NC-based Interoperability Synergy Assessment Model

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Abstract. The future battle space environment is changing from a PCO(platform centric operation) to a NCO(network centric operation). NCO take place not only physical, information, cognitive, but also social domain. Interoperability in a NCO makes the entire command hierarchy ranging from commanders to warriors have the same situational awareness which create synergy from physical to social domain for the forces and enhancing mission effectiveness. NCEI model was developed to measure synergy from physical to social domain which enhances the mission effectiveness through information sharing . NCEI model consists of layer, function, attribute and metric. The assessment criteria for NCEI model were developed to compare organic interoperability with synergy interoperability.

Keywords: Interoperability, Synergy

1 Introduction

Ubiquitous information technology made systems intelligent and connectable between them, and consequently caused paradigm of the military operation to change from platform centric operation to network centric operation[1]. Interoperability in a PCO that includes the point-to-point concept is based on physical and information domains in which equipment, devices and applications are connected with each other to share information. But, interoperability in a NCO that includes the concept of plug and play is based on cognitive domain and social domain in which the entire command hierarchy ranging from commanders to warriors take the same perspective, then helps create synergy from physical domain to social domain to increase mission effectiveness. Interoperability maturity model is also changing from a platform centric maturity model such as LISI model with which interoperability between systems is assessed to net centric maturity model such as SCOPE model with which interoperability between organization and task is assessed[5] .

Interoperability domains for NCO consist of physical, information, cognitive, and social domains[2]. However, until now interoperability maturity model is focusing the point-to-point concept based on platform centric which consist of physical and information domains, don't exist the NC based maturity model.

The objective of this paper provides a NC based interoperability synergy assessment model which measures synergy from physical to social domain which enhances the mission effectiveness through information sharing .

2   NCEI Model

2.1   overview

As shown in Fig. 1, NCEI Model was developed to measure interoperability in physical, information, cognitive, and social domains. In particular, it concentrated on assessment of synergy made by interoperability from physical domain to social domain. NCEI model consists of network layer, organic information layer, individual information layer, awareness layer, understanding layer, decision layer and action layer[4] [5]. Also, each layer consist of functions, quality attributes and metrics[3]. Quality attributes is the characteristics to measure interoperability. Metric must include a measurement formula and unit in measuring quality attributes. There is 1 to N relationship between model components and quality attributes. Quality attributes and metric have 1 to 1 relationship.
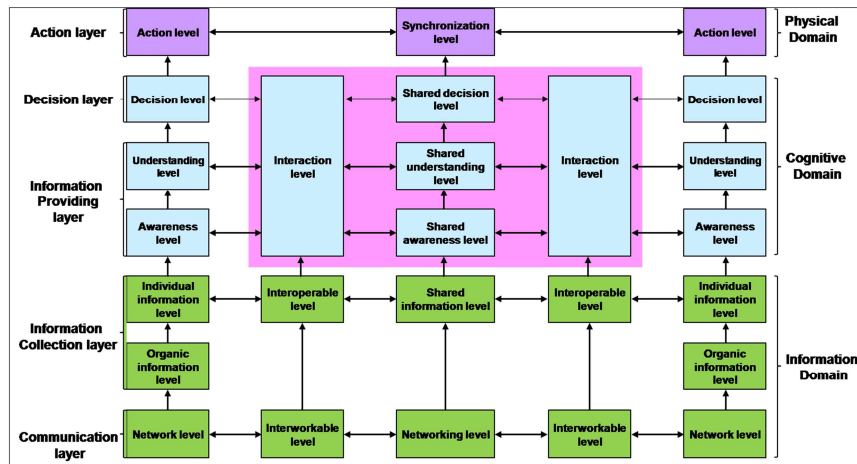

Fig. 1. NCEI Model

2.2   Interoperability measurement method

Assess organic/synergy NCEI.

The assessment of NCEI Model consists of three things. First, entities participating into the scenario (organic interoperability) showed NCEI model layer, and secondly, interaction between the entities (interaction interoperability) showed NCEI model layer, and lastly, of each entity after the reflection of synergy created by interaction (synergy interoperability) showed NCEI Model layer.

The criteria of NCEI Model Assessment

Assessment criteria of organic platform capability

First, the interoperability capability of entities participating into the scenario prior to synergy occurrence is defined as organic interoperability. An assessment grade ranges from 0 to 1. The closer the grade is to 1, the better the capability is.

Assessment criteria of the communication layer ($Com_{organic}$) are described in following. In the case of Air-to-Air of the US air force, data link capability of 0.74 and voice capability of 0.16 were applied[6].

For the assessment criteria of information collection layer($C_{organic}$), two attributes-accuracy and updating-were selected. Accuracy was calculated as the number of collected information items was divided by the number of actual information items. According to an updating cycle of the collected information, updating is set to 1.0 from 0 to 10 seconds, 0.7 from 10 to 60 seconds, 0.5 from 60 seconds to 3 minutes, and 0.3 more than 3 minutes.

Assessment criteria of information offering layer($I_{organic}$) are presented in table 1.

Table 1. Assessment criterial information offering layer capability

Type	Fusion COP generation	Self COP creation		
		Digital	Text & simple digital	Voice
Capability	1.0	0.4	0.2	0.1

Assessment criteria of decision layer($D_{organic}$) are presented in table 2.

Table 2. Assessment criteria of decision layer capability

Accuracy	Capability	Updating cycle	Metric	Decision layer capability
Video	1.0	0 to 10 seconds	1.0	
Symbol	0.7	10 to 60 seconds	0.7	(Accuracy + Updating)/2
Text	0.5	60 to 180 seconds	0.5	
Voice	0.3	more than 3 minutes	0.3	

Lastly, assessment criteria of action layer($A_{organic}$) are following. In the case of shooter system, the capability can be (1) and in the case of non-shooter system, it is 0.

$$A_{organic}=(C_{organic}D_{organic}+I_{organic})/2 \tag{1}$$

Assessment criteria of Synergy platform capability.

In the communication layer, synergy NCEI Model assessment criteria are $Com_{organic.}$ In the information collection layer, assessment criteria are

$$C_{synergy}=C_{organic}+\sum_{i=1}^{n}(Com_i \times C_i)$$

, i is an input value coming from the interaction of other entities. In the information offering layer, synergy assessment criteria is

$$I_{synergy}=I_{organic}+\sum_{i=1}^{n}(Com_i \times I_i)\Big/(i+1)$$ In the decision layer, synergy assessment criteria

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are $D_{synergy} = D_{organic} + \sum_{i=1}^{n} Com_i \times D_i \bigg/ (i+1)$ In the action layer, synergy assessment

criteria are $A_{synergy} = (C_{synergy} \times D_{synergy} + I_{synergy})\big/ 2$.

Instantiate entity.
Once entities, their interoperability characters, and the states of those characters have been identified, then a specific system can be modeled, or instantiated by (2), as a sequence (Bullock, 2006; Amanowicz & Gajewski, 1996) of states of system characters.

$$\Sigma = X(E) = \{\{a,b,c,d\},\{e,f,g,h\},\{i,j,k,l\}\} = \begin{bmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \end{bmatrix}$$

then, $a,b,c,d,e,f,g,h,i,j,k = \{0,1\}$
(2)

Measure interoperability.
To measure Interoperability have been well-studied.(Thomas C.Ford, 2008) Given a pair of s', s" instantiated as $\sigma',\sigma'' \in R \cap [0, c_{max}]$, then $I = Sim_{real} = w \cdot MMS$, written out completely in (3) , is an interoperability function which gives a weighted, normalized measure of the similarity of systems instantiated with real-valued character states where is the average character state value of a pair of system instantiations, MMS is the Modified Minkowski Similarity function, is the number of characters used to instantiate σ,σ'', C_{max} is the maximum character state value, and r is the Minkowski parameter (usually set to r=2).

$$I = Sim_{real} = \frac{\left[\sum_{i=1}^{n} \sigma'(i) + \sum_{i=1}^{n} \sigma''(i) \right]}{2nc_{max}} \left[1 - \left(\frac{1}{\sqrt[r]{n}} \right) \left(\sum_{i=1}^{n} b_i \left(\frac{\sigma'(i) - \sigma''(i)}{c_{max}} \right)^r \right)^{1/r} \right]$$

(3)

2.3   Application

Development scenario.
Participants in this scenario are UAV, Orion, F-111, Arty, ARH, SF, and HQ, among them, UAV, Orion, F-111, and HQ send and receive information over their data link. The rest are assumed to use voice. Moreover, only UAV and ORION can detect the information on enemy threat.
As shown in table 3, each entity's collected information items relating to 9 factors were assumed on the basis of enemy ground target.

Table 3. Collected information

Type	UAV	ORION	F-111	ARH	HQ	Arty	SF
IP	O	O	O	O	X	X	X
Heading	O	O	O	O	X	X	X
Distance	O	O	O	O	X	O	O
TGT Elevation	O	O	O	O	X	O	O
TGT Description	O	X	X	O	X	X	O
TGT Location	O	O	O	O	X	O	O
Type Marks	O	X	X	O	X	X	O
Friendly Location	X	O	X	X	X	X	X
Egress Direction	O	O	O	O	X	X	X

In the scenario, each entity's decision updating cycle was assumed as shown in table 4.

Table 4. Decision updating cycle

Type	UAV	ORION	F-111	ARH	HQ	Arty	SF
Decision updating cycle	None	2 min	1 min	30 sec	Real-time	10 min	30 min

Assessment of NCEI Model

NCEI Model based Organic Platform Capability.
For Organic interoperability in NCEI Model, each layer's organic interoperability assessment criteria are applied. And the application results are presented in Fig. 5.

NCEI Model based Synergy Platform Capability.
For Synergy interoperability in NCEI Model, each layer's synergy interoperability assessment criteria are applied. And the application results are presented in Fig. 5. For example, synergy NCEI Model application result of ARH, is shown as follows. In the information offering layer, synergy assessment criteria is

$I_{synergy} = I_{organic} + \sum_{i=1}^{n} (Com_i \times I_i) \Big/ (i+1)$, $I_{organic}$ is 0.4, i=1, and information offering layer capability is received from HQ. Therefore, as each value is substituted in the formula, ARH's synergy information offering layer capability is 0.48 as shown in 0.4+(0.16*1.0)/2=0.48.

Table 5. NCEI Model Assessment(organic/synergy)

	Com	C	I	D	A
UAV	0.74/0.74	0.945/0.945	0.4/0.4	0/0	0/0
Orion	0.74/0.74	0.89/1	0.4/0.74	0.6/0.97	0.5/1
ARH	0.16/0.16	0.945/1	0.4/0.48	0.7/0.93	0.6/0.71
F-111	0.74/0.74	0.875/1	0.4/0 74	0.7/1	0.51/0.87
HQ	0.74/0.74	0/0.43	1/1	1/1	0/0
Arty	0.16/0.74	0.3.0.42	0.2/0.28	0.4/0.48	0.165/0.241
SF	0.16/0.74	0.43/0.51	0.1/0.18	0.3/0.38	0.115/0.187

Interoperability measurement

The result of Interoperability measurement that applies the formula (3) is shown in Table 6. Interoperability of Synergy NCEI model is higher than organic NCEI model.

Table 6. Interoperability measurement of the NCEI Model assessment(organic/synergy)

	UAV	Orion	ARH	F-111	HQ	Arty	SF
UAV	0.417/0.417	0.509/0.619	0.362/0.454	0.514/0.609	0.353/0.379	0.199/0.264	0.2/0.26
Orion	0.509/0.619	0.626/0.89	0.434/0.531	0.607/0.827	0.459/0.628	0.253/0.251	0.246/0.225
ARH	0.362/0.454	0.434/0.531	0.561/0.656	0.444/0.87	0.437/0.62	0.248/0.263	0.24/0.236
F-111	0.514/0.609	0.607/0.827	0.444/0.656	0.645/0.87	0.476/0.62	0.255/0.263	0.245/0.236
HQ	0.353/0.379	0.459/0.628	0.437/0.375	0.476/0.62	0.548/0.634	0.16/0.236	0.103/0.172
Arty	0.199/0.264	0.253/0.251	0.248/0.292	0.255/0.263	0.16/0.236	0.245/0.316	0.212/0.276
SF	0.2/0.26	0.246/0.225	0.24/0.27	0.245/0.236	0.103/0.172	0.212/0.276	0.221/0.283

3 Conclusion

This study investigated related researches including interoperability definition and interoperability model, and thereby developed NCEI model. The NCEI model was developed to assess interoperability in physical, information, cognitive, and social domains, and especially focused on synergy from physical to social domain. In addition, each layer consists of function, attribute and metric. The developed NCEI model was applied to scenario and then capabilities before and after occurrence of synergy was compared to verify validity. The proposed model can be utilized for effectiveness analysis and establishment of military power (NCW operation concepts and acquisition). In the future, it is necessary to develop additional quality attributes of each layer with metric.

4 References

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