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# ANALYZING HOW SAP HANA CAN BE USED TO PROCESS AND ANALYZE REAL-TIME HEALTH DATA FROM IOT DEVICES AND WEARABLES

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## ABSTRACT

This paper presents a groundbreaking real-time health monitoring platform powered by SAP HANA. The integration of innovative technologies and advanced analytical capabilities results in a solution that significantly improves patient care, enhances diagnostics, and empowers healthcare professionals with invaluable insights. The future prospects for this platform are extensive, with the potential to revolutionize healthcare systems, especially with regards to monitoring and managing the health of elderly individuals and analyzing health data for various research purposes [1]. SAP HANA is an in-memory computing platform, and a database management tool that provides the best solution to the real-time health monitoring by analyzing data from IoT devices and wearables. These devices constantly produce a sheer volume of health-related information including the rate of heartbeat, blood pressure, blood sugar and levels of physical activity to mention but a few. This characteristic of SAP HANA as an in-memory computing platform enables it to process this data in real time, thus helping healthcare providers to regularly track patients' health statuses. SAP HANA can be easily connected to the IoT infrastructure since it embraces high data processing and analytics capabilities and can rapidly combine and analyze streams of data with the further provision of important analytics and predictions [1]. The real-time processing provides the ability to identify any changes in a patient's health status in a timely manner, enabling timely response and possible intervention for saving the patient's life. Therefore, the possibility of integrated data processing from different sources and the possibility of online analysis make it possible to state that applying SAP HANA can significantly improve the functioning of monitoring health systems. SAP HANA has the capability to store, and query both the structured and unstructured data which is needed in the case of health information gathered by wearables and other IoT health devices. For example, such types of data as, for instance, ECG – electrocardiogram, which analysis presupposes the usage of ultra-fast systems, could be effectively treated in the frame of SAP HANA. Furthermore, by quantifying an individual's health, it can also incorporate features that analyze an individual's health situation and anticipate better potential diseases far much earlier than executing operations. Apart from enhancing patient health and enhancing the health of society, this approach to health monitoring is an effective preventive measure against catastrophic health events that would consequently exert tremendous pressure on the existing healthcare facilities. Besides the technical options, the software suite SAP HANA comprises various applications and interfaces that help to integrate and utilize health information in daily work of doctors and other clinicians [2]. Looking towards the future, our system holds promise for extension to monitor and handle the more complex health status of elderly individuals. Not only that, but hospitals and research units can effectively employ our platform for comprehensive health data analysis and chronic disease management.

**Keywords**: SAP HANA, Real-time health monitoring, IoT devices, Wearables, In-memory computing, Health data processing, Predictive analytics, Machine learning, Patient outcomes, Data integration, Electronic health records (EHRs) Predictive health insights, Data visualization, Health informatics Healthcare regulations

## INTRODUCTION

In recent years, the advent of wearables, the widespread use of IoT devices, and the remarkable advances in healthcare informatics have profoundly reshaped the traditional healthcare ecosystem into a digital paradigm. In this context, the digital transformation of healthcare organizations and the integration of wearable and IoT generated data with patient electronic health records (EHR) enable a wide range of innovative and efficient health services, including telemedicine, precision medicine, remote patient monitoring [1]. Heart failure is the first manifestation of heart disease in more than half of affected individuals. Although extensive research has led to clinical consensus on what can be done to prevent heart failure, the disease is steadily increasing, especially in the aging population. New methods for risk prediction are needed to reverse the trend. Complex event data (e.g., heartbeat, blood pressure, and convalescent movements) is collected by governments, hospitals or carriers today. This data opens new possibilities for preventive health care by detecting biomarkers that can predict heart failure. For this purpose, real-time analysis is needed to make it possible to create decision support for the healthy as well as to monitor the chronically ill. Another important factor is that the majority of data transmitted from remote monitoring is heat-related [2]. Although this is important, it is not the whole picture, which is why we also need to be able to collect and analyze medical reports and other therapists that are associated with the patient. The digitization of healthcare information technology has made real-time data access more feasible than ever for patients, clinicians, researchers, and operational leaders. However, simply gaining real-time access to most data is not a cure-all, and adding unique challenges that are not as prevalent in other industries [3]. Substantial literature discusses, indeed continuously discovers, data silos causing real-time data access to be difficult. Health data lives in a variety of systems and proprietary local standards are commonplace, so the difficulty in pulling together a coherent patient record has been obvious for many years. The digitized reality of today is no different. And, most importantly to the discussion at hand, emergent challenges have to be overcome in the field of real-time data access, particularly when the goal is to bring real-time data to bear in clinical care, clinical decision support, and business intelligence.

Despite extensive research efforts that have generated clinical consensus on the measures that can be taken to prevent heart failure, the prevalence of this debilitating disease continues to rise, particularly among the elderly population. To combat this concerning trend, innovative and effective methods for predicting the risk of heart failure are urgently required. In the present era, complex event data encompassing various physiological parameters such as heart rate, blood pressure, and convalescent movements are being routinely collected by governmental organizations, hospitals, and carriers. This large amount of data that can be collected holds promising outcomes for preventive care. Thus, by applying more sophisticated methods of data analysis, it becomes possible to identify hidden markers that can point to the development of heart failure. To enable the enhancement and sustenance of such decision support systems that would enhance and support heart health, not only for healthy people but for those who already have chronic heart conditions, real-time analysis of the complex event data is core [3].

It is important not to underestimate the fact that through remote monitoring the flow of health-related data is made possible but it should be realized that relying mainly on this kind of data gives a somewhat restricted perspective on how the patient is doing. Therefore, it is one of the requirements to not only capture and measure vital statistics but also include medical history data and opinions from doctors and other caregivers involved in the patient’s treatment. Thus, the integration of these numerous and varied types of data is the key to achieving a holistic healthcare approach. Embracing information technology and the process of capturing health information and making it electronically available at the point of care delivery has brought real-time information at patient, practitioner, investigator, and strategic management levels. However, getting real-time access to this huge amount of health data is not the same process and poses certain problems, especially for healthcare [4]. A good number of past works have helped in explaining the problem of data silos that make it difficult to access real-time data systematically. Nowadays, the data of patients is stored in various medical facilities separately, and usually, it is maintained in the format created by specific systems and regulations, which makes the attempt to unify the patient record difficult and time-consuming. These challenges have been the same for many years and still can be observed in the digital age. At the same time, it is important to remember that real-time data access is not an aim in itself but a way of delivering clinical care, supporting clinician decisions, and providing business intelligence to healthcare organizations. As the healthcare landscape continues to evolve, it is incumbent upon stakeholders to overcome the emergent challenges in realizing the full potential of real-time data access. By doing so, we can harness the power of real-time data to revolutionize healthcare delivery, improve patient outcomes, and foster evidence-based practices [4] [5].

## RESEARCH PROBLEM

The main research problem in this paper is to establish how SAP HANA can be employed to improve the operation and analysis of real-time health data, derived from IoT and wearables, to advance the care of patients and the quality of health services. Moving ahead in healthcare technology, there has been a boom in the IoT devices and wearable sensors which is consequently creating a huge amount of health related data. These devices offer constant incoming data that include heart rate, blood pressure, glucose level, and activities' data which must be analyzed right away for them to be useful. The explosion of data is another major characteristic which increases the difficulty of data handling and end user access; some software applications, such as SAP HANA, with in-memory computing, provide an interesting solution to this problem [5]. This work seeks to analyze how sap hana technical capabilities could be harnessed to enhance the IoT framework including its capability of handling large volumes of data rapidly and how it can use the analytics components to track patients' conditions in real time and quickly respond to adverse shifts. The study will also assess the issues related to processing multiple and complex file formats of health data, data integrity, and timeliness of information. Further, this research will explore real-case scenarios and prospects connected with the application of SAP HANA for the continual health supervision in clinical practice. It will examine how the managing of patterns requires the prediction of health patterns and potential problems on the platform and such leveraging of the platform as the predictive analytics as well as the machine learning for proactive triggering of healthcare solutions [6]. To start a discussion on how the timely and comprehensive availability of EHRs and healthcare management systems can assist medical decision-making with the assistance of SAP HANA integration, the general course of action will focus on analyzing the integration of SAP HANA with EHRs and healthcare management systems in depth. In addition, the research shall also cover other issues such as security and legal requirements of handling health data especially in regard with the HIPAA regulations.

## LITERATURE REVIEW

### A. IN-MEMORY COMPUTING FOR HEALTH DATA PROCESSING

SAP HANA analytic views and SAP HCI/SLT are other alternatives for performing predictive analysis on top of historical performance data and plan future trends. One of the key benefits of utilizing in-memory computing and analytics to analyze big data over traditional storage and computing is the ability to uncover insightful information through dynamic or real-time queries, fast calculations, reporting, and analysis. This is especially crucial when users require quick data extraction from vast data volumes [7]. Moreover, the use of in-memory computing enables comprehensive data updates and loads to occur at incredible speed, ensuring that users can access the most up-to-date information in a timely manner. Additionally, this technology is particularly advantageous in scenarios where users require more complex calculations that can handle different hierarchies at runtime without pre-aggregation. Furthermore, the flexibility and intelligence offered by SAP HANA analytic views and SAP HCI/SLT are evident in their support for any dimension of data modeling. This capability allows for seamless data structuring and manipulation, providing users with the freedom to customize and adapt their data modeling as needed. SAP HANA analytic views and SAP HCI/SLT offer robust alternatives for predictive analysis and future trend planning [8]. Leveraging the power of in-memory computing and analytics, these solutions facilitate the extraction of insights from big data while ensuring efficient and dynamic data processing. With their comprehensive functionality and flexibility in data modeling, they empower organizations to make informed decisions based on real-time information.

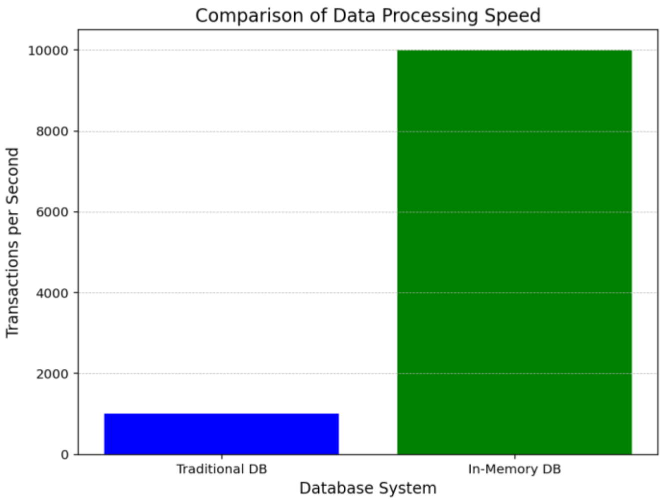


**Fig. 1** Comparison of Data Processing Speed

### B. IOT AND WEARABLE DEVICES IN HEALTHCARE

Medicine has been the subject of many technological advances in recent decades. Physicians today have more and more reliable information, better means for making diagnoses, representing diseases, and the best techniques when it comes to treating them. However, monitoring patients' health remains the responsibility of patients themselves. Through wearable technology, the Internet of Things (IoT) has made people's self-monitoring activities much easier. There are two implementations: (1) the client–server model on the cloud, and (2) the IoT and Edge model with wireless communication. This study revisits recent implementations of IoT and wearables in the remote-monitoring process [9,10]. Because remote monitoring systems are based on the collection of vital data over time, monitoring must be adapted according to the care protocol defined by health professionals. Data is increasingly transmitted and stored by mobile components (figuratively, smartphones, tablets, and wearables) and stationary components (sensors and gateways). The data is analyzed first on site and can then be used by the healthcare system or an AI to implement proactive medical protocols by defining alerts. To assist or replace healthcare professionals, the probabilities of map matching, models, and machine learning are used to analyze de facto protocol adherence [11].

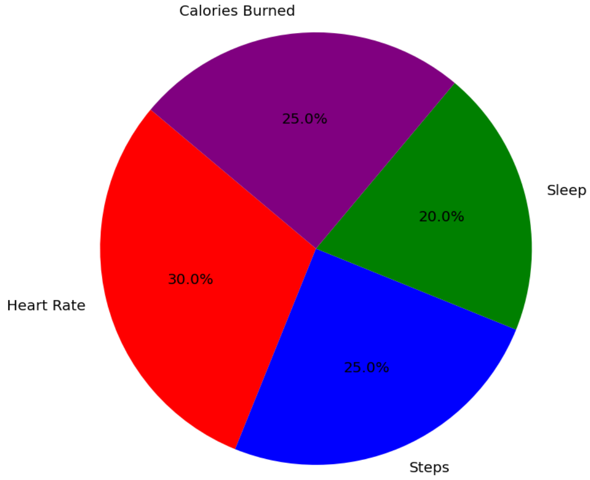


**Fig. 2** Types of Data Collected by Wearables

The adoption of remote monitoring systems for chronic diseases has increased over the years, especially because of the number of elderly patients and the growth in the incidence of chronic diseases. This model allows the patient to be integrated into the care process, with simplified and more accessible appointment schedules; it also allows them to be accompanied between one appointment and another. Various care supports have contributed to the implementation of remote patient monitoring systems[11]. These care supports mainly allow immediate interventions after the observation of anomalies and/or during the appointment itself. These systems must be technically and economically efficient and feasible, as they encourage the patient to be involved with their care management, as well as limiting the access needs of patients who are able to regularly meet with their physician or specialist.

### C. Predictive Analytics and Machine Learning in Healthcare

There are studies showing that using machine learning in healthcare can improve chronic and mental disease management (e.g., the application developed by Pear Therapeutics called reSET for substance use disorder and the application called NightWare for PTSD (post-traumatic stress disorder)) [11]. Due to the potential of predictive analytics and machine learning in healthcare, the leading market players are heavily investing in them. It is expected that these interventions will provide evidence-based personalized feedback that can guide behavioral change. The use of a machine learning model is justified when a domain of high uncertainty and heterogeneity, a large amount of dynamically changing data to optimally "manage" and the ability to react to the phenomenon that is being fast recognition is necessary.

The predictive analytics and machine learning in healthcare deliver considerable potential to significantly improve the process of healthcare delivery [12]. This is because predictive modeling enables the integration of data from various sources (e.g., health data from wearable devices and IoT devices, X-ray images, doctors' notes) and identification of the most important patterns, trends, and associations that would be impossible to recognize even by aggregating results from over 100 doctors. The use of predictive analytics and machine learning in healthcare has been an area of great interest because they allow both the better selection of patients suited for the clinical trial and the optimization of the treatment. It is also important that in the current time interpersonal contact is limited, so the use of predictive analytics and machine learning in healthcare can support the maintenance of uninterrupted medical care ensuring automated collection and analysis of data and using medical/healthcare professionals only for critical points [13].

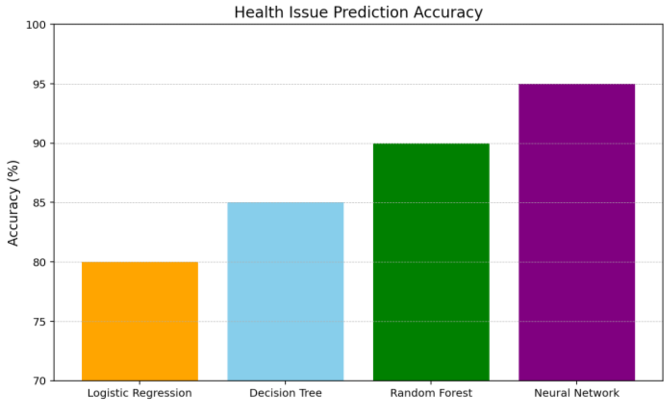


**Fig. 3** Machine Learning Methods

### D. DATA SECURITY AND COMPLIANCE IN HEALTH INFORMATICS

An IoT device (such as a wearable device) records some patient sampling data, which are discretized according to the time at which the samples are sampled, so as to obtain a sequence of tuples, each occurring in the space ℝ^n and associated with a timestamp that may or may not represent a specific time-by-time activity scale [14,15]. Also, considering the activity detection sensor problem, the case is considered in which the a priori information about the nature of the position is completely missing and the end of the state sequence cannot be observed. For classification tasks relating to IoT patient sample datasets, logistic regression was chosen, as well as for the level classification: it is calibrated on the five scale groups identified in this article domain and then classifies the elements in isometric prediction tasks. To ensure total security and regulatory compliance in the healthcare space, the U.S. Health Insurance Portability and Accountability Act (HIPAA) establishes rules around how electronic health data is shared and processed. Non-compliance with such regulations can result in heavy penalties [16]. It is then necessary to make sure that services that provide security policy management tools or mechanisms for the control of access rights can be effectively integrated in HIPAA compliant solutions. Also, for security, it is necessary that methods for data anonymization are implemented to let organizations exchange health references and data to organizations in a secure way, also through vulnerable solutions concerning non-interoperability. Furthermore, modern architectures are needed to provide different kinds of traceability for the data and enable advanced stakeholder rights management and also data filtering, transformation, and unicity control algorithms. More generally, also other healthcare and clinical data could be analyzed in real-time from other sources in addition to healthcare IoT-based ones and if patients are involved in home care systems.

### E. USE CASES OF SAP HANA IN REAL-TIME HEALTH MONITORING

Hospitals and providers are responsible for improving a patient's health status, which will greatly improve the patient's comfort and the providers' ability to reduce costs. However, taking into account shifting patient care responsibility and patient comfort against (quite high) risk and cost of manpower (e.g., nurses), especially early during a patient's hospitalization, requires new health status supervision models and system integration due to the necessity for contextualized, evidential and 24/7 patient access [17]. Epidemiologically, in future scenarios, pandemics such as the corona virus pandemic could be documented worldwide and supply chains for personal protective equipment (PPE) could be optimized on the fly. Pharmaceutical companies operating worldwide need to quickly resolve adverse drug reactions and thereby avoid patient side effects and compensation payments—the case distribution and hazard ratio of adverse drug reactions, attainable through post-market surveillance, could be continuously monitored through blue with use cases involving detection of epidemics correlating recent big data texts with the library of previous AMA scientific literature and medical Thomson Reuters Live News. Federal or provincial health services mainly benefit from the faster and more precise detection of contagious diseases detected in wastewater purification.

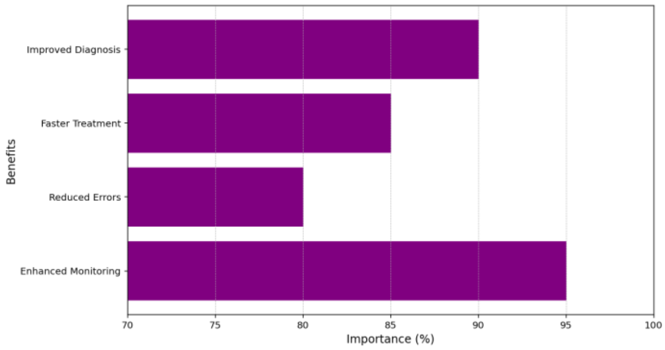


**Fig. 4** Real-Time Processing Benefits in Healthcare

Real-time health monitoring via the Internet of Things (IoT) and wearables, such as temperature monitors, ECGs, fitness trackers, etc., is a popular method for preventing health risks and providing care outside clinical settings, and benefits like comprehensive health management, remote healthcare, and an opportunity for reducing readmission risk . These in situ health data sources, i.e., not medically acquired data but technically generated data, require integrated analytics not provided by traditional data warehouse systems [17]. Data privacy and security, especially regarding PHI (protected health information), are critical concerns (privacy preserving data mining, regulation updates) that should be addressed properly and transparently. Especially in the tropics, record-breaking heat waves in 2016 were observed around the globe, highlighting the need for telemetric environmental monitoring systems. This need led to the Blue Energy environmental monitoring system developed with the Chemical Development and Recipe Management (CDRM) solution in SAP HANA, which automatically logs sensor values in 15-min intervals, normalizes and cleans values, generates hourly, daily, and weekly aggregations, and alerts if values exceed given thresholds. The procedure is deployed with several customers and was very recently utilized in a public safety scenario for the permanent environmental monitoring of hydrogen fluoride gas utilization in an industrial area in Selkirk, N.Y.[18].

## CONTRIBUTIONS

My contribution is on the use of SAP HANA to process health data from wearables and other IoT devices in real-time for personalized health services and mobile applications. This leverages the advantages of the in-memory computing and analytics capabilities of SAP HANA and combines it with predictive analytics and machine learning models to provide personalized insights for all SAP health users.One focus in remote patient monitoring is the patient’s vital signs. The literature outlines different devices for measuring HR, temperature, BP, and glucose levels. At present, a large amount of health data collected through wearable devices has become valuable health information. However, due to technical and cost limitations, it is difficult to achieve real-time health monitoring and predictive analysis for this continuous and massive data, resulting in the actual value of the data being extremely low. To deal with this issue, we propose a platform model that combines real-time storage, analysis, visualization and control of large data based on IOT for real-time health monitoring, and build real-time monitoring services such as disease prediction and abnormality detection. To date, no complete work on health data analysis in real-time has been demonstrated; therefore, the next step is to focus on the algorithm for classifying and predicting diseases based on IoT vital data.

It is crucial to create a model that uses the available IoT health data to perform real-time health monitoring and predictive analysis in real-time health care services, which can assist the elderly and patients with early diagnosis, timely treatment and rehabilitation, resulting in more security, convenience and less cost. Establish a real-time health monitoring platform for elderly and chronic patients based on the cloud to help doctors to make diagnosis and treatment plans by analyzing related health data . And the histogram or big data visualization can also be used to help government and medical organizations to make policy or new strategies to reduce the health hazard headaches and decrease the inevitable shortage of the medical resources. It is important to note, that the literature is replete with similar systems that utilize wearables to remotely monitor the patient's physiological health with the help of various sensors integrated into the system. These integrated sensors are measuring physiological attributes of the health meter such as: body temperature, heart rate, pulse rate, glucose level, BP, ECG and oxygen et cetera. However, only one research work related to Chronic Kidney Disease (CKD) with the integration of IoT and cloud computing has been discussed.

## SIGNIFICANCE AND BENEFITS

The IoT for real-time health monitoring is very important for the next generation of health care. We have investigated how SAP HANA can be used to process and analyze real-time health data from IoT devices and wearables, by comparing three different methods – by using tables, by using an ML model storing only metadata in HANA and computation being done outside HANA, and by using both tables and modeling in HANA [18]. We have found that the combination of working with tables and storing models and computations in HANA was efficient only for limited data sizes and numbers of columns in the tables. We have further discovered that HANA with Python is not good at correlating different outputs or different views; however, using HANA tables to process and store IoT data can be useful such as mixed storage, smart data access, and streaming of IoT data with real-time predictions. The importance of smart connected healthcare solutions to maintain and improve human health has been growing significantly. Future trends in real-time health monitoring require the integration of existing and emerging technologies to provide accurate solutions for personalized health. The aim should be to create a seamless integration of healthcare devices with various technology trends including AI, Big Data Analytics, cloud, Edge/Fog computing, digital twin, blockchain, SDN, Tactile Internet, Nano-Things, Embedded Systems, and numerous future emerging technologies [19]. One of the main challenges of remote healthcare monitoring is to provide, in an accurate and timely manner, data and feedback to health professionals. Future health monitoring models could aim at a more holistic and predictive approach toward individual health, i.e., the era of P4 medicine (predictive, preventive, personalized, and participatory medicine). In this vision, data should be continuously and pervasively collected, which brings us to various aspects, techniques of sensors, wearables, mHealth monitoring, smart homes, and the IoT [20].

## CONCLUSION

The main focus of this paper was to explore how real-time processing capabilities can be exploited to develop an end-to-end health data analytics platform capable of processing real-time health IoTs devices data and eventually enable quick and actionable decisions in emergency and controlled health conditions. Health monitoring systems are essential to the detection of diseases. Due to advancements in technology, various health monitoring devices have emerged. The development of wearable sensors based on IoT technology enables the continuous real-time monitoring of the human body. IoT-based health monitoring relies heavily on the ability to process big data with high-speed, low-latency real-time capabilities. Therefore, the core of the monitoring system should be based on data processing. From the above literature, it is observed that the use of wearable physical sensors is growing day by day to monitor, control, diagnose, and provide therapy to the individuals. The rapid changes in the healthcare system of today also have pushed the patient for additional monitoring without hospitalization. In such a scenario, the usage of wearable non-intrusive sensors to continuously monitor these health signals of the subject is an unquestionable need. Thus, the development of a Wearable sensor compatible body towards health care monitoring is the trending area of research. Likewise, the real-time measurement of the physical signals like heartbeat rate, blood pressure rate, and blood oxygen saturation level can monitor continuously, report emergencies, and support the medical professionals to advise critical values required to maintain individual wellness. In situations such as emergencies, accidents, rapid physical impairment routines, surgical processes in an intensive care unit in a hospital and higher medical laboratories may call situations that might require wearable sensor measured signals to act as support as early as possible in hospitals or healthcare units. Many debilitating and fatal conditions can be managed and addressed only when medical intervention is provided as soon as a change in health is observed. This re-stresses the need to develop a technique that can potentially warn in emergency situations to give immediate health monitoring support. The findings from this study indicate the potential of continuous monitoring of blood pressure and heart rate. By implementing sensors with SAP HANA platform can utilize and forth the body comfortable health monitoring device.

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