An Introduction to Synchronous Data Flow Model

Dr. Haitao Wei
CAPSL at UDEL
Outline

• Synchronous Data Flow Model
  – Definition
  – Example
• Periodic Schedule and Consistency
• Stream Programming Language
  – Structured SDF
• Apply SDF to Bigdata
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Synchronous Data Flow Model

- Synchronous Data Flow (SDF) is represented as a graph
  - Node (actor): Computation
  - Edge: First In First Out (FIFO) Queue
- Each edge has two weights: produce rate and consume rate
- Each edge can also have initial data
- Formal: Tuple<N, E, E_{p,c,i}>,
  - N: node
  - E: edge
  - E_{p,c,i}: Produce rate, consume rate and initial data
Synchronous Data Flow Model

SDF with no initial tokens

SDF with initial token and loop
Synchronous Data Flow Model

A firing
Synchronous Data Flow Model

A firing, B firing
Synchronous Data Flow Model

A firing, B firing, C firing
Synchronous Data Flow Model

A firing, B firing, C firing, C firing
Synchronous Data Flow Model

SDF with initial token and loop
Synchronous Data Flow Model

A firing
Synchronous Data Flow Model

A firing, B firing
Synchronous Data Flow Model

A firing, B firing, C firing
Synchronous Data Flow Model

A firing, B firing, C firing, C firing
Synchronous Data Flow Model

• Question: Can any SDF graph find a firing sequences that makes the state of the graph no changed?
  – State of the graph means: the tokens on each edge are clean, no more no less.
  – Which leads to SDF Consistency Problem
Outline

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  – Example

• Periodic Schedule and Consistency

• Stream Programming Language
  – Structured SDF in StreamIt

• Apply SDF to Bigdata
Periodic Schedule and Consistency

• Firing sequence of a SDF is called a *schedule*

• *A periodic schedule* of an SDF clears all channels and return to its initial status after each node repeats execution a specified finite number of times

• Periodic schedule, permit SDF can process unbounded data with bounded memory

• *A SDF is Consistent* if a periodic schedule exists
Periodic Schedule and Consistency

Periodic Schedule: ABCC
AB2C
Periodic Schedule and Consistency

Can you find the periodic schedule?
Periodic Schedule and Consistency
Periodic Schedule and Consistency

A, B
Periodic Schedule and Consistency

A, B, C
Periodic Schedule and Consistency

A, B, C, A
Periodic Schedule and Consistency

A, B, C, A, B
Periodic Schedule and Consistency

A, B, C, A, B, C

Tokens in channel (A-C) is accumulating which makes the channel unbounded

Inconsistent!
Periodic Schedule and Consistency

Problem: Given a general SDF, how can we know it has periodic schedule or not?
Periodic Schedule and Consistency

Topology Matrix

- Each row presents the edge
- Each column presents a node
- \((i, j)\): the number of data items placed on \(i\) after each invocation of \(j\)
- If \(i\) is an input channel for \(j\), element \((i, j)\) is negative

\[
\begin{pmatrix}
c & -e & 0 \\
d & 0 & -f \\
0 & i & -g
\end{pmatrix}
\]

- \(A\rightarrow B\)
- \(A\rightarrow C\)
- \(B\rightarrow C\)
A necessary condition for the existence of a periodic schedule
• the rank of the topology matrix is \( s - 1 \), where \( s \) is the number of nodes
• Proof: please refer to “Lee’s 87 paper: Synchronous Data Flow”

\[
\begin{pmatrix}
c & -e & 0 \\
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0 & i & -g
\end{pmatrix}
\]

A \rightarrow B
A \rightarrow C
B \rightarrow C
Periodic Schedule and Consistency

A necessary condition for the existence of a periodic schedule
• the rank of the topology matrix is $s - 1$, where $s$ is the number of nodes
• Proof: please refer to “Lee’s 87 paper: Synchronous Data Flow”

\[
\begin{pmatrix}
1 & -1 & 0 \\
2 & 0 & -1 \\
0 & 1 & -1
\end{pmatrix}
\]

$A \rightarrow B$

$A \rightarrow C$

$B \rightarrow C$

Rank$=3 > 2$
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• **Stream Programming Language**
  – Structured SDF
• Apply SDF to Bigdata
while ( true ) {
    int itm = geneDataItem ();
    push(itm);
}

while(inStream.moreData()) {
    int first=peek(0);
    int second=peek(1);
    push ((first+second)/2);
    pop(0);
}

while ( inStream .moreData () )
{
    print(pop(0));
}
Average Pairs to Synchronous Dataflow Graph

Extend the SDF to support “peek” semantic
Average Pairs to Synchronous Dataflow Graph
Average Pairs to Synchronous Dataflow Graph
Average Pairs to Synchronous Dataflow Graph
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Average Pairs to Synchronous Dataflow Graph
Structured SDF In StreamIt

- Filter
- Pipeline
- Split-Join
- Feedback Loop

Part of JPEG transcoding

Weakness of SDF

• Does not support condition (branch)

• Does not support recursion—because it is a static dataflow model

• But still the model is used widely in many application fields
Some Projects Based on SDF model

• Early Ptolemy Project at UC Berkeley
  – Software Synthesis for Embedded system

• StreamIt at MIT
  – streaming program language and compiler

• InforStream and SPL
  – IBM streaming computing product

• Our work COStream
  – hierarchical data flow programming language and compiler

• OpenStream
  – language and compiler support for streaming in OpenMP
Homework

• Write a Fibonacci number generator using Synchronous Data Flow Model
  – Pseudo code for each node in SDF using “peek, push and pop” statements
  – Push Token: PPT animation to show how the tokens flow in SDF graph
  – Periodic Schedule of the SDF
Reference

[1] Early Ptolemy Project at UC Berkeley
   – http://ptolemy.eecs.berkeley.edu/projects/index.htm

[2] StreamIt at MIT
   – http://groups.csail.mit.edu/cag/streamit/

[3] InforStream and SPL

[4] COStream

   – http://openstream.info/