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Daniel Marolt,
Reutlingen

SWARM: A Novel Methodology for Integrated Circuit Layout Automation Based on Principles of Self-organization

Berichte aus dem **Electronics & Drives Lab** der Hochschule Reutlingen · Prof. Dr.-Ing. Jürgen Scheible (Hrsg.)

Hochschule Reutlingen
Reutlingen University

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After more than three decades of electronic design automation, most layouts for analog integrated circuits are still handcrafted in a laborious manual fashion today. This book presents *Self-organized Wiring and Arrangement of Responsive Modules* (SWARM), a novel interdisciplinary methodology addressing the design problem with a decentralized multi-agent system. Its basic approach, similar to the roundup of a sheep herd, is to let autonomous layout modules interact with each other inside a successively tightened layout zone. Considering various principles of self-organization, remarkable overall solutions can result from the individual, local, selfish actions of the modules. Displaying this fascinating phenomenon of *emergence*, examples demonstrate SWARM's suitability for floorplanning purposes and its application to practical place-and-route problems. From an academic point of view, SWARM combines the strengths of procedural generators with the assets of optimization algorithms, thus paving the way for a new automation paradigm called *bottom-up meets top-down*.

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Preface

It is necessary sometimes to take one
step backward to take two steps forward.
Vladimir Ilyich Ulyanov (Russian revolutionary)

On January 9, 2007, in a keynote address at the Macworld Conference & Expo held in San Francisco, Apple CEO Steve Jobs told his audience that "every once in a while, a revolutionary product comes along that changes everything". With these words, Jobs introduced Apple's first-generation iPhone. And indeed, a revolutionary product it was.

How did Apple achieve that? Instead of trying to merely improve the available concepts of smartphones, the developers set out to –as Jobs put it– reinvent the phone. But before inventing something new by exploring promising ideas, they first took a step back and thoroughly investigated the existing problems. In particular, they focused on the downsides of the traditional smartphones' keyboards, which were cumbersome to use, took valuable space away from the display, had fixed control buttons regardless of the application, and stayed always there whether you needed them or not. Based on this examination, Apple came to the conclusion that they had to provide something entirely new: a triple-layered capacitive multi-touch screen. Above everything else, it was this invention that turned the iPhone into a breakthrough device and unleashed a skyrocketing market segment. By 2019, worldwide smartphone revenues have reached an incredible amount of 404.6 billion U.S. dollars.

Below any modern smartphone's surface, the user's finger gestures are processed by an *integrated circuit* (IC) which translates the fingers' actions into discrete digital data. Now, the global pursuit of *digitalization* suggests that analog technology is antiquated, but the opposite is the case. Any machine's external environment –including the user's finger– is (and will always be) analog. With the rising interconnectedness of the world and the increasing interaction between a device and its surroundings due to a sophistication of analog-digital interfaces (for example, a smartphone nowadays has up to a dozen different types of sensory elements), analog circuitry remains indispensable and even gains more and more importance for the functional diversification of microelectronics and therefore the digital transformation of our time.

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Before an IC can be fabricated, the circuit has to be designed and must be turned into a physical layout defining the geometries of the photolithographical masks needed for the fabrication. Both steps can be facilitated via methods and tools from the field of *electronic design automation* (EDA). In fact, modern ICs would –because of their tremendous complexity– be impossible to realize without the aid of EDA, which can thus be considered a key technology for today's unparalleled advancement of semiconductor products and their prominence in every domain of our lives. Unfortunately, in contrast to the digital domain, the circuit design and especially the layout creation of analog circuits still suffers from a low degree of automation because most analog automation approaches keep on struggling to find evident industrial acceptance – despite continuing efforts of improvement. A revolution is required.

The task of analog layout automation is addressed by the dissertation *Layout Automation in Analog IC Design with Formalized and Nonformalized Expert Knowledge* [1], which the book at hand is based on. But reflecting Jobs' attitude, the intent of that thesis is not just to enhance existing automation approaches. Instead, Part I of the dissertation takes a step back and first of all performs a profound examination of the underlying problems. Then, a fundamentally new and highly interdisciplinary automation methodology is conceived, denoted as *Self-organized Wiring and Arrangement of Responsive Modules* (SWARM). Part II of the dissertation conveys several ideas from other disciplines which inspired the conception of SWARM, before describing the new methodology in detail. Finally, Part III covers the first-generation implementation of SWARM and discusses its results.

The latter two parts of the dissertation –which concentrate on the novel approach of the SWARM methodology– are reprinted in the book at hand, thereby encapsulating the practical product of the first part's academic ruminations in tangible form. The book's first three chapters 1 to 3 correspond to the dissertation's chapters 5 to 7 (originally making up Part II). The last three chapters 4 to 6 here match the dissertation chapters 8 to 10 (which constitute the original Part III). Regarding the omitted Part I, the reader is kindly referred to the original dissertation, which is publicly available in electronic form and can be downloaded[1] from OPUS, the publication server of the University of Stuttgart. In the following text, concrete references to the first part of the dissertation have been supplemented with a citation of [1]. Otherwise, the original contents have been adopted without any modifications.

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