Designing a Bodysuit to Counteract Wobbling in Cats with Cerebellar Hypoplasia

Grant Proposal

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Author Note

If needed, write notes here with an indented first line. Be mindful, the text in your lit. review should be between 10-12 font size with a chosen font of Caibri, Times New Roman, or Arial. A Table of Contents is *optional*; however, you should format the section headers appropriately to have them show up in the TOC. Lines should be double-spaced.

Abstract (RQ) or Executive Summary (Eng)

Currently, cerebellar hypoplasia is one of the most common neurological conditions present in cats across the world. This condition can cause gait abnormalities and wobbling movements which can decrease the likelihood of these cats becoming adopted. Assistive devices are crucial for increasing adoption rates as a reduction in this side-to-side movement mitigates the requirements needed to adopt a cat with cerebellar hypoplasia. This study addresses wobbling, a symptom where the body moves uncontrollably from side-to-side, by engineering a wearable bodysuit to stabilize the body that allows these cats to be more independent without needing constant assistance from their owners. This study was simulated through a vertical-spring system and a stuffed animal, the spring mimicking the unpredictable symptoms of a cat with cerebellar hypoplasia. The structure of this device was constructed using nylon webbing, breathable air-mesh, and Velcro straps for adjustment with different cat sizes. This device primarily uses an MPU6050, an IMU chip that combines a 3-axis accelerometer and 3-axis gyroscope to measure linear acceleration and angular velocity, to detect motion and send signals to the electronic speed controllers. The electronic speed controllers regulate the speed and direction of the two brushless motors to allow for proportional speed and in this case, counter-torque for the side-to-side movement in a cat with cerebellar hypoplasia. This device is predicted to have a success rate of over 50%, on track to be effective in combating wobbling in cats with cerebellar hypoplasia.

Keywords: emotion understanding, interest, social development, prosocial behavior, infants

Designing a Bodysuit to Counteract Wobbling in Cats with Cerebellar Hypoplasia

The need of the project derives from cats with cerebellar hypoplasia (CH) often having trouble walking, coordinating movement, and controlling their balance. It can become unpredictable because they are prone to falling and stumbling, so having an assistive bodysuit to help them control their movement more to improve proprioception, the body's sense of its own current position, movement, and action, can reduce the number of wobbles they have. Through oscillations, percentage of mechanical recovery, and diagonality of a mass-spring system, it can improve proprioception, providing this bodysuit can allow the brain to produce a clearer image of their surroundings (P-Themes, n.d.).

The reason as to why I chose to create and design a project like this is because when I was volunteering at the animal shelter I work at, there was a cat that was recently rescued that had issues jumping and getting around our cage rooms. As I continued to work there over a course of a few weeks, I continued to observe her and see what I could do to help better her wellbeing and future quality of life. That's when I thought of my engineering project; I can design a bodysuit that can help stabilize her while not restricting any movement that she exhibits during everyday life. This would positively impact cats with CH as it would encourage more free movements and would allow them to struggle less with everyday tasks like eating and drinking. However, to start this project, I will have to understand biomechanics and proprioceptive feedback.

Biomechanics

Biomechanics is the study of the response of biological systems to mechanics, more commonly known for being the link between structure and function. Scientists across various fields use biomechanics because it allows them to have a deeper understanding of how organisms move and interact with their surroundings. Biomechanics takes the laws of physics about pulleys, levers, and other functions to understand all the forces involved in biological systems to understand conditions such as cerebellar hypoplasia (Hampton, 2023). In terms of cats with cerebellar hypoplasia, the cerebellum's role in the brain is that it has 'feedforward control,' which means the body is able to predict and prepare for movement based on previous experiences. However, since cerebellar hypoplasia doesn't allow the cerebellum to do its proper role, it tries to compensate in unique ways that prevent muscle contractions that help stabilize movement (Straulino et al., 2025). As a result, they tend to 'wobble' because whenever their body leans one way, they try to counteract it by going the other way. It's a persistent issue because they are unable to control it. It's important to have this information and context because if I'm going to be designing an assistive device surrounding cerebellar hypoplasia in cats, it will be very helpful to know the biomechanics of how it works.

Proprioceptive Feedback

Proprioception is the body's internal sense of motion and position. Proprioceptive feedback, on the other hand, is the neural representation of the body's movement and mechanics to the central nervous system (Cleveland Clinic, 2025). This feedback system can be used for calculating error signals between the movement predicted by proprioception and how the body moved. Proprioception can also directly contribute to muscle activity through reflexes and motor loops, which can potentially maintain stabilization when body swaying (Dean, 2013). Proprioception is an important component in my project because even though cats with CH are able to receive the feedback, they cannot do anything to respond to it due to an underdeveloped cerebellum. However, proprioceptive stimulation (sensory therapy technique to provide more input into the body's limbs/muscles) can stimulate and improve motor control through reinforcing spatial awareness into the animal.

Competitor Analysis

Prior to this research project, engineers have designed wheelchairs to combat the mobility issues present in cats with CH. These wheelchair carts were fabricated using PVC pipes and joints, neoprene, a versatile synthetic rubber, and a PLA filament for 3D printed parts, a biodegradable thermoplastic that is used in high detail 3d prints. This cart prevents the swaying/wobbling of the cats with CH due to having the sides of the cart being snug to their body while still allowing for free movement. All the attachments are detachable, the harness is created with soft, breathable fabric, and also contains Velcro that attach to the sides to the cart (Chang, 2024). This model is very well created and allowed easy access for cats with CH. However, although this is a device that allows for free movement, it does not allow for cats with CH to go up and down stairs, jump on top of anything, or bend down to eat without being taken out of the cart. I strive to design a device that will decrease the dependency that cats with CH rely on their owners for through repurposing the components of a self-stabilizing robot to be on their bodies, not supported from the floor.

Section II: Specific Aims

This proposal's objective is to create and test an assistive device that can aid cats with cerebellar hypoplasia in walking with more stability.

Our long-term goal is to decrease the dependency that cats with cerebellar hypoplasia have on their owners. If a device can simulate the reduction of the number of oscillations on a mass-spring system with a weighted stuffed animal, then it can lower the number of wobbles the cat with cerebellar hypoplasia experiences because both a cat leaning in one direction and a mass on a spring oscillate and decay in a similar way that allows experiments to be conducted without potentially causing harm. The rationale is that recent developments for self-stabilizing robots fundamentally have similar systems. A cat with cerebellar hypoplasia (CH) leans from side to side the same way two-wheeled self-stabilizing robots lean forward and backward. The robot's PID controller decides how much the wheels should move in order for the robot to remain upright, just how this CH device would use a PID controller and a small rotating disk to create counter torque for the cat to become more stabilized (Xin et al., 2025). A small brushless motor would prevent the aggressiveness as animals require smoother transitions in comparison to robots. The work we propose here will create a device for cats with CH to reduce the number of wobbles they experience in their everyday life.

Specific Aim 1: Determine how cerebellar hypoplasia (CH) affects a cat's gait, coordination, and balance.

Specific Aim 2: Quantify the oscillations from moving side to side, caused by CH, before and after wearing the assistive bodysuit.

The expected outcome of this work is to create an assistive device for cats with CH developed from a small two-wheeled self-stabilizing robot. Once created, the device will be tested on and off to determine the accuracy of counter torque and stability it had on the mass-spring system.

Section III: Project Goals and Methodology

Relevance/Significance

This relevance of this project stems from a lack of knowledge and assistance with small animals with cerebellar hypoplasia. Although this neurological disorder is not neurodegenerative, it can cause frustration towards the animal as they cannot climb, eat, or drink as efficiently as their peers (Hall, 2024). Therefore, designing a device that can mitigate these factors can allow the user to move more freely without needing constant support from an owner or a wall to keep them upright.

Innovation

Currently, there are few devices made to assist cats with cerebellar hypoplasia, and one device that was recently created was a wheelchair. This cart prevents the swaying/wobbling of the cats with CH because of snug PVC pipes that are attached to sides of their body while still allowing for free movement (Chang, 2024). However, this prevents cats from going up and down the stairs or jumping without needing their owner to remove them from the cart. Therefore, because this device strives for independence and the reduction of wobbles, it will be portable and worn to counteract the issue of it being stabilized on the floor.

Methodology

A vertical mass-spring system was set up to mimic the symptoms of a cat with cerebellar hypoplasia. A vertical mass-spring system is a mechanical system that consists of a mass on top of a spring where the force of the spring is determined by how far or compressed the spring is pulled. The more the spring is compressed or pulled, the stronger the force will push back (Masuzawa et al., 2018). The spring would be grounded while a stuffed animal would be placed on top of the spring. The stuffed animal would be pulled with the same force by using a protractor to pull the object back to the same degree every time. This would ensure that there are no extra forces affecting how long it takes for the object to get back to its center. Prior to creating the device, three datasets would be collected and averaged in order to ensure that the data collected on any of the trials are accurate and not skewed. Bar graphs can be created for the before and after of putting on the bodysuit to see the oscillation reduction and the time reduction. A line graph can also be created to also show the displacement over time, seeing how far the stuffed animal moves from side to side can show if the counter-torque device works in reducing the oscillations of the object.

Specific Aim #1:

Determine how cerebellar hypoplasia affects a cat's gait, coordination, and balance. The objective is to design a device that can combat the way cats with cerebellar hypoplasia leans from side to side through preliminary data gathered from a mass-spring system. Our approach (methodology) is to use a vertical mass-spring system to mimic the symptoms and actions of a cat with cerebellar hypoplasia. This will be compared with a gait with a cat without the disorder in order to determine the severity of how far a cat with CH moves from side to side. In the mass-spring system, the stuffed animal would be pulled with the same force by using a protractor to pull the object back to the same degree every time. This would ensure that there are no extra forces effecting how long it takes for the object to get back to its center. Our rationale for this approach is that the only difference in the gaits of cats with CH is the severity of their wobbling (movement of side-to-side). Therefore, the testing of how cerebellar hypoplasia affects a cat's gait should be through videos comparing the side-to-side action of a cat with and without CH. This will allow for better understanding of how much counter torque should be created for the cat to become more stabilized.

Justification and Feasibility

My methodology is relevant to help address the specific aim because seeing the gait from a mass-spring system is a more efficient way to collect data as it takes more time to constantly go to a cat with CH. In Figure 1, the side-to-side movement is most important, the linear regression shows the percent recovery vs. the percent of stride. The percent recovery shows how well a cat can convert potential energy to kinetic energy. So, the higher the recovery is, the better the energy conservation and gait is. When potential energy increases, the kinetic energy decreases. When kinetic energy decreases, potential energy increases. This is the pattern that cats should follow when they are walking. The diagonality (x-axis) shows how well the cat follows this pattern, and the higher the diagonality, the smoother the gait. The lower the diagonality, the wobblier the gait. This is important towards my project as it shows that using linear regressions to show the difference between cats without the disorder and cats with cerebellar hypoplasia. Using these percentages, it can be shown whether the cat has cerebellar hypoplasia or not from looking at this data.

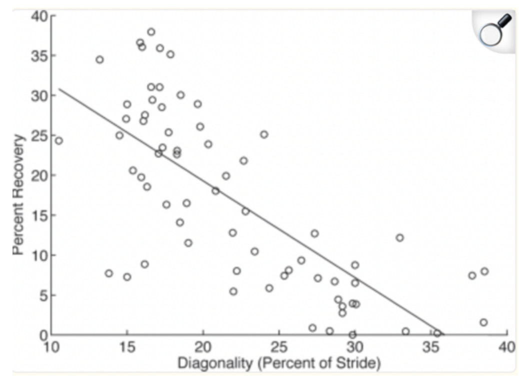


Figure 1: Percentage of Mechanical Energy Recovery vs. Percent of Stride (Bishop et al., 2008).

Summary of Preliminary Data

Figure 2: Photo of Vertical Mass-Spring System

Three mass-spring system prototypes were designed and created using cardboard, a spring, and weights comprised of cardboard on top. Each prototype had a different weight on top of the spring in order to explore the relationship between mass (grams) and the number of oscillations over time (seconds) because it will be necessary to determine how heavy the weight of the device should become. Figure 2 shows a photo of the vertical mass-spring system created that will simulate the cat with cerebellar hypoplasia. This mass-spring system was used to measure the oscillations over seconds and the velocity over time as well.

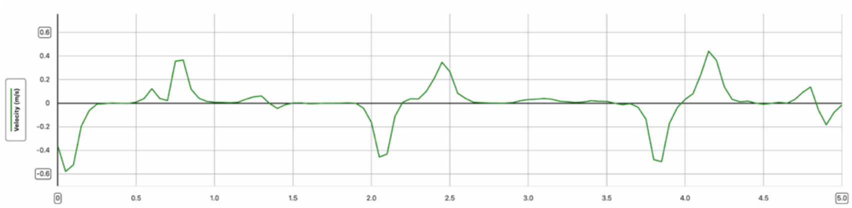


Figure 3: Velocity (m/s) vs. Time (seconds) - 13.4g

By creating a velocity vs. time graph in Figure 3, it provides a baseline for how severe the wobbling is present in a cat with cerebellar hypoplasia, giving information as to how much the wobbling should be suppressed.

Expected Outcomes. The overall outcome of this aim is to see the relationship between a cat's gait velocity and the toll cerebellar hypoplasia has on their day-to-day walking. This knowledge will be used for designing the bodysuit, it provides a clearer picture as to how much counter torque the brushless motors should be producing.

Potential Pitfalls and Alternative Strategies. We expect that there could be some overcorrection initially to see the fluctuations in the suit, which is where the mass-spring system comes into play. Because this system mimics the unexpected wobbling symptoms of a cat with cerebellar hypoplasia, it serves as a good system to test on before trying it on a live animal.

Specific Aim #2:

Determine the number of oscillations from moving from side to side. The objective is to determine the relationship between mass and the number of oscillations per second. Our approach (methodology) is to create a vertical mass-spring system and slow-motion capture the way the system moves to create a linear regression of what the equation is. Our rationale for this approach is because it gives me a better idea as to how heavy the weight of the bodysuit should be. It shouldn't be too heavy as it is being worn on a live animal, but enough to optimize the maximum stability this device can provide

Justification and Feasibility

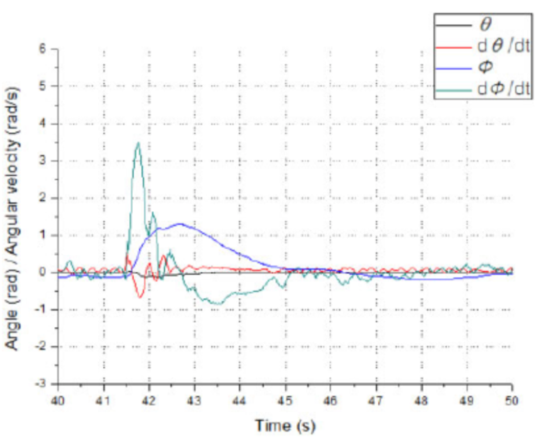


Figure 4: Angle (rad) / Angular velocity (rad/s) of robot body vs. Time (s) (Park & Cho, 2018).

According to Figure 4 in Park and Cho's article on self-balancing robots with a control movement gyroscope (CMG) from 2018, they were able to effectively utilize a CMG to engineer a robot called the KUWAY that could combat the heavy angular velocity and tilt produced by a large disturbance force through their use of the CMG. The CMG is comprised of a DC motor, flywheels, and gimbal stabilizers. The DC motor generates rotational motion and converts it into kinetic energy (KE), the flywheel constantly spins to store KE as a form of angular momentum. The gimbal stabilizer uses that momentum to tilt the box the CMG is stored in to constantly generate counter-torque that will bring the robot back to its center. Figure 2 shows the effectiveness in using the CMG because although there is a large dip in angular velocity as shown in $d\phi/dt$, the process in which they were able to recover had smaller increments of coming back to its center instead of dipping directly from 0, 5, 0, -2, back to its center, 0 rad/s (Park & Cho, 2018). The reason as to why this is relevant to the bodysuit is because the two-wheeled robot moves similarly to a cat with cerebellar hypoplasia (CH). They both only wobble from side-to-side, on one axis. Therefore, the way the KUWAY uses flywheels to generate the angular momentum will be used in the device for cats with CH through smaller brushless motors. As this device will be used on a smaller animal, a small brushless motor and a 3D-printed wheel will be used in place of the flywheel in order to produce the gyroscopic and counter-torque to prevent the cat from swaying from side-to-side, similar to the KUWAY.

Summary of Preliminary Data

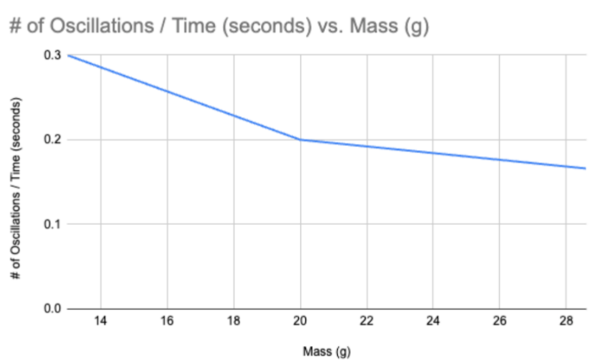


Figure 5: # of oscillations/time (seconds) vs. Mass (g)

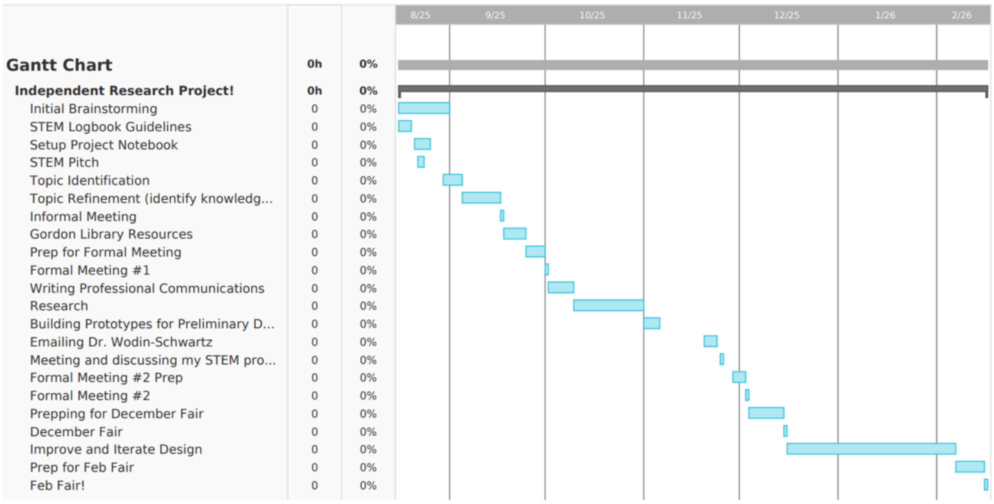
Expected Outcomes. The overall outcome of this aim is to determine how often a cat wobbles per second because the purpose of this device is to reduce the number of wobbling cats with cerebellar hypoplasia experiences on a day-to-day basis. By changing the mass used on the vertical mass-spring system, the weight necessary for optimal stability will be provided to receive the best outcome possible.

Potential Pitfalls and Alternative Strategies. We expect the graph to be linear, however because the calculations involved in determining the oscillations per second, the outcome may have been less accurate than expected. Therefore, a protractor will be used to ensure precise results and to mitigate any external factors that may affect the numbers on this graph.

Section IV: Resources/Equipment

Section V: Ethical Considerations

Section VI: Timeline



Section VII: Appendix

Section VIII: References

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