FRIENDLY & KIND with your Health: Human-Friendly Knowledge-INtensive Dynamic Systems for the e-Health Domain

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Abstract. This paper presents our approach for addressing "Human-friendly Knowledge-INtensive Dynamic Systems" (FRIENDLY & KIND systems) from a methodological point of view, also providing tools and languages for their design, implementation and testing. FRIENDLY & KIND systems are an evolution of multiagent systems and represent a good option for engineering complex and dynamic applications like those in the e-Health domain. We will demonstrate the suitability of our approach by designing and implementing a Remote Monitoring System for oncological patients.

Keywords: Multiagent systems · Multi-context systems · Runtime verification · Computational logic · e-Health

1 Introduction and Motivation

As stated in the guidelines provided by the European Community[1], e-Health

1. *refers to tools and services using information and communication technologies (ICTs) that can improve prevention, diagnosis, treatment, monitoring and management;*
2. *can benefit the entire community by improving access to care and quality of care and by making the health sector more efficient;*
3. *includes information and data sharing between patients and health service providers, hospitals, health professionals and health information networks; electronic health records; telemedicine services; portable patient-monitoring devices, operating room scheduling software, robotized surgery and blue-sky research on the virtual physiological human.*

[1] http://ec.europa.eu/health/ehealth/policy/index_en.htm.

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The American Telemedicine Association (ATA[2]) defines telemedicine as

the use of medical information exchanged from one site to another via electronic communications to improve a patient's clinical health status.

Telemedicine may exploit two-way video, email, smart phones, wireless tools and possibly many other sensor devices. Telemedicine services may include primary care and specialist online consultation (a specialist may interact either with a patient or the primary care physician in rendering a diagnosis, via data detected by dedicated devices) and Remote Patient Monitoring[3] (RPM),

a technology to enable monitoring of patients outside of conventional clinical settings (e.g. in the home), which may increase access to care and decrease healthcare delivery costs.

The features of an autonomous software agent, namely its situatedness, autonomy and flexibility [1], make the agent metaphor extremely suitable to describe, design, and implement RPM systems made up of Personalized Monitoring Agents (PMAs) in charge for the monitored patients. Each PMA should in fact be able to receive input from the sensors that the patient wears and from any device in the environment that may provide useful information (situatedness); it should quickly react to any change in the monitored environment that might be due to some critical situation (reactivity); it should achieve its long term goal of ensuring the patient's well being without distracting precious resources from the healthcare system: to this aim, it should monitor the patient suggesting suitable actions in non-critical situations and warning the doctor only when actually needed (proactivity and autonomy). Finally, the PMA should communicate with both the patient and the doctor, and possibly with other agents in the environment (social ability).

However, there are other features that must be taken into account for developing models, methodologies, and software infrastructures for RPM applications, and which are not considered "core" agent features by the agent-oriented software engineering research community:

User friendliness: the PMA should offer a user-friendly interface to the patient in order to make her feel comfortable with interacting with it.

Knowledge-intensity: a large amount of heterogeneous information and data must be retrieved, shared and integrated in order to reason on the patient's health status.

System dynamics: the high dynamics of the system, due to sensors and devices which may enter and exit it in any moment and to data sources which can change their reliability level over time, must be taken into account.

Runtime monitoring ability: the RPM system should continuously verify that the pattern followed by perceived sensory data is compliant with the expected medical protocol: in order to do so, it should implement a run-time verification mechanism.

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[2] http://www.americantelemed.org/.

[3] https://en.wikipedia.org/wiki/Remote_patient_monitoring.

In this paper we propose an extension of MASs named FRIENDLY & KIND systems (Human-friendly Knowledge-INtensive Dynamic Systems).

FRIENDLY & KIND systems, F&Ks in the sequel, provide flexible access to dynamic, heterogeneous, and distributed sources of knowledge in a highly dynamic computational environment consisting of computational entities, devices, sensors, and services available in the physical environment, in the Internet, and in the cloud.

F&Ks are driven by terminological, bridge, and pattern rules. Terminological rules ensure interoperability among the F&K components by defining a common domain vocabulary. Bridge rules connect knowledge sources together and provide devices for selection, abstraction and conflict resolution among the underlying knowledge sources. Pattern rules can be verified at run-time to guarantee that the system actual dynamics conforms to the expected one. The high dynamism of the F&K computational environment requires models of trust, relevance, and preferences, and of their dynamics. Finally, an F&K must present a human-friendly interface.

The paper is organized as follows: Sect. 2 provides the necessary background to understand our proposal and discusses related works, Sect. 3 describes the proposal objectives and expected results in detail, Sect. 4 concludes and highlights the next steps we will undertake.

2 Background and Related Work

2.1 Background

From a technological point of view, F&Ks user-friendliness is achieved thanks to multilingual interfaces supporting natural language processing, knowledge heterogeneity is managed via the multi-context approach, and ontologies are used to allow for semantic interoperability among knowledge sources, users, and computational entities in the environment. On-the-fly composition of software services is a key requirement for F&Ks functioning as well as runtime verification techniques to monitor that the system behaves as expected. Models of trust and their dynamics must also be considered, as data sources can change their reliability over time. In our approach, computational logic is the basis for expressing terminological, bridge, and pattern rules which drive the F&K engineering and functioning.

Ontology-driven and multilingual text classification. Text classification is the task of assigning a document to one or more classes or categories. The most widespread approaches to text classification are based on machine learning, but alternative approaches based on domain ontologies, that do not require any training set, are also emerging. If the ontology is not hard-wired into the text classifier, it can work on many different domains just by changing the ontology. Also, if the ontology words can be translated on-the-fly into the text language by exploiting suitable resources like BabelNet[4], classification can work independently of the ontology and text languages. A working tool implementing this approach is described in [2] and is the basis for the F&Ks user-friendly interface.

Multi-context systems. In the Artificial Intelligence and Knowledge Representation fields, the Multi-Context Systems (MCS) approach [3–5] has been proposed to model information exchange among heterogeneous sources (contexts), which interact via bridge rules. The added value of the approach is to drop the assumption of making such sources homogeneous: rather, MCSs explicitly deal with different representation languages and semantics. MCSs are successful also in practical applications [6] as they aim at modeling real situations, where a number of sources distributed on the web can contribute to the solution of complex problems. MCSs have been extended to encompass multiagent systems equipped with ontologies and advanced communication capabilities in [7,8].

Runtime verification and self-adaptivenness of multiagent systems. Runtime verification of complex and distributed systems has been recently tackled by exploiting a powerful formalism named "trace expressions" [9] and an interpreter based on computational logic. This approach easily supports self-adaptivennes [10] and monitoring of fail-uncontrolled and ambient intelligence systems [11]. Meta-axioms for agents run-time self-checking and self-correction based upon a special interval temporal logic have also been studied (cf. [12] and the references therein).

Models of trust. Several models of trust exist in the literature, some based upon a third party authority, some on the elaboration of direct experiences and some others on game theory. A model of trust which combines the latter two approaches where trust level evolves in agents playing a game, with players of various typologies described by probabilistic strategies, is discussed in [13].

Software engineering for integration systems. The dynamic composition of software and services often requires to solve mismatch on service/component interface and their interaction protocols. In the last decade, the research community has devoted a significant effort to the synthesis of connectors/mediators that enable automatic software composition by solving such mismatches: a recent contribution is [14], tailored for environments characterized by a wide variety of heterogeneous systems that dynamically decide to interoperate to achieve some goal.

2.2 Related Wok

Our proposal follows the principles outlined in previous existing work, including [15,16]. In [15] the foundations for the development of agent-based platforms for the Tele-health domain are analyzed and discussed. Such platforms should

[4] http://babelnet.org/.

include different types of agents: user, reasoning, and sensor, where the agents role is to intelligently gather, understand and use relevant context. In [16] the construction of ontologies to be exploited in such systems is discussed.

A vast body of literature exists, discussing the application of ICT in general [17], and Artificial Intelligence in particular, to the e-Health field. Consider for instance:

- http://www.hhnmag.com/articles/6561-ways-artificial-intelligence-will-transform-health-care published in 2015 and
- http://www.fastcompany.com/3055256/elasticity/paging-dr-robot-the-coming-ai-health-care-boom published in 2016.

The relevance and the huge impact of this synergy is also claimed by IBM Watson that will implement the Health Platform, http://www.ibm.com/smarterplanet/us/en/ibmwatson/health. Differently from the envisioned Watson Health system, our FRIENDLY & KIND systems will be open and dynamic since sensors, devices, and knowledge sources will be able to enter and exit the system at run-time, hence requiring an on-the-fly interoperability among several sources of knowledge and services. The developed systems will be released under open source licenses making all the achieved results public.

We believe that e-Health tools should also provide personalized healthcare. In a set of seminal papers[5] ([18,19] and the references therein) it was argued that "*The development of ubiquitous systems for maintenance and control of treatment systems to assist individuals in managing their medical treatment plan would provide an improved system for home healthcare. Automation of knowledge base development for each individual patient would allow efficient personalization of each patients treatment plan and allow integration of the doctors individual diagnosis and treatment plan.*" In particular, the authors advocate and present agent-based techniques so as to "*allow efficient development of individually tailored medical treatment knowledge bases*".

A related area is that of correctness of knowledge based systems. Given the nature of medical opinions, for which such systems are unlikely to be deemed as "correct", truth maintenance of knowledge within an individual system is an important area, particularly when complete knowledge of a domain is unlikely to be achievable.

3 FRIENDLY & KIND with Your Health

The objectives of our proposal are the analysis, design, implementation and validation of methods and tools for engineering "human-friendly Knowledge-INtensive Dynamic systems" (FRIENDLY & KIND systems, F&K). The application of F&Ks to the e-Health domain is the major practical expected outcome. F&Ks (Fig. 1).

[5] Interrupted unfortunately in 2009 by the death of the main author.

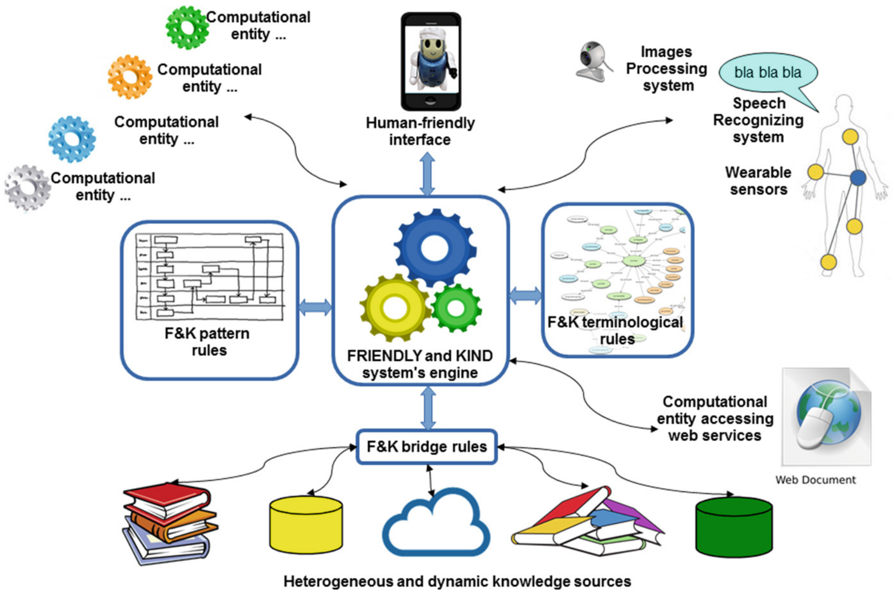

Fig. 1. General architecture of an F&K system.

1. access heterogeneous, distributed and dynamic knowledge sources;
2. integrate heterogeneous, distributed and dynamic computational entities;
3. reason on knowledge stored in sources and on information coming from the computational entities to infer new knowledge;
4. ensure that access to the knowledge sources and interactions among the computational entities follow safe patterns, to guarantee the application security;
5. present a human-friendly interface for accessing the F&K functionalities.

F&Ks operate in complex, open, and dynamic computational environments which include heterogeneous software components, physical devices and sensors including wearable health monitoring devices, intelligent software agents, third part services and data centers available on the Internet. F&Ks are designed and implemented for supporting Fog computing in the perspective of the Internet of Everything. To achieve their goals, F&Ks are driven by:

1. terminological rules to define the vocabulary common to knowledge sources and computational entities;
2. bridge rules to formulate complex queries by bridging the domain knowledge sources together;
3. pattern rules to state which event patterns are safe in the domain.

All these rules are customizable modules characterizing different F&Ks instances. In the e-Health domain, terminological rules will specify the meaning of technical terms related to a specific disease and their semantic relationships, bridge rules will bridge the databases containing patients' medical history and records with legacy knowledge bases and expert systems, and pattern rules will specify correct patterns of events related to the patient's privacy, real-time health conditions, and treatment according to existing medical protocols.

Another relevant F&K aspect is the system high dynamism:

- knowledge sources evolve in time: new knowledge will be discovered and bridge rules must evolve consistently;
- as new knowledge becomes available, the domain model may evolve as well;
- pattern rules might evolve to ensure the software system security and the physical system safety;
- as a consequence, measures of trust, relevance, and preferences can affect the interaction among computational entities and knowledge sources and may evolve in time according to the "performances" of the components participating to the system.

Since the actual instances of F&Ks are used by domain experts and by final users without specific technological background, a human-friendly user interface is provided for interacting with the application exploiting multimodal and multilingual modalities. Results concerning affective computing and theory of emotions in agents are taken into account to make the interface more agreeable to the user and more effective in collecting information and profiling user preferences. To demonstrate the feasibility of our approach, we will adopt a relevant real-world application in the field of e-Health, namely a Personalized Monitoring Agent tailored to oncological patients, as a testbed. The resulting F&K instance, named "e-Health FRIENDLY and KIND" (eHF&K), is presented in Fig. 2.

Competency on the medical domain is ensured by the domain experts[6], who will provide guidelines for the eHF&K features, provide data and knowledge bases for system testing, define and apply system evaluation criteria, and experiment eHF&K on real patients, in full respect of their privacy and comfort.

The objectives of our investigation are:

O1: Developing a software engineering methodology to engineer F&Ks.

O2: Developing models and formalisms for representing terminological, bridge and pattern rules, and for knowledge discovery and preferences/trust management.

O3: Developing software tools for managing and reasoning on terminological, bridge, and pattern rules, taking their dynamic nature into account, and for coping with knowledge discovery and preferences/trust management.

O4: Developing an integrated environment (F&K-IDE) for developing F&Ks.

O5: Implementing the e-Health FRIENDLY and KIND application (eHF&K) as a proof-of-concept of the proposed approach in the e-Health domain.

The results we expect from our research activities are in a one-to-one relationship with its objectives:

R1: The F&K characterization based on its architectural and functional features and the F&K software engineering methodology covering the life-cycle of an F&K.

[6] One of the authors of this paper is an oncological doctor.

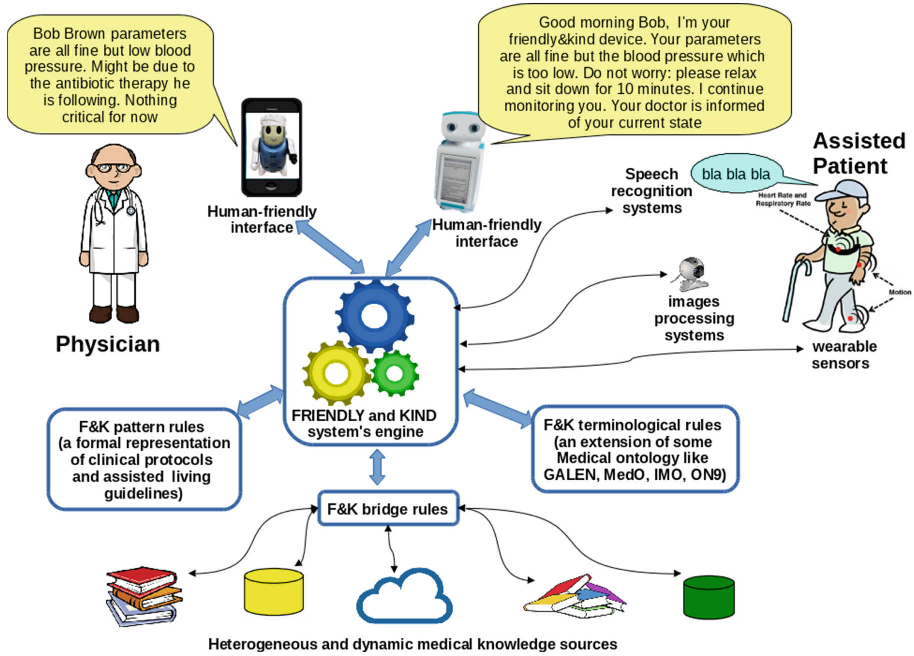

Fig. 2. The e-Health FRIENDLY and KIND system.

R2: Models and formalisms for representing terminological rules, bridge rules, and pattern rules, and for knowledge discovery and preferences/trust management.

R3: Software tools for terminological rules, bridge rules, and pattern rules, including verification of system and interaction properties, and for knowledge discovery and preferences/trust management.

R4: An integrated environment (F&K-IDE) for implementing F&Ks obtained by integrating results R2 and R3 above and coherent with the methodology resulting from R1.

R5: eHF&K, an F&K application in the e-Health domain.

Together with R1, R4 is the most relevant, original, and significant expected result from a scientific viewpoint. In fact results R2 and R3 might turn out to have a limited originality as models, formalisms, and working tools suitable for engineering F&Ks might be already available and others could appear: we might indeed discover that our needs can be satisfied, partly or "in toto", by bricks developed elsewhere. Nevertheless, putting such bricks together in an integrated software system that supports an engineering methodology is far from an easy task, and the originality of the result will be definitely greater than the sum of the bricks originality.

The most relevant practical result is instead R5. Consistently with the H2020 societal challenges, we will apply our approach in the e-Health domain by implementing eHF&K where:

1. Each patient is in charge of a Personal Monitoring Agent (PMA). This agent supervises the patient's welfare and health conditions and the correct administration of therapy according to suitable pattern rules created by the technological partners in collaboration with the domain experts. The PMA must be aware of all illnesses of the patient and manage their comorbidity. It manages the patient's medical history and records, is aware of the therapies and is able to supervise drugs administration according to prescription. The PMA interacts with the patient via an avatar able to communicate in natural language, in the patient's language: the vocabulary shared between the PMA and its user is specified by the eHF&K terminological rules. It is able to filter confusing inputs in order to determine the causes of the patient's distress with more accuracy. It employs Telemedicine techniques to collect data from medical devices the user is equipped with. In case of anomalous symptoms, the PMA exploits bridge rules to access knowledge bases for symptom interpretation, diagnosis and management treatment. The PMA interacts with either the patient or a human specialist or both (e.g., to request specific diagnostic tests), according with the eHF&K pattern rules.
2. Each doctor is provided with a notification system (e.g., a mobile app on smartphone) connected to the PMAs of its patients that send warnings in case the PMA identifies symptoms and side effects which require the doctor intervention.
3. The system provides a directory service so that PMAs are enabled to locate the needed components based upon components roles. The directory is equipped with knowledge discovery capabilities and manages preferences and trust.
4. The directory refers to a set of heterogeneous knowledge bases, expert systems or more generally services, either internal to the system and thus fully reliable, or external, whose reliability is to be evaluated.
5. Via bridge rules, the PMA can obtain pieces of knowledge by querying several sources and by integrating the returned results together. Queries can be positive (to assess that something is the case and/or retrieving/measuring quantities) or negative (to assess that something is not the case).
6. Sources interconnection must follow specific patterns which ensure safe interaction, and correct and complete interaction results. Such patterns rules must be well-defined and verifiable.

4 Conclusions and Future Work

In this paper we have described our proposal for analyzing, modeling, designing and implementing "FRIENDLY & KIND with your Health" systems. Our proposal will advance both the ICT research and the research in the e-Health field.

Impact on ICT. As virtually every application in the Fog Computing and Internet of Everything contexts can be conceptualized following the F&K metaphor, the body of knowledge, methods and tools resulting from our research activities will constitute a substantial advance to the Internet of Everything research field. A distinguishing characteristic of F&K is that of tackling practical applications from a neat formal perspective. This allows the interactions within the system to be clearly specified and verified, which is crucial in many application fields. F&Ks will be self-evolving, able not only to detect any anomalous behavior that should occur, but also to correct it at run-time so as to maintain the system parameters within the desired range. This is of particular importance for Cyber-Physical systems acting in critical situations. F&Ks can smoothly integrate Augmented Reality components, to provide advanced situational awareness. Therefore, other relevant application fields of F&Ks can be prevention, detection, response, and mitigation of the combination of physical and cyber threats to critical infrastructures, and smart cyber-physical systems.

Impact on e-Health. EHF&K systems, namely the instances of F&K systems configured and adapted for the e-Health domain, will provide a uniform, flexible and verifiable platform for implementing Remote Patient Monitoring applications with improved quality of the overall assistance, and with a better patient's satisfaction. EHF&K will in fact provide personalized patient support to locate, select, combine and evaluate the necessary services. EHF&K PMAs will be proactive, and thus able to take measures in consequence of the variations in patient's physical but also psychological conditions. PMAs will be able to consider objective reputation and reliability of sources, as well as the patient's personal preferences and experience. The ability of eHF&K concerning knowledge-sources dynamic retrieval, evaluation and comparison will represent another relevant feature of such systems, as the rapid expansion of the corpus of medical knowledge has made it more difficult than ever for the physician to stay up-to-date with the progress of medicine outside a narrow field. Consultation with a specialist is however not always possible, as it is often the case that expert opinion is either unavailable or not available in a timely fashion. EHF&K PMAs will help physicians to obtain specialist advice either from human consultants, or from trusted knowledge sources.

With respect to the patient care and efficiency, eHF&K will support new ways of delivering care by reducing the risk of medication errors. In fact, eHF&K will decrease the adverse drug events and interaction drugs due to politerapy prescribed by different specialists. Moreover, such eHF&K will assure a more intelligent monitoring of the patient since they will use integrated models of diseases implementing a holistic approach. Another advantage of eHF&K systems, is that they will reduce the inappropriate use of hospital resources since they will support the screening decisions on the basis of information collected during monitoring besides the good clinical practice.

Future work. Characterizing, modeling, and implementing a framework for F&K systems is the objective of a 3 years project proposal submitted to the Italian

Ministry of Education, University and Research (MIUR) under the "Scientific Research Programs with Relevant National Interest" 2015 call ("Programmi di Ricerca Scientifica di Rilevante Interesse Nazionale", PRIN 2015). The project consortium involves the University of Genova (with the "Consorzio Interuniversitario Nazionale per l'Informatica", CINI, as subcontractor) and the University of L'Aquila

The team involved in the project proposal is already working for addressing the ICT objectives, as they are scientifically relevant and coherent with the participants' background in the multiagent systems and computational logic fields. In particular, we started to experiment how trace expressions can be actually exploited to model medical protocols and how interaction driven by a medical ontology in multilingual natural language can take place. We are also devising suitable extensions and generalization of bridge rules so as to make them more flexibly applicable in real applications, and we are developing an implementation.

The e-Health scenario requires major resources so its implementation is part of our future plans, as it depends on the PRIN 2015 outcome.

References

1. Jennings, N.R., Sycara, K.P., Wooldridge, M.: A roadmap of agent research and development. Auton. Agents Multi-Agent Syst. **1**(1), 7–38 (1998)
2. Leotta, M., Beux, S., Mascardi, V., Briola, D.: My MOoD, a multimedia and multilingual ontology driven MAS: design and first experiments in the sentiment analysis domain. In: Proceedings of the 2nd International Workshop on Emotion and Sentiment in Social and Expressive Media, pp. 51–66 (2015)
3. Brewka, G., Eiter, T., Fink, M.: Nonmonotonic multi-context systems: a flexible approach for integrating heterogeneous knowledge sources. In: Balduccini, M., Son, T.C. (eds.) Logic Programming, Knowledge Representation, and Nonmonotonic Reasoning. LNCS, vol. 6565, pp. 233–258. Springer, Heidelberg (2011)
4. Brewka, G., Eiter, T., Fink, M., Weinzierl, A.: Managed multi-context systems. In: Walsh, T. (ed.): IJCAI 2011, Proceedings of the 22nd International Joint Conference on Artificial Intelligence, IJCAI/AAAI, pp. 786–791 (2011)
5. Brewka, G., Ellmauthaler, S., Pührer, J.: Multi-context systems for reactive reasoning in dynamic environments. In: Schaub, T. (ed.): ECAI 2014, Proceedings of the 21st European Conference on Artificial Intelligence, IJCAI/AAAI (2014)
6. Velikova, M., Novák, P., Huijbrechts, B., Laarhuis, J., Hoeksma, J., Michels, S.: An integrated reconfigurable system for maritime situational awareness. In: Schaub, T., Friedrich, G., O'Sullivan, B. (eds.): ECAI 2014–21st European Conference on Artificial Intelligence. vol. 263 of Frontiers in Artificial Intelligence and Applications, pp. 1197–1202. IOS Press (2014)
7. Costantini, S.: Knowledge acquisition via non-monotonic reasoning in distributed heterogeneous environments. In: Calimeri, F., Ianni, G., Truszczynski, M. (eds.) LPNMR 2015. LNCS, vol. 9345, pp. 228–241. Springer, Heidelberg (2015)
8. Costantini, S.: ACE: a flexible environment for complex event processing in logical agents. In: Baldoni, M., Baresi, L., Dastani, M. (eds.) EMAS 2015. LNCS, vol. 9318, pp. 70–91. Springer, Heidelberg (2015). doi:10.1007/978-3-319-26184-3_5
9. Ancona, D., Ferrando, A., Mascardi, V.: Runtime verification with trace expressions and LTL. In: To appear in FdB60, Springer (2016)

10. Ancona, D., Briola, D., Ferrando, A., Mascardi, V.: Global protocols as first class entities for self-adaptive agents. In: Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems, AAMAS 2015, pp. 1019–1029 (2015)
11. Ancona, D., Briola, D., Ferrando, A., Mascardi, V.: Runtime verification of fail-uncontrolled and ambient intelligence systems: A uniform approach. Intell. Artif. **9**(2), 131–148 (2015)
12. Costantini, S., De Gasperis, G.: Runtime self-checking via temporal (meta-)axioms for assurance of logical agent systems. In: Bulling, N., van der Hoek, W. (eds.): Proceedings of LAMAS 2014, 7th Workshop on Logical Aspects of Multi-Agent Systems, held at AAMAS 2014. 241–255 Also, Proceedings of the 29th Italian Conference on Computational Logic, CEUR Workshop Proceedings, p. 1195 (2014)
13. Caianiello, P., Costantini, S., De Gasperis, G., Thakur, S.: Cooperating with trusted parties would make life easier. In: Gavanelli, M., Lamma, E., Riguzzi, F. (eds.) AI*IA 2015. LNCS, vol. 9336, pp. 128–135. Springer, Heidelberg (2015). doi:10.1007/978-3-319-24309-2_10
14. Marco, A.D., Inverardi, P., Spalazzese, R.: Synthesizing self-adaptive connectors meeting functional and performance concerns. In: Litoiu, M., Mylopoulos, J. (eds.): Proceedings of the 8th International Symposium on Software Engineering for Adaptive and Self-Managing Systems, SEAMS 2013, IEEE Computer Society, pp. 133–142 (2013)
15. Jørgensen, D., Hallenborg, K., Demazeau, Y.: Assessment of agent architectures for telehealth. In: Corchado, J.M., et al. (eds.) PAAMS 2014. CCIS, vol. 430, pp. 79–88. Springer, Heidelberg (2014)
16. Jørgensen, D.B., Hallenborg, K., Demazeau, Y.: Patient centric ontology for telehealth domain. In: Geissbühler, A., Demongeot, J., Mokhtari, M., Abdulrazak, B., Aloulou, H. (eds.) ICOST 2015. LNCS, vol. 9102, pp. 244–255. Springer, Heidelberg (2015)
17. Wildevuur, S.E., Simonse, L.W.: Information and communication technologyenabled person-centered care for the big five chronic conditions: Scoping review. J. Med. Int. Res. **19**(3), e77 (2015)
18. Zhang, Y., Lee, M., Gatton, T.M.: Agent-based web healthcare systems for real-time chronic disease. In: 2009 IEEE Congress on Services, Part I, SERVICES I 2009, IEEE Computer Society, pp. 14–21 (2009)
19. Gatton, T.M., Lee, M.R., Kim, T., Lee, Y.-K.: Diagnostic knowledge acquisition for agent-based medical applications. In: Nguyen, N.T., Grzech, A., Howlett, R.J., Jain, L.C. (eds.) KES-AMSTA 2007. LNCS (LNAI), vol. 4496, pp. 626–635. Springer, Heidelberg (2007)