**Development of a Diagnostic Decision-Support System for Allergic Diseases at the Voivodeship Rehabilitation Hospital for Children in Ameryka**

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1. Introduction

The rapid digitalization of healthcare presents new opportunities to enhance clinical outcomes. Among these, artificial intelligence (AI) has emerged as a particularly promising tool, with the potential to transform biomedical research and support the development of advanced clinical systems [1–3]. One area of medicine that is extremely demanding yet often overlooked in the development of medical decision support systems, is allergy diagnosis [4].

Allergic diseases affect up to 35% of children and are steadily increasing worldwide [5]. Their development involves multiple factors, leading to highly diverse symptoms and making diagnosis difficult. Challenges include the wide range of allergens, the role of cofactors, inconsistent test correlations, and the absence of fully standardized diagnostic protocols adapted to different medical examinations, symptoms, and age groups [6, 7]. As a result, effective control of allergic diseases is still difficult, highlighting the pressing need for novel strategies to meet this expanding health problem**.** While both AI and medicine continue to progress rapidly, the integration of AI-based decision-support tools in hospital practice faces significant challenges, including incomplete datasets, variability in laboratory methods, and the absence of unified diagnostic standards [8]. Moreover, transparency remains a critical requirement: diagnostic algorithms must provide explanations that are understandable to both clinicians and patients [9]. Yet many existing approaches, particularly deep learning models, still lack the interpretability needed for safe and reliable clinical application [10].

1. Description of the problem

Although both AI and medicine are advancing quickly, the adoption of AI-driven decision support tools in clinical practice is hindered by major challenges such as incomplete datasets, inconsistencies in laboratory procedures, and the lack of standardized diagnostic criteria. [10, 11]. Furthermore, transparency continues to be a fundamental requirement in the use of diagnostic algorithms. It is not sufficient for these systems to generate accurate predictions; they must also be able to clearly articulate the reasoning behind their decisions in a way that is comprehensible both to clinicians, who rely on this information to guide medical judgment, and to patients, who need understandable explanations in order to build trust and actively participate in their own care [12, 13]. Yet many existing approaches, particularly deep learning models, still lack the interpretability needed for safe and reliable clinical application [14]. A major challenge is the development of a system capable of analyzing noisy data with many missing values while maintaining explainability of the results. It is also essential to integrate different types of data, both continuous and categorical additionally to combine them with unstructured sources such as nursing or medical interviews. Another difficulty in interpreting medical text data is that it is often available in a language other than English, which significantly complicates processing with the most widely used models.

1. Related work

By enabling continuous monitoring, digital technologies allow physicians to adjust treatment strategies more flexibly, helping to improve both outcomes and quality of life for patients with chronic diseases [15]. Allergic diseases present considerable complexity, as they are characterized by diverse clinical manifestations, varied immune mechanisms, and heterogeneous pathogenic pathways. This multifaceted nature poses significant challenges for establishing a reliable, evidence-based clinical diagnosis. Several solutions have been proposed in the field of allergic diseases 1) the development of a clinical support tool aimed at guiding physicians in accurately prescribing allergen-specific immunotherapy [16]; 2) tools designed to support asthma management, such as reminder systems [17], monitoring applications [18] or even comprehensive digital care platforms [19]; 3) mobile apps designed to help doctors assess adverse drug reactions in terms of causality, severity, and preventability [20]; 4) decision support system for providing treatment recommendations of allergic rhinitis [21]. Although many systems are being developed, they often focus mainly on functionalities related to managing processes surrounding allergy care rather than directly supporting the diagnostic and treatment process of allergic diseases, which could provide meaningful assistance to healthcare professionals. Moreover, these systems are frequently designed or tested on very small patient groups, limiting their generalizability.

1. Solution to the problem

To address the previously mentioned challenges faced by clinical decision support systems, such as small amounts of noisy data, numerous missing fields, and the lack of explainability of machine learning models the Comprehensive Abstraction and Classification Tool for Uncovering Structures (CACTUS) was developed. It was decided to implement this system at the Allergy Department at the Voivodeship Rehabilitation Hospital for Children in Ameryka, Poland. The dataset obtained from the hospital consisted of medical test results as well as interviews with nurses and physicians. All data were fully anonymized prior to being shared with us. Test-related information was provided in tabular form and covered a subset of the most frequently performed paediatric examinations. These included routine tests such as complete blood count (CBC) with differential, vitamin D measurement, stool analysis for ova and parasites (including *Giardia lamblia*, *Entamoeba*spp., *Blastocystis* spp., and threadworms), and immunoglobulin quantification (IgA, IgG, IgM, and IgE). In addition, allergy panels were incorporated. These panels measure allergen-specific IgE antibodies in the patient’s blood, indicating potential sensitization to specific allergens. The dataset contained both a respiratory allergy panel and a food allergy panel. Each patient was diagnosed and assigned to one of International Classification of Diseases (ICD-10).

The aim was to assess CACTUS performance in a real-world clinical setting and to examine its ability to enhance diagnostic procedures and assist healthcare professionals. It is important to note that CACTUS operates on tabular data. However, a significant amount of crucial information in hospitals is stored in unstructured form, which made it necessary to extract data from text, transform it into tabular format, and integrate it with data obtained from medical examinations. Information extraction from clinical text was performed using two distinct approaches: rule-based techniques and large language models (LLMs). Their effectiveness of the 2 methods was compared, and additionally the influence of translating the texts into English on extraction performance was also investigated. Once the data had been prepared, a classification process was conducted using CACTUS to identify allergic disease types. The obtained results were compared with those of classic machine learning classification methods to comprehensively assess whether our proposed CACTUS system offers an advantage over widely used approaches. Since explainability is critical when using AI in medicine, we examined how stable the key features for classification were in CACTUS compared to selected traditional machine learning methods.

1. Conclusions and future work

The conducted real-world experiment demonstrates the promising role of CACTUS as a decision-support system for diagnosing allergic diseases. Despite challenges such as missing values and substantial data noise, CACTUS achieved high classification accuracy compared to traditional methods. In addition, the experiments highlighted its stability, which is essential not only for increasing physicians’ trust in the system but also for improving clinical efficiency by identifying and omitting examinations that are not diagnostically meaningful. Additionally, the experiments using unstructured data highlights the advantages and challenges of rule-based and LLMs methods.

Future work will focus on extracting additional information from physicians’ and nurses’ interviews, which can further strengthen the classification process. Another important direction of development will be the creation of a multi-agent system, designed to integrate and combine the most effective diagnostic pathways followed by individual clinicians within the hospital. Such an approach could not only enhance the accuracy and robustness of diagnostic support but also contribute to harmonizing diverse medical practices, ultimately improving the consistency and quality of patient care.

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