IJCCS (Indonesian Journal of Computing and Cybernetics Systems)
Vol.18, No.1, January 2024, pp. 49~60
ISSN (print): 1978-1520, ISSN (online): 2460-7258
DOI: https://doi.org/10.22146/ijccs.88081

Rule-Based Natural Language Processing in Volcanic Ash Data Searching Application

Raden Rangga Kusuma Priandana*[1], Indra[2]
[1,2]Faculty of Information Technology. Universitas Budi Luhur, DKI Jakarta, Indonesia
e-mail: ***[1]1911502365@student.budiluhur.ac.id**, [2]indra@budiluhur.ac.id

Abstrak

Indonesia adalah negara dengan keadaan geografis yang cukup unik. Pertemuan tiga lempeng tektonik yang berlokasi di negara ini mengakibatkan kejadian bencana alam yang cukup sering terjadi, dari gempa bumi hingga aktivitas gunung vulkanik yang cukup banyak. BMKG merupakan badan pengawasan yang bertugas untuk memberi informasi terkait dengan bencana alam tersebut. Namun demikian, salah satu jenis data bencana alam tersebut, yaitu data SIGMET (Significant Meteoroligal Information) yang digunakan untuk memberi informasi abu vulkanik, memiliki format yang cukup rumit sehingga masyarakat awam sulit untuk memahaminya. Maka dari itu, penelitian ini berupaya untuk membuat pencarian informasi terkait dengan abu vulkanik dan letusan gunung berapi di Indonesia lebih mudah dari segi akses maupun komprehensi. Pada penelitian ini, akan dilakukan suatu perancangan aplikasi yang dapat melakukan pencarian data SIGMET dengan mengimplementasikan pengolahan bahasa alami dengan basis aturan produksi. Hasil penelitian memiliki tingkat akurasi sebesar 84% dengan menggunakan 25 kalimat sampel pengujian yang mengkombinasikan kalimat dan kata-kata yang terdapat dalam bagian kata-kata penting dalam program.

Kata kunci— *Pengolahan bahasa alami, aturan produksi, abu vulkanik, SIGMET*

Abstract

Indonesia is a country with a unique geography. The confluence of three tectonic plates located in the country results in frequent natural disasters, from earthquakes to volcanic activity. BMKG is a monitoring agency tasked with providing information about these natural disasters. However, one type of natural disaster data, the SIGMET data (Significant Meteorological Information) used to provide information on volcanic ash, has a complicated format that is difficult for ordinary people to understand. Therefore, this research seeks to make finding information related to volcanic ash and volcanic eruptions in Indonesia easier regarding access and comprehension. In this research, an application design that can search SIGMET data will be implemented by natural language processing with a production rule base. SIGMET data is collected manually from the BMKG Aviation website from January 1, 2023, to May 21, 2023. The research results have an accuracy rate of 84% using 25 test sample sentences that combine sentences and words contained in the essential words section.

Keywords—*Natural language processing, rule-based production, volcanic ash, SIGMET*

1. INTRODUCTION

Indonesia is a country that has many mountains scattered throughout its territory, from mountains in the main islands to those in the small islands. Indonesia's geography is shaped this way due to its location on the Pacific Ring of Fire [1], an area formed by the collision of three different continental plates: the Indo-Australian continental plate to the south, the Eurasian continental plate to the north, and the Pacific continental plate to the east. This is why Indonesia

Received August 16th,2023; Revised December 22th, 2023; Accepted January 4th, 2024

often has disasters such as earthquakes and volcanic eruptions that can take many lives and cause damage to Indonesia's infrastructure, which can affect the economic situation of the people [2].

To prevent loss of life and to anticipate these events, there is an agency that can monitor the geography of Indonesia called the Meteorology, Climatology and Geophysics Agency (BMKG). BMKG has many roles related to Indonesia's geographical conditions such as supervising, coordinating, facilitating, and providing information and services related to the fields of meteorology, climatology, air quality, and geophysics. This role is very important for the safety of the community so the dissemination of information must be carried out quickly and easily.

One type of disaster associated with Indonesia's geography is volcanic eruptions. Based on research conducted in 2017, active volcanoes will emit many types of hazards that can disrupt aviation conditions. The impact is quite diverse, ranging from interference with the pilot's view caused by the rain of ash and rocks by the eruption of the mountain to the materials contained in volcanic ash that can damage the components contained in the aircraft.

Information related to volcanic ash can be accessed on the official website owned by BMKG which focuses on aviation meteorological information (https://aviation.bmkg.go.id). The website provides data on volcanic ash in the SIGMET (Significant Meteorological Hazards) format. Searching for data can be done by entering the FIR (Flight Information Region) code or the desired flight area information code, then the SIGMET data will appear in detail.

Significant Meteorological Information, abbreviated as SIGMET, is an information format used by meteorological agencies to describe an event or weather phenomenon that can affect aircraft flight activities [3][4]. SIGMET information is intended for many types of aviation, ranging from general and commercial aviation to government agencies and the military. SIGMET data generation comes from the meteorological observation site closest to a weather phenomenon that occurs, which will then be distributed to other meteorological stations.

However, because the data displayed by BMKG is only in SIGMET format, it is only possible for aviation experts to read and interpret the meaning of each line of data. Only a few studies can process the language of the volcanic ash data so that ordinary people can easily read it. This problem can be solved by creating a natural language processing system to interpret the content of the data. One way of using natural language processing is by using production rules.

Production rule is a way to store or manipulate knowledge related to the sentence structure that will be used to interpret the information in the sentence [5]. In short, production rules can be formed based on the pattern of a sentence statement that is usually entered into a machine to access a database [6]. Search programs using production rules can be useful for translating a language into a query so that users can access the database without entering an SQL query [7][8]. The process can be done by determining the grammar that is input to the search program which can be formulated with a production rule. Production rules can be designed by formulating a sentence arrangement in the form of commands that can appear in searching the SIGMET dataset. The sentences will be dissected so that sentence patterns can be formed. The patterns are then made into symbols which can then be used as production rules.

Several studies have been done and used as references to carry out this research, with each study using different kinds of data. The first research that has been done is research on natural language processing for the latest earthquake info in Indonesia [9]. With data in the form of tweets and using the production rule method, the research created a system that could accelerate the sharing of the latest earthquake information using the day-to-day language used by Indonesians with 7 sentence types. The second research that serves as a reference is a search system for authorized car repair shop locations that uses natural language processing with production rules [10]. With audio data converted to text, the research has test results with 70% accuracy in finding locations according to the input given by the user. The third research that will be referenced is the search for temple tourism information in Yogyakarta using the production rule [6]. Using the temple database as search material and four types of question categories, the research has 86%

precision results from the tested system. The fourth research that will be referenced is a natural language processing application for XML database queries [11]. XML database used for query contains library bibliography collection. The research was able to convert Indonesian sentences into XQuery by doing lexical analysis, syntax analysis, parsing, and semantic analysis to search for the correct bibliography information inside the XML database.

Compared to existing studies, this paper will contribute to addressing the challenge of interpreting SIGMET data related to volcanic ash, which is crucial for aviation safety. Notably, there is a scarcity of research specifically addressing the interpretation of this SIGMET data. The proposed methodology involves using production rules to create a system that translates aviation-related information into a more understandable language for a wider audience. The aim is to bridge the gap between the technical SIGMET format and individuals needing more expertise in aviation.

2. METHODS

This research used the production rule method to build a SIGMET information and data search application related to volcanic ash in Indonesia. Several steps must be taken first so that the research can run smoothly without any obstacles. These steps can be envisioned by looking at Figure 1.

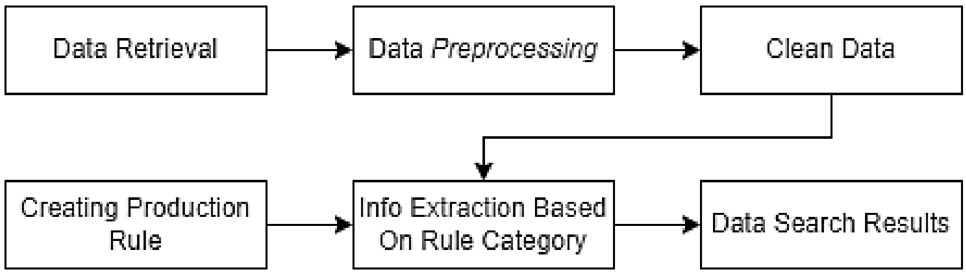

Figure 1 Steps of Method

Figure 1 contains each stage that needs to be done so that the research runs as desired. The first step is to perform a crawling process where SIGMET data will be retrieved as much as possible according to its limitations so that the dataset needed for research is collected. The second step is to preprocess the data where data that is difficult to read due to the SIGMET format, which is full of abbreviations and codes, will become more accessible to read and summarize so that the dataset becomes easier to process and read. The third step is forming production rules that will be the main algorithm in the program designed for this research. The fourth step of the method implementation is data extraction based on the production rules generated from the input to the program.

2.2 Data Collection

In this section, data are retrieved by accessing the BMKG Aviation website, which focuses on data related to aviation and aviation activities. SIGMET VA data was collected with time intervals starting from January 1, 2023, at 00:00 to May 21, 2023, at 00:00. The data will then be retrieved manually and entered into a text document preprocessed.

2.3 Data Pre-processing

This preprocessing action aims to extract every important dataset content to make it easier to process and call the queries that will be entered. This step focuses on deciphering every aspect of the SIGMET data that is difficult to read due to its complex data format. Each part of SIGMET data is shown in Figure 2.

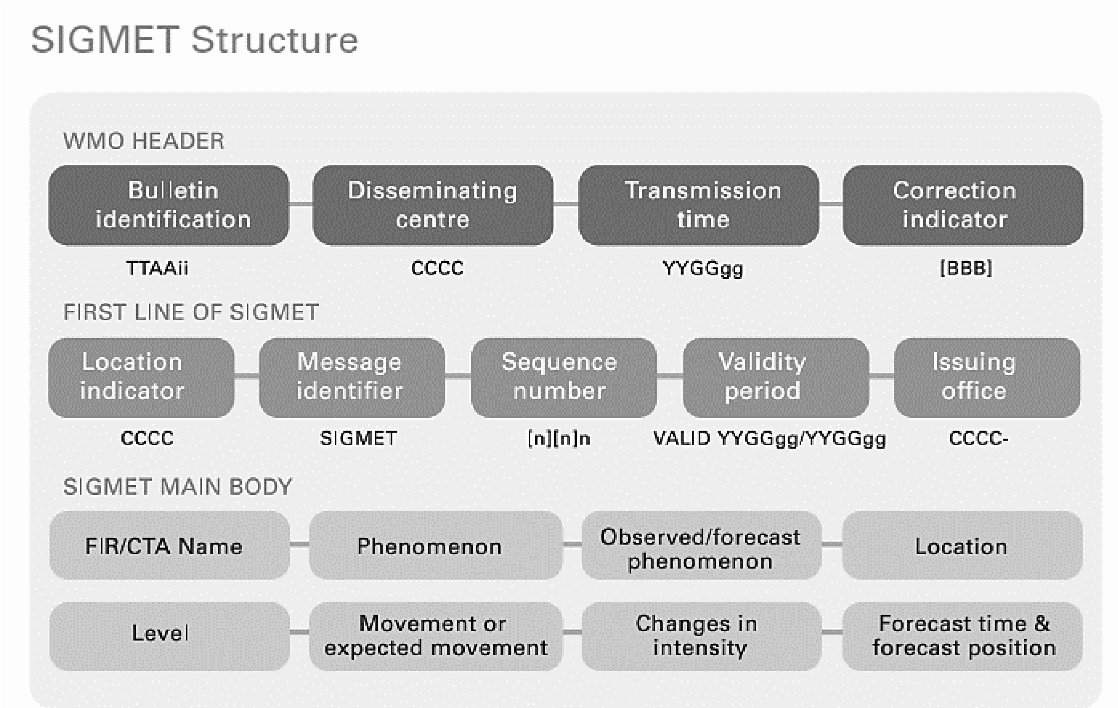

Figure 2 SIGMET in detailed form

SIGMET data has a fairly specific format for each section. The data usually has three lines of text separated by type. Here is a detailed explanation of the data structure:

1. WMO Header
   This header has 4 types of data, namely:
   a. Bulletin identification
      This data section has the structure TTAAii. TT is the SIGMET data type, for example, WV for volcanic ash and WC for hurricane conditions. AA is the country code, for example, ID for Indonesia. The last one is ii, which is the bulletin number determined by the global communication system.
   b. Disseminating center
      This section contains the location code of the communication center in charge of disseminating SIGMET information. This data has the format CCCC which can be filled in with the ICAO (International Civil Aviation Organization) airport location code.
   c. Transmission time
      This section represents the date and time the SIGMET transmission was created and deployed. The format is YYGGgg where YY is the date, GG is the hour, and gg is the minute. The problem with the data format is that there is no month and year data, so the user does not have complete information about the transmission time.
   d. Correction indicator
      This section contains the code that serves as an indicator of SIGMET data correction. The format of this code is CCx where x can contain A for the first correction, B for the second correction, and so on.

2. First line of SIGMET
   This line has 5 types of data, namely:
   a. Location indicator
      This section contains the FIR (Flight Information Region) code which serves to provide an indicator location where the ATS (Air Traffic Service) performs its activities to create SIGMET data.
   b. Message identifier
      This part is the identity of the message which always contains SIGMET.
   c. Sequence identifier
      This data section contains a three-digit string of numbers and letters that indicates the order in which SIGMET messages are generated each day. SIGMET data created for the first time on that day will begin with the number 01.
   d. Validity period
      This data section has the format VALID YYGGgg/YYGGgg, which contains the date, hour, and minute. This data has a function to give a time range for the validity of SIGMET data because SIGMET data is only valid for a short duration. The problem with this data is that it lacks month and year information, making it difficult to find detailed information about the date.
   e. Issuing office
      This data contains the same ICAO code as the disseminating center. This data usually ends with a hyphen or strip at the end of the code.
3. SIGMET Main Body
   This line has 7 types of data, namely:
   a. FIR/CTA Name
      This data section contains the FIR code which indicates the location of the volcanic ash event.
   b. Phenomenon
      This section contains a description of the location where the eruption and volcanic ash were located. The format is VA ERUPTION [mountain name] PSN <location coordinates> VA CLD.
   c. Observed phenomenon
      This data section describes the observation time of the volcanic ash event. The format is OBS AT [GGggZ]. GG contains hours and gg contains minutes.
   d. Location
      This data contains all coordinates of volcanic ash movement that appear in one event to be included in the SIGMET data. The data contains latitude and longitude coordinates in the format Annnn[n] Bnnnnn[n] where A is the north or south code for latitude, B is the east or west code for longitude, and n is a coordinate number that can contain 4 to 5 digits.
   e. Level
      This section contains the height of the volcanic ash. The format is SFC/FLnnn where n contains the height number.
   f. Movement/expected movement
      This part of the data states the movement of the volcanic ash along with its direction. If there is movement, the code is MOV <direction> <velocity>KT where KT means knots as a unit of speed. If there is no movement, the code is STNR which means stationary.

g. Changes in intensity
This part of the data describes changes in cloud intensity. The code can contain either INTSF or intensifying, WKN or weakening, or NC or no change.

From this lot of data, the pre-processing action will create a table containing columns that will affect the data lookup. Some parts of the data will be removed such as bulletin identification, correction indicator, location indicator, sequence number, message identifier, and issuing office. The purpose of this is to eliminate columns that have the same function as other columns and remove columns that have no significant use. In addition, there will be additional columns to provide more detailed information related to the data, such as the meaning of the code of the disseminating center, the provincial location of the mountain, and the separation of the validity period code so that there are two columns containing the start date and end date of the validity of SIGMET. The date information will also be broken down into month and year sections.

2.4 Formulation of Production Rules

Production rules are used to determine what rules apply to a sentence. These rules are formed by exploring and studying the sentence structure that will be entered into the machine. Each difference in structure will produce new types of regulations that will determine which SQL query will be used in calling data in the database.

The production rules will be used in the translator and evaluator parts of the user input processing in the information retrieval process. Ultimately, the SQL query will be selected based on the rules and user input, and the program will output the corresponding data based on the rules.

2.5 Rule-based Information Extraction

This section accommodates all input given to the program. The input sentences will then be scanned and parsed so that the sentences can be processed and production rules can be applied.

The scanning step can be carried out by tokenizing each word in the sentence so that a list of words can later be categorized based on their function, such as command words, conjunctions, adverbs, and various other words.

In the parsing step, the words that have been classified will begin to be reprocessed so that their sentence structure can be examined. A detailed syntax analysis is performed in this step, where each word in the list will be checked for patterns that match the search sentence. The matching pattern will affect how the attributes contained in each type of word are searched, so the conversion into SQL queries can be done.

Translation applies the production rules formed to the tokens that have been parsed. This translation step will produce the types of queries that will be used to search the data. The query is formed by checking the selected attributes based on their tokens, which are then matched with the terms and conditions that apply to the search sentence pattern.

In the last step, there is an evaluator, which functions to run the formed query so that the search results can appear following the expectations of the program user.

3. RESULTS AND DISCUSSION

3.1 Dataset

The SIGMET data needed in the research was taken from the BMKG website (https://aviation.bmkg.go.id/web/sigmet.php). The search for data on the website was conducted by agreeing to the agreement to use information products, which informs that the information on the website has an element of scientific uncertainty, is subject to change without notice, and is sometimes incomplete and inaccurate.

Table 1 Raw SIGMET Data Example

DataID	RawData	DateCreated
1	WVID21 WAAA 202112 WAAF SIGMET 16 VALID 202115/210200 WAAA- WAAF UJUNG PANDANG FIR VA ERUPTION MT SEMERU PSN S0806 E11255 VA CLD OBS AT 1940Z WI S0809 E11256 - S0808 E11252 - S0726 E11305 - S0737 E11326 - S0809 E11256 SFC/FL150 MOV NE 15KT NC=	2023-05-20 21:12:00

To search for the desired data, the FIR (Flight Information Region) code will be entered according to the desired area, then check the box that says volcanic dust, and enter the desired data date in this study, namely data starting on January 1, 2023, at 00:00 until May 21, 2023, at 00:00. After clicking extraction, all the desired data will appear in SIGMET format. The data that appears will be transferred into a text file which will be pre-processed so that the data becomes more organized and easy to understand.

3.2 Pre-processing

At this stage, the data that has been taken from the BMKG website will be transformed into a form of data that is easier to understand. The data has not been separated based on the line of text and the type of data. An example of preprocessing results is shown in Table 2.

Table 2 Preprocessing Result

Column Names	Column Data
DataID	1
Transmisi_WIB	2023-05-21 04:12:00
ValidMulai_WIB	2023-05-21 04:15:00
ValidAkhir_WIB	2023-05-21 09:00:00
AreaPenerbangan	WAAF Ujung Pandang
NamaGunung	Semeru
PosisiGunung	S0806 E11255
ObsWaktu	02:40:00
AreaAbu	S0809 E11256 - S0808 E11252 - S0726 E11305 - S0737 E11326 - S0809 E11256
Ketinggian_Meter	4500
PergerakanAbu	Arah Timur laut 15 knot
IntensitasAbu	Tidak berubah

Some data types were deleted because the values contained in the data were repetitive, such as bulletin identification, location indicator, message identifier, sequence number, issuing office, and phenomenon. Data such as date is added with month and year details so that users can understand the date column section. Columns that have abbreviations will have their contents clarified, such as the ExpectedMovement and IntensityChange columns.

3.3 Formulating Sentence Type and Rule Production

Production rule generation is done by analyzing every possible input that the user will give. Each sentence will be checked for patterns, and the words that appear will be determined for their importance. Here is an example of sentences that will run according to the production rules.

a. *Tampilkan seluruh field untuk info sigmet terbaru*
b. *Berapa ketinggian abu vulkanik untuk gunung Sumeru?*
c. *Dimana lokasi gunung untuk sigmet tanggal 2023-02-21?*
d. *Kapan waktu diobservasinya untuk gunung Ibu?*

e. *Apa intensitas abu vulkanik untuk info sigmet terkini?*

Based on the example sentences, each sentence is categorized based on the question word, which begins with 'Tampilkan' (Show), ‘Berapa' (How Much), ‘Dimana' (Where), 'Kapan' (When), and 'Apa' (What). These words will affect the selection of attributes contained in the sentence so that the query can call the columns and data associated with the sentence. One example of the resulting production rules is shown in Table 3.

Table 3 Rule Production for “Tampilkan” Rule

<table>
<tr><th>Rule Production</th></tr>
<tr><td>Kalimat “tampilkan” → Tampilkan <atribut> <kondisi> <atribut kondisi> <operator> <data></td></tr>
<tr><td><atribut> → seluruh field |<waktu valid>|<nama gunung>|<posisi gunung>|<waktu observasi>|<area abu>| <ketinggian abu>|<pergerakan abu>|<kecepatan abu>|<intensitas abu>|<waktu dikeluarkan></td></tr>
<tr><td><kondisi> → dengan | yang | untuk</td></tr>
<tr><td><atribut kondisi> → <waktu valid> | <nama gunung> | <posisi gunung> | <waktu observasi> | <area abu> | <ketinggian abu> | <pergerakan abu> | <intensitas abu> | <waktu dikeluarkan></td></tr>
<tr><td><operator> → = | > | < | LIKE</td></tr>
<tr><td><nama gunung> → ibu | dukono | karangetang | kerinci | krakatau | lewotolo | merapi | marapi | semeru</td></tr>
<tr><td><waktu> → 08:00 | 21:00 | 13:00 | …</td></tr>
<tr><td><tanggal> → 2023-03-03 | 2023-01-21 | …</td></tr>
<tr><td><posisi> → S10415 E0491 | S10050 E0220 | …</td></tr>
<tr><td><ketinggian abu> → 3000 meter | 2000 meter | …</td></tr>
<tr><td><pergerakan abu> → utara | selatan | timur | barat | …</td></tr>
<tr><td><kecepatan abu> → 10 knot | 5 knot | …</td></tr>
<tr><td><intensitas abu> → Tidak berubah | melemah | intensif</td></tr>
</table>

Some important aspects are classifying attributes, conditions, condition attributes, operators, and data. Attributes indicate what attributes will be displayed on the program output. Condition is a word that suggests that the SQL query will have a condition before the output is displayed. The condition attribute is an attribute that conditions a condition for searching, containing the operator and the data searched for in the condition attribute.

3.4 Information Search Process by User

This stage will process the sentences entered by the application user. This part can be started by typing a sentence in the search box provided. Table 4 contains examples of sentences that will be inputted with different sentence structures.

Table 4 Examples of Input Sentences

No.	Sample Sentences
1	Tampilkan seluruh field untuk info sigmet terkini
2	Berapa lama waktu valid untuk info sigmet terkini
3	Dimana lokasi gunung untuk sigmet tanggal 2023-05-20

3.5 Scanner Process

This stage will perform a scanner process on the sentences that have been entered. Each sentence will be removed symbols that are considered useless, then the sentence will be tokenized. This tokenization will produce a list containing the words of each sentence. The list of words is ready for the parser process which will be explained in the next stage. The results of the scanner can be seen in Table 5.

Table 5 Scanning Results

No.	Scanning Results
1	'tampilkan', 'seluruh', 'field', 'untuk', 'sigmet', 'terkini'
2	'berapa', 'lama', 'waktu', 'valid', 'untuk', 'info', 'sigmet', 'terkini'
3	'dimana', 'lokasi', 'gunung', 'untuk', 'sigmet', 'tanggal', '2023-05-20'

3.6 Parser Process

This process will start reading the words of each sentence to check for rule matches that have been determined in the production rule generation process. The word that will determine the type of production rule that matches the sentence is located at the beginning of the sentence, which after that step will be searched for the attributes needed to process the query. The rules that match the pattern in each sentence are described in Table 6.

Table 6 Selected Rule on each Sentence

No.	Selected Rule	Selected Pattern
1	Aturan 1 (kata 'tampilkan')	Seluruh *field*
2	Aturan 2 (kata 'berapa')	Validitas
3	Aturan 3 (kata 'dimana')	Lokasi gunung

After the rules are selected, the tokenization results will be processed again to check what attributes are associated with the search sentence. These attributes will affect the SQL query that will be used to call the database so that the search results have an output. The selected attributes can be seen in Table 7.

Table 7 Selected Attributes on each Sentence

No.	Attribute	Conditional Attribute	Operator	Data
1	Seluruh *field*	*dataID*	IS NOT	*null*
2	durasi_valid	*dataID*	IS NOT	*null*
3	nama_gunung	tanggal_transmisi	=	2023-05-20

3.7 Translation Process

At this stage, each attribute that has been searched will be assembled into a query that will be executed in the evaluator process. The attributes will be adjusted based on their types and the number of conditions detected in the parser step. The query results for each sentence are shown in Table 8.

Table 8 Query Results for each Sentence

No.	Searched Sentence	Rule	Query Result
1	Tampilkan seluruh field untuk info sigmet terkini	Aturan 1 ('tampilkan')	SELECT tanggal_transmisi, waktu_transmisi, durasi_valid, flight_information, nama_gunung, posisi_gunung, obs_waktu, area_abu, ketinggian_meter, pergerakan_abu, kecepatan_abu_knot, intensitas_abu FROM sigmet_data WHERE dataID IS NOT NULL
2	Berapa lama waktu valid untuk info sigmet terkini	Aturan 2 ('berapa')	SELECT durasi_valid FROM sigmet_data WHERE dataID IS NOT NULL

3	Dimana lokasi gunung untuk sigmet tanggal 2023-05-20	Aturan 3 ('dimana')	SELECT nama_gunung FROM sigmet_data WHERE tanggal_transmisi = '2023-05-20'

3.8 Evaluator Process

This stage runs the query generated in the translation process so that the program output and search results appear according to the user's wishes. The output display is in the form of sentence lines that explain each aspect of the attributes cited in the query. The number of sentence lines also depends on the conditions that have been determined from the search sentence and the translation process. An example of the output display can be seen in Figure 3.

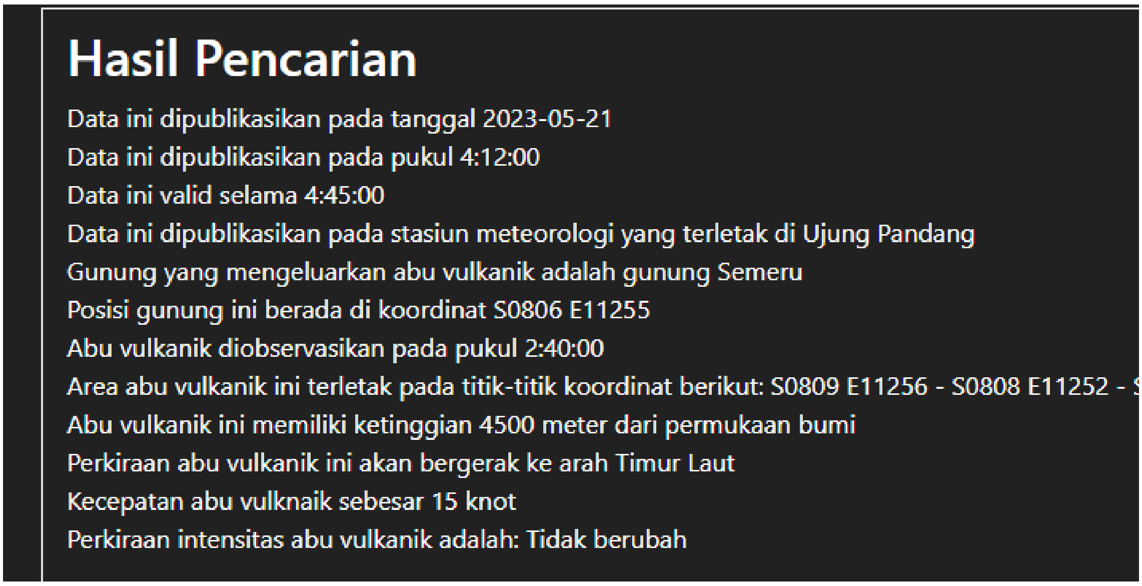

Figure 3 Search Result Display

3.9 Testing Stages

his stage is a test to check whether the program that has been formed runs well or not. This test will use 25 sample sentences with the main attributes that will be combined with the condition attributes that have been created in the program. Some sample sentences are listed in Table 9, shown below.

Table 9 Sample of Testing Sentences

No.	Testing Sentence	Does the query result match the sentence?
1	Tampilkan seluruh field untuk info sigmet terkini	Yes
2	Tampilkan info sigmet terkini yang berada digunung dengan posisi N0129 E12738	No
3	Tampilkan info sigmet terkini dengan ketinggian awan abu vulkanik dibawah 900 meter	Yes
4	Tampilkan info sigmet terkini untuk wilayah penyebaran abu vulkaniknya berada di lintang N0127 E12738	Yes
5	Tampilkan info sigmet terkini dengan waktu valid dari jam 00:00 hingga 23:00	Yes

Each sentence that has been combined will be seen whether the query results are following expert observations. The results of the expert's observations will later be calculated for accuracy. The results of expert observations can be seen in Table 10.

Table 10 Query Testing Results

Description	Calculation
Number of queries that match the sentence	21
Number of queries that do not match the sentence	4
Percentages of responses to queries that match the sentence	84%
Percentages of responses to queries that do not match the sentence	16%

The accuracy results show that 84% of the entered sentences produce queries that match the search sentence. This indicates that the program still needs more detailed patterns to read and process more complex search sentences with specific attributes.

4. CONCLUSIONS

Based on the results of research conducted on the application made to search SIGMET data (volcanic ash) using natural language processing based on production rules, it can be concluded that testing using 25 test sentences with a combination of different types of words and sentences resulted in an accuracy rate of 84%. The stage has a vital role in creating production rules, which can provide a higher level of accuracy if designed more thoroughly.

REFERENCES

[1] N. A. Pambudi, “Geothermal power generation in Indonesia, a country within the ring of fire: Current status, future development and policy,” *Renewable and Sustainable Energy Reviews*, vol. 81. Elsevier Ltd, pp. 2893–2901, Jan. 01, 2018. doi: 10.1016/j.rser.2017.06.096

[2] M. R. Pahleviannur, “Edukasi Sadar Bencana Melalui Sosialisasi Kebencanaan Sebagai Upaya Peningkatan Pengetahuan Siswa Terhadap Mitigasi Bencana,” 2019.

[3] Federal Aviation Administration, “Pilot’s Handbook of Aeronautical Knowledge,” 2016.

[4] International Civil Aviation Organization, “ASIA/PACIFIC REGIONAL SIGMET GUIDE - SEVENTH EDITION,” 2019.

[5] I. Faturohman and G. Hermawan, “Perancangan Translator Bahasa Alami Ke Dalam Format SQL (Structured Query Language) Dengan Fokus Pada Kasus Retrival Informasi,” 2018.

[6] F. Alpino and D. Soyusiawaty, “Pencarian Informasi Wisata Candi di Yogyakarta dengan Bahasa Alami Berbasis Aturan Produksi,” 2020. Available: http://ejournal.unib.ac.id/index.php/rekursif/134

[7] D. Soyusiawaty and A. Hendri Soleliza Jones, “Penerapan Antar Muka Bahasa Alami Dalam Pencarian Informasi Skripsi Pada Suatu Program Studi,” *UNIVERSITAS AMIKOM Yogyakarta*, 2018.

[8] B. Rath, “Converting Natural Language Query to SQL Query,” 2020. Available: http://www.ijeast.com

[9] Indra and S. Hartati, “Aplikasi Pengolah Bahasa Alami untuk Info Gempa Bumi Terkini dengan Sumber Data pada Twitter @InfoBMKG,” 2014. Available: http://data.bmkg.go.id.

[10] A. F. Octaviansyah, D. Darwis, and A. Surahman, “Sistem Pencarian Lokasi Bengkel Mobil Resmi Menggunakan Teknik Pengolahan Suara Dan Pemrosesan Bahasa Alami,” 2020. Available: http://maps.google.com.

[11] S. Hartati and E. Zuliarso, “Aplikasi Pengolah Bahasa Alami untuk Query Basisdata XML,” *Jurnal Teknologi Informasi DINAMIK*, vol. XIII, no. 2, pp. 168–175, 2008.