Open multi-agent architecture for information fusion

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Abstract—**The management of information from multiple sources of information requires processes that can address the sources of information individually and subsequently facilitate the fusion of information efficiently and automatically. There are many types of information fusion techniques and data processing techniques in use today, but it would be interesting to create a system that allows creating information workflow solutions semi-automatically or automatically, and exploring solutions autonomously. This paper proposes a virtual organization of agents that can create a system to facilitate the automatic processing of information. The architecture is applied to a case study in an indoor location where information is taken from different sensors.**

Keywords—virtual organizations, artificial intelligence, optimization.

I. INTRODUCTION

Context aware applications [37][38] currently manage information from multiple sensors [46], each of which gathers information from the environment in order to ensure more accurate decision-making. Information fusion is commonly used in classification [15][16] or mixture of experts techniques [11][13]. However, there are no platforms that offer this type of system, which would reduce the development time integrating new components. This led to the possibility of creating an open platform to integrate different algorithms for generating workflows of information fusion semiautomatically [51][52].

Some existing classifiers include bagging and boosting [15][16] techniques, which allow merging the outputs of several classifiers to improve the results. However, their results are not always satisfactory as we have seen in previous works in the research group [13][14], hence the need to investigate other methods of information fusion. In addition to fusion techniques in classifiers, there are another techniques, referred to as mixture of experts, which merge the information based on the output provided by several experts [11][39][50]. This issue has been explored in several studies to improve the predictions processes [9][11] [37]. It is also common to find tools such as Spring Integration, apache camel or even weka, which can define workflows in data analysis. However, it would be interesting to create a tool that could learn from these workflows and generate new flows automatically or semi-automatically, as previously stated [8]. Using a virtual organization of agents [57][58] to bring together these various aspects, it would be possible to create an open architecture to facilitate data analysis and allow the easy inclusion of new techniques.

This paper proposes an architecture for information fusion. The architecture is divided into a series of layers that integrates different levels of data fusion. The most basic layers contain (i) drivers that can access data from devices and (ii) low level signal processing techniques, while the upper layers include virtual organization of agents that automatically manage the flow of data analysis and fusion. In order to analyze information flows, the system includes metrics based on information gain, which are used to build decision trees [40]. The information fusion is performed by applying different techniques depending on the case study. In addition to classifiers [40], techniques based on neural networks [41][44][45][47][48][49][56] or linear programming [10] can also be applied to minimize certain parameters. The present work was applied to a case study based on location for which we have performed various services for low-level signal processing. The higher-level services are generic and can be applied to different case studies.

This paper is organized as follows: section 2 describes techniques used for information fusion, Section 3 describes the proposed work, section 4 presents the case study in which the platform is applied, and finally section 5 shows the results and conclusions.

II. RELATED WORKS

One of the challenges to be addressed is the procurement of effective management architectures for WSNs[53][54][55]. Until now, WSNs and their applications have been developed without considering a management solution that can dynamically adapt to changes that occur in the environment, and to user needs. Some approaches, such as the MANNA management architecture for WSNs, propose functional, information, and physical management architectures, which take into account the specific characteristics of this type of network [18]. However, this architecture does not take into account either adaptive and organizational aspects, or intelligent information fusion (IF). Lim *et al.* [19][20] propose a sensor grid architecture, called the scalable proxy-based architecture for sensor grid (SPRING), to address these design issues [19]. However, the architecture is focused on a sensor grid design and not on exploitation. H-WSNMS uses the concept of a virtual command set, H-WSNMS, to facilitate management functions for specific WSN applications from the individual WSN platforms [21], but does not take information fusion algorithms into account, and is not designed on the basis of organizational aspects. MARWIS is a management architecture for heterogeneous wireless sensor networks (WSNs). It supports common management tasks such as monitoring, (re-)configuration, and updating program code in a WSN [22]. MARWIS, however, does not take organizational aspects into account and does not fuse information. Yu *et al.* (2008) propose a lightweight middleware system that supports WSNs to handle real-time network management using a hierarchical framework [23]. Although they take organizational aspects into account, they do not consider IF algorithms and user services. G-Sense [24] is an architecture that integrates mobile and static wireless sensor networks in support of location-based services, participatory sensing, and human-centric sensing applications. It does not, however, take organizational aspects into account, nor does it include information fusion technologies. Nowadays it is possible to find different proposals for architectures that manage wireless sensor networks [25][26] however, most of them are designed for specific environments or specific purposes and none of them combine organizational aspects, information fusion techniques, advanced storage mechanisms and open integration design.

Although significant progress has been made in the development of architectures to manage wireless sensor networks, at present there is no single open platform that efficiently integrates heterogeneous WSNs, and provides both intelligent information fusion techniques and intelligent services. Therefore, there is no platform in the market that facilitates the communication and integration of the wide variety of existing sensors, providing intelligent information fusion facilities, intelligent management of user services and security policies, and detection of DoS attacks. The goal of this work, therefore, is to develop such a platform using an efficient agent-based architecture running on a cloud environment. The proposed virtual organization of multiagent architecture is based on the social computing paradigm and will provide intelligence to the platform with adaptation to the needs of the application problem, while the cloud environment will ensure the availability of the required resources at all times.

There are several technologies and areas that can assist in the creation of such a platform. These technologies are continuously evolving and are expected to have a big impact in upcoming years. For example, Cloud Computing [27][28][29], VO and Agent Technology [7][42], WSN [43], Information Fusion [30][31], DoS attack detection techniques [32][33][34][35][36] Indoor Locating Systems [4], etc..

III. PROPOSED SYSTEM

The proposed architecture is divided into a number of layers of directed at information fusion in different levels. The layers are responsible for processing the data and passing the results from a higher level of abstraction to a lower level of abstraction in the architecture, thus providing a degree of independence among the abstraction levels. As the information reaches the higher levels it is merged in order to obtain a single output associated with all data related to the problem. The information is fused hierarchically by defining the flow of information fusion and concatenating services until the system finally becomes efficient with regard to the applied flow, which is evaluated for future flows. The present study proposes an architecture applied to the following fusion levels: Level 0 - Data Assessment; Level 1 - Object Assessment; Level 2 - Situation Assessment; Level 3 − Impact Assessment; Level 4 − Process Refinement; Level 5 − User Refinement; and Level 6 − Mission Management, according to the classification of the JDL fusion model [1][2]. The architecture is created from the PANGEA platform [7] which facilitates the process of integrating virtual organizations of agents to solve different problems. A complete description of the platform can be seen in [3]. Figure 1 shows the overall system architecture. As we can see there are different Layers, each of which is associated with a number of levels of data fusion. Layer 3 is already associated with user applications that use a range of services that connect to the lower layers. Layers 0, 1 and 2 are described below in the following subsections. Other aspects included in the architecture, but not mentioned in this study, are related to security. The security component allows the users to authenticate access to services. The architecture aso provides alternative communication channels to HTTP such as IRC or MQTT, which enable access to persistence API provided by the +cloud system.

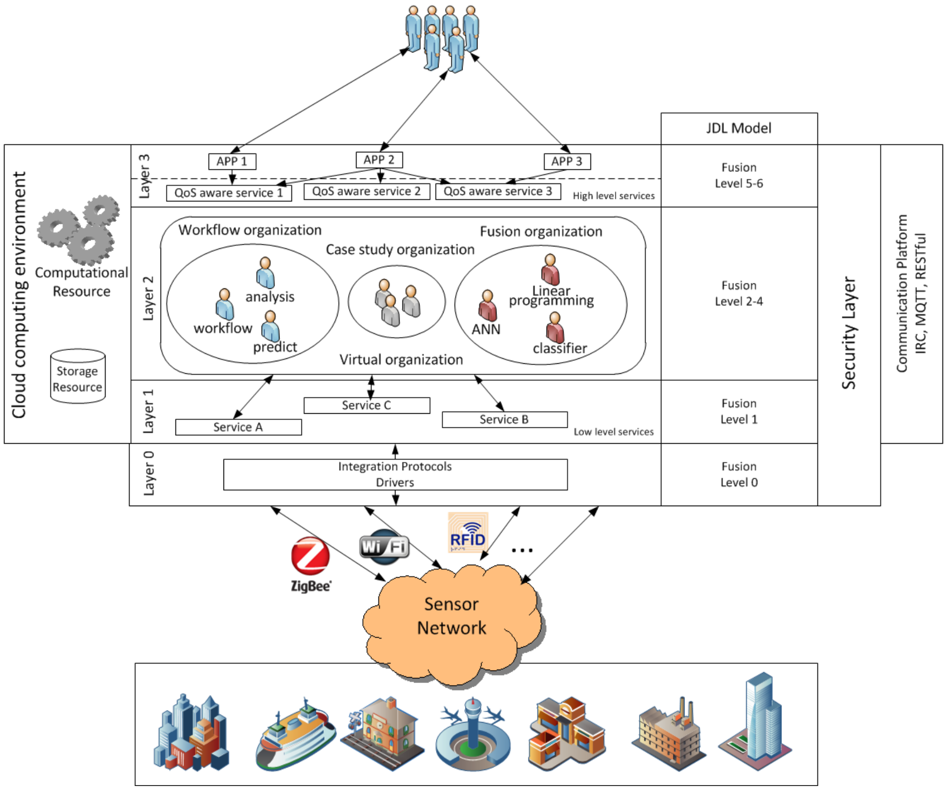


Fig. 1. Data Fusion architecture

A. Layer 0 and 1

Layer 0 of the system is responsible for implementing the necessary drivers to obtain data from the wireless network, while layer 1 perform an initial processing of information

B. Layer 2

Layer 2 of the architecture includes organization of agents that fuse information. The architecture's organizations are: workflow organization and fusion organization. The former aims to explore and find new workflows [8] that can analyze the data more optimally, while the latter creates a series of optimization techniques to optimize the process in terms of different variables. In addition to these two virtual organizations, the architecture will have its own organizations from the PANGEA architecture [7], and those of the case study as well.

1) Workflow organization

The entire process of information processing is managed by the workflow organization.

The agent with the analysis role will be responsible for managing the workflow information. At a later time, this agent will generate new workflow of information processing by using prediction role. The process is as follows.

Each node represents an action which can include any service from layers 1-4 at the fusion levels. The connection value between two nodes is calculated according to expression (1) which is based on the Gini index [14].

$$W(B)=\sum_{j=1}^{|C|}\frac{G(S,B)}{P(S,B)}\frac{n_j^S}{N^S}\frac{E_{\max}-\bar{x}_j^S}{E_{\max}} \qquad (1)$$

Where S is the set of data, B is the selected action that separates S in $S_1,\dots,S_t$, n_j^S the number of elements of class C_j, C is the set of classes belong S, N^S is the total number of elements, $E_{\max}$ is the maximum error in the workflow, $\bar{x}_j^S$ is the average error in the class C_j.

G represents the gain in the Gini index.

$$G(S,B)=I(S)-\sum_{i=1}^{t}\frac{|S_i|}{|S|}I(S_i) \qquad (2)$$

P represents the gain ratio according to Gini; its objective is to have a similar number of elements in groups S_i. The gain ratio is defined as follow

$$P(S,B)=-\sum_{i=1}^{t}\frac{|S_i|}{|S|}\log\left(\frac{|S_i|}{|S|}\right) \qquad (3)$$

$|S_i|$ is the number of elements of the node S_i.

I(S) is the amount of Information belongs to S.

$$I(S) = -\sum_{j=1}^{n} \frac{n_j^S}{N^S} \cdot \log\left(\frac{n_j^S}{N^S}\right) \tag{4}$$

Once the weights have been calculated, the workflow graph is defined. This graph gathers information from the different operation workflows. Using this graph, the agent with the predict role uses the maximum path to calculate the new analysis flows. Figure 2 shows an example of flow graphs. As we can see, there is a fusion information node. This node would be associated to a role in layer 2 and fusion level 4. The nodes take two or more inputs and generate one output. This aspect will be explained in the next subsection.

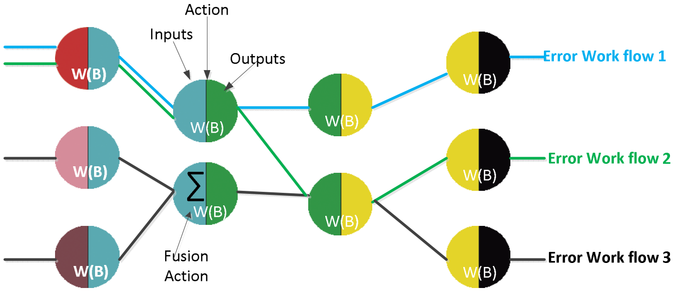


Fig. 2. Workflow graphs

The agent applies Floyd's algorithm [14] to calculate the maximum path from the starting point of information to the information fusion nodes, adding up those paths. The path will be unique and can be merged with other nodes if their paths end in a common information fusion node.

Finally, the agent with the workflow role is responsible for taking and executing the workflow according to the data provided by the Predict agent.

2) Fusion organization

This organization includes the fusion information techniques directed at optimizing the solution. Specifically, it includes optimization mechanisms such as MLP [12], SVM [9] and Linear programming [10]. Although MLP, SVM and linear programming are supervised techniques, linear programming is an optimization technique based on the simplex algorithm which is directed at maximizing or minimizing an objective function.

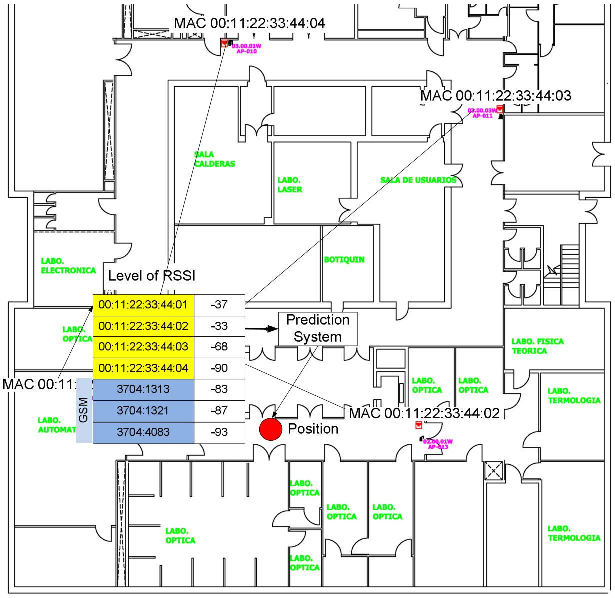
The MLP or SVM operation is similar with regard to the system, since the inputs and outputs are identical except for the classifier [13], which also includes the original entries of the sensors. The original entries are included so that the system can learn where it is weak or fails; this also requires handling the inputs. The inputs could be omitted for case studies with a high number of different classes in the data. MLP is typically used for continuous variables, while SVM is more often used for classification. Its operation is similar to that of existing ensemble techniques for classifiers [16] [17] or mixture of experts [11] [13] where each expert provides a result from which the final result is obtained:

A method based on linear programming optimization is also provided. The method is based on the study found in [10].

IV. CASE STUDY

A. Positioning based on RSSI and Accelerometers

Positioning based on RSSI levels is described in a previous work [4]. Only RSSI signal levels from the WiFi signals were used in this work. The GSM networks were also added for situations where there are few WiFi networks. The algorithm remains the same but in addition to the MAC:RSSI relations, the system also has information from the CELL ID:RSSI for each of the GSM antennas detected, as seen in Figure 3.



00:11:22:33:44:01	-37
00:11:22:33:44:02	-33
00:11:22:33:44:03	-68
00:11:22:33:44:04	-90
3704:1313	-83
3704:1321	-87
3704:4083	-93

Fig. 3. WiFi and GSM network scan

Accelerometers and compass positioning was achieved as described in [4]. A new method for calculating the force vector that provides independence of the state of the gyroscope was also included in order to avoid transformations based on the state of the gyroscope. The force vector is calculated by adding the vectors of each of the coordinates and calculating its module, as shown in equation (2). The forces in the mobile terminals are given by the force on the x, y and z axes.

$$\vec{f}(x,y,z) = (x,y,z) \tag{5}$$

$$\left|\vec{f}(x,y,z)\right| = \sqrt{x^2 + y^2 + z^2} \tag{6}$$

Figure 4 shows the measure of the force for establishing the detection of each step.

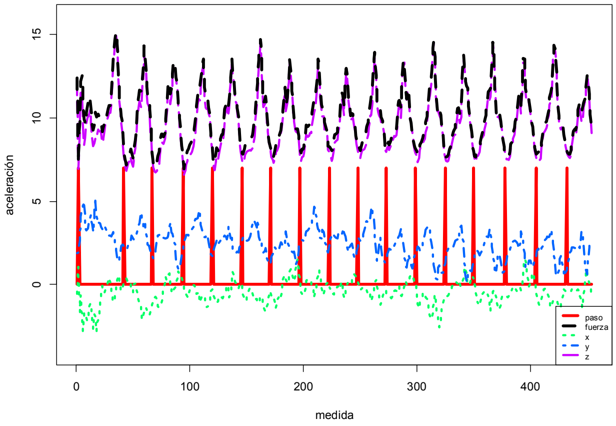


Fig. 4. Measurement of force independent state gyroscope

In addition to sensors used earlier in [4], the camera was added to improve accuracy. Photos capture objects located within one meter throughout the various paths taken by the user. The photos are made with the mobile terminal and create a database of images that are associated with positions in the plane. For each image, the characteristics and descriptors were extracted by using the FAST [4] algorithm, after which a kd-tree [6] was applied to improve the image search. The FAST algorithm is applied in the mobile terminals; the data is sent to a server that performs a search for patterns.

One of the techniques applied to information fusion is a neural network, specifically a multilayer perceptron. MLP estimates the position by using RSSI, sensors, and a camera. The network then calculates the final position where the user is located. The inputs are defined by the data shown in Table 1.

Variable	I/O	Descripción
PositionRSSI	I	(x,y) coordinates x, y estimated. Corresponds to two inputs in the neural networks
PositionSensors	I	(x,y) coordinates x, y estimated. Corresponds to two inputs in the neural networks
PositionCamera	I	(x,y) coordinates x, y estimated. Corresponds to two inputs in the neural networksº
PositionReal	O	(x,y) coordinates x, y. The true position of the user.

Table 1. Input and output variables in the neural network

The number of neurons in the hidden layer was set to 31 since it provided good results. The activation function of the neurons in the intermediate and the output layers is sigmoidal. The input and output values are re-sized in order to vary within the range [0.2, 0.8]. This redefinition of the variables is because of the activation function selected for the neurons.

The techniques incorporated in this work are listed in the table. The techniques defined in other works are referenced.

Service	Description
WiFi	Location system based on WiFi [4].
RSSI (WiFi-GSM)	Location system based on WiFi and GSM.
Accelerometer	Location system based on accelerometer and compass [4].
Acelerómetros2	Location system based on WiFi, GSM and strength vectors(6) .
Step	Step detection [4].
Camera	Image capture
Detector	Pattern recognition in images
Bayes	Classifier according to the work [4].
MLP	MLP to fuse the predictions of the other predictors.
Linear programming	Mixture of experts to fuse the information [10].

Table 2. Services and fusion information techniques

V. *Results and conclusions*

To validate the performance of the system, we proceeded to calibrate the ground floor of the building shown in Figure 5. The ground floor has an area of 1700m2. The hallways and open areas within the building were calibrated. In total 165 RSSI measurements (WiFi and GSM) were taken, equivalent to the 165 steps from one end of the building to the other. A total of 20 images were taken of various objects, such as the fire extinguishers, doors, signs and other easily distinguishable objects. The calibrated zones correspond to the bold lines in Figure 5.

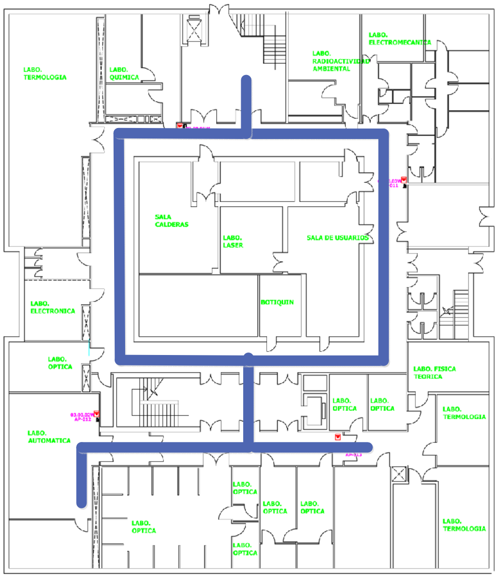


Fig. 5. Calibrated zones highlighted with blue lines

Our first step was to perform a small analysis of how each of the positioning system obtains results according to user behavior. The average error obtained by each of these procedures can be seen in Table 3. In order to obtain the test data, we prepared a route following the same path taken during the calibration process. It should be noted that errors are not fixed and vary in different the different tests carried out. For example in the case of RSSI, the error varied from [2.37, 2.53] since it also has an error in indicating the location on the map during the calibration process.

Classifier	Average error
RSSI	2.41 m
Sensors	2.25 m
Camera	3.68 m

Table 3. Average error according to the different classifiers

Although the error given by the sensors is low, this error varies greatly depending on user behavior. This is because if the user changes stride, turns, or walks back, the error increases considerably. The error also depends on the length of the corridors and the algorithm is always contingent on knowing the initial starting location.

The error in the case of the camera is not very significant since the number of images measured is low with respect to the number of measurements taken for Wi-Fi and sensors. If a new image is not detected, the current position is the last to be detected. Nevertheless, when the camera detects an image, it has a relatively low error rate.

The training of the neural network responsible for merging the data is done in such a way that each pattern containing data taken from the RSSI signal, sensors and camera is inserted as follows: one patter with the three measures, and all patterns containing pairs, leaving the other two values as -1, -1. If there is data from a single position measurement, the procedure the position is given by this procedure and the neural network is not used.

Twenty flows were applied according to the techniques shown in table 2. Figure 6 show some of these flows. The efficiency of each action was estimated according to the efficiency of each flow. The best flow was determined by applying the process presented in section III.B. The result of the predicted best flow is represented in bold. The average error obtained by applying the flow is 1.67 meters, which reduces the error obtained by the previous algorithms.

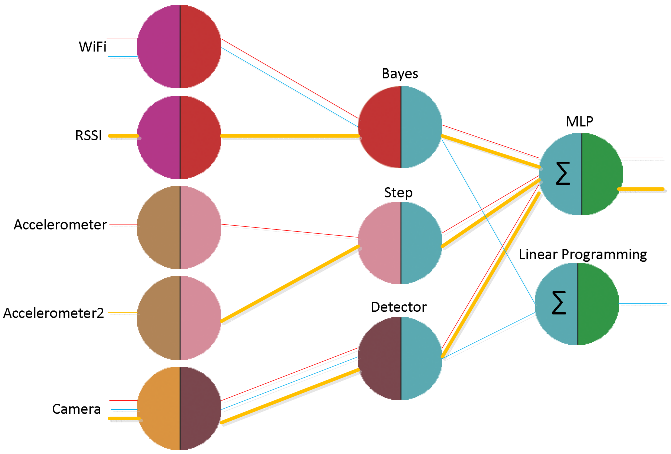


Fig. 6. Execution flows in the system

The system can automatically adjust flows and merge information from different systems to obtain a more precise location. The neural network can perform this task efficiently, improving the precision of other systems such as RSSI signal levels. Systems based on sensors provide good accuracy as long as the user does not have erratic behavior, which can lead to a high error rate, making it complicated to use the system in museums or exhibitions. Future considerations will focus on improving camera positioning to determine more precisely the distance to a recognized object. At the moment when an object is recognized, the system places it in the same position where the image was initially captured. We would also like to include other location procedures using sound frequencies inaudible to humans but that able to be captured by mobile devices. Finally, we would like to analyze the use of lighting and camera to improve accuracy, test the system in other environments such as example health care, and introduce other services in the layers such as concatenation services with a rule engine.

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REFERENCES

[1] E. Blasch, Level 5 (User Refinement) issues supporting Information Fusion Management. 9th International Conference on Information Fusion. 2006, pp. 1-8.

[2] A.N. Steinberg, C. Bowman and F. White, Revisions to the JDL Data Fusion Model, NATO/IRIS Conf. 1998.

[3] E. Blasch and S. Plano, JDL Level 5 fusion model: user refinement issues and applications in group tracking, SPIE Vol 4729, Aerosense, 2002, pp. 270 – 279.

[4] G. Villarrubia, J. Bajo; J.F. De Paz and J.M. Corchado, Real time positioning system using different sensors. 16th International Conference on Information Fusion (FUSION), 2013, pp. 604 - 609

[5] E. Roste: Machine Learning for High-speed Corner Detection, (2006).

[6] Y.S. Kang, J.H. Naha, W.C. Park and S.B. Yang gkDtree: A group-based parallel update kd-tree for interactive ray tracing, Journal of Systems Architecture, 59 (3) 2013, pp. 166–175.

[7] C. Zato; G. Villarrubia, A. Sánchez, I. Barri, E.R. Soler, A.F. del Viso, C.R. Sánchez, J.A. Cabo, T. Álamos, J. Sanz, J., Seco, J., Bajo and J. M. Corchado, PANGEA - Platform for Automatic coNstruction of orGanizations of intElligent Agents., DCAI 2008, 2012, pp. 229-239.

[8] J.F. De Paz, J. Bajo, V.F. López and J.M. Corchado, Biomedic Organizations: An intelligent dynamic architecture for KDD, Information Sciences, 224(1), 2013, pp. 49–61.

[9] J.F. De Paz, J. Bajo, A. González, S. Rodríguez and J.M. Corchado, Combining case-based reasoning systems and support vector regression to evaluate the atmosphere–ocean interaction, Knowledge and Information Systems, 30 (1), pp. 155- 177.

[10] P. Marti-Puig, S. Rodríguez, J.F. De Paz, R. Reig-Bolaño, M.P. Rubio and J. Bajo, Stereo video surveillance multi-agent system: new solutions for human motion analysis, Journal of Mathematical Imaging and Vision, 42(2-3), pp. 176-195.

[11] J.M. Corchado, J.F. De Paz, S. Rodríguez and J. Bajo, Model of experts for decision support in the diagnosis of leukemia patients, Artificial Intelligence in Medicine, 46 (3), pp. 179-200.

[12] J.F. De Paz, D.I. Tapia, R.S. Alonso, C.I. Pinzón, J. Bajo and J.M. Corchado, Mitigation of the ground reflection effect in real-time locating systems based on wireless sensor networks by using artificial neural networks, Knowledge and information systems, 34(1), 2013, pp. 193-217.

[13] C.I. Pinzón, J.F. De Paz, Á. Herrero, E. Corchado, J. Bajo and J.M. Corchado, idMAS-SQL: Intrusion Detection Based on MAS to Detect and Block SQL injection through data mining, Information Sciences, 231, 2013, pp. 15–31

[14] C.I. Pinzón, J.F. De Paz, M. Navarro, J. Bajo, V. Julián, J.M. Corchado, Real-time CBR-agent with a mixture of experts in the reuse stage to classify and detect DoS attacks, Applied Soft Computing, 11 (7), 2011, pp. 4384–4398.

[15] S. Hougardy, The Floyd–Warshall algorithm on graphs with negative cycles, Information Processing Letters, 110, 8–9 (1), 2010, pp. 279–281.

[16] L. Breiman. Bagging predictors. Machine Learning. 24(2), 1996, pp. 123-140.

[17] Y. Freund, R.E. Schapire, Experiments with a new boosting algorithm. In: Thirteenth International Conference on Machine Learning, San Francisco, 1996, pp. 148-156.

[18] L.B. Ruiz, J.M. Nogueira and A.A.F. Loureiro. MANNA: a management architecture for wireless sensor networks. Communications Magazine, IEEE, 41(2), 2003, pp. 116, 125.

[19] J.K. Kok, C.J. Warmer and I.G. Kamphuis, PowerMatcher: multiagent control in the electricity infrastructure. In Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems (AAMAS '05), 2005, pp. 75-82.

[20] H.B. Lim, M. Iqbal, W. Wang, Y. Yao, The National Weather Sensor Grid: a large-scale cyber-sensor infrastructure for environmental monitoring. IJSNet 7(1/2), 2010, pp. 19-36

[21] Y.L. and L.A. Zhiyong. Cooperative Ad Hoc Routing Based on Cluster Agent. IEEE Conference: 7th International Conference on Wireless Communications, Networking and Mobile Computing (WiCOM), 2011, pp. 23-25.

[22] G. Wagenknecht, M. Anwander, T. Braun, T. Staub, J. Matheka, S. Morgenthaler. MARWIS: A Management Architecture for Heterogeneous Wireless Sensor Networks. LNCS 5031, 2008, pp. 177-188.

[23] Z. Wang, L. Wang, A.I. Dounis, R. Yang. Multi-agent control system with information fusion based comfort model for smart buildings, Applied Energy 99, 2012, pp. 247–254

[24] A.J. Perez, M.A. Labrador, S.J. Barbeau. G-Sense: a scalable architecture for global sensing and monitoring. IEEE Network, 24(4), 2010, pp. 57 – 64.

[25] J.O. Gutierrez-Garcia and K.M Sim. Self-organizing agents for service composition in Cloud Computing. In Cloud Computing Technology and Science (CloudCom), 2010 IEEE Second International Conference on, 2010, pp. 59-66.

[26] Y. Liu., B.C. Seet, A. Al-Anbuky. An Ontology-Based Context Model for Wireless Sensor Network (WSN) Management in the Internet of Things. J. Sens. Actuator Netw, 2(4), 2013, 653-674.

[27] R. Buyya, C.S. Yeo, S. Venugopal, J. Broberg and I. Brandic. Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. Future Generation computer systems, 25(6), 2009, pp. 599-616.

[28] I. Foster, Z. Yong, I. Raicu and S. Lu. Cloud Computing and Grid Computing 360-Degree Compared. In: Grid Computing Environment Workshop, 2008, pp. 1-10

[29] P. Mell and T. Grance. The NIST definition of Cloud Computing. In: NIST Special Publication, 2011, pp. 800-145.

[30] D. Schuler.Social Computing. Communications of the ACM 37(1), 1994, pp. 28-29.

[31] N. Steinberg, C. Bowman and F. White. Revisions to the JDL Data Fusion Model. *NATO/IRIS Conf.* October, 1998.

[32] T. Nagata and H. Sasaki. A multi-agent approach to power system restoration. IEEE Transactions on Power Systems, 17, 2002, pp. 457-462.

[33] C. Pinzón, J.F. De Paz, D.I. Tapia, J. Bajo and J.M. Corchado. (2012). Improving the Security Level of the FUSION@ Multi-Agent Architecture. Expert Systems with Applications, 39 (8), pp. 7536-7545.

[34] C. Pinzón, J.F. De Paz, J. Bajo and J.M. Corchado. S-MAS: An Adaptive Hierarchical Distributed Multiagent Architecture for Blocking Malicious SOAP Messages within Web Services Environments. Expert Systems with Applications, 38 (5), 2011, pp. 5486–5499.

[35] J. Bajo, J.M. Corchado, C. Pinzón, Y. de Paz and B. Pérez-Lancho SCMAS: A Distributed Hierarchical Multi-agent Architecture for Blocking Attacks to Databases. International Journal of Innovative Computing, Information and Control (IJICIC) 6(9), 2010, pp. 3787-3818.

[36] S. Madden, J.M. Franklin, J.M. Hellerstein and W. Hong (2002). TAG: A tiny aggregation service for ad-hoc sensor networks. *ACM SIGOPS Operating Systems Review*, *36*(SI), 131-146.

[37] J.M. Corchado, J. Bajo, A. Abraham, GerAmi: Improving Healthcare Delivery in Geriatric Residences, Intelligent Systems, IEEE, 23 (2), 2008, pp. 19 – 25.

[38] J.A. Fraile, Y. de Paz, J. Bajo, J.F. de Paz and B.P. Lancho, Context-aware multiagent system: Planning Home Care Tasks, Knowledge and Information Systems, In Press.

[39] M.H. Nguyena, H.A. Abbassa, R.I. Mckay, A novel mixture of experts model based on cooperative coevolution. Neurocomputing, 70, 2006, pp. 155–163

[40] R. Kohavi and R.R. Quinlan, Decision Tree Discovery Handbook of Data Mining and Knowledge Discovery. Oxford University Press. 1999, pp. 267-276

[41] J. Bajo, M.L. Borrajo, J.F. De Paz and J.M. Corchado, A multi-agent system for web-based risk management in small and medium business, Expert Systems with Applications, 39 (8), 2012, pp. 6921-6931.

[42] C. Zato, J.F. De Paz, A. de Luis, J. Bajo, J.M. Corchado, Model for assigning roles automatically in egovernment virtual organizations, Expert Systems with Applications, 39 (12), 2012, pp. 10389-10401.

[43] R.S. Alonso, D.I. Tapia, J. Bajo, Ó. García, J.F. de Paz and J.M. Corchado, Implementing a Hardware-Embedded Reactive Agents Platform based on a Service-Oriented Architecture over Heterogeneous Wireless Sensor Networks. Ad Hoc Networks, 11, 2013, pp. 151-156.

[44] J.M. Corchado, C. Fyfe. Unsupervised neural method for temperature forecasting. Artificial Intelligence in Engineering 13 (4), 1999, pp. 351-357.

[45] F. Fdez-Riverola, J.M. Corchado. CBR based system for forecasting red tides. Knowledge-Based Systems 16 (5), 2003, pp. 321-328.

[46] D.I. Tapia, A. Abraham, J.M. Corchado and R.S. Alonso. Agents and ambient intelligence: case studies. Journal of Ambient Intelligence and Humanized Computing 1 (2), 2010, pp. 85-93.

[47] J.M. Corchado and B. Lees. Adaptation of cases for case based forecasting with neural network support. Soft computing in case based reasoning, 2001, pp. 293-319.

[48] J.M. Corchado. Redes Neuronales Artificiales: un enfoque práctico. Vigo : Servicio de Publicacións da Universidade de Vigo, 2000.

[49] J. Bajo, J.M. Corchado. Evaluation and monitoring of the air-sea interaction using a CBR-Agents approach. Case-Based Reasoning Research and Development, 2005, pp. 50-62.

[50] J.F. De Paz, S. Rodríguez, J. Bajo and J.M. Corchado. Case-based reasoning as a decision support system for cancer diagnosis: A case study. International Journal of Hybrid Intelligent Systems, 6 (2), 2009, 97-110.

[51] D.I. Tapia, S. Rodríguez, J. Bajo and J.M. Corchado. FUSION@, a SOA-based multi-agent architecture. International Symposium on Distributed Computing and Artificial Intelligence 2008 (DCAI 2008), 2008, 99-107.

[52] S. Rodríguez, B. Pérez-Lancho, J.F. De Paz, J. Bajo and J.M. Corchado. Ovamah: Multiagent-based adaptive virtual organizations. Information Fusion, 2009. FUSION'09. 12th International Conference on, 2009, pp. 990-997.

[53] D.I. Tapia, J.F. De Paz, S. Rodríguez, J. Bajo and JM Corchado. Multi-agent system for security control on industrial environments. International Transactions on System Science and Applications Journal 4 (3), 2008, pp. 222-226.

[54] J.F. De Paz, S. Rodríguez, J. Bajo and J.M. Corchado. Mathematical model for dynamic case-based planning. International Journal of Computer Mathematics 86 (10-11), 2009, pp. 1719-1730.

[55] D.I. Tapia, R.S. Alonso, J.F. De Paz and J.M. Corchado. Introducing a distributed architecture for heterogeneous wireless sensor networks. LNCS 5518, 2009, pp. 116-123.

[56] C.I. Pinzón, J. Bajo, J.F. De Paz and J.M. Corchado. S-MAS: An J.M. Corchado, J. Bajo, J.F. De Paz and S Rodríguez. An execution time neural-CBR guidance assistant. Neurocomputing 72 (13), 2009, pp. 2743-2753.

[57] S. Heras, F. De la Prieta, V. Julian, S. Rodríguez, V. Botti, J. Bajo, V. Botti and J.M. Corchado. Agreement technologies and their use in cloud computing environments. Progress in Artificial Intelligence 1 (4), 2012, pp. 277-290.

[58] S. Rodriguez, V. Julián, J. Bajo, C. Carrascosa, V. Botti, J.M. Corchado. Agent-based virtual organization architecture. Engineering Applications of Artificial Intelligence 24 (5), 2011, pp. 895-910.