IoT-Vision Enabled Assistance for Epileptic Patients

Idea Document

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Submitted by:

Muhammad Ali Murtaza	2020-CS-114
Ali Tariq	2020-CS-142
Khadija Asif	2020-CS-143
Syed Azeem Ali Hashmi	2020-CS-156

Supervised by:

Mr. Samyan Qayyum Wahla

Department of Computer Science

University of Engineering and Technology

Lahore Pakistan

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1 Introduction

1.1 Background

According to World Health Organization (WHO) [11], around 50 million people with epilepsy live on the earth. This count makes epilepsy the most common neurological disorder globally. Around 80% of the patient live in those countries that are low or middle-income wise. The general proportion of active cases (continuously facing seizure attacks or needing treatment on urgent bases) is 4 to 10 for every 1000. Around 70% of people could be cured of this disorder if they are properly treated. It is estimated that 5 million people are diagnosed with epilepsy on yearly basis. And for high-income countries, 49 per 100,000 people got positive for epilepsy each year. And for the country level, Pakistan [6] has 1% of its total population which is about 2.2 million patients with epilepsy. According to the research of the National Library of Medicine [7], epilepsy has quite severe consequences including lifespan shortening, excessive bodily injury, psychological and psychiatric impairment, and social disability. These consequences separate the population of epilepsy from the rest of the world.

1.2 Motivation

With time, life expectancy raises as technology develops. The World Health Organization (WHO) predicts that the proportion of elderly persons in the population will double between 2015 and 2050, from 12% to 24%. Therefore, it is in high demand for medical professionals and researchers to embrace new techniques and develop existing ones that enable elders to live independently.

1.3 Objectives

The following are objectives that would be achieved:

- By using computer vision and the Internet of Things, the device should detect seizures before they happen, allowing the patient's caretaker to take necessary actions to prevent harm or injury.
- The system should be designed to be cost-effective to manufacture and deploy at scale, while still maintaining a high level of quality and reliability.
- To provide knowledge of the methods and algorithms employed in early epilepsy detection.

1.4 Scope

IoT-Vision would install cameras in the environment of the patient (Hospital or Home) and a smartwatch on the wrist of the patient. These devices would send collected data from the environment to the network to which they are connected. Cameras would vary from patient to patient. For a patient lying on a bed may be completely covered with a single camera and a patient doing activities at home might need multiple cameras to cover all his sights. Through these cameras, the main goal is to cover the daily activities of the patient like drinking, sitting, lying, reading, etc. These activities could further be divided into drinking from a bottle, drinking from a cup or drinking from a can, etc. For a person above 60 years, his/her daily activities are limited and in most of the cases have the same pattern for a long time. So, if all these activities are learned by the model, then the model could easily detect abnormality in the pattern.

1.5 Problem Statement

IoT-Vision Enabled Assistance for Epileptic Patients focuses to improve the quality of life and enable independence for older epileptic patients, a cost-effective, reliable, and accessible system for monitoring daily activities, pre-seizure detection and notification, and risk analysis is being developed. The main goal of an Internet of Things (IoT) and Computer Vision (CV)-enabled assistant for epileptic patients is to research the use of multiple cameras and sensors for seizure detection before they occur, recording of lifestyle patterns, and the development of intelligent mechanisms for converting visual input into precise and accurate situational assessment and quick response.

1.6 Challenges and Assumptions

Following are some challenges of IoT-Vision to work for epileptic patients:

- **Different Resolution**
  The resolution of IP cameras used in the project can have a significant impact on the detection of seizures. It can also affect the overall performance of the system. There are a number of factors which it can affect:

  1. Using High-resolution cameras can produce large video files, which can cause storage issues.
  2. To analyze the data also requires more processing power in real time.
  3. High-resolution cameras are also costly to use.

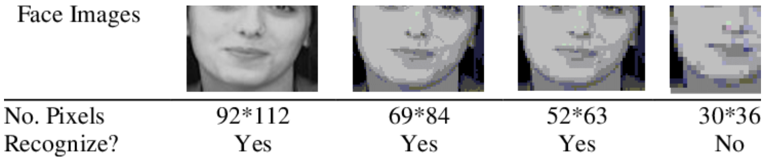

FIGURE 1: Affect of Resolution

- **Different Lighting Condition**
  Light sensitivity may differ in the portion of the room or may differ with the time of the day. And different light sensitivity may change the meaning of the image. Because the camera would face difficulty in detecting the face or different posture of the body of the patient.

FIGURE 2: Face Detection in different lighting conditions

- **Occlusion**
  Occlusion frequently happens when two or more things are too close together and appear to mix or join. It reduces the amount of visual information that is available. Therefore, it can produce false results which may lead to inaccurate data. After occlusion, the system will wrongly identify the initially tracked object as a new object.

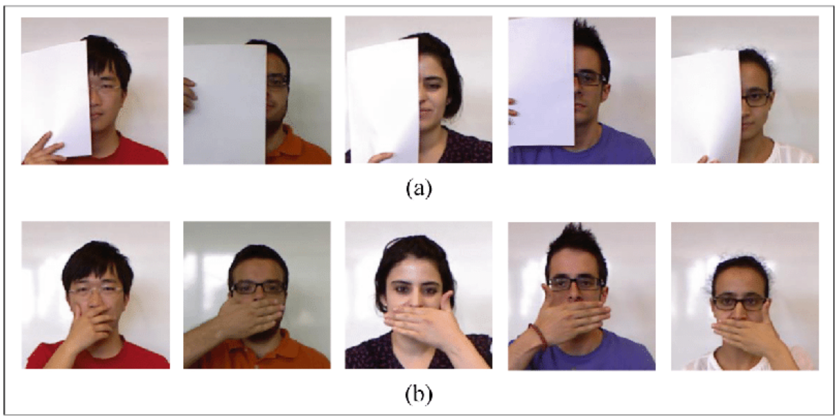

FIGURE 3: Occlusion in image

- **Synchronization of multiple Cameras**
  There can be multiple cameras to monitor the object (elderly patient). Synchronizing multiple cameras can be a challenging task. There can be different frame rates of cameras which makes it difficult to synchronize their video streams. Secondly, each camera has its own internal clock which can cause time drift between cameras making it difficult to align the videos. There can be network latency which can cause synchronization issues. To align the videos in real-time, high processing power will be required which can be challenging.

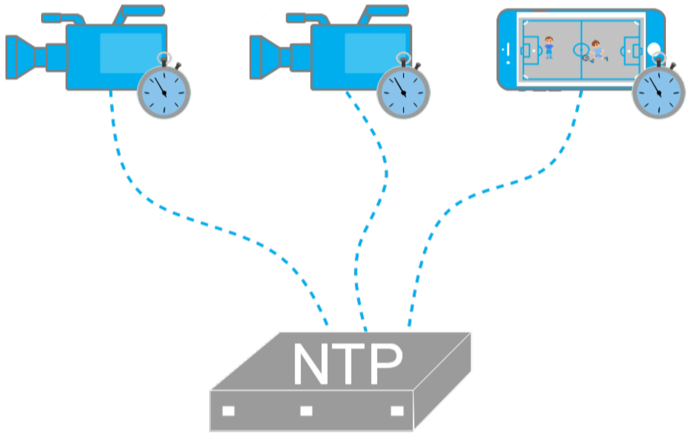

FIGURE 4: Syncing Multiple Camera Streams

1.7 Application Areas

The application area of the project defines the environment in which the project could be deployed or could be made under the use.

- **Hospitals**
  This system could be deployed in hospitals where epileptic patient monitoring makes a burden for staff or caretakers of the patient.

- **Home**
  The system could work for the home where elderly people with epilepsy disorder live and need a person as a caretaker with him.

- **Caring Centers**
  The system could work for the place where caring for people having difficulty in daily activities or needing urgent care due to some emergency situations like falls, seizure attacks, etc.

- **Research Environment**
  IoT-Vision for epileptic is needed in an environment where researchers want to study human activity recognition and explore in-depth how epilepsy detection algorithm works.

2 Comparison with State of Art

2.1 Existing Projects

Many devices are commercially available in markets for epileptic seizure detection. Most of them are sensor-based which uses sensors like accelerometry, a gyroscope, a thermometer, and electrodermal activity which detect many such activities that can help to detect seizures. EEG and Camera-based devices are also available such as Epihunter EEG headcaps, SAMi, etc.

2.1.1 Epihunter

Used to detect absence seizures [5] (characterized by a brief, sudden loss of consciousness, often lasting only a few seconds, during which the person may appear to be staring blankly into space).
Cost: \$825.91 – \$1,515.91 inc GST
Detector Location: Scalp

FIGURE 5: Epihunter

2.1.2 Embrace 2

This device [4] utilizes accelerometry, a gyroscope, a thermometer, and electrodermal activity to detect convulsive seizure activity and communicates it to a paired wireless device which then alerts designated caregivers.
Cost: The watch costs \$249 and the monitoring service requires a monthly subscription, which costs either \$9.90 per month, \$19.90 per month, or \$44.90 per month, depending on several features such as the number of caregivers to be notified.

FIGURE 6: Embrace 2

2.1.3 SAMi

SAMi [1] (Sleep Activity Monitor) is a device that is primarily designed to monitor sleep patterns and detect movements during sleep, including movements that may be associated with seizures. SAMi uses a small infrared camera that is placed near the individual's bed to monitor their movements during sleep.
Cost: Rs.114,700.00 PKR or above for different available packages.

Figure 7: SAMi

2.1.4 Epi-Care Mobile

Epi-Care Mobile [9] consists of sensors placed on the wrist of epileptic patients. it can easily be worn by patients both inside and outside. the sensor device is connected to an app on smartphones that can send alarms by automatically calling the caretakers of a patient for immediate assistance and also forwarding their GPS location through direct message.
Cost: £1,005.00 around 350,545 in PKR
Detector Location: Wrist

Figure 8: Epi-Care

2.1.5 Emfit

Emfit is a bed sensor [3], a thin-sheet device placed under the mattress that can detect GTC (Generalized tonic-clonic seizure) only.
Cost: $249.00 around 80000 in PKR
Detector Location: Under the mattress

Figure 9: Emfit

2.1.6 Brain Sentinel SPEAC

SPEAC [8] is used to detect GTC seizures only and can be used in the home or health-care facilities during periods of rest (designed to detect seizures during sleep or rest).
Cost: Not Available
Detector Location: Arm (over the biceps muscle)

FIGURE 10: SPEAC

2.1.7 MedPage

It can detect tonic-clonic seizures with the help of prolonged unusual movements and will inform the caretaker for early assistance . [12]

Cost: £246.00 around 90000 PKR
Detector Location: Under the mattress

FIGURE 11: MedPage

2.1.8 AlertIt Companion by AlertIt

The Alert-iT Companion Mini is designed to detect tonic-clonic seizures and is placed between the mattress and bed base. It detects the seizure's movements and abnormal physiological symptoms that occur during seizures. It generates an alarm that can alert the caretakers by using radio pager, which has a 450m range. [10]
Cost:£248.33 around 90000 in PKR
Detector Location: Between mattress and Bed base

FIGURE 12: AlterIt

2.2 Comparison and Need of New System

So, why still need something that can help epileptic patients to detect and prevent seizures even though these devices are available?
Although these devices are available there are many issues that can insist to propose something that can actually help patients while considering all the factors.

In [3], the results showed that users indicate that a device should be socially acceptable, as wearing a device that looks unfamiliar, visible, and intrusive may disclose their condition to others and most of the EEG-based devices are not that comfortable and also refer to instances where the device detects a seizure when no seizure is actually occurring (generate false alarms). This can happen for a number of reasons especially when changes in brain activity are unrelated to seizures and the **Epihunter headcap** device is relatively expensive compared to other seizure detection devices.

Embrace2 is also expensive. It is necessary to have an active subscription to the monitoring and alerting service. There are several different epilepsy types for which the Embrace watch is not indicated, such as complex partial seizures and absence seizures. Complex partial seizures are characterized by a decreased level of awareness, with possible movements of the body, usually lasting for a few seconds. Absence seizures are characterized by a decreased level of awareness and staring spells but without involuntary physical movements.

In addition, **SAMi-like** devices have a high rate of false detection for seizures as they can detect simple movements like the movement of limbs because of restlessness may also detect as an epileptic seizure. This product is not affordable for the average person because it is more expensive than others in the market.

Other devices, like **Epi-Care Mobile**, **Emfit**, **Brain Sentinel SPEAC**, **Med-Page**, and **AlertIt Companion by AlertIt**, all have some limitations. They can detect tonic-clonic or convulsive seizures by observing unusual movements using different sensors, which may generate false alarms by considering normal movements as seizure-jerking movements. This may result in disruption for patients and their caregivers. Most of them are not available in all countries, have battery limitations, and may have premium features that are not financially suitable for all epileptic patients, which can also burden their caregivers.
Many other devices with similar services and limitations are also available [2].

TABLE 1: Do currently marketed devices match the needs of users?

Devices	Modality	Comfort	Placement	Seizure Type	Affordable
Epihunter	EEG	×	Scalp	Absence Seizures	Expensive
Embrace 2	Sensors	✓	Wrist	Tonic-clonic Seizures	Moderate
SAMi	Camera	✓		Tonic-clonic Seizures	Affordable
Epi-Care	Sensors	✓	Wrist	Tonic-clonic Seizures	Expensive
Emfit	Sensors	✓	Under the mattress	Tonic-clonic Seizures	Moderate
SPEAC	Sensors	×	Arm	Tonic-clonic Seizures	
N/A heightMedPage	Sensors	✓	Under the mattress	Tonic-clonic Seizures	Moderate
AlertIt	Sensors	✓	Between mattress and Bed base	Tonic-clonic Seizures	Moderate

It is important to note that some devices require different subscription plans to enable premium features which can also include in the overall cost of devices.
A rough estimate of the ratio of available devices for epileptic seizure detection based on EEG, Camera, and Sensors:

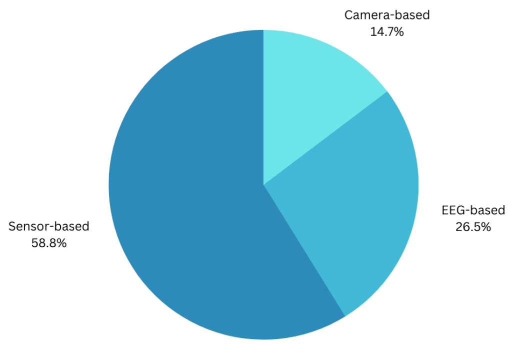

FIGURE 13: ratio of available devices for epileptic seizure detection

Most devices are available for people with epilepsy to monitor seizures associated with convulsive movements only. No single device exists that detects all types of seizures since different types present varying physiological and external symptoms.
Our focus is using sensor and camera-based technologies instead of relying on only one type like EEG-based or accelerometer-based devices. Sensors capture physiological signals like electrodermal activity, heart rate, and breathing patterns while cameras capture visible changes in facial expressions, body movements, etc., providing a comprehensive picture for accurate seizure detection.
Machine learning algorithms personalize the seizure detection process considering the unique physiological characteristics of each individual user. This feature sets our project apart from others that rely on a one-size-fits-all approach resulting in a higher accuracy rate and reliable seizure detection.

3 Impact of Project

According to World Health Organization (WHO), "The Sustainable Development Goals (SDGs) aim to transform our world. They are a call to action to end poverty and inequality, protect the planet, and ensure that all people enjoy health, justice, and prosperity. It is critical that no one is left behind."

Figure 14: Sustainable Development Goals

Our solution mainly promotes or focuses on SDG 3 and SDG 10. The question that now emerges is how, out of all the Sustainable Development Goals, our solution supports SDG 3 and SDG 10. How our strategy reduces inequality while promoting health and well-being.

Around 50 million people worldwide are having epilepsy and 5 million people are diagnosed with epilepsy each year [1]. In Pakistan, more than 2.2 million people are having epilepsy [2].

Currently, most of the people are having less or no resources to ensure their healthy lives. Due to the higher expenses of epilepsy treatment and medication, most of them are unable to maintain their health. Patients having epilepsy require full-time attention from their caregivers in case any seizure occurs to protect them from any serious head or other injuries. Home monitoring systems help epileptic patients in terms of improving their health and well-being for all at all ages, especially for elderly individuals. It can help to eliminate inequality among people by providing a cost-effective solution that can also reduce the burden on caregivers and help them to live their life independently without any concern.

Sustainable Development Goals 3

- Our solution ensures healthy lives and promotes well-being by providing remote monitoring for epileptic patients so that they can maintain their health without any concern for additional medical expenses.
- It reduces the extra burden on caregivers by generating alarms in serious cases which can also prevent serious injuries by providing timely assistance.

Sustainable Development Goals 10

- It eliminates inequality and helps epileptic patients who have lack of resources in terms of health and well-being by providing them with a cost-effective solution.
- All the SDGs are interrelated by promoting goal 3 and goal 10, it can also help in promoting other Sustainable Development Goals like poverty, education, etc.

4 Unique Application Feature

The purpose of IoT-Vision Enabled Assistance for Epileptic Patients is to prevent epileptic seizures by providing early assistance.

Similar devices are also available in the market, so what sets our approach apart from all of them?

- **Use of Camera and Sensor:** No single device exists that detects all types of seizures since different types present varying physiological and external symptoms. Our focus is using sensor and camera-based technologies instead of relying on only one type like EEG-based or accelerometer-based devices. Sensors capture physiological signals like electrodermal activity, heart rate, and breathing patterns while cameras capture visible changes in facial expressions, body movements, etc., providing a comprehensive picture for accurate seizure detection.

- **Different Machine Learning Approach:**
  Our focus is on personalized model techniques rather than a one-fit-all approach to detect and prevent seizures. Machine learning algorithms personalize the seizure detection process considering the unique physiological characteristics of each individual user. This feature sets our project apart from others that rely on a one-size-fits-all approach resulting in a higher accuracy rate and reliable seizure detection.

5 Proposed Architecture

The proposed setup of the whole project is shown below:

By monitoring the patient's behavior using cameras and sensors in real-time and sending data to the cloud for analysis, the system will be accurately able to detect and prevent epileptic seizures with minimal delay possible. In this, the main focus is on personalized model techniques which can improve the accuracy of seizure detection and reduce false positives by utilizing the system for a specific user at a time. The abnormal physiological activities in epileptic patients vary from person to person, using this technique will enhance the user's outcome with the epileptic disorder. Based on the symptoms that occur during seizures, the system will generate an alarm immediately and alert the caretaker for immediate assistance to prevent being harmed by any serious injuries.

It includes an alerting app, and through its user-friendly mobile/web app interface,

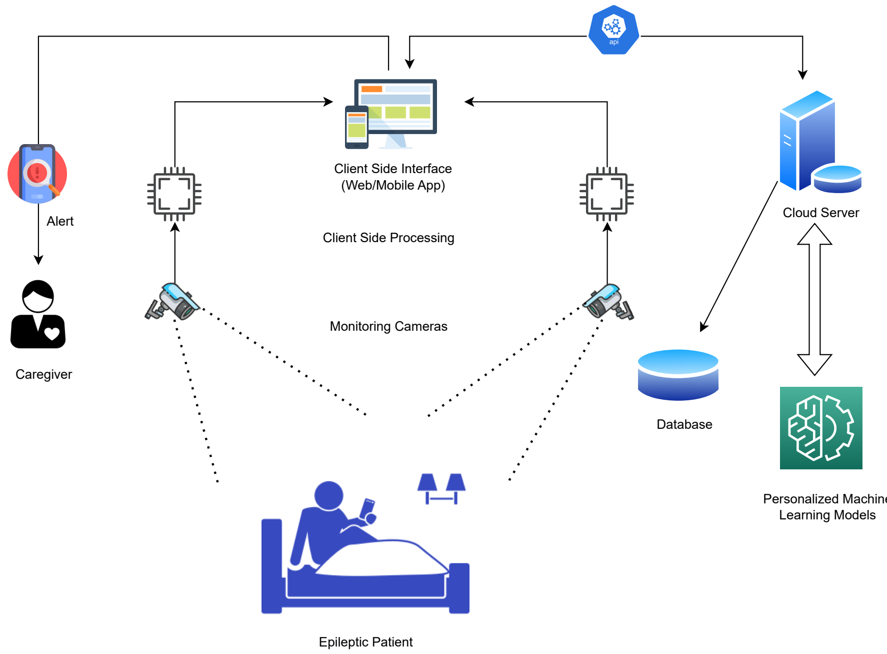

FIGURE 15: Proposed Architecture Diagram

the system will be easily accessible and used by patients and caregivers alike, which will provide a high degree of flexibility and convenience to both of them.
It'll help to provide round-the-clock safety and comfort, help people with epilepsy get help when they need it most, and also reduces the burden on caretakers.

6 Expected Outcome

By continuously monitoring the epileptic patient with a camera and sending the collected data to the cloud or server where it will be analyzed, this project is expected to produce an accurate IoT-Vision enabled assistant that can detect seizures or predict about it happening before it actually happens. This allows seizures, if they occur, to be detected and prevented. If system notices any seizure activity or symptoms of a seizure, it will produce an alarm that will be sent to the patient's caretaker, who will then respond by rescuing the patient. Our system will primarily use personalized model techniques, which will enhance system's prediction, accuracy and lower false-positive responses. Abnormal physiological activities differ from person to person. The personalized model technique will be highly helpful since it will enable learning models to learn specific physiological symptoms of each individual patient, improving the user's outcome with epileptic disease. The generated alarm will be sent to caretakers by an alert feature of Web/Mobile app of our system. This app will be handy, simple to use, interactive, and will give caretakers and guardians constant access to real-time patient monitoring. Our proposed solution will be cost effective as it will lift the financial burden of guardians, which will ultimately lead the epileptic patient living an independent, comfy and healthy life, as well as lessen the burden on shoulders of caretakers.

6.1 Seizures Detection Algorithms

In general, depending on the method or technique being employed, algorithms used to identify epilepsy can differ from one another. We will use machine learning, computer vision, and deep learning models in our project, IoT Vision Enabled Assistant for Epileptic Patients, because our data will be video-based and captured using cameras. We will first use these models for analysis, and then we will train them to detect seizures or other unusual activities. This study will improve our knowledge of algorithms and produce better implementation outcomes, which will spark the curiosity of experts to conduct further in-depth algorithmic research. Both the research community and the development/production industry will benefit from this project.

6.2 Web Portal for Caretakers

The main purpose of web portal for caretaker is to provide patient's health record to caretaker as well as real time monitoring. Through simple and interactive user interface of web application, caretaker can monitor its patient at any time he wants. Application will keep logging the activities of patient into server where they will get analyzed. In case of any seizure or emergency situation, application will trigger the alarm and send it to caretaker so he can rescue the patient. Web application will maintain the patient's profile which includes patient's personal information like name, age etc., his seizure history, his emergency phone numbers which can be contacted at time of emergency and alarms record. Our application will meet all security and privacy standards and all the records can only be accessed by authorized users only.

6.3 Early Alerts of Seizures

Our system's use of the personalized model technique will make it easier to analyze an epileptic patient's behavior in detail. The model will learn from the patient's behavior patterns as they are recorded by cameras and constantly monitor the patient's activities to identify any actions that are high-related or might indicate an impending seizure. Our system will trigger an alarm whenever it notices this kind of action and convey it to the caretaker so he may rescue patient, thereby lowering the possibility of serious injury.

7 Feasibility Study

Feasibility study is a method to analyse whether or not the proposed project could be successful. The reason we perform this study is that, to have a high level view that the project is feasible or not in terms of available resources, skills, money and time.

7.1 Technical Feasibility

The main technologies used in this project are IoT(Internet of Things), Computer Vision, cloud based technologies, web/mobile based application. Each of the above mentioned technologies is easily available and can be implemented in an easy way with having right skills and knowledge.

The project uses IoT cameras, smart watch and sensors for seizure detection and all these devices are available, To process images and videos which requires higher GPU processing, we have many services available on the cloud due to the progress and advancements in technology. So, there is no constraint in technical feasibility of the project.

7.2 Operational Feasibility

The project is totally compatible with the daily environment of elderly people who are epileptic patients in this case. The system is much capable to protect the confidential and sensitive health data of the patient and also assure the privacy. However, still some elderly people may not like it that they are being constantly monitored by a camera and they may find it uncomfortable so we can assure their privacy by blurring their face and we will use type of cameras in which the body is not completely visible. So, we can say that it is operationally feasible.

7.3 Economical Feasibility

The basic things which are required for this project are cameras for constant monitoring, system for user interface which is operated by the caretaker, both these are economically feasible as well as affordable. It also requires high computational powers to process the data collected from patient and get insights from personalized machine learning models which is also feasible economically. Overall the complete cost after summing up all the operational and maintenance costs, the project is still feasible and provide less cost from all the other available solutions.

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