CHAPTER I
INTRODUCTION

1.1 Background

The Javanese script is a traditional writing system of the Indonesian archipelago with high historical, linguistic, and cultural value [1]. The Javanese script serves as a means of passing down values and culture from one generation to the next and is used in classical manuscripts containing history, literature, moral teachings, and local knowledge [1]. Within the Javanese script system, the Nglegena script is the basic Javanese script, with each character representing a consonant with the inherent vowel /a/. Learning the Nglegena script serves as the foundation for developing reading and writing skills before learning more advanced script forms such as Sandhangan and Pasangan [2].

Although it plays a vital role in literacy and culture, the Javanese script faces threats due to low reading and writing proficiency, which is influenced by the number of characters, the complexity of their forms, and the visual similarity between characters [3]. This problem is reflected in formal education, particularly at the secondary school level, where students face challenges in mastering the forms of the script as the foundation for reading and writing skills, including in terms of shape recognition, literacy skills, and phonological and vocabulary understanding [4]. Based on a study of elementary and junior high school students from 11 schools, it was found that 81.4% of students were unable to read and 79% were unable to write Javanese script [5]. Although the Javanese language is still used orally, students' reading and writing practices are predominantly dominated by the Latin alphabet [5].

On the other hand, the Javanese script boasts a vast material heritage consisting of more than 19,000 manuscripts held in public collections in Indonesia and Europe, as well as thousands of other manuscripts believed to be scattered across private collections [6]. However, most of these manuscripts have not yet been adequately cataloged, so access to and preservation of them remain limited [6]. The digitization of ancient manuscripts is a strategic step to ensure the sustainability of this cultural heritage, particularly with the support of digital technology that enables automatic transcription, improved conservation quality, and expanded research access [7].

The Javanese script has been available in the Unicode standard since version 5.2, with 91 characters allocated in the Unicode blocks U+A980 through U+A9DF [8]. However, its implementation still faces practical challenges; the use of Latin-based keyboards requires special adjustments and adds to the complexity of the image-to-text digitization process. Furthermore, the degradation of manuscript image quality and the high variability of handwriting hinder the accuracy of automatic character recognition, thereby reducing the effectiveness of technology-based preservation of the Javanese script [9].

As technology advances, research in the fields of computer vision and deep learning has shown progress in text recognition. While early methods focused on recognizing individual characters, modern research has shifted to end-to-end approaches that process text at the word or line level as a whole to capture the global context. However, handwriting recognition remains a major challenge due to the high variability in human writing styles [10]. A similar challenge is found in the recognition of Javanese script handwriting, where high variation in character shapes and handwriting styles makes it difficult to implement accurate and consistent automatic text recognition systems [11]. End-to-end strategies are crucial because they eliminate the explicit segmentation stage, which is prone to error propagation. This approach addresses the ambiguity of boundaries between characters that often touch or overlap in handwriting [12].

In addition to the complexity of the script's form and the variety of handwriting styles, Javanese script text recognition is often hindered by the limited availability of labeled datasets. Therefore, synthetic data can serve as an alternative, as it enables the automatic generation of annotated text images with a wide range of variations. The study "OCR Synthetic Benchmark Dataset for Indic Languages" demonstrates that synthetic image datasets generated by rendering text into images using fonts can provide a flexible and scalable data source for training non-Latin script text recognition models in low-resource domains [13]. In the context of complex scripts with limited resources, such as Javanese script, the synthetic data approach has the potential to be a key strategy for supporting more effective model training.

Deep learning approaches that combine Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), such as Long Short-Term Memory (LSTM) or Bidirectional Long Short-Term Memory (BiLSTM), are increasingly being used in modern text recognition. In the context of text recognition, CNNs extract visual

features from text images, while RNNs model the sequential dependencies between characters, which helps improve the accuracy of text sequence predictions without requiring explicit character segmentation [14]. One of the main challenges in word-level text recognition is aligning the sequence of visual features extracted by the CNN with the target character sequence. Connectionist Temporal Classification (CTC) was introduced to address this issue and allows the model to learn the mapping from the sequence of visual features to the character sequence without requiring character segmentation. This approach has proven effective in handwriting recognition systems without manual segmentation [15]. Previous research has shown that the CNN-BiLSTM-CTC architecture performs exceptionally well in handwritten word recognition, even for complex scripts such as Arabic [15][16].

Research on traditional Indonesian scripts is still dominated by single-character recognition. Studies specifically addressing the recognition of handwritten Javanese script using an end-to-end approach based on CNN-BiLSTM-CTC remain very limited. This situation highlights a gap between the high cultural value of the Javanese script and the capabilities of modern technology to comprehensively access, recognize, and process traditional texts.

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1.2 Problem Statement

Based on the background described above, the following four research questions can be formulated:

1. How is the design and implementation of a handwritten Nglegena Javanese script text recognition model based on CNN, BiLSTM, and CTC algorithms carried out?
2. Which variation of the CNN-BiLSTM-CTC architecture yields the best performance in recognizing handwritten Nglegena Javanese script text?
3. How does the CNN-BiLSTM-CTC model perform in recognizing handwritten Nglegena Javanese script with varying handwriting styles?

4. How can the developed model be implemented so that it can be used by other systems and end-users in the form of an API and a website?

1.3 Research Objectives

Based on the research questions outlined above, this study has several objectives, namely:

1. Design and implement a handwritten Javanese Nglegena text recognition model based on CNN, BiLSTM, and CTC algorithms.
2. Exploring various architectural variations, particularly regarding the number of CNN and BiLSTM layers, to identify the architectural configuration with the best performance.
3. Evaluating the model's ability to recognize handwritten Javanese Nglegena script text written in participants' varied handwriting styles.
4. Implementing the developed model as an API and website so it can be utilized by other systems and end-users.

1.4 Research Contributions

This study is expected to yield significant benefits; some of the benefits of this study include:

1. To contribute to automatic text recognition without segmentation using the CNN-BiLSTM-CTC algorithm for Nglegena Javanese script, as a modern approach in the field of computer vision.
2. Providing a reference for an effective CNN-BiLSTM-CTC architecture configuration for the task of recognizing handwritten Nglegena Javanese script, thereby serving as a benchmark for future research.
3. Providing an overview of the CNN-BiLSTM-CTC model's ability to handle variations in handwriting styles of the Nglegena Javanese script, thereby determining the model's accuracy level across diverse handwritten data.
4. To produce an implementation of the Nglegena Javanese script text recognition model in the form of an API and a website that can be integrated into digital learning systems, automatic transliteration or translation systems, and technology-based Javanese script preservation platforms.

1.5 Scope and Limitations

To maintain the focus of the study and limit the scope of the discussion, this study has the following limitations:

1. The script used in this study is limited to the 20 Nglegena Javanese characters, in the form of synthetic and digital handwritten images. This study does not cover other types of Javanese scripts such as Murda script, Pasangan, Sandhangan, numerals, or punctuation marks.
2. The scope of text recognition is limited to the recognition of Nglegena Javanese script at the word level, as a fundamental step in the development of an end-to-end text recognition system. This study does not yet cover recognition at the long-line or full-document level.
3. The dataset used refers to the Javanese Script dataset, which consists of digital handwritten text and synthetic image generated by rendering fonts with randomly generated character sequence labels. This study does not perform deep linguistic re-annotation or spelling normalization on the labels.