Automated Decision Support in a Complex Information Space

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Briefing Structure

- Paper vs. Briefing Detail
- A Paradigm Shift
  - Information Models
  - Heuristics
  - Decision Support
- Foundations Needed to Understand Briefing Focus
  - Knowledge Representation
  - Peircean Philosophy
- Induction
- Abduction
- Applications to Date

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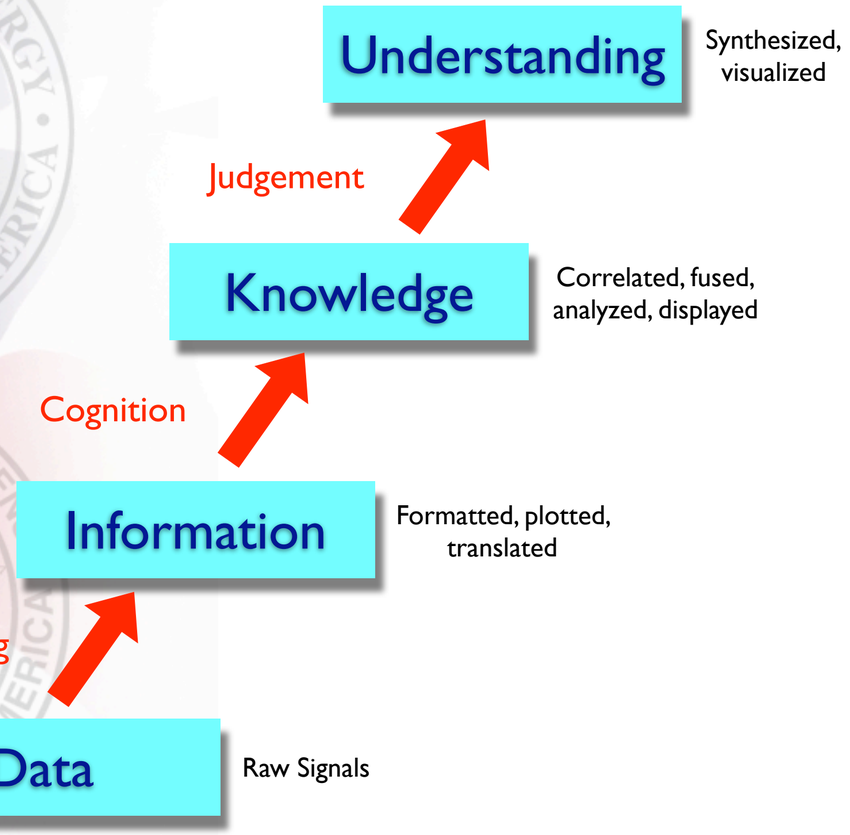
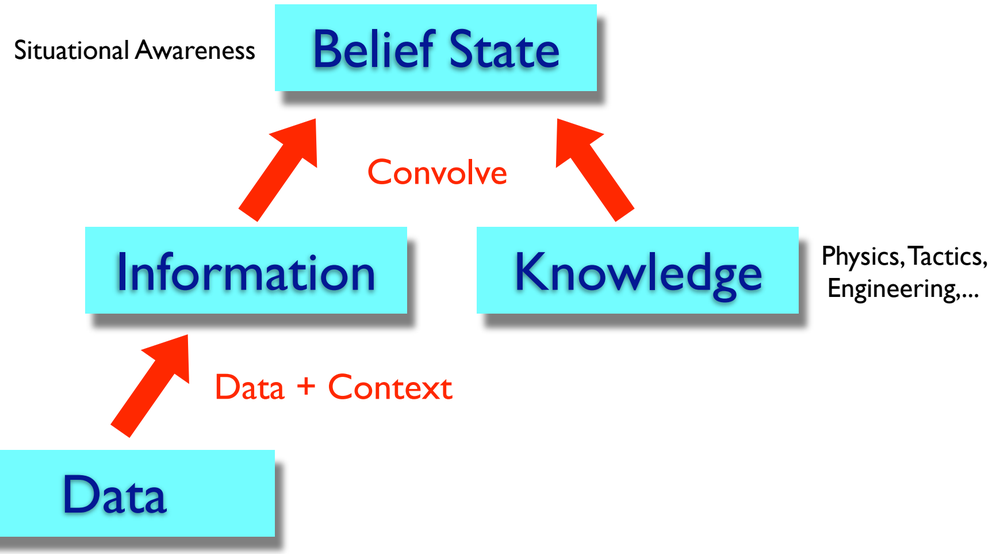
Information Models

Cognitive Hierarchy



Reasoning Hierarchy



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Heuristics vs. Physics

Heuristic	Physics
Formulations based on observation	Algorithms based on physical theory
Heat Transfer	**Statistical Physics**
energy flow = F(temperature difference)	energy flow = F(particle microstates)
Information Operations	**Neuro-physiology**
reasoning = F(logic, philosophy, and mathematics)	cognition = F(neural architecture/dynamics)

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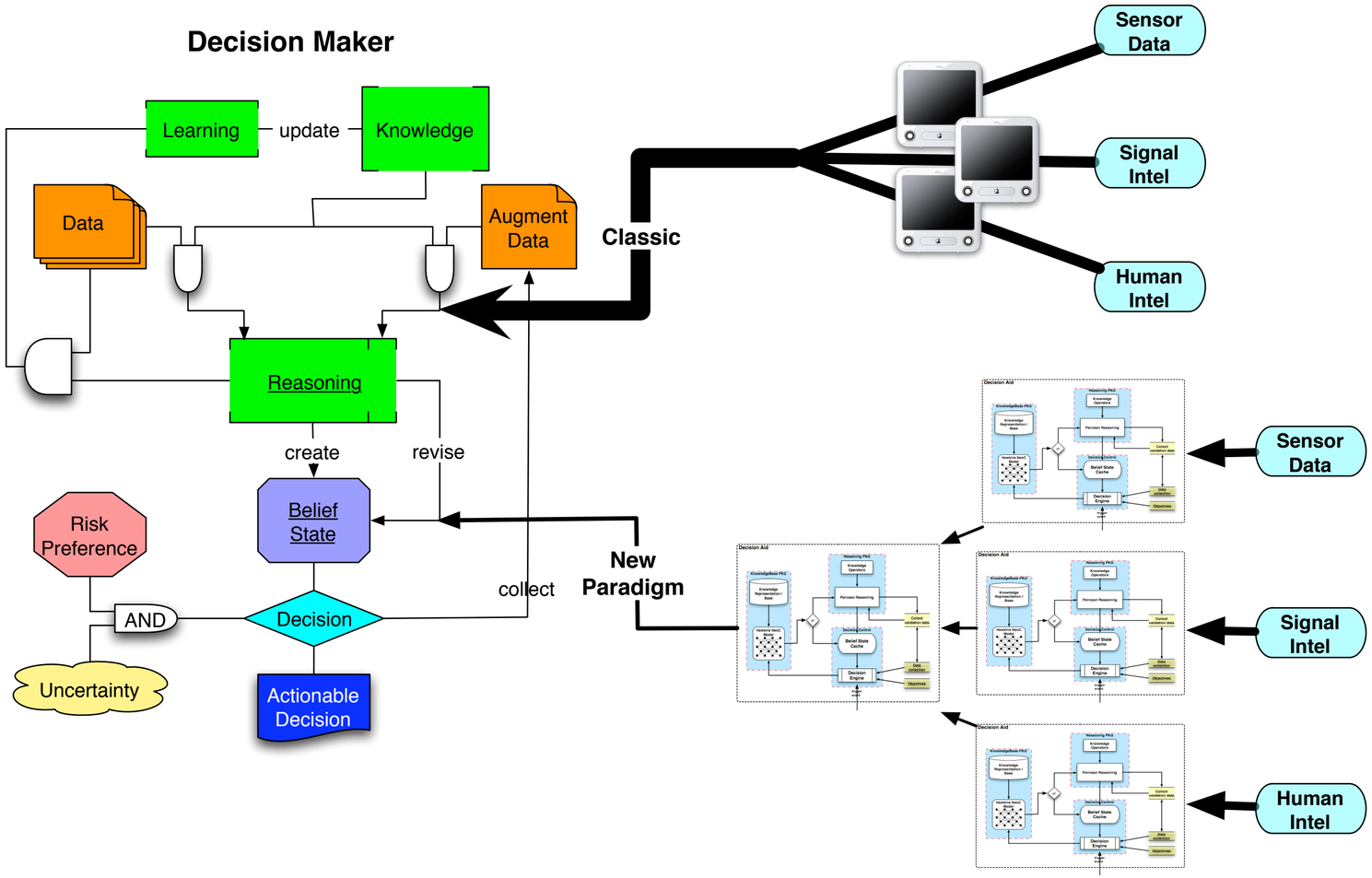
Decision Making Paradigm



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Knowledge Representation

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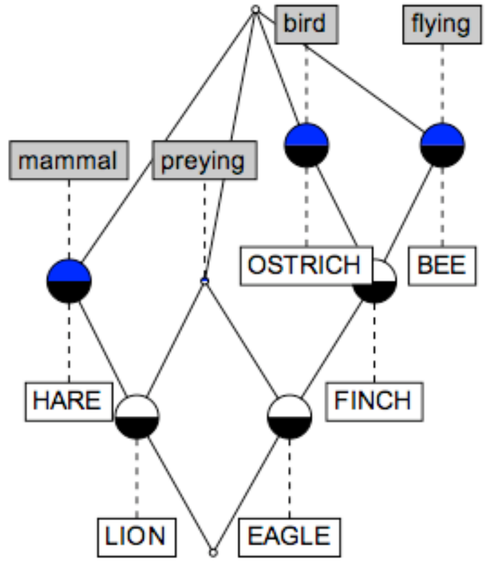
Formal Concept analysis (FCA)

$$K = \{ G, M, \overline{\overline{I}} \}$$

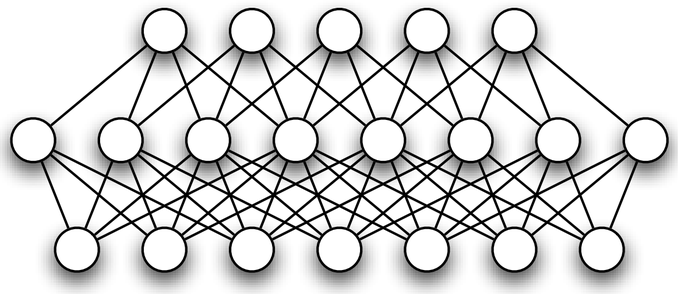
Cross Table

Animals	Preying	Flying	Bird	mammal
Lion	x			x
Finch		x	x	
Eagle	x	x	x	
Hare				x
Ostrich			x	
Bee		x		

FCA Lattice



Neural Processor



Attribute Output Layer

Feature Input Layer

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Formal Concept Analysis*
(Theory)

- Ordered Set Theory, a structure: P = (P,≤)
  - A set P, and a binary relation ≤
    - An ordered set is reflexive, antisymetric and transitive.

$$\begin{array}{l}(i)\ a \le a \\ (ii)\ a \le b \text{ and } b \le a \Rightarrow a = b \\ (iii)\ a \le b \text{ and } b \le c \Rightarrow a \le c\end{array}$$

- Formal Context
  - A triple consisting of a set of objects, a set of attributes and a binary relation between the 2 sets.

$$K_{FC} = (G, M, I)$$

- The 'Prime' operator
  - An operator that returns the set of attributes when applied to a set of objects or the set of objects when applied to a set of attributes.

$$\begin{array}{l}(A)' \equiv \{m \in M \mid (g,m) \in I, \forall g \in A\} \\ (B)' \equiv \{g \in G \mid (g,m) \in I, \forall m \in B\}\end{array}$$

- Concepts
  - A set of sets, the first term a set of objects, the second term the set of common attributes.
    - E.g. the concept (A,B); A={Earth, Mars}, B={near sun, small, has-a-moon}

$$\begin{array}{c}(A,B) \xrightarrow{fc} (G,M,I) \\ \Leftrightarrow \\ A \subseteq G,\ B \subseteq M \\ (A)' = B \,\&\, (B)' = A\end{array}$$

- 'Begriff'
  - The set of all concepts in a context.
    - Concept ordering based on subset-superset structure and a Galois connection.

$$\begin{array}{c}(A_1,B_1) \le (A_2,B_2) \\ \Leftrightarrow \\ A_1 \subseteq A_2 \ \vee \ B_2 \subseteq B_1\end{array}$$

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*** Theory formulated by Ganter & Wille**

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Construction of the 'Begriff'

- Begriff
  - Set of all concepts associated with a context.
  - Identify the intent of the Context
    - The set of all attributes.
  - Next construct the power set of the Intent, set S on the left.
  - Use the 'Prime' operator to identify the extent for each member of the power set.
    - Each member of the power set is a potential intent in the Begriff.
    - Result is a set of concepts for the context.
    - Will have multiple intents for each extent.
  - Construct a union of all intents for each unique extent.
    - Result is the final Begriff of a context.

$$S = \{Intent\}_{\,formal\ context}$$

$$P_s = \{p\} = \{\mathcal{P}(S)\}$$

$$\mathcal{B}^* = \sum_k C^*_k(\mathcal{E}_k, I_k) = \{\sum_k \{(p_k)'\}, \{p_k\}\}$$

in which

$$C^*_k = C_k(\mathcal{E}_k, I^1_k \cup I^2_k \cup I^3_k \ldots \cup I^n_k)$$

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Formal Concept analysis (FCA)
(PDA Variations)

- Real world attributes include 'real' valued attributes.
  - Formal Context refined.
    - The context captures sets of objects G, attributes M, attribute values W, and the binary relations of the sets.
    - Object g has a value w for attribute m.

$$\mathcal{K}_{mv} = (G, M, W, I)$$

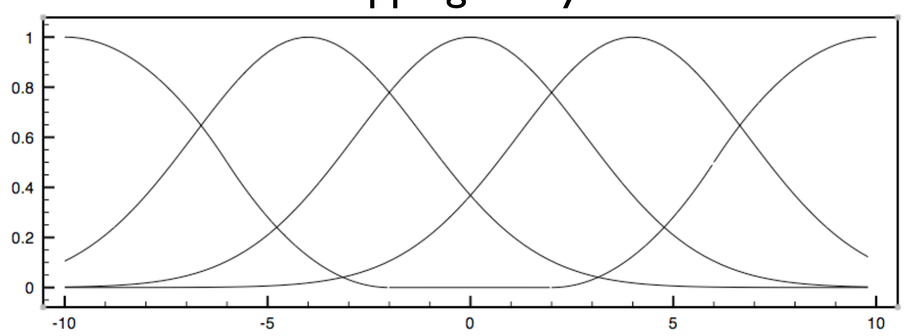
$$D(m) \equiv g \in G \,|\, (g, m, w) \in I, w \in W$$

- PDA relaxes G & W constraints and uses fuzzy set theory to represent real attributes.
  - Variable membership lies in the range [0,1].
    - PDA employs overlapping Gausian membership functions.

$$\text{crisp set} \equiv \mu_A : X \rightarrow \{0, 1\}$$
$$\text{fuzzy set} \equiv \mu_A : X \rightarrow [0, 1]$$

$$\mu_k = e^{[-(x - c_k)^2 / 2\sigma^2]}$$

Overlapping Fuzzy Sets



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Formal Concept analysis (FCA)

- Modification of the binary interaction operator, I, in a formal context.
- Interaction operator I, is replaced by a ‘set’ of interaction operators linked to a set of predicates.
  - P is a set of predicates, Ip is a set of interaction operators, and X defines the linkage between predicates and interaction operators.
    - The sum of the interation operators yields the classic interaction operator.

$$K_{FC} = (G, M, I)$$

$$I_s \equiv (P, I_p, X)$$

$$I = \sum_p I_p$$

Peircean Philosophy

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Peircean Philosophy

- C.S. Peirce; Sept 10, 1839 - April19, 1914.
  - Writings cover 1857 to 1914
    - 12000 printed pages, ~80000 handwritten pages.
- His work touches/impacts:
    - Mathematics and Philosophy
      - Mathematics of logic (tri-logic, existential graphs)
      - Pragmatism
      - Semiotics
- Phenomenology
  - ...qualities of our experience...
- The Normative Sciences: Aesthetics, Ethics, and Logic
  - ...our responses to our experiences...
- Metaphysics
  - ...that which is real...
- Impact on information theory is beginning to be understood.

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Peircean Category & 'Sign'

- Category
  - Firstness is the quality of an object.
    - The taste of banana, redness, or anxiety
  - Secondness is the effect that firstness has on us.
    - E.g. pushing on a closed door, the resistance is secondness.
    - The heat felt from a hot iron on our hand.
  - Thirdness mediates between secondness, fact, and firstness, possibility.
    - Thirdness represents laws that govern facts in the future.
- 'Sign'
  - Sign is a triadic entity. The object "... *for which it stands is called its object; that which it conveys, its meaning (the sign itself); and the idea to which it gives rise, its interpretant.*"
  - There are three types of sign:
    - Icon - linked to firstness, excites an idea naturally.
    - Index - linked to secondness, stands for an object by its real connection to it, like a weather vane is an indication of wind direction.
    - Symbol - linked to thirdness, might be a word, phrase or treatise, such as quantum mechanics.

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Peircean Logic

- Critic
  - Studies the relationship of signs to their objects.
- Speculative Grammar
  - The theory of the meaning of signs.
    - Addresses the means that logical thoughts may be represented.
- Speculative rhetoic
  - Studies the methods that should be pursued in seeking truth.

Peircean Reasoning

- Based on Peirce's Principle of the "Method of Scientific Inquiry'
- Consists of 3 components:
  - Inductive reasoning
  - Deductive Reasoning
  - Abductive Reasoning
    - Including Analogical Reasoning
- As humans, we all reason, some with a greater degree of sophistication.
  - We all appear to be imbued with a native Inductive reasoning capability.

Components of Peircean Reasoning

Deduction

Any M (is / is not) P
(Any / Some) S is M
∴ (Any / Some) S (is / is not) P

Induction

Any M (is / is not) P
(Any / Some) S (is not / is) P
∴ (Any / Some) S is not M

Abduction

(Some / Any) S (is / is not) P
(Any / Some) S is M
∴ Some M (is / is not) P

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Induction

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Induction

Philosophical Perspective

- Induction: *Is a mode of reasoning which adopts a conclusion as approximate.*
  - It is reasoning from a sample to the whole.
- Peirce Identifies Three Forms of Induction.
  - Weak form.
    - When sample and population sizes can be determined.
  - Strong form.
    - Examples where a single counter example can be identified.
      - Find one liberal that is not intellectually bankrupt.
  - 'Gradual' form.
    - Like the strong form but conclusions are updated with new samples.
- Induction Serves Three Functions.
  - Inductive Reasoning
    - Throw a ball in the air N times, observe it falling to the ground each time. If I throw it up the (N +1)st time, I expect it to fall to the ground again.
  - Inductive Learning
    - Draw a rule from observation and use that to predict. (Law of convective heat transfer)
  - Inductive Hypothesis Verification

Induction

Psychological Perspective*

- Heit's article discusses research on Induction in the psychological communities.
  - There appears to be a minimalist understanding / deference to the work of the philosophical communities.
    - Basic definitions of Induction.
      - No reference to which role/function of Induction is being researched.
    - Flawed interpretation of Hume's philosophical dilemma associated with arguing the existence of Induction using inductive arguments.
      - Pragmatism provides a basis for arguing the existence of Induction.
  - There may be(?) an attempt to explore the forms of Induction as defined by Peirce but it is unclear in the write-up.
    - Weak form, Strong form
    - The property dimension does not clarify Induction, rather it confounds results with prior knowledge.
  - The analysis of the 'weak form' of induction fails to consider prior knowledge.
  - No consideration of negative examples.
  - The last issue is the lack of developing a research hypothesis and designing the experiment that would validate the hypothesis if true.
    - Regression analysis on the presumptive variables of the experiment adds no new insights into the theory or functionality of Induction

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*** E. Heit 'Properties of inductive reasoning'**

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Operational Considerations

- Three roles for Induction: Reasoning, Learning, and Hypothesis verification.
- Flinn's method addresses inductive reasoning.
  - Entire 'training' set is used to evaluate a new unknown.
- Peircean Decision Aid (PDA) defines an Inductive learning engine.
  - Based on Finn's Inductive reasoning agorithm.
  - Uses training set to develop a heuristic representation of the underlying knowledge.
  - Categorical knowledge of the heuristic is used to assess new unknown blocks of data.

Finn's Method

- Finn's method is based on Mill's canons
  - 'Method of agreement'
  - 'Method of differences'
  - 'Indirect method'
  - 'Method of concomitant variation'
  - 'Method of residues'.
- The Finn algorithm is based on the first canon.
  - If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or effect) of the given phenomenon.
- Algorithm is based on training sets of positive and negative examples associated with a goal attribute.
  - The examples provide a basis for defining positive & negative Begriffs.
    - The algorithm for determining a Begriff is presented in the next slide.

Construction of the 'Begriff'

- Begriff
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in which

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Finn's Method of Inductive Reasoning

- Based on J.S. Mill's first Canon
  - Method of Agreement
- Procedural description
  - Identify or select a goal attribute, g.
    - E.g. the terrorist group responsible for an incident or the tactics used.
  - Evaluate an unknown against the positive and negative Begriff's to determine if it is a positive, negative or unresolved example.
    - If the intent of an unknown exists in 2 or more concepts of the positive context and does not appear in any concept of the negative context, the unknown can be classed as a positive example. Similarly for a negative classification.
      - g_8 is positive, g_9 negative, g_{10} indeterminate
- Two issues with Method:
  - Must use full sample set for each Unknown.
  - Heuristic of 2 examples does not belong in theory.

$$M = \{a, b, c, d, e\}$$
$$G_+ = \{g_1, g_2, g_3, g_4\}$$
$$G_- = \{g_5, g_6, g_7\}$$

Positive & negative examples

$$g_1^+ = \{a, b, c\} \qquad g_5^- = \{a, c, d\}$$
$$g_2^+ = \{a, b, d\} \qquad g_6^- = \{b, c, d\}$$
$$g_3^+ = \{a, b, e\} \qquad g_7^- = \{a, d, e\}$$
$$g_4^+ = \{a, c, e\}$$

Unknowns

$$g_8^\tau = \{a, b, c, e\}$$
$$g_9^\tau = \{c, d, e\}$$
$$g_{10}^\tau = \{a, b, c, d\}$$

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PDAs Inductive Learning

- Based on Finn's Method
- Process description:
  - Accept entire training context.
  - Construct positive Begriffs based on the selected goal attribute.
  - To define the classification context for a goal 'value', no heuristics are built into the theory.
    - Biases are part of the engineering implementation and user 'set-able'.
  - Remove negative concepts from the positive Begriff of goal value k.
    - Using thresholds and 'likelihood' estimates we can bias the system in the direction of false positives or false negatives.
  - Result is best estimate of attributes describing an object associated with a goal value.

$$B_k \equiv (A_k, B_k) |\ A_k \subseteq A;\ B_k = (A_k)'$$
$$with$$
$$k = goal\ attribute$$

$$B_k^* \equiv B_k^{\sim} - \sum_{m \neq k} B_m^{\sim}$$

$$lh_{k,m} = SizeOf(\ C_{m,E}\ ) \,/\, SizeOf(\ B_k^*\ )$$

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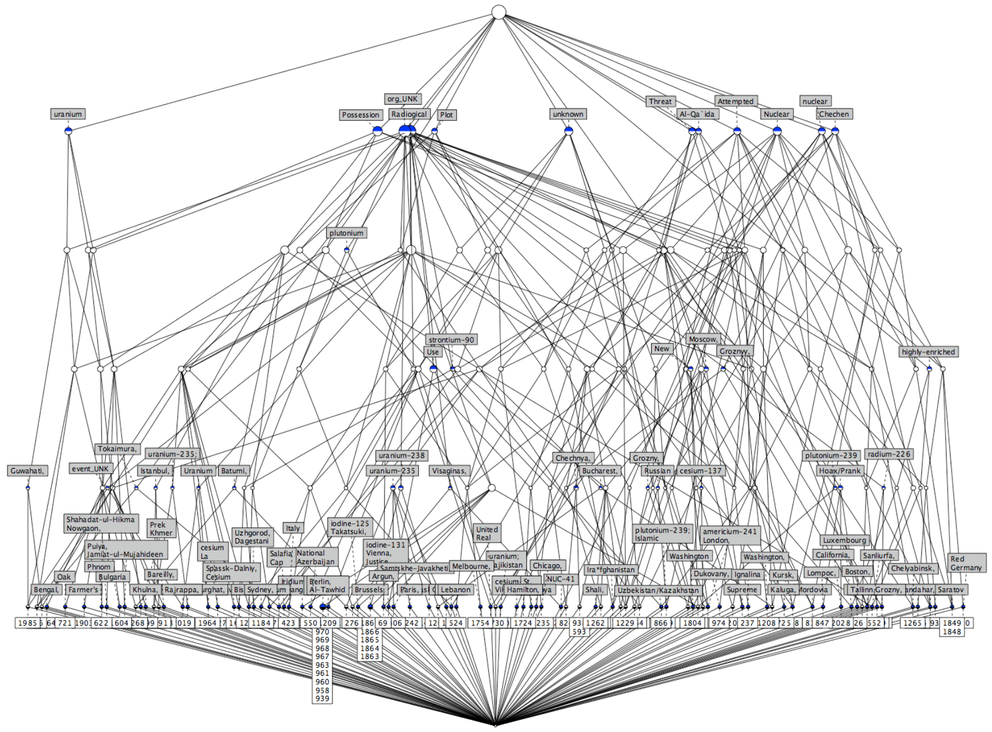
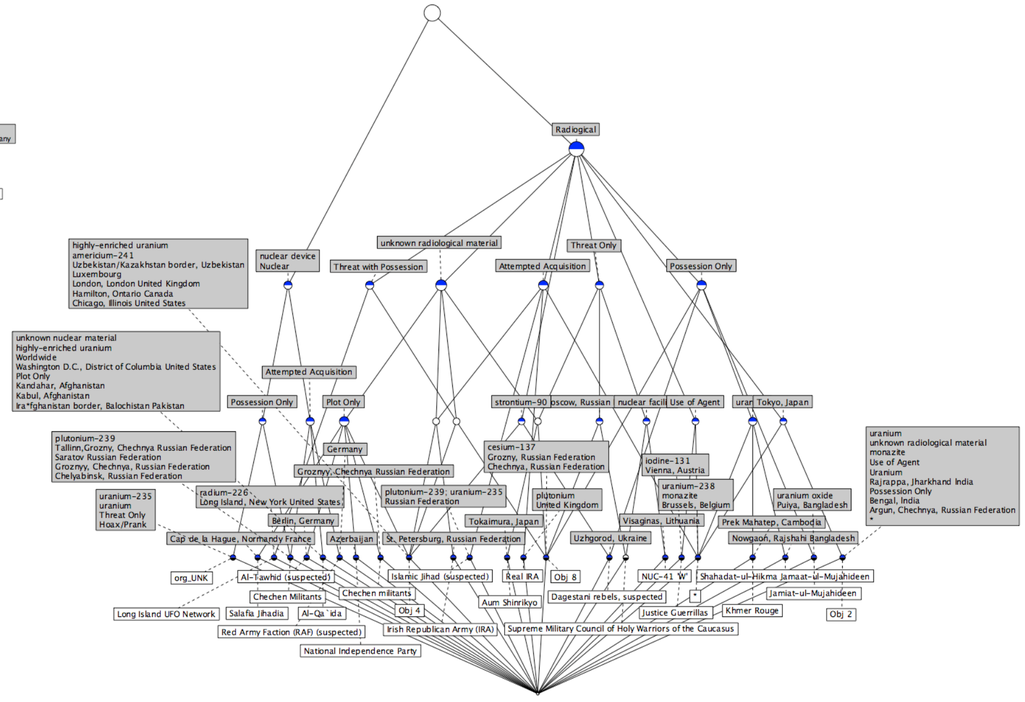
Induction



Raw WMD terror Incidents

Knowledge Induced from Incidents



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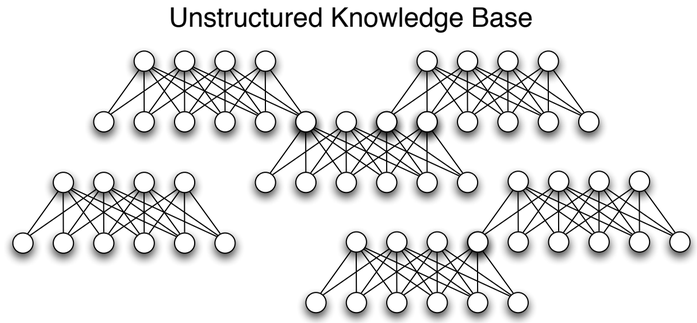
Abduction

Abduction

- Means by which new knowledge is created.
- Abduction begins with the observation of some ‘surprising’ fact.
  - Surprise implies your belief state is in doubt, rationality dictates that we want to eliminate doubt.
- Hypotheses are generated to explain the fact.
  - ...if theory A is correct then observation C would follow...
- Peirce identified a process/criteria for finding an optimal hypothesis.
  - Criteria involve explanation, verifiability, and economy.
  - Peirce’s ‘economy of research’ involves the intrinsic value of the proposed hypothesis, and the effect on future research.

PDA Model of Abduction

- Current version of PDA uses a flat knowledge structure.
  - Any knowledge hierarchy is a product of the collected knowledge.
- Hypotheses are produced by convolving knowledge with information representing some unknown.
  - Using FCA as the knowledge representation technology results in set operations being the mechanism for generating hypotheses.
- Expanding the structure of the knowledge base modifies the process.
  - Process is iterative, use initial hypotheses to augment info and find the next set of hypotheses.
  - Next level of hypothesis involves a disjunctive operation.



$$\{H\} \equiv \sum_j I \cap K_j$$

$$\{I'\} \equiv \{I\} \cup \{H\}$$

$$\{H'\} \equiv \sum_j I' \cap K_j$$

$$\{H_{lev2}\} = H \cap H' - H$$

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Belief Cache

- A belief cache is a mathematical representation of situational awareness.
  - Flat knowledge base belief cache.
    - time tag, activation flag, the hypothesis, support data, validation data, and unresolved collected information.
  - Hierarchical knowledge base would result in a belief cache structure reflecting the abstraction of hypotheses.

$$C_j \equiv \left\langle \begin{matrix} t_j, Active_j \\ \{h_{j,0}, \{d_n^s\}, \{d_m^v\}, \{d_r^{uc}\}\} \end{matrix} \right\rangle$$

$$C_j \equiv \left\langle \begin{matrix} t_j, Active_j \\ \{h_{j,0}, \{d_n^s\}, \{d_m^v\}, \{d_r^{uc}\}\} \\ \vdots \\ \{h_{j,r}, \{h_{j,r-x}\}\{d_n^s\}, \{d_m^v\}, \{d_r^{uc}\}\} \\ \vdots \end{matrix} \right\rangle$$

Abduction

Knowledge + Data = Situational Understanding

Knowledge

ClassName	Type	2004	2005	2006	2007	2008	2009	2010	AssignedNorth	AssignedEast	AssignedSouth	SubmergedSpeed	SurfaceSpeed	SonarCM_Level	Sonar_Level	Noise	BatteryPoints	WeapRounds	FwdTubes	AftTubes	TorpedoRating	Mines	Hull_Numbers	SOF_Teams	Power
Type094	SSBN	0	0	0	1	1	1	2	0	0	0	27	18	CMLev_4	SonarLev_6	VeryQuiet	12	20	6_tubes	No_AftTubes	20	36	Hull_409_412	2_teams	NS
Type093	SSGN	1	1	2	2	3	3	4	1	0	0	30	18	CMLev_4	SonarLev_6	VeryQuiet	12	20	6_tubes	No_AftTubes	20	36	Hull_407_408_410_411_413_414	2_teams	NS
Xia092	SSBN	1	1	1	1	1	1	1	1	0	0	22	12	CMLev_3	SonarLev_5	Average	9	20	6_tubes	No_AftTubes	20	36	Hull_406	2_teams	NS
Han091	SSN	5	5	5	5	5	5	5	1	0	0	26	12	CMLev_2	SonarLev_5	Average	9	20	6_tubes	No_AftTubes	20	36	Hull_401_402_403_404_405	2_teams	NS
KiloIII(AIP)	SS	0	0	0	0	0	3	6	0	0	0	17	12	CMLev_4	SonarLev_6	VeryQuiet	120	18	6_tubes	No_AftTubes	20	36	Hull_381_382_383_384_385_386	1_team	DES
KiloII(636)	SS	2	2	6	10	10	10	10	0	1	0	17	12	CMLev_4	SonarLev_6	VeryQuiet	24	18	6_tubes	No_AftTubes	20	24	Hull_366_367_368_369_370_371_372_373_374_375	1_team	DES
KiloI(877)	SS	2	2	2	2	2	2	2	0	1	0	17	12	CMLev_3	SonarLev_5	Quiet	24	18	6_tubes	No_AftTubes	20	24	Hull_364_365	1_team	DES
SongII(039G)	SSG	6	7	7	9	9	11	11	0	1	1	22	15	CMLev_4	SonarLev_6	VeryQuiet	180	12	6_tubes	No_AftTubes	20	24	Hull_321_322_323_324_314_315_316_317_318_319_325	1_team	DES
SongI(039)	SSG	1	1	1	1	1	1	1	0	1	0	22	15	CMLev_4	SonarLev_5	Quiet	36	12	6_tubes	No_AftTubes	20	24	Hull_320	1_team	DES
MingIII(035AIP)	SS	6	6	6	6	6	6	6	0	0	1	18	15	CMLev_4	SonarLev_6	VeryQuiet	120	18	6_tubes	2_AftTubes	20	326	Hull_361_305_306_307_308_309	1_team	DES
MingII(035E)	SS	12	12	12	12	12	12	12	1	0	0	18	15	CMLev_3	SonarLev_5	Quiet	24	16	6_tubes	2_AftTubes	11	326	Hull_342_352_353_354_355_356_357_358_359_360_362_363	1_team	DES
MingI(035)	SS	2	0	0	0	0	0	0	0	0	0	18	15	CMLev_2	SonarLev_4	Quiet	24	12	6_tubes	2_AftTubes	11	24	Hull_233	1_team	DES
RomeoII(033G)	SSG	1	0	0	0	0	0	0	0	0	0	12	15	CMLev_2	SonarLev_4	Quiet	39	14	6_tubes	2_AftTubes	11	28	Hull_351	1_team	DES
RomeoII(033)	SS	21	18	12	6	6	6	6	1	1	1	12	15	CMLev_3	SonarLev_5	Quiet	39	14	6_tubes	2_AftTubes	11	28	Hull_293_294_295_296_297_298_299_300_301_302_303_304_343 to 349_3	1_team	DES
ReserveRomeo	SS	15	15	15	15	12	9	6	1	1	1	12	15	CMLev_2	SonarLev_4	Quiet	39	14	6_tubes	2_AftTubes	11	28	Hull_268_269_270_271_272_275_276_277_278_279_280_286_287_291_292	1_team	DES
Moth.Romeo	SS	12	12	12	12	12	12	12	0	0	1	12	15	CMLev_2	SonarLev_3	Quiet	39	14	6_tubes	2_AftTubes	11	28	Hull_249_250_251_252_253_254_255_256_257_258_259_260	1_team	DES
Gulf(Auxiliary)	SSBA	1	1	1	1	1	1	0	1	0	0	15	15	CMLev_2	SonarLev_3	Average	14	265	6_tubes	4_AftTubes	11	44	Hull_200	1_team	DES
Sang-O(Xpt)	SSM	1	1	1	1	1	1	1	0	0	1	8	8	CMLev_2	SonarLev_4	VeryQuiet	4	0	No_tubes	No_AftTubes	0	8	Hull_351	1_team	DES

Data

```
<UNK_root>
<Control input="xtable" >  </Control>
  <Intel_Report>

        <Object> Initial_finding <Class type="generic">
                <Attr> noiseLevel <value type="label"> VeryQuiet</value></Attr>
                <Attr> speed <value type="label"> SubmergedSpeed.Q4 </value></Attr>
                <Attr> areaOFops <value type="label"> AssignedSouth </value></Attr>
        </Class> </Object>
  </Intel_Report>
</UNK_root>
```

Hypotheses

2/15/2008 @ 0:0:00 <=> hypthosis <=> Initial_finding ^ MingIII(035AIP)
Support of Hypothesis:
[AssignedSouth, SubmergedSpeed.Q4, VeryQuiet]
Implicit data based on hypothesis:
[1_team, 2_AftTubes, 6_tubes, BatteryPoints.Q2, BatteryPoints.Q3, BatteryPoints.Q4, BatteryPoints.Q5, CMLev_4, Hull_361_305_306_307_308_309, Mines.Q3, Mines.Q4, Mines.Q5, SS, SonarLev_6, SubmergedSpeed.Q2, SubmergedSpeed.Q3, SurfaceSpeed.Q2, SurfaceSpeed.Q3, SurfaceSpeed.Q4, SurfaceSpeed.Q5, WeapRounds.Q1, WeapRounds.Q2, WeapRounds.Q3]
Un-resolved collected data:
[]

2/15/2008 @ 0:0:00 <=> hypthosis <=> Initial_finding ^ SongII(039G)
Support of Hypothesis:
[AssignedSouth, SubmergedSpeed.Q4, VeryQuiet]
Implicit data based on hypothesis:
[1_team, 6_tubes, AssignedEast, BatteryPoints.Q3, BatteryPoints.Q4, BatteryPoints.Q5, CMLev_4, Hull_321_322_323_324_314_315_316_317_318_319_325, Mines.Q1, Mines.Q2, Mines.Q3, No_AftTubes, SSG, SonarLev_6, SubmergedSpeed.Q2, SubmergedSpeed.Q3, SurfaceSpeed.Q2, SurfaceSpeed.Q3, SurfaceSpeed.Q4, SurfaceSpeed.Q5, WeapRounds.Q1, WeapRounds.Q2, WeapRounds.Q3]
Un-resolved collected data:

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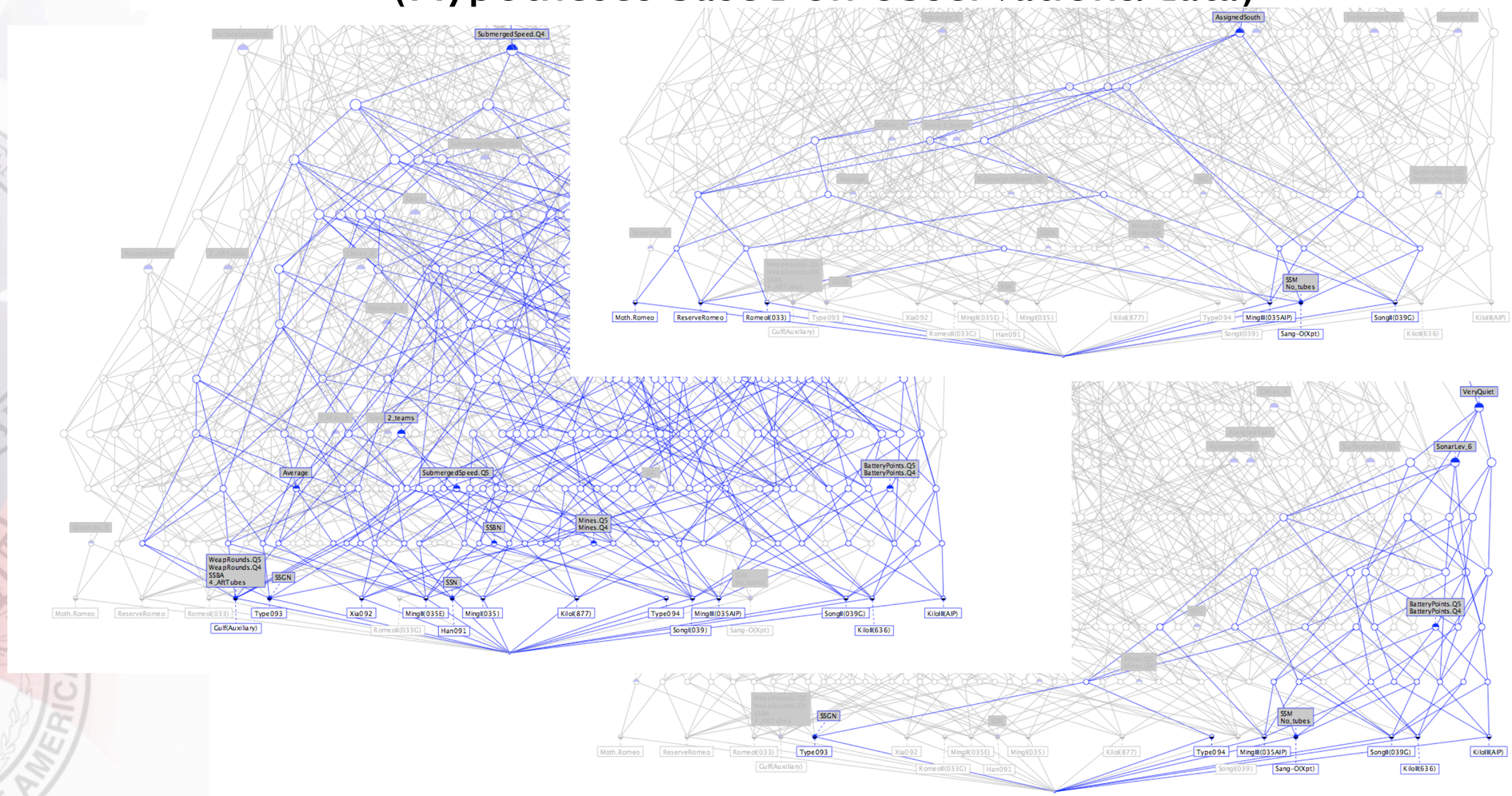
Abduction

(Hypotheses based on observations/data)



Set Intersection of concepts associated with { VeryQuiet }, { AssignedSouth }, { SubmergedSpeed.Q4 }

{ Gulf(Auxiliary), Type093, Xia092, MingII(035E), Han091, MingI(035), KiloI(877), Type094, SongI(039), MingIII(035AIP), SongII(039G), KiloII(636), KiloIII(AIP) }
∩ { Moth.Romeo, ReserveRomeo, RomeoI(033), MingIII(035AIP), Sang-O(Xpt), SongII(039G) }

∩ { Type093, Type094, MingIII(035AIP), Sang-O(Xpt), SongII(039G), KiloII(636), KiloIII(AIP) }

= { MingIII(035AIP), SongII(039G) }

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Mill's Canons

- Method of Agreement

If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or effect) of the given phenomenon.

- Method of Differences

If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance save one in common, that one occurring only in the former; the circumstance in which alone the two instances differ, is the effect, or cause, or a necessary part of the cause, of the phenomenon.

- Indirect Method

If two or more instances in which the phenomenon occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of the circumstance; the circumstance in which alone the two sets of instances differ, is the effect, or cause, or a necessary part of the cause, of the phenomenon.

- Method of Residues

Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.

- Method of Concomitant Variables

Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation.

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Applications
Intel Analysis

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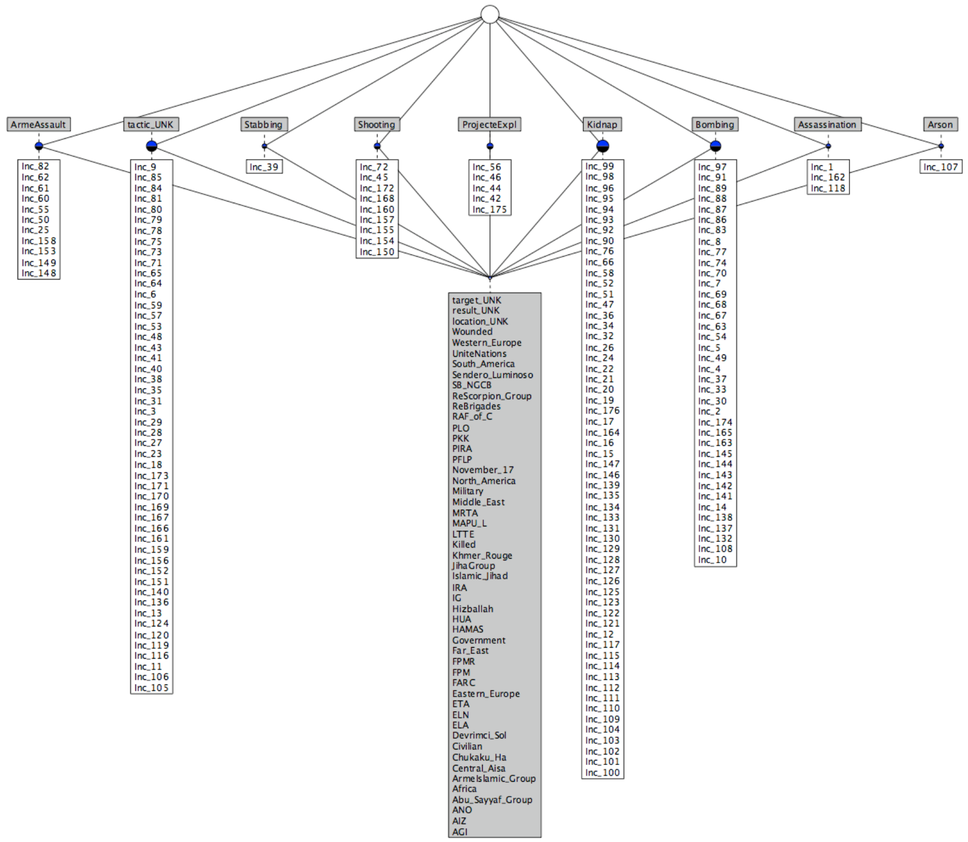
Terrorist Incidents

event	date	location	target	tactic	result	org
Inc_1	1992-10-02	South_America	*	Assassination	*	Sendero_Luminoso
Inc_2	1992-07-21	South_America	*	Bombing	Wounded	Sendero_Luminoso
Inc_3	1992-02-11	South_America	*	*	Killed	Sendero_Luminoso
Inc_4	1992-12-28	South_America	*	Bombing	Wounded	Sendero_Luminoso
Inc_5	1993-05-19	South_America	*	Bombing	*	Sendero_Luminoso
Inc_6	1993-07-07	South_America	Civilian	*	*	Sendero_Luminoso
Inc_7	1994-01-11	South_America	*	Bombing	*	Sendero_Luminoso
Inc_8	1995-05-30	Africa	Civilian	Bombing	*	Sendero_Luminoso
Inc_9	1995-05-15	South_America	*	*	*	Sendero_Luminoso
Inc_10	1996-05-16	South_America	Government	Bombing	*	Sendero_Luminoso
Inc_11	1992-09-10	South_America	Civilian	*	Wounded	SB_NGCB
Inc_12	1992-03-18	Far_East	Government	Kidnap	*	ReScorpion_Group
Inc_13	1993-09-02	Western_Europe	Military	*	*	ReBrigades
Inc_14	1994-01-10	Western_Europe	*	Bombing	*	ReBrigades
Inc_15	1992-03-21	South_America	*	Kidnap	*	RAF_of_C
Inc_16	1994-09-23	South_America	*	Kidnap	*	RAF_of_C
Inc_17	1994-04-01	South_America	*	Kidnap	*	RAF_of_C
Inc_18	1995-09-01	South_America	*	*	*	RAF_of_C
Inc_19	1996-01-22	South_America	*	Kidnap	*	RAF_of_C
Inc_20	1996-12-11	South_America	*	Kidnap	Killed	RAF_of_C
Inc_21	1997-03-07	South_America	Military	Kidnap	Killed	RAF_of_C
Inc_22	1998-03-14	South_America	Civilian	Kidnap	*	RAF_of_C
Inc_23	1993-10-24	Western_Europe	*	*	*	PLO
Inc_24	1998-07-25	South_America	*	Kidnap	*	PLO
Inc_25	1992-09-09	Central_Aisa	*	ArmeAssault	*	PKK
Inc_26	1993-10-19	Central_Aisa	Civilian	Kidnap	*	PKK
Inc_27	1993-06-28	Central_Aisa	Civilian	*	*	PKK
Inc_28	1993-11-20	Western_Europe	Government	*	Killed	PKK
Inc_29	1993-06-30	Western_Europe	Government	*	*	PKK
Inc_30	1994-03-27	Central_Aisa	Civilian	Bombing	*	PKK
Inc_31	1994-06-10	Central_Aisa	Civilian	*	Killed	PKK
Inc_32	1994-08-22	Central_Aisa	*	Kidnap	*	PKK
Inc_33	1994-08-12	Central_Aisa	Government	Bombing	Wounded	PKK
Inc_34	1997-10-16	Central_Aisa	*	Kidnap	*	PKK
Inc_35	1997-03-25	Western_Europe	*	*	*	PKK
Inc_36	1998-06-03	Central_Aisa	Civilian	Kidnap	*	PKK
Inc_37	1998-04-12	Central_Aisa	Civilian	Bombing	Wounded	PKK
Inc_38	1994-03-01	Western_Europe	*	*	*	PIRA
Inc_39	1995-09-05	Middle_East	*	Stabbing	Wounded	PFLP
Inc_40	1996-06-09	Middle_East	*	*	*	PFLP
Inc_41	1994-11-17	Western_Europe	*	*	*	November_17
Inc_42	1994-11-17	Western_Europe	*	ProjecteExpl	*	November_17
Inc_43	1996-11-22	Central_Aisa	Civilian	*	*	November_17
Inc_44	1996-11-17	Western_Europe	Government	ProjecteExpl	*	November_17
Inc_45	1997-11-26	Middle_East	Civilian	Shooting	Killed	November_17
Inc_46	1998-11-17	Central_Aisa	Civilian	ProjecteExpl	Wounded	November_17
Inc_47	1996-12-17	Eastern_Europe	Government	Kidnap	Wounded	MRTA
Inc_48	1993-05-13	South_America	*	*	*	MAPU_L
Inc_49	1996-01-31	Central_Aisa	Civilian	Bombing	Wounded	LTTE
Inc_50	1997-09-26	Central_Aisa	Civilian	ArmeAssault	Killed	LTTE
Inc_51	1997-10-30	Central_Aisa	Civilian	Kidnap	Wounded	LTTE
Inc_52	1997-07-01	Central_Aisa	*	Kidnap	*	LTTE
Inc_53	1997-07-12	Central_Aisa	Civilian	*	*	LTTE
Inc_54	1998-08-21	Central_Aisa	Civilian	Bombing	*	LTTE
Inc_55	1994-07-26	Far_East	*	ArmeAssault	*	Khmer_Rouge
Inc_56	1995-01-15	Far_East	Civilian	ProjecteExpl	Killed	Khmer_Rouge
Inc_57	1996-11-26	Far_East	Government	*	*	Khmer_Rouge
Inc_58	1996-05-09	Far_East	*	Kidnap	*	Khmer_Rouge
Inc_59	1996-03-26	Far_East	Military	*	Killed	Khmer_Rouge
Inc_60	1997-04-22	Far_East	*	ArmeAssault	Wounded	Khmer_Rouge
Inc_61	1997-04-27	Far_East	*	ArmeAssault	Wounded	Khmer_Rouge
Inc_62	1998-04-21	Far_East	Government	ArmeAssault	Wounded	Khmer_Rouge
Inc_63	1995-11-19	Central_Aisa	*	Bombing	*	JihaGroup
Inc_64	1995-04-09	North_America	*	*	*	Islamic_Jihad
Inc_65	1996-03-20	North_America	*	*	*	Islamic_Jihad
Inc_66	1998-12-29	North_America	Civilian	Kidnap	Killed	Islamic_Jihad
Inc_67	1996-06-15	Western_Europe	Civilian	Bombing	Wounded	IRA
Inc_68	1996-02-09	Western_Europe	*	Bombing	Wounded	IRA
Inc_69	1998-08-01	Western_Europe	Military	Bombing	*	IRA
Inc_70	1998-08-29	Western_Europe	*	Bombing	*	IRA
Inc_71	1994-09-27	Middle_East	Civilian	*	Killed	IG
Inc_72	1994-10-23	Middle_East	Civilian	Shooting	Killed	IG
Inc_73	1994-03-04	South_America	*	Kidnap	*	ELN
Inc_74	1994-02-23	South_America	*	*	Killed	ELN
Inc_75	1996-04-18	South_America	Civilian	Bombing	*	ELN
Inc_76	1995-08-13	South_America	*	Bombing	*	ELN
Inc_77	1992-03-29	South_America	*	Kidnap	*	ELN
Inc_78	1993-11-08	South_America	*	*	*	ELN
Inc_79	1995-05-05	South_America	Government	Bombing	*	ELA
Inc_80	1995-03-31	South_America	Military	Bombing	Wounded	ELA
Inc_81	1994-12-25	South_America	*	Bombing	*	Devrimci_Sol
Inc_82	1994-10-14	South_America	*	Bombing	*	Devrimci_Sol
Inc_83	1995-08-21	South_America	*	Bombing	*	Devrimci_Sol
Inc_84	1996-05-13	South_America	*	Bombing	*	Devrimci_Sol
Inc_85	1996-03-19	South_America	*	Bombing	*	Devrimci_Sol
Inc_86	1996-02-26	South_America	*	Bombing	*	Devrimci_Sol
Inc_87	1997-09-12	South_America	*	Bombing	*	Devrimci_Sol
Inc_88	1994-08-18	South_America	*	Bombing	*	Devrimci_Sol
Inc_89	1995-04-05	South_America	*	Bombing	*	Devrimci_Sol
Inc_90	1992-10-23	South_America	*	Bombing	*	Devrimci_Sol
Inc_91	1992-03-27	South_America	*	Bombing	*	Devrimci_Sol
Inc_92	1993-12-31	South_America	*	Bombing	*	Devrimci_Sol
Inc_93	1995-12-10	South_America	*	Bombing	*	Devrimci_Sol
Inc_94	1997-11-12	South_America	*	Bombing	*	Devrimci_Sol
Inc_95	1997-11-16	South_America	*	Bombing	*	Devrimci_Sol
Inc_96	1997-02-22	South_America	*	Bombing	*	Devrimci_Sol
Inc_97	1997-04-27	South_America	*	Bombing	*	Devrimci_Sol
Inc_98	1998-06-27	South_America	*	Bombing	*	Devrimci_Sol
Inc_99	1998-07-25	South_America	*	Bombing	*	Devrimci_Sol
Inc_100	1998-09-22	South_America	*	Bombing	*	Devrimci_Sol
Inc_101	1998-09-21	South_America	*	Bombing	*	Devrimci_Sol
Inc_102	1998-06-26	South_America	*	Bombing	*	Devrimci_Sol
Inc_103	1998-07-14	South_America	*	Bombing	*	Devrimci_Sol
Inc_104	1998-12-08	South_America	*	Bombing	*	Devrimci_Sol
Inc_105	1995-12-09	South_America	*	Bombing	*	Devrimci_Sol
Inc_106	1995-12-16	South_America	*	Bombing	*	Devrimci_Sol
Inc_107	1995-08-27	South_America	*	Bombing	*	Devrimci_Sol
Inc_108	1996-07-20	South_America	*	Bombing	*	Devrimci_Sol
Inc_109	1992-11-30	South_America	*	Bombing	*	Devrimci_Sol
Inc_110	1993-12-23	South_America	*	Bombing	*	Devrimci_Sol
Inc_111	1994-01-14	South_America	*	Bombing	*	Devrimci_Sol
Inc_112	1995-05-31	South_America	*	Bombing	*	Devrimci_Sol
Inc_113	1995-01-26	South_America	*	Bombing	*	Devrimci_Sol
Inc_114	1995-04-19	South_America	*	Bombing	*	Devrimci_Sol
Inc_115	1996-08-14	South_America	*	Bombing	*	Devrimci_Sol
Inc_116	1996-09-14	South_America	*	Bombing	*	Devrimci_Sol
Inc_117	1996-10-10	South_America	*	Bombing	*	Devrimci_Sol
Inc_118	1996-10-26	South_America	*	Bombing	*	Devrimci_Sol
Inc_119	1996-03-23	South_America	*	Bombing	*	Devrimci_Sol
Inc_120	1996-06-10	South_America	*	Bombing	*	Devrimci_Sol
Inc_121	1996-07-14	South_America	*	Bombing	*	Devrimci_Sol
Inc_122	1996-02-06	South_America	*	Bombing	*	Devrimci_Sol
Inc_123	1996-02-16	South_America	*	Bombing	*	Devrimci_Sol
Inc_124	1996-02-17	South_America	*	Bombing	*	Devrimci_Sol
Inc_125	1996-08-10	South_America	*	Bombing	*	Devrimci_Sol
Inc_126	1997-02-20	South_America	*	Bombing	*	Devrimci_Sol
Inc_127	1997-10-15	South_America	*	Bombing	*	Devrimci_Sol
Inc_128	1997-11-28	South_America	*	Bombing	*	Devrimci_Sol
Inc_129	1997-05-16	South_America	*	Bombing	*	Devrimci_Sol
Inc_130	1997-07-27	South_America	*	Bombing	*	Devrimci_Sol
Inc_131	1997-07-19	South_America	*	Bombing	*	Devrimci_Sol
Inc_132	1997-07-30	South_America	*	Bombing	*	Devrimci_Sol
Inc_133	1997-02-24	South_America	*	Bombing	*	Devrimci_Sol
Inc_134	1997-12-18	South_America	*	Bombing	*	Devrimci_Sol
Inc_135	1997-08-30	South_America	*	Kidnap	*	ELN
Inc_136	1997-04-01	South_America	*	*	Killed	ELN
Inc_137	1998-10-19	South_America	Civilian	Bombing	*	ELN
Inc_138	1998-05-27	South_America	*	Bombing	*	ELN
Inc_139	1998-12-08	South_America	*	Kidnap	*	ELN
Inc_140	1999-10-26	South_America	*	*	*	ELN
Inc_141	1994-06-24	Western_Europe	*	Bombing	*	ELA
Inc_142	1994-02-03	Western_Europe	Military	Bombing	Wounded	ELA
Inc_143	1993-09-09	South_America	*	Bombing	*	Devrimci_Sol



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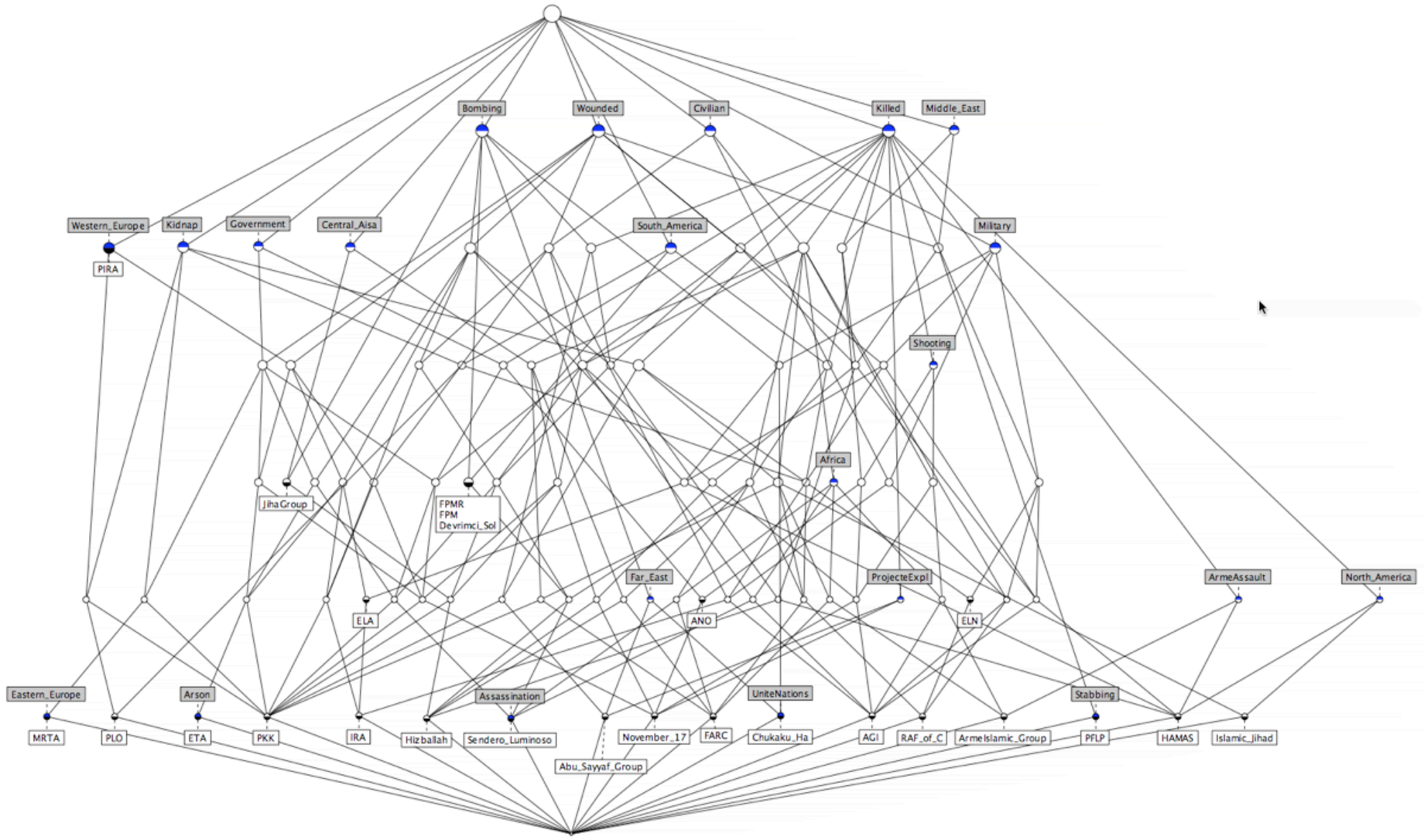
Inductive Learning



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Convolve Information with Knowledge

- Intelligence collected:
  - Loss/Theft of explosives
  - North American AO
  - Link of explosives & bomb making

UNKsoc2.txt

```
<UNK_root>
<Control input="xtable" >  </Control>
  <Intel_Report>

          <Object> material <Class type="generic">
                    <Attr> explosive <value type="real"> 200  </value></Attr>
          </Class> </Object>
          <Object> speculation_capabilities <Class type="generic">
                    <Attr> Tactic <value type="label"> Bombing </value></Attr>
                    <Attr> Location <value type="label">North_America</value></Attr>
                    <Attr> skill <value type="label"> bomb_making </value></Attr>
                    <Attr> Tactic <value type="label"> explosives </value></Attr>
          </Class> </Object>
  </Intel_Report>
</UNK_root>
```

- Single hypothesis:
  - Group is likely to be HAMAS

InfoBase.BeliefCache

```
publishBeliefCache PUBLISH:

8/3/2007 @ 0:0:00   <=>   hypthosis   <=>   speculation_capabilities ^ HAMAS
Support of Hypothesis:
          [Bombing, North_America]
Implicit data based on hypothesis:
          [ArmeAssault, Killed, Middle_East, Military, Wounded, result_UNK, tactic_UNK, target_UNK]
Un-resolved collected data:
          [bomb_making, explosives]

Publish Belief Cache Complete
```

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Alternate / New Information

Collected

UNKsoc2.txt

```
<UNK_root>
<Control input="xtable" > </Control>
  <Intel_Report>

          <Object> material <Class type="generic">
                    <Attr> explosive <value type="real"> 200  </value></Attr>
          </Class> </Object>
          <Object> speculation_capabilities <Class type="generic">
                    <Attr> Tactic <value type="label"> Bombing </value></Attr>
                    <Attr> Location <value type="label">North_America</value></Attr>
                    <Attr> skill <value type="label"> bomb_making </value></Attr>
                    <Attr> Tactic <value type="label"> explosives </value></Attr>
          </Class> </Object>
          <Object> speculation_capabilities <Class type="generic">
                    <Attr> Tactic <value type="label"> ArmeAssault </value></Attr>
          </Class> </Object>
  </Intel_Report>
</UNK_root>
```

Hypotheses

InfoBase.BeliefCache

```
8/3/2007 @ 0:0:00  <=>  hypthosis  <=>  speculation_capabilities ^ ArmeIslamic_Group
Support of Hypothesis:
          [ArmeAssault]
Implicit data based on hypothesis:
          [Africa, Civilian, Kidnap, Killed, Shooting, result_UNK, tactic_UNK, target_UNK]
Un-resolved collected data:
          []


8/3/2007 @ 0:0:00  <=>  hypthosis  <=>  speculation_capabilities ^ HAMAS
Support of Hypothesis:
          [ArmeAssault]
Implicit data based on hypothesis:
          [Bombing, Killed, Middle_East, Military, North_America, Wounded, result_UNK, tactic_UNK, target_UNK]
Un-resolved collected data:
          []


8/3/2007 @ 0:0:00  <=>  hypthosis  <=>  speculation_capabilities ^ Khmer_Rouge
Support of Hypothesis:
          [ArmeAssault]
Implicit data based on hypothesis:
          [Civilian, Far_East, Government, Kidnap, Killed, Military, ProjecteExpl, Wounded, result_UNK, tactic_UNK, target_UNK]
Un-resolved collected data:
          []


8/3/2007 @ 0:0:00  <=>  hypthosis  <=>  speculation_capabilities ^ LTTE
Support of Hypothesis:
          [ArmeAssault]
Implicit data based on hypothesis:
          [Bombing, Central_Aisa, Civilian, Kidnap, Killed, Wounded, result_UNK, tactic_UNK, target_UNK]
Un-resolved collected data:
          []


8/3/2007 @ 0:0:00  <=>  hypthosis  <=>  speculation_capabilities ^ HAMAS
Support of Hypothesis:
          [Bombing, North_America]
Implicit data based on hypothesis:
          [ArmeAssault, Killed, Middle_East, Military, Wounded, result_UNK, tactic_UNK, target_UNK]
Un-resolved collected data:
          [bomb_making, explosives]
```

- Hypothesis testing:
  - Deductive - Inductive process
  - Severe Test Constrained (D. Mayo)

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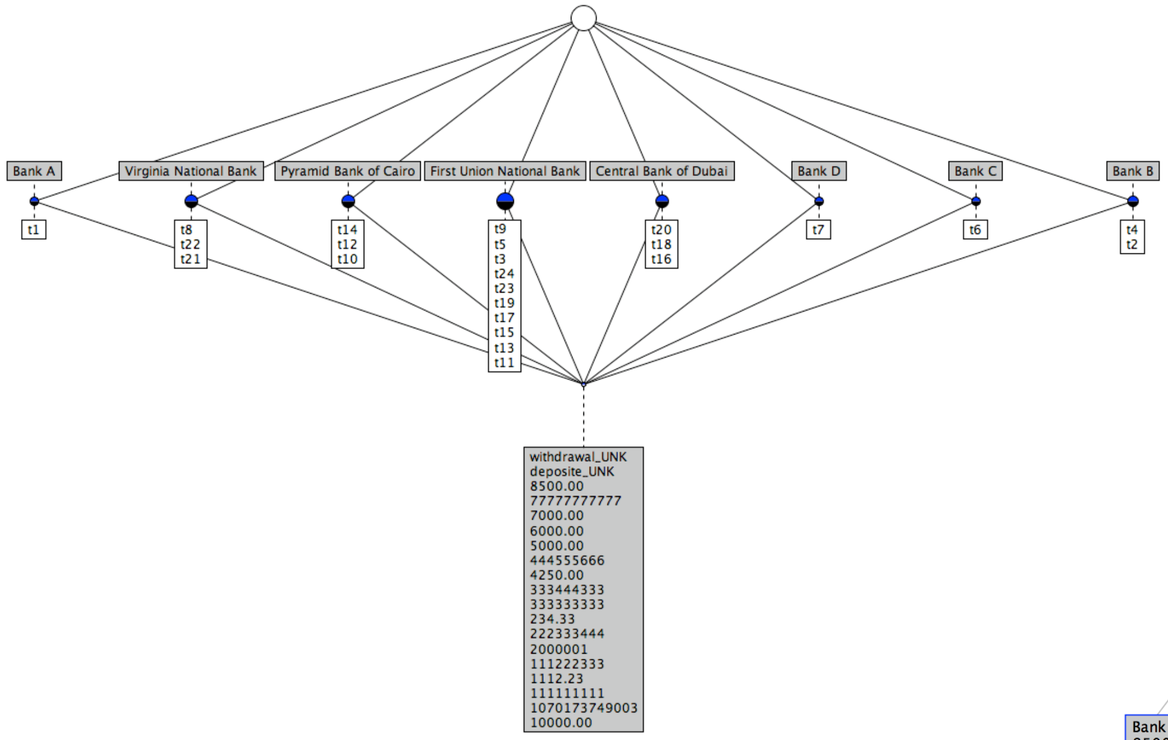
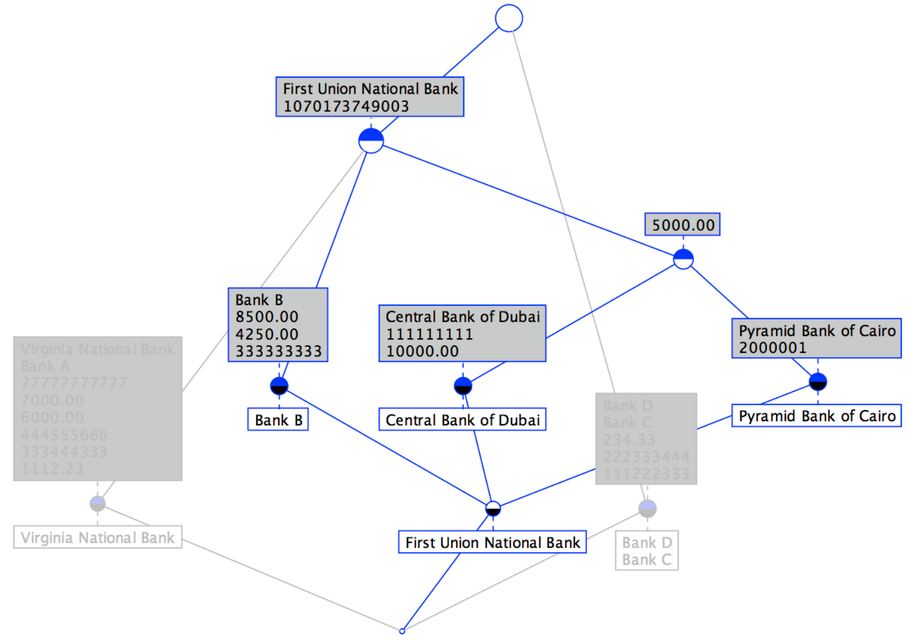
Bank Transactions





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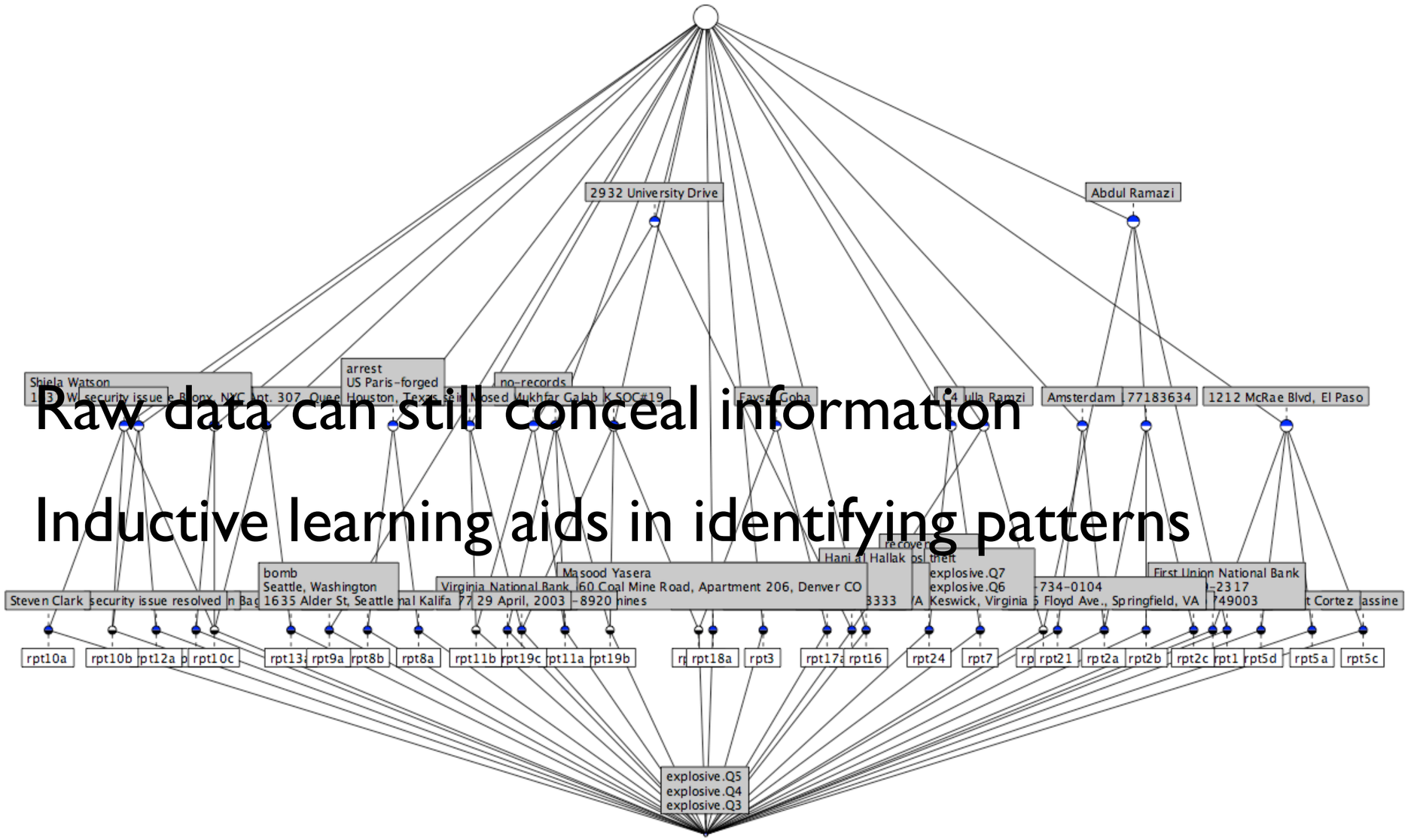
Intelligence Reports



- Raw data can still conceal information
- Inductive learning aids in identifying patterns

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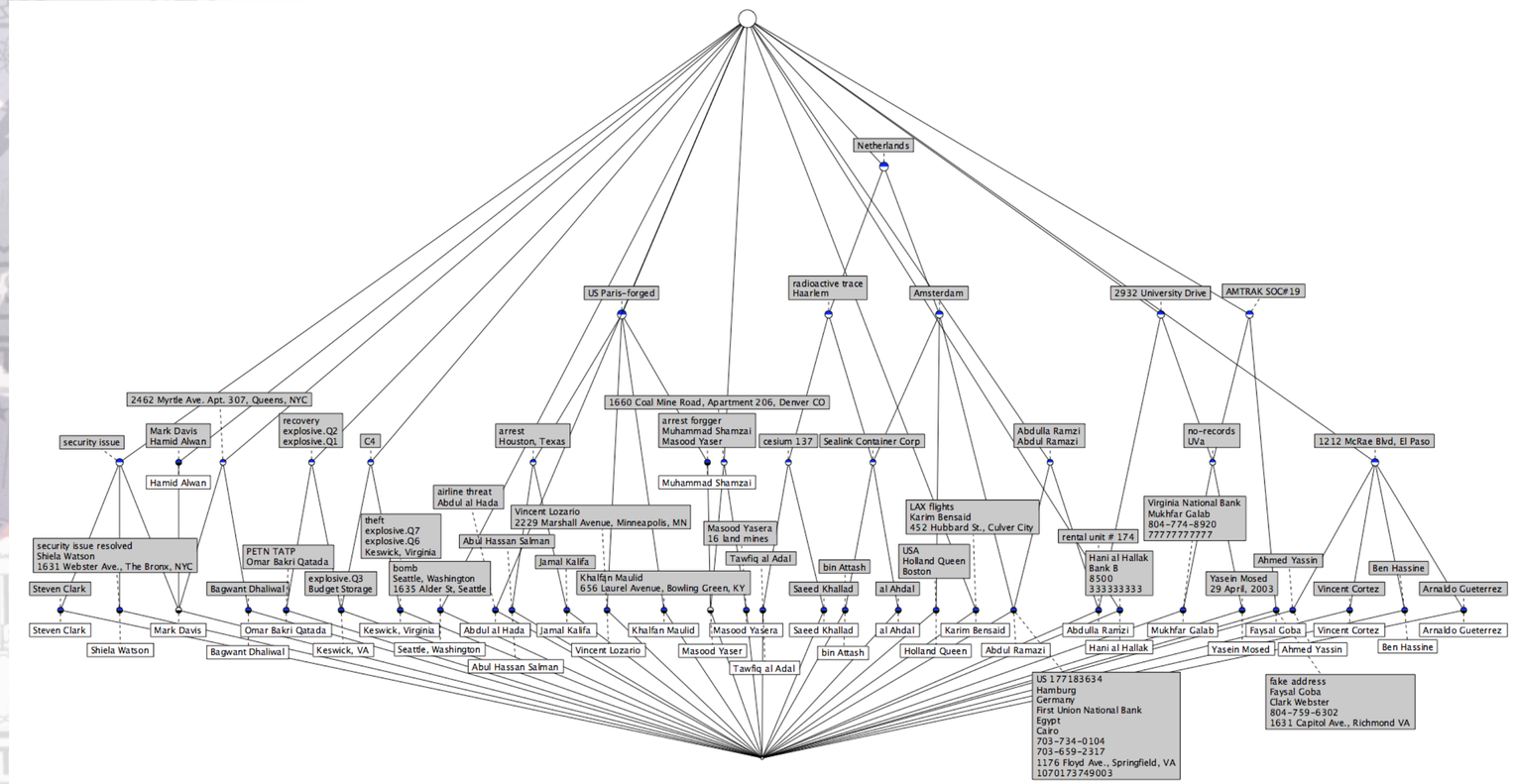
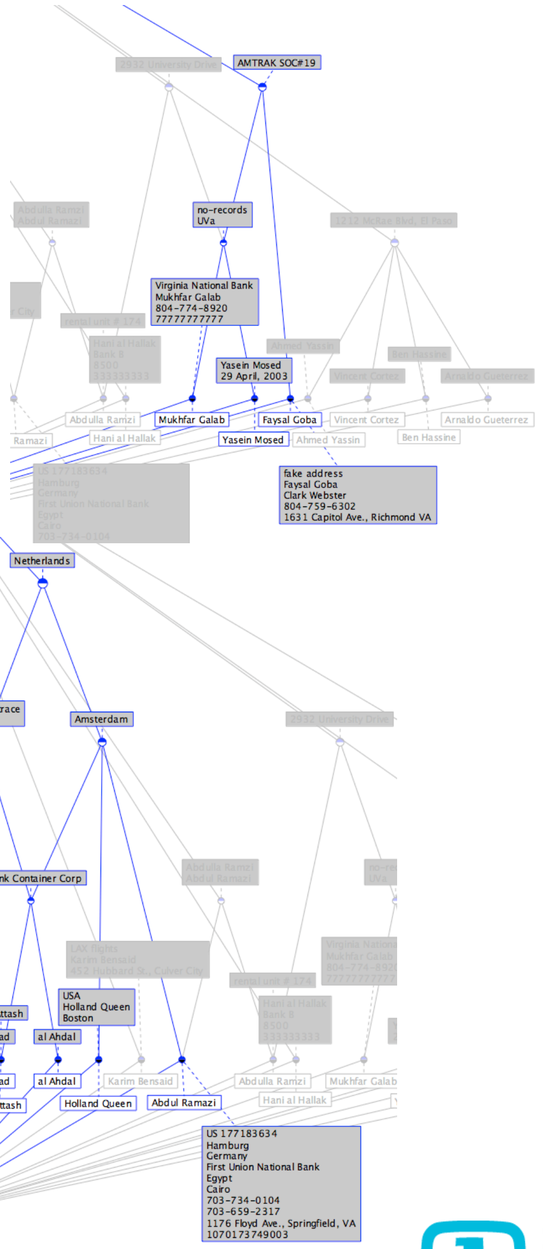
Knowledge from Intel Reports





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Applications
Nuclear Forensics

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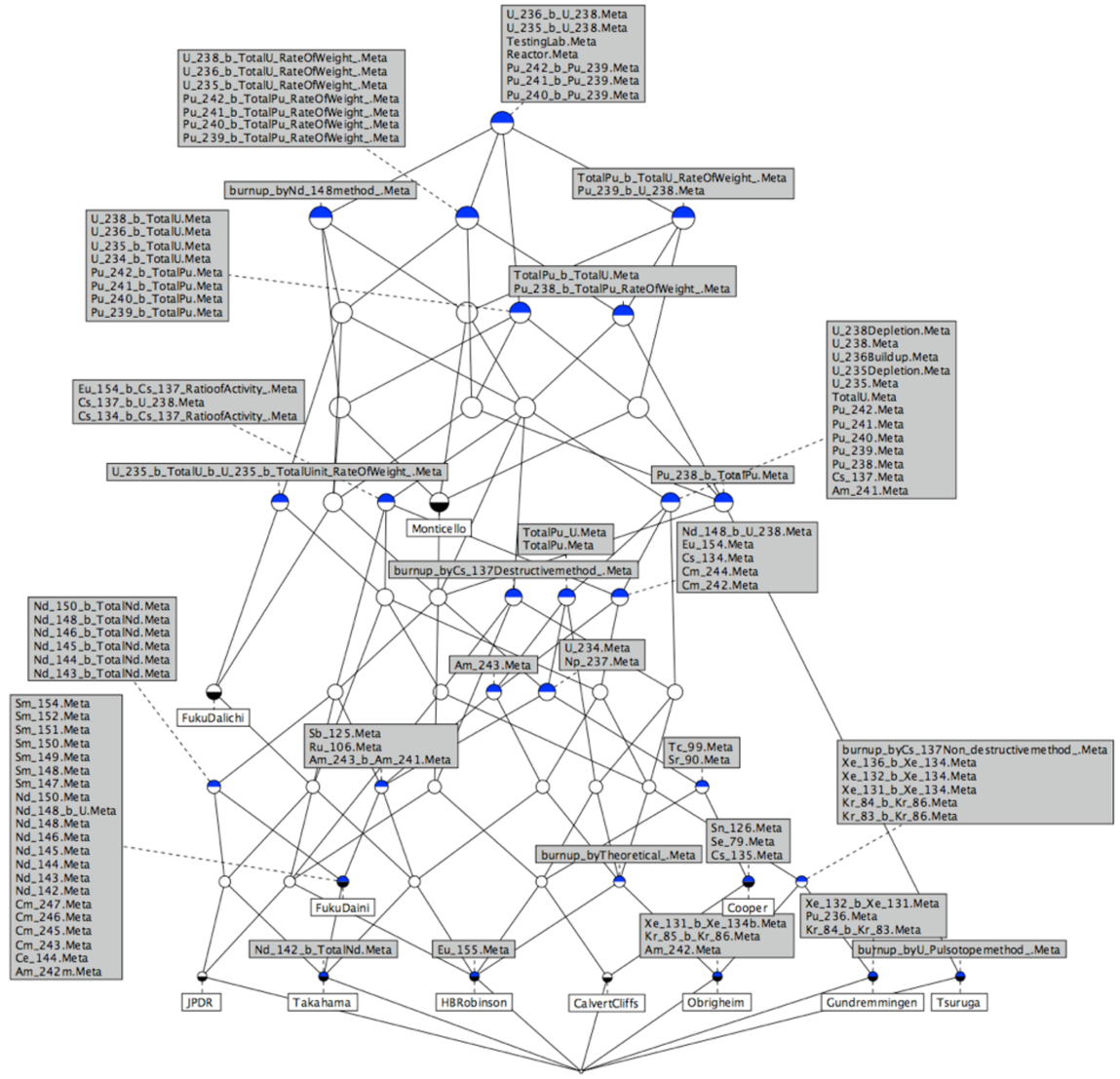
Meta Model of SFCOMPO Data

- New capability that looks at what attributes are being used to describe a context
- Deals with databases that exhibit gaps in information
- Can be used to identify common sets of attributes



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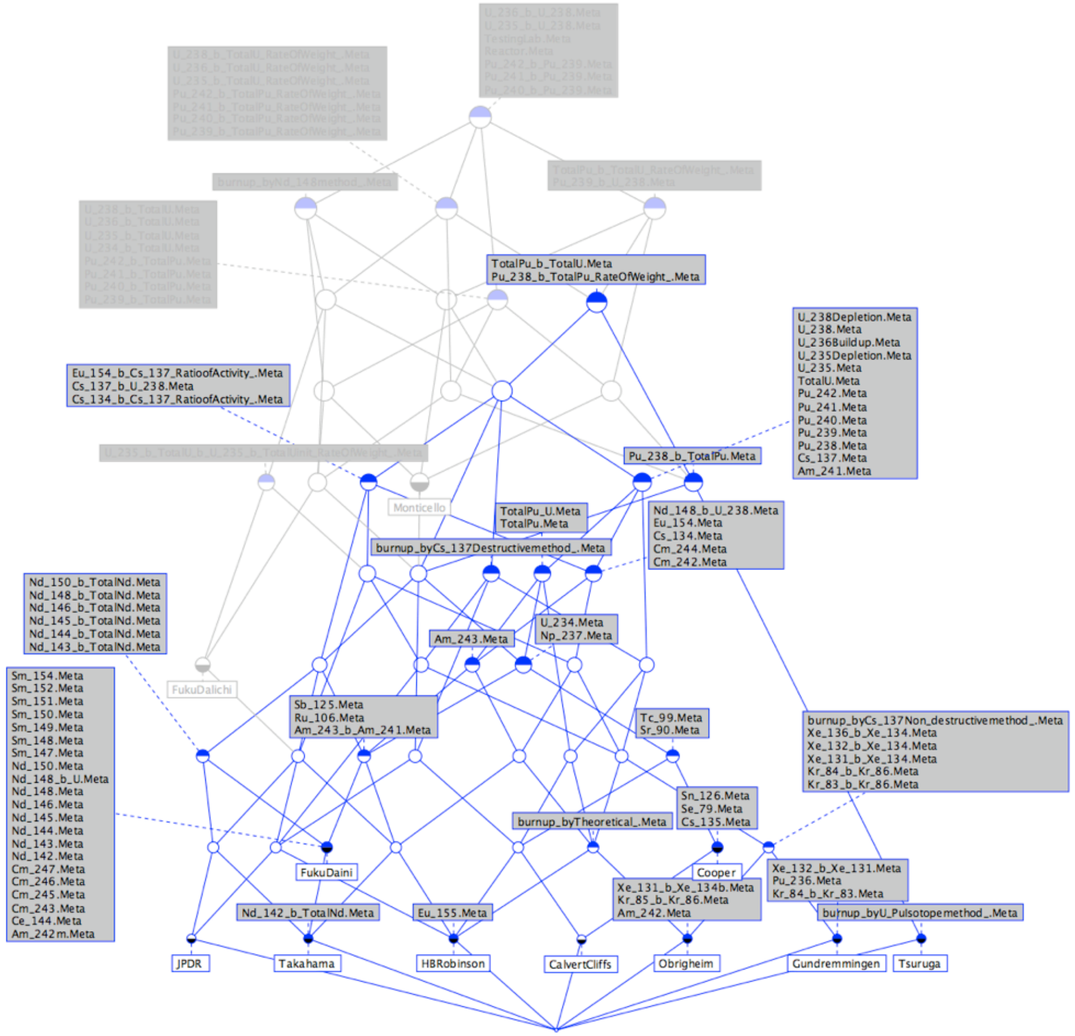
Meta Model Identification of Common Attributes

Node that links all objects



Attributes common to all objects

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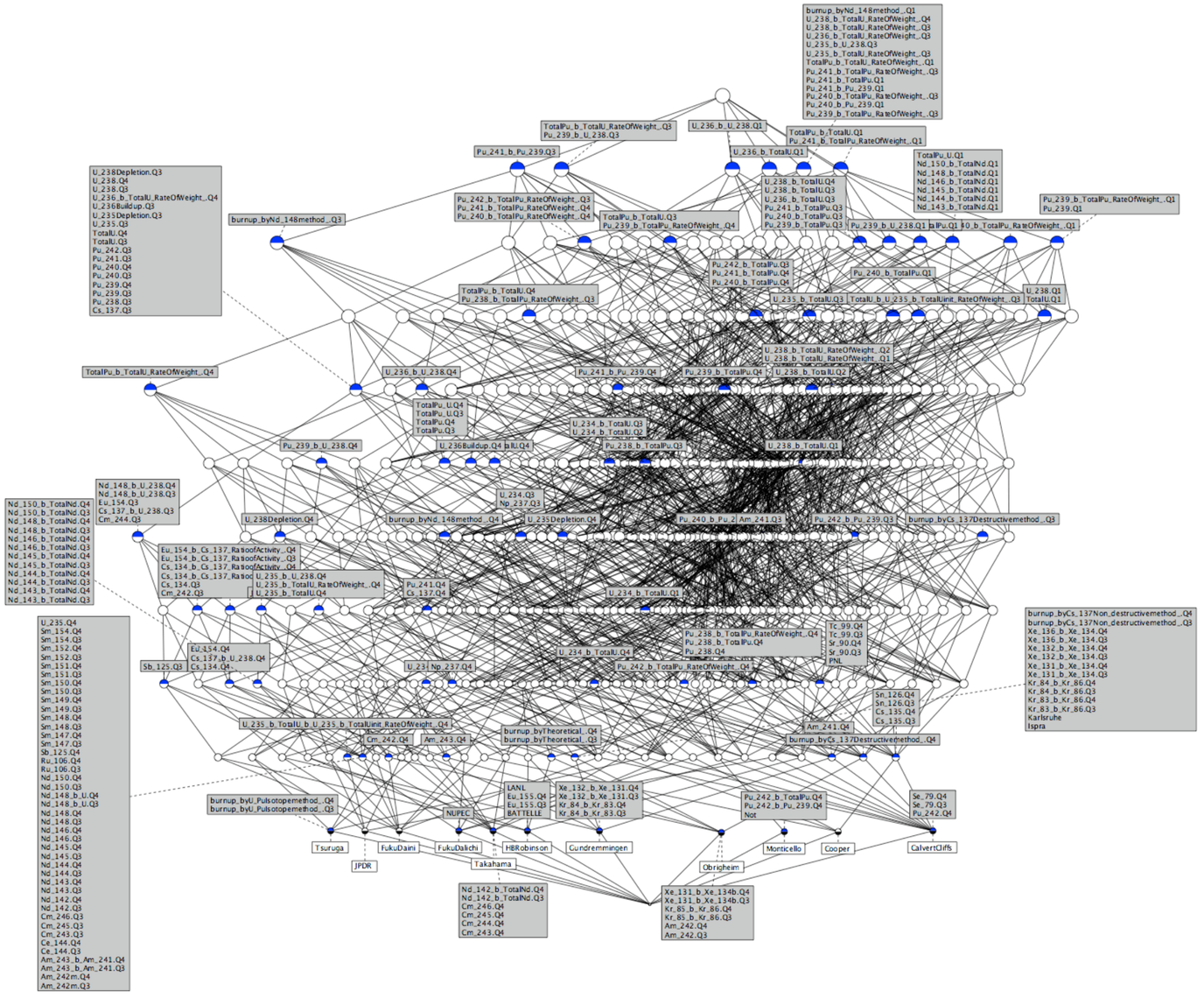
FCA Lattice of SFCOMPO Data



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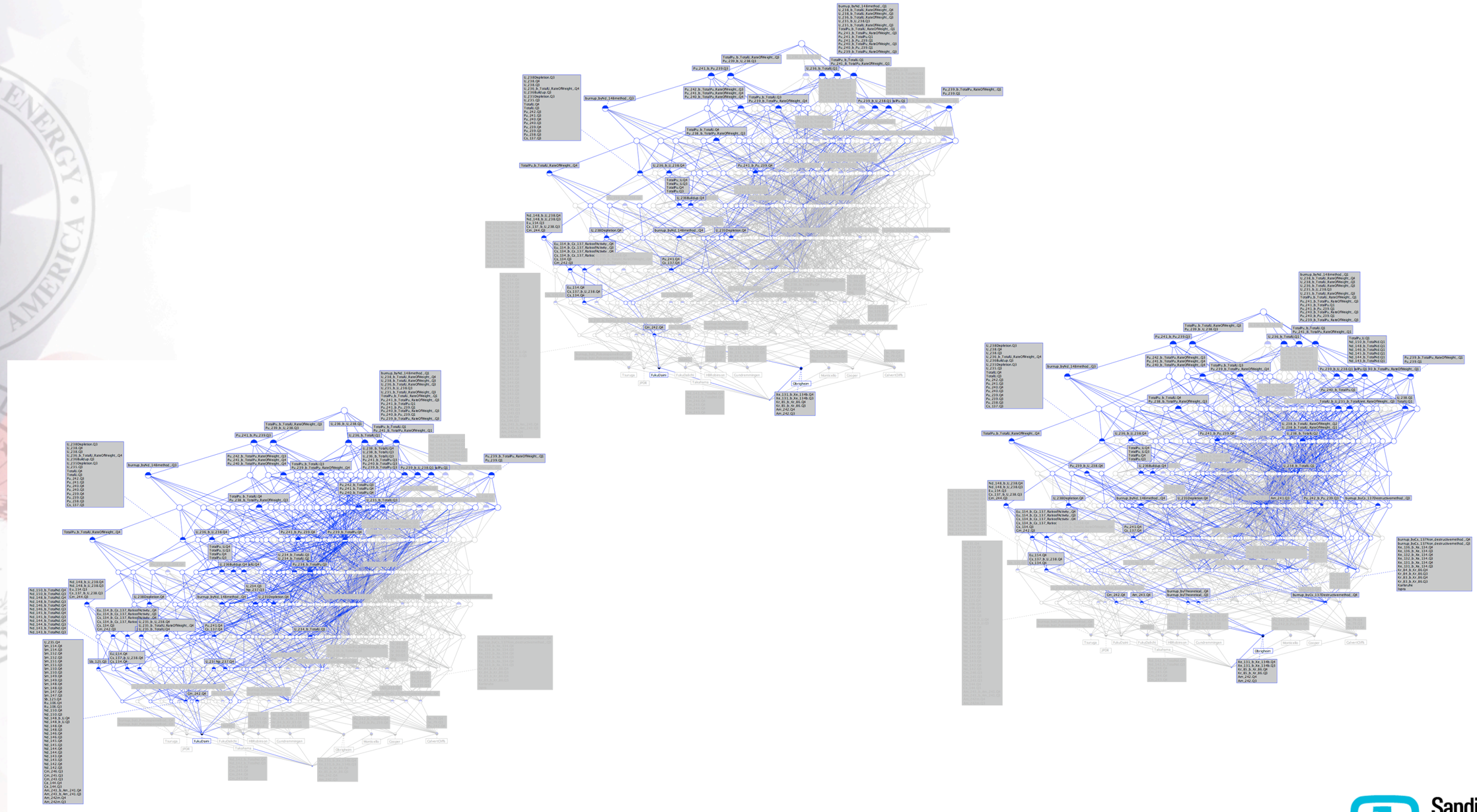
FCA Lattice of SFCOMPO Data (Cont.)



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Status

- Basic functional system complete.
  - Production architecture implemented.
  - Abduction engine operational;
  - Inductive learning engine operational.
  - Accesses information in MySQL databases.
- First order knowledge operators in place.
  - Complete set identified.
- Zero order modal logics implemented.
  - Belief cache revision logic needed.
    - Enabling a more robust "what-if" capability.
- Markov based Temporal attributes to be implemented.
  - Enables a unique 'state based' knowledge representation.
  - Supported by Nuclear Forensics application.
- Current lattice display is 'third party'.
  - 3-D display is in development.

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Needed for Comprehensive Solution

- Hierarchical Knowledge Base Implementation.
  - Enable knowledge 'chunks' to be integrated into a formal structure.
  - Permits system to deal with 'surprise'.
  - Enables system to deploy an analogical reasoning engine.
- Severe (hypothesis) testing paradigm needs to be implemented.
- Hawkins Net implementation for real time application.
  - Enabling fast running, small platform(PDA type) implementation.
- Modal logics supporting knowledge creation and update, Belief revision, and possibly disjunctive logic for automated system deployments(sensors).

Thats All(...enough) Folks...

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Peircean Philosophy

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Peircean Philosophy

- C.S. Peirce; Sept 10, 1839 - April 19, 1914.
  - Writings cover 1857 to 1914
    - 12000 printed pages, ~80000 handwritten pages.
- His work touches/impacts:
    - Mathematics and Philosophy, Phenomenology, the Normative Sciences, and Metaphysics
- Peircean Reasoning based on his 'Method of Scientific Inquiry'.
  - Consists of 3 forms of logic:
    - Deduction
    - Induction
    - Abduction
      - Analogical reasoning
- Impact on information theory is beginning to be understood.