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Customer Success Is Our Mission

Characteristics of Cognitive Applications that Drive Architectural Choices

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COGENT Goals/Objectives

- Broad Cognitive System Model based on spanning set of cognitive components that will efficiently implement current functions and enable new classes of cognitive algorithms
- Scalable computational fabric with morphable, heterogeneous hardware engines supporting multiple cognitive functions
- Extensible, open architecture allows general and special purpose accelerators for signal, data, and cognitive processing
- Communications network enables tight coupling of cognitive processing with classical signal, image, and data processing
- Instrumented hardware architecture for reacting to external environment and dynamic resource demands
- Self awareness, reacts to measured processor & memory activity patterns and the external environment to evaluate progress towards goals and achieves best results within time constraints

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COGENT Architecture Levels

- Specify mission goals & requirements
- Perform goal selection, QoS

- HL OODA+L Cognitive Architecture with problem-solving rules specific to app

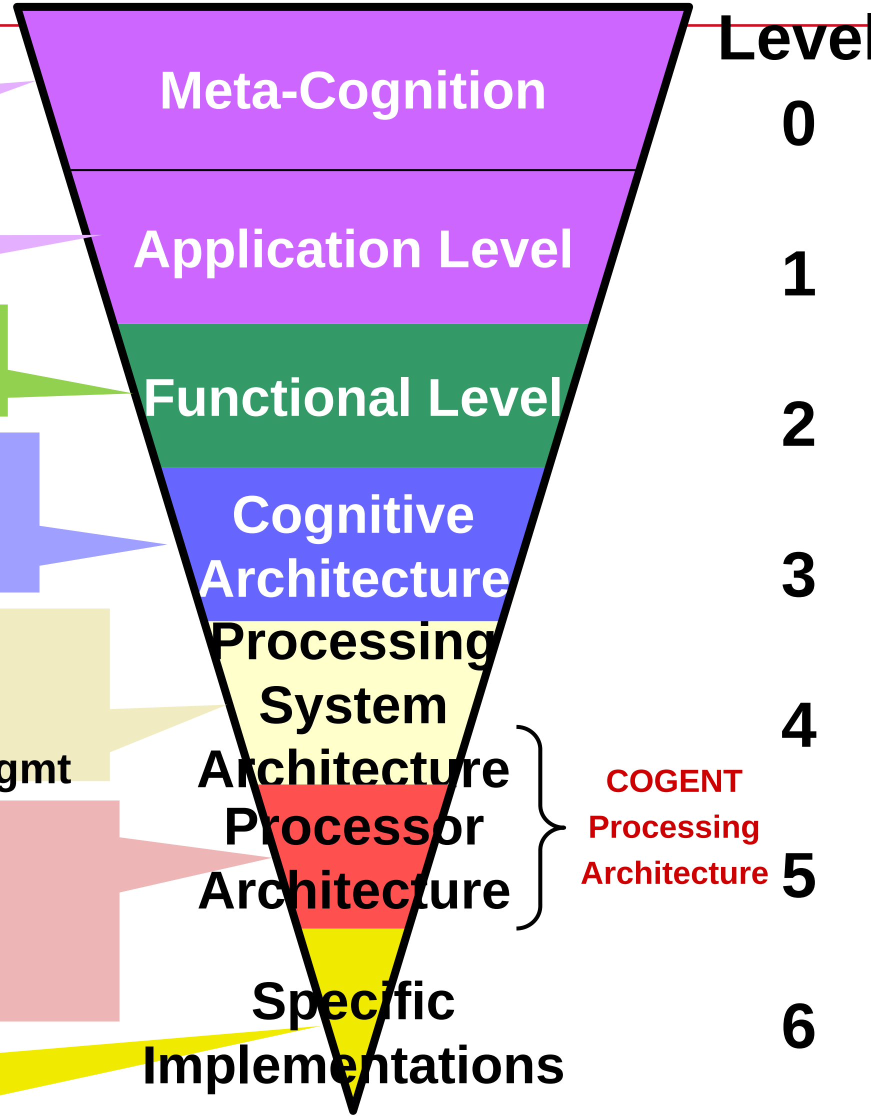
- Cognitive Algorithms & Agent Architecture
  - Newell 7+2

- Common cognitive services
  - Cognitive Agent Oriented Programming
  - Kernels (e.g., Probabilistic Reasoning)

- Run-time High Level Compiler
- Abstract machine Models
- Run-time Low Level Compiler & Resource Mgmt

- Machine organization
- Hardware micro-architectures
  - Graphs, Probabilities
  - Special-Purpose Accelerators (e.g., Bayes Nets)

- Optimized cognitive systems
  - Servers
  - Embedded/real-time



Examples of COGENT Applications

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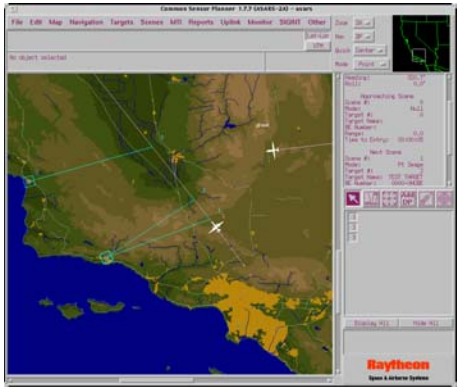


Dynamic Planner: UAV

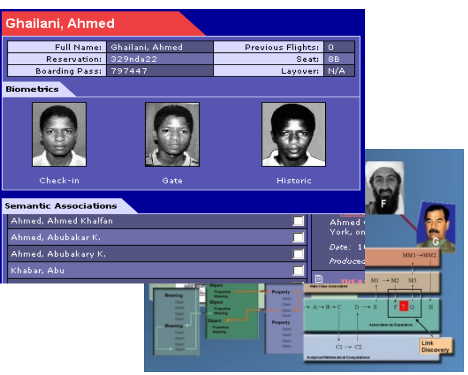
Cognitive Aspects: React appropriately to unpredicted situations, achieve goals despite threats & dynamically revised mission goals

Baseline (human) performance: 3-4 hours for single vehicle, static plan

Why Important: Operation of multiple UAVs with minimal human interaction at higher ops tempo

Customer: Air Force

Impact: Real-time battle-space awareness & preservation of assets; much of actual experience is unique and must be handled by analogy to prior trained instances.



Intelligence Analysis: Group Detection

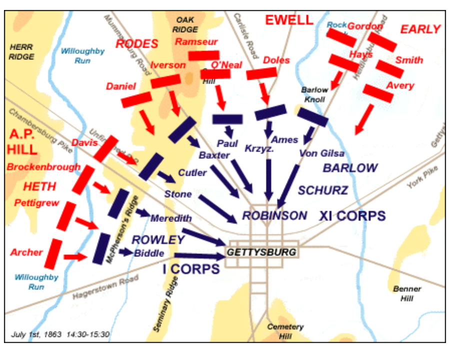
- *Cognitive Aspects*: Understand Analyst Intent, Determine relationships among “unrelated” materials, detect anomalies, posit possible but reasonable connections, verify and prioritize potential impact
- Baseline performance: varies by problem – days to months
- Why important: Covert attacks use multiple overt channels to communicate, fund and prosecute civilian targets – a much more difficult problem than traditional open warfare
- Customer: Intelligence agencies
- Impact: New capability to uncover individual / group interactions at scale that cannot be handled today, without “known bad guy”

Examples of COGENT Applications (2)

Interactive Problem Solving

- *Cognitive Aspects* : Support non-scripted knowledge transfer and problem solving across multiple domains
- Baseline performance : Interactive Voice Recognition
- Why important : Reduced manning requires more intelligent interfaces that can solve problems through collaboration rather than control
- Customer: All services, (e.g., Navy CG(X) reduced manning)
- Impact: Increase mission effectiveness in the face of reduced manning by improving ability of remaining humans in team and increased automation

Effects Based Operations



- *Cognitive Aspects*: Predict opponent actions based on prior actions, models of their social, technical and knowledge aspects
- Baseline (human) performance: 6 months or longer for complex battle set to test out doctrine implications
- Why Important: Current assumptions of symmetric warfare are obsolete, adversaries will want to erode national will and win in a political arena when the chances of winning a direct assault are small
- Customer: War College, Joint Operational Environment
- Impact: Better able to defend against embedded and small numbers of enemies, control issues of disaffection, social change, etc.

Application Characteristics

Problem Element	Dynamic Planner	Intelligence Analyst	Interactive Problem Solving	Effects Based Operations
Size of Problem	600 targets from sensor cues, 100Hz	100M relations, 1M entities, 100 relation & node types, 1K domain & background rules	100K words, 10s of problem solving actions, 100s of gen. domain actions, discourse moves	Millions of elements across social, technological scales, not just battlefield elements.
Change in input	Avoid threats, achieve collection plan plus time critical targets.	10,000 new messages/day resulting in 10,000 new entities and relations/day	2 sec per utterance	Thousands of news articles/day
Data Character	Target priority, sensor type/mode, coverage, look angle, movement of sensor	50-100% observe, <25% corrupt, 0.00008 S/N, 0.02 Signal/Clutter, 10-100% aliases/entity	Mixed initiative domain directed unconstrained conversational/argumentative dialogue	Philosophy, religion, news reports…
Prioritized tradeoffs	(1. Platform survival), 2. target priority / timeliness, 3. collection quality, 4. collection plan completion	1. Anomaly detection, 2. recall, 3. precision, 4. computation	1. Responsiveness, 2. ease of correction, 3. reasonableness, 4. sound/complete	1. Understanding, 2. Hotspot prediction
Response Time	Threats within milliseconds, New requests into collection plan within seconds	Hours to analyze full dataset, minutes to analyze daily increments	Interactive-time (.5-2 sec) to respond; minutes to solve problems	Days
Baseline Perf.	Offline - hours, data - days to analyze prior to plan updates. Update 3-4 hours on Sun	Offline - days to weeks, automated analysis on 1/10th data size, 1-4 hours	No complete solutions exist; planners are not interactive	6 months – several decades
Coarse Parallelism	Examine/predict multiple possible worlds simultaneously	Use of PWs for positive and negative argument chains, assumption scenarios	PWs for interpretations, interaction plan extensions	Game playing
Key Algorithm	Pattern Matching, Analogical Planning	Pattern Matching, Abduction	Pattern Matching, Analogical Planning, Abduction	Pattern Matching, Induction, Metaphor

Key Algorithms

- **Pattern Matching**
  – Cued Semantic Recall: episodic and semantic memory
- **Analogical Planning**
  – Map prior learned template to current problem; learn new templates
- **Abduction**
  – Why doesn't the expected happen?
- **Induction**
  – I've seen something similar to this before, what will happen here?
- **Metaphor**
  – Cross domain analogy – e.g., lessons from parables
- **Algorithm Behavior**
  – Sparse Graphs (pointer chasing)
  – Massive fan-out fan-in
  – Highly dynamic – few compilation opportunities (in the large)
  – Latency is important, but Satisficing is everything

Cognitive Problems Identify Computing Needs

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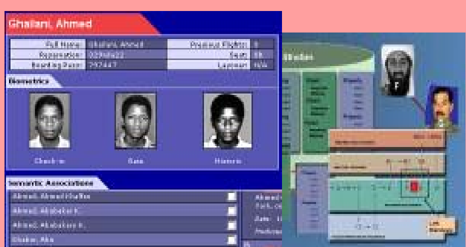
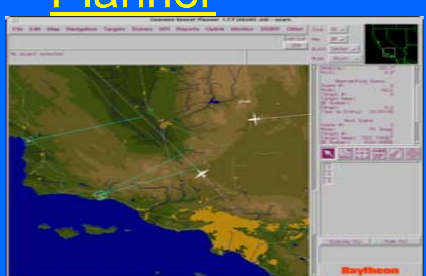
Human Computer Interface

Intelligence Analysis



UAV Dynamic Planner



- Process cognitive applications for military missions
  - *Recognition* of warfighter intent
    - Understanding of warfighter desires in context
    - Interaction driven by cognitive agents intentions
    - ***Human problem understanding & decision making markedly improved***
  - *Analysis* of intelligence data
    - Detection of hidden relationships in very large knowledge bases
    - Slowly changing knowledge base
    - ***Process very large problems***
  - *Planning* for wide range of missions
    - Single autonomous vehicles → battlefield
    - Rapidly changing working data
    - ***Deliver real-time response in highly dynamic environments***
- Lessons learned
  - Applications need a robust Cognitive System Model
    - Adopted an Observe - Orient - Decide – Act + Learn (OODA+L) model based on a combination of research cognitive models
    - Need latency tolerant processing techniques with large memories
    - Need sophisticated memory management techniques for episodic and long term memory
  - Confirmed hardware support needed for agents, graphs, Bayesian networks & a wide range of computational kernels
  - To simplify application development we decouple the computational view from developers view
  - *New classes of algorithms are required to exploit the new computational fabric; must re-think the underlying computational model*

Cognitive Motivation

- *Cognitive applications are characterized by*:
  – Graph based operations and data structures
  – Sparse knowledge representation
  – “Inexact” Information
  – Very large amounts of parallelism at multiple levels
    - **Observe**: Input symbols distributed to multiple agents (***sub/pub***)
    - **Orient/Decide**: Competing Possible Worlds (***OR-parallelism***)
    - **Orient/Decide**: Searching and matching (***Graph parallelism***)
  – Potential for speculative processing – multiple predictive processes
  – Approximate solutions provided by “anytime” and best-available calculations
    - ***Prioritize*** promising processing contexts
    - ***Filter/Prune*** stale (too late) and ineffective (poor solution) processing
  – Learning - dynamic additions to knowledge base
- *Cognition is poor match to conventional systems*
  – ***Limited parallelism with user specified management***
  – **Memory-intensive**
    - Extensive pointer-chasing through graphs
    - Memory access is data dependent, limiting effective use of data caches
      - Profiling experiment: observed 1 IPC on 4-issue SGI system (80% data cache miss)
  – Processors optimized for numeric, not symbolic processing