Vital Signs and Organs related Disease Diagnosis Systems using CMOS Image Sensors

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Abstract

According to the Center for Disease Control and Prevention (CDC), the average human life expectancy is 78.8 years. 3.2 million deaths are reported yearly due to heart disease, cancer, Alzheimer's disease, diabetes, and COVID-19. Diagnosing the disease is mandatory in the current way of living to avoid unfortunate deaths and maintain average life expectancy. CMOS image sensor (CIS) became a prominent technology in assisting the devices for monitoring and clinical diagnosis to treat diseases in the medical domain. To address the significance of CMOS image sensors' usage in disease diagnosis systems, this paper focuses on the CIS incorporated disease diagnosis systems related to vital organs of the human body like the heart, lungs, brain, eyes, intestines, bones, skin, blood, and bacteria cells causing diseases. The main objective is to evaluate the systems' capabilities and highlight the most potent ones with advantages, disadvantages, and accuracy, that are used in disease diagnosis. We used PRISMA workflow for study selection methodology, and the parameter-based evaluation is performed on disease diagnosis systems related to the human body's organs. The corresponding CIS models used in systems are mapped organ-wise and tabulated the data collected over the last decade.

Keywords: CMOS image sensors, medical imaging systems, medical applications, biomedical CMOS image sensors, implantable CMOS image sensors, and smart-phone CMOS image sensors.

Introduction

The brain, heart, eyes, intestines, lungs are the most affected organs in the current way of living. The monitoring of human organs like the brain, eyes, heart, intestine, lungs, and vital signs (shown in Figure 1) observation is mandatory for secure and healthy human living to avoid early deaths. CMOS image sensors are playing a prominent role in medical sciences in such a way that they are implemented in every part of the body. Around fifteen million deaths were caused by ischemic heart disease and stroke globally, and finding the methods to identify them nowadays is crucial. Diagnostic modules like X-ray, magnetic resonance imaging (MRI), computer tomography, and echocardiography are used to rescue many lives. Still, these modules can produce black and white images only. However, the colored images can provide a lot of information to the physicians to detect and apply suitable treatment. The improvements in CMOS Image Sensor technology bring more quality color images. Its miniature size can incorporate anywhere into the human body for diagnosis and provide the patient information accurately to the physicians for better treatments to save lives.

CMOS Image Sensor 's involvement in biomedical applications is rapidly increasing day by day, and technical advancements are being made to meet the design specifications of present-day human needs. Due to CMOS Image Sensor 's compatibility in terms of its characteristics that are high dynamic range, less power consumption, low manufacturing cost, and on-chip functionality. These characteristics made CMOS Image Sensor the preferred imaging component in most biomedical applications to perform all its functions alone or with less power.

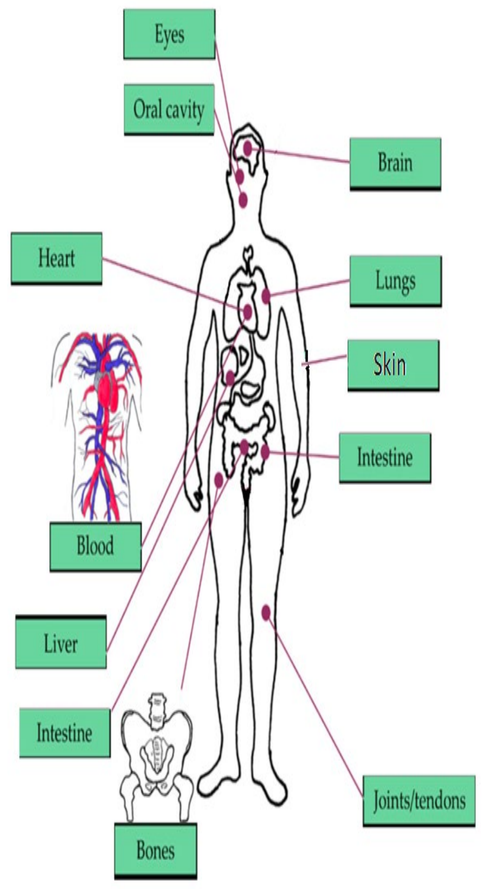
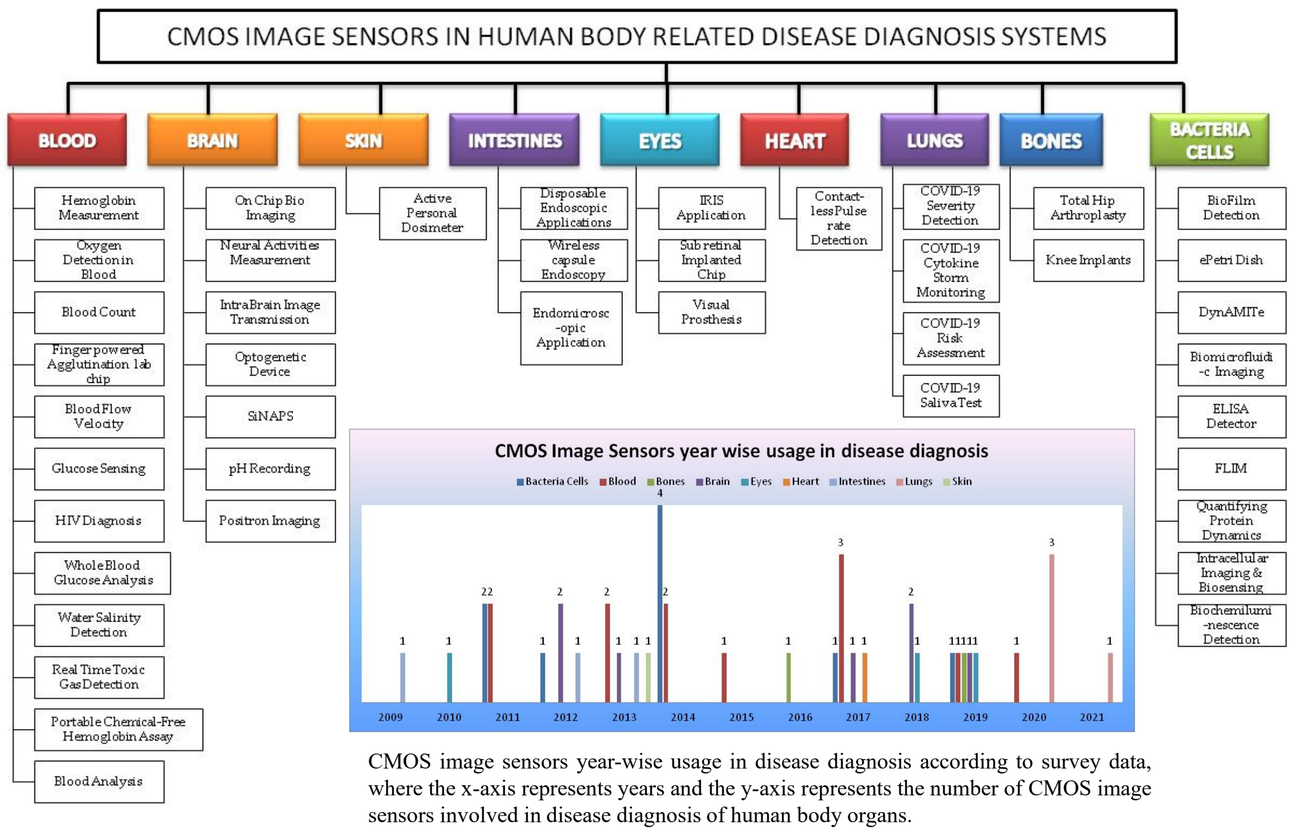


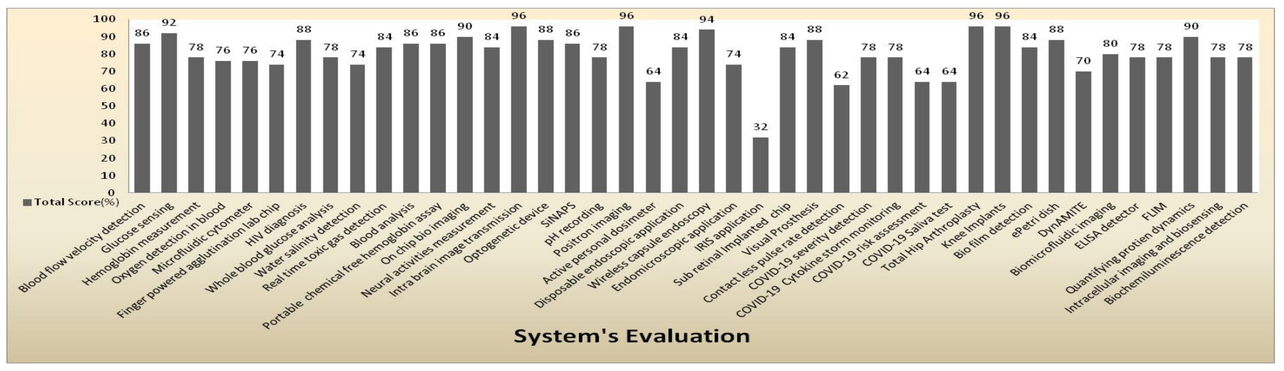
Figure.1: Vital signs and organs of the human body



CMOS image sensors year-wise usage in disease diagnosis according to survey data, where the x-axis represents years and the y-axis represents the number of CMOS image sensors involved in disease diagnosis of human body organs.

Parameter based Evaluation of Disease Diagnosis Systems

System	Related To	Helps in Disease Diagnosis	Score	Testing Method	Score	Remote Sensing	Score	Real-time or not real-time	Score	Pain level	Pain Scale	Total Score
Hemoglobin measurement	Blood	Anemia	10	*In vitro*	6	No	5	Yes	10	Severe	7	78
Oxygen detection in blood	Blood	Diabetes mellitus	10	*In vitro*	6	No	5	Yes	10	Moderate	6	76
Microfluidic cytometer	Blood	Cardiovascular diseases	10	*In vitro*	6	No	5	Yes	10	Moderate	6	76
Finger powered agglutination lab chip	Blood	Bacterial infection	10	*In vitro*	6	No	5	Yes	10	Moderate	5	74
Blood flow velocity detection	Blood	Peripheral artery disease	10	*In vivo*	8	No	5	Yes	10	Severe	9	86
Glucose sensing	Blood	Diabetes mellitus	10	*both*	10	Yes	10	Yes	10	Moderate	5	92
HIV diagnosis	Blood	HIV	10	*In vitro*	6	Yes	10	Yes	10	Severe	7	88
Whole blood glucose analysis	Blood	Diabetes mellitus	10	*In vitro*	6	No	5	Yes	10	Severe	7	78
Water salinity detection	Blood	Diabetes mellitus	10	*In vitro*	6	Yes	10	Yes	10	None	0	74
Real-time toxic gas detection	Blood	Leukemia	10	*In vitro*	6	Yes	10	Yes	10	Moderate	5	84
Portable chemical-free hemoglobin assay	Blood	Anemia	10	*In vitro*	6	Yes	10	Yes	10	Moderate	6	86
Blood analysis	Blood	Anemia	10	*In vitro*	6	Yes	10	Yes	10	Moderate	6	86
On-chip bioimaging	Brain	Brain disorders	10	*both*	10	No	5	Yes	10	Severe	9	90
Neural activities measurement	Brain	Brain disorders	10	*In vivo*	8	No	5	Yes	10	Severe	8	84
Intra brain image transmission	Brain	Brain disorders	10	*In vivo*	8	Yes	10	Yes	10	Severe	9	96
Optogenetic device	Brain	Brain disorders	10	*In vivo*	8	No	5	Yes	10	Severe	10	88
SiNAPS	Brain	Brain disorders	10	*In vivo*	8	No	5	Yes	10	Severe	9	86
pH recording	Brain	Brain disorders	10	*In vitro*	6	No	5	Yes	10	Severe	7	78
Positron imaging	Brain	Brain disorders	10	*In vivo*	8	Yes	10	Yes	10	Severe	9	96
Active personal dosimeter	Skin	Skin cancer	10	N/A	0	Yes	10	Yes	10	Mild	1	64
Disposable endoscopic application	Intestines	GI tract diseases	10	*In vivo*	8	No	5	Yes	10	Severe	8	84
Wireless capsule endoscopy	Intestines	GI tract diseases	10	*In vivo*	8	Yes	10	Yes	10	Severe	8	94
Endomicroscopic application	Intestines	GI tract diseases	10	*In vivo*	8	No	5	No	5	Severe	8	74
IRIS application	Eyes	N/A	0	N/A	0	Yes	10	No	5	None	0	32
Subretinal Implanted chip	Eyes	Retinal diseases	10	*Ex vivo*	6	No	5	Yes	10	Severe	10	84
Visual Prosthesis	Eyes	Retinal diseases	10	*In vivo*	8	No	5	Yes	10	Severe	10	88
Contactless pulse rate detection	Heart	Shortness of breath	10	N/A	0	Yes	10	Yes	10	None	0	62
COVID-19 severity detection	Lungs	COVID-19	10	*In vitro*	6	No	5	Yes	10	Severe	7	78
COVID-19 Cytokine storm monitoring	Lungs	COVID-19	10	*In vitro*	6	No	5	Yes	10	Severe	7	78
COVID-19 risk assessment	Lungs	COVID-19	10	*In vitro*	6	No	5	Yes	10	None	0	64
COVID-19 Saliva test	Lungs	COVID-19	10	*In vitro*	6	No	5	Yes	10	None	0	64
Pose estimation platform for total hip arthroplast	Bones	Arthritis	10	*In vivo*	8	Yes	10	Yes	10	Severe	9	96
Knee Implants	Bones	Arthritis	10	*In vivo*	8	Yes	10	Yes	10	Severe	9	96
Biofilm detection	Bacteria Cells	GI tract diseases	10	*In vivo*	8	No	5	Yes	10	Severe	8	84
ePetri dish	Bacteria Cells	Tissue damage	10	*In vitro*	6	Yes	10	Yes	10	Severe	7	88
DynAMITE	Bacteria Cells	Breast cancer	10	N/A	0	No	5	Yes	10	Severe	9	70
Biomicrofluidic imaging	Bacteria Cells	Cancer	10	*In vitro*	6	No	5	Yes	10	Severe	8	80
ELISA detector	Bacteria Cells	Listeriosis	10	*In vitro*	6	No	5	Yes	10	Severe	7	78
FLIM	Bacteria Cells	Hepatitis	10	*In vitro*	6	No	5	Yes	10	Severe	7	78
Quantifying protein dynamics	Bacteria Cells	Cancer	10	*both*	10	No	5	Yes	10	Severe	9	90
Intracellular imaging and biosensing	Bacteria Cells	Cancer	10	*In vitro*	6	No	5	Yes	10	Severe	7	78
Biochemiluminescence detection	Bacteria Cells	Cholestatic liver disease	10	*In vitro*	6	No	5	Yes	10	Severe	7	78



System evaluation represents the total score of every medical system

Conclusion

We presented a systematic review and parameter-based evaluation of CMOS image sensors incorporated disease diagnosis systems from the last twelve years. Every system is evaluated by considering the parameters related to its capabilities, implementations, and testing methods involved. Despite CMOS image sensors' existence in imaging technology for the past two decades, this is sophisticatedly evolving into diversified demanding fields with the immense collaboration of artificial intelligence, human psychology, chemical compounds, etc., with the medical domain infrastructure.

References

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