INTELLIGENT SYSTEM FOR AUTONOMOUS MICROGRID COOPERATION

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Abstract

The purpose of this paper is to provide support to autonomous microgrids that cannot perform a large contract alone. To fulfil a higher external request, the microgrid managers are obliged to outsource parts of their contracts even to competing microgrids. Inside these business exchanges, each microgrid prefers to maintain their decision autonomy. To model this business interaction, we introduce an intelligent system to manage simultaneous negotiations among autonomous microgrids. The proposed smart system helps the microgrids inside the collaborative network to grow their efficiency and the competitiveness of their market. Furthermore, conserving the interoperability inside the dynamic business environment is hard to realize. In this regard, this paper tackles interoperability issues by proposing negotiation activities as the key solution to settle these problems. Negotiation is the mutual resolution acceptable for all microgrids within the collaborative network. This paper outlines therein a negotiation approach in which intelligent negotiation agents evaluate and change offers and counteroffers. Moreover, the negotiation process is based on a communication protocol among the intelligent agents. The proposed intelligent system for autonomous microgrids cooperation has the potential to synchronize multiple negotiations that occur at the same time in which many partners can participate who can be the initiators of negotiations or guests in the respective negotiations.

Keywords: *Negotiation, microgrid, intelligent agents, collaborative network, dynamic environment.*

1. Introduction

This paper describes how microgrids participate in parallel negotiations and the way in which the negotiation processes are managed. In this regard, this paper introduces an intelligent system for coordinating simultaneous negotiations that take place in a B2B interaction inside a dynamic environment. With respect to this, it is described a scenario of distributed autonomous microgrids. The microgrids manage in an autonomous manner their contracts, programs, and resources.

When an external demand reaches a microgrid, the manager analyses the acceptance of the new task considering the current program and the availability of resources. After the manager accepts the new task, he can decide to perform it locally or to partially outsource it. If the manager agrees to outsource a job, he begins a negotiation inside the collaborative system with the selected microgrids. The initiator microgrid manager can divide the work into slots, notifying the microgrid partners about outsourcing demands for different slots. If the negotiation results in an agreement, a contract is settled between the outsourcer and insourcer microgrid. The proposed collaborative intelligent system is able to support the negotiation processes maintaining the autonomy of the microgrids. The objective of the negotiation process is to achieve a common agreement between the parties to support possible collaborations.

In this regard, many research works[1] propose a framework that incorporates smart components capable of mediating agents participating in negotiations to reach an agreement by deducting mutually acceptable proposals. By comparison to these papers that can limit the autonomy of the negotiation partners, this paper introduces an intelligent system to manage simultaneous negotiations in a dynamic environment, maintaining the autonomy of the participants. The following sections describe the related work, the collaborative intelligent system architecture, the coordination services that manage different negotiations and the final considerations of this paper.

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[1] P. Tolchinsky, S. Modgil, K. Atkinson, P. McBurney and U. Cortes, *Deliberation dialogues for reasoning about safety critical actions*, Autonomous Agents and Multi-Agent Systems, vol. 25, Issue 2, pp. 209-259, 2012.

2. Related Work

Automated negotiations have been the subject of many research papers. In this respect, Fujita[2] proposes automated agents that can estimate the opponents' strategies based on the past negotiations. Caillere *et al.*[3] develop a protocol and rules which help the agents to coordinate their interactions and to reach an agreement.

Other negotiation research approaches tackle the issue related to the design of a negotiation environment, considering two directions: i) the first in which the intelligent agents replace humans in negotiations; and ii) the second direction in which the intelligent software agents assist human user providing a negotiation support. Considering the first direction, Lin and Kraus[4] propose a generic environment where automated agents can proficiently negotiate with human negotiators. Regarding the second direction, several research papers propose a collaborative solution based on a service-oriented architecture which helps inter-organizational information processing in distributed workflows, as in (Badica *et al.*, 2011) and (Penders *et al.*, 2010).

Reference (Arefifar *et al.*, 2012) presents a clustering approach of the distribution system into a set of virtual microgrids with optimized self-adequacy. In the same direction, the authors in (Saleh *et al.*, 2015) highlight the advantages of multiple microgrids clustering in improving their stability, supply availability and resilience during blackouts.

Compared with these works, where the coordination of negotiations is handled at protocol level, this research splits the negotiation process into three discrete processes: *decision-making process*, *coordination process* and *communication process*, allowing, therefore, to be integrated in any multi-agent system or directly as a support in a human interaction negotiation system (Coutinho *et al.*, 2016).

3. Intelligent negotiation system architecture

In the following, we will present the stages of a negotiation and the main dimensions that characterize the mechanisms used during the negotiation process.

A negotiation process is usually composed of two major stages:

i) pre-negotiation (or negotiation planning) - reports to discussions preceding formal negotiations and often includes procedural questions: Who will be involved? Where and when will negotiations take place? How will they be structured? What will be the object of negotiation? The answers to these questions will be values for the dimensions defined above, such as the participant or time. Before answering other questions, new possible dimensions and values must be defined.

ii) Negotiation - refers to the interactions regarding the exchange of proposals and counterpoints formulated starting from the negotiation strategies.

Considering the division of the negotiation process in these two stages, three main dimensions must be taken into account: i) the information handled, the relative dimension of the data that define the framework and the content of the negotiation, (ii) the negotiation protocols, the relative dimension of the messages (Language, content, sequences, number of participants) exchanged between participants, (iii) reasoning or negotiation strategies, relative dimension of modelling the participants involved in negotiation they use to meet their objectives.

In the first stages of negotiation planning, negotiators must determine their goals, foresee what they want to achieve and prepare for the negotiation process. Depending on their goals, the parties will bring together in the complete lists all the information and data that help them define what is negotiated and in what way it is negotiated. Often negotiators change and/or negotiate before the list of issues to discuss. The consultation between the negotiators, before the real negotiation, allows them to agree on the information lists that define the object of the negotiation by attributes to be discussed, as well as on other characteristics of the negotiation such as the location, time and duration of the session, the parties involved in the negotiation and the techniques to be followed if the negotiation fails. The purpose of the negotiation planning phase is not to try to solve the problem, but to obtain information that will allow a clearer image of the real negotiating problems. This image is the basis of choosing the strategy to be used in negotiation by each participant involved. All this preliminary

[2] K. Fujita, *Automated Negotiating Agent with Strategy Adaptation for Multi-times Negotiations*, chapter in Recent Advances in Agent-based Complex Automated Negotiation, Studies in Computational Intelligence, vol. 638, pp 21-37, 2016.

[3] R. Caillere, S. Arib, S. Aknine, and C. Berdier, *A Multiagent Multilateral Negotiation Protocol for Joint Decision-Making*, chapter in Recent Advances in Agent-based Complex Automated Negotiation, Studies in Computational Intelligence, vol. 638, pp 71 - 88, 2016.

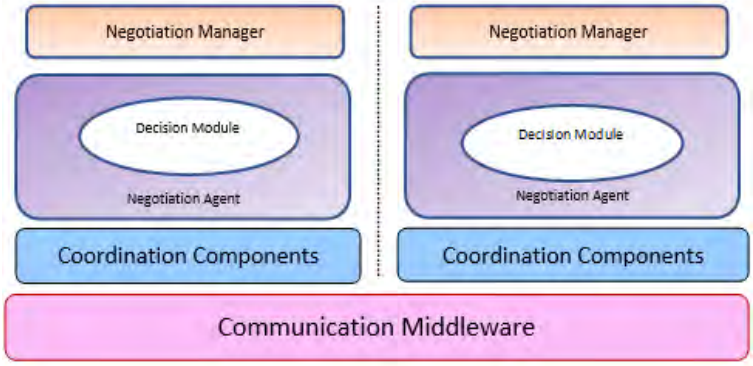
[4] R. Lin and S. Kraus, *Can Automated Agents Proficiently Negotiate with Humans*, Communic. of the ACM, vol. 53/1, pp. 78-88, 2010.

exchange is identified in the economic approaches of negotiation as a conversation by structures. One of these structures, called negotiation object, contains the attributes that one of the participants considers to negotiate. In some cases, only one attribute (for example-price) is negotiated, but in other cases several attributes must be negotiated, such as the time required to fulfill an order, the quality of the products, etc. Before starting the negotiation, a participant fixes not only the attributes of the object but also tries to be very precise in playing these measurable objectives. By fixing the possible values for the negotiating attributes, a participant soon identifies a lot of negotiation objects than a single object. Depending on the values fixed for attributes, the set includes: i) maximum an object - the best possible result, ii) at least one object - the least acceptable result, iii) a target object - a fixed result.

After making the decision regarding the object of the negotiation, the negotiators must give priority to their goals and evaluate the possible differences between them. The negotiators must realize what their goals and positions are and must identify the desires and fears that are the basis of these goals. They must also identify what are the most important questions and if the different attributes on which they negotiate are related or independent. Because negotiation objects typically involve more than one attribute, it is useful for negotiators to provide different ways to classify attributes. Thus, they can identify the attributes that they consider the most important, to be more flexible in negotiating the attributes that they consider less important. Thus, the analysis of the values for this dimension provides the participants a better understanding of the dynamics and the development of the negotiation and allows them to provide which are the best negotiation strategies that can be used immediately.

To implement the proposed approach concerning the division of the negotiating process into three distinct processes (*i.e.*, decision-making process, coordination process and communication process), it has been proposed an architecture structured in four main layers: Negotiation Manager, Negotiation Agent, Coordination Negotiation Components and Communication Middleware.

Fig. 1 The architecture of the intelligent negotiation system



A first layer, Negotiation Manager manages all business decisions regarding the creation of offers, acceptance or rejection of offers, invitation of another partner to participate in the negotiation process etc.

The Negotiation Agent, the second layer, has the role of assisting the Negotiation Manager in making decisions regarding the negotiations at a global level (*i.e.*, negotiations with various participants on different jobs) and at a specific level (*i.e.*, negotiations on the same job with various participants). During a negotiation, the Negotiation Agent handles one or more Negotiation Objects, one Negotiation Framework, as well as a negotiation state represented as a graph structure.

The third layer, Coordination Components, manages the constraints of the coordination process among various concurrent negotiations.

Communication Middleware is the fourth layer, shared by all negotiation participants, ensuring, thus, the communication process.

4. Coordination Negotiation Components

Each Coordination Component models a specific negotiation step or strategy (*i.e.*, selection of negotiation participants, outsourcing or insourcing of a job etc.). In this respect, various Coordination Negotiation

Components have been proposed (Cretan *et al.*, 2012): *Outsrc* (resp. *Insrc*), for outsourcing (resp. insourcing) jobs by exchanging offers among partners known from the beginning of negotiation; *Block* component for assuring that a task is entirely subcontracted by the single participant; *Split* component handles the propagation of constraints among several slots, negotiated in parallel and issued from the split of a single job; *Broker* component deals with the automatic selection of possible participants in the beginning of the negotiation; *SwapIn* (resp. *SwapOut*) components implement a coordination mechanism between two ongoing negotiations to facilitate an exchange between their two tasks; *Transp* component implements a coordination mechanism between two ongoing negotiations in order to facilitate the common transport of their two tasks. These Coordination Components can evaluate the received offers checking whether these are valid and, further, able to reply with new offers constructed based on their particular coordination constraints. At this level, interoperability is sustained by developing a generic coordination framework for the negotiation participants.

The advantages of the proposed negotiation architecture consist of:

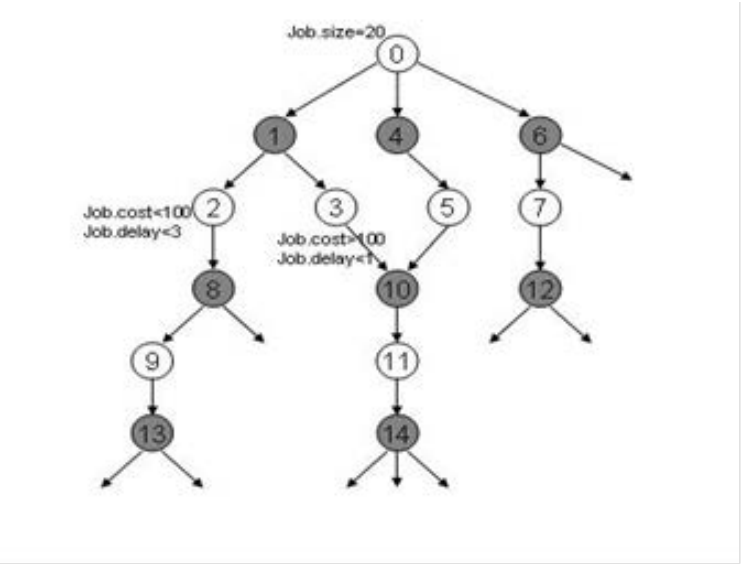
- allowing a precise identification of the coordination objects;
- managing the dependencies among the existing negotiations within the manufacturing environment;
- ensuring the coordination of concurrent negotiations at the Negotiation Components level.

5. Negotiation Communication Approach

A negotiation process is modelled using Xplore, a middleware infrastructure for negotiation components (Andreoli and Castellani, 2001). At the Xplore Middleware level, a negotiation is modelled as a collaborative construction of a negotiation graph among the negotiation participants. Each component has its own (partial) copy of the negotiation graph and expresses negotiation decisions manipulating that copy (Brandl *et al.*,2003). For instance, a proposal made by one of participants (*e.g.*, MG1) that initiated the negotiation is represented in the graph copy visible by the Outsrc component, and the proposals made by potential partners (*e.g.*, MG2 and MG3, called guests in the sequel) are represented in the graph copies visible through their Insrc components. In this way, the evolution of a negotiation in terms of proposals and counter-proposals is modelled by a bicolored graph in which white nodes, representing negotiation contexts, and black nodes, representing decision points with multiple alternatives. Each context (white) node contains a parameter and a set of attributes with associated values. Parameter is the task to be negotiated (Negotiation Object), which is described in a time moment by a set of attributes that have to be negotiated depending on the specific information about the state of the negotiation at that node.

For example, the unique parameter of the negotiation is a delivery job and an attribute can be the cost that can assume a range of possible values. Different branches of negotiation can be created in the negotiation graph, at the initiative either of the initiator or the guests, to explore alternatives (*e.g.*, cost under 100 Euros or over 100 Euros), as shown in Fig. 2. The partners may then create new branches specifying different distribution times (*e.g.*, cost over 100 Euros and distribution time is less than 1 day, or under 100 Euros and the distribution time is less than 3 days). The interaction that specifies the distribution time would occur in the context of one or the other branch created by the interaction concerning the cost.

Fig.2. Example of Negotiation Graph



In accordance with our approach wherein the negotiation process is distributed among the partners of the alliance, the middleware Xplore builds the negotiation graphs, in the same manner, for each of the participants. Therefore, each negotiation partner makes decisions and acts on its own copy of the Xplore graph. Consequently, only the initiating participant has a global view of the negotiation graph, whereas the guests have a partial view corresponding to the propositions sent to each of them by the initiator.

In this context, the purpose of middleware Xplore is to ensure, for each participant, a graphical image of negotiation and synchronize the image with the other partners involved in that negotiation. At the middleware level, this synchronization is modelled by using six operations, called verbs, of the Xplore protocol. The Connect verb allows to dynamically involve a new component instance in a negotiation. The Open and Assert verbs allow a component instance to build the negotiation graph, by creating and populating context nodes with information about the negotiation state at these nodes. The Request verb allows component instances to express their information needs on some given aspects of the negotiation in order to proceed in the negotiation. The Ready and the Quit verbs allow a component instance to declare, respectively, that it is “ready to sign” in the state of a given negotiation context, or, on the contrary, that it wishes to give up the negotiation at that state (but it may pursue the negotiation in other branches) (Cretan *et al*., 2018).

5.1. Algorithm to construct the graph Xplore

In order to describe the graph construction algorithm, we consider the following notations:

Negotiation Object represents the description of the negotiated task. The description refers to the set of possible values for each negotiable attribute indicating the properties of the job. This first description of the task is made by Manager. He also establishes the preferences and dependencies among the attributes.

Negotiation Context represents all data that can be extracted starting from a white node (instantiated attributes, required attributes, and the position of node in the graph structure).

Possible Negotiation Context represents the context resulting of union of two or more white nodes. This context can be considered as attached to a virtual node (*i.e.*, a node that is not present for the moment in the structure of the graph).

Issue Set represents the set of attributes proposed to be negotiated in a negotiation cycle.

Partial_NO_Set represents the set of existing negotiation contexts in which all the attributes of an Issue Set are instantiated.

Proposals_Set represents the set of existing negotiation contexts in which all the attributes of an Issue Set are not instantiated.

Possible_NO_Set represents the set of possible negotiation contexts in which all the attributes of an Issue Set are instantiated.

Possible_Proposals_Set represents the set of possible negotiation contexts in which all the attributes of an Issue Set are not instantiated.

- *OpenWN(n, pni):*

```
Graph.open(n,nb)
New negotiation context N1
  Where N1.nodes =n
If n is a white node
  For every nw parent of nb
    Collect negotiation context(nw) in N1
  If inconsistencies in N1
            Quit(n)
    Else
      If all attributes are instantiated
     Insert the N1 in Partial_NO_Set
   Else
     Insert the N1 in Proposals_Set
     Generate FindObject(N1)
   FindObject(NC)
  For every node n in CN.nodes:
            Create an empty list L(n) of nodes;
            For every white node nw in Graph:
              If first common_ancestor(n, nw) is White Node:
                    Insert nw in L(n);
     Create a list L of nodes where L = ∩n∈N1.nodes L(n);
     For every nw in L:
          New negotiation context CNew;
          CNew.nodes = CN.nodes + nw;
          Collect negotiation context (nw) and CN in Cnew;
          Check content consistency;
            If no inconsistencies in Cnew:
              If all attributes are instantiated:
                Insert the CNew in Possible_NO_Set;
              Else:
                Insert the CNew in Possible_Proposals_Set;
                Generate FindObject(CNew).
```

- *Assert(n,p,i,t):*

```
    Graph.assert(n,p,i,t);
      If i in n.NC:
        Check consistency;
        If inconsistency with the new value t of the attribute i:
Quit(n)
          For every NC in Partial_NO_Set, Proposals_Set, Possible_NO_Set, Possible_Proposals_Set:
  If n∈NC.nodes:
   Delete(NC);
Exit();
        If all attributes are instantiated:
Insert NC in Partial_NO_Set;
For every NC in Proposals_Set, Possible_NO_Set, Possible_Proposals_Set:
  If  n∈NC.nodes:
   Delete(NC);
        Else:
  For every NC in Proposals_Set, Possible_NO_Set, Possible_Proposals_Set:
If n∈NC.nodes:
  Update NC with asserted t;
  Check consistency;
```

If inconsistency in NC:
  Delete(NC);
  Exit();
If NC in *Possible_Proposals_Set* and all attributes are instantiated:
  Move NC in *Possible_NO_Set*.

- *Request(n,p,i):*

If attribute i not in Issues_Set
  Insert i in Issues_Set;
If *Negotiation Object* doesn't contain constraints or possible values for attribute i
  Ask higher authority (*e.g.*: manager);

6. Final considerations

This paper describes the implementation of the negotiation coordination model via a three-layered architecture: Negotiation Agent, Coordination Components and Communication Middleware.

This structure is in line with the proposed approach of splitting the negotiation process into three discrete processes: decision-making process, coordination process and communication process.

The communication process is managed by the middleware layer that defines the generic mechanisms of communication and synchronization among several agents. At the middleware level, communication is based on the Xplore protocol that enables the management of the concurrent negotiations where, at any moment, participants can choose to simultaneously negotiate in several negotiation states.

The coordination process is managed by the coordination components layer.

The main feature of this approach is the fact that the coordination process is fully distributed on several coordination modules allowing to be defined several specialized components that can be used in any negotiation. This distribution of coordination constraints also allowed the components to run simultaneously, which enhanced the efficiency of the system, making it capable of evaluating several negotiations offers at the same time.

The decision-making process is provided by the Negotiation Agent layer that models the support mechanisms for the interaction processes within the collaborative manufacturing environment, mainly, for creating offers and making decisions in a negotiation. This layer manages the decisions that can be made on the negotiation strategy for evaluating and generating offers and on the protocol for sending the offers to the other agents. The goal at this level is to allow the human user to intervene in the decision-making process. We can thus separate the decision-making process from agents, which reinforces the generic applicability of the proposed negotiation system.

References

- P. Tolchinsky, S. Modgil, K. Atkinson, P. McBurney, U. Cortes, Deliberation dialogues for reasoning about safety critical actions. Autonomous Agents and Multi-Agent Systems, vol. 25, issue 2, pp. 209-259, 2012;
- K. Fujita, *Automated Negotiating Agent with Strategy Adaptation for Multi-times Negotiations*, chapter in Recent Advances in Agent-based Complex Automated Negotiation, Studies in Computational Intelligence, vol. 638, pp. 21-37, 2016;
- R. Caillere, S. Arib, S. Aknine, and C. Berdier, *A Multiagent Multilateral Negotiation Protocol for Joint Decision-Making*, chapter in Recent Advances in Agent-based Complex Automated Negotiation, Studies in Computational Intelligence, vol. 638, pp. 71-88, 2016;
- R. Lin and S. Kraus, *Can Automated Agents Proficiently Negotiate with Humans*, Communic. of the ACM, vol. 53/1, pp. 78-88, 2010;
- C. Badica, S. Ilie, M. Kamermans, G. Pavlin, and M. Scafes, *Using Negotiation for Dynamic Composition of Services in Multi-organizational Environmental Management*, Environmental Software Systems. Frameworks of Environment, vol. 359, pp 177-188, 2011;
- A. Penders, G. Pavlin, M. Kamermans, *A Collaborative Approach to Construction of Complex Service Oriented Systems*, Intelligent Distributed Computing IV. Studies in Computational Intelligence, vol. 315, pp. 55-66, Springer, 2010;

- C. Coutinho, A. Cretan, C.F. da Silva, P. Ghodous, and R. Jardim-Goncalves, *Service-based Negotiation for Advanced Collaboration in Enterprise Networks*, Journal of Intelligent Manufacturing, vol. 27, issue 1, pp. 201-216, February 2016, DOI=10.1007/s10845-013-0857-4;
- M.-S. Li, R. Cabral, G. Doumeingts, and K. Popplewell, *Enterprise Interoperability Research Roadmap*, no. July. European Commision - CORDIS, p. 45, 2006;
- R. Jardim-Goncalves, A. Grilo, C. Agostinho, F. Lampathaki, and Y. Charalabidis, *Systematisation of Interoperability Body of Knowledge: the foundation for Enterprise Interoperability as a science*, Enterprise Information Systems, vol. 6, no. 3, pp. 1-26, 2012;
- W. Wang, Y. Xu, and M. Khanna, *A survey on the communication architectures in smart grid*, Computer Networks, vol. 55, issue 15, 27 October 2011, pp. 3604-3629;
- R.H. Lasseter, *Smart Distribution: Coupled Microgrids*, Proceedings of the IEEE, 99(6), 1074-1082, 2011;
- F. Katiraei, R. Iravani, N. Hatziargyriou, and A. Dimeas, *Microgrids management*, IEEE Power and Energy Magazine, 6(3): 54-65, 2008;
- Camarinha-Matos L.M. and Afsarmanesh H., *Collaborative Networked Organizations,* 2004 Kluwer Academic Publisher Boston;
- Singh M.P., *Commitments among autonomous agents in information-rich environments*. In Proceedings of the 8th European Workshop on Modelling Autonomous Agents in a Multi-Agent World (MAAMAW), pages 141-155, May 1997;
- Cretan, A., Coutinho, C., Bratu, B., and Jardim-Goncalves, R., *NEGOSEIO: A Framework for Negotiations toward Sustainable Enterprise Interoperability.* Annual Reviews in Control*,* 36(2): 291–299, Elsevier, ISSN 1367-5788, 2012. *http://dx.doi.org/10.1016/j.arcontrol.2012.09.010*;
- J. Carrasco, L. Franquelo, J. Bialasiewicz, E. Galvan, R. Guisado, M. Prats, J. Leon, and N. Moreno-Alfonso, *Power electronic systems for the grid integration of renewable energy sources: A survey*, IEEE Trans. Power Electron., vol. 53, no. 4, pp. 1002-1016, Aug. 2006;
- M. Shahabi, M. R. Haghifam, M. Mohamadian, and S. A. Nabavi-Niaki, *Microgrid dynamic performance improvement using a doubly fed induction wind generator*, IEEE Trans. Energy Convers, vol. 24, no. 1, pp. 137-145, Mar. 2009;
- H. Kanchev, L. Di, F. Colas, V. Lazarov, and B. Francois, *Energy management and operational planning of a microgrid with a PV-based active generator for smart grid applications*, IEEE Trans. Ind. Electron., vol. 58, no. 10, pp. 4583-4592, Oct. 2011;
- S. A. Arefifar, Y.A-R I. Mohamed, and T. H. M. EL-Fouly, *Supply-adequacy-based optimal construction of microgrids in smart distribution systems*, IEEE Transactions on Smart Grid, vol. 3, no. 3, pp. 1491-1502, Sept. 2012;
- M. S. Saleh, A. Althaibani, Y. Esa, Y. Mhandi, and A. A. Mohamed, *Impact of clustering microgrids on their stability and resilience during blackouts*, 2015 International Conference on Smart Grid and Clean Energy Technologies (ICSGCE), Offenburg, 2015, pp. 195-200;
- Bartolini, C., Preist, C., and Jennings, N., *A generic software framework for automated negotiation*, Technical Report HPL-2002-2, HP Laboratories Bristol;
- Singh., M. P., *Interaction-Oriented Programming: Concepts, Theories, and Results on Commitment Protocols*. In AI 2006: Advances in Artificial Intelligence, LNAI 4304, pp. 5-6, 2006;
- Bamford J.D., Gomes-Casseres B., and Robinson M.S., *Mastering Alliance Strategy: A Comprehensive Guide to Design, Management and Organization*. San Francisco: Jossey-Bass, 2003;
- Sycara K., *Problem restructuring in negotiation*, in Management Science, 37(10), 1991;
- Smith R., and Davis R., *Framework for cooperation in distributed problem solving*. IEEE Transactions on Systems, Man and Cybernetics, SMC-11, 1981;
- Zhang X. and Lesser V., *Multi-linked negotiation in multi-agent systems*. In Proc. of AAMAS 2002 July, Bologna, pg. 1207-1214;
- Barbuceanu M. and Wai-Kau Lo, *Multi-attribute Utility Theoretic Negotiation for Electronic Commerce*. In AMEC III, LNAI 2003, p. 15-30;
- Keeny R. and Raiffa H., *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. JohnWilley & Sons, 1976;
- Bui V. and Kowalczyk R., *On constraint-based reasoning in e-negotiation agents*. In AMEC III, LNAI 2003, pp. 31-46;
- Faratin P., *Automated component negotiation between autonomous computational agent*. Ph.D. Thesis, Department of Electronic Engineering Queen Mary & West-field College, 2000;
- Cretan A., Coutinho C., Bratu B. and Jardim-Goncalves R., *A Framework for Sustainable Interoperability of Negotiation Processes.* In INCOM'12 14th IFAC Symposium on Information Control Problems in Manufacturing, 2011;
- Vercouter, L., *A distributed approach to design open multi-agent system*. In 2nd Int. Workshop Engineering Societies in the Agents' World (ESAW), 2000;
- Muller H., *Negotiation principles.* Foundations of Distributed Artificial Intelligence, 1996.
- Hurwitz, S.M., *Interoperable Infrastructures for Distributed Electronic Commerce.* 1998, *http://www.atp.nist.gov/atp/98wpecc.htm*;

- Ossowski S., *Coordination in Artificial Agent Societies*. Social Structure and its Implications for Autonomus Problem-Solving Agents, no. 1202, LNAI, Springer Verlag, 1999;
- Schumacher M., *Objective coordination in multi-agent system engineering – design and implementation.* In Lecture Note in Artificial Intelligence, no. 2093, Springer Verlag, 2001;
- A. Cretan, B. Bratu, C. Coutinho and R. Jardim-Goncalves, *A negotiation approach to support interoperability in a collaborative manufacturing environment*, 2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC), Funchal, 2017, pp. 1282-1292;
- J.-M. Andreoli and S. Castellani, *Towards a Flexible Middleware Negotiation Facility for Distributed Components*. In Proc. of "E-Negotiation" DEXA, Munich, Germany, 2001;
- R. Brandl, J-M Andreoli, and S. Castellani, *Ubiquitous negotiation games: a case study*, Proc. of DEXA "e-negotiations" Workshop, Prague, Sep 1-5, 2003;
- A. Cretan, C. Coutinho, B. Bratu and R. Jardim-Goncalves, *A Negotiation Cloud-based Solution to Support Interoperability among Interconnected Autonomous Microgrids*, 2018 International Conference on Intelligent Systems (IS), Funchal, Portugal, 2018, pp. 608-615, doi: 10.1109/IS.2018.8710579.