General Information

Paul Joseph WOLLAN

Date of Birth: 21 September 1976

Place of Birth: Seattle, USA

Citizenship: United States of America

Permanent Address and contact:

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Spoken Languages: Italian (fluent), English (native), German (basic)

Education

Georgia Institute of Technology, USA Aug 2001 - Dec 2005

Ph.D. in Algorithms, Combinatorics, and Optimization

- Dissertation title: "Extremal Functions for Graph Linkages and Rooted Minors".
- Advisor: Prof. Robin Thomas.

University of Chicago, USA Sept 1995 - June 1999

Bachelor of the Arts in Mathematics with Honors

Academic Appointments

Dec 2008 - current: **Sapienza University of Rome**, Dip. Informatica *Professore Associato*

- Ricercatore from Dec 2008 - Oct 2013
- Confermato Feb 2012.
- Habilitation *(Abilitazione)* for full professor awarded Jan 2015.

Jan 2007 - Dec 2008: **University of Hamburg**, Dept. of Math, Germany *Humboldt Research Fellow*

Jan 2006 - Jan 2007: **University of Waterloo**, Dept. of C & O, Canada *Postdoctoral Research Fellow*

Aug 2001 - Dec 2005: **Georgia Institute of Technology**, USA *Grad Assistant and PhD Candidate*

Sept 2000 - June 2001: **Los Alamos National Laboratory**, USA *Grad Research Assistant*

Other Appointments - Visited Institutions

Technical University Berlin, Berlin, Germany *Visiting Professor*
Sept 2015

Georgia Institute of Technology, Dept. of Mathematics, USA *Visiting Professor*
Jan - June 2011, Jan - June 2012, Jan - June 2013 , Jan-March 2014, July-August 2016

National Institute for Informatics, Tokyo, Japan *Visiting Professor*
Aug - Sept 2009, Sept 2011, Nov 2014, Oct 2015

Columbia University, New York, USA *Visiting Professor*
July 2013

Hamburg University, Hamburg, Germany *Visiting Researcher*
March - July 2009

Princeton University, Princeton, USA *Visitor*
Dec 2008, March 2010, Feb 2014

INRIA-CNRS Mascote project-team, Sophia-Antipolis, France *Visitor*
July 2008

Teaching Experience - Courses Taught

University of Rome, Rome, Italy: 2009 - present
Instructor
Graph Theory - *Laurea Magistrale*. Lead Instructor, taught 6 times: 2010 - 2016.
Progettazione di Algoritmi - *Laurea Trienale*. Lead Instructor, taught twice 2015 - 2016.
Fondamenti di Programazzione - *Laurea Trienale*. Laboratory Section, taught 4 times: 2010 - 2014.

University of Hamburg, Hamburg, Germany: 2009
Instructor
Graph Minors - PhD course. Lead Instructor, taught once 2009.

University of Waterloo, Waterloo, Canada: 2006
Instructor
Linear Algebra - Undergraduate course. Instructor, taught once 2006.

Georgia Institute of Technology, Atlanta, USA: 2004 - 2013
Lead Instructor
Combinatorics - Undergraduate course. Lead Instructor, taught twice 2004, 2011.
Advanced Combinatorial Optimization - PhD course. Lead Instructor, taught twice 2012, 2013.

Teaching Experience - Supervised Students and Postdocs

- Katherine Edwards, 2015 - 2016 *Assegno di Ricerca*
  - PhD Princeton University 2016
  - Currently Research Staff, Bell Labs
- Gregory Gauthier, 2015 - 2016 *Assegno di Ricerca*
  - PhD Princeton University 2016
- Spencer Backman, 2014 - 2015 *Assegno di Ricerca*
  - PhD Georgia Institute of Technology 2014

- Currently Postdoctoral researcher, University of Bonn

- Ringi Kim, 2014 - 2015 *Borsa di Studio*
  - PhD Princeton University 2016
  - Currently Postdoctoral researcher, University of Waterloo
- Tony Huynh, 2013 - 2015 *Assegno di Ricerca*
  - PhD University of Waterloo 2009
  - Currently Postdoctoral researcher, University of Belgium
- Irene Muzi, current *PhD Student*
- Jan-Oliver Froehlich, 2014-2015 *Assegno di Ricerca*
  - PhD University Hamburg 2013
- Matteo Pontecorvi, 2011 *Laurea Specialistica*
  - Currently PhD Candidate in the University of Austin Department of Computer Science
  - Thesis work published in *J. Combin. Theory Ser B*, entitled "Disjoint cycles intersecting a set of vertices."

Awards and Honors

- 2013: Promoted to Associate Professor at Sapienza University through *chiamata diretta*.
- 2012: Invited to present as representative of the faculty at the Inaugaration of the Academic Year 2012 - 2013 at Sapienza University.
- 2006 - 2007: Humboldt Research Fellowship, awarded by the Alexander von Humboldt Foundation and hosted by the University of Hamburg.
- 2005: "Graduate Student of the Year" 2004-2005, Department of Mathematics, Georgia Institute of Technology.
- 2004: NSF VIGRE research fellowship, Department of Mathematics, Georgia Institute of Technology
- 2000: Presidential Fellow, Georgia Institute of Technology, 2000 - 2005.

Invited Plenary Presentations

1. *When Are Directed Graphs Well-quasi-ordered*, Colloquia in Combinatoric, London School of Economics, May 2014.
2. *A New Proof for the Weak-Structure Theorem with Explicit Bounds*, Dagstuhl Seminar "Bidimensional Structures: Algorithms, Combinatorics and Logic", Germany, March 2013.
3. *Explicit Bounds for the Weak-Structure Theorem*, Workshop on Graphs and Matroids, Maastricht, Netherlands, August 2012.
4. *Excluding a Clique Immersion*, Graph Theory at Georgia Tech, Atlanta, May 2012.
5. *New Proofs in Graph Minors*, Mathematical Foundations of Computer Science (MFCS), Warsaw, Poland, August 2011.
6. *A Shorter Proof of the Unique Linkage Theorem*, Oberwolfach Workshop, Oberwolfach, Germany, March 2010.

Other Invited Presentations

1. Packing cycles in doubly group labeled graphs, SIAM Discrete Mathematics, Atlanta USA, July 2016.
2. *Explicit bounds for the graph minor structure theorem*, Oberwolfach Graph Theory, Oberwolfach, Germany January 2016.
3. *When Are Directed Graphs Well-quasi-ordered*, ICM Satellite Conference on Extremal and Structural Graph Theory, Gyongju Korea, August 2014.
4. *Packing Disjoint A-paths With Specified Ends*, SIAM Discrete Mathematics, Minneapolis USA, July 2014.
5. *Packing A-paths With Specified Endpoints*, Bellairs Workshop on Graph Theory, Holetown, Barbados, March 2014.
6. *Immersions in Highly Connected Graphs*, Oberwolfach Workshop, Oberwolfach, Germany, March 2013.
7. *A Short Proof of the Unique Linkage Theorem*, Atlanta Lecture Series in Combinatorics and Discrete Math, Atlanta, April 2011.
8. *A Shorter Proof of the Unique Linkage Theorem*, SIAM Conference on Discrete Mathematics, Austin, June 2010.
9. *Linking Vortices*, Workshop on Graph Theory, Princeton, May 2009.
10. *Non-zero Cycles in Group Labeled Graphs*, Banf Workshop, Banf, Canada, September 2008.
11. *Packing Disjoint Clique Minors*, Sittard, Netherlands, July 2008.
12. *Complete Minors in Large Six Connected Graphs*, Graph Theory 2007, Fredericia, Denmark, December 2007.
13. *Progress on Removable Paths Conjectures*, Oberwolfach Workshop, Oberwolfach, Germany, March 2007.
14. *K_6 Minors in Large Six Connected Graphs*, SIAM Conference on Discrete Mathematics, Victoria, Canada, June 2006.
15. *Extremal Functions for Linkages and Rooted Minors*, ACCOTA, Combinatorial and Computational Aspects of Optimization, Topology, and Algebra, Guanajuato, Mexico, October 2004.
16. *The Extremal Function for 3-linked Graphs*, SIAM Conference on Discrete Mathematics, Nashville, June 2004.

Professional Activities

- Associate Editor: Discrete Mathematics, 2016 - current.
- Scientific Committee member: SIAM Conference on Discrete Mathematics 2016, Graph Theory at Georgia Tech 2013.
- Program Committee member: SIAM Symposium on Discrete Algorithms (SODA) 2014, Workshop on Approximation and Online Algorithms (WAOA) 2012, 2015, European Symposium on Algorithms (ESA) 2016.
- Reviewer for national scientific funding agencies: National Science Foundation and National Security

Agency (USA), 2008, 2010 - 2013, the Australian Research Council 2011 - 2013, the National Science and Engineering Research Council of Canada 2011, 2014, FONDECYT of Chile, 2011, Czech Science Foundation 2014, and Ministero dell'Instruzione, dell'Universitá e della Ricerca 2015.

- Chaired of invited session "Structural Graph Theory and Methods," at the International Symposium on Math Programming (ISMP) in Berlin in Aug 2012. Chair of the invited session "Graph Structure" at the SIAM Conference on Discrete Math held in Minneapolis in June 2014.
- Organizer of 6 international conferences and workshops: Graph Theory at Georgia Tech in Atlanta, USA 2012, the Bertinoro Workshop on Algorithms and Graphs in 2009, 2011, and 2013, the Southern Italian Workshop on Algorithms and Graphs 2016, and the CIRM Workshop on Graph Theory 2015.

Funding Information

2011 - 2017: ERC DASTCO - *European Research Council Starter Grant* **850,000 €**

Principal Investigator of the ERC project DASTCO, a 5 year project to study structural aspects of signed and directed graphs. Budget includes funding for 2 graduate students and six 1-year post doctoral positions. Awarded by the European Union Research Council.

2007 - 2008: *Humboldt Foundation Research Fellowship:* **69,000 €**

Recipient of a Humboldt Research Fellowship hosted by Prof. Reinhard Diestel at the University of Hamburg. Originally funded for one year, awarded the maximum extension of 1 year in 2008.

2012 - 2013: *ATENEO Grant:* **25,500 €**

Principal Investigator for a project on problems in graph theory and aspects of proof complexity. Funded by the internal funding agency of the University of Rome La Sapienza.

2017 - 2017: *ATENEO Grant:* **8000 €**

Principal Investigator for a project on applications of graph theory in theoretical computer science. Funded by the internal funding agency of the University of Rome La Sapienza.

Research Activities

keywords: Graph Algorithms, Graph Theory, Graph Minors, Disjoint Paths

Brief Description: Paul Wollan utilizes structural graph theoretic techniques to tackle problems on finite structures in graphs. This has yielded numerous algorithmic results: highlights include proving the fixed parameter tractability of topological subgraph testing, proving a conjecture of Downey from 1992, and also of the parity disjoint paths problem, answering several conjectures of Thomassen from 1997. Wollan's approach also has had numerous successes in theoretical graph theory, including the development of a structure theory for excluded graph immersions and in answering an open question of Rota on infinite matroids from 1947.

Summary of Scientific Achievements

Total of 32 published international articles from 2005 - 2016.

27 articles in international journals, 5 articles in international refereed conference proceedings.

Values from Scopus database.

Parameter	**Database**	**Value**
Total impact factor*	researchgate	32.86
Total citations	scopus	250
Average citations per product	scopus	7.81
H-index	scopus	9
Normalized H-index**	scopus	.82

* Total impact factor calculated as the sum of impact factor in the year of publication of all journal publications. When the impact factor for a given year is unavailable, the 5-year impact factor is used.

**Normalized H-index calculated as H-index divided by the number of years since first published article.

Most Significant Publications

1. D. Marx, and P. Wollan, "An Exact Characterization of Tractable Demand Patterns for Maximum Disjoint Path Problems." *Proceedings of the ACM/SIAM Symposium on Discrete Algorithms (SODA) 2015*, 642 – 661.
   - Summary: gives a complete characterization of the demand graphs for which the Maximum Disjoint Paths (MDP) problem is fixed parameter tractable. This is one of first results to study the MDP problem through the structural properties of the demand graph.

2. P. Wollan, "The structure of graphs not admitting a fixed immersion." *J. Combin. Theory, Ser. B.* **110** (2015) 47 – 66.
   - Journal Impact Factor: 1.3
   - citations: 5 - 84th percentile (scopus)
   - Field weighted citation impact: 6.06
   - Summary: develops a structure theory for graph immersions analogous to the graph minor structure theory of Robertson and Seymour, including a general structure theorem and a new width parameter with corresponding grid theorem. Applications include new FPT algorithms for problems not efficiently solvable in graphs of bounded tree-width.

3. D. Marx and P. Wollan "Immersions in highly edge connected graphs." *SIAM Journal of Discrete Math.* **28 (1)** (2014) 503 – 520.
   - Journal Impact Factor: 1.13 (researchgate)
   - citations: 3 - 60th percentile (scopus)
   - Field weighted citation impact: 2.49 (scopus)
   - Summary: gives a characterization of graphs minimally edge connected graphs which exclude a fixed graph immersion. Applications include a characterization of minimal counterexamples to the graph immersion analog of Hadwiger's Conjecture.

4. H. Bruhn, R. Diestel, M. Kriesell, R. Pevindigh, and P. Wollan, "Axioms for Infinite Matroids." *Advances in Mathematics.* **239** (2013) 18 – 46.
   - Journal Impact Factor: 1.79 (researchgate)
   - citations: 10 - 86th percentile (scopus)
   - Field weighted citation impact: 4.37
   - Summary: answers an open problem of Rota from 1947 by developing a theory of infinite matroids with duality, minors.

5. M. Grohe, K. Kawarabayashi, D. Marx, and P. Wollan, "Finding Topological Subgraphs is Fixed Parameter Tractable." *Proceedings of the ACM Symposium on Theory of Computing (STOC) 2011*, 479 – 488.
   - citations: 26 - 98th percentile (scopus)
   - Field weighted citation impact: 6.00 (scopus)
   - Summary: proves the existence of a fixed parameter time algorithm for testing topological minor containment in graphs. This resolved an open question of Downey and Fellows from 1992 and was one of the most significant open problems of the time in the theory of FPT-time algorithms.

6. K. Kawarabayashi and P. Wollan, "A Simpler Algorithm and Shorter Proof for the Graph Minors Decomposition." *Proceedings of the ACM Symposium on Theory of Computing (STOC) 2011*, 451 – 458.
   - citations: 10 - 88nd percentile (scopus)
   - Field weighted citation impact: 2.00 (scopus)
   - Summary: gives a simplified, self contained proof of the graph minors structure theorem which both yields an explicit polynomial time algorithm to find the decomposition and gives explicit bounds on the parameters involved. Moreover, the length of the proof is reduced from over 400 pages in the original work to less than 100.

7. P. Wollan, "Packing Cycles with Modularity Constraints." *Combinatorica* **31**, (2011) 95 – 126.
   - Journal Impact Factor: 1.33 (researchgate)
   - citations: 6 - 60th percentile (scopus)
   - Field weighted citation impact: .89 (scopus)
   - Summary - shows that the Erdős-Pósa property holds for the cycles of non-zero length ($\bmod m$) if and only if m is odd, answering a question of Dejter and V. Neumann-Lara from 1985.

8. K. Kawarabayashi, B. Reed, and P. Wollan, "The Graph Minor Algorithm with Parity Conditions." *Proceedings of the IEEE Symposium on Foundations of Computer Science (FOCS) 2011*, 27 – 36.
   - citations: 8 - 91st percentile (scopus)
   - Field weighted citation impact: 4.16 (scopus)
   - Summary - extends the Robertson-Seymour theory of graph minors to signed graphs, proving that there exists an FPT algorithm for disjoint paths with parity constraints on the path lengths, resolving several conjectures of Thomassen from 1997.

9. K. Kawarabayashi and P. Wollan, "A Shorter Proof of the Graph Minors Algorithm - The Unique Linkage Theorem." *Proceedings of the AMS Symposium on the Theory of Computing (STOC) 2010*, 687 – 694.
   - citations: 21 - 95th percentile (scopus)
   - Field weighted citation impact: 5.59 (scopus)
   - Summary: presents a self-contained proof for the Unique Linkage Theorem, giving a new proof of correctness for the k-disjoint paths algorithm which includes explicit bounds of run-time of the algorithm. The proof is less than 60 pages, as opposed to over 400 in the original proof.

10. K. Kawarabayashi, O. Lee, B. Reed, and P. Wollan, "A Weaker Version of Lovász' Path Removal Conjecture." *J. Combin. Theory, Ser. B* **98**, (2008) 972 – 979.
    - Journal Impact Factor: 1.73 (researchgate)
    - citations: 9 - 62nd percentile (scopus)
    - Field weighted citation impact: 1.22 (scopus)
    - Summary - in the 1970's, Lovász conjectured that if a graph is sufficiently connected, then for any

pair of vertices there exists a path connected them whose deletion leaves the graph k-connected. The conjecture remains open for $k \geq 3$. This paper shows that a variant of the conjecture holds when we delete the edges of the path instead of the vertices.

11. S. Norine, P. Seymour, R. Thomas, and P. Wollan, "Proper Minor-Closed Families are Small." *J. Combin. Theory, Ser. B* **96**, (2006) 754 – 757.
    - Journal Impact Factor: 1.33 (researchgate)
    - citations: 31 - 86th percentile (scopus)
    - Field weighted citation impact: 3.46 (scopus)
    - Summary: gives an asymptotic bound on the number of distinct labeled graphs in minor closed classes, resolving an open question of Welsh from 2004. The result has had numerous applications in proving efficient mixing for markov processes for generating random planar graphs.

12. R. Thomas and P. Wollan, "An Improved Linear Edge Bound for Graph Linkages." *European J. of Combinatorics* **26**, (2005) 309 – 324.
    - Journal Impact Factor (5 year): .62
    - citations: 53 - 96th percentile (scopus)
    - Field weighted citation impact: 6.82 (scopus)
    - Summary: gives a short, first principles proof that all $10k$-connected graphs are k-linked. The proof has become a standard result in the field and is included in its entirety in the third edition of Diestels "Graph Theory".

Full List of Publications

JOURNAL:

1. R. Thomas and P. Wollan, "An Improved Linear Edge Bound for Graph Linkages." *European J. of Combinatorics* **26**, (2005) 309 – 324.
2. G. Brinkmann, S. Greenberg, C. Greenhill, B. McKay, R. Thomas, and P. Wollan, "Generation of Simple Quadrangulations of the Sphere." *Discrete Math.* **305**, (2005) 33 – 54.
3. K. Kawarabayashi and P. Wollan, "Non-zero Disjoint cycles in Highly Connected Group Labeled Graphs." *J. Combin. Theory, Ser. B* **96**, (2006) 296 – 301.
4. S. Norine, P. Seymour, R. Thomas, and P. Wollan, "Proper Minor-Closed Families are Small." *J. Combin. Theory, Ser. B* **96**, (2006) 754 – 757.
5. P. Wollan, "Extremal Functions for Shortening Sets of Paths." *Combinatorics, Probability, and Computing* **15**, (2006) 927 – 932.
6. R. Thomas and P. Wollan, "The Extremal Function for 3-linked Graphs." *J. Combin. Theory, Ser. B* **98**, (2008) 939 – 971.
7. K. Kawarabayashi, O. Lee, B. Reed, and P. Wollan, "A Weaker Version of Lovász' Path Removal Conjecture." *J. Combin. Theory, Ser. B* **98**, (2008) 972 – 979.
8. P. Wollan, "Extremal Functions for Rooted Minors." *J. Graph Theory* **58** vol. 2, (2008) 159 – 178.
9. P. Wollan, "Packing Non-zero A-paths in an Undirected Model of Group Labeled Graphs." *J. Combin. Theory, Ser. B* **100**, (2010) 141 – 150.

10. D. Berg, S. Norine, F. E. Su, R. Thomas, and P. Wollan, "Voting in Agreeable Societies." *AMS Math. Monthly* **117**, (2010) 27 – 39.
11. P. Wollan, "Bridges in Highly Connected Graphs." *SIAM J. Disc. Math.* **24**, (2010) 1731 – 1741.
12. P. Wollan, "Packing Cycles with Modularity Constraints." *Combinatorica* **31**, (2011) 95 – 126.
13. R. Diestel, K. Kawarabayashi, and P. Wollan, "The Erdős-Pósa Property for Clique Minors in Highly Connected Graphs." *J. Combin. Theory, Ser. B* **102**, (2012) 454 – 469.
14. H. Bruhn and P. Wollan, "Finite Connectivity in Infinite Matroids." *European J. of Combinatorics* **33** (2012) 1900 – 1912.
15. M. Pontecorvi and P. Wollan, "Disjoint Cycles Intersecting a Set of Vertices." *J. Combin. Theory, Ser. B* **102** (2012) 1134 – 1141.
16. R. Diestel, K. Kawarabayashi, T. Müller, and P. Wollan, "On the Excluded Minor Structure Theorem for Graphs of Large Tree-width." *J. Combin. Theory, Ser. B* **102** (2012) 1189 – 1210.
17. B. Guenin, I. Pivotto, and P. Wollan, "Relations Between Pairs of Representations of Signed Binary Matroids." *SIAM J. Disc. Math.* **27** (2013) 329 – 341.
18. H. Bruhn, R. Diestel, M. Kriesell, R. Pevindigh, and P. Wollan, "Axioms for Infinite Matroids." *Advances in Mathematics* **239** (2013) 18 – 46.
19. D. Marx and P. Wollan, "Immersions in highly connected graphs" *SIAM J. of Disc. Math.* **28**(1) (2014) 503 – 520.
20. P. Wollan, "The structure of graphs not admitting a fixed immersion." *J. Combin. Theory, Ser. B.* **110** (2015) 47 – 66.
21. B. Guenin, I. Pivotto, and P. Wollan, "Displaying Blocking Pairs in Signed Graphs." *Europ. J. Combin.* **51** (2016) 135 – 164.
22. B. Guenin, I. Pivotto, and P. Wollan, "Stabilizer Theorems for Even Cycle Matroids." to appear: *J. Combin. Theory, Ser B.*
23. Z. Dvorak and P. Wollan, "A structure theorem for strong immersions." to appear: *J. Graph Theory.*
24. K. Kawarabayashi, S. Norine, R. Thomas and P. Wollan, "K_6 Minors in 6-connected Graphs of Bounded Treewidth." to appear: *J. Combin. Theory, Ser. B.*
25. K. Kawarabayashi, S. Norine, R. Thomas, and P. Wollan, "K_6 Minors in Large 6-connected Graphs." to appear: *J. Combin. Theory, Ser. B.*
26. K. Kawarabayashi, R. Thomas, and P. Wollan, "A new proof of the flat wall theorem." to appear: *J. Combin. Theory, Ser B.*
27. D. Marx, P. Seymour, and P. Wollan, "Rooted grid minors." to appear: *J. Combin. Theory, Ser B.*

REFEREED CONFERENCE PROCEEDINGS:

28. K. Kawarabayashi and P . Wollan, "A Shorter Proof of the Graph Minors Algorithm - The Unique Linkage Theorem." *Proceedings of the AMS Symposium on the Theory of Computing (STOC) 2010*, 687 – 694.

29. K. Kawarabayashi, B. Reed, and P. Wollan, "The Graph Minor Algorithm with Parity Conditions." *Proceedings of the IEEE Symposium on Foundations of Computer Science (FOCS) 2011*, 27 – 36.
30. K. Kawarabayashi and P. Wollan, "A Simpler Algorithm and Shorter Proof for the Graph Minors Decomposition." *Proceedings of the ACM Symposium on Theory of Computing (STOC) 2011*, 451 – 458.
31. M. Grohe, K. Kawarabayashi, D. Marx, and P. Wollan, "Finding Topological Subgraphs is Fixed Parameter Tractable." *Proceedings of the ACM Symposium on Theory of Computing (STOC) 2011*, 479 – 484.
32. D. Marx, and P. Wollan, "An Exact Characterization of Tractable Demand Patterns for Maximum Disjoint Path Problems." *Proceedings of the ACM/SIAM Symposium on Discrete Algorithms (SODA) 2015*, 642 – 661.

SUBMITTED ARTICLES:

33. P. Bennett, I. Bonacina, N. Galesi, T. Huynh, M. Molloy, and P. Wollan, "Space proof complexity for random 3-CNFs." submitted to: *Information and Computing*.
34. S. A. Amiri, K. Kawarabayashi, S. Kreutzer, and P. Wollan, "The Erdős-Pósa property for directed graphs."
35. F. Joos, T. Huynh, and P. Wollan, "A unified Erdős-Pósa theorem for labeled graphs." submitted to: *Combinatorica*.