ScuDo
Scuola di Dottorato ~ Doctoral School
WHAT YOU ARE, TAKES YOU FAR

XXXII Cycle

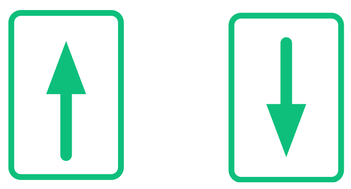
# Design of CAD Tools for Emerging Technologies

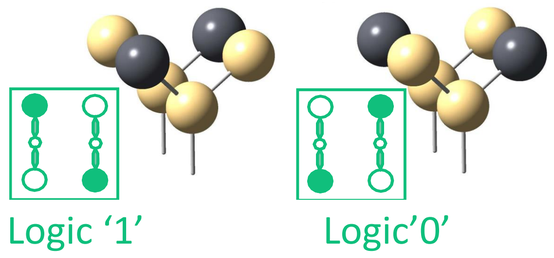

## Umberto Garlando

## Supervisor: Prof. Maurizio Zamboni

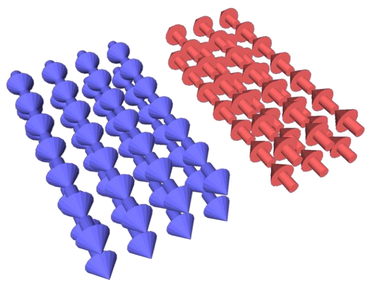

## Research context and motivation

- The scaling of CMOS technology is reaching its limits. **New technologies** are being studied to **overcome CMOS limitations**.
- Among various emerging technologies, **Field Coupled Devices** are the most promising.
- Different implementations: in-plane Nano Magnet Logic (**iNML**)and **Molecular.**

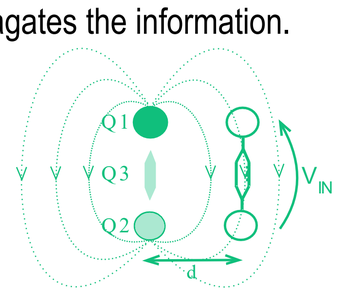



- **In-plane NML** (iNML): the magnetization vector lies in the same plane of the magnets.
- Magnetic interaction among the magnets propagate information.



- **Molecular QCA:** the free electrons in the molecule can occupy only one of the two dots. A couple of molecules defines the QCA.
- Coulomb interaction among the electrons propagates the information.




## Addressed research questions/problems

- **Evaluate complex structures** based on those technologies.
- Circuit level exploration can **give feedback to the technologists**.

| | Device Simulators | System Simulators |
|---|---|---|
| Number of Elements | Limited | High |
| Computation Time | ~hours on GPUs | ~minutes on CPUs |
| Elements type | Cube of a mesh | Technological cell |
| Based on | Physical equation | Physical Models |

## Adopted methodologies

- Study and research of the **key aspect of the technology**.
- Development of a **simplified model** of the technological element.
- Implemented a general algorithm for visiting all the elements.
- Take advantage of C++ capabilities defining **specific implementation** of general methods **for each technology**.

## Future work

- Include the simulator inside the **ToPoliNano Framework**.
- Design a graphical visualization of the simulations.
- Add support for pNML technology.

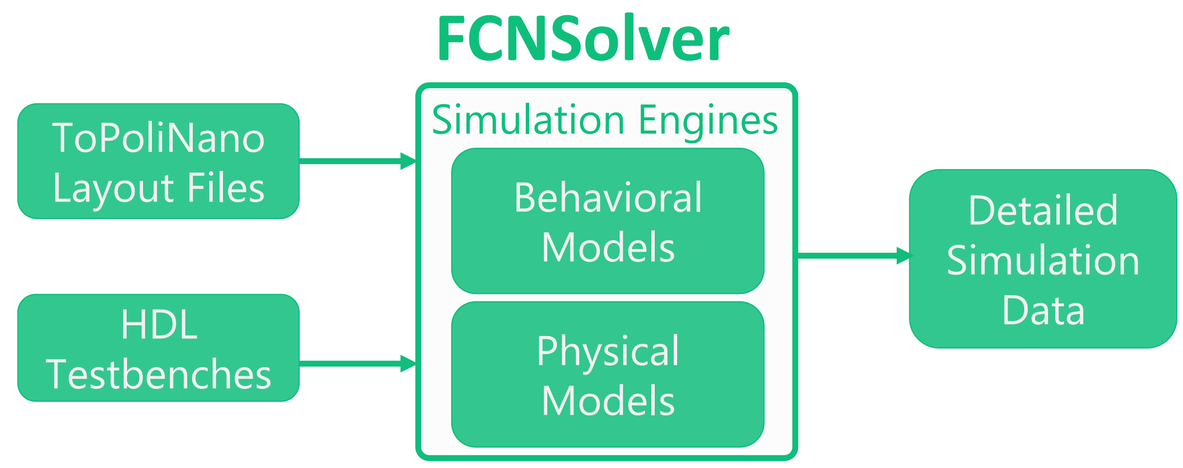
## Awards

- **PRIME 2017 Gold Leaf Award** for paper: 3D Design of a pNML Random Access Memory
- **SMACD 2018 EDA Competition 2nd place**. Paper: ToPoliNano & MagCAD: a Complete Framework for Design and Simulation of Digital Circuits based on Emerging Technologies
- **Young Professional Best Poster award IEEENano2018**. Paper: Design and Characterization of Circuits Based on Emerging Technologies: the MagCAD Approach

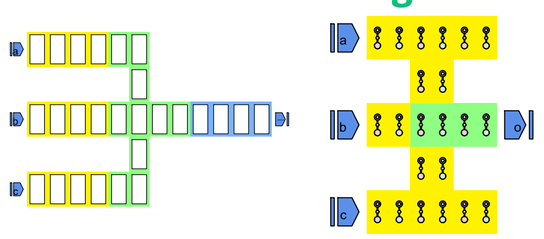
## List of attended classes

- 01MNFIU – Parallel and distributed computing (19/07/2017, 5 CFU)
- 01QTGIU – Advanced techniques for highly reliable electronic system design (04/11/2016, 4 CFU)
- 01QSCIU – Reconfigurable computing (20/07/2017, 4 CFU)
- 01RZHIU – 3D Integration: Challenges and Solutions (01/06/2017, 4 CFU)
- 01SOKOQ – Integrazione di sistemi embedded (08/02/2019, 8 CFU, II livello)
- 01RONKG – Python in the Lab (08/04/2019, 4 CFU)
- 02RHQRV – IPR, Technology Transfer & Hi-tech Entrepreneurship (17/07/2017, 9 CFU)

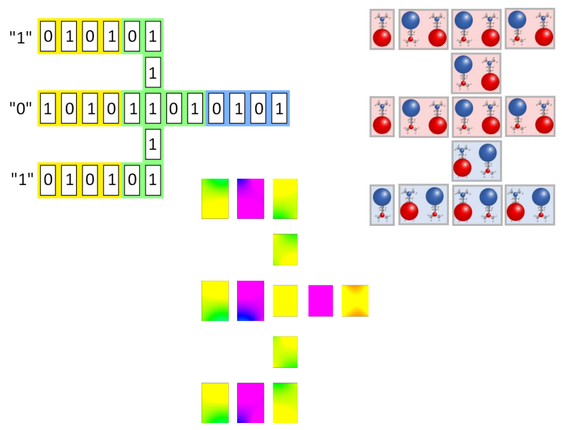
## Novel contributions



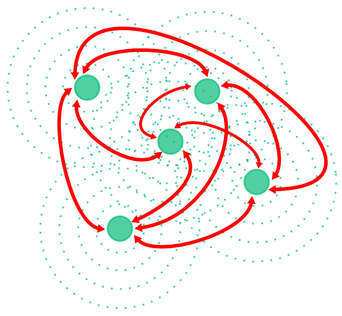

### Different Technologies



### Different Approaches



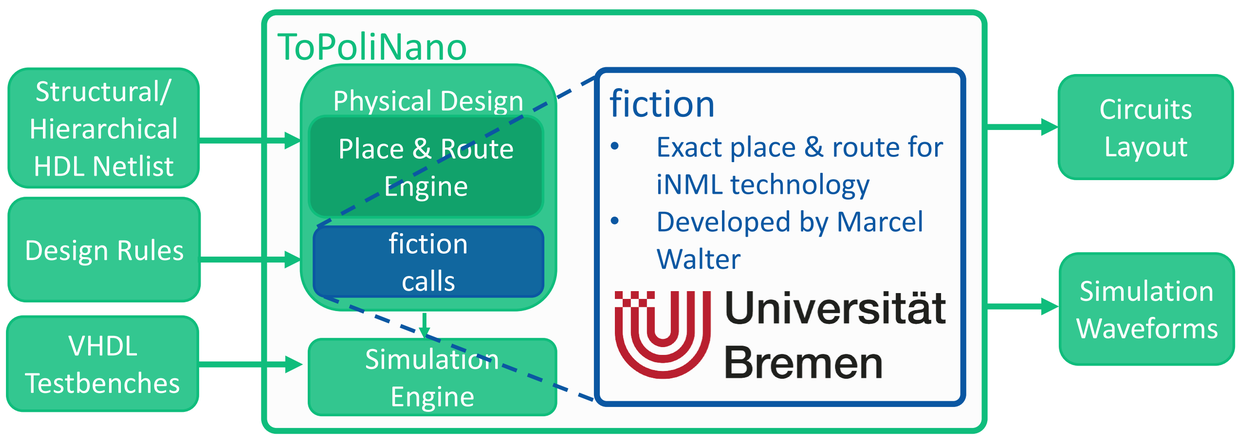

### General algorithm specifically designed for multiple interactions



Download it from: https://topolinano.polito.it

- Fully working on **iNML** and **MolQCA**, with physical and behavioral models
- Verified with state-of-the-art simulators (Mumax3 & SCERPA)
- Possibility to **change physical properties** of the elements
- Fast design of the circuit using **MagCAD**

## International Collaborations




## Submitted and published works


- Turvani, G., Riente, F., Cairo, F., Vacca, M., Garlando, U., Zamboni, M., and Graziano, M. (2017) Efficient and reliable fault analysis methodology for nanomagnetic circuits. Int. J. Circ. Theor. Appl., 45: 660–680.
- G.Causapruno, U. Garlando, F. Cairo, M. Zamboni and M. Graziano, "A Reconfigurable Array Architecture for NML," 2016 IEEE Computer Society Annual Symposium on VLSI (ISVLSI), Pittsburgh, PA, 2016, pp. 99-104.
- M.Bollo, G. Santoro, U. Garlando and M. Zamboni, "NANOcom: A Mosaic Approach for nanoelectronic circuits design," 2017 12th International Conference on Design&Technology of Integrated Systems In Nanoscale Era(DTIS), Mallorca, 2017, pp. 1-6.
- A.Ferrara, U. Garlando, L. Gnoli, G. Santoro and M. Zamboni, "3D design of a pNML random access memory," 2017 13th Conference on Ph.D. Research in Microelectronics and Electronics (PRIME), Giardini Naxos, 2017, pp. 5-8.
- F. Riente, U. Garlando, G. Turvani, M. Vacca, M. Ruo Roch and M. Graziano, "MagCAD: Tool for the Design of 3-D Magnetic Circuits", in *IEEE Journal on Exploratory Solid-State Computational Devices and Circuits*, vol. 3, pp. 65-73, Dec. 2017.
- U. Garlando, F. Riente, M. Zamboni and M. Graziano, "Topolinano & MagCAD: a Design and Simulation Framework for the Exploration of Emerging Technologies", 2018*, Design, Automation and Test in Europe (DATE) 2018*.
- U. Garlando, F. Riente, D. Vergallo, M. Graziano and M. Zamboni, "ToPoliNano & MagCAD: A Complete Framework for Design and Simulation of Digital Circuits Based on Emerging Technologies, " *15th International Conference on Synthesis, Modeling, Analysis and Simulation Methods and Applications to Circuit Design (SMACD)*, Prague, 2018, pp. 153-156.
- U. Garlando, F. Riente, G. Turvani, A. Ferrara, G. Santoro, M. Vacca, M. Graziano, "Architectural exploration of perpendicular Nano Magnetic Logic based circuits", Integration, 2018.
- U. Garlando, F. Riente, G. A. Cirillo, M. Graziano and M. Zamboni, "Design and Characterization of Circuit Based on Emerging Technology: the MagCAD Approach", 2018, 18th IEEE International Conference on Nanotechnology (IEEE-NANO), Cork, Ireland.


POLITECNICO DI TORINO

PhD program in
**Electrical, Electronics and Communications Engineering**