Heavy Committing: Flexible Indexing in Lucene 4

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Presented by

lucid IMAGINATION

Lucene

Apache Solr

My Background

- I am committer and PMC member of Apache Lucene and Solr. My main focus is on development of Lucene Java.
- Implemented fast numerical search and maintaining the new attribute-based text analysis API. Well known as Generics and Sophisticated Backwards Compatibility Policeman.
- Working as consultant and software architect for SD DataSolutions GmbH in Bremen, Germany. The main task is maintaining PANGAEA (Publishing Network for Geoscientific & Environmental Data) where I implemented the portal's geo-spatial retrieval functions with Lucene Java.
- Talks about Lucene at various international conferences like Lucene Revolution, the *previous* Lucene Eurocon, ApacheCon EU/US, Berlin Buzzwords, and various local meetups.

Agenda

- Motivation
- API changes in general
- Codecs
- Future
- Wrap up

Lucene up to version 3.4

- Lucene started > 10 years ago
  - **Lucene's vInt format is old and not as friendly as new compression algorithms to CPU's optimizers *(exists since Lucene 1.0)***
- It's hard to add additional statistics for scoring to the index
  - **IR researchers don't use Lucene to try out new algorithms**
- Small changes to index format are often huge patches covering tons of files
  - **Example from days of Lucene 2.4: final omit-TFaP patch of LUCENE-1340 is ~70 KiB covering ~25 files**

Why Flexible Indexing?

- Many new compression approaches ready to be implemented for Lucene
- Separate index encoding from terms/postings enumeration API
- Make innovations to the postings format easier

Targets to make Lucene extensible even on the lowest level

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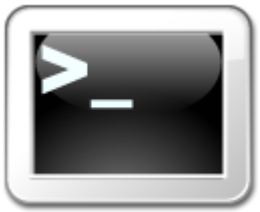
Quick Overview

- Will be **Apache Lucene ≥ 4.0** only!
- Allows to
  - **store new information into the index**
  - **change the way existing information is stored**
- Under heavy development
  - **almost stable API, may break suddenly**
  - **lots of classes still in refactoring**
- Replaces a lot of existing classes and interfaces → **Lucene 4.0** will not be backwards compatible *(API wise)*

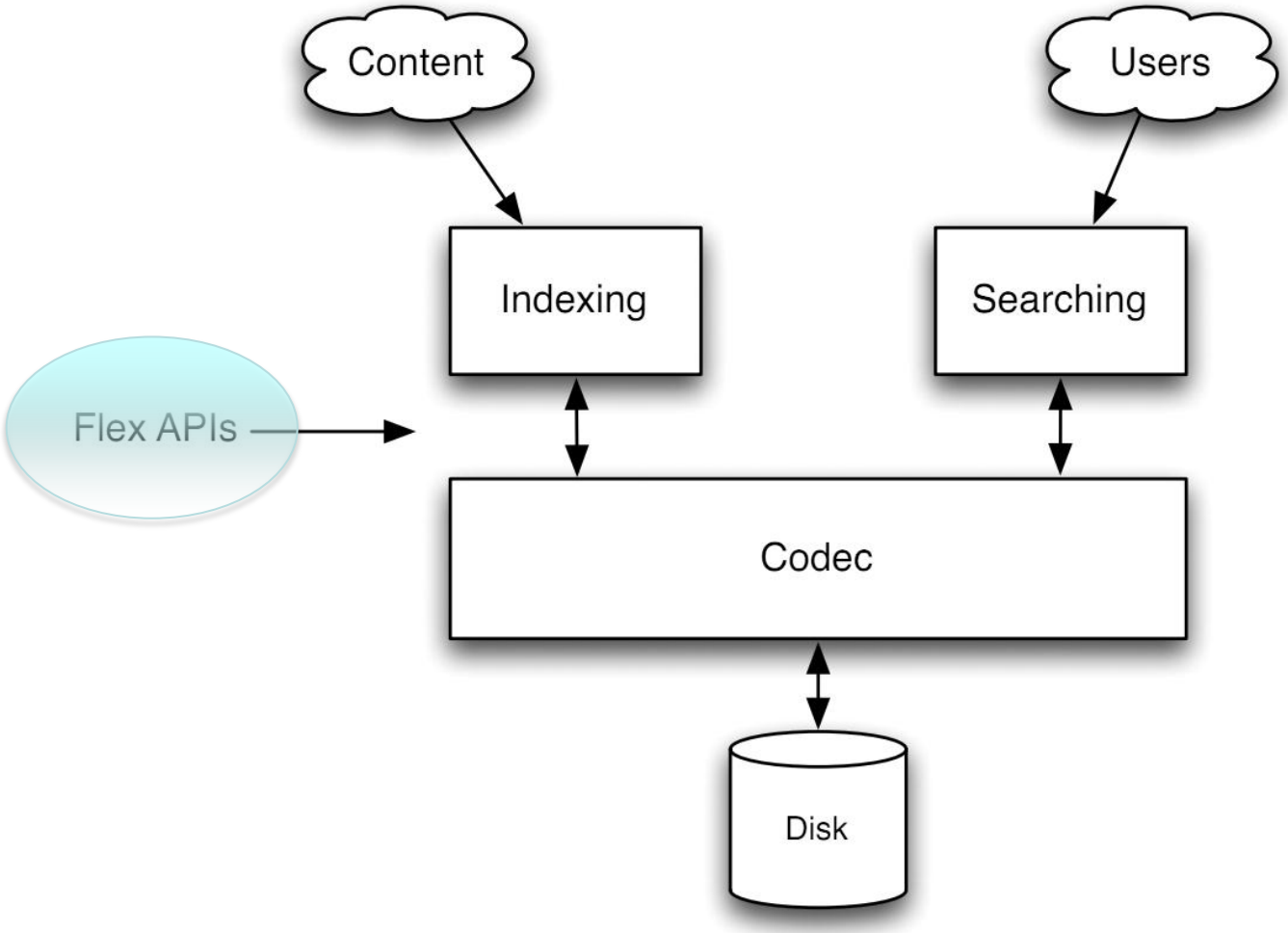
Quick Overview

- **Pre-4.0** indexes are still **readable**, but **< 3.0 is no longer supported**

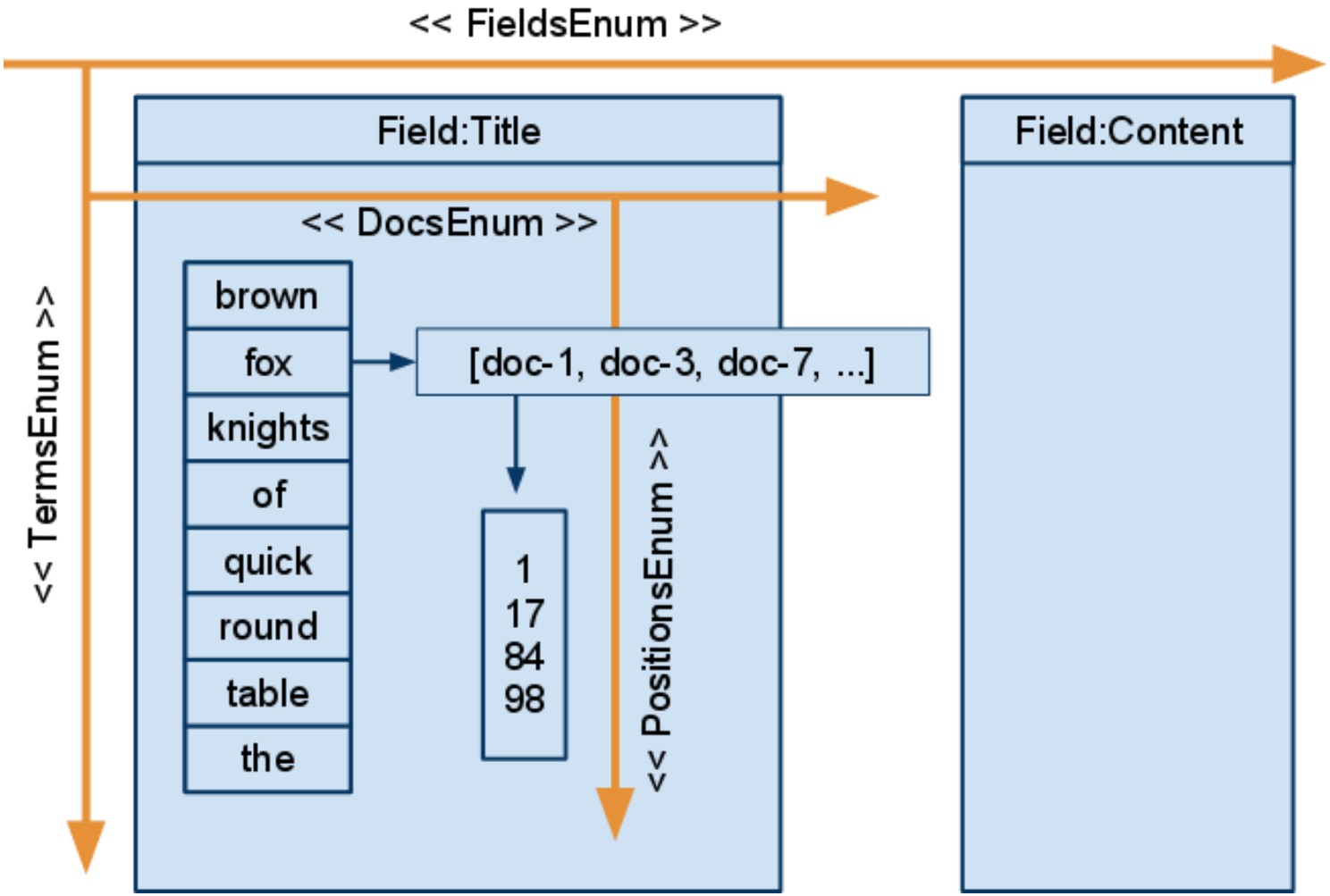
- Index upgrade tool is available since **Lucene 3.2**
  - ***Supports upgrade of pre-3.0 indexes in-place → two-step migration to 4.0*** **(LUCENE-3082)**



Architecture



New 4-dimensional Enumeration-API



Flex - Enum API Properties (1)

- Replaces the `TermEnum` / `TermDocs` / `TermPositions`
- Unified iterator-like behavior: no longer strange `do…while` vs. `while`
- Decoupling of term from field
  - `IndexReader` returns enum of fields, each field has separate `TermsEnum`
  - No interning of field names needed anymore
- Improved RAM efficiency:
  - efficient re-usage of byte buffer with the `BytesRef` class

Flex - Enum API Properties (2)

- Terms are arbitrary byte slices, no 16bit UTF-16 chars anymore
- Term now using byte[] instead of char[]
  - compact representation of numeric terms
- Can be any encoding
  - Default is UTF-8 → changes sort order for supplementary characters
  - Compact representation with low memory footprint for western languages
  - Support for e.g. BOCU1 (LUCENE-1799) possible, but some queries rely on UTF-8 (especially `MultiTermQuery`)
- Indexer consumes `BytesRefAttribute`, which converts the good old `char[]` to UTF-8

Flex - Enum API Properties (3)

- All Flex Enums make use of `AttributeSource`
  - Custom Attribute deserialization *(planned)*
  - E.g., `BoostAttribute` for `FuzzyQuery`
- `TermsEnum` supports seeking *(enables fast automaton queries like `FuzzyQuery`)*
- `DocsEnum` / `DocsAndPositionsEnum` now support separate `liveDocs` property: Custom control of excluded/live documents *(enables to apply filters down-low: LUCENE-1536)*

FieldCache

- FieldCache consumes the flex APIs
- Terms (previously strings) field cache more RAM efficient, low GC load
  - **Used with `SortField.STRING`**
- Shared byte[] blocks instead of separate String instances
  - **Terms remain as `byte[]` in few big `byte[]` slices**
- `PackedInts` for ords & addresses (LUCENE-1990)
- RAM reduction ~ 40-60%

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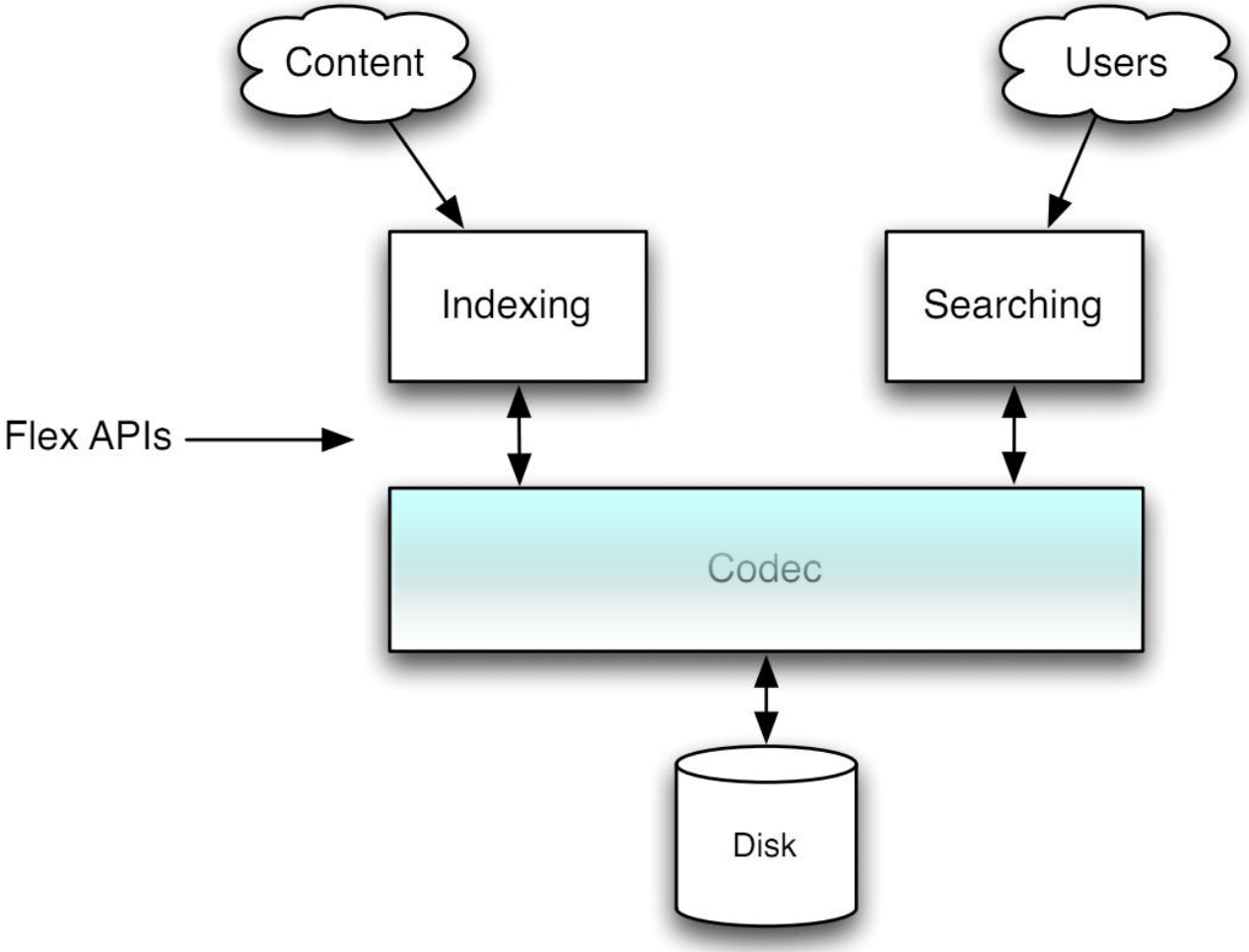
Extending Flex with Codecs

- A Codec represents the primary Flex-API extension point
- Directly passed to `SegmentReader` to decode the index format
- Provides implementations of the enum classes to `SegmentReader`
- Provides writer for index files to `IndexWriter`

Architecture



Components of a Codec

- `Codec` provides read/write for one segment
  - Unique name (String)
  - FieldsConsumer (for writing)
  - FieldsProducer is 4D enum API + close
- `CodecProvider` creates `Codec` instance
  - Passed to `IndexWriter/IndexReader`
  - **Supports per field codec configuration**
- You can override merging
- Reusable building blocks
  - Terms dict + index, postings

Build-In Codecs: PreFlex

- Pre-Flex-Indexes will be “read-only” in Lucene 4.0
- all additions to indexes will be done with `CodecProvider`‘s default codec

Warning: `PreFlexCodec` needs to reorder terms in term index on-the-fly: „surrogates dance“
→ use index upgrader (since Lucene 3.2, LUCENE-3082)

Default: StandardCodec (1)

Default codec was moved out of `o.a.l.index`:

- **lives now in its own package `o.a.l.index.codecs.standard`**
- **is the default implementation**
- **similar to the pre-flex index format**
- **requires far less ram to load term index**

Default: StandardCodec (2)

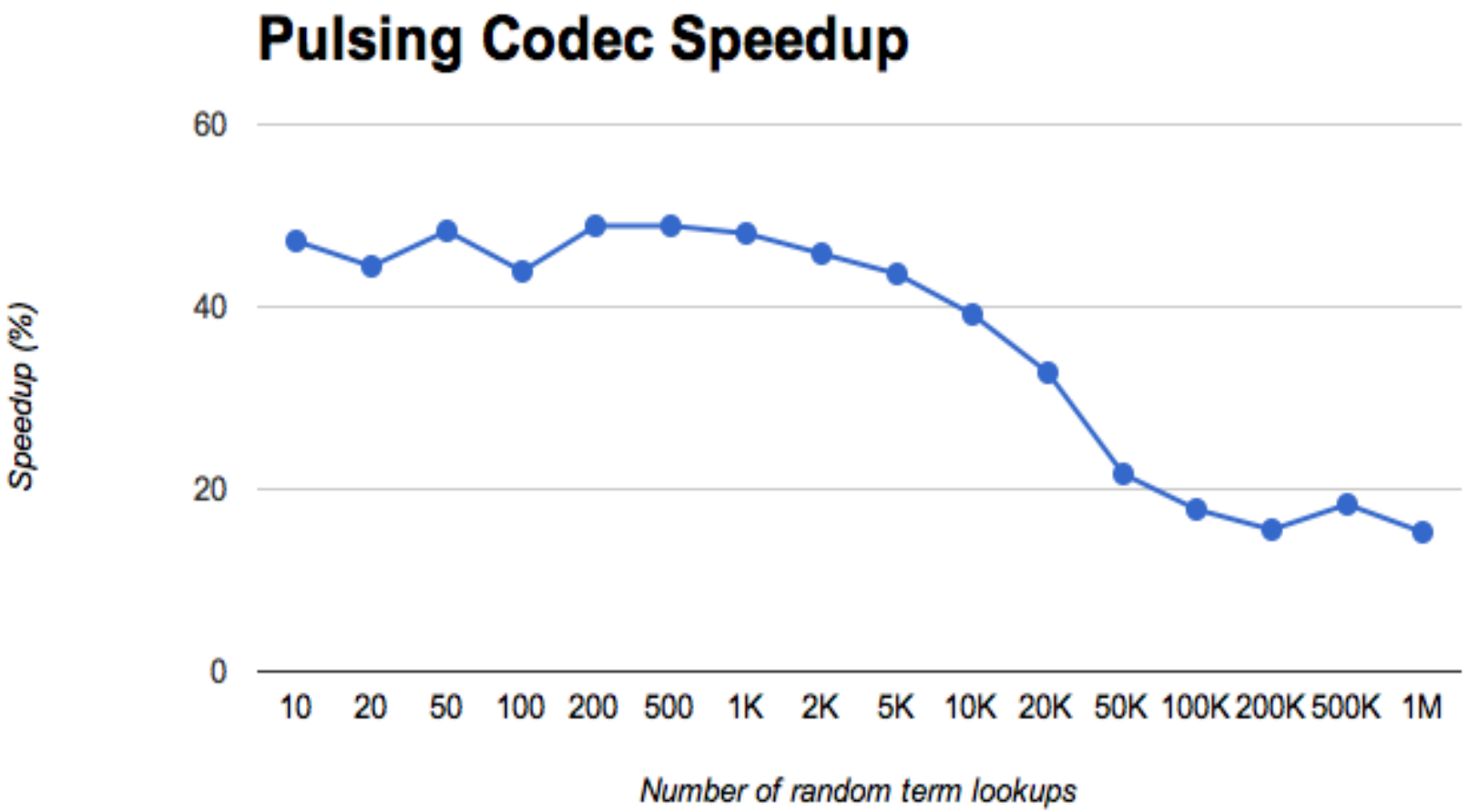
- Terms index: `VariableGapTermsIndexWriter/Reader`
  - **uses finite state transducers from new FST package**
  - **removes useless suffixes**
  - **reusable by other codecs**
- Terms dict: `BlockTermsWriter/Reader`
  - **more efficient metadata decode**
  - **faster TermsEnum**
  - **reusable by other codecs**
- Postings: `StandardPostingsWriter/Reader`
  - **Similar to pre-flex postings**

Build-In Codecs: PulsingCodec (1)

- Inlines low doc-freq terms into terms dict
- Saves extra seek to get the postings
- Excellent match for primary key fields, but also "normal" field (Zipf's law)
- Wraps any other codec
- Likely default codec will use Pulsing

See Mike McCandless' blog:
http://s.apache.org/XEw

Build-In Codecs: PulsingCodec (2)



Build-In Codecs: SimpleText


```
field contents
  term file
    doc 0
      pos 5
  term is
    doc 0
      pos 1
  term second
    doc 0
      pos 3
  term test
    doc 0
      pos 4
  term the
    doc 0
      pos 2
  term this
    doc 0
      pos 0
END
```

- All postings stored in _X.pst text file
- Read / write
- Not performant
  - **Do not use in production!**
- Fully functional
  - **Passes all Lucene/Solr unit tests (slowly...)**
- Useful / fun for debugging

See Mike McCandless' blog:
http://s.apache.org/eh

Other Codecs shipped with Lucene Contrib / Tests

- `AppendingCodec` (contrib/misc)
  - **Never rewinds a file pointer during write**
  - **Useful for Hadoop**
- `MockRandomCodec` (test-framework)
  - **used in tests to select random codec configurations**
- `PreFlexRW` (test-framework)
  - **Used by tests to build pre-flex indexes**
  - **Standard pre-flex codec is read-only**

Heavy Development: Block Codecs

- Separate branch for developing block codecs:
  - http://svn.apache.org/repos/asf/lucene/dev/branches/bulkpostings
- All codecs use default terms index, but different encodings of postings
- Support for recent compression developments
  - **FOR, PFORDelta, Simple64, BulkVInt**
- Framework for blocks of encoded ints *(using `SepCodec`)*
  - **Easy to plugin a new compression by providing a encoder/decoder between a block `int[]` ↔ `IndexOutput/IndexInput`**

Block Codecs: Use Case

- Smaller index & better compression for certain index contents by replacing vInt
  - **Frequent terms (stop words) have low doc deltas**
  - **Short fields (city names) have small position values**
- `TermQuery`
  - **High doc frequency terms**
- `MultiTermQuery`
  - **Lots of terms (possibly with low docFreq) in order request doc postings**

Block Codecs: Disadvantages

- Crazy API for consumers, e.g. queries
- Removes encapsulation of DocsEnum
  - **Consumer needs to do loading of blocks**
  - **Consumer needs to do doc delta decoding**
- Lot‘s of queries may need duplicate code
  - **Impl for codecs that support „bulk postings“**
  - **Classical DocsEnum impl**

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Flexible Indexing - Current State

- All tests pass with a pool of random codecs
  - **If you find a bug, post the test output to mailing list!**
  - **Test output contains random seed to reproduce**

- many more tests and documentation is needed
- community feedback is highly appreciated

Flexible Indexing - TODO

- Serialize custom attributes to the index
- Allow customizing stored fields
- Convert all remaining queries to use internally `BytesRef`-terms
- Die, Term (& Token) class, die! ☺
- Make block-/bulk-postings API more user-friendly and merge to SVN trunk
- More heavy refactoring!

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Summary

- New 4D postings enum APIs

- Pluggable codec lets you customize index format
  - **Many codecs already available**
- State-of-the-art postings formats are in progress

- Innovation is easier!
  - **Exciting time for Lucene...**
- Sizable performance gains, RAM/GC

We need YOU!

- Download nightly builds or check out SVN trunk
- Run tests, run tests, run tests,…
- Use in your own developments

- Report back experience with developing own codecs

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*Many thanks to **Mike McCandless** for slides & help on preparing this talk!*

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