Modelling a Network of Decision Makers

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Testing the impact of shared information on Combat Outcome

- Combat Model
- Collaboration Metric Model (CMM)
- Combat Effectiveness
- Information Flows
  - Scenario
  - Structure

Relate combat effectiveness to HQ structure
Physical - Information - Cognitive - Societal

Ed Smith “Effects Based Operations”

History & Culture

Social Structure

Institutional Culture

Government And Politics

Education

Religion

Economy

Societal Domain

Mental Model

Deep understanding
- Cause and Effect
- Temporal relations
- Dynamic Futures

Prior Knowledge

Sensemaking
- Values
- Anticipated Futures
- Alternatives

Options
- Choices among alternatives
- Choices to wait
- Choices to seek information
- Choices to consult others

Shared Awareness

Judgment

Planning

Directives

Synchronization

Information Domain

Action Objects/events

Physical Domain

Information (data in context)

Data (representation)
Some simplifying assumptions

- Focus on the Information Domain and the Cognitive Domain
- Network comprises nodes and edges between nodes together with flows through the graph
- There are two types of node
  - Decision Making node
  - Information node
- There may be several different flows simultaneously
Network of decision making nodes and Information nodes

Decision Node

Information Node

a

b

c

d

e

f

1

2

3

4

5

1

2

3

4

5

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Cognitive Domain
The Recognition Primed Decision Model

A decision is simply the selection of a Course of Action in response to a situation.
Recognition Primed Decision Model

More accurately, the decision maker bases his decision on perception of the situation.

- Information → Perceived Situation
- Perceived Situation → Decision Maker → Course of Action
Recognition Primed Decision Model

The decision maker scans the environment for clues and cues that might clarify his perception of the given situation.

Key Information Requirements
Recognition Primed Decision Model

Situations from experience are stored in the decision maker’s mind. Each experience is labelled by a region in the “Information Element Space.” To each stored situation is associated a Course of Action.
Recognition Primed Decision Model

The decision maker’s estimate of the current situation is plotted in the Information Element Space - *with a volume of uncertainty*
Recognition Primed Decision Model

How closely must the perceived situation match a stored situation for the stored Course of Action to be chosen?

Is the decision maker feeling lucky?

Stored situation

First Key Information Element

Second Key Information Element

Current Estimate

Stored situation

Stored situation

Stored situation

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Recognition Primed Decision Model

As time goes by, the estimate will change and the degree of uncertainty may increase.
Recognition Primed Decision Model

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Recognition Primed Decision Model

As time goes by, the estimate will change and the degree of uncertainty may increase - until a change in the course of action is desirable or inescapable.

Stored situation

Stored situation

Stored situation

Current Estimate

First Key Information Element

Second Key Information Element
Recognition Primed Decision Model

Situation assessment - OK / Not OK

Not OK → Choose a new CoA

OK → Remain in current CoA
Information domain - Representing Uncertainty

Information Element Space is spanned by a small number of critical information elements

\[ A = \{a_1, \ldots, a_N\} \]

Example:

\[ A = \{\text{location, altitude, speed, direction, missile type}\} = \{a_1, a_2, a_3, a_4, a_5\} \]

Each of these information elements is given by a probability distribution.

The mean vector represents current estimate

\[ \mu = [\mu_1, \mu_2, \Lambda, \mu_N] \]

The covariance matrix of the multivariate distribution represents uncertainty.

\[ \Sigma = \begin{bmatrix} \sigma_1^2 & \Sigma_{1,2} & \Lambda & \Sigma_{1,N} \\ \Sigma_{2,1} & \sigma_2^2 & \Lambda & \Sigma_{2,N} \\ M & M & O & M \\ \Sigma_{N,1} & \Sigma_{N,2} & \Lambda & \sigma_N^2 \end{bmatrix} \]
Representing Uncertainty

Decisions depend on the confidence of the decision maker in the accuracy of the estimation

A measure of Uncertainty from Shannon’s *Theory of Information* is **Information Entropy**

The Information Entropy contained in a joint probability density function $f(X)$ is given by

$$H(X) = E[-\log f(X)] = -\int \int \int f(X) \log f(X) dx_N \Lambda dx_2 dx_1.$$
Representing Uncertainty

Decisions depend on the confidence of the decision maker in the accuracy of the estimation.

A measure of Uncertainty from Shannon’s *Theory of Information* is *Information Entropy*.

The Information Entropy contained in a multivariate normal distribution was calculated by Shannon in 1948.

\[
H(\mathbf{X}) = \frac{1}{2} \log(2\pi)^N |\mathbf{\Sigma}| + \frac{N}{2} = \frac{1}{2} \log \left[ (2\pi e)^N |\mathbf{\Sigma}| \right].
\]
Metrics - How good is my information?

- Precision - function of the covariance
- Accuracy - function of the mean
- Completeness - measure of how critical are the critical information requirements?

These are combined into one single metric - the **Collaboration Measure**
Some Effects of Collaboration

Sharing information reduces uncertainty and leads to greater precision, greater accuracy

Sharing information → more complete information
Some Effects of Collaboration

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Sharing information → more complete information

Sharing information cost - time, volume, disconfirming evidence
Metrics - How good is my network?

- Network Redundancy - measure of the reliability of the network
  - this is simultaneously a cost and a benefit
- Access Cost - connectivity score based on the distance piece of information must travel from source to decision maker
- Information Overload Cost - measure of the process time required to distinguish between needed and unneeded information
Metrics

Information Metrics

- Accuracy
- Precision
- Completeness

Network Metrics

- Information Accessibly
- Network Redundancy
- Information Overload

COLLABORATION

PLECTICITY

OVERALL NETWORK EFFECTIVENESS
First Network of Decision Makers
Supply Case (S)

3rd Line
- FSG

2nd Line
- AA BSA
- Armd Div DSA

1st Line
- AH Regt 1 FOB
- AH Regt 2 FOB
- AH Regt 3 FOB
- Armd Bde 1 BSA
- Arty Regt ACP
- Armd Bde 2 BSA
- Arty Regt ACP
- Mech Bde BSA
- Arty Regt ACP
- MLRS Regt ACP

Decision Nodes in red
Second Network of Decision Makers
Demand Case (D10)

3rd Line

2nd Line

1st Line

FSG

AA BSA

Armd Div DSA

AH Regt 1 FOB

AH Regt 2 FOB

AH Regt 3 FOB

Arty Regt ACP

Armd Bde 1 BSA

Armd Bde 2 BSA

Mech Bde BSA

Arty Regt ACP

Arty Regt ACP

MLRS Regt ACP

Corps Arty BSA

Decision Nodes in red
Third Network of Decision Makers
Demand Case (D3)

Decision Nodes in red
Clusters in green
Input data from the combat model

- Actual use and Consumption
  Unit data for Ammo and Supplies:
  - 120mm, 155mm, 30 mm, 81mm
  - MLRS, HellFire
  - Fuel, Oil+Lub, PW, Rations, Bulk Water
- Variety of first, second and third line log units
- Time steps from 1 minute increment

![Materiel Use Graph]

CU

Time (/10 min)

1 34 67 100 133

120mm
155mm
30mm
1.0
0.9
0.8
0.7
0.6

Supply

Demand: 10 clusters

Demand: 3 clusters

Overall Network Performance
Accuracy and Knowledge

- Demand- 3 cluster
- Demand- 10 cluster
- Supply

Units

Time (minutes / 10)
Study Diagram
CMM / Combat Model Relationship

- Combat Model
- Combat Effectiveness
- Collaboration Metric Model (CMM)
- Collaboration Metric
- Scenario
- Information Flows
- Structure

Relate combat effectiveness to HQ structure

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