# Scientific/technical record during the last five years of the IIIA-CSIC research team on Logic & Reasoning

-August 2023-

The Artificial Intelligence Research Institute (IIIA-CSIC) gathers three research groups, the first one on machine learning, the second one on multiagent systems and the third one in logic and reasoning. The PhD candidate will join the latter, whose research is centered around the logical and mathematical modelling of reasoning, with special attention to logics for incomplete information, and the design of efficient algorithms for solving satisfaction and optimization problems by methods based on SAT, constraints and metaheuristics.

The IIIA research group on Logic and Reasoning currently includes the following members:
- permanent scientific staff: Christian Blum, Gonzalo Escalada-Imaz, Francesc Esteva (Professor Ad-Honorem), Tommaso Flaminio, Lluís Godo, Jordi Levy (Head of the department), Felip Manyà;
- vinculated staff: Pilar Dellunde (UAB);
- contract researchers: María Vanina Martínez and Sara Ugolini (Ramón y Cajal researchers), Amanda Vidal (Marie Curie researcher) and Vicent Costa (Juan de la Cierva researcher).

Regarding the topics of the PhD grant offer, the IIIA research group has a large experience in the investigation of algebraic aspects of non-classical logics, with special attention to many-valued and paraconsistent logics and to mechanisms for handling uncertainty and inconsistency. In these fields, the high reputation of the host institution is highlighted by the number and relevance of the scientific publications, and the intense collaboration with several international and renowned research groups. Indeed, it is worth mentioning that in the last years the IIIA-Research Team has kept international scientific collaborations (funded by bilateral projects, European Cost actions, E-RISE projects, etc.) with several research teams, like the ones of late Prof. Hájek and Prof. Cintula (Prague, Czech Republic), Prof. Chu-Min Li (Marsella, Francia), Profs. Baaz and Fermueller (Vienna, Austria), the late Prof. Montagna and Prof. Noguera (Siena, Italy), Profs. Gilio (Roma, Italia), Prof. Sanfilippo (Palermo, Italy), Profs. Dubois and Prade (Toulouse, France), Profs. Font, Gispert and Verdú (Barcelona, Spain), the late Prof. Cignoli and Prof. Rodriguez (Buenos Aires, Argentina), Prof. Simari (Bahía Blanca, Argentina) and Profs. Carnielli and Coniglio (Campinas, Brazil). The bibliographic references in this document witness the fruitful collaborations of the IIIA-Research Team with the above-mentioned groups.

In the following, we briefly describe the scientific research directions pursued by the IIIA-Research Team in the last years, with special attention to their relevance for the applicant skills: algebraic investigations of many-valued logics, their semantics and applications to non-classical logics of belief, paraconsistent logics and inconsistency handling, conditionals, satisfiability testing and computational argumentation.

**ALGEBRAIC ASPECTS OF MANY-VALUED (FUZZY) LOGICS.** Hájek's influential book [Metamathematics of Fuzzy Logic, Kluwer 1998] is considered the birth of the new subfield in Mathematical Logic, nowadays called Mathematical Fuzzy Logic (MFL), one of the most prominent examples of many-valued logic. This is understood as the study of a variety of formal systems of non-classical logics primarily related to classes of algebras whose set of truth-values are linearly ordered residuated lattices. Hájek's Basic fuzzy Logic BL and Esteva and Godo's Monoidal T-norm based Logic MTL [Monoidal t-norm based Logic: Towards a logic for left continuous t-norms. Fuzzy Sets and Systems, vol. 124:3 (2001) 271-288] are two milestones in this line of research. In the last years a large class of axiomatic extensions of MTL has been studied, along with their related algebraic semantics, and the IIIA-Research Team has contributed with several relevant works in this framework. The relevance of this line of research comes both from its foundational character and usefulness in modelling approximate reasoning, and from its strong relations with highly developed areas of mathematics, including abstract algebraic logic, universal algebra, duality theory, etc. (all of fundamental importance, when developing logic-based formal systems). In the last 5 years, the members of the research team have published a significant number of works in many valued logics, both in international scientific journal papers and in book chapters [CEFG22, EFFG21, FGM+, FU20, I23]. Also, they have made numerous presentations in international scientific conferences and workshops, including conferences with indexed proceedings [FGM+22, FGR19, RFN20].

[CEFG22] M. Coniglio, F. Esteva, T. Flaminio, L. Godo (2022). On the expressive power of Lukasiewicz's square operator. Journal of Logic and Computation, 32, 767-807.

[EFFG21] F. Esteva, A. Figallo-Orellano, T. Flaminio, L. Godo (2021). Logics of formal inconsistency based on distributive involutive residuated lattices. Journal of Logic and Computation, 31, 1226-1265.

[FGM+] T. Flaminio, L. Godo, P. Menchón, R. Oscar Rodríguez (In Press). Algebras and relational frames for Gödel modal logic and some of its extensions. M. Coniglio, E. Koubychkina, & D. Zaitsev (Eds.), Many-valued Semantics and Modal Logics: Essays in Honour of Yuriy Vasilievich Ivlev. Springer.

[FGM+22] T. Flaminio, L. Godo, P. Menchón, R.O. Rodriguez (2022). Rotations of Gödel Algebras with Modal Operators. Davide Ciucci al. (Eds.), 17th Intl. Conference on Information Processing and Management of Uncertainty in Knowledge-Based Systems (IPMU 2022) (pp. 676--688). Springer International Publishing.

[FGR19] T. Flaminio, L. Godo, R.O. Rodriguez (2019). A Representation Theorem for Finite Gödel Algebras with Operators. 26th Workshop on Logic, Language, Information and Computation, WoLLIC 2019 (pp. 223-235). Springer.

[FU20] T. Flaminio, S. Ugolini (2020). Hyperstates of Involutive MTL-Algebras that Satisfy $(2x)^2=2(x^2)$. Shier Ju, Alessandra Palmigiano, & Minghui Ma (Eds.), Nonclassical Logics and Their Applications (pp. 1--14). Springer Singapore.

[I23] G. E. Imaz (2023). A first polynomial non-clausal class in many-valued logic. Fuzzy Sets Syst. 456: 1-37.

[RFN20] U. Rivieccio, T. Flaminio, T. Nascimento (2020). On the representation of (weak) nilpotent minimum algebras. 29th IEEE International Conference on Fuzzy Systems, FUZZ-IEEE 2020, Glasgow, UK, July 19-24, 2020

**NON-CLASSICAL MODAL LOGICS OF BELIEF AND UNCERTAINTY.** A further related topic, which is currently an important research line of the Logic Team of the IIIA, regards logics oriented to express graded intensional notions like epistemic belief, preference, similarity and other related notions. F. Bou, F. Esteva and L. Godo made a very important contribution to the basis of this discipline in the early 2010s [Bou, Esteva, Godo, Rodriguez. On the Minimum Many-Valued Modal Logic over a Finite Residuated Lattice. Journal of Logic and Computation, vol. 21:5, (2011), 739-790], and since then, several works on the topic have been published by the team in international journals and conferences, concerning important basic-theoretical results necessary for the development of the discipline, see e.g. [VEG20, EGS21, RTEG22]

On the other hand, regarding formalisms dealing with uncertainty, the main theory to model uncertainty is probability theory together with their logical counterpart probability logic. Probability and fuzzy logics, although sharing the common feature of evaluating a proposition in a real number between 0 and 1, are deeply different in nature. Indeed, while fuzzy logics are meant to capture the gradual, and possibly partial, truth of a proposition, probability functions are aimed at quantifying the belief that an agent may have about a precise, yet unknown, state of the world. However, if the uncertainty of a formula ϕ is regarded as a physical variable (like pressure or temperature), rather than an atomic sentence, we can imagine a modal assertion P(ϕ) saying “ϕ is probable” in such a way that its truth-degree becomes the probability of ϕ. These ideas were made precise and formalized in [HGE95] where the fuzzy probabilistic logic FP(L) was introduced, axiomatized and proved to be complete with respect to probabilistic models. This original idea of modeling uncertain statements by fuzzy modal formulas, besides providing a reconciliation between fuzzy set theory and probability, paved the way for a research field which aims at understanding up to which extent this approach could be pushed forward and which other uncertainty measures, besides probability, could be captured by the same lines of thoughts. In these lines, two-layered fuzzy modal logics have been introduced to deal with probability of fuzzy events [F20,F21,FGU18,FU23], belief functions [DGP23] possibility and necessity measures [RTEG22, I23-b]. This methodological approach shows the wide applicability of this logics to a wide range of situations [CFGH23].

[BCF21] S. Bonzio, G. Cevolani, T. Flaminio (2021). How to Believe Long Conjunctions of Beliefs: Probability, Quasi-Dogmatism and Contextualism. Erkenntnis 88, pages 965–990, 2023.

[CFGH23] E.A. Corsi, T. Flaminio, L. Godo, H. Hosni (2023). A modal logic for uncertainty: a completeness theorem. 13th International Symposium on Imprecise Probabilities: Theories and Applications - ISIPTA 2023, pp. 119-129.

[DGP23] D. Dubois, L. Godo, H. Prade (2023). An elementary belief function logic. Journal of Applied Non-Classical Logics. In Press.

[EGS21] F. Esteva, L. Godo, S. Sandri (2021). A similarity-based three-valued modal logic approach to reason with prototypes and counterexamples. MJ. Lesot, & C. Marsala (Eds.), Fuzzy Approaches for Soft Computing and Approximate Reasoning: Theories and Applications (pp 45-59), Springer.

[F21] T. Flaminio (2021). On standard completeness and finite model property for a probabilistic logic on Łukasiewicz events. Int. J. Approx. Reason., 131, 136--150

[F20] T. Flaminio (2020). Three Characterizations of Strict Coherence on Infinite-Valued Events. The Review of Symbolic Logic, 1-18.

[FGU18] T. Flaminio, L. Godo, S. Ugolini (2018). Towards a probability theory for product logic: states, integral representation and reasoning. Internationa Journal of Approximate Reasoning, 93, 199-218.

[FU23] T. Flaminio, S.Ugolini (2023). Encoding de Finetti's coherence within Łukasiewicz logic and MV-algebras. Annals of Pure and Applied Logic, 103337.

[I23-b] G. E. Imaz (2023). The possibilistic horn non-clausal knowledge bases. Int. J. Approx. Reason. 152: 357-389.

[RTEG22] R.O. Rodriguez, O.F. Tuyt, F. Esteva, L. Godo (2022). Simplified Kripke Semantics for K45-Like Gödel Modal Logics and Its Axiomatic Extensions. Studia Logica, 110, 1081-1114.

[VEG20] A. Vidal, F. Esteva, L. Godo (2020). Axiomatizing logics of fuzzy preferences using graded modalities. Fuzzy Sets and Systems, 401, 163-18.

**PARACONSISTENCY AND INCONSISTENCY HANDLING.** Members of the IIIA-CSIC have also extensively worked on the problem of handling inconsistency in different types of knowledge bases and in the formalization of paraconsistent many-valued logics.

For relational databases with logical constraints, there is the work in [MPPSV14] where policies for handling inconsistency are formalized to be combined with traditional query answering languages. Considering more expressive knowledge representation languages, the works in [MMSA13, LMS12, GLMS13] develop models that can be applied to a wider variety of domains, particularly to the level of abstraction of multi-agent systems.

In the last few years, there has been much interest in defining inconsistency-tolerant semantics for query answering in Description Logics (DLs) and ontological labguages. The group has worked on inconsistency-tolerant semantics for ontological languages with the goal of defining reasonable semantics and efficient methods of computation, focusing on rule-based languages that allow existentially quantified variables in their consequence (a.k.a. Datalog+/–), which are particularly useful for representing and reasoning over lightweight ontologies (FO logic fragments that allow efficient computation similar to that of querying relational databases) in the Semantic Web. In particular:

- In [DMFS14,DMFS16,DMFS17,DMFS19], methods to solve inconsistencies analyzing the conflicts from a global point of view (looking at the bigger context where the conflict arises rather than the specific pieces of knowledge that cause it) and utilizing domain knowledge (formalized within the framework) in order to solve these issues in a more adequate way depending on the functional and performance goals of the particular applications. [DMFS16] studies incoherence in rule-based ontologies proposing a formalism for restoring both consistency and coherence based on cluster incision functions, where clusters are defined both over facts and rules (incoherence had not received much attention in belief revision).

- The work on [LMS12] develops a general framework for inconsistency management built on top of belief revision operators, characterizing several query answering semantics as special cases; we also proposed the notion of lazy consistent answers, based on a budget that restricts the size of removals that need to be made in a set of facts in order to make it consistent—if the budget is large enough, then we go to the trouble of considering all possible ways of solving the conflicts within the budget, but if it is not enough then we get rid of all the sentences that are involved in that particular conflict.

- An important aspect of ontological languages both from the point of view of the Semantic Web and the fact that they allow for knowledge integration to a high level of conceptual abstraction, is that these languages should be computationally efficient if they are to be used in real world applications; in this sense, the work in [LMPS15,LMPS15] studies in depth different types of computational complexity of CQA for the most tractable fragments of Datalog+/–. Considering a more complex setting where ontologies can be uncertain, in [GLMS13] alternative inconsistency-tolerant semantics that take into account probabilistic information were developed.

- Phenomena of imperfect information like vagueness and inconsistency are not mutually independent, but very often found together in many particular examples. Therefore, one might wish for logical systems to be able to cope up with several of them at once. In particular, it would be desirable to have logics for vague and inconsistent information. Recently, members of the IIIA team, have started to study logical systems living at the intersection of fuzzy logic and paraconsistency, aiming at finding logics that can handle inconsistency and graded truth at once and in a very precise and foundational way. One of the most developed research lines within this area is the representation, within the framework of algebraic logic, of degree-preserving many-valued logics as paraconsistent logics belonging to the family of "logics of formal inconsistency". Members of the IIIA have been very involved in this topic introducing different many-valued and fuzzy logical frameworks in the frame of logics for formal inconsistency [CEG14, EEF+15, CEG16, CEG+19, EFF+21]. These non-explosive logics have the distinctive feature of incorporating a special operator to denote those pieces of information that are taken as consistent. Moreover, a related line of inquiry concerns the investigation of the interval of logics included between a paraconsistent and an "explosive" one [CEG+19, CEG+21]. More recently, we have explored a logical approach that makes use of the well-known many-valued semantics of Lukasiewicz logic in a natural way to encode a set of possibly inconsistent probabilistic constraints, as formulas in a modal theory over that logic, and allows to minimally relaxing the constraints in order to restore consistency of the theory [FGU22, FGU+].

[CEG14] M.E. Coniglio, F. Esteva, L. Godo. Logics of formal inconsistency arising from systems of fuzzy logic. Log. J. IGPL 22(6): 880-904 (2014).

[CEG+19] M.E. Coniglio, F. Esteva, J. Gispert, L. Godo. Maximality in finite-valued Łukasiewicz logics defined by order filters. J. Log. Comput. 29(1): 125-156 (2019).

[CEG+21] M.E. Coniglio, F. Esteva, J. Gispert, L. Godo. Degree-preserving Gödel logics with an involution: intermediate logics and (ideal) paraconsistency. O. Arielli, & A. Zamansky (Eds.), Arnon Avron on Semantics and Proof Theory of Non-Classical Logics (pp 107--139). Springer (2021).

[CEG16] M.E. Coniglio, F. Esteva, L. Godo. On the set of intermediate logics between the truth- and degree-preserving Łukasiewicz logics. Log. J. IGPL 24(3): 288-320 (2016)

[DMFS14] C.A.D. Deagustini, M.V. Martinez, M. Falappa, and G.R. Simari. Inconsistency resolution and global conflicts. In Proc. ECAI, pages 991–992, 2014.

[DMFS16] C.A.D. Deagustini, M.V. Martinez, M. Falappa, and G.R. Simari. Datalog+/– ontology consolidation. J. Artif. Intell. Res., 56:613–656, 2016.

[DMFS17] C.A.D. Deagustini, M.V. Martinez, M. Falappa, and G.R. Simari. How does incoherence affect inconsistency-tolerant semantics for Datalog+/–? AMAI, pp 1-26, 2016.

[DMFS19] C.A. D. Deagustini, M.V. Martinez, M. A. Falappa, G.R. Simari: "Belief base contraction by belief accrual", Artificial Intelligence,Vol.275, pp.78-103, 2019.

[EEF+15] R. Ertola, F. Esteva, T. Flaminio, L. Godo, C. Noguera. Paraconsistency properties in degree-preserving fuzzy logics. Soft Comput. 19(3): 531-546 (2015).

[EFF+21] F. Esteva, A. Figallo Orellano, T. Flaminio, L. Godo. Logics of formal inconsistency based on distributive involutive residuated lattices. J. Log. Comput. 31(5): 1226-1265 (2021).

[FGU22] T. Flaminio, L. Godo and S. Ugolini. An Approach to Inconsistency-Tolerant Reasoning About Probability Based on Łukasiewicz Logic. Proc. of SUM 2022, LNAI volume 13562, Springer, pp. 124-138, 2022.

[FGU+] T. Flaminio, L. Godo, S. Ugolini and F. Esteva. A Lukasiewicz logic-based approach to inconsistency-tolerant probabilistic reasoning. An approach to inconsistency-tolerant reasoning about probability based on Łukasiewicz logic. H. Antunes, A. Rodrigues, & A. Roque (Eds.), Volume in Honour of Walter Carnielli, Springer, To appear.

[GLMS13] G. Gottlob, T. Lukasiewicz, M.V. Martinez, and G.I. Simari. Query answering under probabilistic uncertainty in Datalog+/– ontologies. Ann. Math. Artif. Intell., 69(1): 37–72, 2013.

[LMS12] T. Lukasiewicz, M.V. Martinez, and G.I. Simari. Inconsistency handling in Datalog+/– ontologies. In Proc. ECAI, pp 558– 563, 2012.

[LMPS15] T. Lukasiewicz, M.V. Martinez, A. Pieris, and G. I. Simari. From classical to consistent query answering under existential rules. In Proc. AAAI, pp. 1546–1552, 2015.

[LMM+22] T. Lukasiewicz, E. Malizia, M.V. Martinez, C. Molinaro, A. Pieris, G.I. Simari: Inconsistency-tolerant query answering for existential rules. Artif. Intell. 307: 103685 (2022).

[MMSA13] M.V. Martinez, C. Molinaro, V.S. Subrahmanian, and L. Amgoud. A General Framework for Reasoning On Inconsistency. Springer Briefs in Computer Science. 2013.

[MPPSV14] M.V. Martinez, F. Parisi, A. Pugliese, G.I. Simari, and V.S. Subrahmanian. Policy-based inconsistency management in relational databases. Int. J. Approx. Reasoning, 55(2):501– 528, 2014.

**CONDITIONALS**. Following a logico-algebraic approach, it has been recently shown by IIIA researchers [FGH20] that, in a finite setting, conditional events can be endowed with a structure of Boolean algebra and that a (unconditional) probability measure on the initial algebra of plain events can be canonically extended to a (unconditional) probability measure on the Boolean algebra of conditionals which is in fact a conditional probability. A modal fuzzy logic to reason with (compound) conditionals and conditional probability has also been defined [FG21]. The algebraic setting of Boolean algebras of conditionals has been shown to be general enough to also cope with conditional possibility measures [FGU21], see also [RFB23] for a modal algebraic extension. On the other hand, the original approach to conditionals by Bruno de Finetti, who called them tri-events, goes beyond the realm of conditional probability theory and the bounds of classical logic. This long-standing tradition of three-valued conditionals has been further developed in the last ten years, among others, by Gilio and Sanfilippo by interpreting conditionals as numerical random quantities with betting-based semantics, and where the third value is a conditional probability. Interestingly enough, Flaminio and Godo, together with Gilio and Sanfilippo have shown very recently [FGG+22a, FGG+22b, FGG+23] that the apparent contradiction between these two perspectives on conditionals (i.e. interpreting them elements in suitable algebras and as random quantities), actually dissolves once one precisely sets at which level the numerical and the symbolic representation intervene.

[FGG+23] T. Flaminio, A. Gilio, L. Godo, G. Sanfilippo. On conditional probabilities and their canonical extensions to Boolean algebras of compound conditionals. International Journal of Approximate Reasoning, 159, 108943, 2023.

[FGG+22a] T. Flaminio, A. Gilio, L. Godo, G. Sanfilippo. Canonical Extensions of Conditional Probabilities and Compound Conditionals. Proc. of IPMU 2022, CCIS volume 1602, Springer, pp. 584-597, 2022.

[FG21] T. Flaminio and L. Godo. A fuzzy probability logic for compound conditionals. Proc. of the XX Spanish Congress on Fuzzy Logic and Technologies (ESTYLF 20/21), Actas CAEPIA 20/21, pp. 256-261, 2021.

[FGU21] T. Flaminio, L. Godo and S. Ugolini. Canonical Extension of Possibility Measures to Boolean Algebras of Conditionals. In Proc. of ECSQARU, LNCS 12897, pp. 543-556, 2021.

[FGG+22b] T. Flaminio, A. Gilio, L. Godo, and G. Sanfilippo, Compound Conditionals as Random Quantities and Boolean Algebras. In Proceedings of KR, pp. 141–151, 2022.

[FGH20] T. Flaminio, L. Godo, and H. Hosni, Boolean algebras of conditionals, probability and logic, Artificial Intelligence, vol. 286 (2020), 103347.

[RFB23] G. Rosella, T. Flaminio, S. Bonzio. Counterfactuals as modal conditionals, and their probability. Artificial Intelligence, vol. 323, 103970, 2023.

**COMPUTATIONAL ARGUMENTATION**. Regarding computational argumentation, members of the IIIA have recently work on the formalization of the notion of similarity in semi-structured argumentation frameworks [BEBMS20], presenting a mechanism to determine the similarity between two arguments based on descriptors representing particular aspects associated with these arguments that also takes into account the context in which these arguments are uttered. This similarity measure serves as the basis to compute the result of attacks and supports in a (bipolar) argumentation process, refining the such relations and providing the tools to establish a family of new argumentation semantics that considers the similarity between arguments as a crucial part of the argumentation process.

Also, members of the IIIA have also recently worked on defeasible argumentation handling contextual preferences with application to the planning domain [PG18, TG21, TGS22]. The framework is based on the extension of the DeLP argumentation framework with possibilistic weights (P-DeLP), previously developed by members of the IIIA and UdL teams, in collaboration with researchers from the UNS (Argentina) [ABG+16, ACG+08a, ACG+08b]. More recently, we have also worked toward a probabilistic deafeasible argumentation system similar to DeLP [DGV21a,DGV21b].

On the other hand, relating inconsistency handling to argumentation in a more direct way, the work of [MDFS14] extends ontological reasoning (based on the Datalog+- language) with defeasible argumentation reasoning allowing to represent statements whose truth can be challenged leading to a better handling of inconsistency in ontological languages. The work involves the development of a new operational semantics for the language based on a dialogical process that accounts for all arguments (minimal inconsistent proofs within the language) in favor and against a posed query. They also show the set of answers that can be obtained through this semantics relates to existing inconsistency tolerant semantics by changing the preference criterion that is used when contrasting attacking arguments.

[ABG+16] T. Alsinet, R. Béjar, L. Godo, F. Guitart: RP-DeLP: a weighted defeasible argumentation framework based on a recursive semantics. J. Log. Comput. 26(4): 1315-1360 (2016)

[ACG+08a] T. Alsinet, C.I. Chesñevar, L. Godo, G.R. Simari: A logic programming framework for possibilistic argumentation: Formalization and logical properties. Fuzzy Sets Syst. 159(10): 1208-1228 (2008)

[ACG+08b] T. Alsinet, C.I. Chesñevar, L. Godo, S. A. Sandri, G.R. Simari: Formalizing argumentative reasoning in a possibilistic logic programming setting with fuzzy unification. Int. J. Approx. Reason. 48(3): 711-729 (2008).

[BEB+20] P. D. Budan, M. G. Escañuela Gonzalez, M. C. D. Budán, M.V. Martinez, G. R. Simari. Similarity notions in bipolar abstract argumentation. Argument Comput. 11(1-2): 103-149 (2020).

[DGV21b] P. Dellunde, L Godo and A. Vidal. On probabilistic logical argumentation based on conditional probability. Proc. of CCIA 2021, pp. 7--16, 2021.

[DGV21a] P. Dellunde, L Godo and A. Vidal. Probabilistic argumentation: an approach based on conditional probability -- a preliminary report. Proc. of Logics in Artificial Intelligence - 17th European Conference, (JELIA), LNAI 12678, pp. 25--32, 2021.

[MDFS14] M.V. Martinez, C.A.D. Deagustini, M.A. Falappa, G.R. Simari. Inconsistency-Tolerant Reasoning in Datalog± Ontologies via an Argumentative Semantics. IBERAMIA 2014: 15-27, 2014.

[PG18] P. Pardo, L. Godo (2018). A temporal argumentation approach to cooperative planning using dialogues. Journal of Logic and Computation, 28, 551-580.

[TGS22] J.C. Teze, L. Godo, and G.I. Simari. An Approach to Improve Argumentation-Based Epistemic Planning with Contextual Preferences. International Journal of Approximate Reasoning, 151, 130-163, 2022.

[TG21] J.C. Teze, and L. Godo. An Architecture for Argumentation-based Epistemic Planning: A First Approach with Contextual Preferences. IEEE Intelligent Systems, 36, 43-51, 2021.

**SAT, MaxSAT and MinSAT:** We have more than 25 years of experience in the area of satisfiability testing. Actually, several members of the project already did their PhD Thesis on this topic (at IIIA, J. Coll and F. Manyà, at UdL: J. Argelich, R. Béjar, A. Morgado, J. Planes). Moreover, we include in the work team two recognised researchers in this area (C.M. Li and J. Marques-Silva) with whom we have more than 70 joint publications. We started to work on the SAT problem in many-valued logic, where we studied the complexity of different SAT problems [BHM00] and developed several many-valued SAT solvers [MBE98]. Then, we started to work on Boolean encodings of combinatorial problems [AM04,BM00] and, in 2003, we started to work on MaxSAT. In this line, we have made most of the contributions and, as a recognition of the community, we were invited to write one chapter on MaxSAT in the

Handbook of satisfiability [LM21]. We are well-known for proposing several state-of-the-art techniques for branch-and-bound MaxSAT solvers [LMP07], for creating the MaxSAT Evaluation, and for defining complete resolution and tableaux calculi for MaxSAT [BLM07,LMS19]. More recently, we have proposed a clause learning mechanism for branch-and-bound that shows that branch-and-bound MaxSAT solvers are also competitive in industrial instances [LXC+22]. In parallel, we have made theoretical and practical contributions to the MinSAT problem [ALM+13,LM15, LXM21,LZM+12] and proposed some state-of-the-art techniques for SAT solvers [LXL+20]. Thanks to our vivification and bounded variable elimination approaches we have recently won several medals in the SAT Competition.

[AM04] C. Ansótegui, F. Manyà: Mapping Problems with Finite-Domain Variables into Problems with Boolean Variables. In SAT-2004, pp. 1-15, 2004.

[BM00] R. Béjar, F. Manyà: Solving the Round Robin Problem Using Propositional Logic. In AAAI-2000: 262-266, 2000.

[BHM00] B. Beckert, R. Hähnle, F. Manyà: The 2-SAT Problem of Regular Signed CNF Formulas. In ISMVL 2000, pp. 331-336, 2000.

[ALM+13] J. Argelich, CM. Li, F. Manyà, Z. Zhu. Minsat versus maxsat for optimization problems. In *CP 2013*, pp. 133-142, 2013.

[BLM07] M.L. Bonet, J. Levy, F. Manyà. Resolution for Max-SAT. *Artificial Intelligence*, 171(8–9):240–251, 2007.

[LM15] CM. Li, F. Manyà. An Exact Inference Scheme for MinSAT. In IJCAI 2015, pp. 1959-1965, 2015.

[LM21] CM Li, F. Manyà: MaxSAT, Hard and Soft Constraints. Handbook of Satisfiability, pp 903-927, 2021. (2nd edition)

[LM22] CM Li, F. Manyà: Inference in MaxSAT and MinSAT. The Logic of Software. A Tasting Menu of Formal Methods: 350-369, 2022.

[LMP07] CM. Li, F. Manyà, J. Planes. New Inference Rules for Max-SAT. *Journal of Artificial Intelligence Research*, pp. 30:321–359, 2007.

[LMS19] CM. Li, F. Manyà, J. Soler: A Tableau Calculus for Non-clausal Maximum Satisfiability. In TABLEAUX 2019: 58-73, 2019.

[LMV20] CM. Li, F. Manyà, A. Vidal: Tableaux for Maximum Satisfiability in Łukasiewicz Logic. In ISMVL 2020: 243-248, 2020.

[LXC+22] CM. Li, Z. Xu, J. Coll, F. Manyà, D. Habet, K. He: Combining Clause Learning and Branch and Bound for MaxSAT. In IJCAI 2022: 5299-5303, 2022.

[LXL+20] CM. Li, F. Xiao, M. Luo, F. Manyà, Z. Lü, Y. Li: Clause vivification by unit propagation in CDCL SAT solvers. Artificial Intelligence 279, 2020.

[LXM21] CM. Li, F. Xiao, F. Manyà: A resolution calculus for MinSAT. Log. J. IGPL 29(1): 28-44, 2021.

[LZM+12] CM. Li, Z. Zhu, F. Manyà, L. Simon: Optimizing with minimum satisfiability. Artificial Intelligence 190: 32-44, 2012.

[MBE98] F. Manyà, R. Béjar, G. Escalada-Imaz: The satisfiability problem in regular CNF-formulas. Soft Comput. 2(3): 116-123, 1998.