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# COMMON ALERTING PROTOCOL: HOW TO LEVERAGE SEMANTIC REASONING FOR IMPROVING ITS EFFECTIVENESS

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**ABSTRACT :**
This paper attempts to give a holistic view, semantically coherent, of a set of alerts, which are linked to even different hazards affecting the same area and the same temporal window. More in detail a set of both spatial and temporal relations will be defined. These relations will be applied to recognize relative situations in space and time among different hazards. In order to define those semantic relations a high level qualitative abstraction of both spatial and temporal relationships will be used, as they better reflect the natural language framework and by this way its implementation in a rule based engine will be facilitated. Semantic concepts like near and far, "partially overlapping space-time regions", "moving away from" or "moving to" will be defined in a coherent spatio-temporal semantic framework. The above summarized core concepts of the proposed reasoning approach will be discussed, just after the introduction of CAP format, of its main semantic features and the deepening of those more related with space and time concepts. A software tool for spatio temporal reasoning based on Drools, which is the open source rule engine supported by JBoss community, will be then presented. A real world application of the rule engine will be presented. It will be based on a reconstruction of the flood which affected the town of Giampilieri (Sicily) in 2009, and which killed 37 people. In this paper will be discussed how the behaviour of affected people would have been influenced by the availability of a pervasive alerting system based on CAP, through which people would have been warned by the authorities in charge, together with a semantic tool able to return a holistic and meaningful view of the evolving disaster scenario.

**KEYWORDS:**
warning systems interoperability, Common alerting protocol, spatio-temporal reasoning, warning semantic integration

## 1. INTRODUCTION

Early on the morning of 30th of September 2009, the weather expert group of the Italian National Civil Protection Service was writing the weather statement, which is issued daily. In that morning the weather experts were analyzing the potential impact of a low air pressure area centered near Baleari islands and the outlook was for widespread showers and thunderstorms for the next day across the Sicilian region. And even if the expected rainfall-depth (rain cumulative intensity) was less than moderate, because this persistent convective instability could lead to severe local thundershower conditions, and moreover, since timing, location and intensity of such scattered conditions are unpredictable, an adverse weather outlook had been issued.

Today the weather outlook, which is daily issued by the National Civil Protection Service, is delivered to the network of Regional Functional Centres. Each Regional Functional Center holds the task of forecasting the water runoff that could be generated by the expected rainfall in each location of interest of its own region. Sicily is divided up into 9 hydrological sub-regions, and the above mentioned forecasting task is performed daily for each of these 9 sub-regions. It is planned to increase the number of hydrological sub-regions up to 21 (Figure 1). For each of these new 21 sub-regions, its own characteristic flood frequency growth curve is still under calculation (Brigandì et Aronica, 2015).

At that time the Functional Center of Sicilian Region was not working, because it has been declared up and running only the 4th of November 2014, and in its absence its role was covered by the National Civil Protection Service.

In consequence of the adverse weather outlook, and since the antecedent soil moisture conditions were wet enough, because of a rainfall occurred a couple of days before in the south of Italy, with a rainfall depth of about 40-60 mm in the northeast cost of Sicily; the 30th of September at 04:00 PM the National Civil Protection Service issued for the Sicilian Region a warning about hazardous hydrologic events for the next 36 hours. The level of warning was set to "pre-alarm", which is equivalent to the yellow "be-aware" of National Severe

Weather Warning Service in UK and the "Hazard watch" of National Weather Service in USA.

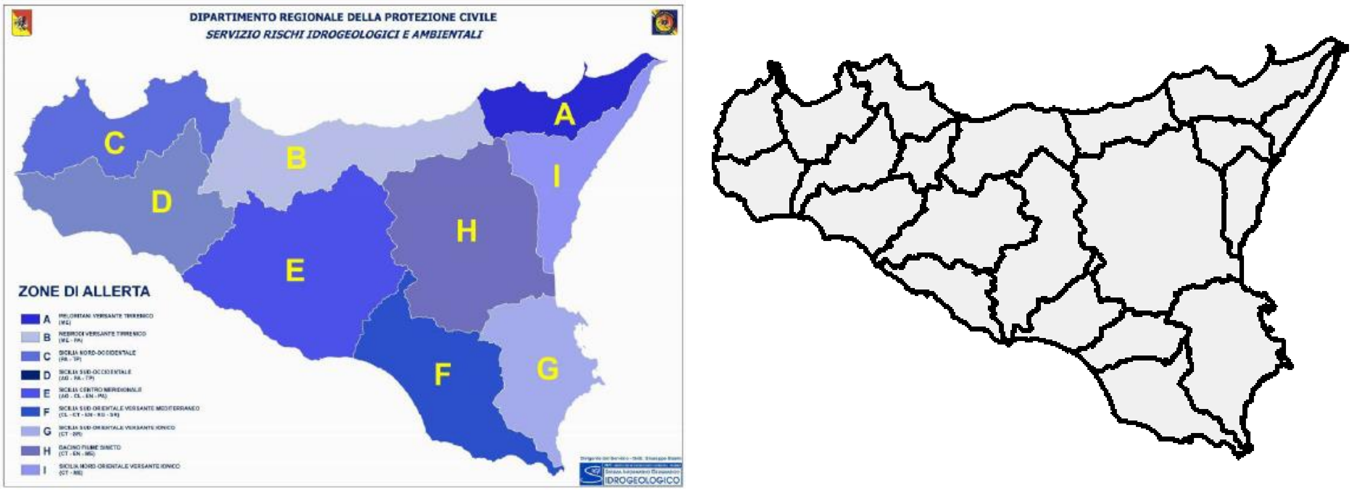


Figure 1 Current Vs. next hydrological sub-regions

According to the Italian standard operating procedures when the "Pre-alarm" warning level is set, all the municipalities and local entities located in the area have to monitor the developing weather situation, and they have to be aware and prepared that the weather could take a turn for the worst. The warning statement, issued by the National Civil Protection Service, had been delivered as usual to all the local authorities of Sicilian Region in charge for the emergency management. This means a list of 390 municipalities, almost one third of them located in the northeast side of Sicily, the Regional Technical Departments, the Department of Sicilian Forest, Fire Brigades, police corps, power and TLC Utilities, roads and railroads authorities and many others. All these both public and private Organizations and Authorities have to cooperate in order to prevent hazards and restore safe conditions for people. The Italian Civil Protection System is structured in compliance with the subsidiarity principle. According to this principle, the closest Authorities to the citizens are in charge for the first response to a Hazardous event, and the closest Authorities are the municipalities. Only in case they are not able to cope with the impact of a disaster, because of its intensity or extension, the regional and national levels of the Civil Protection Organization can be involved.

Going back to the description of the events of 1st of October 2009, the weather in the morning was almost dry over Sicily, but just after the noon in the west side of Sicily it started to rain. The instability front was coming from the Tunisian sea and the strait of Sicily and it was moving from West to Est across Sicily. This front was bringing showers and thunderstorms but it would not be the source of the dramatic events of that evening. In the meantime, as it is shown by the weather satellite image at 01:00 PM a single cell thunderstorm was developing above the Jonic coast of Calabria Region. It was still harmless until 04:30 PM, but just later in the afternoon minute after minute it was getting more and more worse. From 06:00 PM to 08:00 PM the thunderstorm released almost all its energy over a quite concentrated region of about 25 $km^2$ located just South of the Town of Messina. The event was recorded by a single rain-gauge in Santo Stefano di Briga, which is located only a few kilometres away of the affected area. The total recorded rainfall-depth in Santo Stefano di Briga was 225 mm, with a peak intensity of about 53 mm/h (Basile et Panebianco, 2013). Only 2 hours later that the single thunderstorm cell evolved in a "pulse cell", and all its potential dangerousness could be recognized, some early precursors of the disastrous events of that evening took place. At 06:46 PM the news about the motorway A18 closure spread over Internet. A18 is the motorway connecting Messina and Catania, and it had been closed in both directions at 06:30 PM because of a mudslide occurred at the 7th Km from Messina. Since the A18 had been closed, many motorists decided to try to reach their destinations running through secondary roads. However, it was a very bad decision that they took mainly because of a lack of information. In fact at the same time all the road system of the area was collapsing because many stretches of road have been buried by several mudslides.

At that point it would have been clear to anyone who could take a holistic view of what was happening that the situation was very quickly taking a turn for the worst. The soil moisture in the area was so high that anyone who was staying close to a mountain slope was in serious danger. And this was the situation of almost all the inhabitants of the area. And furthermore they were not fully aware for the danger. More than one hour later the motorway closure, in a couple of minutes from 07:40 to 07:50 PM several mudslides surged into some villages located in the area. And than the thunderstorm had been finally over, in fact the instability front coming from west side of Sicily reached the northeast region of Sicily bringing a wind that wiped out the pulse cell. It took several weeks for restoring safe conditions. In the village of Giampilieri (Figure 2), the closest one to the Town of Messina, 21 fatalities and 928 displaced people have been recorded, in the village of Scaletta Zanclea 16 fatalities and 447 displaced people and in the village of Itala 227 displaced people.

Figure 2 Giampilieri, the day after (picture G. Basile)

**2. COLLABORATION AND INTEROPERABILITY BETWEEN CONTROL ROOMS**

As it has been pointed out in the previous paragraph, emergency management may involve several different organizations as they are at least: the municipalities involved, fire brigates, road and rail different authorities, both the national and the regional civil protection organizations. During an emergency, each of these organizations cover a specific role by providing its own knowledge and resources in order to cope with that situation. Furthermore, as it has been highlighted above for the case of the A18 motorway closure, even more the news about the evolving situation reach the people by spreading through internet. In such a context, the exchange of syntactically and semantically well-formed messages between the different control rooms involved, news media and people is a key issue. The receiving of an easily, clearly and sharply understandable message is the basic requirement for being trusted by people. Furthermore, it should be machine-understandable, in order to be automatically readable by software applications, and not exclusively human-understandable as they are in example messages forwarded in a native pdf format. Messages delivered in an open and machine understandable format, first to all can be easily elaborated by computer applications and then, easily and automatically, translated in any preferred format, including video and audio format, for being human- understandable. One of the most promising warning protocol worldwide is the Common Alerting Protocol (CAP). It is a simple and

general XML format for the broadcasting of all kind of hazards emergency alerts over all kind of media. CAP allows public warnings to be disseminated easily and simultaneously over different warning networks and media. The CAP message format can be converted to and from the native formats of all kinds of alerting technologies, forming a basis for a technology independent national and international warning message. CAP provides an open, non proprietary digital message format for all types of alerts and notifications. It does not address any particular application or transmission method. It offers enhanced capabilities, such as flexible geographic targeting using latitude longitude pairs and other geospatial representations in three dimensions, multilingual and multi audience messaging, enhanced message update and cancellation features, template support, facility for digital images and audio.
CAP has been designed within the activities supported by the Organization for the Advancement of Structured Information Standards (OASIS, 2010). It is adopted and supported worldwide by several both public and private organizations, as they are in example: the World Meteorological Organization (WMO), United States Department of Homeland Security, the International Telecommunication Union and Google. In Italy CAP has been adopted by the National Fire Brigades (Marsella et Marzoli, 2014).
A key feature of CAP is that its data structure is easily extendible, preserving in any case both forward and backward-compatibility. This means that each device, designed for reading CAP messages, is able to receive and read also messages produced according to older release of CAP format and each device will be furthermore able to read messages generated according to future CAP formats, perhaps without supporting all new features. This capability pushed several organizations in developing their own CAP dialects, which remain totally compliant each other for the common part of the message. Canada has adopted for its own National Public Alerting System a specific CAP version for taking in count specific requirements like bilingualism and local geocoding system. The same has been done in Australia, Sri Lanka and by the Italian Fire Brigades as well. Other and more challenging CAP extensions has been proposed for enhancing the effectiveness of alerting systems, by adding for example the capability of delivering personalized, culturally sensitive messages as it has been deepen in OPTIALERT, which was a FP7 research project supported by European Commission (Klafft et al., 2014).
CAP wide adoption allows standardized alerts to be disseminated from many sources and to be received from many devices. Each CAP reader can be configured to read the alert of interest, for example according to the geolocation of the device itself. But this alert service as well as the other already existing software applications allows the alerts retrieval and filtering, but considering ever the alerts one by one and, and above all, each of them is considered logically uncoupled from the other ones.

## 3. SPATIO-TEMPORAL REASONING OF WARNING MESSAGES

CAP messages are semantically well-formed XML texts, which carry information about the sender and the time sent, event category, its location, urgency, severity and certainly (forecasted or current event) and the message lifetime (validity period). CAP messages can carry also some other optional information, such as instruction for the recipients and translation in languages other than the main one.
Instead of considering CAP messages one by one, the challenge is to develop a software framework for reading several warning messages, which have been delivered even by different senders at different time, and try to organize and harmonize them in order to give back a holistic view of the evolving scenario. In order to perform this task in this paper a qualitative reasoning approach will be followed. Binary, both spatial and temporal, qualitative relations between two events have been defined. Hazardous events reported through CAP messages, it is supposed they are located in a bidimensional space, and they do have a certain position and extension. These spatial properties describe the event's situation at a particular point of the timeline. These properties can change over the time by translation and scaling. With respect of each spatial property, some spatial static binary relations can be defined. More in detail with respect the position two events can be located near or far away, a medium-dist qualifier of the distance binary relation is usually added (Holzmann, 2007). These qualitative distance qualifiers (near, medium-dist and far) should be then defined in a metric way, according to the characteristic scale of the hazard of interest (eg: 1 km, 10 km, 100 km). Furthermore, some other dynamic spatial relations can be defined. They represent how each spatial static binary relation can change over the time. Again, with respect the distance between two events it can increase or decrease over the time.
Some other temporal relations between events can be also defined (Allen, 1983). The message lifetime validity, as it is defined in the CAP message, is used to represent the expected event's duration, by this way each event can be represented by a **s**tart-**e**nd time interval [**s**,**e**], and some qualitative temporal relations between two

intervals can be easily distinguished at a time, like for example before/after, equals and during. Leveraging the above summarized set of binary spatio-temporal relations, CAP messages of interest can be mined. Main components of the reasoning system are the repository of the CAP messages that are issued by the different organizations (eg: municipalities, civil protection organizations, road and rail authorities), this repository shall be updated in real time, a second repository containing the set of rules that have been defined, and a reasoning engine (Figure 3).

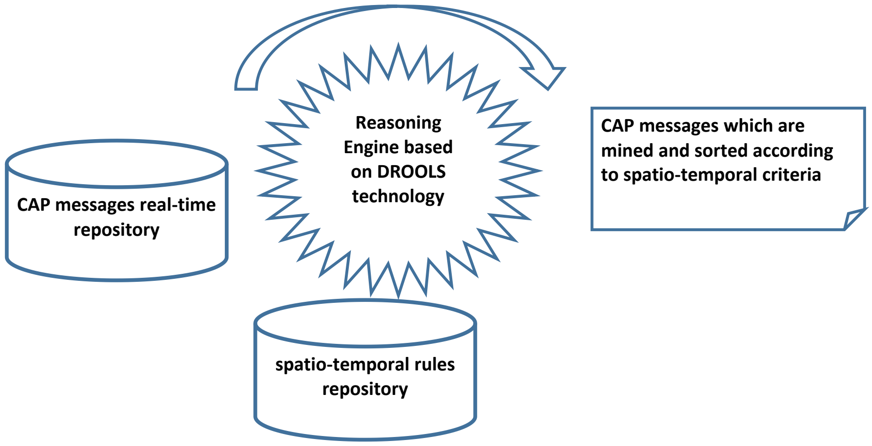


Figure 3 Rule based reasoning

The reasoning engine is based on Drools 6.0 technology (Jboss.org, 2015). Drools is the open source rule engine supported by JBoss community. Drools implement a forward and backward chaining inference engine using an enhanced implementation of the Rete algorithm, which is one of the most used pattern matching algorithm for implementing production rule systems. It is used to determine which of the system's rules should fire based on its data store. Drools include also the Fusion component for the native implementation of temporal reasoning. More in detail Drools Fusion component performs event processing, where an event is defined as “a record of a significant change of state in the application domain at a given point in time”. Drools Fusion allows detection, correlation, aggregation and composition of events, allowing the creation of rules on aggregations of values over a period of time (sliding windows) and supporting temporal constraints in order to model the temporal relationships between events, relations which are previously introduced.

## 4. RETROSPECTIVE ANALYSIS OF THE EVENT OF 1st OCTOBER 2009

The dramatic development of the events of 1st October have been already described above. But the following satellite images taken by EumetSat give a further point of view about what happened that evening. (Figure 4):

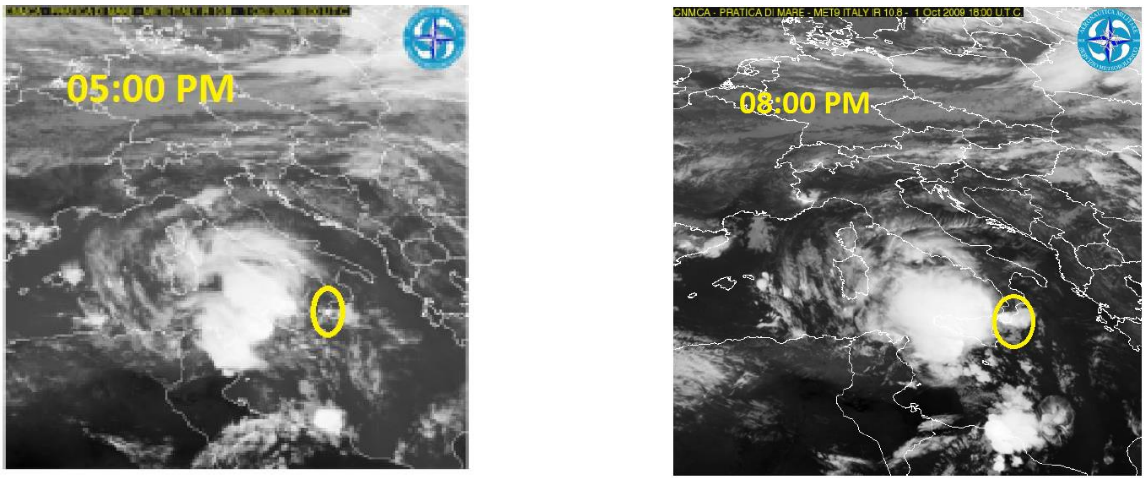


Figure 4 Satellite images at 5:00 PM and at 8:00 PM

The satellite images show that at 5:00 PM almost all the sky above Sicily was clear and that it was an instability front that was moving from the west cost of Sicily to east and it was the source of the approaching moderate shower, which had been forecasted the day before by the National Civil Protection Service. But there was also a small single thunderstorm cell that was located above the Strait of Messina. The development of this small cell should have been monitored in near real time, because this narrow sea passage is characterized by a high-density maritime traffic. We suppose in this paper that it was monitored, and we suppose also that updated news about the thunderstorm development had been provided through a sequence of warning messages issued in the CAP format. We suppose also that as soon as the thunderstorm affected the motorway at 6:30 PM even the road Authority issued a CAP message, and so on with all the list of municipalities and Authorities as soon as they reported damages to civil infrastructures.

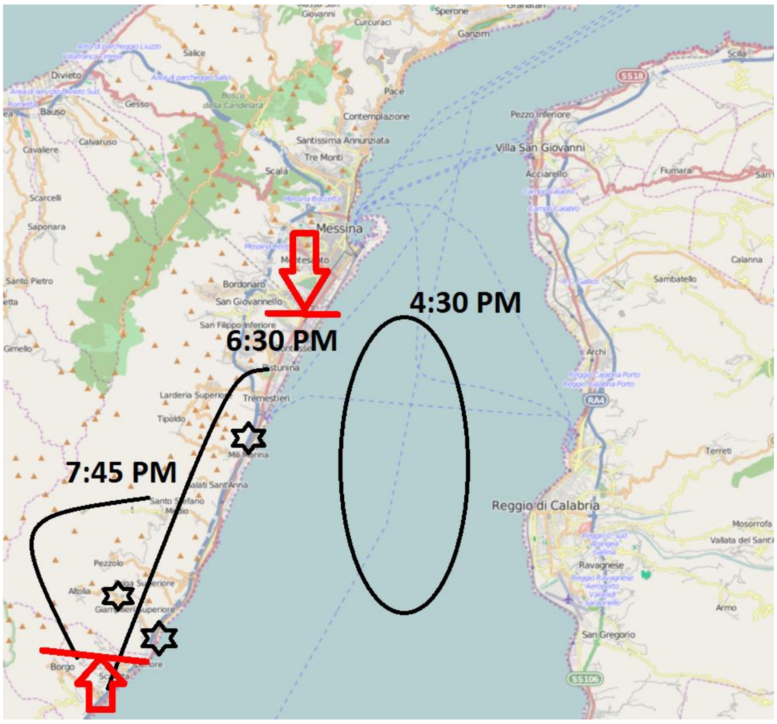


Figure 5 picture representing the events development

The supposed availability through internet of machine-readable messages reporting events as soon as they are happening, open new frontiers in emergency management. We can imagine a world where experts, first responders, affected people as well as sensors (eg: rain-gauges) are able to trigger a machine readable warning as soon as they record a danger. The challenge is about how to effectively leverage this potential scattered mess of information for staying as far as possible away from dangerous situations. The reasoner we are developing is able to give some of the expected answers. It is able first to all to analyze the facts of interest and them alone. The main criterion used for filtering the facts of interest is the current location of people that are querying the set of CAP messages, and the destination they are moving toward. The second criterion is the size of the temporal sliding windows used for selecting the facts of interest. It is an adaptive sliding windows, which adapts its size according to the certainty and the distance from the danger. The closer people are to the danger and the more it is its certainty, the more the warning messages will pop up around them. Consequently, the sliding window will reduce accordingly its size, reducing at the same time the number of rules to be fired, and by this way the warning reasoner will maintain its capability to give answers in near real time. Analyzing facts of interest means looking for patterns that are relevant to what you are happening around you. Questions to be answered are: the dangerous event that has been forecasted for today, is it going to happen now? Somewhere around me is it already happening? And is it exactly the kind of danger that has been forecasted or is it something different and maybe something worse? Am I moving toward an area where the hazard is hitting with more severity or toward a more safer one? And furthermore, can I get instructions, if they have been issued and if they match with my personal profile (parent with small children, commuter, elderly person, people with special needs …). Any of the questions, just mentioned above, can be easily answered, by analyzing the issued CAP messages, because they are structured in a very meaningful way. But there are still many other open questions, and one of them that we are still deepening today is about the question of people's trust in warning messages. More in detail the problem is to find a set of rules able to filter only the more meaningful warning messages in which we can absolutely trust. A trivial solution could be to picking up only the message issued by authorities in which we can trust, but the way we are following is to mine the larger set of messages which are coherent each other. In the latter way even a message issued by an organization in which we can't trust if we look at this alone, could be useful to strengthen the certainty and the meaningfulness of a group of messages if it is coherent with the other ones.

## 4. CONCLUSION AND ACKNOWLEDGEMENTS

The purpose of the current study was to introduce a rule based reasoner, based on Drools technology, for automatically mining warning messages of interest from an XML real time repository of messages compliant with the Common Alerting Protocol format. In this paper it is showed its potential usefulness if applied in the management of severe and scattered weather crisis. This study has been developed within the framework of CLARA project, and supported by Italian Ministry of Education, Research (MIUR) in the framework of the Smart Cities, Communities and Social Innovation program. CLARA is a three years Italian project, which started in September 2014. It is a cooperative research project involving 20 both public and private Research centers, Universities and companies. CLARA aims to acquire a better knowledge of the territory regarding the issue of natural hazards affecting towns, by developing widespread smart technologies, which could facilitate managing, and sharing complex information. CLARA fully adopted the paradigm of open government and open data. CLARA aims furthermore to deepen the themes of trust and risk perception, with special reference to hydrogeological instability, following three integrated perspectives: modeling approach, simulative approach, participative approach. It is also planned to perform an extended time field test in Sicily, with the active involvement of the Regional Department of Civil Protection, for the assessment of CLARA's achievements.

## REFERENCES

Brigandì et Aronica, (2015). A flash flood early warning system based on rainfall thresholds and daily soil moisture indexes. *EGU General Assembly 2015*, **Volume n. 17**, EGU2015-11878, 2015

Basile et Panebianco, (2013). Experimental Alert Model for Hydrogeological Risk: A Case Study in Sicily. *Landslide Science and Practice*, *Springer*, **Volume 2, Early Warning, Instrumentation and Monitoring,** 603-610.

OASIS, (2010). Common Alerting Protocol Version 1.2, OASIS Standard. Copyright © OASIS® 2010.

Marsella et Marzoli, (2014). CAP & European Emergency Response Capacity. *CAP Implementation Workshop*, Negombo, 16 June 2014.

Klafft et al., (2014). Current issues in crisis communication and alerting. Edited by Michael Klafft, Fraunhofer Verlag 2014.

Holzmann, (2007). Rule-based Reasoning about Qualitative Spatiotemporal Relations. *Proceedings of the 5th International Workshop on Middleware for Pervasive and Ad-Hoc Computing (MPAC 2007)*, ACM Press, Newport Beach, CA, USA, pp. 49-54, ISBN: 978-1-59593-930-2/07/11, November 2007.

Allen, (1983). Maintaining knowledge about temporal intervals. *Communications of the ACM*, 26(11): 832-843, 1983.