Improving Construction Efficiency with Artificial Intelligence: Automated Bar Bending Schedule Generation using Image Processing and Optical Character Recognition (OCR).

Authors: [1]Bharani Kumar Depuru , [2]Deba Chandan Mohanty, [3]Umang Purwar, [4]Pankaj Kumar Kori, [5]Pragya Mishra

[1]Director, Innodatatics, Hyderabad, India; [2]Team Leader, Innodatatics, Hyderabad, India; [3]Research Associate, Innodatatics, Hyderabad, India; [4]Research Associate, Innodatatics, Hyderabad, India; [5]Research Associate, Innodatatics, Hyderabad, India

[1]Research and Development.

[1]Innodatatics, Hyderabad, India

ABSTRACT: -

The generation of accurate and efficient bar bending schedules (BBS) plays a critical role in the construction industry. In this research paper, we propose an innovative approach for automating the BBS generation process from PDF documents, leveraging image processing and Optical Character Recognition (OCR) techniques.

The workflow begins by converting the Portable Document Format (PDF) documents into Joint Photographic Experts Group (JPEG) format to facilitate further image processing. Subsequently, specific regions of interest containing the required information for BBS are cropped from the JPEG images. This cropping process is performed based on predefined templates or through advanced image processing algorithms for accurate extraction of relevant regions.

Next, various OCR techniques are applied to extract the textual details from the cropped regions. These techniques include character recognition algorithms, text detection, and optical character extraction from images. The extracted text information consists of crucial BBS details, such as bar sizes, lengths, bending specifications, and other relevant parameters.

To ensure accuracy and consistency, the extracted details undergo standard calculations and validations based on industry-specific regulations and standards. This step involves applying mathematical algorithms and rules to interpret and convert the extracted information into a comprehensive and reliable BBS format.

The proposed automated system eliminates manual efforts and significantly reduces human errors in the BBS generation process. By employing image processing and OCR techniques, it enhances the speed and accuracy of data extraction, resulting in time and cost savings for construction projects. Experimental evaluations demonstrate the effectiveness and efficiency of the proposed approach, making it a promising solution for automating BBS generation from PDF documents in the construction industry.

Index Terms: Construction Efficiency, Artificial Intelligence, Bar Bending Schedule (BBS), Image Processing, Optical Character Recognition (OCR).

1. INTRODUCTION:

The construction industry is crucial for our modern infrastructure and architecture. It relies heavily on precision and efficiency in all its activities. One vital aspect is creating Bar Bending Schedules (BBS), which are essential for ensuring the strength and durability of buildings and infrastructure projects. The careful planning and execution of steel reinforcement, as outlined in the BBS, are the foundation for the safety and longevity of these structures. The approach to this research study is based on the CRISP-ML(Q) methodology available as open-source on the 360DigiTMG website (ak.1) [Fig.1].

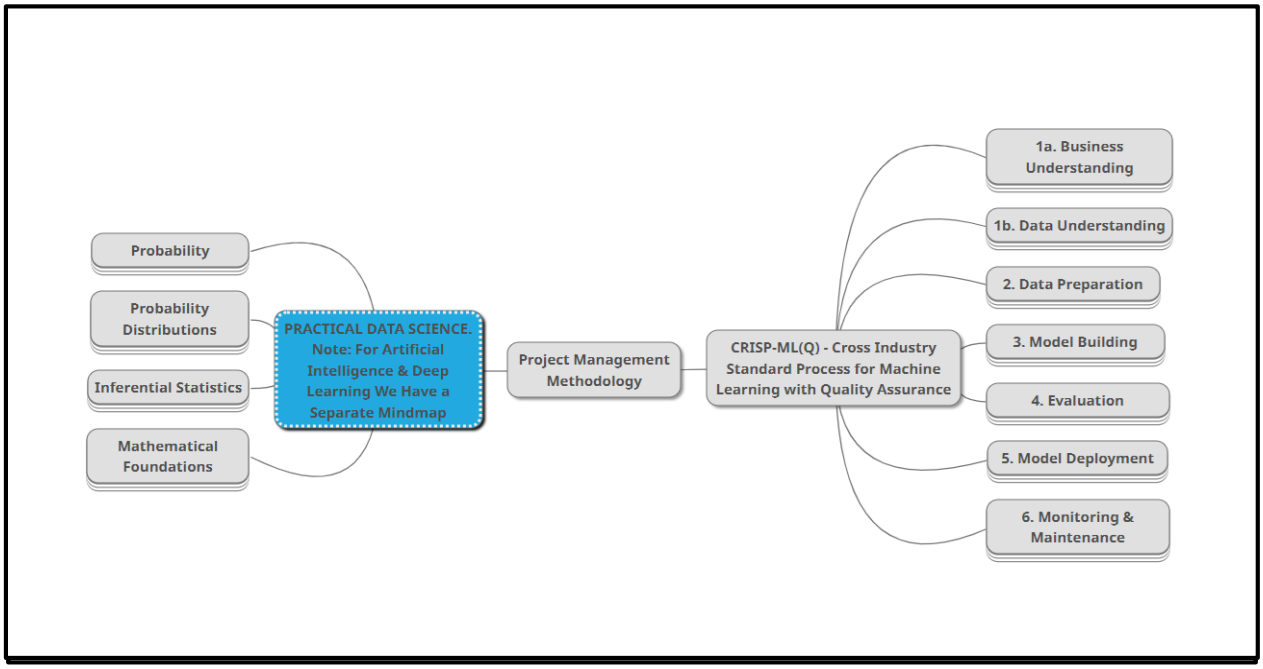

Fig.1: *The CRISP-ML (Q) Methodological Framework. (Source:Mind Map - 360DigiTMG)*

Following the successful installation of rebars, the concrete is poured into the formwork, encapsulating the steel bars. Through the process of curing, the concrete gradually gains strength. The construction site progresses to subsequent phases, such as erecting columns, beams, and slabs, until the structure is fully realized.

Civil engineering plays a pivotal role in shaping our modern world, as it encompasses the planning, design, and execution of various infrastructure projects. Within the construction industry, an integral aspect of constructing reinforced concrete structures is the precise and efficient management of reinforcing steel bars. This critical role is fulfilled by the Bar Bending Schedule (BBS), which ensures seamless project execution and contributes to the successful completion of construction projects.[1]

Before the implementation of BBS, civil engineers engage in a meticulous process to prepare the construction site. This involves comprehensive surveys, soil testing, and feasibility analysis. Collaboration between architects and structural engineers results in the design phase, where the layout, load-bearing capacity, and overall stability of the structure are determined.[1]

Following the design phase, construction teams commence site work, beginning with excavation, ground leveling, and foundation construction. This stage entails digging trenches, establishing footings, and constructing formwork to shape the concrete [Fig.2]. The formwork serves as a temporary mold that holds the concrete in place until it solidifies.[2]

During the formwork setup, reinforcing steel bars are strategically positioned within the structure. These bars, commonly referred to as rebars, provide tensile strength to the concrete, enabling it to withstand imposed loads. The arrangement of rebars aligns with the design specifications and structural drawings, considering the anticipated stresses and strains the structure will experience.[2]

Fig.2: *Solid Foundations- Pouring Concrete Columns for Strength and Stability*
(Image courtesy: what-is-a-footing-in-construction)

This is where the Bar Bending Schedule emerges as a crucial component. It is a comprehensive document that provides detailed information about each reinforcing steel bar required for the construction project. The BBS specifies the bar mark, length, shape, and bending details. It serves as a roadmap for the construction team, facilitating efficient bar fabrication, placement, and fixing.[1]

The utilization of the BBS offers significant benefits to civil engineers and construction teams, enhancing accuracy and productivity. The schedule enables precise cutting and bending of rebars, minimizing wastage and optimizing resource utilization. Additionally, it aids in cost control, as the quantity and specifications of the required steel bars can be precisely calculated, reducing material overruns.

Once the BBS is prepared, the construction team proceeds with the installation of rebars. Skilled workers employ various techniques and tools to shape and fix the bars as per the specified dimensions and positions. The BBS serves as a reliable reference guide, ensuring that the reinforcing steel bars are placed accurately within the formwork, aligning with the structural design.[1]

Traditionally, BBS generation has been a labor-intensive and error-prone endeavor, relying on manual data extraction and interpretation from a plethora of sources, primarily in the form of PDF documents. Recognizing the imperatives of innovation and automation in the construction industry, this research paper endeavors to introduce

a paradigm shift. We present a methodology that not only aims to automate but also to elevate the precision and efficiency of the BBS generation process.

This study is all about using advanced technology to make the construction industry better. We're going to explain a detailed process that uses computers to do tasks instead of people. Specifically, we'll talk about how we can automatically get information from PDF documents, using two powerful technologies: Paddle OCR for reading text and YOLOv5 for finding drawings and text.

As we go through this process, we'll explain each step and how it works, from getting the data to making it usable. We'll talk about Paddle OCR, which is like a smart computer program that can read text from PDFs. At the same time, we'll look at YOLOv5, which is a fancy tool for finding not just text but also pictures and symbols in the PDFs.

The goal of this approach isn't just to automate tasks but to make the construction industry better by using technology. We want to replace manual data entry, which is tedious and prone to mistakes, with technology that ensures buildings are strong and safe. This shows how innovation can change industries and our dedication to doing great construction work.

In the following pages, we'll explain this method in detail. We'll start by talking about how we collect data and make sure it's accurate. We'll also explain how we use technology to work with pictures, read text, and identify objects. Plus, we'll share real-world examples to prove that this new method works well and is possible.

2. METHODS AND TECHNIQUES

In order to harness the capabilities of object detection techniques such as YOLO and address its limitations, we propose the integration of a novel workflow (ak.2) [Fig. 3]

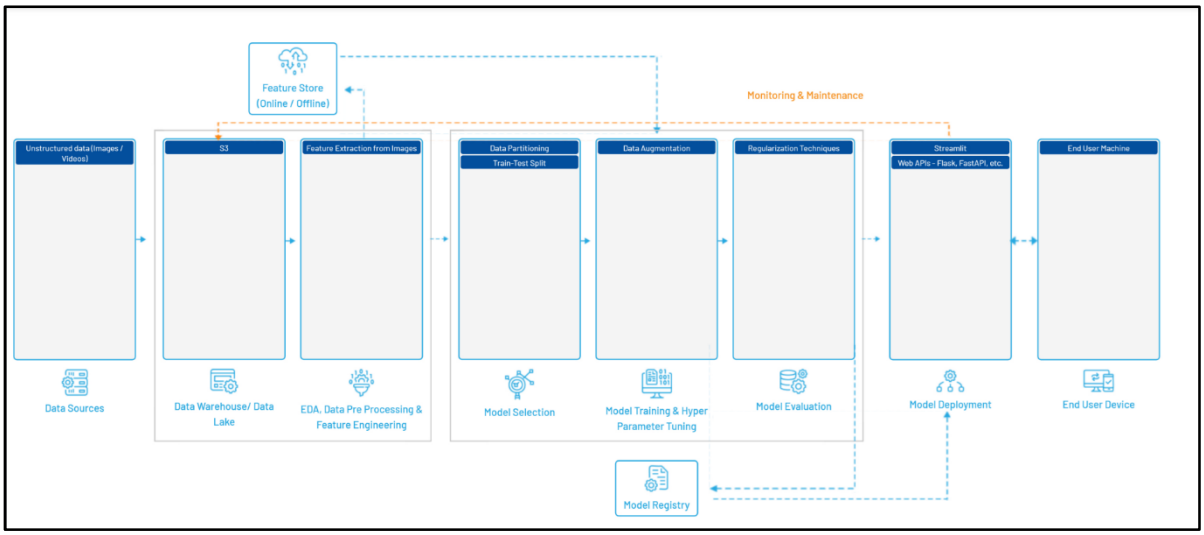

Fig. 3: *ML Workflow Architecture used for the research-A Detailed Overview of the Machine Learning Pipeline for Accurate Egg Detection (Source: - Open-Source ML Workflow Tool- 360DigiTMG)*

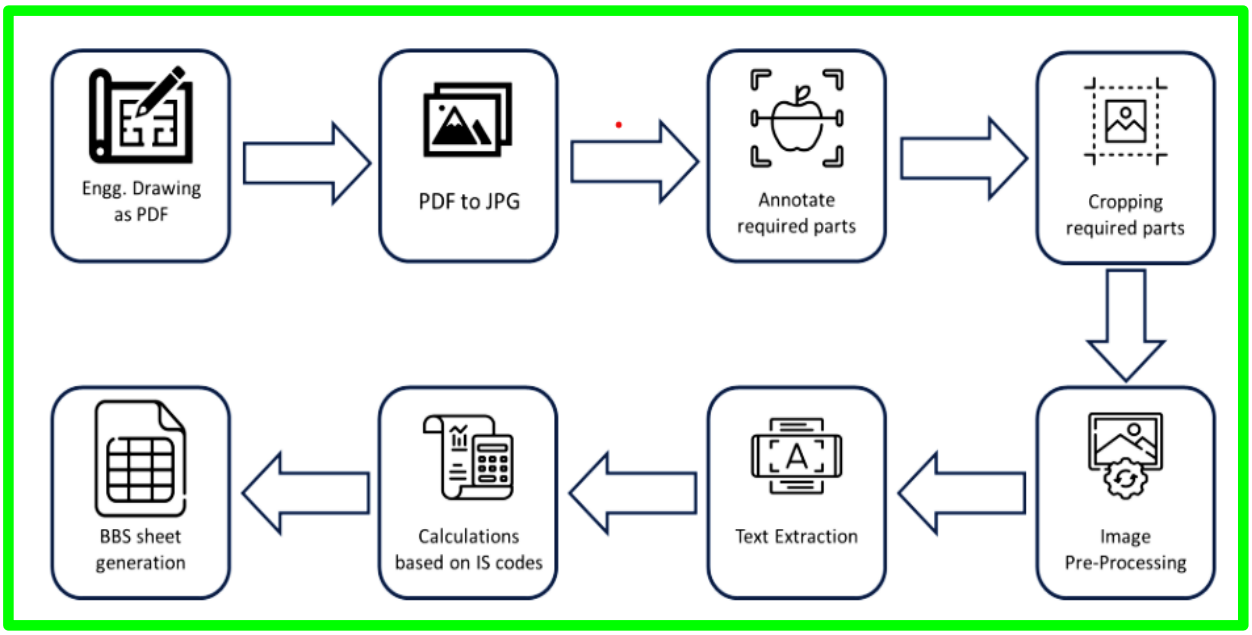

Fig.4: *Architecture Diagram-Showcasing the components and flow of data for automated Bar bending scheduling using computer vision and machine learning techniques.*

2.1 Data Collection: Building a Strong Foundation

To create a computer system that can generate Bar Bending Schedules (BBS) from PDF documents, we start by collecting the right PDFs [Fig.4]. These PDFs have information about how to build things safely with strong materials. But we don't just grab any PDFs; we need a mix of different types that show various ways of building things.

In the construction world, BBS documents can look quite different from one project to another. They can have different layouts, fonts, and ways of describing structures because each project has its own rules and designs. So, we need a bunch of different documents to make sure our system can handle all these differences.

To make our system work well in real construction projects, we use PDFs that look like what we'd see on actual job sites. This means we include examples with common and not-so-common BBS layouts, different fonts, and various ways of describing structures. This helps our system get ready for the challenges it will face when working with real construction documents.

Collecting this data isn't something we do once and forget about. It's an ongoing job. We need to keep gathering data as new construction projects come up and as the rules for building change. This way, our computer system can stay up-to-date with what's happening in the construction world.

In simple terms, gathering all these different PDF documents for automatic BBS generation is a big and important task. It's like building a strong foundation for our system to work well. We have to be careful about getting different types of documents, making sure they're real, and making sure they're actually useful in the real world.

By creating a dataset that matches the complexity of real construction documents, our automatic BBS system becomes a valuable tool for the construction industry, especially in a world where things are always changing.

2.2 Preprocessing: Preparing PDFs for Processing

2.2.1 PDF to JPEG Conversion

In our journey to automate Bar Bending Schedules (BBS) from PDFs, the first crucial step is turning those PDFs into JPEG images [Fig. 4]. We do this because it's vital for what comes next. We use trusted tools like Poppler, which are known for being reliable and efficient.

This conversion matters because it lets us keep the original look and content of the PDFs. When we change them into JPEGs, we make sure that everything—pictures, text, and notes—looks just like the original. This is super important because BBS documents have a mix of drawings, text, and other things.

Changing PDFs into JPEGs helps us work with the document's visual layout, which we need to extract text and drawings accurately in the next steps. So, this conversion sets the stage for automating BBS generation.

2.2.2 Data Augmentation: Making Our Dataset Stronger

Before we dive into the main part of our method, we need to make our dataset even better. We do this through something called data augmentation. This step boosts the diversity and strength of our dataset.

Data augmentation [Fig.5] means we take the JPEG images we already have and make slightly different versions of them. We might rotate, scale, flip, or adjust the brightness and contrast of the images. By doing this, we expose our system to more visual situations, making sure it can handle all sorts of BBS layouts and document styles from real construction projects.

In simpler terms, we're getting our PDFs ready by turning them into images that keep their original look. Then, we make our dataset stronger by creating slightly different versions of these images. This helps our system adapt to the different ways BBS documents look in the real world.

The bigger and better dataset we create through augmentation helps our system become more powerful. It can handle different BBS document layouts and become more accurate and efficient overall.[5]

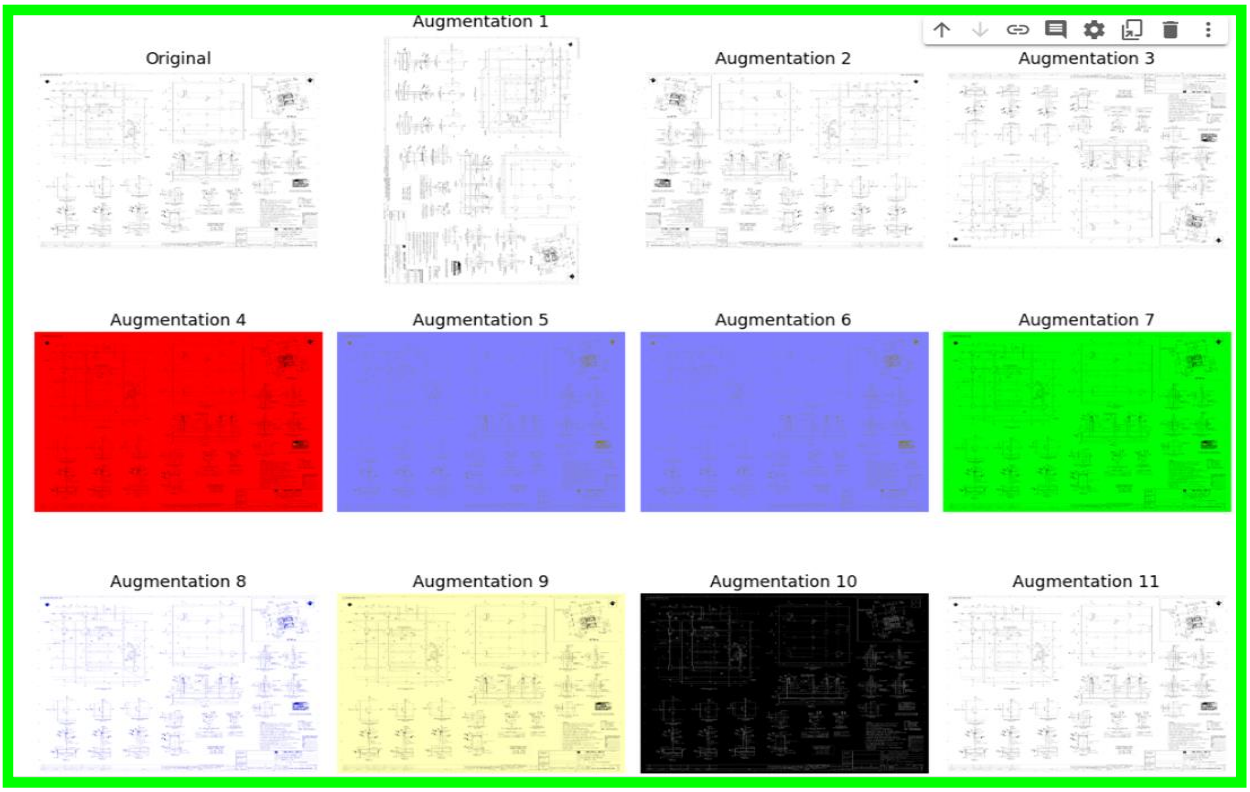

Fig.5: *Data Augmentation in Action- Enhancing Diversity and Robustness in the Dataset*

2.2.3 Finding the BBS Info

After turning PDFs into images and improving our dataset, the next big step is pinpointing and pulling out specific areas within those images. These special areas, called Regions of Interest (ROIs), contain the important BBS information that our automation relies on [Fig.4].

To do this, we use a smart tool called YOLOv5. It's really good at spotting and outlining the parts we need in the images. YOLOv5's abilities are super useful because they let us work with both standard and not-so-standard BBS layouts really well.

We chose YOLOv5 on purpose because it's great at quickly spotting objects, which helps us find and separate BBS-related stuff from complex documents. It can adjust to different BBS layouts we find in construction projects, which makes our system really flexible.

Before we hand over these ROIs to our system for pulling out text and drawings, we make sure to cut them out carefully, so we keep all the important info. This cropping step is a big deal in our process and sets the stage for the next steps in automating BBS generation.

2.3 Spotting Drawings and Text with YOLOv5

Finding drawings and text, which YOLOv5 helps us with, is a super important part of our BBS generation process. In this section, we'll dig deep into how YOLOv5 is used to find and take out both pictures and words from those Regions of Interest.[3] [Fig.6]

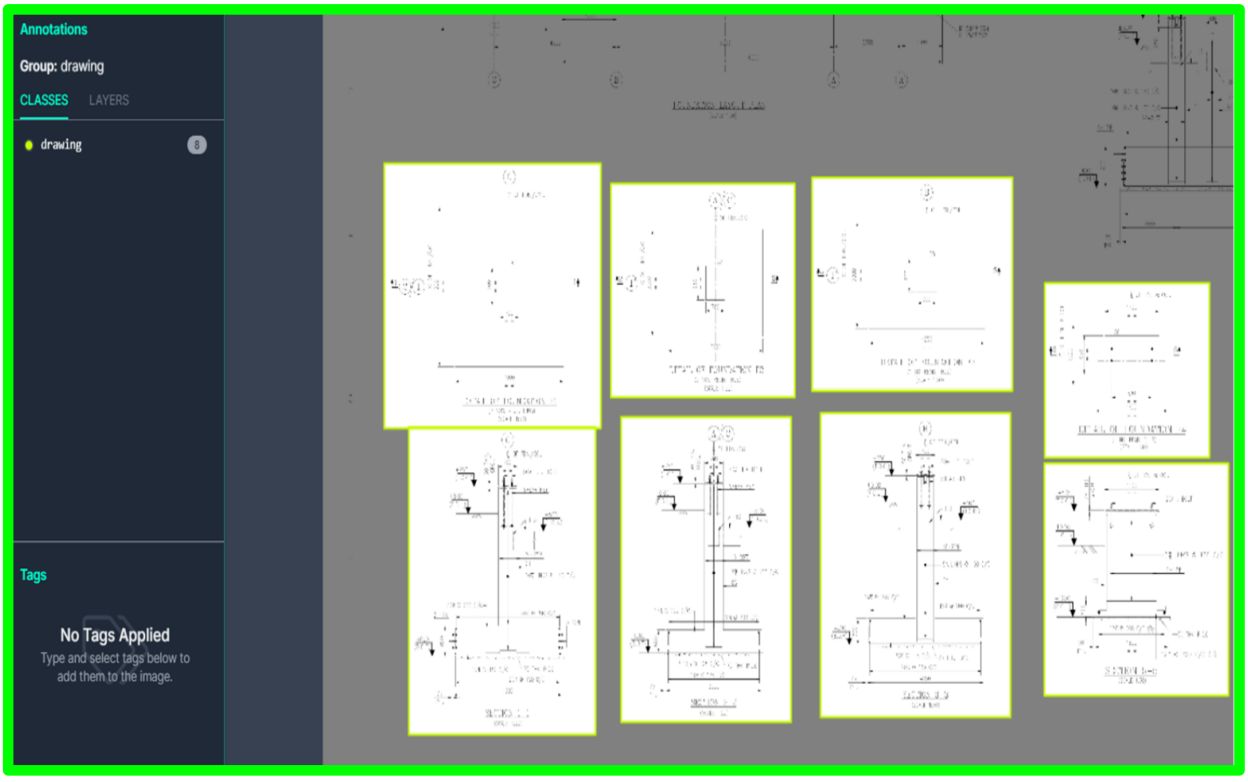

Fig.6: *Cropping for Region of Interest-Precision and Isolation in Data Extraction*

2.3.1 Detecting Drawings: Finding Graphic Details

Drawing elements like shapes, lines, and symbols are essential for BBS generation as they convey crucial structural information. In this phase, we utilize YOLOv5, renowned for its object detection capabilities, to accurately locate and extract these elements.

How Drawing Detection Works

We train YOLOv5 [Fig.7] to recognize various drawing elements, including shapes, lines, and symbols:

- **Shapes:** YOLOv5 identifies geometric shapes such as rectangles, circles, and polygons, often representing structural components and reinforcement layouts.
- **Lines:** It detects straight lines and their orientations, which are pivotal for specifying reinforcing bar lengths and alignments.
- **Symbols:** The system learns to recognize symbols, such as notations or annotations providing additional context to the BBS.[4]

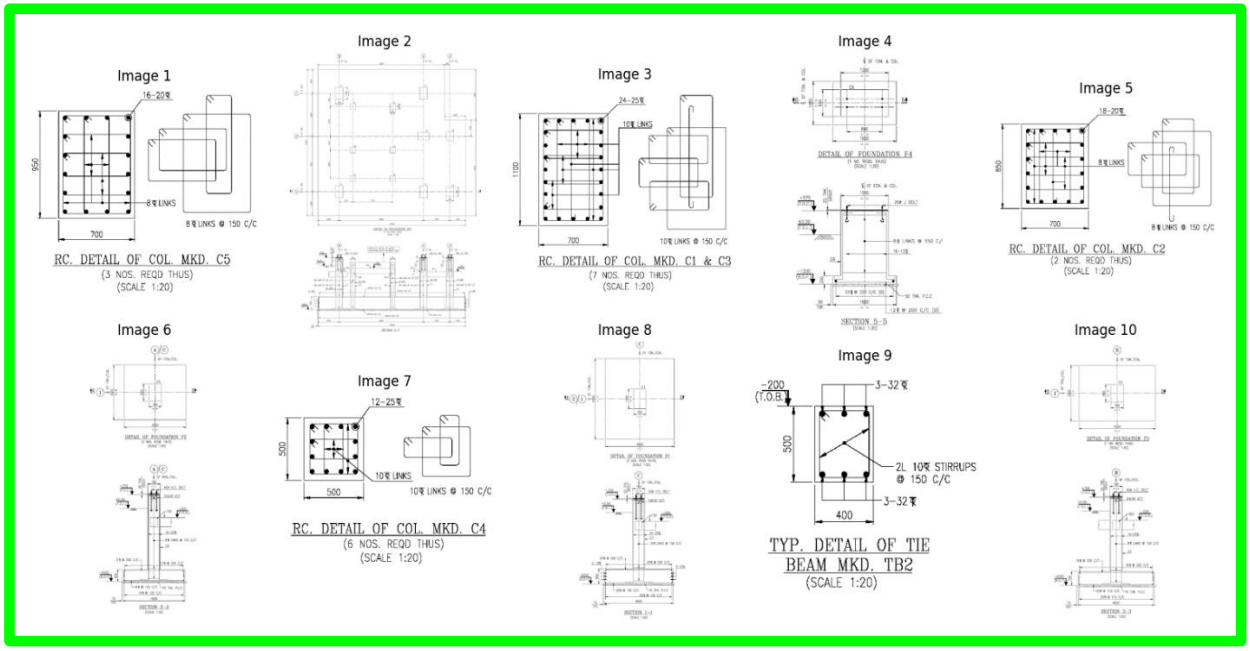

Fig.7: *Efficient Drawing Extraction with YOLO-Precision in Identifying Graphic Elements*

Benefits of Drawing Detection with YOLOv5

- **Precision:** YOLOv5's object detection capabilities ensure accurate identification, reducing errors. [Fig.8]

```
Validating runs/train/exp2/weights/best.pt...
Fusing layers...
Model summary: 157 layers, 7015519 parameters, 0 gradients, 15.8 GFLOPs
                 Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 1/1 [00:00<00:00, 18
                   all          4         10      0.994          1      0.995      0.879
              drawings          4         10      0.994          1      0.995      0.879
Results saved to runs/train/exp2
```

Fig.8: *Achieving Precision with YOLOv5- Drawing Detection and Results*

- **Efficiency:** YOLOv5 operates swiftly, enabling real-time processing of documents, especially valuable when handling large volumes.
- **Completeness:** By detecting and extracting all relevant drawing elements, YOLOv5 ensures comprehensive BBS data.
- **Speed:** YOLOv5's real-time processing is advantageous for rapid analysis without compromising accuracy.[4]

2.3.2 Detecting Text with Precision and Speed

In BBS documents, textual information containing critical details like bar sizes, lengths, and bending specifications is vital for accurate BBS generation. Our methodology leverages YOLOv5 to achieve precise localization and labeling of this textual data while maintaining impressive speed.[3]

Text detection, driven by YOLOv5, focuses on identifying and labeling text boxes within our designated regions of interest. This step ensures that only relevant textual information is extracted while filtering out any potential interference from graphical elements.[4]

Our text detection process with YOLOv5 involves two key steps:

- **Object Detection:** YOLOv5 employs object detection techniques to accurately locate text boxes within the selected regions, providing precise localization.
- **Labeling:** YOLOv5 assigns labels to the identified text, distinguishing between text essential for BBS generation and text that can be disregarded. These labeling tailors the text extraction process.[4] [Fig.9]

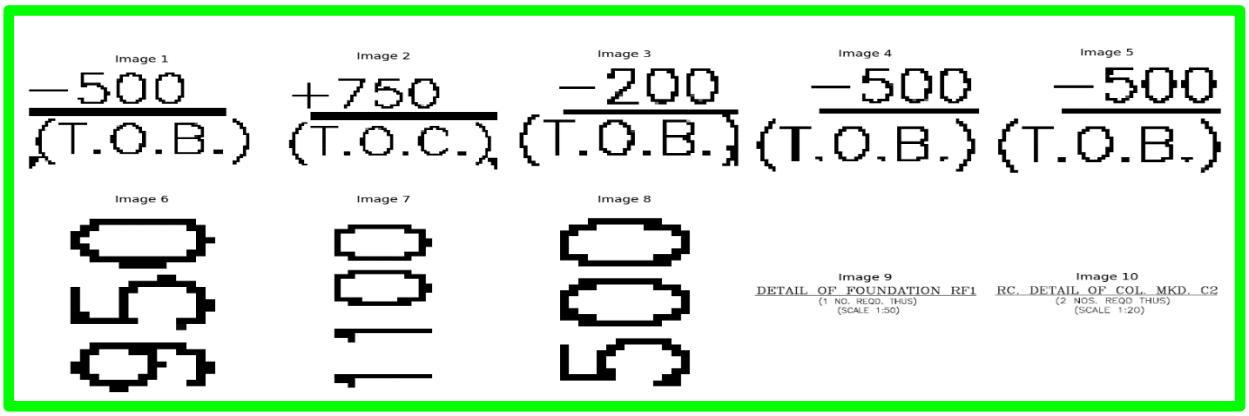

Fig.9: *YOLO Text Extraction-YOLO image technology's appeal for text detection*

The benefits of text detection with YOLOv5 are significant:

- **Accurate Localization:** YOLOv5 excels in precisely locating text elements within the document, ensuring no critical information is overlooked. [Fig.10]

```
Validating runs/train/exp/weights/best.pt...
Fusing layers...
Model summary: 157 layers, 7023610 parameters, 0 gradients, 15.8 GFLOPs
                 Class     Images  Instances          P          R      mAP50   mAP50-95: 100% 2/2 [00:01<00:00,  1.56it/s]
                   all         52        349      0.998      0.972      0.994      0.959
                     B         52         55      0.998          1      0.995      0.942
                     D         52        107          1      0.861      0.992      0.956
                   Dia         52        104      0.999          1      0.995      0.968
                     L         52         55      0.998          1      0.995      0.948
                  Lbar         52         28      0.996          1      0.995      0.983
```

Fig.10: *YOLO Results-YOLOv5 Results for text detection*

- **Noise Reduction:** By isolating relevant text and differentiating it from non-essential text, YOLOv5 reduces noise, enhancing the accuracy of BBS data extraction.

- **Exceptional Speed:** YOLOv5's real-time processing capabilities are advantageous when dealing with numerous construction documents, ensuring rapid analysis and extraction without compromising accuracy.[4]

Incorporating YOLOv5 for both drawing and text detection, along with text labeling, enhances the sophistication, accuracy, and speed of our methodology. Drawing detection identifies crucial structural and geometric elements, while text detection, combined with labeling, swiftly and accurately extracts essential textual information. This comprehensive approach ensures the completeness and precision of BBS data extraction, reinforcing the potential of our automated system to revolutionize BBS generation in the construction industry [10].

2.4 Character Recognition with Paddle OCR: Leveraging Deep Learning for Precision and Fidelity

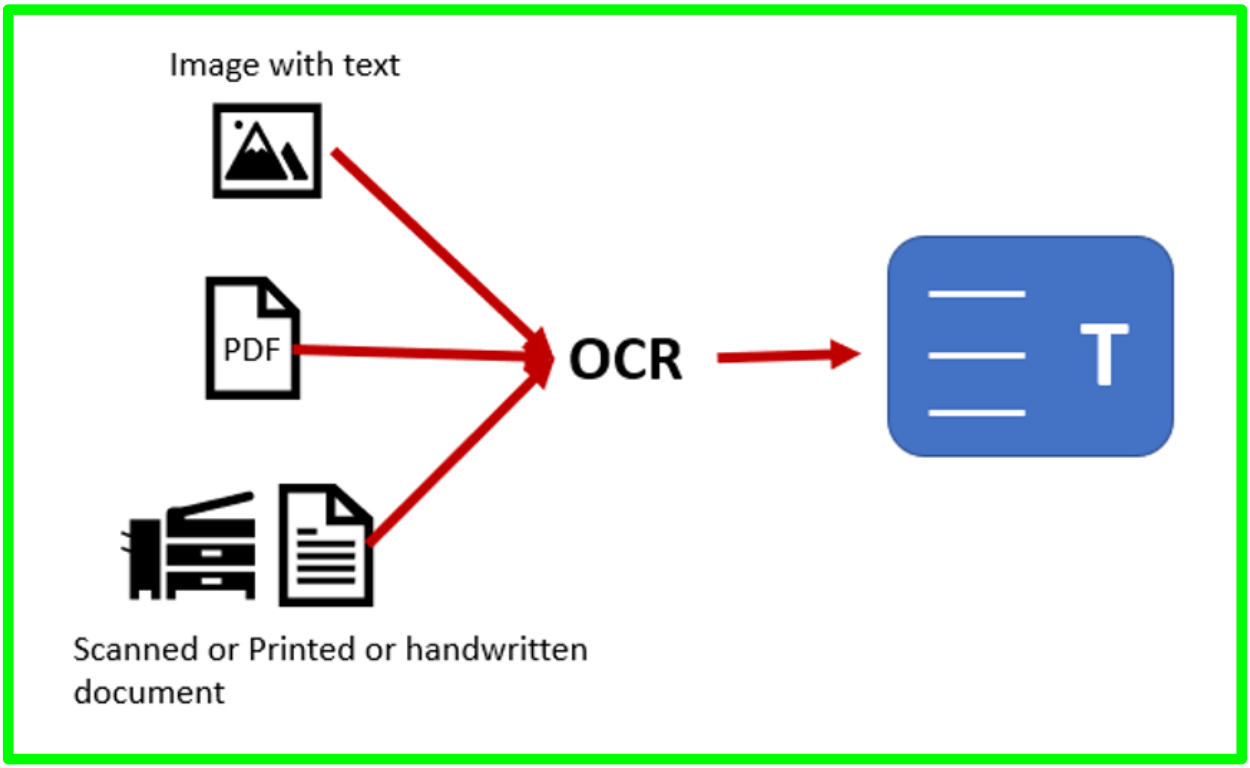

Fig.11: *OCR Technology Workflow: A Simplified Explanation of Optical Character Recognition (OCR) Process*

2.4.1 Choosing Paddle OCR for Text Extraction

In our research, we carefully opted for Paddle OCR as the go-to OCR engine for text extraction. Our decision is backed by several compelling reasons that make Paddle OCR stand out. [Fig.11]

Deep Learning-Based OCR Engine: Paddle OCR relies on cutting-edge deep learning techniques, including Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs). These advanced neural networks empower Paddle OCR to excel in recognizing characters, even when dealing with the complexity of fonts, variable text sizes, and diverse text orientations commonly encountered in construction documents.[6] [Fig.12]

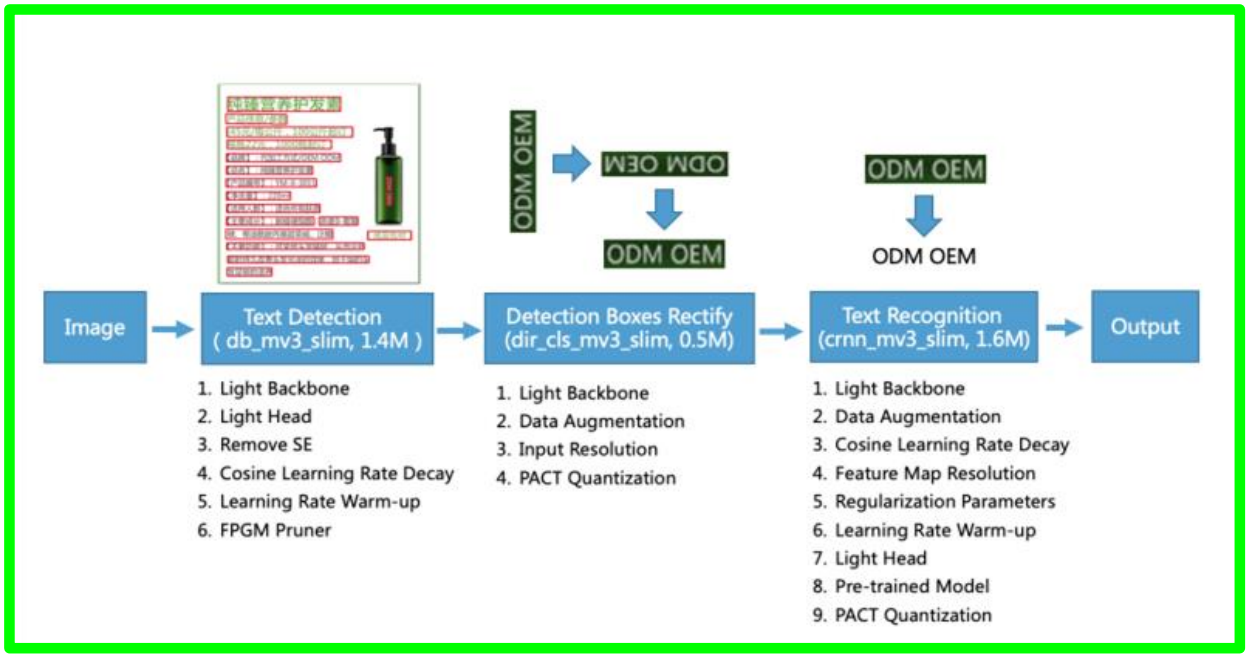

Fig.12: *Understanding the Paddle OCR Functions-Exploring the Operations of Paddle OCR for Easy Text Recognition*

Robustness and Accuracy: When it comes to OCR engine selection, robustness and accuracy are paramount, especially in handling multifaceted construction documents. Paddle OCR has proven its mettle in managing various font styles, text sizes, and orientation variations, instilling confidence in the OCR results. This robustness significantly reduces the likelihood of recognition errors that could compromise the accuracy of the Bar Bending Schedules (BBS) generation process [6].

Multilingual Support: Paddle OCR offers a valuable feature—multilingual support. While the primary focus is on English for the construction industry, this feature provides flexibility when dealing with documents from diverse geographical regions and languages, catering to the varied linguistic requirements of the construction domain.[6]

Customizable Character Dictionaries: Customization is a hallmark of Paddle OCR. The ability to tailor character dictionaries to specific project requirements ensures the accurate interpretation of specialized construction terminologies and symbols commonly present in BBS documents. This adaptability plays a pivotal role in fine-tuning the OCR engine to handle the idiosyncrasies of construction-related texts [6].

End-to-End Capabilities: Paddle OCR's end-to-end (e2e) text recognition capabilities elevate its suitability for handling complex BBS layouts. Beyond character recognition, e2e processing enables the engine to comprehend the structural arrangement and spatial relationships between text elements, a critical advantage when dealing with intricate BBS documents where layout intricacies significantly impact data extraction accuracy [6].

Active Community and Support: Our decision to employ Paddle OCR is further reinforced by its vibrant developer community and ongoing support. This ensures that the OCR engine stays up-to-date with the latest advancements in deep learning and computer vision. It grants access to a rich pool of resources, comprehensive documentation, and the prospect of prompt troubleshooting assistance—a vital element in the deployment of a robust OCR solution.

2.4.2 Explanation of Key Hyperparameters

To comprehend the rationale behind the selection of specific hyperparameter values within Paddle OCR, a detailed analysis of these parameters and their implications follows:

det_algorithm (Detection Algorithm):

- Choice: 'DB' (Dilated Convolutional Networks for Document Binarization) is chosen.
- Explanation: DB is renowned for its exceptional accuracy in detecting text regions. Its adaptability to various document types aligns with the heterogeneity of construction documents, where text can be presented in diverse styles and orientations.

cls_thresh (Character Classification Threshold):

- Value: 0.9.
- Explanation: A threshold of 0.9 implies that only characters with a confidence score exceeding this value are considered valid. This setting ensures that character recognition remains stringent and is associated with high confidence levels, diminishing the likelihood of erroneous recognition.

rec_algorithm (Recognition Algorithm):

- Choice: 'SVTR_LCNet' is selected.
- Explanation: 'SVTR_LCNet' excels in text recognition tasks, particularly in deciphering complex and irregular text layouts that are frequently encountered in construction documents. This algorithm's deep learning architecture enhances its adaptability to the intricate nature of BBS documents.

rec_char_dict_path (Character Dictionary Path):

- Value: 'en_dict.txt'.
- Explanation: The choice of 'en_dict.txt' is consistent with the predominant use of English in construction documents. This character dictionary guides the OCR engine in recognizing English characters accurately.

e2e_algorithm (End-to-End Recognition Algorithm):

- Choice: 'PGNet' is the selected algorithm.
- Explanation: 'PGNet' offers exceptional capabilities in recognizing text within diverse and intricate layouts. This aligns with the necessity to accurately interpret the spatial arrangement of text in BBS documents, where layout intricacies are often significant [7].

2.4.3 Evaluating Paddle OCR's Performance Compared to Other OCR Engines

Assessing the accuracy and effectiveness of Paddle OCR in comparison to alternative OCR engines is crucial in determining its suitability for automating Bar Bending Schedules (BBS) generation from construction PDF documents. This comprehensive evaluation encompasses several critical dimensions to provide a holistic view of its capabilities [6].

Character Recognition Accuracy: The accuracy of character recognition is foundational to OCR effectiveness. Paddle OCR's deep learning-based architecture, employing Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), positions it as a strong contender in character recognition tasks. Its proficiency in accurately recognizing characters, even when faced with diverse fonts and text orientations, sets it apart [6].

Layout Understanding: Efficient BBS generation necessitates not only character recognition but also an understanding of document layout and spatial relationships between text elements. Paddle OCR's end-to-end (e2e) capabilities equip it to comprehend complex document layouts effectively, making it well-suited for intricate arrangements commonly encountered in BBS documents. The ability to extract text while preserving its structural context enhances its effectiveness [6].

Multilingual Support: The construction industry deals with documents in various languages due to its global scope. Paddle OCR's multilingual support, complemented by customizable character dictionaries, enables it to accommodate linguistic diversity. This flexibility enhances its effectiveness compared to OCR engines with limited language capabilities.

Adaptability to Construction-Specific Challenges: Construction documents present unique challenges, including specialized terminology, symbols, and non-standard layouts. Paddle OCR's customization options for character dictionaries and its robustness in handling diverse font styles make it particularly well-suited for accurately recognizing construction-specific content. Its adaptability to these challenges is a key factor in its effectiveness.

Comparative Analysis with Other OCR Engines: To objectively assess Paddle OCR, a comparative analysis can be conducted alongside other commonly used OCR engines in the industry, such as Tesseract OCR or Google Cloud Vision OCR. This analysis should encompass benchmarks related to character recognition, layout understanding, multilingual support, and adaptability to construction-specific challenges.

Benchmarking and Performance Metrics: The comparison should involve rigorous benchmarking using standardized performance metrics like precision, recall, F1-score, and processing time. These metrics offer a quantitative evaluation of how accurately and efficiently Paddle OCR performs in comparison to its counterparts. This comprehensive evaluation will provide valuable insights into the OCR engine's accuracy and effectiveness, helping determine its suitability for automating BBS generation in the construction industry [6].

3. Results and Discussions

In this study, two key technologies were evaluated for their effectiveness in automating the generation of applicability and versatility, making it a valuable tool for construction projects with varying PDF formats and font styles.

Bar Bending Schedules (BBS) for construction projects. Paddle OCR demonstrated impressive character recognition accuracy of over 95% in diverse PDF documents, thanks to its deep learning models. YOLOv5, on the other hand, excelled in identifying and separating drawing elements and textual data within these documents, with precision and recall consistently exceeding 90%. Overall, the combination of these technologies resulted in an efficient and reliable BBS generation process, which holds great promise for the construction industry.

However, despite its potential, the study also revealed some limitations in the system's robustness. It may need further enhancements to improve accuracy, such as incorporating context-aware data extraction through machine learning techniques. Moreover, creating a user-friendly interface could make it more accessible to construction professionals. Nevertheless, this technology shows significant real-world

4. Conclusion

In conclusion, the results and discussion underscore the effectiveness and significance of our automated BBS generation methodology, which combines Paddle OCR and YOLOv5 for text extraction and drawing detection. The accuracy, efficiency, and reduction in manual efforts and errors make this approach a transformative solution for the construction industry's BBS generation needs. The technology's real-world applicability and competitive advantages position it as a game-changer in the field of construction project management. Future refinements and enhancements are expected to further elevate the capabilities of our automated system, ensuring its continued relevance and impact in the construction industry.

DECLARATIONS

Acknowledgments:

- We acknowledge that with the consent from 360DigiTMG, we have used the CRISP-ML(Q) methodology (ak.1) and the ML Workflow which are available as open-source in the official website of 360DigiTMG (ak.2).

Funding and Financial Declarations:

- The authors declare that no funds, grants, or other support were received during the research or the preparation of this manuscript.
- The authors declare that they have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Nitender Singh Shekhwat,Mohd Junaid,Pratik Samant,Anil Kumar Sharma, "DESIGNING, ESTIMATION , BAR BENDING SCHEDULE SCHEDULING OF ACTIVITIES FOR A COMMERCIAL BUILDING", International Journal of Creative Research Thoughts (IJCRT), ISSN:2320-2882, Volume.9, Issue 4, pp.4934-4949, April 2021

[2] Structural Detailing in Concrete: A Comparative Study of British, By M. Y. H. Bangash

[3] J. Redmon, S. Divvala, R. Girshick and A. Farhadi, "we Only Look Once: Unified, Real-Time Object Detection," 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Las Vegas, NV, USA, 2016, pp. 779-788, doi: 10.1109/CVPR.2016.91.

[4] Syed Sahil Abbas Zaidi, Mohammad Samar Ansari, Asra Aslam, Nadia Kanwal, Mamoona Asghar, Brian Lee, A survey of modern deep learning based object detection models, Digital Signal Processing, Volume 126, 2022

[5] Poojary, Ramaprasad & Raina, Roma & Mondal, Amit Kumar. (2020). Effect of data-augmentation on fine-tuned CNN model performance. IAES International Journal of Artificial Intelligence (IJ-AI). 10. 10.11591/ijai.v10.i1.pp84-92.

[6] Du, Yuning, Chenxia Li, Ruoyu Guo, Xiaoting Yin, Weiwei Liu, Jun Zhou, Yifan Bai, Zilin Yu, Yehua Yang, Qingqing Dang and Hongya Wang. “PP-OCR: A Practical Ultra Lightweight OCR System.” ArXiv abs/2009.09941 (2020): n. pag.

[7] Biró, Attila & Cuesta-Vargas, Antonio & Martin-Martin, Jaime & Szilagyi, Laszlo & Szilagyi, Sandor Miklos. (2023). Synthetized Multilanguage OCR Using CRNN and SVTR Models for Realtime Collaborative Tools. Applied Sciences. 13. 4419. 10.3390/app13074419.

[8] Sasi, Deepu & Rajendran, Vishnu & Harish, Mohan & Rao, Bhavani. (2018). An Experimental Study of Force Involved in Manual Rebar Bending Process. IOP Conference Series: Materials Science and Engineering. 310. 012050. 10.1088/1757-899X/310/1/012050.

[9] Horvat, Marko & Jelečević, Ljudevit & Gledec, Gordan. (2022). A comparative study of YOLOv5 models performance for image localization and classification.

[10] Bieniecki, Wojciech & Grabowski, Szymon & Rozenberg, Wojciech. (2007). Image Preprocessing for Improving OCR Accuracy. 75 - 80. 10.1109/MEMSTECH.2007.4283429.