Maxime SENOT — RESEARCH PROJECT*

Research interests: computability and complexity, geometrical computing, unconventional computing. My research interests deals with any form of geometrical computations, like signal machines, cellular automata, tilings, Euclidean machines... This paradigm of geometry underlying some computations can bring new techniques of programming and new points of view on classical notions, such as parallelism, spatial computing and problem complexities. Admittedly, this is very particular to some specific models, but this can help to shed a light a the Church-Turing thesis.

Previous work: the signal machines model. Signal machines have been introduced by J. Durand-Lose in 2003. They come from the world of cellular automata, which are an elegant and widely studied model of discrete computation. Unlike usual models such as Turing machines, signal machines are defined on continuous space and time. The whole evolution of a signal machine takes place in the Euclidean plane and can be represented by a space-time diagram, as shown in Fig. 1.

(a) Meta-signals.

name	speed
s_1	1
s_2	$-1/2$
s_3	3
s_4	0

(b) Collision rules.

$\{s_2, s_1\} \to \{s_2, s_1, s_3\}$
$\{s_3, s_4\} \to \{s_2\}$

(c) Space-time diagram.

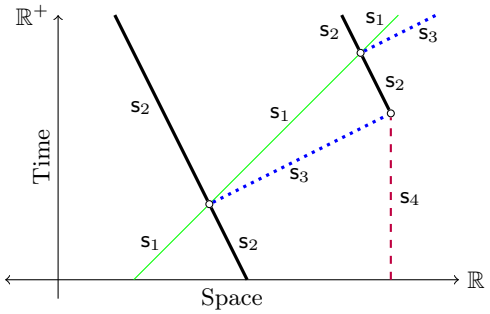


Figure 1: Example of a signal machine and one of its possible evolutions.

My PhD Thesis [Senot, 2013] mainly deals with the definition and the use of classical algorithmic notions in the framework of signal machines. A methodic use of space by signal machines allows to implement efficiently massively parallel algorithms, and to solve hard problems such as **SAT**. To achieve this, I studied some *fractal structures* on signal machines. In order to prove the correctness of these algorithms, I also developped a method of *geometrical modular programming*, which allows to conceive complex constructions from simple basic geometrical elements, whilst certifying the correctness of the global assembly. This method can be viewed as a decomposition of a space-time diagram into geometrical polygons computing functions. In other words, it is a tiling of the whole diagram, corresponding to a composition of functions.

Our study of fractals has lead to another interesting result, showing the ability of signal machines to use space continuity to generate various structures. Indeed, *for any dimension* $d \in]0;1[$*, there exists a signal machine and an initial configuration that generates a fractal set of dimension* d (see [Senot, 2014]). The study of fractal structures also initiated a prospection on a more general phenomenon called *accumulation* (accumulation of signals or collisions). A necessary condition on machines for generating such accumulations has been proved and can be stated as follow: *accumulations can be generated with* 4 *distinct speeds, and only* 3 *if the machine involves an irrational ratio between some of its values* (see [Becker et al., 2013]).

Future work. First, I plan to continue my work on signal machines. The model being quite recent, there is plenty of open problems about signal machines. Specifically, I would like to work on some on them that I think are important: *(i)* get an exact characterization of the computational efficiency of the signal machines basic model *(ii)* characterize signal machines as formal dynamical systems *(iii)* and define a discretization method to link more strongly signal machines and cellular automata.

Second, and in the perspective of this postdoctoral study but not only, I would like to work on a more general and geometrical framework where signals can be used. Signals are known and used for a long time in the world cellular automata, but they can also be very useful for studying tilings (see *e.g* [Becker, 2009]). More generally, I am very interested for working on almost any kind of problems relating to cellular automata, tilings, ... as models of computation. Another point I want to work in the future, is the link between signal machines, and more generally geometrical models of computation, and the "real" world. Signal machines are far away from getting closer to real world. But this is not the case for cellular automata and tilings, for which the real world provides plenty examples for using and working on these models.

References

[Becker, 2009] Becker, F. (2009). Pictures worth a thousand tiles, a geometrical programming language for self-assembly. *Theor. Comput. Sci.*, 410(16):1495–1515.

[Becker et al., 2013] Becker, F., Chapelle, M., Durand-Lose, J., Levorato, V., and Senot, M. (2013). Abstract geometrical computation 8: small machines, accumulations & rationality. Currently submitted at JCSS since July 2013, available at http://arxiv.org/abs/1307.6468.

[Senot, 2013] Senot, M. (2013). *Modèle géométrique de calcul : fractales et barrières de complexité*. PhD thesis, Université d'Orléans. Available at http://tel.archives-ouvertes.fr/tel-00870600. In french.

[Senot, 2014] Senot, M. (2014). Fractals on signal machines. In preparation, available at http://perso.ens-lyon.fr/maxime.senot/files/publications/2014_draft-senot.pdf.

*A detailled version of a research plan focusing only on signal machines can be found at http://perso.ens-lyon.fr/maxime.senot/SENOT_research-project.pdf