the challenge of accurately predicting agent behaviour.