Veterinary Seizure Detector

Report Number 1

Submitted by
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Date: April 27, 2010

Work performed at USC

Abstract

Animal hospitals receive on average 1-2 seizure patients weekly. Seizures in animals occur for the same reason in animals as they do in humans, with causes ranging from epilepsy to low blood sugar to diabetes.

There are detectable signs that warn of an oncoming seizure, such as dizziness or a tightening of the chest, but animals are incapable of communication sensations like these to their healthcare providers when a fit is imminent, save for some symptoms that rarely occur, but that will be discussed during the experimental portion of this report.

To make matters worse, in busy hospitals, an animal in the throes of ictal tremors, which is often soundless, can easily go unnoticed. It is important in many cases that medication like Phenobarbital be administered quickly to avoid a prolonged seizure, which can lead to organ damage from overheat.

Seizures, like most phenomena involving vibrations of some sort, generally have a characteristic set of frequencies which makes them relatively unique. If this particular set of frequencies were to be perceived by a device that would in turn sound an alarm, the problem of an undetected seizure would be history.

This is just the endeavor described here. The veterinary seizure detector will alert hospital staff when any animal in their care is at the onset of a potentially damaging ictal episode.

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Summary

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Seizures occur when abnormal amounts of synapses fire in the brain synchronously. As a result, a seizure patient often goes into violent convulsions, followed by a moment of confusion and transient memory lapse.

When an animal suffering from seizures arrives at an emergency center, it can be fitted with a seizure detector placed on a shaved area, typically on the back paw or the back of the neck between the skin and the collar. The back paw is a favored area for several reasons. The favorable aspect of the neck placement is that the animal has the least access to this area, and the neck muscle is one of the strongest in most quadrupeds, thus yielding a strong electrical signal for sensors on the apparatus. The back paw, however, will give a better amplitude reading by virtue of its position at an extremity.

If and when the seizure does occur, the accelerometer detects and sends a signal to the microcontroller chip, which, in turn, will sound an alarm or flash an LED or both once the signature frequencies surpass a given threshold. In most animals, a strong amplitude in the area of 12-18 Hz is highly abnormal, and likely a sign that a fit is taking place. Obviously, any violent tremor at any higher frequency than 18 Hz is also abnormal, but so unlikely to occur due to seizing that it is omitted here. Thus, frequencies in this area are what the microcontroller scans for when making its decision to warn.

As stated previously, seizures can potentially be destructive events leading to organ damage, and in some cases, permanent facial distortion due to the grimacing muscles being stretched out of their normal bounds for an extended period of time. The prompt administration of sedatives can make a remarkable difference in the damage control aspect of seizure management. The seizure detector ensures that staff can at least be warned in a timely manner.

1. Introduction

As mentioned before, when the signature frequencies are detected beyond a certain amplitude, the microcontroller on the detector will make a decision to sound an alarm. It is also important that the device not alert when no seizure is occurring. This, however, is unlikely as animals do not vibrate at these frequencies all that strongly unless they are in a fit. False positives in animals can occur in instances of high activity, but the assumption here is that the animal being monitored is in a hospital environment where it is in narrow confinement. The only activity left is scratching. As we will see, however, this problem can also be eliminated.

2. Hardware Architecture

The dimensions of the test dongle are 7.5 cm x 2.9 cm x 2.9 cm (length, width, and depth). The dongle contains several different types of sensors (3-axis accelerometer, illuminance, humidity, pressure, and temperature). For our purposes, only the accelerometer is used. Its model is MMA7260QT with 1.5 or 6 g sensitivity settings. The other component in use for our application is a micro-controller (model PIC8F2410). The data collected from the dongle is fed to the computer via a USB connection.

The device has no moving parts, and is self-contained. Its only purpose is to warn if it detects signals within the aforementioned range that have crossed over into excessive amplitude. As will be explained ahead, only one axis of acceleration is truly relevant. If the device were to be installed on the paw, the technician would have to take good care to affix it on top of the paw, along the axis of articulation of the leg.

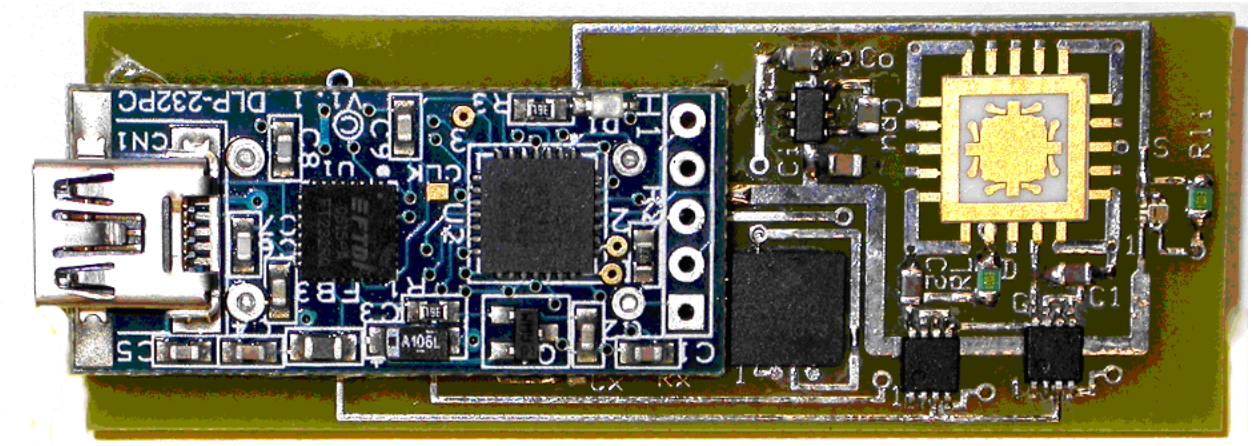


Figure 1: The dongle used for data retrieving.

3.Software

The dongle can be programmed from a laptop using Matlab2009b. The program takes in real-time data from the accelerometer through the microprocessor, and implements a filter to block out unwanted frequencies. Those frequencies remaining, the ones relevant in terms of seizures, are then monitored for the set exceeding amplitude.

4. Performance Measurements

4.1 Introduction

The following analyses and graphs were produced while experimenting with physical seizure-like hand tremors and live canine patients. Since the bulk of the movement happens in one direction due to the axis of motion of the muscle, only the z-axis graph seems to show a notable amount of movement, and is thus the focus of the motion study. The frequency filter is set to exclude any frequency below ~12Hz and above ~18Hz. The reasonable cutoff amplitude used here was 0.20 and 0.15. Predictably, the cutoff amplitude will vary with the size of the seizure victim. However, both canine patients were of similar sizes.

In all, three test subjects were used. The first was a human being faking a seizure. The second is a canine seizure patient named Cisco. Cisco is a 7 year-old male German shepherd mix with a history of epilepsy. He weighs about 60 pounds. He also suffers from separation anxiety, which is common among high strung active dogs such as German shepherds. His seizures were once frequent (about 1 occurrence every two weeks), but have gradually calmed over the years.

The third subject is another dog named Duke. Duke is a 65 pound male yellow Labrador retriever. He is diabetic, which may be the direct cause of his episodes. Regardless of the cause, both canines are approximately the same weight, and thus should produce similar frequency spectra when seizing, unless their fits are of extraordinarily different severities.

For the hand experiment, the dongle is simply held in the right hand extended maximally forward so as to experience the maximum amount of acceleration felt by the dongle. For the animal testing portion of the experiment, the dongle is simply secured to the animals back paw using medical tape and vet wrap. Again, the extremity of the leg is chosen so as to maximize the accelerometer's reading.

4.2 The Scratch Test

Dogs can vibrate at seizure frequencies at a very low amplitude at any given time, and this will not set off any alarm. However, they use their back legs to scratch themselves behind the ears and on the neck quite frequently. To test whether or not scratching would set off the alarm, the dongle was attached using tape and vet wrap to Cisco's back leg. The following graphs show the readings of this activity.

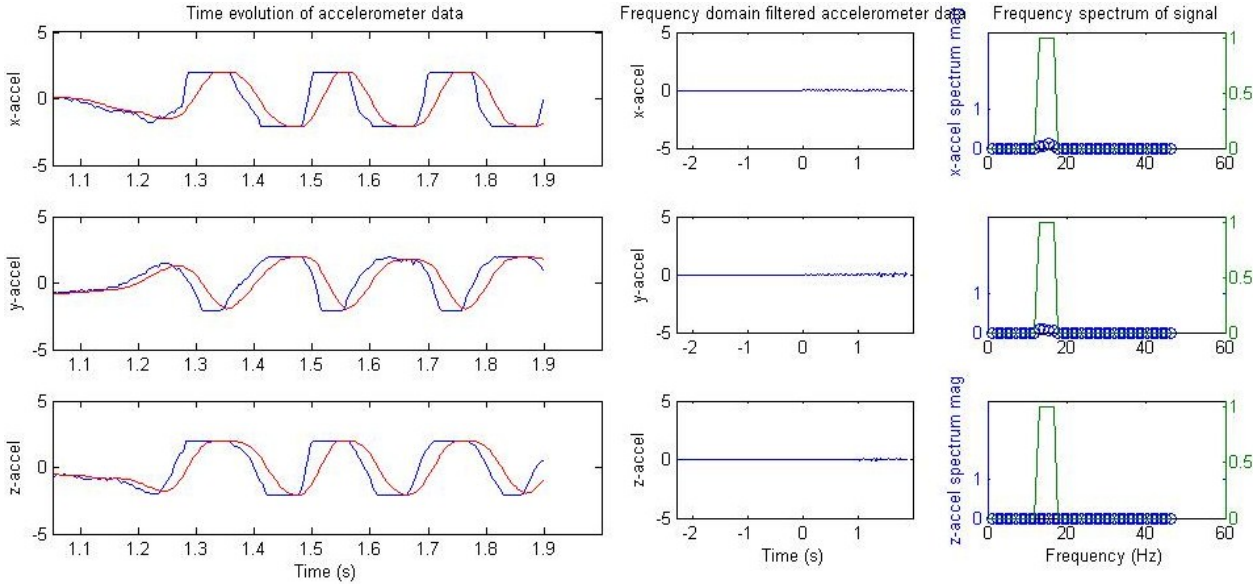


Figure 2: The amplitude versus time and frequency readings of the scratch motion. This is clearly a chaotic movement with all axes being in use at approximately equal amplitude. Although the activity is clearly a strongly articulated one, the critical frequencies are not so pronounced that they can set off a warning.

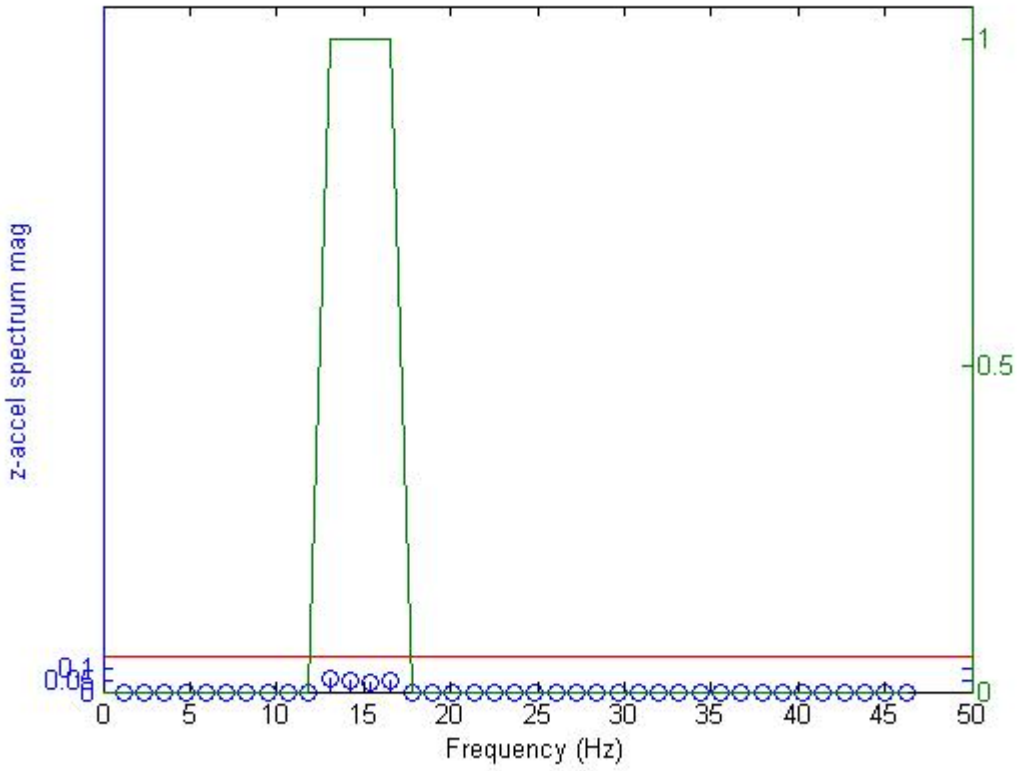


Figure 3: The frequency analysis of the scratch motion. The keys frequencies, as shown here, barely reach halfway to the 1.5 threshold.

Scratching is typically the most repetitive motion a dog can do in a confined space like a hospital cage. Therefore, by removing it from our list of possible false positives, we have effectively shown that our passband filter, the tophat filter shown above,is adequate for weeding out the possibility a warning could sound for any reason other than the occurrence of a fit.

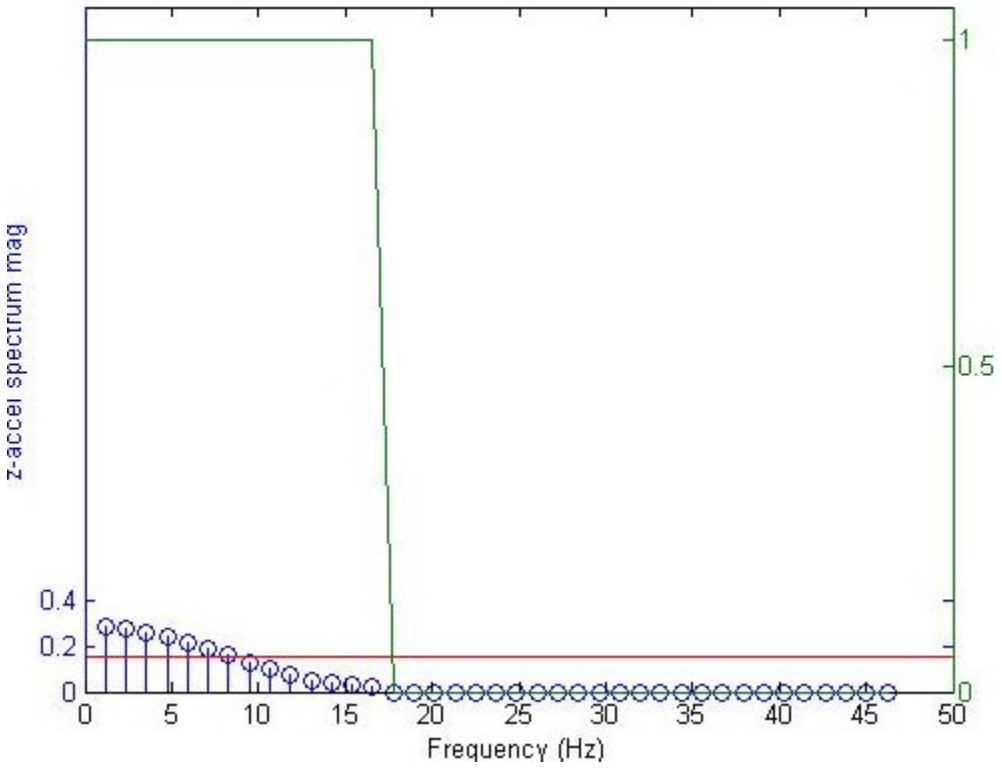


Figure 4: The graph above is the hand mimicking the scratching motion. The code has been altered so that the passband filter is now a lowpass filter, left of the graph, which allows a reading of the frequencies below the key spectrum. Now, one can get an idea why a scratching motion does not trigger anything.

4.3 First Subject: The Hand

As mentioned previously, the first motion tested for seizure frequencies was merely the hand of a human subject mimicking the frenzied tremors of an epileptic episode. The dongle was mainly held with the z-axis parallel to gravitational pull, and shaken in an up-down motion to stay as physically close in resemblance to that of an animal's paw during ictal manifestation.

The following graphs show the results.

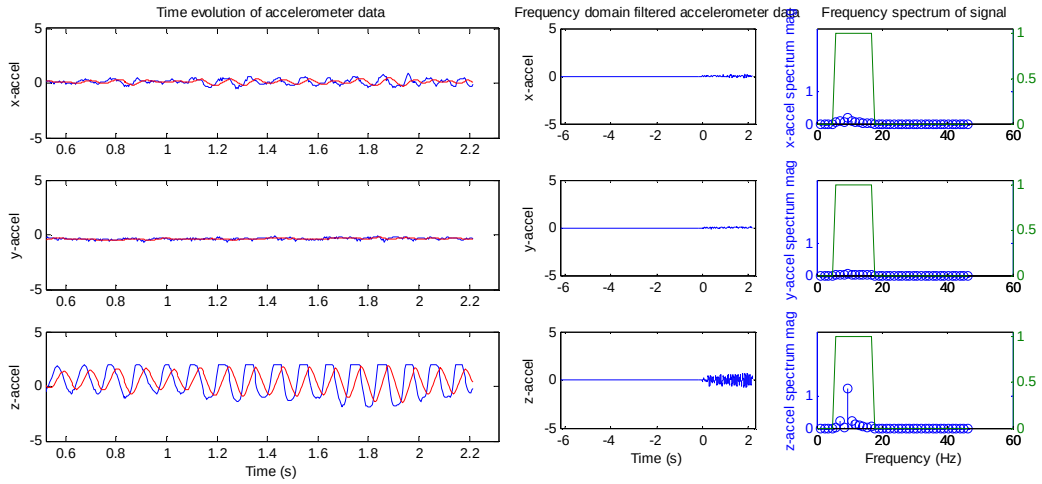


Figure 5: Amplitude of (left) and frequency analysis (right) of hand tremors mimicking a seizure.

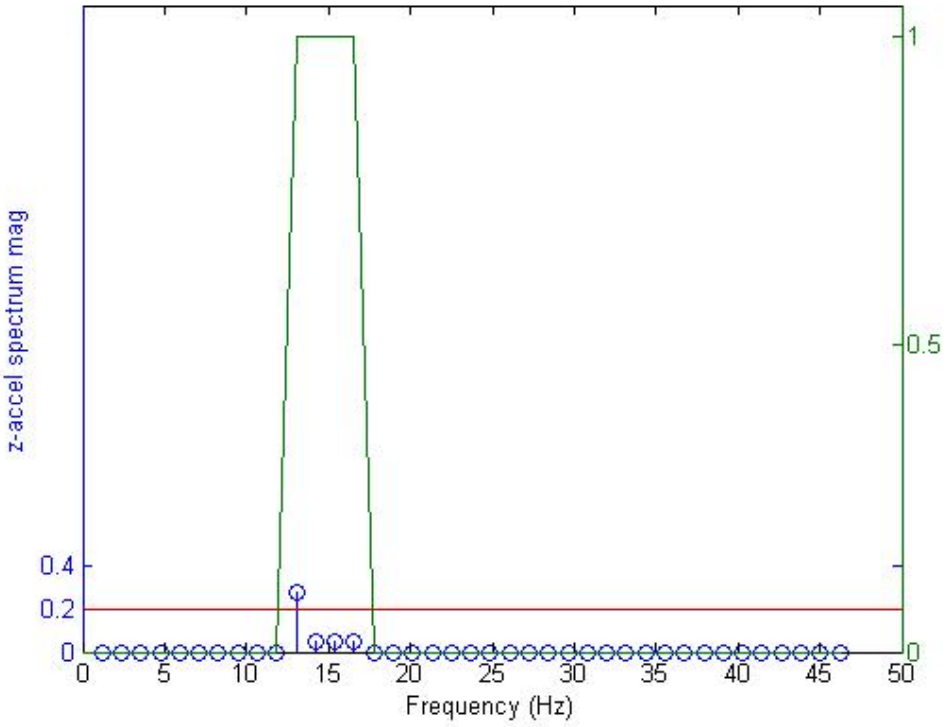


Figure 6: Frequency analysis of the hand tremor mimicking a seizure.

From the first graph on top, one can see the z-axis almost exclusively being the axis of motion while the others remain relatively inactive. Once again, this is a close resemblance to what one can expect to see in a seizing animal if the apparatus is attached to a dog's leg which has a practically unidirectional axis articulation.

The bottom graph shows the frequency spectrum abridged by the top hat shaped passband filter. The frequencies within its borders are the frequencies of interest. There is a particularly strong amplitude spiking at 13Hz. This frequency, as we will see in the trials that follow, seems to be the signature in a seizing subject.

4.4 Second Subject: Cisco

Cisco arrived at the hospital in the middle of a fit. After this had passed, the dongle was fitted to his right rear leg. The reason for this is twofold. The rear leg is the one used to scratch, and so allows us to test to see if his scratching will set off the alarm. The other reason is that the muscle in the back leg is considerably bigger and thus more vibratory during relapse, which may help yield stronger readings.

An electrocardiogram had to be taken to monitor his cardiac functions. For a high strung type of dog like Cisco, and many other shepherds, that means he will have to be restrained, which means he will likely struggle and lapse into crisis. This was the cue to start the reading, and as predicted, Cisco seized a second time due to his struggle against restraint.

In the graph that follows, one can see that, as was the case with the hand, 13Hz seems to be the prevalent frequency when a seizure occurs. This was Cisco's last seizure that day, because it was followed by the administration of a sizeable dose of barbiturates.

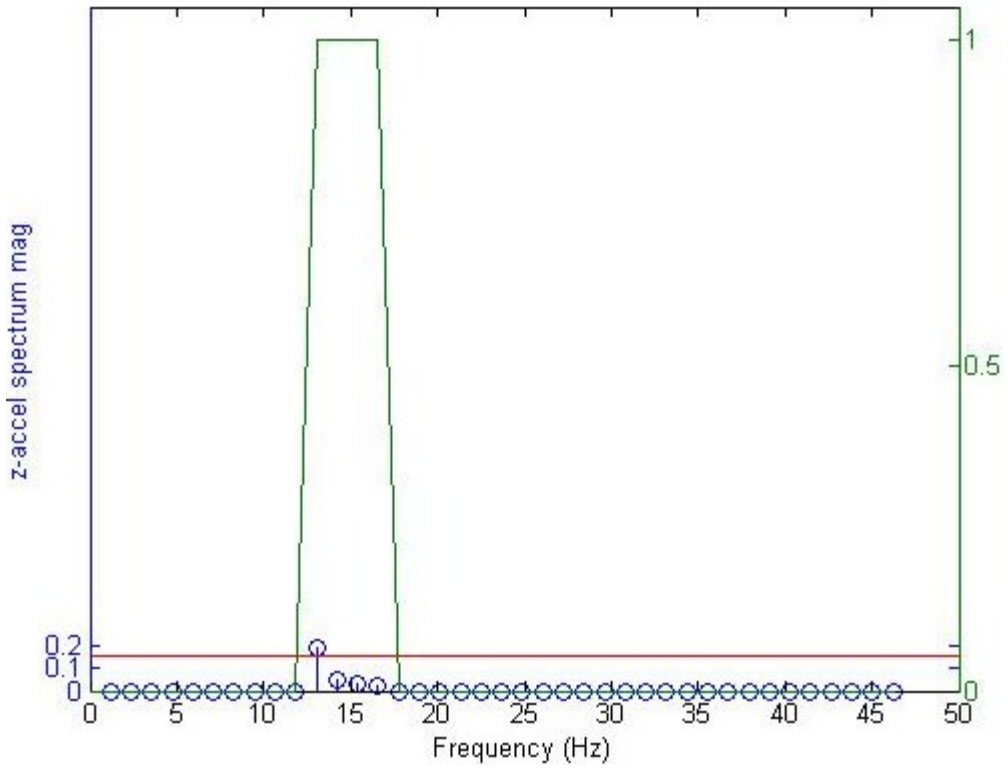


Figure 7: frequency analysis on Cisco's seizure.

4.5 Third Subject: Duke

Duke arrived in the early afternoon a week after Cisco had been hospitalized. He was fine, albeit a bit lethargic when he arrived, but had suffered two seizures that morning, and his owners had become worried that more would follow. Their worries were well founded as Duke had another seizure about two hours later.

Seizure can be compared to earthquakes in that there are no sure fire ways to predict when they will take place. There are a few exceptions, and Duke's case was one. On rare occasions, when dogs are about to seizure, they will become uneasy and shifty, perhaps even vocalize a bit. Duke exhibited these signs and was immediately fitted with the dongle. Moments later, he burst into a violent and erratic seizure that rocked his frame for approximately 15 seconds. The following graphs show the readings obtained from the fit.

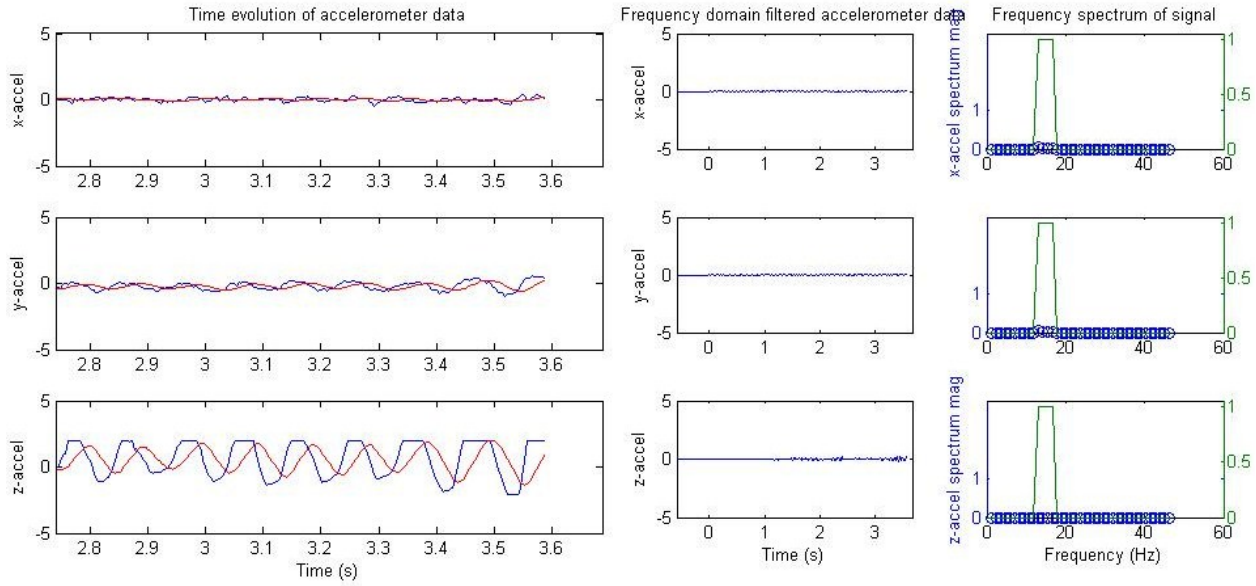
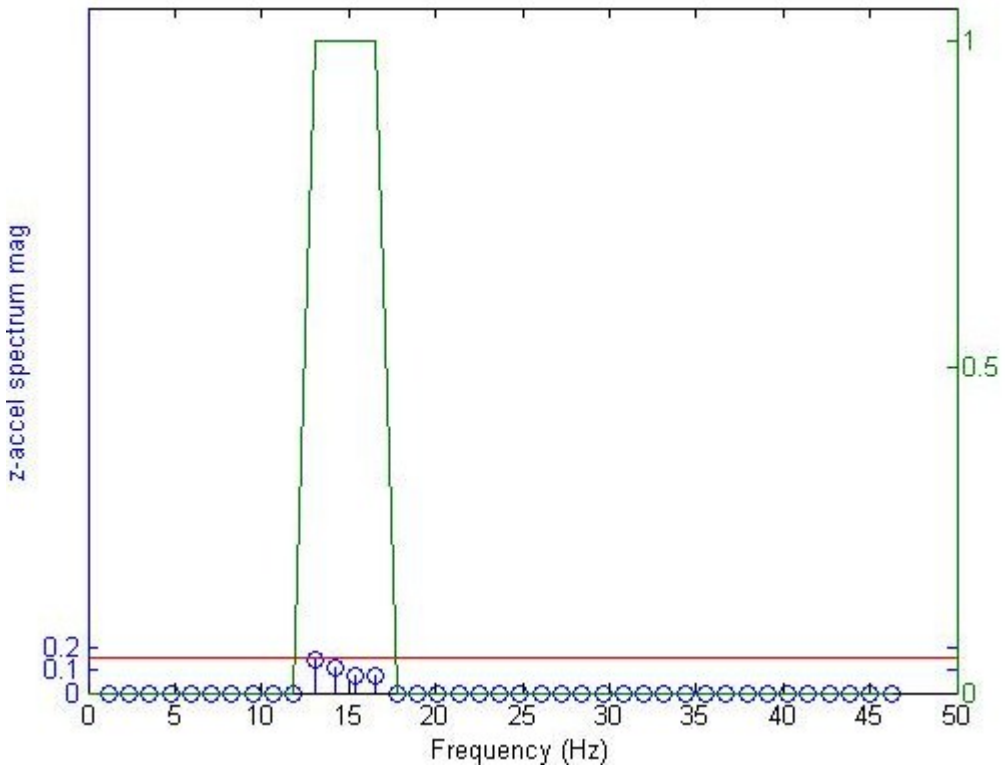


Figure 8: Amplitude and frequency analysis of Duke's seizure.

Figure 9: (below): Frequency analysis of Duke's seizure.



The previous page's top graph is there to show the brutality of the episode. The top of the waveform in the bottom left graph of the z-axis is clipping because the amplitude of the shaking was so high.

In the previous page's bottom graph, we can see that higher frequencies are present in higher amplitudes as opposed to the other two subjects. Again, the seizure was very strong, and, from what is visible, two frequencies present during the fit were strong enough alone to set off the alarm.

After this seizure, Duke was practically immobile for most of the day, so the scratch test was not conducted on him. This is the main reason the second scratch test was carried out using hand mimicry rather than a canine subject.

5.Conclusion

In demonstrating that there exists a signature range of frequencies in the event of a seizure, and that this range can successfully be detected when it exceeds an acceptable value, we have shown that a seizure detector can be realized. Furthermore, the base idea being relatively simple makes for a compact device that can readily come into everyday use in clinical facilities.

This contraption is classified in the medical device market, of which the US possesses the largest market ($85.6 billion in 2008 with an annual growth of about 4%)[1]. Also, the veterinary industry has its largest concentration by far in the small animal practices.

IBISWorld expects the industry to continue to grow steadily in the years to come, mainly due to the aging population in US households[2]. Additionally, seizures in pets being affected by such a wide range of factors are unlikely to decrease in occurrence. These facts combined make for a promising market for this device to enter, despite the competitive nature of the business in the US. There have already been a few demands for the device in a facility where it was tested on live patients without risk to them.

Products & Service

Figure 10: Graph demonstrating the prevalence of small animal practices in the veterinary world.

In the US alone, 72 million dogs are someone are pets and 82 million cats, 50% of which are considered by their owners to be members of the family.[3] Although dogs are the main focus of this particular study,

[1] http://www.medical-distributors.com/countries/united-states
[2] http://www.ibisworld.com/industry/default.aspx?indid=1447
[3] http://www.avma.org/reference/marketstats/sourcebook.asp

cats also suffer from neuropathological problems that cause seizures. Therefore, the following statistics include them as well.

	Dogs	Cats
Percent of households owning	37.2%	32.4%
Number of households owning	43,021,000	37,460,000
Average number owned per household	1.7	2.2
Total number in United States	72,114,000	81,721,000
Veterinary visits per household per year (mean)	2.6	1.7
Veterinary expenditure per household per year (mean)	$356	$190
Veterinary expenditure per animal (mean)	$200	$81

Here are some key statistics concerning the market size of the veterinary industry[4].

Key Industry Statistics

Key Industry Figures	2009	
Industry Revenue	*28,710.3	$Mil
Revenue Growth	*1	%
Industry Gross Product	*18,231.1	$Mil
Number of Establishments	*44,928	Units
Number of Enterprises	*43,352	Units
Employment	*314,312	Units
Exports	--	
Imports	--	
Total Wages	*9,560.5	$Mil

[4] http://www.ibisworld.com/industry/conditions.aspx?indid=1447

Large veterinary device and diagnostic giants like Heska, Antech, or Idexx may find an interest in further developing this contraption, Heska especially. This firm is one of the largest producers of automatic intravenous pumps, and the carrier of similar mechanical and diagnostic products.

If a sufficient 'buzz' was created in the local veterinary community, our primary target, it would be easier to pitch it to a company, because of the leverage already present among the professionals who create the demand for their product.

Setting aside the profitability of the idea, let's discuss its importance. As mentioned earlier in the report, in the busy setting of a hospital environment, an animal in the grips of a seizure can easily be overlooked. Seizures lasting more than 5-10 minutes can easily be deadly. Cluster seizures – several seizures in the space of 24 hours- can also be deadly. So if a dog seizes several times, but only one or two of the episodes are noted, there is a potential for dire consequences.

Although it may look like neglect to an animal owner looking in from the outside, veterinary technicians earnestly try to keep watch over seizing animals. Owners are already panicked at the sight of a member of their family writhing in a trembling disfigured state. When they arrive at the hospital, any additional measure to ensure that their pet will be well looked after is most welcome, and increases the chance that they will elect that particular clinic as their primary animal care provider.

Another aspect to consider is the potential legal ramifications of an animal dying at a clinic because its relapses were not noticed and therefore went without the proper treatment. Here is a quote from Inland News on the subject of malpractice lawsuits.

> Animal-law experts, including American Veterinary Medical Law Association president Karl Salzseider, agree veterinary-malpractice cases have increased, but accurate statistics are difficult to obtain. The American Bar Association reported in 2002 that veterinary-malpractice claims increased 66 percent over a few years starting in the late 1990s, reaching 2,000 claims nationwide in 1999.[5]

In a case of interest, Marc Bluestone of Sherman Oaks won $39 000 in a malpractice lawsuit when his dog Shane died following a treatment for (coincidentally) nonlife-threatening seizures. Normally, California law prohibits such large sum from being dispensed, because an animal is considered property and no amount can be awarded for emotional distress, only the animal's market value. The reason this case is of interest is because it is an indication that the legal system is beginning to pay heed to the importance Americans grant their pets.

Here is another quote from Inland News concerning this trend.

[5] http://www.pe.com/localnews/inland/stories/PE_News_Local_D_pets04.8be18ad.html

> Robert Newman, the Torreses' attorney, estimated pet lawsuits have jumped tenfold over the same period. The increase stems from a greater understanding of pets' importance in humans' lives, Newman said. The Torreses' suit, which is ongoing, seeks damages in excess of $75,000.[6]

The lawsuits are not the only setback a veterinary doctor can face if they are believe to have malpracticed. Since the late 1990's, there have been a large number of private citizen-run websites put in place for the sole purpose of whistle-blowing bad vets in a public forum.

Websites like "vetsfromhell.com", "stempy.net", "vetabusenetwork.com", and many others have sprouted and gained popularity among pet owners. Many in the animal owner community consult these websites before even going to a vet directory.

It is believed by many in the field, that the web presence of whistle blowers combined with lawsuits, have been the driving force behind the increase in animal care technology, and the increase in the quality of the staff.

The device described in this report ensures that proper and immediate care is performed when a seizing pet lapses into an episode. It is another step towards better care, and gives the clinic equipped with it an appearance of being ahead of the times and on beat with new technologies. Its presence will bring peace of mind to the owners of the animal as well as the doctors and technicians.

[6] http://www.pe.com/localnews/inland/stories/PE_News_Local_D_pets04.8be18ad.html

6.Distribution List

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