Editorial: Cloud and semantic approaches and techniques for information and services management

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Many companies and institutions are transitioning their IT to the cloud nowadays, introducing several innovations in their service management and delivery models, with a high level abstract view about computer infrastructures and architectures. Advances in semantic field presage even a bigger transformation in this field, more focused on the information itself than on the systems supporting information. The added value provided by the application of semantic technologies to the cloud are expected to offer a unified landscape for all types of heterogeneous information historically produced, managed and consumed by different systems. However, at the state-of-the-art semantic cloud means different ways to leverage the mutual benefits arising from the combination of cloud computing and semantic web. For example, Eberhart et al. (2011) identified "better clouds through semantic technologies, semantic technologies offered as cloud services, cloud computing for semantic technologies".

Semantic technologies bring a set of tools and mechanisms to describe the information of the cloud and the data describing the state of each resource they offer in a formal way. Semantic models such as ontologies can formalise more details than other traditional modelling techniques. They also enable reasoning, a way to make inferences and gain new knowledge. Such rich models can improve traditional functions.

Applicability of semantic models can address different aspects of cloud services including data, functional, non-functional, and system (Sheth and Ranabahu, 2010). Some examples for modelling not functional requirements at deployment time are the elastic computing modelling language (ECML), elastic deployment modelling language (EDML), and elastic management modelling language (EMML), all based on OWL and published by Elastra 1.

An ontology representation of services assists to discover various services easily. In fact, ontologies can encapsulate the necessary and relevant terms and relationships of each provider. Moreover, they can capture the dependency of services across the layers. In cloud service discovery, cloud ontology is developed for semantic matching and retrieval of appropriate services from the available services. Cloud ontology provides a set of concepts within cloud and the relationships between those concepts. Hoefer and Karagiannis (2010) presented tree-structured taxonomy to classify cloud services across IaaS, PaaS, and SaaS layers and their characteristics making it easier to compare them. An ontology-based representation of cloud computing environment (Rodríguez-García et al., 2013) allows conceptualisation of common attributes among

cloud resources and describes relations among them semantically. Yoo et al. (2009) suggested ontology for classifying and representing the configuration information related to cloud-based IaaS services including compute, storage, and network.

Semantics of data and of the actions one takes on the data and the vocabulary in which these actions are expressed appear to constitute the beginning of an inter-cloud computing language. Its integration within the model is a powerful means to define complex equivalences between terms of the model.

A common understanding and a common management model will ensure consistency and interoperability among different cloud providers. These research directions are expected to significantly contribute to the elimination of the vendor lock-in problem and consequently to facilitate application and data portability (Amato et al., 2013; Di Martino and Cretella, 2013).

The research community agrees that cloud providers can interoperate when they share a common set of APIs and a consensus on the terminology/taxonomies that describe them. PaaS semantic interoperability is defined as the ability of heterogeneous cloud PaaS systems and their offerings to overcome the semantic incompatibilities and communicate. PaaS semantic interoperability studies, models and tries to resolve interoperability conflicts raised during the deployment or the migration of an application. Urquhart (2010) and Sambyal et al. (2010) introduce a model with two main interface points that PaaS systems need to standardise: the management and the delivery. In the same line, Llorente OpenGridForum (2010) identifies two interoperability levels: management and service interoperability.

A number of efforts by the research community have been spent to define a formal representation of cloud resources, services and in general cloud concepts in OWL producing so called *cloud ontologies*. Particularly in Youseff et al. (2009), an ontology which is focused on the technologies involved in the cloud phenomenon is proposed. It describes the different layers of cloud computing, the relationships between them and the users of each cloud layer while in Moscato et al. (2011) proposed an ontology, built upon existing standards, developed to improve interoperability among existing cloud solutions, platforms and services, both from end-user and developer side. Di Martino et al. (2014a) described a unified OWL ontology of cloud resources at PaaS and SaaS level which focuses on the classification and categorisation, based on a functional analysis, of cloud services and virtual appliances. In Di Martino et al. (2014b, 2014c), the description of functional and non-functional characteristics of some specific cloud services is proposed, alongside with information related to exchanged parameters, and collaboration between services.

While cloud patterns can be extremely useful to model cloud solutions and applications and, therefore, can convey meaningful information to support software porting to the cloud and services' inter-operation, they can be hampered by the lack of a shared machine readable formalism for their representation. Works aiming at defining a semantic-based formalism for the accurate description of both static and behavioural aspects of cloud patterns can be found in Di Martino et al. (2014c) and Di Martino and Esposito (2013). Here, cloud patterns' components are described using an OWL ontology, while the orchestration among such components is obtained through OWL-S.

Semantic technologies are also currently provided as cloud services to final users at SaaS level. For example, law-as-a-service (LaaS) (Hu et al., 2012) enhances self-managed SaaS on the automated security and privacy policy in the multi-tenant virtual data centres that provides law-aware semantic policies enforcement in the cloud (Cabuk et al., 2010). It allows for enforcing security and privacy policies without human intervention. In this case, semantic is used for interoperability between different legal domains. The legal knowledge interchange format (LKIF) is a semantic web-based language for representing legal knowledge to support modelling of legal domains (Boer, 2009).

Other kinds of semantic technologies are provided as services for semantic discovery over encrypted cloud data to preserve privacy (Li et al., 2014), or to support the users while processing collected information and resolving uncertainties.

Finally, semantic approaches are proven to be very successful in improving search processes in many other fields; however, the availability of computational resources as any other utility results more and more relevant to the specific requirements which can be affected by data dimension and velocity, needs of interactivity of real-time requirements at the time it is required. For these reasons, cloud computing leverages the development of semantic technologies.

This led to the modelling of a search engine for discovering services on the cloud (Kang and Sim, 2011). Intelligence should be embedded to search systems to administer effective search, retrieval, filtering and presenting relevant information. This can be done by information retrieval techniques based on ontology. Natural language processing (NLP) tools can help in automating the translation of the existent cloud-related natural language descriptions into semantically equivalent ones.

mOSAIC (Petcu et al., 2013; Cretella and Di Martino, 2015) aimed to develop an open-source platform that enables application developers to select cloud services according to their application needs. Using the *cloud ontology*, the *semantic engine* and the *semantic service discovery*, the vendor-agnostic API and various tools, the application developers are able to specify their service requirements and communicate them to the platform. The selection process is based on the multi-agent brokering performed by the cloud agency that search for services matching the applications' request. By using mOSAIC approach and software cloud-application, developers and maintainers are able to postpone their decision on the procurement of cloud services from design time until run-

time, while end-user applications are able to find best-fitting cloud services to their actual needs and efficiently outsource computations and storage.

Targeting the application developer, an entire set of tools was built for an easy design of the cloud applications. In particular, the semantic engine (Cretella et al., 2012; Di Martino and Cretella, 2012) and dynamic semantic discovery service (Cretella and Di Martino, 2013) support the user in discovering the resources and services offered by mOSAIC and various cloud providers, based on application and cloud patterns, and perform their semiautomatic integration in the mOSAIC API. A machine readable (OWL) cloud ontology (Moscato, 2012; Moscato et al., 2011) been defined at these purposes, which is being included in the IEEE Intercloud Standard. The selection of the cloud service to be consumed is semi-automated in mOSAIC by a unique cloud agency (Venticinque et al., 2011; Petcu et al., 2010), a multi-agent system capable to broker and negotiate the resources and to establish the service level-agreements with the selected cloud(s) according to the needs of the applications, and to monitor and possibly dynamically reconfigure the resources provided; six cloud commercial cloud providers and six open-source and deployable infrastructure(-as-a-)services are currently connected.

Sensing and actuation resources will be involved in the cloud and solutions for the convergence and evolution of IoT and cloud computing infrastructures exist. Nevertheless, there are still some challenges to face such as: the interoperability among different ICT systems; a huge amount of data to be processed provided in real-time by the IoT devices deployed in the smart systems; the significant fragmentation deriving from the multiple IoT architectures and associated middle-ware, heterogeneous resources mash-up, namely how to orchestrate resources of the various clouds.

Concerning the last item, the concept of IoT, with underlying physical objects abstracted according to thing-like semantics, seems a valid starting point for the orchestration of the various resources. In this context, the to thing-like semantics, seems a valid starting point for the orchestration of the various resources as discussed in Amato et al. (2014a, 2014b). In this context, the cloud concept could play the role to connect the IoT with the internet of people through the internet of services, by the means of a horizontal integration of various silos. We will refer to this horizontal integration and to the cloud computing associated to the IoT as the cloud of things (CoT). This concept goes towards a smart city based on CoT (Petrolo et al., 2014).

In 'A semantic driven approach for requirements consistency verification' Francesco Gargiulo, Gabiella Gigante and Massimo Ficco propose the utilisation of semantic techniques and ontologies for improving consistency and completeness in software development. The software engineering community has largely investigate how to guarantee these quality attributes, to produce good software products and to reduce costs. Different approaches have been defined to detect and manage inconsistencies in software life cycle. The adoption of ontologies seems promising to achieve the proper level of formalism and to argue on quality properties. This paper presents a survey of the main approaches to consistency in different tasks of software engineering, focusing on the requirement engineering tasks, and proposes an ontological engineering approach to detect inconsistencies among a set of requirements written in natural language.

'Real-time event management in cloud environments' by Konstantinos Kostantos, Dimosthenis Kyriazis and Marinos Themistocleous, falls in the area of quality of service monitoring in cloud computing environments. Any applications, especially the ones implementing multimedia streaming, fall within the context of real-time systems in which only small deviations from timing constraints are allowed. The advancements in distributed computing have made it possible to follow a service-oriented approach, taking advantage of the benefits this provides. As more applications are deployed on cloud environments, one of the main requirements refers to real-time event management during the application execution. In this paper, an adaptable two layer monitoring mechanism which generates appropriate events and an event processing framework to consume these events are presented. The effectiveness of these mechanisms is evaluated through a set of experiments on a large-scale multi-cloud facility. The latter poses challenges with respect to time-constrained execution of applications, since the aforementioned mechanisms need to collect and analyse information from geographically distributed sites, and trigger scaling decisions during the real-time application execution.

In 'VMInformant: an instrumented virtual machine to support trustworthy cloud computing', Taimur Al-Said, Omer Rana and Peter Burnap claim that having a sufficient level of transparency is essential to improve trust between a cloud consumer and provider, especially in the context of a public cloud system. In this paper, authors discuss how trustiness, which generally is assumed to exist between the consumer and the provider, is a key in the cloud context. In fact, relying on that assumption can be limiting. They argue that the VM owner must have greater access to operations that are being carried out on their VM by the provider and greater visibility on how this VM and its data are stored and processed in the cloud. A VM monitoring system, which can keep the user informed and alerted about various events that have taken place on their VM is proposed. A taxonomy of VM security-related events is presented, along with performance overheads associated with monitoring such events using CPU and I/O intensive benchmarks.

'Towards the future internet: the RESERVOIR, VISION Cloud, and CloudWave experiences', by Francesco Longo, Dario Bruneo, Massimo Villari, Antonio Puliafito, Eliot Salant and Yaron Wolfsthal, concerns how the effort by research projects which are contributing to the evolution of future internet is evolving as an internet of services, things and infrastructure. It is required to be fast, flexible and ever-responsive to demands from both humans and machines for access to content, apps and services relevant to

the context and location of the user. RESERVOIR, VISION Cloud and CloudWave are three interesting examples of how infrastructures and data can be managed in an effective way and how applications can adapt to the infrastructure, and the infrastructure to the services requested, in order to improve the overall quality of the service provided. The contribution describes how these three successful projects try to address the challenges described above, providing an important boost to making the future internet vision concrete. Authors' view of the future internet, where sensors, actuators and objects (both static and mobile) in general will be managed according to cloud-based principles, is discussed.

The main research topic of 'Design and implementation of a cloud computing platform for electromagnetic modelling', by Giuseppe Caragnano, Lorenzo Mossucca, Matteo Alessandro Francavilla, Pietro Ruiu and Olivier Terzo, is the development of accurate and efficient EM models, together with an appropriate use of computational resources in cloud. There is a strong industrial interest in it. In fact, cloud computing has recently attracted attention in numerical simulation fields as its appeal is mainly due to the possibility of providing high computational resources at low cost. Computational electromagnetics (CEM), aimed at numerically predicting the electromagnetic behaviour of arbitrary objects (e.g., aircrafts, satellites, ships, antennas, etc.), often requires computational resources unavailable on single workstations. This is where cloud computing comes into play, as a potential low cost solution for the EM analysis. In this work, the authors present the results of the cloud infrastructure for CEM problems developed within the project 'Cloud fast scalable EM modelling – CloudCEM'.

'Exploiting model profiles in requirements verification of cloud systems', by Francesco Moscato, focuses on composition, analysis and validation of cloud services. In fact, even if at the moment service centric models and technologies are mature in the IT scenario, these still are open research challenges. In this work, modelling profile that enables model driven engineering (MDE) analysis of systems and requirements verification of cloud-based services is proposed. The verification process exploits formal methods during the whole life cycle of services. An example of application of the proposed methodology is presented.

'How the cognitive features testing can assist in evaluating collective ontology engineering', by Irina Leshcheva and Tatiana Gavrilova, is devoted to the interplay issues between ontology engineering and cognitive psychology. It describes the study targeted at new visual structuring paradigm of ontology development. The research was performed within the KOMET (knowledge and content structuring via methods of collaborative ontology design) project. The research contribution is devoted to study of correlations between the expert's personal cognitive style features and the peculiarities of expert's subject domain ontology development procedure. Moreover, it deals with a research of relationship between the expert's individual cognitive style and the collective ontology design.

'MIDAS: a cloud platform for SOA testing as a service' by Alberto De Francesco, Claudia Di Napoli, Maurizio Giordano, Giuseppe Ottaviano, Raffaele Perego and Nicola Tonellotto deals with software quality in service-oriented architecture (SOA) approach. In this context, they present research activities of the European FP7 Project MIDAS for building an integrated platform for SOA testing automation, itself designed and architected according to the SOA computing paradigm. The paper discusses the cloud-based software architecture envisioned for the MIDAS platform, by detailing the strategies adopted for both its development, and its deployment on the target cloud infrastructure (Amazon AWS). Also, the strategy adopted to provide the MIDAS platform with an elasticity management service is outlined.

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