Vectors of Research and Teaching Across Universities in the USA

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Abstract

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1 Introduction

The relationship between research and teaching in universities has long been questioned, either from a policy perspective (uz Zaman [2004]), or in the field education research (Hattie and Marsh [1996], Hattie and Marsh [2004]). The consensus has largely been that research and teaching in universities are *not* intimately related, at least in terms of performance of the professors and teachers - success in research does not necessarily indicate success in teaching, or vice versa.

However, most of the questions have largely been focused on the researchers themselves and less about the *kind* of research being done, at the level of universities or cities. A qualitative enquiry into this is incredibly difficult, needing one to closely look at ways research and teaching across departments at universities are being conducted.

Access to large datasets of research and teaching allows us to begin to start asking more complex, larger questions: how similar are research and teaching *within* universities? And how similar research and teaching *between* universities? Apart from the relationship between research and teaching, it is also possible to probe the relationships of research between universities, as well as the relationships of teaching between universities.

To be able to do this, we need to be able to organise these datasets to be *able* to answer these questions, as well as a framework to measure similarities of research or teaching. To do this, I gather large amounts of textual data on research *output* and teaching *intent*, and vectorize them using word embedding techniques.

The data section discusses how I have prepared and organised the data to be able to vectorise them. This was a crucial part of the analysis and project, and allows us to use word embedding methods which can later be used for comparative analysis, which is described in the methods section. The results section describes the information which these vectors can give us about the research and teaching across universities in the USA.

2 Theory

Previous work has largely been to address the relationship between the *performance* of professors teaching and conducting research. The metrics to measure this has been teaching reviews, and research output, while some

studies measure the time spent on preparing for teaching and time spent on research. The papers by Hattie and Marsh (Marsh and Hattie [2002], Hattie and Marsh [2004], Hattie and Marsh [1996]) largely find no correlation between research and teaching, and other studies (Ramsden and Moses [1992], uz Zaman [2004]) conducted across Australian and British universities confirm this. Qualitative studies (Smeby [1998]) suggest that while professors themselves might believe research and teaching are intimately related, performance metrics suggest they are not.

All of this literature suggests that the question of the links between research and teaching are an important question in education research and science of science, but the methods used to probe it, as well as the *intention* of the research are not about patterns of research and teaching across universities. The few which might touch upon the topic use highly qualitative frameworks - the Schimank and Winnes [2000] paper, for example, uses what they describe as a pre-Humboldtian, Humboldtian and post-Humboldtian distinction, where a Humboldtian approach was to being research into universities without displacing teaching. It is largely policy related, and again, doesn't begin to describe the *kinds* of research or teaching being done. Indeed, one of the first points noted in the paper is that the lack of quality data makes that kind of probe very difficult to do.

Now, however, we are beginning to have access to the kind of data previous researchers could have found invaluable. I use this opportunity to begin to probe a new, quantitative way to measure *general* trends and relation-

ships among research and teaching, instead of measuring personal outcomes of research and teaching performance.

3 Data

I use two separate data sources to conduct my analysis - one to identify research output, and the other to identify teaching intent.

3.1 Research Output

To measure the research outputs of universities, I use the widely popular Web of Science dataset Reuters [2012].

Some quick facts about the dataset:

- The database contains publications from 1900 to 2015.
- The publications table contains 57 Million records.
- The references table contains 1.08 Billon records.

While there are a couple of ways to access the dataset online, the massive size makes it very difficult to easily mine. I will be accessing the dataset through the Knowledge Lab at the University of Chicago, where the dataset, in both raw XML and in a SQL database form, is stored on Cloud Kotta, an online platform for managing data.

Accessing the data through Cloud Kotta requires me to create an instance of Cloud Kotta, which I do through Turing Compute, also set up through the Knowledge Lab.

Once I have access, I am able to use SQL queries to access the dataset through the Bastion interface. The massive dataset size means that it is wiser to start accessing the data year by year before joining it, or by accessing a smaller sub-set of the dataset.

The most important parts of the WoS dataset for the purpose of my research are the abstract, the city, and the organisation affiliated with the research paper. The abstract allows me to aggregate research papers for each city and for each organisation.

Using the PyMySL package, I use a python script to extract the WoS ID, the abstract, the year the paper was published, the state and city it was published in, and the organisations affiliated with the authors of the paper.

The dataset contains articles published all across the world; for the purpose of my study I only extract papers which have been published after the year 2006 and in the United States of America. It should also be noted that because each abstract is linked to both a university and a city, I am able to create both university and city vectors of research. The data I have extracted from the dataset is a total of 29 GB.

3.2 Teaching Intent

A similar approach is taken for teaching intent - I use syllabus data for cities and organisations. The data has been collected and organised by the Open Syllabus Project, undertaken by researchers at Columbia University. It is an ongoing project, and has received a fair amount of attention from the press (Nature, Digital Science), and proves to be a promising way to measure what is being taught at universities across America (and the world). While 3rd party access to the dataset is not publicly available, through the Knowledge Lab I have access to the JSON dump of the open syllabus project, until 2018.

Using a python script I have extracted the contents of the syllabus, the year the course was taught, the state, the city and the organisation affiliated with the course. The data itself is patchy, and for the current study, to compare the research and the syllabus output of cities and organisations, I have extracted syllabi of universities in the United States of America, from the year 2006 onward.

Similar to the way I have aggregated data from the WoS dataset, syllabi are associated to both cities and universities.

3.3 Matching Data

The WoS database and the open syllabi project are quite different in the level of pre-processing, in IDs, and in the way universities and cities are made. To make sure I am correctly matching universities across the two databases, I

have written a script which regularises the strings across both the data-sets to a common representation, and use string similarity to match the names. There are a total of 1782 universities which perfectly match across both the databases, and I will be using these universities to conduct my analysis.

4 Methods and Models

Now that I have textual data organised by city and universities, it is possible to start thinking of a framework which will allow us to explore similarities between research and teaching within/between universities.

Textual similarity is a problem with many solutions, ranging from a bag of words, TF-IDF or jaccard similarity match, but these prove to be inefficient when dealing with larger documents. Also, since we are interested in aggregating the texts for each city, merely appending all texts associated with an institution or city would not be the best idea.

Here, vectorization of documents start to become a good idea. By vectorizing documents we can play around them more easily. Aggregating all the documents in an entity (an university, research organisation or city) could become merely adding all the document vectors associated with an entity, and we can also define the vector associated with such an entity as the mean of all the document vectors of that entity.

We can create these vectors associated with the entities by using word embedding methods.

4.1 Creating Entity Vectors

The module developed allows us to use any kind of text vecrtorisation method, and any kind of aggregation method. Since we are interested not in just the count of words (using bag of words, TF-IDF), or in topics (topic model vectors of documents), a word embedding method such as Word2Vec or Doc2Vec which use semantic information will be very useful.

Word embedding algorithms use large collections of text and output a n-dimensional vector-space model in which each unique word is represented as a vector in a vector space. By using the location of a word in a document relative to the other words in the document, it is possible for us to capture the context - words are usually given meaning by the company they keep, and this method soon becomes an efficient way to capture meaning in text. Research has shown that words frequently share linguistic contexts, and thus those words which are located nearby in the vector space tend to share similar meanings.

The first step in creating an entity vector would be to vectorise all the documents associated with that entity. In our case, entities are universities, so we create our university vector by simply finding the mean of all the document vectors associated with that university. I run this algorithm for all the universities associated with the research and teaching datasets.

I have created 2877 university research vectors and 2122 university teaching vectors. 1782 Universities have both research and teaching vectors. Since it would be interesting to see Research-Research relationships, Teaching-

Teaching relationships and Research-Teaching relationship, we will be using the 1782 universities with both research and teaching vectors, as we can have all of the above vectors available.

I use cosine similarity, and the subsequent angle between the vectors to understand the similarity between the vectors.

Again, it should be noted that any vectorisation method can be theoretically used, any vector similarity measure can be used.

5 Results

I will be using the angles between the research and teaching vectors to describe the relationship between them. This will form the crux of my current analysis, though it should be noted that the vectors themselves can be used for a variety of other analyses, some of which I will outline in the Future Work section.

Our research and teaching vectors allow us to calculate similarities/differences between the universities associated with those vectors. I use three different vector relationships:

- Research-Research angles
- Teaching-Teaching angles
- Research-Teaching angles

The research-teaching angles can be further broken into between university angles (for different university pairs), and within university angles (for the same university).

For the purpose of illustrating the utility of this framework, I have used 3 different subsets of the universities dataset. Out of these, one set contains 10 randomly sampled universities, 9 randomly sampled medical or health universities, and 10 community colleges.

The 10 randomly sampled universities are John Hopkins University, Rutgers State University, University of Chicago, University of California at Los Angeles, University of Toledo, University of Notre Dame, Georgetown University, Harvard University, Iowa State University, and San Diego State University.

The 9 randomly sampled medical or health universities are Oregon Health and Science University, Medical College of Wisconsin, University of Arkansas Medical Center, University of Nebraska Medical Center, Eastern Virginia Medical School, New York Medical College, Western University Health Science, SUNY Upstate Medical University.

The 10 randomly sampled community colleges are Flathead Valley Community College, Quinsigamond Community College, Community College Rhode Island, Borough Manhattan Community College, Anne Arundel Community College, Tacoma Community College, Nassau Community College, Florida Community College, Kingsborough Community College, Roane State Community College.

5.1 Research-Research

The average angle between research vectors is **57.62**°

5.2 Teaching-Teaching

5.3 Research-Teaching

6 Future Work

7 Conclusion

References

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