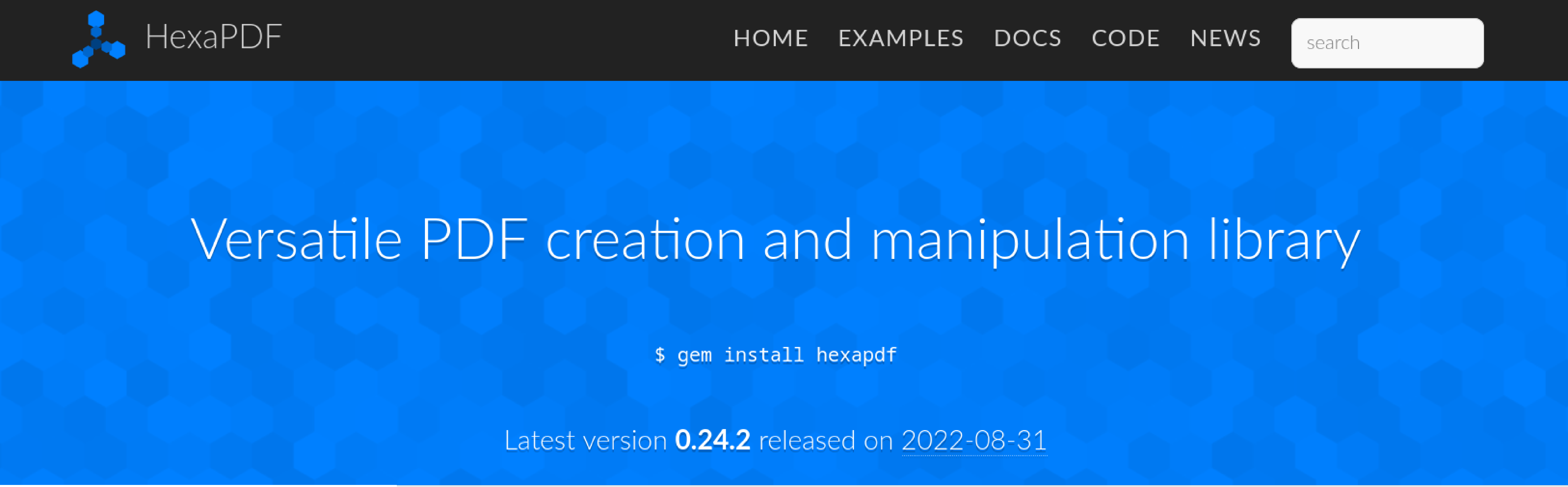

Versatile PDF creation and manipulation library

```
$ gem install hexapdf
```

Latest version **0.24.2** released on 2022-08-31

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Implementing a PDF Library in Ruby

Design and implementation decisions to create a fully-featured, fast and memory-efficient PDF library

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- Parsing
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Why Ruby?

- Language of choice for side projects
- Fast development/feedback loop
- **No existing, feature-complete, pure Ruby PDF library**

Why HexaPDF?

- Scratching an itch (PDF generation library Prawn not good enough)
- Desire to implement a complex, publicly available specification
- Provide high-quality library and **dual-license AGPL+commercial to sustain development**

HexaPDF Code Example

```ruby
require 'hexapdf'

doc = HexaPDF::Document.new
doc.trailer.info[:CreationDate] = Time.now
doc.trailer.info[:Title] = "My Hello World"
canvas = doc.pages.add.canvas
canvas.font('Helvetica', size: 100)
canvas.text("Hello World!", at: [20, 400])
doc.write("hello-world.pdf", optimize: true)
```

Parsing

- Usual separation between tokenizer and parser
- Tokenizer also responsible for parsing whole PDF objects
- **StringScanner and regular expressions used for tokenization**, not byte-by-byte

Parsing - StringScanner Usage

```ruby
# Parses the hex string at the current position.
#
# See: PDF1.7 s7.3.4.3
def parse_hex_string
  @ss.pos += 1                    # @ss is the StringScanner object
  data = scan_until(/(?=>)/)
  unless data
    raise HexaPDF::MalformedPDFError.new("Unclosed hex string found", pos: pos)
  end
  @ss.pos += 1
  data.tr!(WHITESPACE, "")
  [data].pack('H*')
end
```

Parsing - Continued

- First iteration done like described in the specification, then added work-arounds for invalid PDFs
- Now capable of parsing a wide array of invalid PDFs

Object Model

- Many implementations create custom classes for PDF object types
- **HexaPDF uses built-in Ruby classes** where possible for performance, lower memory usage and ease of use
- **Nearly perfect mapping** between PDF object types and Ruby's built-in classes

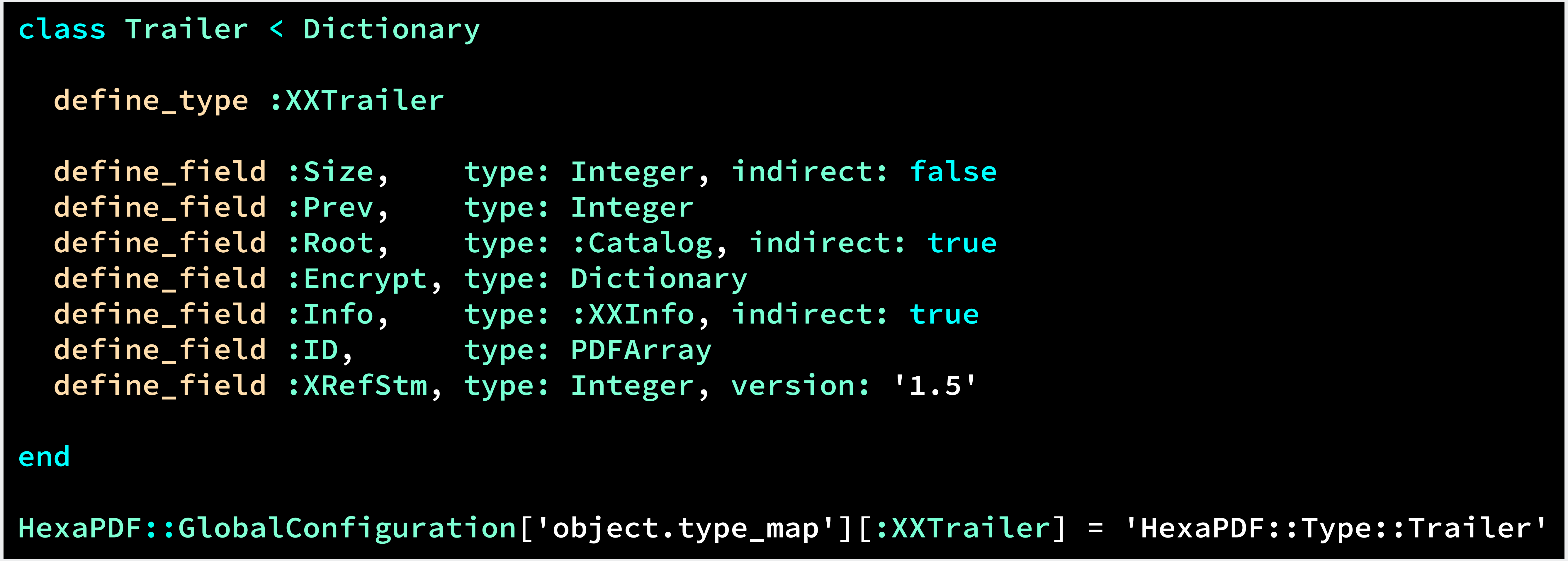
Object Model - Type Mapping

Boolean	true/false
Numeric	Integer, Float
String	String
Name	Symbol
Null	nil
Array	Array, HexaPDF::PDFArray
Dictionary	Hash, HexaPDF::Dictionary
Indirect Objects	HexaPDF::Object
Stream	HexaPDF::Stream

Evolution of Object Model

- Use custom `HexaPDF::Dictionary` class in addition to the built-in Hash class for dictionaries
- Allows **automatic reference resolving** on access
- PDF types like the document catalog as subclasses with **field definitions**

PDF Type Implementation



```
class Trailer < Dictionary

  define_type :XXTrailer

  define_field :Size,    type: Integer, indirect: false
  define_field :Prev,    type: Integer
  define_field :Root,    type: :Catalog, indirect: true
  define_field :Encrypt, type: Dictionary
  define_field :Info,    type: :XXInfo, indirect: true
  define_field :ID,      type: PDFArray
  define_field :XRefStm, type: Integer, version: '1.5'

end

HexaPDF::GlobalConfiguration['object.type_map'][:XXTrailer] = 'HexaPDF::Type::Trailer'
```

Dictionary Fields Usages

- Return **default values** for unset fields on access
- Field information is used for basic **object validation**
- **Automatic conversion** of values based on the field type (e.g. PDF dates but also specific type classes)

Memory Usage vs Ease-of-use

- Auto-converting dictionaries is a trade-off between lower memory usage and ease-of-use
- Core data (object number, generation number, value, stream) is put in `HexaPDF::PDFData` object
- Data object is wrapped by one or more `HexaPDF::Object` instances

Auto-converting Dictionaries

- Automatically convert loaded or added hashes/dictionaries to specific type classes
- Conversion is based on the `/Type` and `/Subtype` entries as well as the required fields
- Problem: False positives, e.g. artifact property list containing `<</Type /Page>>`

Serializing

- Any Ruby object can be serialized, serializer is extendable
- Compact serialization representation by default

Serializing Strings

```
STRING_ESCAPE_MAP = {"(" => "\\(", ")" => "\\)", "\\" => "\\\\", "\r" => "\\r"}.freeze

def serialize_string(obj)
  obj = if @encrypter && @object.kind_of?(HexaPDF::Object) && @object.indirect?
          encrypter.encrypt_string(obj, @object)
        elsif obj.encoding != Encoding::BINARY
          if obj.match?(/[^ -~\t\r\n]/)
            "\xFE\xFF".b << obj.encode(Encoding::UTF_16BE).force_encoding(Encoding::BINARY)
          else
            obj.b
          end
        else
          obj.dup
        end
  obj.gsub!(/[()\\\r]/n, STRING_ESCAPE_MAP)
  "(#{obj})"
end
```

Encryption

- Done at a later stage, kind of "tucked" on but in a good way
- Loading encrypted objects is nearly orthogonal to parsing, only the object loader is amended
- Serialization class adapted to provide encryption

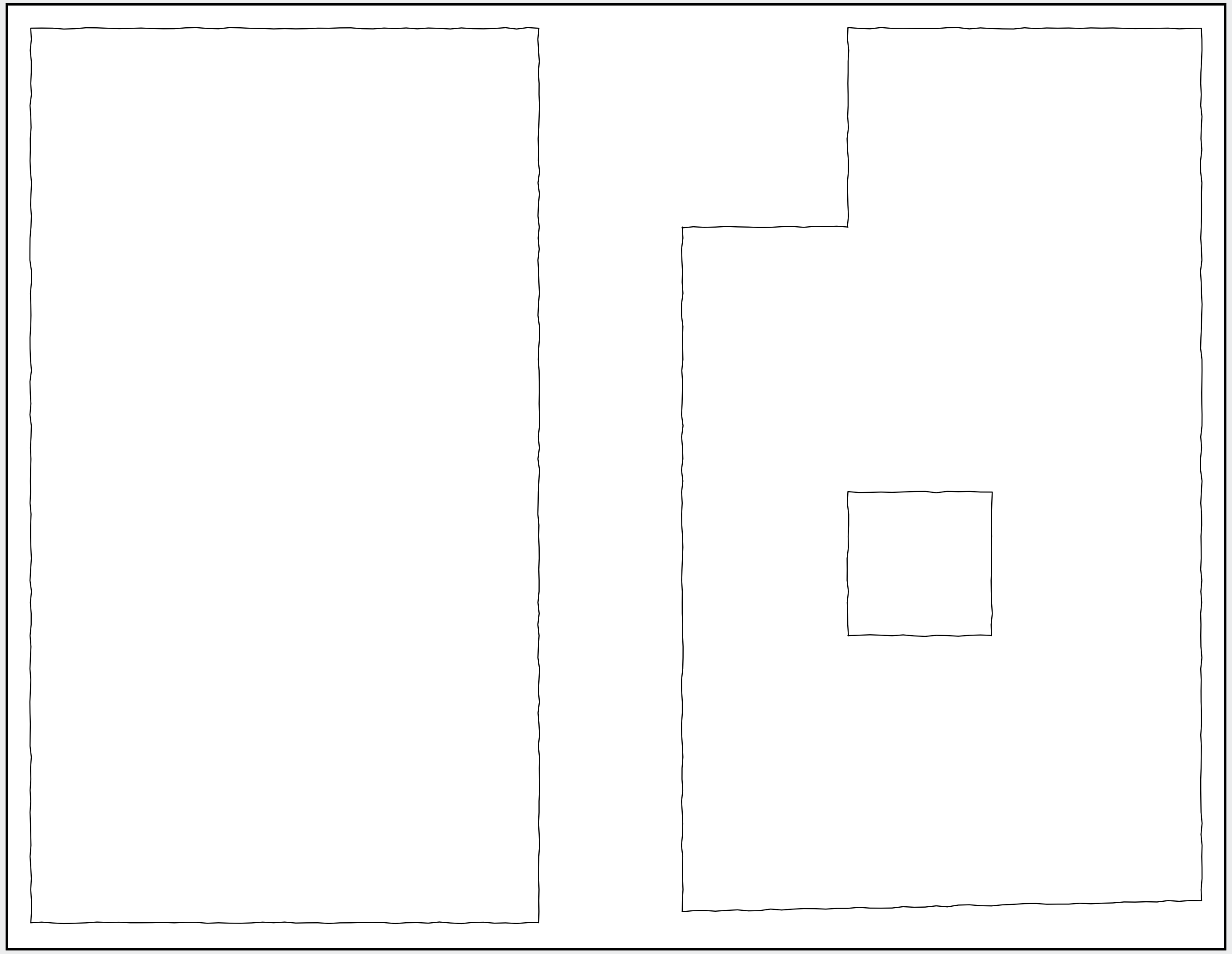
Decryption of Loaded Object

```
document.revisions.each do |r|
  loader = r.loader
  r.loader = lambda do |xref_entry|
    obj = loader.call(xref_entry)
    xref_entry.compressed? ? obj : handler.decrypt(obj)
  end
end
```

Document Layout Engine

- PDF needs explicit glyph positions, conforming **writer does all the layout**
- HexaPDF's layout engine is written from scratch, based on the concept of **frames** and **boxes**
- Frames provide an area to place boxes and know where and how the next box can be placed
- The frame area, its shape, is usually rectangular but can generally be a set of rectilinear polygons

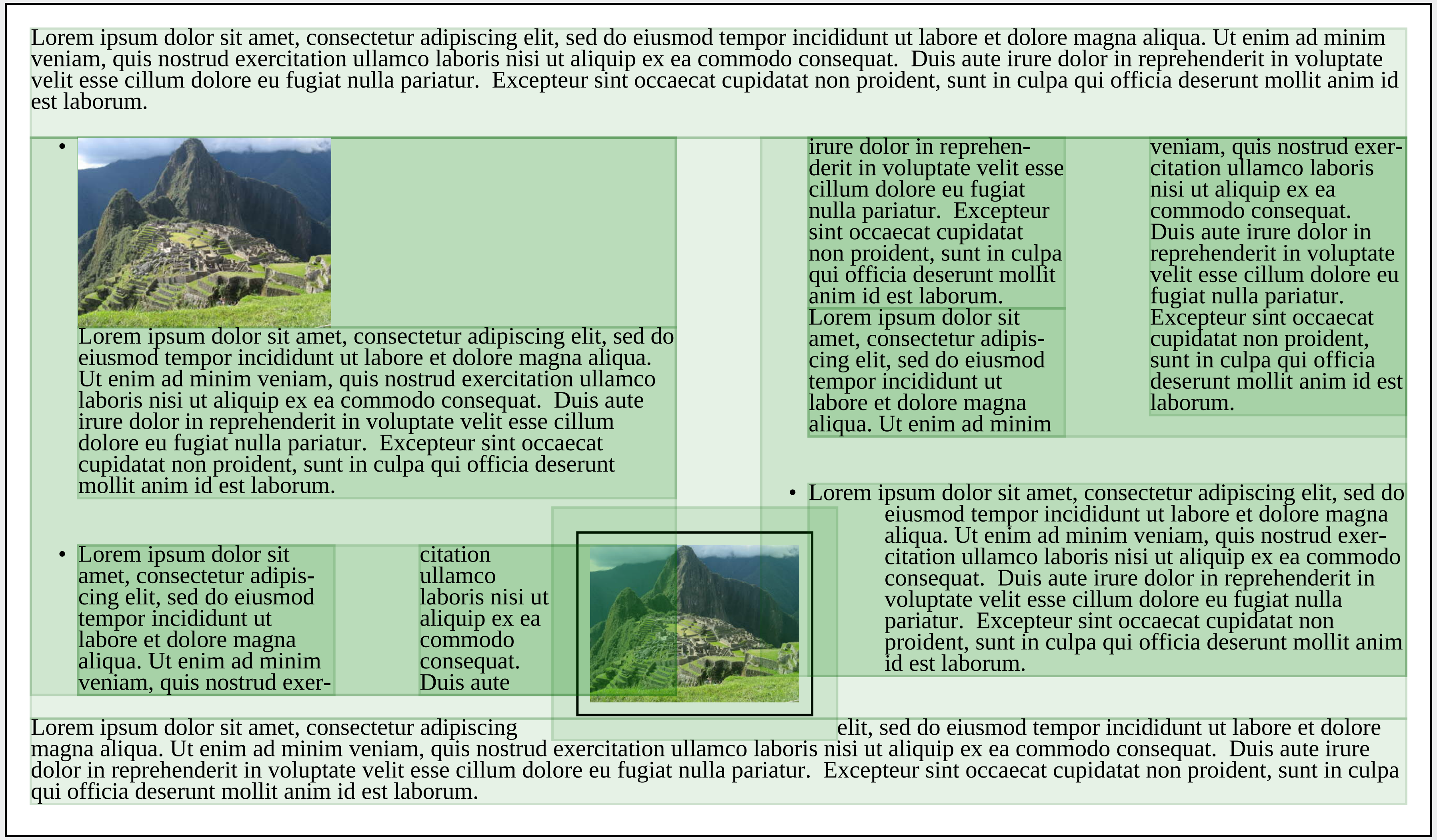
Document Layout - Frame



Document Layout Cont.

- Boxes are responsible for three things: **fitting** their contents, **splitting** the box if necessary and **drawing** their contents
- A box may be fitted into a rectangular area or use the frame's shape to flow its contents
- The text layout engine can **flow text inside a set or arbitrary polygons**

Document Layout - Example



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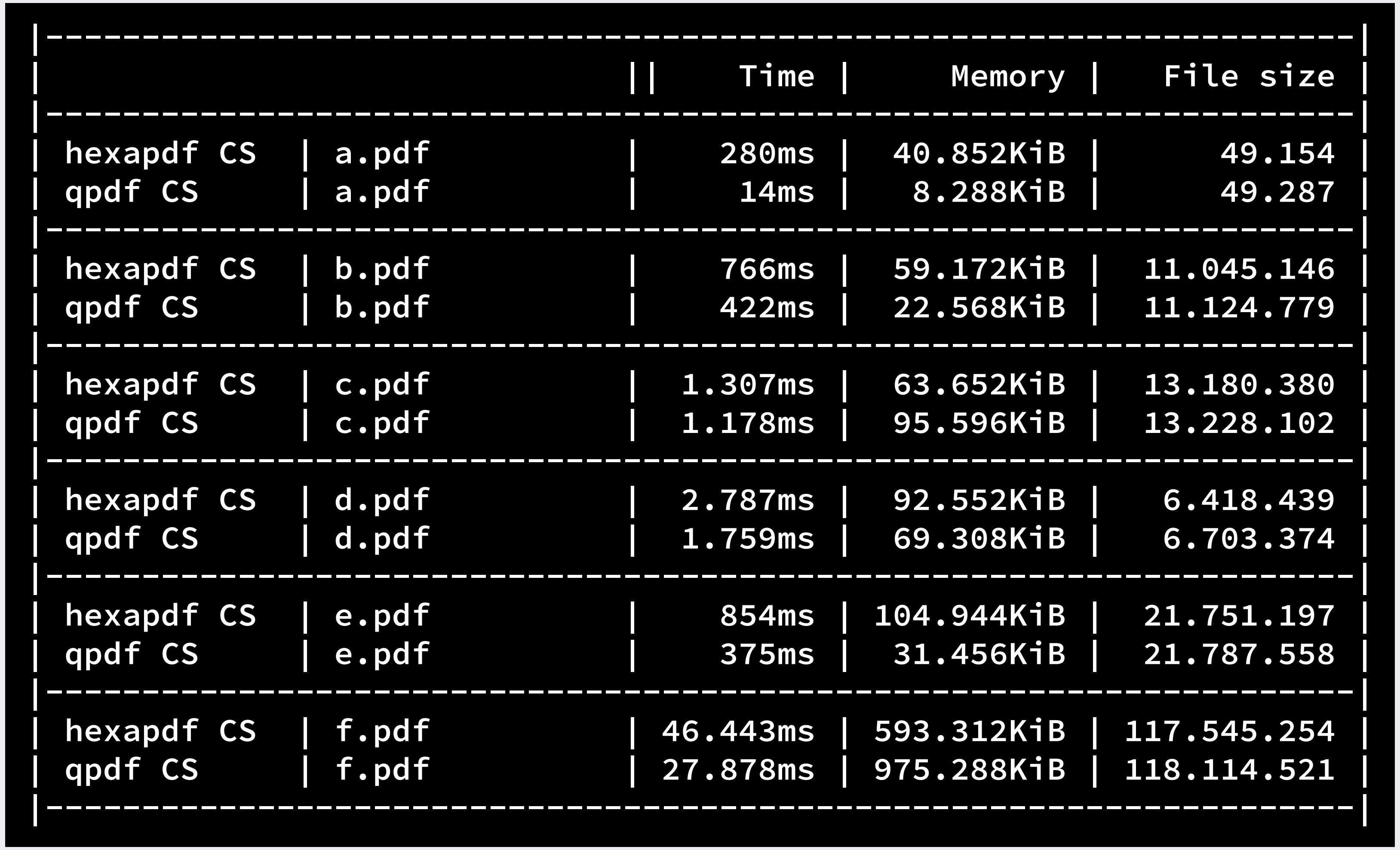
Optimizations

- Stream filters implemented via **fiber pipeline** (allow processing streams in chunks, only apply necessary filters)
- **Optimize size of serialized output** (smaller files and faster operation due to less serialization)
- **Optimize text output** (use most compact representation possible)

Size Optimization Benchmark



```
|--------------------------------------------------------------------|
|                              ||    Time |     Memory |   File size |
|--------------------------------------------------------------------|
| hexapdf CS  | a.pdf          |    280ms |  40.852KiB |      49.154 |
| qpdf CS     | a.pdf          |     14ms |   8.288KiB |      49.287 |
|--------------------------------------------------------------------|
| hexapdf CS  | b.pdf          |    766ms |  59.172KiB |  11.045.146 |
| qpdf CS     | b.pdf          |    422ms |  22.568KiB |  11.124.779 |
|--------------------------------------------------------------------|
| hexapdf CS  | c.pdf          |  1.307ms |  63.652KiB |  13.180.380 |
| qpdf CS     | c.pdf          |  1.178ms |  95.596KiB |  13.228.102 |
|--------------------------------------------------------------------|
| hexapdf CS  | d.pdf          |  2.787ms |  92.552KiB |   6.418.439 |
| qpdf CS     | d.pdf          |  1.759ms |  69.308KiB |   6.703.374 |
|--------------------------------------------------------------------|
| hexapdf CS  | e.pdf          |    854ms | 104.944KiB |  21.751.197 |
| qpdf CS     | e.pdf          |    375ms |  31.456KiB |  21.787.558 |
|--------------------------------------------------------------------|
| hexapdf CS  | f.pdf          | 46.443ms | 593.312KiB | 117.545.254 |
| qpdf CS     | f.pdf          | 27.878ms | 975.288KiB | 118.114.521 |
|--------------------------------------------------------------------|
```

General Design

- Make everything possible using a low-level interface
- Iteratively add classes for the PDF types (for automatic validation and value conversion)
- Add convenience methods for easier usage (e.g. manipulating the page tree)

General Design Cont.

- Provide convenience methods on the class where they are most useful
- If no class fits, create a new one and allow easy access via the main document object
- Make everything extendable and exchangable where possible and useful

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Thank you!