Canine Gait Analysis Device

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Submitted for publication: 5/25/20

Abstract

Many dogs suffer from skeletal diseases which can significantly impact their lives, especially when left untreated. A harness attached IMU was developed to measure acceleration values based on a dogs walking gait along with a software analysis tool to evaluate the regularity of the measured gait. Based on trials on a test dog with no known history of skeletal disease, the system was able to successfully detect gait abnormality in the test dog of both an induced limp and a normally occurring limp.

1.0 Introduction

With almost 90 million dogs in the United States it is estimated that 20% of those dogs have osteoarthritis after one year of life ("Number of dogs", Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017). Dogs with musculoskeletal diseases tend to have an imbalanced gait and it is typically most noticeable when dogs have lameness due to avoiding walking on their injured legs, which is especially problematic because it can lead to a possible disorder in their healthy leg (Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017). Improving the ability to detect osteoarthritis has the potential to both increase the long term quality of life of dogs as well as to decrease long term vet bills by encouraging early diagnosis. Early detection of skeletal diseases is beneficial in dogs so as to know immediately when to go to the veterinarian and seek treatment.

Different methods for human and animal gait analysis include visual inspection, a video system, force plates, and IMUs (inertial measurement unit). Most often for humans and animals, it is easy to notice a gait abnormality just from watching; however, that method is subjective and can often be inaccurate or difficult to notice with an untrained eye or when the gait abnormality is not extreme (Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017). Video gait analysis for humans is relatively common and in a study was seen as the "gold standard", because it was used to measure the effectiveness of data collected from the IMUs (Staab, W et al., 2014). New experiments using IMUs for canine gait analysis show that using worn IMU sensors is more convenient for their lower cost and small size to get objective data and monitor gait progression (Jenkins, G.J., Hakim, C.H., Yang, N. N., Yao, G., & Duan, D., 2018). Force plates are useful for measuring weight distribution and force ratios between hind from forelimbs and left from right limbs (Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017). A standing analysis, instead of gait analysis, of weight applied to each paw is useful information for veterinarians and researchers for diagnosis and treatment, especially because it can indicate unnoticeable lameness, which is very critical for obese dogs (Chalayon, P., Soontornvipart, K., & Tangwongsan, C., 2013). Force plates are useful for measuring gait and weight distribution; however, they are limited to certain environments, tend to be more expensive, and are possibly more stressful for the dog (Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017). Researchers have tested the effectiveness of IMUs for animal science, but IMU's are currently being used predominantly in a clinical setting in the equine industry for lameness detection (Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017). Wearable IMUs are becoming common in human gait analysis and proven a beneficial tool for horses (Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017). Sensors for canine gait analysis worn occasionally over to detect gait abnormalities early could lead to early detection and treatment of osteoarthritis, which would positively impact their health (Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017).

Since animal gait analysis IMUs are not common, the devices are not as developed, accessible, or innovative as human systems and protocols. On specialty websites, like Tekscan, people can purchase a system that uses force plates to measure animal gait ("Animal Gait Analysis"). Although not through gait analysis, IMUs have recently been common in commercial products like *FitBit*, or *Whistle* for dogs (Ladha, C., O'Sullivan, J., Belshaw, Z., & Asher, L., 2017). This project focuses on IMU sensor gait analysis, instead of force plates and video analysis which are most common, because IMUs can be used in a variety of settings and have shown, when implemented in research, to be convenient and effective.

This project is to develop an early detection system for canine osteoarthritis. This will include the development of an IMU device for acquiring canine gait data, and the software analysis tool to aid dog owners in evaluating gait changes over time. The project will make an impact by providing dog owners with a practical and effective way to detect skeletal diseases in their dogs early so as to get a diagnosis and treatment as soon as possible to prevent the painful and fatal effects and monitor the progression of the disease. Early detection of skeletal diseases in dogs is beneficial to prevent the progression and worsening of gait. This device would improve the quality of life of many dogs with these severe diseases because they will be able to receive treatment sooner. The objective data will be helpful because seeing their dog every day, owners may not notice gait abnormalities; however, with this device, they can clearly see in the data a slight change in gait. Because this device is more affordable than other systems and does not require advanced gait analysis training, it will be more convenient for owners of bigger and at-risk dogs to monitor or detect skeletal diseases as soon as possible to have the advantage of preventing a worsening condition early on. This research can improve the world by not only improving the quality of life of many dogs and being helpful for owners, but is useful for future studies. This may be valuable to be used as a starting point for future projects that can make a greater impact focusing on different animal populations, targeting different diseases, or improving specific treatments.

2.0 Methods

2.1 Device

This project is designed to evaluate canine gait using an accelerometer attached to an adjustable dog harness. The device is an Adafruit BNO055 accelerometer connected to an Arduino Uno with the ability to store data on an SD (secure digital) card. This means the unit is mobile and wearable on the harness to collect data to be used and run through processing after the walk test. Data is stored on the SD card in csv format and transferred to a computer for analysis using software developed in Processing.

2.2 Software

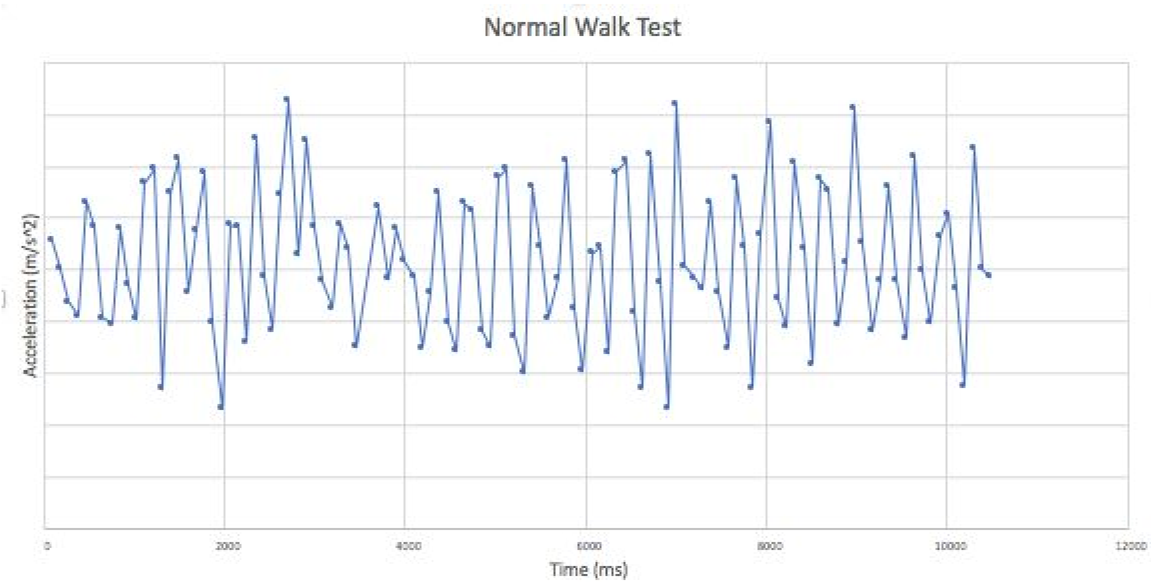
Both Arduino and Processing are used to gather and interpret the data. The Arduino code is utilized to record raw accelerometer data to the SD card and net acceleration is calculated. The recorded data is then transferred to software written in Processing for analysis. Based on the premise that each time a dog paw impacts the ground, an acceleration will be detected, the software is used to identify each paw-ground impact and records the time interval between each step.

2.3 Validation

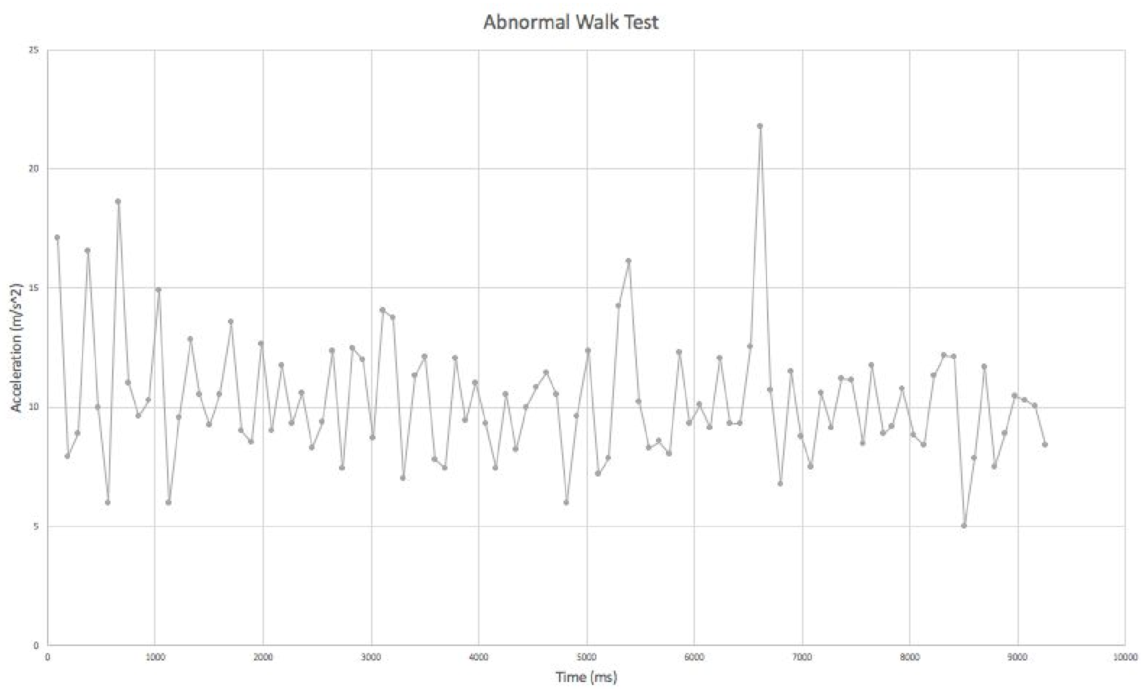
In order for this device to be validated, it was tested by putting the device on a dog with and without a gait abnormality to check if it has the potential to detect a limp. The harness was put on a test dog with no known history of osteoarthritis. For each trial the dog was walked on leash for 30 minutes and 5 trials were completed. For each of these trials, 30 second intervals were extracted from the middle of the 30 minute walk so the dog would be familiar with the harness, and not fatigued. The harness was applied to the same test dog. A limp was forced by loosely tying the dog's feet together. The discrepancies and asymmetry in steps represent possible symptoms of a skeletal disease. This data was acquired from the IMU sensors and the project is effective if the dog has detectable gait asymmetry, lameness, or abnormalities from comparing data from its baseline.

3.0 Results

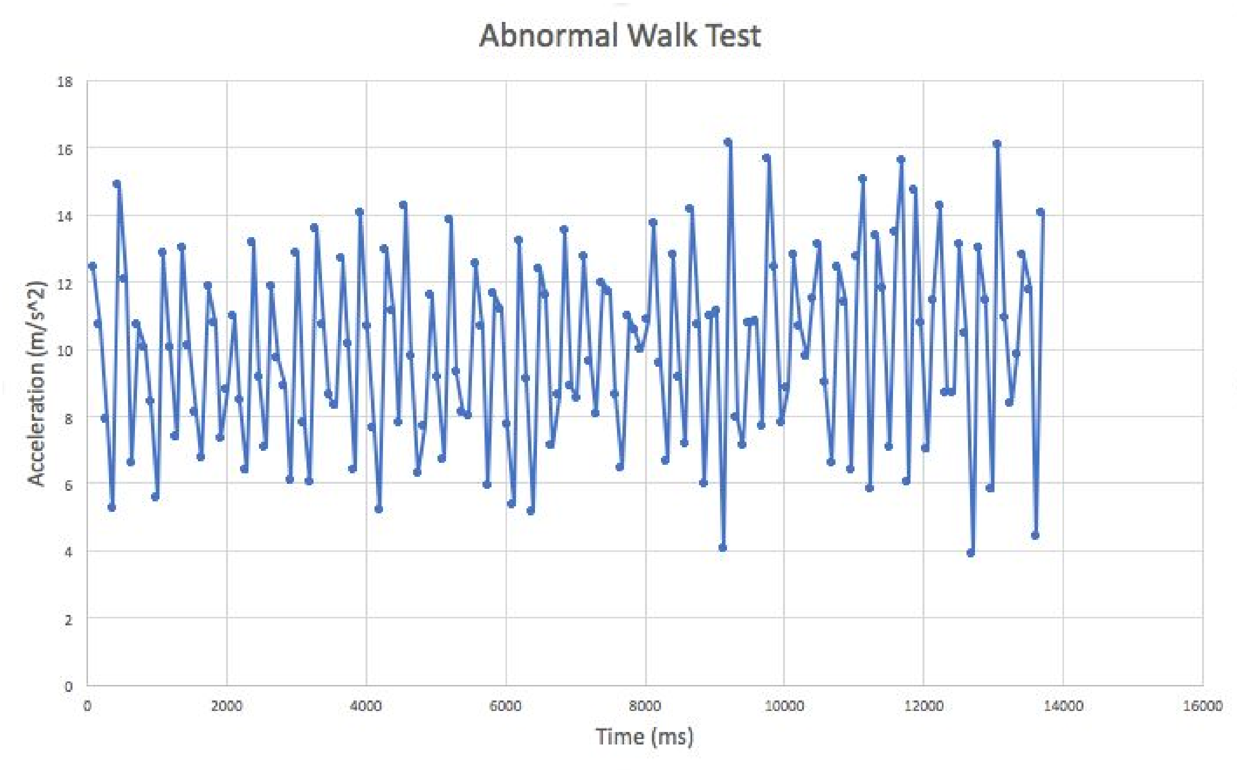
In my results, I used three trials and ran parts of the trials at a time through Processing. I tested my dog's normal walk and discovered that his millisecond time difference between peaks (representing steps) was always somewhere within the range of 340-390 milliseconds. Because my dog is a living creature, his normal walk throughout the test was not perfectly consistent but fell within a 50 ms range. Trial 2, I forced a limp on my dog by tying his right front and back foot together with a loose string. I did not get as much usable data from this trial, but the millisecond difference average between peaks fell between 320-340 with each data set. My dog had a natural limp (visibly noticed limp with an unknown cause) during Trial 3 and the sensor values I got from that trial were 390 and 391. My data sets, among each of the trials, vary in length and time; however, they were typically just below 30 seconds, although some were only about 5. My results show that for my dog, he is walking normally if his average values fall between 340-390 ms. There is some uncertainty in my result based on harness position and if it changed between trials. Taking baseline data with an already "abnormal" gait is another possibility that would impact the validity of the device.



Graph 1: Random sample from normal walk test: Time difference between peaks



Graph 2: Random sample from abnormal walk test (Natural Limp): Time difference between peaks



Graph 3: Random sample from abnormal walk test (Forced Limp): Time difference between peaks

Trial	Range of Average Time Difference Between Peaks (ms)	Number of Data Sets
Trial 1 (Normal)	340-390	7
Trial 2 (Forced Limp- legs on right side tied loosely together)	320-340	3
Trial 3 (Natural Limp)	390+	2

4.0 Discussion

The initial problem is addressed by the canine gait analysis results because the product has the ability to warn owners when their dog's gait is not within the normal range. When the owner attaches the harness with the sensor for a baseline walk test, their dog's average value will be stored. The sensor measures the acceleration of the dog's upper back when the dog is walking. A future development to this device may be for the software to analyze and compare the values and warn the owner when they are out of the normal range.

If the values are lower or higher, the dog may have a limp and benefit from a trip to the vet. The average values for the limp trials represent inconsistencies with each step time as he is walking. If one paw is injured, it will take more or less time to step with that paw, which will affect the average. If one of the steps is longer and slower than the others, the average time will increase, indicating a limp. If the dog injures a leg and steps with one paw quicker than the others, the average time will decrease, and he may need to visit the vet, especially if it continues or worsens with time. The device can't indicate which paw is injured, which is why a dog with gait data showing a limp may likely benefit from a trip to the vet.

Some software improvements that can be made in the future are further suggestions to the owner or analyzing more of the severity of the limp. Providing the owners with suggestions for treatment options related to the dog's physical activity in addition to the suggestion to go to the vet will improve the device. Analyzing the value difference to understand the severity of the limp is another possible refinement. Finding a way to understand what qualifies as an extreme limp versus subtle and what a more extreme limp may be caused by or if at a certain point, there is something the owner can do, like limit activity, in order to help the dog without immediate medical attention. Other improvements include ones related to the hardware and additional sensors for a more comprehensive analysis. Future experiments can also be performed with more sensors on each of the dog's limbs to possibly get more accurate data of where the limp originated and more specific asymmetrical differences. Being able to locate the source of the limp may help the owner and vet in finding a clear diagnosis with much less unknown. To get different data, an adjustment may be to put the sensors on the dog's feet or lower legs rather than back and possibly use a gyroscope to measure tilt or somehow the distance of the dog's strides on each limb. Combining the gyroscope and magnetometer may give a better assessment of the dog's gait. In order to completely prove my device is accurate, it must be put on a healthy dog that will develop osteoarthritis and used to track the dog's gait progression over time to test if the device really does help with early detection. Separating each axis of the accelerometer instead of measuring the overall acceleration may help to discover what exactly the peaks in the data represent and how the dog walks.

5.0 Conclusion

The problem of late detection of canine skeletal diseases was addressed by a gait analysis device that measures the acceleration of a dog's walk from a harness on their back to find values that represent their typical gait. If an owner tests again and the values are outside of their dogs normal range, that represents a limp. This will allow owners to see the progression of their dog's gait and have concrete values rather than relying on visual inspection when their dog's gait gets extremely abnormal. The project was done using the same test subject dog and finding his normal range of time between steps by testing the dog with and without a limp. The results show the test subject's normal gait values in the software are between 340 and 390 milliseconds and with different limps, the values were both above and below that range.

6.0 References

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7.0 Appendices

Device/Software user manual:

https://drive.google.com/open?id=1Z9XlsBJMqzB7uqmGq7pv8yJ7MQKk-pq1n1DQufnjbmE

Commented Code :

Processing:https://drive.google.com/open?id=1xBJA3zdzoi1eHMkGLZGi9UTguFkcV-JZ

Arduino:https://drive.google.com/open?id=1kz2spfbR1kw_KnH_hiMadob5Clt0IQjs

Photo Documentation of project

Project Journal:

https://drive.google.com/open?id=1swK5H2f3U3jXO4z4EYHK-4li98qfIaHPLgwtAMsVCio

Original Proposal:

https://drive.google.com/open?id=19XLoEWkT5pHteS7W-OP4djUXx3Hkx3Z5bHHgj_VMIhM