Machine Reasoning for Determination of Threat Level in Irregular Warfare

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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.

- 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


11 September 2007
“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.”

Technical Approach

**Objective:**

- Development of an irregular warfare decision assist system 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
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 → Expected value of information gain

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 \( x_{i+} \): \([x_i, X_{\max}]\) domain

\( p(x_{i-}) \): 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

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

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

\[
S_i = p_i(0)S_{i0} + p_i(1)S_{i1}
\]

\[
S(x_i) = \arg \min_x S(x)
\]
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 $\langle p \rangle$ (Bayesian Estimate) – “Laplace Rule of Succession”
  - Maximum Entropy based
  - $x_k$: For $k$-th attribute, the total number of samples satisfying the condition and the outcome (event)
  - $n_k$: For $k$-th attribute, the total number of samples satisfying only the condition
  \[ \langle p_k(O) \rangle = \frac{x_k + 1}{n_k + 2} \]

- Uncertainty or Margin of Error($e$)
  - $z$: $z$-score (1.65 for 90% CI, 1.96 for 99%)
  \[ e_k(O) = z \cdot \frac{\langle p_k(O) \rangle \cdot [1 - \langle p_k(O) \rangle]}{n_k + 2} \]
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 an explanatory guide to the Polity Country Trend graphs).
Example 4 – Polity Data

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 **

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 %)

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<tr>
<td>B 3 2 2 0 2 2 1 3</td>
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<tr>
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<tr>
<td>E 0.06832 3.20703 5.33594 1.52441 1.33887 1895 1980 1982</td>
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- Attribute No
- Verdict (Condition)
- Threshold Value

0 (T1)
1 (T0)
2 (F1)
3 (F0)
Polity Data

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

<table>
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<tr>
<td>0</td>
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<tr>
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<td>(T</td>
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<td>3</td>
<td>(F</td>
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</table>

Fragment PARREG XRCONST XROPEN PARCOMP EYEAR YEAR CHANGE

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**

- 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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