START – Self-Tuning Adaptive Radix Tree

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Practical Database Indexes

Learned indexes

- Small and efficient
- Adapt to data distribution
- Fast for read-only workloads

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ART – Adaptive Radix Tree

- Used in practice
- Well understood
- Fast for various workloads
- But:
  limited adaption to data distribution
- and slower than a well-trained machine learning model

Practical Database Indexes

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START
Self Tuning ART

- Bridges the gap
- Adapts to data: 85 % faster!
- Keep robustness

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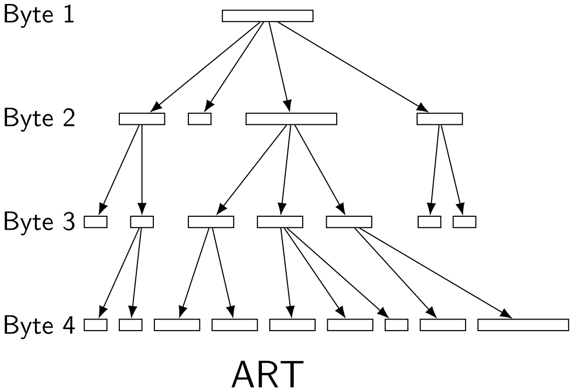
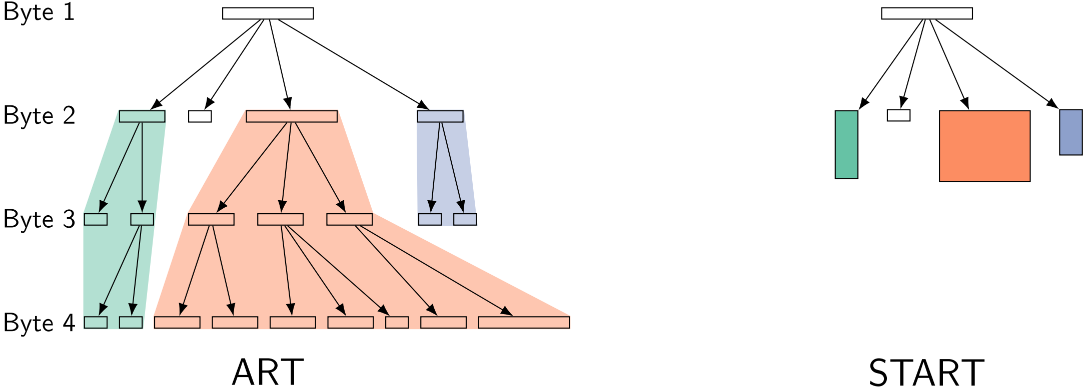
Self-Tuning ART



Self-Tuning ART



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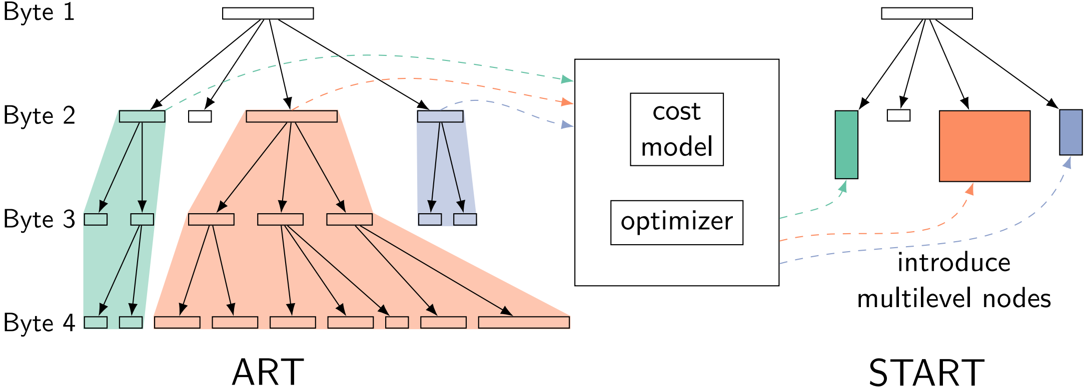

Multilevel Nodes

Rewired memory nodes

- Dense regions with many keys
- Subtrees of full nodes
- Keep data continuous

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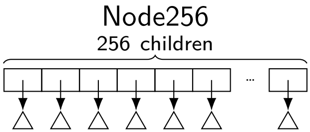
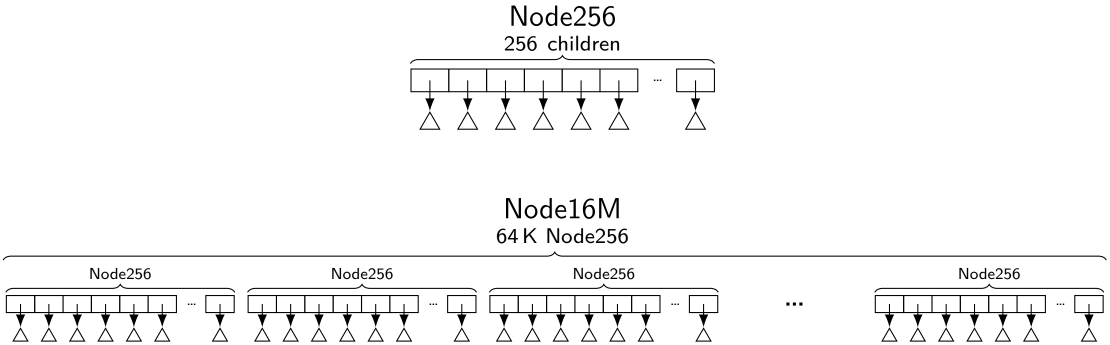
Sparse regions

- Already use path compression
- Still: improve common prefixes
- Reduce chains of small nodes

Rewired Memory Nodes



Rewired Memory Nodes



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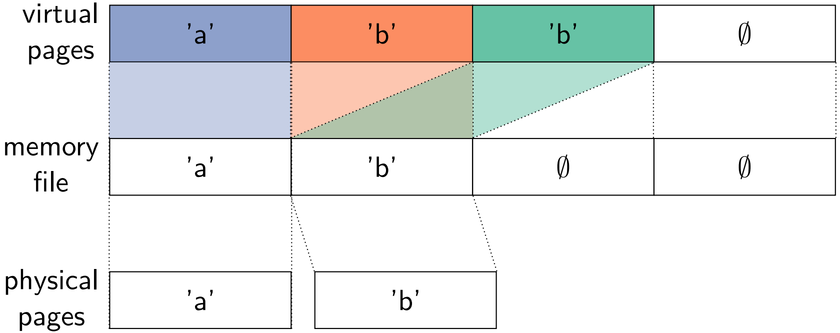

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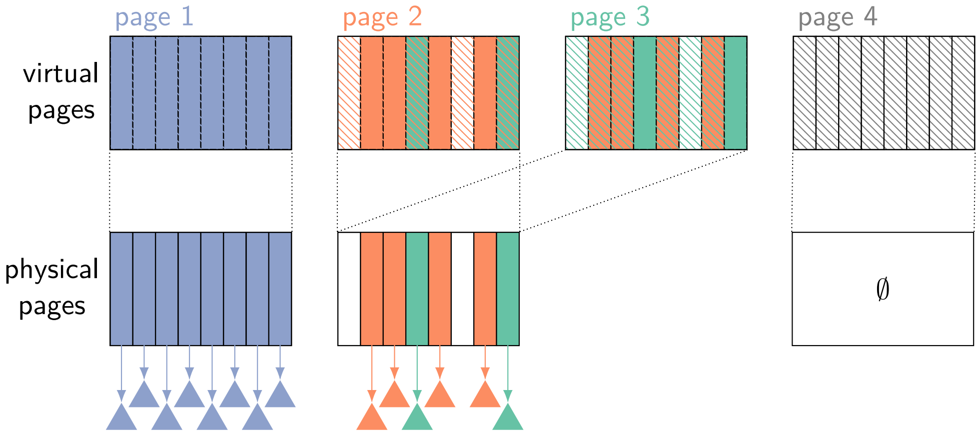
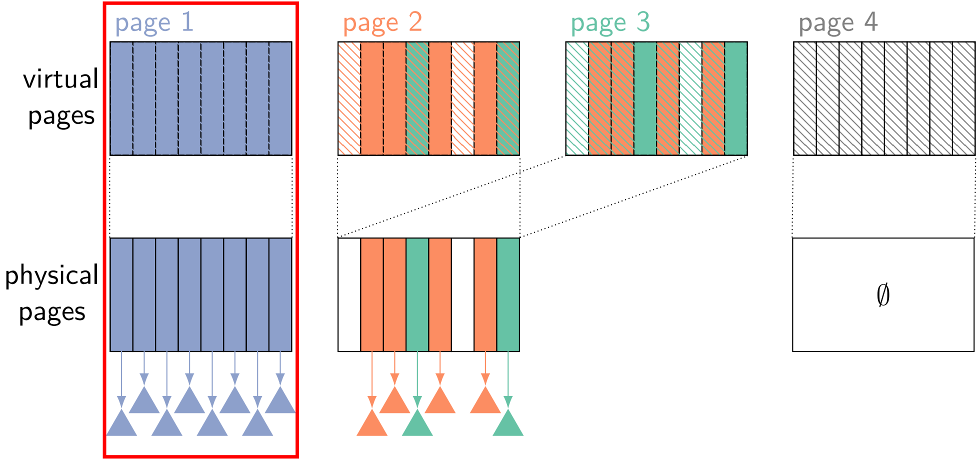


Rewired Memory Nodes



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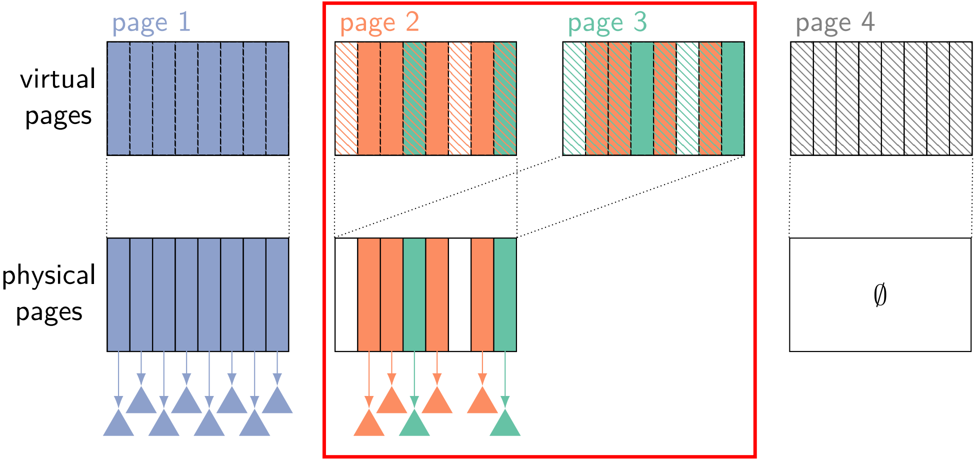

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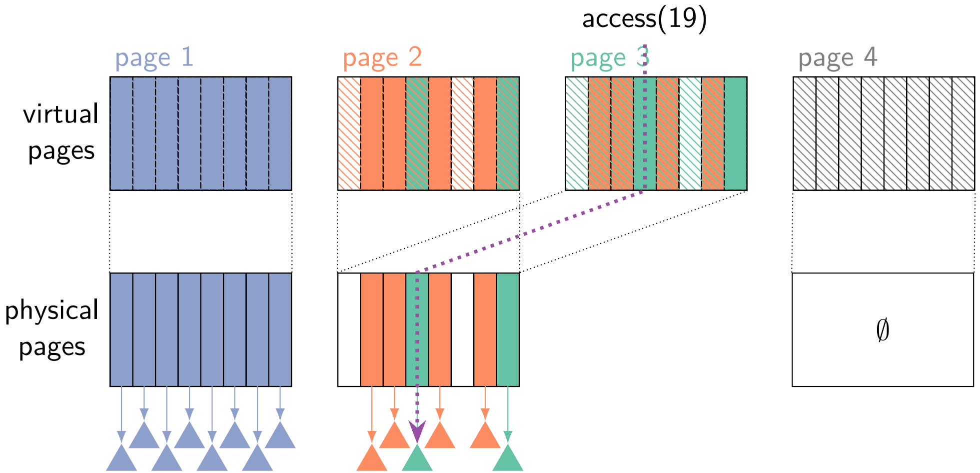

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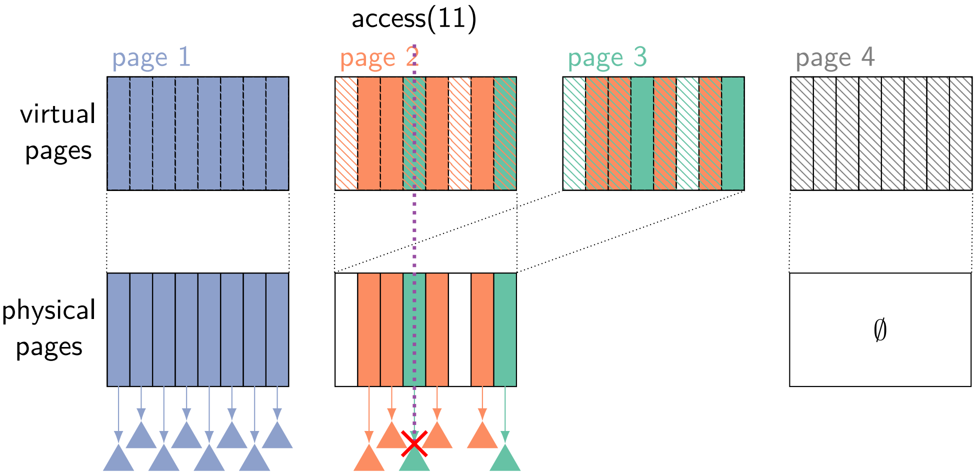
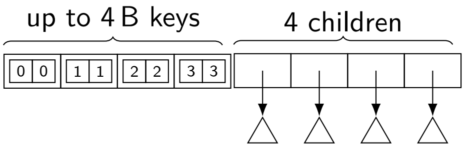


Multilevel Node4

- Helps reduce sparse affix nodes
- Use all 64 Bytes of a cacheline



Cost Model for Node Lookup

- Minimize the average child lookup cost
- Consider individual node cost

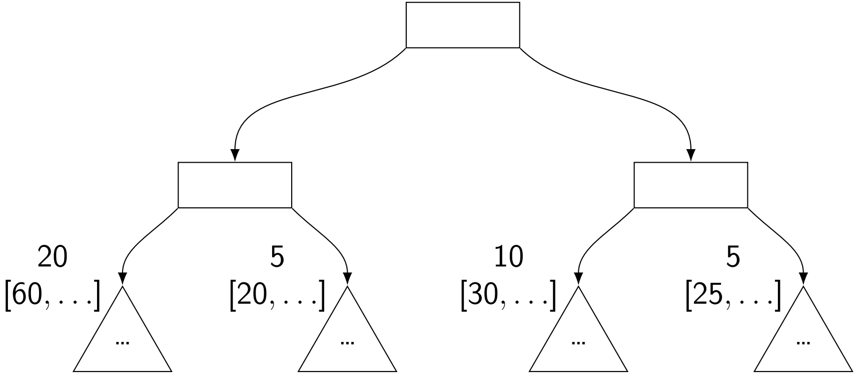
[ns/lookup]	Levels
Node4	1
Node16	1
Node48	1
Node256	1
Rewired64K	2
Rewired16M	3
MultiNode4	2-4

Cost Model for Node Lookup

- Minimize the average child lookup cost
- Consider individual node cost

[ns/lookup]	Levels	Cached	Header Cached	Uncached
Node4	1	7	7	68
Node16	1	5	77	162
Node48	1	2	165	168
Node256	1	2	88	92
Rewired64K	2	6	87	162
Rewired16M	3	6	88	165
MultiNode4	2-4	6	6	68

Bottom-up Optimization



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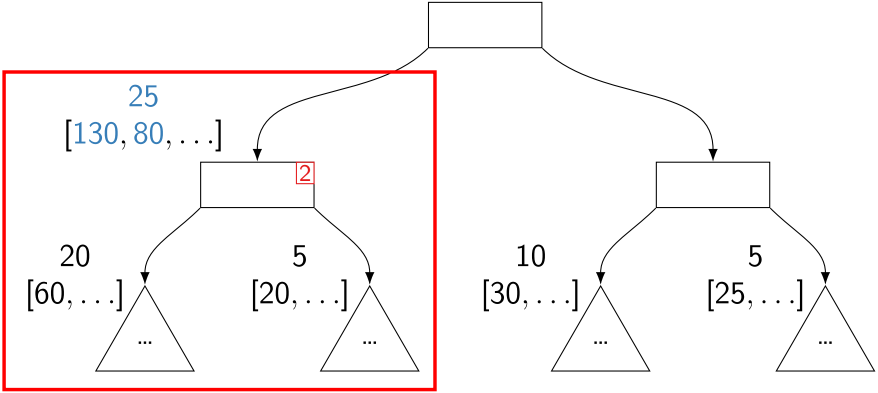

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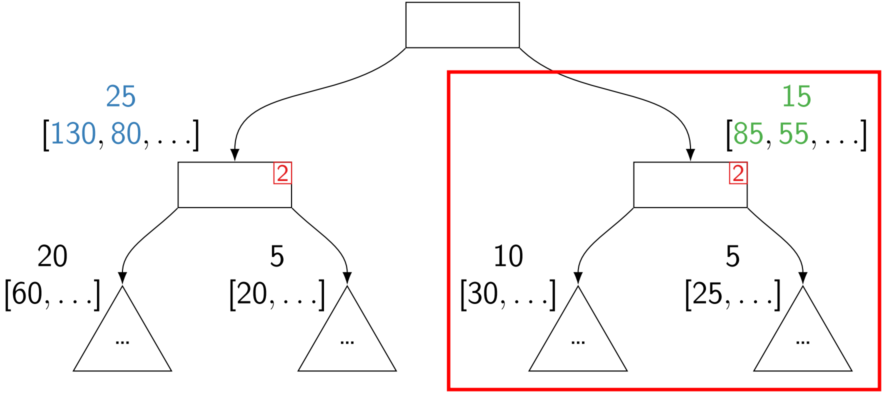
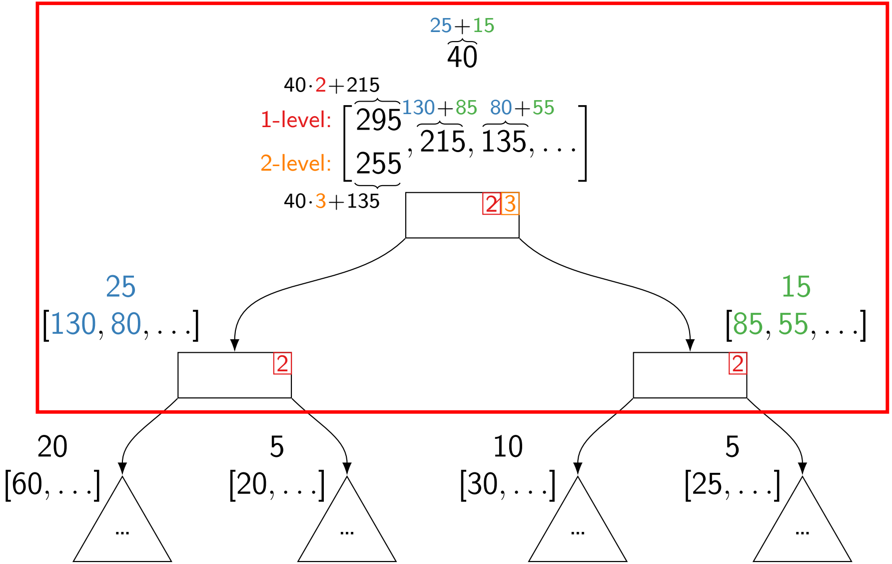
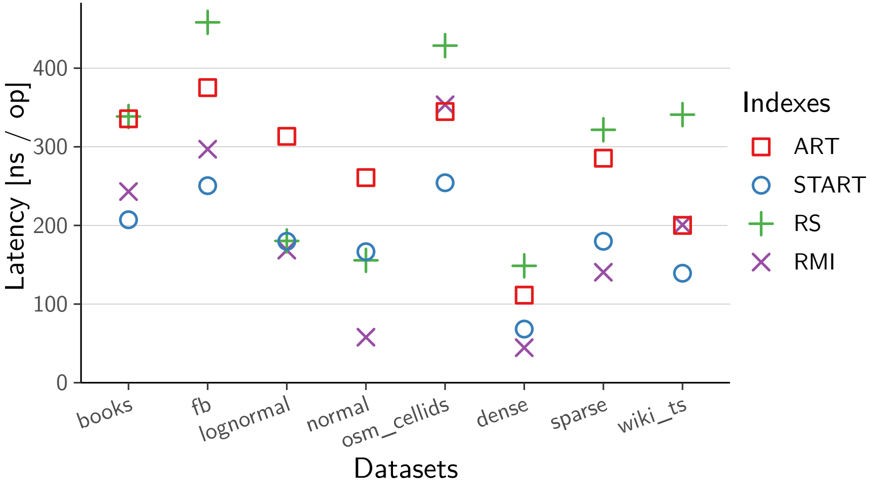



25+15
40
40·2+215
1-level:
2-level:
295
255
130+85
80+55
215, 135, . . .
40·3+135
2
3
25
[130, 80, . . .]
15
[85, 55, . . .]
2
2
20
[60, . . .]
5
[20, . . .]
10
[30, . . .]
5
[25, . . .]
...
...
...
...

Performance

`https://learned.systems/sosd`



Conclusion

- START – Best of both worlds?
- Adapt to real-world data distribution
- Still with robust underpinning of ART
- Inserts still possible and efficient
- But: might degrade multilevel nodes

`github.com/jungmair/START`

`fent@in.tum.de`