

# OpenAlex Award Data Integration

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## 1 Introduction

### 1.1 Problem

The problem of data integration stems from the main issue of record linkage in order to establish relationships between new table and existing schema. There first needs to be a definition of how the table will relate to the existing schema and through which data point a join on tables may be done. Record linkage however becomes much more difficult when the data set to be integrated was formulated and maintained by a source different to the source maintaining the larger database. Therefore, a data matching algorithm must be created to be run on the defined data point to find the most relevant record. Data integration is a difficult problem and requires patience and precision to ensure appropriate data integrity.

### 1.2 Importance

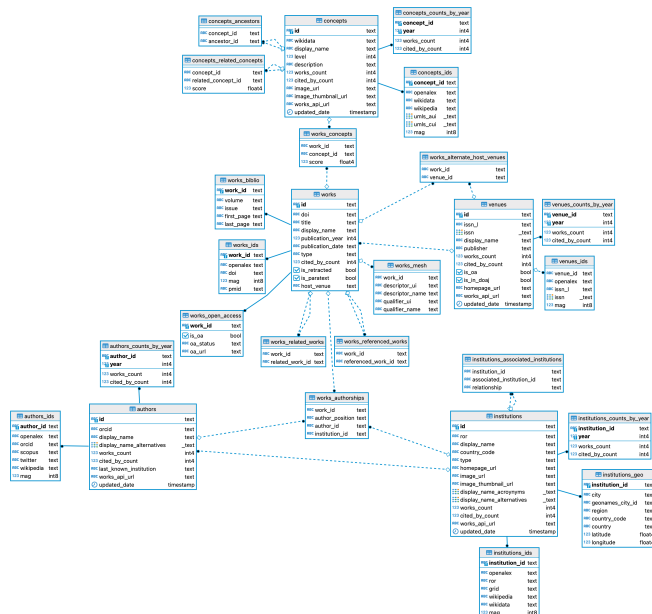


Figure 1: Open Alex Schema

In order to enrich our previously created Academic Database, I was assigned to integrate award data by creating an awards table and formulating relationships to other tables. The awards table should be able to appropriately

connect with institutions, authors, and funders. Specifically, the last known institution, primary investigators, and sponsors columns of the award table should allow for connection to the rest of the OpenAlex schema.

Finding connections to the rest of these tables will allow for these institutions, authors, and sponsors to receive credit for the award they received. Integrating this data will also promote better understanding of the academic landscape. Analysis can be done in order to determine why a specific work received an award. If this can be determined then, it may be better understood how to develop better, more relevant research. Funders, Institutions, and Authors may be able to recognize which fields of study are important to analyze, which can lead to funders and institutions sponsoring more projects in that field of study. Authors may also begin to gravitate to publishing more work in those fields.

The integration of award data is a difficult and complex task, but will further develop the academic database's potential usage and promote academic analysis.

### 1.3 Difficulty

Data integration is a difficult mainly due to the structure of the data in the award data set and the OpenAlex database. Award data has not been kept under strict standardization which allows for hundreds of different variations of name structure for the primary investigators. There are null values, name placeholders, and complicated naming structures all integrated into the primary investigators column. Preprocessing of this data needs to be done in order to enforce a strict naming standard which allows for easier data matching.

Issues also arise within the OpenAlex database where there are many duplicated records which have been deleted but remain in the database or records exist of authors with their last known institution being a previous institution in their timeline. Also authors in OpenAlex have many different versions of spelling the same author. There is also no naming stan-

dard for authors names, which requires to me to enforce the same standardization to the names in OpenAlex to the ones within the awards data set. This issue within the database increases the difficulty of finding records in the data matching algorithm, because many different authors may be matched up to an award record and then a decision needs to be made in order to select the best match.

The most significant difficulty of this project is the number of records that exist within both data sources. There are 2 million award records and around 300 million authors in OpenAlex. Linearly searching for the best data match would make the algorithm to have a quadratic time complexity which will take a very long time given the large quantity of records. Optimizations need to be made in order to reduce searching through all records or to reduce the time complexity of the algorithm.

Finally, a decision needs to be made on how to determine which record is the best match for any given award record. This problem is one of name matching which is one that has been encountered and solved for many years and in many different projects. It is important to decide which one of the methods is the best one in order to be able to create the best matches with the available data, and capable feature engineering.

## 1.4 Previous Solutions

Data integration is a complex problem that has many moving parts and a variety of sub-problems. In the past, work has been in order to make this process simpler and successful. My goal with this project was to take the a combination of works and compile them into my own solution that would work well with this problem.

Ideally, I would have worked to use previously built API's or modules to link the records, but many times these would not be kept up to date and would have required in-depth analysis to be able to fix or understand the undocumented code. Instead, I created my own solution based on the logical steps that other developers/researchers have taken in order to solve this problem.

After doing in-depth research on the problem of data integration, a pattern seemed to emerge from the presented solutions. Each solution pre-

sented the following sub problems:

- Data Normalization/Standardization between disparate data sets.
- Data Deduplication to prevent false positives
- Feature Engineering to select most important parts of a name.
- Data Indexing/Filtering to reduce unnecessary similarity calculations.
- Matching Function based on well-known name similarity algorithms.

These five key steps were discussed in many other problems were what I used in order to structure my work in this project.

## 1.5 My Approach

After determining the general pattern in order to be able to match records together, I decided to formulate my own version of this solution that will suit the needs of my problem. It was very difficult to exactly replicate other developers solutions to this problem, due to the reason that the data was inherently different. There were different edge cases that they needed to handle which were not present in mine, and my data had features which at times required more complicated preprocessing. Overall my solution is complicated, requires many moving parts, and still requires further development to optimize:

- Extract raw award data and store into local database.
- Retrieve data from local database, perform data normalization to handle all cases, build a conformed layer of data to store normalized data.
- Perform feature/data engineering on the conformed data to determine most relevant features to index data.
- Build indexes on display name column data in the Open Alex database to be able to retrieve and manipulate data faster.
- Generate a timeline for each author to be able to further index authors that have their last known institution to be one in the timeline of the given author.

- Build a weighted equation of values calculated through a variety of name similarity algorithms: n-gram, soundex, metaphone, double metaphone, and levenshtein distance. These algorithms were apart of modules installed directly to the PostgreSQL schema.
- Generate a SQL query to send to our Open Alex database to retrieve the most similar data with the appropriate filtering conditions and similarity matching equation.
- Retrieve most similar author and store within a mapped authors data source. This is where data deduplication can then occur, and a table can be created to be able to join the awards table to the rest of the Open Alex schema.

## 1.6 Key Results

As a result of the detailed approach to solving this data integration problem, I was able to build a data matching algorithm capable of finding the correct match 95% of the time. This calculation was generated by mappings of authors where the found records have a name similarity of above 90% and the institution of the author existed within the timeline of the award data.

These results were also generated on set of 5000 authors in the award data. This is a smaller number because it takes about 5-7 minutes for the timeline to be generated for authors. This is the most significant bottle neck in my algorithm. Once the timeline is generated, an author will statistically always be found. Improving the run time of this algorithm will allow for faster data linkage and a final table can be created to be integrated into the database.

## 2 Related Work

The main related works that inspired my solution for this project were a variety of different works that focus on data integration. Many different developers and researchers have worked on this problem and have discovered a set of steps to take in order to appropriate record linkage. From the beginning of the semester, I researched novel methods in order to match up names together. The main method that appeared from

this matching was one of fuzzy name matching. Fuzzy name matching is the principal used to use different features and structures of a name to detect the most similar name.

The main algorithm that I used in order to be able to detect the most similar name in a database was using tri-gram similarity which was presented in a work created by Peter Gleeson. Gleeson presented a method of using a PostgreSQL extension by the name of pg-trgm. This extension is able easily execute and generate all groups of three consecutive letters in a name. Which can be used then to detect similarity between that of another string. Statistically, proven by Josh Taylor, the n-gram similarity tool can easily match up names together with high percentage of correct matches.

The secondary algorithm that I am using in combination with the tri-gram similarity is the double metaphone algorithm. The double metaphone algorithm was first conceived over a hundred years ago, and was created in order to effectively index the English language. In the case of my problem, I was able to easily use PostgreSQL's extension fuzzystmatch. This extension has a version of the double metaphone algorithm which I can use to generate metaphones for a name and compare them.

List of works:

- <https://www.freecodecamp.org/news/fuzzy-string-matching-with-postgresql/>
- <https://towardsdatascience.com/python-tutorial-fuzzy-name-matching-algorithms-7a6f43322cc5>
- <https://towardsdatascience.com/fuzzy-matching-at-scale-84f2bfd0c536>
- <https://medium.com/bcggamma/an-ensemble-approach-to-large-scale-fuzzy-name-matching-b3e3fa124e3c>
- <https://towardsdatascience.com/fuzzy-matching-people-names-6e738d6b8fe>
- <https://medium.com/compass-true-north/fuzzy-name-matching-dd7593754f19>
- <https://www.crunchydata.com/blog/fuzzy-name-matching-in-postgresql>

### 3 Solution

My solution for this problem of data integration is one that is complex and contains several moving parts in order to achieve accurate data linkage. Below you can see the architecture of the solution, and can observe how each part of the module interacts with each other. This solution is not final, but it does cover the five main aspects developers generally take in order to complete the assignment of data integration. The benefit of this design is that it is able to be scaled up and easily changed to be able to be further developed.

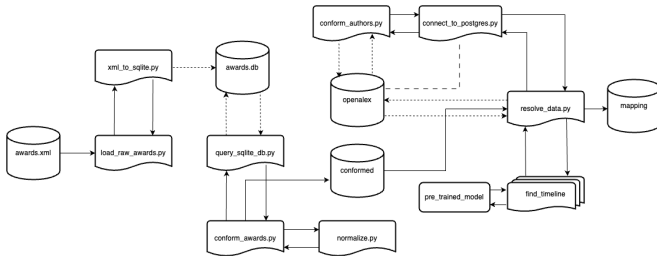


Figure 2: Solution Architecture

#### 3.1 Detailed Explanation

Data is initially loaded from the awards.xml file using a lxml parser and a sqlite database, awards.db, is created for this data in order to ensure rapid data access. Now that this data is located in quick access storage, the data needs to be conformed in preparation for the matching process. There are a variety of different patterns that appear within the names of the primary investigators of the raw award data. Enforcing strict rules, FIRST MI LAST, for standardization of names within the award data will ensure for quicker and easier record linkage, specifically due to data filtering and then name matching. Once the names are standardized, they can be moved into the conformed data source.

Before the data matching process can begin, however, some preprocessing on the institution name needs to be done in order to properly filter out names in the algorithm. In conform authors, a connection to the OpenAlex database is created to be able to retrieve data on the institutions. Currently in our OpenAlex database, the authors last known institution is made up of a url. In order to use the institutions name, we can pull the data and use the OpenAlex API to retrieve the name for each of these institutions. Then we can make a new table that contains the

name for all of these institutions. This can further benefit future projects by allowing tables to join and retrieve new information. Conform authors builds this table to then be used when records are being filtered out based on the intuitions generated in the timeline.

Then the resolve data file picks up the conformed data to begin the data matching process. In this process, resolve data iterates through each of the conformed names conducts the following steps: generates author timeline, filters out records using timeline data and display name information, and finally uses a combination of tri-gram similarity, soundex, double metapone, metapone, and levenshtein distance to find the most similar author. Once the most similar author is found then it is placed in a mapping data source which will then be used to generate another dimension table to join the awards table to the authors table.

### 4 Results

The data matching algorithm is the most integral aspect of this module as it generates the PostgreSQL query needed in order to find the most similar matches for each of the principal investigators found for each of the records in the award data.

Using the timeline generation algorithm and name feature/data engineering, I was able to reduce the number of linearly search through authors by millions. This allows for the algorithm to quickly search through the most probable authors and determine the most similar one.

The overall results of this algorithm are as follows:

- Matched Authors Accuracy (5000 Authors): 95%



Figure 3: Mapped Authors

- Average Time to Match: 6 minutes



Figure 4: Query Result

These results are not perfect specifically due to the time bottleneck in building a timeline for each author instead of having that information previously stored to use during the query. Overall this module still needs work to be able to reduce the run time of the algorithm, but as we see it with the small subset of authors the algorithm is working accordingly. I have also gone into to look into the results and analyze the matches by reviewing the works published by the matched author to determine if the awarded work existed within these works, and it did.

## 5 Future Work

The current state of the module is still not at a point that is complete. There are still further developments and iterations that this needs to go through in order to ensure that the most accurate data is being retrieved in order to perform the data linkage. OpenAlex is currently in the process of rolling out a new updated database in 2023, which is a lot more normalized and much of the unnecessary data will be removed. This will make it easier to be able to retrieve the appropriate information and potentially decrease the processing time of matching authors.

Work also needs to be done in order to decrease the processing time of the algorithm. Once this can be completed then the process of matching up data will be much faster and more complete. At that point we can make a better definition of the accuracy of the module, and

can build a accurate table that easily integrates to the OpenAlex Schema.

The module is at a point where it can accurately link records, but it needs to be done in a reduced time to be able to handle the mass amounts of data.

One potential weak point of the query processing time is one where there are many full-text searching. There needs to be a way to be able to remove searching through each of the characters of a string each time. This could possibly lead to developing some hashing algorithm to more quickly determine matches.

Finally, one more area to look into for data match validation is to be able to look at the works cited by the author and check if the project that was given the work exists in this work. This will then ensure that data is completely and accurately matched.

## 6 Conclusion

The task of data integration of disparate data sets requires data normalization, data preprocessing, feature engineering, data engineering, fuzzy name similarity matching, and data filtering for optimization. All of these parts are integral in order to quickly find a match for data records and build a table that can seamlessly join to other tables in the database.

Integrating this award data will allow for the database to be enriched with more information to be able to further understand the academic landscape. We can determine which authors have received the most awards and for what reason. We can determine trends in research to determine the next major advancement in technology. Overall, we can retrieve a lot of important information from these awards, so it is important to be able to accurately and carefully integrate the data into the academic database. My intricate solution to completing this task is not complete, but is currently in a state where we can easily move forward and continue to optimize.