Analyzing Research and Development Trends Using Administrative Data

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2020 FCSM Research and Policy Conference

September 21, 2020
SDAD & NCSES Partnership

• Social and Decision Analytics Division (SDAD)
  • leading research group in the Biocomplexity Institute and Initiative at the University of Virginia.
  • research has a history of measuring the social condition and economic innovation from multiple perspectives – societal, economic and statistical - with the goal of understanding the bias-precision tradeoffs using new and diverse data sources

• National Center for Science and Engineering Statistics (NCSES)
  • NSF’s statistical agency
  • pursuing opportunities to assess the feasibility and ability to use non-survey data flows to supplement or enhance its current efforts in collecting Science, Technology, and Innovation (STI) indicators.
We have been collaborating with NCSES since 2016 to explore the feasibility of identifying and collecting data that naturally exists and are emerging for other reasons and repurposing those data to measure innovation and related concepts.
Project Aims

• Examine the use of administrative records to supplement or enhance data collected by NCSES.

• Use **Natural Language Processing (NLP)** and **machine learning techniques** to extract relevant Research and Development (R&D) topics from administrative records to supplement methods based on data collected in the NCSES Federal Funds Survey and Federal Support Survey.
Approach – UVA SDAD Data Science Framework

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**Problem Identification:**
Reviewed prior work, conducted a literature review on finding emerging topics & topic model visualization.

Approach – UVA SDAD Data Science Framework

**Data Discovery:**
Acquired the most recent data from Federal RePORTER.

**Approach – UVA SDAD Data Science Framework**

Data Wrangling:
Deduplicated, cleaned & processed abstracts to prepare for their use in topic modeling.

Statistical Modeling & Analyses:
Found an optimal topic model, identified emerging topics, designated topics as 'hot' or 'cold', & conducted a case study on emerging topics in pandemic related research.

Approach – UVA SDAD Data Science Framework

Ethics:
Did not collect/utilize any individual or demographic data, recognized that our dataset only included federally funded grants within the US and implicit bias in research funding could affect the topics represented in the dataset.

Data Source

• 2008-2019
• Over 1 million grants from multiple agencies, i.e., DOD, ED, EPA, HHS, NASA, NSF, USDA, VA
• Includes grant abstracts and metadata

Federal RePORTER
Topic Modeling

• Unsupervised machine learning technique for grouping text data into themes

• A topic is a list of words clustered together by the algorithm that should share semantic relationships

  • Example topics:

    aging  management  imaging
    age      soil       image
    older    crop       mri
    adult    production  resolution
    related  agricultural  optic
    decline  practice   mr
    life     pest       pet
    aged     farm       contrast
    lifespan economic   micro
    cognitive farmer    probe
Data Preparation for Emerging Topics

- We needed to:
  - fill in missing information for project start date
  - decide on a deduplication strategy for dealing with duplicate abstracts in the corpus, and
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Dataset after Deduplication

• 690,814 abstracts for unique projects

Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations
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Topic Modeling using Non-negative Matrix Factorization (NMF)

- Linear algebra technique that can be used for clustering groups of words into topics

Graphic Source: Dynamic Topic Modeling via Non-negative Matrix Factorization by Dr. Derek Greene, slide 6.
We do not know the number of topics in advance, so we tested a number of topic models in order to find an optimal model.

Measure for “goodness of fit” for topic models: $C_v$ Topic Coherence
Tuning the Number of Topics

• Single topic model runs on the full dataset – sample results
• The best model of these is an NMF topic model with 75 topics.

Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations
Tuning the Number of Topics

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Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations
Optimal Topic Model Results

Measuring the percentage of documents in which each topic occurs

- Full dataset
- NMF - 75 topics

Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations
Optimal Topic Model Results

Measuring the percentage of times each topic was “dominant,” i.e., the topic with the highest weight for a document.

• Full dataset
• NMF - 75 topics

Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations
Emerging Topics Method

• Using our optimal topic model, an NMF model with 75 topics, we analyze its results to discover and characterize 'hot' and 'cold' topics.

• We follow the approach of [2] using our optimal NMF topic model. We also use the work in [3] as a reference.

• To categorize a topic as “hot” or “cold”, we
  1. Find the average weight of each topic in each year between 2010-2019.
  2. Model the relationship between the average weights and years for each topic using linear regression.
  3. Topics that have regression lines with positive slopes are considered ‘hot' and those that have regression lines with negative slopes are considered ‘cold'.
Emerging Topics Results

Full dataset, NMF - 75 topics

Top Five Hottest Topics

Top Five Coldest Topics

Note: “cold” topics can still be popular, but just trending downward in prevalence

Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations
We explore emerging topics around the research areas of pandemics and coronavirus.

1. We use information retrieval techniques to create two smaller corpora: one that focuses on pandemics, and one that focuses on coronavirus.

2. We use an NMF topic model of 30 topics on each smaller corpus and conduct the emerging topics analysis.

### Smaller Corpora Sizes

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<td>Coronavirus</td>
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Data Source: [Federal RePORTER](https://www.frpt.gov/), 2008-2019, University of Virginia, Social and Decision Analytics Division computations.
Case Study Results – “Pandemic” Corpus

Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations
Case Study Results – “Pandemic” Corpus

NMF - 30 topics

Top Five Hottest Pandemic Topics

Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations

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Case Study Results – “Coronavirus” Corpus

Top Five Coldest Coronavirus Topics

---|---|---|---|---|---|---|---|---|---|---
n  | 89  | 74  | 71  | 69  | 62  | 80  | 89  | 51  | 45  | 30

Data Source: Federal RePORTER, 2008-2019, University of Virginia, Social and Decision Analytics Division computations
Takeaways

• We discovered that emerging topics methods can give the user valuable information about the popularity of topics over time and current research trends.

• We implemented topic modeling for specific areas of interest:
  • We combined a search engine strategy and topic model
  • This can quickly give users a “deeper dive” into a specific area
  • Allows for finer grained topics

• Our dashboard provides results and documentation for the project: http://rnd.policy-analytics.net/ (temporary link)
Next Steps

• Assess whether the slopes of each topic trend line are significantly different from 0.
• Quantify uncertainty around topic model results.
• Investigate hierarchical models and how we may integrate them into our research.
• Begin researching methods for statistically aggregating results from multiple topic model runs.
Acknowledge our Data Science for the Public Good Students

Lara Haase  
Graduate Fellow  
Lara is pursing a Masters of Science in Public Policy & Management - Data Analytics at Carnegie Mellon.

Martha Czernuszenko  
Intern  
Martha recently graduated from The University of Texas where she studied Information Systems & Business Honors.

Liz Miller  
Intern  
Liz is an incoming senior at William and Mary where she studies International Relations & History.

Sean Pietrowicz  
Intern  
Sean recently graduated from Notre Dame where he studied Applied Computational Math & Statistics.
References


Other references are on the dashboard