Two Topics Ahead Membrane Computing

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Summary. Two topics from the area of probability theory and randomness challenging membrane computing together with open problems and research proposals are discussed.

1 Introduction

We outline in the paper the following two topics challenging membrane computing [16]:

1) new mathematical approaches to causes and origins of uncertainty resulting from critique of old approaches to probability and randomness,
2) western polyphony musical scores as predecessor of an exact (as mathematical) approach to concurrency and parallelism in computer science: looking for mutual inspiration.

These topics together with new open problems and research proposals for membrane computing are discussed in subsequent Sections 2 and 3, respectively.

2 New mathematical approaches to uncertainty with a regard to membrane computing

The critical discussion of foundations of probability theory from the points of view of quantum theory[a], computation theory[b], and philosophy (general methodology) of exact sciences[c] inspired the following new mathematical approaches to the causes and origins of uncertainty:

[a] see, e.g., the papers and book by L. Accardi, D. Aerst and I. Pitowsky quoted in Subsection 1.2 of [1].
[b] see [18] for some brief and comprehensive summary of the discussion of a concept of randomness in a context of algorithmic information by various scientists.
[c] see, e.g., the paper [5] due to M. Bunge and his other papers quoted in [5].

A1) measurement (quantum) uncertainty approached by nonclassical (non-Bayesian, non-Markovian) probability theory proposed among others in [1], where also some new non-physical applications of quantum formalism are presented,
A2) algorithmic approaches to randomness, see [18] for some their survey,
A3) interactive randomization (e.g., via oracles), cf. [2], versus classical and massively parallel Monte Carlo randomizations used e.g. in [7], [12] in classical case, and in [14], [15] in massively parallel case, where the massively parallel randomization was inspired also by the critical discussion of massive quantum parallelism in [17], [6].

The attempts to fill the gap between formal reasoning about correctness of programs and heuristic estimations of error probability and computation time of randomized algorithms (cf., e.g., [12], [13]) resulted in an invention of

A4) probabilistic functional programming systems approached by monad theory and related systems of proving correctness of probabilistic programs (e.g. in Coq), cf. [3], [8].

The approaches outlined in A1)–A4) give rise to the following open problems and research proposals for membrane computing:

P1) searching for non-classical probabilistic P systems respecting measurement interactions and eventually simulating quantum computers (see A1)), where the P systems in [14], [15] may be treated as an attempt of this simulation respecting quantum massive parallelism,
P2) establishing the relationships (eventually an equivalence) between interactive randomization and Monte Carlo massively parallel randomization (see A2), A3)), where some ideas from membrane computing, like assembly of massively parallel computing device by membrane division, are applied, see [14], [15],
P3) modifications of P lingua [19] programming environment by introducing probabilistic aspects like in the case of probabilistic functional programming, see A4).

Similar ideas to P3) have been already discussed in [10].

3 Western polyphony musical scores as a predecessor of an approach to concurrency and parallelism in computer science

Western polyphony from Middle Ages, through J. S. Bach's (implied) polyphony, to G. Ligeti's sound-mass music contains an exact (as mathematical) approach to concurrency and parallelism appearing in performance according to musical scores for many voices.

Writing a musical score for many simultaneously appearing voices resembles writing a program (e.g. in NESL [4]) which respects simultaneously working processors, where e.g. the restrictions for sharing an access to central memory could correspond to counterpoint rules of polyphony.

The following quotation:

> *Ligeti's goal was apparently to entangle the voices to such a degree that they become imperceptible as individual entities ...*

together with remarks about randomization of beats in a bar according to K. Stockhausen from J. J. Iverson's Ph.D. thesis [11] suggests that

- Ligeti's sound-mass music could serve as a metaphor for quantum massive parallelism,
- randomized spiking neural P systems [9] (respecting the timing of spikes by counting time by beats in the bars) could be mathematical models for this metaphor, where membranes—neurons could correspond to voices.

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