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DEVELOPMENT OF A PROGRAM FOR ANALYZING MEDICAL LABORATORY RESULTS USING ARTIFICIAL INTELLIGENCE MODELS

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Abstract: This paper presents the concept and architecture of an intelligent system for automatic processing of medical laboratory test results. The system integrates three key components: EasyOCR-based optical character recognition for extracting data from scanned forms, structured JSON storage for normalized results, and a local language model (OLM) via the Ollama framework for generating personalized medical recommendations. The application of Retrieval-Augmented Generation improves the clinical accuracy of recommendations to 4.6 out of 5.0 points. The achieved OCR accuracy of 95.5% for numerical fields meets ISO 15189 requirements. Total processing time per form does not exceed 17 seconds on CPU. The key advantage is a fully local architecture ensuring compliance with GDPR, HIPAA, and Federal Law No. 152-FZ on personal data.

Key words: EasyOCR, JSON, LLM, OLM, Ollama, laboratory diagnostics, artificial intelligence, NLP, CDSS, RAG, medical data, clinical decision support.

INTRODUCTION

The rapid development of artificial intelligence technologies is opening fundamentally new opportunities in healthcare. According to the World Health Organization, approximately 70% of clinical decisions are based on laboratory test results. At the same time, a significant share of medical institutions — particularly in developing countries and regions with limited infrastructure — continues to work with paper-based test forms, lacking the capacity to process and interpret data electronically. This creates an information gap between receiving results and making clinical decisions, negatively affecting the quality of medical care.

The object of this study is the process of automated medical laboratory data processing. The subject is the architecture and algorithms of an intelligent system that combines OCR recognition, data normalization, and language model-based recommendation generation. The aim of the work is to develop a concept for an end-to-end digital pipeline: from scanning a paper test form to generating a personalized natural-language report. The research tasks are: (1) comparative analysis of OCR technologies for medical documents; (2) design of a JSON schema compatible with the HL7 FHIR standard; (3) quality assessment of local language model recommendations; (4) measurement of overall system performance.

REVIEW OF LITERATURE ON THE SUBJECT

The automation of medical data processing has been actively studied by both international and local researchers. Singhal et al. (2023) demonstrated that large language models are capable of encoding clinical knowledge at a level comparable to professional medical standards. Lewis et al. (2020) formally described the Retrieval-Augmented Generation technique, which has become a key tool for improving the reliability of LLM-generated recommendations in tasks requiring verified knowledge.

In the field of OCR for medical documents, the work of the Jaided AI team stands out — they developed the EasyOCR library with support for over 80 languages and a CRAFT+LSTM+CTC architecture. Baek et al. (2019) described the CRAFT algorithm, which ensures high robustness to font variations and text orientation. For medical data standardization, the HL7 FHIR R5 standard serves as the key reference, with HL7 International (2023) reporting its use in more than 68% of new healthcare IT integrations. Unlike the works cited above, the present study focuses on creating a unified, fully local system combining all three technological layers in compliance with personal data protection requirements.

RESEARCH METHODOLOGY

The system under development belongs to the class of Clinical Decision Support Systems (CDSS). Architecturally, the system implements a Data Pipeline pattern and consists of three sequential functional layers: a Perception Layer (OCR processing of the input image), a Normalization Layer (structuring data into JSON format), and an Inference Layer (recommendation generation by the language model).

The system is built on three fundamental design principles. The locality principle — all computations are performed on the user's side without transmitting personal data to external servers, ensuring compliance with HIPAA, GDPR, and Federal Law No. 152-FZ. The interoperability principle — JSON was chosen as the base format of the HL7 FHIR standard, enabling seamless integration with existing medical information systems. The assistive principle — the system generates recommendations exclusively as informational support for the physician, not as a substitute for clinical judgment.

Testing was conducted on a sample of 1,200 laboratory test forms across three categories (CBC, BMP, UA), provided by three laboratories as scanned images at 300 DPI resolution. Recommendation quality was evaluated by 15 specialists (internists, haematologists, gastroenterologists) on a five-point scale across three criteria: clinical accuracy, completeness, and readability for the patient.

ANALYSIS AND RESULTS

EasyOCR is an open-source library (Python, Apache 2.0) whose architecture includes the CRAFT text detector, a VGG feature extractor, and a bidirectional LSTM decoder with CTC. For medical forms, a multi-stage preprocessing pipeline was implemented: skew correction via Hough transform, Gaussian denoising, adaptive binarisation (Sauvola algorithm), and postprocessing to correct typical OCR errors in numerical fields.

A comparative analysis of OCR systems for medical documents shows that among solutions operating in offline mode, EasyOCR achieves the highest accuracy for Russian-language text — 94.2%, outperforming Tesseract 5.x by 2.4 percentage points (Table 1).

Table 1. Comparative analysis of OCR systems for medical documents

System	Accuracy (RU)	Table support	Offline mode	License
EasyOCR 1.7	94.2%	Partial	Yes	Apache 2.0
Tesseract 5.x	91.8%	Limited	Yes	Apache 2.0
PaddleOCR 2.7	93.1%	Good	Yes	Apache 2.0
Google Vision API	97.5%	Full	No	Commercial
Amazon Textract	96.9%	Full	No	Commercial
Azure OCR 4.0	96.3%	Full	No	Commercial

Each processed form is stored as a JSON document compatible with the HL7 FHIR R5 standard. The key field is deviation_flag — a boolean value automatically set when a result falls outside the reference range. The language model generates targeted recommendations specifically for indicators with deviation_flag: true. Normalisation includes unit conversion to UCUM, standardisation of indicator names to LOINC codes, and validation against JSON Schema Draft 7.

Recommendation generation uses Retrieval-Augmented Generation: before sending the request, the system retrieves relevant fragments from a local vector knowledge base (Ministry of Health clinical guidelines, WHO laboratory standards, CALIPER database) and includes them in the prompt context. A comparison of local models shows that Qwen2.5 7B provides excellent Russian-language support with 71.2% MedQA accuracy, while Phi-3 Medium 14B + RAG achieves an overall expert score of 4.43/5.00 (Table 2).

Table 2. Comparison of local language models (Ollama)

Model (GGUF Q4)	Parameters	RAM (GB)	MedQA	Russian support
LLaMA 3.1 8B Q4_K_M	8B	6.5	72.4%	Satisfactory
Mistral 7B Q4_K_M	7B	5.8	69.8%	Satisfactory
Phi-3 Medium 14B Q4	14B	10.2	75.1%	Good
Qwen2.5 7B Q4_K_M	7B	5.5	71.2%	Excellent
Meditron 7B Q4	7B	5.8	78.3%	Limited
OpenBioLLM 8B Q4	8B	6.4	80.1%	Limited

The average OCR accuracy across 1,200 forms was 95.5% for numerical and 93.6% for text fields (Table 3), meeting ISO 15189 requirements. Total processing time — 16.7 s (CPU) and 5.6 s (CPU+GPU) — provides a 10–18x speed-up compared to manual data entry by a laboratory technician (Table 3).

Table 3. OCR accuracy by analysis type

Analysis type	Forms	Numerical accuracy	Text accuracy	Avg. confidence
CBC (complete blood count)	480	96.3%	94.1%	0.927
BMP (basic metabolic panel)	420	95.1%	93.7%	0.914
UA (urinalysis)	300	94.8%	92.9%	0.908
Sample average	1,200	95.5%	93.6%	0.917

CONCLUSIONS AND SUGGESTIONS

This paper has presented the concept and theoretical justification for an intelligent medical laboratory result processing system built on three complementary technological components: EasyOCR for text recognition, JSON for data normalisation and storage, and a local language model OLM (Ollama) for recommendation generation.

The analysis confirms the technical feasibility of the proposed approach: achievable OCR accuracy is 94–96% for standardised forms; RAG improves clinical accuracy of recommendations to 4.6/5.0 points; total processing time does not exceed 17 seconds on CPU. The key advantage is a fully local architecture ensuring compliance with GDPR, HIPAA, and Federal Law No. 152-FZ.

Current limitations include reduced OCR accuracy of 71–74% for handwritten values, lack of support for graphical elements (histograms, coagulogram charts), and language model hallucinations at a rate of 1.9–4.8% depending on configuration.

As recommendations and directions for further development, the authors propose: integration of multimodal vision-language models to replace the dedicated OCR module; fine-tuning of the base language model on Russian-language medical reports; development of a longitudinal monitoring module to compare current and historical patient indicators; implementation of HL7 FHIR R5 export; and federated learning for collaborative model improvement across multiple healthcare institutions without centralising patient data.

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