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Guest Editorial

Context-based information fusion

"Context-awareness" might have entered the mainstream language and gained popular attention thanks to the ever increasing adoption of smart portable devices making their way into every activity of our lives. This has happened to the point that the concept of "smart" app (or device) has been paired if not surpassed by the concept of "context-aware" app (or device). The importance of exploiting contextual information (CI) for adaptively react to the surrounding environment is something that has been widely researched in the fields of distributed and mobile computing [1].

In the past few years it has become more and more apparent that fusing data from multiple sources is probably not enough. Even combining a potentially large number of sensory sources could lead to some surprises if the value being estimated, the error characteristics of the sources, and the fusion process itself, are not properly referenced to their current relevant context. For example, the state of the target is very likely to have some form of dependence on the environment surrounding the target, on the relationships and interaction with nearby entities, maybe the time of the day and weather conditions. Think for example of the case of estimating position and speed of a car driving through city traffic. The state of the car is going to be influenced by bends and turns of the road, condition of the asphalt, traffic signs, state of preceding and following vehicles, traffic rules, road works, overall traffic conditions, time of the day, weather conditions, and so on.

As already understood in the mobile computing world since at least fifteen years, context is more than just location [2]. However, a clear definition of it is far from being commonly agreed upon. Mostly because of the diversity of the research fields in which the term "context" is picking up popularity. Very loosely speaking, context-awareness involves considering, representing, and exploiting information and knowledge that does not characterize the focal element(s) of interest but the surrounding environment or current situation.

The understanding and principled exploitation of context in Information Fusion (IF) systems is still rather limited. Domain knowledge has been traditionally acquired ad hoc from experts or static archives and applied to stove-piped solutions that could hardly scale or adapt to new conditions. However, "context", considered as locally relevant (and possibly dynamic) domain knowledge, should play a key role at any level of a modern fusion system to gain adaptability and improved performance.

Following the positive response that special sessions on context-based IF at the International conference on Information Fusion have received in the past few years, this special issue aims at providing an outlook on current research, bringing together papers covering many aspects of the inclusion of contextual elements at different levels of the fusion process.

1. Papers in this issue

The scope of the papers in the present issue is threefold. The first group presents frameworks and architectures to integrate CI in the fusion process. Representation and interchange of contextual elements in decision systems and context-aware applications are discussed. The second group focuses on the processing of the CI in combination with human-generated (soft) data. In particular, they present solutions dealing with information coming from human observers for situation assessment with application to security and counter-insurgency. The third group discusses the fusion of sensory data, high-level knowledge and CI in maritime/harbour surveillance and vehicular applications.

1.1. Frameworks and architectures

1.1.1. "A conceptual definition of a holonic processing framework to support the design of information fusion systems"

Starting from the concepts of *holon* and *informon*, Solaimanet al. develop an IF processing model exploitable to design complex IF systems. In particular, the work aims at defining what could be considered the abstraction of a basic element of information drawing from archetypal dynamics and complex systems theory. A processing cell is then defined with its features, capabilities and functionalities. The framework explicitly considers the role of context as something that can produce effects on the proposed Holon functional model, the latter capturing the relationship between input and output values. To this end, "Internal Context" is intended as intrinsic characteristics and constraints about the input–output relation (e.g. capabilities of a sensor), while "External Context" is intended as all exogenous information that can influence the relation. The application of the proposed framework is discussed with a walk-though example in the remote-sensing domain.

1.1.2. "Architecture for management and fusion of context information"

The paper by Fernandez-de-Alba et al. presents a network architecture where context elements are managed at abstract level by containers and observers, with mechanisms to subscribe and release them, and blackboard interactions to connect the nodes working complementarily on the same context elements. A case study demonstrates that the framework can deal with contextual information for Ambient Intelligence, with an exemplifying scenario in a teaching environment for guiding meetings attendees.

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1.1.3. "Patterns for Context-Based Knowledge Fusion in Decision Support Systems"

The paper by Smirnov et al. describes from a general perspective context-based knowledge fusion processes and proposes a classification related to their use in Decision Support Systems (DSS). Some general patterns are identified, analyzing the effects that knowledge fusion process produce in the system for the preservation of internal structures representing the knowledge and their autonomies. The applicability of the patterns is related to a methodological approach to DSS design in relation to user requirements.

1.2. Context and soft data

1.2.1. "Towards context aware data fusion: Modeling and integration of situationally qualified human observations to manage uncertainty in a hard + soft fusion process"

Jenkins et al. present a framework for aligning the uncertainty of human observations (soft data) for intelligence data analysis. The authors postulate how the error characteristics of human generated data are significantly affected by contextual effects. Notably, the paper develops a classification scheme of human observations as relevant to the counterinsurgency domain and proposes a way to quantify the benefit of the uncertainty alignment process to the fusion tasks of data association and situation assessment. According to the authors, the knowledge of relevant impacting contextual factors and their effects on the accuracy of soft observations allows the representation of uncertainty models that could be used to automate at least part of the intelligence analysis process.

1.2.2. "Providing SIEM Systems with Self-Adaptation"

Suarez-Tangil et al. describe typical problems in the domain of Security Information, addressed with an Event Management paradigm (SIEM) for intrusion detection with self-adaptive systems. Machine learning is applied for rule extraction to classify reported events accordingly to a context-based pattern definition of attacks. The focus is on integrating security events reported from heterogeneous sources, where context assists to the correlation process to identify related events in a complex multi-steps attack scenario.

1.3. Fusion of sensory data and high-level knowledge in maritime/harbour surveillance and vehicular applications

1.3.1. "Fusing uncertain knowledge and evidence for maritime situational awareness via Markov Logic Networks"

Snidaro et al. discuss the problem of fusing uncertain information for maritime situational awareness. Starting from the premise that events and anomalies are key elements in the process of assessing and understanding the observed environment, the paper arguments how building an effective situational picture for a surveillance system in the maritime domain involves combining high-level information with sensory data. In particular, the Markov Logic Networks framework is employed to both encode a priori and contextual knowledge and to fuse evidence from multiple sources, possibly reasoning over incomplete data. Knowledge is expressed by formulas in first-order logic with the possibility of associating to each of them a level of uncertainty encoded by a weight factor. Since sensory data may be not enough to represent and identify complex situations, explicit contextual knowledge is exploited to augment general a priori knowledge establishing relationships and rules between objects of interest and the local surrounding environment.

1.3.2. "Context-based multi-level information fusion for harbour surveillance"

In the paper by Gomez-Romero et al. a proposal to dynamically represent context knowledge with ontologies and evaluate anomalous situations is detailed. It arranges the architecture of the system in two processing levels. The first includes rule-based reasoning to extend tracking data and classify objects according to pre-defined categories, while in the second a belief-argumentation system (BAS) is used to determine the threat level of situations which are non-compliant to the normality model. The system is applied to an exemplar scenario for harbour surveillance.

1.3.3. "A Complex Event Processing Approach to Perceive the Vehicular Context"

Terroso-Saez et al. describe an on-board context-aware application which analyses the usual itineraries of a vehicle. The system follows a Complex Event Processing (CEP) approach to detect the vehicular occupancy of the vehicle along with a set of significant points describing frequent itineraries. It is based on density-based clustering algorithms, dealing with issues like discrimination between irrelevant stops and real ones determining section segments, identification of itinerary repetitions or distinction between passengers and load.

2. Conclusions

The current trend in IF research shows an increasing interest in the inclusion of contextual factors in order to provide effective solutions in complex and dynamic domains. The examples in this issue illustrate how relevant local domain knowledge is an essential aspect to understand situations and integrate a priori knowledge. A number of applications are addressed including situational reasoning, threat detection in surveillance and counter-insurgency scenarios, intrusion detection and ambient intelligence.

We hope this special issue can provide a valuable sample of the added-value that CI can bring to fusion processes. Secondly, we also hope that it may show some key directions for future research efforts in a recent area yet to be explored.

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These final words give us the occasion to congratulate the new Editor in Chief Prof. Francisco Herrera and thank him for assisting us in the final publishing phase.

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