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Decision Support Tools for Situation and Courses of Action Estimation from Open Source Data

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***Abstract*—This paper presents two tools which provide analytics and Artificial Intelligence (AI) enabled decision support through integration, processing and analysis of huge volumes of OSD to augment the situation understanding and assessment of alternate outcomes. Successfully achieved proof-of-concept applications of these tools supporting the courses of action to achieve the user objectives in three very different domains are presented.**

***Keywords*— open source data, data/information fusion, artificial intelligence, natural language processing, decision support**

I. Introduction

Human reasoning in any domain involves situation understanding and assessing alternate outcomes in support of defining the courses of action (COA) to achieve certain objectives. If these activities are aided by an automated decision support system, a situation understanding, estimation of the situation hypothesis scores and COA are usually compiled through application of the data/information fusion (DF) technology. The DF technology enables integration of observations about entities and their relationships modelled by the domain ontology, and the assessment of possible outcomes, modelled by hypotheses, supporting the selection of courses of action. This can be done by various model and/or data driven methods, including artificial intelligence (AI) methods where the correlation and combination of observations are achieved by computing the statistical distance, spatiotemporal, semantic similarity and possibly other similar metrics of detection attributes and other contextual information.

There is a huge volume of literature authored over the last few decades by the researchers involved in the International Society of Information Fusion (ISIF)[1] describing use of hard and soft DF for situation understanding. The methods make use of observations from physics-based sources, also known as "hard" data, while with the proliferation of internet and mobile technologies more recently plenty of research has been reported about processing unstructured information from various sources (open-source data (OSD) such as social media, blogs, news articles, and other text and audio observations), also known as "soft" data.

In this paper, we present two advanced analytics and AI enabled tools that make the assessments based on soft data providing situation understanding and estimation of hypothesis scores, assessing possible outcomes, supporting the selection of courses of action:

- Open Source information Collection, Analyses and Reasoning (OSCAR), which extracts actionable knowledge from OSD, and estimates observations in a situation through fusion of soft data.
- Hypotheses Tool, which estimates and evolves alternate outcome hypothesis likelihood through combination and aggregation of observations and contextual parameters associated to the situation.

The OSCAR and the Hypotheses Tool rely on domain ontologies to orient the search and extraction of information and can be used alone or be integrated synergistically. While this paper represents the initial efforts to present the both developed decision support methods/tools together with the approach to their collaboration through the realistic use-cases from different domains of application using real OSD, a more detailed description on the reasoning method within OSCAR and its preliminary quantitative assessment can be found in [1].

The paper is organized as follows. Sections 2 and 3 present OSCAR and the Hypothesis Tool and their capabilities, respectively. Section 4 presents and discusses examples of various domain applications while Section 5 provides the conclusions and outlines future work.

II. OSCAR

OSCAR is a Natural Language Processing (NLP) analytics tool that extracts pertinent domain specific information from OSD. It orients the search and extraction of information using appropriate ontologies describing:

- Entities of interest (actors, events)
- Relationships between entities (interactions)

while addressing five big data challenges depicted in Figure 1. OSCAR has the capability to ingest data from a variety of structured and unstructured data sources such as social media (e.g. Twitter, blogs, etc.), news reports, scientific documents, and others. New types of data can be easily added to fit in a unified data model used by OSCAR thus greatly simplifying the NLP analyses. OSCAR extracts pertinent information from the raw data using a set of detection rules and the domain taxonomies. A detection rule describes the general structure of information we wish to capture from the text while the taxonomy represents a collection of terms (or a controlled

[1]https://isif.org/events/conference/concluded

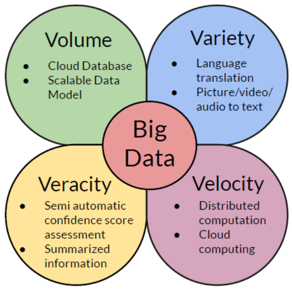

Fig. 1. Big data Challenges.

vocabulary) that can be used to describe a concept and encapsulates the various ways one can express a single notion. Besides information/knowledge extraction, this tool can also perform message content categorization, sentiment analysis, and fusion of groups of similar messages. Its processes are illustrated in Figure 2. OSCAR can present the estimated

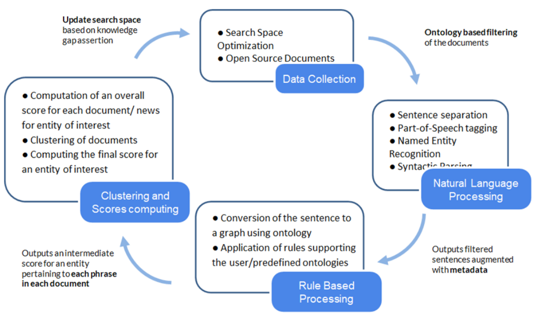

Fig. 2. OSCAR processes.

situational picture in a variety of ways. As an example, Figure 3 depicts the situational picture for intelligence fusion for space deterrence analysis presented as a social network diagram.

III. Hypothesis Tool

The Hypotheses Tool is a decision-aid tool for estimating situation outcomes related to user objectives. It provides a quantitative assessment of all hypotheses' outcomes, helping choose the best hypothesis from evidence, the user's opinion and/or expert knowledge. More specifically, given a situation of interest, different outcomes are identified within the context of the user objectives and a hypothesis is formulated for each outcome. The Hypotheses Tool then ingests pertinent and relevant data to assess/compute the likelihoods of all hypotheses/outcomes. Its processes are presented in Figure 4. The Hypotheses Tool's reasoning engine is based on a preference based fuzzy argumentation framework adopting key elements of Dung's framework [2], a number of follow-up extensions to it [3], and our modifications to accommodate the processing of OSD. It includes both support and attack relationships, uses fuzzy values in the computations, and incorporates user preference in terms of argument credibility and weight [4], [5].

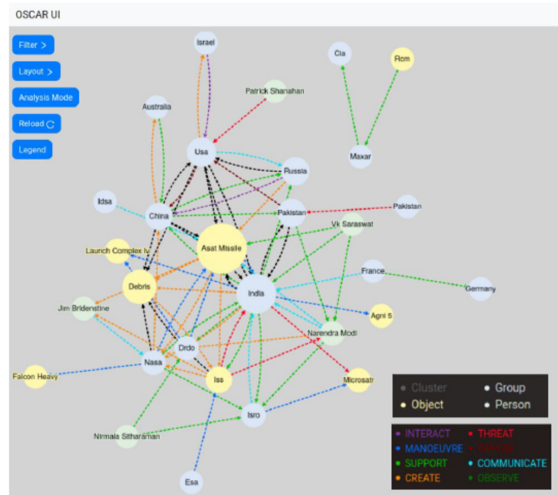

Fig. 3. Decision support for space deterrence analysis.

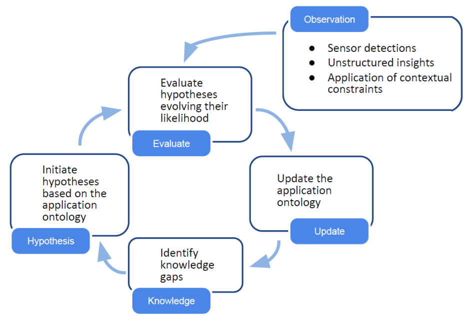

Fig. 4. Hypotheses Tool processes.

The former metric denotes how likely the argument holds true and the latter denotes how much impact the argument would have over the hypothesis if true. An example of a hypothesis and corresponding arguments is shown in Figure 5, where:

- A proposition is a hypothesis/argument. It can be supported or attacked by another proposition;
- A proof is a piece of data that supports a proposition;
- An inference link is a connection between two propositions. It denotes an attack/support relationship between the two; and
- A premise is a combination of a proposition and an inference link

The Hypothesis Tree is constructed by including all propositions for the corresponding outcomes. The ingestion of any pertinent data that support/attack the arguments in the tree will result in the computation of the likelihoods of the outcomes.

A. *Integration of OSCAR and Hypotheses Tool*

OSCAR and the Hypotheses Tool can be used independently in various applications, but they can also be used in collaboration providing decision support covering the complete decision cycle, namely Observe, Orient, Decide and Act (OODA). OSCAR provides decision support in the Observe and Orient

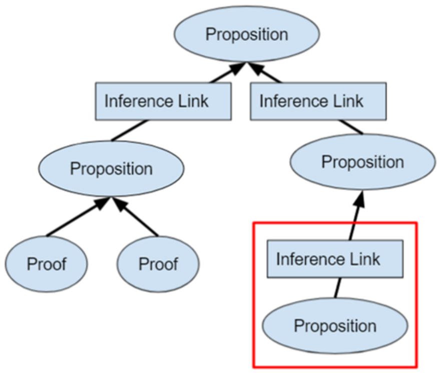

Fig. 5. Hypothesis and Corresponding Arguments Example.

phases, mining pertinent knowledge to understand a situation, and the Hypotheses Tool provides decision support in the Decide and Act phases, assessing alternate outcomes, supporting the selection of actions to achieve the activity goals. OSCAR and the Hypotheses tools can continuously collaborate in the decision cycle, with OSCAR assessing evidence of the actions and the Hypotheses Tool assessing how the outcomes support the activity goals, supporting selection of subsequent actions. OSCAR uses the taxonomy to derive detection rules to extract pertinent information and the same taxonomy is used to build the hypotheses and corresponding arguments in the Situation Tool. When a new argument is created in the hypothesis tree, appropriate detection rules are necessary in OSCAR to generate corresponding detections, enabling the Hypotheses Tool to match the detections to the corresponding arguments. Such collaboration between OSCAR and the Hypotheses Tool provides a continuous refinement of information collection and augmentation of outcome likelihoods, enabling appropriate courses of action selection.

IV. Applications

The proof-of-concept decision support has already been demonstrated by applying OSCAR and the Hypotheses Tool for situation understanding and outcomes analyses in the three domains listed below starting with the most recent:

1. Health Monitoring: "A Capability to Identify an Emerging Health Emergency and Estimate its Community-Level Disease Transmission Patterns"
2. Government policy: "A New Framework for Proactive Space Deterrence"
3. Military Intelligence: "Improved Intelligence Capability Through Fusion of Actionable Intelligence from Social Media and Other Open Sources".

A. Health Monitoring

The overall decision support integration and visualization architecture has matured over the three proof of concept capability demonstration projects to the status shown in Figure 6.

HEM was demonstrated using huge volumes of available OSD including scientific literature, news articles and Twitter data about the COVID-19 pandemic. In this project the

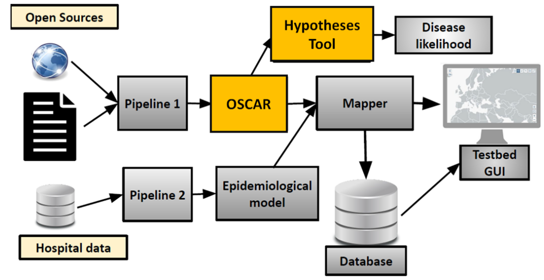

Fig. 6. Health Emergency Monitoring (HEM) Architecture.

collaboration of OSCAR and Hypotheses Tool successfully demonstrated the capability to observe the emergence of the COVID-19 disease as early as January 2020 in side-by-side monitoring the two hypotheses about the two disease outbreaks. The scope of this project included integration of another situation modeling and analysis tool (epidemiological model) within the established architecture, providing ability to predict the evolution of the situational picture, once the pandemic is on-going. In this phase the Situation tool for early detection and other disease analysis pipelines of HEM are not integrated, however a potential for collaboration between the Hypotheses Tool and epidemiological model is foreseen to enhance the disease behaviour analysis capabilities.

B. Government Policy

This project provided a proof-of-concept capability to help examine how OSD based geo-political situational analysis tools influence the decision-making processes of rational adversaries, leading to development theory for how this applies to deterrence activities and decision-making in the outer space domain. The purpose of the tool was to aid the collaborating political scientists to do off-line exhaustive examination of the established OSD based situational picture in conjunction with government intelligence sources. Figures 3 and IV-B are the examples of such decision support providing appropriate visualization and visual analytics tools.

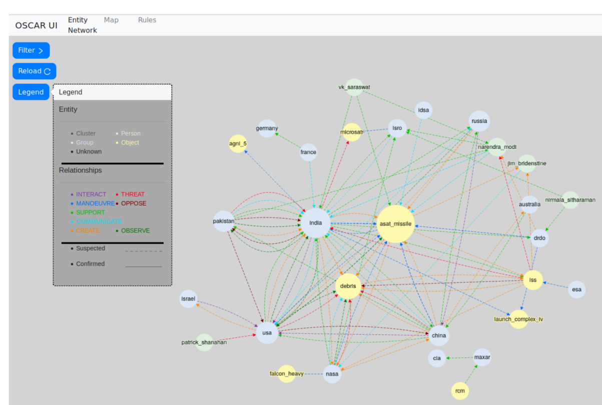

Fig. 7. Decision Support for Space Deterrence Analysis.

The provided decision support brought the increased understanding of actor's behavioural decision making in the considered use case and this methodology for proactive deterrence was deemed paramount by the political scientists.

C. Military Intelligence

This project evaluated the potential value of the OSD information in the military intelligence analysis process. The proof-of-concept solution utilises OSCAR's processes to compile a situation understanding using OSD supporting the military intelligence analysis and its feasibility was demonstrated using the 2019 crisis in Venezuela as a use case [1]. The social network diagram approach was selected for visualising the situation understanding with decision support visualization for filtering and examining the fused assessments from OSD. The project also evaluated the potential for sentiment analysis approaches from the OSD as well as developed deep learning models for emergency situations detection. The development of the Hypotheses Tool has been initiated through this project where a constructed Hypotheses tree for the Venezuela use-case is shown in Figure IV-C.

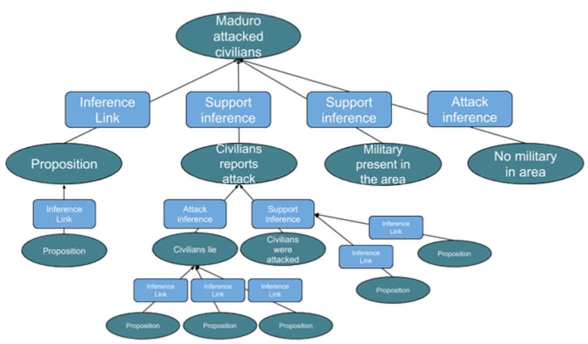

Fig. 8. Hypothesis tree for military intelligence.

However, insufficient information was available to demonstrate alternate outcomes and courses of action selection.

V. CONCLUSIONS AND FUTURE WORK

This paper reports the principal concepts behind the two tools which provide decision support through integration and analysis of huge volumes of OSD to augment the situation understanding and assessment of alternate outcomes supporting the courses of action to achieve the user objectives have been presented. These tools evolved through proof-of-concept decision support capability development for three distinct domains for which the use-cases have been described.

Through the work in these projects a good appreciation of both the benefits and challenges of extracting and using knowledge from OSD over all the phases of the decision cycle in various domains has been acquired. The ability to extract the pertinent OSD detections using appropriate domain taxonomies and detection rules is crucial. In each project the development of detection rules and taxonomies have been challenging and required close collaboration with the domain experts to ensure successful document selection and data extractions from OSD. To address this challenge in the near term, in the current implementations the user interfaces have been developed for the domain experts to augment the rules and taxonomies while also introducing the iterative refinement cycle for the rules and taxonomies. In the long term, machine learning and knowledge graph approaches are envisaged to support the development of the detection rules and taxonomies, again in collaboration with the domain experts.

The design of the collaboration between OSCAR and the Hypotheses Tool, the selection of the appropriate set of propositions and arguments, the design of the Hypothesis Tree and the decision support that enables the users to select the desired outcomes in a situation are also challenging. Participation of the domain experts in the early design phases will ensure not only an optimal initial design but it can also provide a better understanding of the domain and a vision of how to continue to evolve the application with integration of additional analytic and AI approaches within the already established infrastructure. Future works will address the systematic quantitative and qualitative assessments of both presented decision support methods.

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