UDC 378
DOI: 10.15587/1729-4061.2024.306726

USING RELATIONAL LEARNING IN EXPLORING THE EFFECTIVENESS OF USING HASHTAGS IN FUTURE TOPICS AND USER RELATIONS IN X

Ahmad Rahmatika
Corresponding author
Master of Mathematics Education*
E-mail: ahmadrahmatika@umsu.ac.id
Al-khowarizmi
Doctor of Computer Science*
Akrim
Professor of Education
Department of Islamic Education**
Okvi Nugroho
Master of Computer*
Tri Andre Anu
Master of Computer*
*Department of Information Technology**
**Universitas Muhammadiyah Sumatera Utara
Kapten Muchtar Basri str., 3, Glugur Darat II, Kec. Medan Tim.,
Kota Medan, Sumatera Utara, Indonesia, 20238

This research has a research object, namely relational learning with a mathematical modeling approach from graph queries for exploring future topics and user relationships. The problem in this research is the large and varied number of tweets that are produced every day, where each use of hashtags always increases, which has an impact on the accumulation of data that needs to be processed to obtain information because users on social media X can interact to influence trends so as to solve the problem. This requires the application of relational learning by utilizing graph query mathematical models. The results obtained from this research are in the form of a model that can produce predictions of future topics and see user relationships based on interactions on social media with relationships between entities at interconnected nodes. In applying relational learning with mathematical models utilizing graph queries there will be a process of examining the relationships between entities, content and communication interactions in accordance with the definitions and theorems that have been described to observe each node. In relational learning, there will be each node according to the entity used, then the mathematical model with graph queries will connect all the entities to form a graph that can be used as a model for predicting future topics and relationships between users. This research is research with a level of novelty in applying graphical queries to mathematical models to predict future topics and applying relational learning to user relationships so that it can add information related to future communication. Graph queries aim to model a node between relations in the data so that it can represent a relationship between variables

Keywords: user relationships, future topics, mathematical models, graph queries, relational learning

Received date 22.03.2024
Accepted date 14.06.2024
Published date 28.06.2024

***How to Cite**: Rahmatika, A., Al-khowarizmi, A., Akrim, A., Nugroho, O., Anu, T. A. (2024). Using relational learning in exploring the effectiveness of using hashtags in future topics and user relations in X. Eastern-European Journal of Enterprise Technologies, 3 (2 (129)), 62–68. https://doi.org/10.15587/1729-4061.2024.306726*

1. Introduction

The current technological advancement has influenced many people, especially those involved in social interaction. Social interactions that used to be conducted traditionally through face-to-face communication or two-way communication are now often carried out through online platforms due to the development of communication technology. One of the rapidly growing platforms is social media platform X, which is one of the most popular social media platforms used by millions of users worldwide [1]. X allows users to share information, follow the latest news, as well as participate in discussions on various topics of interest to them [2, 3]. One of the important features in X is the use of hashtags (#) which help users organize and search for content based on certain topics [4]. Apart from being a social media platform, X is also used as a very important source of information in various fields, including politics, business and entertainment. Therefore, a good understanding of how hashtag usage and user interactions can influence discussions and trends in X [5, 6]. However, with such a large and diverse number of tweets generated every day, it is important to understand how the use of hashtags on future topics and user relationships on X can influence discussions and conversations on the X platform [7, 8]. In recent years, interest in the use of hashtags in social media has increased, especially in research related to sentiment analysis and social data analysis [9]. The use of hashtags is also an important factor in predicting topics that will become trends in the future. Therefore, research on the effectiveness of using hashtags on future topics and user relationships in X is expected to contribute to the field of research as well as practical applications in the real world [10, 11].

In Relational learning, there will be an analysis of relationships between objects which will be analyzed in the process, then there will be entities such as hashtag trends, relationships between users and content that are related to each other. Basically, Relational learning can learn and process forming relationships between large amounts of data which is useful in the context of social media exploration as has been done by [12] which discusses relationships with different types of structures in the field of computing on social networks, classifying content and users. based on communication interactions and identifying fake account characters [13]. In Relational learning, there are approaches that are often used, such as the latent feature approach and the approach based on entity patterns. The latent fit approach can effectively solve various problems in relationships between entities on social media, then the approach based on entity patterns has problems and is less effective. What is highlighted in the pattern-based approach is the complexity in the computational process that arises from the exploration of relationships with relational queries. In relational query systems, it is widely used, which is based on the concept of graph isomorphism. In this context, a query is performed by checking whether a graph described in the question is the same as an existing graph in the database. The computational complexity becomes NP-complete, which means in many cases there is no time-efficient algorithm to solve this problem. This is a challenge in developing an efficient and effective database system [14].

Therefore, the studies specifically aim to explore the query graph against a model capable of effectively matching entity patterns, thus having scholarly relevance in relational learning using data from social media X to assess the effectiveness of hashtag usage on future topics and user relationships in X.

2. Literature review and problem statement

The research [15] indicates that this study has produced a predictive model capable of clustering and visualization with an accuracy rate reaching 93 %. However, there are unresolved issues related to knowledge graph extraction in specific domains such as future knowledge and the relationship between knowledge and interactions. This research faces difficulties in creating a domain-based embedding framework with current credibility, which in its process will obtain knowledge sources and the relationship of knowledge with several domains. One way to address these challenges is through a graph query approach to mathematical modeling; all of these suggest that it is advisable to apply graph queries to mathematical models.

Research [16] indicates that the outcome of this study is a weather prediction model using data from weather stations. However, there are unresolved issues in clustering artificial neural networks in the context of meteorology, leading to errors in clustering due to difficulties in modeling time complexity. One way to address and overcome these challenges is through mathematical models utilizing graph queries, which can mitigate the shortcomings. All of these suggest that it is highly recommended to apply graph queries to mathematical models.

The research [17] yields a model to track discussion trends related to crimes committed on the platform. However, there are unresolved issues in extracting information from product reviews. This study encounters difficulties in applying crowdfunding techniques closely linked to fraudulent activities. One way to address these issues is through a language model combined with basic mathematical graph queries that can identify patterns in product comment columns to form a model architecture. All of these indicate that it is advisable to apply graph queries to mathematical models

Research [18] produces a model capable of predicting inventory production in the laboratory, but there are unresolved issues regarding the time complexity of inventory management in the laboratory. These issues include inaccurate analytical testing and inefficient laboratory equipment processing, making prediction challenging. One way to address these problems is by leveraging machine learning methods and mathematical graph query models to optimize laboratory operations, both in the short term-down to the hour and minute-for immediate needs, and in the long term, even on a monthly basis, enabling precise reagent planning. All of these suggest that it is advisable to apply graph queries to mathematical models.

Research [19] Produced an innovative strategy that combined machine learning and predictive analysis approaches. However, there is an unresolved problem, namely that supply chain risk management relies on post-event analysis and historical data, which limits its ability to overcome disruptions in real-time. This approach includes the use of time series analysis and anomaly detection, as well as the application of natural language processing. In addition, risk evaluation models are continuously updated and improved using machine learning algorithms, ensuring accuracy and adaptability in a changing environment. Through this research, it is very relevant to apply graphic query models with a mathematical basis to the relationship between predictive analysis, machine learning, and supply chain flexibility, explained using theoretical synthesis and practical evidence. All this shows that it is advisable to apply graph queries to mathematical models.

Research [20] produces an estimation model based on graph neural networks, but there are still problems such as time complexity in graph query execution at the workload creation and operation stages, graph-based feature modeling and representation, training and estimation. One way to solve this problem is to group the query workload in the database so that there is information when the query is processed and executed. All this shows that it is advisable to apply graph queries to mathematical models.

Research [21] Generates complex query models for temporal knowledge graphs based on hierarchical patterns. This study has problems with the application of machine learning and relational learning which only focuses on static knowledge graphs and ignores semantic information which has a time element in query question information. To overcome this problem, the semantic relationship method will be applied with a graph query mathematical model that accurately studies constraints such as time and quantity in the problem so that it can form effective machine learning and relational learning on mathematical models.

3. The aim and the objectives of the study

The aim of this research is to implement a mathematical model utilizing query graphs in relational learning to form a predictive model for future topics and user relationships in social media X.

To achieve this aim, the following objectives are accomplished:

– to refinement of relational learning tools;

– to become a parameter in application to machine learning applications.

4. Materials and methods

In the context of relational learning, in exploring the effectiveness of using hashtags on future topics and user relationships, X has an important role as a solution to computational complexity problems in using a pattern-based approach based on entities, content and interactions. Object of the study the research focuses on relational learning using a mathematical modeling approach for exploring future topics and user relationships through graph queries.

The main hypothesis in this research is the use of mathematical models as a framework for graph queries. Based on the context that in the pattern-based model approach there is a computational complexity problem where all processing time dimensions become NP-complete. The problem addressed in this research involves applying mathematical formulations to graphical queries within relational learning. The approach implemented uses several stages such as data analysis, model refinement, and the application of relational learning to machine learning. By applying effective relational learning with mathematical formulations to graph queries, one can achieve the best solution in examining future topics through exploring hashtag usage and observing relationships between users. In this research, the research objects include the application of relational learning to explore hashtag usage and user relationships using hardware, specifically a Core i7 laptop, and software such as Microsoft Word, Anaconda, and Jupyter. The research starts with a framework architecture as shown in Fig. 1.

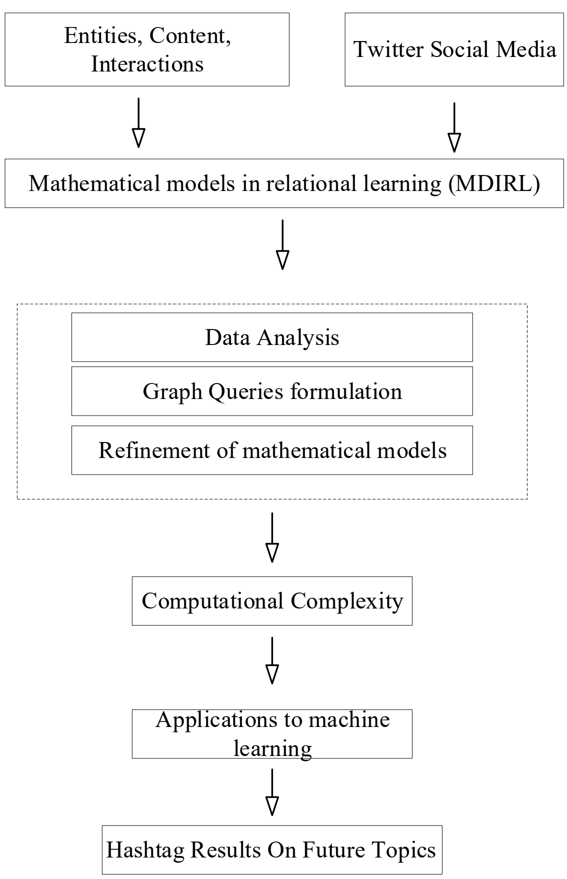

Fig. 1. Proposed architecture

In Fig. 1, there are stages of architecture to be used in this research. The list of stages includes the methods used to build Models in Relational Learning (MDIRL). In this research, a method is employed, specifically determining entities, content, and interactions, and applying them to a graph query formulation. This formulation is then refined using several equations, which are explained in the next section. After perfecting the mathematical model, it is then applied to the discipline of machine learning, which can be used to determine hashtags and topics in the future. In Fig. 1, the Mathematical Models in Relational Learning (MDIRL) model is displayed, aiming to serve as the primary framework for analyzing future topics based on hashtag exploration and relationships between users on social media. This model includes entities, content, and communication interactions within social media data, forming a framework capable of conducting relational learning on data using graphical query mathematical models. Equations shall be used in this research, obtained from the query graph model approach which is a systematic step in interpreting in the context of predicting future topics and user relationships on social media X Here is the formulation of the stated graph query.

Given a set v, which is then expressed with a formulation:

$$v^0=\theta, v^1=v, v^{n+1}=v^n x v, v^*=\bigcup_{n\geq 0} v^n. \quad (1)$$

In equation (1) there will be a set domain v^n which present nodes in graph theory that will look at the relationship between content entities and interactions in social media that will be used to improve relational learning in graph queries, while for symbols which will generally be expressed in v, v^{n+1} as a substitute for θ v^1 on every social media data that will process every node on every value in the graph query to form a relational learning model. For the V symbol, an ordered set is established according to the data analysis carried out so that repetition considerations can be made as in the formulation:

$$G=(v,E,\mu). \quad (2)$$

In (2) it will relate to the sets v and E, each of which will have an edge from G. in the set μ it will associate a set of elements such as $\cup E\times R$ which will come together with J and then associate it with the set R so that relational learning graph queries can be formed. To do association learning graph queries there needs to be an additional set which will be symbolized γ so that relationships can occur between these sets which makes it easier to apply relational learning to graph queries. When using the symbol γ, the symbol (v) will be added so that it can display the value of each relationship node in the relationship to social media data which will form the formulation in (3), (4) below:

$$N(v)=Se\in\gamma(v)\gamma(e), \quad (3)$$

$$v_s=\{v_1,v_2\},\ \ E_s=\{e_1\}\gamma|V_s\bigcup E_s. \quad (4)$$

After forming (3) and (4) in perfecting middle relational learning. In the mathematical model in the query graph there will be a formulation as in (5):

$$\alpha=V_A\cup E_A. \quad (5)$$

Then in (5) the symbol A will be connected to form a relationship with the symbol G in (2) so that it is explained in formula form as follows:

$$\theta_a(v,s)=v\in S, \quad (6)$$

$$\theta_b(v,s)=\exists z\in S(z-v), \quad (7)$$

$$\theta_e(p,s)=\exists y,z(y-z\wedge y\notin S\wedge z\in s). \quad (8)$$

Based on the equations that have been explained, each equation (1)–(8) will be used to apply improvements to relational learning so that it can be used to see relationships between users on social media and see future trends based on hashtags in the data.

5. Results of graph query mathematical models in relational learning on future topics and user relations

5. 1. Refinement of relational learning sets

To carry out classification so that the relationship between users on social media can be seen in relational learning, it is necessary to characterize it according to the data in the graph effectively so that mathematical computing methods can carry out the process well in making queries with predetermined formulations. So this research will match entities, content and communication interactions in relational learning. The refinement of mathematical formulations in relational learning includes definitions and theorems:

Definition 1: giving $A_{1,} A_2 € A$ that which states.

A_1 will make improvements *to* A_2 in symbol G:

$$(A_1 \preceq_G A_2) \text{ if } : \forall S \subseteq G (S \neq A_1 - S \neq A_2).$$

In one query it expressed by the same graph so that from the definition above the following theorem formulation produced:

$\preceq_G$ partial of A will thus be expressed for each entity as $A_1, A_2, A_3 \in S$ so it:

$$A_1 \preceq_G A_1,$$

$$A_1 \preceq_G A_2 \wedge A_2 \preceq_G A_1 \equiv_G A_2,$$

$$A_1 \preceq_G A_2 \wedge A_2 \preceq_G A_1 \equiv_G A_2.$$

Then, in the next process, an examination of the relationship between entities, content, and communication interactions with queries and their functions in the graph is conducted with the following definitions and theorems.

Let's express $A_1, A_2 \in A$ then give A_1 as an extension of the vector field with A_2 $(A_2 \subseteq^- A_1)$ which becomes a theorem $(A_2 \subseteq A_1)$.

Then there is a process of examining the relationship between entities, content, and communication interactions in accordance with the described definitions and theorems to observe each node. The following is a graph of the refinement of relational learning in Fig. 2.

In Fig. 2, a relational learning refinement query is displayed, with each set explained using data such as entity data, content, hashtags, and communication interactions that describe the relationships between users on social media in relational learning.

5. 2. Parameter in Application to Machine Learning Applications

The data used is obtained from crawling social media X from the period of 2018 to 2022. In the application of machine learning, data is processed using a mathematical model utilizing query graphs, allowing machine learning to explore future hashtags based on node data from existing hashtags. With the Graph query model, it is possible to observe the use of hashtags related to future topics, which can be systematically analyzed to generate trends commonly used in the future. In this social network phase, user interactions and posts will be structured into a graph representing each entity at each node to depict relationships between entities. By utilizing the graph query model, it is possible to view each node in the graph to aid in understanding their interconnected relationships. The entities related to each other in hashtags are depicted in Fig. 3 below.

Fig. 3 represents a portion of interconnected node data that will undergo a process to determine forthcoming topics using a mathematical model for relational learning with basic graph queries using Equation 6 to identify topics with the highest word (term) count. In Equation 6, all nodes with the highest word frequencies will be aggregated to form relationships with users, enabling the identification of each user's content and interactions to develop frequency in hashtag content that will be processed into machine learning for Models in Relational Learning (MDIRL). This approach can assess the effectiveness of hashtag usage on future topics and user relationships on social media. Below are the predicted outcomes of future topics using the mathematical model applied to machine learning, as illustrated in Fig. 4.

In Fig. 4 there will be future topics that have been successfully predicted and made connections between nodes using graph queries. In Fig. 4, each topic has a relationship between other topics so that it can be used as trend information in the future. In this prediction there are words with the highest frequency which are processed using relational learning based on mathematical models. After knowing the future topic, user relationships on social media will be explored using relational learning with mathematical models that produce interconnected nodes. In the relationship between users, out of 100 users there will be words that are related to each other as in Fig. 5 below.

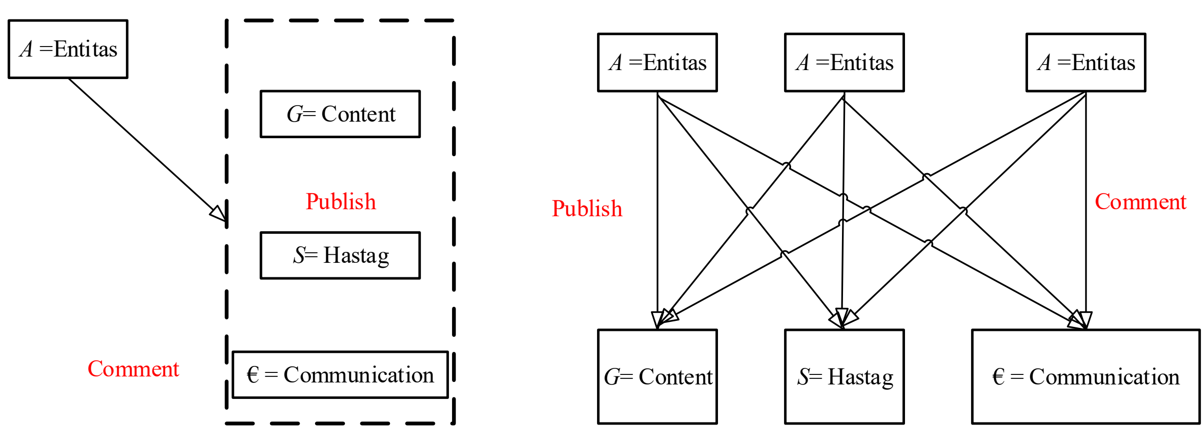

Fig. 2. Relational learning refinement query graph

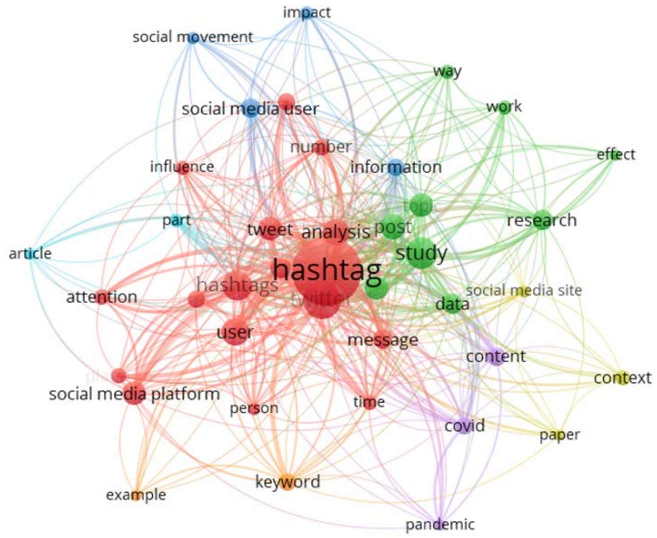

Fig. 3. Hashtag entity graph

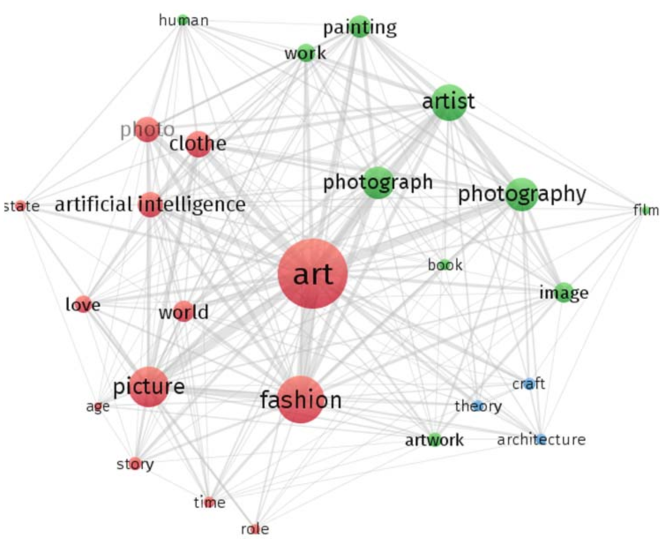

Fig. 4. Future topic entity graph

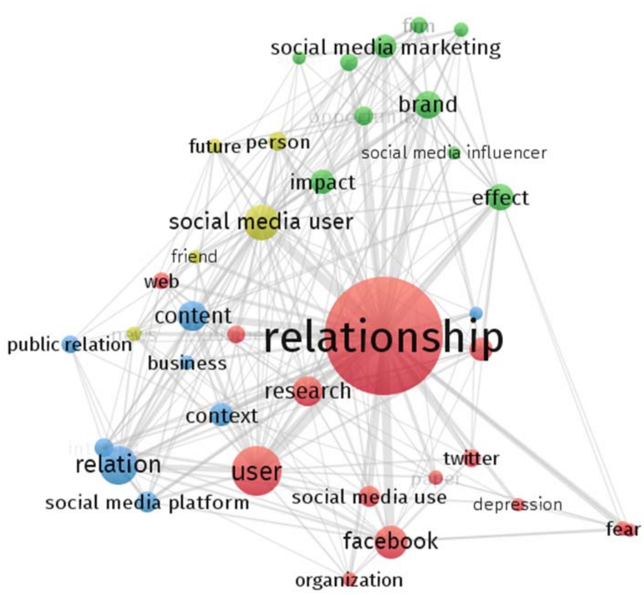

Fig. 5. Relationship between users

The relationships between users in Fig. 5 will connect related words based on user posts which form entity nodes which are united by the mathematical model in (3)–(5). In the relational learning mathematical model there will be words that are related to each other in the 3 clusters listed in the following Table 1.

Table 1

User relationships based on words

Depression	Brand	Business	Friend
Facebook	Customer	content	future
Fear	Relationship	context	news
Fomo	effect	empiricial	person
interaction	firm	study	social
number	impact	interest	Media
organization	opportunity	relation	–
paper	social	public	–
relationship	social media	platform	–
research	Media	–	–
Social Media	Marketing	–	–
Twitter	Influencer	–	–

In Table 1, there will be related words grouped into three categories, which are words related to the interactions among users on social media. Users on social media engage in communication interactions, and then all communication data is extracted using a mathematical model to obtain the most relevant words regarding the relationships among users.

6. Discussion of the results of applying the graph query mathematical model in relational learning to social media

This research holds significant importance within the realm of social media analysis and modernization. The utilization of a mathematical approach leveraging graph queries facilitates the extraction of behavioral information within the context of digital advancements, as well as understanding how hashtag usage can influence future topics and user relations on the social media platform X. The study aims to produce models capable of discerning social media user relationships and predicting future hashtags. In this regard, the application of graph queries grounded in mathematics and relational learning is highly relevant. Relational learning is employed to observe user relationships, resulting in models utilizing functions (1) and (2), alongside mathematical models employing graph queries. The process of testing entity relationships, content, and communication interactions adheres to predefined definitions and theorems, analyzing each interconnected node. Subsequently, in the implementation of mathematical graph query models using functions (3), (4), equations are applied to create models capable of predicting future topics using hashtag interaction entities from social media user data, as depicted in Fig. 2, which illustrates query refinement. The relational learning of each dataset will be elucidated with data such as entity data, content, hashtags, and communication interactions, showcasing the relationships among social media users concerning relational learning.

The results of the mathematical model will be depicted in Fig. 4, showcasing predictions of upcoming topics using (6). Each topic is interconnected with others, thus serving as future trend indicators. In this prediction, words with the highest frequencies are processed using relational learning based on mathematical models. Following the identification of future topics, user relationships on social media will be explored using relational learning with mathematical models, generating interconnected nodes. Regarding user interactions, among 100 users, there will be closely associated words, as illustrated in Fig. 5, where this model resolves data density issues on social media and extracts information from user interactions, posts, and hashtags. The obtained results provide insights into future topics and user relationships on social media. Unlike [19], which exhibits shortcomings in its mathematical model due to data noise, leading to model complexity, this issue can potentially be addressed through graph queries and relational learning applied to mathematical models. The novelty of this research is Models in Relational Learning (MDIRL) which can see the effectiveness of using hashtags on future topics and user relationships on social media. In this model there are indicators used for model requirements so that the effectiveness of using hashtags on future topics can be identified. These indicators are entities on social media X, the content discussed and posted as well as communication interaction indicators involving verb sentences.

Limitations of this study include the need for annotated input data processing, as there is currently no comprehensive and detailed Indonesian literature library available. Therefore, entities must be processed individually based on the theorems provided in (1), (6). Another drawback lies in the limited data obtained from the social media platform X, and the implementation of relational learning requires a substantial number of user interaction nodes to enhance user relationships. This research could be extended by integrating relational learning with social media entity variables such as communication interactions, posts, and user profiles aligned with graph queries, thereby enhancing the model's effectiveness. Practical use of the results obtained will be applied and will need to be extended to the e-commerce industry to predict customer trends based on purchasing variables.

7. Conclusions

1. This research yields Models in Relational Learning (MDIRL) to explore hashtag usage on future topics and user relationships on social media platform X. Subsequently, Models in Relational Learning (MDIRL) are applied to machine learning, producing predictions on future topics and user relationships on social media X. The results obtained exhibit characteristics such as the number of users using hashtags, frequency of hashtag usage, and user interactions.

2. In Models in Relational Learning (MDIRL) applied to machine learning, it involves using data obtained from crawling social media X. The characteristics of the results indicate that data quality is crucial for building Models in Relational Learning (MDIRL) to effectively predict future topics and user relationships. Comparatively, the implementation of Models in Relational Learning (MDIRL) and machine learning depends on the complexity of time in text data processing, making time complexity an issue to be addressed in the future.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

The study was performed without financial support.

Data availability

Manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

1. Wu, F., Wu, T., Yuce, M. R. (2019). Design and Implementation of a Wearable Sensor Network System for IoT-Connected Safety and Health Applications. 2019 IEEE 5th World Forum on Internet of Things (WF-IoT). https://doi.org/10.1109/wf-iot.2019.8767280
2. Liu, J., Zhao, Z., Ji, J., Hu, M. (2020). Research and application of wireless sensor network technology in power transmission and distribution system. Intelligent and Converged Networks, 1 (2), 199–220. https://doi.org/10.23919/icn.2020.0016
3. Swamy, S. N., Jadhav, D., Kulkarni, N. (2017). Security threats in the application layer in IOT applications. 2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC). https://doi.org/10.1109/i-smac.2017.8058395
4. Shivalingagowda, C., Ahmad, H., Jayasree, P. V. Y., Sah, D. K. (2021). Wireless Sensor Network Routing Protocols Using Machine Learning. Lecture Notes in Networks and Systems, 99–120. https://doi.org/10.1007/978-981-16-0386-0_7
5. Khutsoane, O., Isong, B., Gasela, N., Abu-Mahfouz, A. M. (2020). WaterGrid-Sense: A LoRa-Based Sensor Node for Industrial IoT Applications. IEEE Sensors Journal, 20 (5), 2722–2729. https://doi.org/10.1109/jsen.2019.2951345
6. Wang, A., Dara, R., Yousefinaghani, S., Maier, E., Sharif, S. (2023). A Review of Social Media Data Utilization for the Prediction of Disease Outbreaks and Understanding Public Perception. Big Data and Cognitive Computing, 7 (2), 72. https://doi.org/10.3390/bdcc7020072
7. Hajiakhoond Bidoki, N., Mantzaris, A. V., Sukthankar, G. (2019). An LSTM Model for Predicting Cross-Platform Bursts of Social Media Activity. Information, 10 (12), 394. https://doi.org/10.3390/info10120394

8. Ertam, F., Kilincer, I. F., Yaman, O., Sengur, A. (2020). A New IoT Application for Dynamic WiFi based Wireless Sensor Network. 2020 International Conference on Electrical Engineering (ICEE). https://doi.org/10.1109/icee49691.2020.9249771
9. Yahya, O. H., Alrikabi, H., Aljazaery, I. A. (2020). Reducing the Data Rate in Internet of Things Applications by Using Wireless Sensor Network. International Journal of Online and Biomedical Engineering (IJOE), 16 (03), 107. https://doi.org/10.3991/ijoe.v16i03.13021
10. Mejjaouli, S., Babiceanu, R. F. (2015). RFID-wireless sensor networks integration: Decision models and optimization of logistics systems operations. Journal of Manufacturing Systems, 35, 234–245. https://doi.org/10.1016/j.jmsy.2015.02.005
11. You, G., Zhu, Y. (2020). Structure and Key Technologies of Wireless Sensor Network. 2020 Cross Strait Radio Science & Wireless Technology Conference (CSRSWTC). https://doi.org/10.1109/csrswtc50769.2020.9372727
12. Taherdoost, H. (2023). Enhancing Social Media Platforms with Machine Learning Algorithms and Neural Networks. Algorithms, 16 (6), 271. https://doi.org/10.3390/a16060271
13. Gutierrez-Osorio, C., Gonzбlez, F. A., Pedraza, C. A. (2022). Deep Learning Ensemble Model for the Prediction of Traffic Accidents Using Social Media Data. Computers, 11 (9), 126. https://doi.org/10.3390/computers11090126
14. Huang, J.-Y., Lee, W.-P., Lee, K.-D. (2022). Predicting Adverse Drug Reactions from Social Media Posts: Data Balance, Feature Selection and Deep Learning. Healthcare, 10 (4), 618. https://doi.org/10.3390/healthcare10040618
15. Xu, Z., Qian, M. (2023). Predicting Popularity of Viral Content in Social Media through a Temporal-Spatial Cascade Convolutional Learning Framework. Mathematics, 11 (14), 3059. https://doi.org/10.3390/math11143059
16. Abu-Salih, B., Al-Tawil, M., Aljarah, I., Faris, H., Wongthongtham, P., Chan, K. Y., Beheshti, A. (2021). Relational Learning Analysis of Social Politics using Knowledge Graph Embedding. Data Mining and Knowledge Discovery, 35 (4), 1497–1536. https://doi.org/10.1007/s10618-021-00760-w
17. Malozyomov, B. V., Martyushev, N. V., Sorokova, S. N., Efremenkov, E. A., Valuev, D. V., Qi, M. (2024). Analysis of a Predictive Mathematical Model of Weather Changes Based on Neural Networks. Mathematics, 12 (3), 480. https://doi.org/10.3390/math12030480
18. Shafqat, W., Byun, Y.-C. (2019). Topic Predictions and Optimized Recommendation Mechanism Based on Integrated Topic Modeling and Deep Neural Networks in Crowdfunding Platforms. Applied Sciences, 9 (24), 5496. https://doi.org/10.3390/app9245496
19. Regulski, K., Opaliński, A., Swadźba, J., Sitkowski, P., Wąsowicz, P., Kwietniewska-Śmietana, A. (2024). Machine Learning Prediction Techniques in the Optimization of Diagnostic Laboratories' Network Operations. Applied Sciences, 14 (6), 2429. https://doi.org/10.3390/app14062429
20. Aljohani, A. (2023). Predictive Analytics and Machine Learning for Real-Time Supply Chain Risk Mitigation and Agility. Sustainability, 15 (20), 15088. https://doi.org/10.3390/su152015088
21. Sбnchez Lasheras, F. (2021). Predicting the Future-Big Data and Machine Learning. Energies, 14 (23), 8041. https://doi.org/10.3390/en14238041
22. He, Z., Yu, J., Gu, T., Yang, D. (2024). Query execution time estimation in graph databases based on graph neural networks. Journal of King Saud University - Computer and Information Sciences, 36 (4), 102018. https://doi.org/10.1016/j.jksuci.2024.102018
23. Zhu, L., Zhang, H., Bai, L. (2024). Hierarchical pattern-based complex query of temporal knowledge graph. Knowledge-Based Systems, 284, 111301. https://doi.org/10.1016/j.knosys.2023.111301