A novel feature engineering algorithm for air quality datasets

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Article Info

ABSTRACT

Feature engineering (FE) is one of the most important steps in data science research. FE provides useful features to be used later in the study. Due to climate change, the research focus is moving towards air quality estimation and the impacts of air pollution on health in Malaysia. Malaysia has 66 air quality monitoring (AQM) stations, and the air quality data for research is provided in an excel worksheet format by the Department of Environment, Malaysia. The data generated by the AQM stations is in a raw custom format, and it is virtually impossible to clean and engineer this data manually due to the sheer number of files. Hence, we propose a novel feature engineering algorithm to transform and combine this data into a useable format. The results show that the proposed feature engineering algorithm was able to efficiently extract and combine the hourly and daily values for pollutant and meteorological variables in useful row format. This algorithm will help all the researchers using the data from the AQM station in Malaysia as well as other countries using the same AQM station. The implementation of the feature engineering algorithm is also available to use at GitHub (https://github.com/rajasherafgun/featureengineeringaq) under AFL-3.0 license.

Keywords:
Air pollution
Air quality
Air quality monitoring station
Data cleaning
Feature engineering

1. INTRODUCTION

Feature engineering is one of the most critical tasks performed by data scientists and researchers in general. Feature engineering provides good features, giving the flexibility to choose between various algorithms. The flexibility of choice means less complex algorithms will provide good accuracy with good features [1]. Hence, on average, data scientists spend 80% of their time collecting, capturing, cleaning, and organizing data [2]. Moreover, 75% of the data scientists report that cleaning and engineering data is the least enjoyable part of their work [2].

Feature engineering process can be applied to the data at any stage. It can transform raw data into useable data, as well as already engineered data into useable data for a specific task. The process of feature engineering consists of the transformation of collected/recorded parameters, generation of new parameter values from available features or patterns, extraction of features from raw data, selection of features based on a specific criteria, analysis and evaluation of the usefulness of features and automated methodologies for generating and selecting features [3]. Another definition of feature engineering is to use a data mining algorithm to extract features from raw data using domain knowledge [4]; hence, classifying feature engineering to be a domain-specific process. Feature engineering is applied to virtually every field, including image processing [5], signal processing [6], natural language processing [7], estimation, and prediction, among others.

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Recently, climate change has forced researchers to study air pollution and other major causes of climate change. The air quality data is collected using various devices and air quality monitoring (AQM) stations. The air quality monitoring in Malaysia was carried out through a private company known as Alam Sekitar Malaysia Sdn Bhd (ASMA) until recently. ASMA was appointed by the Department of Environment (DOE), Malaysia and the Malaysian Meteorological Department (METMalaysia). ASMA was responsible for collecting, processing, analyzing, and distributing the air pollutant measurements. There are 66 AQM stations across Malaysia, 14 Manual Sampling (High Volume Sampler) stations were operated by METMalaysia, and ASMA [8] operated 52 continuous air-quality monitoring (CAQM) stations. The DOE has increased the number of CAQM station to 68 [9]. The location-wise details of the CAQM stations are provided in Figure 1. Under the new Environmental Quality Monitoring Programme (EQMP), the DOE is closely monitoring the environmental parameters. The new system provided by private contractor Transwater gathers and stores real-time data on river, sea, and air conditions.

![Figure 1. Air quality monitoring stations in Malaysia](image)

Air pollution is the driving force behind climate change, and it is considered to be one of the biggest environmental challenges faced by humanity in the 21st century [10]. The primary motivation behind air pollution studies is the health impacts involving air pollution. The air pollutants have a severe and harmful effect on health, and it has become a serious global threat to human health and welfare [11]. In Malaysia, the rapid economic growth and the commitment to achieve the industrial country status under Vision/Wawasan 2020 has contributed to the degradation of the urban environment and air quality. Industrialization and haze episodes combined, the air pollution has turned from bad to worse in recent years [12]. The air pollution in Malaysia is affecting ecosystems, forest species, agricultural crops [13], and human health [14].

Apart from the motivations to study air pollution, the motivation to propose this feature engineering algorithm is the sheer amount of information in data generated by AQM stations. The AQM station data is recorded and exported in excel worksheet format every month. The data is presented in a custom format by the AQM station reporting system, therefore, it requires a custom solution or manual work to clean and process. For every year, 12 excel worksheet files are generated with 23 sheets in each excel worksheet. With 66 CAQM stations in Malaysia, it makes 18,216 sheets in 792 excel worksheets for one year only. This feature engineering work is part of a research project which is using 11 years of data from CAQM stations, with 156,170 sheets in 6,790 worksheet files. This makes it virtually impossible to do feature engineering manually as it will take a considerable amount of time and effort to get this data in a simple row format. Due to these hurdles and challenges, we propose a novel feature engineering algorithm to engineer the data provided by AQM stations to a usable form. Recently, the data generated by AQM stations is being used in various research studies to forecast air pollution, study seasonal variation and spatial distribution of air pollution, the trend analysis and mitigation of air pollution, and the economic and health impacts of air pollution. The details of these studies are provided in Table 1.

The main contribution of this paper is to provide a novel feature engineering algorithm for researchers working in the domain of air pollution. The proposed algorithm takes all the files as input and provides usable CSV files efficiently. This algorithm will help all the researchers using the data from the AQM station in...
Malaysia as well as other countries using the same AQM station. The rest of the paper is organized as follows: In Section 2, presents the data used as input for our study and the feature engineering algorithm. Section 3 includes the results, discussion and future work, and lastly, conclusions are presented in Section 4.

### Table 1. Studies using DOE air quality data 2010-2020

| Study Year | Aim/Objective | Location | Dataset Years |
|------------|---------------|----------|---------------|
| 2020 [15]  | Forecasting of Air Pollution Index (API) | Cheras, Kuala Lumpur | 2012-2017 |
| 2019 [16]  | Identification of main challenges in ozone mitigation | Petaling Jaya, Shah Alam and Cheras | 2012 to 2014 |
| 2018 [17]  | Evaluating the variability of air pollutants and meteorological conditions at Langkawi Island | Langkawi | 1999-2011 |
| 2018 [18]  | Investigating the level of PM10 due to seasonal variation in Sabah | Sabah | 2012 |
| 2018 [19]  | exploring the concentration of air pollutants in monsoon season | Kedah | 1999-2011 |
| 2017 [20]  | Prediction of spatial variation of Air Pollution in Johor | Pasir Gudang, Johor | - |
| 2017 [21]  | Description of Air Pollution concentrations in Klang Valley | Klang City | 2012-2014 |
| 2017 [22]  | Spatial distribution of concentration of Ozone | Shah Alam, Kajang, Petaling Jaya and Port Klang | 2014 |
| 2016 [23]  | Investigates the variability of PM2.5 in industrial Location | Klang Valley | Aug. 2011-Jul |
| 2015 [24]  | Detection of daily PM10 concentration | Klang, Kuala Selangor and Petaling Jaya | 2005-2010 |
| 2015 [25]  | Investigates the trend of Air Pollution in Klang Valley | Klang Valley | - |
| 2015 [26]  | Detect changes of Air Pollution and its impact of on human health | Selangor | 2013 |
| 2014 [27]  | Explores the effects of haze days on daily mortality in Klang Valley | Klang Valley | 2000-2007 |
| 2014 [28]  | Predicts the concentrations of Air Pollution in Malaysia | Pasir Gudang, Kuching, Bukit Rambai, Tasek, Nilai, Klang, Balok Baru, Pengkalalan Chepa, Paka, and Labuan | 2005–2011 |
| 2014 [29]  | Predicts Air Quality Index using Artificial Neural Network and Multiple Linear Regression | Pasir Gudang, Bukit Rambai, Nilai, Johor Bahru, Bachang, Muar, Seremban, and Tampoi | 2005–2007 |
| 2014 [30]  | Assessed the economic value due to haze related illness | Kuala Lumpur | 2005, 2006, 2008, 2009 |
| 2013 [31]  | Describes spatial and temporal variation of Air Pollutants | Petaling Jaya, Malacca city centre and Kuching | 2000–2010 |
| 2013 [32]  | Evaluates the variability of ozone level in Malaysia | Seberang Perai, Pulau Pinang Jerantut, Pahang Bakar Arang, Kedah Kajang, Selangor | 2009 |
| 2012 [33]  | Influence of meteorological conditions on a daily PM10 and NO2 pollutants | Shah Alam, Johor Bahru, and Kuching | 2007-2009 |
| 2012 [34]  | Description of Air Pollution changes in Klang Valley | Klang Valley | 2001-2009 |
| 2012 [35]  | Explores the costs and benefits of Foreign Direct Investment (FDI) in the Malaysian Location | - | - |
| 2012 [36]  | Concentration and variability of ozone in Klang Valley | Klang Valley | 2004-2008 |
| 2012 [37]  | Examines the spatial patterns and sources of Air Pollutants in Malaysia | Kuching, Sibu, Kota Kinabalu and Tawau, Klang, Shah Alam, Ipoh and Johor Baharu | 2008-2009 |
| 2011 [38]  | Relationship between the changes of PM10 in monsoon season in Klang Valley | Klang Valley | 2003-2006 |
| 2011 [39]  | The trend of Air Quality | Kajang, Nilai and Banting | 1996-2006 |
| 2010 [40]  | The trend of Air Quality in Klang Valley | Klang Valley | 1997-2006 |

2. METHOD

2.1. Data

DOE, Malaysia provides the data used for input in this algorithm. The data is provided in a specific directory structure, as displayed in Figure 2. This feature engineering work is part of a research project which is using 11 years of data from CAQM stations, with 156,170 sheets in 6,790 worksheet files. Inside the files, the data is stored in a custom format. There are 23 sheets in each file. The first sheet contains a monthly summary of air contaminants. The other 22 sheets contain hourly readings and daily average for each air pollutant and meteorological variable. Table 2 provides the detail of these sheets.

The generated file names contain information about the year, month, and AQM station, as shown in Figure 2. This filename structure is advantageous because it helped to extract the information by year, month, and AQM station.

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Table 2. Sheet & variable details

| Sheet# | Variable Name          | Sheet# | Variable Name        | Sheet# | Variable Name                                                                 |
|--------|------------------------|--------|----------------------|--------|-------------------------------------------------------------------------------|
| 1      | Monthly Report Summary | 9      | NO₂                  | 17     | SO₂ API                                                                      |
| 2      | CO                     | 10     | Methane (CH₄)        | 18     | Total API                                                                    |
| 3      | CO 8 Hour Running      | 11     | NMHC                 | 19     | Wind Direction & Wind Speed xxM (uofM) Avg                                   |
| 4      | Ozone                  | 12     | Total Hydrocarbons   | 20     | Ultraviolet-B                                                               |
| 5      | PM₁₀                   | 13     | CO API               | 21     | Wind Direction & Wind Speed                                                 |
| 6      | SO₂                    | 14     | NO₂ API              | 22     | Humidity (%) Avg                                                             |
| 7      | NOx                    | 15     | Ozone API            | 23     | Wind Speed 10m Avg                                                           |
| 8      | NO                     | 16     | PM₁₀ API             |        |                                                                               |

![Figure 2. Directory & file name structure of dataset](image)

2.2. The algorithm

The feature engineering algorithm is designed to be generic as it has to handle multiple pollutants. The algorithm uses two data structures, `AirPollutionData` and `AirPollutionDataCombined`. `AirPollutionData` is used to collect hourly information about a variable, station wise and `AirPollutionCombinedData` collects the daily average of all variables, station wise. Station ID is a unique number that represents a station. The data structures are shown in Figure 3.

![Figure 3. Data structures used in algorithm](image)

The algorithm is divided into two parts, i.e., `LoadData` and `LoadDataFromExcel`. `LoadData` is the entry point of the algorithm, it takes all the file paths as input, and the output is engineered Comma Separated Values (CSV) files. `LoadData` is shown in Algorithm 1. The `LoadData` algorithm goes through all files, validates, extracts the information, populates appropriate lists and creates CSV files. It creates monthly CSV files for each station by combining the data in pollutant lists by date, hour, and station ID. It also creates a combined CSV file for all stations by combining the data in pollutant lists by date and Station ID.
Algorithm 1: Load Data

Data: All file names
Result: CSV files for Hourly and Daily air quality data

1. **Function** LoadData

   2. allFiles = Load all file names
   3. pollutantNames = Load all pollutant names
   4. **foreach** fileName in allFiles do
      5. if fileName[0] != 'T' OR fileName[1] != 'D' then
         6. continue;
      7. year = Get year from fileName;
      8. month = Get month from fileName;
      9. stationID = Get stationID from fileName;
     10. **foreach** pollutantName in pollutantNames do
         11. LoadDataFromExcel(fileName, pollutantName, listToSaveIn, stationID, year, month);
     12. end
     13. CombinedList = Combine all pollutant lists, join by date, hour and stationID
     14. Create CSV for CombinedList, join by date
     15. end
     16. Create CSV for DailyListCombined, join by date, stationID
     17. end

Algorithm 2: Load Data from Excel

Data: fileName, pollutantName, listToSaveIn, stationID, year, month
Result: Populate Hourly and Daily Lists

1. **Function** LoadDataFromExcel(fileName, pollutantName, listToSaveIn, stationID, year, month)

   2. DataRows = Load Data From File using fileName
   3. for i=1; i<=24; i++ do
      4. apObject = Read Hourly Values;
      5. end
   6. Add apObject to listToSaveIn
   7. if apObject exists in DailyListCombined then
      8. Populate pollutant information
   9. else
      10. Populate apObject with date, stationID and pollutant information
      11. Add to DailyListCombined
   12. end
   13. end

3. RESULTS & DISCUSSION

Air pollution is one of the significant causes of climate change. Air pollution poses a variety of challenges for humans, ranging from economic to health. Researchers nowadays are focusing on the research on air quality and its health impact. It is helpful that the air quality data is readily available in most countries. In Malaysia, this data is generated by AQM station in the form of excel worksheets. These excel worksheets contain hourly readings for all the recorded pollutants and meteorological variables. As this data is provided in a specific format, it needs to be engineered before it can be used in any research. As discussed in section 2, the sheer amount of information in these files need considerable time and resources to clean and engineer. The second part of the feature engineering algorithm is the part where we read the data and create two types of lists. The first list has hourly values for the pollutant, and the second part has the daily averages of the pollutant. It read the hourly data and saves in the respective list and then checks whether this data is already in the DailyListCombined, if it exists, it will update the entry with the pollutant value. If it does not exist, it will create a new entry in the DailyCombined List.

The algorithm will take the thousands of files from the dataset with custom format and extract, clean and combine the data into separate monthly useable CSV files with hourly values for the whole month. It also creates a combined file with all the data from all stations, all years and all months with daily averages. The example data is shown in Figure 4 and the example output is shown in Figure 5.

![Figure 4. Example CO monitoring data in excel workbook](image-url)
A novel feature engineering algorithm for air quality datasets (Raja Sher Afgun Usmani)

We propose a novel feature engineering algorithm to save time and resources. To give an example of the amount of feature engineering required to process air quality datasets, this study is a part of research project to find the health impact of air pollution, using the data from AQM stations. To extract the Air Pollution Index and major 6 pollutants i.e. PM_{10}, NO_{2}, NO, O_3, CO and SO_2. We have to go through 48,048 sheets to get hourly and daily averages. This will require a considerable amount of time and resources to engineer them into a usable form. Figure 5 shows the sample output of our algorithm. We also use CSV as our output format as it is considered to be a standard format, and no propriety software is needed to read, parse, and use a CSV. Also, the best advantage of CSV is that it is smaller in size and processed by almost all existing applications.

The CAQM stations used in Malaysia are a product of MET One Instruments, Inc. CAQM stations by MET One Instruments are used all around the world, and ASMA is the primary distributor of MET One Instruments in Malaysia [41]. Hence, the algorithm provided in this study is useful for air pollution researchers around the world. In this study, we found 27 studies using AQM stations data in the last 11 years only. Our feature engineering algorithm will help many researchers to save time and resources. The DOE has also increased the number of AQM stations. Hence, more data is available in a variety of locations in Malaysia for research.

This algorithm is designed to extract information about major air pollutants (PM_{10}, O_3, CO, NO_x, NO_2, NO, SO_2 and API) and meteorological variables (Ambient Temperature, Humidity), but it can easily be expanded to extract all the air pollutants and meteorological variables from all 22 sheets.

4. CONCLUSION
Air pollution is one of the biggest environmental challenges in the 21st century, and it has a substantial economic and health effect. As with the rest of the world, air pollution is becoming a significant problem in Malaysia due to industrialization, a huge trend of using private cars, and haze episodes. Due to these reasons, air pollution has become a significant research area for researchers in Malaysia. These researchers are using the air quality datasets provided by the DOE and powered by MET One Instruments, Inc. The sheer number of files and information in these air quality datasets are overwhelming. In this study, we propose a feature engineering algorithm to extract, clean, and combine these features efficiently. The provided algorithm will save time and resources for researchers using air quality datasets in Malaysia as well around the world. The implementation of the feature engineering algorithm is also available to use at GitHub (https://github.com/rajasherafgun/featureengineeringaq) under AFL-3.0 license.

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