Role-Based Collaboration and E-CARGO

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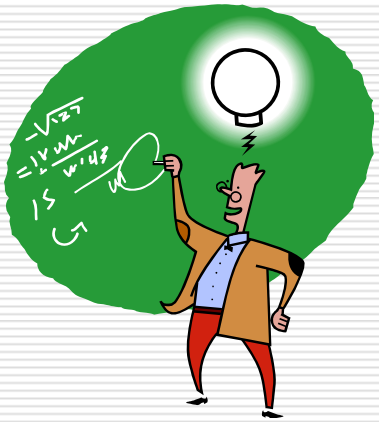

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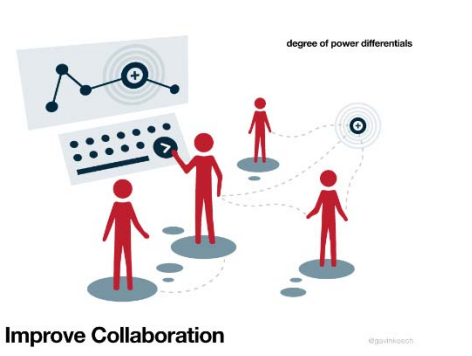


Collaboration

Collaboration

- Collaboration is an activity/process that involves more than one agent to participate in.
- To be skilful in collaboration requires a life-long time to learn and practice.
- A team is a group of people who are mutually dependent on one another to achieve a common goal.
- Without collaboration, there would be no team.

Collaboration = Team Work

Collaboration made easy/efficient!

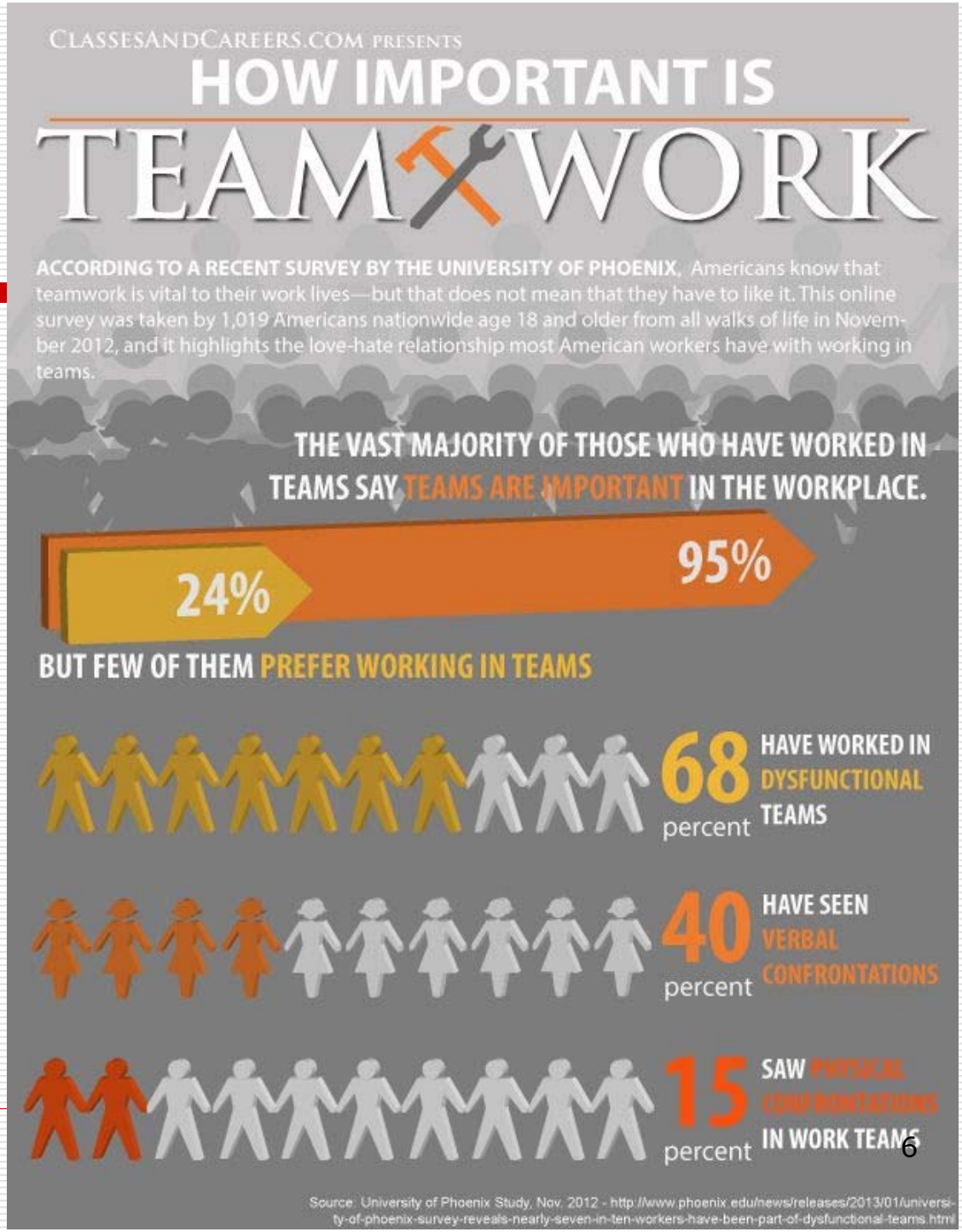
-The goal of E-CARGO

-Through modeling and algorithms

Challenge!

2013 Survey

https://www.pinterest.ca/pin/331296116308388145/



Why do we do research on collaboration?

Goal

Collaboration made easy and efficient!

Properties

Collaboration is required!

Collaboration is challenging!

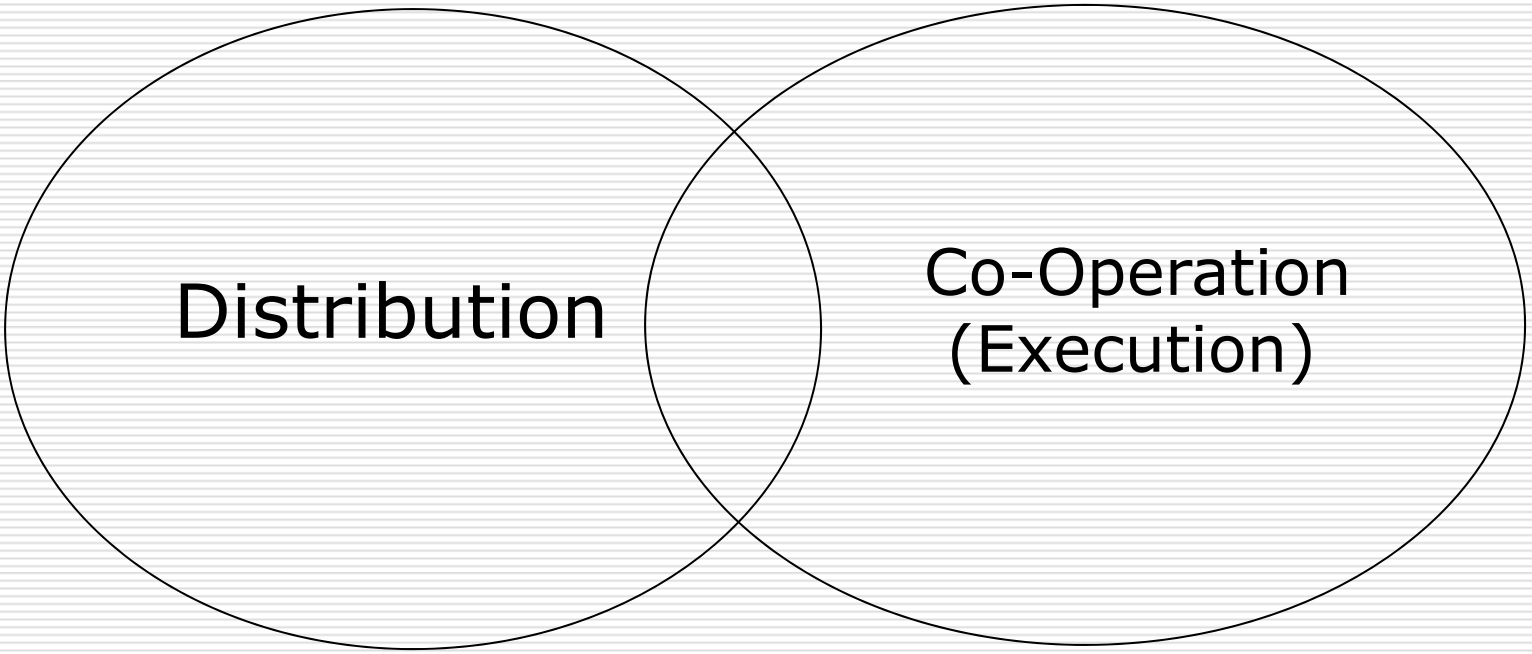
Collaboration is valuable!

Collaboration is interesting!

Nature of Collaboration

- (Task) Distribution
- Task specification, Agent evaluation, Task assignment, Optimization.
- (Task) Execution [(Co-)Operation]
  - Process, Sharing, Negotiation, Interaction, Coordination, Decision making.

Why collaboration is hard?



Distribution and execution are interleaved!

If we divide them clearly:

Role-Based Collaboration (RBC)

(Standing on the Shoulders of Giants)

Giants: Object-Orientation, Agent Systems, Distributed systems, Chinese Culture and Philosophy

Why RBC?

“名不正，则言不顺；言不顺，则事不成。”

“Ming bu zheng, ze yan bu shun; yan bu shun, ze shi bu cheng”.

“If terminology is not corrected, then what is said cannot be followed. If what is said cannot be followed, then work cannot be accomplished. ”

- ----Confucius, Lun Yu: Zi Lu, No. 13, Section 3.
- Role Specification （角色定义/规范）。

Role Theory (Confucius)

- 君君臣臣父父子子。
- “The king is king, and the minister is minister, the father is father, and the son is son.”
- Meaning: Good government obtains only when all the relative duties are maintained.
- Distribution.

What is RBC?

Role-based collaboration (RBC)

is

a *computational* methodology

that mainly uses

<u>roles as underlying mechanisms</u>

to facilitate collaboration activities

(abstraction, classification, separation of concerns, dynamics, coordination and interactions).

2006

RBC and E-CARGO have been investigated for >15 years!

Haibin Zhu(朱海滨)

FOLLOW

Nipissing University
Verified email at nipissingu.ca - Homepage

Role-Based Collaboration Adaptive Collaboration Software Engineering
Collaborative Systems and ... Agent Systems

TITLE	CITED BY	YEAR
A novel feature selection algorithm for text categorization W Shang, H Huang, H Zhu, Y Lin, Y Qu, Z Wang Expert Systems with Applications 33 (1), 1-5	255	2007
Role-based collaboration and its kernel mechanisms H Zhu, MC Zhou IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and ...	234	2006
Group role assignment via a Kuhn–Munkres algorithm-based solution H Zhu, MC Zhou, R Alkins IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and ...	102	2012
Roles in information systems: A survey H Zhu, MC Zhou IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and ...	100	2008

What is RBC?

Role-based collaboration (RBC)
is emerging into
an *investigative* methodology
that mainly uses
<u>roles as the key component</u>
to model and formalize problems
in collaboration and complex systems.

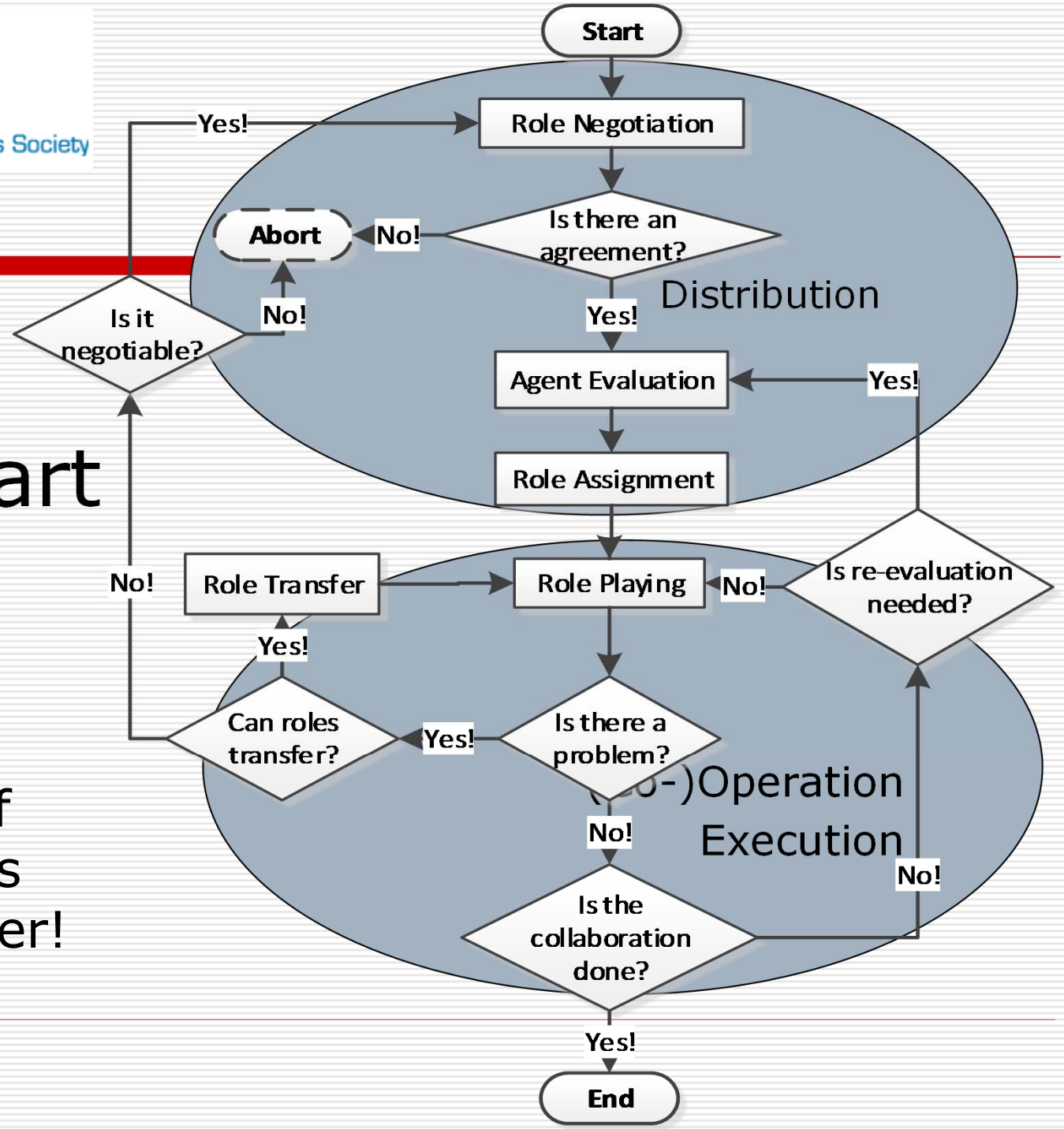
2016

RBC is such a research topic to deal with complex systems

- Distribution, The king is the king: Role Assignment
- [Co-]Operation: Role Execution
- Right titles: Role Specification
- Collectivism, Decision Making, Optimization and tradeoff , Save against a rainy day: Group Role Assignment (GRA), GRA+
- Dynamics, Survival of the fittest: Adaptive Collaboration, Roles as Team Dynamics
- Multiplayer game: Role Assignment, Execution

+Combinatorics

Flowchart of RBC



The user of this chart is the manager!

The Model

E-CARGO

The E-CARGO model

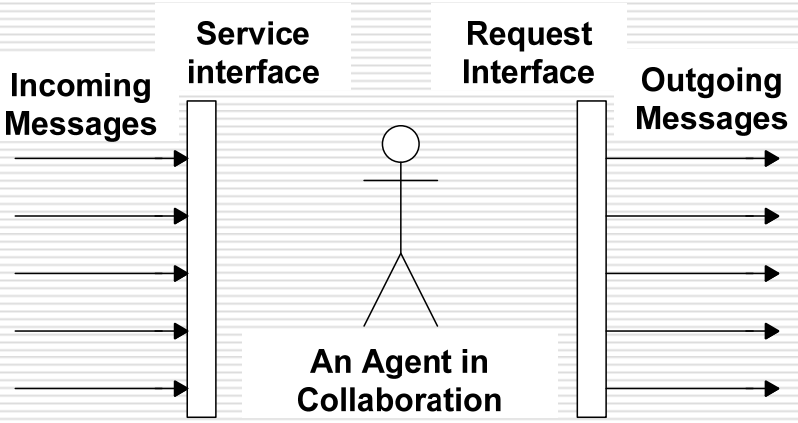
- $\Sigma ::= \langle \mathcal{C}, \mathcal{O}, \mathcal{A}, \mathcal{M}, \mathcal{R}, \mathcal{E}, \mathcal{G}, s_0, \mathcal{H} \rangle$
- **E**nvironments
  - **C**lasses
  - **A**gents
  - **R**oles
  - **G**roups
  - **O**bjects

Object-Oriented
(C, O)天时 The Universe

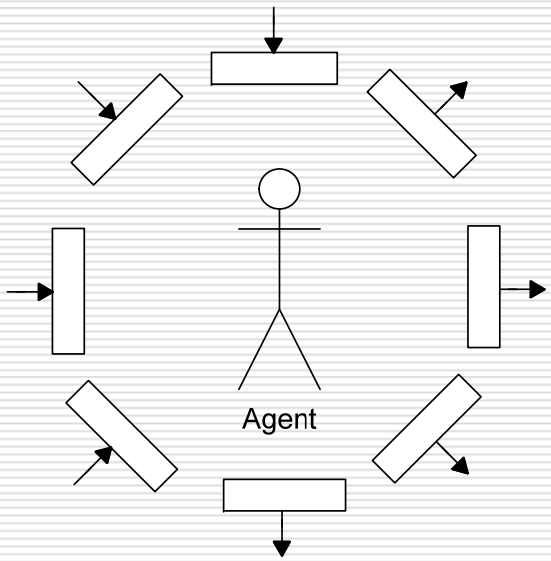
Agent-Oriented
(C,O,A,G)天时+人和
The Universe + The People

Role-Based
(C,O,A,R,E,G)天时地利人和
The Universe + The Earth +The People

The views on an agent



A role is the interface for an agent to interact with others.



An agent is playing roles.

E-CARGO explains Shakespeare

All the world's a stage (E, C, O),

And all the men and women are merely players(A);

They all have their exits and entrances(G);

And one man in his time plays many parts(R).

- -----W. Shakespeare , As You Like It, Act II, Scene 7

Role-Based Collaboration and Its Kernel Mechanisms

Haibin Zhu, *Senior Member, IEEE*, and MengChu Zhou, *Fellow, IEEE*

***Abstract*—Computer-supported cooperative work (CSCW) systems are computer-based tools that support the collaborative activities of human users. They should not only support virtual face-to-face collaborative environments but also improve face-to-face collaboration by providing more mechanisms to overcome the drawbacks of usual face-to-face collaboration. Introducing roles into CSCW systems is important in achieving this. This paper's contributions include establishing the requirements f a role-based collaboration, presenting the concept, requiremen and principles of role-based collaboration, proposing a mo E-CARGO for role-based collaboration, and describing the ker mechanisms and their implementation to facilitate the developme of role-based collaborative systems for industrial applications.**

***Index Terms*—Collaboration, computer-supported cooperati work (CSCW), role.**

associated with users. In CoWeb, many concrete roles are specified such as purpose agents, site designers, developers, central users, peripheral users, administrators, and support staffs.

Edwards [10] introduces access control policies and roles to avoid chaos in collaborative applications. The term role in role-based access control (RBAC) is used in assigning differ-

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Role mechanisms in collaborative systems

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(*Received May 2005*)

Computer-supported cooperative work (CSCW) systems are computer-based tools that support collaborative activities. They should meet the requirements of normal collaborative efforts among people. They should not only support virtual face-to-face collaboration among people at a distance, but also improve face-to-face collaboration by providing more mechanisms to overcome the drawbacks of face-to-face collaboration among people. Therefore, introducing roles into CSCW systems is extremely important. By roles, one can avoid users of

The Initial Internal Elements of E-CARGO (2006)

$$c ::= \langle n, D, F, X \rangle$$

$$o ::= \langle n, c, s \rangle$$

$$r ::= \langle n, I, N_a, N_o \rangle$$

$$a ::= \langle n, c_a, s, N_r, N_g \rangle$$

$$e ::= \langle n, B \rangle$$

$$g = \langle n, e, J \rangle$$

$$m ::= \langle n, v, l, P, t \rangle$$

H. Zhu, and M. Zhou, "Role-Based Collaboration and its Kernel Mechanisms," *IEEE Trans. on Systems, Man, and Cybernetics, Part C: Applications and Reviews*, vol. 36, no. 4, 2006, pp. 578-589.

The Revised Internal Elements of E-CARGO (2015)

$\mathcal{C}, \mathcal{O}$ No change!

$$r ::= <id,\ \mathcal{M}_r,\ s,\ d, \alpha, \beta,\ \mathcal{A}_c, \mathcal{A}_p, \mathcal{A}_o, \mathcal{R}_r, O_r>$$

$$a ::= <id,\ c,\ s, \mathcal{V}, \alpha, \beta,\ r_c, \mathcal{R}_p, \mathcal{R}_o,\ \mathcal{N}_g>$$

$$e ::= <id,\ \mathcal{R}_e,\ \textcircled{\$}, \mathcal{B}>$$

$$g = <id, e, \mathcal{A}_g, \bar{\mathcal{T}}>$$

$$\text{♪} ::= <id, r,\ f, \mathcal{P}, l, \alpha, \beta>$$

H. Zhu, "Adaptive Collaboration Systems", *IEEE Systems, Man, and Cybernetics Magazine*, vol. 1, no. 4, Oct. 2015, pp. 8-15.

Role Assignment

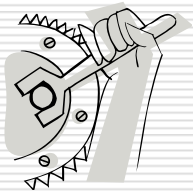
Major Symbols/Concepts

- m – the number of agents, (i =0, …, m-1) --$\mathcal{A}$
- n – the number of roles, (j =0, …, n-1) --$\mathcal{R}$
- L – the vector of lower ranges of roles(vs. U)-- $\mathcal{E}$
- Q – the matrix of agent evaluation --$\mathcal{G}$
- T – the assignment matrix – working $\mathcal{G}$

- <u>By combing with $\mathcal{C}$ and $\mathcal{O}$, we can investigate more!</u>

The *Q* Matrix:

result of role negotiation and agent evaluation

r_0  r_1  r_2  r_3 

a_0 

a_1 

a_2 

a_3 

a_4 

a_5 

$$\begin{bmatrix} 0.71 & 0.6 & 0.0 & 0.22 \\ 0.29 & 0.67 & 0.44 & 0.76 \\ 0.69 & 0.92 & 0.92 & 0.6 \\ 0.0 & 0.0 & 0.53 & 0.0 \\ 0.97 & 0.51 & 0.77 & 0.65 \\ 0.58 & 0.64 & 0.24 & 0.0 \end{bmatrix}$$

Workable roles and group

- T is a matrix, $T[i, j]$ belongs to $\{1, 0\}$
- $T[i, j]=1$ means agent i is assigned to role j, otherwise not.
- <u>$L[j]$ expresses how many agents are required by role j</u>
- Role j is workable *if* $\sum_{i=0}^{m-1} T[i,j] > L[j]$
- Group g is workable when all its roles are workable.

Definition : Given Q, and L, *Group Role Assignment* ***(GRA)*** is to find a matrix T to

$$\max \sigma = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} Q[i,j] \times T[i,j]$$

subject to

$$T[i,j] \in \{0, 1\} \qquad (0 \le i < m, 0 \le j < n) \qquad \ldots(1)$$

$$\sum_{i=0}^{m-1} T[i,j] = L[j] \quad (0 \le j < n) \qquad \ldots(2)$$

$$\sum_{i=0}^{n-1} T[i,j] \le 1 \quad (0 \le i < m) \qquad \ldots(3)$$

$L = [2 \quad 1 \quad 1 \quad 2]$

$$\begin{bmatrix} 0.71 & 0.6 & 0.0 & 0.22 \\ 0.29 & 0.67 & 0.44 & 0.76 \\ 0.69 & 0.92 & 0.92 & 0.6 \\ 0.0 & 0.0 & 0.53 & 0.0 \\ 0.97 & 0.51 & 0.77 & 0.65 \\ 0.58 & 0.64 & 0.24 & 0.0 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}$$

(a) (b)

A qualification matrix Q and an assignment matrix T

Algorithm

- Exhaustive Search

$$\prod_{j=0}^{n-1}\binom{m}{L[j]}$$

  - Approximately $O(m!)$, not practical
- After adapting the Kuhn-Munkres Algorithm
  - $O(m^3)$

GRACAR/G

- Group Role Assignment with Conflicting Agents on Roles / in a Group.
- New matrix A^c
- $A^c[i_1, i_2]=1$ means that agents i_1 and i_2 *are in conflict.*
- That agents i_1 and i_2 *are in conflict means that* agents i_1 and i_2 *cannot be assigned with the same role (GRACAR) or in the same group (GRACAG).*

*Group Role Assignment with Conflicting Agents on Roles (**GRACAR/G**)* is to find a workable *T* to

$$\max \sigma = \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} Q[i,j] \times T[i,j] \qquad \text{subject to}$$

$$T[i,j] \in \{0,1\} \qquad (0 \le i < m, 0 \le j < n) \qquad (1)$$

$$\sum_{i=0}^{m-1} T[i,j] = L[j] \qquad (0 \le j < n) \qquad (2)$$

$$\sum_{i=0}^{n-1} T[i,j] \le 1 \qquad (0 \le i < m) \qquad (3)$$

$$A^c[i_1,i_2] \times (T[i_1,j] + T[i_2,j]) \le 1 (0 \le i_1, i_2 < m, i_1 \ne i_2, 0 \le j < n) \qquad (4) /$$

$$A^c[i_1,i_2] \times (T[i_1,j_1] + T[i_2,j_2]) \le 1 (0 \le i_1, i_2 < m, i_1 \ne i_2, 0 \le j1, j2 < n) \qquad (5)$$

How to solve

- IBM ILOG CPLEX Optimization Package (CPLEX), Matlab, Maple, ……
- Our contribution?
  - Problem formalization;
  - Estimation of the problem complexity;
  - A practical solution based on CPLEX;
  - Conditions for feasible solutions;
  - Guidelines for using such a solution; and
  - Confirm common sense by simulations.

$L^a[i]$ expresses how many roles can be assigned to by agent i

RBC is an innovative discovery methodology in engineering research.

omputer Science 618 (2016) 30–41

Contents lists available at ScienceDirect

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Solving the Many to Many assignment problem by improving the Kuhn–Munkres algorithm with backtracking

Haibin Zhu [b], Dongning Liu [a,*], Siqin Zhang [a], Yu Zhu [c], Luyao Teng [d], Shaohua Teng [a]

[a] School of Computer Science and Technology, Guangdong University of Technology, Guangzhou, China
[b] Department of Computer Science and Mathematics, Nipissing University, North Bay, Canada
[c] Faculty of Mathematics, University of Waterloo, Waterloo, Canada
[d] College of Engineering and Science, Victoria University, Melbourne, Australia

GMRA-Group Multi-Role Assignment

GMRA is to find a workable T to max $\sigma = \sum_{i=0}^{m-1}\sum_{j=0}^{n-1} Q[i,j] \times T[i,j]$

subject to

$$T[i,j] \in \{0,1\} \qquad (0 \le i < m, 0 \le j < n) \qquad (1)$$

$$\sum_{i=0}^{m-1} T[i,j] = L[j] \qquad (0 \le j < n) \qquad (2)$$

$$\sum_{j=0}^{n-1} T[i,j] \le L^a[i] \qquad (0 \le i < m) \qquad (3)$$

where

(1) is a 0-1 constraint;

(2) makes the group workable;

(3) makes an agent be assigned with a limited number of roles.

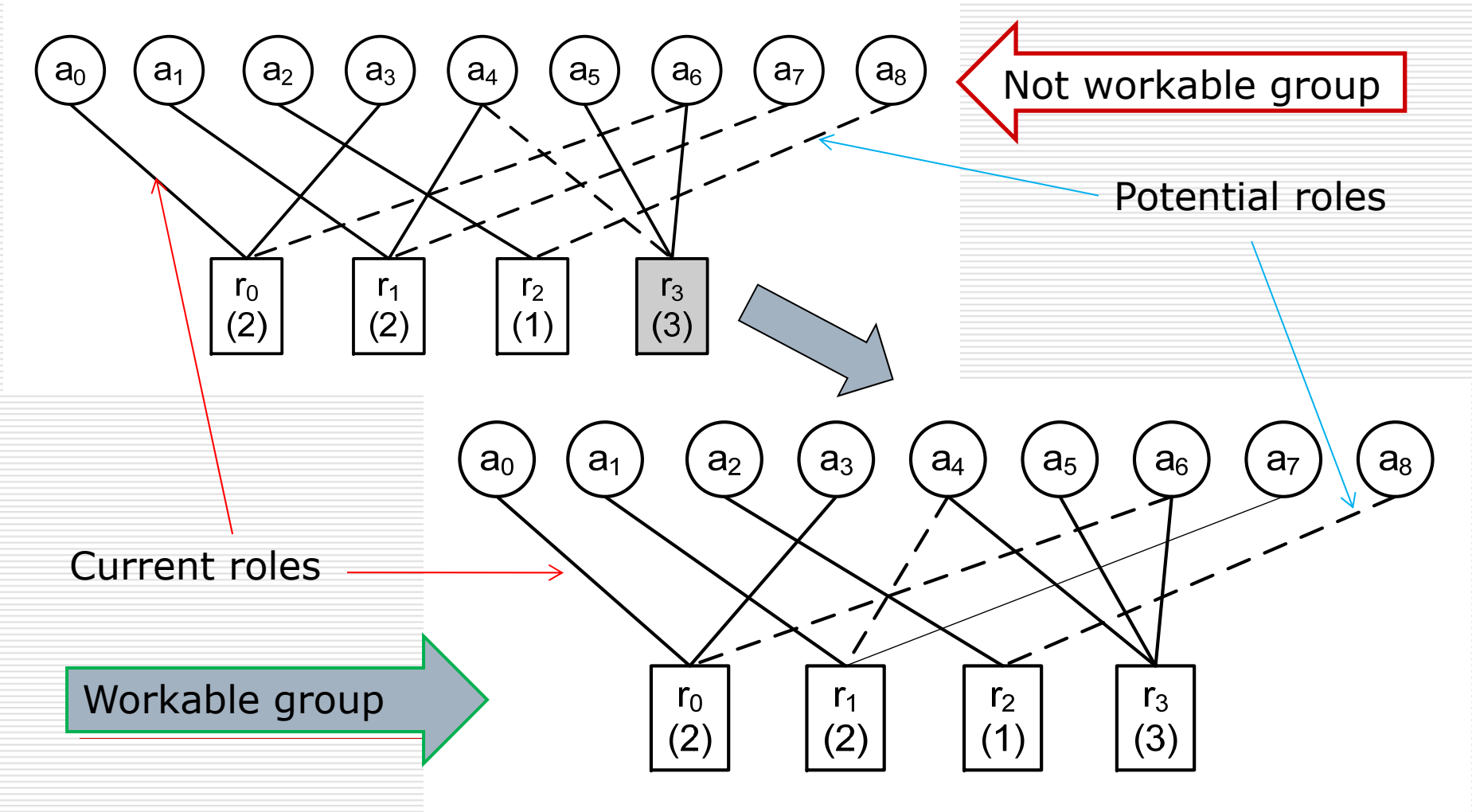
Solutions: CPLEX or KM_B

Role Transfer (RT)

- is required when initial assignment is done and dynamic evaluation is not available.

- It can be solved by group role assignment, called role re-assignment, where only some of agents needs to change their roles.

Role transfer problems



Complexity

- Exhaustive Search

$$\prod_{j=0}^{n-1}\binom{m}{L[j]}$$

  - Approximately $O(m!)$, not practical
- Adapted Kuhn-Munkres Algorithm
  - $O(m^3)$
- Temporal Role Transfer(Strong Restriction) is still complex even with the Kuhn-Munkres Algorithm.

Y. Sheng, H. Zhu, X. Zhou, and W. Hu, "Effective Approaches to Adaptive Collaboration via Dynamic Role Assignment", *IEEE Trans. on Systems, Man, and Cybernetics: Systems*, vol. 46, no. 1, Jan. 2016, pp. 76 - 92.

Effective Approaches to Adaptive Collaboration via Dynamic Role Assignment

Yin Sheng, Haibin Zhu, *Senior Member, IEEE*, Xianzhong Zhou, *Member, IEEE*, and Wenting Hu

***Abstract*—Adaptive collaboration (AC) is essential for group performance optimization in collaborative systems. This paper begins by introducing AC within the context of solving a real-world problem. Next, AC problems are formalized based on the**

up but declines due to fatigue as the game progresses. Each member in collaboration makes an effort to achieve a common goal, and the changing of an individual's per-

GRA+Time->DGRA

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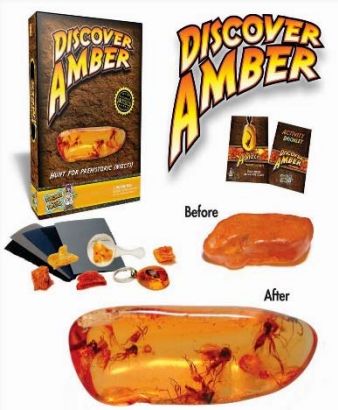
How to Discover by RBC and E-CARGO?



General Coverage (RBC) + Special Points (E-CARGO)

- Role Negotiation in $\mathcal{A}$, $\mathcal{R}$, $\mathcal{E}$
- Agent Evaluation + special requirement in $\mathcal{A}$, $\mathcal{R}$, $\mathcal{E}$
- Role assignment/transfer + special conditions in $\mathcal{A}$, $\mathcal{R}$, $\mathcal{E}$
  - GRACAR/G, GMRA
- Role Execution: Simplify the problems of Multi-Agent Systems and solve them.

GRA=>GRA$^+$

(GRACAR/G, GMRA, GRACCF, GRAB, GRABC)

(A^c, L^a , C^{cf} , P_a , B)

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS: SYSTEMS

Group Role Assignment With Cooperation and Conflict Factors

Haibin Zhu, *Senior Member, IEEE*, Yin Sheng, Xianzhong Zhou, *Member, IEEE*, and Yu Zhu

***Abstract*—Collaboration is complex. To solve a p**
occurring in collaboration, using computers, we must firs
and specify the problem. This paper presents a chal
problem in collaboration, called group role assignment wit
eration and conflict factors (GRACCFs). This problem's

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

IEEE TRANSACTIONS ON CYBERNETICS

Balance Preferences with Performance in Group Role Assignment

Dongning Liu, *Member, IEEE*, Yunyi Yuan, Haibin Zhu, *Senior Member, IEEE*, Shaohua Teng, and Changqin Huang, *Member, IEEE*

This article has been accepted for inclusion in a future issue of this journal. Content is final as presented, with the exception of pagination.

IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS: SYSTEMS

Maximizing Group Performance While Minimizing Budget

Haibin Zhu, *Senior Member, IEEE*

1

work in RBC has clarified the differences between
RBC [1], [6]. In short words, RBC utilizes roles as
tal mechanisms to facilitate collaboration but RB
control. Roles in RBC specify both rights and respo
but those in RBAC emphasize rights [1], [6].

How to verify?

-Simulation

-Comparison

How to compare (Method 1)? (Team Performance)

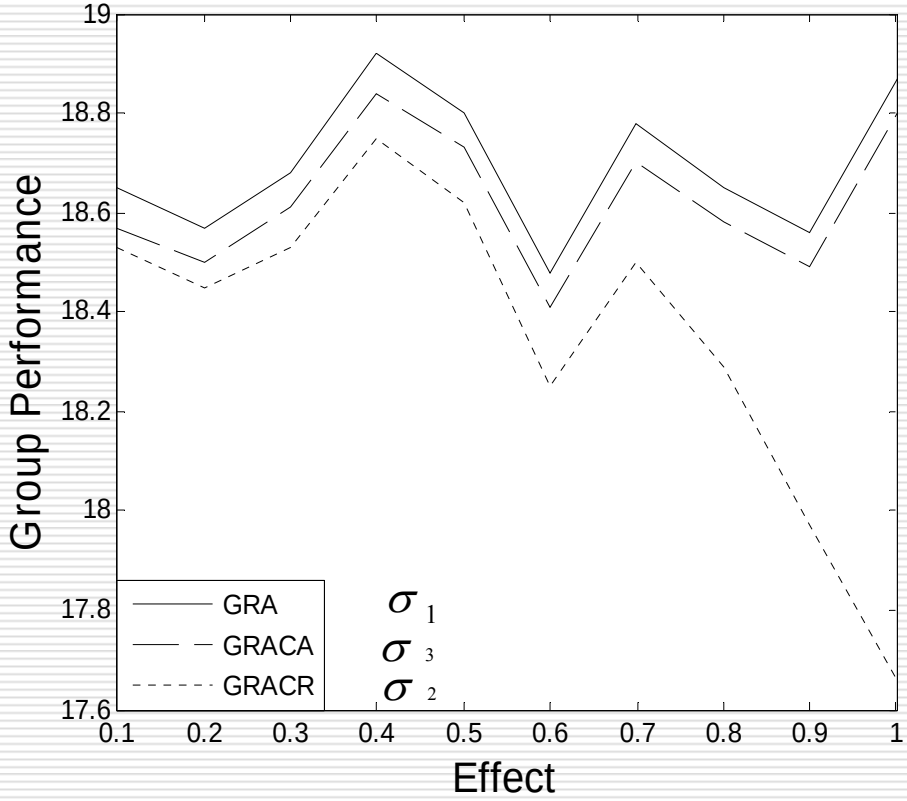
$$\sigma_1 = \sum_{i=0}^{m-1}\sum_{j=0}^{n-1} Q[i,j] \times T[i,j](GRA[ideal])$$

$$\sigma_2 = \sum_{i=0}^{m-1}\sum_{j=0}^{n-1} Q[i,j] \times T'[i,j](GRA+)$$

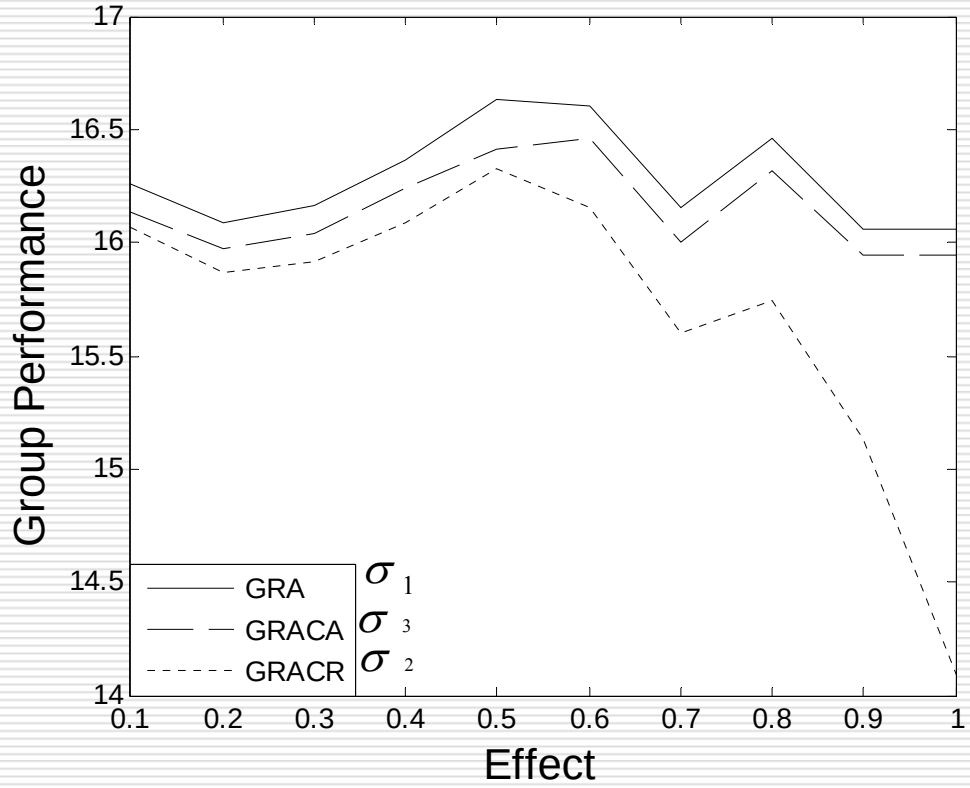
$$\sigma_3 = \sum_{i=0}^{m-1}\sum_{j=0}^{n-1} Q'[i,j] \times T[i,j](GRA[real])$$

$$\lambda = (\sigma_2 - \sigma_3)/\sigma_3$$

Example: (GRACAR)



m =30, n =10, p_c =10%, 1≤$L[j]$ ≤3.



m =30, n =6, p_c=10%, 1≤$L[j]$≤5.

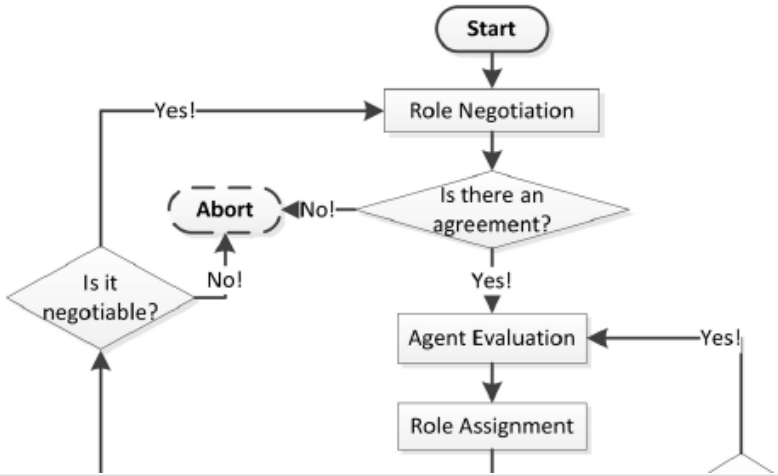
H. Zhu, "Avoiding Conflicts by Group Role Assignment", *IEEE Trans. on Systems, Man, and Cybernetics: Systems*, vol. 46, no. 4, April 2016, pp. 535-547.

IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS: SYSTEMS, VOL. 46, NO. 4, APRIL 2016 535

Avoiding Conflicts by Group Role Assignment

Haibin Zhu, *Senior Member, IEEE*

***Abstract*—Role assignment is a critical element in the role-based collaboration process. There are many constraints to be considered when undertaking this task. This paper formalizes the group role assignment problem when faced with the constraint of conflicting agents, verifies the benefits of solving the problem, proves that such a problem is a subproblem of the extended integer linear programming (x-ILP) problem, proposes a practical approach to the solution, and assures performance based on the results of experiments. The contributions of this paper include: 1) formalization of the proposed problem; 2) verification of the benefit achieved by avoiding conflicts in role assignment through simulation; 3) theoretical proof that conflict avoidance is a subproblem of the x-ILP problem that is nonpolynomial-**



How to compare (Method 2)? (Solution efficiency)

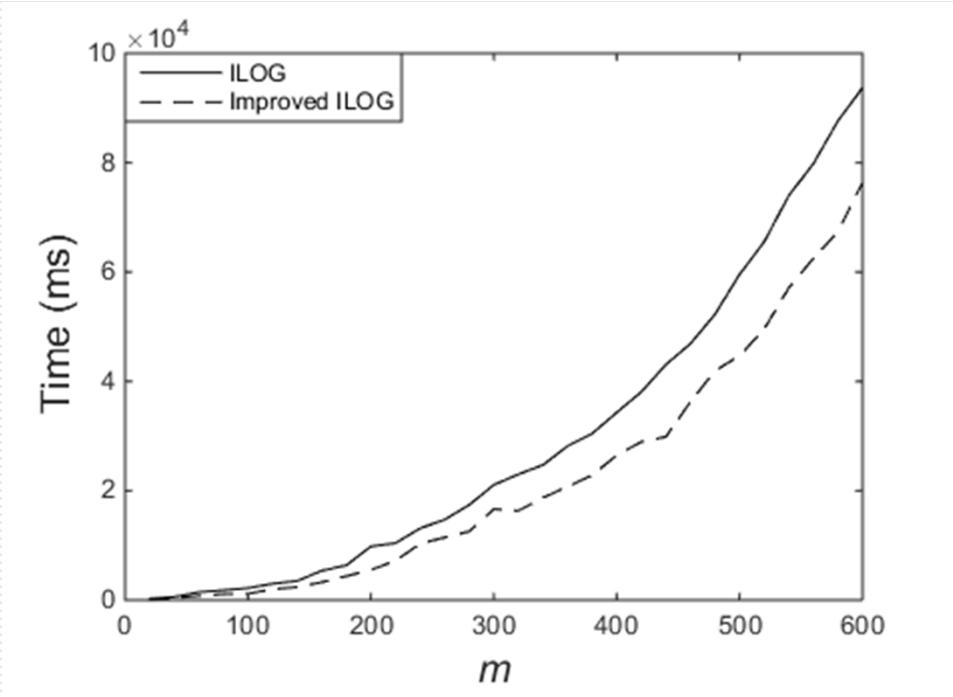
- 1. Find necessary/sufficient conditions for a GRA+ problem;
- 2. Design algorithms to check the necessary/sufficient conditions;
- 3. Set up simulation cases;
- 4. Compare with CPLEX by solving 100 problems.

Example: Theorems for GMRA

- *Theorem 1:* The necessary condition for the GMRA problem to have a feasible solution is that $\sum_{i=0}^{m-1} L^a[i] \geq \sum_{j=0}^{n-1} L[j]$
- *Theorem 2:*

  GMRA (with Q, T, L, and L^a) has a feasible solution if and only if there exists an integer q, such that L_q is empty and for each i, $L_i^* \leq | L_{i-1} L^a_i |$ $(0 < i \leq q)$.

Comparison with ILOG CPLEX solutions



The times used by processing 100 problems
(n=m/2,1≤$L[j]$≤20, and 1≤$L^a[j]$≤10)

H. Zhu, D. Liu, S. Zhang, S. Teng, and Y. Zhu, "Solving the Group Multi-Role Assignment Problem by Improving the ILOG Approach", *IEEE Trans. on Systems, Man, and Cybernetics: Systems*, vol. 47, no. 12, Dec. 2017, pp. 3418-3424.

Correspondence

Solving the Group Multirole Assignment Problem by Improving the ILOG Approach

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***Abstract*—Role assignment is a critical element in the role-based collaboration process. There are many different requirements to be considered when undertaking this task. This correspondence paper formalizes the group multirole assignment (GMRA) problem; proves the necessary and sufficient condition for the problem to have a feasible solution, provides an improved IBM ILOG CPLEX optimization package solution, and verifies the proposed solution with experiments. The contributions of this paper include: 1) the formalization of an important engineering problem, i.e., the GMRA problem; 2) a theoretical proof of the necessary and sufficient condition for GMRA to have a feasible solution; and 3) an improved ILOG solution to such a problem.**

by GMRA, we mean assigning a limited number of different roles to each agent within the scenario of GRA.

GMRA is, in fact, a GRA problem while considering the current role and potential roles together, based on our previous work in solving role transfer problems [20]–[26].

GMRA is common in the real-world. For example, in a team, different people (agents) may be assigned with a limited number of jobs (roles). In a university, a professor (agent) is assigned with at most three different courses (roles) to teach and a student (agent)

RBC & E-CARGO could contribute to or be contributed:

- Optimization
  - More problems are discovered with E-CARGO
  - Use Opt methods to solve RBC problems
- Multi-Agent Systems
  - Combine Collectivism/Individualism
- Parallel Computing
  - Parallel algorithms for RBC problems.
  - Solving RBC problems may provide solutions to the key problems of parallel computing, e.g., load balance, resource management, and CPU scheduling.
- Cutting-Edge Technologies
  - IoT, Smart City, Social Networking, Social Simulation, Scheduling, Adaptive Systems, AI () …
- Health
  - Human Body Simulation/Teamwork for diagnosis and treatment

Conclusion

结语

The greatest is the simplest! Keep it simple!

Collaboration

=

Task Distribution

+

(Co-)Operation (Task Execution)

RBC is…

- A computational methodology
- A discovery methodology

E-CARGO is the model for RBC

- Negotiation, Evaluation, Assignment, and Execution
- m, n, L, Q, T, A^c, L^a, C^{cf}, P, B,
- i, j

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Question?

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