
BISINDO Sign Language Recognition: A Systematic Literature Review of Deep Learning Techniques for Image Processing

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Abstract

This study uses the Systematic Literature Review (SLR) method to examine the application of deep learning techniques focusing on BISINDO (Bahasa Isyarat Indonesia) image recognition. This is crucial for enhancing communication accessibility for the hearing-impaired community. The SLR process involves three stages: planning, conducting, and reporting. During the planning stage, research topics, questions, and search criteria are established, while the conducting stage involves comprehensive article retrieval and rigorous filtering. In the reporting stage, the study highlights the significance of various deep learning methodologies, including the implementation of several algorithms that are in image recognition. For example, Convolutional Neural Network (CNN), Long Short Term Memory (LSTM), and a combination of the two methods, each with unique advantages and limitations. Along with that, this paper aims to find gaps in previous research and act as a guide for future deep learning model development. Moreover, the research outlines the development of a high-performance model, emphasizing key phases such as image augmentation and data preprocessing, as well as model optimization. These efforts contribute to a better understanding of BISINDO image recognition, offering valuable insights for researchers and practitioners aiming to support easier accessibility and communication for the hearing-impaired community through advanced deep learning approaches.

A. Introduction

Communication is an important thing that contributes to the survival of humans [1]. It helps people in expressing themselves and understanding other people's goals. This is also in line with human nature as social creatures who need other people and communication. Likewise with people with disabilities who require special attention to hearing or what are commonly referred to as deaf. In Indonesia, there are 2,615,000 people with hearing disabilities [2]. Along with that, sign language serves as a strong basis for effective communication in the deaf community and also supports their social inclusion. The two sign languages that are developed and used are SIBI (Sistem Isyarat Bahasa Indonesia) and BISINDO (Bahasa Isyarat Indonesia).

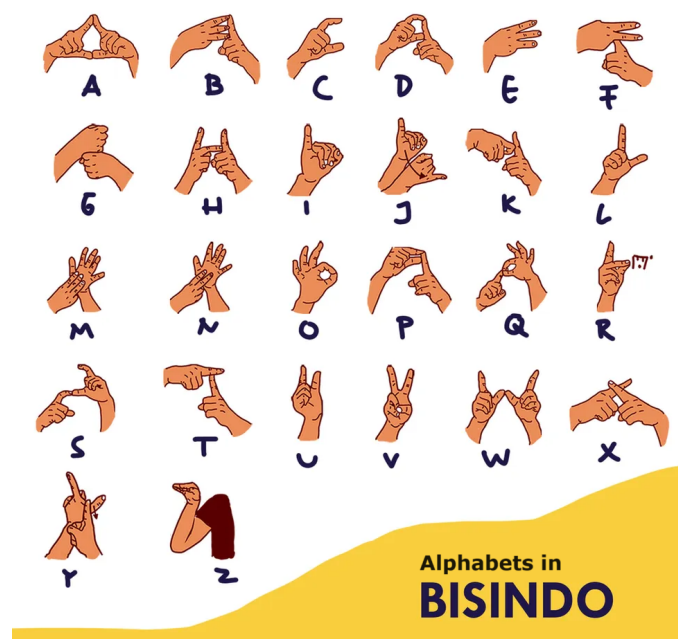


Figure 1. BISINDO Alphabetic [3]

SIBI is a visual medium commonly used by deaf people to communicate with the wider community. SIBI is a sign language that has been officially recognized by the Indonesian government and is used in teaching at Sekolah Luar Biasa (SLB) [4]. However, SIBI is considered more difficult as it observes the prefixes and suffixes of a word. Another difference with BISINDO is that SIBI is delivered using only one hand. On the other hand, BISINDO is a mother language that grows naturally in the Indonesian deaf community, the difference is shown in figure 1 and figure 2. BISINDO is a language that is easier in terms of use and understanding. Therefore, it is a more preferred language as it is considered more optimal, effective and expressive [5]. BISINDO plays an important role in facilitating communication and social integration for deaf people in Indonesia. This language, which is conveyed through hand gestures and facial expressions, has developed over time based on cultural influences and regional factors. This shows BISINDO's flexibility in adapting to diverse communication needs and contexts.



Figure 2. SIBI Alphabetic [3]

Good communication is achieved when the recipient and sender of the language both understand the message being expressed [6]. The challenge currently being faced by Indonesia is equal access and understanding of sign language among its people. Problems can arise when deaf people feel frustrated and isolated without having mediators around them which results in barriers to communication [7]. This needs to be addressed considering that every individual without exception has the right to express themselves through communication. In this era, almost everything depends on technology. One example is how technology has become the main supporting medium for communication. Unfortunately, there are no adequate communication facilities for the deaf community who use BISINDO as their main language. Therefore, the implementation of machine learning and deep learning algorithms can give a big impact through image recognition technology that can recognize BISINDO. Implementation of this model can help increase the sense of deaf people's inclusivity in modern society and achieve equality in communication for all individuals.

The understanding of BISINDO is still relatively low in Indonesia. This is an obstacle for deaf people in terms of establishing effective communication. Along with that, designing a BISINDO recognition system should be helpful. It can be done through the use and development of deep learning algorithms. Various previous studies with a similar focus have been carried out, but the accuracy values obtained are still relatively low. On the other hand, numerous studies about image recognition have used the combination of the two algorithms and succeeded in obtaining high accuracy values. Therefore, this study contributes to act as a guidance for future research in hopes of intensifying the socialization of BISINDO

in Indonesia through the analysis and evaluation of several model development and application of deep learning algorithms in the scope of BISINDO.

B. Research Method

This study focuses on the application of deep learning algorithms in BISINDO image recognition. Systematic Literature Review (SLR) is chosen as the research method for its ability to comprehensively identify, evaluate, consolidate, and summarize relevant studies, with well-documented steps with the aim to provide objective evidence [8]. The selected protocol for this SLR is PRISMA, which stands for Preferred Reporting Items for Systematic Reviews and Meta-Analyses [9]. This protocol has been adopted in a wide range of fields as a great assistant in conducting reviews of research literature [10]. PRISMA is proven to have helped improve report writing in obtaining a more structured, comprehensive, and rigorous review [11]. It was registered on August 14, 2021 in the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) [12]. The research questions are as follows: (RQ1) What are the common-used algorithms for image recognition?, (RQ2) What are the prevalent deep learning methods used in BISINDO recognition?, (RQ3) What steps should be done to enhance the performance of the deep learning models?, and (RQ4) How can high-performance models be developed in the context of BISINDO recognition?

The review process consists of three stages, such as planning, conducting, and reporting [13]. The planning stage is the initial phase of an SLR which sets the foundation for the entire review. This stage includes several key activities. First, the researchers must define the specific research questions or objectives focused on a certain topic that the SLR aims to address. In this case, the research questions could pertain to the types of deep learning methods used, their performance, and their applications in BISINDO recognition. Second, inclusion and exclusion criteria must be defined as the requirements that should be met by the articles reviewed. For example, this study reviews numerous researches that are in the range of 2019 to 2023 with specific keywords such as “BISINDO recognition”, “deep learning”, and “image recognition” obtained through a tool named Publish or Perish (POP). The identification procedures conducted are important to increase the chances of obtaining articles that are more pertinent or relevant to the review [14].

The conducting stage is the execution phase of the SLR which involves article retrieval, screening and selection, as well as data extraction. The researchers have to collect a large number of articles within the same focus. Then, the screening process requires the researchers to review titles and abstracts to determine whether the articles meet the inclusion criteria. Articles that pass this stage will be moved to the next step which is data extraction. Some of the essential data are the research methods, findings, and other relevant information related to the research questions.

The reporting stage is where the findings of the SLR are documented and presented. This stage involves the process of analyzing the results and key

findings, writing the review in a structured and systematic way, summarizing the paper, and highlighting the limitations. The researchers can also suggest some recommendations for future research.

C. Result and Discussion

From the 50 articles collected, 15 of them succeed in fulfilling the inclusion criteria. These articles are then extracted and analyzed in order to answer the two research questions that have been defined before (RQ1, RQ2, RQ3, and RQ4). The summary of the 15 chosen articles can be seen from the table 1.

Table 1. Reference Comparison of Sign Language and Image Recognition

No	Title and References	Object	Algorithm	Research Result
1.	Indonesian Sign Language Image Detection Using Convolutional Neural Network (CNN) Method [7]	SIBI and BISINDO Alphabet	CNN	SIBI sign language showcases an impressive 93.29% accuracy, revealing CNN's proficiency in recognizing its intricate signs, though it is not without room for improvement with a 9.1% loss. On the other hand, BISINDO, while still respectable at 82.32% accuracy.
2.	Real-time BISINDO Hand Gesture Detection and Recognition with Deep Learning CNN [15]	BISINDO Alphabet	CNN	Real-time BISINDO Hand Gesture Detection and Recognition using Deep Learning Convolutional Neural Networks (CNN) resulting in a low accuracy rate of 59.54%.
3.	Development of the Indonesian Sign Language (BISINDO) Translator Application using the Long-Short Term Memory Method [16]	BISINDO Alphabet	LSTM	The development of an Indonesian Sign Language (BISINDO) Translator Application using the Long-Short Term Memory (LSTM) have better accuracy at 85%.
4.	Android-Based Application for Real-Time Indonesian Sign Language Recognition Using Convolutional Neural Network [17]	BISINDO Alphabet	CNN	The CNN resulting in 75.38% at BISINDO dataset.
5.	A CNN-LSTM Approach to Human Activity Recognition [18]	Intelligent Signal Processing Lab (iSPL) and University of California Irvine Human Activity Recognition (UCI HAR)	CNN-LSTM	The combination of CNN and LSTM methodologies has better result accuracy of 99.06% for the iSPL dataset and 92.13% for the UCI dataset. The precision of the model in discerning intricate patterns is further underscored by low loss rates, measuring at 3.92% for iSPL and 29.53% for UCI.
6.	A CNN-LSTM network with multi-level feature extraction-based approach for automated detection of coronavirus from CT scan and X-ray images [19]	SARS-CoV-2 CT Scan, SIRM Covid-19 CT Scan, and Chest CT Scan	CNN-LSTM	The integration of a CNN-LSTM network employing a multi-level feature extraction-based approach has proven highly effective in the automated detection of coronavirus from diverse imaging datasets,

No	Title and References	Object	Algorithm	Research Result
				including SARS-CoV-2 CT Scan, SIRM Covid-19 CT Scan, and Chest CT Scan. The evaluation results underscore the robust performance of the model, with an impressive accuracy of 98.94% for SARS and 83.03% for SIRM. Additionally, the high precision, recall, and F1 score values for both datasets further validate the model's capability in not only achieving accurate detection but also maintaining a balance between true positives and false positives.
7.	Classification of benign and malignant subtypes of breast cancer histopathology imaging using hybrid CNN-LSTM based transfer learning [20]	Breast Cancer Histopathology Imaging	CNN-LSTM	The application of hybrid CNN-LSTM based transfer learning for the classification of benign and malignant subtypes in breast cancer histopathology imaging has demonstrated remarkable efficacy, achieving an impressive accuracy of 99.75% and a recall rate of 99%.
8.	Development of CNN-LSTM combinational architecture for COVID-19 detection [21]	Chest CT Scan of Normal People and COVID-19 Infected	CNN-LSTM	A CNN-LSTM combinational architecture for COVID-19 detection, utilizing Chest CT scans of normal individuals and those infected with COVID-19, has yielded highly promising results. With an accuracy of 98.91%, precision of 100%, recall of 97.82%, and an impressive F1 score of 98.90%.
9.	A novel CNN+LSTM classification model based on fashion-MNIST [22]	Fashion MNIST	CNN-LSTM	The CNN+LSTM classification model applied to the Fashion-MNIST dataset has demonstrated notable effectiveness, achieving an accuracy of 91.36%.
10.	A combined deep CNN-LSTM network for the detection of novel coronavirus (COVID-19) using X-ray images [23]	Chest CT Scan of Normal People and COVID-19 Infected	CNN-LSTM	A deep CNN-LSTM network for the detection of novel coronavirus (COVID-19) through X-ray images has proven highly effective, attaining an impressive accuracy of 99.2% and an F1 score of 98.9%.
11.	Recognition of offline handwritten Urdu characters using RNN and LSTM model [24]	Hand-written Urdu Characters	CNN-LSTM	The comparison of RNN and LSTM resulting in different result, the RNN could produce 73.62% of accuracy, while the LSTM has higher accuracy at 91.30%
12.	Classification of Guava Fruit Ripeness Levels Based on Skin Color Using the Naïve Bayes Method [25]	Guava Image	Naïve Bayes	The Naive-Bayes on Image Recognition for Guava, resulting in 75% of accuracy.
13.	Establishment of a Recurrent Neural Network Model and Connectionist Temporal Classification in	Hand-written Words	RNN and Connectionist Temporal Classification	The combination of RNN and Connectionist Temporal Classification of Hand-Written words, has an accuracy of 82.12%.

No	Title and References	Object	Algorithm	Research Result
	Offline Handwritten Word Recognition [26]		n	
14.	Development of the SIBI Alphabet Sign Language Recognition Application Using the Convolutional Neural Network (CNN) Method [27]	SIBI Alphabet	CNN	The SIBI, another Indonesian Sign Language is classified using CNN and resulting 80.76% of accuracy, 80.76% precision and 80.76% recall.
15.	Implementation of the Convolutional Neural Network Method for Identifying Digital Images of Leaves [28]	Leaf Image	CNN	The other example of Image Recognition using CNN for leaf image resulting in 92% accuracy, 89% of precision, 87% recall and 88.51% f1 score.

The research mind map on deep learning approaches for BISINDO (Bahasa Isyarat Indonesia) image recognition encompasses a diverse set of objects, including BISINDO alphabet, SIBI alphabet, ISPL & UCI HAR datasets, Covi19 CT Scan images, and Handwritten Words. The investigation focuses on leveraging advanced techniques to effectively recognize and interpret these diverse visual elements that shown on figure 3.

In terms of methodology, several deep learning techniques are explored. Convolutional Neural Networks (CNN) are employed to capture spatial hierarchies and patterns within the images, making them well-suited for tasks such as alphabet and handwritten word recognition. Long Short-Term Memory networks (LSTM) are utilized for their ability to model sequential dependencies, making them effective for datasets like Covi19 CT Scans, where the spatial and temporal aspects are crucial. Additionally, combinations of CNN-LSTM and Recurrent Neural Networks (RNN) are explored to harness the strengths of both spatial and sequential processing. Naive Bayes, a probabilistic classifier, is also investigated for its simplicity and efficiency, especially in scenarios with limited computational resources.

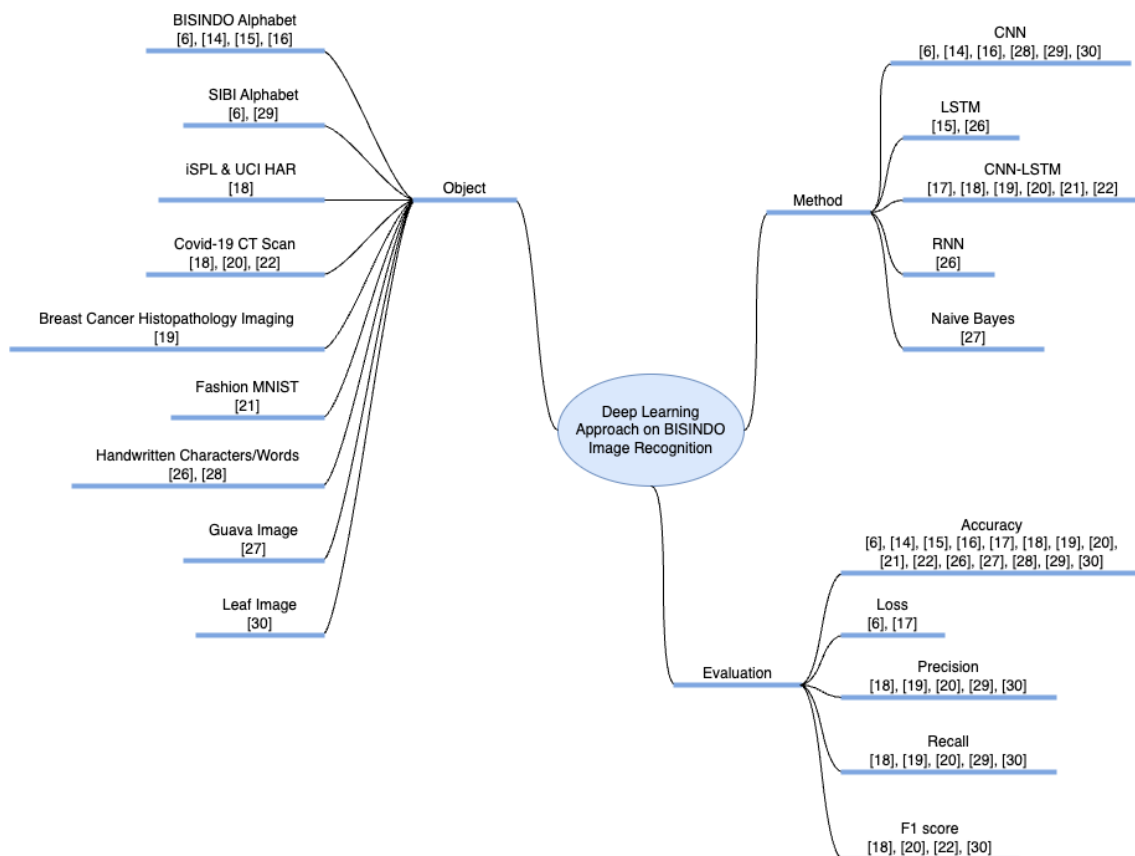


Figure 3. Research Mindmap

The evaluation of the proposed models is conducted using various metrics to ensure a comprehensive understanding of their performance. Metrics such as accuracy provide an overall measure of the model's correctness, while loss functions quantify the difference between predicted and actual values. Precision and recall metrics offer insights into the model's ability to minimize false positives and false negatives, respectively. The F1 score, which combines precision and recall, is employed to strike a balance between these two metrics, providing a holistic performance measure.

This research aims to contribute to the advancement of deep learning applications in sign language recognition and image interpretation, with a particular focus on the unique challenges posed by BISINDO, SIBI, ISPL & UCI HAR datasets, Covi19 CT Scan images, and Handwritten Words. The combination of diverse objects, state-of-the-art methods, and thorough evaluation metrics ensures a comprehensive exploration of the deep learning landscape in the context of BISINDO image recognition.

In the realm of Sign Language Recognition (SLR), the landscape of image recognition and deep learning methods has witnessed substantial growth, catalyzed by the increasing demand for accurate and efficient communication systems. This systematic literature review (SLR) embarks on an exploration of critical research questions to unravel the intricacies surrounding image recognition algorithms and their prevalence in the domain of BISINDO (Bahasa Isyarat Indonesia) recognition. Our first research question (RQ1) delves into the

identification of common algorithms employed in image recognition, shedding light on the foundational methodologies shaping the landscape. Moving forward, our second research question (RQ2) seeks to unravel the prevalent deep learning methods specifically applied to BISINDO recognition, emphasizing the unique challenges posed by sign language gestures. The third research question (RQ3) directs our attention towards understanding the steps essential for enhancing the performance of deep learning models in this specialized domain. Finally, our fourth research question (RQ4) aims to discern the strategies and techniques conducive to the development of high-performance models tailored to the nuanced intricacies of BISINDO recognition. Through these inquiries, this SLR endeavors to offer comprehensive insights, fostering a deeper understanding of the current state and future directions in the intersection of image recognition, deep learning, and BISINDO recognition.

(RQ1) What are the common-used algorithms for image recognition?

Based on the SLR conducted, here are several algorithms that are suitable for image recognition. These include Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), a combination of CNN and LSTM (CNN-LSTM), Recurrent Neural Networks (RNN), and Naïve Bayes. Due to their demonstrated effectiveness in various studies and applications, these algorithms have emerged as popular choices in the field of image recognition. Moreover, the exploration of the literature also highlights the importance of choosing the most appropriate algorithm based on specific application requirements and the nature of the image data being processed. The selection should consider numerous factors such as the processing complex level, the size of the dataset, and the computational resources available. This approach to algorithm selection allows researchers and practitioners to tailor their image recognition solutions to suit the unique demands of their projects as well as ensuring optimal results and performance in diverse applications.

(RQ2) What are the prevalent deep learning methods used in BISINDO recognition?

In developing the BISINDO image recognition model, there are several deep learning algorithms that can be used. Convolutional Neural Network (CNN) is believed to be one of the most popular and reliable methods specialized in image recognition [29]. This is also in line with the fact that a lot of previous research uses CNN as the chosen algorithm. Other than CNN, Long Short Term Memory (LSTM) is also a well-known algorithm in this matter along with a combination of the two methods, which is CNN-LSTM. The combined algorithm incorporates the use of feature extraction from CNN and the ability to predict and classify time series data by LSTM. Along with that, it can be seen that CNN-LSTM in several previous studies generally outperforms other predictive models based on the evaluation metrics used.

The CNN architecture usually consists of several layers, such as convolutional layers, pooling layers, a fully-connected layer, and output layer. First, the convolution operation is carried out with the aim of extracting features from the input data through filters or kernels to detect certain patterns, such as edges,

corners or textures. This process is normally assisted by the ReLU activation function. The component after convolution is pooling. This layer will help reduce the dimensions or resolution of the feature representation produced by the convolutional layer. It is also able to prevent overfitting through computational efficiency. Then, the process continues at the fully connected layer which consists of various neurons that are interconnected within layers and functions to make final decisions or classify modeling results [30]. Conversion of 3-dimensional data into 1 dimension is also carried out at this layer using the flatten function.

(RQ3) What steps should be done to enhance the performance of the deep learning models?

The experiments conducted are more than once with different scenarios in each case to explore the possibilities of generating a model with the best performance. There are also some studies that use the same model on two different datasets and result in different values in the evaluation metrics too. Numerous factors can be the cause of this situation. For example, the image preprocessing wasn't done properly which results in the poor quality of the data used [7]. Noise in pictures can be detrimental to the learning model's performance for several reasons, such as reduced robustness, increased dimensionality, difficulty in feature extraction, and longer training time. Also, various struggles can be faced according to the dataset used. For example, predicting BISINDO's alphabets can be a hassle since a few letters are quite similar to each other if the model wasn't able to do enough learning of the training data [15]. Some of the alphabets that are hard to predict are B, D, J, K, and P.

The size of a dataset also matters, where a bigger dataset can help the model to learn better [16]. The reason is because a larger dataset typically contains a more extensive variety of examples. This diversity is important as it exposes the model to a broader range of scenarios, variations, and data patterns. The model will be able to distinguish different classes better through more well-defined decision boundaries between categories. In other words, the model will be less likely to make errors. It also allows the model to become more adaptable when encountering new unseen data in real-world applications. Another reason is that using a larger dataset can help reduce the risk of overfitting and improve generalization.

Cross-validation in deep learning models with divergent folds is essential for robust model evaluation. However, in some cases, randomized data separation should be done instead of cross-validation [19]. Some of the reasons are computational complexities, resource constraints, time constraints, and others. This is because cross-validation involves training and evaluating the model multiple times where it can be impractical and time-consuming if there are no sufficient resources.

(RQ4) How can high-performance models be developed in the context of BISINDO recognition?

Numerous previous researches about BISINDO chose either CNN or LSTM as the algorithm. However, these models still have poor performance in BISINDO recognition. On the other hand, various studies with different focuses have used a

combined algorithm (CNN-LSTM) and proven to be able to obtain a predictive model with outstanding performance. One of the supporting factors is how CNN-LSTM combines spatial and temporal aspects of data that allows them to recognize complex patterns and relationships in the input data. CNN is equipped with hierarchical feature learning that enables it to detect low-level features to high-level features from the raw data, while LSTM can capture the dependencies and relationships between data over time, which also supports the establishment of more accurate predictions [31]. Therefore, the deep learning models can be developed by combining the two algorithms into one and gain all advantages from each method.

Another way is to improve the dataset in terms of lighting conditions, varying angles, and incorporating diverse gestures other than alphabets [16]. Lighting conditions can enhance the model robustness as it will help in the learning process of recognizing patterns and features even when the lighting varies. This is also crucial for real-world applications where the change in lighting is unpredictable and inevitable. Improving object recognition in models can then be done through the variation in camera angles. Lastly, applicability of the BISINDO recognition system can be expanded by incorporating a wider range of gestures. This can also enhance the user experience on using the system, especially for the hearing-impaired community, as it allows a more natural, intuitive, and richer interaction or communication.

D. Conclusion

In conclusion, the SLR conducted aims to give information about how to develop the image classification model in BISINDO recognition. Based on the 15 articles analyzed, CNN, LSTM, and CNN-LSTM are the three most used algorithms in image recognition. Second, it is also found that the use of combined algorithm CNN-LSTM and improved dataset in terms of lighting conditions, variative angles, and diverse gestures can help enhance the performance of the predictive model. This is because it supports generalization and reduces bias in the model that might lead to inaccurate results. It also introduces the model to more scenario varieties an image might have. However, it is imperative to acknowledge that BISINDO, or Indonesian Sign Language, still faces challenges that necessitate continuous efforts for refinement. Both the model and dataset demand ongoing attention and enhancement to yield more accurate and reliable results. This recognition of the evolving nature of BISINDO image recognition serves as a call to action, emphasizing the importance of sustained research and development to achieve superior outcomes in the dynamic landscape of sign language interpretation through deep learning models.

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