A Framework for Cohesive Healthcare Coalition Formation

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Abstract. The mobilisation of cohesive and effective groups of healthcare human resource is important in ensuring the success of healthcare organisations. However, forming the right team or coalition in healthcare organisations is not always straightforward due to various human factors. Traditional coalition formation approaches have been perceived as 'materialistic' or focusing too much on competency or pay-off. Therefore, to put prominence on the human aspects of working together, we present a cohesiveness-focused healthcare coalition formation methodology and framework that explores the possibilities of social networks, i.e. the relationship between various healthcare human resources, and adaptive resonance theory.
Keywords: Coalition Formation, Social Networks, Adaptive Resonance Theory.

1. Introduction

The practice of healthcare and the success of healthcare organisations are highly dependent on the expertise and experience of various healthcare human resources. Although each doctor, nurse or technician is responsible in their respective specialised task, the mobilisation of cohesive and effective groups of healthcare human resource is equally if not more important. Well-established healthcare organisations, while being aware of the need for effective knowledge and human capital management, stand to gain more when cohesive teams or coalitions are formed within the organisation for knowledge and experience-intensive tasks such as surgery and trauma management.

Efforts to define computational frameworks for coalition formation in organisations are actively being pursued, especially from an organisational behaviour or human resource perspective [1]. However, forming the right team in healthcare organisations is not always straightforward especially when human factors come into play. Traditional coalition formation approaches such as Game Theory [2][3][4] and Social-dependence Theory [5][6] have their limitations in view that they are perceived to be 'materialistic' or focusing primarily on competency, performance and pay-off.

To put prominence on the human aspects of working together, we present a cohesiveness-focused healthcare coalition formation methodology and framework. Here, we aim is to explore the potentials of social networks (that focus on the relationship between various healthcare human resources) and adaptive resonance theory (ART).

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2. Overview of the Healthcare Coalition Formation Methodology

Our proposed methodology for healthcare coalition formation consists of two phases (see Figure 1):

1. Coalition Formation: Upon receiving a work request and relevant inputs from the user, this phase checks for the physical availability of human resources and their cohesiveness, i.e. whether or not a particular group of doctors, nurses or technicians can work together effectively and comfortably. This phase not only utilises a straightforward lookup mechanism to check the physical availability of human resources, it also ensures the cohesiveness of a candidate coalition. The latter employs a novel combination of social networks and ART. The result of this phase is a candidate coalition.
2. Scheduling: The available group of employees is checked to ensure that they are available for the duration of the task. If there is a mismatch in the schedule of the employees, an alternative candidate coalition is generated via the coalition formation phase. When the candidate coalition clears the scheduling phase, a finalised coalition is obtained.

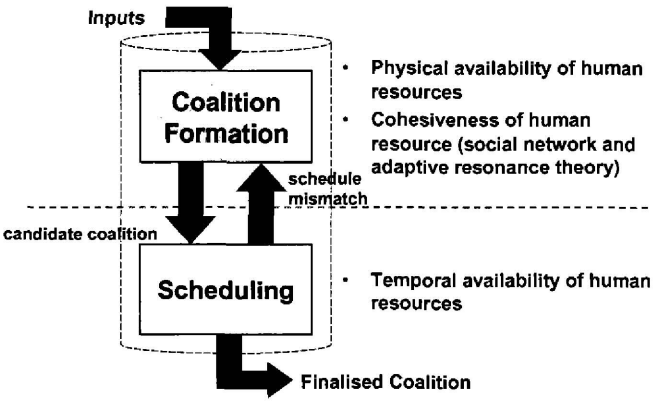

Figure 1: Overview of the Coalition Formation Methodology

Our two-phased methodology can be translated into a framework consisting of the following three layers (see Figure 2):

1. Object Layer: In general, this layer stores various resources. For our purposes, it stores human resource knowledge (e.g. of specialists, nurses, technicians, etc.). This can be viewed as a virtual community of agents represented as nodes, each having its own public and private knowledge. Public (or social) knowledge includes the agent's profile, constraints and schedule; while private knowledge refers to personality, preferences and credibility [7][8].
2. Manager Layer: Three manager components interact with the object layer agents and delivery layer interface to carry out their tasks.
   - Interface Manager: The interface manager receives requests from the user and passes on the relevant inputs to the other manager components to initiate the coalition formation activity. Upon receiving a finalised coalition as the result, the interface manager passes it on to the user.
   - Coalition Manager: The coalition manager carries out the tasks of the coalition formation phase mentioned earlier. It receives the relevant

inputs from the interface manager and identifies which human resource agents at the object layer are available to form a coalition. Following this, the coalition agent analyses the social network of the available human resources by determining their relationship values. It then applies ART on the relationship values to produce a candidate coalition.

- Scheduling Manager: The scheduling manager performs the scheduling phase of our healthcare coalition formation methodology. It checks the candidate coalition for scheduling mismatches. Mismatched human resources are sent back to the coalition manager for other coalition alternatives, while a candidate coalition that does not have mismatched schedules are returned to the interface manager as a finalised coalition.

3. Delivery Layer: This layer is basically the user interface from which the user can submit requests for coalitions with accompanying inputs, and receive the finalised coalition results.

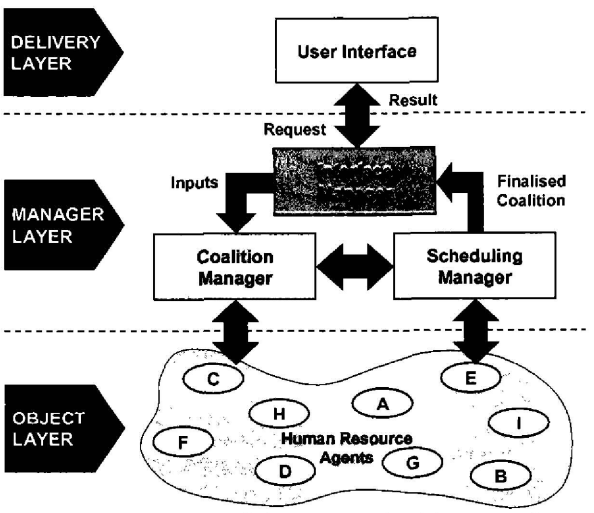

Figure 2: The Coalition Formation Framework

Presently, we aim to focus on the first phase of our coalition formation methodology, i.e. to ensure cohesiveness by employing social networks and ART. The second phase, i.e. scheduling, is beyond the scope of this paper. We now present details of the coalition manager, i.e. the main component for the coalition formation phase.

3. The Coalition Manager

The coalition manager carries out two main functions: social network management and ART.

3.1. Social Network Management

The coalition manager interacts very closely with the human resource agents at the object layer. The community of human resource agents, i.e. doctors, nurses,

technicians, etc., is represented as nodes and the relationships between agents are represented as arcs (with corresponding relationship values) (see Figure 3). Their relationships are asymmetrical, i.e. the relationship doctor A has on technician B is not necessarily the same as the relationship technician B has on doctor A, as each agent has its own personality, preferences and credibility. The relationship value an agent has on another agent is a composite value derived from questionnaire-based credibility and personal trait assessments during their past interactions [8][9].

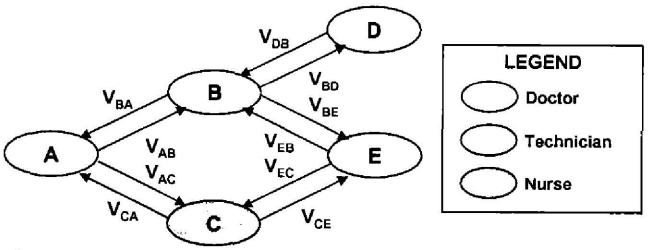

Figure 3: Nodes and arcs representing human resource agents and their relationships

Let us assume the following:

- $V_{X\text{-}|\text{-}Z}$ = relationship value between X and Z, and
- agents X and Z are coherent, i.e. having a significant amount of positive or good experience working together, if $V_{X\text{-}|\text{-}Z} > e$ (the coherency threshold).

Let us also assume three possible ways for agent Z to be connected to agent X:

1. if Z is directly connected to X ($V_{X\text{-}Z}$ = relationship value of X on Z, $V_{Z\text{-}X}$ = relationship value of Z on X), then $V_{X\text{-}|\text{-}Z} = V_{X\text{-}Z} = (V_{X\text{-}Z} + V_{Z\text{-}X})/2$,
2. if Z is indirectly connected to X via Y, then $V_{X\text{-}|\text{-}Z} = V_{X\text{-}Y\text{-}Z} = V_{X\text{-}Y} \bullet V_{Y\text{-}Z}$, and
3. if Z is connected to X via n different paths $(V_{X\text{-}|\text{-}Z})_1 \ldots (V_{X\text{-}|\text{-}Z})_n$, i.e. with multiple indirect connections, then $V_{X\text{-}|\text{-}Z} = \dfrac{\sum_{i=1}^{n} (V_{X\text{-}|\text{-}Z})_i}{n}$.

As an example, let us consider a healthcare environment with a number of human resources agents as shown in Figure 3. Doctor A has previously worked directly with technician B and nurse C; but not with doctor D or technician E. However, technician B has prior experience working with doctor D and technician E. These result in doctor A being indirectly connected to doctor D and technician E via technician B. Therefore, in order to calculate doctor A's relationship with all colleagues, various direct, indirect and multiple indirect relationships need to be considered.

Table 1 summarises the relationship values for all agents from Figure 3. By default, $V_{X\text{-}X} = 1$; and $V_{X\text{-}Y} = 0$ when $V_{X\text{-}Y} < e$.

Table 1: Relationship values for all human resource agents

Agent	A	B	C	D	E
A	1	$V_{B\text{-}\|\text{-}A}$	$V_{C\text{-}\|\text{-}A}$	0	$V_{E\text{-}\|\text{-}A}$
B	$V_{A\text{-}\|\text{-}B}$	1	$V_{C\text{-}\|\text{-}B}$	0	$V_{E\text{-}\|\text{-}B}$
C	$V_{A\text{-}\|\text{-}C}$	$V_{B\text{-}\|\text{-}C}$	1	0	$V_{E\text{-}\|\text{-}C}$
D	0	0	0	1	0
E	$V_{A\text{-}\|\text{-}E}$	$V_{B\text{-}\|\text{-}E}$	$V_{C\text{-}\|\text{-}E}$	0	1

coalitions. These candidate healthcare coalitions are then passed on to the scheduling manager that would then ensure the human resource agents, whilst being socially cohesive, are available during the period of the task.

4. Concluding Remarks

In general, our cohesiveness-focused healthcare coalition formation methodology can be viewed as a hybrid methodology that takes into account the human factor in social interactions as well as artificial intelligence techniques such as ART in order to form suitable coalitions for a particular task.

Presently, we have laid out details of the coalition manager. The development of the entire healthcare coalition formation framework is still in progress. The way forward would be to explore details of the scheduling and interface managers. We expect constraint-related techniques as well as evolutionary algorithms [11] to be relevant, especially for the scheduling manager. This would be challenging due to the complex nature of shift work in the healthcare environment. Ultimately, we hope that this framework can be integrated into existing healthcare-related groupware to capitalise on existing human resource profiles that may have already been stored. This can further enhance the quality of coalitions formed in healthcare organisations.

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Having obtained a set of relationship values for each human resource agent in the community, the coalition manager represents each column of Table 1 as a vector $I \equiv (I_1, \ldots, I_M)$, where M is the number of human resource agents in a community. For instance, the vector for agent A is $I_A \equiv (1, V_{A\text{-}|\text{-}B}, V_{A\text{-}|\text{-}C}, 0, V_{A\text{-}|\text{-}E})$. The M number of input vectors serve as inputs for the coalition manager to carry out adaptive resonance to generate the candidate healthcare coalitions.

3.2. Adaptive Resonance Theory

ART is basically an artificial neural network employing unsupervised learning [10]. It is characterised by comparison (input) and recognition (output) fields, a vigilance parameter and a reset module. A basic ART network is shown in Figure 4.

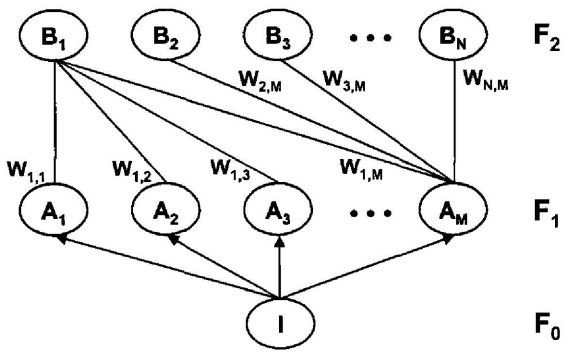

Figure 4: ART network architecture

The coalition manager maintains three levels of ART field activity vectors:

- Level F_0: This level consists of a node which represents the current input vector, I for an agent (obtained from the social network management's relationship value calculation).
- Level F_1: This level consists of as many nodes as there are human resource agents. The F_1 activity vector, i.e. the values of the nodes, is denoted as $A = (A_1, \ldots, A_M)$.
- Level F_2: Nodes at this level represents the candidate healthcare coalitions formed. The F_2 activity vector is denoted as $B = (B_1, \ldots, B_N)$.

Associated with each candidate healthcare coalition node j ($j = 1, \ldots, N$) of F_2 is a vector $w_j \equiv (w_{j1}, \ldots, w_{jM})$ of adaptive weights. The number N, which indicates possible 'slots' for candidate healthcare coalitions, may be arbitrarily large.

The ART network takes input vectors from F_1 and sends them to F_2. In the process, the weights between F_1 and F_2 are updated and the matching process of comparing the relationship value of each F_1 node with the respective weights from the previous cycle would result in certain F_2 nodes to be chosen (representing candidate healthcare coalitions). As more input vectors are put into the network, and as these inputs meet the required vigilance criteria (which determines whether the coalitions are fine-grained or general), the formation of the candidate healthcare coalitions strengthens in line with the concept of establishing resonance.

The human resource agents associated with the same candidate healthcare coalition node in F_2 are deemed coherent to each other and thus, form cohesive candidate

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Information technology helps to improve the quality of health care by disseminating and systematizing knowledge of diagnostic and therapeutic possibilities as well as the organization and management of care. Unobtrusive, active, non-invasive technologies, including wearable devices, allow us to continuously monitor and respond to changes in the health of a patient. Such devices range from micro-sensors integrated in textiles, through consumer electronics, to belt-worn personal computers with head mounted displays.

Such ubiquitous computing allows us to identify new ways of managing care that promises to be considerably easier in letting patients maintain their good health while enjoying their life in their usual social setting, rather than having to spend much time at costly, dedicated health care facilities. It may prove essential for ensuring quality of life as well as health care for increasingly aging societies.

In addition to the "traditional" topics of health and biomedical informatics, "ubiquity: technologies for better health in aging societies", a promising field for the future of health care, has been chosen as special topic for MIE2006.

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