

## **Giovanni Manzini**

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### PROFESSIONAL EXPERIENCE

- 2010-** Research associate, Institute of Informatics and Telematics of the Italian National Research Council.
- 2006-** Professor of Computer Science, University of Eastern Piedmont.
- 2000-2006** Associate professor of Computer Science, University of Eastern Piedmont.
- 1995-2000** Assistant professor of Numerical Analysis, University of Eastern Piedmont.
- 1995** PhD in Mathematics, Scuola Normale Superiore, Pisa.

### RESEARCH INTERESTS

My current research interests are algorithms and data structures for data compression and indexing, with applications to Bioinformatics and Web Information Retrieval. My main contribution to this field is the theoretical and practical development of the so-called FM-index, which was the first data structure to support efficient substring searches in a compressed, indexed text. This result has started the new field of compressed text indexing which has flourished and found many applications and whose concepts have been recently extended to other domains (e.g., representation of trees and graphs).

### MAIN SCIENTIFIC ACTIVITIES

Member of the Program Committee (also Chair) for the Conferences SPIRE, CPM, IWOCA, WABI, AICoB, LATIN, ICTCS and FUN. Co-organizer of the DIMACS Workshop *The Burrows-Wheeler Transform: Ten Years Later* (2004), and Guest Editor of two special issues of *Theoretical Computer Science*.

Invited Professor at the John Hopkins University (Baltimore) and the University of Melbourne. Invited speaker at the conferences CPM, WCTA, IWOCA and MFCS.

Referee for the journals: Journal of the ACM, SIAM Journal on Computing, Algorithmica, ACM Journal on Experimental Algorithmics, ACM Computing Surveys, ACM Transactions on Information Systems, ACM Transactions on Algorithms, IEEE Transactions on Computers, IEEE Transactions on Parallel and Distributed Systems, Theoretical

Computer Science, The Computer Journal, INFORMS Journal on Computing, Artificial Intelligence, IEEE Transactions on Knowledge and Data Engineering, and others.

## RESEARCH PROJECTS

Participant in the project *RepeatALS* founded by AriSLA (Italian Research Association on Amyotrophic Lateral Sclerosis) on the study of Tandem Repeats Polymorphism in ALS patients (2014–2015). Site leader for the Italy-Israel FIRB Project *Pattern Matching and Discovery Algorithms in Discrete Structures with Applications to Bioinformatics* (2006–2009). Participant in many projects funded by MIUR and the National Research Council on Algorithms and Scientific Calculus (1994–2002).

## AWARDS AND PATENTS

**2007** US Patent 8156156 B2 “Method of structuring and compressing labeled trees of arbitrary degree and shape” (with P. Ferragina, F. Luccio; S. Muthukrishnan).

**2004** The software library Deep-Shallow Suffix Sorter [16] licensed for use in the commercial package LEDA by Algorithmic Solutions GMBH.

**2002** Research Capital Award from the University of Pisa.

## PUBLICATIONS

According to Google Scholar, as of January 2017 my publications got 4436 citations and my H-index is 31.

### International Journals

- [1] Travis Gagie, Giovanni Manzini, Jouni Sirén:  
*Wheeler graphs: A framework for BWT-based data structures.*  
**Theor. Comput. Sci.** 698: 67-78 (2017)
- [2] T. Gagie, G. Manzini, D. Valenzuela.  
*Compressed Spaced Suffix Arrays.*  
**Mathematics in Computer Science**, 11(2): 151-157 (2017).
- [3] L. Egidi, G. Manzini  
*Multiple seeds sensitivity using a single seed with threshold.*  
**J. Bioinformatics and Computational Biology**, Vol. 13, (2015).
- [4] L. Egidi, G. Manzini  
*Design and Analysis of Periodic Multiple Seeds.*  
**Theoretical Computer Science**, Vol. 522, (2014), 62-76.

- [5] L. Egidi, G. Manzini  
*Spaced Seeds Design Using Perfect Rulers.*  
**Fundam. Inform.**, Vol. 131, (2014), 187-203.
- [6] L. Egidi, G. Manzini  
*Better Spaced Seeds using Quadratic Residues.*  
**Journal of Computer and System Sciences**, Vol. 79, (2013), 1144-1155.
- [7] P. Ferragina, T. Gagie, G. Manzini  
*Lightweight Data Indexing and Compression in External Memory.*  
**Algorithmica**, Vol 63 (2012), 707–730.
- [8] T. Gagie, G. Manzini.  
*Move-to-Front, Distance Coding, and Inversion Frequencies revisited.*  
**Theoretical Computer Science**, Vol. 411, (2010), 2925–2944.
- [9] P. Ferragina, F. Luccio, G. Manzini, S. Muthukrishnan.  
*Compressing and Indexing Labeled Trees, with Applications.*  
**Journal of the ACM**, Vol. 57, n. 1, (2009).
- [10] P. Ferragina, R. Giancarlo, G. Manzini.  
*The Myriad Virtues of Wavelet Trees.*  
**Information and Computation**, Vol. 207, (2009), 849–866.
- [11] P. Ferragina, R. Giancarlo, V. Greco, G. Manzini, G. Valiente.  
*Compression-based Classification of Biological Sequences and Structures via the Universal Similarity Metric: Experimental Assessment.*  
**BMC Bioinformatics**, Vol. 8, (2007).
- [12] P. Ferragina, G. Manzini, V. Mäkinen, G. Navarro.  
*Compressed Representations of Sequences and Full-Text Indexes.*  
**ACM Transactions on Algorithms**. Vol. 3, n. 2, (2007).
- [13] P. Ferragina, G. Manzini.  
*Indexing Compressed Text.*  
**Journal of the ACM**, Vol. 52, (2005), 552–581.
- [14] P. Ferragina, R. Giancarlo, G. Manzini, M. Sciortino.  
*Boosting Textual Compression in Optimal Linear Time.*  
**Journal of the ACM**, Vol. 52, (2005), 688–713.
- [15] G. Manzini. M. Rastero  
*A Simple and Fast DNA Compressor.*  
**Software: Practice and Experience**, Vol. 34, (2004), 1397–1411.
- [16] G. Manzini, P. Ferragina.  
*Engineering a Lightweight Suffix Array Construction Algorithm.*  
**Algorithmica**, Vol. 40, (2004), 33–50.

- [17] M. D'amico, G. Manzini, L. Margara.  
*On Computing the Entropy of Cellular Automata.*  
**Theoretical Computer Science**, Vol 290, (2003), 1629–1646.
- [18] G. Manzini.  
*An Analysis of the Burrows-Wheeler Transform.*  
**Journal of the ACM**, Vol. 48, n. 3, (2001), 407–430.
- [19] P. Ferragina, G. Manzini.  
*An Experimental Analysis of a Compressed Index (invited paper).*  
**Information Sciences**, Vol. 135, (2001), 13–28.
- [20] D. Bini, G. M. Del Corso, G. Manzini, L. Margara.  
*Inversion of Circulant Matrices over  $\mathbf{Z}_m$ .*  
**Mathematics of Computation**, Vol. 70, (2001), 1169–1182.
- [21] R. Kosaraju, G. Manzini.  
*Compression of Low Entropy Strings with Lempel-Ziv Algorithms.*  
**SIAM J. Computing**, Vol. 29, n. 3, (2000), 893–911.
- [22] G. Cattaneo, E. Formenti, G. Manzini, L. Margara.  
*Ergodicity, Transitivity, and Regularity for Linear Cellular Automata over  $\mathbf{Z}_m$ .*  
**Theoretical Computer Science**, Vol. 233, n. 1–2, (2000), 147–164.
- [23] B. Codenotti, G. M. Del Corso, G. Manzini.  
*Matrix Rank and Communication Complexity.*  
**Linear Algebra and its Applications**, Vol. 304, n. 1–3, (2000), 193–200.
- [24] M. Leoncini, G. Manzini, L. Margara,  
*Parallel Complexity of Numerically Accurate Linear System Solvers.*  
**SIAM J. Computing**, Vol. 28, n. 6, (1999), 2030–2058.
- [25] G. Manzini, L. Margara.  
*Attractors of Linear Cellular Automata.*  
**Journal of Computer and System Sciences**, Vol. 58, n. 3, (1999), 597–610.
- [26] G. Manzini, L. Margara.  
*A Complete and Efficiently Computable Topological Classification of  $D$ -dimensional Linear Cellular Automata over  $\mathbf{Z}_m$ .*  
**Theoretical Computer Science**, Vol. 221, n. 2, (1999), 157–177.
- [27] G. M. Del Corso, G. Manzini.  
*Finding Exact Solutions to the Bandwidth Minimization Problem.*  
**Computing**, Vol. 62, n. 3, (1999), 189–203.
- [28] G. Manzini, L. Margara.  
*Invertible Linear Cellular Automata over  $\mathbf{Z}_m$ : Algorithmic and Dynamical Aspects.*  
**Journal of Computer and System Sciences**, Vol. 56, n. 1, (1998), 60–67.

- [29] M. Finelli, G. Manzini, L. Margara.  
*Lyapunov Exponents Vs Expansivity and Sensitivity in Cellular Automata.*  
**Journal of Complexity**, Vol. 14, n. 2, (1998), 210–233.
- [30] G. Manzini.  
*Lower Bounds for Sparse Matrix Vector Multiplication on Hypercubic Networks.*  
**Discrete Mathematics and Theoretical Computer Science**, Vol. 2, (1998), 35–47.
- [31] G. M. Del Corso, G. Manzini.  
*On the Randomized Error of Polynomial Methods for Eigenvector and Eigenvalue Estimate.*  
**Journal of Complexity**, Vol. 13, n. 4, (1997), 419–456.
- [32] B. Codenotti, G. Manzini, L. Margara, G. Resta.  
*Perturbation: an Efficient Technique for the Solution of Very Large Instances of the Euclidean TSP.*  
**INFORMS/ORSA Journal on Computing**, Vol. 8 (1996), 125–133.
- [33] G. Manzini.  
*On the Ordering of Sparse Linear Systems.*  
**Theoretical Computer Science**. Vol. 156 (1996), 301–313.
- [34] G. Manzini.  
*Perimeter Search in Restricted Memory.*  
**Computers and Mathematics with Applications**, Vol. 32 n. 7 (1996), 37–45.
- [35] G. Manzini, L. Margara.  
*Minimal Residual Algorithm and Matrix-Vector Information.*  
**Computers and Mathematics with Applications**, Vol. 32 n. 4 (1996), 57–63.
- [36] G. Manzini.  
*BIDA\*: an Improved Perimeter Search Algorithm.*  
**Artificial Intelligence**, Vol. 75 (1995), 347–360.
- [37] B. Codenotti, G. Manzini, L. Margara.  
*Algebraic Techniques in Communication Complexity.*  
**Information Processing Letters**, Vol. 56 (1995), 191–195.
- [38] G. Manzini.  
*Sparse Matrix Computations on the Hypercube and Related Networks.*  
**Journal of Parallel and Distributed Computing**, Vol. 21 (1994), 169–183.
- [39] G. Manzini.  
*Sparse Matrix Vector Multiplication on Distributed Architectures: Lower Bounds and Average Complexity Results.*  
**Information Processing Letters**. Vol. 50 (1994), 231–238.
- [40] G. Manzini.  
*Large Sorting and Routing Problems on the Hypercube and Related Networks.*  
**Parallel Processing Letters**, Vol. 1 (1991), 113–124.

- [41] G. Manzini.  
*Radix Sort on the Hypercube.*  
**Information Processing Letters**, Vol. 38 (1991), 77–81.
- [42] G. Manzini.  
*Searching Graphs Using Mixed Strategies.*  
**Journal of Experimental and Theoretical Artificial Intelligence**, Vol. 1 (1991),  
 311–317.

## Book Chapters, Proceedings, and Special Issues

- [43] P. Ferragina, S. Kurtz, S. Lonardi, G. Manzini,  
*Computational Biology.*  
**Handbook of Data Structures and Applications**, 2nd Ed., D. Mehta, S. Sahnii  
 (Editors), CRC Press, To appear.
- [44] P. Ferragina, G. Manzini,  
*Boosting Textual Compression.*  
**Encyclopedia of Algorithms**, Ming-Yang Kao (Editor), Springer (2016).
- [45] P. Ferragina, G. Manzini,  
*Burrows-Wheeler Transform*  
**Encyclopedia of Algorithms**, Ming-Yang Kao (Editor), Springer (2016).
- [46] T. Gagie, G. Manzini,  
*Dictionary-Based Data Compression*  
**Encyclopedia of Algorithms**, Ming-Yang Kao (Editor), Springer (2016).
- [47] R. Giancarlo, G. Manzini (Editors),  
 Special issue on *Combinatorial Pattern Matching.*  
**Theoretical Computer Science**, Vol. 483 (2013).
- [48] R. Giancarlo, G. Manzini (Editors),  
*Proc. 22nd Annual Symposium on Combinatorial Pattern Matching (CPM '11).*  
 Springer Verlag Lecture Notes in Computer Science n. 6661. (2011).
- [49] P. Ferragina, G. Manzini, S. Muthukrishnan, (Editors).  
 Special issue on *The Burrows-Wheeler Transform and its applications.*  
**Theoretical Computer Science**, Vol. 387, n. 2, (2007).

## International Conferences

- [50] T. Gagie, G. Manzini, R. Venturini,  
*An Encoding for Order-Preserving Matching.*  
**Proc. European Symposium on Algorithms (ESA '17)**, Vienna, Austria, 2017.

- [51] L. Egidi, G. Manzini,  
*Lightweight BWT and LCP Merging via the Gap Algorithm.*  
**Proc. 24th Int. Symposium on String Processing and Information Retrieval (SPIRE '17)**, Palermo, Italy, 2017. Springer Verlag Lecture Notes in Computer Science n. 10508, Pages 176–190.
- [52] G. Decaroli, T. Gagie, G. Manzini,  
*A Compact Index for Order-Preserving Pattern Matching.*  
**Proc. IEEE Data Compression Conference (DCC '17)**, Snowbird, USA, April 2017.
- [53] A. Fariña, T. Gagie, G. Manzini, G. Navarro, A. Ordóñez Pereira,  
*Efficient and Compact Representations of Some Non-canonical Prefix-Free Codes.*  
**Proc. 23rd Int. Symposium on String Processing and Information Retrieval (SPIRE '16)**, Beppu, Japan, 2016. Springer Verlag Lecture Notes in Computer Science n. 9954, Pages 50–60.
- [54] G. Manzini,  
*XBWT Tricks.*  
**Proc. 23rd Int. Symposium on String Processing and Information Retrieval (SPIRE '16)**, Beppu, Japan, 2016. Springer Verlag Lecture Notes in Computer Science n. 9954, Pages 80–92.
- [55] C. Boucher, A. Bowe, T. Gagie, G. Manzini, J. Sirén,  
*Relative Select.*  
**Proc. 22nd Int. Symposium on String Processing and Information Retrieval (SPIRE '15)**, London, UK, 2015. Springer Verlag Lecture Notes in Computer Science n. 9303, Pages 149–155.
- [56] D. Belazzougui, T. Gagie, S. Gog, G. Manzini, J. Sirén,  
*Relative FM-Indexes.*  
**Proc. 21st Int. Symposium on String Processing and Information Retrieval (SPIRE '14)**, Ouro Preto, Brazil, 2014. Springer Verlag Lecture Notes in Computer Science n. 8799, Pages 52–64.
- [57] T. Gagie, G. Manzini, D. Valenzuela.  
*Compressed Spaced Suffix Arrays.*  
**Proc. 2nd Int. Conference on Algorithms for Big Data**, Palermo, Italy, 2014. CEUR Workshop Proceedings 1146. Pages 37–45.
- [58] L. Egidi, G. Manzini,  
*Spaced Seeds Design Using Perfect Rulers.*  
**Proc. 18th Int. Symposium on String Processing and Information Retrieval (SPIRE '11)**, Pisa, Italy, 2011. Springer Verlag Lecture Notes in Computer Science n. 7024, Pages 32–43.
- [59] P. Ferragina, T. Gagie, G. Manzini  
*Lightweight Data Indexing and Compression in External Memory.*  
**Proc. 9th Latin American Theoretical Informatics Symposium (LATIN '10)**,

- Oaxaca, México, 2010. Springer Verlag Lecture Notes in Computer Science, n. 6034, Pages 698–711.
- [60] P. Ferragina, G. Manzini  
*On Compressing the Textual Web.*  
**Proc. 3rd ACM International Conference on Web Search and Data Mining (WSDM '10)**, New York City, USA, 2010. ACM Press, Pages 391–400.
- [61] G. Manzini.  
*Succinct Representations of Trees* (invited paper).  
**Proc. 20th International Workshop on Combinatorial Algorithms (IWOCA '09)**. Hradec nad Moravicí, Czech Republic, 2009. Springer Verlag Lecture Notes in Computer Science, n. 5874, Pages 11–18.
- [62] J. Kärkkäinen, G. Manzini, S. Puglisi.  
*Permuted Longest-Common-Prefix Array Revisited.*  
**Proc. 20th Symposium on Combinatorial Pattern Matching (CPM '09)**, Lille, France, 2009. Springer Verlag Lecture Notes in Computer Science, n. 5577, Pages 181–192.
- [63] T. Gagie, G. Manzini.  
*Space-conscious compression.*  
**Proc. 32nd Int. Symposium on Mathematical Foundations of Computer Science (MFCS '07)**, Cesky Krumlov, Czech Republic, 2007. Springer Verlag Lecture Notes in Computer Science, n. 4708, Pages 206–217.
- [64] T. Gagie, G. Manzini.  
*Move-to-Front, Distance Coding, and Inversion Frequencies Revisited.*  
**Proc. 18th Symposium on Combinatorial Pattern Matching (CPM '07)**, London, Ontario, Canada, 2007. Springer Verlag Lecture Notes in Computer Science, n. 4580, Pages 71–82.
- [65] P. Ferragina, R. Giancarlo, G. Manzini.  
*The Engineering of a Compression Boosting Library: Theory vs Practice in BWT compression.*  
**Proc. 14th European Symposium on Algorithms (ESA '06)**, Zürich, Switzerland, 2006. Springer Verlag Lecture Notes in Computer Science, n. 4168, Pages 756–767.
- [66] P. Ferragina, R. Giancarlo, G. Manzini.  
*The Miryad Virtues of Wavelet Trees.*  
**Proc. 33th Int. Colloquium on Automata, Languages, and Programming (ICALP '06)**, Venice, Italy, 2006. Springer Verlag Lecture Notes in Computer Science n. 4051. Pagg 561–572.
- [67] P. Ferragina, F. Luccio, G. Manzini, S. Muthukrishnan.  
*Compressing and Searching XML Data Via Two Zips.*  
**Proc. World Wide Web Conference 2006 (WWW '06)**. Edinburgh, Scotland, 2006. Pages 751–760.

- [68] P. Ferragina, F. Luccio, G. Manzini, S. Muthukrishnan.  
*Structuring labeled trees for optimal succinctness, and beyond.*  
**Proc. 46th IEEE Symposium on Foundations of Computer Science (FOCS '05).** Pittsburgh (PA), 2005. Pages 184–193.
- [69] P. Ferragina, G. Manzini, V. Mäkinen, G. Navarro.  
*An Alphabet-Friendly FM-index.*  
**Proc. 11th Symposium on String Processing and Information Retrieval (SPIRE '04),** Padova, Italy, 2004. Springer Verlag Lecture Notes in Computer Science n. 3246. Pages 150–160.
- [70] G. Manzini.  
*Two space saving tricks for linear time LCP array computation.*  
**Proc. 9th Scandinavian Workshop on Algorithm Theory (SWAT '04),** Humlebæk, Denmark, 2004. Springer Verlag Lecture Notes in Computer Science n. 3111. Pages 372–383.
- [71] P. Ferragina, G. Manzini.  
*Compression boosting in optimal linear time using the Burrows-Wheeler Transform.*  
**Proc. 15th ACM-SIAM International Symposium on Discrete Algorithms (SODA '04).** New Orleans LA, 2004. Pages 655–663.
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*Engineering a lightweight suffix array construction algorithm.*  
**Proc. 10th European Symposium on Algorithms (ESA '02),** Rome, Italy, 2002. Springer Verlag Lecture Notes in Computer Science n. 2461. Page 698–710.
- [73] P. Ferragina, G. Manzini.  
*An Experimental Analysis of an Opportunistic Index.*  
**Proc. 12th ACM-SIAM International Symposium on Discrete Algorithms (SODA '01),** Washington DC, 2001. Pages 269–278
- [74] P. Ferragina, G. Manzini.  
*Opportunistic Data Structures with Applications.*  
**Proc. 41st IEEE Symposium on Foundations of Computer Science (FOCS '00),** Redondo Beach, CA, 2000. Pages 390–398.
- [75] G. Manzini.  
*An Analysis of the Burrows-Wheeler Transform.*  
**Proc. 10th ACM-SIAM International Symposium on Discrete Algorithms (SODA '99),** Baltimore MD, 1999. Pages 669–677.
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*The Burrows-Wheeler Transform: Theory and Practice* (invited paper).  
**Proc. 24th International Symposium on Mathematical Foundations of Computer Science (MFCS '99),** Szklarska Poreba, Poland, 1999. Springer Verlag Lecture Notes in Computer Science n. 1672. Pages 34–47.

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*Efficient Algorithms for On-line Symbol Ranking Compression.*  
**Proc. 7th European Symposium on Algorithms (ESA '99)**, Prague, Czech Republic, 1999. Springer Verlag Lecture Notes in Computer Science n. 1643.
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*Characterization of Sensitive Linear Cellular Automata with Respect to the Counting Distance.*  
**Proc. 23rd International Symposium on Mathematical Foundations of Computer Science (MFCS '98)**, Brno, Czech Republic, 1998. Springer Verlag Lecture Notes in Computer Science n. 1450.
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*Inversion of Circulant Matrices over  $\mathbf{Z}_m$ .*  
**Proc. 25th Int. Colloquium on Automata, Languages, and Programming (ICALP '98)**, Aalborg, Denmark, 1998. Springer Verlag Lecture Notes in Computer Science n. 1443.
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**Proc. 15th Int. Symp. on Theoretical Aspects of Computer Science (STACS '98)**, Paris, France, 1998. Springer Verlag Lecture Notes in Computer Science n. 1373.
- [82] M. Leoncini, G. Manzini, L. Margara.  
*On the Parallel Complexity of Matrix Factorization Algorithms.*  
**Proc. 9th ACM Symposium on Parallel Algorithms and Architectures (SPAA '97)**, Newport, Rhode Island, USA, 1997.
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**Proc. Int. Conference on Compression and Complexity of Sequences (SEQUENCES '97)**, Positano, Italy. IEEE Press, 1997.
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*A Complete and Efficiently Computable Topological Classification of  $D$ -dimensional Linear Cellular Automata over  $\mathbf{Z}_m$ .*  
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- (**ICALP '97**), Bologna, Italy, 1997. Springer Verlag Lecture Notes in Computer Science n. 1256.
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*On Ergodic Linear Cellular Automata over  $\mathbf{Z}_m$ .*  
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*Parallel Complexity of Householder QR factorization.*  
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*Improving the Efficiency of Backtrack Search.*  
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*Global Strategies for Augmenting the Efficiency of TSP Heuristics.*  
**Third Workshop on Algorithms and Data Structures, (WADS '93)** Montreal, Canada, 1993. Springer Verlag Lecture Notes in Computer Science n. 709.