FY2025 Grant for International Project Research IMI Joint Use Research Program Proposal

2026/01/06

所属・職名 University of Queensland・Senior Lecturer

Name: Guillermo Badia

		整理番号	2025b002	
1.研究計画題目	Logic, Algebra and Category Theory: Applications in Computer Science			
2.新規・継続	Continued			
3.種別	国際プロジェクト研究			
4.種目	研究集会（Ｉ）			
5.開催方法				
6.研究代表者	氏名	Guillermo Badia		
	所属 部局名	University of Queensland	職名	Senior Lecturer
7.研究実施期間	2025年09月29日～2025年10月03日			
8.キーワード	logic, algebra, category theory, logic in computer science			
9.参加者人数	32			

10.本研究で得られた成果の概要

The 2nd Workshop on Logic, Algebra and Category Theory (LAC 2025), held in Fukuoka from September 29 to October 3, 2025, continued the LAC series' mission of fostering interdisciplinary research at the intersection of logic, algebra, and category theory, with a strong emphasis on applications in computer science. The workshop provided a platform for exploring foundational mathematical frameworks and their role in specification, verification, database theory, and programming language semantics. A key theme was the use of category theory and universal algebra as unifying tools to reveal structural connections among diverse logical systems and support principled language and tool design.

LAC 2025 featured a balanced mix of academic and industrial contributions, including invited talks on query optimization techniques for Datalog-inspired languages and model-theoretic games with computational tools. The program also highlighted advances in database theory, and the Maude system, alongside discussions on transition algebra and strategy-based rewriting. By combining theoretical insights with practical perspectives, the workshop strengthened ties between foundational research and real-world applications, promoting collaboration across traditionally separate communities.

Further details, including abstracts and slides, are available at https://imi.kyushu-u.ac.jp/lac/2025/index.html.

IMI Workshop of the Joint Usage Research Projects

Workshop on Logic, Algebra and Category Theory: Theory and Applications

Editors: Guillermo Badia, Daniel Găină and Tomasz Kowalski

Aims and Scope The 2nd Workshop on Logic, Algebra and Category Theory (LAC 2025), held in Fukuoka between September 29 and October 3 in 2025, continued the LAC series' objective of fostering interactions between logic, algebra, and category theory, with a strong focus on their applications to computer science. Building on the success of the first edition, LAC 2025 aimed to provide a forum for researchers interested in foundational mathematical methods and their use in areas such as specification, verification, database theory, and programming language semantics.

As outlined in the workshop abstract, one of the core motivations of LAC 2025 was the observation that many specification languages and formal systems are supported by dedicated logics that are often developed in isolation. This proliferation of logical systems can obscure common structures and relationships between logical properties. The workshop therefore emphasized the use of category theory and universal algebra as unifying tools, enabling abstract and reusable reasoning principles that apply across a wide range of logical systems. By focusing on such general mathematical frameworks, the workshop sought to clarify causal relations between logical properties and to support principled language and tool design.

Participants and format LAC 2025 successfully brought together a diverse community of participants from both academia and industry, underscoring the workshop's mission to bridge foundational theory with real-world applications. The audience included early-career researchers (ECRs), who gained valuable exposure to cutting-edge developments and benefited from meaningful interactions with senior experts experienced in both theoretical advances and practical implementations.

Most of the talks were delivered face-to-face, enabling intensive discussions during sessions and informal exchanges during breaks. At the same time, the workshop successfully incorporated a significant number of online speakers, which broadened the participation and allowed contributors who could not travel to present their work and engage in discussions.

Speakers from industry A distinctive feature of LAC 2025 was the presence of high-profile speakers from the industrial sector, highlighting the relevance of logic- and algebra-based methods in real-world systems.

One such talk was delivered by Hung Q. Ngo (RelationalAI), entitled "Optimization Techniques for a Datalog-Inspired Query Language." His presentation focused on the query optimizer used in RelationalAI's logic engine and surveyed a collection of optimization and evaluation techniques developed in the database theory community over the past 15 years. These included worst-case optimal join algorithms, sum-product queries over semirings, variable elimination, tree decomposi-

tions, and tensor decompositions. The talk illustrated how these theoretically grounded techniques can be combined to efficiently evaluate expressive Datalog-inspired query languages, demonstrating a clear and compelling transfer of foundational research into industrial practice.

Another invited industrial talk was given by Jonathan Lenchner (IBM Research), titled "On Some Relatives of the Ehrenfeucht–Fraïssé Game and Software for Helping with the Analysis of these Games." Lenchner introduced the Multi-Structural (MS) game, a variation of the classical Ehrenfeucht–Fraïssé game that measures the total number of quantifiers required to express a first-order sentence, rather than just quantifier depth. He argued that this measure can be strictly more powerful and informative in certain settings. A key aspect of the talk was the presentation of software tools designed to support the analysis of such games, thereby linking abstract model-theoretic concepts with practical computational assistance.

Speakers from academia Beyond Hung Ngo's contribution, the workshop featured several additional talks in database theory, underscoring the strong presence of this topic at LAC 2025. Guillermo Badia presented "Containment of Conjunctive Queries with Equations and Disequations for Databases over Semiring", addressing query containment problems in enriched algebraic settings. Carles Noguera, who participated online, gave a talk entitled "Fagin's Theorem for Semiring Turing Machines", extending classical results in descriptive complexity to semiring-based computation models.

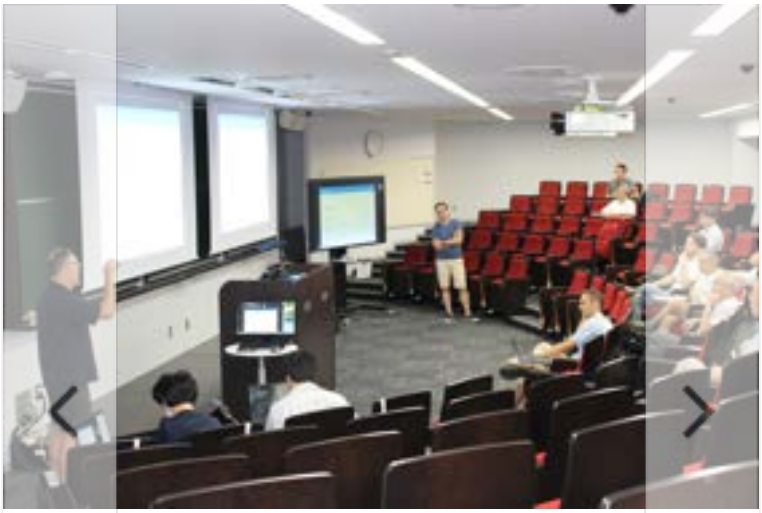
Another major theme of the workshop was the Maude system and its underlying theory. Two talks were directly dedicated to Maude and its tooling: Santiago Escobar presented "Unification and Narrowing in Maude 3.5", reporting on recent advances in unification and narrowing techniques in the latest version of Maude, while Francisco Durán introduced "NuITP: An Inductive Theorem Prover for Maude", showcasing an inductive theorem prover tightly integrated with the Maude environment.

In addition, the program included talks on transition algebra, which provide a theoretical foundation for the Maude strategy language. These contributions strengthened the conceptual links between algebraic theory and practical strategy-based rewriting highlighting how abstract algebraic frameworks can directly inform and justify concrete language design and tool support.

General remarks Beyond the individual technical contributions, LAC 2025 highlighted how advances in logic, algebra, and category theory can have a ripple effect across multiple areas of computer science. New theoretical insights presented at the workshop influence the design of specification languages, database query optimization, and strengthen the foundations of tools such as Maude. In turn, these developments propagate to practical applications in verification, data management, and industrial systems. By bringing together foundational theory and industrial perspectives, the workshop fostered interactions whose impact shapes future research directions and enables the transfer of ideas across traditionally separate communities.

Details about the workshop, including program abstracts and slides, can be found at the following link: `https://imi.kyushu-u.ac.jp/lac/2025/index.html`. This work was supported by the Institute of Mathematics for Industry, Joint Usage/Research Center in Kyushu University. (FY2025 Grant for Project Workshop I Joint Research "Logic, Algebra and Category Theory: Applications in Computer Science" (2025b002))

...PROGRAMME



Monday (Chair: Daniel Găină)

10:00–10:10 Opening

10:10–11:10 Hung Q. Ngo, Optimization techniques for a Datalog-inspired query language

Abstract Slides

11:10–11:40 Guillermo Badia, Containment of Conjunctive Queries with Equations and Disequations for Databases over Semiring

Abstract Slides

11:40–14:30 *Lunch break*

14:30–15:00 Sasha Rubin (online), Tight inference and real-valued logic

Abstract Slides

15:00–15:30 Krzysztof Krawczyk (online), Structural completeness among finitary extensions of R-mingle

Abstract

Tuesday (Chair: Ionut Tutu)

10:00–10:30 Hiroakira Ono, A glance at extensions of bi-intuitionistic logic

Abstract Slides

10:30–11:00 Zbyszek Krol, On some forms of logical connections between theories

Abstract Slides

11:00–12:00 Mark Reynolds, A tree-shaped tableau for Linear Time Temporal Logic

Abstract Slides

12:00–14:00 *Lunch break*

14:00–15:00 Kazuhiro Ogata, Formal Specification and Verification of Post-quantum Cryptographic Protocols with Proof Scores

Abstract Slides

15:00–16:00 Kokichi Futatsugi, Constructing proof scores in CafeOBJ

Abstract Slides

18:00–20:00 Dinner party

Wednesday (Chair: Guillermo Badia)

10:00–11:00 Jonathan Lenchner, On Some Relatives of the Ehrenfeucht-Fraïssé Game and Software for Helping with the Analysis of these Games

Abstract Slides

11:00–12:00 Tomasz Kowalski, Hybrid-Dynamic Ehrenfeucht-Fraïssé Games

Abstract Slides

12:00–14:30 *Lunch break*

14:30–15:00 Diamant Pireva (online), Many-Sorted First-Order Logic with Quantification over Inter-Sort Functions

Abstract

15:00–15:30 Carles Noguera (online), Fagin's Theorem for Semiring Turing Machines

Abstract

Thursday (Chair: Adrian Riesco)

10:00–11:00 Santiago Escobar, Unification and Narrowing in Maude 3.5

Abstract Slides

11:00–12:00 Francisco Durán, NuITP: An Inductive Theorem Prover for Maude

Abstract Slides

12:00–14:00 *Lunch break*

14:00–15:00 Marcel Jackson (online), Minimal signatures for undecidability of representability for relation algebras

Abstract Slides

15:00–16:00 Narciso Martí Oliet (online) and Ruben Rubio, Strategies, qualitative and quantitative model checking in Maude

Abstract Slides

16:00–16:30 Beatriz Alcaide García (online), MongoDB specification in Maude

Abstract Slides

Friday (Chair: Tomasz Kowalski)

10:00–11:00 Ionuț Țuțu, Forcing, Transition Algebras, and Calculi

Abstract Slides

11:00–12:00 Adrián Riesco Rodríguez, Executable Specifications in Transition Algebra

Abstract Slides

12:00–14:00 *Lunch break*

14:00–14:30 Go Hashimoto, Model-theoretic Forcing in Transition Algebra

Abstract Slides

15:00–15:10 Closing