OPEN DATA SCIENCE CONFERENCE

Europe | Nov. 19 - Nov. 22, 2019

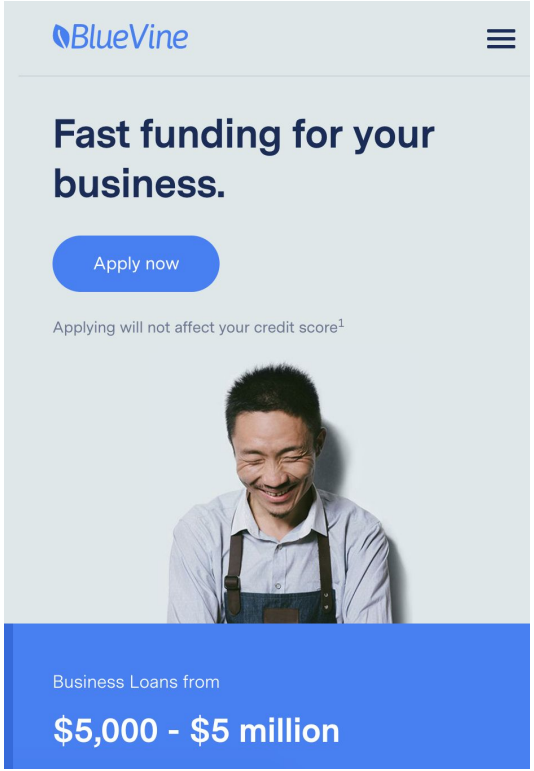
Building an Industry Classifier

Scrapy / BERT / PyTorch / SageMaker

Ido Shlomo - BlueVine

About BlueVine

- Fintech startup up based in Redwood City, CA
- Provides working capital (loans) to small & medium sized businesses
- Over $2 BN funded to date
- Mission of DS team:
  - Automate
  - Scale
  - Improve



About Me

- Data Science Manager @ BlueVine
- Lead BlueVine's DS team in Redwood City, CA (total of ~20 people across RWC & TLV)
- Team focus:
  - Risk / Fraud
  - Financial Strength
  - Marketing
- Personal interests: Unstructured data and DS Infrastructure.

Slides at: https://github.com/ido-sh/odsc_presentations

Why do we care about Industry?

- **Compliance:**

  We can’t work with some industries: Weapons, gambling, other finance companies, etc

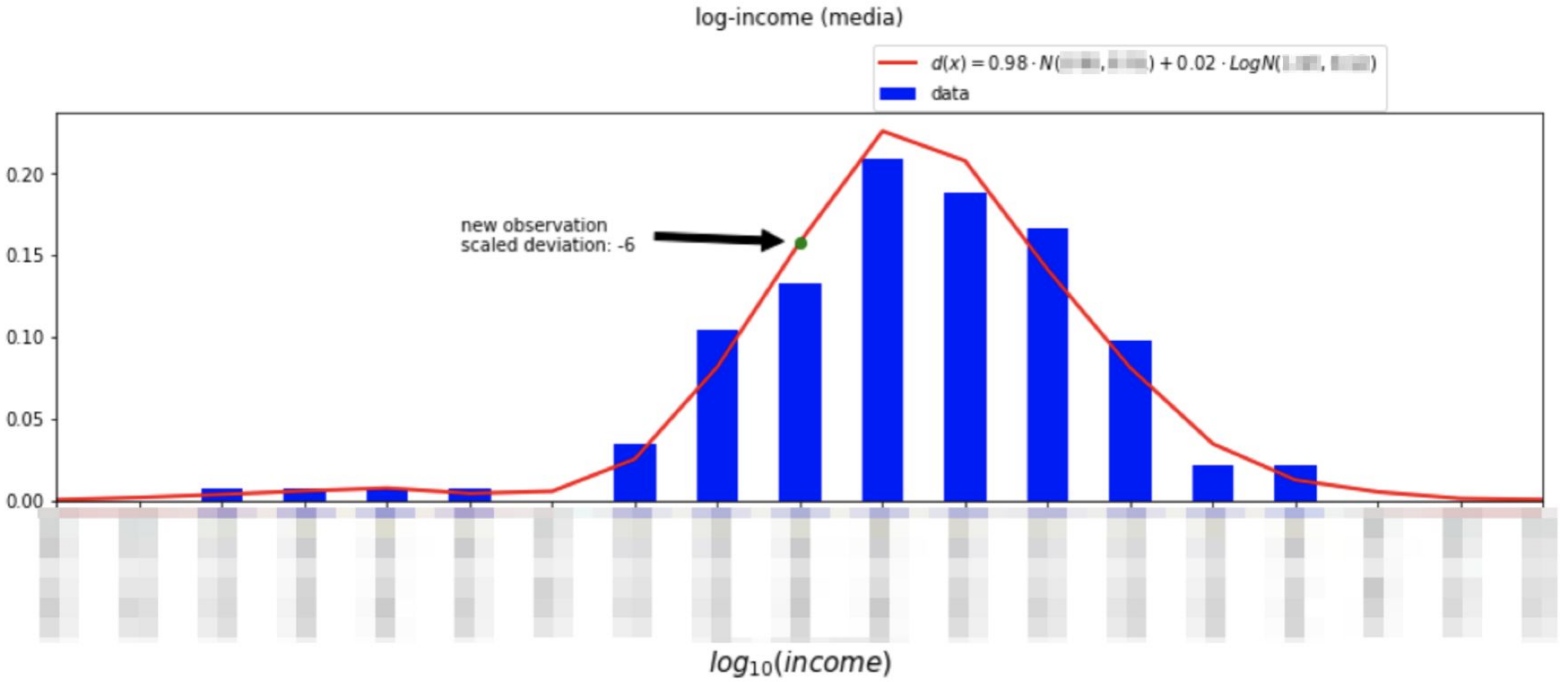
- **Portfolio management:**

  Limit exposure to specific risky sectors, general balancing, etc.

- **Smarter decision making:**

  For key metrics (e.g income, credit score), “normal” and “abnormal” differs across industries.

Why do we care about Industry?



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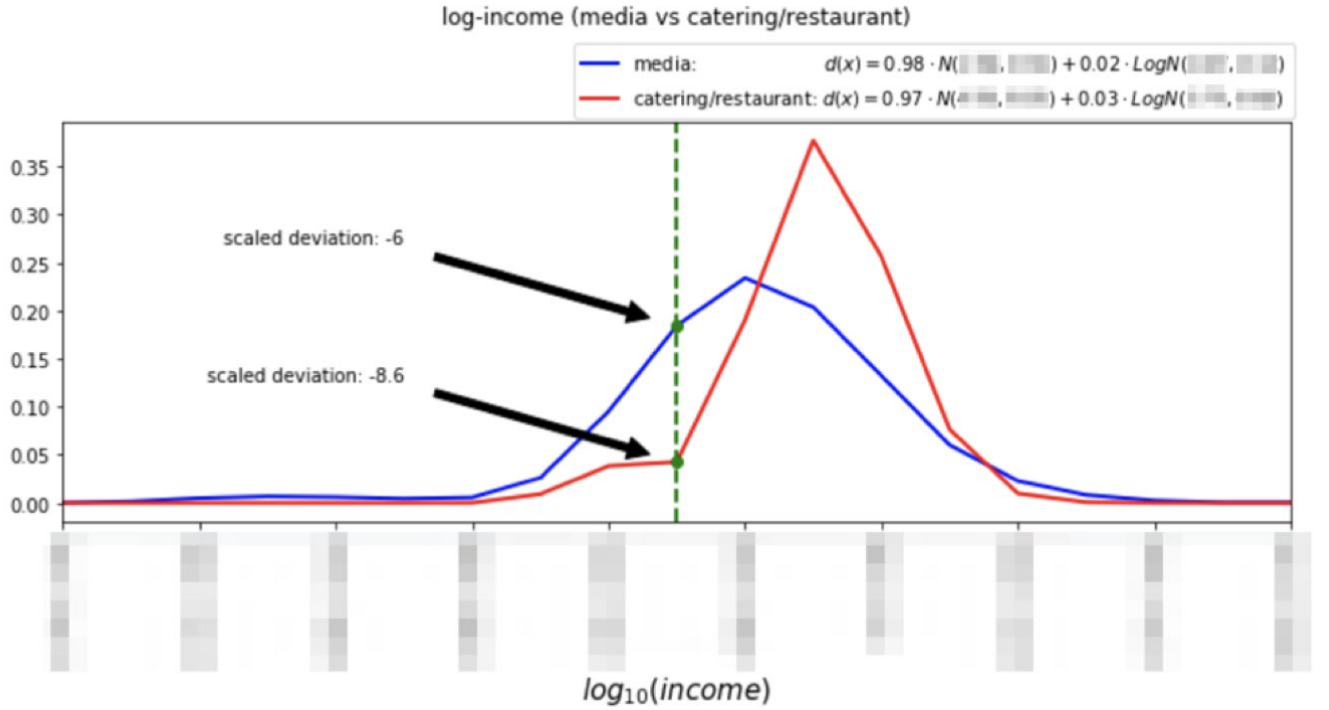
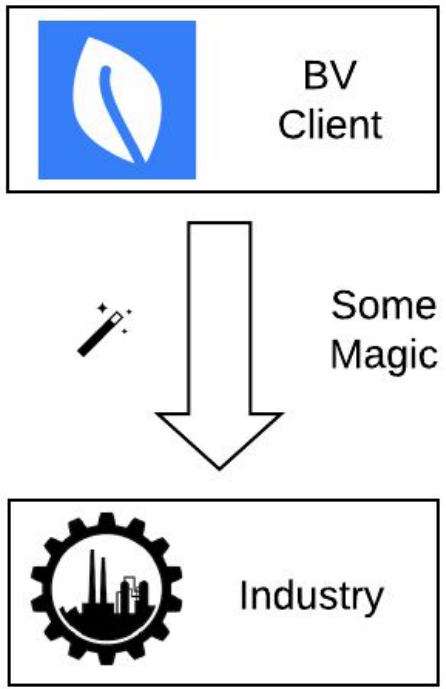


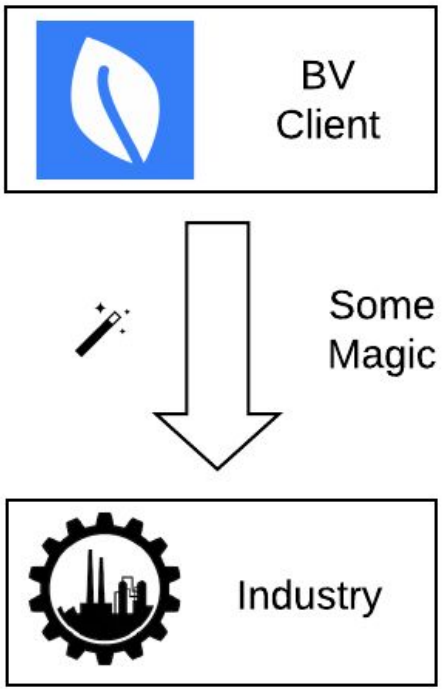
The Point of this Presentation

- Business need: For every client → Predict their Industry
- Industry can be one of 135 categories, e.g:
  - Electrician
  - Marketing
  - Steel manufacturing
- Problem: Traditional sources are pricey, inaccurate and not widely available

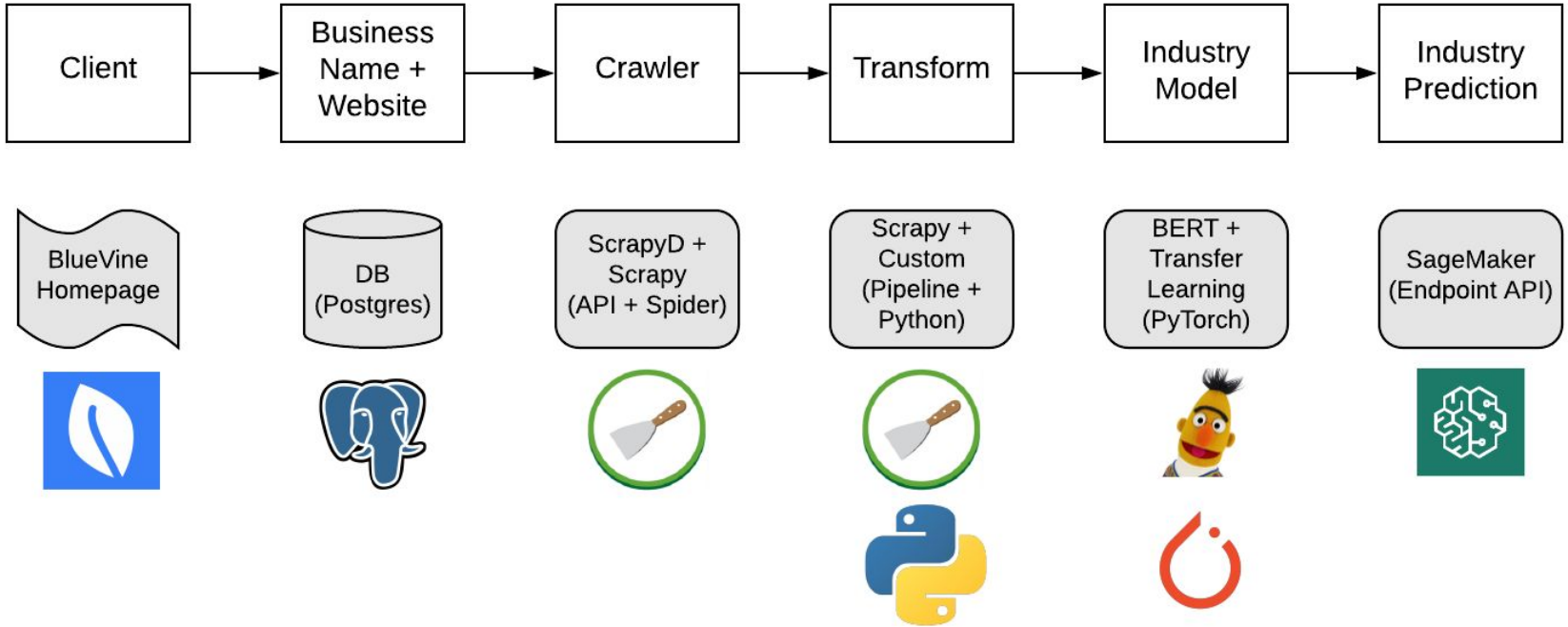


The Point of this Presentation

- Our solution: Infer industry from the business website
- Main Challenges
  - High quality sample
  - Efficient crawling
  - Strong NLP model
  - Scalable & independent deployment
- Main tools: Scrapy D, Scrapy, PyTorch, BERT, Amazon SageMaker



Inference Pipeline



Run example

<end to end notebook>

Presentation Overview

1. Target
   - Gathering websites
   - Tagging the industry

2. Data
   - Building the crawler
   - Crawling at scale

3. Model
   - Design (BERT)
   - Train
   - Deploy

4. Conclusion
   - Summary
   - Key takeaways

Target - Gathering websites

Potential sources:

- Internal BV data

  E.g: Client provided information

  - Not very big
  - Skewed scope

- Directed web searches

  E.g: “car dealerships in the US”

  - High effort
  - Limited scope

- Proprietary Databases

  E.g: Various vendors

  - Big
  - Pricy
  - Outdated

Target - Gathering websites

Problem:

- We have 135 industries
- Want sample to be balanced
- In order to balance, need to know the Industry
- If we knew the Industry, wouldn’t need the model...

Target - Gathering websites

Problem:

- We have 135 industries
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Solution:

- Use proxy to "guess" the industry
  - Internal BV Data: User provided
  - Web Searches: Search term
  - Proprietary Data: NAICS codes
- Fingers crossed, hope for the best...

Target - Tagging the Industry

Goals:

- Get quality tags
- Reasonable Timeframe
- Stay within budget

Crowdsourcing challenges:

- Understanding 135 industry categories is hard
- Understanding what a business does is hard
- Tie-breaking is hard

Row Id	Url	Biz Name	Industry
1	a.com	a inc	X
2	b.com	b corp	Y
3	c.bom	c llc	Z
4	d.com	d	X
5	e.com	e	Y
...	...	...	...

Target - Tagging the Industry

Crowdsourcing Strategies:

- Break up the task into smaller parts:
  - One obs requires multiple decisions
  - More tasks → more $$$
- Get multiple judgements for every website:
  - If everybody are bad, result will still be bad
  - More judgements → more $$$
- Train team for complex decision making:
  - Time intensive → more $$$
  - Slow

Target - Tagging the Industry

What we did:

- Set max $$$ Budget
- Set max time per task (in seconds)
- Developed small in-house tagged test set
- Held vendor trials for all strategies
- From vendors within max time cap: chose one with highest accuracy
- PLUG: CloudFactory (they are great) **https://www.cloudfactory.com/**

Target - Tagging the Industry

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Outcome:

- Overall time: 3 months
- Overall size: 250K observations (business names + websites)
- NOT balanced, BUT sufficient
- Fingers crossed, hope for the best...

Data - Building the Crawler

For each URL, we need:

- Home page text cleaned (no HTML)
- Internal page(s) text cleaned (no HTML)
- Page metadata

  E.g: Path, title, click text, etc.
- Ability to choose

  E.g. do I even want this page?
- Raw data as backup

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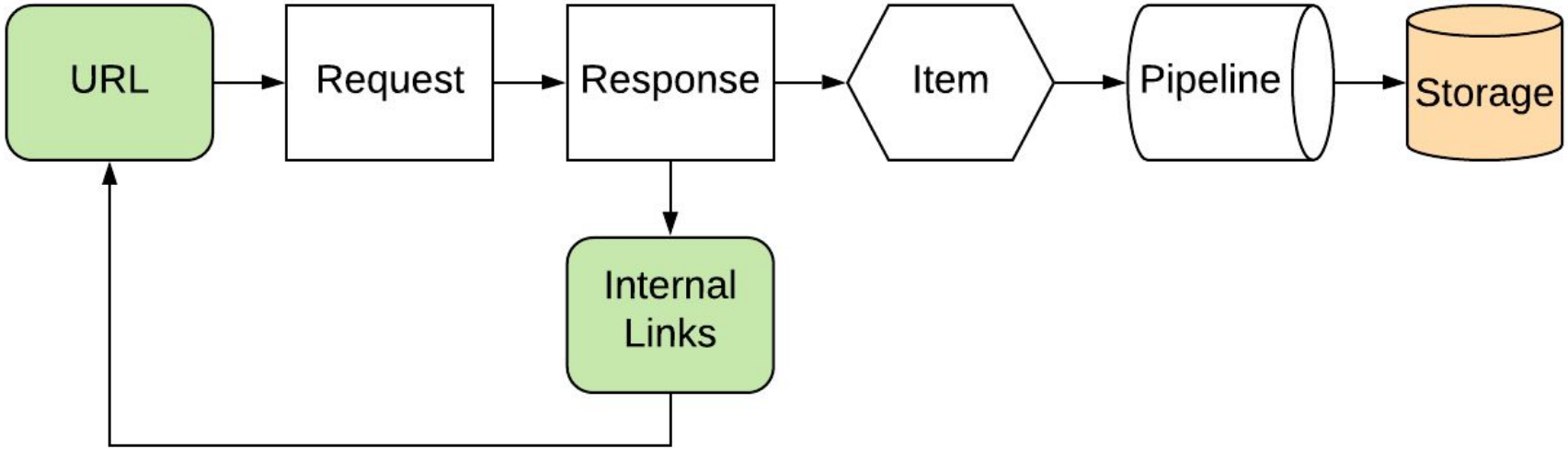
Our tool:

- Scrapy: fast high-level web crawling and web scraping framework

  https://github.com/scrapy/scrapy

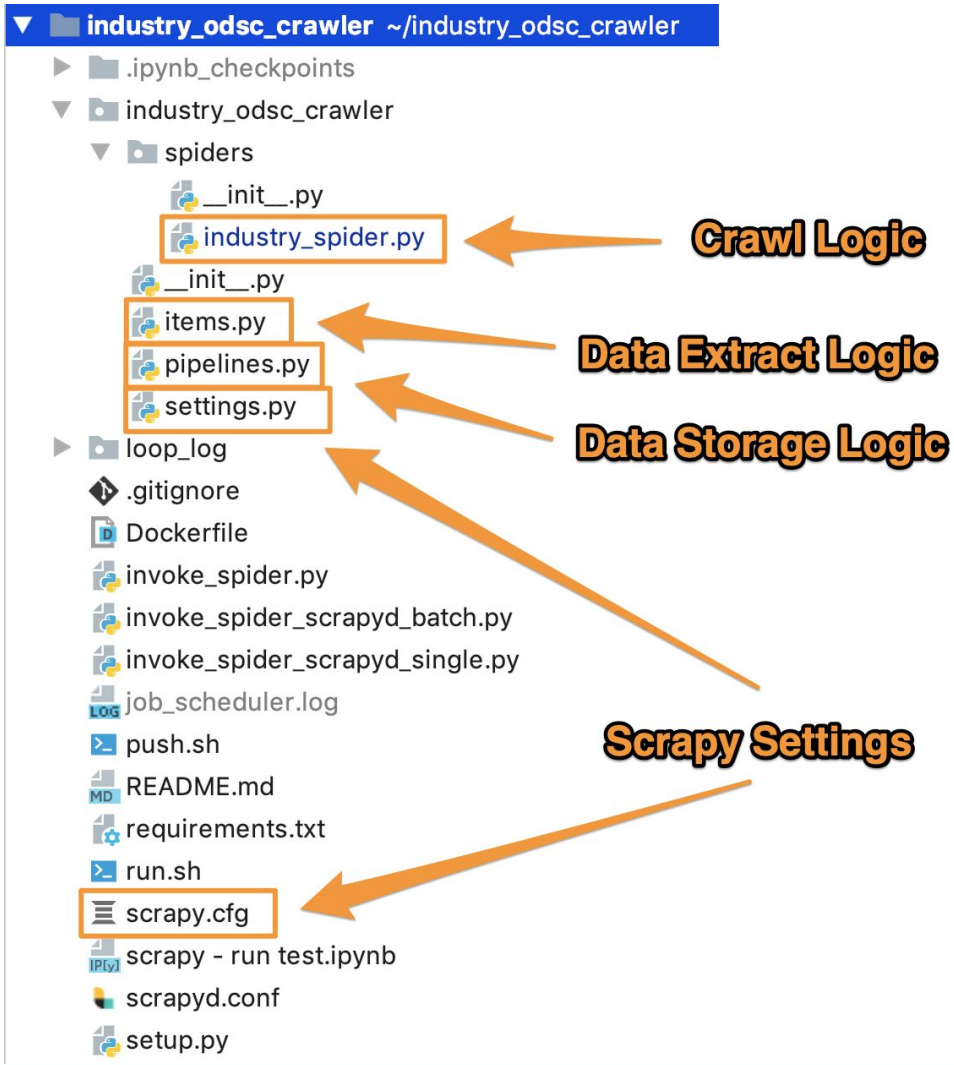
Data - Building the Crawler

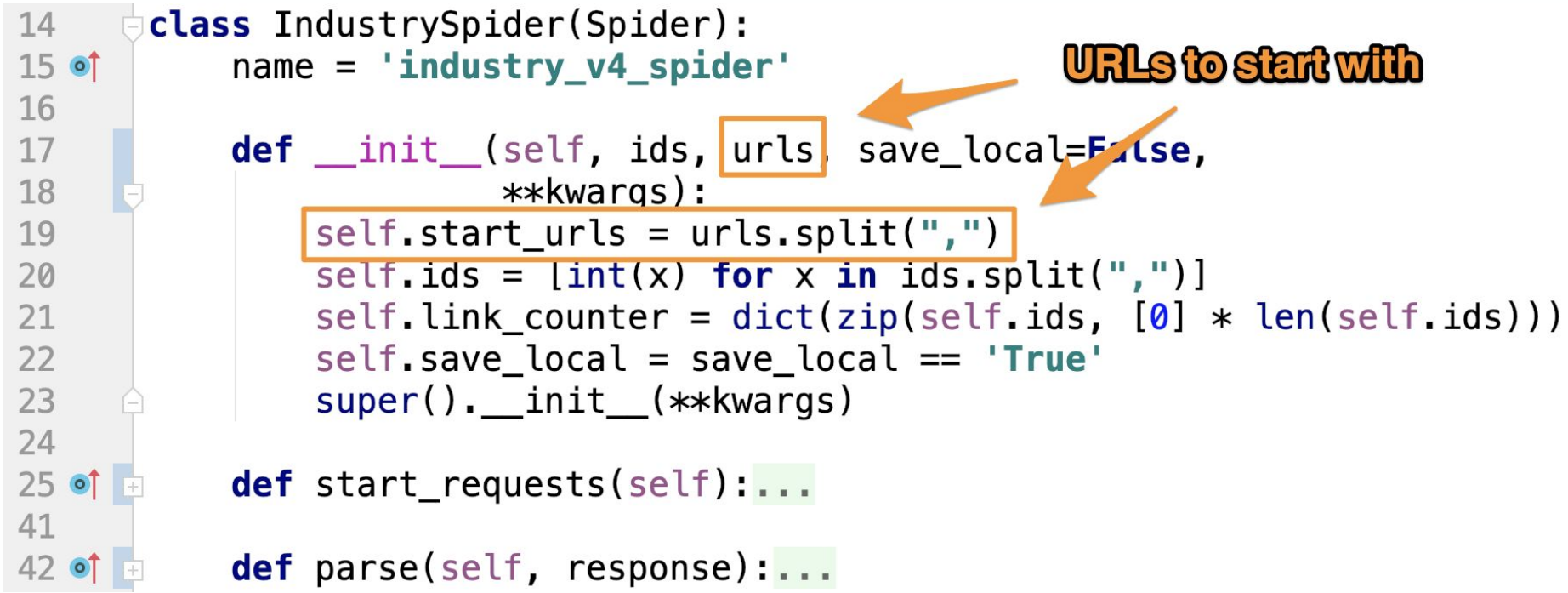
Scrapy Flow: Single URL



Data - Building the Crawler

<scrapy - run test notebook>


industry_odsc_crawler ~/industry_odsc_crawler
.ipynb_checkpoints
industry_odsc_crawler
spiders
__init__.py
industry_spider.py
__init__.py
items.py
pipelines.py
settings.py
loop_log
.gitignore
Dockerfile
invoke_spider.py
invoke_spider_scrapyd_batch.py
invoke_spider_scrapyd_single.py
job_scheduler.log
push.sh
README.md
requirements.txt
run.sh
scrapy.cfg
scrapy - run test.ipynb
scrapyd.conf
setup.py
Crawl Logic
Data Extract Logic
Data Storage Logic
Scrapy Settings


URLs to start with
class IndustrySpider(Spider):
name = 'industry_v4_spider'
def __init__(self, ids, urls, save_local=False,
**kwargs):
self.start_urls = urls.split(",")
self.ids = [int(x) for x in ids.split(",")]
self.link_counter = dict(zip(self.ids, [0] * len(self.ids)))
self.save_local = save_local == 'True'
super().__init__(**kwargs)
def start_requests(self):...
def parse(self, response):...

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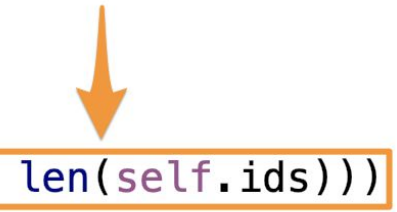

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For every URL,
make 1st Request

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For every 1st Response, parse & follow links

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28                  request = Request(url=url, callback=self.parse,
29                                    dont_filter=True,
30                                    errback=self.handle_error)
31              except ValueError:...
36              request.meta.update(url_id=url_id, url_order=1,
37                                  url_rank=1,
38                                  url_click_text=None,
39                                  url_domain=urlparse(url).netloc)
40              yield request
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Loop over URLs

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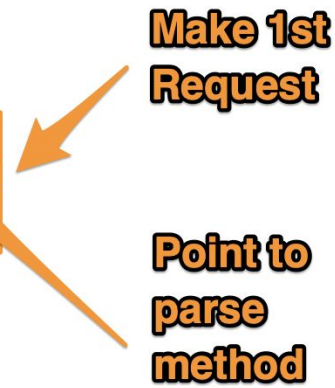

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Update Meta with custom stuff

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For every 1st Response, parse & follow links

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42  def parse(self, response):
43      web_page = self.make_item(response)
44      yield web_page
45
46      allowed_domains = self.configure_allowed_domains(response)
47      links = self.extract_internal_links(allowed_domains, response)
48
49      for link in links:
50          is_below_limit = self.link_counter[response.meta['url_id']] < \
51                           MAX_PAGES_PER_DOMAIN
52          if is_below_limit:
53              request = self.make_internal_link_request(link, response)
54              yield request
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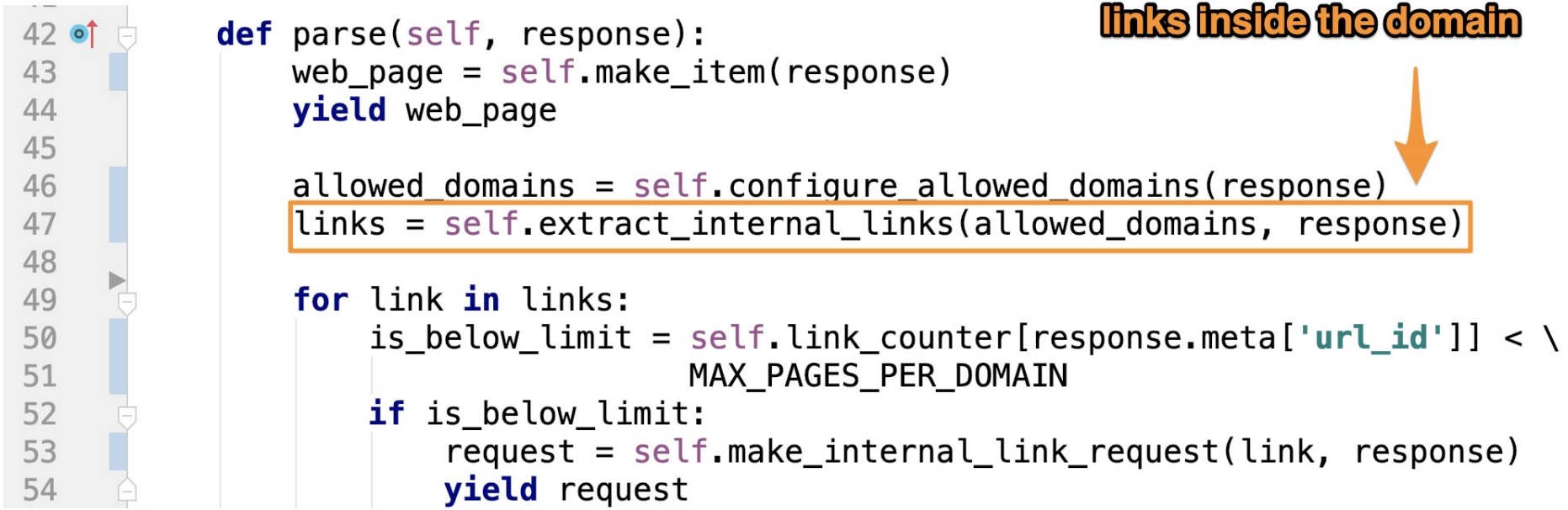
Extract things from Response and store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Check domain link counter, break if limit passed

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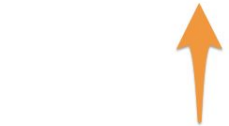

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Extract things from Response and store

```
88      def make_item(self, response):
89          web_page = WebPage()
90          web_page['url_id'] = response.meta['url_id']
91          web_page['url_order'] = response.meta['url_order']
92          web_page['input_url'] = response.meta['download_slot']
93          web_page['depth'] = response.meta['depth'] if \
94              'depth' in response.meta.keys() else None
95          web_page['url'] = response.url
96          web_page['path'] = urlparse(response.url).path
97          web_page['url_click_text'] = response.meta['url_click_text']
98          web_page['response_raw'] = response.text
99          web_page['url_rank'] = response.meta['url_rank']
100         web_page['response_text'], web_page['url_title'] = \
101             text_from_html(response.text)
102         web_page['status_code'] = response.status
103         web_page['is_error'] = False
104         self.link_counter[response.meta['url_id']] += 1
105         return web_page
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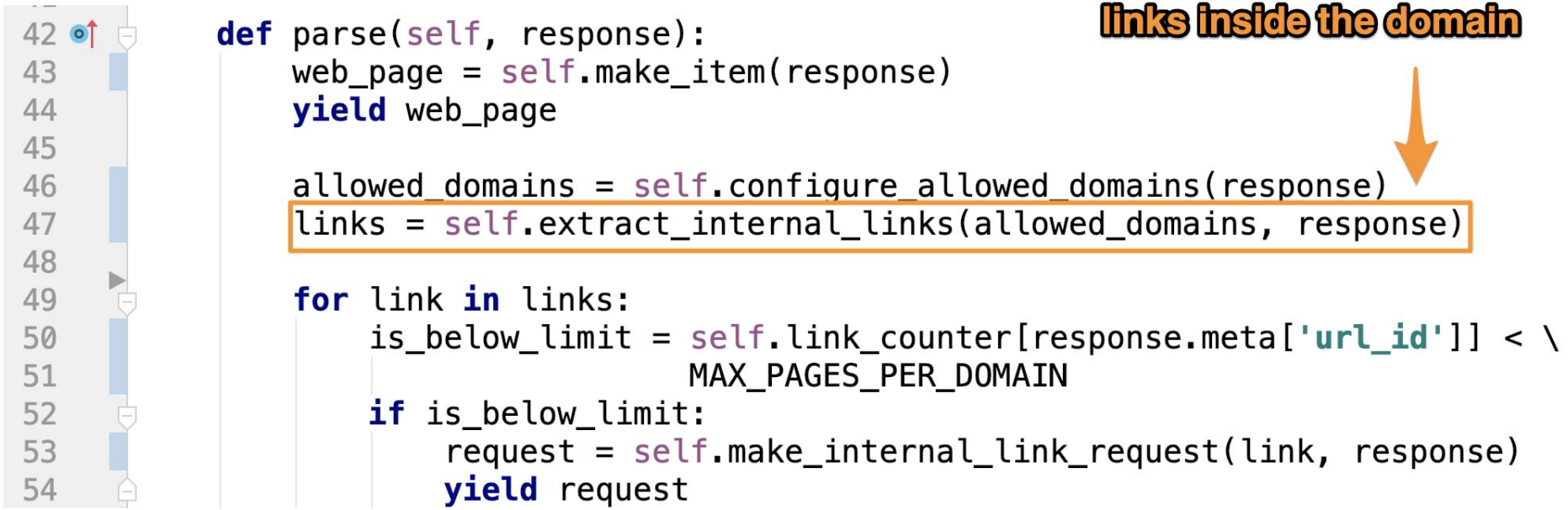
Update domain counter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```
67      def extract_internal_links(self, allowed_domains, response):
68          links = LinkExtractor(canonicalize=True, unique=True). \
69              extract_links(response)
70          links = [link for link in links if self.is_link_allowed(
71              allowed_domains, link.url)]
72          links = sorted(links, key=self.get_link_rank)
73          return links
```

Sort links by custom ranking

```
107     def get_link_rank(self, link):
108         priority_keywords = [
109             ('about', 2),
110             ('story', 2),
111             ('what we do', 3),
112             ('capabilities', 3),
113             ('services', 4),
114             ('products', 4),
115             ('amenities', 5),
116             ('overview', 6)
117         ]
118         default_page_url_rank = 100
119         default_page_text_rank = 100
120         link_rank = self.set_link_rank(
121             link, priority_keywords,
122             default_page_text_rank, default_page_url_rank)
123         return link_rank
```

Prioritize more informative links

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```

Send item to pipeline

```
9   class ConvertToDataFramePipeline:
10      def __init__(self):
11          self.item_list = []
12
13      def process_item(self, item, spider):
14          self.item_list += [item]
15
16      def close_spider(self, spider):
17          data_clean_json, fn_clean = combine_items(
18              self.item_list, spider, is_raw=False)
19
20          data_raw_json, fn_raw = combine_items(
21              self.item_list, spider, is_raw=True)
22
23          if spider.save_local:
24              self.save_data_locally(data_clean_json, data_raw_json,
25                                     fn_clean, fn_raw)
26          else:
27              self.save_data_in_s3(data_clean_json, data_raw_json,
28                                   fn_clean, fn_raw)
```

For every item, collect

```
9   class ConvertToDataFramePipeline:
10      def __init__(self):
11          self.item_list = []
12
13      def process_item(self, item, spider):
14          self.item_list += [item]
15
16      def close_spider(self, spider):
17          data_clean_json, fn_clean = combine_items(
18              self.item_list, spider, is_raw=False)
19
20          data_raw_json, fn_raw = combine_items(
21              self.item_list, spider, is_raw=True)
22
23          if spider.save_local:
24              self.save_data_locally(data_clean_json, data_raw_json,
25                                     fn_clean, fn_raw)
26          else:
27              self.save_data_in_s3(data_clean_json, data_raw_json,
28                                   fn_clean, fn_raw)
```

```
class ConvertToDataFramePipeline:
    def __init__(self):
        self.item_list = []

    def process_item(self, item, spider):
        self.item_list += [item]

    def close_spider(self, spider):
        data_clean_json, fn_clean = combine_items(
            self.item_list, spider, is_raw=False)

        data_raw_json, fn_raw = combine_items(
            self.item_list, spider, is_raw=True)

        if spider.save_local:
            self.save_data_locally(data_clean_json, data_raw_json,
                                   fn_clean, fn_raw)
        else:
            self.save_data_in_s3(data_clean_json, data_raw_json,
                                 fn_clean, fn_raw)
```

Send to S3

Data - Crawling at Scale

For our list of 250K URLs, we need to:

- Run batches, in parallel
- Persistent process that’s always up
- Some logging / UI mechanism to follow progress

Data - Crawling at Scale

For our list of 250K URLs, we need to:

- Run batches, in parallel
- Persistent process that's always up
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Our tool:

- ScrapyD: a service for running Scrapy spiders
  https://github.com/scrapy/scrapyd
- Deploy Scrapy projects and control their spiders using an HTTP JSON API

```
[scrapyd]
eggs_dir    = eggs
logs_dir    = logs
items_dir   =
jobs_to_keep = 500
dbs_dir     = dbs
max_proc    = 0
max_proc_per_cpu = 4
finished_to_keep = 100
poll_interval = 5.0
bind_address = 0.0.0.0
http_port   = 6800
debug       = off
runner      = scrapyd.runner
application = scrapyd.app.application
launcher    = scrapyd.launcher.Launcher
webroot     = scrapyd.website.Root

[services]
schedule.json     = scrapyd.webservice.Schedule
cancel.json       = scrapyd.webservice.Cancel
addversion.json   = scrapyd.webservice.AddVersion
listprojects.json = scrapyd.webservice.ListProjects
listversions.json = scrapyd.webservice.ListVersions
listspiders.json  = scrapyd.webservice.ListSpiders
delproject.json   = scrapyd.webservice.DeleteProject
delversion.json   = scrapyd.webservice.DeleteVersion
listjobs.json     = scrapyd.webservice.ListJobs
daemonstatus.json = scrapyd.webservice.DaemonStatus
```

```
1  #!/usr/bin/env bash
2  set -m
3  scrapyd > /dev/null 2>&1 &
4  sleep 5
5  scrapyd-deploy
6  fg %1
```

Start Server

Deploy Project
(Spider)

```
19  from scrapyd_api import ScrapydAPI
20
21  def chunks(l, n):
22      """Yield successive n-sized chunks from l."""
23      for i in range(0, len(l), n):
24          yield l[i:i + n]
25
26
27  scrapyd_host = 'http://localhost:6800'
28  project_name = 'industry_odsc_crawler'
29  spider_name = 'industry_v4_spider'
30  scrapyd = ScrapydAPI(scrapyd_host)
31
32  data_fn = 'big_url_list.csv'
33  data_fp = os.path.join(os.path.dirname(__file__),
34                         'data', data_fn)
35  data_df = pd.read_csv(data_fp)
36
37  url_id_chunks = chunks(data_df['url_id'], 100)
38  url_id_chunks = list(enumerate(url_id_chunks))
39  total_num_chunks = len(url_id_chunks)
40
```

Import ScrapyD API constructor

```
19  from scrapyd_api import ScrapydAPI
20
21  def chunks(l, n):
22      """Yield successive n-sized chunks from l."""
23      for i in range(0, len(l), n):
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34                         'data', data_fn)
35  data_df = pd.read_csv(data_fp)
36
37  url_id_chunks = chunks(data_df['url_id'], 100)
38  url_id_chunks = list(enumerate(url_id_chunks))
39  total_num_chunks = len(url_id_chunks)
40
```

Specify ScrapyD host and Scrapy spider

```
from scrapyd_api import ScrapydAPI

def chunks(l, n):
    """Yield successive n-sized chunks from l."""
    for i in range(0, len(l), n):
        yield l[i:i + n]


scrapyd_host = 'http://localhost:6800'
project_name = 'industry_odsc_crawler'
spider_name = 'industry_v4_spider'
scrapyd = ScrapydAPI(scrapyd_host)

data_fn = 'big_url_list.csv'
data_fp = os.path.join(os.path.dirname(__file__),
                       'data', data_fn)
data_df = pd.read_csv(data_fp)

url_id_chunks = chunks(data_df['url_id'], 100)
url_id_chunks = list(enumerate(url_id_chunks))
total_num_chunks = len(url_id_chunks)
```

Load big file with URLs, split into chunks

```
55  max_running = 10
56
57  max_pending = 5
58
59  sleep_interval = 15
60
61  while len(url_id_chunks) > 0:
62      server_status = scrapyd.list_jobs(project_name)
63
64      num_pending = len(server_status['pending'])
65      num_running = len(server_status['running'])
66
67      if (num_pending > max_pending) or \
68              (num_running > max_running):...
77
78      i, url_id_chunk = url_id_chunks.pop(0)
79      urls = get_urls_from_ids(data_df, url_id_chunk)
80
81      scrapyd_schedule_job(urls)
```

Define params for parallelism

```
55  max_running = 10
56
57  max_pending = 5
58
59  sleep_interval = 15
60
61  while len(url_id_chunks) > 0:
62      server_status = scrapyd.list_jobs(project_name)
63
64      num_pending = len(server_status['pending'])
65      num_running = len(server_status['running'])
66
67      if (num_pending > max_pending) or \
68              (num_running > max_running):...
77
78      i, url_id_chunk = url_id_chunks.pop(0)
79      urls = get_urls_from_ids(data_df, url_id_chunk)
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81      scrapyd_schedule_job(urls)
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```
55  max_running = 10
56
57  max_pending = 5
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59  sleep_interval = 15
60
61  while len(url_id_chunks) > 0:
62      server_status = scrapyd.list_jobs(project_name)
63
64      num_pending = len(server_status['pending'])
65      num_running = len(server_status['running'])
66
67      if (num_pending > max_pending) or \
68              (num_running > max_running):...
77
78      i, url_id_chunk = url_id_chunks.pop(0)
79      urls = get_urls_from_ids(data_df, url_id_chunk)
80
81      scrapyd_schedule_job(urls)
```

If limits exceeded, break

Otherwise, schedule job

Model - Design (BERT)

BERT (grossly simplified):

- Can turn string of text into a vector of length 768 (or 1024)
- Max 512 tokens allowed
- Open source pre-trained models available for transfer learning (cased, uncased, base, large)
- For PyTorch: **https://github.com/huggingface/transformers**

Model - Design (BERT)

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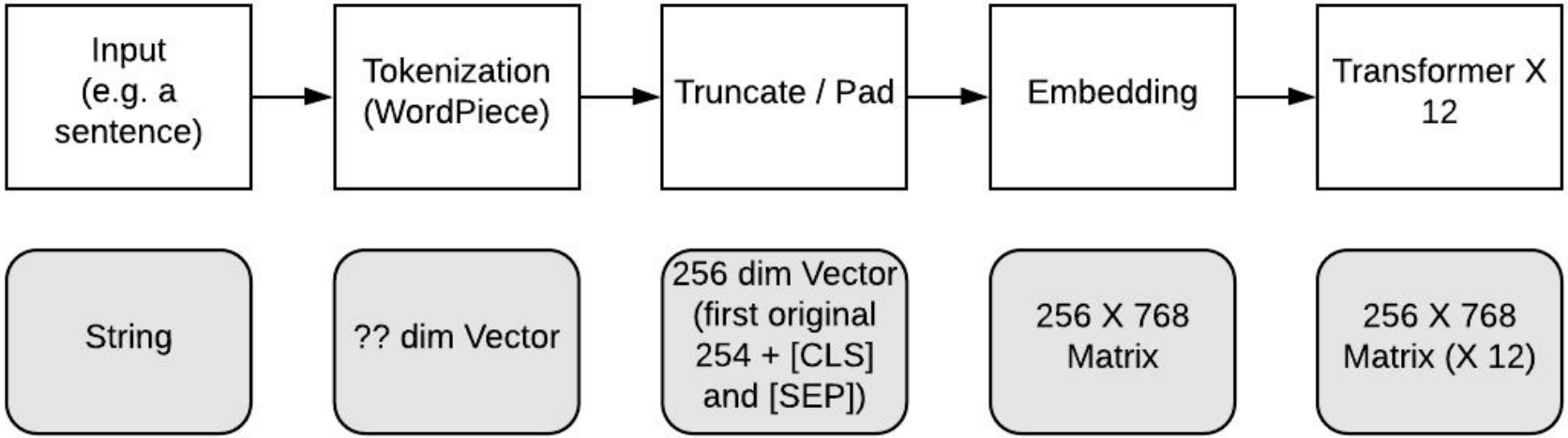
- Max 512 tokens allowed
- Open source pre-trained models available for transfer learning (cased, uncased, base, large)
- For PyTorch: **https://github.com/huggingface/transformers**

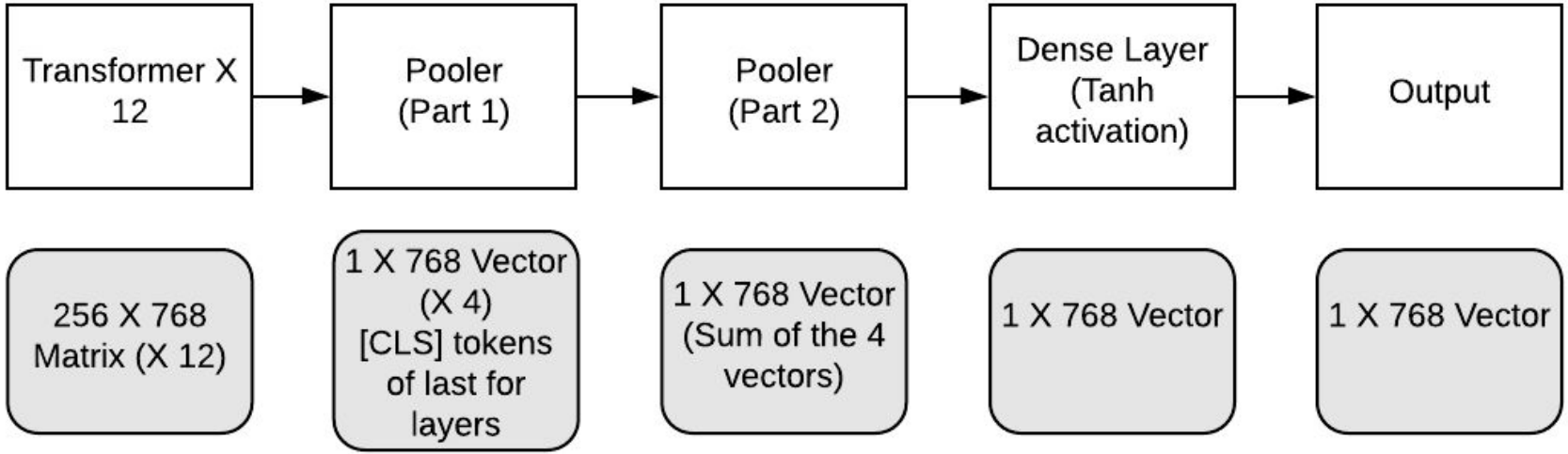
A bit more context:

- Uses WordPiece tokenization to split words into tokens
- Uses Transformers to perform “attention”, i.e: consider same token in different contexts
- Bi directional
- Achieves SOTA performance on benchmark NLP tasks

Model - Design (BERT)



Model - Design (BERT)



Model - Design

The basic idea:

- A single observation is a pair of:

  Business name & Website
- Organize data for every obs into a clear set of inputs
- Use BERT to convert all free text into numeric vectors
- Wrap this into a single model to classify our 135 industries

Model - Design

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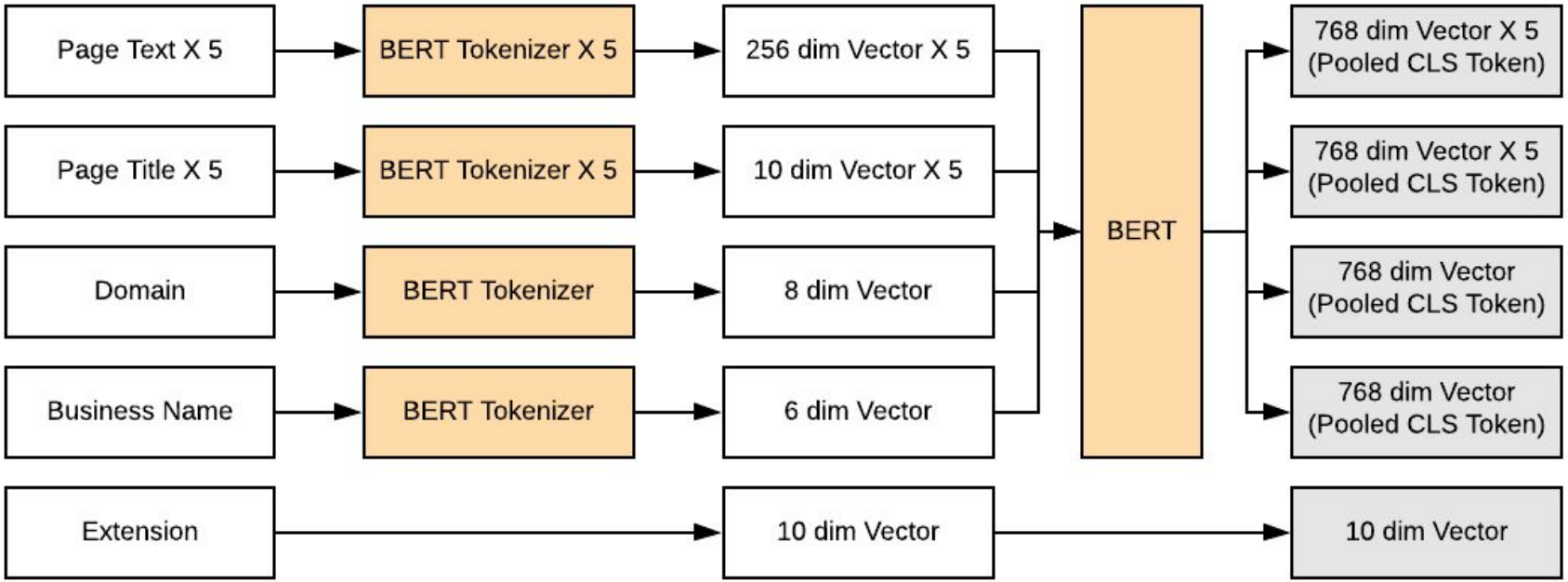
- A single observation is a pair of:
  Business name & Website
- Organize data for every obs into a clear set of inputs
- Use BERT to convert all free text into numeric vectors
- Wrap this into a single model to classify our 135 industries

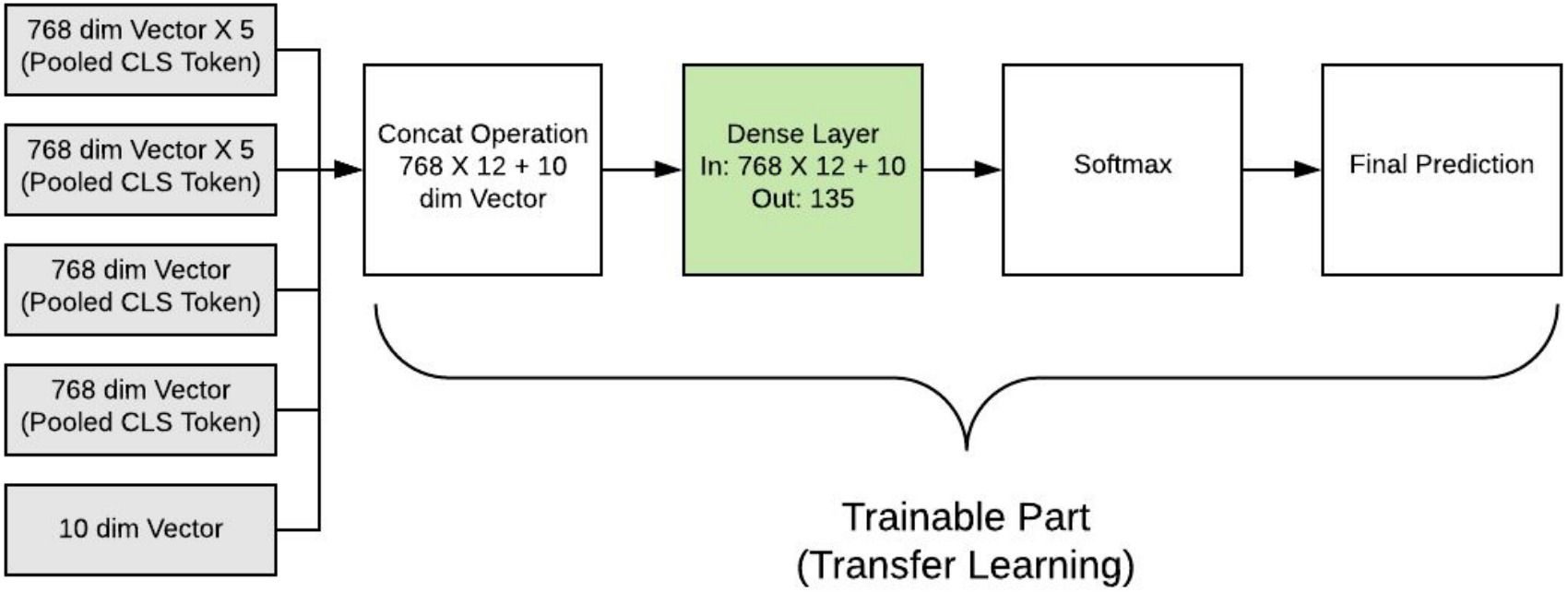
Implementation (moderate complexity)

- Use first 5 links per domain
- Free text:
  - Page Text
  - Page Title
  - Website Domain
- Metadata: Domain extension
- Other: Business Name

Model - Design



Model - Design



Model - Train

Tool:

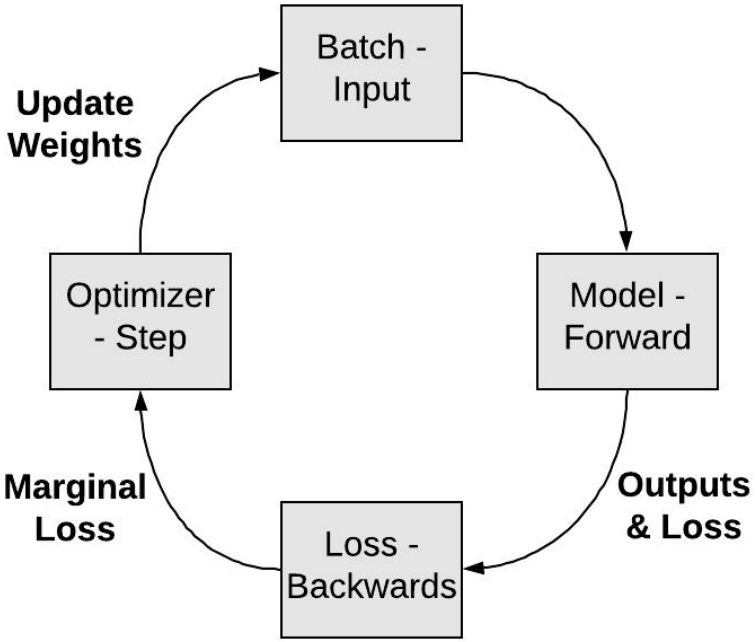
- PyTorch

  https://github.com/pytorch/pytorch
- Basically NumPy + GPUs
- Autograd
- Relatively easy to debug

Model - Train

NN / PyTorch Train Cycle:

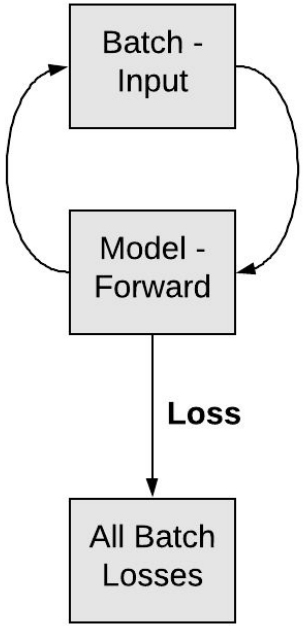
1. Select input batch (e.g. size 16)
2. Calc current outputs (forward)
3. Calc loss: Outputs VS labels
4. Calc marginal loss (backwards)
5. Update weights (step)
6. Again! Until batches / epoch done.



Model - Train

NN / PyTorch Validation Cycle:

1. Select input batch (e.g. size 16)
2. Calc current outputs (forward)
3. Calc loss: Outputs VS labels
4. Collect loss for all batches
5. Again! Until batches / epoch done
6. Report avg loss



Model - Train

Organizing the dataset:

- Convert all text elements into numeric vectors
- Convert everything to tensors
- Put everything together such that:
    - One “item” has all inputs per obs
    - Can be loaded in batches (GPU memory limits)

```
def make_dataset(input_df,
                 bert_tokenizer, num_pages=5, max_len_page_text=256,
                 max_len_page_title=16, max_len_domain=8, max_len_biz_name=10,
                 chunk_size=300, n_jobs=None):
    """transform crawl data input into model readable tensor dataset..."""

    # split input data into separate pages
    data_pages = split_data_into_pages(input_df.copy(), num_pages)

    # generate dummies for top 10 url extensions
    top_extensions = [...]
    url_ext_mat = gen_url_extension_dummies(data_pages[0], top_extensions)

    # extract domain from url
    data_pages[0]['url_domain_text'] = data_pages[0]['url'].apply(
        extract_domain_from_url)

    # tokenize & truncate all input fields
    biz_name_masks, biz_name_tokenized, domain_masks, domain_tokenized, \
        page_text_masks, page_text_tokenized, page_title_masks, \
        page_titles_tokenized = tokenize_and_truncate_fields(...)

    # combine into tensor dataset
    data_set = combine_inputs_into_tensor_dataset(...)

    return data_set
```

BERT settings

Parallelism settings

```
203 def make_dataset(input_df,
204
205                     bert_tokenizer, num_pages=5, max_len_page_text=256,
206                     max_len_page_title=16, max_len_domain=8, max_len_biz_name=10,
207
208                     chunk_size=300, n_jobs=None):
209     """transform crawl data input into model readable tensor dataset..."""
223
224     # split input data into separate pages
225     data_pages = split_data_into_pages(input_df.copy(), num_pages)
226
227     # generate dummies for top 10 url extensions
228     top_extensions = [...]
229     url_ext_mat = gen_url_extension_dummies(data_pages[0], top_extensions)
230
231     # extract domain from url
232     data_pages[0]['url_domain_text'] = data_pages[0]['url'].apply(
233         extract_domain_from_url)
234
235     # tokenize & truncate all input fields
236     biz_name_masks, biz_name_tokenized, domain_masks, domain_tokenized, \
237         page_text_masks, page_text_tokenized, page_title_masks, \
238         page_titles_tokenized = tokenize_and_truncate_fields(...)
242
243     # combine into tensor dataset
244     data_set = combine_inputs_into_tensor_dataset(...)
248
249     return data_set
```

Split and limit data to X pages per domain

```python
def make_dataset(input_df,

                 bert_tokenizer, num_pages=5, max_len_page_text=256,
                 max_len_page_title=16, max_len_domain=8, max_len_biz_name=10,

                 chunk_size=300, n_jobs=None):
    """transform crawl data input into model readable tensor dataset..."""

    # split input data into separate pages
    data_pages = split_data_into_pages(input_df.copy(), num_pages)

    # generate dummies for top 10 url extensions
    top_extensions = [...]
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    # tokenize & truncate all input fields
    biz_name_masks, biz_name_tokenized, domain_masks, domain_tokenized, \
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    # combine into tensor dataset
    data_set = combine_inputs_into_tensor_dataset(...)

    return data_set
```

Tokenize and Truncate all fields

```
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243      # combine into tensor dataset
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249      return data_set
```

Combine into tensor data set

```python
def make_dataset(input_df,

                 bert_tokenizer, num_pages=5, max_len_page_text=256,
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    # tokenize & truncate all input fields
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        page_text_masks, page_text_tokenized, page_title_masks, \
        page_titles_tokenized = tokenize_and_truncate_fields(...)

    # combine into tensor dataset
    data_set = combine_inputs_into_tensor_dataset(...)

    return data_set
```

Tokenize and Truncate all fields

```
79  def _tokenize_and_truncate_chunk(page_sequences_text, bert_tokenizer, max_len):
80      page_sequences_tokenized = []
81      for seq_text in page_sequences_text:
82
83          seq_tokenized = bert_tokenizer.tokenize(seq_text)
84
85          seq_ids = bert_tokenizer.convert_tokens_to_ids(seq_tokenized)
86          if hasattr(seq_ids, '__iter__'):
87              seq_ids = pad_sequences([seq_ids], maxlen=max_len, dtype="long",
88                                      truncating="post", padding="post")[0]
89          else:
90              seq_tokenized = bert_tokenizer.tokenize("[CLS] [SEP]")
91              seq_ids = bert_tokenizer.convert_tokens_to_ids(seq_tokenized)
92
93          page_sequences_tokenized.append(seq_ids)
94
95      return page_sequences_tokenized
```

For every text (i.e sentence) ...

```
79  def _tokenize_and_truncate_chunk(page_sequences_text, bert_tokenizer, max_len):
80      page_sequences_tokenized = []
81      for seq_text in page_sequences_text:
82
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93          page_sequences_tokenized.append(seq_ids)
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```

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90              seq_tokenized = bert_tokenizer.tokenize("[CLS] [SEP]")
91              seq_ids = bert_tokenizer.convert_tokens_to_ids(seq_tokenized)
92
93          page_sequences_tokenized.append(seq_ids)
94
95      return page_sequences_tokenized
```

Handle empty string

```python
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                 bert_tokenizer, num_pages=5, max_len_page_text=256,
                 max_len_page_title=16, max_len_domain=8, max_len_biz_name=10,

                 chunk_size=300, n_jobs=None):
    """transform crawl data input into model readable tensor dataset..."""

    # split input data into separate pages
    data_pages = split_data_into_pages(input_df.copy(), num_pages)

    # generate dummies for top 10 url extensions
    top_extensions = [...]
    url_ext_mat = gen_url_extension_dummies(data_pages[0], top_extensions)

    # extract domain from url
    data_pages[0]['url_domain_text'] = data_pages[0]['url'].apply(
        extract_domain_from_url)

    # tokenize & truncate all input fields
    biz_name_masks, biz_name_tokenized, domain_masks, domain_tokenized, \
        page_text_masks, page_text_tokenized, page_title_masks, \
        page_titles_tokenized = tokenize_and_truncate_fields(...)

    # combine into tensor dataset
    data_set = combine_inputs_into_tensor_dataset(...)

    return data_set
```

Tokenize and Truncate all fields

```
203  def make_dataset(input_df,
204
205                   bert_tokenizer, num_pages=5, max_len_page_text=256,
206                   max_len_page_title=16, max_len_domain=8, max_len_biz_name=10,
207
208                   chunk_size=300, n_jobs=None):
209      """transform crawl data input into model readable tensor dataset..."""
223
224      # split input data into separate pages
225      data_pages = split_data_into_pages(input_df.copy(), num_pages)
226
227      # generate dummies for top 10 url extensions
228      top_extensions = [...]
229      url_ext_mat = gen_url_extension_dummies(data_pages[0], top_extensions)
230
231      # extract domain from url
232      data_pages[0]['url_domain_text'] = data_pages[0]['url'].apply(
233          extract_domain_from_url)
234
235      # tokenize & truncate all input fields
236      biz_name_masks, biz_name_tokenized, domain_masks, domain_tokenized, \
237          page_text_masks, page_text_tokenized, page_title_masks, \
238          page_titles_tokenized = tokenize_and_truncate_fields(...)
242
243      # combine into tensor dataset
244      data_set = combine_inputs_into_tensor_dataset(...)
248
249      return data_set
```

Combine into tensor data set

```
71
72
73
74
75
78
81
82
83
84
85
86
87
88
```

```
bert_model_name = 'bert-base-cased'
bert_tokenizer = BertTokenizer.from_pretrained(bert_model_name,
                                               do_lower_case=False)

train_data = make_dataset(...)
test_data = make_dataset(...)

train_sampler = RandomSampler(train_data)
train_dataloader = DataLoader(train_data, sampler=train_sampler,
                              batch_size=16)

test_sampler = SequentialSampler(test_data)
test_dataloader = DataLoader(test_data, sampler=test_sampler,
                             batch_size=16)
```

```
71
72  bert_model_name = 'bert-base-cased'
73  bert_tokenizer = BertTokenizer.from_pretrained(bert_model_name,
74                                                 do_lower_case=False)
75
75  train_data = make_dataset(...)
78  test_data = make_dataset(...)
81
82  train_sampler = RandomSampler(train_data)
83  train_dataloader = DataLoader(train_data, sampler=train_sampler,
84                                batch_size=16)
85
86  test_sampler = SequentialSampler(test_data)
87  test_dataloader = DataLoader(test_data, sampler=test_sampler,
88                               batch_size=16)
```

Convert raw train / test into tensor datasets

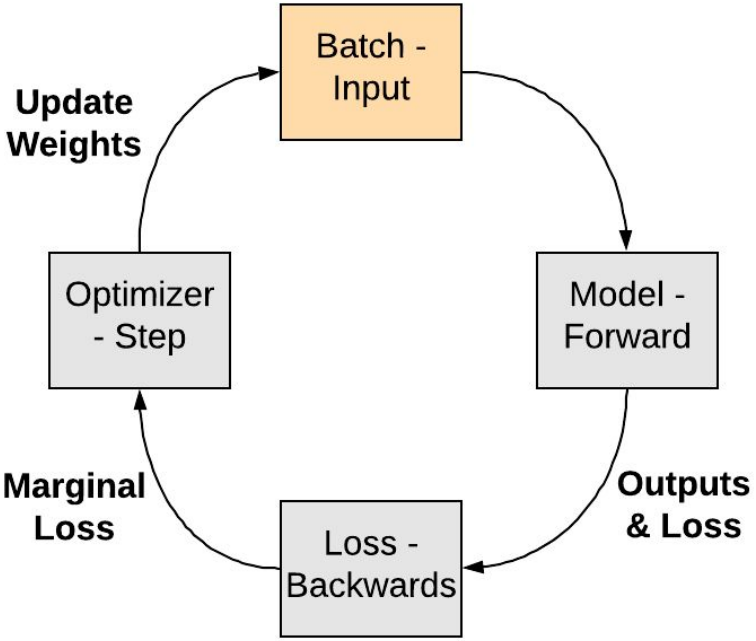
```
71
72  bert_model_name = 'bert-base-cased'
73  bert_tokenizer = BertTokenizer.from_pretrained(bert_model_name,
74                                                 do_lower_case=False)
75
78  train_data = make_dataset(...)
81  test_data = make_dataset(...)
82
83  train_sampler = RandomSampler(train_data)
84  train_dataloader = DataLoader(train_data, sampler=train_sampler,
85                                batch_size=16)
86
87  test_sampler = SequentialSampler(test_data)
88  test_dataloader = DataLoader(test_data, sampler=test_sampler,
                                 batch_size=16)
```

Create test / train data loaders for GPU

Model - Train

Batch - Input:

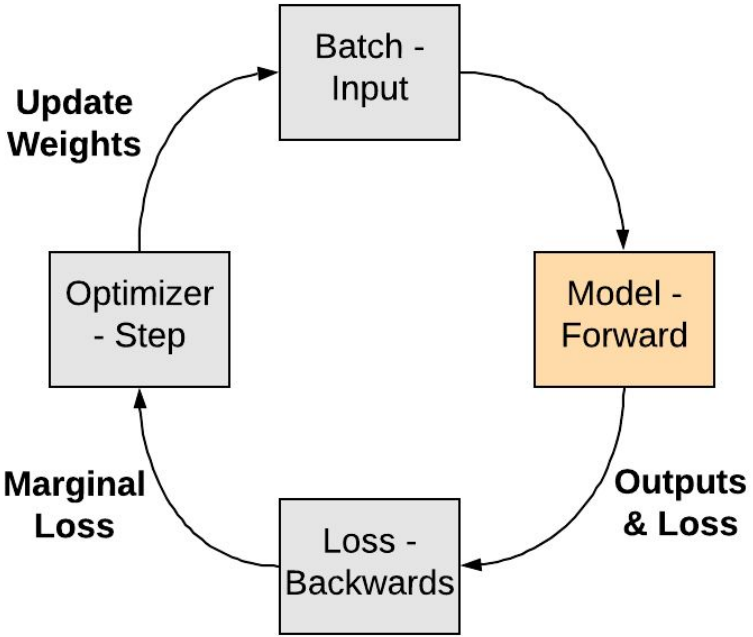
- Create Train / Test Dataloaders
- Extract Batch



Model - Train

Forward method:

- Define the graph of the model:
  - Layers
  - Transformations
  - Combinations
- Is invoked with inputs, calculates outputs
- Using labels and a loss metric, calculates loss

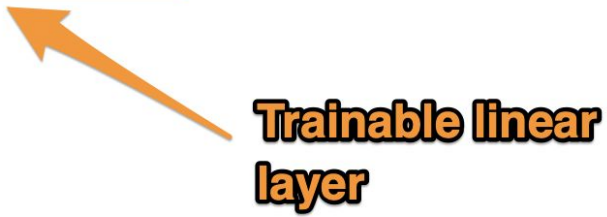


```
class BertWebsiteClassifier(BertPreTrainedModel):
    def __init__(self, config):
        super(BertWebsiteClassifier, self).__init__(config)
        self.bert = BertModel(config)
        self.dropout = nn.Dropout(config.hidden_dropout_prob)
        self.classifier = nn.Linear(config.hidden_size * 12 + 10,
                                    self.config.num_labels)

        self.num_labels = None
        self.num_pages = None
        self.max_len_page_text = None
        self.max_len_page_title = None
        self.max_len_domain = None
        self.max_len_biz_name = None
        self.industry_map_dict = None

        self.init_weights()
```

Extending a BERT pre-trained model class

```
class BertWebsiteClassifier(BertPreTrainedModel):
    def __init__(self, config):
        super(BertWebsiteClassifier, self).__init__(config)
        self.bert = BertModel(config)
        self.dropout = nn.Dropout(config.hidden_dropout_prob)
        self.classifier = nn.Linear(config.hidden_size * 12 + 10,
                                    self.config.num_labels)

        self.num_labels = None
        self.num_pages = None
        self.max_len_page_text = None
        self.max_len_page_title = None
        self.max_len_domain = None
        self.max_len_biz_name = None
        self.industry_map_dict = None

        self.init_weights()
```

```
class BertWebsiteClassifier(BertPreTrainedModel):
    def __init__(self, config):
        super(BertWebsiteClassifier, self).__init__(config)
        self.bert = BertModel(config)
        self.dropout = nn.Dropout(config.hidden_dropout_prob)
        self.classifier = nn.Linear(config.hidden_size * 12 + 10,
                                    self.config.num_labels)

        self.num_labels = None
        self.num_pages = None
        self.max_len_page_text = None
        self.max_len_page_title = None
        self.max_len_domain = None
        self.max_len_biz_name = None
        self.industry_map_dict = None

        self.init_weights()
```



```
47      def forward(self,
48                  page_text_ids, page_text_masks,
49                  page_title_ids, page_title_masks,
50                  domain_ids, domain_masks,
51                  biz_name_ids, biz_name_masks,
52                  url_exts,
53                  token_type_ids=None,
54                  position_ids=None, head_mask=None,
55                  labels=None):
56
57          biz_name_pooled_output = self.bert(...)[1]
63          domain_pooled_output = self.bert(...)[1]
69
70          page_text_outputs = []
71          for page_text_id, page_text_mask in \
72                  zip(page_text_ids, page_text_masks):
73              page_text_outputs += [self.bert(...)[1]]
79
80          page_title_outputs = []
81          for page_title_ids, page_title_masks in \
82                  zip(page_title_ids, page_title_masks):
83              page_title_outputs += [self.bert(...)[1]]
```

All inputs: tokens, masks and dummies

```
47      def forward(self,
48                  page_text_ids, page_text_masks,
49                  page_title_ids, page_title_masks,
50                  domain_ids, domain_masks,
51                  biz_name_ids, biz_name_masks,
52                  url_exts,
53                  token_type_ids=None,
54                  position_ids=None, head_mask=None,
55                  labels=None):
56
57          biz_name_pooled_output = self.bert(...)[1]
63          domain_pooled_output = self.bert(...)[1]
69
70          page_text_outputs = []
71          for page_text_id, page_text_mask in \
72                  zip(page_text_ids, page_text_masks):
73              page_text_outputs += [self.bert(...)[1]]
79
80          page_title_outputs = []
81          for page_title_ids, page_title_masks in \
82                  zip(page_title_ids, page_title_masks):
83              page_title_outputs += [self.bert(...)[1]]
```

Pass everything through pre-trained BERT

```
47  def forward(self,
48              page_text_ids, page_text_masks,
49              page_title_ids, page_title_masks,
50              domain_ids, domain_masks,
51              biz_name_ids, biz_name_masks,
52              url_exts,
53              token_type_ids=None,
54              position_ids=None, head_mask=None,
55              labels=None):
56
57      biz_name_pooled_output = self.bert(...)[1]
63      domain_pooled_output = self.bert(...)[1]
69
70      page_text_outputs = []
71      for page_text_id, page_text_mask in \
72              zip(page_text_ids, page_text_masks):
73          page_text_outputs += [self.bert(...)[1]]
79
80      page_title_outputs = []
81      for page_title_ids, page_title_masks in \
82              zip(page_title_ids, page_title_masks):
83          page_title_outputs += [self.bert(...)[1]]
```

Vectors of size 1X768

Pass everything through pre-trained BERT

```
90  # combine all outputs
91  outputs_all = page_text_outputs + page_title_outputs + \
92                [domain_pooled_output, biz_name_pooled_output, url_exts]
93  pooled_output = torch.cat(outputs_all, dim=1)
94  pooled_output = self.dropout(pooled_output)
95
96  logits = self.classifier(pooled_output)
97
98  outputs = (logits,)
99
100 if labels is not None:...
111 return outputs
```

Concat all vectors into one big vector

```
90          # combine all outputs
91          outputs_all = page_text_outputs + page_title_outputs + \
92                        [domain_pooled_output, biz_name_pooled_output, url_exts]
93          pooled_output = torch.cat(outputs_all, dim=1)
94          pooled_output = self.dropout(pooled_output)
95
96          logits = self.classifier(pooled_output)
97
98          outputs = (logits,)
99
100         if labels is not None:...
111         return outputs
```

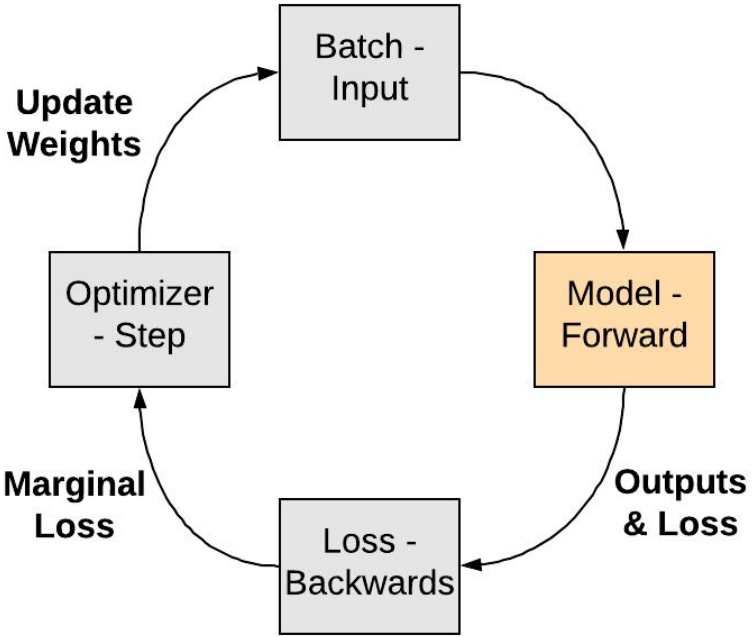
```
90          # combine all outputs
91          outputs_all = page_text_outputs + page_title_outputs + \
92                        [domain_pooled_output, biz_name_pooled_output, url_exts]
93          pooled_output = torch.cat(outputs_all, dim=1)
94          pooled_output = self.dropout(pooled_output)
95
96          logits = self.classifier(pooled_output)
97
98          outputs = (logits,)
99
100         if labels is not None:...
111         return outputs
```

Return outputs (+ Loss for training)

Model - Train

Forward method:

- Define the graph of the model:
  - Layers
  - Transformations
  - Combinations
- Is invoked with inputs, calculates outputs
- Using labels and a loss metric, calculates loss



```
237  bert_website_mdl = BertWebsiteClassifier.from_pretrained(
238      sample_meta['bert_model_name'], sample_meta['num_labels'])
239
240  if torch.cuda.device_count() > 1:
241      print("Let's use", torch.cuda.device_count(), "GPUs!")
242      bert_website_mdl = nn.DataParallel(bert_website_mdl)
243
244  device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
245  bert_website_mdl.to(device)
```

```
237     bert_website_mdl = BertWebsiteClassifier.from_pretrained(
238         sample_meta['bert_model_name'], sample_meta['num_labels'])
239
240     if torch.cuda.device_count() > 1:
241         print("Let's use", torch.cuda.device_count(), "GPUs!")
242         bert_website_mdl = nn.DataParallel(bert_website_mdl)
243
244     device = torch.device("cuda" if torch.cuda.is_available() else "cpu")
245     bert_website_mdl.to(device)
```

Set up for multiple GPUs

```
265     for _ in trange(epochs, desc="Epoch"):
266
267         bert_website_mdl.train()
268
269         tr_loss, tr_accuracy = 0, 0
270         nb_tr_examples, nb_tr_steps = 0, 0
271
272         for step, batch in enumerate(train_dataloader):
273
274             # Add batch to GPU
275             batch = tuple(t.to(device) for t in batch)
276
277             # Unpack the inputs from our dataloader
278             page_text_ids1, page_text_ids2, page_text_ids3, \
279                 page_text_ids4, page_text_ids5, \
280                 page_text_masks1, page_text_masks2, page_text_masks3, \
281                 page_text_masks4, page_text_masks5, \
282                 page_title_ids1, page_title_ids2, page_title_ids3, \
283                 page_title_ids4, page_title_ids5, \
284                 page_title_masks1, page_title_masks2, page_title_masks3, \
285                 page_title_masks4, page_title_masks5, \
286                 domain_ids, domain_masks, biz_name_ids, biz_name_masks, \
287                 url_exts, batch_labels = batch
288
```

Allow model to update weights

```
265     for _ in trange(epochs, desc="Epoch"):
266
267         bert_website_mdl.train()
268
269         tr_loss, tr_accuracy = 0, 0
270         nb_tr_examples, nb_tr_steps = 0, 0
271
272         for step, batch in enumerate(train_dataloader):
273
274             # Add batch to GPU
275             batch = tuple(t.to(device) for t in batch)
276
277             # Unpack the inputs from our dataloader
278             page_text_ids1, page_text_ids2, page_text_ids3, \
279                 page_text_ids4, page_text_ids5, \
280                 page_text_masks1, page_text_masks2, page_text_masks3, \
281                 page_text_masks4, page_text_masks5, \
282                 page_title_ids1, page_title_ids2, page_title_ids3, \
283                 page_title_ids4, page_title_ids5, \
284                 page_title_masks1, page_title_masks2, page_title_masks3, \
285                 page_title_masks4, page_title_masks5, \
286                 domain_ids, domain_masks, biz_name_ids, biz_name_masks, \
287                 url_exts, batch_labels = batch
288
```

Iterate over all batches in train

```
265     for _ in trange(epochs, desc="Epoch"):
266
267         bert_website_mdl.train()
268
269         tr_loss, tr_accuracy = 0, 0
270         nb_tr_examples, nb_tr_steps = 0, 0
271
272         for step, batch in enumerate(train_dataloader):
273
274             # Add batch to GPU
275             batch = tuple(t.to(device) for t in batch)
276
277             # Unpack the inputs from our dataloader
278             page_text_ids1, page_text_ids2, page_text_ids3, \
279                 page_text_ids4, page_text_ids5, \
280                 page_text_masks1, page_text_masks2, page_text_masks3, \
281                 page_text_masks4, page_text_masks5, \
282                 page_title_ids1, page_title_ids2, page_title_ids3, \
283                 page_title_ids4, page_title_ids5, \
284                 page_title_masks1, page_title_masks2, page_title_masks3, \
285                 page_title_masks4, page_title_masks5, \
286                 domain_ids, domain_masks, biz_name_ids, biz_name_masks, \
287                 url_exts, batch_labels = batch
288
```

Unpack all inputs in batch

```
289         # Clear out the gradients (by default they accumulate)
290         optimizer.zero_grad()
291
292         # Forward pass
293         loss, logits = bert_website_mdl(
294             page_text_ids=(
295                 page_text_ids1, page_text_ids2, page_text_ids3,
296                 page_text_ids4, page_text_ids5),
297             page_text_masks=(page_text_masks1, page_text_masks2,
298                              page_text_masks3, page_text_masks4,
299                              page_text_masks5),
300             page_title_ids=(...),
301             page_title_masks=(...),
302             domain_ids=domain_ids,
303             domain_masks=domain_masks,
304             biz_name_ids=biz_name_ids,
305             biz_name_masks=biz_name_masks,
306             url_exts=url_exts,
307             token_type_ids=None,
308             labels=batch_labels)
```

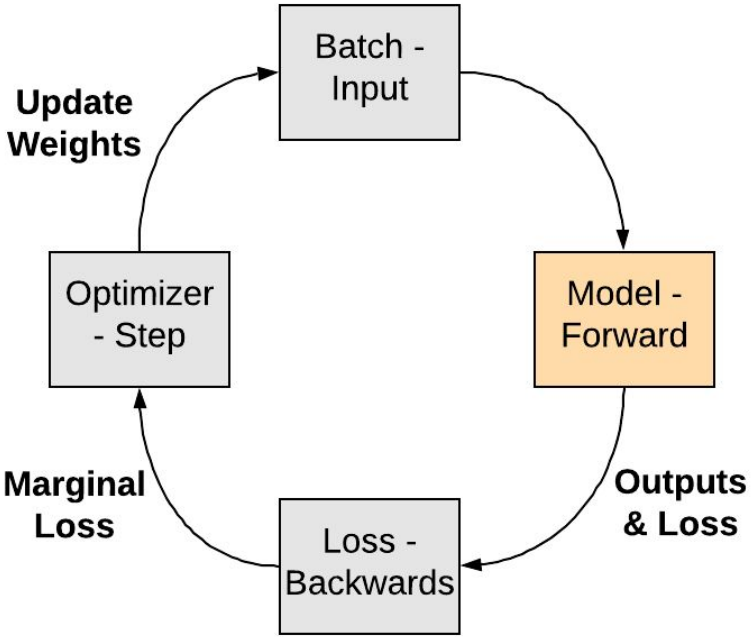
Pass all inputs to forward method

```
289         # Clear out the gradients (by default they accumulate)
290         optimizer.zero_grad()
291
292         # Forward pass
293         loss, logits = bert_website_mdl(
294             page_text_ids=(
295                 page_text_ids1, page_text_ids2, page_text_ids3,
296                 page_text_ids4, page_text_ids5),
297             page_text_masks=(page_text_masks1, page_text_masks2,
298                              page_text_masks3, page_text_masks4,
299                              page_text_masks5),
300             page_title_ids=(...),
301             page_title_masks=(...),
302             domain_ids=domain_ids,
303             domain_masks=domain_masks,
304             biz_name_ids=biz_name_ids,
305             biz_name_masks=biz_name_masks,
306             url_exts=url_exts,
307             token_type_ids=None,
308             labels=batch_labels)
```

Model - Train

Forward method:

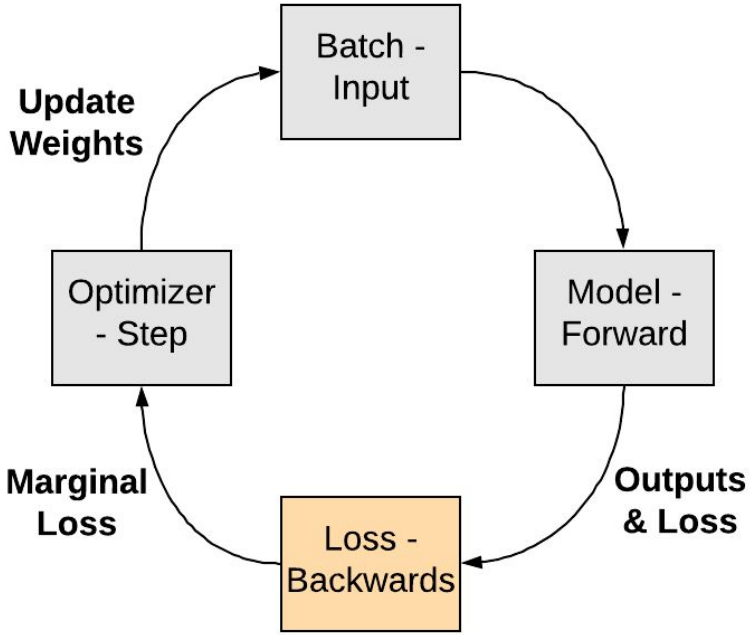
- Define the graph of the model:
  - Layers
  - Transformations
  - Combinations
- Is invoked with inputs, calculates outputs
- Using labels and a loss metric, calculates loss



Model - Train

Loss metric:

- Compares outputs with labels, calculates actual loss
- “backward” method computes the marginal loss w.r.t all the trainable parameters (i.e the loss gradient). Updates “grad” attribute of tensors.
- E.g: Cross Entropy Loss for multi-class problems



```
289         # Clear out the gradients (by default they accumulate)
290         optimizer.zero_grad()
291
292         # Forward pass
293         loss, logits = bert_website_mdl(...)
309
310         train_loss_set.append(loss.mean().item())
311         loss.mean().backward()
312         optimizer.step()
313
314         # Move logits and labels to CPU
315         logits = logits.detach().cpu().numpy()
316         label_ids = batch_labels.to('cpu').numpy()
```

Aggregate loss from multiple GPUs

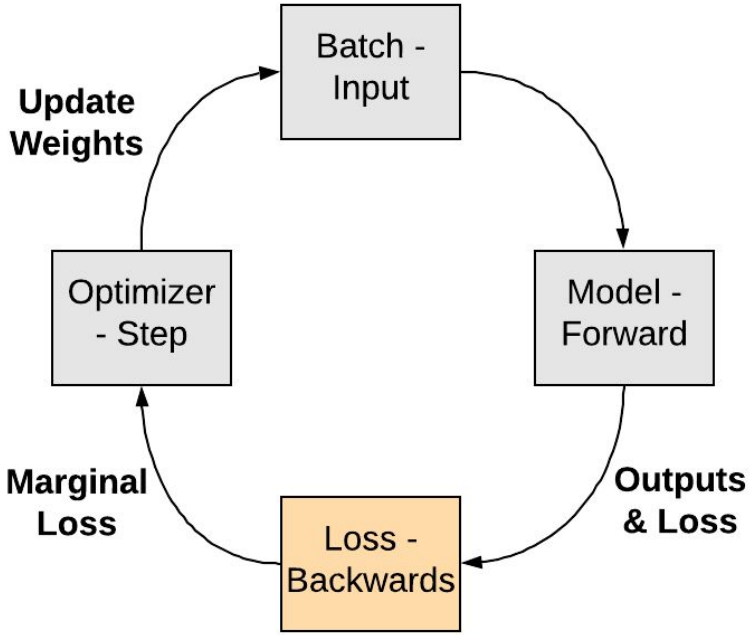
```
289         # Clear out the gradients (by default they accumulate)
290         optimizer.zero_grad()
291
292         # Forward pass
293         loss, logits = bert_website_mdl(...)
309
310         train_loss_set.append(loss.mean().item())
311         loss.mean().backward()
312         optimizer.step()
313
314         # Move logits and labels to CPU
315         logits = logits.detach().cpu().numpy()
316         label_ids = batch_labels.to('cpu').numpy()
```

Calculate marginal loss

Model - Train

Loss metric:

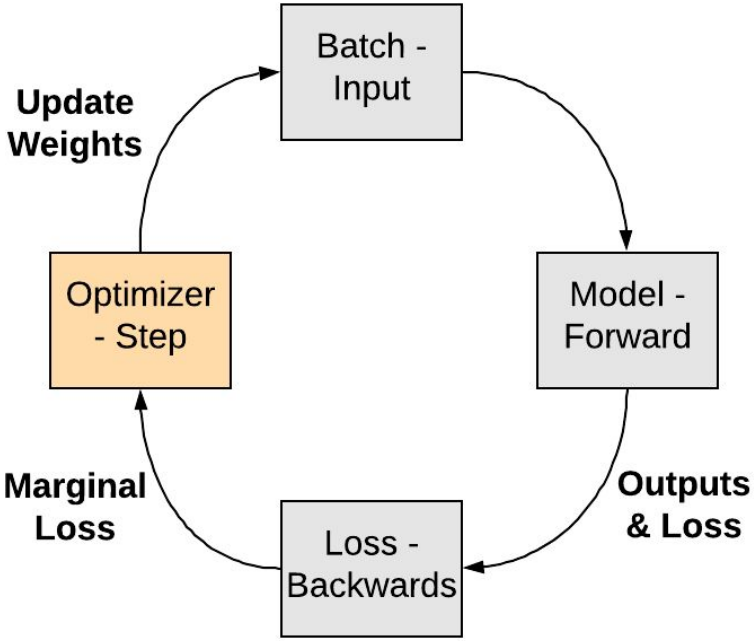
- Compares outputs with labels, calculates actual loss
- “backward” method computes the marginal loss w.r.t all the trainable parameters (i.e the loss gradient). Updates “grad” attribute of tensors.
- E.g: Cross Entropy Loss for multi-class problems



Model - Train

Optimizer:

- Specifies which gradient-based optimization method to use for gradient descent
- “step” method updates all relevant weights (i.e. tensor values) according to the marginal loss (stored in the grad attribute of the tensors)
- E.g: AdamW Optimizer



```
param_optimizer = list(custom_bert_mdl.named_parameters())
no_decay = ['bias', 'gamma', 'beta']
optimizer_grouped_parameters = [
    {'params': [p for n, p in param_optimizer if
                not any(nd in n for nd in no_decay)],
     'weight_decay_rate': 0.01},
    {'params': [p for n, p in param_optimizer if
                any(nd in n for nd in no_decay)],
     'weight_decay_rate': 0.0}
]

optimizer = AdamW(optimizer_grouped_parameters, lr=2e-5)
```

```
289         # Clear out the gradients (by default they accumulate)
290         optimizer.zero_grad()
291
292         # Forward pass
293         loss, logits = bert_website_mdl(...)
309
310         train_loss_set.append(loss.mean().item())
311         loss.mean().backward()
312         optimizer.step()
313
314         # Move logits and labels to CPU
315         logits = logits.detach().cpu().numpy()
316         label_ids = batch_labels.to('cpu').numpy()
```

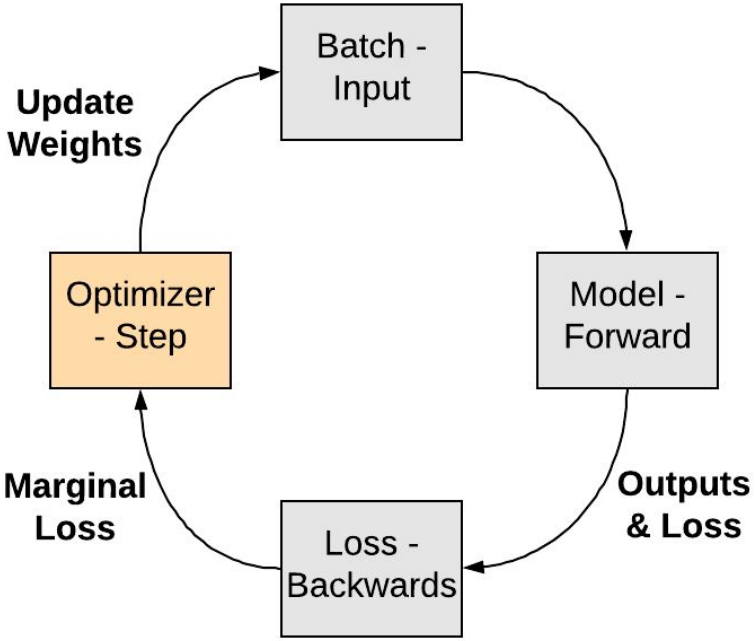
```
289         # Clear out the gradients (by default they accumulate)
290         optimizer.zero_grad()
291
292         # Forward pass
293         loss, logits = bert_website_mdl(...)
309
310         train_loss_set.append(loss.mean().item())
311         loss.mean().backward()
312         optimizer.step()
313
314         # Move logits and labels to CPU
315         logits = logits.detach().cpu().numpy()
316         label_ids = batch_labels.to('cpu').numpy()
```

Update weights based on marginal loss

Model - Train

Optimizer:

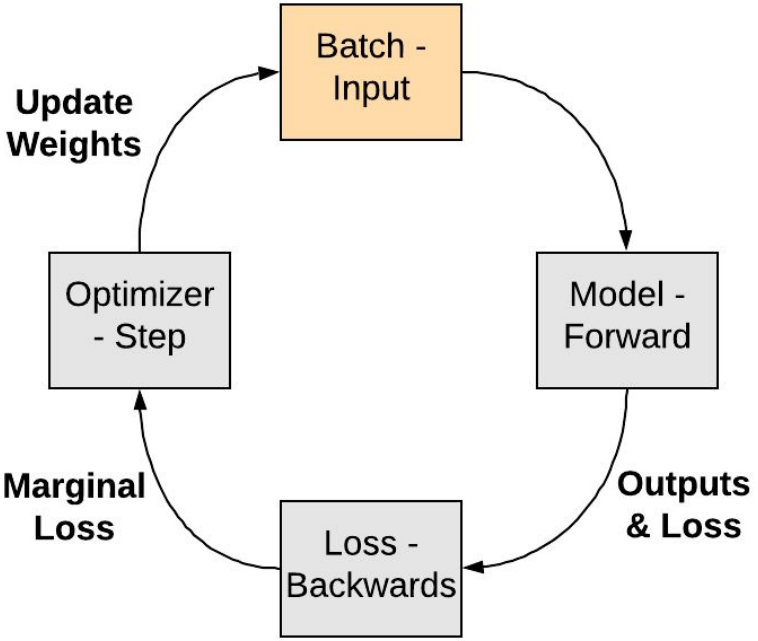
- Specifies which gradient-based optimization method to use for gradient descent
- “step” method updates all relevant weights (i.e. tensor values) according to the marginal loss (stored in the grad attribute of the tensors)
- E.g: AdamW Optimizer



Model - Train

Batch - Input:

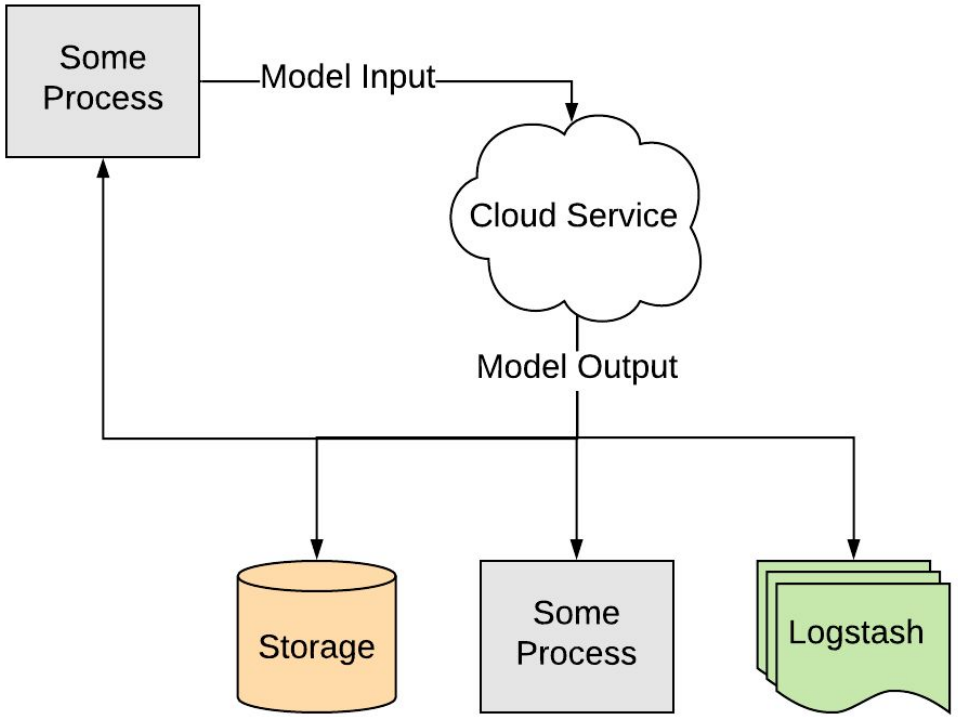
- Next Batch



Model - Deploy

Goal:

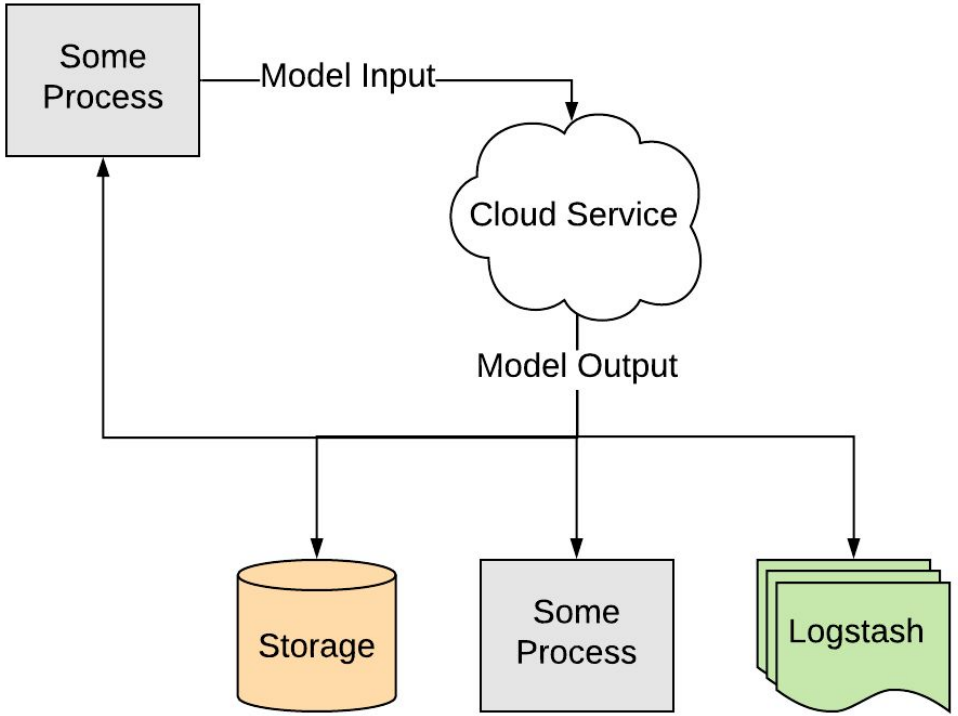
- Model hosted in the cloud
- Always up (persistence)
- Communicates via API
- Can scale



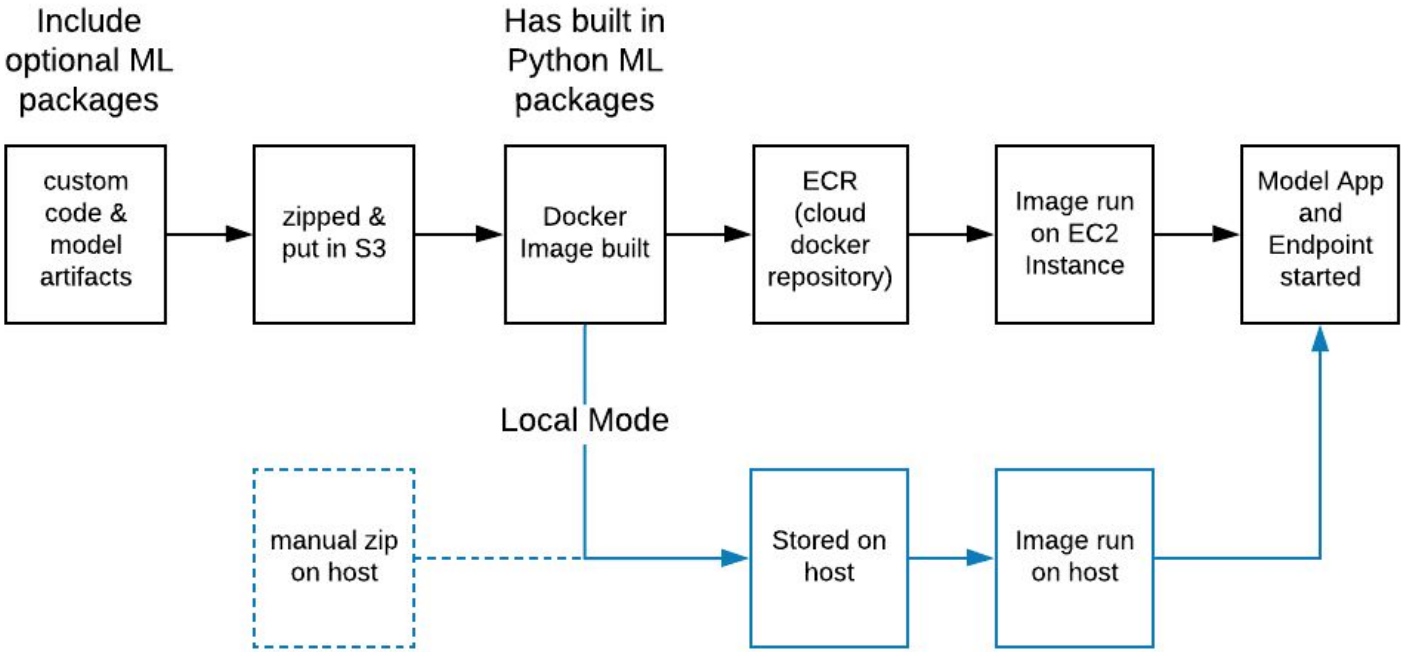
Model - Deploy

Tool:

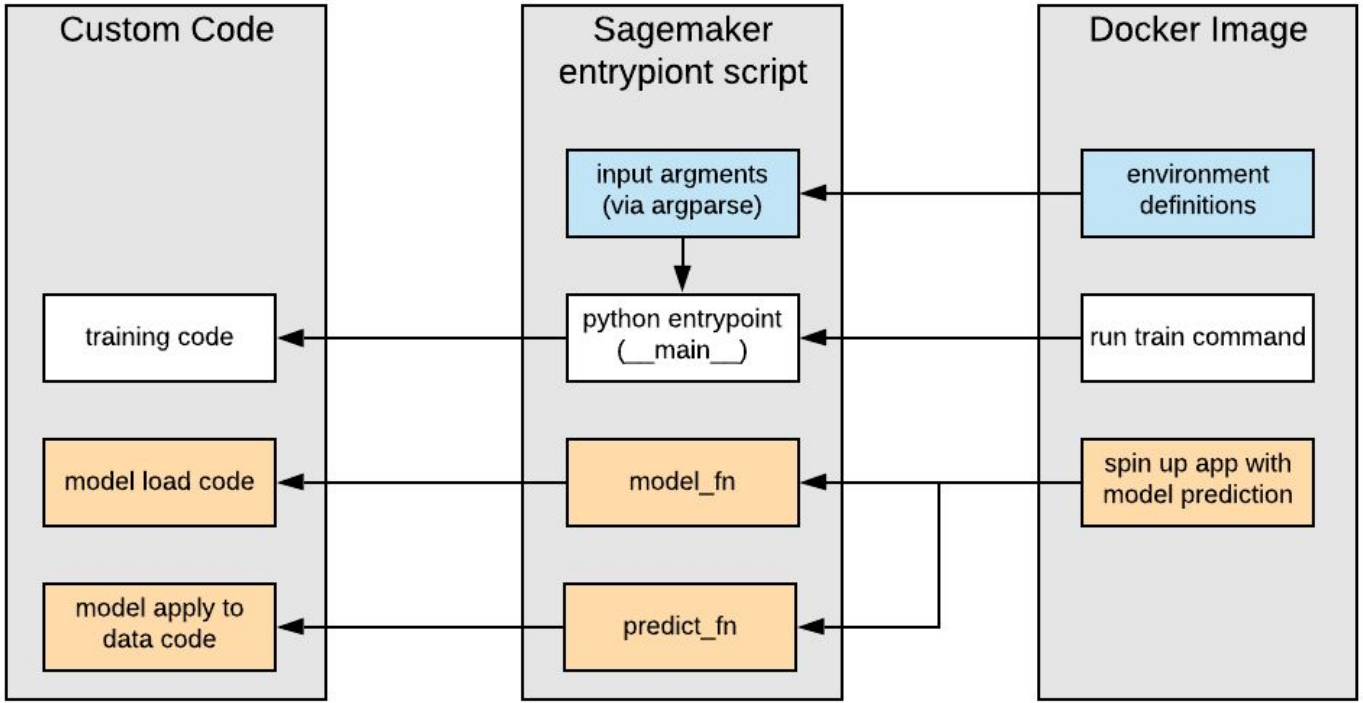
- Amazon SageMaker https://aws.amazon.com/sagemaker/
- All the pros of docker deployment without writing any docker code
- Supports four modes: Tag, Explore, Train and Deploy
- Auto Scaling



Model - Deploy (SageMaker)



Model - Deploy (SageMaker)



```
11  def model_fn(model_dir):
12      """
13      initialize resources during service startup
14      """
15      # load model
16      from industry_sagemaker_service.bert_website_classifier \
17          import BertWebsiteClassifier
18      bert_mdl = BertWebsiteClassifier.from_pretrained(
19          os.path.join(model_dir, 'data_files', 'model_e'))
20
21      # set up for GPU if exists
22      device = torch.device("cuda" if torch.cuda.is_available()
23                            else "cpu")
24
25      if device.type == 'cuda':
26          bert_mdl.cuda()
27
28      # load tokenizer
29      bert_tokenizer = BertTokenizer.from_pretrained('bert-base-cased',
30                                                     do_lower_case=False)
31
32      return bert_mdl, bert_tokenizer
33
```

Load trained model

```
def model_fn(model_dir):
    """
    initialize resources during service startup
    """
    # load model
    from industry_sagemaker_service.bert_website_classifier \
        import BertWebsiteClassifier
    bert_mdl = BertWebsiteClassifier.from_pretrained(
        os.path.join(model_dir, 'data_files', 'model_e'))

    # set up for GPU if exists
    device = torch.device("cuda" if torch.cuda.is_available()
                          else "cpu")

    if device.type == 'cuda':
        bert_mdl.cuda()

    # load tokenizer
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                                                   do_lower_case=False)

    return bert_mdl, bert_tokenizer
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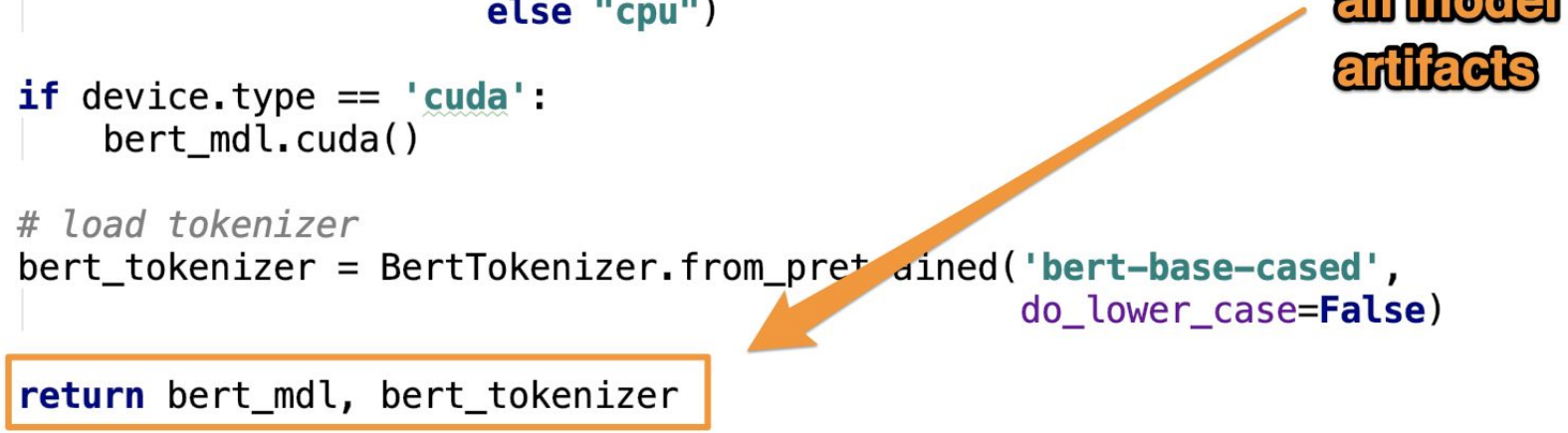

```
66  def predict_fn(urls, crawl_df, model_fn_input):
67      """
68      apply model to input, return inference
69      """
70      bert_mdl, bert_tokenizer = model_fn_input
71
72      from industry_sagemaker_service.bert_website_classifier \
73          import predict_industry
74      output_with_urls = predict_industry(urls, crawl_df, bert_mdl,
75                                          bert_tokenizer, batch_size=16,
76                                          top_n=3)
77
78      return json.dumps(output_with_urls)
79
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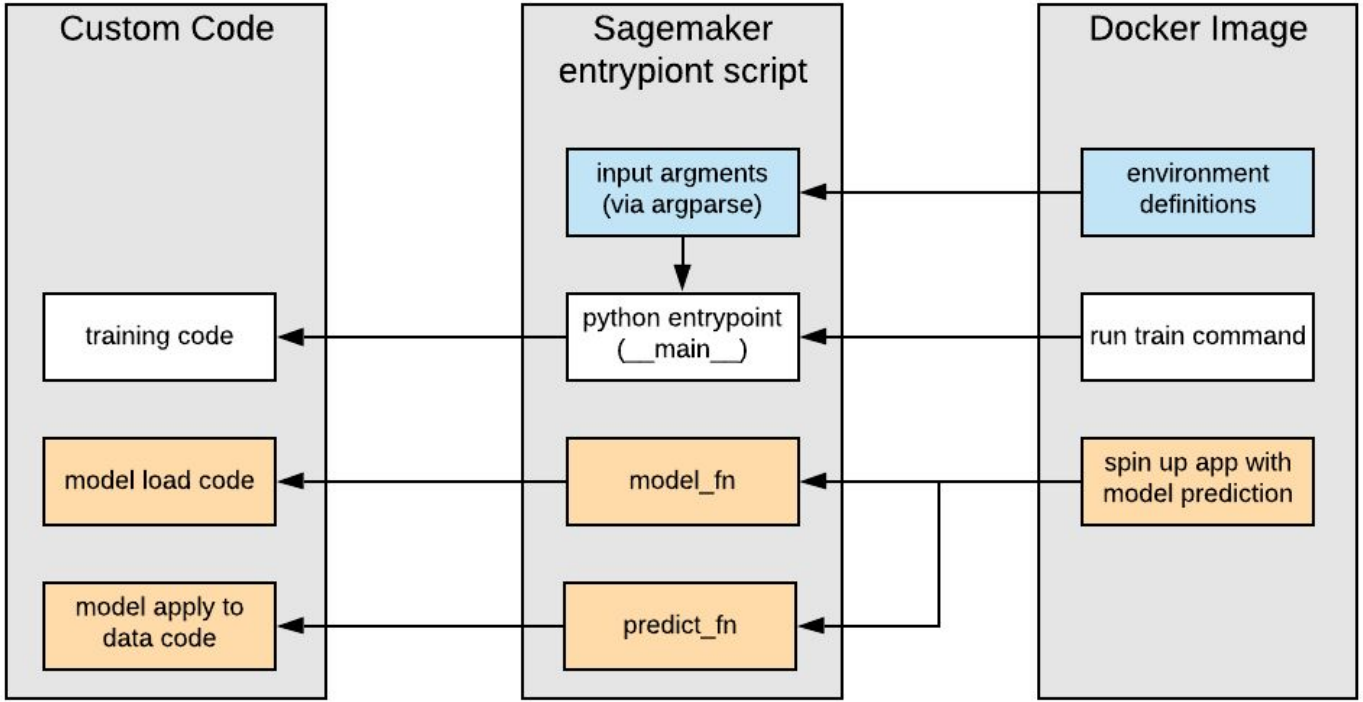
Model - Deploy (SageMaker)



```python
import sagemaker
from boto3 import Session as BotoSession

# create sagemaker session
boto_session = BotoSession(profile_name='default',
                           region_name='us-east-1')
sagemaker_session = sagemaker.Session(boto_session=boto_session)
sagemaker_role = 'ido-sagemaker-test'

from sagemaker.pytorch import PyTorchModel

industry_cloud_model = PyTorchModel(

    entry_point='sagemaker_entry_point.py',

    model_data='s3://ido-sagemaker-test/ind_mdl_data.tar.gz',

    framework_version='1.1.0',
    py_version='py3',

    role=sagemaker_role,
    source_dir='.')
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```

Specify SageMaker PyTorch Docker container

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```

Location of entrypoint script

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    py_version='py3',

    role=sagemaker_role,
    source_dir='.')
```

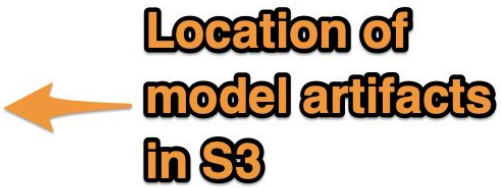

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    role=sagemaker_role,
    source_dir='.')
```

Specify PyTorch and Python versions

```
24  industry_cloud_predictor = industry_cloud_model.deploy(
25      initial_instance_count=1,
26      instance_type='ml.p2.xlarge')
```

```
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```

Call "deploy" method on the model

Amazon SageMaker > Endpoints

Endpoints

Update endpoint | Actions | Create endpoint

Search endpoints

1

Our Endpoint

Name	ARN	Creation time	Status	Last updated
sagemaker-pytorch-2019-10-30-03-50-29-502	[redacted]	Oct 30, 2019 03:50 UTC	InService	Oct 30, 2019 04:00 UTC
sagemaker-scikit-learn-2019-10-08-21-54-08-741	[redacted]	Oct 08, 2019 21:54 UTC	InService	Oct 25, 2019 19:34 UTC

```
29  from sagemaker.predictor import json_serializer
30
31  # define input format as JSON
32  industry_cloud_predictor.serializer = json_serializer
33  industry_cloud_predictor.content_type = 'application/json'
34
35  input_json = ''  # load some input data
36
37  preds = industry_cloud_predictor.predict(input_json)
38
```

Specify input will be JSON

```
29  from sagemaker.predictor import json_serializer
30
31  # define input format as JSON
32  industry_cloud_predictor.serializer = json_serializer
33  industry_cloud_predictor.content_type = 'application/json'
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38
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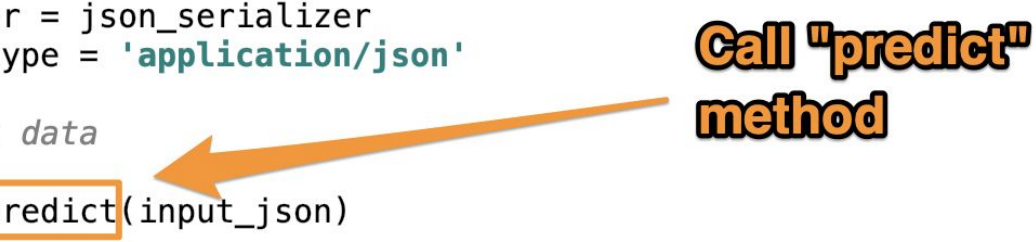

Conclusion - Summary

What we did:

- Built a 250K sized sample of websites
  - Search strategies
  - Balancing strategies
- Tagged that sample
  - Crowdsourcing considerations & strategies
- Crawled all of the websites in it
  - Scrapy for small scale
  - ScrapyD for large scale

Conclusion - Summary

What we did:

- Built a 250K sized sample of websites
  - Search strategies
  - Balancing strategies
- Tagged that sample
  - Crowdsourcing considerations & strategies
- Crawled all of the websites in it
  - Scrapy for small scale
  - ScrapyD for large scale
- Built an NLP industry classification model
  - Transfer learning using BERT
  - Dealt with 512 length limit
- Trained that model with multiple GPUs
  - Pretrained BERT models with PyTorch
- Deployed that model using SageMaker
  - Docker deployment, no docker code

Conclusion - Key Takeaways

- Crowdsourcing has to be done carefully to produce real value
  - Vendor trials
  - Enforce QA
- You can build a very efficient crawler using Scrapy / ScrapyD
- You can build a very powerful NLP model using pretrained BERT
  - Use available wrappers (e.g HuggingFace for PyTorch)
- You can train / deploy models on very powerful machines (e.g. 16 GPUs) using SageMaker
  - No docker knowledge required
- Hope for the best

Questions? + Thanks!

ido.shlomo@bluevine.com