Hypothesis Management in support of Inferential Reasoning

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Agenda

- Background & Hypothesis Framework
- North Atlantic Smuggling Scenario
- Hypothesis Management Engine
- Hypothesis Discovery Engine
- Interaction with PROGNOS

Background & Framework

Hypothesis Management

Control of exponential growth in fusion hypotheses created by incoming data reports, without which the computational capability of hardware is quickly overwhelmed

Hypothesis Management Module

- Development in two phases to support the PROGNOS project
  - Phase I: Hypothesis Management Engine
    - Essential to the successful operation of the system
    - Manages the creation, modification, administration, storage and movement of hypotheses
    - Ensures that only attributes relative to the current context are presented for inferential reasoning
  - Phase II: Hypothesis Discovery Engine
    - Provides decision support to system operator
    - Supports recognition of observation trends leading to most likely hypotheses and the discovery of unpredicted hypotheses to provide asymmetric possibilities that match the incoming data
- Component engines operate independently, allowing success of the PROGNOS project before completion of Phase II

Hypothesis

- A specifically defined plan of execution in which an actor will conduct an action against a target with a location, time and methodology of his choosing
- Statement of anticipated action
- Captured as an *m-tuple* of attributes and an associated weight vector

$$Hypothesis_k = \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ \vdots \\ a_m \end{bmatrix} \quad (1)$$

$$Weight_k = \begin{bmatrix} c_1 \\ \ddots \\ c_{m-1} \\ r \end{bmatrix} \quad (2)$$

attributes associated, $a_1 \ldots a_{m-1}$
context, a_m

c_i~ credibility
r_i~ relevance

North Atlantic Hypothesis Domain

Organization		Target		Delivery	Method		Location		Time		Context	
AQ	Al Quaida	CA	Canada	C_Cruise Ship	AD	Amphibious Drop	NE	Northeast	2W	2 Weeks	A	Air
ID	Islamic Dawn	MX	Mexico	M_Merchant	SB	Small Boat Transfer	MA	Mid-Atlantic	4W	4 Weeks	L	Land
TT	Tamil Tigers	PR	Puerto Rico	W_Warship	CP	Container in Port	SE	Southeast	6W	6 Weeks	M	Maritime
OT	Org. Other	US	United States	O_Ship Other	OM	Method Other	GC	Gulf Coast	8W	8 Weeks	S	Space
		OC	Country Other				OL	Loc. Other	FU	Future		

- Example of a *7-tuple* attribute field domain for North Atlantic Ocean maritime awareness scenario
- Each attribute category contains possible characteristics and an identifier
- Answers the questions of who, what, when, where, and how

Query Hypothesis

A domain-specific inquiry is posed to PROGNOS by the System Operator

- Captured as an *m-tuple*
- Compared with the stored metadata

Associated *m x 1* Priority Vector

- System Operator prioritization of attribute fields
- Used by HMM to retrieve and prioritize hypotheses from Hypothesis Knowledge Base

$$Priority_i = \begin{bmatrix} p_1 \\ \ddots \\ \ddots \\ p_m \end{bmatrix} \quad (3)$$

North Atlantic Smuggling Scenario

North Atlantic Smuggling Scenario

enario:

Mediterranean Sea and North Atlantic Ocean. Agents of the terrorist organization Islamic Dawn operating out of Izmir, Turkey, plan to smuggle radiological material into the United States on a bulk cargo vessel to build radiological dispersal devices. They intend to move the material ashore from the motor vessel *Mustafa Kamal* by offloading to commercial fishing craft off the Grand Banks and Cape Hatteras.

ation	Target	Delivery	Method	Location	Time	Context
ida	CA Canada	C_Cruise Ship	AD Amphibious Drop	**NE Northeast**	2W 2 Weeks	A Air
c Dawn	MX Mexico	**M_Merchant**	**SB Small Boat Transfer**	MA Mid-Atlantic	4W 4 Weeks	L Land
Tigers	PR Puerto Rico	W_Warship	CP Container in Port	SE Southeast	**6W 6 Weeks**	**M Maritime**
ther	**US United States**	O_Ship Other	OM Method Other	GC Gulf Coast	8W 8 Weeks	S Space
	OC Country Other			OL Loc. Other	FU Future	

Smuggler's Perspective

$Hypothesis_{True}$ summarizes the situation

$$Hypothesis_{True} = \begin{bmatrix} Islamic\ Dawn & \ldots is\ smuggling\ to\ the \\ United\ States & \ldots on\ the \\ M\_Mustafa\ Kamal & \ldots using \\ Small\ boat\ transfer & \ldots near\ the \\ Northeast & \ldots in\ the\ next \\ 6\ weeks & \ldots in\ the \\ Martime\ Domain & \end{bmatrix} \quad (4)$$

$Weight_{True}$ represents the relevance, credibility, and force of each of the six attributes in the hypothesis

$$Weight_{True} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \quad (5)$$

PROGNOS Perspective

Hypothesis is created for each ship entered into PROGNOS

- Possible that a single ship has multiple hypotheses
- Created by the HMM from incoming data, or
- Resides in the Hypothesis Storage Module from a previous episode in a similar environment

The weight vector

- Represents the credibility and relevance of attributes
- Represents the context in which it occurs
- Initialized using weights based on content and source of data report
- Updated from incoming data related to same hypothesis

System Operator's Perspective

Hypothesis$_{Query}$:"What ships match the profile of Islamic Dawn smuggling material into the United States by sea in the next 6 weeks?"

$$Hypothesis_{Query} = \begin{bmatrix} Islamic\ Dawn \\ United\ States \\ M\_* \\ - \\ - \\ 6\ weeks \\ Martime\ Domain \end{bmatrix} \quad (6)$$

Priority $_{Query}$:

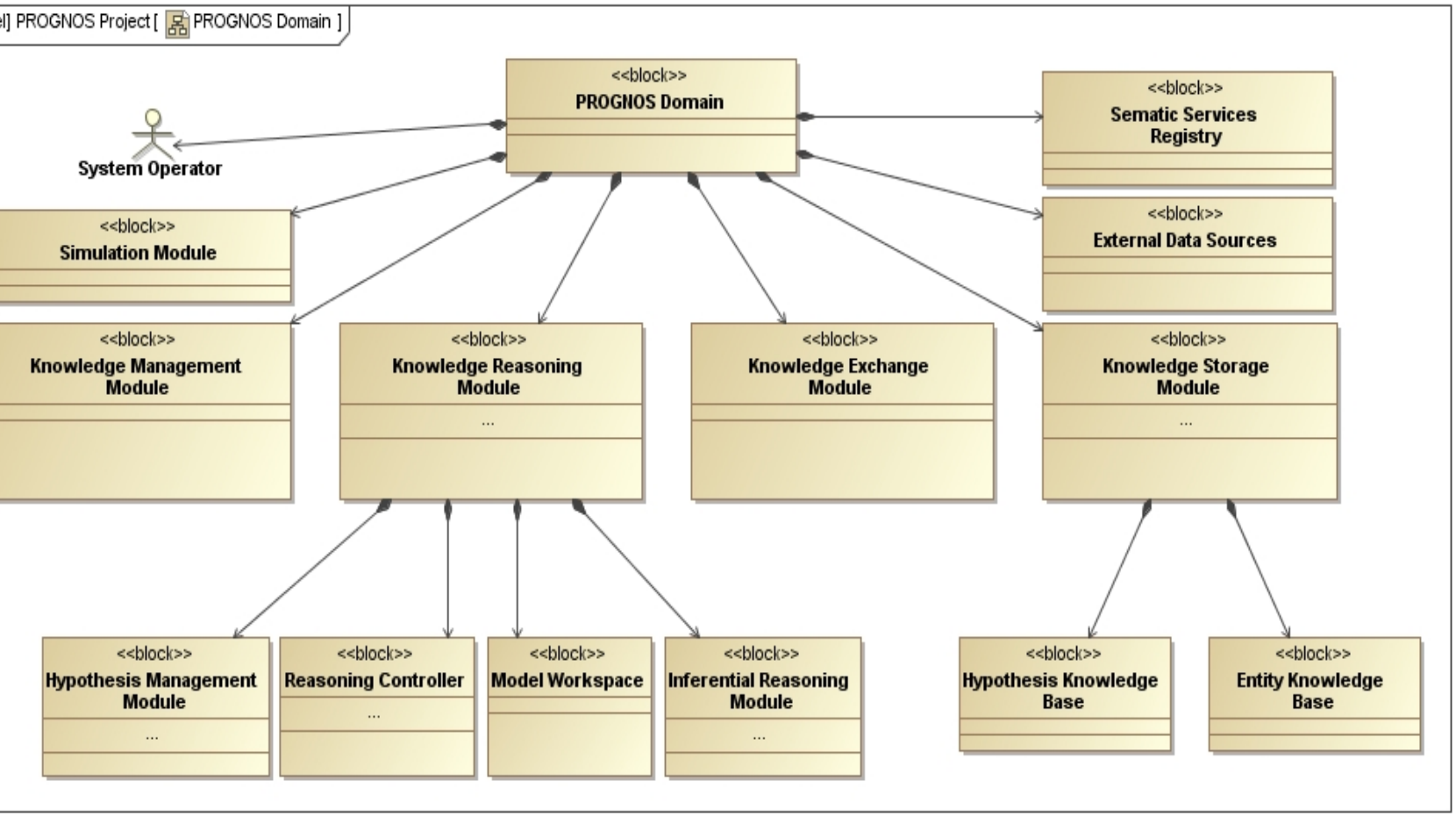
- Certain of Islamic Dawn
- Strong belief in US as target
- Confident of timeline and medium

$$Priority_{Query} = \begin{bmatrix} 1.0 \\ 0.9 \\ - \\ 0.75 \\ 0.75 \end{bmatrix} \quad (7)$$

Hypothesis Management Module

Hypothesis Management Engine

PROGNOS Domain



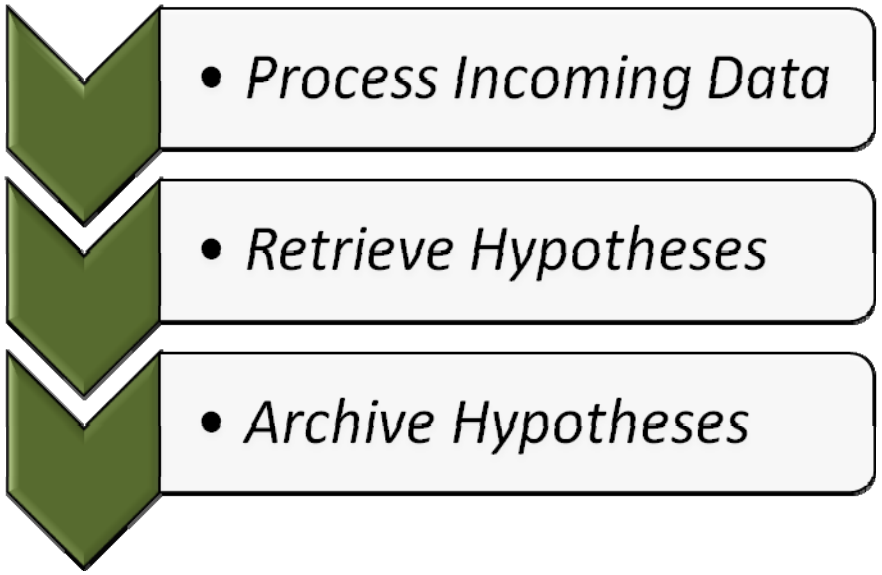
Hypothesis Management Module

The Hypothesis Management Module manages the creation, modification, administration and movement of hypotheses between the Knowledge Storage Module and the Model Workspace in response to tasks assigned by the Reasoning Controller. It also predicts behavior and identifies original hypotheses based on observation of incoming data.

Components

ypothesis Management Engine | Hypothesis Discovery Engine

Hypothesis Management Engine

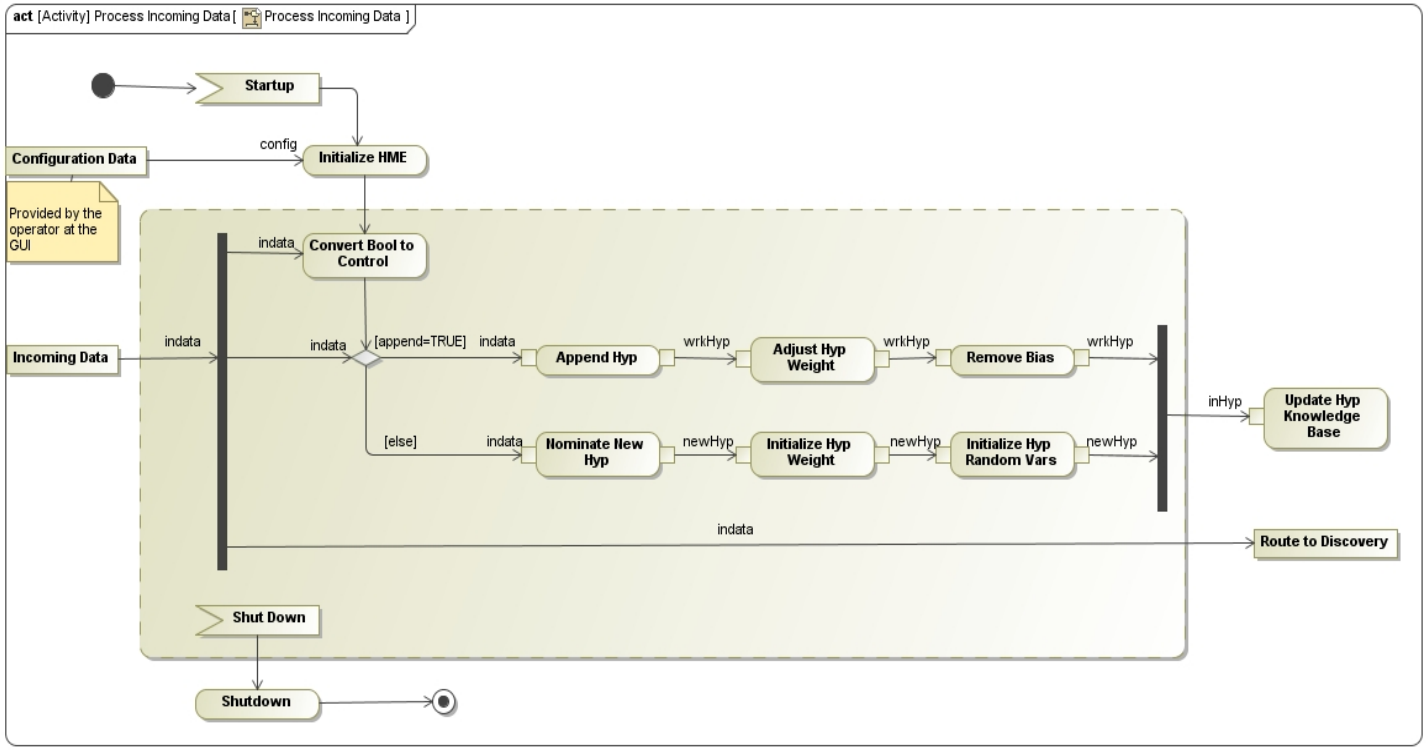


Creates, updates, administrates, filters and routes hypotheses

Coordinates with Hypothesis Knowledge Base for retrieval and storage of hypotheses

Delivers set of contextually relevant hypotheses to the Model Workspace in response to Reasoning Controller demand as a result of an operator query

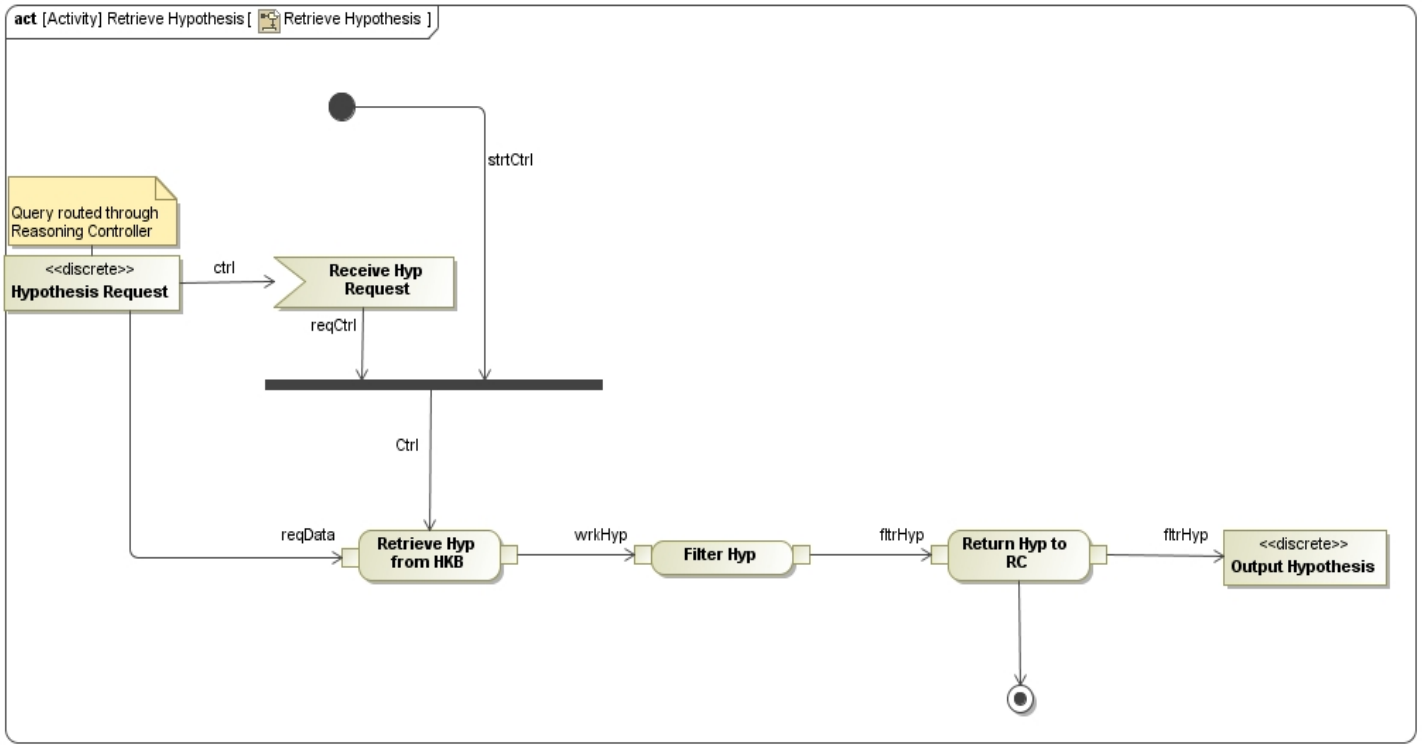
Process Incoming Data Activity Diagram



Continuously creates and updates hypotheses from data

Operations within the shaded interruptible region execute continually on incoming streaming data until shutdown

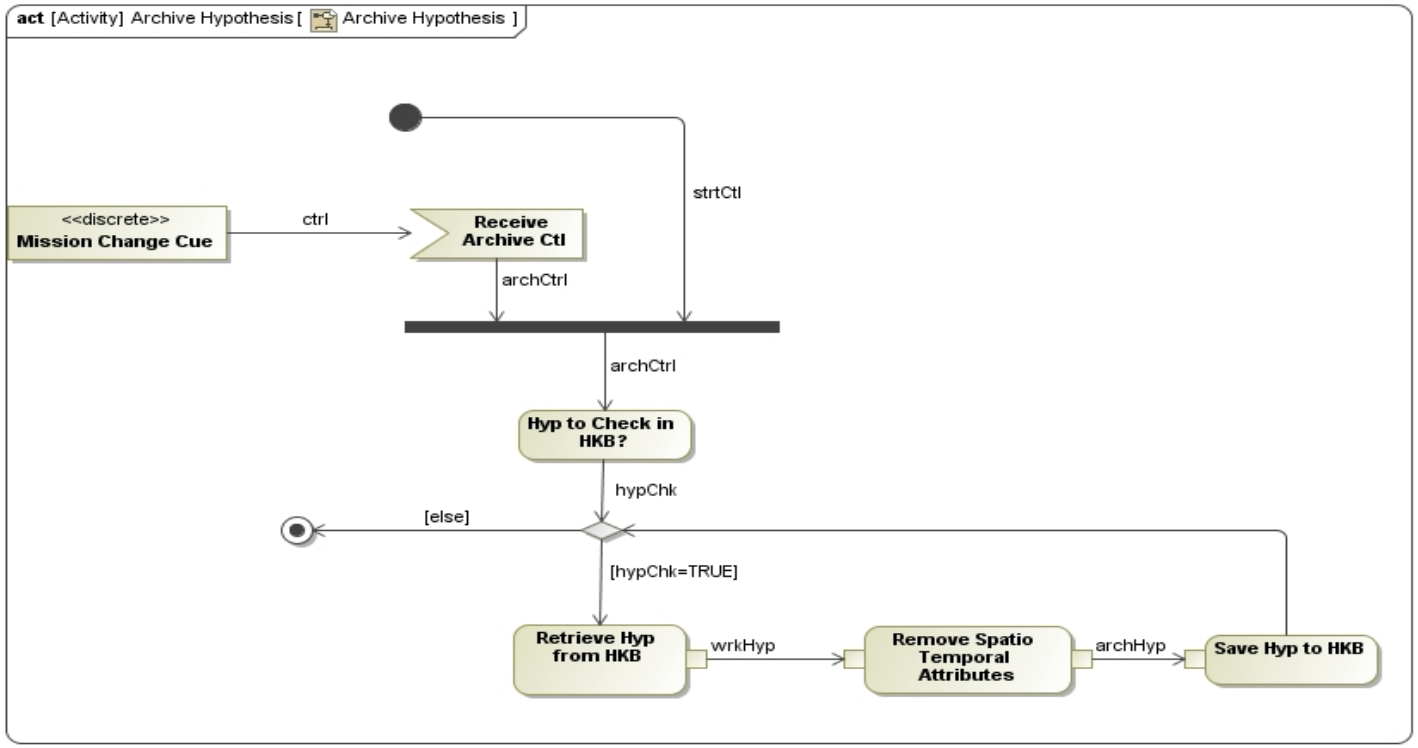
Retrieve Hypothesis Activity Diagram



Reasoning Controller requests candidate hypotheses

HME coordinates with the Hypothesis Knowledge Base for retrieval, filters and prunes the hypotheses within the context of the query, and forwards the filtered hypotheses

Archive Hypothesis Activity

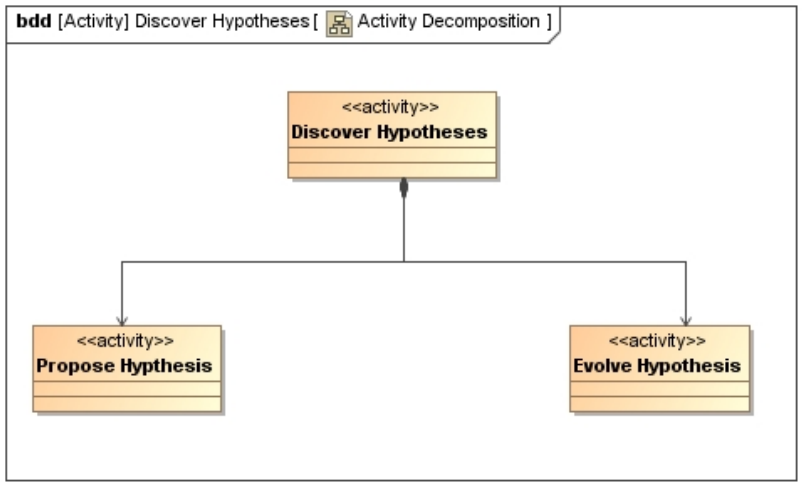


Allows non-time sensitive attributes of hypotheses to be archived in the Hypothesis Knowledge Base in anticipation of building upon them upon return to the area of operations

Hypothesis Management Module

Hypothesis Discovery Engine

Hypothesis Discovery Engine

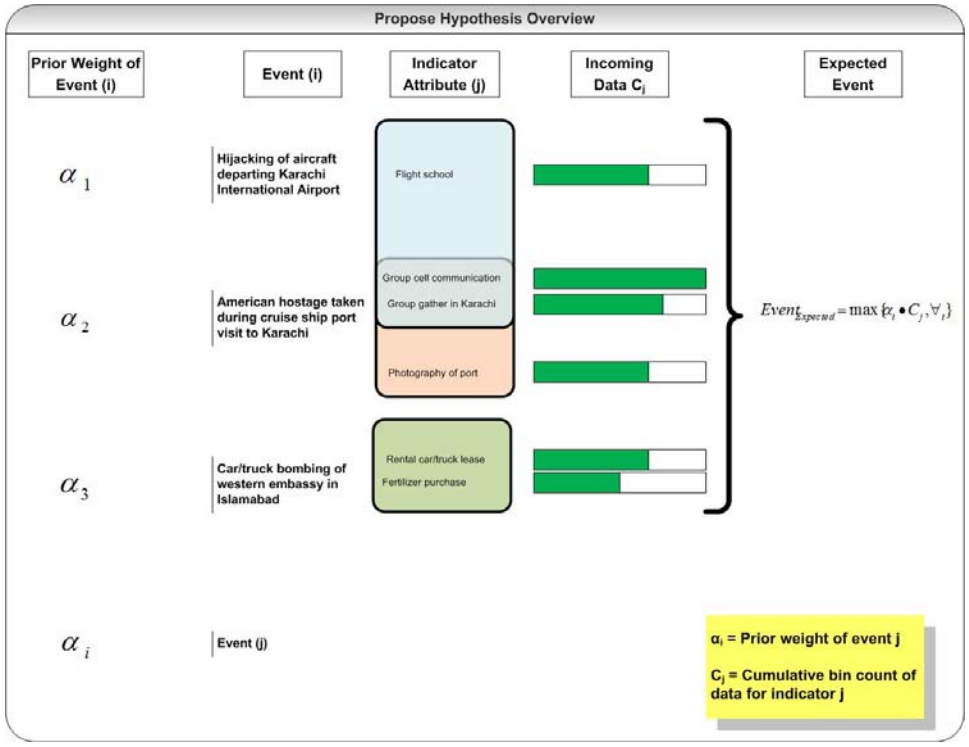


Produces original hypotheses from observed attribute data and recommends queries to pose

Decision aid for wading through data

Identifying potential asymmetric actions

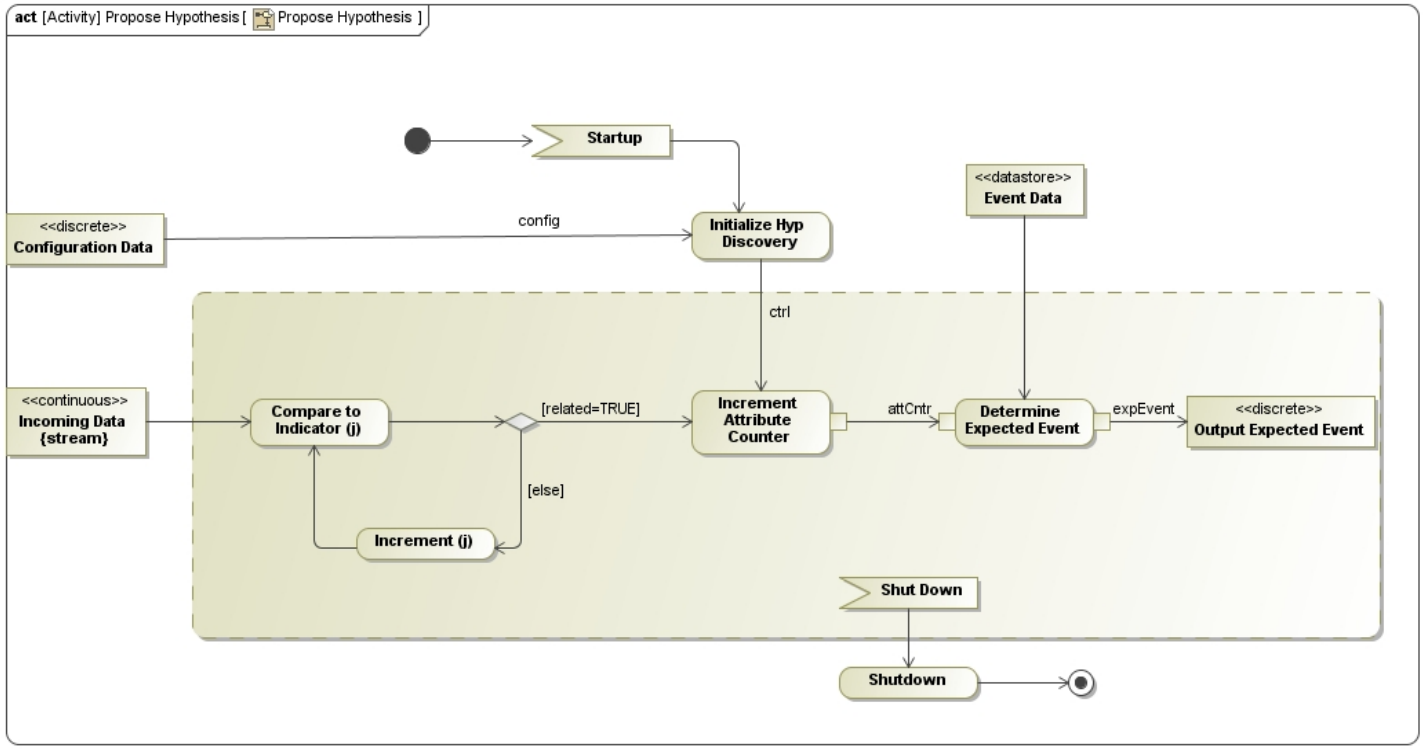
Propose Hypothesis Activity



Collects statistical information on incoming data and bins it into hypothesis areas

Periodically dump of prioritized list of likely events and associated queries

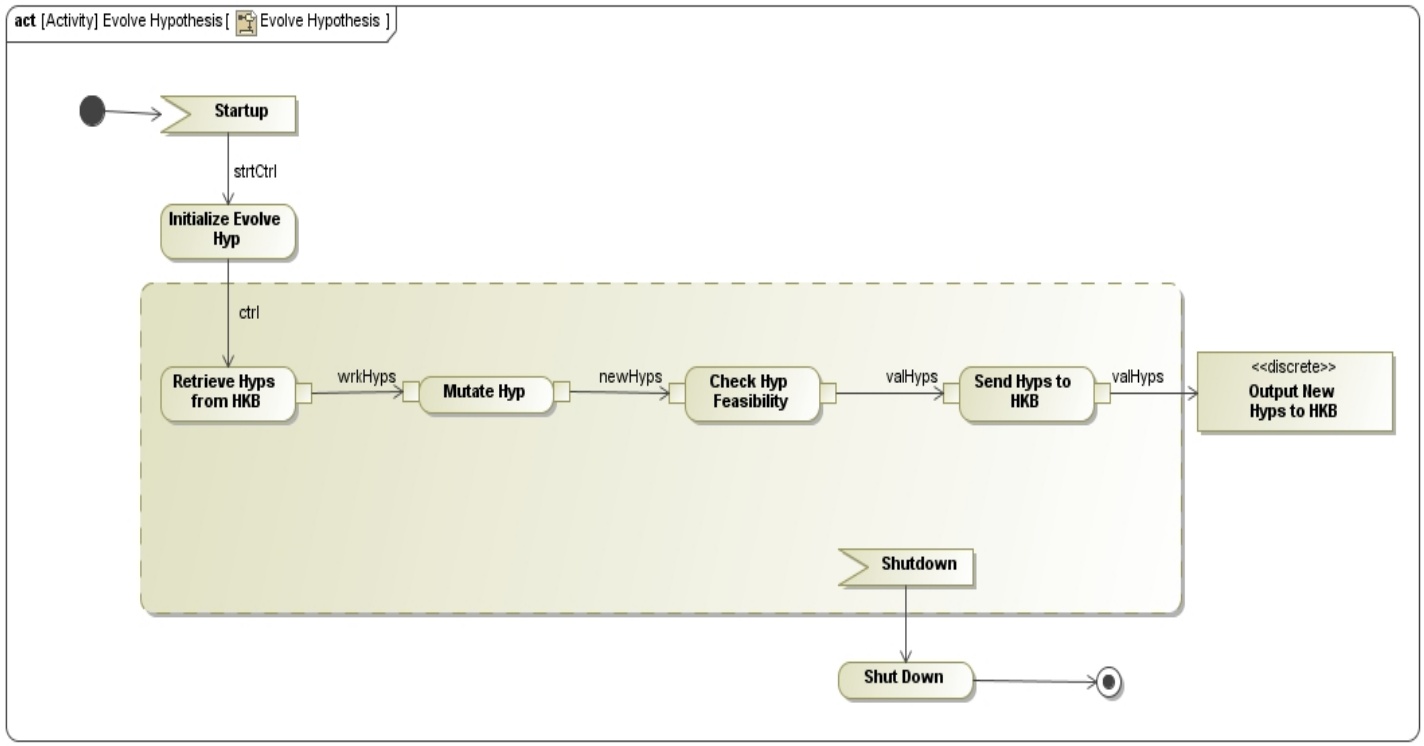
Propose Hypothesis Activity Diagram



Streaming data compared to indicators pre-identified by regional subject matter experts

Weights associated with each event that are stored in the Event Data datastore

Evolve Hypothesis Activity



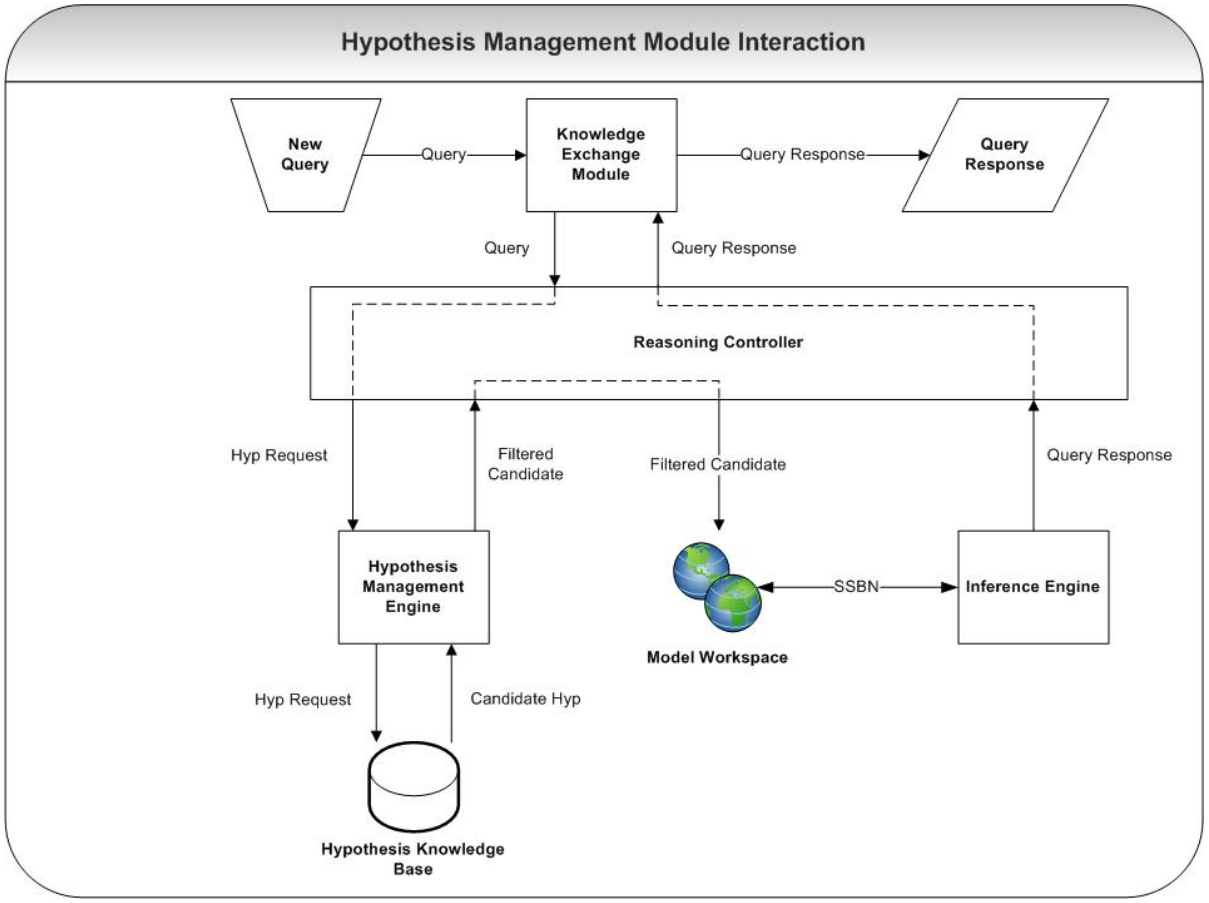
Create unforeseen hypotheses to identify asymmetric actions

Transforms existing hypotheses in HKB

Genetic mutation of hypotheses is the transformation planned for initial implementation of the activity

Interaction with PROGNOS

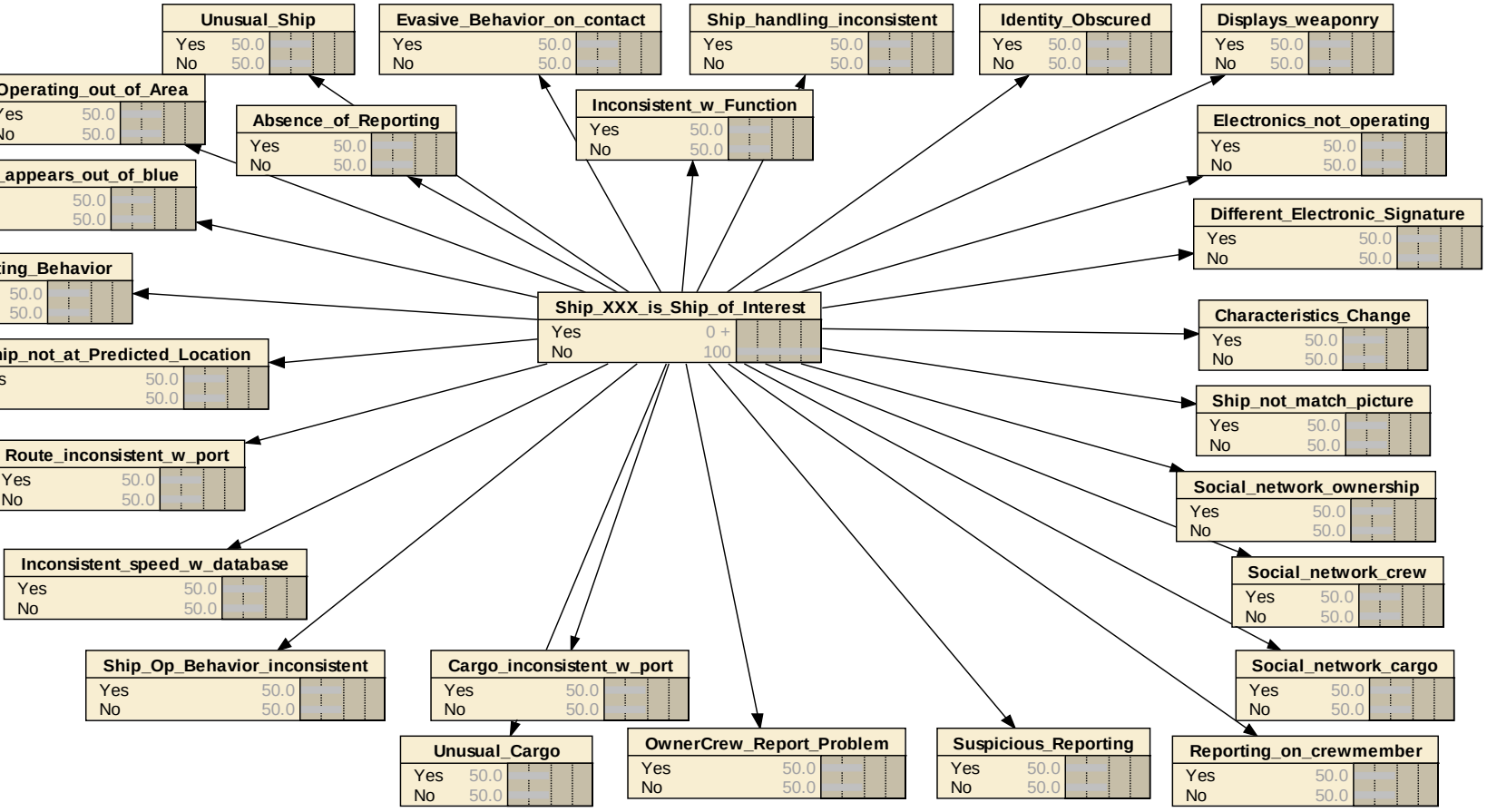
HMM Interaction with PROGNOS



Primarily through the query process – *Retrieve Hypothesis*

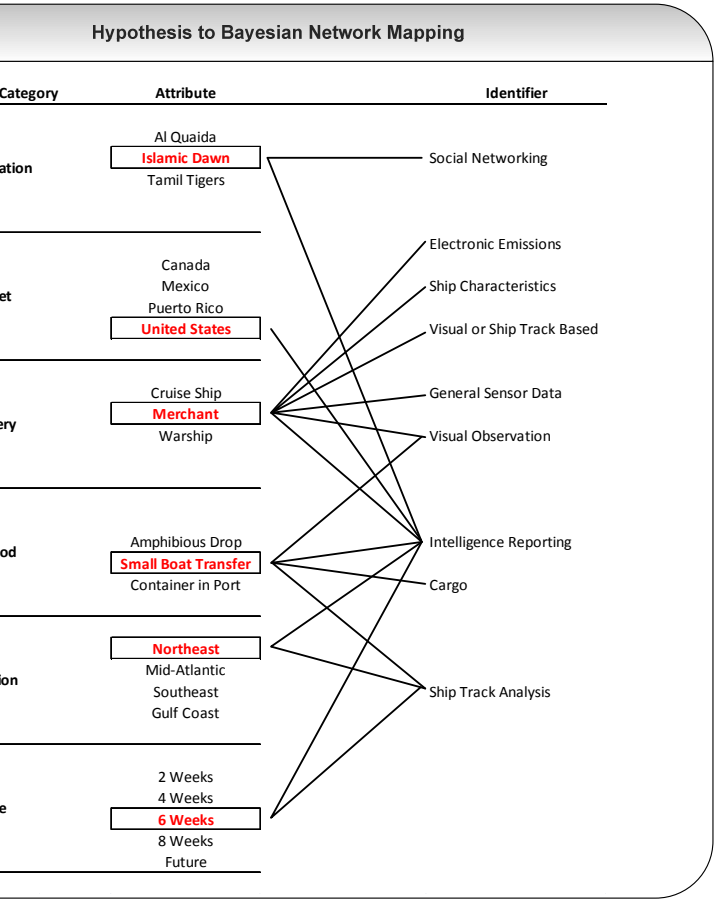
Continuously processes incoming data, proposes hypotheses, and discovers hypotheses

Naïve Bayesian Network Example (M. Locher)



copy is generated for each surface ship in the system, updated
th incoming data, and stored in the Entity Knowledge Base

Hypothesis Pruning Example



$$Hypothesis_{Query1} = \begin{bmatrix} Islamic\ Dawn \\ United\ States \\ M\_* \\ - \\ - \\ 6\ weeks \\ Maritime \end{bmatrix} \quad (8)$$

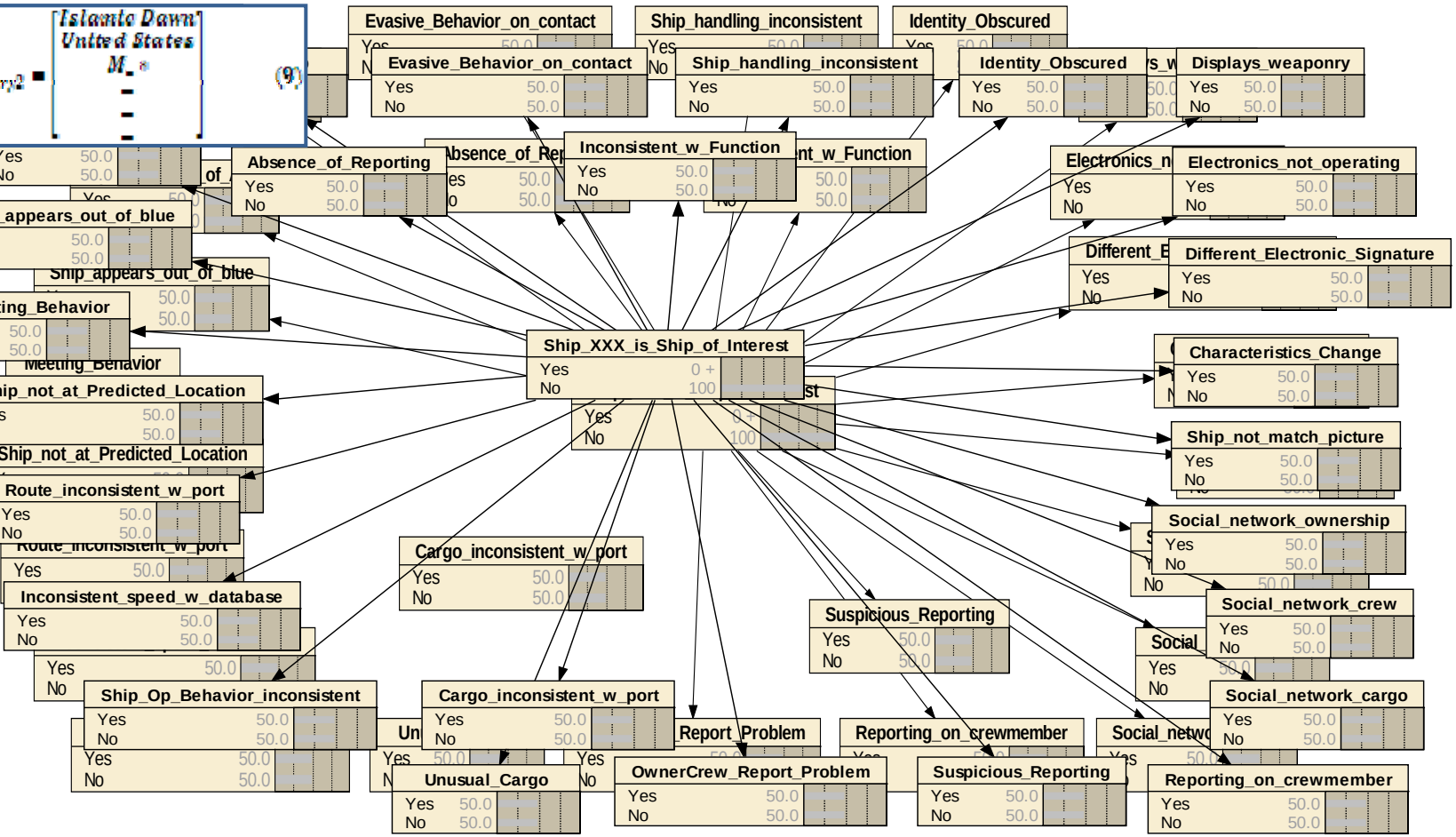
Unknowns:
- Method of delivery
- Location

$$Hypothesis_{Query2} = \begin{bmatrix} Islamic\ Dawn \\ United\ States \\ M\_* \\ - \\ \_ \end{bmatrix} \quad (9)$$

Unknowns:
- Method of delivery
- Location
- Timeline

Eliminates information not relevant to the current query or context

Pruned **Network Example**



Original reasoning network associated with $Hypothesis_{Query}$

Pruned reasoning network associated with $Hypothesis_{Query2}$

Conclusions

Creation

- Revision
  - Movement
    - Filtering
      - Archiving of hypotheses

Focus on corrective action, vice data fusion

ENTER

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Hypothesis Management in support of Inferential Reasoning