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TIME LATENCY OF INFORMATION IN NETWORKED OPERATIONS: EFFECT OF 'HUMAN IN THE LOOP'

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Motivation

- "*in a typical discussion of Command and Control, it is taken as axiomatic that the information presented to the commander must be timely as well as accurate, complete etc*." Lawson (1981)

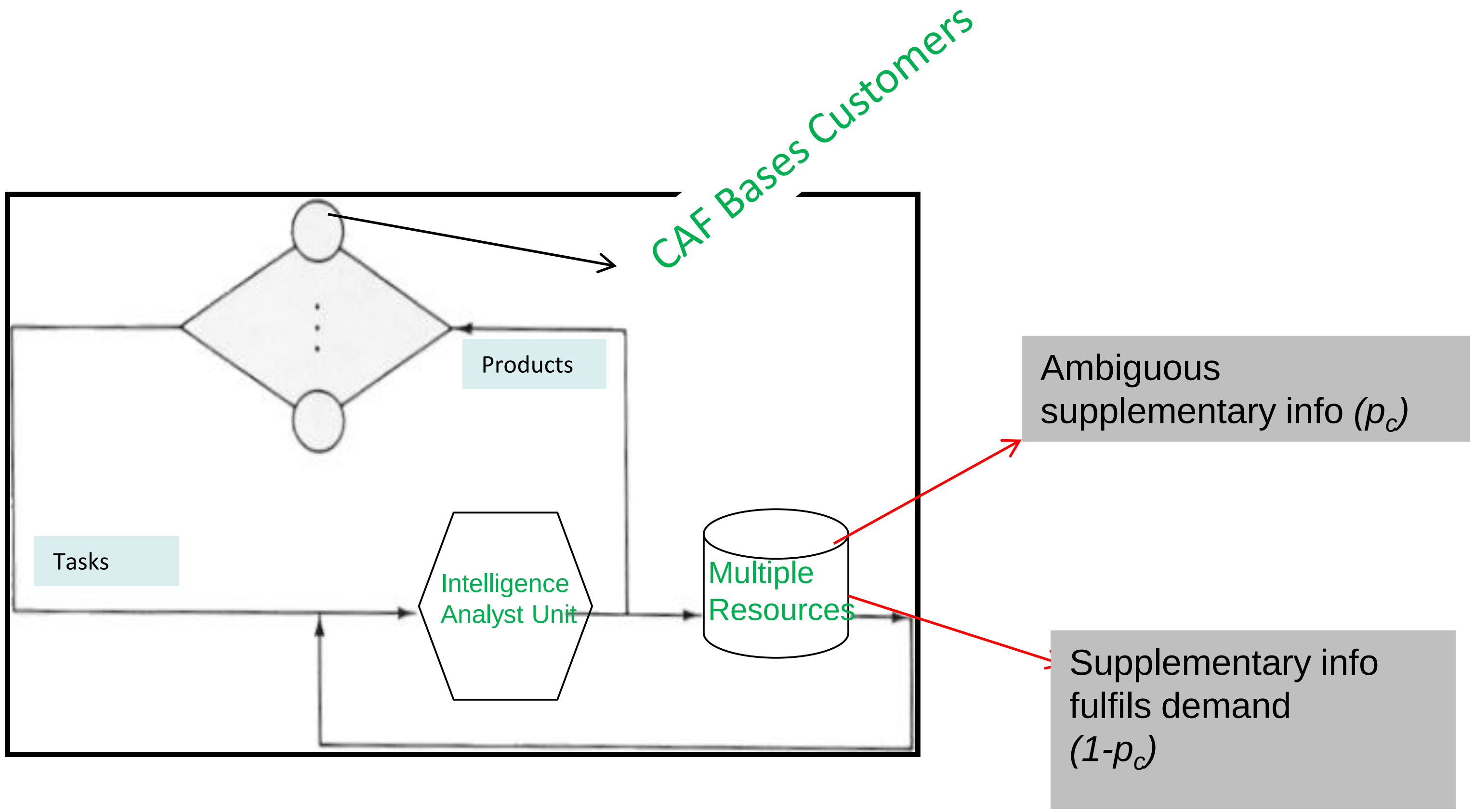
- **We do not attempt the quantification of timeliness, instead**
  - **we suggest means to reduce the time latency of information through *Training***
  - Training which is a subset of readiness accounts for 14% of the Canadian Military Budget (roughly $2.8B in current $)
  - According GAO US Army's Network Enabled Mission Command about $3.8B in FY 2013 which is 3% of the Army's total budget
  - NEO for rapidly gather and distribute information
    - Accelerate the observation-orientation-decision-action (OODA) loop

- **Ultimately the goal is to Understanding the Risks Involved in Networked Operations**
  - **Effect of Human-in-the-Loop**
    - **Explore Inherent Risks of NCW/NEO**

Terms

- Latency
    - transmission, queuing and propagation delays
    - together with the time required for quality evaluation of human operator activities in interpreting information.
- Timeliness
    - Of critical importance in military networked operations and combat.
    - Timeliness is the degree to which mission performance depends on timely and perhaps perishable information
- Accuracy and Completeness
    - Information presented to the commander must be timely as well as accurate and complete
        - Completeness of information implies that it is relevant, comprehensive, sufficient and/or adequate.
        - Information accuracy is difficult to gauge a-priori and can be verified only after the fact. The current mathematical model does not address information accuracy.

Information Flow for the Intelligence Unit Cell



the existing information might be:
Incomplete (*p*) or complete (*1-p*)

Action Outcomes:
Deduction on the completeness of info:
wrong (p_d) or right ($1-p_d$)

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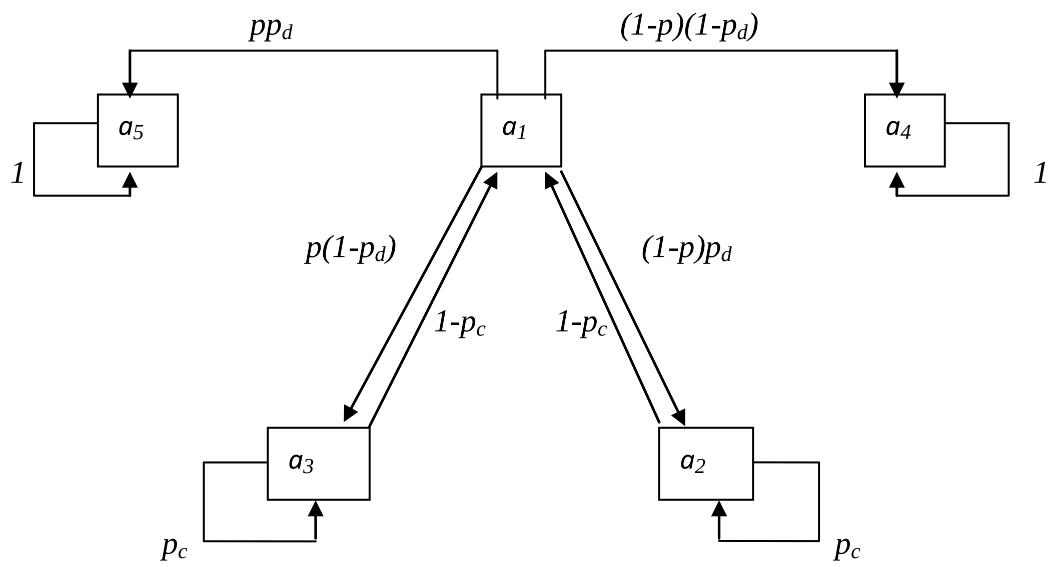
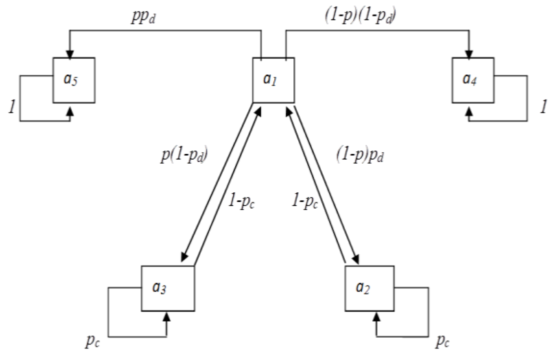
Transition Diagram of a Discrete Time Markov Chain Model



Aside from the initial state where unit analyst receives tasking from customers, there are 4 other distinct states corresponding to the 2 possibilities on the perception of completeness of existing information in the intelligence database and the 2 different courses of action.

Discrete Time
Markov Chain Model



- a_1 = unit analyst receives tasking from customers;
- a_2 = unit analyst requests supplementary information but database is complete; (wrong deduction);
- a_3 = unit analyst requests supplementary information and existing information in database is incomplete; (right deduction)
- a_4 = existing information in database is complete; analyst makes right deduction and provides assessment/analysis to customers;
- a_5 = existing information in database is incomplete; analyst makes wrong deduction and provides assessment/analysis to customers.

Homogeneous Discrete Time Markov Chain Transition Matrix

	a_1	a_2	a_3	a_4	a_5
a_1	0	$(1-p)p_d$	$p(1-p_d)$	$(1-p)(1-p_d)$	pp_d
a_2	$1-p_c$	p_c	0	0	0
a_3	$1-p_c$	0	p_c	0	0
a_4	0	0	0	1	0
a_5	0	0	0	0	1

$$T = \frac{2p_d p - p - p_d - 1 + p_c}{p_c + 2p_d p_c p - p_d p_c - p_c p - 1 - 2p_d p + p_d + p}$$

Fictional Example

- Consider the following three sets of fictional data representing the Intelligence unit performance in the 1st week of May, June and July 2013 respectively. Each data entry in the matrices represents the frequency of transitions between the states.

	a_1	a_2	a_3	a_4	a_5
a_1	0	14	12	21	8
a_2	8	5	0	0	0
a_3	8	0	4	0	0
a_4	0	0	0	21	0
a_5	0	0	0	0	8

Data collected in *1*st week of May

	a_1	a_2	a_3	a_4	a_5
a_1	0	14	12	22	7
a_2	9	5	0	0	0
a_3	8	0	5	0	0
a_4	0	0	0	22	0
a_5	0	0	0	0	7

Data collected in 1st week of June

	a_1	a_2	a_3	a_4	a_5
a_1	0	13	11	20	7
a_2	8	5	0	0	0
a_3	8	0	4	0	0
a_4	0	0	0	20	0
a_5	0	0	0	0	7

Data collected in 1st week of July

Use of Data for Training Decision

- Given the above experimental data, it would be pertinent to ask whether these three sets of transition probabilities reflect the same consistent behavior on the part of the intelligence analyst across the time period under consideration. If so, the data can be pooled to give a single transition count matrix and hence a single set of estimates.

- We use the **likelihood ratio test** to determine if this is the case. This will tell us whether unit analysts shared similar experience and logic in perceiving the information across May to July.

- If this is TRUE, then the data can be used to
  - Produce a polled transition matrix
  - Use the pool to Reduce T through recommendations to reduce p_c or p_d through training.

Test of Stationarity and Pooling counts

n_{ij}	a_1	a_2	a_3	a_4	a_5	Total
a_1	0	41	35	63	22	161
a_2	26	14	0	0	0	40
a_3	24	0	13	0	0	37
a_4	0	0	0	63	0	63
a_5	0	0	0	0	22	22

Pooled transition counts

$\hat{p}_{ij}$	a_1	a_2	a_3	a_4	a_5
a_1	0.00	0.26	0.22	0.39	0.14
a_2	0.65	0.35	0.00	0.00	0.00
a_3	0.65	0.00	0.35	0.00	0.00
a_4	0.00	0.00	0.00	1.00	0.00
a_5	0.00	0.00	0.00	0.00	1.00

Transition Matrix for pooled counts

Future Directions

- Incorporate Learning Models
- Lessons from behavioral economics/Psychology
- From Discrete time to dynamic (continuous)
- Datafarming applications for Intelligence organizations

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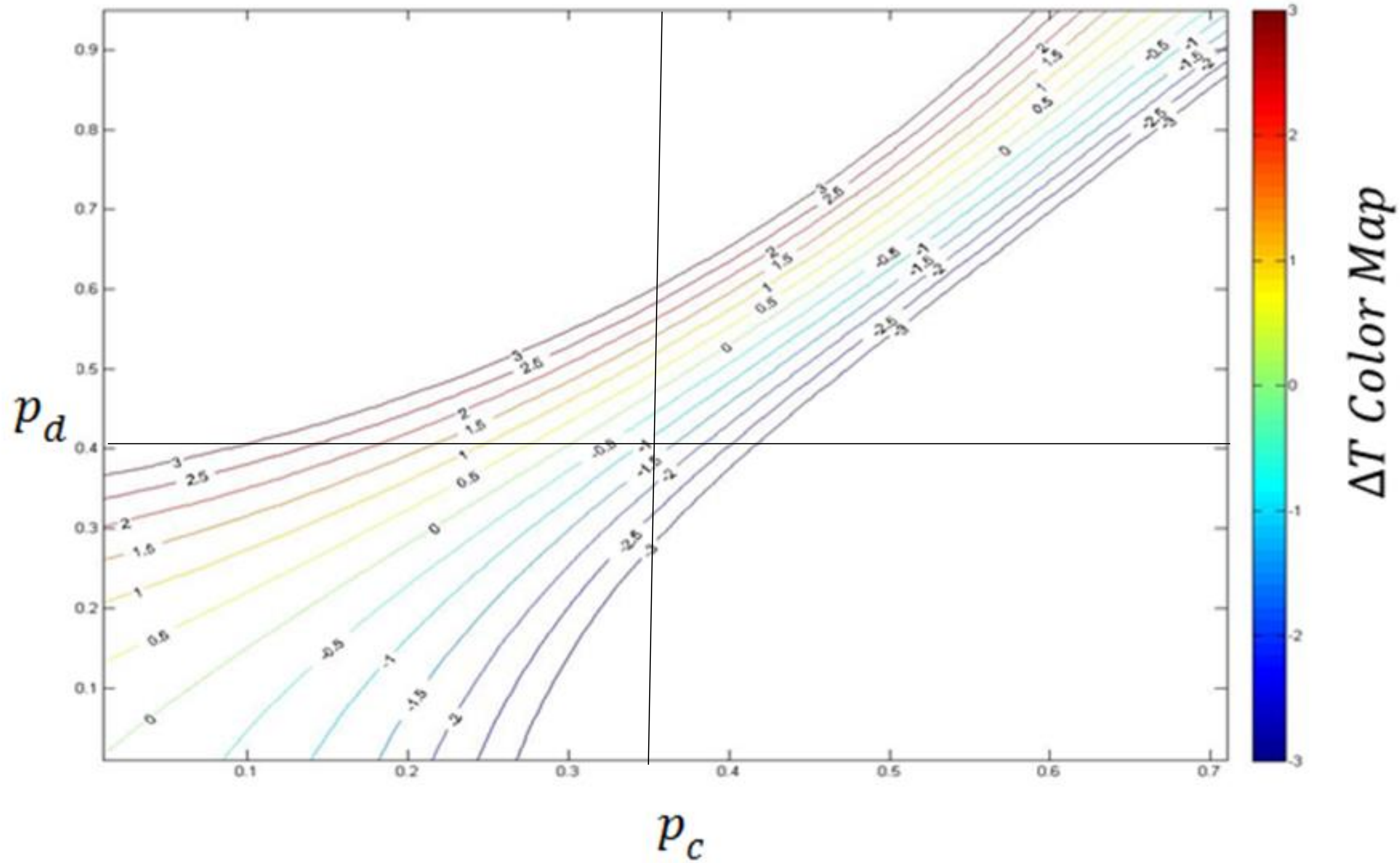

p_d
p_c
ΔT Color Map