Levels of Interoperability in Coalition Systems[1]

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Abstract

Systems of different command centers that are brought together in a coalition operation must have some level of interoperability in order to work together. Bares [2000] has introduced a formalism of three interoperability domains that describe the ability of the systems to define their own level of interoperability within the coalition by assessing their own and the other systems' ability to interact on actions of the coalition. The lowest domain, interconnectivity, reflects the ability to exchange messages; this level must already have been achieved in order for the systems to participate in the coalition. The second domain, interoperability, reflects a system's ability to identify what tasks it is able to interoperate on. The third level, intercooperability, indicates that all systems have the ability to evaluate all other systems in the coalition. By describing the interoperability domains in this manner, the domains represent increasing levels of awareness of each system's own capabilities and those of the other systems; it represents the transition from exchanging data to exchanging knowledge. This research looks particularly at the interoperability level and the ability of systems to evaluate their own interoperability on the coalition's actions by using Bares' formalism of interoperability to assign actions to systems participating in the coalition.

1.0 Introduction

As organizations from different nations join together to form a coalition, the capability of their systems to interoperate determines the effectiveness of the coalition. As new organizations join the coalition, and also when organizations leave, the coalition needs to determine what tasks each system should participate in and how to reassign tasks that were allocated to departing organizations. This is one aspect of interoperability, assessing which systems are able to interact on what functional areas or tasks, and which particular systems are capable to carry out particular actions that compose the tasks of the coalition mission. In order to make these assessments, systems can be characterized at different levels of their understanding of their own abilities and those of the other systems in the coalition.

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Bares [2000] defined a cooperative framework for systems in a coalition that distinguishes three levels, or domains, of interoperability. Each domain is a prerequisite for the following domain and each domain can be characterized by the definition of the relationship between the coalition systems and their ability to assess their own and other systems interoperable actions as defined in that domain. The first or lowest level is interconnectivity. Interconnectivity refers to all the necessary means to allow systems to communicate with each other; some standards or protocols may be required. Interconnectivity is necessary in order for a system to define what other systems it can interoperate with in the coalition context.

The next level, or domain, is interoperability[2]. Interoperability is described by the ability to assess meaning between cooperative systems. This enables the systems to assist in their cooperative actions in order to reach a common objective and to understand what they are capable of doing. The interoperability domain is characterized by the ability of every system in the coalition to assess its own competence on actions within the coalition.

Intercooperation, the highest domain, implies that the systems are able to share much, if not all, information relating to their common activity and can act to assist each other. "This represents the final objective to reach, through the definition of a world, in which all cooperative systems are able to share all elements constituting their common activity in the cooperation, but also, to take systematically advantage of everything that is appealing to intelligent behavior" [Bares, 2000]. The intercooperability domain is characterized by the ability of every system in the coalition to assess its own, and every other system's in the coalition, competence on the actions in the coalition.

Much work has been done in defining levels of interoperability for information systems in the C4ISR area, in particular, the Levels of Information Systems Interoperability (LISI) Reference Model [LISI, 1998]. The LISI model was developed to define interoperability between information systems and identifies the stages through which systems should logically progress or "mature" in order to improve their ability to interoperate. The five levels are identified by terms that describe both the level of interoperability and the environment in which it occurs. While the LISI model is technical in nature, and does not include the role of people and knowledge in C2 support, it does expand the definition of interoperability beyond the ability to move data from one system to another: it considers the ability to exchange and share services between systems. This approach is different than Bares' in the sense that each level is evaluated based on its technical attributes at that level, rather than its assessment of knowledge.

Clark and Jones [1991] have also proposed a model of organizational interoperability that extends the LISI model into the more abstract layers of C2 support, i.e., the organizational layers. It examines, in particular, the role of people and knowledge within a C2 system. Even though information systems may be compatible and interoperable, if the participating organizations do not have the ability to interoperate, their effectiveness

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[2] Interoperability is the ability of systems, units, or forces to provide services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together (Joint Pub 1-02).

in a given situation will be substantially reduced. This model proposes an organizational interoperability model that defines attributes with a "people" emphasis.

The composition of a coalition may change over time, i.e. new organizations may join after the initial coalition has been formed, and some organizations may leave before the mission is accomplished. This means that the allocation of the coalition's systems to tasks becomes an important aspect of the coalition, as it may change dynamically. Bares' approach is from the participating systems' point of view and the different levels of interoperability represent increasing system sophistication. The coalition must define and assign the actions required for its mission. In the initial phase of the coalition, the lead organization may be in the best position to establish the initial assignments. This is similar to the heuristic used by Perdu and Levis [1999] to maintain a balanced "workload" across all systems. The mission may also be defined in a way that the actions are divided into geographic sectors [Heacox, 1999]. However, if a system can state a measure on its ability to perform each action as it enters the coalition, then the system can be mapped to actions based on its strengths; this is hypothesized to result in superior coalition performance.

Models can be used to test hypotheses about the behavior of coalitions. The model represents a template for the coalition design; it can be populated with data from different coalition architectures in order to evaluate different aspects of coalition operations, including interoperability of heterogeneous systems. Virtual experiments can be conducted in order to evaluate alternative coalition architectures by simulating their behavior under different scenarios. Using an executable model of a coalition composed of interacting systems, a virtual experiment was conducted that compared four different methods of assigning systems to actions in a coalition operation. The model was populated with data from a scenario created for investigating heterogeneous command center interactions. Applying Bares' interoperability concepts to the coalition problem contributes to the larger question of designing heterogeneous command centers that can dynamically adapt over time.

In the next section Bares' interoperability formalism is described. Section 3 describes the coalition model to be used in a virtual experiment, while Section 4 describes the experimental design and results. Section 5 concludes the paper.

2.0 The Interoperability Formalism

In a coalition, systems from different organizations are joined together to resolve a specified mission in a specified domain. The goal of the systems is to obtain a shared understanding of the mission and then act together to effect transformations on the domain to accomplish the mission. In order for this to occur, each individual system must understand the domain, its abilities within this domain, and which systems are best for which actions within the domain. Bares [2000] has defined a set of formalisms which characterize the interoperability domain based on this concept.

A system in the coalition is designated by S^i where $i \in [1, n]$, n being the number of systems in the coalition. Each system in the coalition is aware of what functionality it brings to the coalition. A set of interoperable actions compose a functional area or a task. A task is designated by T_k where $k \in [1,q]$, q being the number of tasks of the coalition. Each task includes a variable number of actions depending on the mission; an action will be designated by A_j. An action is assigned to an individual system to perform. A mission, M_c can be regarded as a set of systems participating in a series of tasks and performing actions specified by mission orders, O_p indicating the order of operations, established under particular conditions and valid in a temporal interval θ_M. The mission can then be characterized as

$$M_c(O_p(T_k,S^i,(A_j,\theta_M))).$$

The key concept at this level of interoperability becomes the mapping of the appropriate system to specific actions that, when completed, will achieve the mission, $S^i(A_j,\theta_M)$. The temporal interval, θ_M, may be dropped if the time window's limits are well defined in the coalition order of operations [Bares, 2000]. Mapping a system to an action implies that the system is capable on and available to carry out that action and that the system has the current knowledge on that action. However, there may be precedence constraints in mapping systems to actions, that is, one action may need to be completed before another can be initiated, as indicated by the order of operations. There also may be alternatives or conflicts in mapping systems to actions, as one action may be completed by a choice of systems; or when a system is mapped to one action it may become unavailable to be mapped to alternative actions.

An intermediary domain, the openness domain, is defined which groups systems based on their competence on the different tasks. The openness context enumerates for each system all the tasks it is competent to act on. Systems that are competent on the same tasks are grouped together. These "interoperable groups" are then required to have a basic interoperability; this implies that they have achieved interconnectivity and share some basic knowledge on the task and understand some common fundamental orders. By defining the openness structure of the coalition, the subject matter relevant to the interoperability domain of each interoperable group of systems is limited. In this way, *not every system in the coalition has to be interoperable, only those systems working together in an interoperable group.*

Every system within an interoperable group evaluates every action within its openness context and indicates whether or not the system is competent to interoperate on that action, i.e., systems in the coalition evaluate their own abilities to perform actions. This allows each system to determine a first condition of its interoperability on each action. The relation $\Re$ defines an effective interoperability: if S^i gauges itself to be competent on action A_j, $\Re$ takes the value 1; if S^i gauges itself to be incompetent on action A_j, $\Re$ takes the value 0. This determines a vector of the interoperable capacity of system S^i on action A_j:

$$[\Re (S^i, A_j)] \qquad \forall\, i \in [1,n] \ \text{ and } \ \forall\, j \in [1,p].$$

For a given system S^i, by successively applying the relation $\Re$ to pairs (S^i, A_j), j varying from 1 to p, a binary vector is obtained with as many elements as there are actions. These elements, indicators of the interoperability of S^i on A_j, form the vector of effective interoperability for system S^i. By applying the relation $\Re$ to all S^i, i varying from 1 to n, there will be as many vectors as systems in the coalition. These vectors are then combined to form the interoperability matrix. This matrix can be used to indicate what is theoretically the most interoperable system relative to a determined action and gives the most acceptable system to operate under the indicated conditions.

3.0 The Coalition Model

A model of a coalition has been developed in order to evaluate the effect of different attributes of coalition architectures, including system interoperability. The purpose of the model is to provide a mathematical platform to conduct virtual experiments on different aspects of coalition design. The coalition model is generic in nature and can be instantiated with different coalition architectures and scenarios. The basis of the model is the interacting five-stage decision maker model.

3.1 The Five-Stage Interacting Decision Maker Model

Levis [1992] described a five-stage decision maker model that was the culmination of years of research and evolution. It began with the investigation of tactical decision making in a distributed environment with efforts to understand cognitive workload, task allocation, and decision making. The five-stage model allows the algorithm in each stage to be defined and makes explicit the inputs and outputs of the decision maker, and has a well-defined algorithm for computing workload. This has become a consistent model for fixed and variable structure organizations. Perdu and Levis [1998] described an adaptive decision maker model that used an object class to represent the ability of decision makers to dynamically adapt with local adaptation. Handley et al. [1998] explored pre experimental modeling for subject experiments. This model allowed decision makers to complete coordinated tasks. Finally Handley [1999] returned to the five-stage paradigm to create an adaptive five-stage decision maker model that combined local and global adaptation within the five-stage approach. The term "decision maker" is used to represent a processing node that can make a determination between alternative actions; it can be either human or non-human.

The five-stage decision maker model of Levis [1992] is shown in Figure 1. The decision maker receives a signal, x, from the external environment or from another decision maker. The Situation Assessment stage (SA) represents the processing of the incoming signal to obtain the assessed situation, z, which may be shared with other decision makers. The decision maker can also receive situation assessment signals z' from other decision makers within the organization; z' and z are then fused together in the Information Fusion (IF) stage to produce z''. The fused information is then processed at the Task Processing (TP) stage to produce v, a signal that contains the task information necessary to select a response. Command information from other decision makers is received as v'. The Command Interpretation (CI) stage then combines v and v' to

produce the variable w, which is input to the Response Selection (RS) stage. The RS stage then produces the output y to the environment, or the output y' to other decision makers.
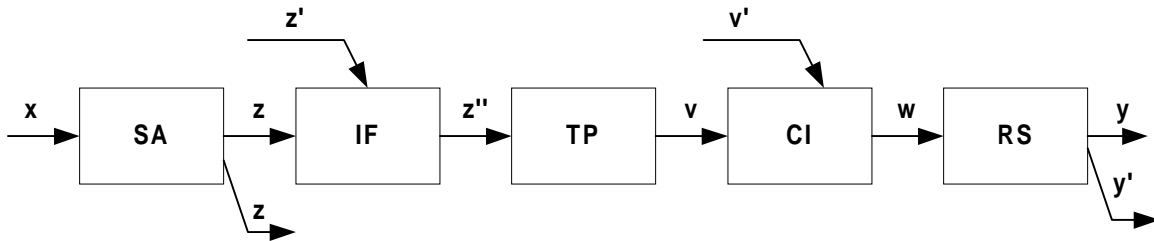

Figure 1: Five-Stage Interacting Decision Maker [Levis, 1992]

The model depicts the stages at which a decision maker can interact with other decision makers or the environment. A decision maker can receive inputs from the external environment only at the SA stage. However, this input x can also be from another decision maker's y'. A decision maker can share his assessed input through the z output at this stage. The z' input to the IF stage is used when the decision maker is receiving a second input. This input must be generated from another decision maker and can be the output of the SA or RS stage. The fused information from the IF stage, z', is the input to the TP stage. The decision maker's function is performed at this stage and results in the output v. In the CI stage, the decision maker can receive command information as the input v'. This is also internally generated and must originate from another decision maker's RS stage. In the RS stage, an output is produced; y is the output to the environment and y' is the output to another decision maker. Thus the interactions between two decision makers are limited by the constraints enumerated above: the output from the SA stage, z, can only be an input to another decision maker's IF stage as z', and an internal output from the RS stage, y', can only be input to another decision maker's SA stage as x, IF stage as z', or CI stage as v'.

The implications of interoperability on the five-stage decision making model can be identified. Interconnectivity establishes the links between the decision makers; if interconnectivity is not present between the decision makers, the decision makers cannot receive information through the x, v' and z' inputs or share information through the z and y outputs. Interoperability provides the ability to accept, process, and share information; interoperability occurs at the stages where decision makers exchange messages, i.e., the SA, IF, CI and RS stages. Interoperability is implemented in the algorithms of these stages of the model by establishing different rules for the assignment of actions to decision makers. Intercooperability allows changes in task processing based on shared information; this occurs at the TP stage. In order to evaluate the effect of interoperability on the interactions of the decision maker and on the coalition performance, an executable model must be created. Colored Petri nets are used to create the executable model.

3.2 The Colored Petri Net Model

Petri nets provide a graphical modeling language with which to represent a system and an underlying mathematical theory for rigorous analysis [Murata, 1989]. They can represent the external interactions of the decision makers as well as any internal algorithms the decision maker must perform, such as the inclusion of interoperability rule sets. Ordinary Petri nets are bipartitie directed graphs [Peterson, 1981]. There are two sets of nodes: places denoted by a circle node and transitions modeled by a bar node. The arcs or connectors that connect these nodes are directed and fixed. They can only connect a place to a transition or a transition to a place. A Petri net also contains tokens. Tokens are depicted graphically by indistinguishable dots and reside in places. A marking of a Petri Net is a mapping that assigns a non-negative integer, representing the number of tokens, to each place. A transition is enabled by a marking if and only if all of its input places contain at least one token. An enabled transition can fire. When the firing takes place, a new marking is obtained by removing a token from each input place and adding a token to each output place. The dynamical behavior of the system is embedded in the changing of the markings.

Colored Petri nets are an extension of Petri nets [Jensen, 1990]. Instead of indistinguishable tokens, tokens now carry attributes or colors. Tokens of a specific color can only reside in places that have the same color set associated with them. The requirements to fire a transition are now specified through arc inscriptions; each input arc inscription specifies the number and type of tokens that need to be in the place for the transition to be enabled. Likewise, output arc inscriptions indicate what tokens will be generated in an output place when the transition fires. A global declaration node of the Colored Petri net contains definitions of all variables, color sets, and domains for the model. Figure 2 shows the top level of the hierarchical, executable model.

The transitions that represent the individual stages of the five-stage model are compound transitions; each represents a separate page of the model that contains the functionality of that stage. The first stage, Situation Assessment, represents a decision maker, or a system, receiving an action for processing. This indicates that interconnectivity has been achieved between the sending and receiving systems. The system first assesses what skill or competency is needed to complete the action. The system then checks to see if it possesses that skill. If it does not, then the accuracy measure for this task is decreased by one, imparting a penalty for an action mapped to a system that is inoperable on that task. Recall that a task is composed of a series of actions; the accuracy is for the task itself, not the individual actions.

The Information Fusion stage for this model contains no unique processing and is simply a pass-through stage. The Task Processing stage represents the completion of the action by the system. First the location of the action is identified; if the action's location is not included in the system's current area of responsibility, then the task is delayed one time unit, representing the requirement to obtain current knowledge on this location. At the

end of this stage, a delay of one time unit is incurred to process the action and the task's accuracy value is increased by one to indicate that this step is complete.


```
color Ident = string;
var DM,Id,NwDM,NwSk : Ident;
color Cont = string timed;
var Msg,NwMsg : Cont;
color Penal = int;
var Acc : Penal ;
color Mode = with m1|m2|m3|m4;
var Md : Mode;
color Loc = with sec1|sec2|sec3;
var NwGeo : Loc;
color FctTime = int timed;
var t : FctTime;
color RecIn = product Ident*Cont*Ident*Penal*Mode;
color OneVal =product Ident*Cont*Ident*Penal*Mode;
color NextMsg = product Ident*Cont*Loc*Ident*Ident*Penal*Mode;
color ReadySend = product Ident*Cont*Ident*Penal*Mode;
```
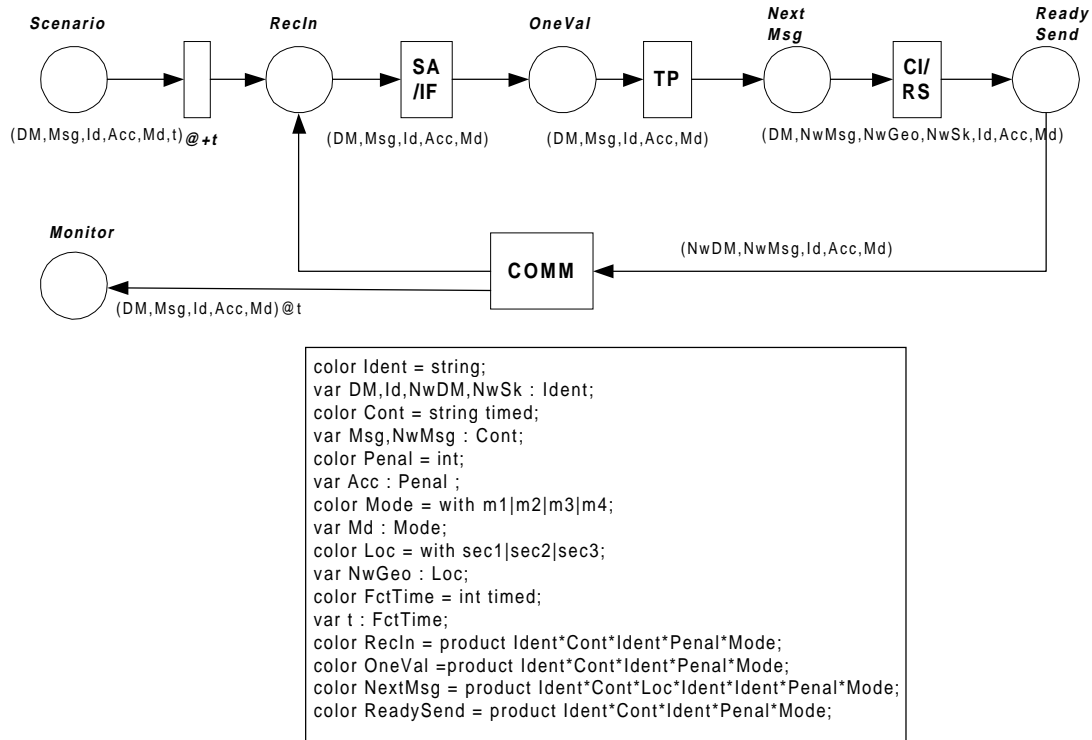
Figure 2: Top Level Net of Executable Model

The Command Interpretation stage in this model is also a pass-through stage with no unique processing. The final stage is the Response Selection stage, which prepares the task to be sent to the next system to perform the next action. First the required skill and location of the next action of the task are identified. Then, depending on the state of an external mode signal, different methods are used to select the next system to perform the next action required to complete the task. Mode 1 selects the next system based on the geographic location of the next action; it is sent to the system responsible for that location. Mode 2 uses the Bares formalism and selects any system that has indicated that it is interoperable on that action, i.e., self-assessment. Mode 3 randomly assigns the next system based on either geographic location or self-assessment. Mode 4 is a combination of Modes 1 and 2: first all the systems which have indicated they are competent on the action are obtained, and then, if multiple systems exist, the one that is responsible for the action's geographic location is chosen. This represents the inclusion of interoperability in the model; if the next system is selected purely on the task attributes, then interoperability has not been considered, Modes 1 and 3. If however, the assessment of the systems on their ability to complete the task has been considered, then interoperability is present in the model, Modes 2 and 4.

The communications page simply provides the logic to route messages between systems until the task is complete. The input to the communication page is the output of the system's Response Selection stage. The message is routed to the next system's Situation Assessment stage. When a task is finished, an output is generated at the Message Monitor place where the task id, the task accuracy, and the task processing time will be used to score the performance of the task.

4.0 The Experimental Design and Results

In order to evaluate the impact of Bares' interoperability formalism on coalition performance, a virtual experiment was conducted. The experimental design was created to stimulate the coalition model with a set of tasks, each composed of a series of actions, which were completed by different systems. The system was chosen for each action by one of four different modes. The coalition design used to populate the coalition model and the task graphs used to create the input scenario were extrapolated from a scenario currently being used for coalition research.

The Decision Support Systems for Coalition Operations (DSSCO) project is developing tools that US military planners can use to improve the effectiveness of multi-national coalition operations involving diverse military and civilian organizations. A prototype is being developed by SPAWAR Systems Center - San Diego to support the Operations Planning Team (OPT) of the Commander in Chief, United States Pacific Command. The goal of DSCCO is to apply and integrate organizational design concepts and decision support technologies in planning and executing multi-national coalition operations. As part of this development, an operational scenario, an Indonesian "Rebel Territory" scenario, has been developed to provide a context for development and demonstration of DSSCO tools and products [Heacox, 1999]. This scenario was used as the basis of the experimental design.

The scenario depicts a situation where growing tensions among multiple ethnic groups has lead to armed conflict between a rebel militia group and the host country's military. The rebel group has fled to an enclave of land on the eastern portion of the island nation and has detained a large number of citizens within the rebel-secured territory. Many of these citizens are unsympathetic to the rebels and are considered to be at risk. The host government recognizes that they are unable to maintain peace and that the tide of world opinion has turned against them; the government then asks the US to lead the anticipated coalition operation in an effort ensure aid is delivered to the rebel-secured territory where the food and water supply and sanitation facilities are limited.

The first step in the experimental design was to identify the systems in the coalition. This example is being conducted at a high level and so each country involved in the coalition was considered as a system; therefore three systems were identified: the United States (USAForces), Australia (AUSForces), and the Republic of Korea (ROKForces). In order to establish interconnectivity, it is assumed that all three systems can communicate and the communication network of the model reflects this.

The next step was to identify the different tasks or functional areas that compose the coalition mission that induce actions that the systems must interoperate on. The input scenario used to simulate the model was taken from DSSCO Task Blocks Section C ("Complete Listing of Sector Tasks"). Each high level task, composed of individual actions, was considered as a functional area. Five tasks were identified: C4 ("Provide Emergency Medical Treatment"), C6 ("Acquire and Warehouse HA Goods"), C7 ("Provide Displaced Civilian Services"), C8 ("Provide Refugee Administration), and C11 ("Provide Civil Engineering Infrastructure Support"). Each task occurs three times, once for each sector of the scenario. The openness context, which indicates which systems can interoperate on which tasks, is shown in Table 1.

Table 1: Openness Context

	C4	C6	C7	C8	C11
USAForces	X	X	X	X	X
AUSForces		X	X	X	X
ROKForces		X	X	X	

The information from the openness context can then be used to identify the interoperable groups, as shown in Table 2. The interoperable groups are used to identify what systems will work together on which tasks. In this case, three interoperable groups are identified: USAForces alone for task C4, USAForces and AUSForces together on task C11, and all three systems on tasks C6, C7, and C8; these three tasks were chosen for the virtual experiment. The use of interoperable groups has an impact on coalition design. Notice that two of the tasks, C4 and C11 are not interoperable by all systems. This implies, especially in the use of sectors, that if these systems are forced to interoperate on these tasks, coalition performance may suffer.

Table 2: Interoperable Groups

NULL	
USAForces	C4
AUSForces	
ROKForces	
USAForces,AUSForces	C11
USAForces,ROKForces	
AUSForces, ROKForces	
USAForces,AUSForces,ROKForces	C6,C7,C8

For each of the three tasks, the actions that compose the task must be assigned to the different systems in the interoperable group to complete. When the actions are complete, then the task is achieved. As an example, Task C7 ("Provide Displaced Civilian Services") is composed of eight actions, is shown in Table 3.

Table 3: Task C7

Action	Description
C7a	Construct Emergency Shelter
C7b	Provide Local Security
C7c	Provide Food Distribution
C7d	Provide Water Distribution
C7e	Provide Sanitation Services and Sewage Disposal
C7f	Provide Waste Disposal
C7g	Provide Laundry and Bath Services
C7h	Conduct Refugee Monitoring and Reporting

Coalition systems were assigned to actions by four different modes. In the first mode, actions were assigned to the system responsible for the geographical sector that contained the task, regardless of other task requirements. "It is apparent from the start that the use of sectors for the mission is the most effective way to divide up the effort" [Heacox, 1999]. In the scenario, the joint operations area is divided into three equal sectors, one each for the United States, Australia, and the Republic of Korea. US Coalition Support Teams are assigned to the coalition partners to assist in communications and liaison; this ensures that interconnectivity has been achieved.

The second mode was by system self-assessment, the Bares' formalism. The action was assigned to the system that indicated it could perform it. For task C7 the self-assessment vectors that were used in the experiment are shown in Table 4.

Table 4: Task C7 Self-Assessment Vectors

	USAForces	AUSForces	ROKForces
C7a	1	1	0
C7b	0	0	1
C7c	1	1	0
C7d	1	1	1
C7e	1	0	0
C7f	1	1	1
C7g	1	1	0
C7h	1	0	1

The third mode was a random assignment of actions to systems based on either system self-assessment or geographic location. The fourth mode was a combination of both system self-assessment and geographic location; the systems that indicated they could perform the action were first identified, if there were more than one, the one in the same geographical sector as the task was chosen. The coalition's performance was then evaluated under all four modes by monitoring the accuracy and timeliness of the

coalition's response to the tasks in order to evaluate the coalition's output as a function of system to action assignment strategy.

Timeliness expresses the coalition's ability to respond to an incoming task within an allotted time. The allotted time is the time interval over which the output produced by the coalition is effective in its environment. This allotted time can be described as a window of opportunity whose parameters are determined a priori by the requirements of the task. Different task types may have different windows of opportunity. Two quantities are needed to specify the window of opportunity: the lower and the upper bounds of the time interval, t_s and t_f, respectively, or one of the bounds and the length of the interval, e.g. t_s and Δt [Cothier and Levis, 1986]. The timeliness of each coalition output was scored based on the task's window of opportunity; if the response was within the window, it was given a score of two, if it was on the boundary it was given a score of one, otherwise it received a score of zero.

Similarly, accuracy expresses a coalition's ability to make a correct response to an incoming task. The accuracy for each task can be described as an interval that contains the correct or predicted response plus or minus a margin of error within which the response is still acceptable. The accuracy value of each coalition output was scored based on the accuracy interval determined a priori for each task; if the value was within the interval it was given a score of two, if it was on the limits of the interval, it was given a score of one, otherwise it received a score of zero.

The coalition operating under the fourth mode, a combination of task allocation based on system self-assessment and geographic sector, was hypothesized to out perform the other methods. When a system performs an action on a task outside its current geographic location, the task incurs a delay. When a system performs an action on a task without the required competency, the accuracy of the task decreases. Task assignments based on geography are predicted to be timely but less accurate; this situation represents maximum duplication of effort, but minimum integration of coalition partners within sectors. Assignments based on system self-assessment are predicted to be accurate but less timely; this situation represents a more integrated approach, with all partners present in all sectors, but at the cost of a dispersed effort.

Figure 3 shows the results of the virtual experiment. The use of sectors had the best timeliness score but the worst accuracy; this is due to the fact that in many cases the system responsible for the sector was not capable on the individual actions. The Bares' formalism, on the other hand, had the best accuracy score, but the worst timeliness score due to similar reasons: the action was assigned to a system not in the same sector as the task. The combined method had the best balanced scores as it did not try to maximize either performance measure. The random method scores fell in between.
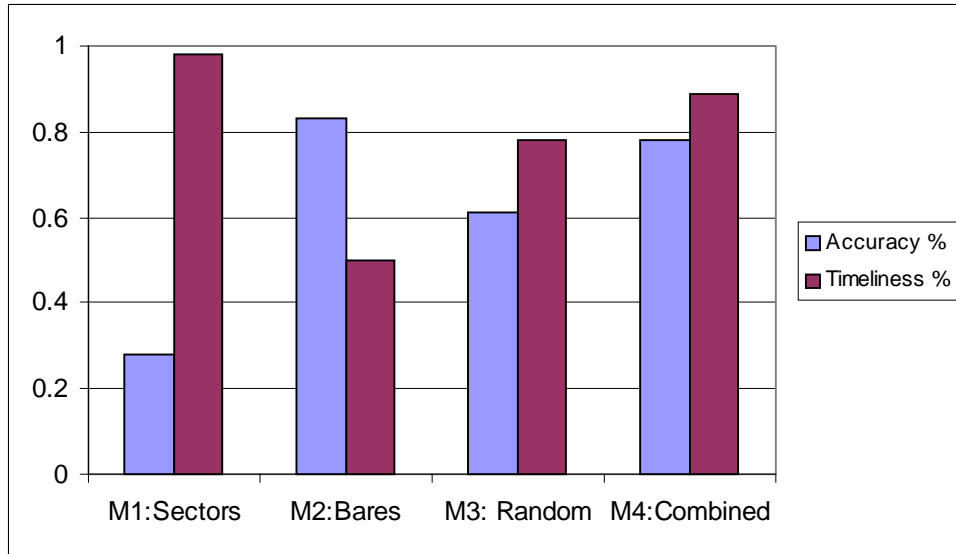
Figure 3: Experimental Results

5.0 Conclusion

An executable model was used to study coalition behavior under different conditions in order to address questions on interoperability. By incorporating interoperability concepts into the five-stage interacting decision maker model, the performance of a coalition completing tasks under four different modes of system to action mapping was evaluated. The results of this research indicate that interoperability is an important aspect in improving coalition performance. However, it may not be the only factor. Including geographic sectors as well as the Bares formalism additionally improved performance. In this particular scenario, all sectors were of equal size, regardless of the size or abilities of the participating nations. In this case, and in many cases, the US contingent is so much larger than the other countries' contingents that it has two advantages: it includes specialized units that may be the only ones available to interoperate on specialized tasks, and it can handle a larger sector more efficiently than the other countries. In future coalition operations it may be more appropriate to adjust the sector size proportionally to troop strength and specialties in order to achieve a balance across the participating nations.

In this paper, only Bares' formalisms concerning the interoperability domain were considered. However, interoperability is only a prerequisite for intercooperability. In the intercooperability domain, any system can evaluate any other system's ability to interoperate on actions. This ability to judge requires the systems to share knowledge with each other. However, cultural differences may affect the ability to advance from interoperability to intercooperability. Different beliefs about information sharing can affect the ability of different organizations within the coalition to achieve inter-cooperation. Intercooperability can be represented with a dynamic coalition model where mappings may change over time based on feedback from the individual systems, including the effect as organizations join and leave the coalition.

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