A Fairness Based Framework to Resolve Political Disputes

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Abstract—**This paper presents FISA Framework for Intelligent Situation Analysis. Specifically we present a software tool to solve political disputes. Such a tool can be used successfully to cross the gap between the looseness of political situations specifications and the tightness of formal logical methods. This adaptation is performed by making use of data mining to discover both relevant topics and sequences associated with actors, which represent the underlying dispute by an arbitrary set of meaningful events that are arranged in temporal order. This allows performing probabilistic reasoning to determine the resources of the dispute by using Communicating Sequential Processes to ensure the solution correctness. More importantly, we propose exploiting fairness to tackle the nondeterministic nature of the dispute. In the proposed work, fairness techniques are relied upon to allow each country to reach the goal (which is not reachable before applying fairness) by investigating all possible paths. Consequently, fair solutions could be devised. In addition a two actor case study is given in details to illustrate capabilities of FISA. Currently such tool resolves complicated political disputes and manipulates various practical considerations.**

Keywords: Situation analysis, formal methods, Bayesian networks, sequential mining, communicating sequential processes, temporal logic, weak fairness, strong fairness.

1. INTRODUCTION

There is a Common agreement that formal methods are sound, complete and capable to afford proofs [1, 2]. They have been used in various situation analysis applications that range from critical military situations [3] to complex traffic and road situation analysis [4]. However, such methods have not been employed to analyze political situations; this is due to the fact that political situations are complex, nondeterministic, interfered, uncertainty and subject to starvations and deadlocks. Therefore, political experts prefer to introduce their own vocabulary, language, rules and theorems, which ignore completely the formal methods of reasoning that are based on logical modeling. To cross the gap between the tightness of formal methods and the looseness of the political situations, we have designed a Framework for Intelligent Situation Analysis, (FISA) to carefully mitigate such contradiction at several levels. These levels are pointed out in the following:

A. *Knowledge Level*

First, as knowledge representation, a set of relevant topics S and the set of underlying sequential events E are represented by an arbitrary set of predefined meaningful patterns, where $S \Lambda A \neq \phi$.

Second, as knowledge discovery, two functions are used, one for topic mining and the other for sequent mining [5].

B. *Event Level:*

At event level, key words representing temporal remarkable incidents are handled as tokens in a parser that forms the output sequences as a syntactic structure of event order.

C. *Reasoning Level:*

At reasoning level, a carefully designed Bayesian network "BN" is used. Since Concepts are a right way to represent topics to formalize a domain and BNs are the right means for obtaining the cause from its effects; we propose a reasoning approach over "BNs". The idea is that BNs are a semantic organization of topics that can provide the conditional probability dependencies among such topics and the frequencies of data instances provide the necessary probability distributions.

D. *Application Level:*

At the application level, we propose the following considerations to ensure the solution correctness:

- *Liveness:*Liveness is a term used for free deadlocks. This is guaranteed by exploiting communicating sequential processes "CSP" formalism [6, 7] in order to avoid deadlocks. For situations in which deadlocks appear, counter examples are announced to help decision makers.

- *Reachability:*Reachability of a reasonable solution is checked by making use of a depth-first search that ensures that the generated solution is loop-free.

- *Fairness:*Fairness is the term used to deal with nondeterminism. Linear temporal logic, LTL [6, 7], is exploited to provide five levels of fairness (Event-Level Weak Fairness, Process-Level Weak Fairness, Event-Level Strong Fairness, Process-Level Strong Fairness, Strong Global fairness). All these levels of fairness make use of the property of nondeterminism in political applications. In practice, sometimes the application suffers from the fact that it cannot reach a particular situation "solution" unconditionally. However, in such a case one can realize the target by imposing the proper fairness conditions. In this case, the system nondeterminism is utilized by studying all the possible alternatives in a fair sense. Such a capability provides major advice(s) for political specialists to resolve political disputes.

This paper is organized as follows. Section 2 presents the related work to FISA. Section 3 illustrates the different modules of FISA framework, while Section 4 presents a proof of concept and experimental work illustrating power of FISA. Section 5 includes a comparison of FISA to other related work, while section 6 contains our recommendations and conclusions.

2. Related Work

The present decade witnessed interest in studying the problem of situation analysis for different applications [4]. We are here interested only in those works which provide situation analysis for political and/or military applications. Such works is summarized in the following:

An overview of the field of recommender systems [8] describes several recommendation methods that are usually classified into the following three main categories: 1) content-based, 2) collaborative, and 3) hybrid recommendation approaches. This work also discusses possible extensions that can improve recommendation capabilities. These extensions include, among others, an improvement of understanding of users and items, support for multi-criteria ratings.

Also, in [3] the authors conducts a theoretical investigation of a complex command and control operation (Army land-battle), based on cognitive task analyses and interviews with experts to make inferences on the battle activities, then summarizing several critical human factors issues associated with planning in a rapidly evolving environment. Their aim is to distribute collaborative planning of battle activities.

An interesting work in [1] considers the problem of reaching situation awareness from textual input and proposes an approach to probabilistically model uncertain event locations described by human reporters in the form of free text. The authors design techniques to store and index the uncertain locations, to support the efficient processing of queries. The goal is to represent accurately uncertain location specified in reports to allow for efficient execution of analytical queries. In their project, they use two data sets, namely, the reports issued after 9/11 attacks and news that covered the Asia Tsunami disaster.

Another system is introduced in [9] to carry out complex systems that include political and military - emergent "unexpected" behavior. Such systems require approaches that are based on a comprehensive study of both the structure and the dynamics of these systems. Therefore, the author utilizes several analysis and planning techniques to provide a Program named COMPOEX capability of handling complex operations. Such techniques can enable systems analysts to compose conceptual and computational models for regional and nation situations. He integrates agent-based models, systems dynamics models, Bayesian networks, linear programming models, and other discrete-time models into Political-Military-Economic-Social-Infrastructure and Information (PMESII) simulation. Also, discusses the results of his experiments using PMESII, and reports his deductions.

According to decision making, [2, 10] explores an approach to model-driven engineering (MDE) of situation analysis decision support systems for marine safety and security operations. An Abstract State Machine (ASM) modeling is paired with CoreASM tool and has been used to analyze and validate ASM models. That approach, as such, facilitates analysis of the problem space and supports reasoning about design decisions and conformance criteria in order to ensure that they are properly established and well understood prior to building the underlying system.

Later, [10] has applied his Abstract State Machine "ASM" method and the CoreASM tool to design and analyze Situation Analysis Decision Support "SADS" systems. SADS system engineering relies upon systematic formal modeling approaches in order to manage complexity through modularization, refinement and validation of abstract models.

Recently, [11] proposed a framework named GECR in order to help non-expert persons to discover political risk stability across time based on sample political news. He employs a Bayesian network approach to model uncertain domains. His proposed framework is used as a decision support tool to predict the political risk level with a reasonable degree of accuracy.

It is obvious that existing systems and prototypes to-date are based on a heuristic design approach. Some of them partially lack formalisms while the others lack the use of formal methods entirely.

3. FISA Framework

This section details the proposed FISA Framework. It reads raw data news as its input and consequently infers critical situations, if any, as its output. Actually, such situations represent deep implication of what has been embedded in the input. It is then recommended that such input enters FISA via an extractor. That Extractor: reads raw data as input, exploits the idea of concept search to seek relevant paragraphs, and produces relevant paragraphs as output. FISA then consists mainly of four modules as depicted in Figure 1:

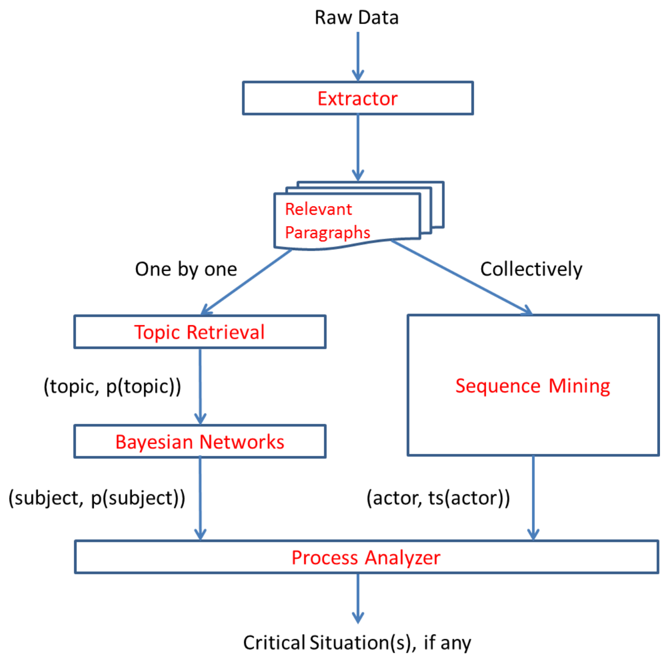

Figure 1: Framework for Intelligent Situation Analysis, FISA,
p( ) denotes the probability and ts( ) denotes the temporal sequence

The main functionality of each module is as follows:

1) *Topic Retrieval:*

a. Comes after the extractor, it takes relevant paragraphs from the extractor as input,
b. Looks for expressive words representing the topic.
c. Ranks the topic significance by evaluating a corresponding weight associated with that topic.
d. Output the pair (topic, P(topic)), where p() denotes the probability.

2) *Sequence Mining:*

a. Reads the relevant paragraphs form the extractor as input.
b. For certain tokens [12] (before, after, next,…) uses temporal-based syntactic analyzer to construct sequences of events.
c. Relate every sequence to its actor.
d. Output the pair (actor, its event sequence).

3) *Bayesian Network:*

BN is for probabilistic reasoning about resources of conflicts (subjects). The underlying Bayesian networks are constructed by domain experts taking into consideration the node ordering property so that each node interacts only with a bounded number of nodes. Thus, we add the symptoms obtained from the topic retrieval first, then the variables they influence and so on until we reach the leaves which are the real resources of conflict (subject). After construction, each BN works as follows:

a. It takes, as input, the symptom(s) expressed by the pair (topic, P(topic)).
b. It applies the joint probability distribution.
c. It gets the probability of resource of conflict P(res). If P(res) is less than a predefined threshold, ignore such resource, else call the Process Analyzer and pass the resource of conflict to it. If the dispute topics were changed, then either the expert is reviewed or another expert is consulted.

4) *Process Analysis:*

Here, every process is expressible in Hoare notation and can described as: x:B → F(x)

This notation means that every process may be regarded as a function of F with a domain B, defining the set of events in which the process is initially prepared to engage, and for each x in B, F(x) defines the future behavior of the process if the first event was x [6].

For every actor (object) and resource of conflict (subject), use communicating sequence processes, CSP [6], labeling transition systems, LTS and Temporal properties to analyze the input sequences of events, if critical situations (deadlock, others) are not found (reached), accept the solution, else use a counter-example to propose a proper solution.

5) *Linear temporal logic Fairness:*

Fairness properties state that if something is enabled efficiently often, then it must eventually happen. Most likely, fairness assumptions are necessary to prove liveness. Here deferent event annotations are used to associate fairness constraints with particular events [13].

Five levels of fairness namely (Event-Level Weak Fairness, Process-Level Weak Fairness, Event-Level Strong Fairness, Process-Level Strong Fairness, Strong Global fairness) are employed [7] and they are defined as follows:

- Event-Level Weak Fairness:

Event-level weak fairness states that if an action becomes enabled forever after some steps, then it must be engaged infinitely often.

Thus, the event E satisfies event-level weak fairness if and only if, for every action “a”, if “a” eventually becomes enabled forever in E, then a = a_i for infinitely many i's. Thus, with [] and <> denote always and eventually, respectively one can write as in (1):

([] <> a is enabled) implies ([] <> a is engaged). (1)

An equivalent formulation is that every computation should contain infinitely many positions at which “a” is disabled or has just been taken. It means that an enabled action shall not be ignored infinitely.

- Process-Level Weak Fairness:

Process-level weak fairness states that if a process becomes enabled forever after some steps, then it must be engaged infinitely often.

The event E satisfies process-level weak fairness if and only if, for every process “p”, if “p” eventually becomes enabled forever in E, then p is participated in a_i for infinitely many i's, as in (2):

([] <> p is enabled) implies ([] <> p is engaged). (2)

- Event-Level Strong Fairness:

Strong local fairness states that if an action is infinitely often enabled, it must be infinitely often engaged. This means that an event E satisfies event-level strong fairness if and only if, for every action "a", if "a" is infinitely often enabled, then a = a_i for infinitely many i's, as in (3):

([ ] <> a is enabled) implies ([] <> a is engaged). (3)

Strong fairness is stronger than weak fairness, since (<> [] a is enabled) implies ([] <> a is enabled).

- Process-Level Strong Fairness:

Strong local fairness states that if a process is infinitely often enabled, it must be infinitely often engaged.

An event E satisfies process-level strong fairness if and only if, for every process "P", if "P" is infinitely often enabled, then P participates in a_i for infinitely many i's, as in (4):

([] <> P is enabled) implies ([] <> P is engaged). (4)

- Strong Global fairness:

An event E satisfies global fairness if and only if, for every triple (s, a, s`); in which s and s` are the present state and the next state, respectively; s = s_i for infinite many i's, then s_i = s and a_i = a and $s_{(i+1)}$ = s` for infinite many i's. Such strong global fairness states that if a step (from a state s to a state s' by engaging in action a) can be taken infinitely often, then it must actually be taken infinitely often.

Strong global fairness concerns both actions and states, instead of actions only. It can be shown by a simple argument that strong global fairness is stronger than strong fairness. Strong global fairness requires that an infinitely enabled action must be taken infinitely often in all contexts, whereas event-level strong fairness only requires the enabled action to be taken in one context.

4. EXPERIMENTAL WORK

This section will elaborate one possible implementation of our proposal and a sample case study.

4.1 The Software Environment

As a proof of concept, our Framework is developed under windows 7 operating system. We install the following set of tools, Figure 2:

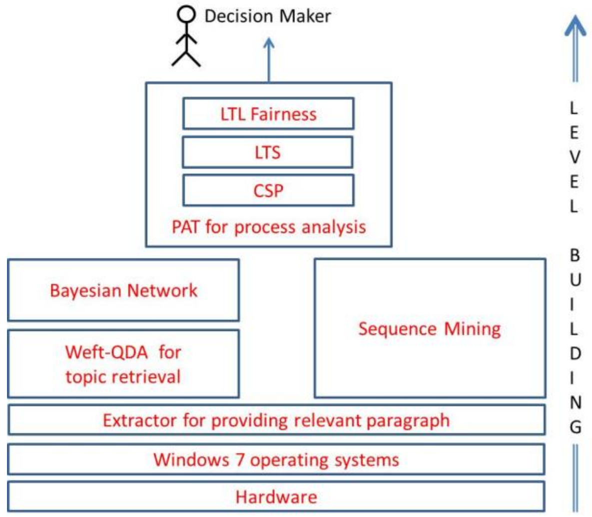

Figure 2: FISA hardware setup

a) *Weft-qda:*

Weft-QDA [14] is used to extract the relevant paragraphs from raw data. It is also used for extracting topics and their probabilities from relevant data.

b) *Text Template Parser:*

Text Template Parser [15] is used for sequence mining to extract sequences of events and their actors.

c) *Netica:*

Netica [16] is used for Bayesian networks; this provides the subjects with certain probabilities. This is done with the help of experts since automatic supervised leaning will usually not be possible with the political domain.

d) *PAT:*

PAT [17] is used to flag the critical situation(s), if any, and guide the way of solving the underlying dispute.

4.2 Case Study

We consider a dispute between two neighboring countries C1 and C2. Each country is struggling to obtain the available resources (Land and Peace) regardless of the needs of its neighbor. A lot of details are published in several documents as unstructured textual news. Such documents are simulated in the sense of disguising identities that may be revealed by the actual data. This simulated data is taken as input to an extractor module, Figure 1, which extracts a set of relevant paragraphs that contain the keywords provided by an expert in our case, these keywords are: getland, holdland, getwater, holdwater, The paragraphs are schematically processed to illustrate the four main modules of FISA:

4.2.1 *Topic Retrieval Module:*

Topic retrieval module receives from the extractor the relevant paragraphs that contain the keywords driven from the experts and extracts topics and their corresponding probabilities. The output of that module is expressed in the pair (topic, P(topic)) where the set of topics as specified by a user are {Land, Water, Wealth, Peace, Security, Naturalize} and P() denotes the corresponding topic probability that is computed by enumerating and counting each topic instance. Eventually, the paragraph length is used to normalize the obtained values. We use the output from this level as an input to the BNs module.

4.2.2 Sequence Mining:

In sequence mining, we input the relevant paragraphs extracted from the Text Template Parser. Here, we can decide the main influencing actors in the current situation (C1(), C2()) and their corresponding sequence of events that each actor can run. This is pointed out in the following:

C1

After waitland and holdpeace Then treat Next getland

C2

After waitpeace and holdland Then treat Next getpeace

Here it is obvious that the main influencing actors in the current situation are: C1(), C2() and the sequence of events controlled by it. That output will be passed to the PAT module.

4.2.3 Bayesian Networks:

BNs allow us to perform probabilistic reasoning and to obtain the resources of dispute from the observed topics. Figures 3a and 3b shows the two BNs for resources Land() and Peace().

As part of probabilistic reasoning, Netica should flag nodes that exceed the threshold probability, or by default it returns the highest probability node if the threshold is not reached. After examining our Bayesian networks, we found out that the two subjects (land and peace) are true with probability more than 60%. Since their probabilities are of highest values, such subjects are chosen, along with their prior nodes (events) to enter the Final module, namely, the process analysis module.

The outputs from this module together with the output from the sequence mining are used as input to the PAT module.

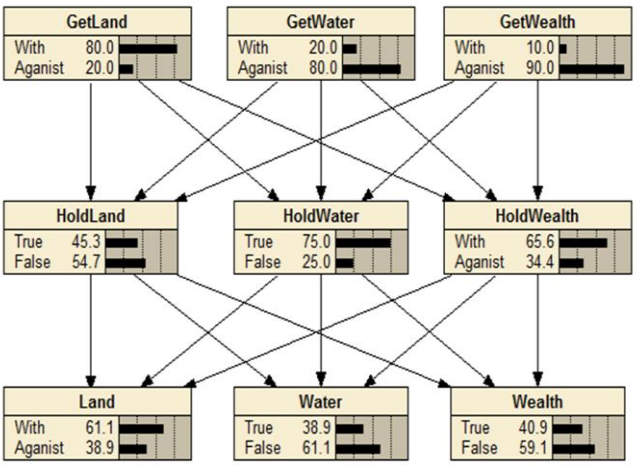

Figure 3a: The Bayesian network for Land( )

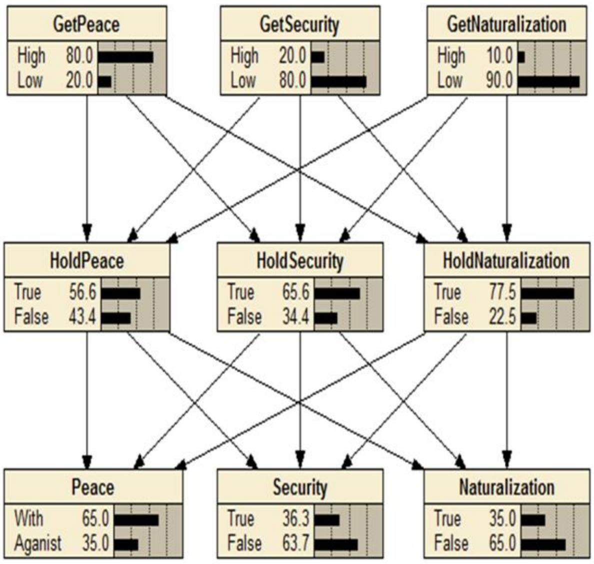

Figure 3b: The Bayesian network for Peace()

4.2.4 Process Analysis:

In the process analysis module it is important to notice that PAT gets its inputs from two different modules, namely Bayesian networks and sequence mining. These inputs are combined together to provide a unified model that represent the dispute. An input format adaptation is carried out syntactically in two steps:

1. The sequences of C1 and C2 (sec. 4.2.2) are transformed to PAT processes.
2. The Bayesian subjects (sec. 4.2.3), along with their prior nodes, are again transformed to PAT processes.

In addition the following experimental steps are performed:

1. The dispute is described by:

    College() = C1() || C2() || land() || peace();

    where || denotes parallelism.

Unfortunately, such representation leads to a deadlock, a counter example is given in Figure 4.

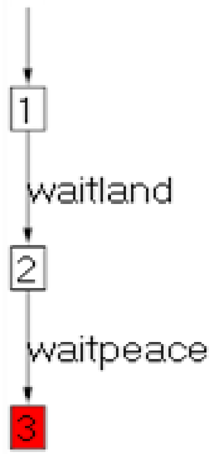

Figure 4: counter example

2. To solve the deadlock interleaving is introduced to yield the following representation:
   College( ) = C1( ) || C2( ) ||| land( ) ||| peace( );
   where ||| denotes interleaving.
   Hence, a solution is obtained, and we reach a deadlock free model. However, such solution is unfair i.e. unrealistic in the sense that neither C1 can get land nor C2 can get peace.
3. By imposing "event-level weak fairness", a fair solution, Figure 5, could be obtained.

i. The solution is realistic in the sense that such a solution can be reached upon getting peace from C1 is interleaved (exchanged) by getting land from C2.

ii. The underlying weak fairness approach has utilized the dispute nondeterminism to obtain nondeterministic finite automaton, in which all alternatives are fairly treated. Figure 6, contains several traces (for the solution) that have been extracted from the random graph of Figure 5.

iii. Since random graph do not afford straight forward solutions, FISA exploits user intervention to obtain step-by-step solutions, Figure 7. Obviously, in such a solution the goals of C1 for getting land and C2 for getting peace are reachable.

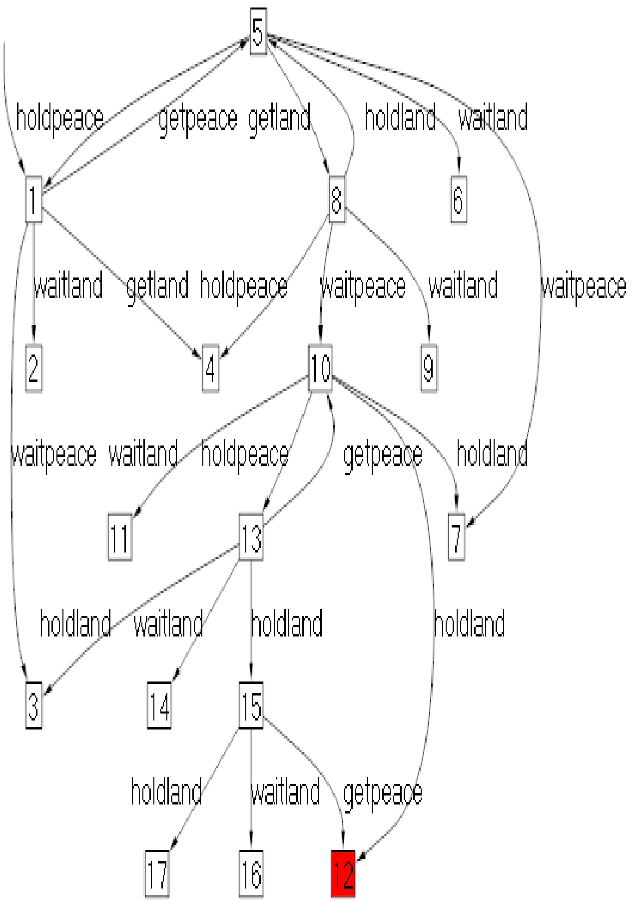

Figure 5: Random Graph simulation

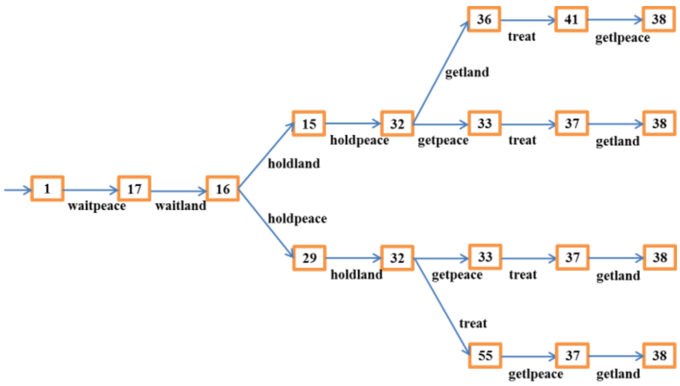

Figure 6: Possible traces extracted from random graph simulation

Figure 7: Reach our goal after fined trace using step-by-step simulation

5. COMPARISON

This section includes a comparison of FISA with the works of other two groups [9, 1] that work in domain of situation awareness and situation analysis. To our knowledge, still there is no similar works to solve political disputes, but the comparable works are considered the nearest to FISA. The comparison indicates that FISA have the advantages of finding the model deadlock (if exists) and offer one trace or more to solve the dispute.

It should be noted that our comparison will be qualitative. Work in this area is still in its enfant, and to our knowledge, all published results to date are qualitative. The comparison is given in Table .1:

Table 1. Compare FISA to other related work.

	Item	SAW and SA [1]	SA [9]	SAW and SA *FISA*
1	Sources	Uncertain spatial location information about real-world events (PDF files) from two different sources (Police department reports and news paper articles).	Structure reports from non-physical systems (e.g. political, social networks, economics, and information flows). Intertwined with physical systems (e.g. infrastructures, and military systems).	Raw data news (text files and PDF files).
2	Tools/Methods to obtain Concepts	Mapping free text into Spatial Expressions (such as *near*, *behind*, and *infrontof*), Identify of the query requirements of SA applications using Quad-Tree Indexing framework, and algorithms for efficient query processing using U-Grid (Uncertain Grid to index uncertain event data).	Agent-based models, systems dynamics models, Bayesian networks, Linear program models, and discrete-time models.	Extractor to obtain relevant paragraphs, Topic mining to get topics and their probabilities, Sequence mining for obtain events sequences, Bayesian networks to decide the active resources and events and Process analysis to check the possibility to find a solution(s).
3	Deadlock Discovery	Non	Non	Yes
4	Solution Paths	No	No	Yes
5	Tasks	Improving the accuracy and reliability of the information available to the decision makers.	Describes analysis and planning tools.	Solve the political dispute problems.

6. CONCLUSION

This paper has presented a software tool base on a proposed framework FISA that could be used to resolve political disputes. Such a tool succeeded to cross the gap between the looseness of political situations specifications and the tightness of formal logical methods. Accordingly, FISA consists of four main modules for topic retrieval, sequence mining, probabilistic reasoning and process analysis. The last module exploits fairness as a means for dealing with nondeterminism. To authors' knowledge, this is the first such attempt and gives promising results. Hence, the process analysis contains an explicit sub-module for linear temporal logic. Such a sub-module employs fairness to utilize the dispute nondeterminism in order to propose fair solution(s). To prove the concept, a software tool is implemented and an illustrative example is thoroughly explained. The underlying dispute includes two neighboring countries. Each country is struggling to obtain any available resources regardless of the needs of its neighbor. Other large case studies have been successfully performed by involving a third actor approving the power of the system in handling more complex cases. In future it is planned to enhance FISA by making use of various learning techniques that allow the system to achieve sensible solution.

REFERENCES

[1] M., Yiming V., Dmitri and M., Sharad "Toward Managing Uncertain Spatial Information for Situational Awareness Applications", in: IEEE Transaction on Knowledge and Data Engineering Vol. 20, NO. 10, pp. 1408–1423, 2008.

[2] R., Farahbod V., Avram U., Glasser and A., Guitouni "Engineering Situation Analysis Decision Support Systems", in: Intelligence and Security Informatics Conference (EISIC), Greece, 2011.

[3] J., Riley M., Endsley C., Bolstad and H., Cuevas "Collaborative planning and situation awareness in Army command and control", SA Technologies Inc., 3750 Palladian Village Drive, Suite 600, Marietta", GA 30066, USA.10-22;49 (12-13):1139-53, 2006.

[4] H., Cheng N., Zheng U., Zhang J., Qin and H., Wetering "Interactive Road Situation Analysis for Driver Assistance and Safety Warning Systems: Framework and Algorithms", in: IEEE Transactions on Intelligent Transactions Systems, Vol. 8, NO. 1, pp. 157–167, 2007.

[5] X., Wang X., Jin M., Chen K., Zhang and D., Shen "Topic Mining over Asynchronous Text Sequences. Knowledge and Data Engineering", in: IEEE Transactions", Vol. 24, 1 pp. 156 – 169, 2012.

[6] C., Hoare "Communicating Sequential Processes", first published in 1985 by Prentice Hall International, http://www.usingcsp.com/cspbook.pdf, 2004.

[7] Y., Liu J., Sun and J., Dong "Scalable Multi-Core Model Checking Fairness Enhanced Systems", in 11th International Conference on Formal Methods and Software Engineering, ICFEM, Brazil, 2009.

[8] G., Adomavicius and A., Tuzhilin "Toward the Next Generation of Recommender Systems: A Survey of the State-of-the-Art and Possible Extensions", in: IEEE Transaction on Knowledge and Data Engineering, Vol. 17, NO. 6, pp. 734–749, 2005.

[9] E., Waltz "Situation Analysis and Collaborative Planning for Complex Operations", in: 13th ICCRTS C2 for Complex Endeavors, Conference paper, 4301 N, Fairfax Drive, Arlington, VA 22203 703-622-4385, 2008.

[10] R., Farahbod V., Avram U., Glasser and A., Guitouni "A Formal Engineering Approach to High-Level Design of Situation Analysis Decision Support Systems", in: ICFEM'11 Proceedings of the 13th

international conference on Formal methods and software engineering, pp. 211-226, Springer-Verlag Berlin, Heidelberg, 2011.

[11] S., Ghajarloo "Mining Implicit Knowledge to Predict Political Risk by Providing Novel Framework with Using Bayesian Network", in: World Academy of Science, Engineering and Technology, Vol. 74, p656, 2011.

[12] B., Burns and t., Morrison "Temporal Abstraction in Bayesian Networks", University of Massachusetts, Amherst, MA 01003, 2003.

[13] S. Nabil, N.Darwish, and M. Zaki, "Design of A Formal Method Approach to Resolve Disputes", Computer Engineering Department, Cairo University, Cairo, Egypt, 2013.

[14] A.,Fenton PRESSURE.TO, "WEFT QDA" http://www.pressure.to/qda/, 2006.

[15] Nsasoft, http://www.template-parser.com/, 2008.

[16] Norsys Software Corp., http://www.norsys.com/netica.html, 2010.

[17] L.,Yang Process Analysis Toolkit, http://www.comp.nus.edu.sg/~pat/, 2009.