Rule-Based Trust Among Agents Using Defeasible Logic

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TALK OVERVIEW

- Introduction on Trust / Reputation Models
  - Centralized approaches
  - Distributed approaches
  - Hybrid approaches
- Rule-based Trust / Reputation Models
  - HARM
  - DISARM
- Summary / Conclusions

TRUST AND REPUTATION

- Agents are supposed to act in open and risky environments (e.g. Web) with limited or no human intervention
- Making the appropriate decision about who to trust in order to interact with is necessary but challenging
- Trust and reputation are key elements in the design and implementation of multi-agent systems
- Trust is expectation or belief that a party will act benignly and cooperatively with the trusting party
- Reputation is the opinion of the public towards an agent, based on past experiences of interacting with the agent
- Reputation is used to quantify trust

TRUST / REPUTATION MODELS

- Interaction trust: agent's own direct experience from past interactions (aka reliability)
  - Requires a long time to reach a satisfying estimation level (cold start)
- Witness reputation: reports of witnesses about an agent's behavior, provided by other agents
  - Does not guarantee reliable estimation
    - Are self-interested agents willing to share information?
    - How much can you trust the informer?

IMPLEMENTING TRUST / REPUTATION MODELS

- Centralized approach:
  - One or more centralized trust authorities keep agent interaction references (ratings) and give trust estimations
    - Convenient for witness reputation models (e.g. eBay, SPORAS, etc.)
  - \+ Simpler to implement; better and faster trust estimations
  - \- Less reliable; Unrealistic: hard to enforce central controlling authorities in open environments
- Decentralized (distributed) approach:
  - Each agent keeps its own interaction references with other agents and must estimate on its own the trust upon another agent
    - Convenient for interaction trust models
  - \+ Robustness: no single point of failure; more realistic
  - \- Need more complex interaction protocols

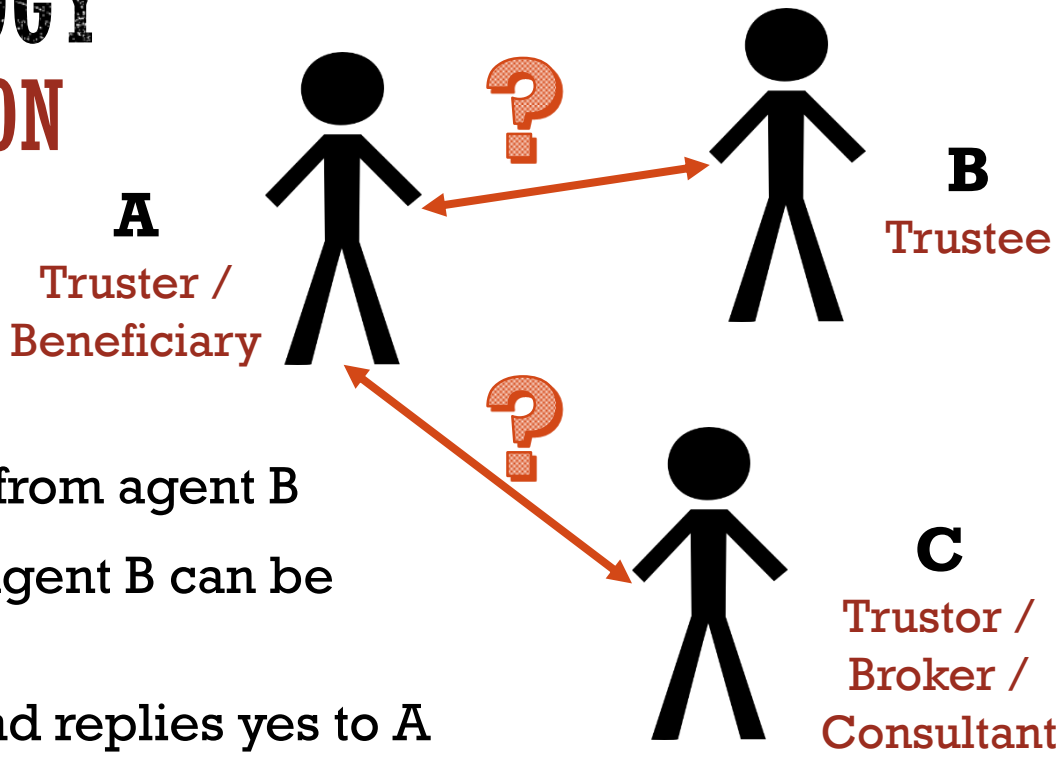
OTHER TRUST / REPUTATION MODELS

- Hybrid models: Combination of Interaction Trust and Witness Reputation
  - Regret / Social Regret, FIRE, RRAF / TRR, CRM
  - T-REX / HARM / DISARM
- Certified reputation: third-party references provided by the agent itself
  - Distributed approach for witness reputation

Centralized / Distributed

Underlined -> rule-based

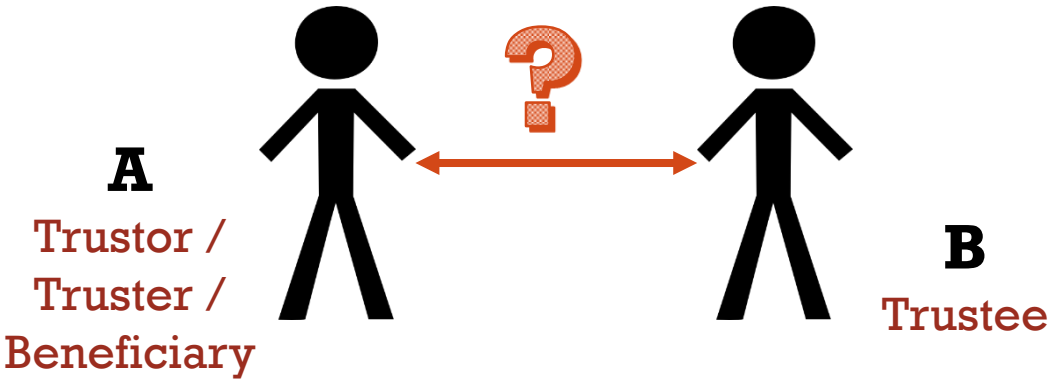
SOME TERMINOLOGY
WITNESS REPUTATION



- Agent A wants a service from agent B
- Agent A asks agent C if agent B can be trusted
- Agent C trusts agent B and replies yes to A
- Agent A now trusts B and asks B to perform the service on A's behalf
- A = truster / beneficiary,
  C = trustor / broker / consultant,
  B = trustee

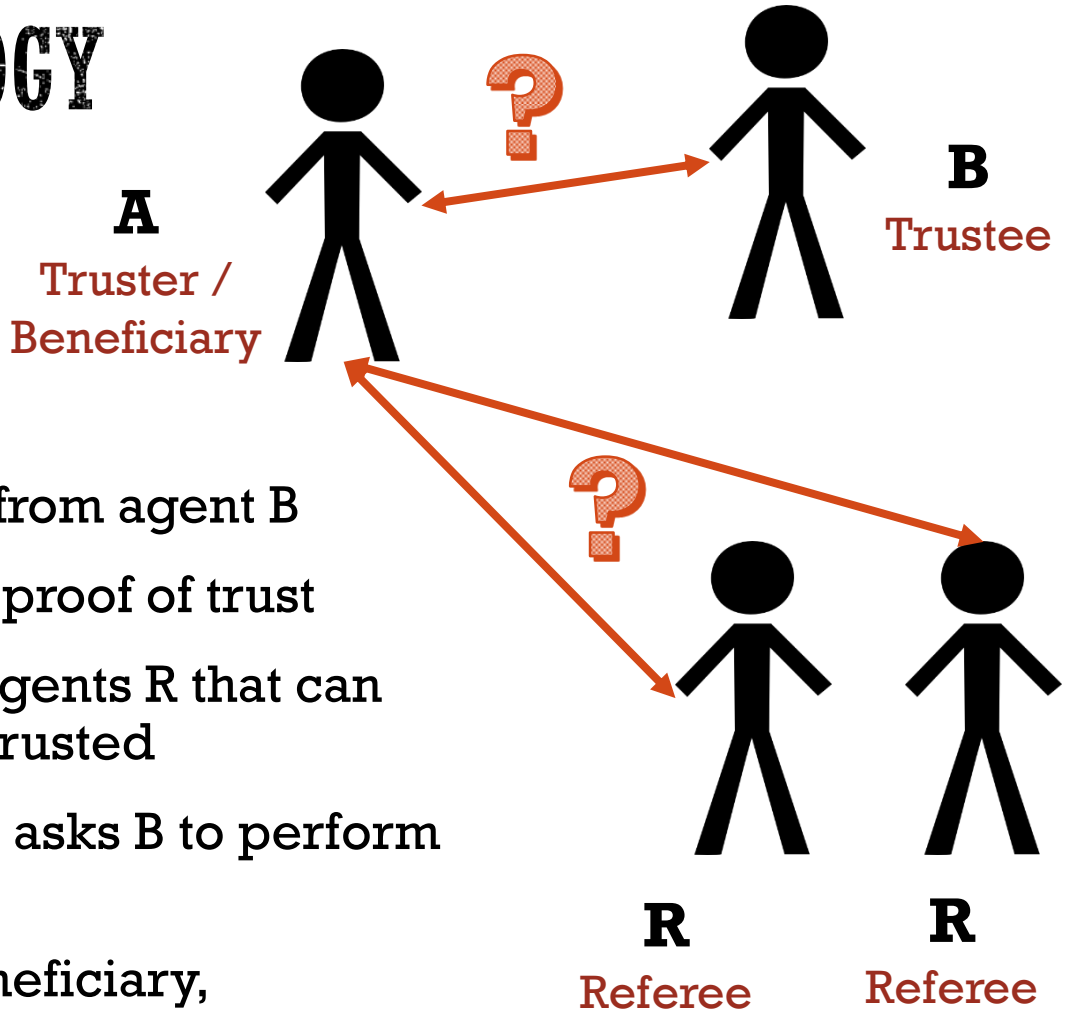
SOME TERMINOLOGY

INTERACTION TRUST



- Agent A wants a service from agent B
- Agent A judges if B is to be trusted from personal experience
- Agent A trusts B and asks B to perform the service on A's behalf
- A = trustor / truster / beneficiary,
  B = trustee

SOME TERMINOLOGY
REFERENCES



- Agent A wants a service from agent B
- Agent A asks agent B for proof of trust
- Agent B provides some agents R that can guarantee that B can be trusted
- Agent A now trusts B and asks B to perform the service on A's behalf
- A = trustor / truster / beneficiary,
  B = trustee,
  R = referee

RULE-BASED REPUTATION MODELS

RULE-BASED TRUST / REPUTATION MODELS

- Centralized
  - HARM
    - Hybrid
    - Knowledge-based
    - Temporal Defeasible Logic
- Distributed
  - DISARM
    - Hybrid
    - Knowledge-based, Defeasible Logic
    - Social relationships

HARM

Kravari, K., & Bassiliades, N. (2012). HARM: A Hybrid Rule-based Agent Reputation Model Based on Temporal Defeasible Logic. 6th International Symposium on Rules: Research Based and Industry Focused (RuleML-2012). Springer, LNCS 7438: 193-207.

HARM OVERVIEW

- Centralized hybrid reputation model
  - Combine Interaction Trust and Witness Reputation
- Rule-based approach
  - Temporal defeasible logic
  - Non-monotonic reasoning
- Ratings have a time offset
  - Indicates when ratings become active to be considered for trust assessment
- Intuitive method for assessing trust
  - Related to traditional human reasoning

(TEMPORAL) DEFEASIBLE LOGIC

- Temporal defeasible logic (TDL) is an extension of defeasible logic (DL).
- DL is a kind of non-monotonic reasoning
- Why defeasible logic?
  - Rule-based, deterministic (without disjunction)
  - Enhanced representational capabilities
  - Classical negation used in rule heads and bodies
  - Negation-as-failure can be emulated
  - Rules may support conflicting conclusions
  - Skeptical: conflicting rules do not fire
  - Priorities on rules resolve conflicts among rules
  - Low computational complexity

DEFEASIBLE LOGIC

- Facts: e.g. student(Sofia)
- Strict Rules: e.g. student(X) $\rightarrow$ person(X)
- Defeasible Rules: e.g. r: person(X) $\Rightarrow$ works(X)

  r': student(X) $\Rightarrow \neg$works(X)
- Priority Relation between rules, e.g. r' > r
- Proof theory example:
  - A literal q is defeasibly provable if:
    - supported by a rule whose premises are all defeasibly provable AND
    - $\neg$q is not definitely provable AND
    - each attacking rule is non-applicable or defeated by a superior counter-attacking rule

TEMPORAL DEFEASIBLE LOGIC

- Temporal literals:
  - Expiring temporal literals l:t
    - Literal l is valid for t time instances
  - Persistent temporal literals l@t
    - Literal l is active after t time instances have passed and is valid thereafter
- Temporal rules: $a_1:t_1 \ldots a_n:t_n \Rightarrow^d b:t_b$
  - d is the delay between the cause and the effect
- Example:

(r1) => a@1

(r2) a@1=>^{7} b:3

Literal a is created due to r1.

It becomes active at time offset 1.

It causes the head of r2 to be fired at time 8.

The result b lasts only until time 10.

Thereafter, only the fact a remains.

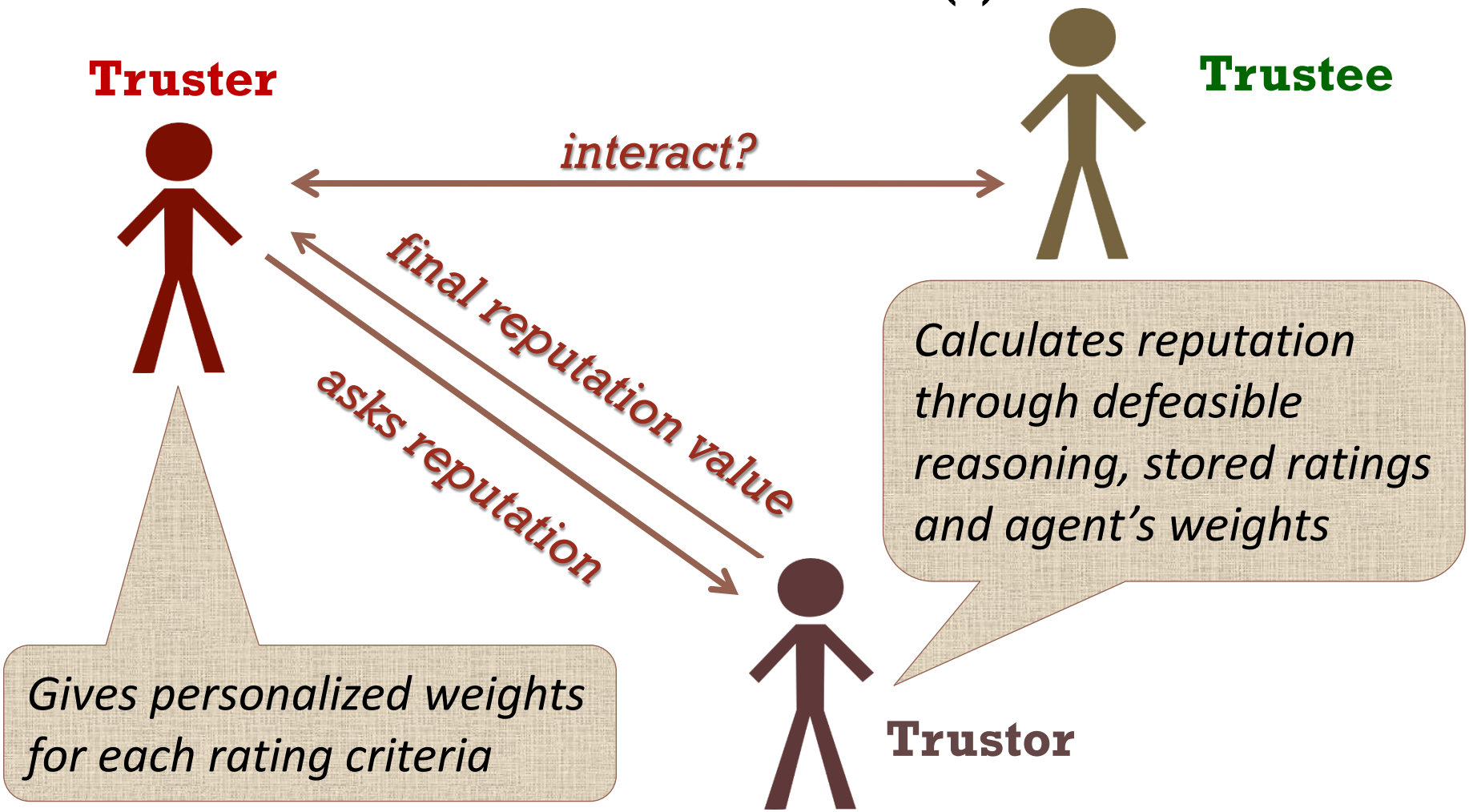
HARM – AGENT EVALUATED ABILITIES

- Validity
  - An agent is valid if it is both sincere and credible
    - Sincere: believes what it says
    - Credible: what it believes is true in the world
- Completeness
  - An agent is complete if it is both cooperative and vigilant
    - Cooperative: says what it believes
    - Vigilant: believes what is true in the world
- Correctness
  - An agent is correct if its provided service is correct with respect to a specification
- Response time
  - Time that an agent needs to complete the transaction

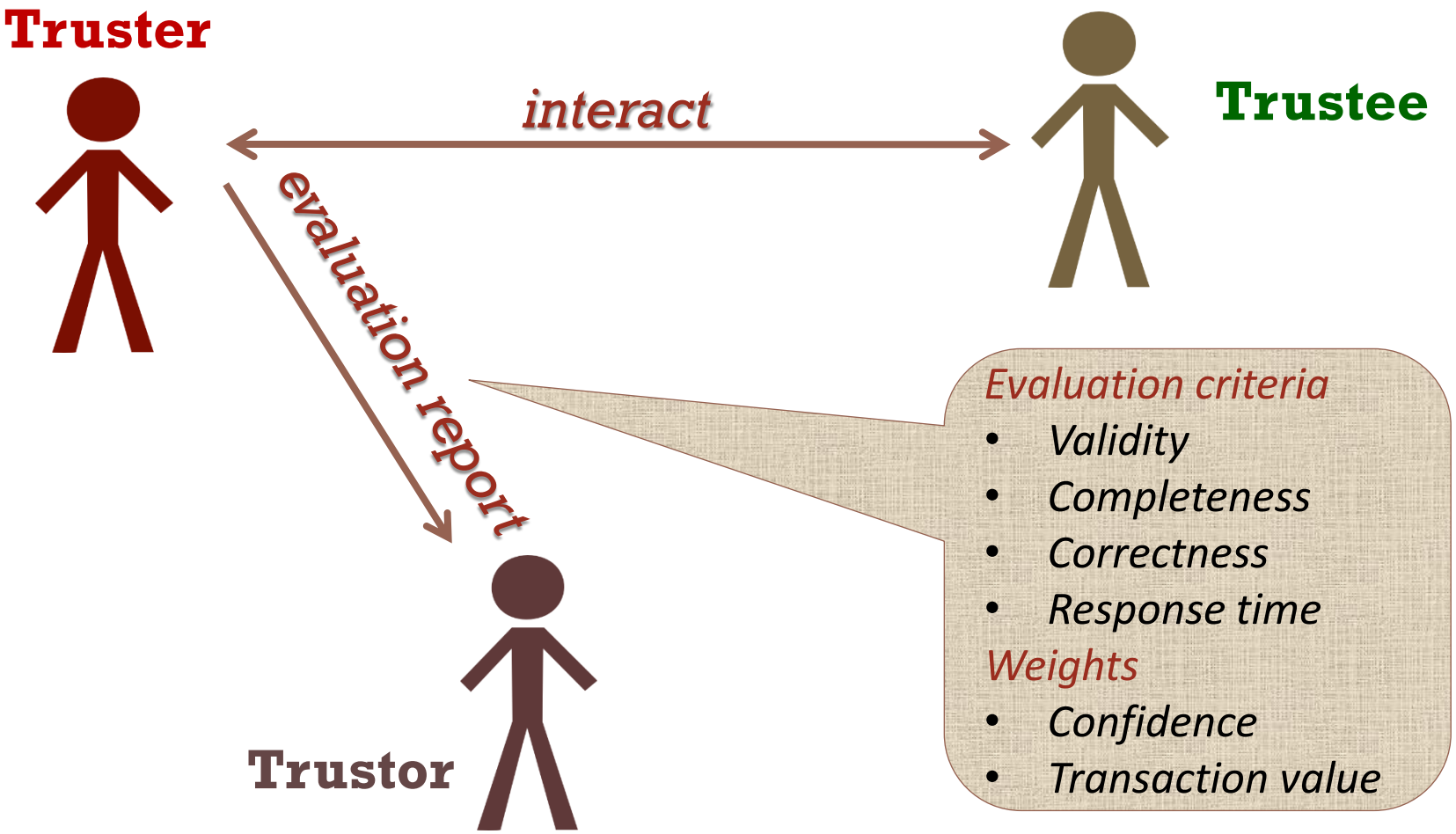
HARM INTERACTION MODEL

- Central ratings repository: Trustor
  - A special agent responsible for collecting, storing, retrieving ratings and calculating trust values through defeasible reasoning
  - Considered certified/reliable
- Interacting agents
  - Truster / Beneficiary: an agent that wants to interact with another agent that offers a service
  - Trustee: the agent that offers the service
- Role of Trustor
  - *Before* the interaction, Truster asks from Trustor calculation of Trustees trust value
  - *After* the interaction, Truster submits rating for Trustee's performance to Trustor

HARM RATING MECHANISM (I)



HARM RATING MECHANISM (II)



HARM - RATINGS

- Agent A establishes interaction with agent B:
  - (A) Truster is the evaluating agent
  - (B) Trustee is the evaluated agent
- Truster's rating value has 8 coefficients:
  - 2 IDs: Truster, Trustee
  - 4 abilities: Validity, Completeness, Correctness, Response time
  - 2 weights (how much attention agent should pay on each rating?):
    - Confidence: how confident the agent is for the rating
      - Ratings of confident trusters are more likely to be right
    - Transaction value: how important the transaction was for the agent
      - Trusters are more likely to report truthful ratings on important transactions
  - Example (defeasible RuleML / d-POSL syntax):

```
rating(id→1,truster→A,trustee→B,validity→5,completeness→6,
       correctness→6,resp_time→8,confidence→0.8,transaction_val→0.9).
```

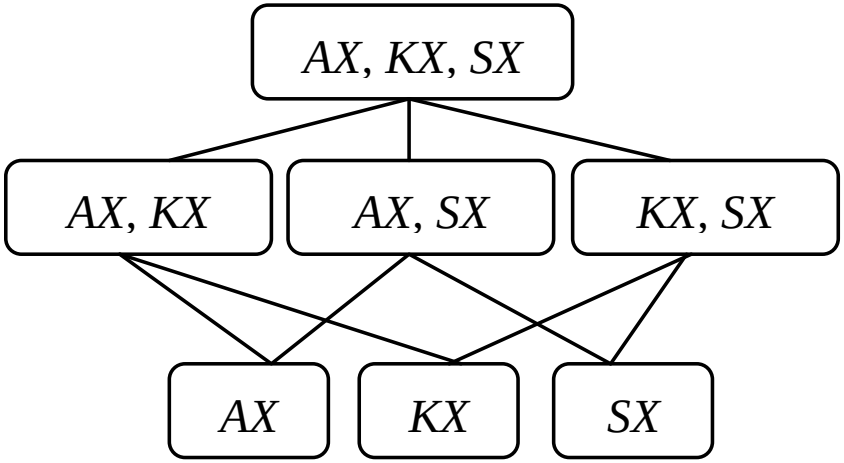
HARM – EXPERIENCE TYPES

- Direct Experience (PR_{AX})
- Indirect Experience
  - reports provided by strangers (SR_{AX})
  - reports provided by known agents (e.g. friends) due to previous interactions (KR_{AX})
- Final reputation value
  - of an agent X, required by an agent A

$$R_{AX} = \{PR_{AX}, KR_{AX}, SR_{AX}\}$$

HARM – EXPERIENCE TYPES

- One or more rating categories may be missing
  - E.g. a newcomer has no personal experience
- A user is much more likely to believe statements from a trusted acquaintance than from a stranger.
  - Personal opinion (AX) is more valuable than strangers' opinion (SX) and known partners (KX).
- Superiority relationships among rating categories



HARM – FINAL REPUTATION VALUE

- R_{AX} is a function that combines each available category
  - personal opinion (AX)
  - strangers' opinion (SX)
  - previously trusted partners (KX)

$$R_{AX} = \Im\left(PR_{AX}, KR_{AX}, SR_{AX} \right)$$

- HARM allows agents to define weights of ratings' coefficients
  - Personal preferences

$$R_{AX} = \Im\left[\frac{AVG\left(w_i \times \log\left(pr_{AX}^{coefficient} \right) \right)}{\sum_{i=1}^{4} w_i}, \frac{AVG\left(w_i \times \log\left(kr_{AX}^{coefficient} \right) \right)}{\sum_{i=1}^{4} w_i}, \frac{AVG\left(w_i \times \log\left(sr_{AX}^{coefficient} \right) \right)}{\sum_{i=1}^{4} w_i} \right],$$

$$coefficient = \{validity, completeness, correctness, response\_time\}$$

HARM- WHICH RATINGS "COUNT"?

r_1: count_rating(rating→?idx, truster→?a, trustee→ ?x) :=

confidence_threshold(?conf), transaction_value_threshold(?tran),

rating(id→?idx, confidence→?confx, transaction_val→?tranx),

?confx >= ?conf, ?tranx >= ?tran.

r_2: count_rating(…) :=

…

?confx >= ?conf.

r_3: count_rating(…) :=

…

?tranx >= ?tran.

$r_1 > r_2 > r_3$

- *if both confidence and transaction importance are high, then rating will be used for estimation*
- *if transaction value is lower than the threshold, but confidence is high, then use rating*
- *if there are only ratings with high transaction value, then they should be used*
- *In any other case, omit the rating*

HARM - CONFLICTING LITERALS

- All the previous rules conclude positive literals.
- These literals are conflicting each other, for the same pair of agents (truster and trustee)
  - We want in the presence e.g. of personal experience to omit strangers' ratings.
  - That's why there is also a superiority relationship between the rules.
- The conflict set is formally determined as follows:

$$C[\text{count\_rating}(\text{truster}\rightarrow ?a, \text{trustee}\rightarrow ?x)] =$$

$$\{ \neg\ \text{count\_rating}(\text{truster}\rightarrow ?a, \text{trustee}\rightarrow ?x) \} \cup$$

$$\{ \text{count\_rating}(\text{truster}\rightarrow ?a1, \text{trustee}\rightarrow ?x1) \mid ?a \neq ?a1 \wedge ?x \neq ?x1 \}$$

HARM - DETERMINING EXPERIENCE TYPES

known(agent1→?a, agent2→?y) :-

count_rating(rating → ?id, truster→?a, trustee→?y).

Which agents are considered as known?

count_pr(agent→?a, truster→?a, trustee→?x, rating→?id) :-

count_rating(rating → ?id, truster→? a, trustee→ ?x).

count_kr(agent→?a, truster→?k, trustee→?x, rating →?id) :-

known($agent_1$→?a, $agent_2$→?k),

count_rating(rating→?id, truster→?k, trustee→ ?x).

count_sr(agent→?a, truster→?s, trustee→?x, rating→?id) :-

count_rating(rating → ?id, truster →?s, trustee→ ?x),

not(known($agent_1$→?a, $agent_2$→?s)).

Rating categories

HARM – SELECTING EXPERIENCES

- Final step is to decide whose experience will "count": direct, indirect (witness), or both.
- The decision for R_{AX} is based on a relationship theory
- e.g. Theory #1: All categories count equally.

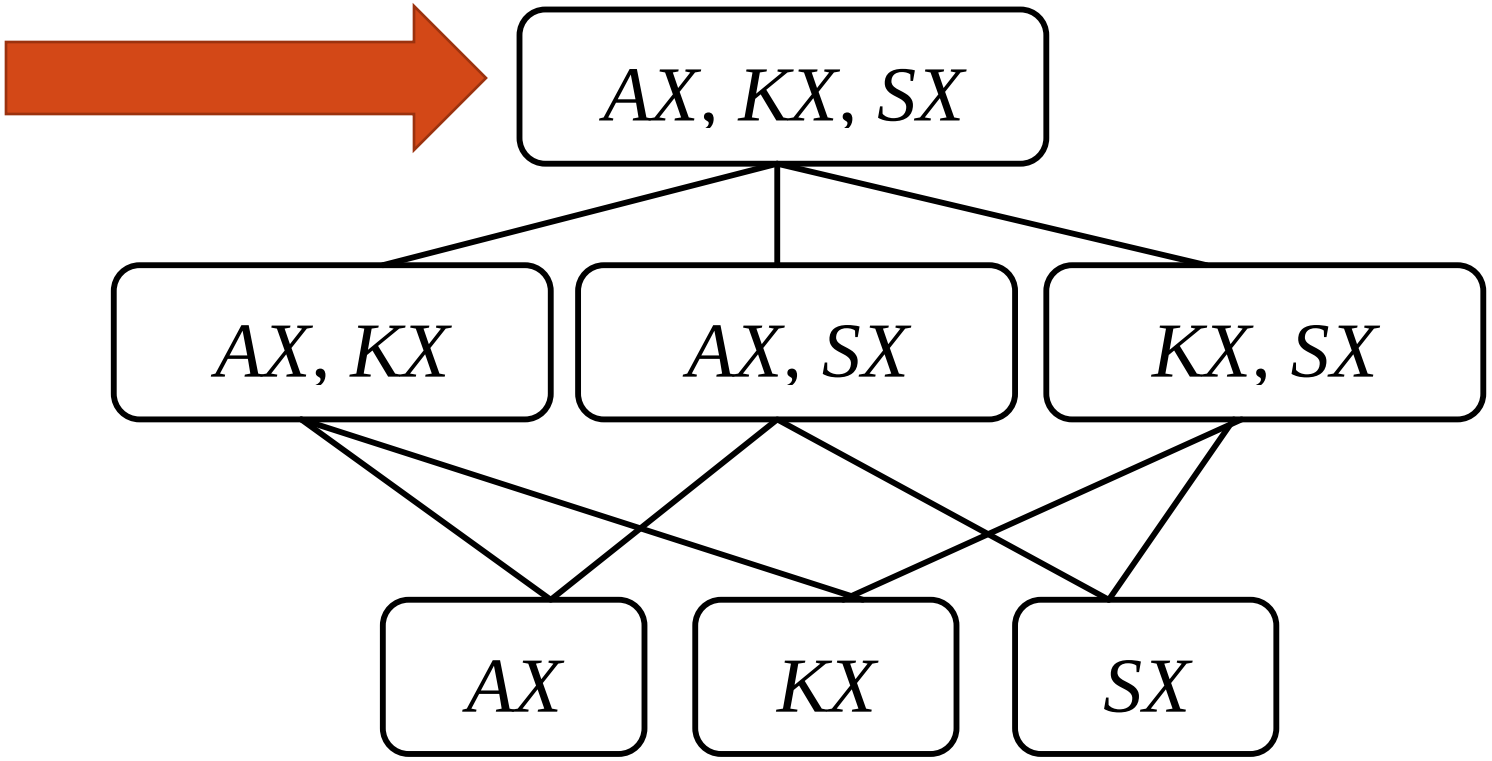
r_8: participate(agent→?a, trustee→?x, rating→?id_rating$_{AX}$) :=
count_pr(agent→?a, trustee→?x, rating→ ?id_rating$_{AX}$).

r_9: participate(agent→?a, trustee→?x, rating→?id_rating$_{KX}$) :=
count_kr(agent→?a, trustee→?x, rating→ ?id_rating$_{KX}$).

r_{10}: participate(agent→?a, trustee→?x, rating→?id_rating$_{SX}$) :=
count_sr(agent→?a, trustee→?x, rating→ ?id_rating$_{SX}$).

SELECTING EXPERIENCES

ALL CATEGORIES COUNT EQUALLY



SELECTING EXPERIENCES - THEORY #2
PERSONAL EXPERIENCE IS PREFERRED TO FRIENDS' OPINION TO STRANGERS' OPINION

r_8: participate(agent→?a, trustee→?x, rating→?id_rating$_{AX}$) :=
count_pr(agent→?a, trustee→?x, rating→ ?id_rating$_{AX}$).

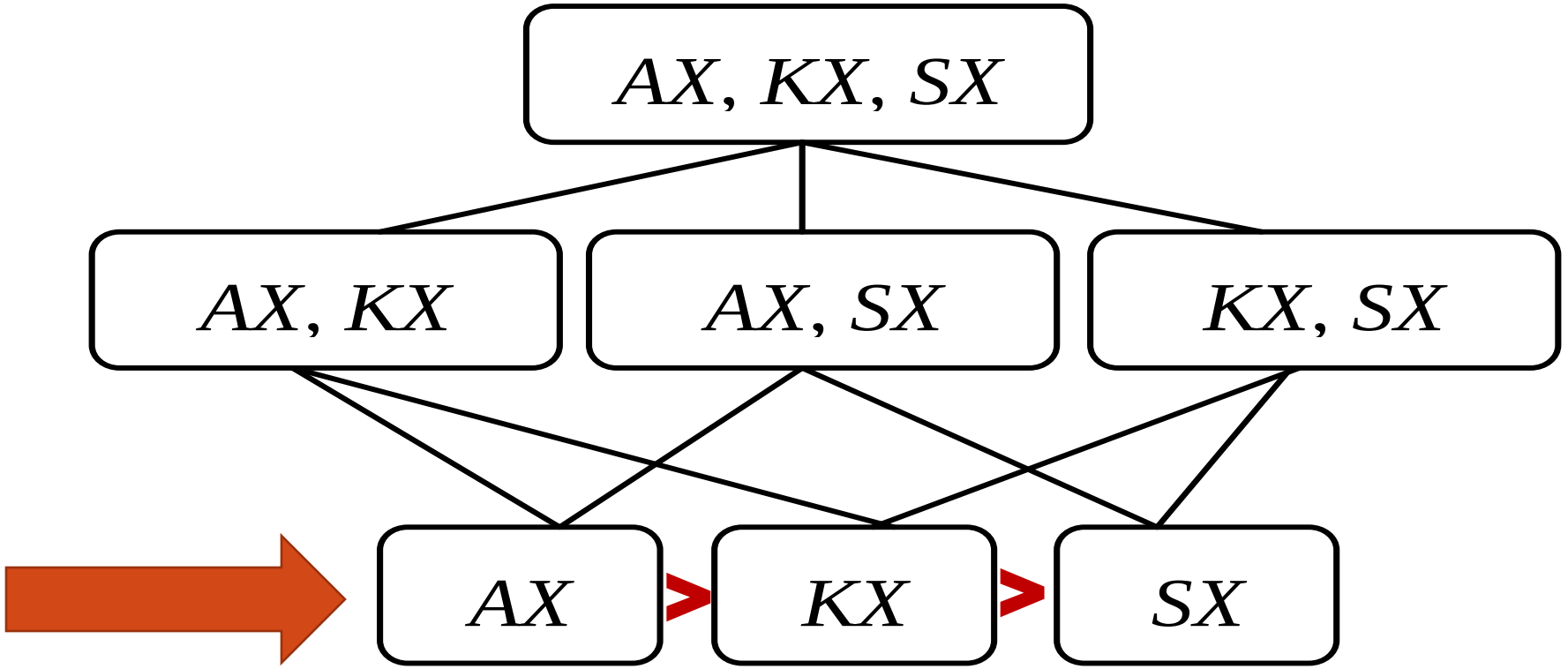
r_9: participate(agent→?a, trustee→?x, rating→?id_rating$_{KX}$) :=
count_kr(agent→?a, trustee→?x, rating→ ?id_rating$_{KX}$).

r_{10}: participate(agent→?a, trustee→?x, rating→?id_rating$_{SX}$) :=
count_sr(agent→?a, trustee→?x, rating→ ?id_rating$_{SX}$).

$r_8 > r_9 > r_{10}$

SELECTING EXPERIENCES

PERSONAL EXPERIENCE IS PREFERRED TO FRIENDS' OPINION TO STRANGERS' OPINION



SELECTING EXPERIENCES - THEORY #3
PERSONAL EXPERIENCE AND FRIENDS' OPINION IS PREFERRED TO STRANGERS' OPINION

r_8: participate(agent→?a, trustee→?x, rating→?id_rating$_{AX}$) :=
count_pr(agent→?a, trustee→?x, rating→ ?id_rating$_{AX}$).

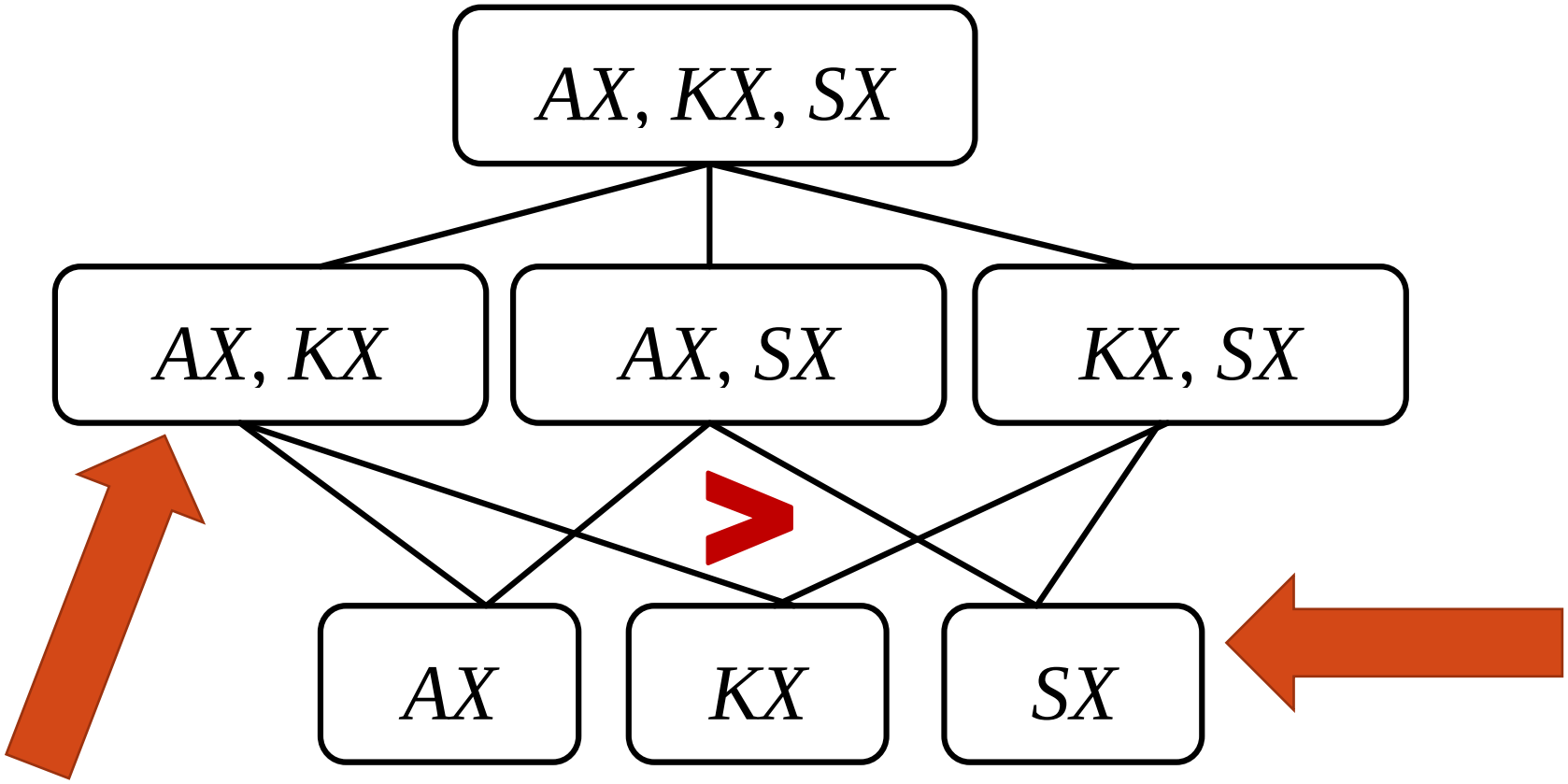
r_9: participate(agent→?a, trustee→?x, rating→?id_rating$_{KX}$) :=
count_kr(agent→?a, trustee→?x, rating→ ?id_rating$_{KX}$).

r_{10}: participate(agent→?a, trustee→?x, rating→?id_rating$_{SX}$) :=
count_sr(agent→?a, trustee→?x, rating→ ?id_rating$_{SX}$).

$r_8 > r_{10}, r_9 > r_{10}$

SELECTING EXPERIENCES

PERSONAL EXPERIENCE AND FRIENDS' OPINION IS PREFERRED TO STRANGERS' OPINION



HARM - TEMPORAL DEFEASIBLE LOGIC EXTENSION

- Agents may change their behavior / objectives at any time
  - Evolution of trust over time should be taken into account
  - Only the latest ratings participate in the reputation estimation
- In the temporal extension of HARM:
  - each rating is a persistent temporal literal of TDL
  - each rule conclusion is an expiring temporal literal of TDL
- Truster's rating is active after time_offset time instances have passed and is valid thereafter

$$\text{rating}(\text{id}\rightarrow \text{val}_1, \text{truster}\rightarrow \text{val}_2, \text{trustee}\rightarrow \text{val}_3, \text{validity}\rightarrow \text{val}_4,$$
$$\text{completeness}\rightarrow \text{val}_5, \text{correctness}\rightarrow \text{val}_6, \text{resp\_time}\rightarrow \text{val}_7,$$
$$\text{confidence}\rightarrow \text{val}_8, \text{transaction\_val}\rightarrow \text{value}_9)@\text{time\_offset}.$$

HARM - TEMPORAL DEFEASIBLE LOGIC EXTENSION

- Rules are modified accordingly:
  - each rating is active after t time instances have passed
  - each conclusion has a duration that it holds
  - each rule has a delay between the cause and the effect

count_rating(rating→?idx, truster→?a, trustee→?x):duration :=^{delay}

confidence_threshold(?conf),

transaction_value_threshold(?tran),

rating(id→?idx, confidence→?conf$_x$,transaction_value→?tran$_x$)@t,

?conf$_x$ >= ?conf, ?tran$_x$ >= ?tran.

DISARM

K. Kravari, N. Bassiliades, "DISARM: A Social Distributed Agent Reputation Model based on Defeasible Logic", Journal of Systems and Software, Vol. 117, pp. 130–152, July 2016

DISARM OVERVIEW

- Distributed extension of HARM
- Distributed hybrid reputation model
  - Combines Interaction Trust and Witness Reputation
  - Ratings are located through agent's social relationships
- Rule-based approach
  - Defeasible logic
  - Non-monotonic reasoning
- Time is directly used in:
  - Decision making rules about recency of ratings
  - Calculation of reputation estimation (similar to T-REX)
- Intuitive method for assessing trust
  - Related to traditional human reasoning

DISARM - SOCIAL RELATIONSHIPS

- Social relationships of trust among agents
  - If an agent is satisfied with a partner it is more likely to interact again in the future
  - If dissatisfied it will not interact again
- Each agent maintains 2 relationship lists:
  - White-list: Trusted agents
  - Black-list: Non-trusted agents
  - All other agents are indifferent (neutral zone)
- Each agent decides which agents are added / removed from each list, using rules
- Personal social network

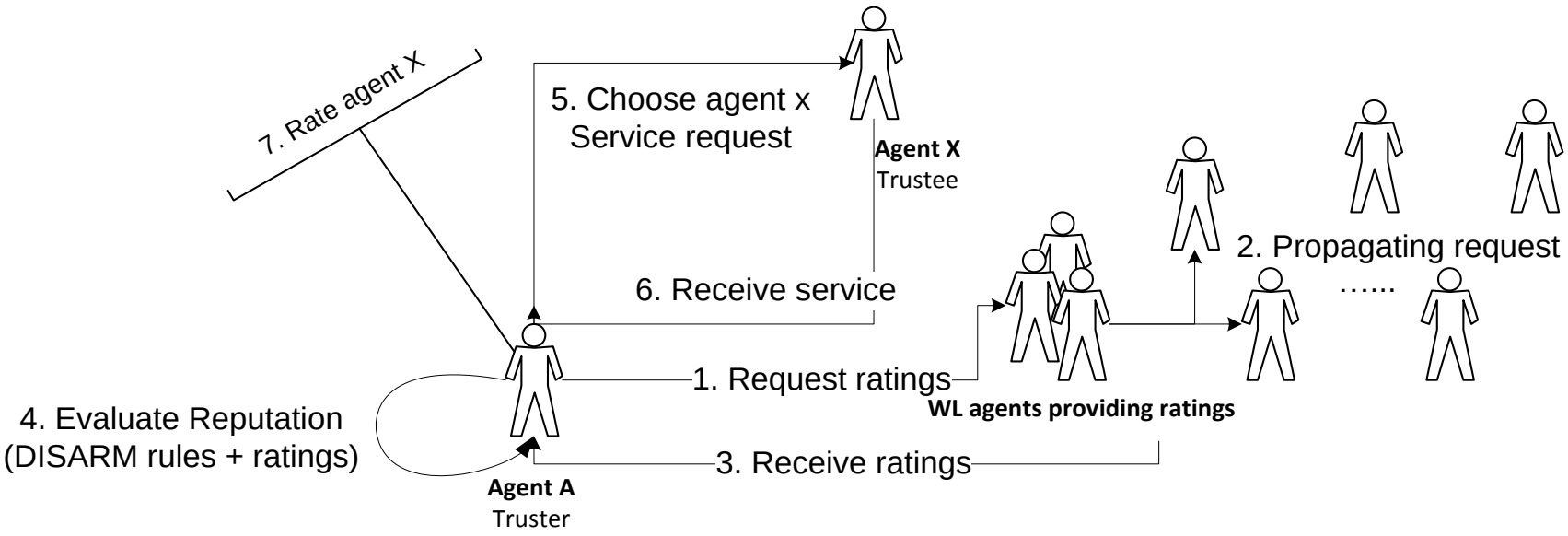
DISARM - RATINGS

- Truster's rating value has 11 coefficients:
  - 2 IDs: Truster, Trustee
  - 4 abilities: Validity, Completeness, Correctness, Response time
  - 2 weights: Confidence, Transaction value
  - Timestamp
  - Cooperation: willingness to do what is asked for
    - Important in distributed social environments
  - Outcome feeling: (dis)satisfaction for the transaction outcome
    - Degree of request fulfillment
  - Example (defeasible RuleML / d-POSL syntax):

3 more than HARM

rating (id→1, truster→A, trustee→X, t→140630105632, resp_time→9, validity→7, completeness→6, correctness→6, cooperation→8, outcome_feeling→7, confidence→0.9, transaction_val→0.8)

DISARM MODEL



DISARM - BEHAVIOR CHARACTERIZATION

good_behavior(time → ?t, truster→ ?a, trustee→ ?x, reason → all) :-

resp_time_thrshld(?resp), valid_thrshld(?val), …, trans_val_thrshld(?trval),

rating(id→?id_x, time → ?t, truster→ ?a, trustee→ ?x, resp_time→?$resp_x$,

validity→?val_x, transaction_val→?$trval_x$, completeness→?com_x,

correctness→?cor_x, cooperation→?$coop_x$, outcome_feeling→?$outf_x$),

?$resp_x$<?resp, ?val_x>?val, ?com_x>?com, ?cor_x>?cor, ?$coop_x$>?coop, ?$outf_x$>?outf.

bad_behavior(time → ?t, truster→ ?a, trustee→ ?x, reason → response_time) :-

rating(id→?idx, time → ?t, truster→ ?a, trustee→ ?x, resp_time→?$resp_x$),

resp_time_thrshld(?resp), ?$resp_x$ >?resp.

- Any combination of parameters can be used with any defeasible theory.

DISARM - DECIDING WHO TO TRUST

- Has been good twice for the same reason

add_whitelist(trustee→ ?x, time → ?t2) :=

good_behavior(time→?t1, truster→?self, trustee→?x, reason→?r),

good_behavior(time→?t2, truster→?self, trustee→?x, reason→?r),

?t2 > ?t1.

- Has been bad thrice for the same reason

add_blacklist(trustee→ ?x, time → ?t3) :=

bad_behavior(time→?t1, truster→?self, trustee→?x, reason→?r),

bad_behavior(time→?t2, truster→?self, trustee→?x, reason→?r),

bad_behavior(time→?t3, truster→?self, trustee→?x, reason→?r),

?t2 > ?t1, ?t3 > ?t2.

DISARM - MAINTAINING RELATIONSHIP LISTS

Add to the blacklist

blacklist(trustee→ ?x, time → ?t) :=

¬whitelist(trustee→ ?x, time → ?t1),

add_blacklist(trustee→ ?x, time → ?t2), ?t2 > ?t1.

Remove from the blacklist

¬blacklist(trustee→ ?x, time → ?t2) :=

blacklist(trustee→ ?x, time → ?t1),

add_whitelist(trustee→ ?x, time → ?t2),

?t2 > ?t1.

Add to the whitelist

whitelist(trustee→ ?x, time → ?t) :=

¬blacklist(trustee→ ?x, time → ?t1),

add_whitelist(trustee→ ?x, time → ?t2), ?t2 > ?t1.

...

DISARM - LOCATING RATINGS

- Ask for ratings about an agent sending request messages
- To whom and how?
  - ~~To everybody~~
  - To direct "neighbors" of the agent's "social network"
  - To indirect "neighbors" of the "social network" though message propagation for a predefined number of hops (Time-to-Live - P2P)
- "Neighbors" are the agents in the whitelist
- Original request:

send_message(sender→?self, receiver→*?r*,

msg →*request_reputation*(*about*→*?x*,*ttl*→*?t*)) :=

ttl_limit(?t), whitelist(?r), locate_ratings(*about*→*?x*).

DISARM - HANDLING RATINGS REQUEST

- Upon receiving request, return rating to the sender

send_message(sender→?self, receiver→?s,
msg →rating(id→ id_x, truster→ ?self, trustee→ ?x, …)) :=

receive_message(sender→?s, receiver→?self,
msg →request_rating(about→?x)),

rating(id→?id_x, truster→ ?self, trustee→ ?x, …).

- If time-to-live has not expired propagate request to all friends

send_message(sender→?s, receiver→?r,
msg →request_reputation(about→?x, ttl→?t1)):=

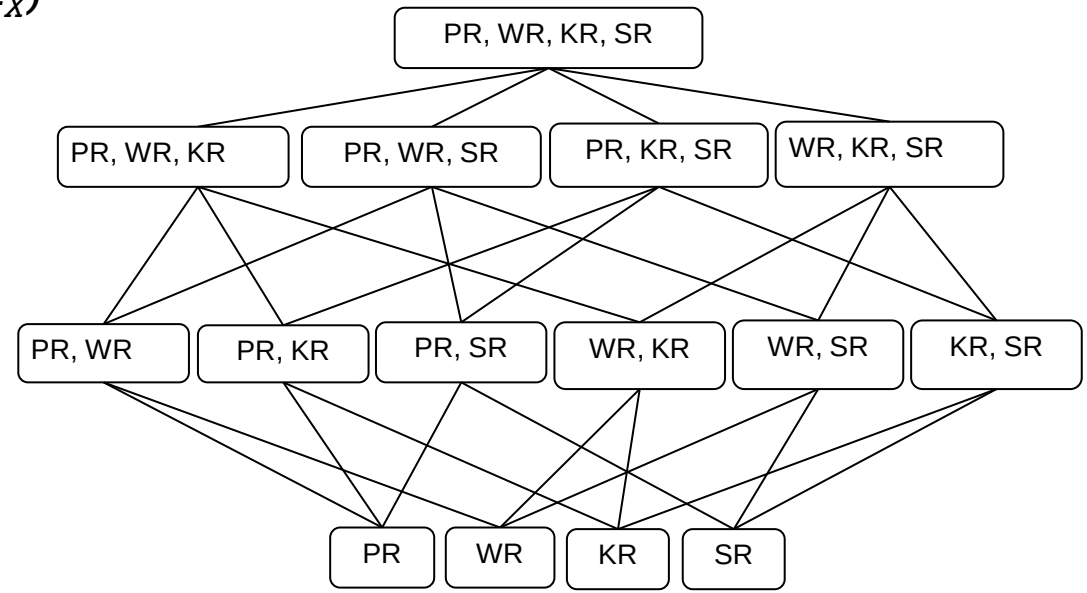
receive_message(sender→?s, receiver→?self,
msg →request_rating(about→?x,ttl→?t)),

?t >0, WL(?r), ?t1 is ?t - 1.

DISARM - RATING CATEGORIES

- Direct Experience (PR_X)
- Indirect Experience (reports provided by other agents):
  - "Friends" (WR_X) – agents in the whitelist
  - Known agents from previous interactions (KR_X)
  - Complete strangers (SR_X)
- Final reputation value
  - $R_X = \{PR_X, WR_X, KR_X, SR_X\}$

New compared to HARM



DISARM - SELECTING RATINGS

- According to user's preferences

eligible_rating(rating→?id_x,truster→?a,trustee→?x,reason→cnf_imp) :=

conf_thrshld(?conf), trans_val_thrshld(?tr),

rating(id→?id_x,truster→?a,trustee→?x,conf→?$conf_x$,trans_val→?tr_x),

?$conf_x$ >= ?conf, ?tr_x >= ?tr.

- According to temporal restrictions

count_rating(rating→?id_x, truster→?a, trustee→?x) :=

time_from_thrshld(?ftime), time_to_thrshld(?ttime),

rating(id→?id_x, t→?t_x, truster→?a, trustee→ ?x),

?ftime <=?t_x <= ?ttime.

DISARM – DETERMINING RATING CATEGORIES

count_wr (rating →?id_x, trustee→?x) :-

eligible_rating(rating → ?id_x, cat→?c, truster→?k, trustee→ ?x),

count_rating(rating→?id_x, truster→?k, trustee→ ?x),

known(agent→?k),

whitelist (trustee →?k).

count_kr (rating →?id_x, trustee→?x) :-

eligible_rating(rating→?id_x, cat→?c, truster→?k, trustee→ ?x),

count_rating(rating→?id_x, truster→?k, trustee→ ?x),

known(agent→?k),

not(whitelist(trustee →?k)),

not(blacklist (trustee →?k)).

DISARM - FACING DISHONESTY

- When ratings provided by an agent are outside the standard deviation of all received ratings, the agent might behave dishonestly

bad_assessment (time → ?t, truster→ ?y, trustee→ ?x) :-
standard_deviation_value(?t,?y,?x,?stdev$_y$),
standard_deviation_value (?t,_,?x,?stdev),
?stdev$_y$ > ?stdev.

- When two bad assessments for the same agent were given in a certain time window, trust is lost

remove_whitelist(agent→ ?y, time → ?t2) :=
whitelist(truster→ ?y),
time_window(?wtime),
bad_assessment(time → ?t1, truster→ ?y, trustee→ ?x),
bad_assessment(time → ?t2, truster→ ?y, trustee→ ?x),
?t2 <= ?t1 + ?wtime.

CONCLUDING…

TRUST / REPUTATION MODELS FOR MULTIAGENT SYSTEMS

- Interaction Trust (personal experience) vs. Witness Reputation (Experience of others)
  - Hybrid models
- Centralized (easy to locate ratings) vs. Distributed (more robust)
- Rule-based trust / reputation models
  - HARM (centralized, hybrid, knowledge-based, temporal defeasible logic)
  - DISARM (distributed, hybrid, knowledge-based, defeasible logic, time decay, social relationships, manages dishonesty)

CONCLUSIONS

- Centralized models
  - + Achieve higher performance because they have access to more information
  - + Simple interaction protocols, easy to locate ratings
  - + Both interaction trust and witness reputation can be easily implemented
  - - Single-point-of-failure
  - - Cannot scale well (bottleneck, storage & computational complexity)
  - - Central authority hard to enforce in open multiagent systems
- Distributed models
  - - Less accurate trust predictions, due to limited information
  - - Complex interaction protocols, difficult to locate ratings
  - - More appropriate for interaction trust
  - + Robust – no single-point-of-failure
  - + Can scale well (no bottlenecks, less complexity)
  - + More realistic in open multiagent systems

CONCLUSIONS

- Interaction trust
  - + More trustful
  - - Requires a long time to reach a satisfying estimation level
- Witness reputation
  - - Does not guarantee reliable estimation
  - + Estimation is available from the beginning of entering a community
- Hybrid models
  - + Combine interaction trust and witness reputation
  - - Combined trust metrics are usually only based on arbitrary / experimentally-optimized weights

CONCLUSIONS – PRESENTED MODELS

- Centralized models
  - Cannot scale well (bottleneck, storage & computational complexity)
  + HARM reduces computational complexity by reducing considered ratings, through rating selection based on user's domain-specific knowledge
- Distributed models
  - Less accurate trust predictions, due to limited information
  - Complex interaction protocols, difficult to locate ratings
  + DISARM finds ratings through agent social relationships and increases accuracy by using only known-to-be-trustful agents
- Hybrid models
  - Combined trust metrics are usually only based on arbitrary weights
  + HARM & DISARM employ a knowledge-based highly-customizable (both to user prefs & time) approach, using non-monotonic defeasible reasoning

ACKNOWLEDGMENTS

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  - Former PhD student, currently postdoctorate affiliate
- Other contributors:
  - Dr. Efstratios Kontopoulos (former PhD student, co-author)
  - Dr. Antonios Bikakis (Lecturer, University College London, PhD examiner)

RELEVANT PUBLICATIONS

- K. Kravari, E. Kontopoulos, N. Bassiliades, "EMERALD: A Multi-Agent System for Knowledge-based Reasoning Interoperability in the Semantic Web", *6th Hellenic Conference on Artificial Intelligence (SETN 2010)*, Springer, LNCS 6040, pp. 173-182, 2010.
- K. Kravari, N. Bassiliades, "HARM: A Hybrid Rule-based Agent Reputation Model based on Temporal Defeasible Logic", *6th International Symposium on Rules: Research Based and Industry Focused (RuleML-2012)*. Springer Berlin/Heidelberg, LNCS, Vol. 7438, pp. 193-207, 2012.
- K. Kravari, N. Bassiliades, "DISARM: A Social Distributed Agent Reputation Model based on Defeasible Logic", *Journal of Systems and Software*, Vol. 117, pp. 130–152, July 2016


THANK
YOU


Any
Questions

A FEW WORDS ABOUT US…

- Aristotle University of Thessaloniki, Greece
  - Largest University in Greece and South-East Europe
  - Since 1925, 41 Departments, ~2K faculty, ~80K students
- Dept. of Informatics
  - Since 1992, 28 faculty, 5 research labs, ~1100 undergraduate students, ~200 MSc students, ~80 PhD students, ~120 PhD graduates, >3500 pubs
- Software Engineering, Web and Intelligent Systems Lab
  - 7 faculty, 20 PhD students, 9 Post-doctorate affiliates
- Intelligent Systems group (http://intelligence.csd.auth.gr)
  - 4 faculty, 7 PhD students, 17 PhD graduates
  - Research on Artificial Intelligence, Machine Learning / Data Mining, Knowledge Representation & Reasoning / Semantic Web, Planning, Multi-Agent Systems
  - 430 publications, 35 projects

EVALUATION OF TRUST / REPUTATION MODELS

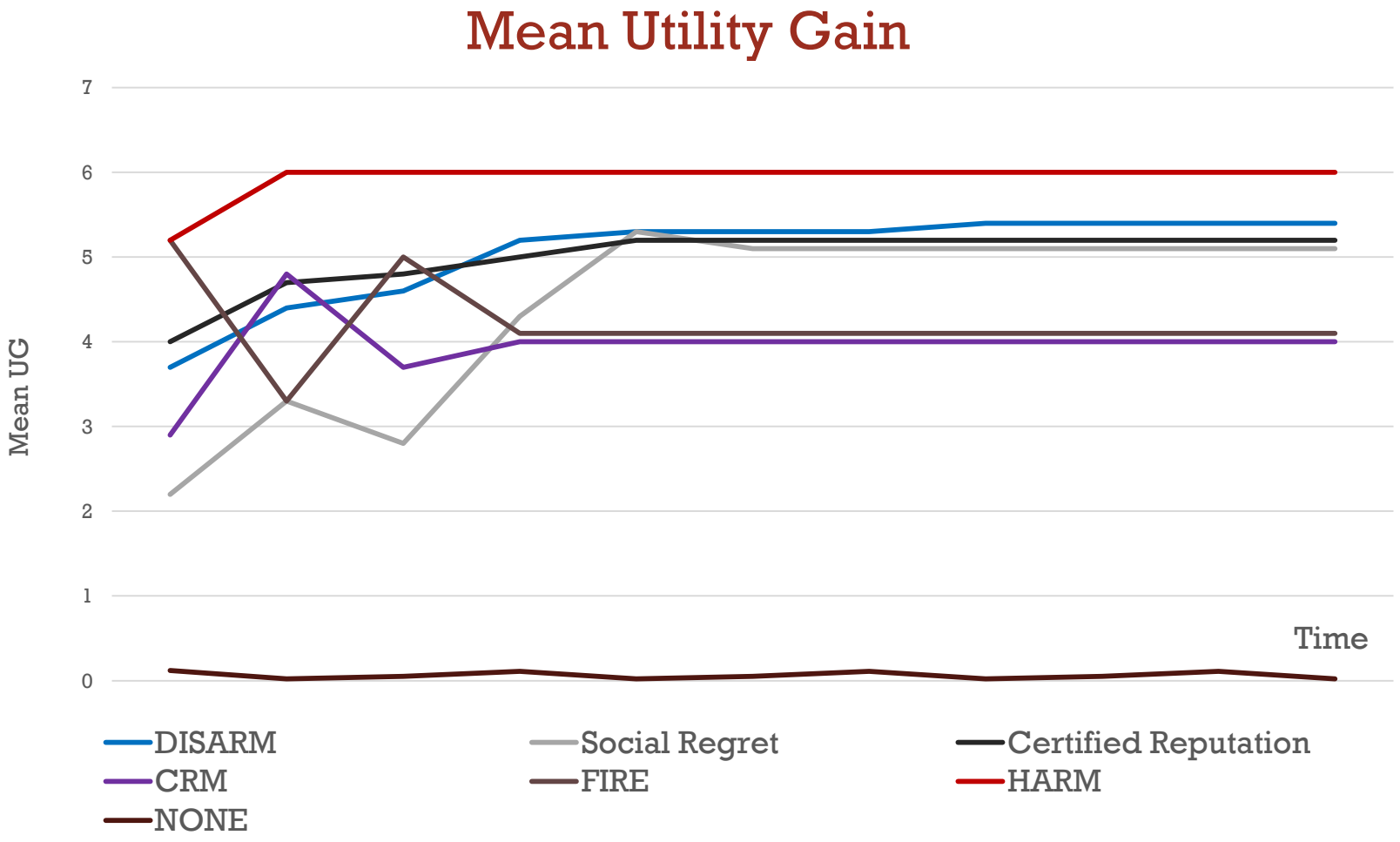
EVALUATION ENVIRONMENT

- Simulation in the EMERALD* multi-agent system
- Service provider agents
  - All provide the same service
- Service consumer agents
  - Choose provider with the higher reputation value
- Performance metric: Utility Gain

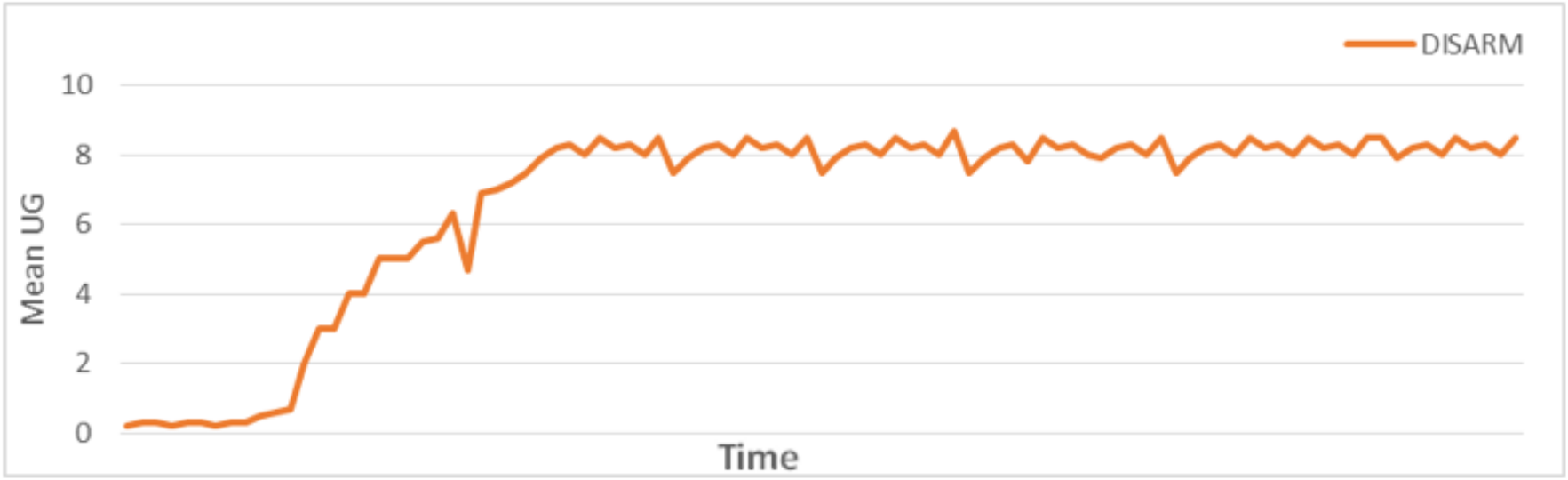
Number of simulations: 500 Number of providers: 100	
Good providers	10
Ordinary providers	40
Intermittent providers	5
Bad providers	45

*K. Kravari, E. Kontopoulos, N. Bassiliades, "EMERALD: A Multi-Agent System for Knowledge-based Reasoning Interoperability in the Semantic Web", 6th Hellenic Conference on Artificial Intelligence (SETN 2010), Springer, LNCS 6040, pp. 173-182, 2010.

DISARM VS. HARM VS. STATE-OF-THE-ART

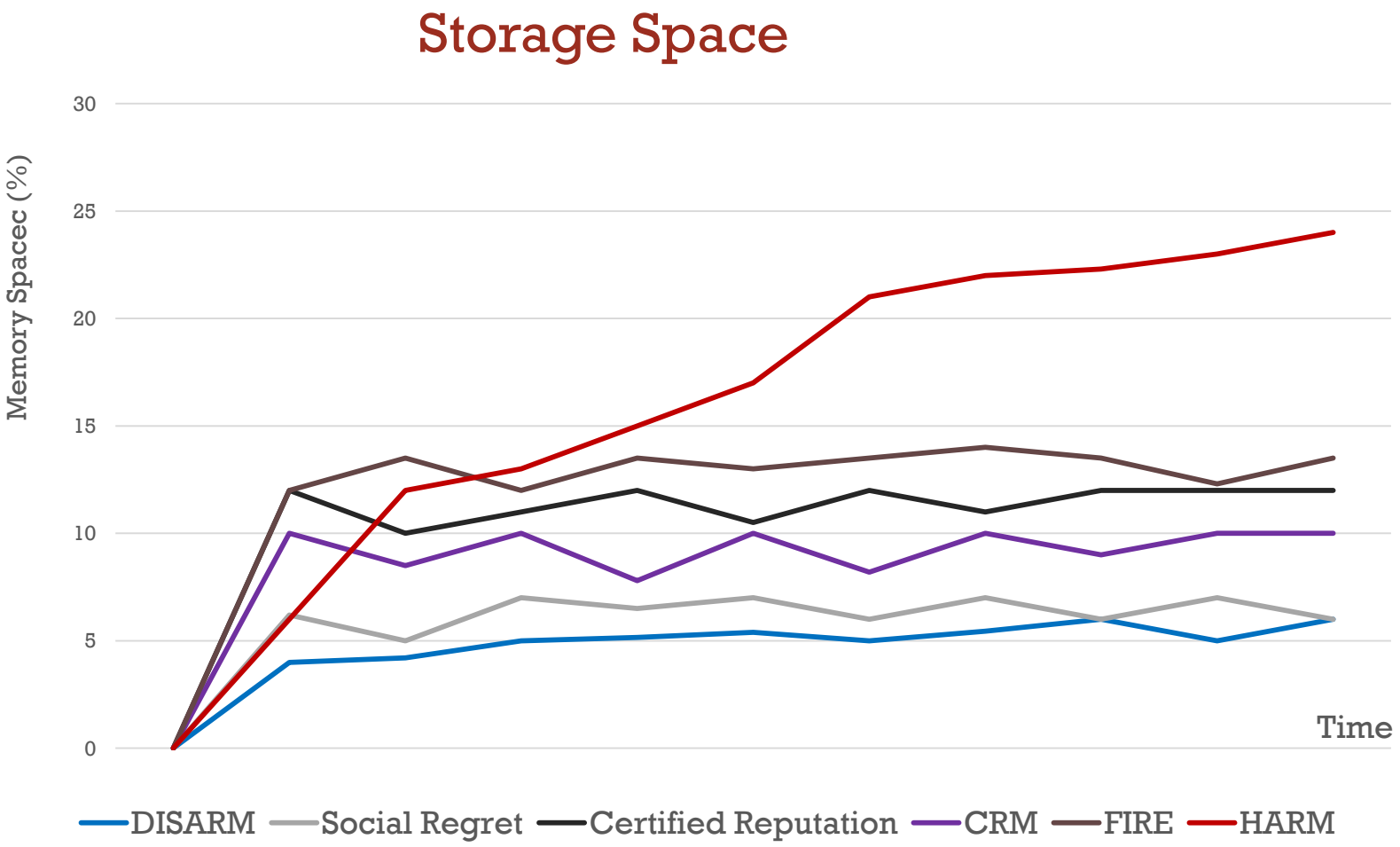


DISARM - ALONE



Better performance when alone,
due to more social relationships

DISARM VS. HARM VS. STATE-OF-THE-ART



EVALUATING DISHONESTY HANDLING