

Report

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Abstract

This report addresses various processes and stages of building the project - Librarian, to provide full-text search capabilities against local filesystem.

To achieve planned filetypes support, detailed documentations and third-party libraries are needed to implement a working system consists of indexing, searching, and data persistence functionalities.

Most planned functionalities of Librarian were built, tested and fully-functional, including API, Web API, and Cross-platform GUI. However some advanced features are still under development, given the time constraint of this project. Some other features and additional support are planned in future work.

Introduction

During my pre-master, I often find myself going through nested directories with lots of documents trying to find the one I need by opening every single one of them up in different applications and searching for the keyword i need. Which is very annoying and time-consuming. Then it occurs to me, why not build an application that can do those repeated steps for me. The initial idea of this project was born.

Literature Review

Following paragraphs are the literature review around the chosen topic.

Full-Text Search Engine

Full-Text search engines perform linguistic searches against text data in target document or collection of text data based on the rules of a particular language (Microsoft Docs, 2020). Full-Text search engines consider the basic unit of Full-Text search as a token rather than a word (Melton & Buxton, 2006). Full-Text queries can include simple words and phrases or multiple forms of a word or phrase. A Full-Text query returns any documents that contain at least one match (also known as a hit). A match occurs when a target document contains all the terms specified in the Full-Text query, and meets any other search conditions, such as the distance between the matching terms. It widely used in modern technology like web search (Google Search, Bing Search, etc.), desktop search (search for local files) and even email search.

As the need of semantic-aware Full-text search and indexing against databases and documents keeps increasing in the past decade, full-text search systems became available to no-expert users who aren't familiar with documents they are searching, don't know the exact vocabulary used to index relevant documents, or don't know how to formulated advanced search queries (Tekli, Chbeir, et al., 2018). All of those issues mentioned above result in noisy or irrelevant search results and false positives & false negatives in the search result (See [Precision and Recall](#)).

Precision and Recall

Precision and recall are often used to measure the performance of information retrieval or extraction systems, precision (aka. positive prediction value) is the fraction of relevant results among all results returned (in other words, how many returned results are relevant?), while recall (aka. sensitivity) is the fraction of the amount of returned relevant results among all relevant results in the dataset (in other words, how many relevant results are returned?) (Makhoul, Kubala, et al., 1999) (see [Appendix a.](#)).

In general, there is a trade-off between "precision" and "recall". High precision means that fewer irrelevant results are returned as a result of the query (fewer false positives), while high recall means that fewer relevant results are missing (fewer false negatives). traditional text-matching systems such as the LIKE operator in SQL gives you 100% precision with no concessions for recall. A full text search facility gives you a lot of flexibility to tune down the precision for better recall (Erickson, 2008).

For example, the SQL LIKE operator can be extremely inefficient. If you apply it to an un-indexed column, a full scan will be used to find matches (just like any query on an un-indexed field). If the column is indexed, matching can be performed against index keys, but with far less efficiency than most index lookups. Therefore, most full text search implementations use an "inverted index" system to improve performance (see [Inverted Index](#)) (Erickson, 2008).

Inverted Index

Inverted Index is an index where the keys are individual terms, and the associated values are sets of records that contain the term. Full text search is optimized to compute the intersection, union, etc. of these record sets, and usually provides a ranking algorithm to quantify how strongly a given record matches search keywords (Erickson, 2008).

As mentioned earlier, non-expert users of full-text search system often don't know how to formulate advanced queries or don't know the vocabularies used when indexing the documents (Tekli, Chbeir, et al., 2018). To address said issue the authors designed and constructed an extended version of inverted index called *SemIndex*, which empowered standard inverted index with a semantic network and a general keyword query model, in order to yield semantic-aware results (ibid.).

Semantic Search

"Semantics" means the concepts or ideas expressed by words, when people speak to each other, words are not just words but a medium that conveys semantics. Therefore when it comes to web searches, semantic analysis plays a huge part in making search queries easier for a machine to understand (Search Engine Watch, 2019), which then provides users with semantic enabled web searching services (i.e. search with meaning).

Semantic search engine tries to understand the user's intent of a search query and also the contextual meaning of search keywords. Search engine providers (e.g. Google and consequently SEOs) are dealing with two main concepts behind semantic search, which are semantic mapping (i.e. finding the relationships or connections between words / phrases) and semantic coding (i.e. embedding meaning into webpages using code, to tell search engine what types of information can be found on this page) (ibid.).

Apache Tika

Tika was formally a sub-project of [Apache Lucene](#). Lucene is a Java library for indexing, searching. Lucene also has many other powerful features (e.g. spellchecking, analysis/tokenization, etc.) (Apache Lucene, 2020).

[Apache Tika](#) is an open-source toolkit that detects and extracts metadata and text from over a thousand different file types (such as PPT, XLS, and PDF). All of these file types can be parsed through a single interface, making Tika useful for search engine indexing, content analysis, translation, and much more. You can find the latest release on the download page. Please see the Getting Started page for more information on how to start using Tika (Apache Tika, 2020).

DocFetcher

[DocFetcher](#) is an existing open-source desktop search application written in Java programming language and Apache Tika framework (see [Apache Tika](#)). DocFetcher provides very powerful

searching capabilities and as well as a wide range of support document formats (DocFetcher, 2020).

Gantt Chart

The planning of this project is done by utilizing Gantt chart (See [Appendix b.](#)).

There're several complications result in a shift of priority to develop a functional cross-platform full-text search API which return search result either from CLI (command-line interface) or `JSON` via REST Web API, instead of building both cross-platform UI and API.

The main processes of this project were requirements analysis, implementation, testing and reporting.

Rationale

This project idea was formed based on specific needs for customisable full-text searching against a huge amount of local documents, and was then inspired by the open-source desktop search application - DocFetcher (see [DocFetcher](#)).

As powerful as DocFetcher is, it lacks the full-support for macOS 64-bit platform, also has some minor performance issues. Same thing goes with other existing desktop search applications. So, I decided to build a local document search engine to address said issues and to fit my specific needs.

At first I planed to build both GUI (Graphic User Interface) and API (Application Programming Interface), which later turns out to be not feasible enough given the complexity of implementing GUI document previewer and the time constrain for this project. That said, I decided to shift my focus onto API alone.

Tika came into the picture, as I was going through DocFetcher's source code try to understand the implementations behind its powerful features. Given the fact that there're no good alternatives to Tika in C# ecosystem, then it occurs to me that i should implement a similar API for text-extraction or content-analysis in C#.

Methodology & Design

This part will demonstrate and explain the design of API and UI.

API Design



The class diagram above showed the structure and relationship between classes in the API project.

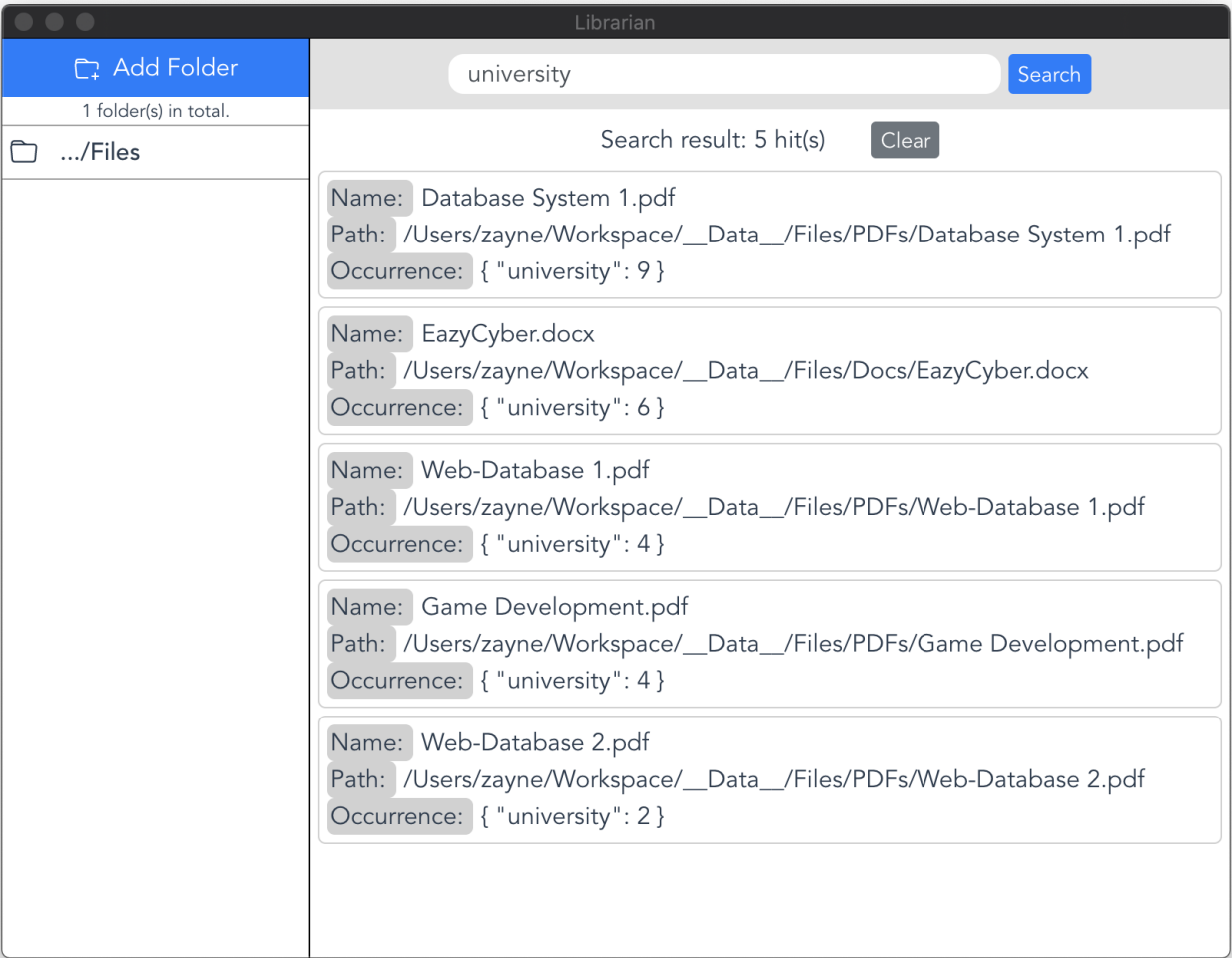
Where **Custodian** class is the entry point of the API, which then initialise a **Folder** instance with a given folder path to index containing supported documents.

Folder will then go through the given directory to find supported documents, and **DocumentFactory** will instantiate the correct document class for each supported document based on its file extension. Upon instantiation, each **Document** instance will begin indexing process.


UI Design

I'm using Vue.js + NW.js for the cross-platform UI implementation.

As of now, the UI is still rather simple and act only as a visual user interface for demonstration of **Custodian API**'s functionalities.



Progress

Icon	<input type="checkbox"/>	<input checked="" type="checkbox"/>	
Meaning	Planned	Done	WIP

- UI
 - ☒ Index folders.
 - ☒ Retrieve indexed folders.
 - ☒ Search function.
 - ☐ Advance search query.
 - ☒ Display search result.
- Web API
 - ☒ API Documentation.
 - ☒ Indexing.
 - ☒ Searching.

☐ Advanced search query.

- API

☒ 64-bit multi-platform support.

☒ Indexing.

☒ Searching.

☐ Semantic Search. !!!

- File type support

☒ Microsoft Office 2007+ documents support.

☒ `.docx` , `.docm` | Word 2007+ documents.

☒ `.pptx` , `.pptm` | PowerPoint 2007+ documents. ⚠

☒ `.xlsx` , `.xlsm` | Excel 2007+ documents. ⚠

☐ Plain-text documents.

☒ `.txt` | Text documents.

☐ `.md` | Markdown documents. ⚠

☐ `.rtf` | Rich text format documents.



☐ `.pdf` | PDF documents.






☒ Text-based PDF.

☐ Image-only PDF. ⚠

☐ `.epub` , `.mobi`

- Testing

Icon	Meaning
	Fully Tested
	Partially Tested (Basic functionalities)

File Type	Testing Status
<code>.txt</code>	
<code>.docx</code> , <code>.docm</code>	
<code>.pptx</code> , <code>.pptm</code>	
<code>.xlsx</code> , <code>.xlsm</code>	
<code>.pdf</code>	

- Report

Implementation

Tools & Third-party Libraries

This part contains general background information regarding tools, languages and third-party libraries used in this project.

Tools

Visual Studio Code

Visual Studio Code is an open-source cross-platform code editor developed by Microsoft, with great extensibility and support for syntax highlighting, debugging, IntelliSense (code completion tool developed by Microsoft), etc. And VSCode supports a large variety of programming languages by installing dedicated extensions (VSCode, 2020).

Languages

C Sharp

C# is a modern, general-purpose, object-orient programming language which was released by Microsoft in 2000 as a part of .NET Framework (ECMA, 2017). C# is type-safe and the syntax of it is highly expressive. In addition, C# also benefits from Language-Integrated Query (LINQ) which provides built-in query capabilities across many different kinds of data sources (Microsoft, 2015).

TypeScript

TypeScript (abbr. TS) is an open-source language that is built on top of JavaScript. TypeScript empowers JavaScript with static type checking and type inference capabilities by adding static type definitions (Microsoft, 2020).

Frameworks

.NET Core

.NET Core is an open-source, general-purpose development platform, which can be used to create .NET Core applications for Windows, macOS, and Linux for x64, x86, ARM32, and ARM64 processors using C#, Visual Basic, and F# programming languages (Microsoft Docs, 2020).

ASP.NET Core

[ASP.NET](#) Core is a high-performance cross-platform open-source framework for building web applications / cloud services, IoT, and mobile backends (Microsoft Docs, 2020).

NW.js

NW.js is previous called node-webkit, it's an application runtime based on [Chromium](#) (i.e. open-source chrome engine) and [node.js](#). NW.js provides developers the ability to build cross-platform native applications with Web technologies (Nw.js, 2020).

Vue.js

Vue.js is a progressive framework that focuses on data binding for view layer in web development. And Vue.js also has the concept of component which is perfectly for powering sophisticated SPA (i.e. Single Page Application) (Vue.js, 2020).

Third-party Libraries

This project also utilizes several third-party libraries to implement certain functionalities.

LiteDB

[LiteDB](#) is a embedded No-SQL single-file Database. It's used in this project as an object storage for indexed data.

Open XML SDK

[Open-XML SDK](#) is an SDK that provides tools for working with Office (2007+) Word, Excel, and PowerPoint documents developed by [OfficeDev Team](#) at Microsoft.

Office Open XML (aka. OpenXML or OOXML) is an XML-based format for office documents, including word processing documents, spreadsheets, presentations, as well as charts, diagrams, shapes, and other graphical material. Since Office 2007 the file formats and structure of all office documents has changed. Instead of older binary formats (i.e. [.doc](#), [.xls](#), and [.ppt](#)), they have adopted Open XML to be the default format of all Microsoft Office documents ([.docx](#), [.xlsx](#) and [.pptx](#)) (Office Open XML, 2012).

OpenXML files can be decompressed into many [.xml](#) files by compression software or tools.

iText Core

[iText Core](#) is a versatile programmable PDF solution for both .NET (C#) and Java languages. iText provides developers with the ability to create, read, modify PDF documents (iText, 2020).

axios

Axios is a promise based HTTP client for the browser and node.js (Axios, 2020). Axios supports Promise API which is a built-in javascript API used to represent the eventual completion (or failure) of an asynchronous operation, and its resulting value (MDN, 2020), promise API also supports method chaining to add more asynchronous actions.

```
// Promise method chaining.
const promise2 = doSomething().then(successCallback, failureCallback);
```

CustodianAPI Implementation

Detailed implementations regarding Indexing, Searching and WebAPI functionalities of this project will be given in the this section.

Document Indexing

Inverted Index Implementation

Code below is responsible for extract words from pre-processed paragraphs or sentences, and add each word into the Dictionary where inverted index is implemented.

```
protected void AddToIndex(string texts)
{
    using var words = texts.Split(" ", StringSplitOptions.RemoveEmptyEntries).AsEnumerable();
    while (words.MoveNext())
    {
        var word = words.Current;
        var processedWord = ExtractWord(word);
        if (processedWord == null) continue;

        if (Thumbnail.ContainsKey(processedWord))
        {
            Thumbnail[processedWord]++;
            continue;
        }
        Thumbnail.Add(processedWord, 1);
    }
}
```

The figure (see [Appendix r.](#)) shows the partial structure of implemented inverted index in the memory. Based on current implementation each file type will eventually be processed into Dictionaries like this.

The structure of composing `.xml` files for `.docx` documents is similar to the picture (see [Appendix c.](#)).

The main document story of the simplest WordprocessingML (`.docx`) document consists of the following XML elements (Microsoft Docs, 2017):

Element	Description
document	The root element for a WordprocessingML's main document part, which defines the main document story.
body	The container for the collection of block-level structures that comprise the main story.
p	A paragraph.
r	A run.
t	A range of text.

Implementation of extracting and indexing text from Word documents can be found in ([Appendix e.](#))

There are still some special formats or cases haven't been taken into consideration, which will be covered in future work.

Excel 2007

The document structure of a SpreadsheetML document consists of the `workbook` element that contains `sheets` and `sheet` elements that reference the worksheets in the workbook (Microsoft Docs, 2017). (see [Appendix d.](#))

The main parts of a SpreadsheetML document:

Name	Element	Description
Workbook	workbook	The root element for the main document part.
Worksheet	worksheet	A type of sheet that represent a grid of cells that contains text, numbers, dates or formulas.
Table	table	A logical construct that specifies that a range of data belongs to a single dataset.
Shared Strings Table	sst	A construct that contains one occurrence of each unique string that occurs on all worksheets in a workbook.

Example of `sheet1.xml` :

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<worksheet xmlns="http://schemas.openxmlformats.org/spreadsheetml/2006/main" >
  <sheetData>
    <row r="1" spans="1:3" x14ac:dyDescent="0.2">
      <c r="A1" t="s">
        <v>0</v>
      </c>
      <c r="B1" s="1">
        <v>123</v>
      </c>
      <c r="C1" s="3">
        <v>36078</v>
      </c>
    </row>
    <row r="2" spans="1:3" x14ac:dyDescent="0.2">
      <c r="A2" t="s">
        <v>1</v>
      </c>
      <c r="B2" s="1">
        <v>123</v>
      </c>
      <c r="C2" t="s">
        <v>3</v>
      </c>
    </row>
  </sheetData>
</worksheet>
```

However, based on the implementation standard of SpreadsheetML documents, strings sometimes can be stored in `sharedStringTable` , which is similar to an Array in programming languages.

Example content of `sharedStrings.xml` .

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<sst xmlns="http://schemas.openxmlformats.org/spreadsheetml/2006/main" count="4">
  <si>
    <t>university</t>
  </si>
  <si>
    <t>of</t>
  </si>
  <si>
    <t>hertfordshire</t>
  </si>
</sst>
```

In the example of `sheet1.xml` above, each `<c>` element with `t="s"` attribute mean that it's a reference to shared strings table, with the value inside `<v>` element as the index of the string it's referencing.

Hence in the implementation below, there's a part code for retrieving the `sharedStringTable`. And in the text extraction process,

Implementation of extracting and indexing text from Excel documents can be found in ([Appendix f.](#))

However, there's still an issue with retrieving formatted date value. Pending for further fixes.

PowerPoint 2007

Detailed Implementation of extracting and indexing text from PowerPoint Documents can be found in ([Appendix g.](#))

There are already known issues with the implementation above which will be fixed in the future, thus no detailed documentation is provided at this point.

Plain-text Documents

Implementation of extracting and indexing text from plain-text documents can be found in ([Appendix h.](#))

In all the indexing implementations mentioned above, i'm using `Enumerator` instead of `for / foreach` loops for performance and memory consumption concerns. `using` keyword is also heavily used for garbage collection (i.e. disposal of no-longer need objects).

PDF Documents

Detailed implementation of extracting and indexing text from PDF documents can be found in ([Appendix i.](#)).

However, extracting text from image-only pdf documents with OCR is not yet supported, which will be added in future work.

Searching

Implementation of searching capability for `Custodian` class can be found in [Appendix j.](#)

Advanced queries and semantic search supports will be added in future updates.

Web API Implementation

Implementation of REST Web API can be found in ([Appendix k.](#)). Including 3 routes responsible for indexing folders, retrieving indexed folders, and searching.

Testing

API

Unit testing was used to test the behaviours of each corresponding class for different file types.

Unit Test for Custodian API:

The code in [Appendix l.](#) is an unit test class for Indexing a given folder and Searching capabilities of `Custodian` class.

Unit Test for Word documents:

The code [Appendix m.](#) is an unit test class for `Index` functionality of `Word2007Document` class.

Unit Test for Excel documents:

The code in [Appendix n.](#) is an unit test class for `Index` functionality of `Excel2007Document` class.

Unit Test for PowerPoint documents:

The code in ([Appendix o.](#)) is an unit test class for `Index` functionality of `PowerPoint2007Document` class

The unit test above found some inconsistencies where some words inside header or other non-standard elements in `.pptx` / `.pptm` files are not indexed properly. Pending for further fixes.

Unit Test for PDF documents:

The code in ([Appendix p.](#)) is an unit test for `Index` functionality of `PdfDocument` class.

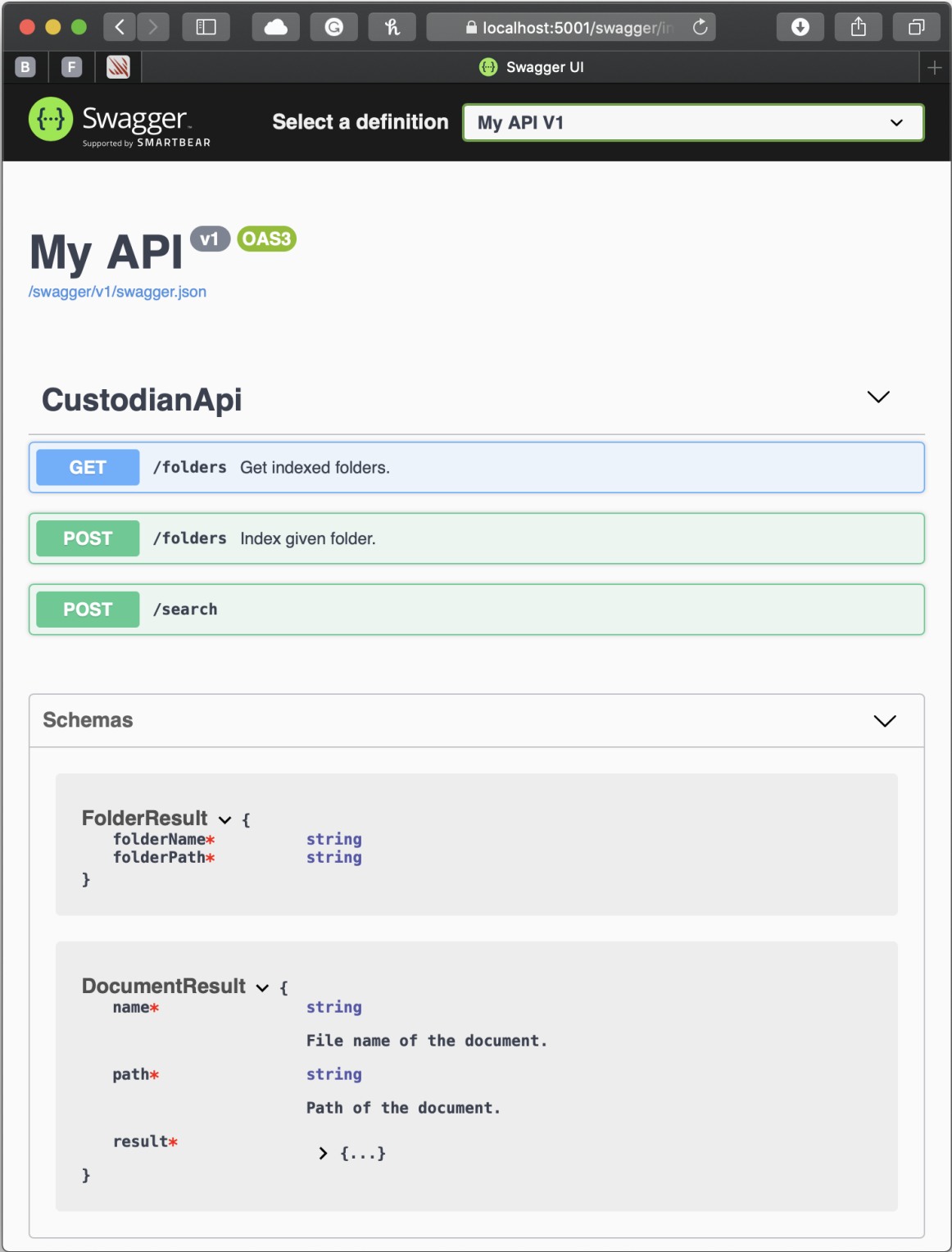
Unit Test for Text documents:

The code in ([Appendix q.](#)) is an unit test for `Index` functionality of `TextDocument` class.

Web API

Web API was documented and tested with `SwaggerUI` .

Web API Overview



Web API Index Folder

POST

/folders

Index given folder.

Parameters

Try it out

Name	Description
folderPath string (query)	Path to the folder to be indexed. <div>folderPath - Path to the folder to be indexed.</div>

Responses

Code	Description	Links
200	Success	No links

Web API Get Indexed Folders

GET

/folders

Get indexed folders.

Parameters

Try it out

No parameters

Responses

Code	Description	Links
200	<div>Success</div> <div>Media type</div> <div>text/plain</div> <div>Controls Accept header.</div> <div>Example Value Schema</div> <div>[{ "folderName": "string", "folderPath": "string" }]</div>	No links

Web API Search

POST

/search

Parameters

Try it out

Name	Description
keyword string (query)	<div>keyword</div>

Responses

Code	Description	Links
200	Success	No links

Media type

text/plain

Controls Accept header.

Example Value | Schema

```
[
  {
    "name": "string",
    "path": "string",
    "result": {
      "additionalProp1": 0,
      "additionalProp2": 0,
      "additionalProp3": 0
    }
  }
]
```

UI

Basic functionality of cross-platform UI was tested manually. Some styling issue was found.

Conclusion & Future Work

Conclusion

The development progress can be found [here](#).

Given the time constraint, unfortunately, i was unable to finish all planed features for this project, however most planned functionalities are well-implemented and tested.

Indexing and searching capabilities for most supported file types are fully functional. However some potential bug fixes are needed for some file type support (which are mentioned in the [implementation](#) chapter).

Web API was originally planned to use `Flask` (Python), instead of `ASP.NET Core`. That was changed due to performance concerns, as HTTP requests themselves are much slower than native function calls, and given the fact that `Python` as an interpreted language is relatively slower than `C#` (compiled language).

As for Cross-platform UI, it was originally planned to use `Electron`. Unfortunately, due to local file accessibility issues and flexibility concerns, `NW.js` was adopted working along with `Vue.js` serve as the cross-platform UI of this project. The UI at this stage is not fully completed as other features (e.g. Document Preview, etc.) are still pending to be implemented in future work.

During the development process, I was struggle with many tech stacks, i've also done many demos to find suitable stacks for my purpose. The API is always planned to used `.NET Core` for it's great performance and cross-platform capabilities.

Due the fact that native function calls is way faster than HTTP requests, I dropped planned web api + electron / nw.js structure and started exploring `Xamarin` framework (open-source cross-platform application framework using `.NET` and `C#`) for a possible work-around which later turned out to have some compatibility issues, as `Xamarin.Mac` is based on `.NET Standard` framework while the API is built with `.NET Core`. Thus I reverted back into web api + NW.js approach. However, there is a possibility where Custodian API is built with a CLI (Command-Line Interface) which GUI application can run shell commands to interact with Custodian API, this would possibly solve the latency issues with HTTP requests, and also improve usability to fit other use cases, this solution is for future reference.

Apart from technical conclusion, I've leaned a lot about software development as well. This is the first time I actually used unit testing on a project, which revealed the importance of unit testing in software development. In the past, I tended to do a lot of demos using all kinds of different and interesting technologies, but none of them were a proper project. This occurred to me a couple weeks ago when i was browsing LinkedIn for potential job opportunities, the fact that I don't have any proper project to demonstrate my software development skills, all I've got are demos. And as my research showed the gap of text extraction framework in `C#` ecosystem, that's when I decided to treat this project more seriously, to try to following best practices, to have unit tests, to have detailed documentations, and many other things that can make it a usable and maintainable project.

Future Work

This project was originally considered only to be a tool to do full-text searches against local file system. However, along the development process of the project, I discovered that there's a gap for full-text search (or text extraction, content analysis) framework in .NET ecosystem (even though Apache Tika has a .NET wrapper API, it's still not a pure C# implementation which might result in issues with a non-C# origin). Thus, I decided to focus mainly on API, try to push this into next steps as a library written in C# for full-text searching. Furthermore, as mentioned earlier Custodian API as a library should also have a CLI to improve usability.

Up until this point, there're still many dependencies with various licences which can be tricky for potential use cases in the future. That said, until all planned features of this project is implemented and fully tested, I'll then look into replacing some dependencies that have licence issues with other licence compatible libraries or possibly my own implementations of the dependencies.

Hopefully, this project can be an alternative to Apache Tika in C# ecosystem.

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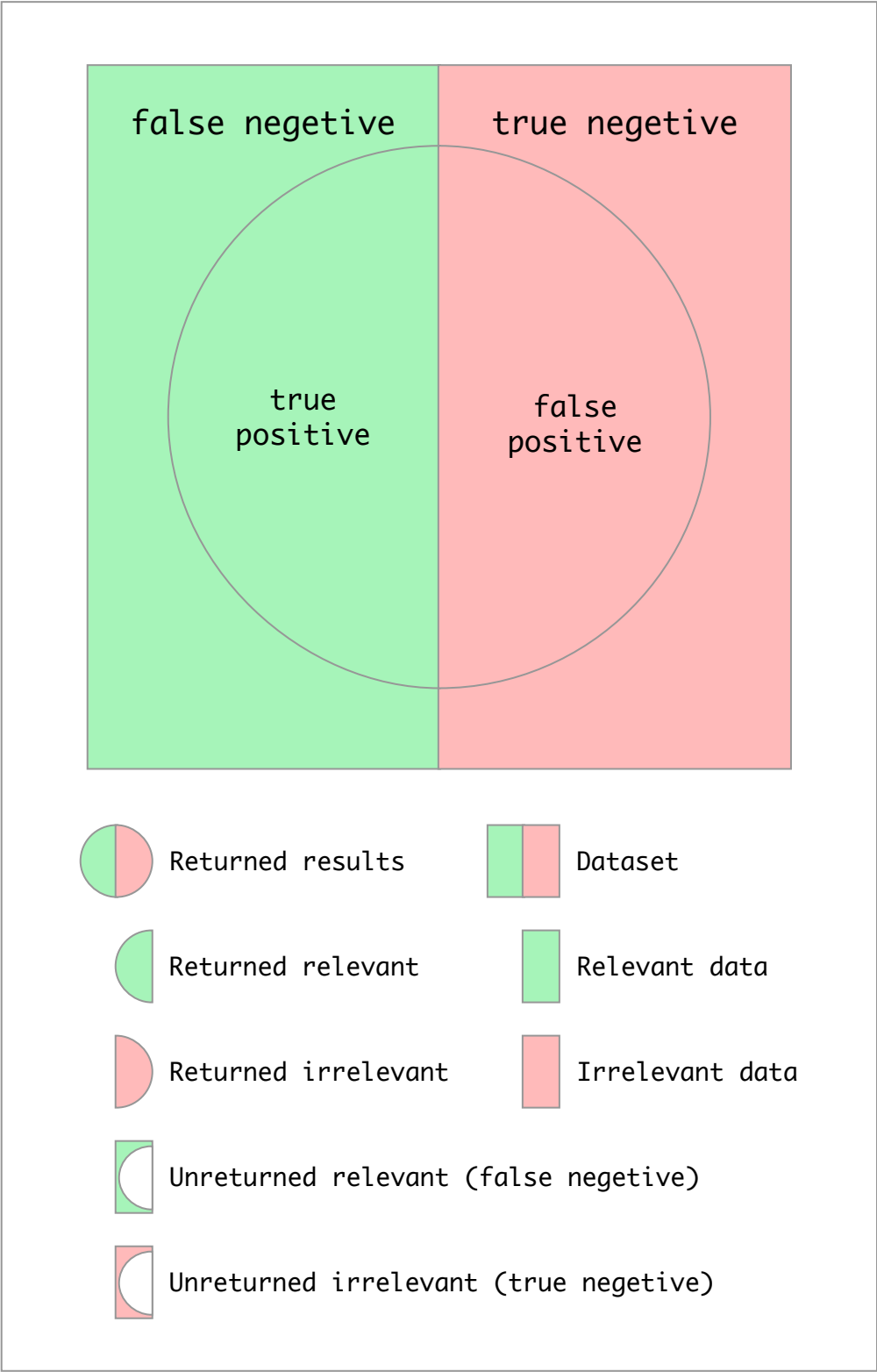
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Appendix

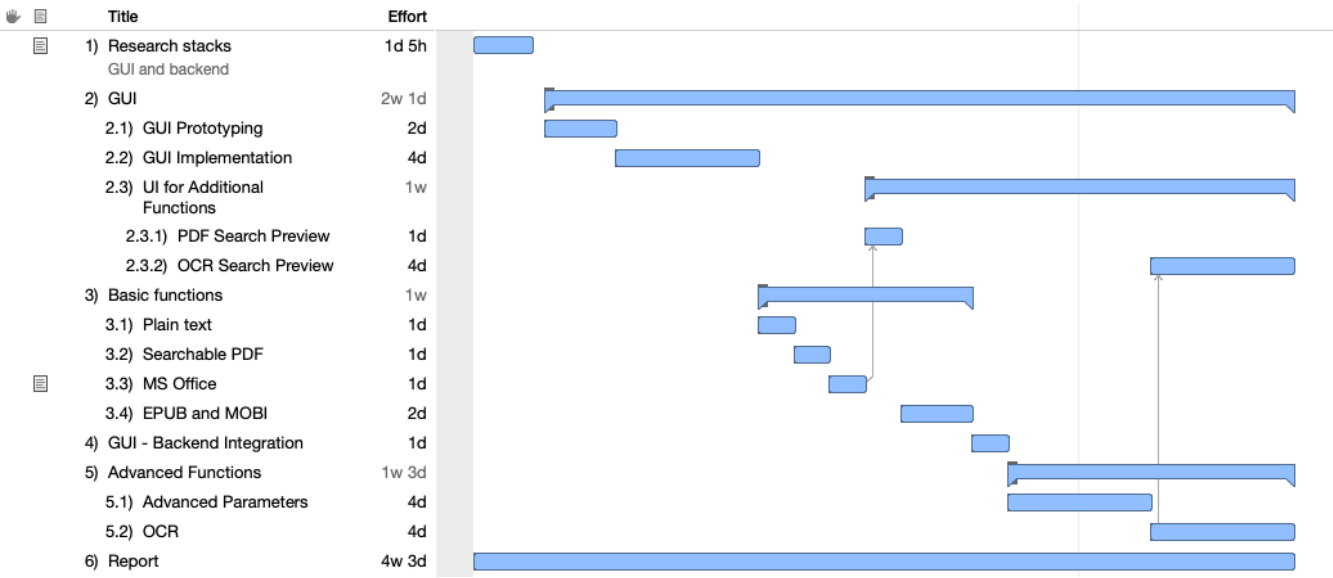
a. Precision and Recall

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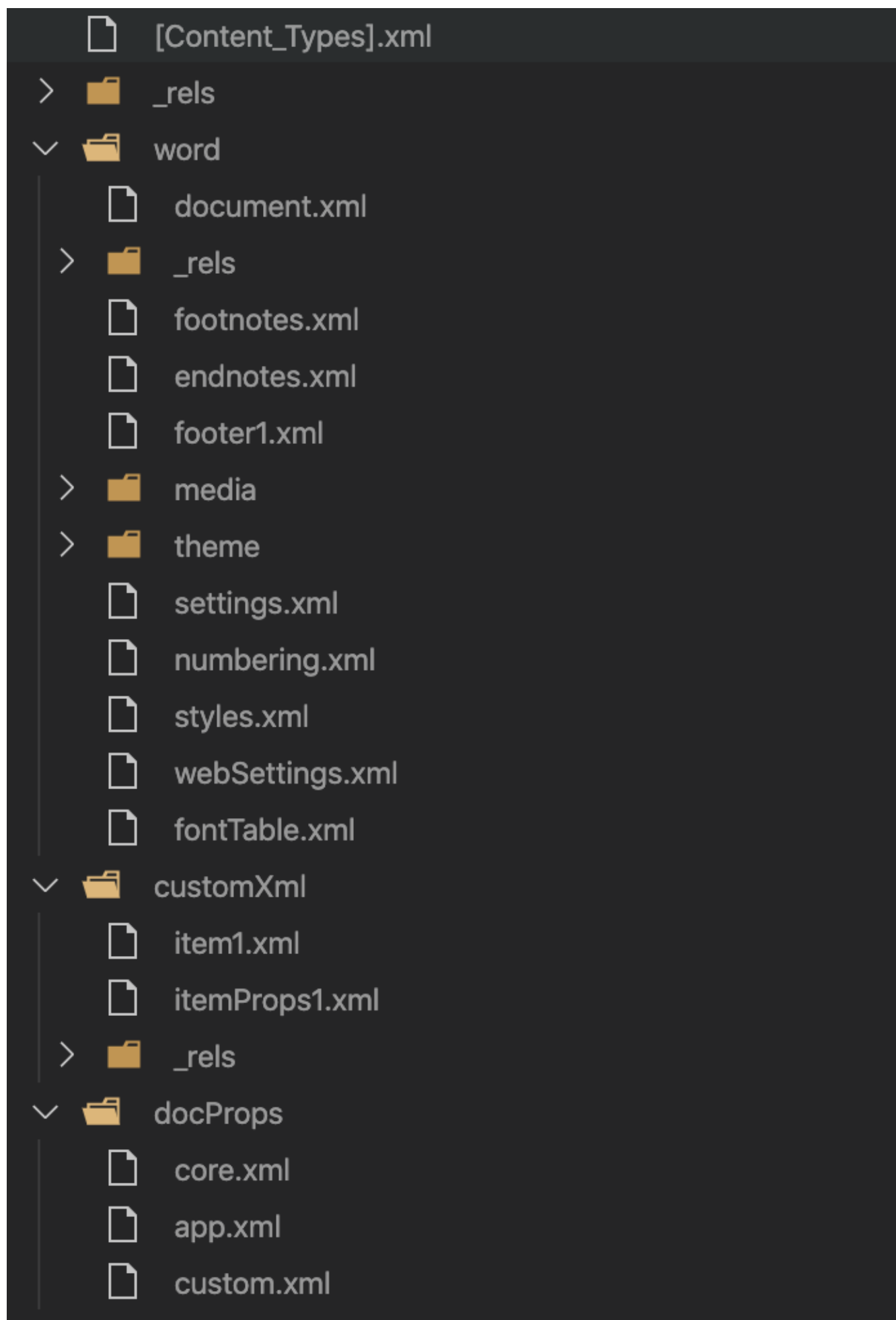
b. Gantt Chart

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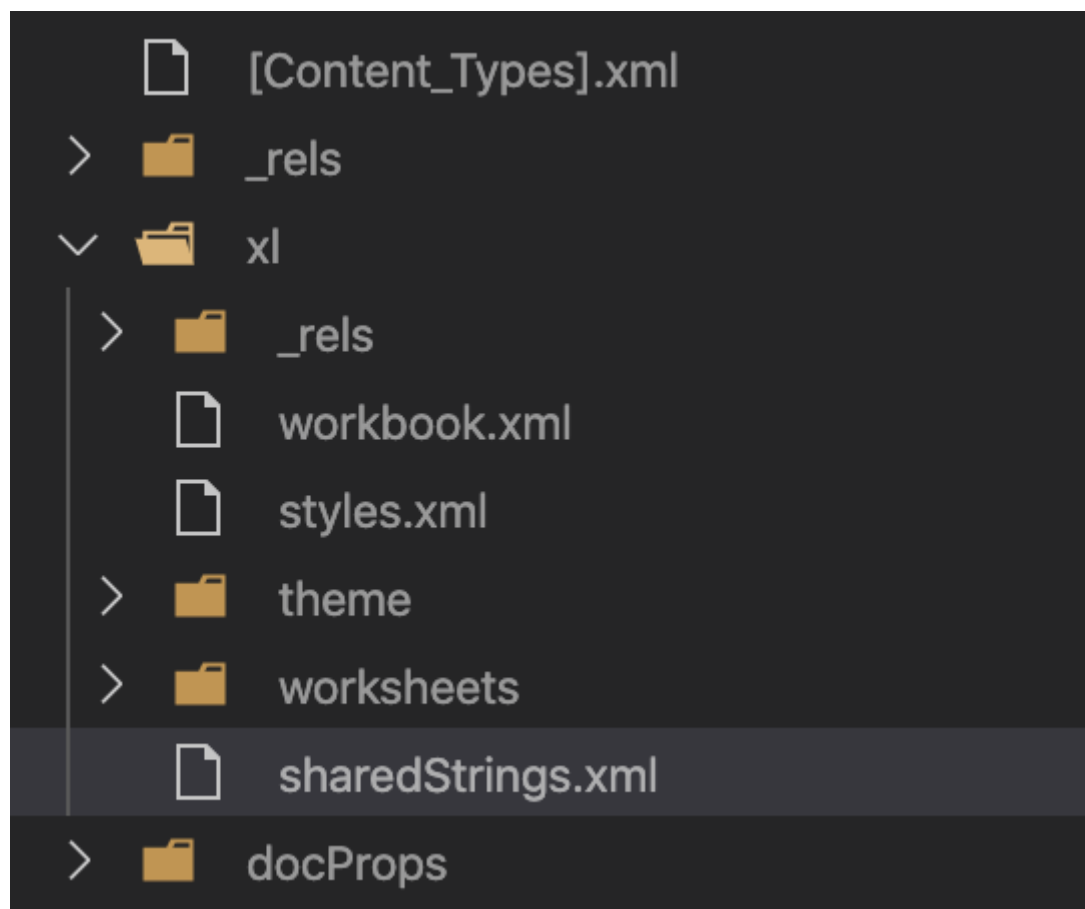
c. Structure of decompressed .docx file

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d. Structure of decompressed .xlsx file

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e. Implementation of Word2007Document.cs

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```
protected override void Index()
{
    var startTime = DateTime.Now;
    Console.WriteLine($"Indexing {Name}");

    #region Index Word Document
    // ReadFiles
    using var doc = WordprocessingDocument.Open(path: Location, isEditable: false);
    var body = doc.MainDocumentPart.Document.Body;
    // Get all <w:p> elements.
    using var paragraphParts = body.Descendants<Paragraph>().GetEnumerator();
    while (paragraphParts.MoveNext())
    {
        var currentParagraph = paragraphParts.Current;
        // Find all <w:t> elements inside each <w:p> element.
        var textParts = currentParagraph.Descendants<Text>().AsQueryable();
        var paragraphTemp = from text in textParts
                            where text.Text != ""
```

```

        // Last char is number, possibly page number in Table
        select char.IsNumber(text.Text, text.Text.Length - 1)
    }
    var paragraph = string.Concat(paragraphTemp);

    if (new[] { "" }.Contains(paragraph)) continue;
    if (paragraph == null) continue;

    this.AddToIndex(texts: paragraph);
}
#endregion

Console.Write(
    $" >==> {Thumbnail.Count} unique words. {(DateTime.Now - startTime).TotalSeconds} seconds"
);
}

```

f. Implementation of Excel2007Document.cs

[Back to content](#)

```

protected override void Index()
{
    var startTime = DateTime.Now;
    Console.WriteLine($"Indexing {Name}");

    #region Excel
    var xlsx = SpreadsheetDocument.Open(path: Location, isEditable: false);
    var workSheets = xlsx.WorkbookPart.WorksheetParts.GetEnumerator();

    # region Get sharedStringTable
    IQueryable<string> sharedStringTableList = null;
    using (var parts = xlsx.RootPart.Parts.GetEnumerator())
    {
        while (parts.MoveNext())
        {
            var b = parts.Current.OpenXmlPart;
            if (b.GetType() == typeof(SharedStringTablePart))
            {
                var part = (SharedStringTablePart)parts.Current.OpenXmlPart;
                sharedStringTableList = from item in part.SharedStringTable.Elements()
                                        select item.InnerText;
            }
        }
    }
    #endregion

    while (workSheets.MoveNext())
    {
        var sheet = workSheets.Current;
        using var sheetData = sheet.Worksheet.Elements<SheetData>().GetEnumerator();
        while (sheetData.MoveNext())
        {

```

```

    {
        using var rows = sheetData.Current.Elements<Row>().GetEnumerator();
        while (rows.MoveNext())
        {
            var row = rows.Current;
            using var cells = row.Elements<Cell>().GetEnumerator();
            while (cells.MoveNext())
            {
                var cell = cells.Current;
                var text = "";
                // TODO: Potential issue with the cell type
                // FIXME: The value the cells with type `Date`
                if (cell.DataType == null)
                    text = cell.CellValue.InnerText;
                else if (cell.DataType == CellValues.SharedString)
                    text = sharedStringTableList.ElementAt(int.Parse(cell.C
                else
                    text = cell.CellValue.InnerText;

                this.AddToIndex(text);
            }
        }
    }
}
#endregion

Console.WriteLine($">==> {Thumbnail.Count} unique words. {(DateTime.Now - start
}

```

g. Implementation of PowerPoint2007Document.cs

[Back to content](#)

```

protected override void Index()
{
    var startTime = DateTime.Now;
    Console.WriteLine($"Indexing {Name}");

    # region PowerPoint
    var ppt = PresentationDocument.Open(path: Location, isEditable: false);
    // Get all slides in current presentation.
    using var slides = ppt.PresentationPart.SlideParts.GetEnumerator();

    while (slides.MoveNext())
    {
        var slide = slides.Current;
        // Get all Text elements inside current slide
        using var text = slide.Slide.Descendants<TextBody>().GetEnumerator();
        while (text.MoveNext())
        {

```

```

        this.AddToIndex(texts: text.Current.InnerText);
    }
}
#endregion

Console.Write($" >==> {Thumbnail.Count} unique words. {(DateTime.Now - start
}

```

h. Implementation of `TextDocument.cs`

[Back to content](#)

```

protected override void Index()
{
    if (Location is null)
        return;

    var startTime = DateTime.Now;
    Console.Write($"Indexing {Name}");

    #region txt
    // Get encoding of current document.
    var encoding = new StreamReader(Location, true).CurrentEncoding;
    // Get all lines in `.txt` file as an Enumerator.
    using var lines = File.ReadAllLines(Location, encoding).AsEnumerable().GetEnumerator();

    while (lines.MoveNext())
    {
        var currentLine = lines.Current;
        if (currentLine == null) break;

        this.AddToIndex(texts: currentLine);
    }
    #endregion

    Console.Write($" >==> {Thumbnail.Count} unique words. {(DateTime.Now - start
}

```

i. Implementation of `PdfDocument.cs`

[Back to content](#)

```

protected override void Index()
{
    var startTime = DateTime.Now;
    Console.Write($"Indexing {Name}");
}

```

```

# region PDF
// Get the PDF document from a `FileStream` via `PdfReader`.
var pdfDocument =
    new Pdf.PdfDocument(new Pdf.PdfReader(new FileStream(Location, FileMode.
var totalPageNumber = pdfDocument.GetNumberOfPages();

for (var i = 1; i <= totalPageNumber; i++)
{
    var text = PdfTextExtractor.GetTextFromPage(pdfDocument.GetPage(i));

    this.AddToIndex(texts: text);
}
#endregion

Console.WriteLine($" >==> {Thumbnail.Count} unique words. {(DateTime.Now - start
}

```

j. Implementation of searching in Custodian.cs

[Back to content](#)

```

public List<Document> Search(string[] keywords)
{
    var result = new List<Document>();
    using var folders = Folders.GetEnumerator();
    try
    {
        while (folders.MoveNext())
        {
            var current = folders.Current;
            if (current == null)
                throw new Exception("no folders indexed.");

            using var docs = current.Documents.GetEnumerator();
            while (docs.MoveNext())
            {
                var currentDoc = docs.Current;
                if (currentDoc == null)
                    throw new Exception("no documents indexed.");
                // Calculate the intersection of search keywords and index data.
                var intersection = currentDoc.Thumbnail.Keys.Intersect(keywords);
                // Check if there is any intersected items.
                if (intersection.Any())
                {
                    result.Add(currentDoc);
                }
            }
        }
    }
    catch (Exception e)

```

```

    {
        Console.WriteLine(e);
    }
    finally
    {
        folders.Dispose();
    }

    // Preliminary ranking based on the occurrences of search keyword.
    result.Sort((a, b) => b.Thumbnail[keywords[0]].CompareTo(a.Thumbnail[keyword]));
    return result;
}

```

k. Implementation of CustodianApiController.cs

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```

[ApiController]
[Route("/")]
public class CustodianApiController : Controller
{
    public static readonly Custodian Custodian = new Custodian();
    public static readonly char PathDelimiter = Path.DirectorySeparatorChar;

    // Method `GET`
    // URL: "/folders"
    /// <summary>
    /// Get indexed folders.
    /// </summary>
    /// <returns>List of indexed folders</returns>
    [HttpGet("folders")]
    public ActionResult<List<FolderResult>> GetIndexedFolders()
    {
        var result = new List<FolderResult>();

        var folders = Custodian.Folders;
        folders.ForEach(
            folder => result.Add(
                new FolderResult
                {
                    FolderName = folder.Location.Split(PathDelimiter).Last(),
                    FolderPath = folder.Location
                }
            );
        return result;
    }

    // Method `POST`
    // URL: "/folders"
    /// <summary>

```



```

/// Index given folder.
/// </summary>
/// <param name="folderPath">Path to the folder to be indexed.</param>
/// <returns>Indexed folder info.</returns>
[HttpPost("folders")]
public IActionResult IndexGivenFolder(string folderPath)
{
    if (folderPath == null) return new JsonResult(new { msg = "folderPath ca

    var result = Custodian.TakeCareOf(folderPath);
    // Console.WriteLine();
    var folderName = result.Location.Split(PathDelimiter).Last();

    return new JsonResult(
        new
        {
            folder = new { location = result.Location, files = result.Docume
            msg =
                $"folder {folderName} is indexed with {result.Documents.Cour
        }
    );
}

// Method `POST`
// URL: "/search"
[HttpPost("search")]
public ActionResult<List<DocumentResult>> Search(string keyword)
{
    if (keyword == null)
    {
        return new List<DocumentResult>();
    }
    keyword = keyword.ToLower();
    var result = new List<DocumentResult>();
    var keywords = keyword.Split(" ", StringSplitOptions.RemoveEmptyEntries);

    Console.WriteLine(Custodian.Search(keywords));
    using var resultDocList = Custodian.Search(keywords).GetEnumerator();
    while (resultDocList.MoveNext())
    {
        var currentDoc = resultDocList.Current;
        if (currentDoc == null)
            throw new Exception("No Doc!");

        var resultDict = keywords.ToDictionary(kw => kw, kw => currentDoc.Th
        result.Add(
            new DocumentResult()
            {
                Name = currentDoc.Name,
                Path = currentDoc.Location,
                Result = resultDict
            }
        );
    }
}

```

```

        return result;
    }
    // Return type for schemas in Swagger Doc
    public class FolderResult
    {
        [Required] public string FolderName { get; set; }

        [Required] public string FolderPath { get; set; }
    }
    // Return type for schemas in Swagger Doc
    public class DocumentResult
    {
        /// <summary>
        /// File name of the document.
        /// </summary>
        [Required]
        public string Name { get; set; }

        /// <summary>
        /// Path of the document.
        /// </summary>
        [Required]
        public string Path { get; set; }

        /// <summary>
        /// Key-value pairs of each keyword and its occurrences.
        /// </summary>
        [Required]
        public Dictionary<string, int> Result { get; set; }
    }
}

```

I. Unit testing for Custodian API

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CustodianTest.cs

```

using Xunit;

namespace CustodianAPI.Test
{
    public class CustodianTest
    {
        [Fact]
        public void IndexTest()
        {
            // Given
            var folderPath = SharedTestData.TestDocFolderPath;
            var custodian = new Custodian();

```

```

        // When
        custodian.Reset();
        var result = custodian.TakeCareOf(folderPath: folderPath);

        // Then
        Assert.Equal(10, result.Documents.Count);
    }
    [Fact]
    public void SearchTest()
    {
        //Given
        var keywords = new string[] { "university" };
        var folderPath = SharedTestData.TestDocFolderPath;
        var custodian = new Custodian();

        //When
        custodian.TakeCareOf(folderPath);
        var result = custodian.Search(keywords);
        var resultSize = result.Count;

        //Then
        Assert.Equal(expected: 6, resultSize);
    }
}

```

m. Unit testing for Word 2007 Documents

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Word2007DocumentTest.cs

```

using CustodianAPI.Utils;
using Xunit;

namespace CustodianAPI.Test
{
    public class Word2007DocumentTest
    {
        [Fact]
        public void Word2007IndexTest()
        {
            // Given
            var docXPath = SharedTestData.TestDocFolderPath + "test.docx";
            var docmPath = SharedTestData.TestDocFolderPath + "test.docm";

            // When
            var docx = new Word2007Document(docXPath);

```

```

        var docm = new Word2007Document(docmPath);

        // Then
        Assert.Equal(6, docx.Thumbnail["university"]);
        Assert.Equal(6, docm.Thumbnail["university"]);
    }
}

```

n. Unit testing for Excel 2007 Documents

[Back to content](#)

Excel2007DocumentTest.cs

```

using CustodianAPI.Utils;
using Xunit;

namespace CustodianAPI.Test
{
    public class Excel2007DocumentTest
    {
        [Fact]
        public void ExcelIndexTest()
        {
            //Given
            var xlsmPath = SharedTestData.TestDocFolderPath + "test.xlsm";
            var xlsxPath = SharedTestData.TestDocFolderPath + "test.xlsx";

            //When
            var xlsx = new Excel2007Document(xlsxPath);
            var xlsm = new Excel2007Document(xlsmPath);

            //Then
            Assert.Equal(1, xlsx.Thumbnail["university"]);
            Assert.Equal(3, xlsx.Thumbnail["123"]);

            Assert.Equal(1, xlsm.Thumbnail["university"]);
            Assert.Equal(3, xlsm.Thumbnail["123"]);
        }
    }
}

```

o. Unit testing for PowerPoint 2007 Documents

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PowerPoint2007DocumentTest.cs

```
using CustodianAPI.Utils;
using Xunit;

namespace CustodianAPI.Test
{
    public class PowerPoint2007DocumentTest
    {
        [Fact]
        public void PDFIndexTest()
        {
            //Given
            var pptxPath = SharedTestData.TestDocFolderPath + "test.pptx";
            var pptmPath = SharedTestData.TestDocFolderPath + "test.pptm";

            //When
            var pptx = new PowerPoint2007Document(pptxPath);
            var pptm = new PowerPoint2007Document(pptmPath);

            //Then
            //FIXME: Check for `tx:body` issue
            // Find another test doc?
            Assert.Equal(expected: 1, actual: pptx.Thumbnail["harikala"]);
            Assert.Equal(expected: 44, actual: pptx.Thumbnail["programming"]);
            Assert.Equal(expected: 28, actual: pptx.Thumbnail["paradigm"]);

            Assert.Equal(expected: 1, actual: pptm.Thumbnail["harikala"]);
            Assert.Equal(expected: 28, actual: pptm.Thumbnail["paradigm"]);
            Assert.Equal(expected: 44, actual: pptm.Thumbnail["programming"]);
        }
    }
}
```

p. Unit testing for PDF Documents

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PdfDocumentTest.cs

```
using CustodianAPI.Utils;
using Xunit;

namespace CustodianAPI.Test
{
    public class PdfDocumentTest
    {
        [Fact]
        public void IndexTest()
```

```

    {
        // Given
        var filePath = SharedTestData.TestDocFolderPath + "Database System :

        // When
        var testDoc = new PdfDocument(filePath);

        // Then
        Assert.Equal(expected: 9, actual: testDoc.Thumbnail["university"]);
    }
}

```

q. Unit testing for TextDocuments

[Back to content](#)

TextDocumentTest.cs

```

using Xunit;
using CustodianAPI.Utils;

namespace CustodianAPI.Test
{
    public class TextDocumentTest
    {
        [Fact]
        public void IndexTest()
        {
            //Given
            var txt = new TextDocument(SharedTestData.TestDocFolderPath + "test,
            //When

            //Then
            Assert.Equal(30, txt.Thumbnail["castle"]);
        }
    }
}

```

r. Inverted index memory structure

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✓ Thumbnail [Dictionary]: Count = 1463

```
> [0] [KeyValuePair]: {[university, 6]}
> [1] [KeyValuePair]: {[of, 190]}
> [2] [KeyValuePair]: {[hertfordshire, 2]}
> [3] [KeyValuePair]: {[international, 7]}
> [4] [KeyValuePair]: {[college, 3]}
> [5] [KeyValuePair]: {[educational, 12]}
> [6] [KeyValuePair]: {[leaning, 2]}
> [7] [KeyValuePair]: {[application, 81]}
> [8] [KeyValuePair]: {[for, 95]}
> [9] [KeyValuePair]: {[young, 35]}
> [10] [KeyValuePair]: {[people, 8]}
> [11] [KeyValuePair]: {[eazycyber, 6]}
> [12] [KeyValuePair]: {[csp102, 1]}
> [13] [KeyValuePair]: {[mini, 1]}
```