
DEVELOPMENT OF
FORECASTING MODEL
TO IDENTIFY EMERGING
BUSINESS TOPIC
VIA TEXT MINING APPROACH
USING WEB-CRAWLED
PATENT DATA

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GOAL OF THIS PROJECT

- Developing the prototype of program to process and analyze the data
 - To forecast future emerging business topics within specific industry
 - Via designing, developing & implementation of algorithm, analysis framework and process

SCOPE OF THIS PROJECT

- Range of interesting industry for web-crawling of input data
 - Digitalization, Digital Asset Management, Automation of documentation or working process
 - Scope of methodology
 - Data acquisition by web-crawling
 - Text analysis & Clustering by Topic Modeling
 - Network & Citation analysis to develop evaluation principle
-

PROJECT AT A GLANCE

Key Phrase identification

- Patent Search(for setting the analysis range) via web crawling
- Data cleansing due to the duplication issue from ,Patent Family‘
- Key-phrases extraction : via RAKE(Rapid Automatic Keyword Extraction) approach
- Patent-keyword matrix with the frequency after TF-IDF conversion

Identifying innovative topic

- Topic modeling via LDA(latent dirichlet allocation) approach
- Topic – keywords distribution matrix
- Patent – topic distribution matrix -> adjusting with threshold via VSM approach & labeling

Identifying potentiality

- Compute potentiality and verify emerging topics
- via OFIT(Opportunity-focused innovation topic) map
- Visualization and writing report

Data preparation

Discovering Topics

Identifying potential Topics

Data preparation via Patent search

Data Acquisition via web crawling

Key-phrases extraction via RAKE

Create VSM matrix with TF-IDF score

Topic modeling via LDA

Optimization via Grid search

Compute potentiality index

Identifying potential topics

DATA ACQUISITION BY WEB CRAWLING

- Python Script for web crawling

```
import sqlite3
from bs4 import BeautifulSoup
import requests
import time

conn = sqlite3.connect('test.sqlite3')

for patent in conn.execute('select id from gp_search_new'):

    patent = patent[0]
    url = conn.execute('select url from gp_search_new where id = ?', (patent,)).fetchone()[0]
    print(url)
    if type(url) is str and 'https' in url:
        try:
            website = requests.get(url)
        except requests.exceptions.ConnectionError:
            status_code = "Connection refused"
            print(website.status_code)
            soup = BeautifulSoup(website.content, 'html.parser')
            full_text = ''
            for i in ["%04d" % x for x in range(1, 1000)]:
                try:
                    part = soup.find(id='p-' + i).text
                    full_text += ' ' + part
                except Exception as e:
                    print(e)
                    break

            print(full_text)
            conn.execute('replace into gp_search_new(id,full_text) values(?,?)', (patent,full_text,))
            conn.commit()
            time.sleep(5)
```

- Web-crawled input data for this project
 - From Google Patents

	patent_id	full_text	priority_id
0	US-2019147554-A1	Embodiments of the disclosure relate generally...	US201762584246P
1	US-2017329307-A1	This application claim priority to U S Provi...	US201662336332P
2	US-2018211465-A1	The present patent application patent claim th...	US201762448697P
3	US-2017116693-A1	This application claim priority under U S C ...	US201562246992P
4	US-2018307759-A1	This application claim the benefit of priority...	US201762487820P
5	US-2018189887-A1	The present disclosure relates generally to sy...	US15/859,890

RAKE KEYWORDS EXTRACTION

- Python Script for RAKE keywords extraction

```
import sqlite3
import nltk
from rake_nltk import Rake, Metric
import nltk
from nltk.stem import WordNetLemmatizer
import re
nltk.download('punkt')
conn = sqlite3.connect('test.sqlite3')

from nltk.corpus import stopwords
stop_words = set(stopwords.words('english'))

pool = []

for i in conn.execute('select distinct id, full_text from gp_search_new'):
    str(i[1]).replace("[^a-zA-Z]", " ") # remove non-letters
    str(i[1]).replace("\d+", " ") # remove numbers
    str(i[1]).replace(r'\"', '') # remove quotation

    # Lemmatize list of words and join
    lemma = WordNetLemmatizer()
    text1_lemma= [lemma.lemmatize(x) for x in str(i[1])]

    try:
        if len(text1_lemma) > 10:
            # Keywords extraction by RAKE
            r = Rake(stopwords=None,
                    punctuations=None,
                    language="english",
                    ranking_metric=Metric.DEGREE_TO_FREQUENCY_RATIO,
                    max_length=50,
                    min_length=10)
            r.extract_keywords_from_text(text1_lemma)
            # Append patent's id column
            pool.append((i[0], r.get_ranked_phrases_with_scores() ) )
    except:
        pass
```

- Final VSM matrix after keywords extraction

[illegible]

LDA TOPIC MODELING AND MODEL OPTIMIZATION

- Python Script for LDA Topic Modeling/GridSearch
- Model Optimization & Final selection of best model

```
[ ] ##### new LDA model #####
# Build LDA Model
lda_model = LatentDirichletAllocation(n_components=20,      # Number of topics
                                     max_iter=10,          # Max learning iterations
                                     learning_method='online',
                                     random_state=100,      # Random state
                                     batch_size=100,        # n docs in each learning iter
                                     evaluate_every = -1,    # compute perplexity every n iters, default: Don't
                                     n_jobs = -1,           # Use all available CPUs
                                     )

lda_output = lda_model.fit_transform(data_vectorized)

print(lda_model) # Model attributes
```

```
[ ] ##### new LDA model #####
## Diagnose model performance with perplexity and log-likelihood
# Log Likelihood: Higher the better
print("Log Likelihood: ", lda_model.score(data_vectorized))

# Perplexity: Lower the better. Perplexity = exp(-1. * log-likelihood per word)
print("Perplexity: ", lda_model.perplexity(data_vectorized))

# See model parameters
pprint(lda_model.get_params())

[ ] ##### new LDA model #####
## GridSearch the best LDA model
# Define Search Param
search_params = {'n_components': [10, 15, 20, 25, 30], 'learning_decay': [.5, .7, .9]}

# Init the Model
lda = LatentDirichletAllocation()

# Init Grid Search Class
model = GridSearchCV(lda, param_grid=search_params)

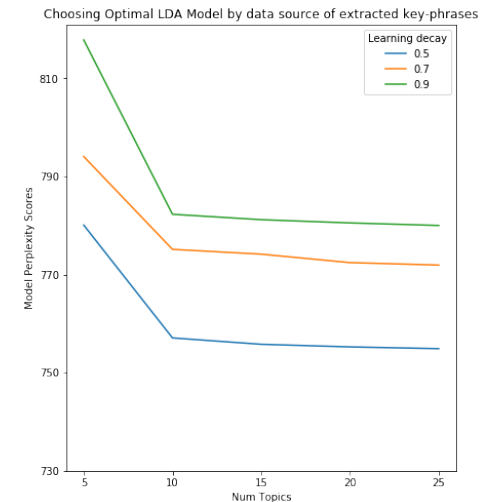
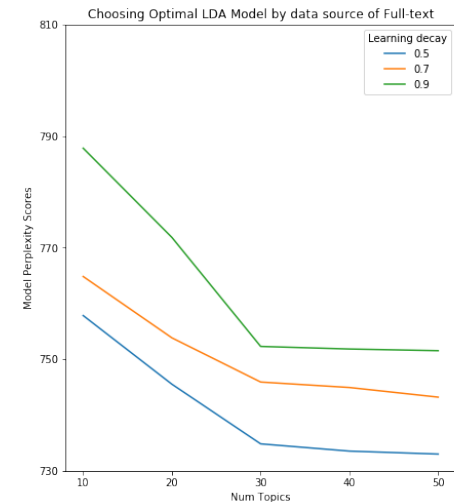
# Do the Grid Search
model.fit(data_vectorized)
```

```
[ ] ##### new LDA model #####
## Model Tuning, find the best topic model and its parameters
# Best Model
best_lda_model = model.best_estimator_

# Model Parameters
print("Best Model's Params: ", model.best_params_)

# Log Likelihood Score
print("Best Log Likelihood Score: ", model.best_score_)

# Perplexity
print("Model Perplexity: ", best_lda_model.perplexity(data_vectorized))
```



Metric		Value for the model by full-text data source	Value for the model by extracted key-phrase
Best model's parameters	Learning decay	0.5	0.5
	Number of topics	30	10
Best Log Likelihood Score		-35130325.64	-37261401.92
Best Model Perplexity		734.83	755.79

NETWORK ANALYSIS FOR IMPORTANCE INDEX

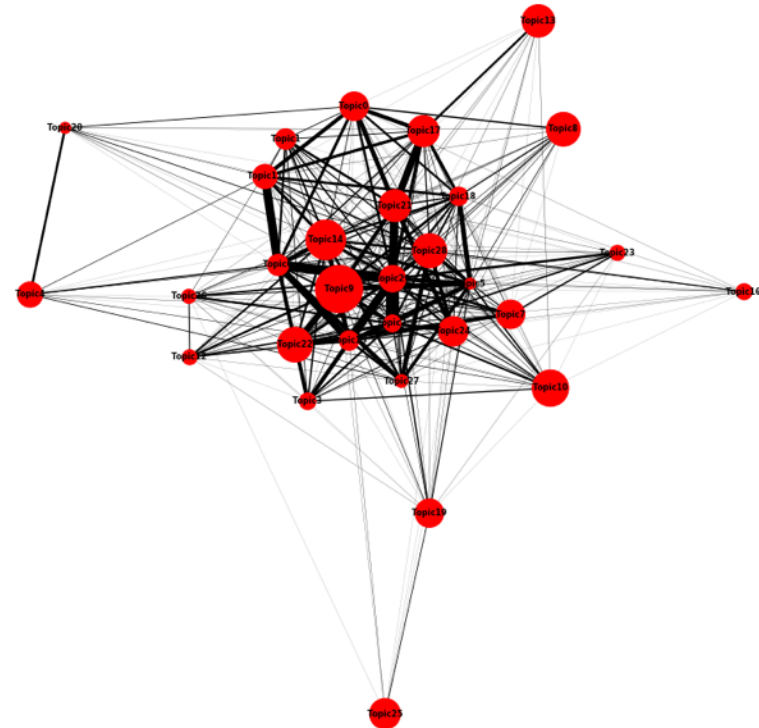
- Python Script for Network Analysis
- Model Optimization & Final selection of best model

```
#add weights to edges
edge_list = [] #test networkx
for index, row in coocc.iterrows():
    i = 0
    for col in row:
        weight = col
        edge_list.append((index, coocc.columns[i], weight))
        i += 1

#Remove edge if 0.0
updated_edge_list = [x for x in edge_list if not x[2] == 0.0]
#create duple of char, occurrence in novel
node_list = []
for i in topicnames:
    for e in updated_edge_list:
        if i == e[0] and i == e[1]:
            node_list.append((i, e[2]))
for i in node_list:
    if i[1] == 0.0:
        node_list.remove(i)
#remove self references
for i in updated_edge_list:
    if i[0] == i[1]:
        updated_edge_list.remove(i)
#set canvas size
plt.subplots(figsize=(14,14))
#networkx graph time!
G = nx.Graph()
for i in sorted(node_list):
    G.add_node(i[0], size = i[1])

G.add_weighted_edges_from(updated_edge_list)

node_order = topicnames
#reorder node list
updated_node_order = []
for i in node_order:
    for x in node_list:
        if x[0] == i:
            updated_node_order.append(x)
#reorder edge list - this was a pain
test = nx.get_edge_attributes(G, 'weight')
updated_again_edges = []
for i in nx.edges(G):
    for x in test.keys():
        if i[0] == x[0] and i[1] == x[1]:
            updated_again_edges.append(test[x])
#drawing customization
node_scalar = 2
edge_scalar = 0.0001
sizes = [x[1]*node_scalar for x in updated_node_order]
widths = [x*edge_scalar for x in updated_again_edges]
#draw the graph
pos = nx.spring_layout(G, k=0.42, iterations=17)
nx.draw(G, pos, with_labels=True, font_size=8, font_weight='bold', node_color='r',
        node_size=sizes, width=widths)
plt.axis('off')
plt.savefig("test_network.png") # save as png
## calculate degree centrality,
c = nx.closeness centrality(G)
# convert to dataframe
closeness centrality = pd.DataFrame(list(c.items()), columns=['topic', 'closeness centrality'])
```



- Compute importance level ($C_c(v)$) : via closeness centrality

$$C_c(v) = \frac{(N - 1)}{\sum_{v \neq t \in V} d(v, t)}$$

- $d(v, t)$ = the distance, which is the shortest path, between nodes v and t
- N = the number of nodes in the network for obtaining normalized closeness centrality values

CITATION ANALYSIS FOR MATURITY INDEX

- Python Script for Network Analysis

```
topic_list = df_document_topic.loc[:, 'Topic0':'Topic29']
citation_list = df_citation_final['citation']
citation_list = citation_list.astype(float)

satisfy = []

# Yields a tuple of column name and series for each column in the dataframe
for (columnName, columnData) in topic_list.iteritems():
    sum=0
    citation_stock=0
    for i in range(len(columnData)):
        init_citation_stock = columnData[i]*citation_list[i]
        sum += init_citation_stock
    citation_stock = sum
    satisfy.append((columnName, citation_stock))

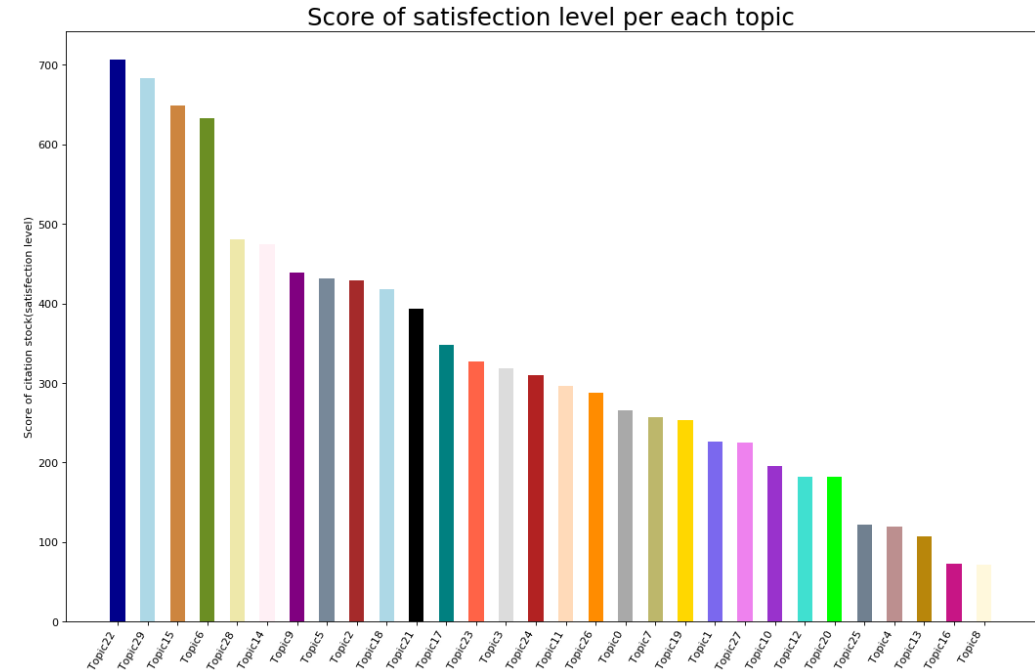
print(columnName, citation_stock)

# convert list to data frame
final_satisfy = pd.DataFrame(satisfy, columns = ['topic' , 'citation_stock'])
#####
# plotting bar chart for satisfaction level
import random
import matplotlib.pyplot as plt
# Prepare Data
new_final_satisfy = final_satisfy.sort_values('citation_stock',ascending=False)
n = new_final_satisfy['topic'].unique().__len__()+1
all_colors = list(plt.cm.colors.cnames.keys())
random.seed(100)
c = random.choices(all_colors, k=n)

# Plot Bars
plt.figure(figsize=(16,10), dpi= 80)
plt.bar(new_final_satisfy['topic'], new_final_satisfy['citation_stock'], color=c, width=.5)

# Decoration
plt.gca().set_xticklabels(new_final_satisfy['topic'], rotation=60, horizontalalignment= 'right')
plt.title("Score of satisfaction level per each topic", fontsize=22)
plt.ylabel('Score of citation stock(satisfaction level)')
#plt.ylim(0, 45)
plt.show()
plt.savefig("citation_stock.jpg")
```

- Model Optimization & Final selection of best model



- Compute satisfaction level : via computing citation stock (CS_i)

$$CS_i = \sum_{j \in S} CP_{ij} \times FC_j,$$

- CP_{ij} = contribution probability of innovation topic i in patent j
- FC_j = the number of forward citations of j

FORECASTING FUTURE EMERGING OPPORTUNITY

- Python Script for Network Analysis

```
ofit_map = pd.merge(closeness centrality, final_satisfy, how='left', on=['topic'])
# OFIT mapping : x-axis('closeness centrality'), y-axis('citation_stock')
# scatter plot here..
import matplotlib.pyplot as plt
import matplotlib.lines as mlines
import matplotlib.transforms as mtransforms

# average of importance
avg_cent = closeness centrality['closeness centrality'].mean()
print(avg_cent) # => avg_cent = 0.7940293400835674

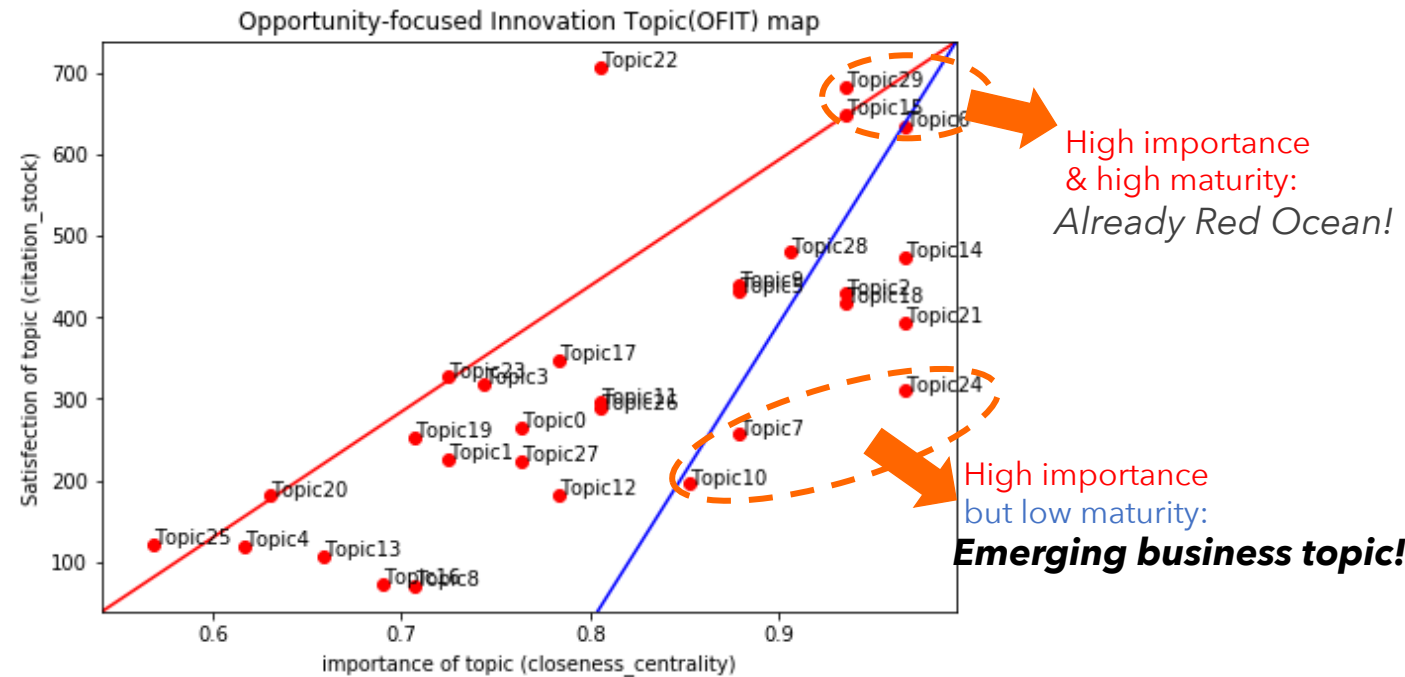
fig=plt.figure()
ax=fig.add_axes([0,0,1,1])
ax.scatter(ofit_map['closeness centrality'], ofit_map['citation_stock'], color='r')
ax.set_xlabel('importance of topic (closeness centrality)')
ax.set_ylabel('Satisfaction of topic (citation_stock)')
ax.set_title('Opportunity-focused Innovation Topic(OFIT) map')
for i, txt in enumerate(ofit_map['topic']):
    ax.annotate(txt, (ofit_map['closeness centrality'][i], ofit_map['citation_stock'][i]))

line = mlines.Line2D([0, 1], [0, 1], color='red')
transform = ax.transAxes
line.set_transform(transform)
ax.add_line(line)

# 0.618 = (avg_cent-0.45)/0.55 (* avg_cent = 0.7940293400835674)
line = mlines.Line2D([0.6232073678495466, 1], [0, 1], color='blue')
transform = ax.transAxes
line.set_transform(transform)
ax.add_line(line)
ax.fill_between(ofit_map['closeness centrality'], line, color= 'skyblue')

plt.show()
plt.savefig("test_OFIT.png") # save as png
```

- Model Optimization & Final selection of best model



POSSIBLE APPLICATION



Supporting **data driven strategy**

- *Identifying investment opportunity*
- *Forecasting emerging opportunity*



Data driven Long-term planning

- *Identifying potential M&A candidate*
- *Finding out potential Start-Up with emerging technology*



Market analysis

- *Landscaping the market's interest*
 - *Examination of customer's interest trend*
-