Fast GiST index build

Alexander Korotkov
PostgreSQL Conference Europe 2011, Amsterdam
Ordinal GiST index build

We have to insert index tuples one by one

L9, L10, L11, L12, L13, L14, L15, L16
When something go wrong with ordinal GiST index build algorithm?
Index too large to fit into cache

Significant fraction of index tuple inserts cause random IO

Random read
High concurrency

If even index can fit to entire cache, other backends also use cache. So, even not too large index can be out of cache.
What helps to original GiST index build algorithm?
**High overlap**

`gistchoose` selects the first path with zero penalty (if any).
Ordered datasets

Ordered dataset causes inserts to be in the recently accessed part of the index. That's very good for caching.

L9, L10, L11, L12, L13, L14, L15, L16
The buffering GIST index build technique
General idea

Remember index tuples which are going to specific part of tree, and then process pack of them later.
Buffering algorithm is a recursive application of that idea.
Buffer emptying

Lowest level overflowed buffer can be emptied to leaf pages.

I1  I2
I3  I4
L1  L2  L9  L14
L3  L4  L11 L15
L5  L6  L12 L13
L7  L8  L10 L16

L9, L10, L11, L12, L13, L14, L15, L16
Buffer emptying

Higher level overflowed buffers can be emptied to lower level buffers.
Page splitting

When page is splitting, attached buffer is splitting too.
Final buffers emptying

When all the tuples are inserted, final buffers emptying stage is starting. All even non-overflowed buffers are emptying in up-to-down manner.
Buffer size and level step selection

- Subtree of level step height should fits to cache. Therefore, operations inside subtree are IO efficient.
- Buffer size should be comparable with size of subtree. Thus, IO would be comparable with size of inserted data.
Varlena data

Level step and buffer size parameters are depending on index tuple size.

- Level step is determined for worst case. Subtree should fits to cache, even if all varlena tuples are of minimal size.
- Buffer size is in runtime tuning based on average size of inserted index tuples.
Analysis
When does buffering help?

• Somebody may be dissapointed, but buffering helps only if bottleneck of index build is IO (it could be rather dramatic help).

• GiST is also CPU expensive in comparison with, for example, Btree, because many penalty and consistent calls (it have to do that calls for each index tuple in page which is in use). Buffering doesn't do any help with that.
Node splitting algorithm tradeoff

- With buffering build we can now be sure that even large index tree with low overlaps doesn't require enormous time to construct.
- With buffering build, it's a good time to decrease overlaps by new node splitting algorithm.
Double sorting node splitting

- Is based on more comprehensive consideration of splits along axis.
- Has complexity $O(n \cdot \log(n))$, $n$ — tuples count.
- On large datasets it shows much better index quality, because of less overlap (page accesses can be less in times or even dozens of times!)
IO vs CPU tradeoff

- Buffering technique is optimizing IO, but it costs additional CPU load.
- When index fits to cache, buffering is just waste of CPU.
"buffering" parameter of GiST index

- on — try to use buffering anyway (if have enough of RAM)
- off — don't use buffering anyway
- auto (default) — try to switch to buffering when index size exceeds effective_cache_size
## Testing

Test setup with 2Gb of RAM builds index on 100M of row.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Split method</th>
<th>Build method</th>
<th>Actual time</th>
<th>Search time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform</td>
<td>New linear</td>
<td>regular</td>
<td>17 h 39 m</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>buffering</td>
<td>3 h 23 m</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Double sorting</td>
<td>regular</td>
<td>9 d 10 h</td>
<td>0.089</td>
</tr>
<tr>
<td></td>
<td></td>
<td>buffering</td>
<td>4 h 11 m</td>
<td>0.089</td>
</tr>
<tr>
<td>USNOA2 (ordered)</td>
<td>New linear</td>
<td>regular</td>
<td>56 m</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>buffering</td>
<td>1 h 27 m</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Double sorting</td>
<td>regular</td>
<td>45 m</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>buffering</td>
<td>1 h 29 m</td>
<td>0.36</td>
</tr>
<tr>
<td>USNOA2 (shuffled)</td>
<td>New linear</td>
<td>regular</td>
<td>10 h 12 m</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>buffering</td>
<td>3 h 16 m</td>
<td>0.89</td>
</tr>
<tr>
<td></td>
<td>Double sorting</td>
<td>regular</td>
<td>8 d 20 h</td>
<td>0.072</td>
</tr>
<tr>
<td></td>
<td></td>
<td>buffering</td>
<td>4 h 20 m</td>
<td>0.067</td>
</tr>
</tbody>
</table>
Analysis

Buffering technique:

- Accelerate build of non-overlapping trees on shuffled data in dozens of times!
- Might accelerate build of even high-overlapping trees (depending of OS cache strategy)
- Adds some slowdown to index build on well-ordered datasets.
Future work

- Improve automatic switching to buffering build mode (detect concurrent load and ordered datasets)
- Decrease CPU usage
- Extend GiST interface with special features for index build (for example, Hilbert's curve).
Acknowledgement

- Oleg and Teodor for giving direction and advices
- Heikki Linnakages for mentoring and his work on this patch
- GSoC for funding of this project
Thank you for attention! Questions are welcome!