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Research and Challenges in Diagnosis of Convulsion Patients

Sneha Mukund Deore[1], Pravin A. Dhulekar[2], Dr. S.T.Gandhe[3]
[1]*PG Student Department of Electronics & Telecommunication, Sandip Institute of Technology & Research Center, Nashik, India*
[2]*Professor Department of Electronics & Telecommunication, Sandip Institute of Technology & Research Center, Nashik, India*
[3]*Professor Department of Electronics & Telecommunication, Sandip Institute of Technology & Research Center, Nashik, India*

Abstract*:* Convulsion is one of the most common neurological disorder whose outward effects is a medical condition where body muscles contract and relax rapidly and repeatedly, resulting in an uncontrolled jerking of the body as subtle as a momentary loss of awareness. Even the majority of patients can be treated through medication or surgery, a significant group of patients cannot be treated. For this latter group of patients it is advisable to follow the evolution of the disease. This can be done through a long-term automatic monitoring.

Keywords: *Convulsions, Diagnostic Methods, Methods of Treatment, Convulsion Detection.*

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I. INTRODUCTION

People are considered to have convulsions when they suffer from more than one convulsion which is not related to a clear cause such as fever, a head injury or drug use. A convulsion is caused by a sudden brief excess surge of electrical activity in the brain.

Convulsion is one of the most common neurological disorders which affect almost 1% of the world's population. 25% to 30% of convulsion patients cannot be treated by medication or surgery, they suffer from so-called refractory convulsions.

Convulsions mainly occur as paroxysmal events, which mean that they occur at a sudden, unexpected timing. The frequency of the convulsions varies from patient to patient. Some patients suffer from multiple convulsions during the day and/or night, while others only have one a month or less. To be able to track the progress of the disease and to alarm caregivers during a convulsion, these patients should be monitored. The gold standard in convulsions monitoring uses EEG-electrodes attached to the scalp. However, these electrodes are difficult to attach, hamper the patient's sleep during the night, and therefore are prohibiting long term home monitoring [1]

Furthermore during sleep the convulsions occur more or less in a controlled reproducible manner without too much interference of other noise sources such as voluntary movement. The types of convulsion we focus on in this thesis are Hypermotor convulsions and Myoclonic convulsions.

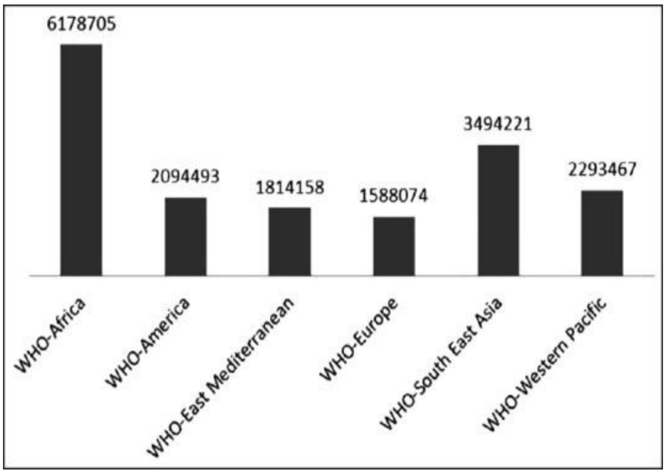
Hypermotor convulsions manifest themselves as violent, uncontrolled movements of the arms and legs, e.g. by making a pedalling movement. The movements can last from a couple of seconds to multiple minutes. Due to the possible heavy movements, the patients can injure themselves or even die. Patients may suffer from confusion after a convulsion, and even when they don't, they often recall the convulsion as a 'strange feeling' and need comforting.

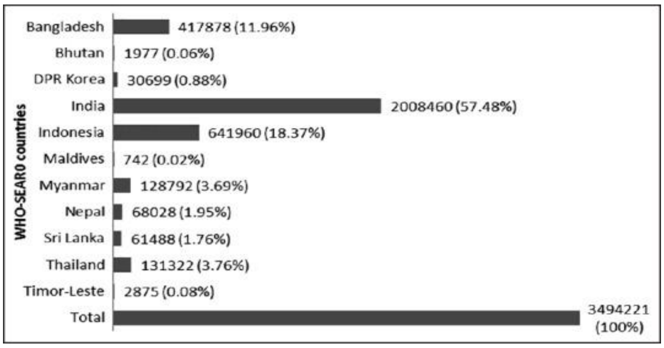
Myoclonic convulsions are small jerk-like movements that can occur as a single convulsion or precede others like tonic convulsions. A more challenging problem with these types of convulsions is the occurrence of non-convulsion jerks like the hypnic jerk that is experienced before falling asleep, as this jerk-like movement does not denote abnormal neurological activity.

Due to the different nature of both convulsions, the aim for detecting both types is different [2]. Because the Hypermotor convulsions are violent and the potential danger for the patient is high, it is necessary to detect (almost) all convulsions of this type. False detections are less of an issue. The detection of Myoclonic jerks, on the other hand, is not critical. For this type of convulsions no alarm is needed, but the aim is to get an idea of the number of convulsions that occurred. Although it is relatively rare, sometimes, convulsions can be fatal. When a patient suffering from convulsions dies without a clear cause for his death (such as drowning or caused by a trauma), the term SUDEP (Sudden Unexpected Death in Convulsions) is used. Most of the time it is presumed that the death occurs during convulsions, however, this is not the case in all situations and this is not a requirement for the diagnosis of SUDEP.

II. MOTIVATION

As per the GBD (Global Burden of Disease) analysis for 2010, it is estimated that nearly 70 million people suffer from convulsion and the prevalence of convulsion across the globe is estimated to be 5-9 per 1,000population[3]. Nearly 90% of these were reported from low and middle-income countries (LMICs). In 2013 it resulted in 116,000 deaths up from 80,000 deaths in 1990.





As per the Bangalore Urban Rural Neuro-Epidemiological Survey (BURNS) about 10 million persons with convulsin are there in India[4].

Age range (years)	Urban		Rural	
	Popula-tion	Age-Specific rate/100,000	Populati-on	Age-Specific rate/100,000
< 10	11,116 (22%)	495	12,303 (24%)	1357
11-20	11,476 (22%)	835	11,987 (23%)	1518
21-30	10,762 (21%)	595	8788 (17%)	1924
31-40	7883 (15%)	589	6719 (13%)	1086
41-50	5116 (10%)	332	4907 (10%)	978
51-60	2946 (6%)	339	3387 (7%)	886
> 60	2283 (4%)	350	2964 (6%)	641

It might be due to the lack of knowledge of anticonvulsant drugs; poverty, cultural beliefs, stigma, poor health infrastructure, and shortage of trained professionals contribute for the treatment gap.

III. RELATED WORK

(METHOD WISE)

A. *Methods of Treatment*

In almost 70% of the patients with convulsions the convulsions can be controlled by using medication. A wide range of medication is available for convulsion control. When the medication doesn't have a positive effect on the convulsions, different types of anticonvulsant drugs (AED) can be employed. However, the probability of an AED to be effective decreases with the number of different AEDs tested. Therefore, after trying out for example three different types of drugs, the neurologist may decide to use different treatment strategies. Convulsions that are resistant to drug treatment are called refractory epilepsies. Some patients are treated with a combination of different drugs to control the convulsions.

In case of these refractory epilepsies, the neurologist can decide to consider convulsions surgery. This is not suitable for all patients. The convulsion origin of - only focal - convulsions in the brain has to be clearly defined. During the surgery the area in the brain causing the convulsions is disconnected from the rest of the brain or removed [5, 6]. A more recent development is the implantation of an electrode in the brain to apply deep brain stimulation, by sending electrical pulses to the part of the brain that causes the convulsions. This type of therapy is still in a clinical testing phase.

A novel treatment is the vagus nerve stimulation (VNS). The vagus nerve is a cranial nerve that mainly transports information from the body organs to the central nervous system. DeGiorgio et al. showed in their doulbe-blind study on 195 patients that a stimulation of the vagus nerve can reduce the number of convulsions by more than 50% in 35% of the patients [4]. The median reduction of the convulsions was 45%, and in 20% of the patients there was even a reduction of more than 75%. Lulic et al. give an overview of the different clinical studies that are conducted to investigate the effect of VNS treatment on convulsion patients. Cyberonics already commercialized this therapy.

Another alternative method is the ketogenic diet. In this special diet, the consumption of fat is high and carbohydrates are low. The name ketogenic means that it produces ketones in the body. These ketones are formed when the body uses fat as an energy source. In this diet the body changes from burning carbohydrates, as they are only provided in very small amount, to using fat as fuel. A higher level of ketones in the body often lead to an improved convulsion control, although it is not fully clear why this helps in reducing the frequency of convulsions.

B. *Diagnostic Methods*

Before a convulsion is diagnosed, the patients are typically monitored during a 24-hour video/EEG. The exact diagnosis is based on a wide range of information of the patients, such as medical history, blood tests, the EEG-monitoring or other brain imaging such as MRI or CT scans.

When no treatment seems to be successful, the patients can be monitored to keep track of the evolution of the disease and maybe alter the medication to get a reduction in the convulsion frequency anyway, and to alarm if a serious convulsion occurs that needs care during or after the convulsion.

C. *Gold Standard*

The Gold Standard for the diagnosis for convulsions is video-electroencephalogram (EEG) monitoring. In the EEG monitoring, electrodes are placed on the scalp. It measures the potential differences that occur caused by the electrical discharges in the brain related to brain activity. Only the activity of thousands or millions of parallel firing neurons can be detected. The EEG is employed to detect convulsions and transients that can denote convulsion activity in the brain. To provide a good conductivity between the scalp and the electrode, the skin is first lightly abraded, to remove the dead skin cells, and then a conductive paste is applied. The electrode is glued to the scalp. This method, however, is patient-demanding as the attached electrodes are uncomfortable to wear for long-term monitoring. Moreover, it is labor-intensive for the technical staff as it takes 20 to 40 minutes to glue all the electrodes on the scalp. Furthermore if the impedance between the electrode and the scalp is too high, no good acquisition of the EEG is possible. Hence, multiple weeks of home monitoring is not feasible [7]. The number of electrodes depends on which montage is used. In high-density arrays using a cap, it can go up to 256 electrodes. The measurements that are recording in our study use 24 electrodes including the reference. As the gathered signals are weak, they have to be amplified by specialized hardware. Typical sampling rates are around 256 to 512 Hz.

III. AUTOMATIC CONVULSION DETECTION

There is a clear distinction between the diagnosis of convulsions and the detection and monitoring of convulsion convulsions [8]. The former needs no exact information about the number and timing information of the convulsion occurrence. A global view on the patient is more important incorporating for example the medical background as explained in Section. Convulsion detection for alarming and monitoring purposes, however, does need this information.

The diagnosis of convulsions is only possible in a clinical setting, due to the different aspects of the disorder that are investigated. Whereas convulsion detection is, next to the detection in the traditional clinical setting, also feasible in a home situation if based on the alternative methods explained in the next section. The next sections give an overview of the different alternative methods for convulsion detection. The detection based on accelerometry (ACM) and video are discussion in separate sections.

IV. ALTERNATIVES METHODS FOR DETECTIONS

*A. **Detection Based on Motor Information***

1. ACM or Video: As the main modalities that are investigated in this work are ACMs and video, we will discuss them more extensively in two separate sections.

2. Bed Sensors: EmFit *bed sensors* (Emfit Ltd.) are already used for the detection of clonic and tonic-clonic convulsions. In the literature, studies can be found that use the sensor for sleep monitoring and as a sensor for cardiac measurements , but to our knowledge there are no papers about the performance of convulsion detection with the EmFit system. Other systems where no clinical studies are available are for example the Epi-Care by Danish Care (Denmark), Sensalert by Sensorium (UK), the Epi-Watcher by Vahlkamp (The Netherlands) and Ep-It by Alert-It (UK)[9]. Van de Vel *et al.* published an overview of these different systems. One other system is evaluated in a published clinical study. The MP-5 monitor of Medpage (UK) makes use of sensors that are attached to the bed. In a study, 64 subjects were monitored for a total of 1528 hours, having eight tonic-clonic convulsions in total. The MP-5 monitor was able to detect five of these eight convulsions, generating 269 false positives (during 146 hours). This resulted in a sensitivity of 62.5% and specificity 90.4%. Due to the relative high number of false positives compared to the number of convulsions, the positive predictive value had a low value of 3.3%.

3. EMG (Electromyogram): EMG measures the muscle tension, and it is therefore also a good modality for measuring the motor activity. This is also very suited for the detection of tonic convulsions, as in this type of convulsion the muscles contract. Adriaans *et al.* Investigated the EMG signals to detect tonic and clonic convulsions. In another study of Conradsen et al., the zero-crossing rate of the EMG signal from the deltoid muscle was used to detect tonic-clonic convulsions with a sensitivity of 100.00% and a median latency of 13.7 seconds [10, 11]. Furthermore, they also investigated the dynamics of the EMG activity during tonic-clonic convulsions in a clinical study.

*B. **Detection Based on Other Modalities***

Not only the detection and classification of convulsions based on the manifestation of the movements is investigated as an alternative for the video/EEG monitoring. Also other modalities are investigated, including several autonomic signals such as heart rate, temperature, skin conductivity (sweating) and respiration [5]. Some of these modalities are, for example, already used in the polysomnography (PSG) for the study of sleep, such as EOG, ECG and respiration monitoring. Below, a list of the different modalities that are used or investigated is given.

1. Audio Signals: Audio signals can indicate the occurrence of a convulsion, as the patients may utter sounds during convulsions such as stereotyped screams, singing or humming, (autonomic) laughing or weeping, lip smacking or bed noises as a result of movement. The advantage of recording audio is that the equipment has a low cost and is easy to install in the patient's room. Furthermore, the sensor is non-invasive and even contactless, so there is a maximal comfort for the patient. However, detection systems based on audio generally perform poorly. It is hard to distinguish the specific sound during convulsions from normal vocalizations such as speech or snoring or noises that originate from the background. Sometimes these types of noise can also be
Part of a convulsion manifestation. Tonic-clonic convulsions for example are often followed by stertorous breathing (snoring) in the post-ictal period.

2. Thermal Cameras: Thermal cameras are used in the recognition of human motions. Capturing infrared light, they can overcome the problem of normal cameras as they may detect movement under sheets, if they do not block the heat too much. Furthermore, they can give extra information about the body temperature of the patients which may be a distinctive feature for separating convulsions from normal movement [12]. However, the resolution is lower than in conventional cameras and most of all, the cost of these cameras is much higher which make them less applicable in a home situation.

3. Radar System: Radar systems are already developed to detect heart beats, respiration and movements in patients. This contactless way of measuring these vital signs is more comfortable for the patient than the sensors that normally have to be attached. Suzuki et al. Used this approach for detecting vital signs (ECG and respiration) in an ambulance. Another advantage is that the RF6 waves pass through the blankets so they are able to detect movement even if the patients are covered in their bed.

*4. The Electrocardiogram (EGC):*The electrocardiogram (ECG) shows the electrical activity of the heart. The heart rate, the heart rate variability (HRV) which indicates the changes in the beat-to-beat interval and the ECG morphology can be indicators of convulsions. Changes in the heart rate might precede the clinical manifestations of the convulsions or even the electrographic onset 7 of the convulsions in some cases. Because of this, ECG can be interesting for early convulsion detection. And although the ECG electrode still have to be attached to the patient, it is still easier to attach to the body and easier to interpret the signal compared to the EEG electrodes and signals.

*5. Respiration Monitoring:*Next to arousals or sleep apnea, respiration monitoring can also detect sighs or yawns which may be an indication for convulsions. Also, a low arousability can be a sign for near-SUDEP (sudden unexplained death in convulsions). Respiration can be monitored in different ways, for example by sensing the airflow temperature, pressure or velocity. These methods need a mask covering the nose and mouth of the patient. And although this is a common way to monitor the respiration, it is uncomfortable for the patient. Another way for respiration monitoring is by making use of belts attached around the chest or abdomen [13], to record the respiratory rate, depth and effort. Alternatively this motion can also be monitored by EMG-sensors, ACMs, video or radar, as discussed above.

Pulse oximetry measures the concentration of oxygen in the blood. The sensor can be easily attached to the patient's finger or ear, and by measuring the reflected infrared light from two different wave lengths it determines the levels of oxygenated and deoxygenated hemoglobin. The reflected light differs from the emitted light, as for example the skin tissue and blood absorb part of it. From this signal, different characteristics can be derived, such as heart rate and respiration. There is a complex interaction between the brain, heart and respiration, and data on oxygenation is crucial in addition to respiration and ECG monitoring. Related to convulsions this is mainly important for SUDEP prevention as the oxygenation level can indicate for example if there is a blockage of the airway in the patient. Additional to (or combined with) the pulse oximetry, finger plethysmography can be used for the monitoring of blood pressure or blood flow. Finally, respiration can also be detected via audio, either by using a microphone at a certain distance from the patient, which has the advantage of being contactless. Another possibility is to attach a small microphone to the suprasternal notch in the neck as done by Corbishley and Rodr´ıguez-Villegas [14]. This device is able to detect even shallow breathing, by recording the sound created by the turbulence in the human respiratory system. Combining the oxygen saturation and chest and abdominal movement, extra information can be generated in the detection of convulsions. A fall in both pressure and saturation combined with a slower, more irregular or absence of respiration and with tachycardia, indicates an convulsion.

6. The Electrooculogram: The electrooculogram records both eyelid and ocular movements. It is measured by electrodes, the same as for EEG, only the placement is such that the electrical muscle activity of the eyes and eyelids is recorded. Eye movement can be a discriminating factor in differentiating convulsion convulsions from non-convulsion convulsions (PNES), which are events that look like convulsion convulsions but do not have the same EEG manifestation. At the onset of a convulsive convulsion, the eyes of the patient tend to be open in contrast to convulsive PNES where the eyes are typically closed. The suprasternal notch is a small dip at the base of the neck, at the top of the sternum. Fast heart rate, typically over 100 beat per minute.

7. Electrodermal Activity: The electrodermal activity (EDA) is a measure to define the ability of the skin to conduct electricity. During convulsions, patients might start sweating, which influences the conductivity of the skin. The changes in this conductivity can simply be measured by an Ohmmeter. EDA reflects sympathetic activity10, in contrast to blood pressure, heart rate or respiration which are ortho- and parasympathetic activities11. For example tonic-clonic convulsions show an increase in especially sympathetic discharges. A humimeter can also be used for the detection of sweating [15], but also for other symptoms that can be related to convulsion convulsions such as salivation, vomiting or incontinence, although they are not related to convulsions only. Some commercial systems are already available such as the Comf-It by Alert-It and the Epi-Wet by Danish Care.

8. The Body or Skin Temperature: The body or skin temperature may be an indicator for convulsions. It is a measure that can be used in the detection of febrile convulsions 12, although the relationship between this type of convulsion and convulsions is not exactly known.

*C. **Video***

Human motion analysis has already been studied extensively in other applications such as gesture recognition or surveillance. Bonroy et al. monitor the visual expression of humans using a camera system for pain assessment. This automatic vision-based monitoring can also be a solution for monitoring of convulsion patients. Vision based human action recognition has been widely studied, and various methods have been proposed. Based on representations, these approaches can be broadly categorized into global representations and local representations. In the former, the entire body or its articulated poses are encoded in the model. In this work, because the body is usually occluded and not fully observed [16], local representations are used, where the observation is described as a collection of local descriptors. In one of the investigated approaches, we use space-time interest point detectors and descriptors proposed by Ivan Laptev in, which achieves state-of-the-art performance in action recognition in video on real life actions. In that study, different realistic actions from movies (such as kissing, answering the phone and getting out of a car) are learned. This method outperforms the other algorithms on the KTH actions dataset and reaches an accuracy of 91.8%.

Video based detection is part of the gold standard for convulsion detection and it is the most common way (and most of the time the only way) for clinicians to judge the detected event visually. Next to these diagnostic purposes, this modality can also be used for detection. It has the advantage of being non-invasive and contactless, that is, in the case that no (reflective) markers attached to the patient are used. A downside here is that most video based detection approaches make use of markers or other ways to track limbs, like using colored pyjamas. Another remark is that in most of the studies no real convulsion detection algorithm is developed. The movement quantification is mainly used to investigate the behaviour and motion pattern of the specific convulsions and some features to quantify these patterns are proposed. Although R´emi et al. investigated different features to identify hyperkinetic13 convulsions from non-hyperkinetic convulsions. Karayiannis et al. did not use any markers, but the moving limbs of the patients were clearly visible as they were monitored in the Neonatal Intensive Care Unit (NICU) of the hospital[17]l. The best obtained result had sensitivity above 90% and specificity above 85%, in patients with myoclonic and focal convulsions. Another disadvantage of using video for convulsion detection is the difficulty of detecting movement under the sheets or blanket, and that the system is not ambulant as the patient should be in the view of the camera at all the time.

IV. HOME MONITORING

*A. **Why Home Monitoring?***

In recent years, a number of trends are observed that are expected to increase in importance in the near future. First, there is a tendency in society of an aging population. The related geriatric ailments and the extended institutionalized care will increase the health care costs. If elderly could live in their familiar home environment for a longer period of time, this would not only increase their independence and their quality of life but also lower the medical costs by postponing institutionalized care. A prolonged stay in the home environment is possible by improving their (medical) safety by telemonitoring their vital signs or e.g. detects fall incidents.

Sensor technologies are used in consumer electronics, such as accelerometers in cell phones. Thanks to the internet and wireless communication, data can be transmitted easily from patient’s home to the caregiver’s office [18]. This brings care closer to the patient and provides for a greater involvement of the patient in the treatment strategy. In this way, home monitoring can be an answer to follow up chronic diseases, have more objective information about the evolution of the disease, and it can allow a quicker response to a sudden critical situation of the patient.

*B. **Challenges***

One of the key challenges in home monitoring is the acceptance of the technology by the patient. Acquiring the vital signs of the patient can be an extra burden to the patient next to coping with the disease. Especially if the patient has to attach different sensors to the body for example monitoring the heart rate. After all, most of the time the data have to be acquired all day and every day. If the home monitoring system is not easy in use, the patient will stop using it after a while.

Next to the easy applicability, it is also important that the system is comfortable for the patient. Especially if it is used during sleep, the user should not be hampered. In both issues, being easy to use and the comfort, it is advisable that the sensors are contactless or at least wireless.

Also the performance of the system has to be acceptable. If a monitoring system is designed to detect risky situations such as fall incidents, or as convulsions, it becomes useless or even annoying for the patient if there are too many false positives.

C. Current State-of-Art

The first applications of home monitoring are already available on the market, for example push button operated alarm systems for elderly to indicate fall incidents, such as the Philips Life Line, LifeFone or Medical Alert by Connect America. The fall detector by Tunstall and the Philips Life Line also offer automatic fall detection based next to the more common alarm buttons. Recently, more research is conducted about the detection of fall using camera systems. Also systems that monitor patients with heart problems are already available. Although some studies indicated that for the monitoring of heart failure in specific, Telemonitoring can be an additional tool on top of the usual care[19], without replacing the latter one. And more studies are required to investigate the cost-efficacy. Other studies, however, show that remote monitoring in the patients with heart failure leads to fewer admissions and shorter hospital stays.

A large study in the UK, the Whole System Demonstrator Programme, evaluated the implementation of home monitoring involving 6191 patients. Half of the subjects suffered from either diabetes, heart failure or COPD3. This study showed a general reduction in emergency and elective admissions in the hospital with 20% and 14%, respectively. The mortality rate was reduced by 45% compared to the control group[20]. This indicates that home monitoring has an added value to the health care, and leads to a reduction in hospitalization costs. Different telehealth devices were used in this study which varied among the different trial sites, although they all used a pulse oximeter for chronic obstructive pulmonary disease,a glucometer for diabetes, and weighing scales for heart failure.

V. CONCLUSION

As per the literature review done in above sections, authors observed that there is need of improvement in the diagnosis of Convulsion. As all pervious methods need hospitalisation of patient. Medical practitioner needs to do continuous monitoring leads to wastage of valuable time of Medical Practitioner.

As per patient's point of view, there are so many limitation in all previous convulsion diagnosis methodology. Due to more frequency of hospitalisation of patient, cost expenditure is more. Caregiver also needs to pay continuous attention to convulsion patient. But caregiver cannot classify emergency situation, so for caution purpose caregiver needs to hospitalize patient each time. Because of all above limitations, patient cannot live a comfort life and don't get normal sleep as well, creates many another issues related to health.

VI. FUTURE WORK

So to overcome all limitations of diagnosis methods for convulsion, we need to develop a system which can provide comfortness to patient, without interruption normal sleep, Long term stay at home and reduces hospitalization. A system which can provide a Medical Practitioner remote monitoring of patient. So that he can save valuable time of each and makes consultancy easier and faster.

As par caregiver point of view, a system which we need to develop is automatic notification and classification of emergency situation of convulsion patient. So makes overall reduction in treatment cost.

We propose the novel integrated system consist of video cameras connected with central processor located at suitable corner of the patient's room. The output of video camera is processed using computer vision algorithms capable of detecting and classifying the Fit. These tasks are with no doubt the most challenging within the study of human motion based on video. The proposed system is also enabled with remote monitoring using IoT which will help the medical practitioner to observe the current status of the patient distantly.

The novelty of the proposed system is it will hardly disrupt the normal sleep of the patient. This led to a home monitoring system where patients can be monitored minutely for long duration; therefore it will contribute to improve the diagnosis and thus the quality of patient's life.

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