Knowledge-Based Systems for Strengthening African Health Systems

Wendgounda Francis Ouedraogo[a] and Andreas Nürnberger[b]
Faculty of Computer Science, Otto-von-Guericke University Magdeburg, Universitätsplatz 2 39106 Magdeburg, Germany

Keywords: Knowledge-Based Systems, Expert System, Healthcare, Health System, Sub-Sahara Africa.

Abstract: The set of difficulties characterizing health systems in Sub-Saharan Africa (SSA) are caused by many factors, among others, the very limited number of specialists, the predominance of paramedical personnel and micro-health centers, the poor distribution of large medical centers, the almost absence of continuing training and missing means of maintaining and updating knowledge. These difficulties, however, find a response in the development of targeted intelligent solutions such as expert systems capable of providing continuous assistance to professionals and structures of health systems in African countries and transforming them into effective organizations. Unfortunately, the design of such systems still face many challenges, e.g., they have to promote circulation and simplified access to current targeted information (e.g. current knowledge) that healthcare professionals need in their daily lives and they have to take into account local needs to be better adapted and useful for the heterogenous group of users. This article provides a short overview of the current urgent needs of the health systems in SSA, motivates requirements on targeted digital support technology and discusses first prototypical solutions to motivate possible research directions.

1 INTRODUCTION

Should African countries invest in research and development of knowledge-based systems (KBS) to sustainably strengthen their health systems? Faced with insufficient human resources (e.g. few specialists), infrastructure problems (e.g. predominance of micro-health centers) and organization (e.g. virtual absence of continuing training), sub-Saharan African countries are trying more actively to introduce technological solutions into medicine (MSHP, 2022; TdH, 2019). The delicate nature of healthcare decisions and tasks makes it a complex field that most often requires expert knowledge. Tolmie and Du Plessis highlighted more than 25 years ago the apparent advantages of KBS for medicine in developing countries and in Africa, allowing us to legitimately ask the question of knowing even today whether it is a question of a luxury or a necessity to use these intelligent systems in medicine in sub-Saharan Africa (SSA) (Chikhata & Chivivi, 2017; Kendal & Creen, 2007; Tolmie & Du Plessis, 1997). KBS, which have proven themselves for years in solving complex problems by providing coherent solutions to repetitive decisions, processes and tasks, appears to be a highly recommendable solution for strengthening the capacities of African health systems (Ajanaku & Mutula, 2018; Dey & Rautaray, 2014).

In order to illustrate our position on the possible contribution and research challenges of KBS in resolving the difficulties that the health systems in SSA are currently facing, we first discuss the current health needs in SSA, give a short overview of possible contributions of knowledge-based systems for healthcare and finally briefly present results of a project that was initiated in Burkina Faso with the outcome of prototyping an intelligent digital solution focused on specific challenges. The assistance system "@san" facilitates the sharing of targeted knowledge between paramedical personnel and with specialists in sub-Saharan African areas, through the storage and retrieval of collected expert knowledge.

2 AFRICAN HEALTH NEEDS

The weakness of sub-Saharan African (SSA) health systems is exposed through the management of tropical diseases (e.g. malaria, meningitis) throughout the year and the responses provided to various epidemics

[a] https://orcid.org/0000-0002-1860-3526
[b] https://orcid.org/0000-0003-4311-0624

Ouedraogo, W. and Nürnberger, A.
Knowledge-Based Systems for Strengthening African Health Systems.
DOI: 10.5220/0012691900003690

In *Proceedings of the 26th International Conference on Enterprise Information Systems (ICEIS 2024) - Volume 1*, pages 779-783
ISBN: 978-989-758-692-7; ISSN: 2184-4992

and/or pandemics (e.g. Lassa Fever, Ebola, Covid-19). The growing health care needs constitute a set of pressure factors on SSA health systems. This is due to the absence of an adequate system to facilitate sharing of health information, the lack of health personal (> 85% of paramedical personnel), and the limited number of public health infrastructures, of which about 80% are poorly equipped micro-health centers (MSHP, 2022). Among solutions to face these challenges, the most commonly explored in the last two decades is the introduction of information and communication technologies (ICT) in the health systems (TdH, 2019; Watkins et al, 2018).

If medicine is recognized as a knowledge-intensive field in which the adoption of new processes is undertaken with great caution, it is imperative to think of intelligent solutions to overcome the above-mentioned difficulties in SSA (Moahi & Bwalya, 2018). Telemedicine – so far the technological solution that has received the most attention thanks to its varied successes – does not adequately solve these problems due to the need for continuously available expert assistance. Strengthening the autonomy of actions of health workers through the use of KBS is a solution to explore, given the advantages and means of indirect use of expert knowledge proposed (e.g., storage in documents). Guaranteeing competent health personnel – implying the need for better sharing of medical knowledge – appears obligatory for the development of the capacities of health structures in SSA and therefore of health systems in more general (Ajanaku & Mutula, 2018; TdH, 2019). It amounts to transforming health systems into learning organizations thanks to innovative solutions such as intelligent targeted knowledge-based systems.

3 KNOWLEDGE-BASED SYSTEMS IN HEALTHCARE

Knowledge-Based System supports decision-making based on available knowledge and understanding the context of the data processed. Although there are other types of KBS (e.g. systems that are making use of genetic algorithms, data mining, etc.), we focus in this article on expert systems, which are often considered synonymous with KBS in the domain of health. Capable of imitating human reasoning processes in decision-making, an expert system is the embodiment of a knowledge-based component of an expert skill (e.g., medical expertise) in a computer. It aims to offer intelligent advice or an intelligent decision according to the request made to deal with the case presented (Achmadi et al., 2018; Kendal & Creen, 2007). Expert systems are designed to compensate for the unavailability of specialists by providing access to their knowledge and experience. Like the healthcare professional who (re)uses up-to-date knowledge on patient healthcare, the knowledge contained in these systems can be (re)used whenever necessary and easily updated (Dey & Rautaray, 2014; Nkuma-Udah et al., 2018). Thus, an expert system facilitates the diagnosis of a disease by matching the patient's symptoms with the existing rules in the knowledge base passing through the inference engine.

Expert systems make major contributions such as continuous learning following the evolution of science, continuous improvement of healthcare performance with a focus on the patient, evaluation of alternatives for elimination issues related to healthcare administration, improving working relationships between healthcare professionals and effective management of expert knowledge (Nkuma-Udah et al., 2018; Khan MK, Munive-Hernandez, 2018; WHO, 2006). Since the first expert systems, the best known of which is MYCIN, used to diagnose and treat infectious diseases caused by antibiotics, this field has continued to gain importance in medicine. Many programs have emerged to assist decision-making in specific areas: Computer-Assisted DIAGnostic (CADIAG) which is a consultation system capable of assisting in depth with the differential diagnosis and possibly the therapeutic process in internal medicine (Milan et al., 1997), clinical decision support system (CDSS) which provides specific knowledge and information to facilitate health care, Aidoc Medical for accident management stroke, pulmonary embolism, cervical fracture, intracranial hemorrhage, intra-abdominal free gas and accidental pulmonary embolism, etc. (Cheichk et al., 2022; Kendal & Creen, 2007; Musen et al., 2021). Recent progress in AI has also influenced KBS and allowed them to establish themselves in crucial sectors such as medicine. These solutions are, however, designed to meet the needs of developed countries, not taking into account the realities of SSA countries. The main issues are the different diseases treated by these systems (e.g., absence of a focus on tropical diseases), that the technologies used almost always requires an internet connection, the type of knowledge base used (e.g., requiring availability of experts for document linking) and the missing insertion of local African expertise (e.g., pharmacopoeia, alternative medicine for certain diseases).

The initiatives of recent years (e.g., Iconic visual ontology, KBS for African Traditional Herbal Medicine) (Devine et al., 2022; Kouame, 2018) showing the need to implement specific expert systems have

motivated the @san project, a mobile assistance application which allows nurses and midwives to access useful and up-to-date knowledge to carry out their daily tasks in rural and remote areas of SSA. In addition to the components of an expert system, where expert knowledge is identified, acquired and stored in the form of documents, @san also offers the possibility of active acquisition of knowledge between health workers through direct exchanges in thematic forums.

4 USEFULNESS OF KNOWLEDGE-BASED SYSTEMS FOR AFRICAN HEALTH SYSTEMS

The usefulness of Knowledge-Based Systems for health is in SSA is especially based on their ability to respond in a practical way and to tackle quite different challenges. Most important, such systems should make it possible to develop the skills of human resources, to facilitate the close collaboration between different levels of healthcare professionals, to guarantee their autonomy in the management of patient care, and to reduce the various costs while thinking about sustainable development.

Difficulties of organizing continuing training (e.g. cost, impassable roads, and insecurity) pose a major challenge to health systems in sub-Saharan Africa. An expert system should offer health professionals in remote rural areas the possibility of accessing relevant targeted information indirectly and in near real time (e.g. via contextualized thematic forums). It also should allow users to be attentive to advances in medicine (the state of knowledge) and therefore to continually improve the efficiency of the health system in more general. Access to current specialized knowledge (experts) has a positive impact on the skills of health workers, particularly paramedical staff (nurses and midwives) responsible for managing micro-health centers in rural areas without a doctor. Fairly accurate decision-making helps reduce uncertainties about diseases and provide safer treatments in response to the urgent health needs of populations (Cheikh et al., 2022; Nkuma-Udah et al., 2018).

Special exemption allows paramedical staff (nurses and midwives) responsible for managing micro-health centers in rural areas to carry out tasks normally reserved for doctors (e.g., medical prescriptions, patient transfer) (MSHP, 2022). Although their training is much lower than that of physicians and they are often engaged in these complex tasks (important decisions) many times a day, these healthcare professionals rarely have training opportunities to acquire new or updated knowledge (Abdulwadud et al., 2019; TdH, 2019). By providing access to new knowledge without constraints of time or location, an expert system should tackle the difficulties of continuous learning. In this way, healthcare professionals will be able to reduce errors in their tasks and thus avoid tragedies for many patients (e.g., delays in patient transfers) (Achmadi et al., 2018; Nkuma-Udah et al., 2018). The systems should also provide modes to work offline in order to provide continuous support during internet outages or to avoid high online costs in rural areas.

Sustainability may not be the hottest topic in healthcare yet, but it is of paramount importance to developing countries. For compliance with the proposals of the UNDP Sustainable Development Goals of 2015 and those of the Astana Declaration in 2018, SSA health systems must evolve significantly in efficiency and capacity by trying to obtain the maximum positive results with minimal resources (Chotchoungchatchai et al., 2020; Mehra & Sharma, 2021; Scherenberg, 2012; UNDP., 2015; WHO, 2018). Sustainability in health care encompasses a harmonious combination of economic, health, and social dimensions. One possible way to achieve quick improvements is through the use of targeted expert systems. They could help to rationalize expenses by reducing costs related to the organization of training, travel to share targeted information, investments in printing manuals, etc. Due to the digitalization of the information processing process, environmental aspects must also be observed, which will have a strong impact on the excessive use of mass paper for circulars in cases of emergency, the sharing of research results, etc. Investing in digital infrastructure to facilitate data storage not only reduces the costs associated with printing on paper and updating information but also optimizes the wide portfolio of training and information sessions for all minimal changes or new scientific advances. These aforementioned advantages are in line with the 2005-2009 strategic orientations defined by the WHO Regional Office for Africa regarding knowledge management (WHO, 2006).

4.1 A Prototypical Assistance System

In order to motivate the challenges of targeted expert systems for the SSA health system, we present results of a project that was initiated in Burkina Faso. The main outcome was an assistance system called @san. As a central operating element, @san includes an information retrieval system which models the logic of

reasoning of health professionals (mimicry of logical thinking) in the search for targeted information to guide their decision-making. When receiving a patient, the health worker proceeds by questioning and observing clinical signs to make a diagnosis and circumscribe the disease using a combination of symptoms. It is important to note that from a general perspective in the medical field, that all symptoms have the same importance (MSHP, 2022). Therefore, a Boolean retrieval model was chosen for the IR module implementation in @san. Each term in a document collection implicitly defines the set of documents in which the term appears (exact match retrieval). The three basic operators of Boolean algebra are conjunction (AND), disjunction (OR), and negation (NOT) (Manning et al., 2009; Pohl, 2012).

A documentary database with a focus on tropical illnesses was chosen for the storage of targeted information concerning each disease in @san. This has the advantage of facilitating the indexing of useful information, thus linking – for example – the symptoms to the diseases for which there are clinical signs. Each disease (e.g. malaria, fever, meningitis) is dedicated to a file, which can undergo variations according to the criterion of gender ("pregnant" woman, man) or age (infant, child, adult, old person). During research, a symptom whose presence disturbs the process and does not allow us to find a disease is removed and can be the subject of research with a view to creating new knowledge. The interface was designed for easy interactive use as a smart phone app. An online and offline mode functions of @san is planned to make it possible to regulate the constraints linked to the training offer such as costs, organization, and availability of experts and the workload of health workers. The platform developed was made available to end users for a test phase.

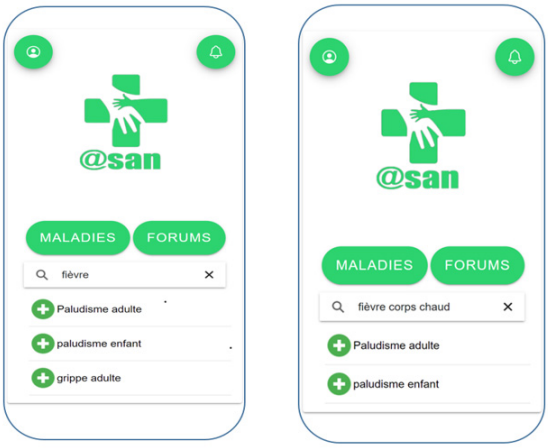

Figure 1: @san information retrieval page on a mobile device.

Figure 1 shows 2 images of the user interface of @san in a disease diagnosis activity. As a health professional proceeds in his logic of reasoning, improbable diseases are eliminated and a circumscription follows as the number of symptoms identified increases.

4.2 Limits

Although the prototype gives quite encouraging results and reinforces the idea that an expert system is a solution to explore it is merely an initial step that can be used to raise awareness and show potentials of such systems for the health system. More research projects are necessary, e.g., improvements must be made to properly satisfy the recovery of targeted information (knowledge). As challenges to be overcome, we can note among others for the moment the rather incomplete information in the knowledge base leading to non-satisfying fulfilment of information needs, the format of presentation of the information retrieved, and access to information in offline mode to circumvent the difficulty of unstable internet connections in SSA. Furthermore, the usability needs to be improved and integrations of existing knowledge resources needs to be done.

5 SUMMARY

Knowledge-based Systems (KBS) have proven themselves for decades and have established themselves comfortably in the field of medicine. With recent progress in artificial intelligence, these technological solutions have gained more visibility and are becoming more and more essential. Despite its great advantages, KBS seems to have been forgotten with regard to Africa where we still find a large deficit in terms of research initiatives. The solutions previously proposed in developed countries cannot be used on a large scale in Africa without undergoing certain adaptation because their development did not take into account local realities and needs. Access to timely, useful and targeted information on tropical diseases (e.g. malaria, meningitis and Ebola) via a knowledge-based system is what end users in SSA need. An expert system must, however, also take into account the difficulties of internet connection in Africa, the cost of its creation and its large-scale deployment, the type of knowledge base for the representation of knowledge and its updating, the availability of knowledge experts, the technological habits and skills of end users. @san's design observed these aspects in Burkina Faso by enlisting the help of potential end users (nurses and midwives) in its design and implementation. In this

sense, there is an urgent need for cooperation on research projects and funding guidance to make health systems in SSA effective learning organizations.

ACKNOWLEDGEMENTS

I greatly thank Neris Technologies SARL for the collaborations in the design and development of @san. Thanks to Ms Golane / Ouedraogo Adam Ariane as well as to all the other nurses and midwives who participated freely and voluntarily in the process.

REFERENCES

Abdulwadud, O., Nyareza, S., Mthoniswa, P.J., Nonde, L., Mlasha, F., Lifuka, E. (2019). Knowledge of Cochrane, evidence-based medicine and the Cochrane Library at Defence Force Medical Services: a baseline cross-sectional survey among military health personnel in Zambia. Medical Journal of Zambia; 46(1), 1-9.

Achmadi, S., Mahmudi, A., Gita, A.N. (2018). Expert System Design to Diagnose of Virus Infection Disease in Children with Certainty Factor Method. Journal of Science and Applied Engineering; 1(2), 88-95.

Ajanaku, O.J., Mutula, S. (2018). The relationship between knowledge management and nursing care performance. South African Journal of Libraries and Information Science; Vol. 84, No. 2, 39-51.

Cheikh, B.A., Gorincour, G., Nivet, H., May, J., Seux M., Calame P., et al. (2022). How artificial intelligence improves radiological interpretation in suspected pulmonary embolism Imaging. Informatics and Artificial Intelligence Volume 32, pages 5831–5842.

Chikhata, F., Chivivi, O.O. (2017). The Significance of Knowledge Management in Improving the Quality of Health Care in the Public Sector in Zimbabwe. International Knowledge Sharing Platform. 7(5): p. 16-30.

Chotchoungchatchai, S., Marshall, I.A., Witthayapipopsakul, W., Panichkriangkrai, W., Patcharanarumol, W., Tangcharoensathien, V. (2020). Primary health care and sustainable development goals. PubMed Central; 98(11), 792–800.

Devine, S.N.O., Kolog, E.A., Atinga, R. Toward a Knowledge-Based System for African Traditional Herbal Medicine: A Design Science Research Approach. Front. Artif. Intell 2022; 5:856705, 1-15.

Dey, M., Rautaray, S.S. (2014). Study and analysis of data mining algorithms for healthcare decision support system. International Journal of Computer Science and Information Technologies; 5(1), 470-477.

Kendal, S.L., Creen, M. (2007). An introduction to knowledge engineering. Springer..

Nkuma-Udah, I.K., Chukwudebe, A.G.,Ekwonwune, N.E.. (2018). Medical Diagnosis Expert System for Malaria and Related Diseases for Developing Countries, E-Health Telecommunication Systems and Networks, Vol.7 No.2.

Khan, M.K., Hernandez, M. (2018). Assessing quality management system at a tertiary hospital in Oman using a hybrid knowledgebased system. International Journal of Engineering Business Management; 10, 1-13. 13.

Kouame, A. (2018). Système de gestion de la médecine traditionnelle dans une plateforme web social et sémantique : une approche basée sur une ontologie visuelle. Université Gaston Berger, Saint Louis, Sénégal. [Ph.D. dissertation]

Manning, C., Raghavan, P., Schütze, H. (2009). Introduction to Information Retrieval. Cambridge University Press; 1-65, 151-175.

Mehra, R., Sharma, K.M. (2021). Measures of Sustainability in Healthcare. Sustainability Analytics and Modeling; Vol 1, 1-15

Milan, D., Petr H., Phuong H.N.. (1997). CADIAG-2 and MYCIN-like systems. Artificial Intelligence in Medicine Volume 9, Issue 3, Pages 241-259.

Moahi, H.K., Bwalya, J.K. (2018). Knowledge Sharing for Healthcare and Medicine in Developing Countries: Opportunities, Issues, and Experiences. IGI Global.. [dissertation]

MSHP - Burkina Faso. Annuaire statistique 2021. (2021). Available from: https://www.sante.gov.bf/fileadmin/annuaire_2021_mshp.pdf (accessed 26 Aug 2023)

Musen, A.M., Middleton, B., Greenes, A.R. (2021). Clinical Decision-Support Systems. Biomedical Informatics, Spinger. pp 795–840

Pohl, S. (2012). Boolean and Ranked Information Retrieval for Biomedical Systematic Reviewing. The University of Melbourne, Victoria, Australia.. [Ph.D. dissertation]

Scherenberg, V. (2012). Nachhaltigkeit im Gesundheitswesen : Nur ein Modewort oder Anstoß zum Umdenken? Dr. med. Mabuse 200; 9(1), 72-74.

TdH. IeDA: using technological innovations to improve primary healthcare. (2019). Available from: https://www.tdh.org/de/projekte/ieda (accessed 25 Jan 2024)

Tolmie, C. J.,, Du Plessis, J.P. (1997). The use of knowledge-based systems in medicine in developing countries: A luxury or a necessity? Methods of information in medicine; 36(02), 154-159. 12.

UNDP. (2015). Sustainable Development Goals by 2030. Available from: https://www.undp.org/sustainable-development goals?gclid=Cj0KCQjw0IGnBhDUARIsAMwFDLn29zR07vU3rrWfE2R74XHfphMpPvUY7ijN bx3loEO971fatibAKnEaAk7yEALw_wcB (accessed 25 Jan 2024)

Watkins, J., Goudge, A., Gòmez-Olivé, F.X., Griffiths, F. (2018). Mobile phone use among patients and health workers to enhance primary healthcare: A qualitative study in rural South Africa. Soc Sci Med.; 198:139-147.

World Health Organization (WHO), Regional Office for Africa. (2006). “Knowledge Management in de WHO Region Africa,” Addis Ababa, Ethiopia. Available from: https://www.afro.who.int/sites/default/files/2017-06/AFR-RC56-16%20Knowledge%20Management%20-%20Final.pdf (accessed 25 Jan 2024)

World Health Organization (WHO). (2018). Available from: https://apps.who.int/iris/bitstream/handle/10665/347879/WHO-EURO-1978-3938-43697-61471-eng.pdf?sequence=1&isAllowed=y (accessed 25 Jan 2024)