Role-Based Collaboration and E-CARGO

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Sponsors: IBM, NSERC, OPIC, and DRDC-Canada
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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/

How Important is Team Work

According to a recent survey by the University of Phoenix, Americans know that teamwork is vital to their work lives—but that does not mean that they have to like it. This online survey was taken by 1,019 Americans nationwide age 18 and older from all walks of life in November 2012, and it highlights the love-hate relationship most American workers have with working in teams.

The vast majority of those who have worked in teams say teams are important in the workplace.

- 24% prefer working alone
- 95% say teams are important

But few of them prefer working in teams.

- 68% have worked in dysfunctional teams
- 40% have seen verbal confrontations
- 15% saw physical confrontations in work teams

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:

Task Distribution  Task Execution

Task Distribution  Task Execution
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 roles as underlying mechanisms to facilitate collaboration activities (abstraction, classification, separation of concerns, dynamics, coordination and interactions).

2006
RBC and E-CARGO have been investigated for >15 years!

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

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

Role-based collaboration (RBC) is emerging into an *investigative* methodology that mainly uses roles as the key component 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
The user of this chart is the manager!
The Model

E-CARGO
The E-CARGO model

\[ \Sigma ::= \langle C, O, A, M, R, E, G, s_0, H \rangle \]

**Environments**

- **Classes**
- **Agents**
- **Roles**
- **Groups**
- **Objects**

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 of a role-based collaboration, presenting the concept, requirements, and principles of role-based collaboration, proposing a model for role-based collaboration, and describing the kernel mechanisms and their implementation to facilitate the development of role-based collaborative systems for industrial applications.

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


Role mechanisms in collaborative systems

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(Received May 2005)
The Initial Internal Elements of E-CARGO (2006)

c ::= ⟨n, D, F, X⟩
o ::= ⟨n, c, s⟩

r ::= ⟨n, I, Na, No⟩
a ::= ⟨n, ca, s, Nr, Ng⟩
e ::= ⟨n, B⟩

\[ g = \langle n, e, J \rangle \]

m ::= ⟨n, v, l, P, t⟩

The Revised Internal Elements of E-CARGO (2015)

\[ r ::= \langle id, M_r, s, d, \alpha, \beta, A_c, A_p, A_o, R_r, O_r \rangle \]
\[ a ::= \langle id, c, s, V, \alpha, \beta, r_c, R_p, R_o, N_g \rangle \]
\[ e ::= \langle id, R_e, \$, B \rangle \]
\[ g = \langle id, e, A_g, J \rangle \]
\[ \mathcal{J} ::= \langle id, r, f, P, l, \alpha, \beta \rangle \]

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 $\mathcal{G}$

- By combing with $C$ and $O$, we can investigate more!
The *Q* Matrix: result of role negotiation and agent evaluation

$$
\begin{array}{cccc}
  & r_0 & r_1 & r_2 & r_3 \\
 a_0 & 0.71 & 0.6 & 0.0 & 0.22 \\
 a_1 & 0.29 & 0.67 & 0.44 & 0.76 \\
 a_2 & 0.69 & 0.92 & 0.92 & 0.6 \\
 a_3 & 0.0 & 0.0 & 0.53 & 0.0 \\
 a_4 & 0.97 & 0.51 & 0.77 & 0.65 \\
 a_5 & 0.58 & 0.64 & 0.24 & 0.0 \\
\end{array}
$$
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.
- $L[j]$ expresses how many agents are required by role $j$
- 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

\[
T[i, j] \in \{0, 1\} \quad (0 \leq i < m, 0 \leq j < n) \quad \ldots(1)
\]

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

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

\[
L = \begin{bmatrix}
2 & 1 & 1 & 2
\end{bmatrix}
\]

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

(a) 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

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

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

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

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

$$A^c[i_1, i_2] \times (T[i_1, j] + T[i_2, j]) \leq 1 (0 \leq i_1, i_2 < m, i_1 \neq i_2, 0 \leq j < n) \quad (4) /$$

$$A^c[i_1, i_2] \times (T[i_1, j_1] + T[i_2, j_2]) \leq 1 (0 \leq i_1, i_2 < m, i_1 \neq i_2, 0 \leq j_1, j_2 < n) \quad (5)$$
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 $i$ by agent $i$.

RBC is an innovative discovery methodology in engineering research.

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

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$^c$ 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

$T[i, j] \in \{0, 1\}$ \hspace{1cm} $0 \leq i < m, 0 \leq j < n$ \hspace{1cm} (1)

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

$\sum_{j=0}^{n-1} T[i, j] \leq L^a[i]$ \hspace{1cm} $0 \leq i < m$ \hspace{1cm} (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

Current roles

a0  a1  a2  a3  a4  a5  a6  a7  a8

r0  (2)
r1  (2)
r2  (1)
r3  (3)

Potential roles

a0  a1  a2  a3  a4  a5  a6  a7  a8

Not workable group

Workable group

r0  (2)
r1  (2)
r2  (1)
r3  (3)
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.
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 performance may affect the team performance and the team GRA+Time->DGRA
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)

Group Role Assignment With Cooperation and Conflict Factors
Haibin Zhu, Senior Member, IEEE, Yin Shene, Xianzhong Zhou, Member, IEEE, and Yu Zhu

Abstract—Collaboration is complex. To solve a problem occurring in collaboration, using computers, we must first define and specify the problem. This paper presents a class of problems in collaboration, called group role assignment with cooperation and conflict factors (GRACF). This problem’s

Balance Preferences with Performance in Group Role Assignment
Dongning Liu, Member, IEEE, Yunyi Yuan, Haibin Zhu, Senior Member, IEEE, Shaohua Teng, and Changxin Huang, Member, IEEE

Maximizing Group Performance While Minimizing Budget
Haibin Zhu, Senior Member, IEEE
How to verify?
- Simulation
- Comparison
How to compare (Method 1)?
(Team Performance)

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

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

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

\[
\lambda = \left(\sigma_2 - \sigma_3\right) / \sigma_3
\]
Example: (GRACAR)

\[ m = 30, n = 10, p_c = 10\%, 1 \leq L[j] \leq 3. \]

\[ m = 30, n = 6, p_c = 10\%, 1 \leq L[j] \leq 5. \]
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

\[ n = \frac{m}{2}, 1 \leq L[j] \leq 20, \text{ and } 1 \leq L^a[j] \leq 10 \]
Correspondence

Solving the Group Multirole Assignment Problem by Improving the ILOG Approach

Haibin Zhu, Senior Member, IEEE, Dongning Liu, Siqin Zhang, Shaohua Teng, and Yu Zhu

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
- $m, n, L, Q, T, A_c, L^a, C_{cf}, P, B,$
- $i, j$
Question?

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