Non-Linear Compression: Gzip Me Not!

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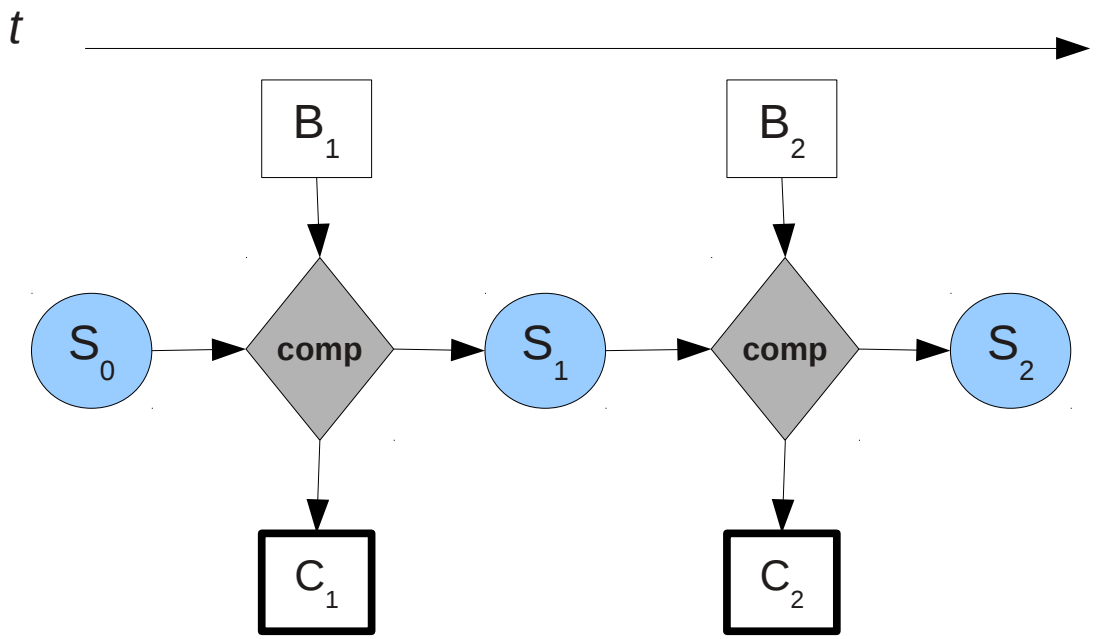
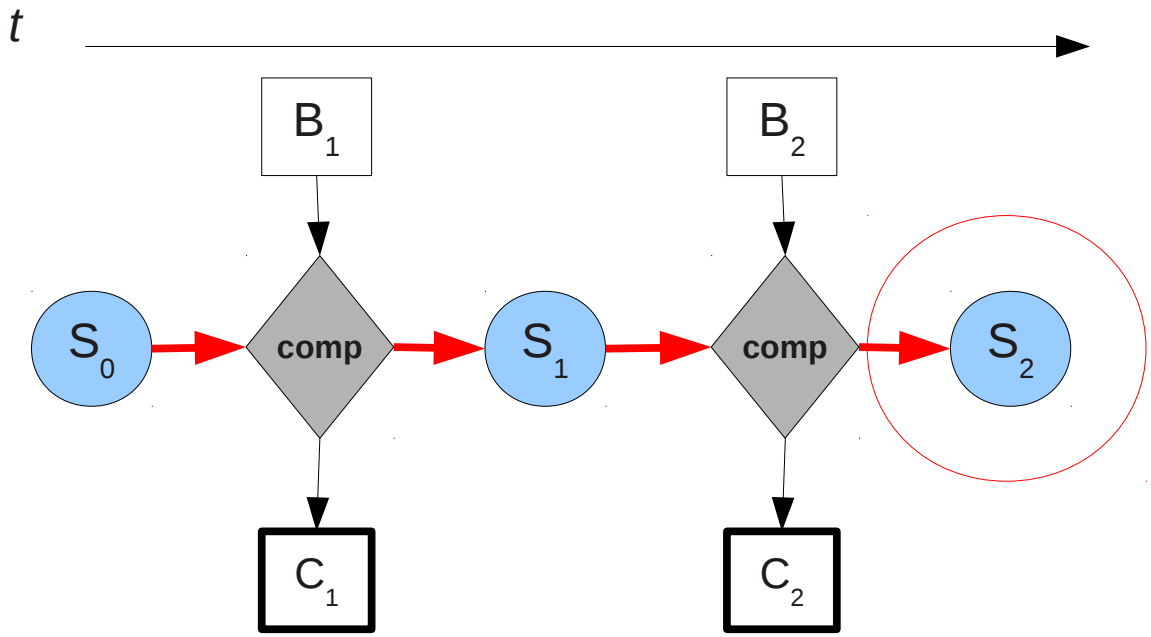
Linear Compression

The popular compression schemes (i.e., gzip, bzip2) are ***linear***.



Linear Compression

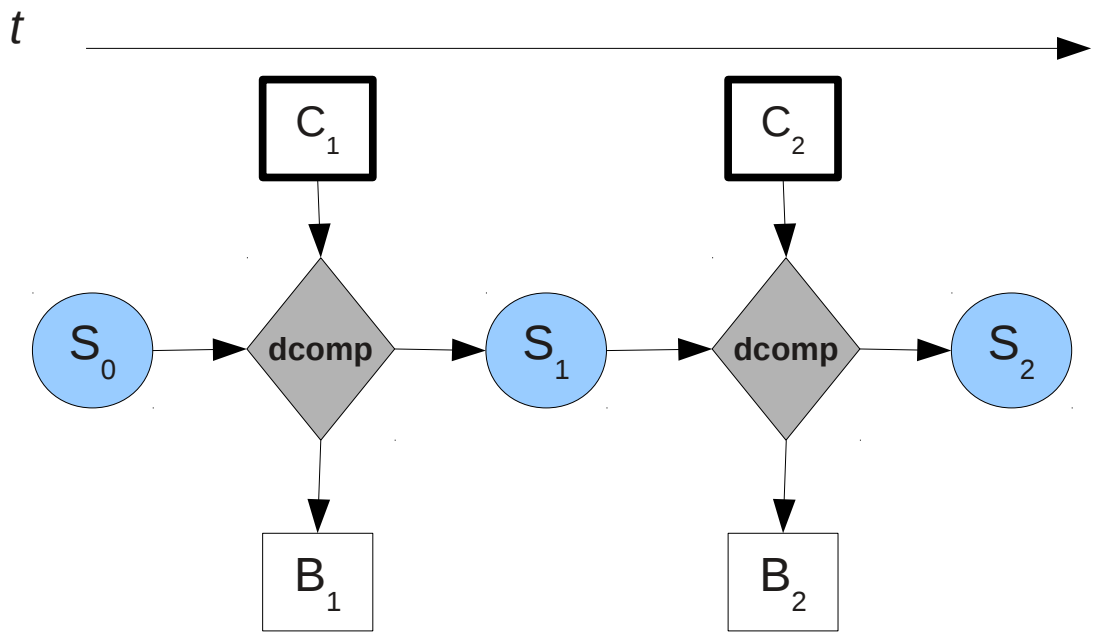
Compression state accumulates sequentially, with each successive block of data that is compressed.



Any given state depends on ***all*** previous compression states.

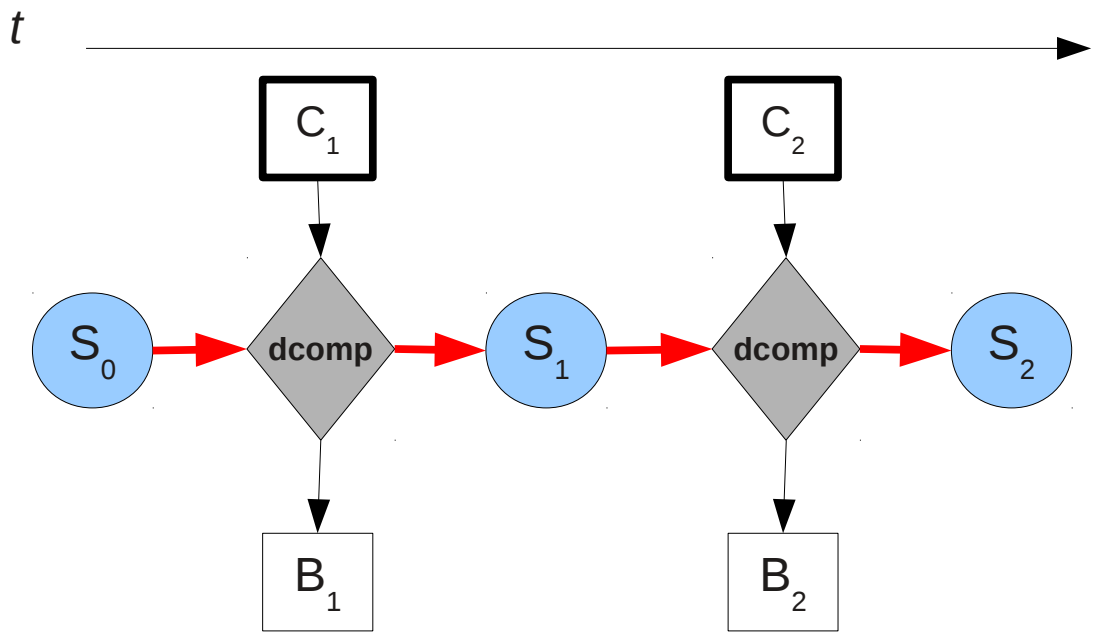
Linear Compression

This dependency chain is ***restrictive***.



Linear Compression

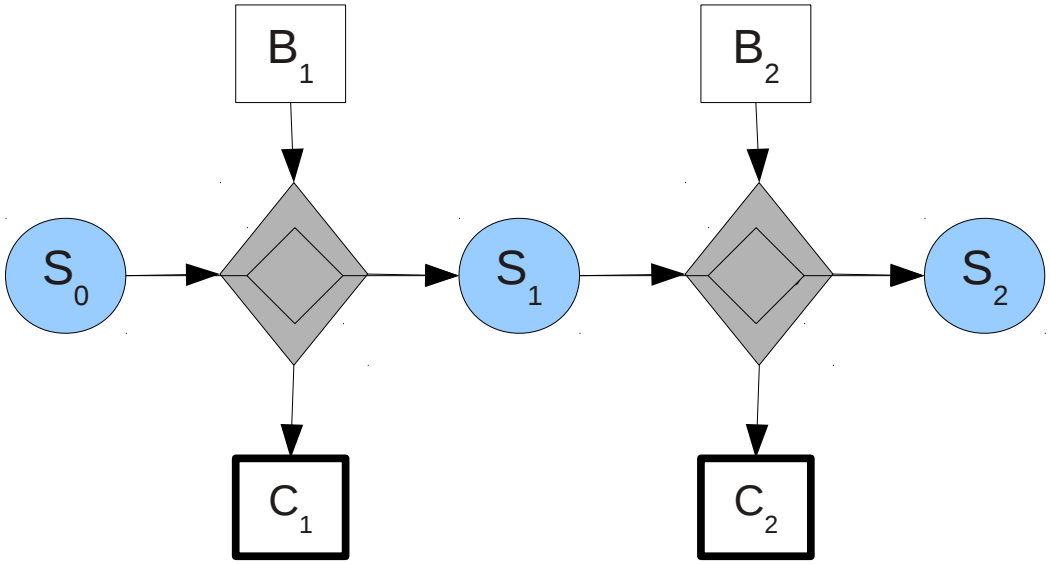
This dependency chain is ***restrictive***.



It forces decompression to proceed in the same order as compression (i.e., prohibits ***random-access***).

Linear Compression

In summary: Popular compression schemes transform compression state ***linearly***.



Outline

- Linear Compression
- Compression in Storage Systems
  - Storage Requirements
  - Linear Limitations
- Non-Linear Compression
  - Architecture and API
  - Example Applications
- Prototype Implementation
  - Preliminary Results
- Future Work

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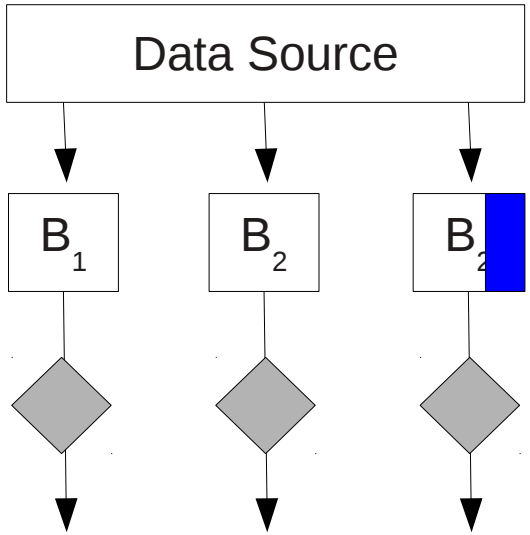
Compression in Storage Systems

Storage systems that use compression generally perform:

1) block compression, and/or
2) delta-encoding



Examples include:

- De-duplicating file systems
- Distributed source control management
- Collaborative editing systems

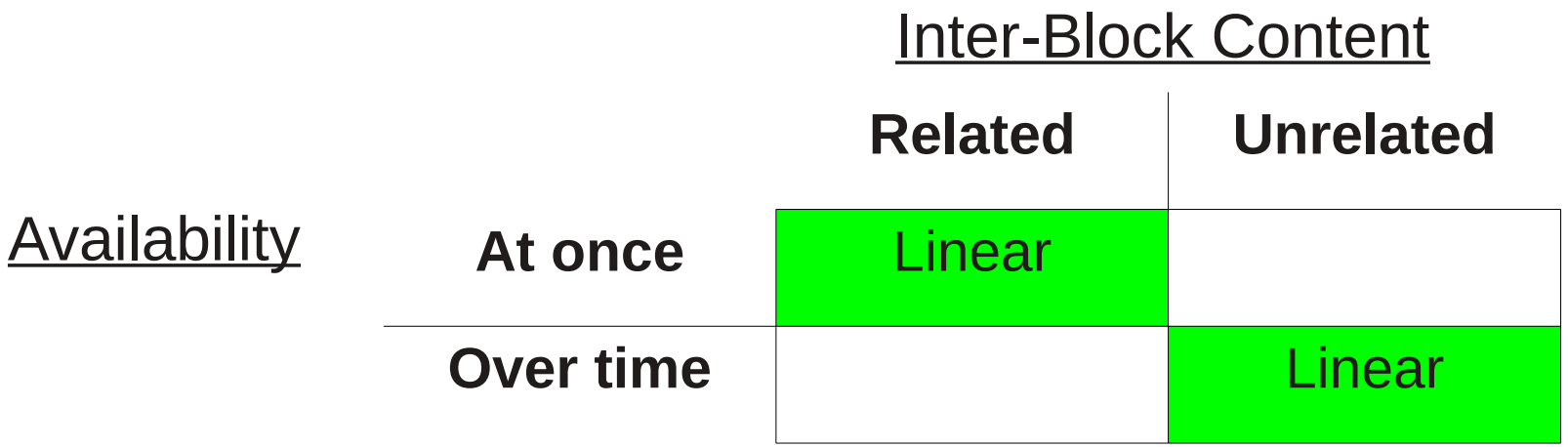
Storage Requirements

Data blocks may be related, or not, and they may be available at different times (e.g., versions of a file), or all at once.

		Inter-Block Content: **Related**	Inter-Block Content: **Unrelated**
Availability	**At once**		
	Over time		

Storage Requirements

Data blocks may be related, or not, and they may be available at different times (e.g., versions of a file), or all at once.



Storage Requirements

Data blocks may be related, or not, and they may be available at different times (e.g., versions of a file), or all at once.

Availability	Inter-Block Content: Related	Inter-Block Content: Unrelated
At once	Linear	???
Over time	???	Linear

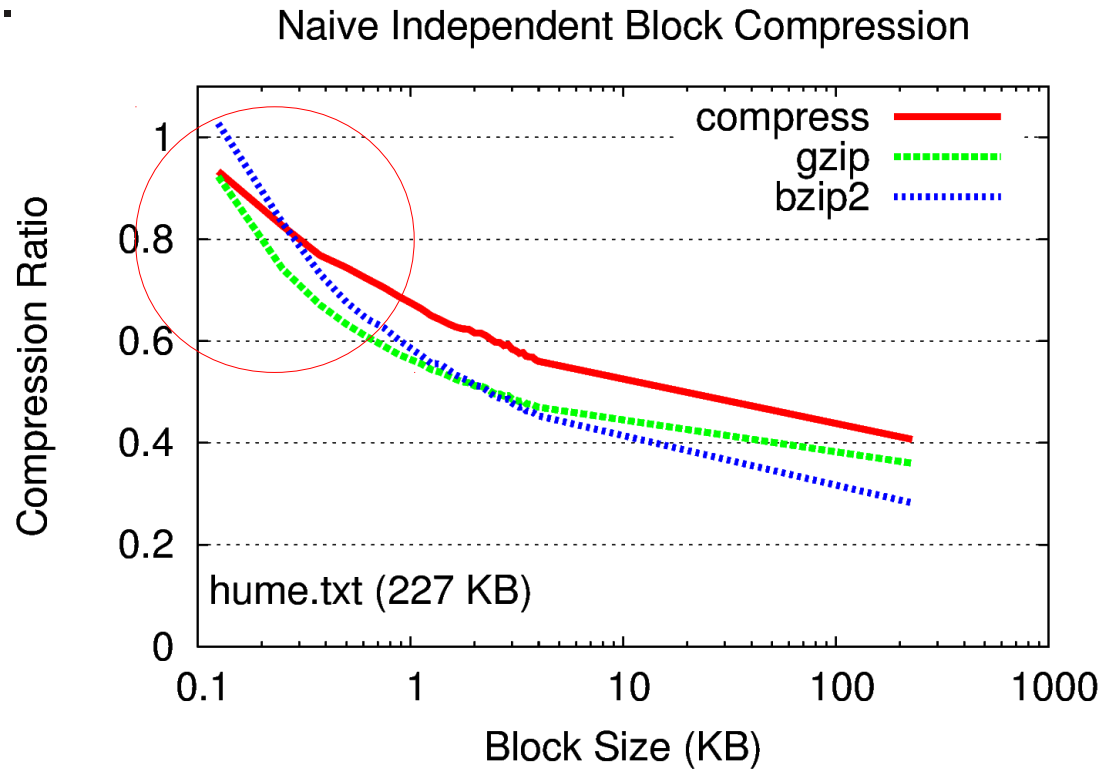
Linear Limitations

	Related	Unrelated
At once		???
Over time		

Random Access

Linear Limitations

Resetting compression state between blocks enables random access...



but significantly reduces the compression ratio for small blocks.

Linear Limitations

	Related	Unrelated
At once		
Over time	???	

Reuse
Compression
State

No abstraction for doing this!

Linear Limitations

Linear compression forces an **all-or-nothing** choice

(especially for blocks < 1KB) of:

(Random-access) vs. (Compression ratio)

and no notion of copying, or reusing, compression state.

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NLC API

Non-Linear Compression API

Linear Compression API

- `State` **`initialize`**`();`
- `int` **`compress`**`(State, void*, int);`
- `int` **`decompress`**`(State, void*, int);`

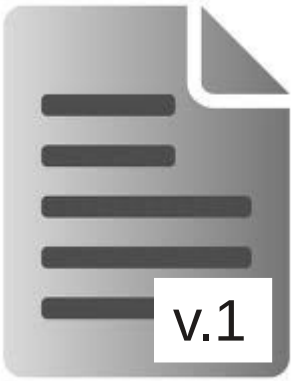
- `State` **`fork`**`(State);`

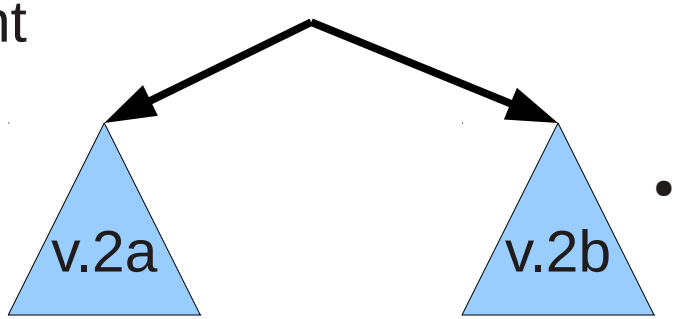
NLC Fork

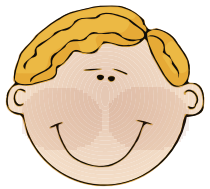
Alice

- Small delta w/ Content dependency

Foo.c





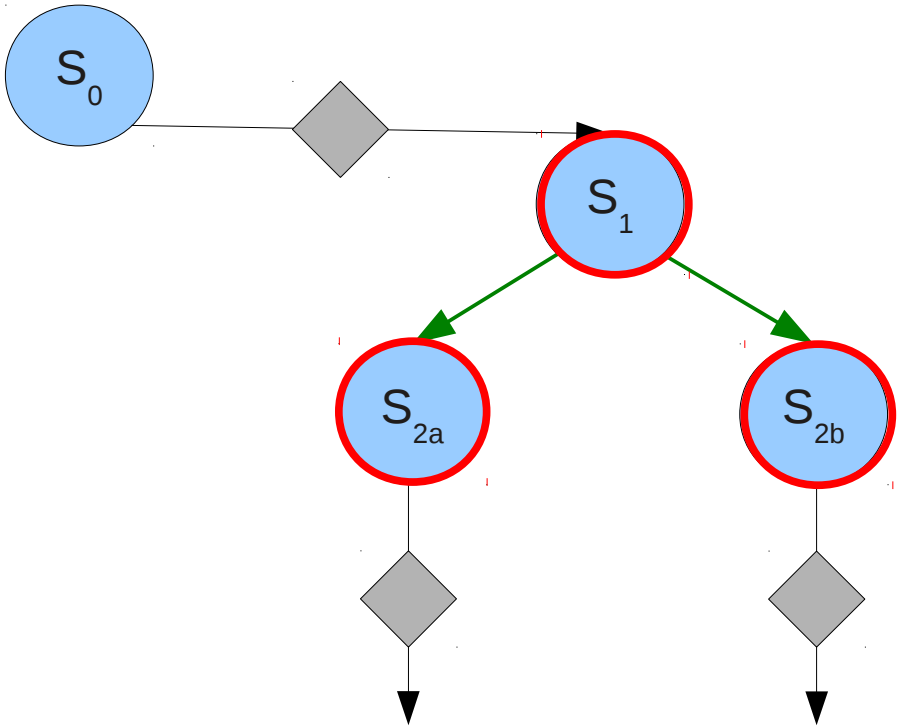


Bob

- Small delta w/ Content dependency
- Independent of v.2a

NLC Fork

Intuition: Fork copies compression state to allow independent compression, or decompression, using previous compression state.



Compress v.1

Fork

Compress Independently

NLC API

Non-Linear Compression API

Linear Compression API

- `State` **`initialize`**`();`
- `int` **`compress`**`(State, void*, int);`
- `int` **`decompress`**`(State, void*, int);`

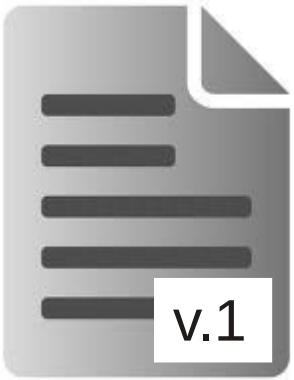
- `State` **`fork`**`(State);`

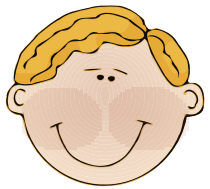
- `State` **`merge`**`(State, State);`

NLC Merge

Alice

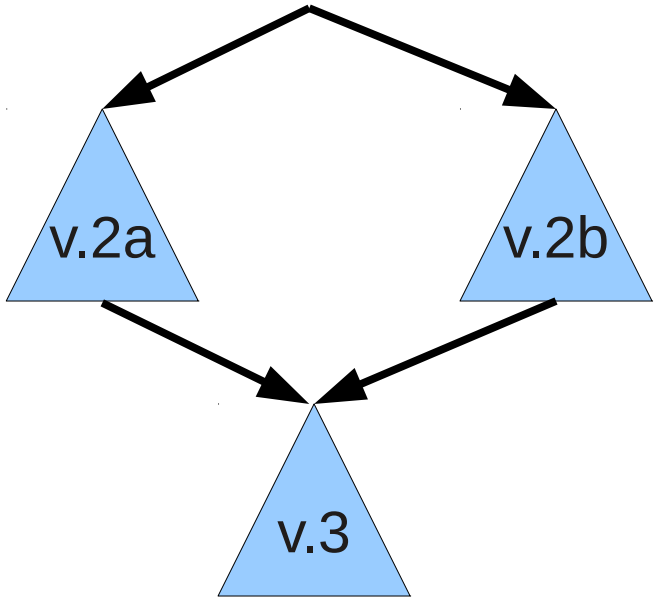
Foo.c





Bob

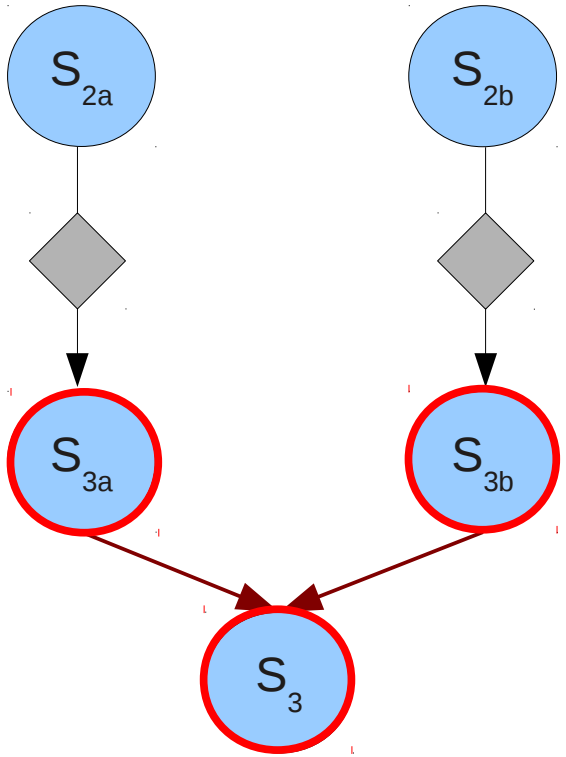
```
…
int func_alice() {
    …
}
```




```
…
int func_bob() {
    …
}
```

NLC Merge

Intuition: Merge combines compression state to allow future compression to use all acquired state between two nodes.



Compress Independently

Merge

NLC API

Non-Linear Compression API

Linear Compression API

- `State` **`initialize`**`();`
- `int` **`compress`**`(State, void*, int);`
- `int` **`decompress`**`(State, void*, int);`

- `State` **`fork`**`(State);`

- `State` **`merge`**`(State, State);`

NLC Architecture

- NLC module provided by the OS.
- Single abstraction for all outstanding state nodes.
- Independent of any specific compression scheme.
  - Supports Huffman, Arithmetic, LZW, LZ77, etc.
- No expectation of random access ***within*** a block.
  - Normal linear compression within blocks.
- Application can use different paths through the DAG for logically distinct “streams” of data.
- Application keeps compressor in-sync with decompressor, but Future Work discusses potential NLC “naming”, or “identification”, schemes.

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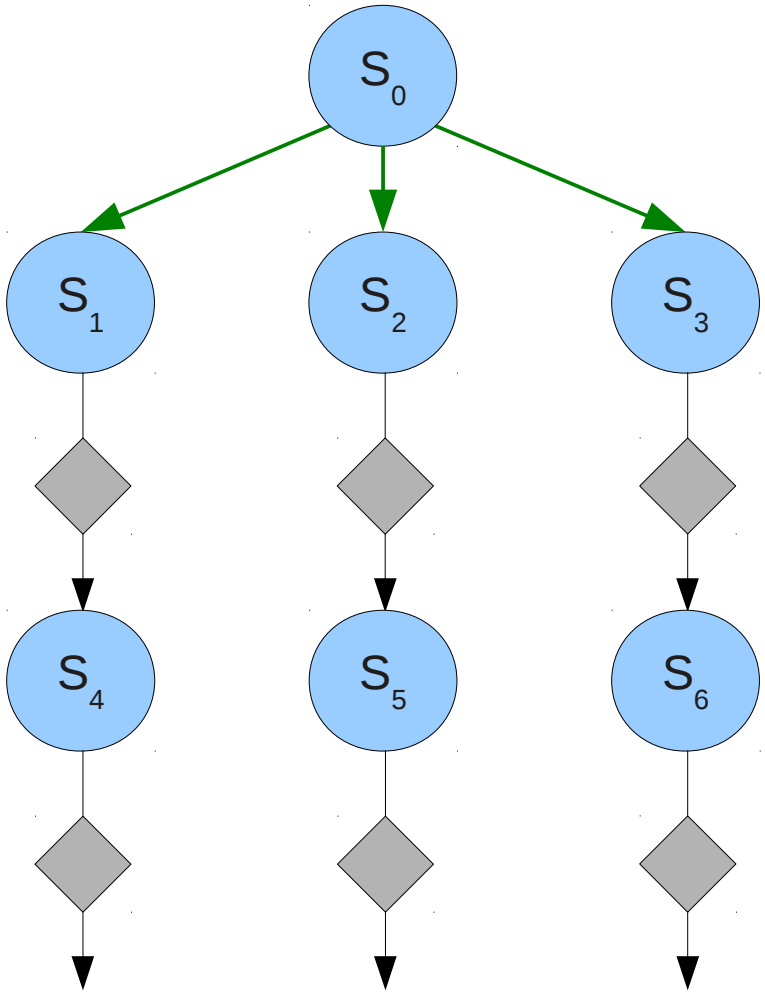
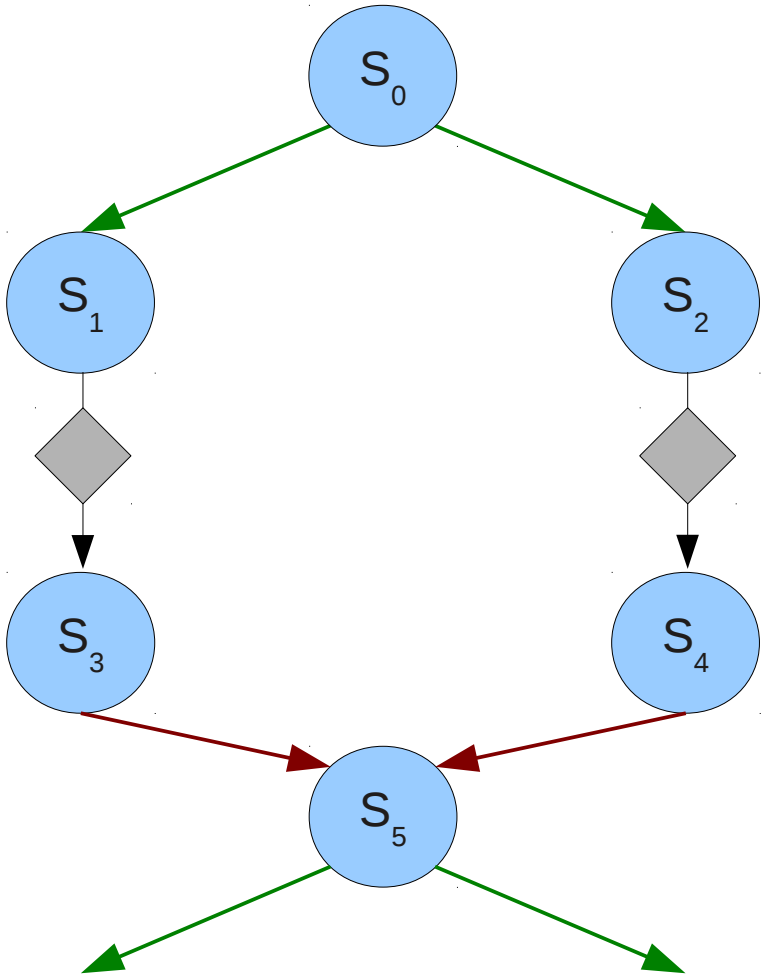
NLC – Parallel Compression



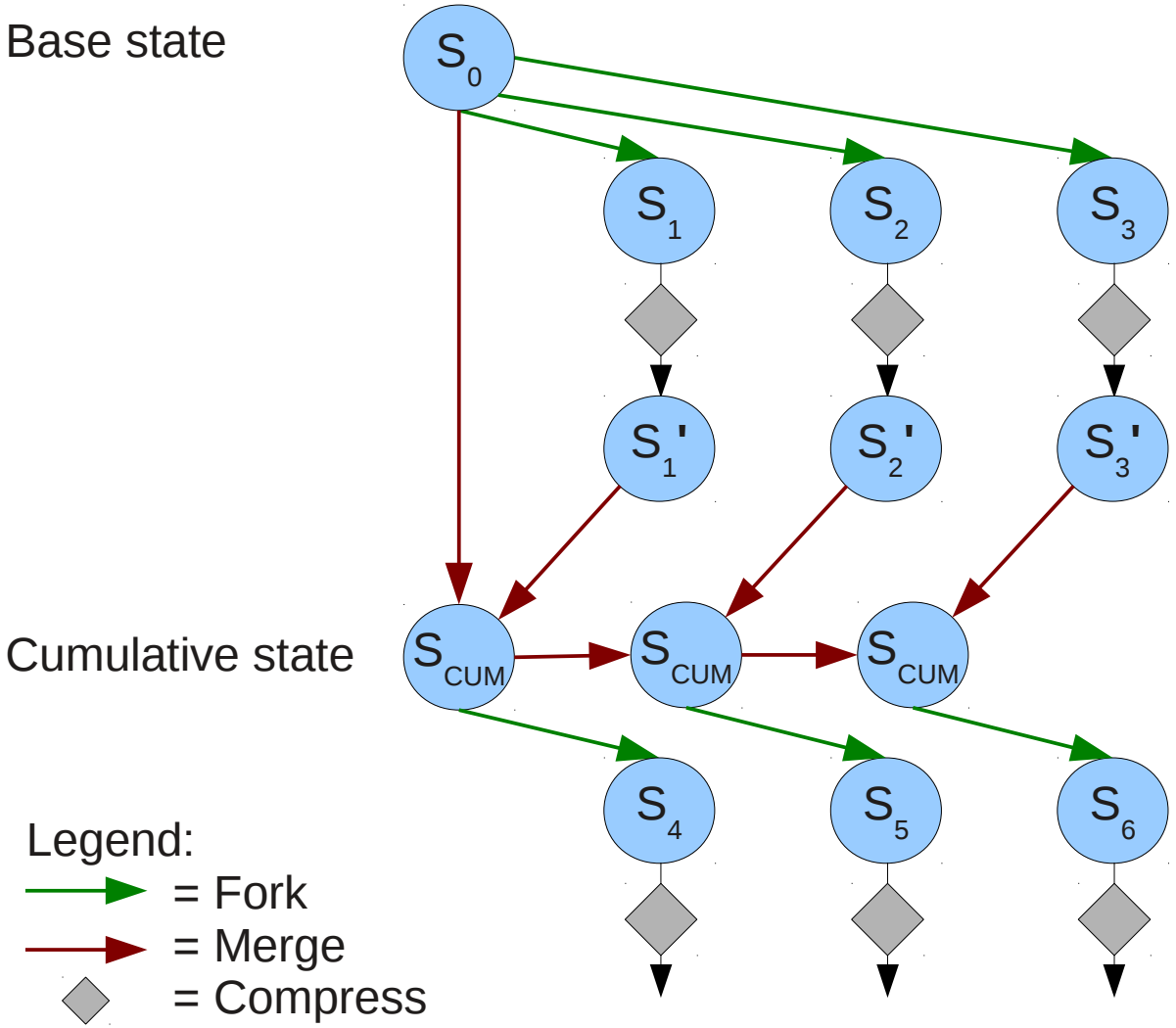
Legend:
= Fork
= Merge
= Compress

NLC – Synchronized Streams



Legend:
- = Fork
- = Merge
- = Compress

NLC – Windowed Compression



Window, ***w***, = 3.

For any given state, ***x***, and current state, ***c***, ***x*** is merged into the Cumulative State when:

x <= (***c*** - ***w***)

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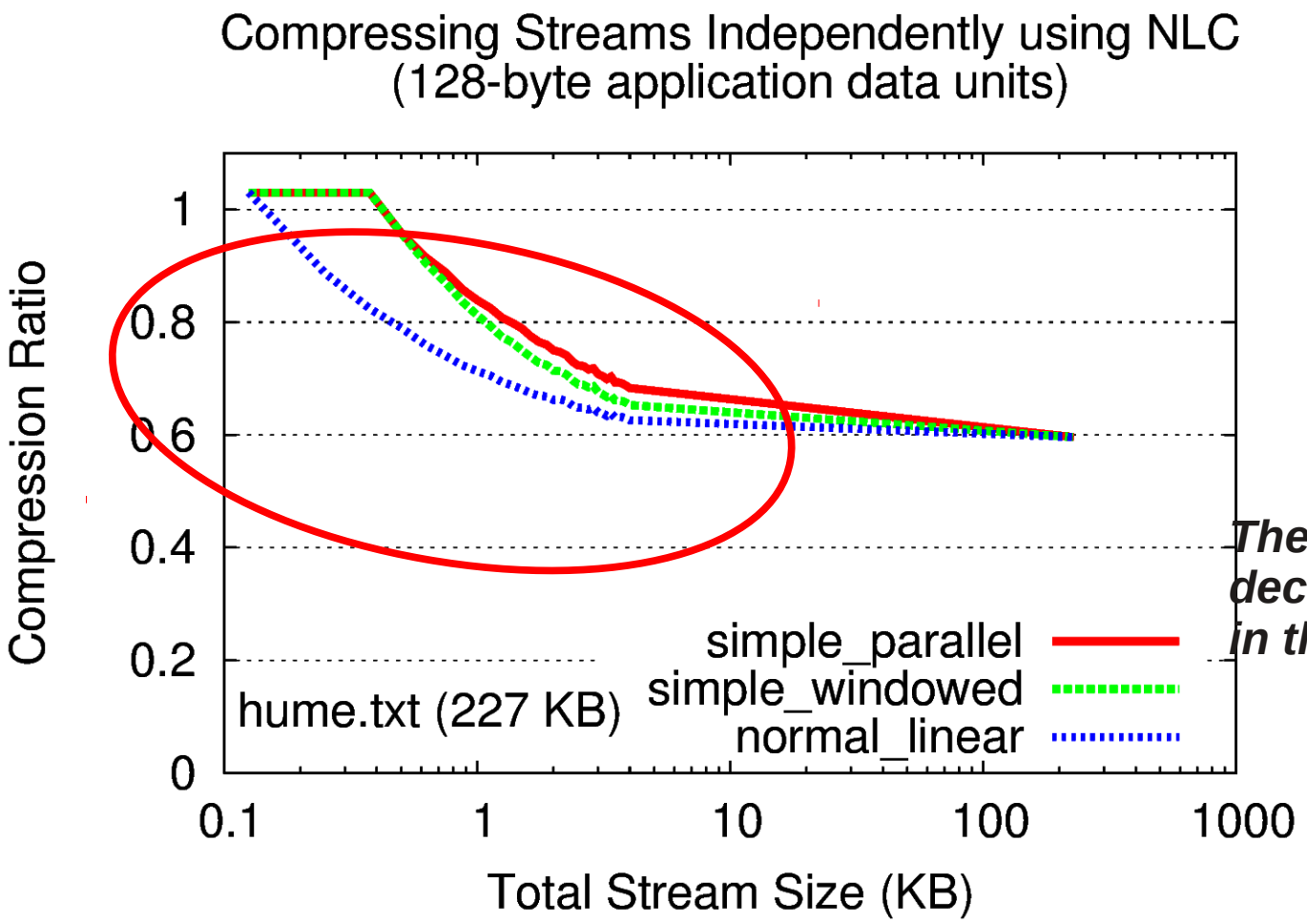
Prototype Implementation

- We have an Adaptive Huffman compressor in C++
- Proof-of-concept; Not meant to compete head-to-head with gzip or other compressors.
  - Order of magnitude slower
  - Fork and Merge are very expensive
  - Compression ratios approach optimal depending on application fork/merge strategy.
  - Merge allows eventual usage of all compression state.

Preliminary Results



Block size =
128 bytes
Window size =
3 blocks

The cost for "unordered decompression" is paid in the first 10 KB.

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Future Work – Challenges

- Merge, Merge, Merge
  - It's computationally expensive and slow.
  - Is it even needed? Are approximation heuristics good enough?
- Fork/Merge behaviors
  - Should we use Fork and Merge sparingly?
- Block size vs. Memory overhead
  - As block sizes decrease, the compression overhead ratio increases.
- State node “naming” or “identification”
  - NLC module should do it for the application.

Conclusion

- Data Compression is used everywhere.

  However, the API is one-size-fits-all.

- Non-Linear Compression aims to be a superset of the traditional compression API by offering Fork and Merge.
- Fork and Merge allow compression state to follow the data's natural logical dependencies.
- This provides localized compression and unordered decompression in many instances.

Thanks to Jana Iyengar, Avi Silberschatz, Michael Fischer, Rob Ross, the anonymous reviewers...

And all of you for listening!

Questions?

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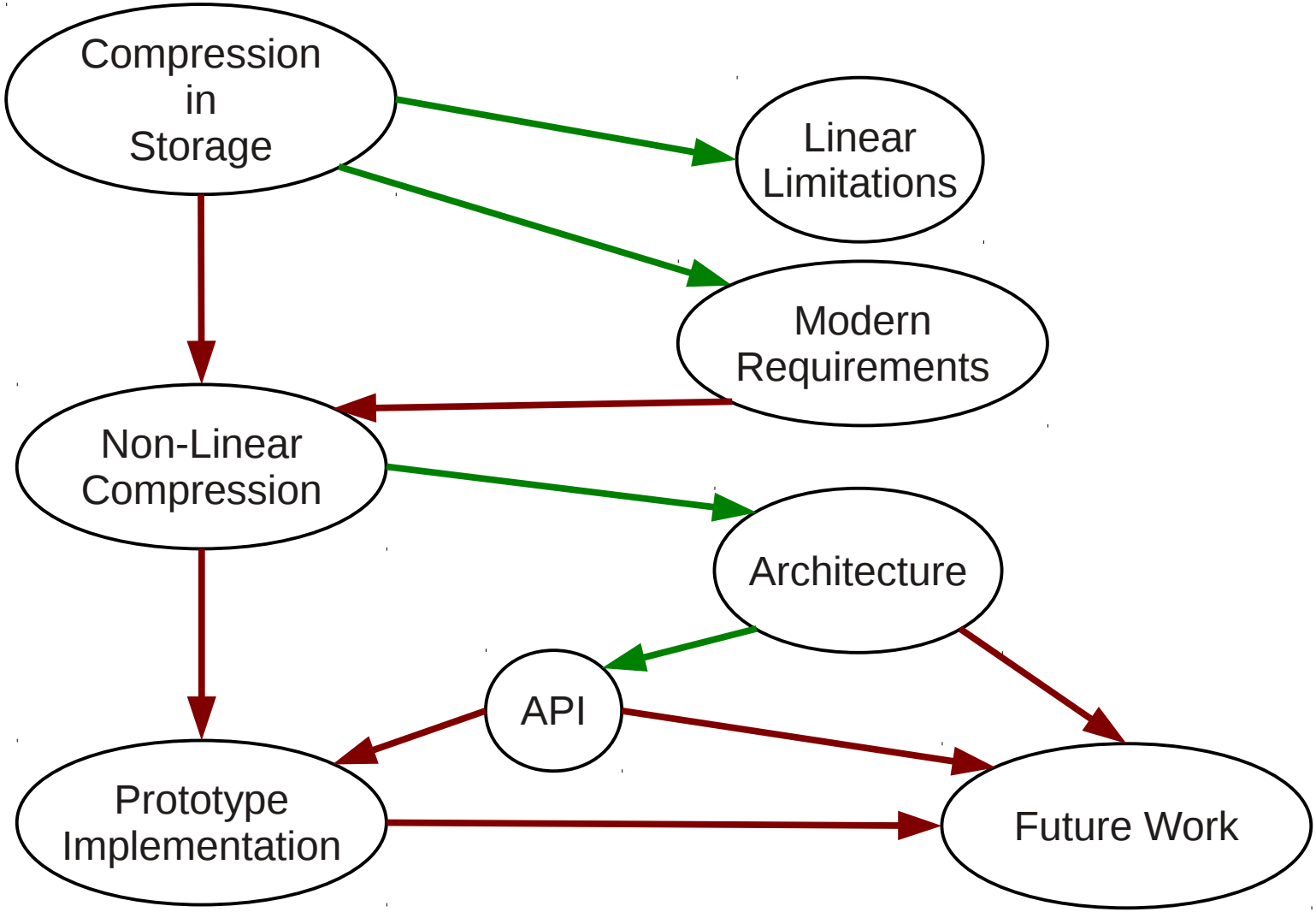
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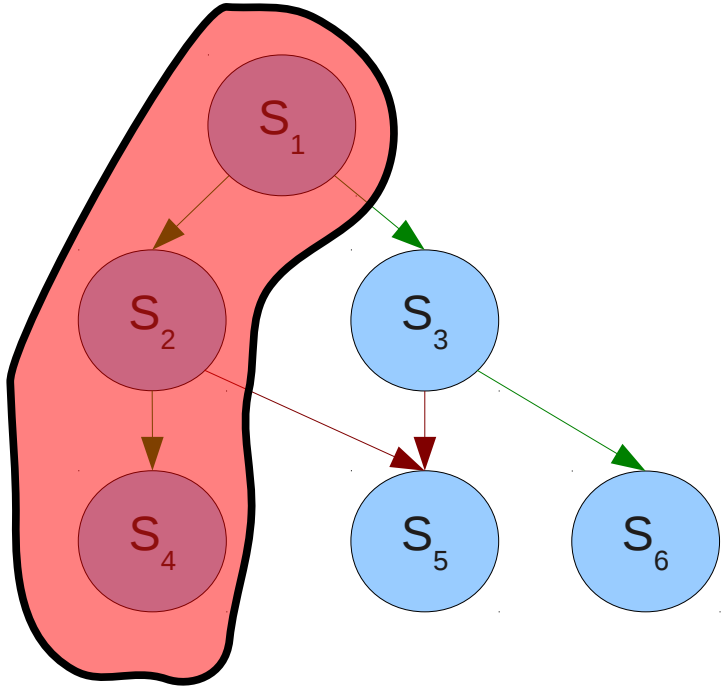
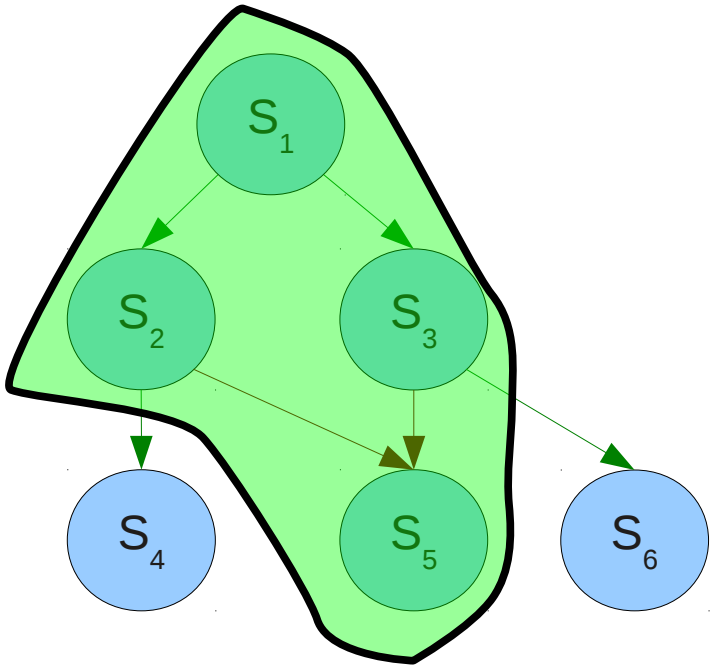
Non-Linear Compression



Non-Linear Compression



Non-Linear Compression