Sensorial Investigation for Automated Patient Data Collection in Hospital Triage: An Exploratory Assessment of the Literature

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This paper delves into the proposal of integrating a comprehensive system of vital signs sensors to advance the BayIEEEmax project, which aims to develop an autonomous robot to aid in the triage process within hospital settings. A thorough investigation was conducted to explore commercially available sensor types capable of measuring patients' body temperature, heart rate, and blood pressure. The research focused on assessing the identified sensor models' feasibility and compatibility with the prototype's requisite automation criteria. Ultimately, the selected set of sensors will be incorporated into a printed circuit board and integrated into the physical model of the robot for experimental validation.
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Over the years, as the population has grown, the methods of collecting and storing important data have evolved significantly. The progression has been marked from oral communication to handwritten records and from typewritten documents to printed reports. However, despite the advancements in data storage technologies, such as ample storage clouds, the methods of data collection in certain domains have not kept pace with this evolution [1].

In hospitals, one of the most critical factors for a patient's outcome is often not the treatment itself but the time spent waiting for triage. Consequently, process automation, coupled with mobile robotics, has emerged to streamline simple, repetitive tasks previously performed by professionals, thereby optimizing their time for more critical matters. Automating the triage process could significantly enhance efficiency and effectiveness within healthcare facilities [1,2].

The quest for automation and mobile robotics solutions in hospitals is increasingly prevalent [3,4]. For instance, the "Relay" robot developed by Swisslog autonomously navigates hospital premises, transporting medications, laboratory samples, and other vital materials to optimize resource allocation within healthcare facilities [5]. Similarly, the SpeciMinder robot, developed by CSS Robotics, serves a similar purpose and can map environments and interact with doors and elevators [6]. This paper aims to propose a sensor system integrated with a mobile robot to collect patient data non-invasively, thereby reducing waiting times in hospital triage efficiently.

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Materials and Methods

The work employs an exploratory methodology to investigate bibliographic materials, including scientific articles, informational websites, and sensor datasheets. This approach facilitates a comprehensive exploration of an innovative integrated assistive robotic model. By synthesizing information from diverse sources, this methodology aims to provide a nuanced understanding of the technological landscape and inform the development of the proposed robotic system.

General System

We conducted research to identify sensors capable of safely, reliably, and non-invasively measuring vital signs crucial for initial diagnosis and prioritization of patient care to propose a model for a robot capable of automating the in-hospital triage process. These vital signs encompass heart rate, respiratory rate, oxygen saturation, body temperature, and blood pressure, collectively offering a comprehensive assessment of the patient's physiological status.

In hospital settings, continuous monitoring of vital signs is paramount to ensuring patient safety and well-being. We facilitated this with sensors to transmit pertinent data swiftly and efficiently.

Sensor Types

Among the diverse array of sensors available, those commonly utilized in hospital environments include [7]:

- **Temperature Sensors:** Designed to measure skin and body temperature in health monitoring applications, digital thermometers, health tracking devices, and portable temperature monitors are prevalent. Notably, infrared temperature sensors enable contactless measurements, while digital temperature sensors offer readings with a digital output signal in a compact printed circuit board format. PPG (Photoplethysmography) Sensors: These sensors monitor heart activity.

- **PPG Sensors:** They employ low-intensity infrared light to detect an individual's blood flow rate. Given the prevalence of various heart diseases, PPG sensors are ideal for tracking a patient's cardiac conditions [8].

- **ECG (Electrocardiogram) Sensors:** These sensors record the electrical signals of the heart, commonly used to detect heart problems and monitor heart status in various situations. ECG examinations allow for identifying different cardiac conditions, such as arrhythmias or dysrhythmias, in a non-invasive, painless manner and with rapid results [9].

- **Blood Pressure Sensors:** Vital for assessing the patient's physiological and functional status, blood pressure sensors are indispensable. Examples include the sphygmomanometer, available in analog or digital formats, which non-invasively measures blood pressure accurately, providing crucial information for evaluating the patient's clinical condition [10].

Incorporating these sensors into an in-hospital triage robot model facilitates continuous and precise collection of vital signs. This integration optimizes the patient care process by ensuring efficient and reliable triage.

Main Techniques in Health Signs Sensors

Health-related sensors are pivotal in capturing and measuring vital signs continuously and non-invasively, facilitating monitoring of the patient's condition. The data collected from these sensors find applications across a broad spectrum of healthcare scenarios. The primary techniques pertinent to the present work are:

- **Automated Auscultatory Method:** This method automates the process of auscultating Korotkoff sounds, which are the sounds produced by blood flow in an artery as the pressure of a sphygmomanometer cuff is gradually released [11]. The cycle of events involves inflating the cuff to stop blood flow, gradually reducing cuff pressure to detect the first Korotkoff sound, and identifying the periods of muffling and silence. Systolic and diastolic pressure values are presented [10].

- **Oscillatory Method:** This technique aims to measure blood pressure in an automated manner, eliminating the need for auscultating Korotkoff sounds. Pressure sensors, applied to the patient's arm, detect oscillations caused by pulsating blood flow in the arteries, which are then converted into digital values. These oscillations are interpreted by the electronic device to automatically display systolic, diastolic, and mean blood pressure [10].

- **Optical Method + Machine Learning:** This approach involves continuous and accurate monitoring and interpretation of vital signs. It utilizes sensors that use light to gather physiological information from the patient, measuring characteristics such as light absorption or reflection from biological tissue and providing vital signs data. By applying Machine Learning, these data can be used to detect anomalies, predict trends in vital sign behavior, personalize treatment, and more. This combination enables faster diagnosis and timely intervention, improving clinical outcomes [12].

- **Electric Currents Measurement Method:** This technique utilizes the electrical activity generated by the human body to monitor and obtain information about the patient's condition. It is commonly employed in EEG, ECG, and EMG, where the electrical activities of the heart and muscles are measured [13].

These methodologies collectively enhance patient monitoring, diagnosis, and treatment, fostering improved healthcare outcomes.

Results and Discussion

The data collected during the research of each type of sensor was grouped according to its functionalities: blood pressure sensors (Table 1), heart rate sensors (Table 2), and body temperature sensors (Table 3).

The data in Table 1 shows that the set of analog sphygmomanometers and stethoscopes is unfeasible for manufacturing the desired robot model. The need for a technician or nurse demonstrates a failure to comply with the central premise of the project to allow the reallocation of these employees to more requested areas and, therefore, cannot be adopted.

The digital sphygmomanometer, on the other hand, does not require the presence of a technician but needs to be placed accurately on the arm to obtain accurate measurements. The digital pulse blood pressure monitor circumvents this limitation but is inherently less accurate than the digital sphygmomanometer. Digital photoplethysmography, on the other hand, does not require direct contact with living tissue but is very sensitive to light.

Table 2 shows that the oximeter is an easy-to-use sensor, requiring only the approach of the patient's finger. In this sensor, no position adjustment is required. The smart bracelet, although also easy to use, has low reliability. It can, however, be easily connected to other systems.

The heart rate sensor can collect information by being inserted into the ear or squeezed by the patient's fingers. This makes collection as simple and easy as the oximeter. The chest sensor is not feasible as it needs to be attached around the patient, which would need a very complex mechanism for interfacing with the robot compared to the other sensors. Finally, the ECG would require the accompaniment of a technician to operate, which again would be counterproductive with the goal of automating certain functions through mobile robotics solutions.

The data presented in Table 3 shows that the digital infrared thermometer offers a non-invasive, rapid, and easily interpretable system. However, its high cost and performance reliance on battery levels limit its feasibility.

Conversely, the thermal camera provides a non-invasive data collection method unaffected by battery variations, maintaining the critical advantages of the digital infrared thermometer. While accurate and cost-effective, the digital thermometer necessitates physical contact with the patient and would require technician intervention and sanitization, rendering it impractical to integrate with the desired mobile robotics solution.

In pursuit of creating a mobile robotics platform capable of intra-hospital screening to reduce waiting times and perform non-invasive data collection, the chosen sensors are the thermal camera, oximeter, and digital sphygmomanometer.

Table 1. Blood Pressure Sensors.

Measuring Instruments	Technique	Advantages / Disadvantages	Example
Analogic sphygmomanometer + stethoscope	Automated auscultatory method (not autonomous)	Requires a technician or a nurse to operate the instrument	
Digital sphygmomanometer	Oscillatory method	No need for a technician, but require a specific position of the patient's arm	
Photoplethysmography	Optical method + machine learning	Non-invasive, do not require physical contact, sensible to light. Not commercial.	
Digital pulse blood pressure monitor	Oscillatory method	Easy manipulation and utilization with the patient, less liable than the arm sphygmomanometer	

Source: Photo references were acquired by Center Medical [14].

Table 2. Heart rate sensors.

Measuring Instruments	Technique	Advantages / Disadvantages	Example
Oximeter	Optical method	Easy patient use, no need for a specific finger position adjustment	
Smart bracelet	Optical method	Easy patient use, low reliability, easily connected to external systems	
Digital pulse blood pressure monitor	Oscillatory method	Easy manipulation and utilization with the patient	
Heart rate sensor	Optical method	Easy functionality, but needs to be attached to the ears to the patient	
Chest monitor	Electric currents measurement	Must be attached to the chest of the patient	
ECG	Electric currents measurement	Requires a technician or a nurse to operate the instrument	

Source: Photo references were acquired by Center Medical [14].

Table 3. Body temperature sensors.

Measuring Instruments	Technique	Advantages / Disadvantages	Example
Digital infrared thermometer	Infrared Method	Non-invasive, fast, easy to read, data can be saved, but has high cost, is very sensitive to product battery variation	
Thermal camera	Computational method + infrared	Non-invasive, fast, easy to read, data can be saved, but high-cost	
Digital Thermometer	Temperature sensor	Accurate and cost effective, however has physical contact with patient, would need a technician and sanitization	

Source: Photo references were acquired by Center Medical [14].

Conclusion

This study aimed to propose a mobile robotics platform capable of facilitating the in-hospital screening process by swiftly, effectively and non-invasively collecting patient data. Through a comparative analysis of various sensor types, the study determined that the oximeter, digital sphygmomanometer, and thermal camera best fulfilled the requirements for heart rate, blood pressure, and body temperature data collection, respectively.

The following steps entail investigating the integration of these circuits into a mobile robotics platform based on TurtleBot3. Additionally, the study will involve creating a Computer-Aided Design (CAD) and the simulation of this model utilizing the ROS 2 platform. These efforts will contribute to developing a robust and efficient mobile robotics solution tailored to the needs of intra-hospital screening, ultimately enhancing patient care and streamlining healthcare processes.

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