Using Bitmap Index for Interactive Exploration of Large Datasets

INFO3504 Presentation

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- Are efficient for big data and data warehouse solutions with read-only records
- Do not reorder data, unlike some other algorithms

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This is quite a quick and efficient operation.

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- 1.6 GiB
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Storing these in a typical database with a `Bitmap Index` took $3\times$ the size, similar to when using a `B-Tree Index` = Not ideal!

Bitmap Compression

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- Run-Length Encoding

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- Word-Aligned Hybrid (WAH)

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A patent exists for it:

Publication number	US6831575 B2
Publication type	Grant
Application number	US 10/701,655
Publication date	Dec 14, 2004
Filing date	Nov 4, 2003
Priority date ?	Nov 4, 2002
Fee status ?	Lapsed
Also published as	US20040090351
Inventors	Kesheng Wu, Arie Shoshani, Ekow Otoo
Original Assignee	The Regents Of The University Of California
Export Citation	BiBTeX, EndNote, RefMan

Patent Citations (2), Referenced by (15), Classifications (9), Legal Events (7)

External Links: USPTO, USPTO Assignment, Espacenet [1]

[1] https://www.google.com/patents/US6831575

[2] http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1214955

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Using Bitmap Index for Interactive Exploration of La

Kesheng Wu, Wendy Koegler, Jacqueline Chen, and Arie Shos

Abstract

Many scientific applications generate large spatio-temporal datasets. A common way of exploring these datasets is to identify and track regions of interest. Usually these regions are defined as contiguous sets of points whose attributes satisfy some user defined conditions, e.g. high temperature regions in a combustion simulation. At each time step, the regions of interest may be identified

velocity throughout a volume of are then identified as meeting so these properties, e.g. regions in t is very hot. Datasets can have hu as pressure, concentrations, etc. be defined based on any of the at well as combinations of differen usually has to explore a number before proceeding to subsequent [2]

[1] https://www.google.com/patents/US6831575

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Differs from Run Length Encoding in **two** major ways:

- It only records long groups of 0s or 1s using Run Length Encoding (the short groups are represented *literally*)
- It requires groups of a certain size so that operations on the compressed data are efficient

How Does It Work?

Understand: What Is A Fill?

A group of consecutive identical bits.
A fill with only 0s is called a 0-fill and a fill with only 1s is called a 1-fill.

Understand: Word-Size?

The word size is dependent on the computer architecture. On x86 machines (32-bit), the word size is 32-bits. On x86_64/amd64 machines, the word size is 64-bits.

How Does It Work?

1. Split the bitmap index into multiple rows of size: `word-length` − 1
2. If the row is **NOT** entirely made up of either 1s or 0s (i.e. not a 0-fill or a 1-fill), then keep as is (*literal*) and prefix row with a 0
3. Otherwise, determine how many following rows are also fill rows. Prefix the row with a 1 (fill bit), mark the second bit with the type of bit that is to be filled, then the rest of the bits are how many subsequent rows also match this criteria

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Who understands all of that?

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Let's go back to our example:

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How Does It Work?

Preamble:

- Let's turn it on its side: $A_1 = 01100$
- Assume that our word size is 16 bits.
- Assume that there are 60 tuples (i.e. $R_1, R_2, \cdots, R_{31}, R_{32}$)

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Result from applying WAH:

$$A_1 = 0 \quad 011001001011010$$

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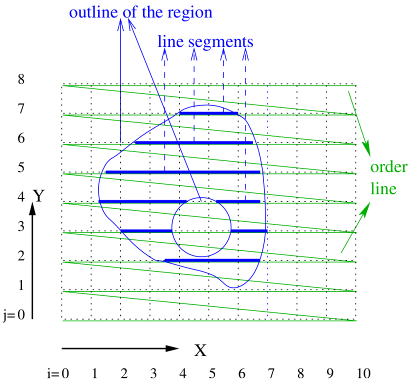
Example From Paper



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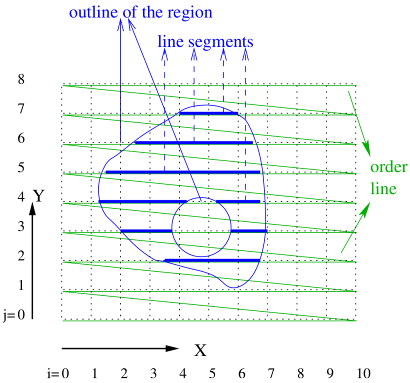

Run-Length Encoding: 26×0, 3×1, 6×0, 2×1, 2×0, 1×1, 6×0, 3×1, 1×0, 1×1, 6×0, 5×1, 7×0, 4×1, 8×0, 3×1, 15×0

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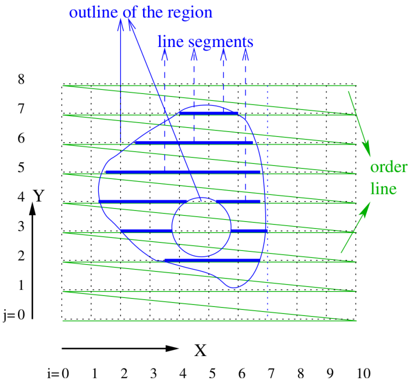

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WAH Encoding (in hex):
`0000001C 0640E81F 00F00E00 00000000`

Versus Run Length Encoding

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- Logical operations on WAH compressed bitmaps can work *directly* on the compressed data and *generate compressed answers*. Because of this, the time to perform these operations is proportional to the sizes (bytes) of the bitmaps involved.
- We can generate bitmap indices efficiently. Using WAH compression, it is possible to only insert bits that are 1 when creating a bitmap index. In practice, generating a bitmap index has the computational complexity of $O(N\log(b))$ (where b is number of bitmaps generated), compared to generating an uncompressed bitmap index: $O(Nb)$ (significantly worse).

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To visualise this data we need the boundaries of connected regions, and how they change in time.

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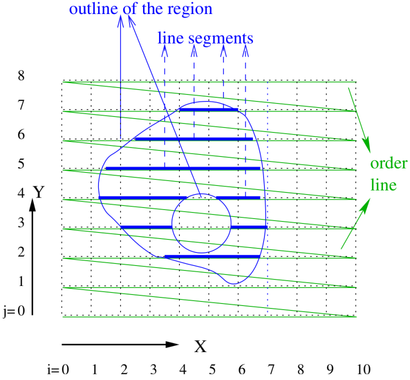

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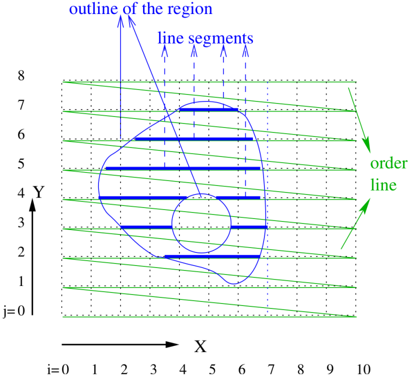

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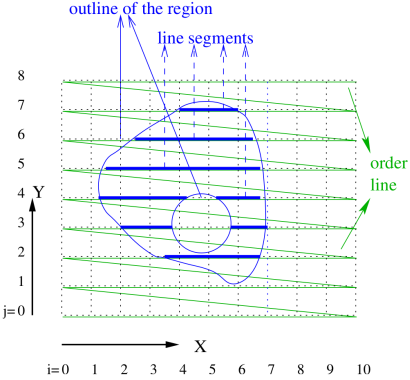

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- Line segments are aligned along the x-axis
- Discovers line segments in order of j and k

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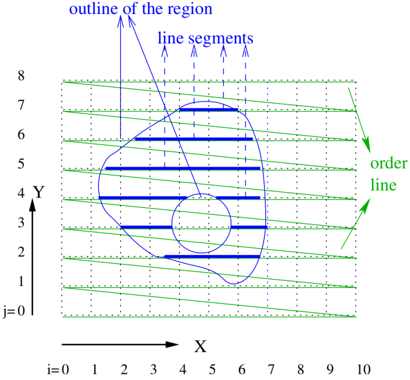

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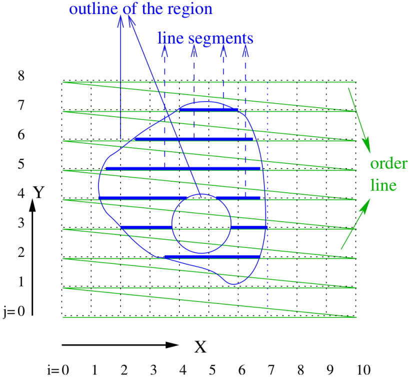

- For each line segment with coordinates (j, k) we compare with all line segments with coordinates (j-1, k), (j, k-1), and maybe (j-1, k-1)
- If the line segments overlap then they are connected

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- Overall takes $O(s)$ time.
  - vs $O(v)$ time for a straightforward algorithm.

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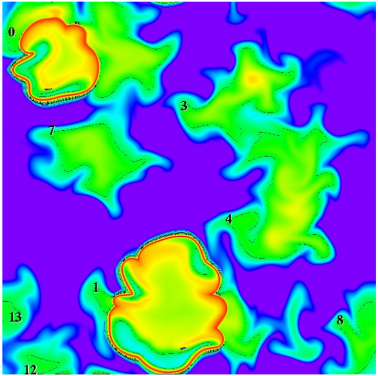
Region Tracking

With spatio-temporal datasets we want to be able to track the evolution of regions of interest over time.

- We produce bitmaps for each connected region identified during region growing.
- These bitmaps are used to determine the overlap of regions in neighbouring time steps.
- Can do a bitwise AND operation and count the number of 1s.
- Has a time and space complexity of $O(s_1 + s_2)$ which is optimal.
  - Compared to $O(v_1 v_2)$ for a straightforward approach.

Region Tracking

A simple approach assigns numbers to regions which identifies them over time.



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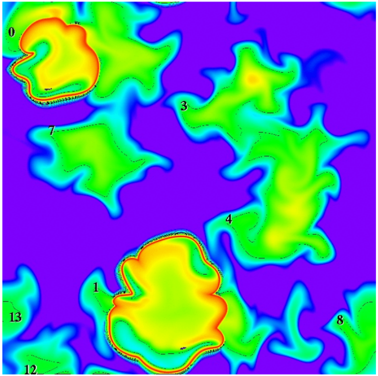

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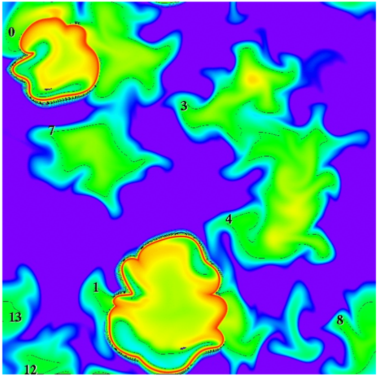

- At the first time step, regions are arbitrarily numbered.
- A region in time step p gets assigned the number of the region in time step $p-1$ with maximal overlap
  - or an arbitrary number if it does not overlap.

Thanks!

Slides can be found online:

`http://tinyurl.com/info3504-bitindex`