Modeling Ramadan Hilal Classification with Image Processing Technology Using YOLO Algorithm

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Abstract

This research aims to create a model for classifying hilal using the YOLO algorithm. The determination of the beginning of the month of Ramadan is an important aspect of the Islamic calendar that has an impact on the implementation of fasting. With technological advances, especially in image processing, there is potential to overcome the limitations of conventional methods currently used in hilal detection for determining the beginning of Ramadan. This research uses the prototyping method in its implementation. The dataset in this research comes from videos on the BMKG Youtube channel and images from various sources such as NASA Planetary Data System and Google Images. YOLOv5 and YOLOv8 algorithms are used to develop the object detection model. The novelty of this research is the use of the YOLO algorithm with video datasets to detect hilal to determine the beginning of the month of Ramadan and Shawwal. The best-performing model, YOLOv5m with 100 epochs and a batch size of 30, achieved a precision of 0.838 and a mAP of 0.5-0.95 of 0.735. The results indicate that YOLOv5m is more effective in hilal detection, providing a novel approach to determine the beginning of Ramadan and Shawwal with greater accuracy and consistency. This integration of advanced object detection technology with religious practice offers a significant improvement over traditional method.

Keywords: Hilal Ramadhan, Object Detection, YOLO, Deep Learning, Observation

1. Introduction

In a country where the majority of people are Muslims, such as Indonesia, determining the beginning of the month of Ramadan is an important aspect that must be ascertained accurately. This is because the determination of the beginning of the month of Ramadan will have an impact on the timing of the beginning of fasting. There are two basic methods in determining the beginning of Ramadan and the beginning of Shawwal every year in Indonesia, namely the opinion of wujudul Hilal based on Hisab (the moon is above the horizon) and the opinion of Rukyatul hilal (the moon is above the horizon with provisions) [1]. The Hisab method, which means calculation, is a more systematic approach and allows for more accurate predictions [2]. It relies on careful astronomical calculations to determine the exact position of the moon and estimate when the new moon will be visible above the horizon. In contrast, the rukyatul hilal method, or visual observation of the new moon crescent, relies heavily on direct observation conditions [3]. Factors such as weather conditions and visibility play an important role in the success of this method, adding variability and subjectivity to the determination of 1st Ramadhan [4]. The differences between these two methods often lead to in-depth discussions on the more valid approach to determining this important date in the Islamic calendar.

Although determining the beginning of the month using the hisab method is more efficient, the use of the observation method is still widely used, especially in Muslim circles [5]. Hilal (new moon) is the key to determining the beginning of the month in the lunar/Hijriyah calendar. With a simple calculation, the circulation of the moon can be transformed into a unit of time measurement, which we often know as a calendar. The process of starting the calendar on the lunar calendar spurs by looking at the moon phase from the surface of the earth which consists of certain criteria and aspects. The hilal observation criteria have existed since Babylonian times [6]. There are several Muslim astronomers, including Ibn Tariq, Habash, Al-Khwarzmi, Al-Khazin, Al-Tabari, Al-Fahhad, Al-Farghani, Thabet Ibn Qurrah, Al-Battani, Ibn Maimon, Al-Biruni, Al-Sufi, Ibn Sina, At-Tusi, and Al-Kashani. In this day and age, these criteria are growing and many such as Indonesia use neo-MABIMS (Ministers of Religious Affairs of Brunei, Darussalam, Indonesia, Malaysia, and Singapore). These criteria are only a benchmark and do not guarantee that the hilal can be observed, such as under

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unfavorable weather conditions such as cloudy or rainy skies, or even when all the criteria are met but the hilal is still not visible. All religions utilize the concept that there is a limit beyond which the Moon cannot be seen regardless of weather conditions and no matter how good the observer's eyes are [7]. The meeting point between the hishab method and the rukyat method is to find criteria for both hishab and rukyat in interpreting the hilal in accordance with shari'a and astronomical scientific principles. There are no strict quantitative criteria in the Qur'an or hadith, such as prayer times that are easily interpreted quantitatively astronomically [8]. For example, in Ramadan 1443 H or April 2022, there were differences in the beginning of Ramadan in Indonesia with several Muslim countries in the world. Some other countries such as Saudi Arabia and the United Arab Emirates set the 1st of Ramadan 1443 H on April 2, 2022, while countries in Southeast Asia who are members of MABIMS (Ministers of Religious Affairs of Brunei, Darussalam, Indonesia, Malaysia, and Singapore) set it on April 3, 2022. In addition, in Ramadhan 1432 H (August 2011), there was a delay in the trial process which was held at 20:00 WIB. The late news resulted in irregular tarawih prayers, especially in Eastern Indonesia which is 2 hours apart from Java.

Technology, which is an application of science, has proven to provide convenience in human daily life [9]. Advances in information technology have become a major driver of transformation that has a significant impact on various aspects of human life, including health, education, transportation, and other sectors more broadly. In today's era of rapid technological development, technology has become an essential element in human life. Among the various types of information technology that are growing rapidly, Big Data and artificial intelligence are examples of technologies that have experienced the most significant growth. Today, we can hardly imagine our lives without artificial intelligence (AI)-based solutions. For example, autonomous vehicles have become a reality and are almost a standard feature in all recent vehicle models [10]. To keep up with today's technological developments such as the development of artificial intelligence, the discussion about the integration between technology and religion has become a hot topic among Muslims around the world because technological advances can affect the practice of worship and the way a Muslim learns religion, for example, IoT technology can also be used as a support in the religious field [11], [12], [13], [14], [15], [16]. Features such as prayer reminder apps, digital Quran, and online religious courses have made daily religious practices easier for Muslims. Technological advances have also brought innovations such as image processing technology that focuses on digital processing of visual images to improve quality or to extract useful information [17]. One of the implementations of image processing technology is object detection. Object detection is the process of image recognition by computers to recognize visual objects of a certain class (such as animals or plants) in a digital image [18], [19], [20]. The goal is to develop computational models and techniques that can determine what and where the detected object is. The development of object detection technology has opened up new opportunities in various fields, including religious life. The integration of object detection technology in religious practice offers an innovative way to overcome traditional challenges in rukhiyatul hilal.

We conducted a literature study by looking for research related to object detection on hilal. Research [21] and [22] used Mask R-CNN algorithm to detect hilal and got high accuracy even in extreme weather. The YOLO algorithm is most widely used for object detection, for example in research [23], [24], [25], [26], [27]. Research [28] aims to develop a multi-object detection system on mobile devices capable of providing real-time nutritional information. The main focus is on the detection of food items in various complex contexts, using a quantized YOLOv7 model to improve the performance of mobile applications in real-time object detection. However, this research focuses on model efficiency and size reduction for mobile applications, using quantized YOLOv7 and is not specific to moon detection. Interesting things found in the research [29] that used conventional image processing techniques and Circular Hough Transform for young crescent detection from video data, but did not use deep learning or YOLO which could provide a more robust and automated approach. All of the above studies show the potential of utilizing object detection but require further development to be able to produce a model that can detect hilal quickly and accurately.

From the literature review related to the use of image processing technology and the YOLO algorithm in various object detection applications, several research gaps were identified that are relevant to the research on Ramadan new moon classification using YOLO based on video datasets. First, although the YOLO algorithm has been widely applied for real-time object detection on mobile devices and in diverse contexts, its use for the detection of astronomical phenomena such as hilal, especially those associated with the Hijri calendar, has not been widely explored. Secondly, most previous studies have used static image data rather than video. The use of video as a dataset can be advantageous in hilal detection, as it allows the analysis of temporal information that can improve the accuracy of detection.

This research will adopt a more integrated and comprehensive approach. We will use a video model taken from BMKG's Youtube channel because there are several hilal rukyat livestream videos. This is expected to provide more dynamic and representative visual data compared to the static images used in the previous 3 studies. Furthermore, for data collection, we will train the model using images available at NASA Planetary Data System, BMKG website, and several other sites. The dataset that the author has taken includes all the data displayed on the available page without omitting any data. The comprehensive data extraction from the page is due to the page being of very high quality and, of course, trustworthy, as it has undergone repeated checking and validation processes. By using this dataset, we have a broader and more diverse database, which increases the reliability and validity of the research results. Finally, we will use the YOLO (You Only Look Once) algorithm in the model that will be developed because it has been proven effective in detecting objects from images [30].

2. Method

2.1. Data Collection Method

The use of data collection methods is aimed at obtaining accurate and relevant information to answer research questions and test hypotheses that have been formulated and designed to ensure sample representativeness, reduce bias, and improve data reliability and validity. Research with this data collection method begins with a literature study that aims to identify and obtain references that are relevant to the research topic. The reference search was conducted comprehensively through various online platforms, including electronic books, and scientific journals/articles. Once the references were collected, the next critical step was to select relevant and significant information to support the theoretical and methodological framework of the research used to develop the study.

2.2. System Development Method

This research uses a system development method, namely prototyping. According to Cambridge Dictionary [31], a prototype is an early model of an object, such as a machine or other industrial product, that serves as the basis for the development of later forms. The decision to use the prototyping method was based on several key factors. Firstly, this approach is particularly effective for systems that need continuous adjustments, which is often the case when developing machine learning models. It allows researchers to quickly experiment with and tweak hyperparameters, crucial for avoiding overfitting and ensuring accuracy. Secondly, prototyping makes it easier to compare different versions or setups of algorithms. In this study, we compared two versions of the YOLO algorithm to see which one worked better for classifying crescent moons. The ability to rapidly iterate and assess models through prototyping provided us with valuable insights into the performance of each version. Lastly, this method is well-suited for projects without clear, defined specifications, offering the flexibility needed for early-stage research. Early discoveries and testing in such projects can significantly shape the development of the model going forward. The use of the prototype method helps in identifying user needs, planning appropriate technical solutions, and ensuring that each stage of development is carried out to quality standards. The steps of the prototype method are shown in figure 1.

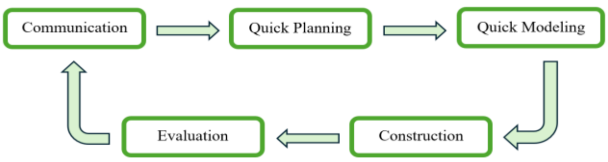

Figure 1. Flow of Prototype Method

Communication. We communicate to related parties who have sources of information or related data that are in accordance with the research. BMKG (Meteorological, Climatological, and Geophysical Agency) which is one of the official Indonesian government agencies that provides datasets in the form of hilal images collected from various other related institutions in Indonesia. Then, we searched and collected other dataset sources through the ICO UK institution. The dataset collection began in November 2023, until it reached a total of 714 hilal images. The entire collection was stored in one organized folder, with the aim of facilitating data pre-processing. This single-class storage aims to simplify the data structure and facilitate subsequent stages of analysis, ensuring efficiency and consistency in the use of the dataset for the developed model.

Quick Planning. we use the data preprocessing stage, which includes various technical steps aimed at transforming the raw data into a more structured format ready for analysis. This process involves data formatting, annotation, splitting, and data augmentation as necessary to ensure data quality and consistency. As such, data pre-processing not only improves the orderliness and readability of the data, but also maximizes accuracy and efficiency in subsequent data analysis.

In the data pre-processing stage, the first step is data formatting. Data formatting refers to the process of organizing and grouping data in a specific format. In this research, the formatting process is done by changing the image format to PNG to ensure data consistency and prevent missing images during the training process. To achieve this, researchers used the PILLOW library to convert image files that were not yet PNG format. This format alignment aims to ensure that all data meets the required standards, so that it can be processed effectively during the model training stage. Figure 2 shows a collection of crescent moon images that have been converted to PNG after using the PILLOW library.

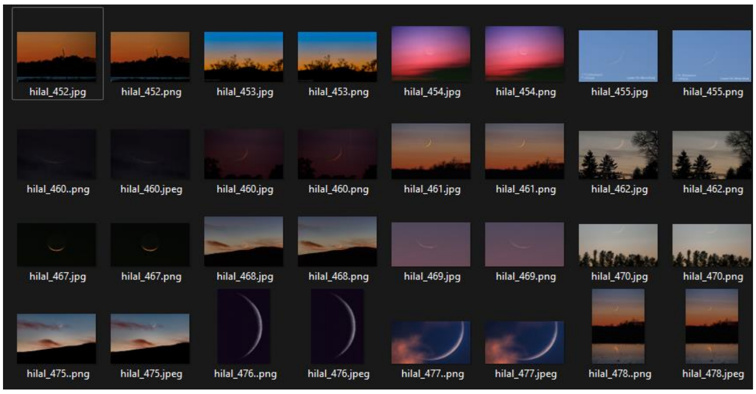

Figure 2. Formatting results using PILLOW

The next step performed is the labeling or annotation of the data. Each image is labeled according to its category using labeling software, which allows adding bounding boxes to each image individually as shown in figure 3. The labeling process is essential for determining the specific areas in the image that will be the focus of analysis by the machine learning model. As such, labeling ensures that the data fed into the model is verified and matches the needs of the analysis, thus supporting the overall accuracy and effectiveness of the model.

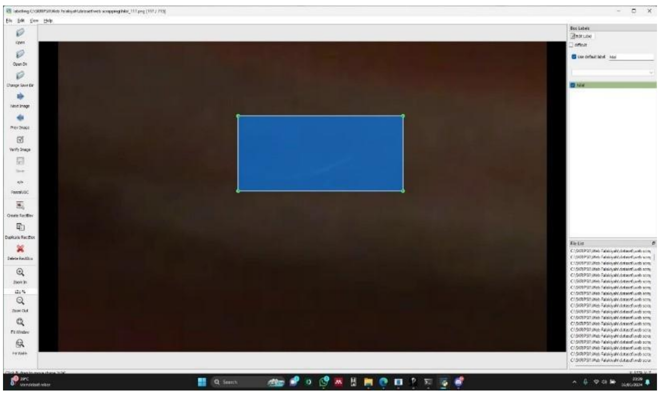

Figure 3. Data Annotation (Labeling) Process

Once the labeling process is complete, the labeled data is then separated into three different folders, one each for training, validation, and testing purposes. The details of the data division are shown in table 1. Care was taken to ensure that each subset represented a consistent distribution of data. The purpose of such separation is to provide sufficient data sets for model training, while validation and testing are used to evaluate the performance of the model independently, thus ensuring that the model not only learns from the training data, but is also able to generalize well on data that has never been seen before.

Table 1. Dataset Division

Dataset	Percentage	Total
Training_data	96%	684
Valid_data	2%	20
Testing_data	1%	10
Dataset Total	714	

The final stage in data pre-processing is augmentation, which aims to add variety to the dataset to improve the model's ability to deal with various real-world situations. We apply augmentation techniques such as gray-scaling to convert images to different shades of gray and mirroring as shown in figure 4 to create flipped versions of the images in the training dataset folder. The augmentation techniques serve to make the model more adaptive, help increase the diversity of the training data, thereby improving the model's ability to generalize to new unseen data, and reduce the risk of overfitting. As a result of the augmentation process, the number of images increased from 714 to 802, providing more variety for the model to learn and strengthening its ability to recognize patterns more effectively.

Figure 4. Gray-scaling

Quick Modeling. This stage involved using two YOLO models, YOLOv5 and YOLOv8. The selection of these two models aims to evaluate whether the latest model is always superior to the previous model and to consider the stability of the two models, which is the reason why YOLOv9 was not selected. The reason for choosing YOLOv5 is because the model was developed by Ultralytics using Pytorch as its main backbone. Pytorch is known as a popular and user-friendly machine learning framework, making it easy to develop, debug, and deploy models, which supports dynamic graphing that simplifies model development and optimization. Furthermore, YOLOv5 has improved detection capabilities for anchor boxes. Anchor boxes are an important technique in object detection that allows the model to handle various object sizes more effectively. So, the use of YOLOv5 is suitable for finding solutions that are fast, easy to use, and have proven reliable in many applications. The YOLOv5 algorithm includes several types of models: YOLOv5s, YOLOv5n, YOLOv5m, YOLOv5L, and YOLOv5x. In this study, the authors chose to use the YOLOv5m model due to its higher efficiency and speed compared to the other models. While the reason for choosing YOLOv8 is because YOLOv8 uses the c2f module on the backbone which can help in processing detection by overcoming bottlenecks in concat, which will increase efficiency, detection speed, and reduce computational overhead. Furthermore, YOLOv8 adopts the latest technologies and innovations in network architecture, which provides improved performance and accuracy over previous versions. The combined use of YOLOv5 and YOLOv8 is used to leverage the strengths of both versions to optimize the object detection system for various needs and scenarios, ensuring the best performance with a high degree of flexibility. The first step in this process is to train the model with both versions of YOLO to develop a hilal detection model based on the previously prepared dataset. The main objective of this stage is to optimize the hilal detection process with a high level of accuracy, so as to overcome the limitations of vision due to unusual weather conditions. After the training process is completed, the model will be evaluated and tested to ensure its performance. Then, the training of the YOLO models begins by determining the hyperparameters in each model. Hyperparameters are values that control the model learning process and determine the model result. Hyperparameters determined in this YOLO models including image size, epochs/iterations, batch/number of images for both YOLOv5 and YOLOv8, plus learning rate for exclusive for YOLOv8. Determining these hyperparameters is very important because if they are too large, it can lead to overfitting. As shown in table 2, epochs of 30, 100, and 110 were selected with batches of 8 and 30 using the Random Search method. The random search method for hyperparameter optimization is conducted by defining a range or distribution of hyperparameters to be searched, then an algorithm searches for hyperparameter values within the previously given range [32]. this process conducted systematically, rather than manually adjusting them.

Table 2. Hyperparameters Division

	Model	Epoch	Batch
	1	30	8
YOLOv5	2	100	30
	3	110	30
YOLOv8	4	100	30

Construction. The model testing stage is to measure its ability to accurately detect objects. Testing is done using data sets that are not included in the training process to ensure that the model is able to generalize well as shown in figure 5. This testing is essential to assess the effectiveness of the model in classifying and localizing objects in real conditions. In addition, an error analysis will be conducted to identify the types of objects or situations that frequently cause prediction errors by the model. This analysis provides important insights for further refinement of the model, ensuring the model is not only effective but also reliable in various situations.

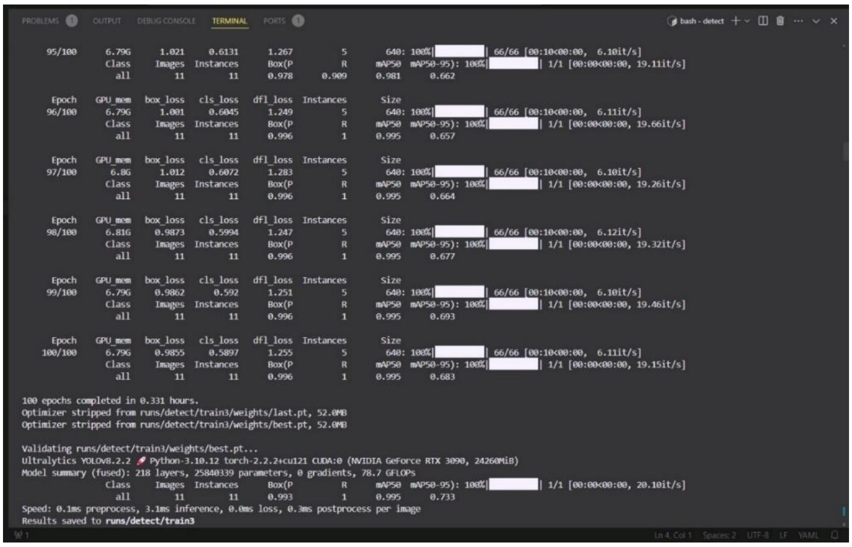

Figure 5. Training and testing process with hyperparameters

Evaluation. The trained model will be evaluated using images that are not included in the training dataset. The results of the evaluation are shown in table 3. The evaluation aims to measure the model's capabilities with a series of metrics, such as accuracy, precision, recall, and F1 score. The reason these metrics are used is to ensure that the model is not only effective in identifying the presence of hilal (as measured by recall), but also accurate in minimizing false detections (as measured by precision). F1-score combines these two aspects in one metric to balance the need for complete hilal detection. Accuracy provides an overview of the model's effectiveness across all classes. The use of these metrics together supports the development of models that are not only accurate but also practical and reliable for real applications in the determination of important dates in the Hijriyah calendar. The evaluation process is designed to provide a comprehensive overview of the model's ability to classify objects accurately. By using these metrics, the evaluation not only assesses classification accuracy but also the balance between type I and type II errors, thus providing a deeper understanding of the model's performance under various real-world conditions.

Table 3. Precision-Recall-F1

	Model	Precision	Recall	F1-score
YOLOv5	1	0.9945	1	0.786
	2	0.9947	1	0.787
YOLOv8	3	0.9951	1	0.473

4	0.9964	1	0.553

3. Results and Discussion

The training and testing stages were conducted by testing four models with different hyperparameters to determine the best model in classifying hilal objects in images. The first model uses a batch of 8 with 30 epochs of iteration. Then, the second model uses a batch of 30 with an iteration of 100 epochs. Furthermore, the third model uses a batch of 30 with an iteration of 110 epochs. Finally, the fourth model uses a batch of 30 with an iteration of 100 epochs. The architecture used in models one and two is YOLOv5m, while the architecture used in models three and four is YOLOv8. To find which model has the best results, Random Hyperparameter Tuning was first conducted. The test results in Table 4 showed that model 2 had the best results with a precision of 0.838 and a mAP of 0.5-0.95 of 0.735. Then, models using YOLOv5m architecture have a tendency to increase model performance if the number of batches and epochs is added. On the contrary, the increase in the number of epochs or batches in the model using the YOLOv8 architecture actually shows signs of overfitting or causes a decrease in the value of accuracy results.

Table 4. Random Hyperparameter Tuning Test Results on Model

Model	Epoch	Batch	P	R	MaP-0.5	MaP0.5-0.95
1	30	8	0.836	1	0.995	0.634
2	100	30	0.838	1	0.995	0.735
3	110	30	0.525	1	0.996	0.722
4	100	30	0.599	1	0.995	0.683

Furthermore, in the training and validation process, there are 3 losses consisting of bounding boxes loss, object loss, and class loss. The training and validation process is done by taking a sample dataset from the augmented dataset and then testing it. Among the four models trained, the model with YOLOv5m architecture has a lower loss rate than the model with YOLOv8 architecture. This indirectly shows the effectiveness of the YOLO architecture on the number of batches and epochs applied to the hyperparameters.

Table 5. Loss in Train Process

	Model	Box_loss	Cls_loss
YOLOv5	1	0.31	0
	2	0.207	0
YOLOv8	3	1.001	0.62
	4	0.985	0.59

After the random hyperparameter tuning and loss evaluation stages, the direct testing process is carried out by testing the previously created models using seven images with hilal objects and two videos with hilal objects. The direct testing process is carried out using a random dataset that does not exist in the training dataset to test the ability of the model in various scenarios. testing using 9 hilal images in Ramadan 1445H with 7 images in the form of True Positive and 2 images in the form of True Negative. The results show that model 2 and model 4 fail to detect the presence of hilal in samples that have hilal objects in them. This is because the hyperparameters of the two models are not suitable for cases with variable or random datasets. But overall, the model with YOLOv5m Architecture has a much higher average accuracy than the model with YOLOv8 architecture. This is because the backbone used in YOLOv5m provides greater flexibility and control during training, processing augmented data helps the model generalize better, and extensive documentation facilitates hyperparameter optimization. In contrast, YOLOv8 tends to experience overfitting due to its higher model complexity and inadequate hyperparameter adjustment, as evidenced by the high loss values as shown in table 5. This finding further reinforces that the YOLOv5m architecture is suitable for sizable hyperparameters. In addition, the average confidence level of the model with the YOLOv5m architecture is very high, making it very suitable to be used as a model for classifying hilal. Direct testing, as shown in table 6, further supports these conclusions.

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Table 6. Results of Direct Testing of Random Images

Images	Value			
	Model 1	**Model 2**	**Model 3**	**Model 4**
1	82%	91%	56%	77%
2	74%	73%	39%	52%
3	42%	-	30%	28%
4	29%	41%	42%	31%
5	69%	70%	43%	59%
6	-	-	-	-
7	64%	89%	38%	54%
8	58%	28%	71%	-
9	-	-	-	-

While the direct testing results indicate promising performance, it is crucial to discuss the potential biases and limitations of the test images and videos used in this study. The test dataset may not fully represent all possible scenarios encountered in real-world applications. For instance, variations in lighting conditions, weather, and environmental factors might not be adequately covered, potentially leading to biases in the model's performance when applied to different or unseen conditions. Additionally, the quality of the test images and videos, such as resolution, noise levels, and focus, can influence the model's accuracy. Lower quality inputs might result in reduced performance, underscoring the need for high-quality data in practical implementations.

4. Conclusion

Based on the tests conducted in this study, the YOLO algorithm proved to be suitable for hilal classification. This algorithm, with its fast and accurate architecture, shows satisfactory performance in detecting the hilal, even under complex and varied visual conditions. Using the YOLOv5m version, performance improvements were achieved through batch and epoch adjustments, while the YOLOv8 version experienced overfitting challenges in similar configurations.

In this test, the YOLOv5m model showed significant success by achieving a precision of 0.838 and a mean average precision (mAP) value between 0.5 and 0.95 of 0.735. This percentage of success indicates the model's ability to identify and classify the hilal with a high level of accuracy. Furthermore, in terms of loss, the YOLOv5m model has a lower loss compared to YOLOv8. The loss in the YOLOv5m model is in the range of 0.207 for class loss and 0.31 for box loss, which indicates the efficiency of the model in minimizing errors during the learning process. This is in contrast to YOLOv8 which recorded a higher loss, with 1.001 for box loss and 0.62 for class loss, indicating overfitting that could potentially degrade the model's performance under diverse dataset conditions.

Then, direct testing using datasets that are not included in the training set shows a higher average accuracy of YOLOv5m in classifying hilal. This test involved seven True Positive and two True Negative images of hilal in Ramadan 1445H, where the YOLOv5m model consistently showed better results. These overall results confirm that the YOLO algorithm, particularly the YOLOv5m version, is the right choice for hilal classification applications, combining speed, accuracy and reliability in one effective technology package.

This study on hilal classification using the YOLO algorithm is anticipated to have further improvements in upcoming research. One improvement involves increasing the dataset collected through photographs and videos recorded directly via observatory telescopes at various locations in Indonesia. This approach will help ensure the dataset is more objective and accommodates all potential weather conditions. Secondly, it is hoped that research on hilal classification can be directly tested through.

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5. Declaration

5.1. Author Contributions

Conceptualization: N.A.; Methodology: N.A.; Software: N.A.; Validation: Z., and N.H.; Formal Analysis: N.A., Z., and N.H.; Investigation: N.A.; Resources: N.A.; Data Curation: N.A.; Writing - Original Draft Preparation: N.A.; Writing - Review & Editing: N.A., Z., and N.H.; Visualization: N.A.; All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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5.4. Institutional Review Board Statement

Not applicable.

5.5. Informed Consent Statement

Not applicable.

5.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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