Panel: Machine Reasoning for Decision Support

Machine Reasoning for Determination of Threat Level in Irregular Warfare

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EMPOWERING A SOLDIER'S SUCCESS

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Irregular Warfare (IW)

Irregular warfare (IW) is defined as a violent struggle among state and non-state actors for legitimacy and influence over the relevant populations. IW favors indirect and asymmetric approaches, though it may employ the full range of military and other capabilities, in order to erode an adversary's power, influence, and will. It is inherently a protracted struggle that will test the resolve of our Nation and our strategic partners.

Irregular Warfare (IW)

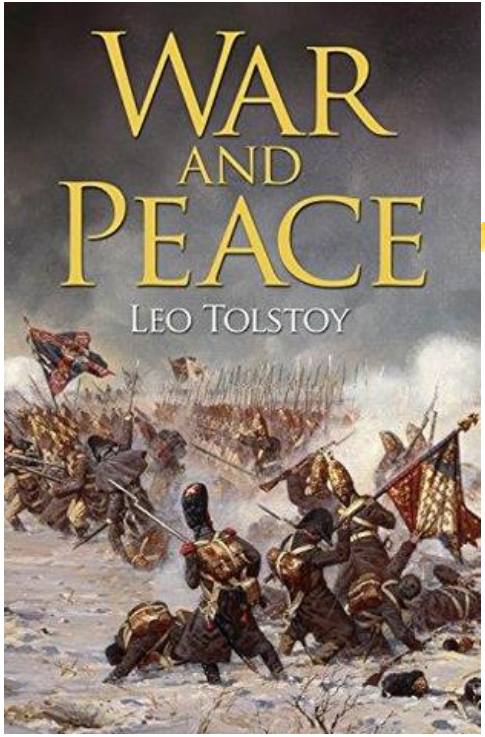
Joint Operating Concept (JOC)

11 September 2007

- IW campaign depends on military power and (more on) understanding of social dynamics
- "People will be the key to IW success"*
- Social Dynamics
  - Tribal politics, social networks, religious influences, and cultural change

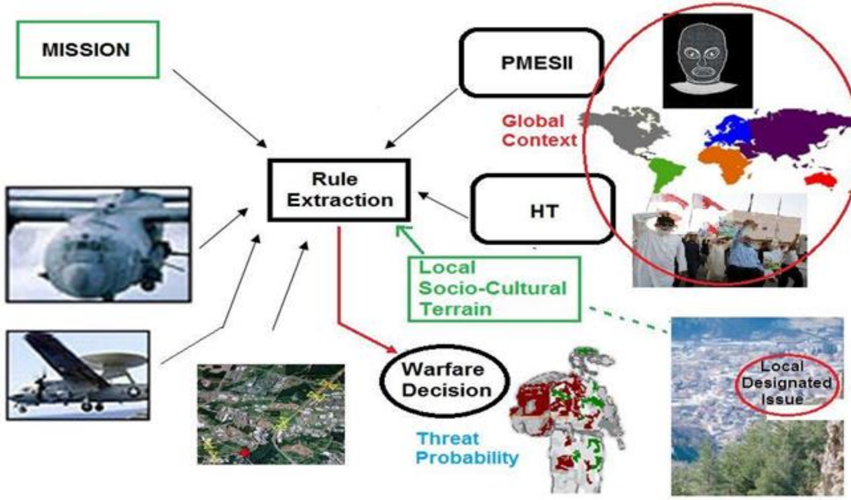
- * Irregular War (IW) Joint Operation Concept (JOC)", version 1.0, 9/11/2007. Department of Defense

“Spirit of Army” and “Human Terrain”



- Retreat of Napoleon and French Army
- Sudden Russian partisan war and winning
- “A war was determined by the spirit of army not by mass nor by genius” Leo Tolstoy, War and Peace.
- Importance of people and human activities in field operation in IW and Counterinsurgency (COIN)
- “Sociocultural, political, psychological, collective behavior” → **Human Terrain**
- **Human Terrain**: In field operations, “the social, political, and economic environment, belief systems, and forms of interaction of the people among whom soldiers operate.”*
- * A. M. de Vries, “The Human Terrain of Counterinsurgency Operations: Developing the Military Mindset and Social Science Support,” Defense Science and Technology Laboratory, Wiltshire, UK, 2010.

Technical Approach



Objective:

- Development of <u>an irregular warfare decision assist system</u> for determining and predicting the operating environment threat level by utilizing diverse HT (human terrain) data of past and real-time transient socio-cultural events.

Benefits:

- Incorporation of the global perspective in to local decision making for irregular warfare in determining threat under diverse and transient social and military situations → Operational Benefit
- Answer to :"With the local populace info gathered by Sp Op, what is the insurgency/tribal uproar threat?

Approach

- Human-Like Reasoning → Inductive Reasoning
- Information Entropy based Algorithm for Applying inductive inference → machination → Update and Learning
- Extraction of dominant contributors (of high separability) toward Rule Generation with Prob and margin of error

Expectation, Surprise, Information, Entropy

- Information measure
  - Comparison of the contents of new data (evidence) with the prior state of expectation
  - The higher prior estimate of the probability for an outcome to occur, the lower will be the information gain by observing it to occur, and less "Surprise"
  - Information Quantity (I_Q) "Prior estimate of a probability (expectation)"

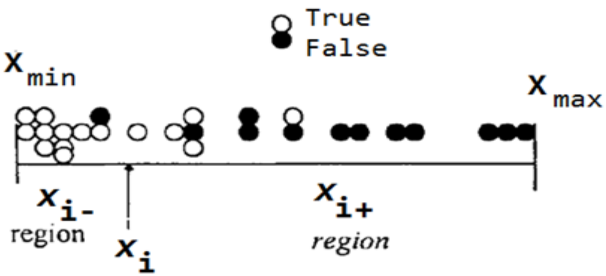
$$I_Q = -k \ln P$$

- Information Entropy: A measure of the "amount of uncertainty" in probability distribution → <u>Expected value of information gain</u>
- Claude Shannon:

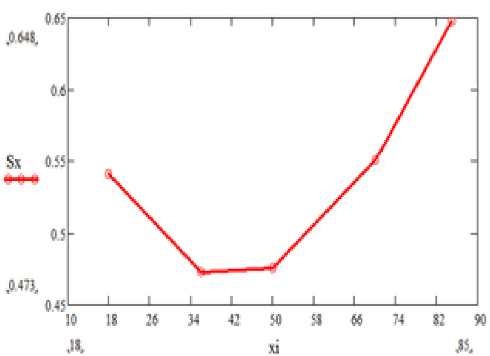
$$S = -k \sum_i P_i \ln P_i$$

Attribute Values and Conversion to Binary Values

- Analog Value Attributes
- Threshold value determination (for binary designation)
- Conditional Entropy and Entropy Minimization



$$x_{th} = \arg\min\{S(x_i) = p(x_{i-})S(x_{i-}) + p(x_{i+})S(x_{i+})\}$$



$S(x_{i-}) = -[p(T\,|\,x_{i-})\ln p(T\,|\,x_{i-}) + p(F\,|\,x_{i-})\ln p(F\,|\,x_{i-})]$: Conditional entropy for x_{i-}: $[X_{\min}, x_i]$ domain,

$S(x_{i+}) = -[p(T\,|\,x_{i+})\ln p(T\,|\,x_{i+}) + p(F\,|\,x_{i+})\ln p(F\,|\,x_{i+})]$: Conditional entropy for x_{i+}: $[x_i, X_{\max}]$

$p(x_{i-})$: is the ratio of the number of samples in the x_{i-}: $[X_{\min}, x_i]$ domain and the total number of samples,

$p(x_{i+})$is the ratio of the number of samples in the x_{i+}: $[x_i, X_{\max}]$ domain and the total number of samples,

$p(T\,|\,x_{i-})$: the ratio of the number of samples in x_{i-}: $[X_{\min}, x_i]$ domain which belongs to outcome T and the total number of samples in x_{i-}: $[X_{\min}, x_i]$ domain,

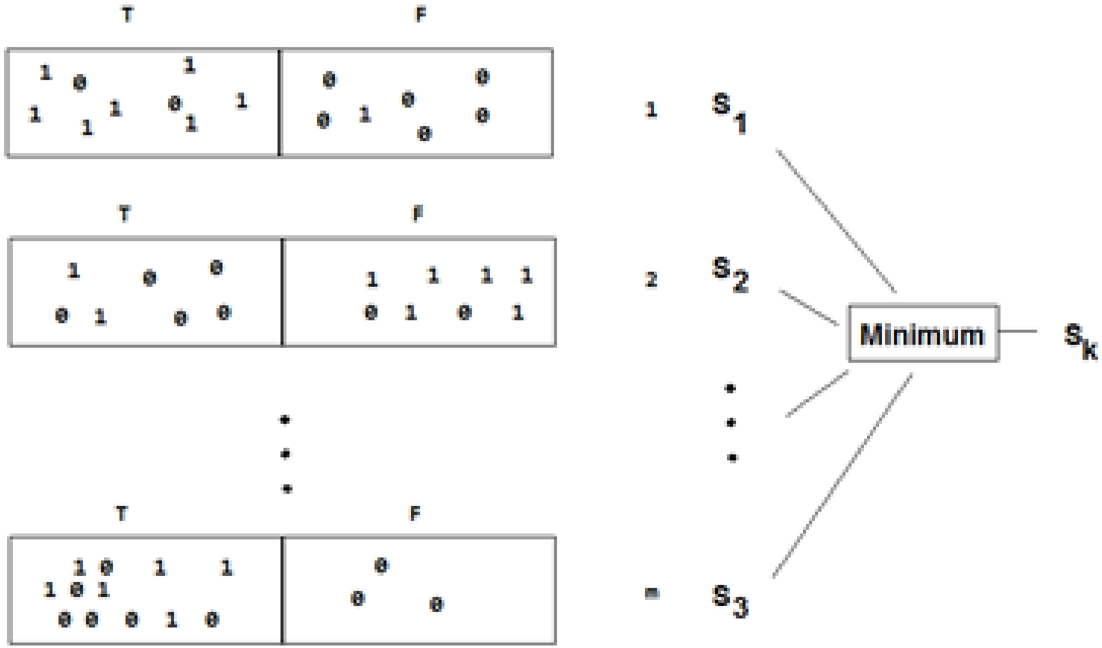
$p(F\,|\,x_{i-})$: the ratio of the number of samples in x_{i-}: $[X_{\min}, x_i]$ domain which belongs to outcome F and the total number of samples in x_{i-}: $[X_{\min}, x_i]$ domain,

Dominant Contributors – Order of Importance

$$S_{i1} = -[p_i(T|1)\ln p_i(T|1) + p_i(F|1)\ln p_i(F|1)]$$

$$S_{i0} = -[p_i(T|0)\ln p_i(T|0) + p_i(F|0)\ln p_i(F|0)]$$

$$S_i = p_i(0)S_{i0} + p_i(1)S_{i1}$$



$$S(x_i): \arg\min_x S(x)$$

Decision Rule with Dominant Contributors

- Prediction rule R_k for the k-th attribute
  - Highest conditional probability from

$$p_k(T\,|\,1),\ p_k(T\,|\,0),\ p_k(F\,|\,1),\ p_k(F\,|\,0)$$

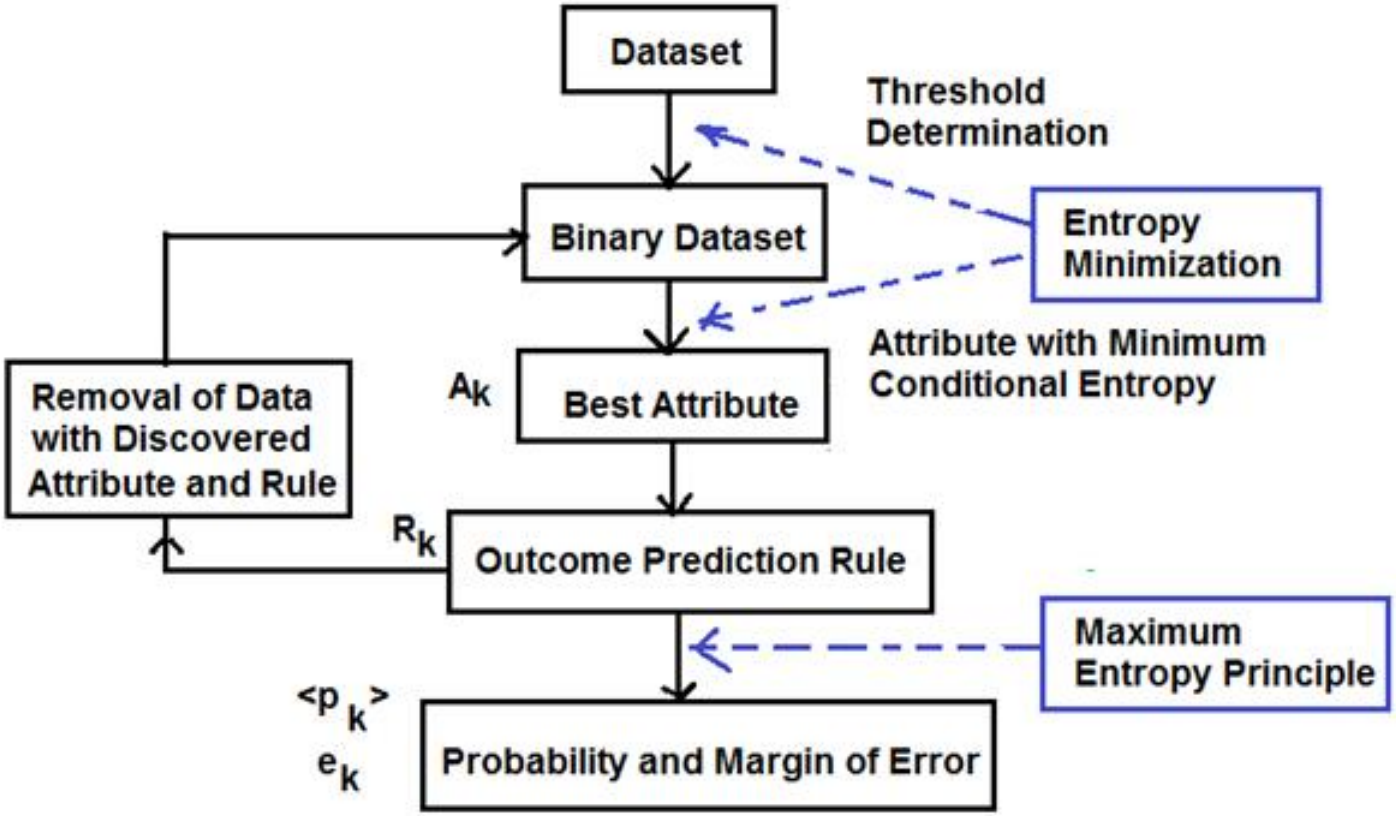
- Unbiased Probability <p> **(Bayesian Estimate) – "Laplace Rule of Succession"**
  - Maximum Entropy based
  - x_k: For k-th attribute, the total number of samples satisfying the <u>condition</u> and the <u>outcome</u> (event)
  - n_k: For k-th attribute, the total number of samples satisfying <u>only the condition</u>

$$< p_k(O) >= \frac{x_k + 1}{n_k + 2}$$

- Uncertainty or Margin of Error(e)
  - z: z-score (1.65 for 90% CI, 1.96 for 9 99%)

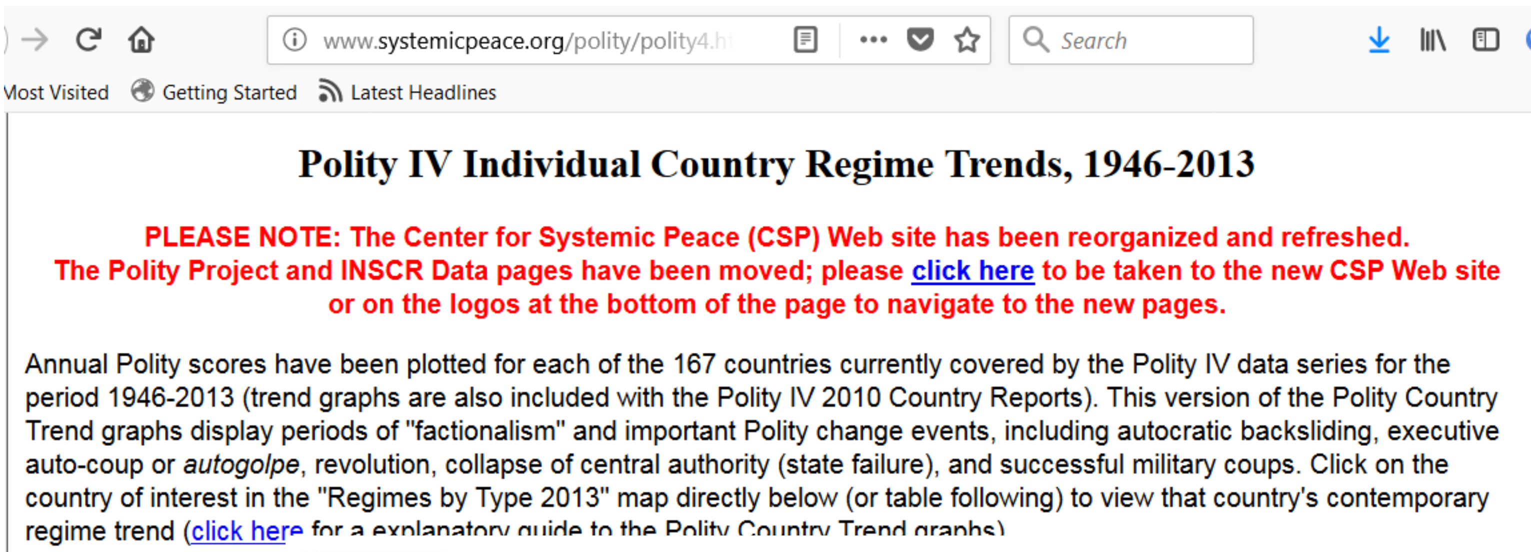
$$e_k(O) = z \cdot \frac{< p_k(O) > \cdot \{1 - < p_k(O) >\}}{n_k + 2}$$

Structure of Algorithm



Polity Data

- Lack of or No access to Real Data of Human Terrain
- Polity Database: Polity IV Project
  - Political Regime Characteristics and Transition
  - Sponsored by PITF (Political Instability Task Force)



Polity IV Individual Country Regime Trends, 1946-2013

PLEASE NOTE: The Center for Systemic Peace (CSP) Web site has been reorganized and refreshed. The Polity Project and INSCR Data pages have been moved; please click here to be taken to the new CSP Web site or on the logos at the bottom of the page to navigate to the new pages.

Annual Polity scores have been plotted for each of the 167 countries currently covered by the Polity IV data series for the period 1946-2013 (trend graphs are also included with the Polity IV 2010 Country Reports). This version of the Polity Country Trend graphs display periods of "factionalism" and important Polity change events, including autocratic backsliding, executive auto-coup or *autogolpe*, revolution, collapse of central authority (state failure), and successful military coups. Click on the country of interest in the "Regimes by Type 2013" map directly below (or table following) to view that country's contemporary regime trend (click here for a explanatory guide to the Polity Country Trend graphs)

Center for Systemic Peace

INSCR
Integrated Network for Societal Conflict Research

Example 4 – Polity Data

Center for Systemic Peace INSCR

www.systemicpeace.org/inscrdata.html

Getting Started · Latest Headlines

Polity IV: Regime Authority Characteristics and Transitions Datasets

User's Manual PDF	Polity IV Annual Time-Series, 1800-2016	**Polity IV Project, Political Regime Characteristics and Transitions, 1800-2016**, annual, cross-national, time-series and polity-case formats coding democratic and autocratic "patterns of authority" and regime changes in all independent countries with total population greater than 500,000 in 2016 (167 countries in 2016) (SPSS and Excel data; PDF codebook) Click here for the list of changes made during the year 2016 annual data update (SPSS and Excel file; PDF codebook).	SPSS Series	Excel Series
	Polity IVd Polity-Case Format, 1800-2016		SPSS Case	Excel Case

1.0* **PRESENT** Present Polity (p4d)
1.1 **CYEAR** Country Year (p4)
1.2 **CCODE** Numeric Country Code
1.3 **SCODE** Alpha Country Code
1.4 **COUNTRY** Alpha Country Name
1.5 **YEAR** Year Coded (p4)
1.6 **FLAG** Tentative Coding (p4)
1.7 **FRAGMENT** Polity Fragmentation (p4)

2.1 **DEMOC** Institutionalized Democracy
2.2 **AUTOC** Institutionalized Autocracy
2.3 **POLITY** Combined Polity Score
2.4 **POLITY2** Revised Combined Polity Score (p4)
2.5 **DURABLE** Regime Durability (p4)
2.6* **PERSIST** Number of Years Polity Has Persisted (p4d)

3.1 **XRREG** Regulation of Chief Executive Recruitment
3.2 **XRCOMP** Competitiveness of Executive Recruitment
3.3 **XROPEN** Openness of Executive Recruitment
The Independence of Executive Authority........................
3.4 **XCONST** Executive Constraints (Decision Rules)
Political Competition and Opposition..............................
3.5 **PARREG** Regulation of Participation
3.6 **PARCOMP** The Competitiveness of Participation

4.1 **PRIOR** Prior Polity Code (p4)
4.2 **EMONTH** Polity End Month
4.3 **EDAY** Polity End Day
4.4 **EYEAR** Polity End Year
4.5 **EPREC** End Date Precision
4.6 **INTERIM** Interim Polity Code (p4)
4.7 **BMONTH** Polity Begin Month
4.8 **BDAY** Polity Begin Day
4.9 **BYEAR** Polity Begin Year
4.10 **BPREC** Begin Date Precision
4.11 **POST** Post Polity Code (p4)
4.12 **CHANGE** Total change in POLITY value (p4)
4.13 **D4** Regime Transition Completed (p4)
4.14 **SF** State Failure (p4)
4.15 **REGTRANS** Regime Transition (p4)

- For Testing
- **16 Attributes**
- 1 Classification (RegTrans)
- 1369 Samples
- Randomly divided to 4 sub-samples of almost equal size
  - A, B, C, and D
- (1) Train by A & Test by BCD subset
- (2) Train by AB & Test by CD subset

Polity Data

- Train by A (387 samples) and Test by BCD (1081 samples)
- RULE

FRAGMENT PARREG PRIOR XROPEN PARCOMP EYEAR YEAR BYEAR

A	B	C	D	E	F	G	H
1	10	12	8	11	13	0	14
3	2	2	0	2	2	1	3
0.60303	0.8457	0.96777	0.67871	0.6001	0.625	0.61914	0.6665
0.12079	0.06384	0.06216	0.09985	0.24792	0.33545	0.14685	0.53369
0.05832	3.20703	5.33594	1.52441	1.33887	1895	1980	1982

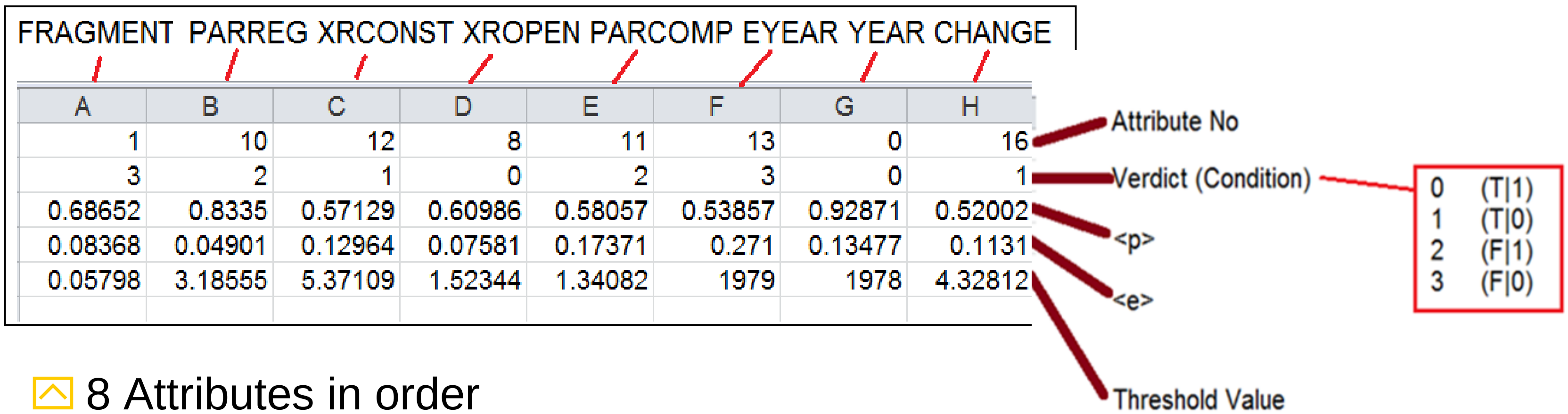
Row labels: Attribute No; Verdict (Condition); <p>; <e>; Threshold Value

0	(T|1)
1	(T|0)
2	(F|1)
3	(F|0)

- 8 Attributes in order
- Correct (66.51%)
  - True Positive (19.00 %)
  - True Negative (47.51 %)
- Incorrect (33.49 %)
  - False Positive (15.71 %)
  - False Negative (17.78 %)

Polity Data

- Train by AB (749 samples) and Test by CD (719 samples)
- RULE



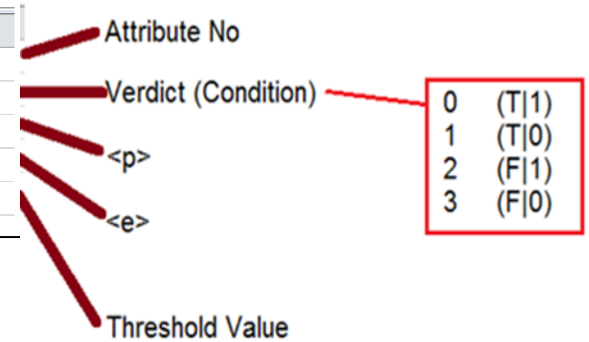
FRAGMENT	PARREG	XRCONST	XROPEN	PARCOMP	EYEAR	YEAR	CHANGE
A	B	C	D	E	F	G	H
1	10	12	8	11	13	0	16
3	2	1	0	2	3	0	1
0.68652	0.8335	0.57129	0.60986	0.58057	0.53857	0.92871	0.52002
0.08368	0.04901	0.12964	0.07581	0.17371	0.271	0.13477	0.1131
0.05798	3.18555	5.37109	1.52344	1.34082	1979	1978	4.32812

- 8 Attributes in order
- Correct (64.12%)
  - True Positive (27.82 %)
  - True Negative (36.30 %)
- Incorrect (35.88 %)
  - False Positive (24.48 %)
  - False Negative (11.40 %)

Polity Data

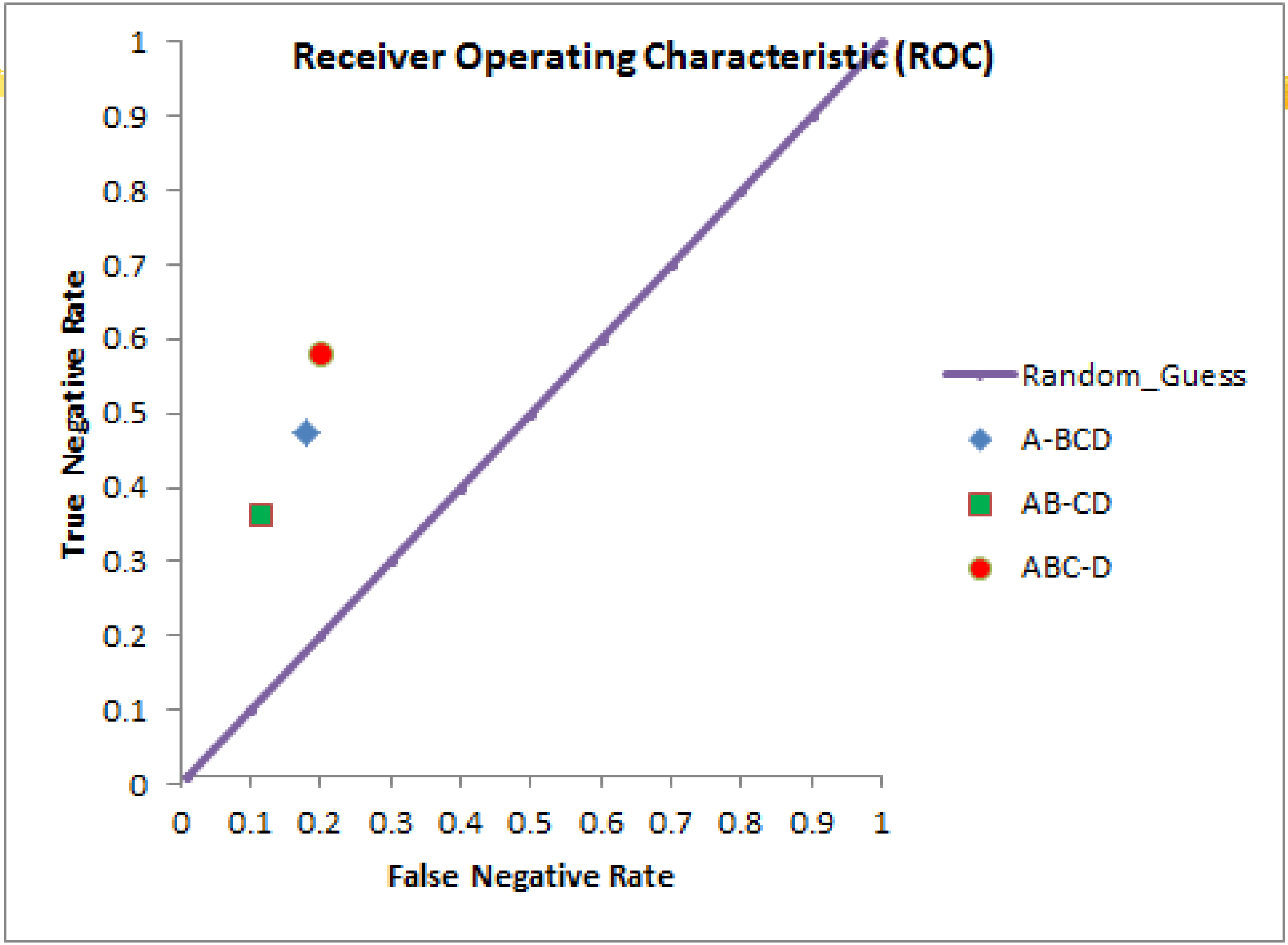
- Train by ABC (1121 samples) and Test by D (347 samples)
- RULE

FRAGMENT	AUTOC	PRIOR	EYEAR	CHANGE	YEAR
A	B	C	D	E	F
1	3	12	13	16	0
3	2	2	3	1	3
0.72217	0.86816	0.88867	0.5332	0.60645	0.6665
0.06543	0.03714	0.05307	0.25244	0.08667	0.53369
0.05591	4.85547	3.13867	1967	4.27734	2004



  - 6 Attributes in order
  - Correct (71.07 %)
    - True Positive (13.21%)
    - True Negative (57.86 %)
  - Incorrect (28.93 %)
    - False Positive (8.8 %)
    - False Negative (20.13 %)
- Fewer Number of Attributes
- Accuracy Improved
- <p> raised and <e> lowered

Polity Data – ROC (Receiver Operating Characteristic)



Conclusions

- Machine Reasoning Prototype Implementation
- Dominant Contributor Extraction ("High Separability")→ Data Size Reduction
- Rule Extraction with Quantified Probability and Margin of Error
- Update with New Data and Decision Experience (Success or Failure)
- Theoretical Rigor in Data Analytics
- Other Application Areas
  - Behavioral Security for cybersecurity enhancement or lapse
    - Insider Threat Detection
  - Radicalization Detection
    - When do people snap?

Acknowledgment

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  - #DO1-W911SR-14-2-0001-0015 “Irregular Warfare Decision Assist System for Determining Threat” 8/1/2017 – 7/31/2019 (funded period)
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  - POC: Raymond McGowan, CIV USARMY RDECOM

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