Romain Pascual

Current Position	Postdoc, KASTEL, Karlsruhe Institute of Technology
Address	KASTEL - Institute of Information Security and Dependability Am Fasanengarten 5 76131 Karlsruhe, Germany
Email	romain.pascual@centralesupelec.fr
OrcId	0000-0003-1282-1933
IdHal	romain-pascual
Website	romainpascual.fr

Current situation

I am starting a postdoc position in the Application-oriented Formal Verification group lead by Prof. Bernhard Beckert in the Institute of Information Security and Dependability (KASTEL) at Karlsruhe Institute of Technology. I am part of the CRC 1608 Convide project about consistency in the view-based development of cyber-physical systems. More precisely, I work on the subproject dealing with formalising and relating different notions of consistency and the subproject about the complexity of consistency. The first subproject's goal is to formalise various notions of consistency and understand their properties and relations. The two central notions of consistency are consistency between logical formulas (i.e., formulas which can simultaneously be satisfied) and consistency between (meta)-models (i.e., the existence of a transformation between models). The second project deals with semantics overlaps, i.e., constraints on the same semantic feature of the system to be designed. The subproject aims to provide metrics to measure the impact of approaches that solve such semantic overlaps to guide the integrations of various models within a single meta-model.

Academic career

2024 - : **Postdoc** in the CRC Convide project
Application-oriented Formal Verification group lead by Prof. Bernhard Beckert at KIT.

2022 - 2023: **Attaché temporaire d'enseignement et de recherche**
(postdoc with teaching duties, 192hours/year) Computer Science Department of CentraleSupélec, Université Paris-Saclay.
Affiliated with the MICS laboratory for research.

2019 - 2022: **PhD Student in Computer Science**

Defended on 29 November 2022 at Université Paris-Saclay. Funded by the Ministère de l'Enseignement supérieur, de la Recherche et de l'Innovation (MESRI).

Link: https://romainpascual.fr/uploads/phdthesis.pdf

Title: Inference of graph transformation rules for the design of geometric modeling operations.

Supervision: Pascale Le Gall (supervisor - MICS, CentraleSupélec), Hakim Belhaouari (co-supervisor - XLIM, Université de Poitiers) and Agnès Arnould (co-supervisor - XLIM, Université de Poitiers).

Céline Hudelot	Professor - Université Paris-Saclay	(president of the jury)
Guillaume Damiand	CNRS research director - Université Lyon 1	(reviewer, examiner)
Reiko Heckel	Professor - Leicester University	(reviewer, examiner)
Nicolas Behr	CNRS researcher - Université Paris-Cité	(examiner)
Bedrich Benes	Professor - Purdue University	(examiner)
Jean-Luc Mari	Professor - Université Aix-Marseille	(examiner)

2015-2019: **MSc in Engineering** at CentraleSupélec, top French graduate engineering school of Université Paris-Saclay

Student in the research program at the MICS laboratory (working in the laboratory half a day every week for three years).

Major in computer science and research.

Participation in the SWERC (https://swerc.eu/2018) in 2018. The SWERC is a 5-hour programming contest in teams of three and is the regional selection for the International Collegiate Programming Contest. Along with Adam Hotait and Sébastien Lubineau, we were representing CentraleSupélec, on the invitation of Christoph Dürr, who was teaching advanced algorithms at CentraleSupélec at the time.

Internship at the MICS laboratory in CentraleSupélec.

Title: Graph transformations for the design of geometric modeling operations.

Supervision: Pascale Le Gall (MICS, CentraleSupélec).

2017-2018: **MSc in Theoretical Computer Science** at École normale supérieure Paris-Saclay, top French graduate research-and- higher-education school of Université Paris-Saclay.

Research-oriented master in Computer Science: Algorithmics and Foundation of Programming, ex-MPRI.

Internship in the HPCG laboratory at Purdue University, Indiana, US.

Title: User-assisted urban modeling by simulation of inner-city growth.

Supervision: Bedrich Benes (Purdue University) and Marie-Paule Cani (LIX, École Polytechnique).

Research activities

My research activities focus on utilising **graph transformation rules** for **topology-based geometric modelling**. In a few words, nD objects can be represented by graphs respecting specific constraints, enabling object creation and modification operations to

be modelled through graph transformations. In particular, I studied the **consistency preservation of the model** and the **genericity of operations** described via graph transformation rules.

Consistency preservation is the primary motivation for graph transformations, ensuring the production of well-formed objects by operations. I studied the preservation of topological and geometric consistency through **statically verified syntactic conditions** on rules. To obtain rules that accurately describe the typical operations handled in geometric modelling, I extended the standard rules that describe precisely a transformation with functorial, product-based construction of rule schemes that abstract the underlying topology to simulate the application of a renaming function. Adding geometric information to generalised maps assumes that each topological cell (vertex, edge, face, volume, ...) has a unique value per embedding. However, these topological cells are encoded by subgraphs called orbits, meaning nodes in the same orbit should share the same embedding value. Thus I proposed conditions that ensure the preservation of geometric consistency in graph rewriting rules applied to embedded generalised maps, which are then relaxed by a rule completion mechanism that leverages both topology and geometry.

My thesis deals with the automatic inference of operations to simplify the design of modelling operations. The idea is to retrieve an operation from a representative example consisting of a starting object and a target object, typically chosen by an expert. The inference mechanism exploits the regularity of generalised maps and the dedicated language defined by graph transformation rules. The inference of topological modifications is viewed as the reverse construction of the specialisation of a rule schema to an operation. The question of retrieving algebraic expressions for modifying geometric values can admit multiple solutions depending on the type of geometry and the desired nature of the operations. I proposed reconstructing affine transformations of values in a vector space, solved as a constraint satisfaction problem. The main difficulty here is finding expressions consistent with the topological abstraction of rule schemes. This inference mechanism has been **implemented** in the Jerboa platform, a tool to design geometric modellers, extending it to JerboaStudio.

The initial phase of my work relies on defining a formal framework de facto hidden from the end user yet playing a crucial role in designing geometric modelling operations through the inference mechanism.

Keywords:
Graph transformations: rewriting · formal language · typed attributed graphs · consistency preservation · rule schemes · functorial and product generalisation.
Topology-based geometric modeling: combinatorial maps · operation inference from example · procedural modelling · meshes.
Software engineering: domain-specific language · code synthesis and generation · prototyping · statical analysis.

Work in progress

Following the defence of my PhD, I started two new research projects in collaboration with colleagues from my thesis jury at the intersection of geometric modelling and graph

transformations. I also initiated a collaboration on abstract categorical logic, building on fruitful discussions I had during my PhD with a colleague from the laboratory.

Rule-independent Nested Conditions for Topological Graph Rewriting with Nicolas Behr (IRIF, Paris) and Pascale Le Gall (MICS, Gif-sur-Yvette).
In my PhD thesis, I developed an algorithm verifying the consistency preservation of the models used in geometric modelling. The algorithm exploits a static verification of a rule by analysing the local neighbourhood of the rule's nodes. The algorithm contrasts with the usual methods used by the graph rewriting community [4, 2], where the preservation of global properties usually relies on global computations on the rule. I started a collaboration with Nicolas Behr (IRIF, Paris) and Pascale Le Gall (MICS, Gif-sur-Yvette) to define a categorical framework in which computation and proof methods similar to those developed in my thesis can be applied.

Multicell query-replace for combinatorial maps with Guillaume Damiand and Vincent Nivoliers (LIRIS, Lyon).
The work conducted in my thesis demonstrated the relevance of rewriting techniques for geometric modelling. Following my defence, I was contacted by Guillaume Damiand and Vincent Nivoliers to refine their work on a query-replace approach for combinatorial maps [3]. Intuitively, the goal is to exploit the structure of the model to perform efficient graph-transformation-like rewriting for geometric modelling. Currently, their approach is incompatible with a modification applied at the scale of several topological cells. I co-supervised Jordan Goncalves (M2 intern at LIRIS) on the signatures of combinatorial maps to broaden the scope of their method. I obtained 'mobility' funding from the GDR IGRV for this project, which enabled me to visit LIRIS from 30 May to 2 June 2023.

Ultraproducts in categorical logic with Marc Aiguier (MICS, Gif-sur-Yvette) and Isabelle Bloch (LIP6, Paris).
Abstract categorial logic [1] introduced by Marc Aiguier and Isabelle Bloch relies on an abstraction of quantifiers as natural transformations and provides an interpretation of formulae via the internal logic of a prop-category. I am currently working on a generalization of the ultra-product method in this logic, i.e., a version of Łoś theorem in abstract categorical logic. I will then obtain a quantifier-independent compactness theorem.

Publications

Publications in international peer-reviewed journals:

1. Romain Pascual, Pascale Le Gall, Agnès Arnould and Hakim Belhaouari. "Topological consistency preservation with graph transformation schemes". In: *Science of Computer Programming* 214 (2022), p. 102728. ISSN: 0167-6423. DOI: 10.1016/j.scico.2021.102728
   50 pages.

2. Agnès Arnould, Hakim Belhaouari, Thomas Bellet, Pascale Le Gall and Romain Pascual. "Preserving consistency in geometric modeling with graph transformations". In: *Mathematical Structures in Computer Science* 32.3 (2022), pp. 300–347. ISSN:

0960-1295, 1469-8072. DOI: 10.1017/S0960129522000226
48 pages.

3. Romain Pascual, Hakim Belhaouari, Agnès Arnould and Pascale Le Gall. "Inferring topological operations on generalized maps: Application to subdivision schemes". In: *Graphics and Visual Computing* 6 (2022), p. 200049. ISSN: 2666-6294. DOI: 10.1016/j.gvc.2022.200049
23 pages.

Book chapter:

4. Pascale Le Gall and Romain Pascual. "Transformations de graphes décorés". In: *Informatique Mathématique, Une photographie en 2023*. Ed. by Laurent Fuchs. CNRS Editions, 2023. Chap. 4, pp. 133–176
44 pages.

Publication in a national peer-reviewed conference:

5. Romain Pascual, Pascale Le Gall, Hakim Belhaouari and Agnès Arnould. "Une approche pour inférer les expressions de calcul géométrique en modélisation à base topologique". In: *Approches Formelles dans l'Assistance au Développement de Logiciels (AFADL 2023)*. 2023, p. 11
11 pages.

Talks and presentations

School for young researchers:

- École Jeunes Chercheurs, Jeunes Chercheuses en Informatique Mathématique (school for young researchers organized by the mathematics and computer science CNRS group). 19 - 23 June 2023. Poitiers. With Pascale Le Gall, we presented a course about graph transformations and their application to geometric modeling.
https://ejcim23.sciencesconf.org

National conference:

- AFADL 2023 (Approches Formelles pour l'Assistance au Développement de Logiciels). 6 - 8 June 2023. Rennes.
https://gdrgpl2023.sciencesconf.org/resource/page/id/1

Posters:

- GDR IM national days, JNIM 2023 (mathematics and computer science CNRS group). 4 - 7 April 2023. Paris. Poster **supported by the GTMG**.
https://www.gdr-im.fr/jnim

- Eurographics. 25 - 29 April 2022. Reims. Poster.
  https://eg2022.univ-reims.fr

Presentations in research working group:

- GTMG days (working group on geometric modeling). 16 - 17 March 2022. Dijon. Accessit prize.
  https://gtmg2022.sciencesconf.org
- GReTA Seminar. Combinatorial maps: transformations and application to geometric modeling. 24 September 2021. Online.
  https://www.irif.fr/ greta/event/2021-sep-24
- GTMG days (working group on geometric modeling). 18 - 19 March 2021. Online.
  https://gtmg2021.sciencesconf.org

Presentations in laboratory and team seminars:

- MICS seminar. 14 December 2023. Gif-sur-Yvette.
  http://www.mics.centralesupelec.fr
- Formal Methods seminar at KIT. 16 November 2023. Karlsruhe.
  https://formal.kastel.kit.edu/teaching/researchseminar
- Groupe de travail toposique at Centre Lagrange. 10 November 2023. Paris.
- FM&AI working group at LMF. 6 October 2023. Gif-sur-Yvette.
  https://lmf.cnrs.fr/Research/AI
- APR team seminar at LIP6. 11 April 2023. Paris.
  https://www-apr.lip6.fr/web/doku.php?id=home
- PPS seminar at IRIF. 30 March 2023. Paris.
  https://www.irif.fr/seminaires/pps/index
- G-Mod team seminar at LIS. 3 March 2023. Marseille.
  https://g-mod.lis-lab.fr
- IG team seminar at XLIM. 2 February 2023. Poiters.
  https://www.xlim.fr/recherche/pole-mathematiques-informatique-image/synthese-analyse-dimages/ig
- IG team seminar at XLIM. 16 June 2022. Poiters.
  https://www.xlim.fr/recherche/pole-mathematiques-informatique-image/synthese-analyse-dimages/ig
- MICS seminar. 7 December 2021. Gif-sur-Yvette.
  http://www.mics.centralesupelec.fr
- IG team seminar at XLIM. 5 March 2020. Poitiers.
  https://www.xlim.fr/recherche/pole-mathematiques-informatique-image/synthese-analyse-dimages/ig

Event participation

- MDENet France Workshop 2023. 15 December 2023.
  https://international.mde-network.org/paris23

- GDR GPL national days (software engineering CNRS group). 5 - 8 June 2023. Rennes.
  https://gdrgpl2023.sciencesconf.org
- GDR IG-RV national days (computer graphics CRNS group). 30 - 31 May 2023. Lyon.
  https://plenieres-igrv.sciencesconf.org
- European Joint Conferences on Theory and Practice of Software (ETAPS 2023). 22 - 27 April 2023. Paris.
  https://etaps.org/2023/
- GTMG days (working group on geometric modeling). 15 - 16 March 2023. Strasbourg. Talk by Charles Lepaire.
  https://gtmg2023.sciencesconf.org
- International Conference on Graph Transformation (ICGT 2022), part of STAF. 5 - 8 July 2022. Nantes.
  https://icgt2022.gitlab.io
- International Conference on Graph Transformation (ICGT 2021), part of STAF. 21 - 25 June 2021. Online.
  https://icgt2022.gitlab.io
- International School on Rewriting. 5 - 16 July 2021. Online.
  https://dalila.sip.ucm.es/isr2021

During my doctoral studies, I participated in the Défi 6' competition organized by the Graduate School Sciences de l'Ingénierie et des Systèmes. This competition aims to popularize our thesis projects, similar to the Three Minute Thesis competition. I competed in December 2021 and was part of the jury in January 2023.

Software development

Contributor to the Jerboa platform. Source code available online.
https://gitlab.com/jerboateam

Jerboa is a platform for rapid prototyping of topology-based geometric modelers. Operations are defined as rules and automatically checked by a static analyser. The formal rules are then converted into code (`Java`) used to modify the objects.

- Implementation of the topological analyser ($\sim$ 750 lines of `Java`).
- Implementation of a rule inference module and the JerboaStudio tool ($\sim$ 8500 lines of `Java`).
  https://gitlab.com/jerboateam/jerboa-studio

Teaching

All of my teaching activities were conducted at CentraleSupélec, first during my PhD thesis and then as an ATER. I have currently thought for 366 hours since 2019:

Algorithmics	85,5 hours
Programming in `Python`	149,5 hours
Tutoring	12 hours
Theoretical computer science	119 hours

Collective and administrative responsibilities

2022: Elected doctoral student representative on the laboratory board.

2019: Organisation of the Congrès Scientifique du Campus de Saclay (CS^2)
I co-organisation a one-day event featuring scientific talks on engineering-related topics for higher-education students in Saclay.
https://cs2-2019.sciencesconf.org

References

[1] Marc Aiguier and Isabelle Bloch. "Abstract Categorical Logic". In: *Logica Universalis* 17 (Mar. 2023), pp. 23–67. ISSN: 1661-8300. DOI: 10.1007/s11787-022-00320-w.

[2] Nicolas Behr and Jean Krivine. "Compositionality of Rewriting Rules with Conditions". In: *Compositionality* 3.2 (Apr. 2021), p. 51. ISSN: 2631-4444. DOI: 10.32408/compositionality-3-2.

[3] Guillaume Damiand and Vincent Nivoliers. "Query-replace operations for topologically controlled 3D mesh editing". In: *Computers & Graphics* (June 2022). ISSN: 0097-8493. DOI: 10.1016/j.cag.2022.06.008.

[4] Annegret Habel and Karl-Heinz Pennemann. "Correctness of high-level transformation systems relative to nested conditions". In: *Mathematical Structures in Computer Science* 19.2 (Apr. 2009). Publisher: Cambridge University Press, pp. 245–296. ISSN: 1469-8072, 0960-1295. DOI: 10.1017/S0960129508007202.