Lempel-Ziv-Markov Chain Algorithm Modeling using Models of Computation and ForSyDe

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Outline

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Introduction

- Aircraft data link optimization trough data compression
- LZMA: widely used lossless compression algorithm (Benchmark by SPEC)
- Model-Based Design (MBD) to cope with the avionics safety-critical systems standards (DO-331)
- Synchronous dataflow: adequate to model the dataflow behavior of compression algorithms

Introduction

We present the formal model and simulation of Lempel-Ziv Markov Chain algorithm (LZMA) using the synchronous dataflow (SDF) model of computation (MoC)

Outline

Background

- **Model of Computation (MoC)**
  According *tagged signal model* (TSM)[1] framework, systems can be modeled as compositions of processes acting on signals

  - **Signal**: a set of events $e_i = (t_i, v_i)$, which are elementary units of information composed by a tag $t_i \in T$ and a value $v_i \in V$

  - **Process**: a set of possible relations between input signals S^I and output signals S^O. The set of output signals is given by the intersection between the input signals and the process $S^O = S^I \cap P$

[1] Lee1998a.

Background

- **Synchronous dataflow (SDF) MoC**
  - Dataflows are *untimed* MoCs
  - Directed graphs where each node represents a process and each arc a signal path[2]
  - Each input and output port is associated with a *token rate*
  - An actor can fire only if the input signal paths have enough tokens to supply the amount needed

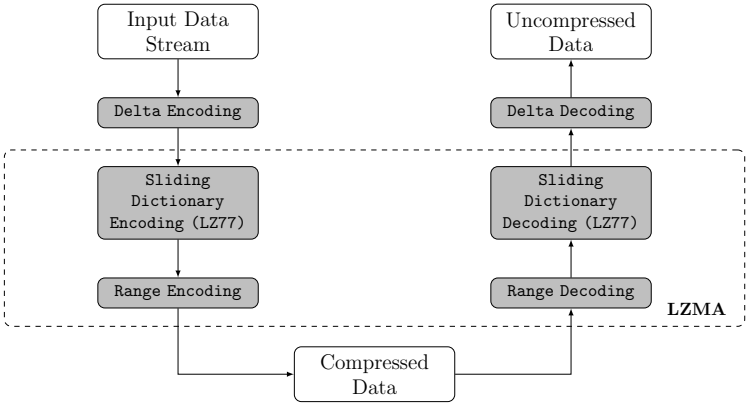
[2] Lee1987a.

Background

- **Lempel-Ziv Markov Chain Algorithm (LZMA)**
  - Compression algorithm based on Lempel-Ziv 1977 (LZ77)[3]
  - Higher compression rate, faster decompression, controlled necessary memory[4]
  - Open source, implemented in many languages (C, C++, Java)

[3] Ziv1977a.
[4] Salomon2007a.

Background



LZMA Flowchart[5]

Outline

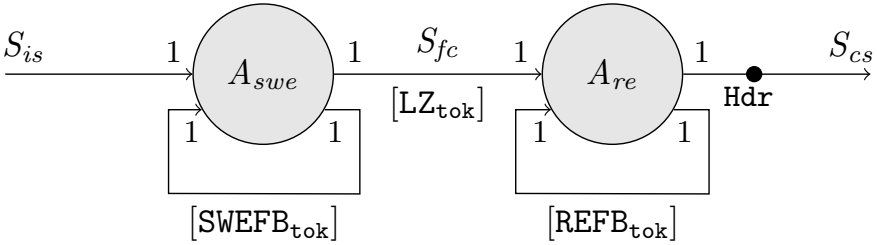
Lempel-Ziv-Markov Chain Modeling

- LZMA formal model - SDF MoC
- ForSyDe framework

It was used the following tools' versions:

- ForSyDe v3.3.2.0
- Glasgow Haskell Compiler v8.0.1

Lempel-Ziv-Markov Chain Modeling



LZMA SDF model

- Inputs: stream to be compressed S_{is}
- Processes: A_{swe} and A_{re}
- Output: compressed stream S_{cs}

Lempel-Ziv-Markov Chain Modeling

LZMA signatures and definitions

```
1  -- LZ (Sliding Window) Encoding actor definition
2  -- Input is the lzma input stream Sis
3  -- Output is the first step compressed stream Sfc
4  lzA :: Signal Char -> Signal (Maybe (Maybe Int, Char))
5  lzA Sis = Sfc
6    where (Sfc, fb) = actor22SDF (1,1) (1,1) lzF Sis fb'
7          fb' = delaySDF [([],"",0)] fb
8
9  -- Range Encoding actor definition.
10 -- Input is the first step compressed stream Sfc
11 -- Output is the compressed LZMA stream output Scs
12 rgA :: Signal (Maybe (Maybe Int, Char))
13         -> Signal [Char]
14 rgA sFc = sCs'
15   where (sCs,sFb) = actor22SDF (1,1) (1,1) rangeFunc sFc sFb'
16         sCs' = delaySDF initHdr sCs
17         sFb' = delaySDF [(rangeInit,0, chr 0)] sFb
18         initHdr = [([dictsize] ++ [inpLen])]
19         inpLen = (intToDigit (lengthS sFc))
```

Lempel-Ziv-Markov Chain Modeling

LZMA model process network

```
1  lzmaSdf :: Signal Char -> Signal [Char]
2  lzmaSdf sLzmaIs = sLzmaOut
3      where sLzmaOut = rgA (lzA sLzmaIs)
```

- Input: `sLzmaIs`
- Process: `lzmaSdf`
- Output: `sLzmaOut`

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Summary

Our paper presented

- a simplified LZMA modeling based on the SDF MoC using the ForSyDe framework
- Some configurations and behaviors assumptions were adopted towards the definition of actors ports fixed token rates
- Future work: model LZMA based on the scenario-aware dataflow (SADF) MoC, which supports variable token rates

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Thank you for your attention

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