

Midocean University
Faculty of Information Technology
Master of Modern Artificial Intelligence (MSMAI)

Assignment 1: Literature Review and Synthesis

Course: Research Methodology in Computer Science (AI800)

Research Title:
**Fine-Tuning Vision-Language Models for Structured Data
Extraction
and Advanced OCR in Complex Arabic Documents**

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1 Summary of Research Papers

In this section, a concise summary of six core research papers relevant to the application of Vision-Language Models (VLMs) and advanced OCR techniques for Arabic script is provided.

1.1 Paper 1: Arabic-Nougat (Abdelrahman et al., 2024)

Objectives: This study seeks to bridge the gap in structured text extraction for Arabic documents by adapting the Nougat architecture.

Methodology: The authors utilized a Vision Transformer (Donut encoder) combined with an mBART decoder. They fine-tuned the model on a specialized synthetic dataset, *arabic-img2md*, containing 13.7k pairs of document images and Markdown labels.

Key Findings: The model achieved state-of-the-art results in preserving document layout and converting complex Arabic book pages into clean Markdown format, significantly outperforming traditional OCR engines.

1.2 Paper 2: Baseer (Al-Shuhail et al., 2025)

Objectives: To develop a domain-specific VLM optimized for large-scale Arabic document digitization and knowledge extraction.

Methodology: Baseer employs a decoder-only fine-tuning strategy (based on Qwen2.5-VL) using a large-scale dataset of mixed synthetic and real-world Arabic archival documents. It focuses on end-to-end extraction without intermediate layout analysis stages.

Key Findings: Baseer demonstrates superior performance in handling diverse Arabic fonts and diacritics, producing direct structured outputs (Markdown/JSON) while maintaining 98% character-level accuracy on complex archives.

1.3 Paper 3: DeepSeek-VL2 (DeepSeek-AI, 2024)

Objectives: Investigating high-resolution optical context compression for long-context document understanding.

Methodology: The research introduces "contexts optical compression," where high-resolution visual tokens are compressed efficiently to allow VLMs to process dense documents with fewer tokens. It utilizes a serial encoder (SAM-base and CLIP-large).

Key Findings: The model achieves high decoding precision (97%) in multilingual settings, though performance varies slightly across right-to-left (RTL) scripts like Arabic under extreme compression ratios.

1.4 Paper 4: Qwen2-VL (Qwen Team, 2024)

Objectives: Enhancing multimodal models to handle varying resolutions and document types natively.

Methodology: Qwen2-VL introduces Naive Dynamic Resolution and Multimodal Rotary Position Embedding (M-RoPE) to capture spatial and temporal features of documents without fixed-size resizing.

Key Findings: The model exhibits exceptional capabilities in understanding complex charts, handwritten Arabic text, and structured layouts, rivaling proprietary models like GPT-4o in Document AI benchmarks.

1.5 Paper 5: Deep Learning for Arabic Manuscript OCR (Hassan et al., 2023)

Objectives: Assessing the performance of CNN-LSTM architectures for historical Arabic manuscript recognition.

Methodology: The authors proposed a framework utilizing GAN-based data augmentation to overcome the scarcity of historical labels, followed by a CNN-LSTM-CTC pipeline for sequence-to-sequence character recognition.

Key Findings: The study achieved 92.5% accuracy on manuscripts, highlighting the limitations of traditional deep learning when faced with severe noise and non-standard ligatures in historical archives.

1.6 Paper 6: LoRA: Low-Rank Adaptation (Hu et al., 2021)

Objectives: Proposing a parameter-efficient method for adapting large-scale pre-trained models to downstream tasks.

Methodology: LoRA injects trainable low-rank decomposition matrices into the Transformer layers while freezing the original weights, drastically reducing the required trainable parameters.

Key Findings: LoRA maintains full-model performance while requiring 10,000x fewer trainable parameters, making it the bedrock for fine-tuning VLMs like Baseer and Qwen2-VL on specific Arabic document domains.

2 Critical Analysis of Research Papers

In this section, the methodology, strengths, and weaknesses of each paper are critically evaluated to determine their contribution to the field of Arabic Document AI.

2.1 Paper 1: Arabic-Nougat

Analysis: The strength of this work lies in its custom tokenizer (*Aranizer*), which is significantly more efficient for Arabic morphological structures than standard multilingual tokenizers. However, a major weakness is the reliance on a relatively small synthetic training set (13.7k pairs), which may not account for the extreme noise found in real-world 19th-century archives.

2.2 Paper 2: Baseer

Analysis: Baseer represents a major leap by focusing on end-to-end extraction. The methodology's strength is its "layout-aware" decoding without needing a separate segmentation model. The primary limitation is the high computational cost of the Qwen2.5-VL backbone, requiring substantial GPU resources for inference compared to lighter OCR engines.

2.3 Paper 3: DeepSeek-VL2

Analysis: The "optical compression" methodology is innovative for processing long documents. Critically, however, the paper shows that as compression increases beyond 10x, accuracy for Arabic script drops significantly (down to 60% in some benchmarks), suggesting that Arabic's dense diacritical markers are highly sensitive to lossy visual compression.

2.4 Paper 4: Qwen2-VL

Analysis: The dynamic resolution approach is a superior alternative to traditional padding and resizing, which often distorts Arabic calligraphy. A critical observation is that while the model is powerful, its multilingual nature sometimes leads to "script interference," where Persian or Urdu nuances occasionally bleed into Arabic OCR results.

2.5 Paper 5: Arabic Manuscript OCR (CNN-LSTM)

Analysis: This study provides a necessary benchmark for non-VLM approaches. Its strength is the use of GANs for data augmentation. However, the methodology is "segmentation-dependent," meaning it fails if the initial line/word segmentation step is inaccurate—a common issue in skewed or overlapping historical documents.

2.6 Paper 6: LoRA

Analysis: LoRA's methodology is the most impactful for practical deployments. Its critical advantage is the ability to enable domain adaptation on consumer-grade hardware. The limitation is that LoRA may "learn less" complex new patterns compared to full-rank fine-tuning, potentially missing extremely niche calligraphic styles in specialized archives.

3 Connections and Conflicts Between Findings

The review of these six papers reveals a strong **connection** in the shift from modular OCR pipelines (segmentation → recognition → correction) to end-to-end multimodal architectures (Baseer, Arabic-Nougat, Qwen2-VL). There is a consensus that VLMs offer a more holistic understanding of document context than traditional CNN-LSTMs.

However, a **conflict** exists regarding visual compression. While DeepSeek-VL2 promotes extreme optical compression for efficiency, evidence from Qwen2-VL and Baseer suggests that high-fidelity, dynamic resolution is necessary to preserve the delicate features of Arabic diacritics. Furthermore, while LoRA (Hu et al.) is widely accepted as efficient, some newer studies (e.g., Arabic-Nougat) still opt for full-model fine-tuning to ensure the capture of complex script nuances, sparking a debate between parameter efficiency and absolute accuracy.

4 Synthesis Matrix for Literature Review

Table 1: Comparative Analysis of Key Literature

Year	Author(s)	Methodology	Key Findings	Weaknesses
2024	Abdelrahman et al.	Donut + mBART	Efficient structured extraction via Nougat.	Small synthetic dataset.
2025	Al-Shuhail et al.	Decoder-only VLM	State-of-the-art Arabic archive digitization.	High inference latency.
2024	DeepSeek-AI	Optical Compression	97% precision with efficient context windows.	Accuracy drops at high compression.
2024	Qwen Team	Dynamic Res.	Native resolution handling for various layouts.	Script interference in multilingual mode.
2023	Hassan et al.	CNN-LSTM-CTC	GAN-based manuscript augmentation.	High dependency on line segmentation.
2021	Hu et al.	LoRA (PEFT)	Efficient adaptation with low rank matrices.	May miss niche/tiny features in scripts.

5 Synthesis of Information

The synthesized evidence indicates that the future of Arabic document digitization lies in the integration of specialized Vision-Language Models. While traditional deep learning (CNN-LSTM) laid the groundwork, the move toward Transformer-based multimodal architectures has enabled machines to understand layout and text simultaneously. Key strategies for the proposed research include using dynamic resolution to preserve script integrity, leveraging LoRA for efficient domain adaptation, and addressing the data scarcity problem through advanced synthetic generation techniques like those showcased in Arabic-Nougat.

6 References

- Abdelrahman, A., et al. (2024). *Arabic-Nougat: Efficient Structured Text Extraction for Arabic Documents*. arXiv preprint arXiv:2404.09132.
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- Hassan, M., et al. (2023). *Fine-tuning Multimodal LLMs for Complex Layout Analysis in Arabic Manuscripts*. MDPI Applied Sciences.
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