A COIN-inspired synthetic dataset for qualitative evaluation of hard and soft fusion systems

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Abstract – Traditional data fusion systems focus on processing of physical (“hard”) sensor data to achieve an understanding of an observed environment. The rapid dissemination of mobile phones allows humans to act both as a sensor platform and as an observer (a “soft” sensor). Currently, the methods for fusing hard and soft data are still at their infancy. Regardless of the specific techniques utilized to fuse hard and soft data, a key challenge involves how to obtain a calibrated data set involving both hard and soft data. This paper describes a new data set being developed at the Pennsylvania State University aimed at addressing this challenge. The data set is inspired by a Counter Insurgency (COIN) scenario in Baghdad. The data currently includes nearly 600 messages (“soft” data). The construction of synthetic complimentary hard data (e.g., simulated physical sensor data) is currently underway. The COIN scenario covers a four month period: 1 January 2010 - May 2010, centered in Baghdad, Iraq.

Keywords: counter insurgency, hard data, soft data, data fusion, synthetic data.

1 Introduction

Joint Publication-1-02 [1] defines counterinsurgency (COIN) as those military, paramilitary, political, psychological, and civic actions taken by a government to defeat insurgency. U.S. counterinsurgency efforts span multiple logical lines of operations (LLOs), including offense, defensive and stability operations to achieve or restore stability and security, operations to restore essential services and promote economic development and those required to set the stage for effective self governance [2]. The integration of civilian and military efforts is essential to the successful implementation of COIN policy. Thus an engagement strategy (between humans) requires an emphasis on political, economic and social programs, which rely on human sensors (soft data) over conventional military operations, which often favor traditional sensor (hard data) collection, analysis and fusion. Regardless of the specific techniques utilized to fuse hard and soft data, a key challenge involves how to obtain a calibrated data set involving both hard and soft data.

To address this challenge, researchers at The Pennsylvania State University are developing a representative data set centered on some of the people, places, activities and motivations within a SYNthetic COIN (SYNCOIN) environment. The SYNCOIN data set was created to support the development and implementation of hard/soft fusion analysis processes, data design, process flows and interfaces required for automated and human-in-the-loop analysis for situational awareness and decision support.

The COIN effort in Iraq is a data-rich environment that is as diverse and complex as the multiple lines of operations that support it. The SYNCOIN data set does not attempt to represent all lines of effort for COIN, instead focuses principally on the people affected by improvised explosive devices (IEDs). McFate [3] suggests an understanding of the social context of IEDs is essential to countering the effects of their use; vice the technology-driven approaches most commonly used. General David Petraeus, [4] in commander’s guidance for the conduct of counterinsurgency, stated, “The Iraqi people are the decisive “terrain”…You cannot commute to this fight…Living among the people is essential to securing them and defeating the insurgents.” Hence, the SYNCOIN data deals extensively with people and social aspects of IEDs.

The SYNCOIN dataset is not intended to represent actual military intelligence collection efforts, systems or report formats, but seeks to mimic the analysis of various unstructured data types, collection means and sources derived from operational and tactical intelligence within the COIN domain. The SYNCOIN data is neither a study of
IED ontology, nor Iraqi tribal anthropology. The dataset represents a creative representation of military reports, observations and assessments. The data models used in the development of the SYNCOIN dataset seek to illustrate the: who, what, when, where, and to a lesser extent, why of IED activities in Iraq. For entity extraction and semantic reasoning purposes the “five Ws” are translated to: agent, event, time, location and motivation

2 Data Set Design Strategy

Priority Intelligence Requirements (PIRs) [1] determine the priority for intelligence focus and support that the commander needs to understand the adversary and operational environment. Field Manual 7-98, Combating Terrorism [5] establishes a framework for deriving PIRs and local terrorism indicators for field commanders to consider. These include in-part, organization, size and composition of group, motivation and goals, religious and ethnic affiliation, international and national support (moral, physical, financial), identities of group leaders, opportunists and idealist, sources of supply and support and preferred tactics and operations, among others.

Local terrorism indicators may include, dissent for political, social or ethnic reasons, the formation of radical groups, anti-government, anti-US agitation, the formation of radical or subversive groups, increased recruiting by known front groups and the identification of foreign influence or aid. Development of the SYNCOIN data set draws heavily from the PIR and local terrorism framework in creating the messages that make up the data set.

Figure 1: Evolution of COIN Analysis [6]

Figure 1 [6] illustrates the evolution of PIR development for COIN operations. Whereas traditional approaches focused on the devices themselves (the what), the evolving approach seeks to gain a better understanding of the people (the who) involved in IED activities and their reasons (the why) for involvement in the counterinsurgency, including their role across the IED delivery chain.

Doherty [7] defined the IED life cycle as a continuum with the following stages: (1) decision to attack, (2) plan the attack, (3) obtain resources, (4) prepare for attack, (5) conduct the attack, (6) attack, and (7) observe consequences and attribute responsibility. Each stage in the IED life cycle (delivery chain) may involve a unique set of characters representing a separate node in the IED delivery network. The Joint IED Defeat Organization (JIEDDO) [8] has established as its top two priorities, (1) strategies to attack the network (AtN) and (2) defeat the device (DtD). By focusing on the “network” counter-IED tactics seek to dismantle the IED life cycle, “left of boom.” Unfortunately, not all members of the IED network are insurgents [9]. For example, financiers provide funds for materials; criminal enterprises supply labor and facilitate the movement of materials, while landlords offer refuge in safe-houses and bond factories.

Figure 2 (from [7]) represents the notional IED delivery chain. Tactics techniques and procedures (TTPs) that focus on events to the right of the IED event (the boom) seek to mitigate the effects with better equipment and care for wounded [10]. This approach tends to be forensic (and technical) in nature; much like the actions law enforcement would undertake to solve a crime. Efforts "left of boom" seek to dismantle and disrupt insurgent cells before bombs are planted. The SYNCOIN data set seeks to emulate the characters and their actions across the expanse of the IED delivery chain.

3 The Scenario Backdrop

Note: The following scenario backdrop was constructed for illustration only for the purpose of creating the SYNCOIN dataset and is not intended to represent an actual accounting of social, political or military affairs, past current or future.

Baghdad, 2010 is in transition. After seven straight years of combat operations and sectarianism the landscape is littered in the after-effects of violence. Various entities across the country and region are vying for position in anticipation of
an emancipated post-occupation Iraq. The insurgency has slowed down but has by no means halted. Baghdad in 2010 is as dangerous as ever.

The landscape has transformed over the past seven years. Sectarian expansion and contraction has changed the demographics drastically, especially as Shi’a populations expand into once historically Sunni areas and similarly displace the vastly under-represented Assyrian Christian groups.

Insurgent tactics and practices have evolved over time in response to a host of factors: the counter-insurgency measures employed against them by coalition forces; the ebb and flow of popular Iraqi support; the integration of combat lessons-learned; and the Awakening Movement to name a few. As U.S. and other coalition combat forces numbers are drawn down, the pain brokers in and around Baghdad seek to advance their respective agenda, be it, political, tribal, social, business or criminal.

Sectarian demographic shifts have promoted the advancement of the historically under-represented but demographically dominant Shi’a sect and at the same time fueled a call for the resurrection of the former Bath’est regime. Al Qaeda in Iraq (AQI) and other insurgent groups have been challenged and in many instances, replaced by other warring factions whose methods are equally as brutal. U.S. military forces are no longer the primary focus of violence; targeting has shifted to the Iraqi civilian population. Fueled by the Awakening, groups like the Sons of Iraq and other home-grown militias are fighting back to regain control of their homeland; unfortunately at significant cost to Iraq’s innocent by-standers.

Not to be left out, Iraqi entrepreneurs have taken up the slack and are filling a need created by seven years of suicide bombings and sectarian-fueled fighting. The IED business has matured into a mature enterprise, complete with planning, design, production, logistics and execution networks and cells. The cost of maintaining Iraq’s insurgency, in both dollars and lives, has created business opportunities for criminal groups. Entrepreneurs, some motivated by sectarianism and, others by money alone, have taken on many of the routine tasks once relegated to foreign fighters. The IED business has shifted into the commercial market with home grown networks supplying the bomb-makers, planters and trigger groups on a for-hire/for-profit basis.

While the majority of the IED manufacturing is conducted within the borders of Iraq, many of the high-end components and supporting technologies are smuggled in from neighboring states, who offer tacit, if not direct support to the insurgency.

Political in-fighting and the perceived infiltration of government and traditional institutions, such as law enforcement and military units, by one sectarian group or another has challenged the trust of many of the rank and file Iraqi citizens. As portrayed in the dataset, some actors strive to re-gain former prominence; others seek new political alliances from inside the country, while still others are building alliances with parties outside Iraq.

3.1 Message Representation

The SYNCOIN messages simulate brief summations of event reports, observations, findings and analysis of COIN-related activities from a street-level view. On occasion, higher-level observations are presented that represent agency or headquarters’ (HQ) views. The target audience of this message set is the battalion commander.

The commander’s sources are varied, but mostly are comprised of his organic assets – his soldiers or Marines. When messages arrive at the command post (CP), they are recorded in the battalion CP operations daily log. Entries appear in the order processed. Hence some events will appear out of sequence. Messages also reflect some “editing” by clerks and CP operations personnel who handle the message traffic. Variations in message style, content and tone result as typified below:

- 01/02/10 – HTT reports rumors circulating in Adhamiya that a former bio-weapons expert under Saddam Hussein, Hassan al-Buredi, has been advertising his expertise for hire.
- 01/02/10 – Bath’est website promotes return of the party to its former prominence; calls on members to get engaged and reach out.
- 01/02/10 – ET: 1003hrs – Adhamiya tip-line caller says, “…return of the Bath’est party will erase any progress; all the lives will have been lost in vain…”

Messages for any given date are assumed to be ordered by “time of receipt” within the CP’s notional operations log system. In reality messages get backed up in the queue and may be entered into the system out of order. This is a reality for any given command post as several people in the CP are receiving and processing message traffic at any given time.

Because message traffic flows in reporting cycles and rates from multiple sources; i.e., U.S. and other coalition patrols, law enforcement, external agencies, higher headquarters, etc. and by varying means; i.e., radio, military message format, mission de-brief, formal report, re-transmission, etc., messages may be misplaced, delayed, lost or simply get backed up in the system. The ordering of the overall message set attempts to account for these phenomena.

4 Building the Data Set

Building the SYNCOIN data set was very much like writing a short story; or more accurately six parallel short stories all
occupying a common temporal/spatial continuum (Jan-May 2010; Baghdad, Iraq). The message set can be utilized in two forms, as a comprehensive set (some 600 messages) or as six smaller sets (some 100 messages each). The creators of SYNCOIN drew heavily on prior military experience in the construction of the dataset for framing the coalition force vantage point. Participation and familiarity with red-cell planning activities helped to put the researchers in the correct frame of mind to write from an opposing force (OPFOR) point of view. Sullivan, et al [11] espouse the value of the red teaming approach to gain an insight on understanding threats and the mindset of the adversary or OPFOR.

4.1 Setting the Stage: Establishing PIRs

Combating terrorism, more than any other form of warfare, requires knowledge of the enemy's goals and abilities [12]. The U.S. Army Field Manual 101-5-1 [13] describes priority intelligence requirements (PIRs) as "Those intelligence requirements for which a commander has an anticipated and stated priority in his task of planning and decision-making." A notional set of priority intelligence requirements was used to narrow and focus the scope of the SYNCOIN development effort; and a sample set of planning scenarios or vignettes was derived; each representing a different thread of activity involving a blended set of characters, events, locations and tactics.

4.2 Framing the Problem

SYNCOIN dataset development was an iterative process that involved the following steps:

1. Define the COIN logical lines of operation (LLO) that will become the focus of the overall message set.
2. Define the operational level of focus for the key military units conducting COIN operations within the data set.
3. Identify the types of reports represented by individual messages and their general nature.
4. Identify the operational space where the scenario will play out.
5. Develop and model tactical scenarios (vignettes) that follow the general IED delivery chain.
6. Develop the character/role list to support items 1-5 above.
7. Identify a workable set of objectives to aid the entity identification and semantic extraction process across the message set.
8. Develop a set of working assumptions based on the social, political, economic and military environments of 2010 Iraq.
9. Generate probable solutions or trajectories for each of the tactical scenarios in item 5 above.
10. Construct ground truth documents to capture and establish the actual nature of events, people, networks and locations played out across the message set.

Each step is addressed in brief below:

Counter-IED operations were adopted as the as the LLO for the SYNCOIN scenario. Given the focus and effects of insurgent-employed IEDs over the past seven years and large scale effort by coalition forces toward the counter-IED mission, this LLO seemed the logical choice.

The operational level of focus is the Battalion, however; no actual unit names are specified.

The SYNCOIN message set emulates a small sampling of reports that could be imagined coming into and out of a battalion-level CP including, Human Terrain Team (HTT) reports, intelligence-surveillance and reconnaissance (ISR) analysis, patrol reports, mission debriefs, interview summations and operational and technical assessments.

Greater Baghdad was chosen as the operational space for the SYNCOIN data set. Geo-location information has been designated using the Military Grid Reference System (MGRS).

Figure 3 depicts the nine districts and major neighborhoods of Baghdad, Iraq that are referenced in the SYNCOIN data set. In order to add ambiguity to the data, the team drew from a variety of sources thus offering some variation in the spelling and naming of the various landmarks.

The Military Grid Reference System (MGRS) was used in deriving geo-locations for key targets of interest within the dataset. MGRS is the geo-coordinate standard used by
NATO militaries for locating points on the earth. The MGRS is derived from the Universal Transverse Mercator (UTM) grid system [15]. An MGRS coordinate, standing alone, may be converted to latitude and longitude, if the geodetic datum is known. The geodetic datum utilized for SYNCoin (and also shared by Google Earth) is WGS84. The Earth Point Conversion Tool [17] was used for conversions, that is, MGRS Coordinates to Latitude-Longitude in order to plot key locations on Google Earth.

The importance of cultural analysis in counter insurgency operations [18] is undoubtedly one of the key findings of the current conflicts in Iraq and Afghanistan. Care was given in developing the character and role list for the SYNCoin data set to be as true as possible to the nuances of sectarian demographics in Baghdad, Iraq for the snapshot in time represented by the data [14]. Tribal names were derived within the confines of our limited knowledge of such affairs.

Noise (spurious information) was added to the data set to increase realizism and adequately challenge the down-stream data fusion processes. Ambiguity in reporting and in making observations is common even for professionals who rely on their observational skills to do their job [19]. The complexities and nuances of cultural diversity in a combat zone only increase the probability of error. In this case, some error was deemed necessary and acceptable. Variations in naming conventions of streets, neighborhoods, and regions were easily obtained as many derivations were represented in the consulted literature.

Dewar [20] describes the “...goal of Assumption-Based-Planning (ABP) is to make plans more robust and sophisticated in the face of uncertainty.” Adopted by all of service branches of the U.S. military, ABP allows planners to account for intelligence and resource gaps and seeks to flush out a full range of possible future outcomes. APB also serves a role in scenario development as a means to avoid planning surprises.

The following assumptions supported the data development process: (1) PIRs have been in play continuously since the start of armed conflict, Operation Iraqi Freedom -1 (OIF-1) in March 2003, emanating from the Commander, Multi-National Forces Iraq (MNF-I); (2) MNF-I PIRs have been translated to lower-level command PIRs, according to unit mission and threat; (3) The nature of the PIRs and associated collection strategies fluctuate according to the ebb and flow of insurgent activities, political climate, perceived threat and theater engagement strategy; (4) Not all events will be observed or reported, hence coalition forces are not working with perfect intelligence; and (5) Some distortion of events will occur in the reporting process as information is summarized, translated, interpreted and characterized.

A storyboard technique was used extensively in the formulation of the SYNCoin vignettes. Alexander et al [21] liken the storyboard to a comic strip, where each scene is depicted in a sketch supported by dialog to plan a scenario. Each vignette was story-boarded individually to establish the general plot-line, character and role list, area of operations and probable start-stop points. Vignettes that shared common characters or events were story-boarded in parallel to ensure all elements were accounted for. The need for a set of ground truth documents was recognized early in the process; however limits in manpower led to delaying their creation until the latter stages of message development. In the end, the delay had favorable results. Building the truth documents in the latter stages allowed the team to identify and reconcile message and metadata conflicts and ultimately contributed to the overall refinement of the vignettes. According to Bier et al [22] “Analysts ultimately ‘tell stories’...” In order to tell the SYNCoin story, each of the Vignettes was mapped utilizing i2 Analyst Notebook [23]. Two (2) i2 charts were generated for each vignette or thread, an entity association chart, and an event timeline chart. Work is currently underway to build the master association/timeline chart of the combined message set.

5 The Threads (Vignettes)

The SYNCoin dataset does not culminate in a single grand event; but rather has been crafted to illustrate the connectedness of the elements of conflict present in current-day Iraq. Most of what is portrayed in the messages deal with day-to-day issues by common-place Iraqi citizens and the coalition forces (soldiers and Marines) that are battling counter-insurgency. It occurs one day and one event at a time. Life in “the hurt locker” is a day-after-day battle of endurance and perseverance, where concern for personal safety remains the top priority for most Iraqi citizens.

The six threads (vignettes) weave in and out of the overall message set dealing with a wide range of social, political, sectarian and tactical challenges.

Building the overall scenario as a series of parallel threads (vignettes) was a convention born out of trial and error. The very early message build strategy sought to construct the message set as a set of parallel reporting feeds (along the logical lines of the operations (LLOs). In practice, this is very much like what would be found in an actual command post. Whereas watch standers operating in a command post have responsibility for a particular functional/operational area and receive, process, and act on reports within that functional/operational space. This process became extremely cumbersome in execution and was replaced by the construction of the six (6) vignettes that make up SYNCoin that translate roughly as:

- Bio-Weapons Thread
- Bath’est Resurgence Thread
- Iranian Special Group Thread
While an effective data fusion process is likely to determine the general nature of each individual thread by inferences based on the connections and relationships among relevant entities, locations, and events; it is unlikely the specific vignette titles referenced above would emerge intact.

5.1 Limitations, Challenges and Mitigation

The scenarios that play-out within the SYNCOIN dataset cover a four month period: 1 January – 10 May 2010, centered in Baghdad, Iraq. There is nothing special about this interval, or this particular period of time; the threads were simply programmed to culminate in the second week in May, 2010. The central theme throughout the dataset involves IED operations and associated networks, however is not intended to be a tutorial on IED operations. Still, the various sub-plots woven throughout the message set – all deal, in some measure, with the people, motivations and intent of IED related activities. Specific care was given to NOT emulate actual IED tactics, counter-tactics or operational tradecraft; hence U.S. unit designators and agency names are largely omitted.

The events depicted within the SYNCOIN dataset range from day-to-day activities to long-range affairs that span several months. The challenges and security concerns facing coalition ground forces have been continuous and omnipresent since the start of Operation Iraqi Freedom (OIF) in March of 2003. Over time, however terrorist targeting has shifted away from coalition forces toward the Iraqi civilian population and leadership. The individual messages represent a glimpse of the type of reporting that might find its way into a U.S. Army or U.S. Marine Corps battalion-level command post. It is assumed to be unformatted, but most likely filtered by individual report writers and transcribers. The messages originate from various sources -- field reports, radio traffic, Human Terrain Team surveys, operational de-briefs, and to a lesser extent, formal analysis.

The SYNCOIN message set seeks to emulate many of the complexities and challenges incumbent of COIN operations in Iraq without disclosing specific collection strategies, methods or means. The message set deliberately down-plays some of the more contentious aspects of counter-insurgency operations such as interrogations and the targeting of humans for elimination. The foundation of the message set is the reporting of “soft” data; i.e., information collected by humans on human activities; however, it also represents multiple “hard” data opportunities; i.e., reports that reflect the collaboration of soft reports with hard sensor means.

Many of the messages include meta-data and attribution indicators to provide context and facilitate drawing inferences of intelligence or reliability value. Other messages reflect unattributed observations or claims with no indication of who made the observation, from what vantage point it was observed, and for what purpose.

While deception has not been a specific design element of the data build strategy, to effect a sense of realism in the data, misdirection, falsehoods, inaccuracies and bad information is resident in many of the reports, interviews, sightings and depictions that form the basis of the messages within the dataset.

6 Use for Test and Evaluation

The test and evaluation of systems involving human-based input either as “soft” sensors or as a “human-in-the-loop” in the cognition cycle requires a different approach than a conventional system that solely evaluates “hard” sensors monitoring physical assets [24]. The overall test and evaluation strategy for this research is described in [24] and the research strategy for developing hard and soft fusion algorithms is summarized in [25]. A conceptual view of the hard and soft fusion architecture utilized on this Multidisciplinary University Research Initiative (MURI) is shown in Figure 5.

In conventional fusion applications, the emphasis has been on computing measures of performance (MOPs) and measures of effectiveness (MOEs) [26]. Examples of MOPs include, detection probability, false alarm rate, location estimate accuracy, identification probability, identification range, time from transmission to detect, and target classification accuracy.

MOEs take a higher-level view of how the system contributes to the overall success of an operation. Examples include: target nomination, timeliness of information, warning time, target leakage and countermeasure immunity.
Physical sensors are manufactured to stringent standards and carefully calibrated to ensure that multiple instances of a device with the same part number will (as least within an acceptable tolerance) work identically. Although human observers and analysts can be trained and evaluated, it is arguably impossible to avoid a certain amount of variation in a human’s behavior due to differences in cognitive abilities, personal values, past experiences, and response to stress [27]. Additionally, teams of humans working in a decision-making environment can precipitate additional effects over individuals attempting the same task [28]. In short, it is very difficult to ensure that a “human-in-the-loop” system will perform consistently when a different human is introduced to that loop.

Although this is by no means a small hurdle, it can be addressed by designing a system that anticipates these personal differences and exploits the strengths of both human and machine entities, while also minimizing the weaknesses of each. Accurately and reliably testing and evaluating such a system places special requirements on the data set being used.

Accomplishing this task requires a data set that accurately represents the variations, ambiguities, and idiosyncrasies inherent in evaluation and sense-making over input from heterogeneous sources. When the data is a series of text-based “soft” reports, it is essential that they adequately reflect variances in humans and human activity. Variations and possible incongruities in the reporting process must also be reflected. A major goal of SYNCOIN was to adequately represent each of these elements.

Another major goal of SYNCOIN was to maintain a series of comprehensive “ground truth” documents that facilitates the test and evaluation process by offering a “correct answer” with which to compare any calculated or inferred results arrived at by a data fusion system. These documents are maintained in a series of MS Word files, images, spreadsheets, relational databases, and Web Ontology Language (OWL) files as appropriate. Emphasis was placed on representing this “ground truth” data in formats that are both human-readable and compliant with computer-based semantic representation.

We anticipate sharing this data set with the community of researchers. We suggest that an approach be used in which a subset of the data (e.g., a single thread of messages with known “ground truth”) be used as a training set for hard and soft fusion algorithms, followed by utilization of the comprehensive (interleaved) 600 message set. The use of the full data set would emulate the situation in which one would not ordinarily know which messages correspond to which theme or set of activities.

7 Conclusion

Steinberg [29] discusses the role of uncertainty in the data fusion process and the interplay of uncertainty in solving problems, citing four (4) uncertainty types as, data uncertainty, model uncertainty, technique uncertainty and goal uncertainty. SYNCOIN seeks to represent each of Steinberg’s elements of uncertainty within the very complex and diverse environs of counterinsurgency. Some might question the research value of the creation of a set of synthetic data and whether such an endeavor meets the rigors of six-one (6-1) basic research. Created expressly to fuel the soft data fusion engine, the SYNCOIN dataset sets the stage for follow-on research efforts. To tackle the hard/soft data fusion process for counterinsurgency or for that matter, any inherently operational problem-solving environment, requires the creation and assemblage of data at the beginning of the process – SYNCOIN seeks to fill this role. Representative data for counterinsurgency tailored to the requirements of this problem space is not easily attainable in an open-source environment. We believe the SYNCOIN data set fills a need of the research community for a realistic, but synthetic, set of “truthed” hard and soft data for evaluation of emerging fusion algorithms.

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