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TRUST AND REPUTATION MECHANISMS FOR MULTI-AGENT ROBOTIC SYSTEMS

Igor A. Zikratov*, Ilya S. Lebedev*, Andrei V. Gurtov
Aalto University & ITMO University

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Overview

- Analyze the functioning of multi-agent robotic systems with decentralized control in conditions of destructive information influences from robots-saboteurs
- Suggest a mechanism of information security in which robots-agents produce levels of trust to each other on the basis of the situation analysis developing on a certain step of an iterative algorithm with the use of onboard sensor devices.
- We give an example showing the use of the developed mechanism for detection of saboteurs in different situations in using the basic algorithm of distribution of targets in a group of robots.

Distribution of targets in the presence of saboteurs

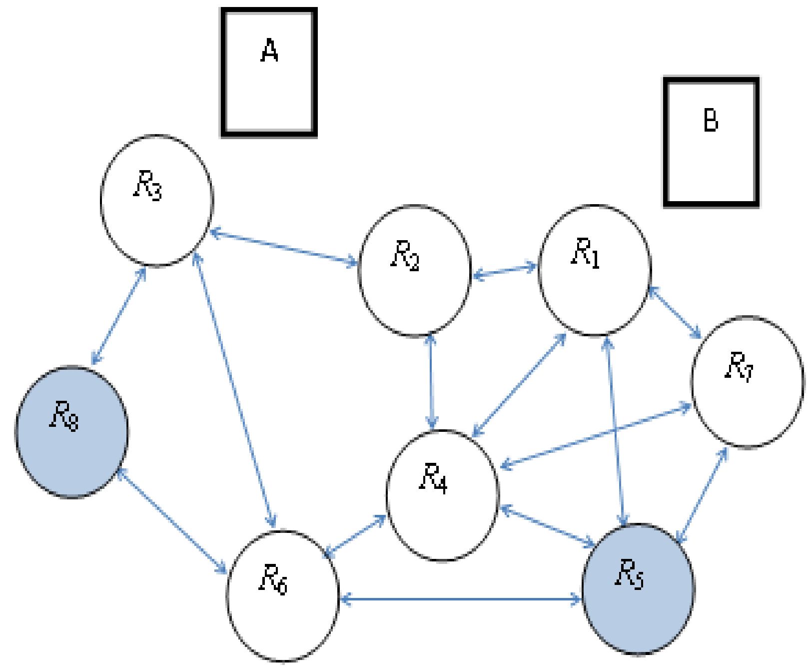
Circles – robots

Grey circles – saboteurs

Squares – targets

Arrows – communication links between robots

D_1	3.2	1.0
D_2	1.9	2.5
D_3	0.7	5.4
D_4	3.6	3.5
D_5	**0.8**	3.4
D_6	4.2	5.6
D_7	5.8	1.4
D_8	3.1	**0.2**



Target function

Assume there are *M targets and a group of robots which consists of N robots*

$$\mathbf{Y}_c = \sum_{j,l=1}^{N} d_{jl} n_{jl} \rightarrow max, \qquad (1)$$

$$\sum_{l=1}^{N} n_{jl} = 1,$$

$$\sum_{j=1}^{N} n_{jl} = n_l^{max},$$

$$d_{jl} \geq 0,$$

Matrix "D" with dimensionality (*N*, *M*), *which elements are estimates of efficiency of the robot "j" for target "l"*

$$n_{jl} = \begin{cases} 1, & \text{if "}j\text{" robot selects "}l\text{" target,} \\ 0, & \text{otherwise.} \end{cases}$$

Here $j = \overline{1, N}$, $l = \overline{1, N}$, a n_l^{max} is a necessary number of robots which must select "l" target.

Definitions

Trust (W)

Readiness to interact with an agent

Agent is blocked if trust is below a threshold

Reputation (T)

Public opinion created over time about qualities of an agent

Sum of poisitive and negative votes assessing agent’s behavior

Algorithm

Step 1. Each robot-agent creates a vector of efficiency estimates, and tells the estimates to all members of a group

*Step 2. Agents by means of their sensors execute verification of data in an array **D.***

Step 3.Computation of agents' reputation.

Step 4. Accounting of change of reputation level.

Step 5. Calculation of trust level

Step 3: Array of action estimates of members of a group

$$w_i = \frac{\gamma^+}{\gamma^+ + \gamma^-}$$

Trust level is the ratio of positive voices

	1	2	3	4	5	6	7	8
1	1	1	0	1	-1	0	1	0
2	1	1	1	1	0	0	0	0
3	0	1	1	0	0	1	0	-1
4	1	1	0	1	-1	1	1	0
5	-1	0	0	-1	1	-1	-1	**1**
6	0	0	1	1	-1	1	0	-1
7	1	0	0	1	-1	0	1	0
8	0	0	-1	0	**1**	-1	0	1

Trust vector of all agents

T=[0.8,1.0,0.75,0.83,0.33,0.6,0.75,0.33].

Array S of reputation level estimates of agents

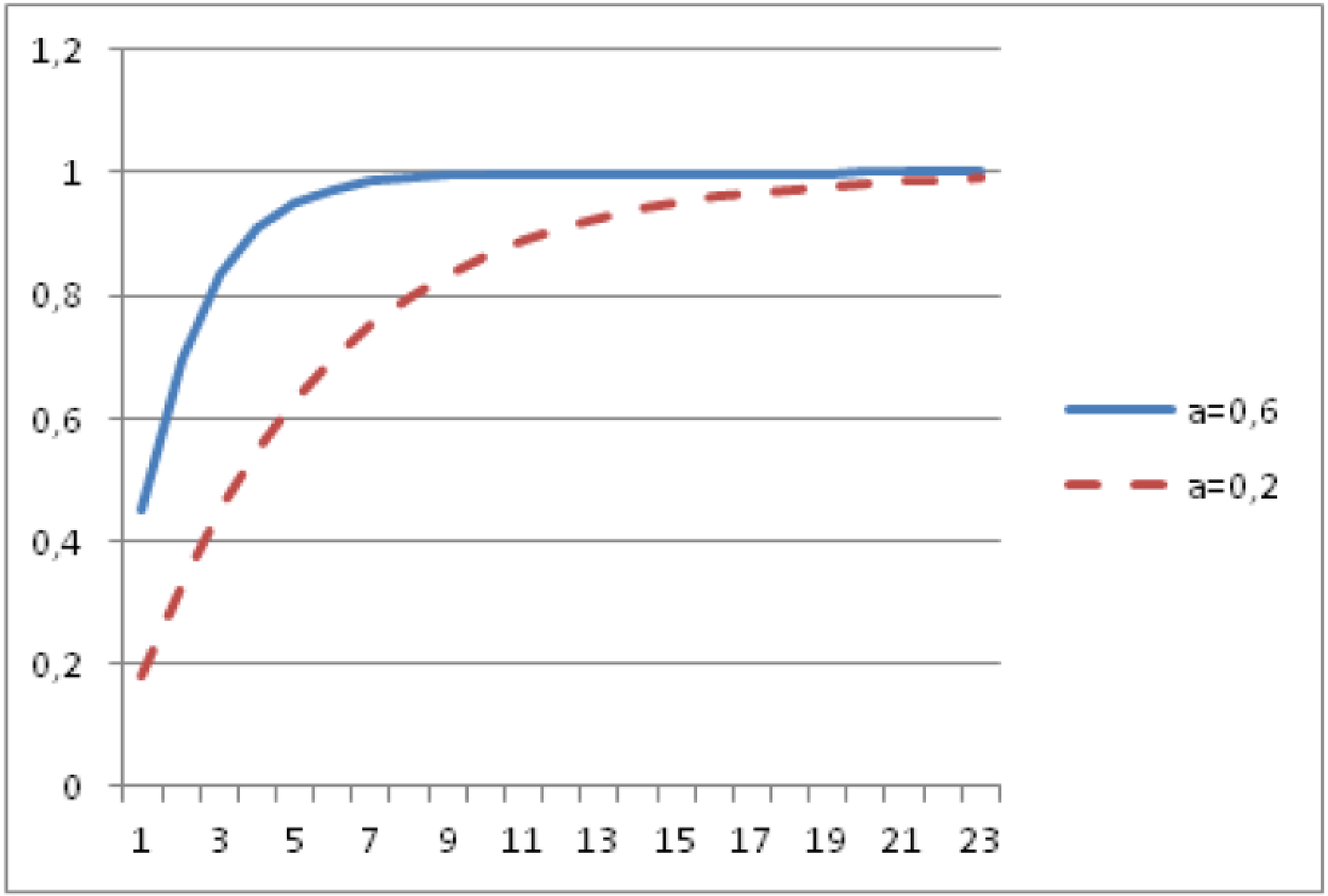
Reputation increases if agents give each other positive marks Or if they give same marks to another agent, otherwise decreasing

	1	2	3	4	5	6	7	8
1		2	1	4	-3	2	3	-1
2	2		1	2	-2	2	2	-2
3	1	1		2	-1	2	0	-2
4	4	2	2		-4	2	3	-1
5	-3	-2	-1	-4		-2	-3	1
6	2	2	2	2	-2		2	-2
7	3	2	0	3	-3	2		0
8	-1	-2	-2	-1	2	-2	0	

Step 4: Influence of parameter “a” on the reputation level with an increase in the number of iterations “I”

$$F(t) = 1 - e^{-at^k}$$

Weibull-Gnedenko function



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Step 5: Trust Computation

$$w_i = \frac{p_i}{p_i + n_i}, \qquad (4)$$

where

$$p_i = \sum_{j=0}^{N} h_{ij} \cdot q_j \cdot F(l),$$

$$n_i = \sum_{j=0}^{N} g_{ij} \cdot q_j \cdot F(l).$$

Values h_{ij} and g_{ij} are defined by the analysis of estimates v_{ij} of array $\mathbf{V}$:

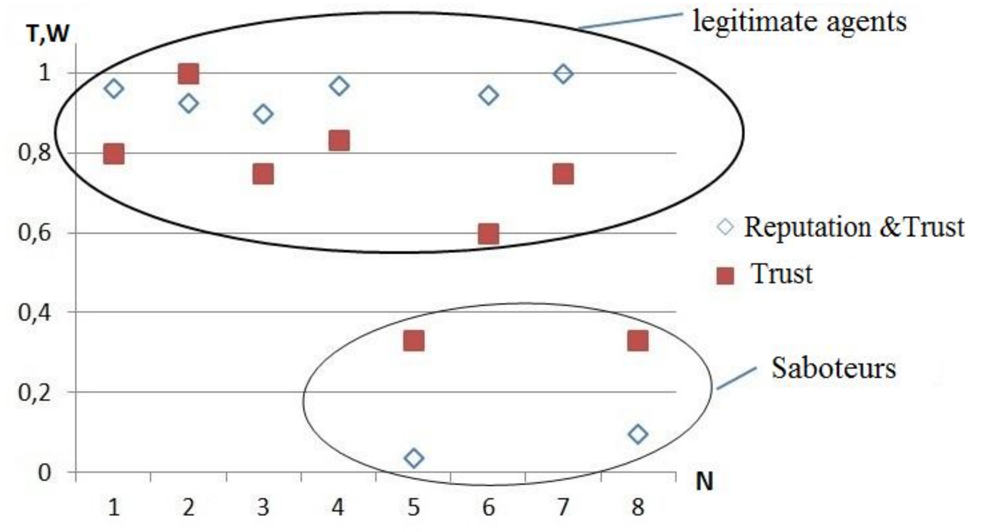
$$h_{ij} = \begin{cases} 1, & \text{if robot "}j\text{" positively estimated actions of robot "}i\text{"}, \\ 0, & \text{otherwise} \end{cases}$$

$$g_{ij} = \begin{cases} 1, & \text{if robot "}j\text{" negatively estimated actions of robot "}i\text{"}, \\ 0, & \text{otherwise.} \end{cases}$$

Characteristics of agents on the trust level T and reputation & trust level W

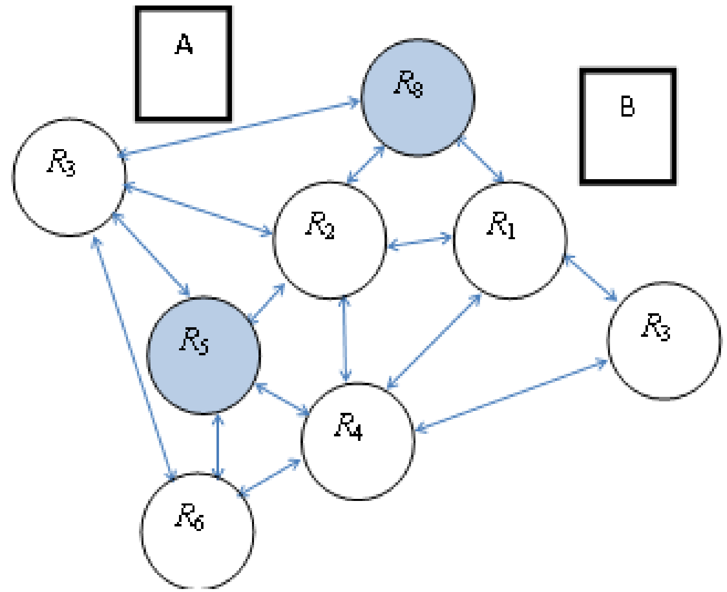
Robots are placed to two clusters

W = [0.96, 1.0, 0.94, 0.97, 0.071, 0.9, 0.95, 0.08]



Situation development on the second step of iterative process of target distribution

Inter-cluster distance increases between legitimate agents and sabouterus
as robots change their position and another iteration of target distribution is carried out



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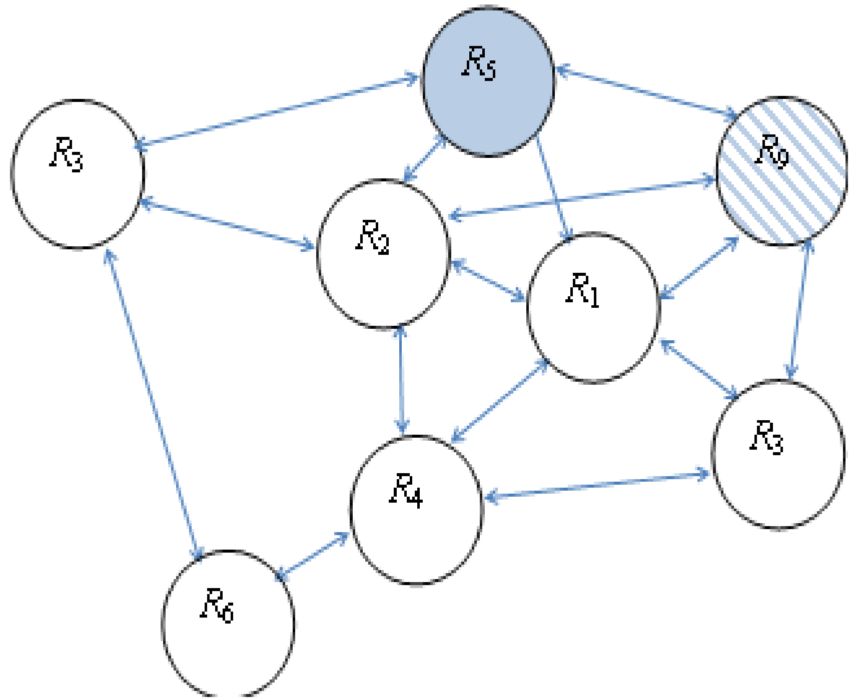
Operation in case of appearance of a new agent

A new robot R9 starts with zero reputation, but it quickly increases if it behaves correctly (subject to parameter a)



Conclusions

- Considered a swarm of mobile robots that act together to achieve a set of goals
- Designed a mechanism for determining trust to other robots in a group
- Trust increases with
  - Correct assessment of others' behavior
  - Correct execution of the task
- Iterative process