Cognitive Computing and Serious Gaming – Providing Superior Strategic Planning to Stabilize World Water Resources for the Future Human Race

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ABSTRACT

The effects of population, urbanization and industrial growth will be creating competition for natural resources between Nation-States to sustain economic growth and social and environment stability. Water is a natural resource that's core to human food and energy security, environmental health and social well-being. Current unsustainable industrial development in energy and agriculture production, poor water management governance and global warming are reducing the world's ability to replenish freshwater supply to meet future socio-economic demands. The competition for diminishing water resources between Nation-States and lack of access to basic water and sanitation services may cause social unrest that leads to future conflicts.

Water is a universal resource that doesn't respect geopolitical boundaries. Stress related water conflicts are already potentially impacting on NATO's Area of Interest.

Modeling future conflict related water stress is shown to be possible using model-simulation-analytics-looping (MSAL) and technologies of Big Data, Cognitive Computing and Serious Gaming. The model is applied to the Indus River Basin as an example.

1.0 INTRODUCTION

How can NATO planners detect where and when the next water related conflict will arise? There have already been important challenges with the Black Sea, Caucasus and the Georgian coast along with conflict over shared river systems. NATO planners are dealing with the great challenges of migrants flooding into Europe from Africa, the Middle East and South Asia caused by the multiple negative feedback loops of water scarce areas that have created socio-economic instability and lead to war conflicts. How could have NATO planners predict the water scarcity situations in Africa, the Middle East and South Asia on future impacts to regional socio-economic stability? Yet despite the escalating human toll, the European Union's collective response to its migrant influx has been ad hoc and, critics charge, more focused on securing the bloc's borders than on protecting the rights of migrants and refugees. [16] Given the complexities and uncertainties related to the events unfolding in Africa, the Middle East and South Asia caused by water scarcity – how can NATO planners strategic plan and prepare stability missions to successfully achieve goals in restoring governance and basic servicing needed for human well-being before unfolding events escalate into war conflict?

The NATO naval strategy [15] has to deal with water related challenges. Clearly there are multiple inputs into each tansboundary water system; the natural environment as well as man made changes. The water challenges of six shared rivers in the Indus River Basin will be used as an example of how NATO can embrace new technologies to strategically plan and prepare stability missions to successfully achieve goals in restoring governance and basic servicing needed for human well-being.

1.1 The Impact of Water Scarcity

The competition for basic resources and lack of sanitation services have become a source of destabilization leading to conflicts in regions around the world. For example, three instances involving at least two countries in dispute over water rights of shared rivers [5] to support irrigation and hydropower have been between: 1) Egypt and Ethiopia over the Nile; 2) Kyrgyzstan and Uzbekistan over the Syr Darya; and 3) India and Pakistan over the Indus River.

As illustrated in Figure 1, each of the water rights disputes listed above has been between countries located in high stress water areas. As the populations and degree of urbanization grow, climate change and poor water management reduce the accessibility to future freshwater supplies in these water stressed areas. The ability to predict future water stressed areas and their impact on regional social, economic and ecological stability will become a critical strategic capability. This critical strategic capability will be a necessity to determine the optimal strategic preparations and planning actions to secure and manage water resources for nation-state prosperity and stabilization. Access patterns to water are also changing, leading to the contemplation of a new class of "water refugees". According to the United Nations refugee agency, UNHCR, approximately 58 percent of irregular migrants who crossed into Europe by sea in the first six months of 2015 came from Syria (34%), Afghanistan (12%) and Eritrea (12%). Deteriorating security and growing poverty in Iraq, Libya, Nigeria and Somalia have also contributed to the migrant influx. [17]

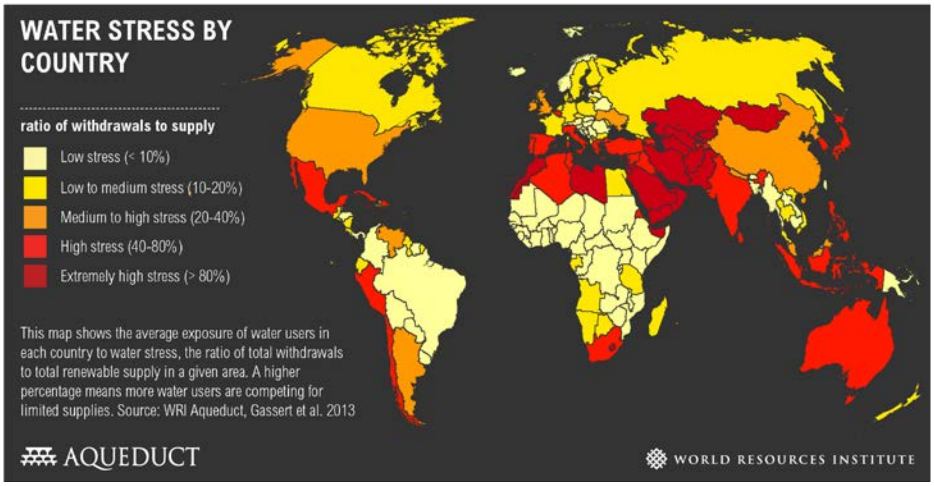

Figure 1: Water Stress By Country[1]

[1] Gassert, Francis. "Aqueduct Country and River Basin Rankings." World Resources Institute, Web. Dec. 2013. Available at: http://www.wri.org/resources/maps/aqueduct-country-and-river-basin-rankings

1.2 The Effects of Population Growth and Climate Change on Water

The expansion in world economies, population growth and migration towards urbanization increases food and energy consumption. This in turn will lead to a projected increase in global water demand 55% by 2050 [1]. The world population of 7.2 billion in 2013 is projected to increase to 9.6 billion by 2050 [2]. The continuing urbanization and overall growth of the world's population is projected to add 2.5 billion people to the urban population by 2050, with nearly 90 percent of the increase concentrated in Asia and Africa. The growth in populations and industrialization, chemicals and fertilizers water contamination, unsustainable development pathways and water mismanagement have affected the availability of clean water, compromising the capacity to meet the world's growing demand for water.

In the 130 years between 1884 to 2014, the world's temperature has risen at an unprecedented rate by 0.68 centigrade due to global carbon dioxide (CO2) levels passing 400 parts per million as illustrated in Figure 1. This is the greatest CO2 levels in the last 650,000 years. The continuous increase in global Greenhouse Gases (GHG) concentrations is expected to increase Earth's average temperature between 1 and 5.5 degrees centigrade and raise sea levels up to 60cm in the year 2100 [4]. Currently, climate change is rising sea levels, increasing severe weather (droughts, floods and fire) and raising acid levels in oceans. These effects negatively influence agricultural yields, human health and adverse changes to forests and other ecosystems.

But the world's water supplies are finite. Only 3% of the world's water supply is fresh water and of that, only 0.5% is available for use [3]. The effects of climate change and poor water management will reduce the world's freshwater resources needed by Nation-States to create the food and energy demands to support their growing populations. The impacts will cause continual instability in water stressed regions like Asia, Africa and the Middle East. The water migration trends of fleeing refugees to Europe will increase. In 2015, UNHCR anticipates that approximately 400,000 new arrivals will seek international protection in Europe via the Mediterranean. In 2016 this number could reach 450,000.[17] What will be the impact to Europe?

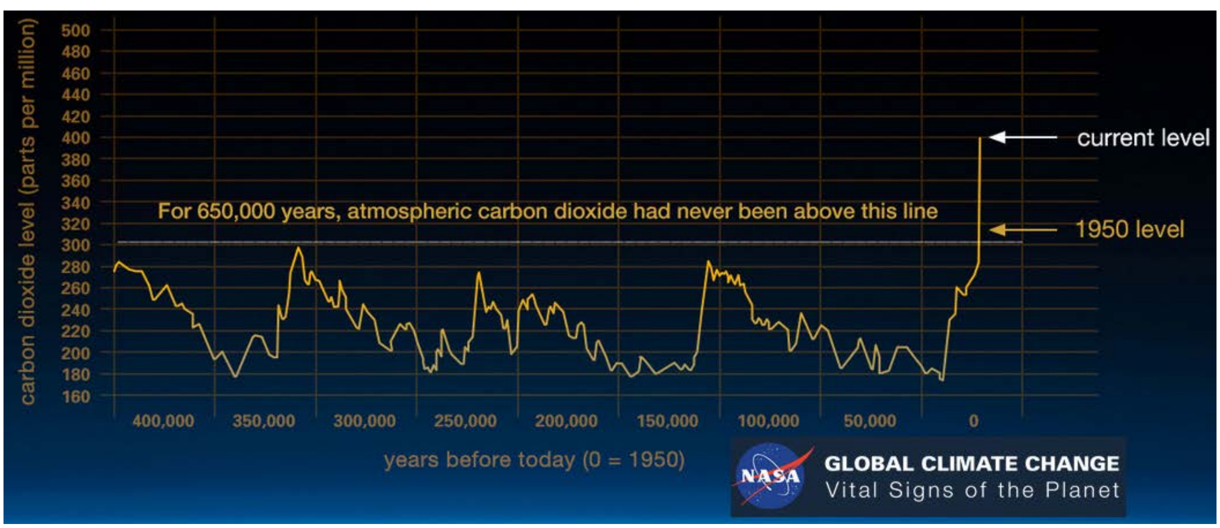

Figure 2: Carbon Dioxide in the atmosphere[2]

[2] This graph, based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, provides evidence that atmospheric CO_2 has increased since the Industrial Revolution. (Credit: Vostok ice core data/J.R. Petit et al.; NOAA Mauna Loa CO2 record.)

1.3 The Complexity of Water Scarcity Problems

The world's water scarcity problems are becoming more complex and more unpredictable due to the situations' multiple factors, feedback loops and inter-correlated effects such as climate change, overpopulation, water pollution, poor sanitation, human health issues, poor water management, etc. These factors and inter-correlated effects contributing to water scarcity have different impacts on underdeveloped, emerging and developed nation-states and their geographic locations. The world's water scarcity problems can be described by McCabe's cyclomatic complexity number – where complexity in the real-world environments increases as the number of entities (nodes), connected edges (relationships and inter-correlated effects) and active paths (feedback loops) increases. This complexity and uncertainty in M&S climate change and water scarcity problems produce a wide range of variations in predicted results. For instance, the IPCC report has multiple scenarios used to predict future temperatures that range from 1.1°C to 6.1°C by 2100 [7].

The increased variability, complexity and uncertainty of regional water scarcity situations as they continually evolve makes it challenging to predict future disaster and conflict types and their impact to regional economic sustainability and social stability, loss of human life and costs. These wide range of uncertain situations make it challenging for decision-makers to prepare strategic plans and a wide variety of goal-based scenarios and stability missions to maintain or reestablish a safe and secure environment.

1.4 Challenges Using Traditional Model & Simulation

The world water scarcity problems generates multi-intelligence (multi-INT) structured and unstructured data sources, multiple data types and ever changing content. Traditional relational analytics modeling and simulation (M&S) systems have challenges in data fusing volume, variety, veracity and velocity of the multi-INT unstructured data. The traditional methods have challenges in exploring and discovering the nth interrelationships between indirect variables within/across networks needed to model real-world water scarcity and climate change scenarios. Decision-makers need the strategic capability to:

- predict water scarcity
- assess its impacts on regional economic sustainability and social and ecological stability
- strategically plan for hard water' (irrigation systems, dams, groundwater wells) and soft water (water rights, trading, and efficiency incentives) solutions that will help mitigate and/or resolve water conflicts.

To do this, decision-makers need strategic preparation and planning solutions that apply system thinking (top-down) methodologies, intelligence frameworks and advanced M&S techniques (such as Model Simulation Analytics Looping (MSAL) integrated with Big Data and cognitive computing technologies) that can provide cost-effective IT infrastructure and tools to model and predict complex world water scarcity problems. Decision-makers may need to embrace a serious-gaming environment that engages leaders to work in mutually beneficial partnership with each other in a transboundary collaborative environment. This will involve the coordination of projects to meet mutual goals and make trade-off decisions in relation to irrigation, power generation, crop diversification, institutional development, etc.

2.0 NEW CAPABILITIES TO ADDRESS WATER SCARCITY PROBLEMS

Decision-makers can predict severe water stress areas, the impacts to regional stability and decide/act on optimal set of solutions using a top-down systems thinking paradigm supported by an integrated suite of technologies. This involves using the MSAL methodology along with technologies in the areas of Big Data and Advanced

Analytics, cognitive computing and serious gaming. This top-down systems thinking paradigm of integrated technologies will enable modeling and simulation of complex water scarcity problems that contain systems of systems (SoS) working in:

- Multi-Mission, decentralized control, uncertain environments
- Un/semi-structured, modular and loosely coupled
- Distributed decision making
- Human-on-the-loop decisions under uncertainty.

2.1 Top-down systems thinking paradigm

Modeling-Simulation-Analytics-Looping (MSAL) provides a framework to model systems of systems (SoS) that enable decision-makers to apply systems thinking in understanding complex and uncertain behavior patterns in real-world environments. Decision-makers can weigh/make trade-offs to meet mission goals by simulating an optimal set of solutions. MSAL is based on iterative looping between modeling, simulation and Big Data and advanced analytics. It applies mathematical architecture techniques that focus on the mission objectives and environment of mission threads (plausible outcomes). These are based on the underlying combinatory effects to quantitatively answer key questions about water scarcity prediction and solution alternatives. Architectures are evaluated early and often in run time environments providing for an understanding of break points and performance boundaries.

MSAL is a set of three nested loops about a common Mission Model. The Uber Loop is the intersection of the real or tactical world with the virtual run-time environment. The Uber Loop is a process where modelers use a construct called the **mission environment** to create real-world system thinking model of the Area of Interest (AoI). The mission environment model allows decision-makers to visualize the real-world water scarcity environments (entities, behaviors and interconnections) as a set of nodes, edges and paths/walks in the graph. The Model-Analysis-Loop (MAL) creates the static models (**mission model**) that are abstractions of the real world mission environment model that is under test. In the MAL process, decision-makers define the **goals** and supporting **mission threads** (sequence of nodes and events/stimulus) to achieve the goals. The Simulation-Analysis-Loop (SAL) tests the dynamic behavior of a model along a goal-based, mission thread via simulation to quantify both performance and uncertainty [6].

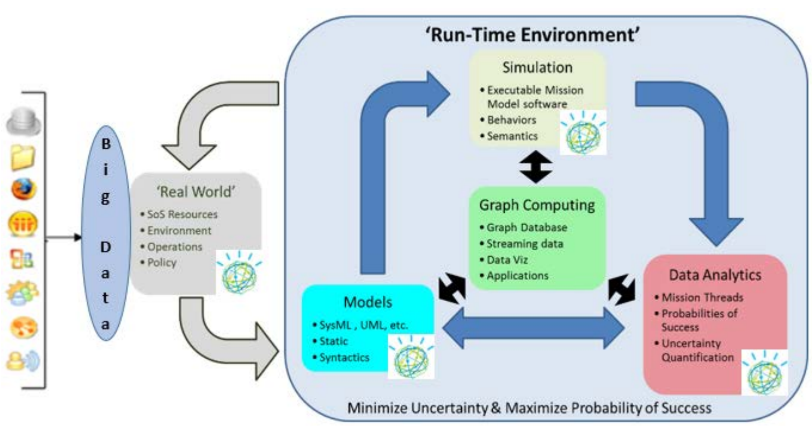

Figure 3: Model-Simulation-Analysis-Looping Approach

2.2 Capability to analyze large data sets

Big Data is defined as a term that describes large volumes of high velocity, complex and variable data that require advanced techniques and technologies to enable the capture, storage, distribution, management and analysis of the information. Big Data is often defined along four dimensions: ***volume (***the amount of data), ***velocit***y (data in motion), ***variety (***different types of data and data sources) and ***veracity (***data uncertainty). [8] Big Data provides the platform capabilities to:

1) collect multi-INT data (text, audio, images and video);
2) apply Natural Language Processing (NLP)/relationship extractions to automatically extract entities (people, places, locations, events, etc.);
3) apply analytic models (values, sociology, expectations, customs, behaviors, needs, patterns of life, etc.);
4) graphically depict a Common Operating Picture (COP) as a set of inter-connected graphical paths that represents the systems thinking models.

Big Data provides the ability to collect, ingest, analyze and visualize real-time and historical multi-INT data that better represents the real-world water scarcity situations. The Big Data capabilities and graphical analytics database allows system modelers to store data temporally. The decision-makers can use these different graphical and analytical mission models representing COPs to understand the dynamics related to various sub-systems. These sub-systems comprise of political, economic, social, ethical, etc. factors within an area of interest (AoI).

2.3 Symbiotic Cognitive Systems (Cogs)

Cognitive computing technologies comprise natural language processing (NLP), hypothesis generation and evaluation and machine learning. These cognitive computing technologies can be used to develop Symbiotic Cognitive Systems (Cogs) that can represent intelligent human thinking agents (nodes) in water scarcity models. The NLP capabilities enables Cogs to understand human language (textual) information by extracting relationships from textual data and determining how entities influence and affect one another in specific situations. Figure 4 illustrates how Cogs work together in a distributed simulated/live environment to apply probabilistic computing to every stimulus event and learn through feedback loops. This will enable cognitive information to flow across Bayes network that leverages multi-inferences to look across entire corpus of knowledge enabling discovery of unknowns and applying machine learning to better perform complex data-driven decision-making. Cogs can apply probabilistic computing and machine learning on a corpora of knowledge to computationally derive an optimal set of solutions towards solving water scarcity, management and security problems.

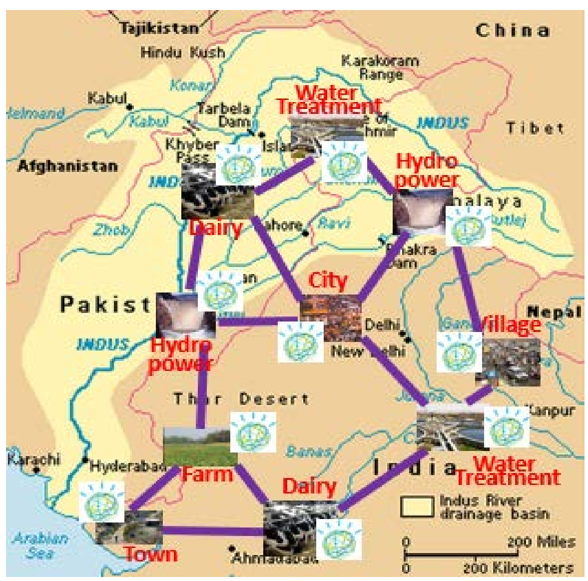

Figure 4 – Distributed Cognitive Environment[3]

[3] "The Indus River" 30 March 2008. HowStuffWorks.com. <http://geography.howstuffworks.com/asia/the-indus-river.htm> 10 September 2015.

2.4 Serious Gaming

Serious gaming applied to MSAL enables decision-makers to:

- move backward and forward in time
- interject new live/historical data into the runtime environment
- work in mutual benefit with Cogs across multiple sub-environments
- collaborate and coordinate in selecting an optimal set of missions to meet operational planning goals.

3.0 MODELING SYSTEM COMPLEXITY AND UNCERTAINTY

The observe-orient-decide-act (OODA) loop shown in figure 5 is used as a model for representing the decision-making behavior in a System of Systems (SoS) simulation [6]. The OODA model provides a good model to shows how M&S (serious gaming), Big Data and advanced analytics and cognitive computing can be integrated together to provide near real-time command and control (C2) systems for decision-makers to address the complexities and uncertainties of water scarcity problems. The idea behind OODA is that decision-making occurs in recurring cycles and processing the cycle quickly, observing and reacting to unfolding events rapidly.

The remaining sections of this paper will use the Indus River Basin as an example to describe how to apply top-down systems thinking and the supporting integration suite of technologies to:

- understand situational awareness of complex and uncertain water scarcity areas of interests (AoI)
- identify root causes and predict/simulate water sever areas and consequence analysis effects
- predict impacts to local and regional economic sustainability and social and environmental stability
- computationally derive hypothesis tests and solutions to meet strategic, operational and tactical goals
- simulate to determine optimal solutions
- apply serious gaming to collaborate between multi-decision makers; boundless in time to better understand unknowns/risks; and iteratively test hypotheses and missions to achieve optimal goals.

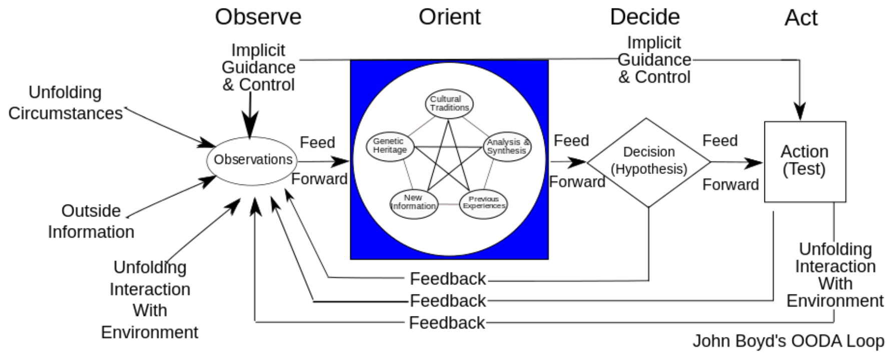

Figure 5: The OODA Loop

3.1 Modeling the Indus River Basin

The world water scarcity problems as described above are composed of complex and uncertain interconnected parts and behaviors. System thinking provides decision-makers a paradigm to understand situational awareness and determine best course of actions (cost, perform, and schedule) to intervene in the operational environment. The MSAL architecture provides modelers/analysts a method to create a mission model that graphically depict the actors, resources, behaviors, functions and the relationships between them as they exist in their AoI.

For example, the Indus River Basin in figure 6 hosts a major network of rivers flowing between India and Pakistan. It is comprised of six shared rivers - the Indus, Jhelum, Chenab, Ravi, Beas and Sutlej. System thinking allows us to take a top-down approach to describe all the inter-connected parts of the Indus River. The upper portion of the Indus is fed by snow and glacial meltwaters. It converges in the Punjab region of Pakistan with the five other rivers in the system. The Indus River is the source for hydroelectricity, agriculture, economic, transportation and other basic human needs. All the parts of the Indus River are connected. System thinking allows the understanding of how connections cause the behavior of one part to affect another at a local level, or how a change to any part or connection affects the entire system at a holistic level.

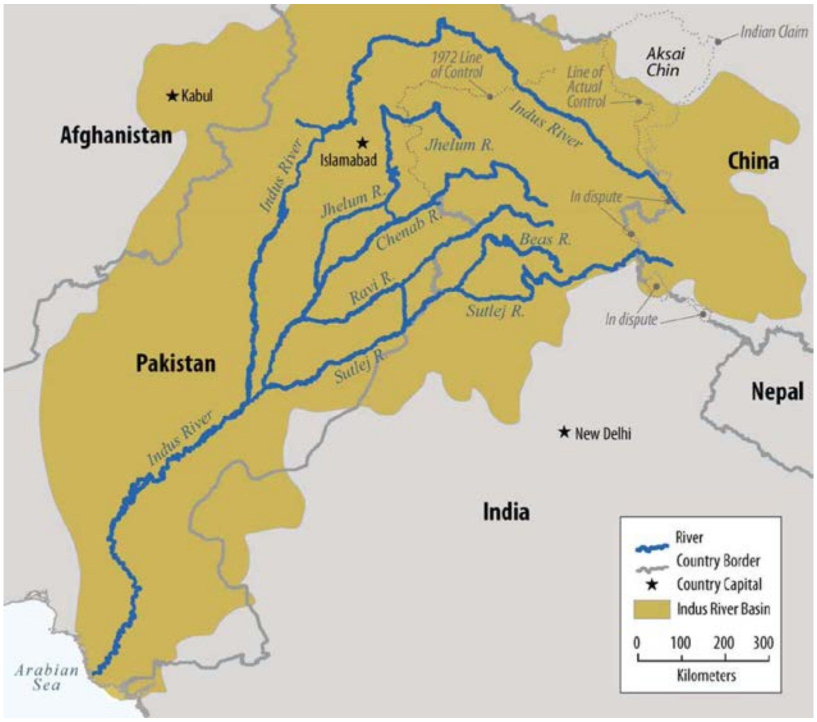

Figure 6: Map of Indus River Basin[4]

[4] Image source: United States Senate, AVOIDING WATER WARS: WATER SCARCITY AND CENTRAL ASIA'S GROWING IMPORTANCE FOR STABILITY IN AFGHANISTAN AND PAKISTAN, MAJORITY STAFF REPORT, PREPARED FOR THE USE OF THE COMMITTEE ON FOREIGN RELATIONS (Washington, DC: U.S. Government Printing Office, February 22, 2011), 1.

3.2 Understanding the Real-World Environment

The MSAL architecture provides graph analytics to create an abstract model that represents the complexities and uncertainties of the real-world water situation(s). Big Data technologies like Hadoop, Apache SPARK, Internet of Things and Streams allows modelers to collect, process (data fusion), analyze and store real-time/historical information from multi-INT data sources ito real-time/test simulation runs.

Stream processing dynamically supports analytics on data in motion. In traditional computing, you access relatively static information to answer evolving and dynamic analytic questions. With stream processing, you can deploy an application that continuously applies analysis to an ever-changing stream of data before it ever lands on disk – providing real-time analytics capabilities in live simulation runs not possible before. [8]

Context analytics provides the analytics-driven search solution that uses natural language processing (NLP) and text analytics to extract information from textual data that helps identifies the conceptual objects and relationships between them within the content passage. NLP techniques use annotators to infer the meaning of terms and phrases by analyzing their syntax, context, usage patterns and converts textual data into structured data. Annotators are built according to the Unstructured Information Management Architecture (UIMA). Annotators support an array of analytical processing capabilities such as language identification, linguistic analysis, entity extraction, entity type extraction, parts of speech tagging, tokenization, machine translation, speaker identification and tagging, etc. Context analytics consist of crawlers, document processors, indexers and search run time. [9]

Modelers can use the context analytics components to created specialized web crawlers to collect Open Source Intelligence (OS-INT) data and dynamically fuse data a big data cluster. NLP/relations extractions can analyze OS-INT data (text, audio, and video) to extract concepts and meanings. The information can be store as structured text that represent these intelligence frameworks entities, relations and inter-correlations as they exist in the real-world:

- political, military, economic, social, information, infrastructure, physical environment and time (PMESII-PT)
- civilian characteristics: area, structures, capabilities, organizations, people and events (ASCOPE)
- diplomatic, information, military and economic (DIME) characteristics that may affect operation
- non-state actors characteristics: funding, recruitment, information and support (FRIS)

Modelers can use graph analytics and visual analytics to dynamically display a graphical depiction of the various sub-systems (political, economic, state, non-state actors, organizations, social, ethical, funding, recruiting, etc.), relations and inter-correlation types captured in the annotated data as they exist in the real-world AoI (mission environment) as shown in Figure 7. Language analytics can be applied to simultaneously monitor, translate and analyze live foreign social media (video) messages in near-real time (Arabic, Chinese, English, Farsi, Spanish, Portuguese, etc.). Location analytics can be applied to capture mentions of locations in the text and map them to their geo-codes using advanced text analytics. Modelers can use machine learning and agent base models to model the entities (nodes) behaviors, interactions (multi-connections and multi-directional), and relations (values, beliefs, morals, expectations, values, customs, behaviors, needs, patterns of life, sociology and so on) modeled in the graph.

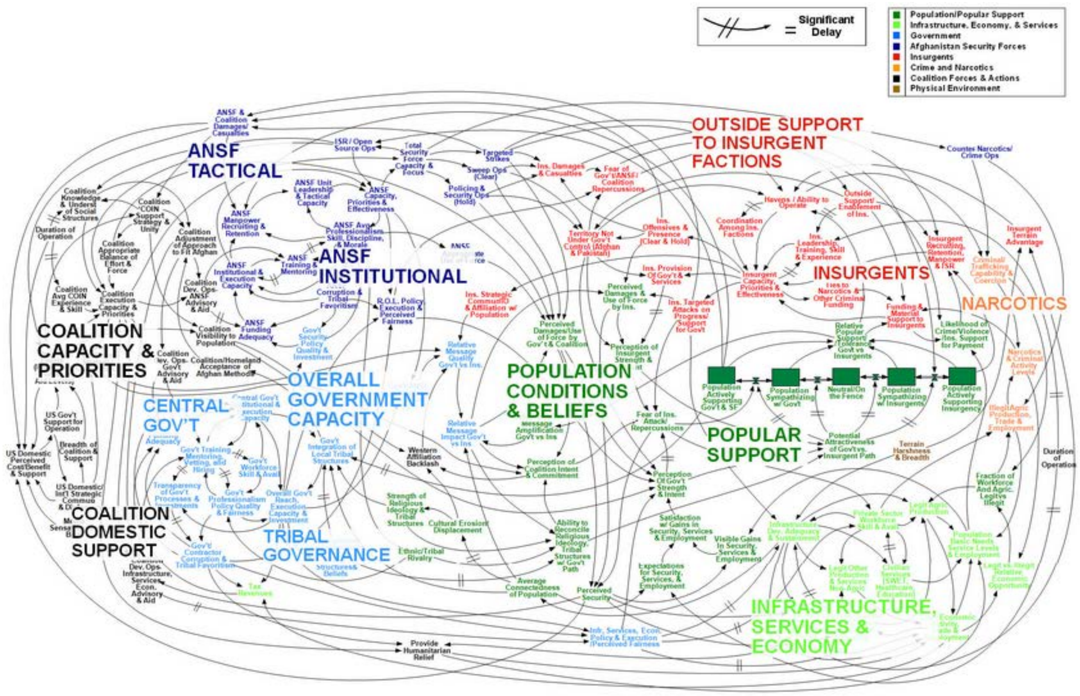

Figure 7: The Conflict Ecosystem

3.3 Abstracting the real world environment

The purpose of the Model-Analyze-Loop (MAL) is to create the static models that are abstractions of the real world environment under test. The **mission models** (scenarios) are abstract models that represent the things in the AoI real-world environment that decision-makers want to test (model under test). The mission models are a conceptual description of the capabilities, tactics techniques-procedures (TTP), conceptual operations (CONOPS), policies, behavior and relationships (interactions) between these major system/player over time and a specification of relevant environmental conditions (for example, terrain, atmospherics)[10]. It is common to think of scenarios as event based and cast as a directed acyclic graph (DAG) with branches at decision points. Unlike a fault tree, scenarios are described as a success tree. The mission models represent different scenarios of what to do given specific stimulus.[6]

The graph analysis allows segments of the overall model (holistic view of the Indus River) to be modeled and interconnected over time. MSAL's graphical model architecture allows modelers to dynamically change applications, data schemas and data sources that are required to represent the dynamic nature of complex SoS like the Indus River. Modelers can use geospatial tools to overlay mission environments on top of geospatial maps that represent the Indus River for example.

Next define the **goals** and associated **mission threads** (solutions) to be achieved in the model under test. Each mission thread is a sub-graph of mission models that explicitly defines the event sequencing through the prosecution of a mission starting with the introduction of a stimulus and ending with the completion of the mission goal [6]. For example, if the city of Multan builds a 300 Mega-Watt hydroelectric plant on Ravi River to support new economic growth between Pakistan and India, how much water will India need to release from the Bhakra Dam to maintain current agriculture yields in Hyderabad?

During the MAL process, modelers can use agent-based models (ABMs) for simulating the actions and interactions of autonomous agents (both individual and collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole [11]. It combines elements of game theory, complex systems, emergence, computational sociology, multi-agent systems, evolutionary programming.

Modelers can apply linguistic analytics on OS-INT to infer a person's personality and social characteristics, including personality characteristics, intrinsic needs and values to help understand their behaviors/reactions in abstract models. Psycholinguistics analytics can be used to infer a person's cognitive and social characteristics that help describe motivating factors that influence a person's decision making [12]. In the Indus River example, ABMs can be applied to help decision-makers analyze an AoI's military, economic, social cultural (shared beliefs, values, customs, behaviors and artifacts members of a society use to cope with the world and each other) and stability.

3.4 Using Symbiotic Cognitive Systems Agents

In modeling and simulating complex real-world water problems such as the Indus River, there are many entities, behaviors and interactions that involve human thinking. Figure 8 shows an example of a cognitive computing deep questions and answer (DeepQA) pipeline and provides the technologies listed below to mimic human thinking agents in models:

- Natural language processing by helping to understand the complexities of unstructured data. Apply advanced NLP parsing and Part of Speech Tagging techniques to determine how entities influence and affect one another in specific situations.
- Hypothesis generation and evaluation (probabilistic computing) by applying advanced analytics to weigh and evaluate a panel of responses based on only relevant evidence. Apply network reasoning algorithms to computationally derive obvious and non-obvious hypothesis, patterns and relationships
- Dynamic learning (machine learning (ML)) by helping to improve learning based on outcomes to get smarter with each iteration and interaction [13].

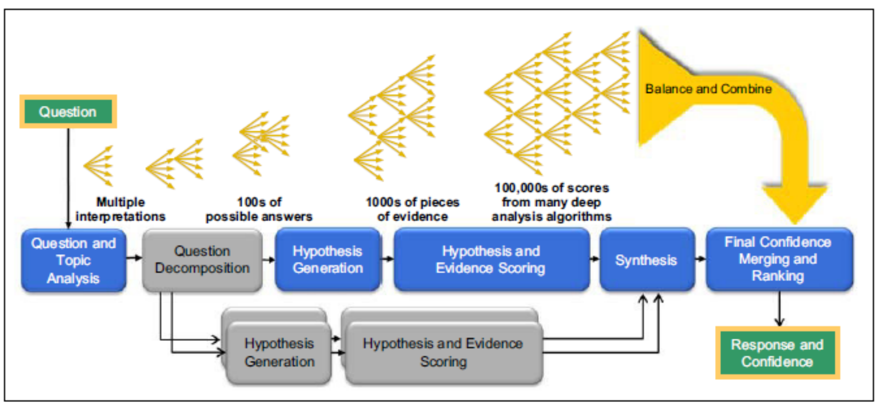

Figure 8 – Cognitive Computing DeepQA Pipeline

Cogs can be used to model human agents (nodes) in an abstract model. Cogs apply cognitive computing technologies such as NLP, probabilistic computing and ML to enable human intelligence decision making, learning and human interactions between nodes to computationally derive an optimal set of mission thread outcomes based on weighted evidence. Cogs capabilities to perform human inference chaining (determining that *this* infers *that*, which infers *something else* and so on) enable them to dynamically create deeper insight through each simulation run [13]. These types of multilevel inferences can be captured as an inference graph from which Cogs can observe a broad spectrum of downstream considerations that are contained in complex water scarcity problems contributing to uncertain behavior.

Cogs multilevel inference capabilities enable them to computationally derive a set of solutions unknown to humans. More importantly, convergence in the graph is a powerful way of deriving more significant inferences, such as answers that can reveal deeper insights and hidden consequences. By coalescing preceding confidence values, Cogs can aggregate and establish higher confidence in an answer as being the preferred answer to the question. In addition, Cogs can produce reverse inferences, which in effect means that they discover the questions/hypotheses to answers that were never asked [13]. Cogs ability to perform multilevel interferences helps decision-makers identify known unknowns and unknown unknowns to water scarcity problems.

In the MSAL framework, Cogs work in a mutually beneficial partnership with each other to enable better complex data-driven decision-making. Cognition does not occur solely (or even mostly) within an individual Cog (entity representing a human mind in MSAL), but rather is distributed across Cogs, artifacts and environments. Cogs are designed to follow and interact with humans and other cogs across a variety of everyday environments. They engage individually or collectively with humans through a combination of traditional interfaces and adaptive multi-modal interfaces based upon spoken dialog, gesture and advanced visualization and navigation techniques [14].

3.5 Deriving the Optimal Solution Set

The purpose of the Simulation-Analysis-Loop (SAL) is to test the dynamic behavior of a model along a goal-based, mission thread via simulation to quantify both performance and uncertainty. SAL is completely in the run-time environment and is Live, Virtual, Constructive (LVC) [6]. Big Data techniques allow modelers to stream real-time data and/or historical data into the simulation environment. The first step is to drive the simulation by one-at-a-time parameter sensitivity studies. Key variables are selected and then binned to run optimization campaigns and calculate local uncertainty for areas of noteworthy performance (ANP). Forward propagation of combined ‘known unknowns’ and ‘unknown unknowns’ uncertainty is then conducted to define local uncertainty [6].

Cognitive computing technologies (probabilistic computing, ML, etc.) can be used in the SAL environment to learn from past simulations and hypothesize new mission threads and mission models to reduce uncertainty in achieving mission goals. The MSAL, Big Data and Cognitive computing integrated system solution provides a strategic planning tool that provides low-to-high probabilities (hypothesizes) to meet goals by simulating end-to-end mission threads. MSAL provides the ability to measure the performance, costs and schedule of each mission model/thread to achieve goals.

Data scientist can create social, economic, military (PMESII-PT, ASCOPE, COGs, RAFT) Cogs to identify potential threats and regional de-stabilization factors buried in volumes of unstructured data fed into the system. The MSAL system will enable decision-makers to predict how climate change effects will influence monsoon dynamics that are vital for river systems dependent on their seasonal rains. The distributed environment of Cogs will be able to perform systems thinking to predict the impacts of the changing summer monsoon season due to climate change. These changes will impact the Indus River agriculture, water supply, economics, ecosystems and human health of Bangladesh, India, Nepal and Pakistan. The Cogs will be able to infer geospatially and temporally into the future. For example, the potential impact of a shift in monsoon seasons on water scarcity, which can result in regional instability leading to water wars is shown in figure 9.

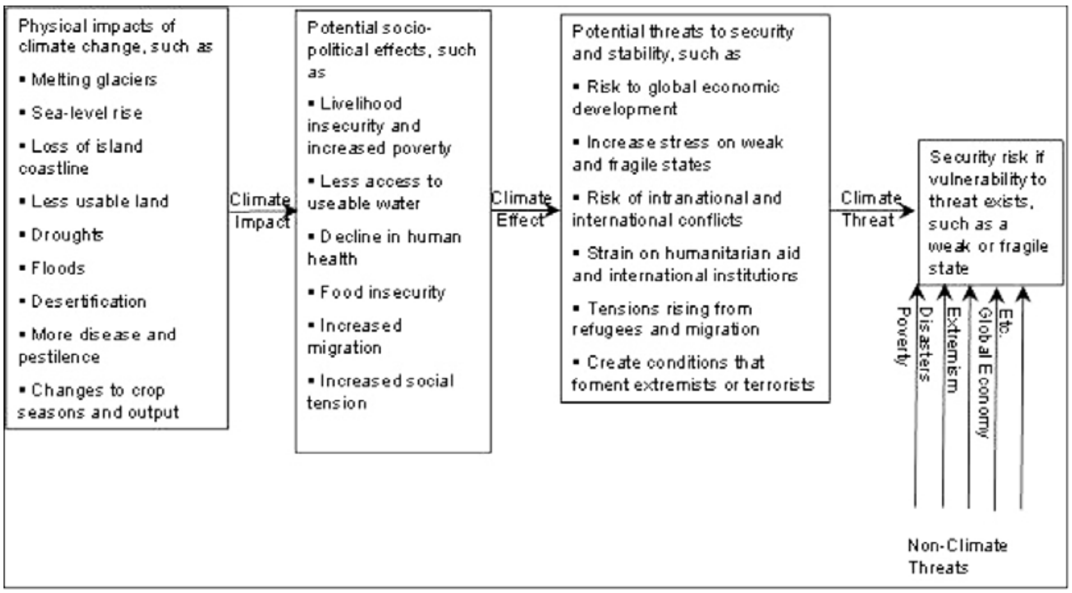

Figure 9: Illustrative Pathway of How Climate Change May Affect Security[5]

4.0 CONCLUSION

The authors have shown through this paper, the system thinking (top-down) paradigm supported by the integration suite of technologies provides a way to model and simulate complex and uncertain water problems such as the Indus River Basin. The MSAL graphical analysis framework and three iterative loops (Uber, MAL and SAL) provide modelers the ability to dynamically build, test, interconnect segments of the entire SoS problem over time, as shown in the example of the Indus River Basin.

The Big Data capabilities enable decision-makers to use real-time/historical structured and unstructured data to recreate the real-world environment to test. The MSAL graphical framework provides a simple method for modelers to leverage Big Data capabilities to automate the creation of a graphical systems thinking model depicting the Indus River's entities. The Big Data fusion capabilities will enable a continuous flow of multi-INT data – dynamically updating and enriching the mission environment model. The Big Data and advanced analytics capabilities allow the modeling of individuals/groups motives, behaviors, values and needs driving their actions. The ability to ingest and derive structure information from OS-INT data can provide access to a wealth of public data around all aspects of water supplies, demands and issues related to a regional area.

[5] Image source: United States Senate, AVOIDING WATER WARS: WATER SCARCITY AND CENTRAL ASIA'S GROWING IMPORTANCE FOR STABILITY IN AFGHANISTAN AND PAKISTAN, MAJORITY STAFF REPORT, PREPARED FOR THE USE OF THE COMMITTEE ON FOREIGN RELATIONS (Washington, DC: U.S. Government Printing Office, February 22, 2011), 1.

Serious gaming will provide a collaborative environment for nation-state decision-makers to determine an optimal set of hard/soft water solutions. Where decision-makers have identified high uncertainty, they can dynamically add more data to reduce uncertainty during each simulation run. The simulated environment will provide a strategic planning and preparation tool where decision-makers can measure each solution's performance, costs and schedule. Leveraging the advanced analytics models in the simulated environment – decision-makers can use a wealth of structured and unstructured data to predict the future effects climate change, population and urbanization growth, poor water sanitation, water mismanagement and water population will have on a region. Decision-makers can use the simulation environment to better perform consequence analysis and predict the impacts on impacts to regional economic sustainability and social and environmental stability.

These Cog capabilities combined with serious gaming technologies will enable government and military operations and strategic planners the ability to better understand the impacts of global water challenges on their national security interests. Potential sources of water related conflicts can be modeled. Cogs will be able to interact with each other over a distributed cognition environment and work in a mutually beneficial partnership with humans to enable better complex data-driven decision-making towards an optimal set of 'hard water' and 'soft water' solutions that will help resolve water conflicts diplomatically and/or improve water consumption and management.

ACKNOWLEDGEMENTS

The authors wish to thank Fred Maymir Ducharme, Ph.D., Executive Architect, IBM US Federal CTO Office Adjunct Professor, University of Maryland University College (UMUC), USA; Frank Stein (Director, Analytics Solution Center, IBM Federal CTO Office); R. K. Garrett, Jr. Prime Solutions Group, INC.; and Nickolas Kwiatkowski (Global Business Services IBM Australia Ltd Executive IT Architect) for their technical review and discussions.

10.0 REFERENCES

[1] UNESCO (United Nations Educational, Scientific and Cultural Organization). 2015. *Water for a sustainable world*. UNESCO Natural Sciences Sector News. Paris, UNESCO.

[2] UN News. (2013, June 13). *World population projected to reach 9.6 billion by 2050-UN Report*. Retrieved from UN News Centre: http://www.un.org/apps/news/story.asp?NewsID=45165#.Ve3GnPlVhBd

[3] Reclamation, U. D. (2015, May 21). *Water Facts - Worldwide Water Supply*. Retrieved from Reclamation: http://www.usbr.gov/mp/arwec/news/water_facts_worldwide.html

[4] IPCC, 2014: *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[5] Shlomi Dinar, L. D. (2012, October 18). *No Wars for Water: Why Climate Change Has Not Led to Conflict*. (Foreign Affairs) Retrieved from MIT Joint Program on the Science and Policy of Global Change: http://globalchange.mit.edu/news-events/news/news_id/210#.Ve3RzvlVhBc

[6] Garrett, R., & Loper, M. (2015, June 3). *A Comparison of Traditional Simulation and the MSAL Approach*. Georgia Tech Research Institute Information & Communications Laboratory. Retrieved from http://www.slideshare.net/BobGarrett1/a-comparison-of-traditional-simulation-and-msal-632015

[7] United States Senate, *AVOIDING WATER WARS: WATER SCARCITY AND CENTRAL ASIA'S GROWING IMPORTANCE FOR STABILITY IN AFGHANISTAN AND PAKISTAN*, MAJORITY STAFF REPORT, PREPARED FOR THE USE OF THE COMMITTEE ON FOREIGN RELATIONS (Washington, DC: U.S. Government Printing Office, February 22, 2011), 1.

[8] Maymir-Ducharme, Fred and Angelelli, Lee "*Cognitive Analytics: A Step Towards Tacit Knowledge?*" proceedings of the 8th International Multi-Conference on Society, Cybernetics and Informatics, July 2014

[9] IBM Redbooks form number, SG247877 - IBM Watson Content Analytics Discovering Actionable Insight from Your Content, 2014.

[10] MSCO DoD Modeling and Simulation (M&S) Glossary, 2011. Available at: http://www.msco.mil/MSGlossary.html

[11] Wikkipedia *Agent-based model*, accessed August 2015. Available at: https://en.wikipedia.org/wiki/*Agent-based_model*

[12] Mahmud, J. (2015, March). *IBM Watson Personality Insights: The science behind the service.* (IBM Research) Retrieved from IBM DeveloperWorks Watson: https://developer.ibm.com/watson/blog/2015/03/23/ibm-watson-personality-insights-science-behind-service/

[13] High, Rob. (December 2012). *The Era of Cognitive Systems: An Inside Look at IBM Watson and How it Works*., REDP-4955-00: http://www.redbooks.ibm.com/redpapers/pdfs/redp4955.pdf

[14] IBM Research, (April 2015). *A Symbiotic Cognitive Experience Human-computer collaboration at the speed of thought.* (IBM Research) Retrieved from IBM Research: http://researcher.ibm.com/researcher/view_group.php?id=5417

[15] Safarova, T. (2010) *The Geopolitical Premises of NATO's Naval Strategy*. Retrieved from http://cenaa.org/analysis/the-geopolitical-premises-of-natos-naval-strategy/

[16] Park, Jeanne. "Europe's Migration Crisis." CFR.org. Council on Foreign Relations, 28 Apr. 2014. Web. 10 Sept. 2015.

[17] Neehay, Stephanie. "U.N. says 850,000 to cross sea to Europe this year and next." Reuters., Web. 9 Sep. 2015. Available at: http://www.reuters.com/article/2015/09/09/us-europe-migrants-idUSKCN0R71EX20150909