Biochemical Application Compilation and Architecture Synthesis for Fault-Tolerant Digital Microfluidic Biochips

Alistar, Mirela; Pop, Paul; Madsen, Jan

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A biochemical protocol is modeled as a directed graph, where the nodes represent the operations and the edges represent the relationship between them. An operation is ready to execute when its inputs have arrived. Examples of operations are: dispensing, mix, dilution, optical detection, merge. Droplets are transmitted through the edges from one operation to its successor operation.

A biochip architecture is modeled as an array of electrodes. Operations execute within specified areas called modules, which can be placed on any electrodes of the biochip. These architectures are general-purpose and highly reconfigurable.

The applications have high sensitivity to volume variations. Faults during runtime, such as an unbalanced split, can compromise the result of the application.

**Biochemical Application Model**

**Runtime Compilation**

**Recovery Methods**

- a) Time redundancy
- b) Space redundancy

**Compilation Tasks**

- Allocation
- Binding
- Scheduling

**Application Specific Architecture**

**Cost Evaluation**

\[
Cost = \sum N_M \times Cost_M
\]

where

- A is the architecture
- \( N_M \) is the number of components \( M_i \)
- \( Cost_M \) is the cost of the physical component \( M_i \)

**Problem Formulation**

- Given
  - Biochemical application
  - Deadline requirements
  - Library of components
- The number \( k \) of permanent faults
- **Determine** an application-specific architecture \( A \), so that
  - the cost is minimized
  - the application completes within deadline for any occurrence of the \( k \) permanent faults

**Evaluation of fault-tolerant overhead**

(faults are marked with X)