

Notes and approaches to OCR

Rohan Alexander, John Tang, Diego Mamanche Castellanos

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Abstract

TBD

Introduction

A crucial step in the data analysis workflow is gathering data. This step involves tools and methods to collect raw data in an systematic way. In this paper we are interested in gathering data from Portable Document Format (PDF) files, in particular, when these PDFs were created by scans, and hence must be processed before their data can be analysed. Such PDF files are unstructured data, meaning that the data are not tagged and are not organised in a regular way.¹ While tags could be assigned manually, typically a statistical model is used for reasons of efficiency, and this process is called Optical Character Recognition (OCR). We evaluate several pre-trained commercial OCR options accessed via APIs: 1) X, 2), and 3), ; additionally several OCR options that are run locally: 4) X, 5), and 6), ; and finally 7) training our own model. We find... [TBD].

PDF files were developed in 1993 by the technology company Adobe and are useful for documents because they should display in a consistent way independent of the environment that created them or the environment in which they are being viewed. One feature of PDFs is that they can include a variety of objects, for instance, text, photos, figures, etc. However, this variety can limit the capacity of PDFs to be used directly as data inputs for statistical analysis. The data first needs to be extracted from the PDF.

Sometimes it is possible to copy and paste the data from the PDF. This is more likely when the PDF only contains simple text or regular tables. In particular, if the PDF has been created by an application such as Word then often the text can be extracted in this way because they are stored as text. But it is not as easy if the text has been stored as an image which is then part of the PDF.

Furthermore, there is a linguistic component that adds more complexity. For instance, it is well known that non-Latin characters such as Japanese, Chinese, Arabic, among others, generate several difficulties in different stages of the text mining process [ADD CITE]. It is because those characters have complicated structures, a large number of categories (for instance, compare the 26 characters in the English alphabet with the thousands of characters in Japanese kanji), and resemblance among characters, font unevenness, or writing styles. In those cases, the need for reliable tools or methods with the ability to elicit data becomes extremely important.

Optical character recognition (OCR),is a process that transforms a bitmapped image of printed or hand-written text into text code [ADD CITE]. It thereby becomes machine-readable. It has been used to parse images of characters since the 1950s [ADD CITE]. These initial approaches used mechanical and optical

¹Structured data is organized in a highly regular manner or a pre-defined data model where the regularities apply to all the data in a particular dataset. Some examples are tables and relations. Semi-structured data contains this same information, but instead of having regular structures applied to all items in the dataset, the data might be interpreted with structural information. It can be supplied as tags e.g. name = "Bob" but also other markers to separate semantic elements and enforce hierarchies of records and fields within the data. Unstructured data, such as texts or images, holds information with no explicit structured data, such as tags. However, these tags may be assigned using manual or automatic techniques, converting the unstructured data to semi-structured data (Losee 2006). This diversity and complexity of data structures complicate, even more, the data gathering process as each data type may require a specific gathering approach(es) when needed.

means of rotating disks and photomultiplier flying spot scanner with a cathode ray tube lens, followed by photocells and arrays of them [ADD CITE]. The OCR process was slow, and one line of characters could be digitized at a time. These days once a printed or handwritten text has been captured optically by a scanner or some other optical means, the digital image goes through the following stages of a computer recognition system (Cheriet et al. 2007):

- The preprocessing stage that enhances the quality of the input image and locates the data of interest.
- The feature extraction stage that captures the distinctive characteristics of the digitized characters for recognition.
- The classification stage that processes the feature vectors to identify the characters and words.

In this paper we review various OCR options for researchers who need to gather data from PDFs in which the text must be extracted to be reused, edited, or reformatted; the text should be available for full-text information retrieval; the text is to be coded in HTML or SGML; the text should be available to adaptive equipment for the visually impaired; the file size is of concern (in terms of storage or bandwidth to transmit); or the resources are available to perform OCR and correct the output.

Although this step remains the same regardless of the field of study, the methods used vary between those fields of study because of their different interests. Moreover, the diversity of data types adds complexity to the process of gathering data.

When they consider a primer on what OCR options exist these days depending on your technical ability and then how they perform for an easy example and then how they perform for a hard example (the Japanese extract) and finally some suggestions for what is needed in the future....

Our paper represents...

The remainder of this paper is structured as follows...

Data

Test Samples

Japanese dictionaries...[Rohan]

For the purpose of this study, one page from the letter a in the Japanese dictionary was taken to assess the selected OCR tools. The image contains 3293 characters. Words in English were counted as one character for this analysis. Moreover, the sample text was divided into four images called **sections** as illustrated in Figure @ref(fig:sections). These new images were assessed across all OCR tools.

This example is in a vertical form, meaning that it should be read it from right to left and from the top to the bottom. This is important since it is expected to obtain from each OCR tool the correct sequence of characters. For instance, from section 1 in figure xx, the first five characters from the first line are []. We expect to see the same sequence from each OCR tool.

The following figures corresponds to each section extracted from the sample:

OCR options

The following list contains the OCR APIs and libraries available that will be evaluated in this study:



Figure 1: UPDATE CAPTION

一本の傘を二人でさすこと。多く男女二人の場合にいふ。あひがせ。
アイアン [Iron] (名) (普通にはなまいで「アイロン」といふ) ①鐵又は鐵製品。②西洋ひのし。③髪の毛をあらわせる小形の鏡。④ゴルフ用の鐵の杖。—**ド・イシップリ** [Iron discipline] (名) 【社】軍人に對する軍律、又は共産黨員に對する黨律【社】對する軍律、又は共産黨員に對する黨律の如く、絕對に破るべきらざる規律。—**ロード・トロント法則** ①人間の意思では變更することの出来ない法則。現在の資本主義では、労働者の賃銀は増加させる望みがないといふラッサールの説。即ち労働賃銀が上れば労働者が増加し、賃銀が低下する。故に労働者は生活費用として必要な額以上の賃銀を、永久得ることがあらへん。好んで飲用すること。
アイヴァンホー [Ivanhoe] (名) 【文】イギリスの文豪サー・ウォーラントの歴史小説。騎士アーヴィング主人公としたもの。一八二〇年刊。
アイヴォリー [Ivory] (名) ①象牙など。②象牙色の光澤ある厚い洋紙。—**タワー** [Ivory tower] (名) 象牙塔。①現代物質文明の醜惡な生活。②自己の好みや詩的の美の生活をするため文藝家などが一人籠る別天地。
アイ・エ・ティ・ー [I-E-T-U] (名) ナヒト・ヨルムンガルと號する。
あいえん [愛縁] (名) 【佛】恩愛の縁。

Figure 2: UPDATE CAPTION

一本の傘を二人でさすこと。多く男女二人の場合にいふ。あひがせ。
あいえん [哀婉] (名) 哀れにやかしいこと。
あいえん [哀猿] (名) 悲しい聲で啼く猿。
あいえん [合縁] (名) むつみあふことのできる縁。—**きえん** [合縁奇縁] (名) ①合ふも合はぬも縁によること。②不思議な縁。
あいおい [哀生] (名) じつしに生ひ出ること。おなじどし。—**さし** [相生插] (名) 男松と女松とを挿し、根じりに蘚柑子を用ひたもの。—**のまつ** [相生松] (名) 兵庫縣加古郡高砂町高砂神社の境内の雌松。高砂の松。—**ほん** [相生盆] (名) 婚禮の折に用ひる男島と女島とを並べた盆景。
あいのい [相生結] (名) 普通の女結びの一端を更にその結目に通した紐の結び方。
アイ・オーラー [I.O.U.] (名) 【商】 I owe you の略語。あなたから借用しましたの意。借用をあらはす商業用の略語。—**て**、兩端の尖った釘。
あいのか [哀歌] (名) 悲しい心持をあらはした歌。
あいのかき [哀合鍵] (名) 合鍵の木又は石を接合するに、その端を互に半分づつ缺いて合はせること。又、その物。
あいかぎ [合鍵] (名) 一つのかぎの外に、そのあいかたある合鍵。
あいかき [合方] (名) ①芝居のせりふの間に入れる三味線。②謡の大鼓・小鼓・太鼓・笛の囃子。
あいがも [哀間鶴] (名) 【動】野生の真鶴と青首鶴(あおつる)とのあひのこ。
あいがん [哀玩] (名) 大切にしてあってそぶきを述べて熱心に願ふこと。
あいがん [哀願] (名) なげきねがふこと。
あいぎ [愛妓] (名) かばゆく思ふ藝娼妓。
あいぎじょ [相聞] (名) 萬葉集中の歌體の「で、男女親子・兄弟夫婦・知己等の相思の歌。さうしゆ(相聞)。
あいきゅう [哀泣] (名) かなしみ泣くこと。
あいきよら [哀鍔] (名) ①鉢の年を経たもの。②子持鉢の鹽漬。
あいきょう [愛鄉] (名) 生まれ故郷を愛する

Figure 3: UPDATE CAPTION

「...。一しん〔愛鄉心〕(名)愛郷の精神。
 あいきょう〔愛敬〕(名) ①人づきのよいこと。あいそのよいこと。世辭のよいこと。②顔のかはやらしいこと。③俳優が花道で見物の方へ見えをすること。
 一あいぜん〔愛敬愛染〕(名)【佛】(あいぜんみょうおう)(愛染明王)。一あばた〔愛敬痘痕〕(名)愛敬があるやうに見えるあばた。
 一げ〔愛敬毛〕(名)女の髪や頭髪のおくれ毛。顔に愛敬を添へるからいふ。
 一しようばい〔愛敬商賣〕(名)待合。遊郭。愛敬がなくては立ちゆかぬからいふ。
 一すきあい〔愛敬附合〕(名)なみなみのつきあひ。普通の交際。一ずく〔愛敬附〕(名)〔自動、カ四〕愛敬があるやうになる。
 一そう〔愛敬相〕(名)佛の容貌。
 一び〔愛敬日〕(名)【經】(Days of Grace)手形満期の後支拂を延期する日數。恩裏日。
 一べに〔愛敬紅〕(名)月尻や頬・耳たぶにつけれる紅。一ぼくろ〔愛敬黒子〕(名)かはゆく見えるほくる。
 一まもり〔愛敬守〕(名)婚禮の時、新婦が襟にかける守。一もち〔愛敬餅〕(名)婚禮後三日目に舅姑に贈る餅。みかのもち(三日餅)。
 あいきょう〔愛嬌〕(名) (あいきょう)(愛敬)。
 あいきょう〔愛敬〕(名)(あいきょう)。(古語)
 あいきょう〔愛樂〕(名)【佛】愛し好むこと。
 あいぎん〔愛吟〕(名)愛する詩歌を吟すること。
 又、その詩歌。
 あいぎん〔哀吟〕(名)悲しい情をうつし表はした
 あいぐすり〔合藥〕(名)その人の病に特效ある薬。通葉。

Figure 4: UPDATE CAPTION

あいぐんじょうやく〔愛輝條約〕(名)
 愛輝は滿洲國黒龍江省の都會。咸豐八年(一八五八)清露の間に黒龍江を兩國の國境とすることに就いて、この地で結ばれた條約。
 あいけ〔ある...藍氣鼠〕(名)藍色を帶びてゐること。
 あいけい〔愛敬〕(名)拳の遊技で二人が同じ手を出すこと。③馴れあひ。合意。
 あいげん〔愛眼〕(名)【佛】佛の慈悲の眼。
 あいこ〔愛顧〕(名)目をかけてやること。引立てること。ひいき。
 あいご〔愛護〕(名)かはゆがり保護すること。
 あいご〔愛語〕(名)【佛】菩薩が衆生に對し慈しみのことをば。
 あいこう〔愛好〕(名)愛しのむこと。
 あいこう〔愛幸〕(名)かはゆがること。きにいり。
 あいこう〔隘巷〕(名)せまくるしくさない。
 あいこう〔哀號〕(名)人の死をかなしんで泣きさけぶこと。
 あいこく〔哀哭〕(名)聲を擧げて悲しみ泣くこと。
 あいこく〔愛國〕(名)我が國を愛すること。
 あいこく〔愛國心〕(名)自分の生まれた國士を愛する精神。祖國愛。
 一ちよきん〔愛國貯金〕(名)外債を早く返還する目的で、一人一日一錢つつ預け入れて、六年間の据置郵便貯金をすること。
 一ふじんかい〔愛國婦人會〕(名)明治三十四年、奥村五百子の創設した婦人團體。戦死者の遺族・廢兵の救護と一般社會事業に貢獻する目的とする。
 あいことば〔合詞〕(名)かねてうちあはせてある合圖の詞。かねてしめし合せてある暗語。
 アイコノクラズム〔Iconoclasm〕(名)偶像破壊。③アイコン(像又は偶像)を壊すこと。④哲學・宗教・道德上、絶対権威と目されてゐた神や道徳信條を無視して、正確な認識を得ようとすること。⑤迷信的的思想を打破すること。

Figure 5: UPDATE CAPTION

OCR Tool	Company	Type	Monthly
			Price Tech
			Aug/2020 Requirements
Azure Cognitive Services (OCR)	Microsoft	API	Free Web Con- tainer: 5000/Free; S1 Web Con- tainer: 0- 1M/\$1.50 per 1,000 trans, 1M- 5M/\$1 per 1,000 trans, 5M- 10M/\$0.65 per 1,000 trans, 10M- 100M/\$0.65 per 1,000 trans, +100M/\$0.65 per 1,000 trans

OCR Tool	Company	Type	Monthly Price	Tech Aug/2020 Requierements
Amazon Rekognition	Amazon	API	First 1 million images: \$0.001 per image Next 9 million images \$0.0008 per image Next 90 million images \$0.0006 per image Over 100 million images \$0.0004 per image	
PyTesseract (Wrapper Google's OCR Engine) Standard: \$0.002 per trans		Python Library	Free	
Kraken (Linux OS)		Python Library	Free	
Google Vision (for Text recognition)	Google	API	1000/Free, 5 mill/\$1.5, >5mill/\$0.6	
Amazon Textract	Amazon	API	First 1 Million pages: \$0.015 - \$0.05 per page, Over 1 Million pages: \$0.01 - \$0.04 per page	

OCR Tool	Company	Type	Monthly Price	Tech	Aug/2020 Requierements
Kindai-OCR	Result of n2i Project	Python Library	Free		

Azure Cognitive Services - Computer Vision OCR

Among the Microsoft Azure's portfolio, Azure Cognitive Services offers Computer Vision, an API that processes images and returns information based on the visual features the user is interested in. Those services comprise object detection of an image, visual features tagging, image categorization, Optical Character Recognition (OCR), among *others*⁴. The OCR API processes an image and returns the language of the document, orientation, regions, lines, boundaries, and finally, the characters.

In python we need several libraries for calling the API.

```
import os
import sys
import requests
# If you are using a Jupyter notebook, uncomment the following line.
#%matplotlib inline
import matplotlib.pyplot as plt
from matplotlib.patches import Rectangle
from PIL import Image
from io import BytesIO
import matplotlib
from os import path
import ast
```

Then, we need to create headers and parameters necessary for calling the API. The library **requests** is commonly used in python to do that. The method **post** is needed as the API uses the HTTP method POST.

```
#Create the URL for the API call. The endpoint corresponds to the Azure's
# endpoint of the account.
ocr_url = endpoint + "vision/v3.0/ocr"

#Create the header using the Azure's subscription key.
headers = {'Ocp-Apim-Subscription-Key': subscription_key}

#In params language': 'ja' for japanese only. 'unk' means self detection
params = {'language': 'unk', 'detectOrientation': 'true'}
data = {'url': image_url}

#Call and save the response using the method post from the library request
response = requests.post(ocr_url, headers=headers, params=params, json=data)
```

Here we have an example of the response:

```
{'language': 'ja',
'textAngle': 0.0,
'orientation': 'Up',
'regions': [{"boundingBox": '31,30,1521,2721',
'lines': [{"boundingBox": '730,30,44,2718',
'words': [{"boundingBox": '735,30,34,34', 'text': ' '}],
```

```

{'boundingBox': '736,71,34,26', 'text': ' '},
{'boundingBox': '749,100,6,11', 'text': ' '},
{'boundingBox': '735,116,34,27', 'text': ' '},
{'boundingBox': '736,149,33,33', 'text': ' '}

```

Language and Orientation

Figure xx presents a sample that corresponds to the section 1 of the image containing Japanese text, but it also includes English text in some fragments of the text. The API offers the possibility to do self-detection, which in this case is helpful, but also the opportunity to specify the language in advance. Moreover, the orientation can also be self-detected or not.

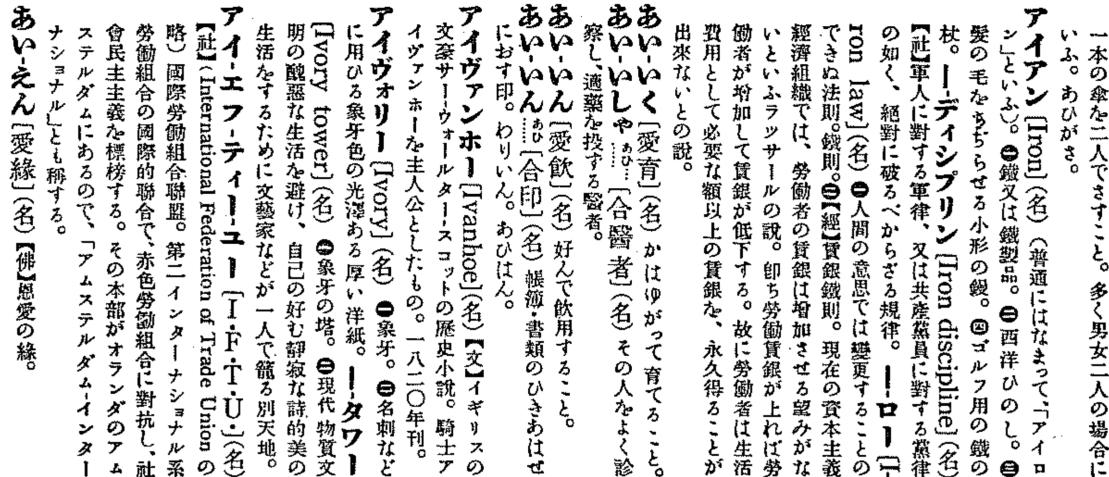


Figure 6: UPDATE CAPTION

Regions

The blue line figure xx denotes the segment from the image that includes the characters. In this example, there is only one blue line because the document is only text. In other cases, it may contain images requiring more than one region.

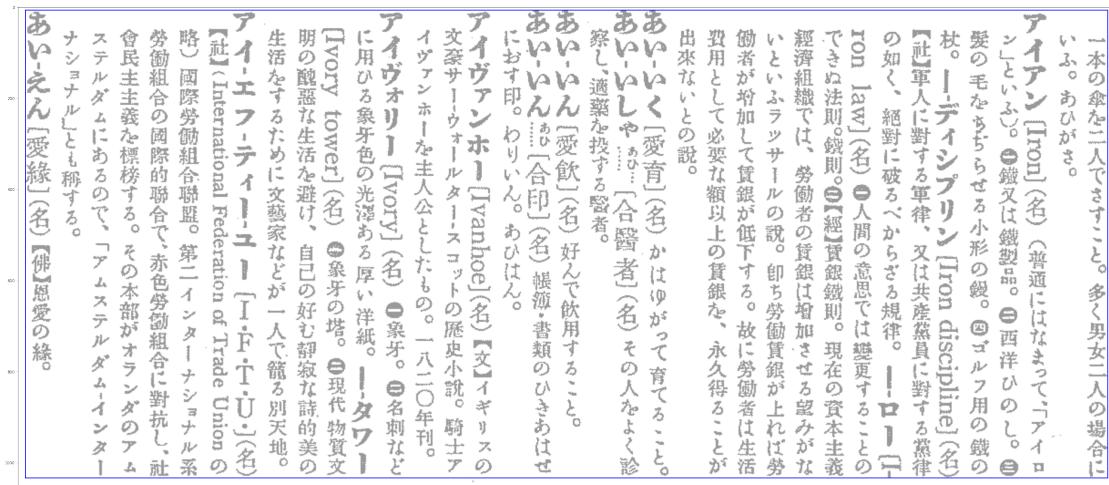


Figure 7: UPDATE CAPTION

Lines

Once the region is defined, the API provides in figure xx (red rectangles) the subsets of characters of the region called Lines. From the example, we can see that some characters are not included in any of the lines. Those characters are not recognized by the API.

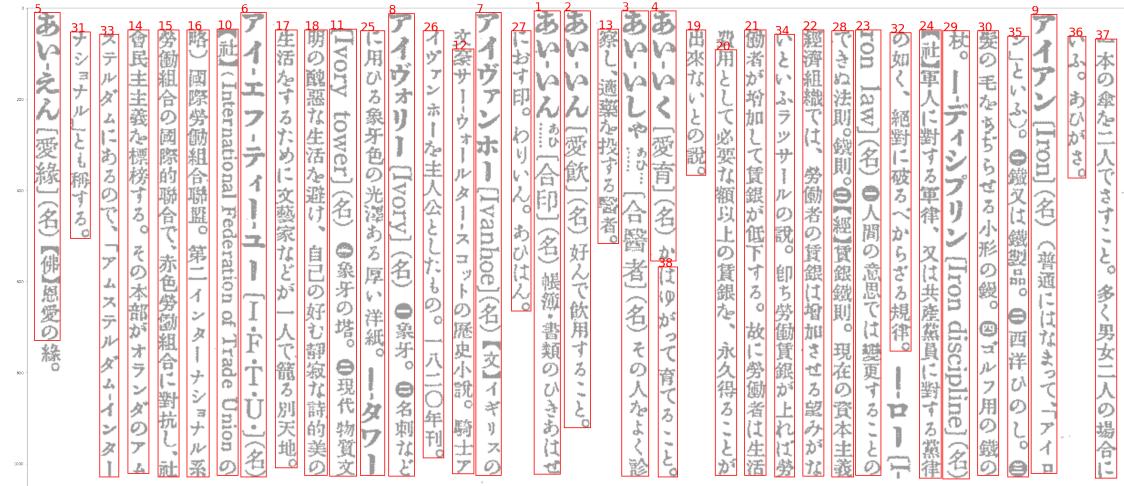


Figure 8: UPDATE CAPTION

The Character Boundaries

After the lines are identified, the API provides in figure xx each recognized character bounding boxes (yellow regions). Those without a yellow square were not recognized by the API in this example.



Figure 9: UPDATE CAPTION

Characters

Once the bounding boxes are located, each character takes its corresponding place, as it is shown in figure xx.

あいえん【愛縁】(名)【佛】恩愛の縁。	一本の傘を三人でさすこと。多く男女二人の場合にいふ。あひがさ。
アイアン [Iron] (名)【普通】(1)はなま。(2)アイロン」といふ。(3)鐵又は鐵製品。(4)西洋ひのし。(5)髪の毛をかぶらせる小形の鉄。(6)ゴルフ用の鐵の枚数。—・ディシpliN [Iron discipline] (名)	【社】軍人に對する軍律、又は共産黨員に對する黨律の如く、絕對に破るべきからざる規律。—・ロー [Iron law] (名) ①人間の意圖では變更することのできない法則。鐵則。(2)【經】賃銀鐵則。現在の資本主義經濟組織では、労働者の賃銀は増加させる望みがないといふラッサーの説。即ち労働賃銀が上れば労働者が増加して賃銀が低下する。故に労働者は生活費用として必要な額以上の賃銀を、永久得ることが出来ないとの説。
アイバーンホー [Ivanhoe] (名)【文】イギリスの文豪サー・ウォルター・スコットの歴史小説。騎士アーヴィングホーが主人公としたもの。(一八二〇年刊)におす印。わりいん。あひはん。	【文】イギリスの文豪サー・ウォルター・スコットの歴史小説。騎士アーヴィングホーが主人公としたもの。(一八二〇年刊)におす印。わりいん。あひはん。
アイヴォリー [Ivory] (名)【象牙】(1)象牙。(2)名刺などに用ひる象牙色の光澤ある厚い洋紙。—・タワー [Ivory tower] (名)【象牙の塔】(1)現代物質文明の醜惡な生活を避け、自己の好む静寂な詩的美の生活心をるために文藝家などが一人で築る別天地。	【文】イギリスの文豪サー・ウォルター・スコットの歴史小説。騎士アーヴィングホーが主人公としたもの。(一八二〇年刊)におす印。わりいん。あひはん。
アイ・エフ・ティ・エー・ユー [I.F.T.U.] (名)【社】(International Federation of Trade Union)の略)国際労働組合聯盟。第一インター・ナショナル系労働組合の國際的聯合で、赤色労働組合に對抗し、社會民主主義を標榜する。その本部がオランダのアムステルダムにあるので、「アムステルダム・インター・ナショナル」とも稱する。	【社】(International Federation of Trade Union)の略)国際労働組合聯盟。第一インター・ナショナル系労働組合の國際的聯合で、赤色労働組合に對抗し、社會民主主義を標榜する。その本部がオランダのアムステルダムにあるので、「アムステルダム・インター・ナショナル」とも稱する。

Figure 10: UPDATE CAPTION

Advantages and Disadvantages

Advantages The API is easy to use after reading the documentation. It offers an example of how to use it in different programming languages. It also offers the possibility to self-detect languages and the orientation of the document. The response is clear, and extract the information from the JSON file is not complicated.

Disadvantages Even though the API offers the possibility to self-detect the language, It changes the order in which the characters should be in the output. In figure xx we can see that the first line provided by the self-detection approach is located in the middle. This situation does not allow a correct interpretation of the text because it does not follow the reading pattern. In this case, it is a vertical orientation, which means we have to read it from right to left.

あいえん【愛縁】(名)【佛】恩愛の縁。	一本の傘を二人でさすこと。多く男女二人の場合にいふ。あひがさ。
アイアン [Iron] (名)【普通】(1)はなま。(2)アイロン」といふ。(3)鐵又は鐵製品。(4)西洋ひのし。(5)髪の毛をかぶらせる小形の鉄。(6)ゴルフ用の鐵の枚数。—・ディシpliN [Iron discipline] (名)	【社】軍人に對する軍律、又は共産黨員に對する黨律の如く、絕對に破るべきからざる規律。—・ロー [Iron law] (名) ①人間の意圖では變更することのできない法則。鐵則。(2)【經】賃銀鐵則。現在の資本主義經濟組織では、労働者の賃銀は増加させる望みがないといふラッサーの説。即ち労働賃銀が上れば労働者が増加して賃銀が低下する。故に労働者は生活費用として必要な額以上の賃銀を、永久得することが出来ないとの説。
アイバーンホー [Ivanhoe] (名)【文】イギリスの文豪サー・ウォルター・スコットの歴史小説。騎士アーヴィングホーが主人公としたもの。(一八二〇年刊)におす印。わりいん。あひはん。	【文】イギリスの文豪サー・ウォルター・スコットの歴史小説。騎士アーヴィングホーが主人公としたもの。(一八二〇年刊)におす印。わりいん。あひはん。
アイヴォリー [Ivory] (名)【象牙】(1)象牙。(2)名刺などに用ひる象牙色の光澤ある厚い洋紙。—・タワー [Ivory tower] (名)【象牙の塔】(1)現代物質文明の醜惡な生活を避け、自己の好む静寂な詩的美の生活心をために文藝家などが一人で築る別天地。	【文】イギリスの文豪サー・ウォルター・スコットの歴史小説。騎士アーヴィングホーが主人公としたもの。(一八二〇年刊)におす印。わりいん。あひはん。
アイ・エフ・ティ・エー・ユー [I.F.T.U.] (名)【社】(International Federation of Trade Union)の略)国際労働組合聯盟。第一インター・ナショナル系労働組合の國際的聯合で、赤色労働組合に對抗し、社會民主主義を標榜する。その本部がオランダのアムステルダムにあるので、「アムステルダム・インター・ナショナル」とも稱する。	【社】(International Federation of Trade Union)の略)国際労働組合聯盟。第一インター・ナショナル系労働組合の國際的聯合で、赤色労働組合に對抗し、社會民主主義を標榜する。その本部がオランダのアムステルダムにあるので、「アムステルダム・インター・ナショナル」とも稱する。

Figure 11: UPDATE CAPTION

When the parameter language is stated as Japanese since the beginning, as we can observe in figure xx, it

recognizes the first line correctly.

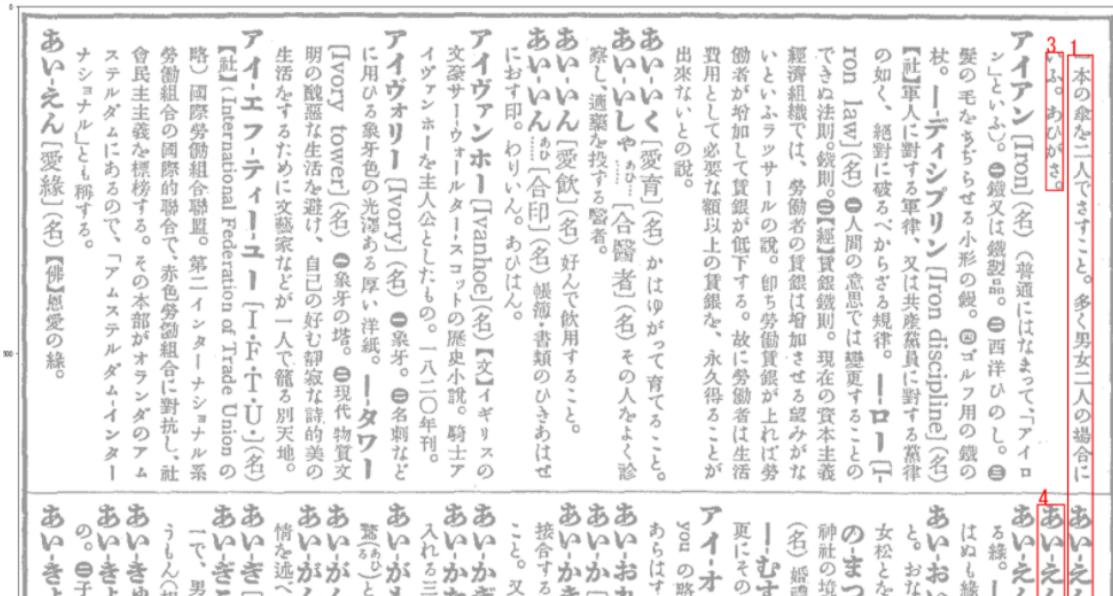


Figure 12: UPDATE CAPTION

Google Vision OCR

Google Vision API can integrate vision detection features, including image labeling, face and landmark detection, optical character recognition (OCR), and tagging of explicit content. The text recognition process detects text in images and recognizes the text contained therein. Once detected, the recognizer then determines the actual text in each block and segments it into lines and words.

To evaluate this OCR option, we need the following python libraries.

```
from os import path
from PIL import Image
from PIL import ImageFont
from PIL import ImageDraw
from PIL import ImageEnhance
import base64 #Convert an image into base64 form for API requests
import requests #API request - GET/POST
import json
import ast
```

Same as the Azure API, we need to create the headers and parameters necessary for calling the API. We also need the python library **requests** to make the API call. The method **post** is needed as the API uses the HTTP method POST.

The following example illustrates how to state the headers and parameter, but also create two functions. The first one, called `encode_image` converts an image into base64 format, an encoding process designed to carry data stored in binary formats across channels that only reliably support text content. It can embed image files or other binary assets inside textual assets. The second one makes an HTTP POST request that calls Google's Vision API.

```
#Create the URL for the API call. The endpoint corresponds to the Azure's
# endpoint of the account.
url = "https://vision.googleapis.com/v1/images:annotate"
```

```

querystring = {"key": google_vision_api_key }
headers = {'Content-Type': "application/json"}

def encode_image(image_path):
    with open(image_path, "rb") as image_file:
        return base64.b64encode(image_file.read())

def image_request(image_path):

    payload = '{\"requests\": [{\"image\": {\"content\": \"' + \
    encode_image(image_path).decode('utf-8') + \
    '\"}, \"features\": [\"type\": \"TEXT_DETECTION\"]}]}' 

    response = requests.request("POST", url, data=payload, headers=headers, params=querystring)

    return ast.literal_eval(response.text)

```

This is an example of the response:

```

{'responses': [ {'textAnnotations': [ {'locale': 'ja',
    'description': '-\n\n          - [ ]()\n]() \n  0   \n    p®( ]()     \n \nV \n\n      \n',
    'boundingPoly': { 'vertices': [ { 'x': 26, 'y': 21},
        { 'x': 1556, 'y': 21},
        { 'x': 1556, 'y': 2748},
        { 'x': 26, 'y': 2748} ] },
    {'description': '-',
    'boundingPoly': { 'vertices': [ { 'x': 1227, 'y': 686},
        { 'x': 1227, 'y': 677},
        { 'x': 1262, 'y': 677},
        { 'x': 1262, 'y': 686} ] },
    '\n' } ] }
    {'description': '',
    'boundingPoly': { 'vertices': [ { 'x': 785, 'y': 880},
        { 'x': 814, 'y': 880},
        { 'x': 814, 'y': 914},
        { 'x': 785, 'y': 914} ] },
    {'description': '(',
    'boundingPoly': { 'vertices': [ { 'x': 775, 'y': 916},
        { 'x': 814, 'y': 916},
        { 'x': 814, 'y': 940},
        { 'x': 775, 'y': 940} ] },
    ... ],
    ...
  ]
}

```

From the previous example, we can observe that the response returns a list of nested dictionaries. The first nested dictionary called **textAnnotations** consists of a list of dictionaries. Each one of those has a description (character) and boundingPoly (boundaries of the characters).

BoundingPoly

Each boundingPoly consist of vertices in which the symbol is located.

Region The first object in the nested dictionary contains all identified characters in the image as well as the boundaries that comprises the location of those characters. This object can resemble the idea of the region provided in the Azure's API.

Figure xx shows the region identified by the API.

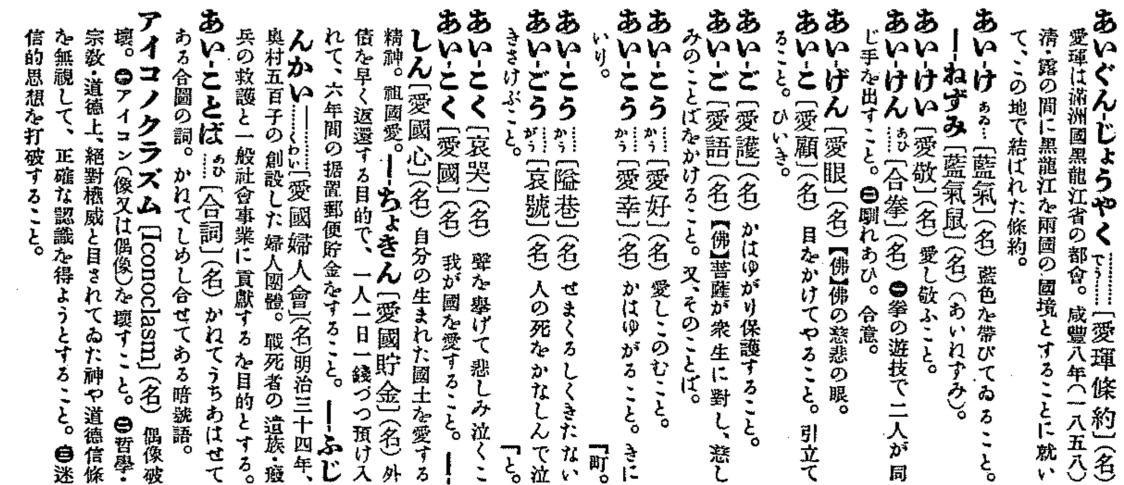


Figure 13: UPDATE CAPTION

The Character Boundaries The remaining objects enclose the boundaries of the characters. As it is shown in figure xx, each boundingPoly node can include one or more characters.

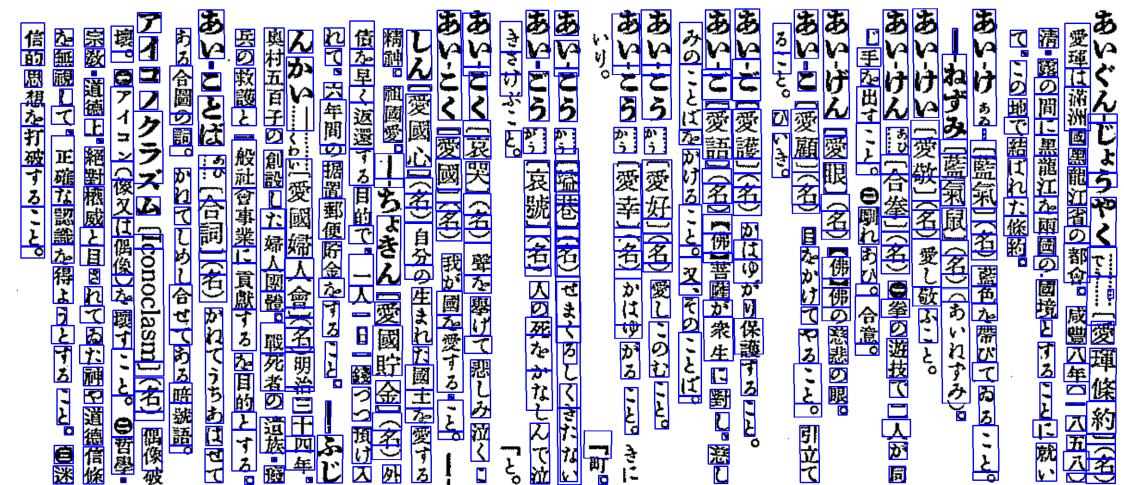


Figure 14: UPDATE CAPTION

Characters

Once the bounding boxes are located, each character takes its corresponding place, as it is shown in figure xx. Pending find a way to plot the text in vertical form to make it readable.

languageHints

Google Vision API offers the advantage of including in the request language hints. It consists of a list of languages the user knows in advance the image contains. For this study, we run two versions, one without

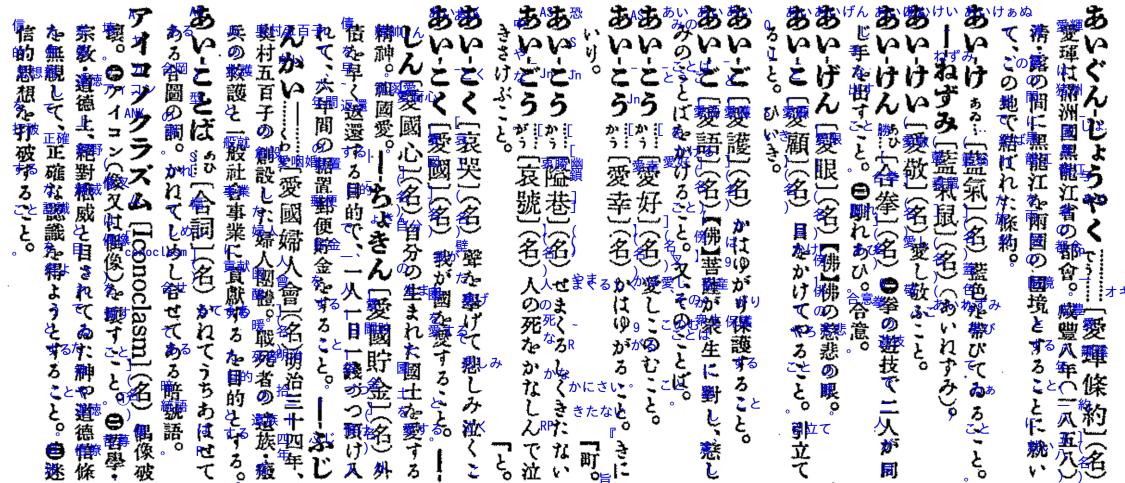


Figure 15: UPDATE CAPTION

hints and the other one with a list of two hints, such as Japanese and English, as the image contains some words in English. Both versions returned the same output.

Advantages and Disadvantages

Advantages Same as the Azure API, this is also easy to use after reading the documentation. It also offers several examples in different programming languages using the Google libraries for Python. It gives the possibility to include languages in advanced as hints, and identifies the orientation automatically. The response contains an object with all identified characters in the correct order.

Moreover, the API gives the opportunity to send the image in base64 format or using an internal (google storage) or external URL.

Disadvantages Unlike Azure Cognitive Services, which returns each recognized character individually, Google Vision groups characters in some cases. This situation adds some degree of complexity when processing the response from the API. [Not sure if it is a disadvantage in real life]

PyTesseract - Python Library

Python-Tesseract is an optical character recognition (OCR) library for python. It is a wrapper for Google's Tesseract-OCR Engine. PyTesseract can read all image types such as png, jpeg, gif, tiff, BMP, among others. It is widely used to process everything from scanned documents. This inbuilt python library performs the OCR techniques on the image to produce the digitized output text in a readable and editable form.

To use this library, we need to install Tesseract. For this study, we use version 4. It is necessary to call the .exe file to use Tesseract with PyTesseract. See the following example.

```
#Call .exe location for Windows
pytesseract.pytesseract.tesseract_cmd = r'C:\Program Files\Tesseract-OCR\tesseract.exe'
```

Along with the PyTesseract library, the following libraries are used.

```
from PIL import Image
from PIL import ImageOps
import pytesseract
from os import path
import pandas as pd
```

```

import matplotlib.pyplot as plt
from matplotlib.patches import Rectangle

```

PyTesseract offers several methods with different outputs when processing an image to extract text. According to Pypi.org, the uses of those methods are:

- **image_to_string**: Returns the result of a Tesseract OCR run on the image to string
- **image_to_boxes**: Returns result containing recognized characters and their box boundaries
- **image_to_data**: Returns result containing box boundaries, confidences, and other information. Requires Tesseract 3.05+. For more information, please check the Tesseract TSV documentation
- **image_to_osd**: Returns result containing information about orientation and script detection.
- **image_to_alto_xml**: Returns result in the form of Tesseract's ALTO XML format.
- **run_and_get_output**: Returns the raw output from Tesseract OCR. Gives a bit more control over the parameters that are sent to tesseract.

For this analysis, we use the method `image_to_data` as this offers the boundaries and the recognized characters in a handy form so we can understand the process. Furthermore, in PyTesseract, it is needed to specify the language in advance. Since PyTesseract is a wrapper of Google's Tesseract-OCR Engine, Tesseract-OCR must have installed all required languages. In this case, it is Japanese, which is not included in its out-of-the-box version. To include a new language, adding the `.traineddata` file into the Tesseract-OCR/tessdata folder is sufficient. However, since the text in the image is vertical Japanese. It is necessary to include two files: `jpn.traineddata` and `jpn_vert.traineddata`. Once the files are located correctly, the following code extracts the text from the image.

```

img1 = Image.open(r'~\inputs\00-sample-pages_1.png')
image_to_data = pytesseract.image_to_data(img1, lang = 'jpn_vert')

```

The output from the previous code converted into a pandas dataframe is shown in figure xx.

	1	result.head(8)										
J:												
	level	page_num	block_num	par_num	line_num	word_num	left	top	width	height	conf	text
0	1	1	0	0	0	0	0	0	1588	2776	-1	NaN
1	2	1	1	0	0	0	898	30	654	657	-1	NaN
2	3	1	1	1	0	0	898	30	654	657	-1	NaN
3	4	1	1	1	1	0	1522	70	30	616	-1	NaN
4	5	1	1	1	1	1	1522	70	28	44	13	本
5	5	1	1	1	1	2	1525	123	26	35	92	の
6	5	1	1	1	1	3	1525	170	25	20	87	拿
7	5	1	1	1	1	4	1525	199	26	20	78	を

Figure 16: UPDATE CAPTION

From figure xx, we can observe that the output in the column `level` generates five levels. Those are pages, blocks, paragraphs, lines, and words (characters). Each one is a subset of the previous one.

Page

For this example, the page resembles the concept of region, which is the largest area of the image enclosing all recognized characters. Figure 12 illustrates the page area.

あいぐんじょうやく [愛珲條約] (名)	愛珲は滿洲國黒龍江省の都會。咸豐八年(一八五八)清・露の間に黒龍江を兩國の國境とすることに就いて、この地で結ばれた條約。
あいづみ [藍氣鼠] (名)	藍色を帶びてゐること。
あいづみ [愛敬] (名)	愛し敬ふこと。
あいげん [合拳] (名)	●拳の遊技で二人が同じ手を出すこと。●馴れあひ。合意。
あいげん [愛眼] (名)	【佛】佛の慈悲の眼。
あいご [愛顧] (名)	目をかけてやること。引立てること。
あいご [愛護] (名)	かはゆがり保護すること。
あいご [愛語] (名)	【佛】菩薩が衆生に對し、慈しみのことばをかけること。又、そのことば。
あいご [愛好] (名)	愛しのむこと。
あいご [愛幸] (名)	かはゆがること。きにいり。
あいこう [隘巷] (名)	せまくるしくきだない町。
あいこう [哀號] (名)	人の死をかなしんで泣きをけぶこと。
あいこう [哀哭] (名)	聲を擧げて悲しみ泣くこと。
あいこう [愛國] (名)	我が國を愛すること。
あいこう [愛國心] (名)	自分の生まれた國土を愛する精神。祖國愛。●ちよきん [愛國貯金] (名)
あいこう [愛國婦人會] (名)	明治三十四年、奥村五百子の創設した婦人團體。戰死者の追族賑兵の救護と一般社會事業に貢獻するを目的とする。
あいことば [合詞] (名)	かるねてしまし合せてある暗號語。
アイコノクラズム [Iconoclasm] (名)	偶像破壊。●アイコン(像又は偶像)を壊すこと。●哲學、宗教道徳上、絶對權威と目されてゐた神や道徳信條を無視して、正確な認識を得ようとすること。●迷信的的思想を打破すること。

Figure 17: UPDATE CAPTION

Blocks

The blocks are subsets of the page area that consist of small groups of recognized characters. In figure 13, we can see that most of the blocks are well ordered. In terms of correctness of the boundaries, we can see that some of them overlap several characters that are not recognized by the library.

あいぐんじょうやく [愛珲條約] (名)	愛珲は滿洲國黒龍江省の都會。咸豐八年(一八五八)清・露の間に黒龍江を兩國の國境とすることに就いて、この地で結ばれた條約。
あいづみ [藍氣鼠] (名)	藍色を帶びてゐること。
あいづみ [愛敬] (名)	愛し敬ふこと。
あいげん [合拳] (名)	●拳の遊技で二人が同じ手を出すこと。●馴れあひ。合意。
あいげん [愛眼] (名)	【佛】佛の慈悲の眼。
あいご [愛顧] (名)	目をかけてやること。引立てること。
あいご [愛護] (名)	かはゆがり保護すること。
あいご [愛語] (名)	【佛】菩薩が衆生に對し、慈しみのことばをかけること。又、そのことば。
あいご [愛好] (名)	愛しのむこと。
あいご [愛幸] (名)	かはゆがること。きにいり。
あいこう [隘巷] (名)	せまくるしくきだない町。
あいこう [哀號] (名)	人の死をかなしんで泣きをけぶこと。
あいこう [哀哭] (名)	聲を擧げて悲しみ泣くこと。
あいこう [愛國] (名)	我が國を愛すること。
あいこう [愛國心] (名)	自分の生まれた國土を愛する精神。祖國愛。●ちよきん [愛國貯金] (名)
あいこう [愛國婦人會] (名)	明治三十四年、奥村五百子の創設した婦人團體。戰死者の追族賑兵の救護と一般社會事業に貢獻するを目的とする。
あいことば [合詞] (名)	かるねてしまし合せてある暗號語。
アイコノクラズム [Iconoclasm] (名)	偶像破壊。●アイコン(像又は偶像)を壊すこと。●哲學、宗教道徳上、絶對權威と目されてゐた神や道徳信條を無視して、正確な認識を得ようとすること。●迷信的的思想を打破すること。

Figure 18: UPDATE CAPTION

Paragraphs

Similar to the blocks, the paragraphs are subsets of blocks. These follow the same idea of subareas containing a set of characters. In this case, for example, we can look at paragraphs three and four, which are subsets of block four (figure xx). It is interesting to see how the only paragraph four of block four is a very small area compared to its parent block. This situation happens in several other blocks. See figure xx for a better understanding.

32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
信的の思想を打破すること。	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

あいぐんじょうやく [愛珲條約] (名)
愛珲は瀋洲國黒龍江省の都會。咸豐八年(一八五八)清・露の間に黒龍江を兩國の國境とすることに就いて、この地で結ばれた條約。

あいねずみ [藍氣鼠] (名) 藍色を帶びてゐること。
あいねずみ [藍氣鼠] (名) (あいねずみ)。

あいけい [愛敬] (名) 愛し敬ふこと。
あいけい [愛敬] (名) (あいけい)。

あいけん [合拳] (名) ①拳の遊技で二人が同じ手を出すこと。②剛れおひ。合意。

あいこ [愛顧] (名) 目をかけてやること。引立てること。
あいこ [愛顧] (名) (ひいき)。

あいご [愛護] (名) かはゆがり保護すること。
あいご [愛護] (名) (かはゆがり)。

あいご [愛護] (名) 善薩が衆生に對し、慈しむこと。
あいご [愛護] (名) (かはゆがり)。

あいこう [愛好] (名) 愛しきのむこと。
あいこう [愛好] (名) (かはゆがる)。

あいこう [愛幸] (名) かはゆがるのこと。
あいこう [愛幸] (名) (かはゆがる)。

あいこう [隘巷] (名) せまくるしくきたない町。
あいこう [隘巷] (名) (かいきょう)。

あいごう [哀號] (名) 人の死をかなしんで泣き声をあげること。
あいごう [哀號] (名) (あいごう)。

あいごく [哀哭] (名) 声を擧げて悲しみ泣くこと。
あいごく [哀哭] (名) (あいごく)。

あいごく [愛國] (名) 我が國を愛すること。
あいごく [愛國] (名) (あいこく)。

あいこく [愛國心] (名) 自分の生まれた國土を愛する精神。祖國愛。一ちよきん [愛國貯金] (名) 外債を早く返還する目的で、一人一日一錢づつ預け入れて、六年間の据置郵便貯金をする。一ぶじんかく [愛國婦人會] (名) 明治三十四年、奥村五百子の創設した婦人團體。戦死者の遺族、兵の救護と一般社會事業に貢獻するを目的とする。あいことば [合詞] (名) かねてうちあはせてある合圖の詞。かねてしめし合せてある暗號語。

アイコノクラズム [Iconoclasm] (名) 偶像破壊。①アイコン (像又は偶像) を壊すこと。②哲學・宗教・道徳上、絶對權威と目されてゐた神や道徳信條を無視して、正確な認識を得ようとすること。自迷

Figure 19: UPDATE CAPTION

Lines

Once the paragraphs are defined, the library provides in figure xx, the last subsets of characters called Lines. From the example, we can see that most of the characters are located in one of the lines. However, several others are not. For some cases there is no clear reason why those characters are not included. For instance, between the lines 14 and 15, two clear lines are not recognized by the library.

32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
信的の思想を打破すること。	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

あいぐんじょうやく [愛珲條約] (名)
愛珲は瀋洲國黒龍江省の都會。咸豐八年(一八五八)清・露の間に黒龍江を兩國の國境とすることに就いて、この地で結ばれた條約。

あいねずみ [藍氣鼠] (名) 藍色を帶びてゐること。
あいねずみ [藍氣鼠] (名) (あいねずみ)。

あいけい [愛敬] (名) 愛し敬ふこと。
あいけい [愛敬] (名) (あいけい)。

あいけん [合拳] (名) ①拳の遊技で二人が同じ手を出すこと。②剛れおひ。合意。

あいこ [愛顧] (名) 目をかけてやること。引立てること。
あいこ [愛顧] (名) (ひいき)。

あいご [愛護] (名) かはゆがり保護すること。
あいご [愛護] (名) (かはゆがり)。

あいご [愛護] (名) 善薩が衆生に對し、慈しむこと。
あいご [愛護] (名) (かはゆがり)。

あいこう [愛好] (名) 愛しきのむこと。
あいこう [愛好] (名) (かはゆがる)。

あいこう [愛幸] (名) かはゆがるのこと。
あいこう [愛幸] (名) (かはゆがる)。

あいこう [隘巷] (名) せまくるしくきたない町。
あいこう [隘巷] (名) (かいきょう)。

あいごう [哀號] (名) 人の死をかなしんで泣き声をあげること。
あいごう [哀號] (名) (あいごう)。

あいごく [哀哭] (名) 声を擧げて悲しみ泣くこと。
あいごく [哀哭] (名) (あいごく)。

あいごく [愛國] (名) 我が國を愛すること。
あいごく [愛國] (名) (あいこく)。

あいこく [愛國心] (名) 自分の生まれた國土を愛する精神。祖國愛。一ちよきん [愛國貯金] (名) 外債を早く返還する目的で、一人一日一錢づつ預け入れて、六年間の据置郵便貯金をする。一ぶじんかく [愛國婦人會] (名) 明治三十四年、奥村五百子の創設した婦人團體。戦死者の遺族、兵の救護と一般社會事業に貢獻するを目的とする。あいことば [合詞] (名) かねてうちあはせてある合圖の詞。かねてしめし合せてある暗號語。

アイコノクラズム [Iconoclasm] (名) 偶像破壊。①アイコン (像又は偶像) を壊すこと。②哲學・宗教・道徳上、絶對權威と目されてゐた神や道徳信條を無視して、正確な認識を得ようとすること。自迷

Figure 20: UPDATE CAPTION

Character Boundaries

These boundaries enclose the characters. Figure xx shows that a character boundary can include one or more characters. However, some character boundaries overlap each other. Moreover, same as the previous areas, several characters have been skipped with no apparent reason.

Characters

In terms of character-level recognition, we can observe that many characters are not recognized. Interestingly those characters are in a correct block, paragraph, line, and character boundary, but it was skipped. For

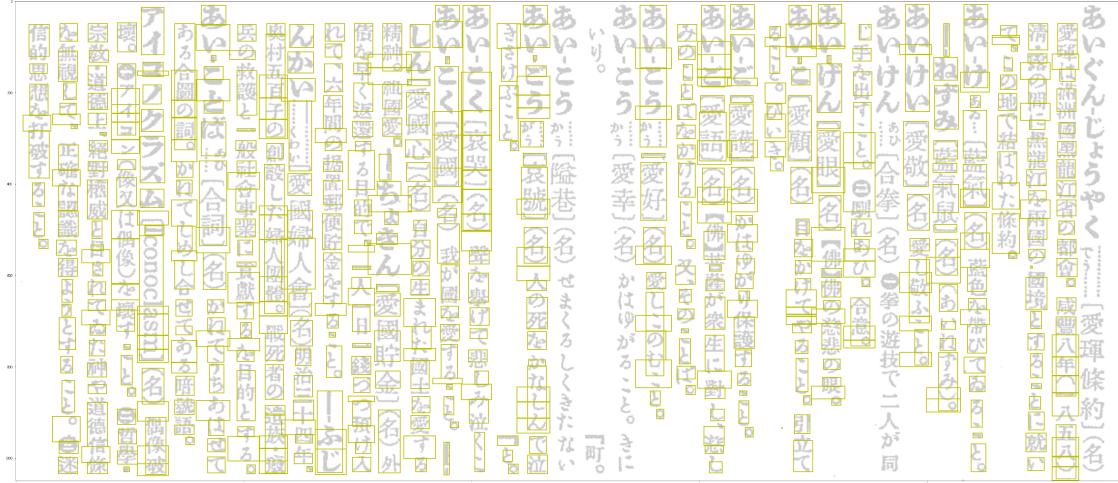


Figure 21: UPDATE CAPTION

example, in the first line of recognized characters and the first character boundary of this line, there are two words, but one of them is not recognized. Figure xx illustrates this case.

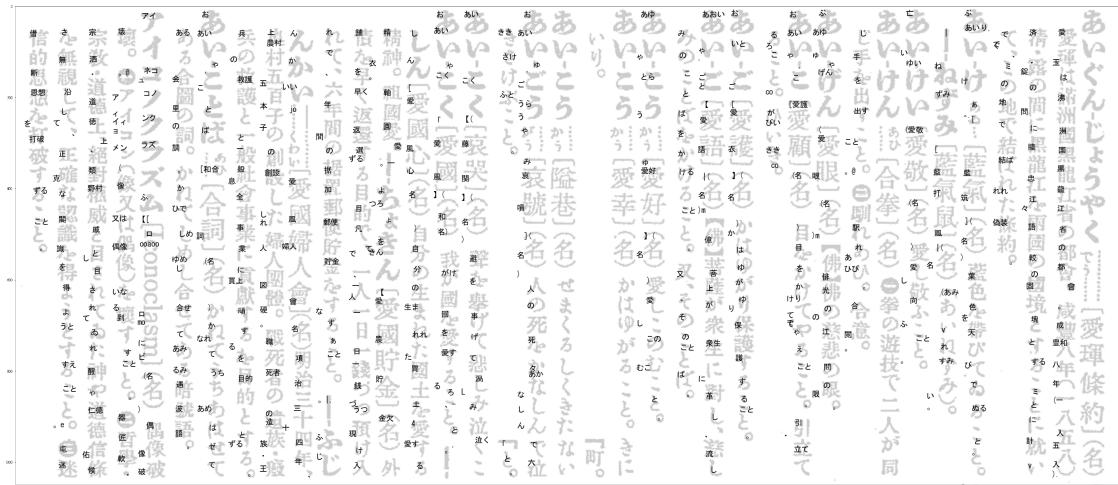


Figure 22: UPDATE CAPTION

Advantages and Disadvantages

Advantages The most important advantage is that this is a free library. It is also a wrapper from Google’s Tesseract Engine. Moreover, the way it presents the covered areas are very detailed. It offers blocks, paragraphs, lines, boundaries, and finally the character level.

Disadvantages Some lines were completely ignored by Pyteseract, even thought it was clear enough to be recognized by the tool. Moreover, same as Google Vision, this library groups more than one character sometimes.

Kindai-OCR

According to the Center for Open Data in the Humanities, Kindai-OCR is an OCR system for modern Japanese documents. It was built under the N2I project that study state-of-the-art statistical models for

OCR, and work on the development of infrastructure and providing open access to data. The datasets were constructed by the University of Tokyo Center for Education and Research and the National Institute of Japanese Language and are used for OCR machine learning. These datasets are commonly known as the Modern Magazine Datasets.

The Kindai-OCR code was developed in Python and released as an open source code in August 2020 on Github. The Github folder contains all the necessary code and instructions to assess the OCR tool. [not sure if it is necessary to mention the modification in the file test.py I did, in order to run the model using GPUs.]

After running the Kindai-OCR for our samples, the system generated two main outputs. They are explained as follows:

File result.xml

This file is presented in an Extensible Markup Language (XML) format containing a tree with the identified lines, as well as the corresponding characters. An example of the xml file is shown as follows:

```
<?xml version='1.0' encoding='Shift_JIS'?>
<paper xmlns="http://codh.rois.ac.jp/modern-magazine/"><page dpi="100" file="00-sample_pages_3_sec_3.png">
```

After transforming this file into a dataframe form, we found that 238 lines with their corresponding characters, were generated. In figure XX we can see that the result.xml file provides information such as the corresponding level (paper, page, or line) in the tag column, the identified characters in the text column, the associated image file column, among other attributes.

	tag	attributes	text	dpi	file	number	width	height	x	y
0	{http://codh.rois.ac.jp/modern-magazine/paper}			None						
1	{http://codh.rois.ac.jp/modern-magazine/}page	{"dpi": "100", "file": "00-sample_pages_3_sec_3.png"}		None 100	sample_pages_3_sec_3.png	1	2430	1040		
2	{http://codh.rois.ac.jp/modern-magazine/}line	{"height": "905", "width": "72", "x": "あいくるし發路事。愛くるし (形。...", "y": "332", "..."}	あいくるし發路事。愛くるし (形。	100	sample_pages_3_sec_3.png	1	72	905	332	0
3	{http://codh.rois.ac.jp/modern-magazine/}line	{"height": "1026", "width": "76", "x": "あいくち島 (合巳, 名。あれせも。ものよ...", "y": "466", "..."}	あいくち島 (合巳, 名。あれせも。ものよ	100	sample_pages_3_sec_3.png	1	76	1026	466	0
4	{http://codh.rois.ac.jp/modern-magazine/}line	{"height": "1026", "width": "69", "x": "あいくすりし ((きき)名。その人の爲に信身あ...", "y": "592", "..."}	あいくすりし ((きき)名。その人の爲に信身あ	100	sample_pages_3_sec_3.png	1	69	1026	592	0

Figure 23: UPDATE CAPTION

New version of the image

Kindai-OCR generated a new version of the image containing the identified lines and characters. An example is shown as follows in figure xx.

Advantages and Disadvantages

Advantages Same as libraries such as Pytesseract, one of The most important advantages is that it is a free tool. Moreover, the recognition process is very easy. To obtain results, just by putting the images in the test folder and running the file called test.py on Python is enough to obtain the results.

Disadvantages At the time of this assessment, the use of GPUs is required which is a limitation to take into account. For this study, we used Colab from Google, which offers this capability. Moreover, Kindai-OCR returns the characters grouped by lines. They are not generated individually.

Kraken - Python Library

Kraken is a python library created by Benjamin Kiessling from Université PSL in France and Leipzig University. This library is a combination of a fork (independent development built on an existing one) from the

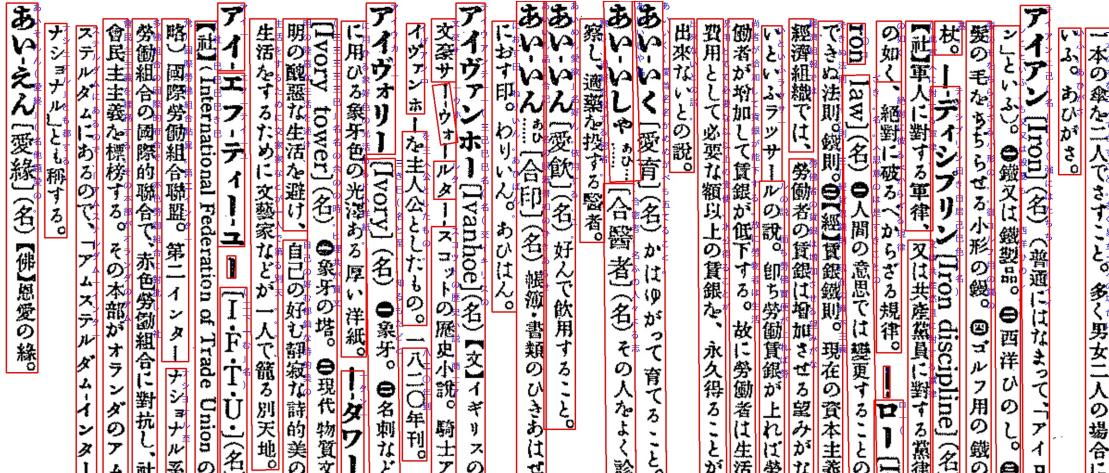


Figure 24: UPDATE CAPTION

Ocropolis package and CLSTM neural network library. Its purpose was to improve accuracy and performance rates compared with Ocropolis. It has been tested with languages such as Arabic, Persian, Syriac Polytonic Greek, Latin, among other. However, there is no information about japanese-trained models.

To assess the performance of this library, it is necessary to train a model for japanese texts. To do that, Kraken offers a function called **train**. This function expects a series of images that according to Kraken's website, these images must be high quality scans, preferably color or grayscale, and at least 300dpi. Images in PDF format are not allowed. Each image must be accompanied with a text file with extension .gt.txt. This file will contain the character(s) that correspond(s) to the image with the same name. For instance in figure xx we see the image file is called **sec1_line1.png**, the pair-wise text element for this image is **sec1_line1.gt.txt**.

After the training stage, Kraken analyses the layout and extracts text lines from an input image for later processing by the recognition. A step by step process is provided by Kraken's website (<http://kraken.re/index.html>) to recognize text from an image using the model we want.

Training process challenges

The training process itself is very friendly. However, the data preparation is the most important part as it generates the samples we feed into the model. Other studies pointed out that for languages such as Arabic, at least 800 lines are required to train a descent model. For the Japanese text of this study we trained 36 lines in which several characters appear more than once. The result after the training process was not good, indicating that the need of greater sample data is needed, which is not in the scope of this study.

Other limitations

In order to use this library it is required to have either Linux or Mac. In this study, we use Google Colab which offers a Linux environment to assess the library.

Amazon Textract

According to Amazon's website, Amazon Textract can detect Latin-script characters from the standard English alphabet and ASCII symbols.

<https://aws.amazon.com/textract/faqs/>

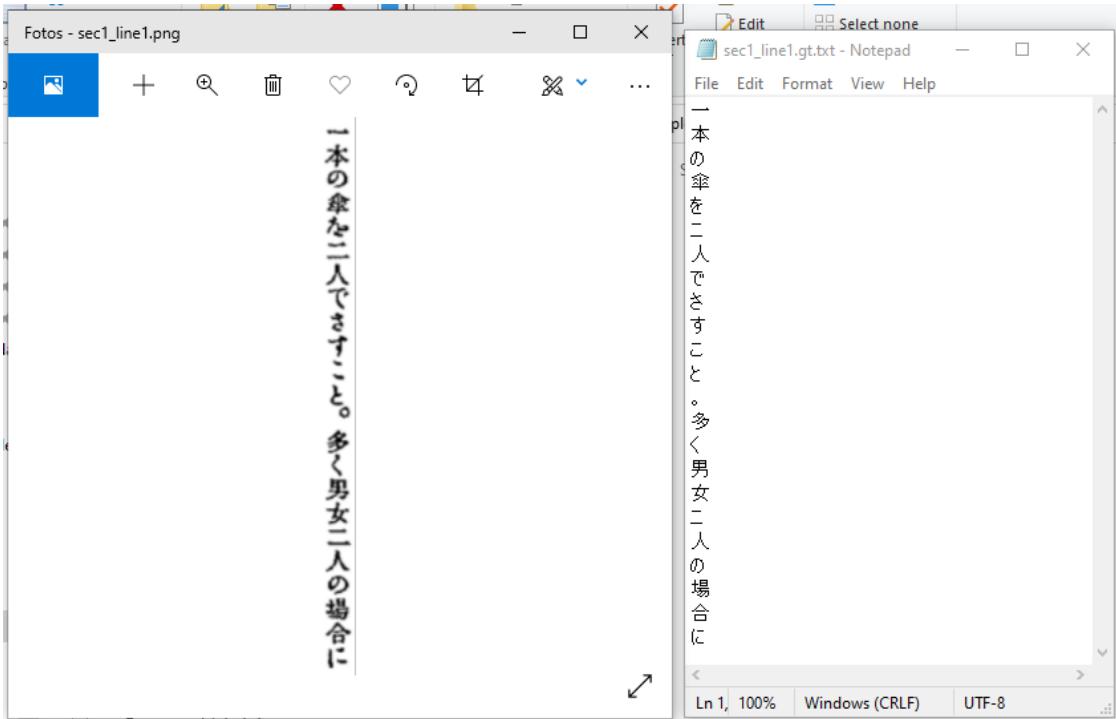


Figure 25: UPDATE CAPTION

Amazon Rekognition

According to Amazon's website, Amazon Rekognition supports text in most Latin scripts and numbers. Text detection recognizes up to 50 sequences of characters per the image or video frame and lists them as words and lines.

<https://aws.amazon.com/rekognition/faqs/>

Evaluation

For each option, we rank them based on two scales: results and difficulty. We need to work out a definition for each of these.

Diego's comment: From what I learned so far, it could be easiness (an API is more straightforward than a library), number of characters correctly recognized, flexibility, and cost. Moreover, some APIs such as Google's groups more than one character, whereas Azure returns only one character per boundary.

In terms of flexibility...

Sequence of the characters...

Output given...xml, json, flat file, csv...

Number of characters well recognized...(Accuracy)

The main aspect of the end product will be a graph with two axis, and dots for where each service is positioned, coloured or faceted by the test.

Discussion

Appendix

References

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