Handling Collusion in Dynamic Desktop Grids

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Outline

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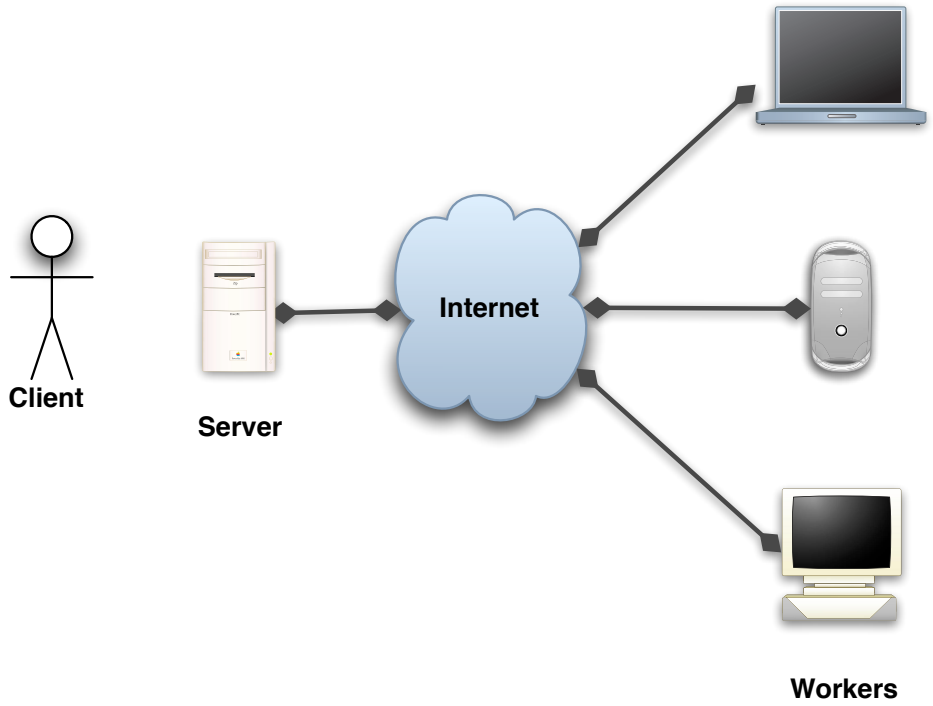
Principles of Desktop Grid



Distributed Computing

The server assigns **job** ($j \in J$) to each active **worker** ($w \in W$).
Each worker returns a **result** ($r \in R$) for the corresponding job.
The client wants to have the *correct* result for each submitted job.
Example: SETI@Home, BOINC-based projects.

Cheating

Byzantine fault

Unreliability or malicious isolated peer (worker).
35% of workers gives at least one wrong result (Derrick Kondo *et al.* 2007).
Allow to increase credit for example.

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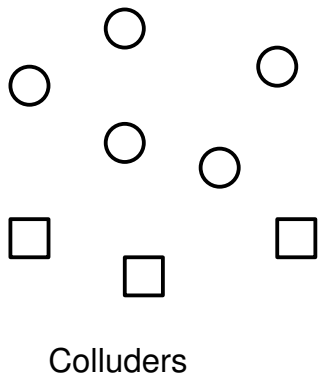
k-majority

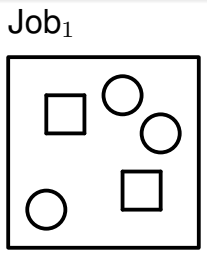
Assign a job to *k* distinct peers (redundancy) and select the result that has the majority.
BOINC use a quorum-based system.

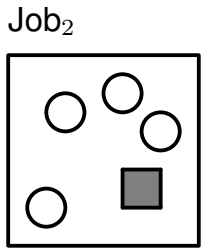
Organized cheaters

Collusion

A subset of the workers produces the same wrong result for some given job.
Against Sybil attack or library with platform specific bugs.







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Mechanisms

Generality

Generic and non-intrusive mechanism: no information available on the structure of the jobs and their results.
No trustworthy computation resources.
Blacklisting is not necessary (risk of churn and whitewashers).

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Main components

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Objectives (Zhao and Lo, 2005)

Overhead minimum redundancy.

Accuracy maximum of correct certified results.

Grouping strategies

Detection orientation

Large groups with workers with unknown interactions (exploration).

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Need for informations

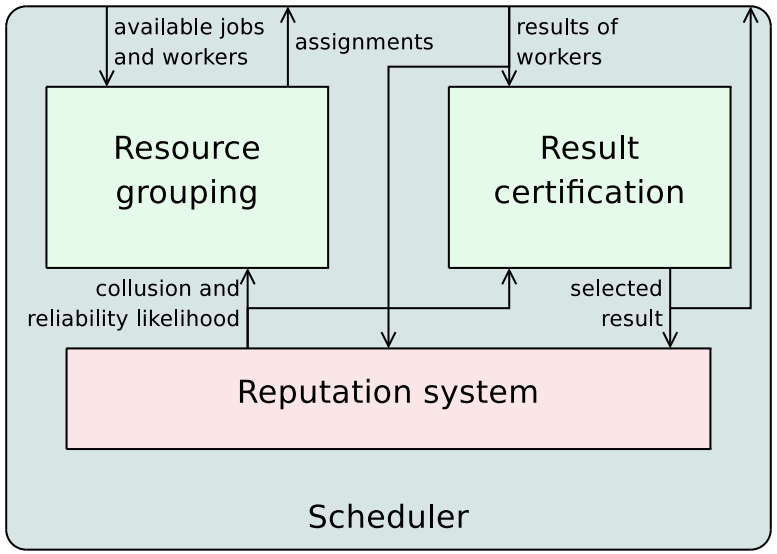
In either cases, the probability to collude of a set of workers is needed.
More generally, the colluding characteristics of the system.

Outline

Reputation system: an underlying problem

Problem description

Based only on the generated results, what can we say?
Build a **reputation system** that will then be used at higher level.



Objectives of the reputation system

Goal

Determine the probability of collusion of any subset of workers.

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Criteria (Jøsang, Ismail, and Boyd, 2007)

Accuracy Root Mean Square Deviation (RMSD) of all generated informations

Adaptativeness or dynamicity #iterations to acknowledge changes

Robust resistant to attacks

Smooth aggregated difference between 2 iterations

Introspection RMSD of error estimations

Observations

Input

$< t, w, j, r >$ (timestamp, worker, job, result)
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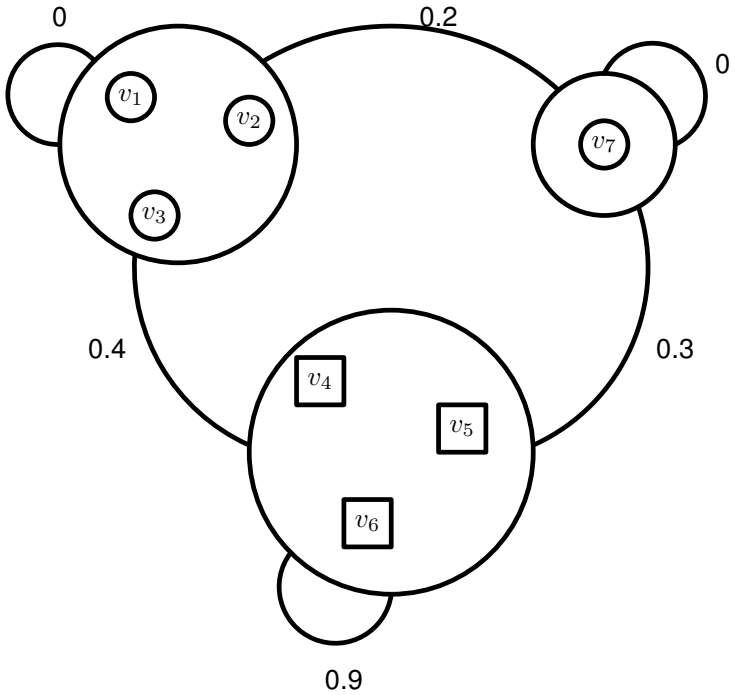
Observations = group interactions

Consider that an observation informs us on the interaction between group(s) of workers. This involves to characterize the group to which each worker belongs.

Architecture

Data structure

Graph: each node corresponds to a set of worker; each edge, to some collusion characteristics.



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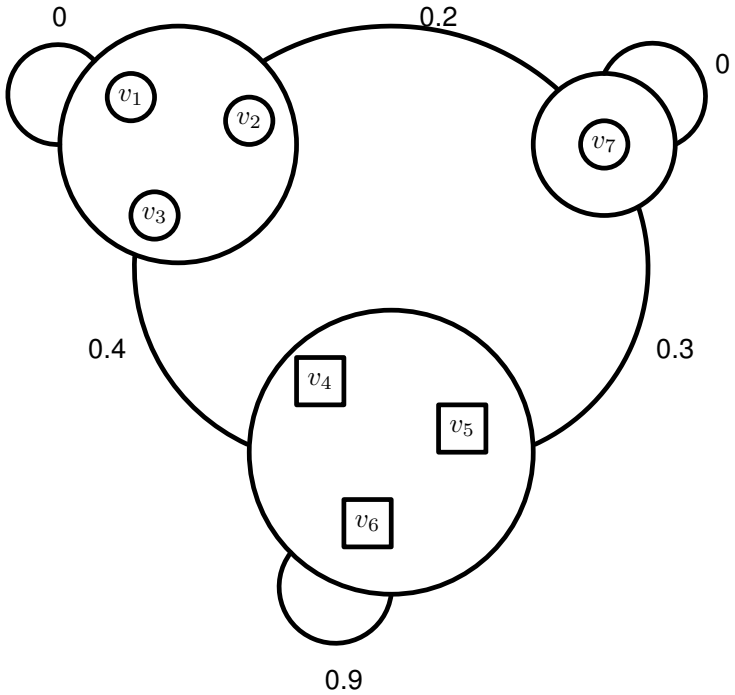

Algorithm

Initially, each worker is in a singleton.
We proceed by succession of merges and splits operations.

Reputation representation

Representation

- collusion likelihood between workers from set i and set j: c_{ij}
- agreement likelihood: a_{ij}

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Comparison

$\{c_{ij}\} \rightarrow \{a_{ij}\}$ but $\{c_{ij}\} \nleftarrow \{a_{ij}\}$, then collusion likelihood has more informations.

Agreement likelihood is easier to manage, faster and more stable.

Example of a merging criterion

Merging sets i and j with collusion representation.
Input: c_{ii}, c_{ij} and c_{jj}

$$c_{ii} \approx c_{ij} \approx c_{jj} \wedge \min(N(c_{ii}), N(c_{ij}), N(c_{jj})) > \max(\Sigma, \frac{n}{m}) \times \frac{\alpha}{(1-d_1)(1-d_2)(1-d_3)}$$

$N(c)$ number of observations with which c is estimated

Σ sum of size of sets i and j

n number of workers

m number of characterized groups

d_k difference between c_{ii} and c_{ij}

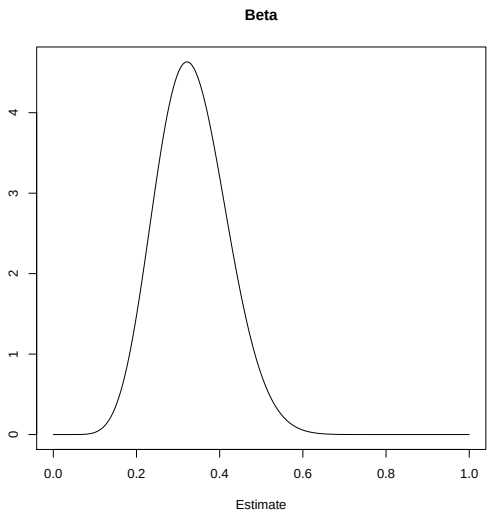
$$\alpha = \begin{cases} 2.5 & \Sigma > B \\ 1 & \text{otherwise} \end{cases}$$

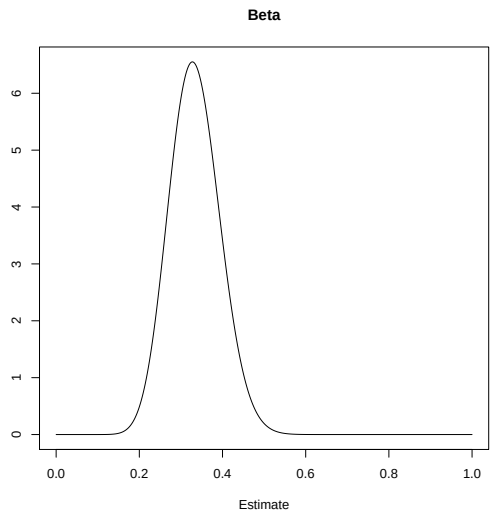
B is the size of the biggest characterized set

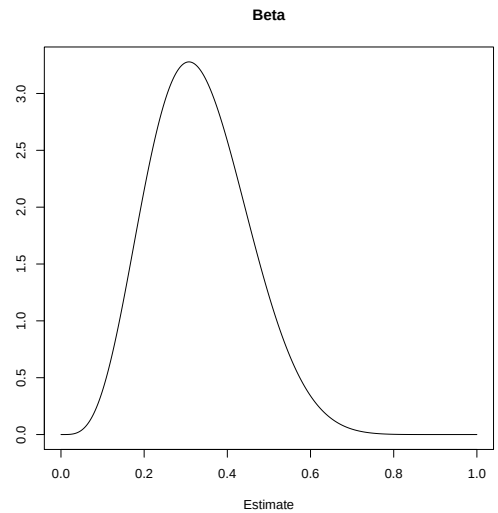
Estimator

How to deal with uncertainty (sparse observations)?

Values are modeled by random variables, *e.g.* Beta function (Jøsang, Ismail, 2002).
Arithmetic operation propagates errors (variance).







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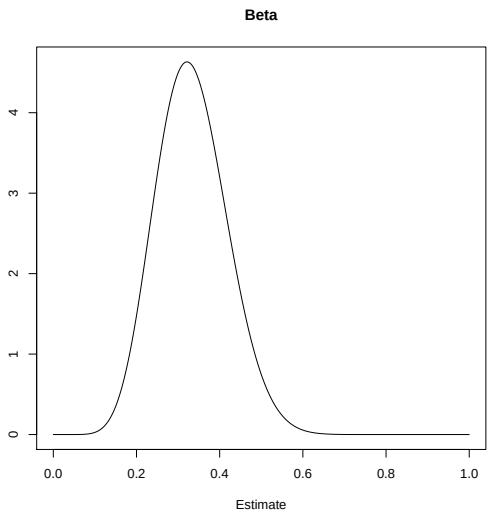
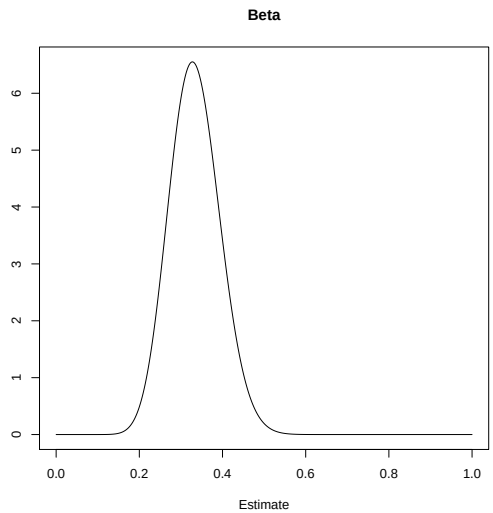
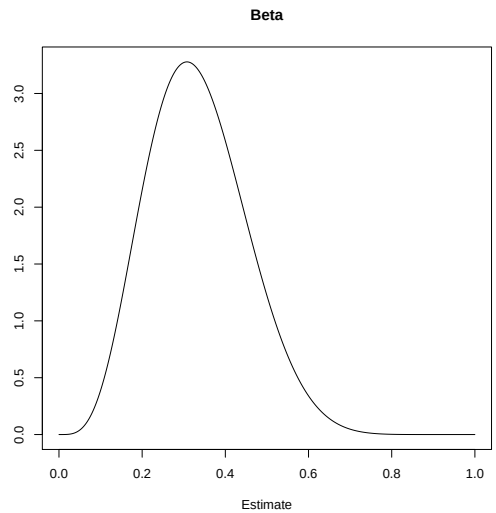
How to deal with dynamicity?

Bayesian inference is used to reinitialize each estimator when estimation is too far from recent observations.







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We want $< t, w, j, r >$.
We have availibility traces (FTA, . . .), workload archive (GWA, . . .) and one performance file (FTA/SETI@home).

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Other adjustment

The same performance file is used for distinct availability trace because availability and power are uncorrelated on SETI@home.

Trace preparation (2)

Scheduling

Redundancy-based scheduler: achieve a quorum of q with initial and maximal duplication l and l_{max}.
Jobs scheduled on workers when available (durations determined with the performance file and the normal duration of the job).
Result computations are based on reliability and colluding probabilities.

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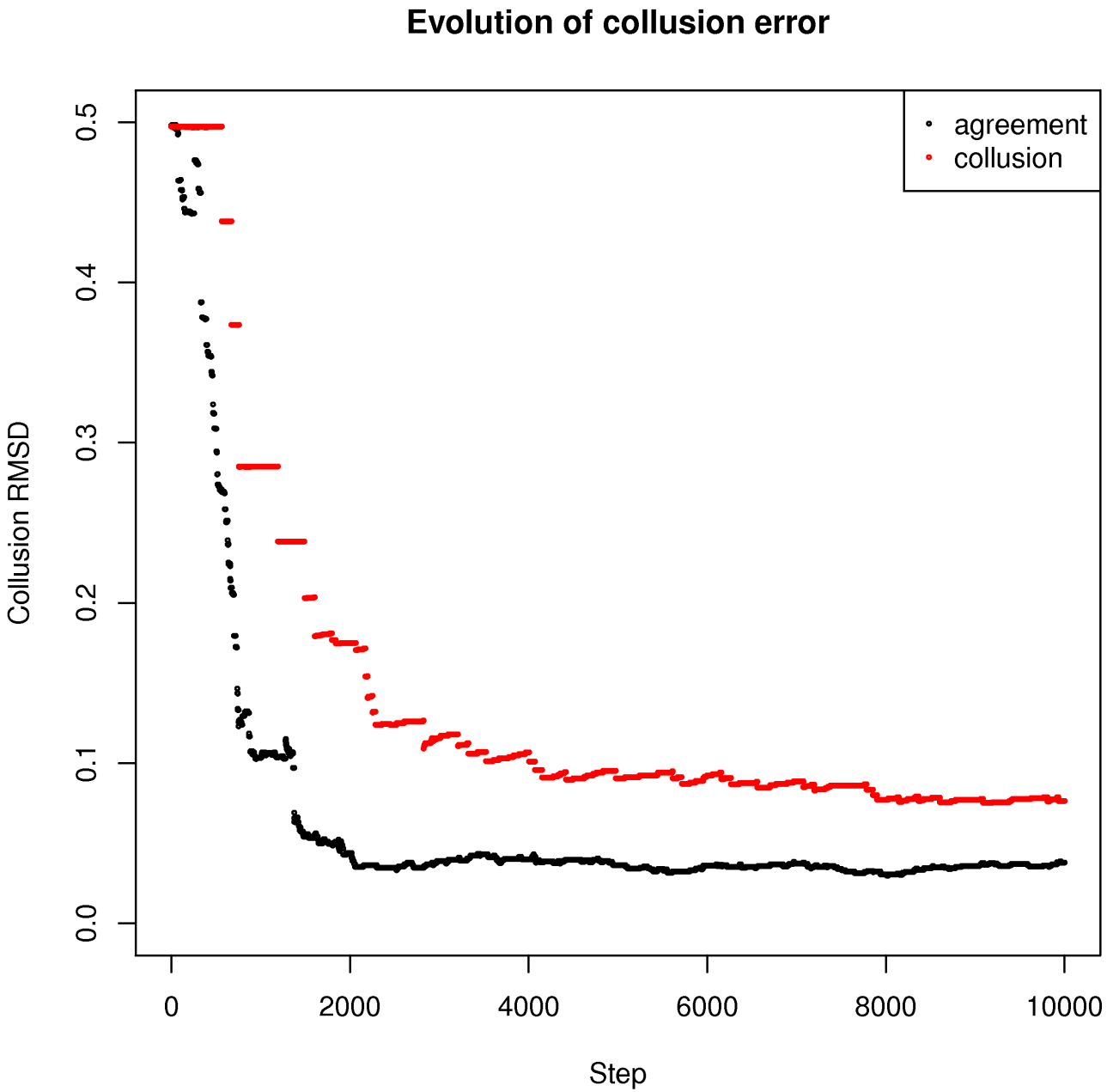
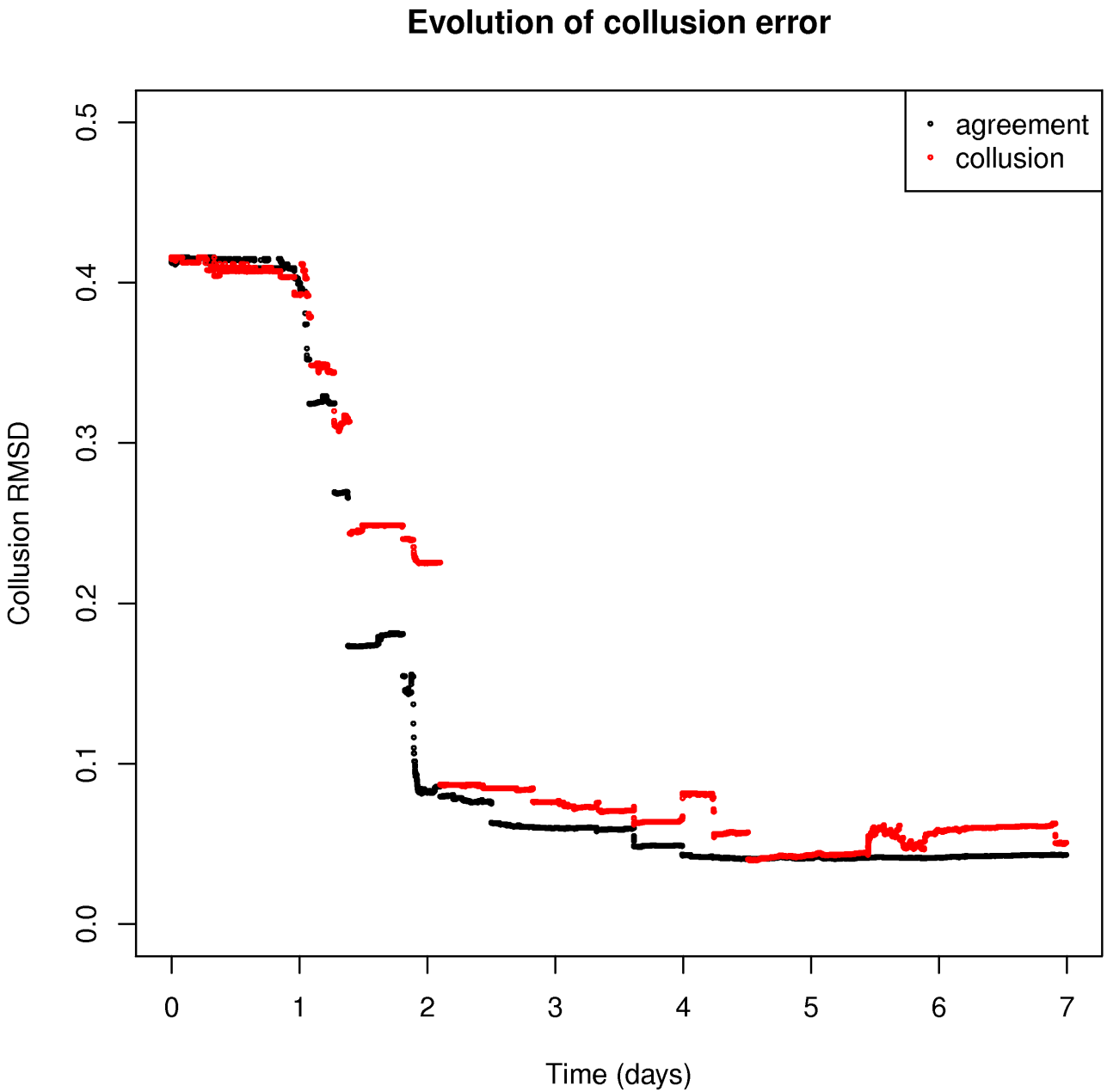
Trace that could have been useful

Job-centric traces on Desktop Grid: start and end times of the computation of a job; hash of the result.

Results with synthetic input



Results with traces



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Conclusion and future directions

Main contributions

- Propose a reputation system
  - that observes interaction between groups of workers
  - with 2 representations (agreement, collusion)
- Use a realistic input based on existing traces

Perspective

- Correct the dependance reliability/collusion (the system does not converge)
- Apply clustering techniques based on agreement distance