Fresh Breeze Streams

Programming Model and Architecture for Real Time Streaming

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What is a Program Execution Model?

User Code
- Application Code
- Software Packages
- Program Libraries
- Compilers
- Utility Applications

System
- Hardware
- Runtime Code
- Operating System
Today’s Conventional Software Stack

Each system layer compensates for inadequacies of the layers below, leading to an inefficient whole.
a) Fresh Breeze Multicore Chip

Chip Balancer

Scheduler 0
Core 0
AutoBuffer 0

L2 Cache Memory

Scheduler n-1
Core n-1
AutoBuffer n-1

b) Fresh Breeze System Structure

System Balancer

MultiCore Chip 0

MultiCore Chip m-1

DRAM Memory Units

SSD (Flash) Memory
Dynamic Resource Management

Flexibility of resource management requires a unit of exchange for memory and for processing

- Unit of Memory – Fixed Size Memory Chunk
- Unit of Processing – Execution of a Codelet
A chunk holds sixteen data items that may be data values or pointers to (handles of) other memory chunks.
Data Structures as Trees of Chunks

- Fan-out as large as 16
- Arrays: Three levels yields 4096 elements (longs or doubles)
- Write-Once then Read Only
A Stream as a Chain of Chunks

- New elements appended at tail of chain
- Elements removed from the head of the chain
- Basic operations implemented by Fresh Breeze machine instructions.
What is a Codelet?

- A block of Instructions scheduled for execution when needed data objects are available.
- Results made available to successor codelets.
- Data objects are trees of chunks.
Work and Continuation Codelets
(Data Parallel Computation)

Master Codelet

\[ \text{SyncCreate} \ (\text{cont}, \ n) \rightarrow \text{sync} \]
\[ \text{TaskSpawn} \ (\text{work}, \ \text{sync}, \ 0) \]
\[ \text{TaskSpawn} \ (\text{work}, \ \text{sync}, \ n-1) \]
\[ \text{TaskQuit} () \]

Work Codelet

\[ \text{SyncUpdate} \ (\text{sync}, \ 0, \ \text{data}) \]

Work Codelet

\[ \text{SyncUpdate} \ (\text{sync}, \ n-1, \ \text{data}) \]

Continuation Codelet
Example: The Dot Product

5 levels:
Vector length = $16^5 = 1,048,576$

Each of 65536 Leaf Tasks:
Dot Product of two 16-element vectors:
16 multiplies; 15 adds
Simple Streaming Example

Source One

Merge

Filter

Analyze

Source Two
Stream Data Types and Operations

In *funJava* a stream may be created for any type T:

```java
Stream<T> strm = new Stream<T>();
```

Three methods may be applied to values of type Stream<T>:

- **append** method appends an element of type T to the stream.
- **first** method returns the head element of the stream.
- **rest** method returns a stream equal to the given stream with its head element removed.
Fresh Breeze Multicore Chip

S - Scheduler
P - Processor Core
AB - AutoBuffer

Innovations:
AutoBuffer - AB
Load Balancer

Off-Chip Memory System
Codelets access chunks using chunk handles held in processor registers. Once a chunk is assigned a buffer, its index is held by the register containing the handle, providing direct access to the chunk.
The load Balancer monitors the number of tasks queued at each processor and instructs each local scheduler to send a task from a processor with high load to a processor with low load.
Fresh Breeze Compiler

- Bytecode Class Files
- Read Class Files
  - DFGs of Methods
- Transform Graphs
  - DFGs for Codelets
- Construct Code
  - Fresh Breeze Codelets

- Processor Simulator
- javac
- funJava