Estimating the Value of Intelligence, Surveillance and Reconnaissance in Manoeuvre Warfare

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EXTENDED ABSTRACT

Australia is a relatively secure country (Commonwealth of Australia 2000). An attack is unlikely, and a full-scale invasion is credible only in a major dispute.

Nevertheless, the Australian Defence Force (ADF) keeps a close watch on Australia's strategic environment (Commonwealth of Australia 2000). Significant changes, like increased instability in Australia's nearer regions, could require simultaneous deployments of Australian forces, which may stretch resources.

As a result, the ADF aspires to conduct Manoeuvre Warfare (MW) (Australian Defence Force 2002). The Australian Defence Force (1998) describes MW as the means for the military to disrupt the adversary's strength or will to fight. This requires knowledge about the adversary's capabilities and vulnerabilities, and firepower sufficient to destroy, capture or neutralise the adversary's key elements.

As such, the ADF has much interest in the problem of balancing knowledge and firepower. In the battlespace, knowledge is mainly provided by Intelligence, Surveillance and Reconnaissance (ISR) systems, and firepower is provided by Weapons systems. Therefore, the ADF needs the ability to select ISR and Weapons that achieve a desired level of effectiveness at the lowest cost or are the most effective systems for a fixed cost.

In this paper, we focus on measuring the effectiveness of ISR systems.

We consider a scenario where the ADF may want to use MW. The scenario involves Blue and Red forces. The Blue Force's Commander wants to transit a relatively large number of troops and their equipment to a specified location. He or she assigns a fleet for the convoy, and a satellite to assist the convoy by gathering information about the Red Force's disposition. The Red Force's Commander wants to prevent the Blue Force's convoy from reaching its destination. He or she assigns a submarine and aeroplane to locate and engage the convoy.

We measure the effectiveness of the Blue Force's ISR systems in this scenario using the proportion of paths the Blue Force's Commander finds acceptable. The Blue Force's Commander wants to plan 5 paths for the convoy, which has speed of advance of 10, 15, 20, 25 and 30 knots for the first, second, third, fourth and fifth path respectively. He or she finds these paths acceptable if the convoy's probability of winning is greater than or equal to 0.75 at all times and the convoys mean probability of winning is at least 0.9. Consequently, the proportion of these paths that are acceptable is a quantitative surrogate for the Commander's objective, which is to position the convoy where engagements it is unlikely to win are avoided when conducting MW.

We determine the paths using discrete optimisation. First, we partition the operational area into regions. Next, we construct a network whose nodes correspond to the regions, arcs correspond to links between two regions that are adjacent (share a boundary) and arc weights represent the convoy's probability of winning when it moves between regions. Calculating these probabilities is a major task. Then, we formulate a Shortest Path Problem to determine the path that maximises the convoy's overall probability of winning from the source node to the sink node.

We calculate results that suggest the ISR systems in this scenario are 100% effective according to the criteria of the Blue Force's Commander. The convoy's probability of winning for the arcs in the paths are all in excess of 0.75, and the convoy's mean probability of winning for the arcs in the paths are greater than 0.9. Hence, all of the 5 paths are acceptable.

We conclude that our modelling concepts are useful for measuring the effectiveness of ISR not only in the scenario discussed but also in other scenarios where MW can be conducted.

1 INTRODUCTION

Australia is a relatively secure country (Commonwealth of Australia 2000). The likelihood of an attack on Australia is low. A full-scale invasion is the least likely military contingency Australia might face. A major attack, including the seizure of territory and damage to Australia, may be possible, but would be credible only in a major dispute.

The Australian Defence Force (ADF) has 5 strategic objectives in this strategic environment (Commonwealth of Australia 2000). They include ensuring the defence of Australia and its direct approaches; fostering stability, integrity and cohesion in Australia's immediate neighbourhood; working with nations in South East Asia to maintain stability and co-operation; supporting strategic stability in the wider Asia Pacific region; and supporting the efforts of the international community in upholding global security.

Consequently, the ADF keeps a close watch on Australia's strategic environment (Commonwealth of Australia 2000). Significant changes could introduce a major risk, and would require a fundamental shift in Australia's strategic planning. Moreover, increased instability in Australia's nearer regions could require simultaneous deployments of Australian forces, which may stretch resources.

As a result, the ADF aspires to conduct Manoeuvre Warfare (MW) (Australian Defence Force 2002). The Australian Defence Force (1998) describes MW as the means for the military to disrupt the adversary's strength or will to fight. This requires knowledge about the adversary's capabilities and vulnerabilities, and firepower sufficient to destroy, capture or neutralise the adversary's key elements.

We want to help the ADF achieve its aspirations. We will discuss our contribution in 6 parts. In Section 2, we will look at the problem that the ADF must address if MW is to be feasible. In Section 3, we describe a scenario where the ADF may want to use MW. In Section 4, we develop a model for this scenario. In Section 5, we provide some results. In Section 6, we discuss the utility of the model. In Section 7, we make some concluding remarks.

2 PROBLEM

The ADF has much interest in the problem of balancing knowledge and firepower. In the battlespace, knowledge is mainly provided by Intelligence, Surveillance and Reconnaissance (ISR) systems, and firepower is provided by Weapons systems. Therefore, the ADF needs the ability to select ISR and Weapons that achieve a desired level of effectiveness at the lowest cost or are the most effective systems for a fixed cost.

We can address these problems using cost-effectiveness analyses. These require measuring the cost and effectiveness of the systems. The values for the cost and effectiveness of the systems provide an objective comparison, which can be used to determine the cost-effective systems.

In this paper, we will focus on measuring the effectiveness of ISR systems.

3 SCENARIO

At this stage, it will be helpful to consider the scenario that we use to test the effectiveness of the systems. It consists of a Blue Force that represents the ADF and a Red Force that represents the ADF's adversary. The Blue Force's Commander, who we will call Blue Commander, intends to transport a relatively large number of troops and their equipment to a specified location. He or she assigns a fleet, called Blue Fleet, for the convoy and a satellite, called Blue Satellite, to assist the convoy by gathering information about the Red Force's disposition. The Red Force's Commander wants to prevent the Blue Force's convoy from reaching its destination. He or she assigns a submarine, called Red Submarine, and an aeroplane, called Red Aeroplane, to locate and engage the convoy.

We illustrate the scenario in Figure 1. This shows the area of operations, which is about 1 million square nautical miles (the shorter width is a result of using a regular hexagonal tessellation in the model, which is discussed in the next section). Blue Fleet is located at S. It is required to transit to T at speeds that are expected to be made good over the ground, known as speeds of advance, of 10, 15, 20, 25 or 30 knots. Blue Satellite operates over the area of operations for 12 of 24 hours, and can search 95% of the operational area in these 12 hours. Red Submarine operates along the line AB, which is 600 nautical miles in length. Its speed of advance is 10 knots, which results in a search duration along AB or BA of 60 hours. Red Aeroplane operates along the line CD, which is 960 nautical miles in length. Its speed of advance is 320 knots, which results in a search duration along CD and DC of 3 hours.

Now, Blue Commander will plan 5 paths for the convoy. The Commander wants Blue Fleet to transit safely at a speed of advance of 10, 15, 20, 25 and 30 knots for the first, second, third, fourth and fifth path respectively. Under MW, this is achievable if the Commander has sufficient knowledge to position Blue Fleet where engagements it is unlikely to win are

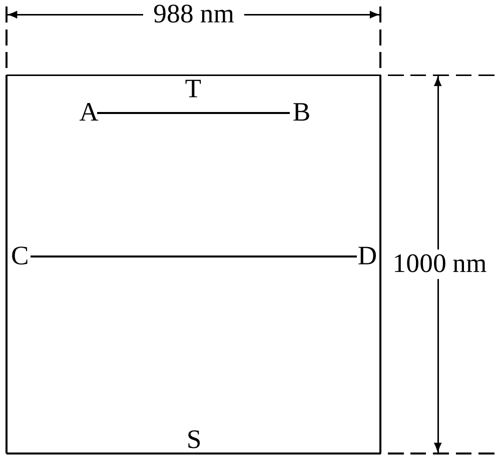

Figure 1. Area of operations.

avoided. Essentially, the Commander would prefer the paths to steer clear of Red Submarine and Red Aeroplane, so the Commander specifies danger ranges of 50 nautical miles for Red Submarine and 100 nautical miles for Red Aeroplane. These form danger zones centred around the submarine and aeroplane. We illustrate Red Submarine's Danger Zone (SDZ) and Red Aeroplane's Danger Zone (ADZ) in Figure 2. Blue Fleet should try to stay outside the SDZ or ADZ, but this may be impracticable because the Commander is unaware of the dangerous situations or the dangerous situations are unavoidable.

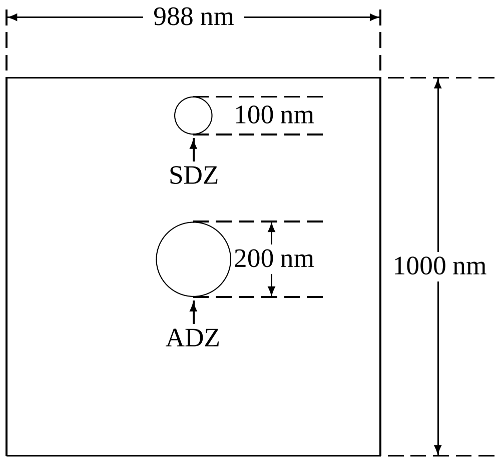

Figure 2. The Submarine's Danger Zone (SDZ), and the Aeroplane's Danger Zone (ADZ).

Consequently, Blue Commander may have to accept paths that transit some dangerous areas. For the purpose of this paper, the Commander finds a path acceptable if he or she estimates Blue Fleet's probability of winning is greater than or equal to 0.75 at all times and Blue Fleet's mean probability of winning is at least 0.9. The Commander estimates Blue Fleet's probability of winning is 1, 0.2, 0.8 and 0.4 if he or she knows Blue Fleet is outside the SDZ and ADZ, inside the SDZ only, inside the ADZ only, and inside the SDZ and ADZ respectively. On the other hand, the Commander estimates Blue Fleet's probability of winning is 0.8, 0.1, 0.6 and 0.2 if he or she does not know Blue Fleet is outside the SDZ and ADZ, inside the SDZ only, inside the ADZ only, and inside the SDZ and ADZ respectively.

Blue Commander's knowledge of Blue Fleet's situation at any instant mainly results from information gathered by Blue Fleet and Blue Satellite. Blue Fleet gathers information that correctly suggests the area it is searching is outside both the SDZ and ADZ 40% of the time, only inside the SDZ 10% of the time, only inside the ADZ 99% of the time, and inside both the SDZ and ADZ 20% of the time. Similarly, Blue Satellite gathers information that correctly suggests the area it is searching is outside both the SDZ and ADZ 70% of the time, only inside the SDZ 15% of the time, only inside the ADZ 100% of the time, and inside both the SDZ and ADZ 25% of the time.

4 MODEL

Now, we want to develop a model that measures the effectiveness of ISR systems in this scenario. The Command and Control Research Program (2002), Jaiswal (1997), and Moder & Elmaghraby (1978) describes a measure of effectiveness (MOE) as a quantitative surrogate for the Commander's objective, which is to plan 5 paths that permit Blue Fleet to transit safely. Consequently, the MOE is the proportion of the paths that Blue Commander finds acceptable.

We determine the paths using discrete optimisation. A network that models Blue Fleet's transitions through space and time is constructed, and then a Shortest Path Problem (SPP) that determines Blue Fleet's safest path through the network is formulated. The construction of the network and formulation of the SPP are described in Sections 4.1 and 4.2 respectively.

4.1 Network

Our network $G = (\mathscr{N}, \mathscr{A})$ is planar, time-expanded, directed, and defined by a set of nodes $\mathscr{N}$ and a set of arcs $\mathscr{A}$. Constructing it involves 4 steps.

First, we superimpose a grid on the operational area. The grid has consists of a set of 2958 regular hexagonal cells $\mathscr{C}$. The length of the each cell's side is about 11.55 nautical miles, and the distance between the centre points of cells that are adjacent is 20 nautical miles. We illustrate this step in Figure 3. Here, the grid consists of 4 regular hexagonal cells.

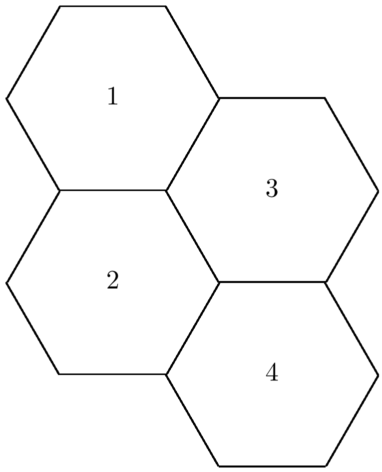

Figure 3. An example of the grid.

Next, we determine the nodes that belong in $\mathscr{N}$. There is the source node s, which is where Blue Fleet commences its transit. There is the sink node t, which is where Blue Fleet concludes its transit. There are 357,918 additional nodes, which represent the centre points of the cells that belong in $\mathscr{C}$ at 121 instances of time. Time starts at 0 hours. It increments by 2 hours, 1 and $\frac{1}{3}$ of 1 hour, 1 hour, $\frac{4}{5}$ of 1 hour and $\frac{2}{3}$ of 1 hour when Blue Fleet's speed of advance is 10, 15, 20, 25 and 30 knots respectively. It ends at 240, 160, 120, 96 and 80 hours when Blue Fleet's speed of advance is 10, 15, 20, 25 and 30 knots respectively. We illustrate this step in Figure 4. The nodes represent the centre points of the cells in the grid that is shown in Figure 3 at 3 instances of time. Node 1_0 represents the centre point of cell 1 at time 0 for instance.

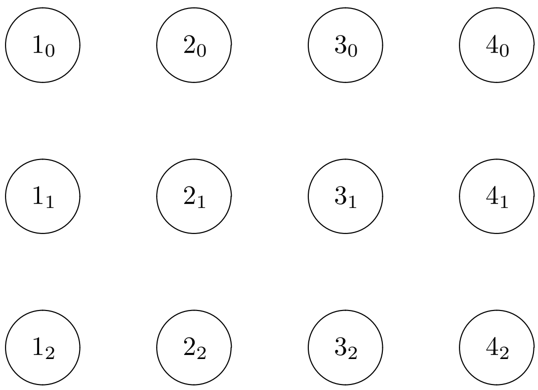

Figure 4. An example of the nodes.

Then, we determine the arcs that belong in $\mathscr{A}$. There is an arc that joins s to the node that represents the cell with centre point $(502.3, 10)$ at time 0. There are 121 arcs that join the nodes that represent the cell with centre point $(502.3, 1010)$ at all instances of time and t. There are additional 2,074,666 arcs that join adjacent nodes. Nodes are adjacent if the distance between the centre points of the cells they represent is 20 nautical miles and their duration is 2 hours, 1 and $\frac{1}{3}$ of 1 hour, 1 hour, $\frac{4}{5}$ of 1 hour and $\frac{2}{3}$ of 1 hour when Blue Fleet's speed of advance is 10, 15, 20, 25 and 30 knots respectively. We illustrate this step in Figure 5. The arcs join the adjacent nodes that are shown in Figure 4. Arc $(1_0, 2_1)$ joins nodes 1_0 and 2_1 for instance.

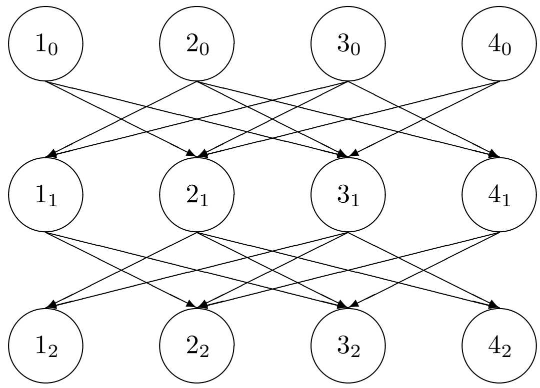

Figure 5. An example of the arcs that join the nodes.

Finally, we determine the arc weight p_{ij} for each arc (i, j) that belongs in $\mathscr{A}$. We set p_{ij} equal to Blue Commander's estimate of the probability Blue Fleet wins at j if j is not equal t and 1 otherwise. To calculate this probability, we model Blue Satellite's information quality, Blue Fleet's information quality, Blue Commander's knowledge and Blue Commander's estimate of the outcome, which are described in Sections 4.1.1, 4.1.2, 4.1.3 and 4.1.4 respectively.

4.1.1 *Probability Distribution for Blue Satellite's Information Quality*

Let us develop the probability distribution for Blue Satellite's information quality for node i, which belongs in $\mathscr{N}$. It involves 3 steps.

Firstly, we need a probability distribution for Blue Satellite persistence. The set of all possible outcomes is Blue Satellite is operational and Blue Satellite is not operational. Thus, we define Blue Satellite is operational to be the event A, and Blue Satellite is not operational to be the event $\bar{A}$. Now, we set both $P(A)$ and $P(\bar{A})$ equal to 0.5 because Blue Satellite can operate for 12 of 24 hours.

Secondly, we need a probability distribution for Blue Satellite's coverage of i. The set of all possible outcomes is Blue Satellite is searching i and Blue Satellite is not searching i. Therefore, we define Blue Satellite is searching i to be the event B_i, and Blue Satellite is not searching i to be the event $\bar{B}_i$. Now, we calculate the probability of B_i and $\bar{B}_i$ using the equations

$$P(B_i) = P(A)P(B_i|A) + P(\bar{A})P(B_i|\bar{A}) \quad (1)$$

and

$$P(\bar{B}_i) = P(A)P(\bar{B}_i|A) + P(\bar{A})P(\bar{B}_i|\bar{A}) \quad (2)$$

respectively, where $P(B_i|A)$ and $P(\bar{B}_i|A)$ are set equal to 0.95 and 0.05 because Blue Satellite searches 95% of the operational area when it is operational, and $P(B_i|\bar{A})$ and $P(\bar{B}_i|\bar{A})$ are set equal to 0 and 1 because Blue Satellite searches none of the operational area when it is not operational.

Finally, we need the probability distribution for Blue Satellite's information quality for i. The set of all possible outcomes is Blue Satellite provides information that correctly suggests the situation in i and Blue Satellite does not provide information that correctly suggests the situation in i. Therefore, we define Blue Satellite provides information that correctly suggests the situation in i to be the event C_i, and Blue Satellite does not provide information that correctly suggests the situation in i to be the event $\bar{C}_i$. Now, we calculate the probability of C_i and $\bar{C}_i$ using the equations

$$P(C_i) = P(B_i)P(C_i|B_i) + P(\bar{B}_i)P(C_i|\bar{B}_i) \quad (3)$$

and

$$P(\bar{C}_i) = P(B_i)P(\bar{C}_i|B_i) + P(\bar{B}_i)P(\bar{C}_i|\bar{B}_i) \quad (4)$$

respectively, where $P(C_i|\bar{B}_i)$ and $P(\bar{C}_i|\bar{B}_i)$ are set equal to 0 and 1 respectively for all of the situations, and $P(C_i|B_i)$ and $P(\bar{C}_i|B_i)$ are set equal to 0.7 and 0.3 respectively if i is outside SDZ and ADZ, 0.15 and 0.85 respectively if i is inside SDZ only, 1 and 0 respectively if i is inside ADZ only, and 0.25 and 0.75 respectively if i is inside SDZ and ADZ.

4.1.2 *Probability Distribution for Blue Fleet's Information Quality*

Let us develop the probability distribution for Blue Fleet's information quality for node i, which belongs in $\mathscr{N}$. The set of all possible outcomes is Blue Fleet provides information that correctly suggests the situation at i and Blue Fleet does not provide information that correctly suggests the situation at i. Therefore, we define Blue Fleet provides information that correctly suggests the situation at i to be the event D_i, and Blue Fleet does not provide information that correctly suggests the situation at i to be the event $\bar{D}_i$. Now, we set $P(D_i)$ and $P(\bar{D}_i)$ equal to 0.4 and 0.6 respectively if i is outside SDZ and ADZ, 0.1 and 0.9 respectively if i is inside SDZ only, 0.99 and 0.01 respectively if i is inside ADZ only, and 0.2 and 0.8 respectively if i is inside SDZ and ADZ.

4.1.3 *Probability Distribution for Blue Commander's Knowledge*

Let us develop the probability distribution for the Blue Commander's knowledge of the situation at node i, which belongs in $\mathscr{N}$. The set of all possible outcomes is the Commander knows the situation at i and the Commander does not know the situation at i. Therefore, we define the Commander knows the situation at i to be the event E_i, and the Commander does not know the situation at i to be the $\bar{E}_i$. Now, the Commander knows the situation at i if he or she receives information that correctly suggests the situation at i from Blue Fleet or Blue Satellite. Conversely, the Commander does not know the situation at i if he or she does not receive information that correctly suggests the situation at i from Blue Fleet and Blue Satellite. As a result, we calculate the probability of E_i and $\bar{E}_i$ using the equations

$$P(E_i) = 1 - [1 - P(D_i)][1 - P(C_i)] \quad (5)$$

and

$$P\left(\bar{E}_i\right) = P\left(\bar{D}_i\right) P\left(\bar{C}_i\right) \quad (6)$$

respectively because Blue Fleet and Blue Satellite are independent systems.

4.1.4 *Probability Distribution for Blue Commander's Estimate of the Outcome*

Let us develop a probability distribution for the Blue Commander's estimate of the outcome at node i, which belongs in $\mathscr{N}$. The set of all possible outcomes includes Blue Fleet wins at i, Blue Fleet draws at i and Blue Fleet loses at i. We are interested in the probability Blue Fleets wins. Therefore, we define Blue Fleet wins at i to be the event F_i, and Blue Fleet draws or loses at i to be the event $\bar{F}_i$. Now, we calculate the probability of F_i and $\bar{F}_i$ using the equations

$$P(F_i) = P(E_i) P(F_i|E_i) + P\left(\bar{E}_i\right) P\left(F_i|\bar{E}_i\right) \quad (7)$$

and

$$P\left(\bar{F}_i\right) = P(E_i) P\left(\bar{F}_i|E_i\right) + P\left(\bar{F}_i\right) P\left(\bar{E}_i|\bar{F}_i\right) \quad (8)$$

respectively, where $P(F_i|E_i)$, $P(\bar{F}_i|E_i)$, $P(F_i|\bar{E}_i)$ and $P(\bar{F}_i|\bar{E}_i)$ are set equal to 1, 0, 0.8 and 0.2 respectively if i is outside SDZ and ADZ, 0.2, 0.8, 0.1 and 0.9 respectively if i is inside SDZ only, 0.8, 0.2, 0.6 and 0.4 respectively if i is inside ADZ only, and 0.4, 0.6, 0.2 and 0.8 respectively if i is inside SDZ and ADZ.

4.2 Shortest Path Problem

Our SPP determines the arcs in Blue Fleet's path x_{ij} that maximise the product of $p_{ij}x_{ij}$ for all

(i,j) that belong in $\mathscr{A}$ from s to t. To solve our SPP, we transform it into standard form. Firstly, we convert the product into a summation. Maximising $\prod p_{ij} x_{ij}$ is algebraically equivalent to maximising $\sum \log_{10}(p_{ij}) x_{ij}$. Secondly, we convert the maximisation to a minimisation. Maximising $\sum \log_{10}(p_{ij}) x_{ij}$ is equivalent to minimising $-\sum \log_{10}(p_{ij}) x_{ij}$. In standard form, our SPP is

$$\text{Minimise } z = -\sum_{(i,j)\in A} log_{10}(p_{ij}) x_{ij} \quad (9)$$

subject to

$$\sum_{\{j:(s,j)\in\mathscr{A}\}} x_{sj} - \sum_{\{j:(j,s)\in\mathscr{A}\}} x_{js} = 1, \quad (10)$$

$$\sum_{\{j:(i,j)\in\mathscr{A}\}} x_{ij} - \sum_{\{j:(j,i)\in\mathscr{A}\}} x_{ji} = 0 \quad (11)$$

if i does not equal s, does not equal t and belongs to $\mathscr{N}$,

$$\sum_{\{j:(t,j)\in\mathscr{A}\}} x_{tj} - \sum_{\{j:(j,t)\in\mathscr{A}\}} x_{jt} = -1, \quad (12)$$

and

$$x_{ij} = \{0,1\} \quad (13)$$

for all (i,j) belonging to $\mathscr{A}$. Constraints 10, 11 and 12 ensure a path from s to t. Constraint 13 ensures that x_{ij} equals 1 if Blue Fleet transits arc (i,j) and 0 otherwise. Here, we are assuming p_{ij} is independent for all (i,j) that belongs in $\mathscr{A}$. This may be justifiable with a our gird, but clearly this is not justifiable as the grid's resolution becomes fine.

Now, we will identify some algorithms that can be used to solve our SPP. We used Dijkstra's algorithm, but could have used the Bellman-Ford or Floyd-Warshall algorithms. Ahuja, Magnanti & Orlin (1993), Bertsekas & Gallager (1999), Hu (1969), Ravindra, Magnanti & Orlin (1993), Ravindran, Phillips & Solberg (1987), Rosen, Michaels, Gross, Grossman & Shier (2000), and Taha (1995) describe Dijkstra's algorithm. Bertsekas & Gallager (1999) describe the Bellman-Ford algorithm. Bertsekas & Gallager (1999), Ravindra et al. (1993), and Rosen et al. (2000) describes the Floyd-Warshall algorithm.

5 RESULTS

Let us look at the paths to start our discussion of the results. They are shown in Figure 6. Blue Fleet commences its transit at 0 hours for all the paths, and concludes its transit at 102, 72, 51, 42.4 and 34.6667 hours for the first, second, third, fourth and fifth path respectively. The spatial variation of the paths is small. They all tend to head directly towards the destination. The largest difference is just under 100 nautical miles.

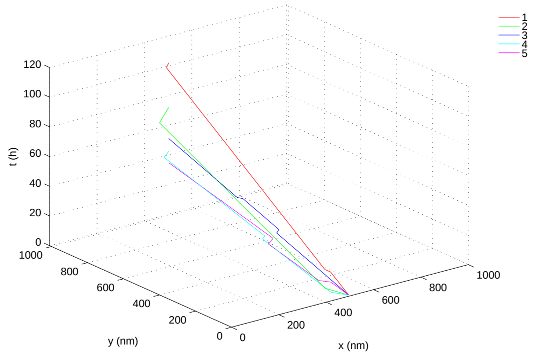

Figure 6. The paths.

We expected the paths to exhibit these trends. The duration of the path is likely to increase when the Fleet's speed of advance decreases. The only time this will not hold is when the path distances vary considerably. However, large variations in distances did not result in this scenario. This trend is intuitive too. The products of the probabilities for the optimal paths is plotted over time in Figure 7. The products of the probabilities are approaching 0 for all of the paths. Consequently, the product of the probabilities for a path with a relatively large distance is likely to be closer to 0 because a larger number of probabilities are multiplied. The only time this will not hold is when the probabilities approach 1.

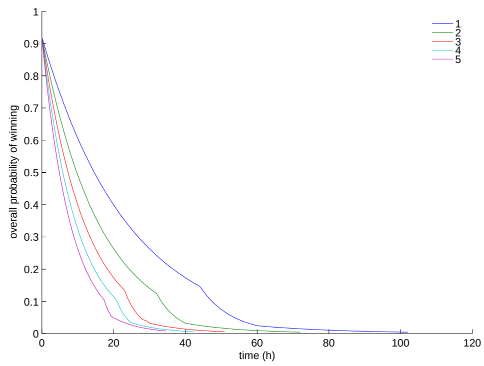

Figure 7. The product of the probabilities of winning.

Now, let us look at the viability of the paths. We show the minimum and mean probabilities for the paths in Table 1. The minimum probabilities are greater than 0.75 for all 5 paths, and the mean probabilities are greater than 0.9 for all 5 paths. Consequently, all 5 paths are viable, which suggests the systems are 100% effective according to Blue Commander's criteria in this scenario.

6 DISCUSSION

Now, we want to discuss the utility of the model. We demonstrated it can be used to quantitatively assess

Table 1. Minimum and mean probabilities of winning.

Path	Minimum Probability	Mean Probability
1	0.79895	0.901292
2	0.79895	0.906705
3	0.79895	0.905944
4	0.79895	0.908701
5	0.79895	0.913054

the value of the systems in this scenario, but can it be used to examine ways of improving the outcome or determine the most valuable systems from the available systems?

The model can be used to improve the outcome in this scenario. Blue Fleet's firepower could be strengthened. This may increase Blue Commander's confidence about Blue Fleet winning engagements that were unavoidable. Alternatively, the ISR's persistence, coverage and information quality could be bolstered by including additional ISR Systems or replacing the Satellite with ISR systems that perform better. This may enable Blue Fleet to transit paths that avoid engagements more successfully than before.

The model can be used to determine the most valuable systems from the available systems for this scenario. Suppose we could use either the Satellite or an Unmanned Aerial Vehicle (UAV) to gather information about the adversary. We could create one model to represent the Satellite's performance and another model to represent the UAV's performance. The results gained from the models can then be compared.

Additionally, we want to discuss the utility of the MOE. In Section 5, we talked about the overall probability of winning (Figure 7) and node-to-node probability of winning (Table 1). The latter type is more directly related to the idea of the proportion of viable paths, and should be more easily related to generic properties of MW, such as mobility, knowledge and firepower. The overall probability of winning depends more on the particular scenario, and relating it to the generic properties of MW is likely to be more difficult. However, we are still investigating the utility of both types of MOE for analysis of ISR.

7 CONCLUSION

We have demonstrated a model for measuring the effectiveness of ISR in a scenario that required the safe transit of a convoy. The modelling concepts, however, are not limited to this scenario. They can be applied to a variety of scenarios where MW can be conducted.

8 ACKNOWLEDGEMENT

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