Convolutional Neural Networks for Automatic Cobb Angle Detection

Why Is Treatment for Scoliosis Stuck in the 5th Century?

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

What is AIS, and what are the treatment and detection procedures and outcomes?

Adolescent Idiopathic Scoliosis (AIS) affects up to 3% of children in the U.S., and approximately 5% of the global adolescent population. "Idiopathic" means that the condition has no identifiable causes, and AIS it is the most common form of spinal deformation.[1] This disease develops in late childhood and results in abnormal curvature of the spine. As the cause of this disease is unknown, treatment for correction arises once the disease physically presents itself. Symptoms include a prominence on the back or rib, shoulder height asymmetry, torso leaning, and lower back pain. A spinal exam is performed by a physician and multiple X-ray images are taken before official diagnosis.[10] Scoliosis is generally treated with one of two methods, a back brace or spinal fusion surgery. The discovery of scoliosis and both of these methods traces back to the Greeks of the classical era in 5th century BC.[11] More advanced and more desirable approaches remain undiscovered, but when taking the technology present today into account, the burning question is: Why? This piece will not only explore this question but also current treatment options and new potential approaches and projects.

Treatment

What do current treatment approaches look like externally?

It is estimated that 30,000 children are fitted with a brace and 38,000 patients undergo spinal fusion surgery. Additionally, females are eight times more likely to reach a curve magnitude that requires treatment.[9] But even today these methods still do not cure the scoliosis condition. Despite surgical fusion, curves still slowly increase throughout time with rather high

complication rates. Additionally, spinal fusion surgery results in a significant deduction in spinal movement and rotation, as fused vertebras can no longer function properly. Early detection of scoliosis is ideal and beneficial, as it helps in preventing and managing curvature progression. Cobb angle measurements of a curvature on an x-ray image is the sole means in determining scoliosis and treatment options, and evaluating treatment success, which is a condemning flaw in scoliosis management.[4] The Cobb angle is a measurement of the curvature of the spine. Specifically, a Cobb angle of at least 10º is defined to be Scoliosis (Bunnell WP, 2005). Within current approaches, the Cobb angle is measured by hand from an X-ray of the patient's spine, and this process and corresponding calculations actually takes a sufficient amount of the doctors' time that could be spent tending to other patients. Currently the process is prone to error as the doctor will use a ruler, pencil, and protractor to make the measurement (Safari et. Al, 2016). How can new and improved methods be constructed to give rise to more correct treatment regimens and diagnosis for patients, in addition to saving doctors time?

New Approaches

What are some new approaches and their respective adequacy?

There has been some improvement in current approaches, for example, one approach developed by a physician in Spain is a new type of brace. The brace is lighter than other traditional scoliosis braces, and thinner, so it does not get as hot. It is easier to take on/off and provides three-dimensional correction where as old braces only provide side-side pressure.[3] This method is effective although back braces are uncomfortably restrictive and cumbersome, and are not generally desired and accepted by patients. Another method is a new type of physical therapy, called Schroth exercises, developed in Germany and tailored over time by various

therapists across the world. The exercises are fitted to the patient-specific spinal curvature problems and focus on posture, strength, breathing and other life related aspects including self-image.[3] The efficacy of this method still remains vague. Despite these adjustments, both are not considerably practiced as current medical approaches. Although improvements have been made, successful ones are roughly based off of the two fundamental treatment methods, bracing or surgery, with no differential, noteworthy breakthroughs. Patients and doctors still remain at a standstill with treatment options, and unfortunately, since there is no care, many patients still suffer and live through pain management. Doctors are having to spend considerable time seeing and treating scoliosis as constant adjustments are needed to be made, scoliosis patients make more than 600,000 to private physician officials, taking time away from the doctor to see other patients in need.[9]

Inhibitions to Treatment Advancement

Why have more technically advanced methods been explored and conducted?

The lack of improved treatment methods is a result of scoliosis being a complex, metabolically-related, genetic disease. Scoliosis crosses over and is organized on multiple body systems far more than just the spine.[11] Since DNA codes for the basics and core of our body's organization, a mutation or variant within the genome can have a drastically negative effect on the overall performance of the gene, and cause a disruption in the production of necessary proteins, neurotransmitters, and hormones.[4] This disruption in brain-to-body communication becomes apparent when children with the genetic mutation for scoliosis begin to grow, resulting in Adolescent Idiopathic Acoliosis.[11] However, there is no "scoliosis gene," as the condition results from multiple genetic variants that alter the metabolic pathways to create the

neurotransmitter and hormonal attributes that cause idiopathic scoliosis.[4] More advanced methods for treating scoliosis genetic mutations would require identifying the mutations and interpreting them for proper treatment. Personal genetic testing services like 23andMe provide accurate and affordable genetic testing results to society but lack providing any meaning to the identified genes, such as how severe the defects are and to which metabolic process they are derived from.[4] Further clinical testing is necessary to locate the underlying cause, which is considerably costly. After highly specific information is discovered, genetic metabolic interventions and various gene therapy techniques can be used to alter the natural course of idiopathic scoliosis. However, not only is this very cost inefficient, but the efficacy remains unknown. This is because there lie many challenges with gene therapy and since it is roughly a newer field, the success and viability are still being explored. In gene therapy, improper targeting of the gene can cause random gene integration, certain aspects of the gene delivery can cause an immune system rejection response in patients, and the risk of disrupting normal functioning genes also presents as a major flaw potential. Additionally, gene therapy requires further skill training and funding for doctors, medical device companies/researchers, and hospital facilities. Gene therapy methods also undergo a rather extensive and long process of being passed for successful use. Methods must not only undergo amble and repetitive clinical trials, but also reach and transcend FDA, NIH or even congressional approval. Insurance companies with coverage policies are also a group to consider as development of new treatment methods requires creating a standard of use and sufficient evaluation of the approach, including its success rate, cost etc. On the other hand, with success, doctors' time will be saved and used more effectively, and patient overall well-being will be enhanced.

New Project Approach (CAPSTONE)

What is the capstone project and how will it be performed?

In response to the lack of more conspicuous approaches, we are designing a project to correct spinal deformity more accurately and efficiently. With respect to resource tangibility, as gene therapy remains costly, a more mechanical and computational approach to treating scoliosis is explored. Minimally Invasive Spinal Technology (MIST) is developing the Thoracolumbar Interbody ReAlignment (ThIRA^{TM}) system, which is a device implant for the spine that may be used to treat cases of spinal deformity at younger ages, thereby hindering excessive curvature growth. Working closely for MIST, my capstone project intends add to MIST's project, by designing and developing a curvature prediction method using computer vision aided neural networks. More specifically, the project will expand machine learning techniques in respect to image data analysis of an X-ray, in order to detect and diagnose scoliosis and measure the Cobb angle. Machine learning will allow the program to recognize patterns amongst large sets of data without being explicitly programmed to do a certain task, avoiding the innate human error present in current methods.[5] Technically speaking, the plan is to build a Convolutional Neural Network algorithm that uses machine learning techniques to recognize spinal X-ray image patterns to automatically determine Cobb angle among patients at risk for Adolescent Idiopathic Scoliosis. Neural networks, in their most basic form, are nodes which take in a single input or lists of inputs and perform a translation. In such networks, the set parameters, 'weights', perform the transformations on the inputs. By using machine learning, a network with optimized weights that performs at a desired accuracy can be obtained. Convolution is the result of taking the dot product between an input image, and a small, two-dimensional array, a "kernel matrix." A kernel matrix computes the dot product with the input image to create a block of the output image, and are then shifted along the image to generate corresponding values of output. Using the

convolution property to compute better features, which can be then used to classify images. Images will be obtained from the UVA hospital upon deidentification. By giving the program multiple images and their correlated Cobb angles, the program will become iteratively more accurate, ultimately yielding at least 80% angle detection accuracy (SHARMA S, 2019).

New Project Benefits

How will this new technology be beneficial and important to the involved groups

This technology will benefit the 6 to 9 million people in the U.S. who undergo imaging for scoliosis by automating this Cobb Angle detection process. Additionally, this new program will reduce the time doctors will need to spend on each patient, thereby increasing their total patient throughput.[6] It was calculated that the intended algorithm could save at least 15,800 physician hours per year across the US. This product is also crucial for MIST's business strategy. In addition to this project MIST has also developed a new long-term implant, that could fix scoliosis. Unfortunately, it will take multiple years to gain FDA approval. As such, MIST will use our product to increase income while trying to gain FDA approval. Though completion of the previously stated aims, we can accurately identify scoliosis among adolescents, increase patient throughput among doctors by automating Cobb angle detection, and strengthen MIST's scope in proactively identifying AIS cases throughout the U.S.

Conclusion

Considering the amount and degree of advanced technology we have today, it is almost unbelievable that stronger and more efficient methods, that are less invasive and cumbersome, have not been created and adapted. The types of scoliosis treatment methods currently used, the

back brace and the spinal fusion surgery, date back to ancient times, but the difficulty in inventing and creating new methods remains unfavorable and arduous. Concrete advancements seem to be limited unless independent and private associations invest time and money into further pathways and then reach hierarchal approval. Although this current lack of advanced practiced methods persists, the future in revolutionary approaches is promising. Companies like MIST and associated team members are actively seeking out and conducting work to improve and elaborate treatment methods. Genetically guided clinical tests are new innovative approaches that are being clinically tested for part of an overall more effective treatment strategy. Genetic approaches have the ability to allow for a future where scoliosis can be treated as a whole condition and not just as the resulting spinal curve.

References

1. Adolescent idiopathic scoliosis - Genetics Home Reference - NIH. (n.d.). Retrieved from https://ghr.nlm.nih.gov/condition/adolescent-idiopathic-scoliosis
2. Bunnell WP. Selective Screening for Scoliosis. Clinical Orthopaedics and Related Research®. 2005 May;434:40.
3. Children's Hospital. (2017, October 24). New Ways to Treat Scoliosis (Curvature of the Spine) without Surgery. Retrieved from https://www.chop.edu/news/health-tip/new-ways-treat-scoliosis-curvature-spine-without-surgery.
4. Genetically Guided Clinical Testing for Scoliosis. (n.d.). Retrieved from https://www.treatingscoliosis.com/scoliosis-genetically-guided-testing/.
5. Machine Learning: What it is and why it matters [Internet]. [cited 2019 Sep 22]. Available from: https://www.sas.com/en_us/insights/analytics/machine-learning.html
6. Patient throughput [Internet]. Cancer Therapy Advisor. 2019 [cited 2019 Sep 30]. Available from: https://www.cancertherapyadvisor.com/home/decision-support-in-medicine/hospital-medicine/patient-throu ghput/
7. Safari A, Parsaei H, Zamani A, Pourabbas B. A Semi-Automatic Algorithm for Estimating Cobb Angle. 2019 Jun 16;9:317–26. (3 in the paper)
8. SHARMA S. Epoch vs Batch Size vs Iterations [Internet]. Medium. 2019 [cited 2019 Sep 22]. Available from: https://towardsdatascience.com/epoch-vs-iterations-vs-batch-size-4dfb9c7ce9c9 (5 in the paper)
9. Scoliosis. (n.d.). Retrieved from https://www.aans.org/patients/neurosurgical-conditions-and-treatments/scoliosis.

10. Scoliosis Research Society. (n.d.). Retrieved from https://www.srs.org/patients-and-families/conditions-and-treatments/parents/scoliosis/adolescent-idiopathic-scoliosis.
11. Scoliosis Treatment: Past, Present & Future (Timeline). (2019, August 15). Retrieved from https://www.treatingscoliosis.com/BLOG/SCOLIOSIS-TREATMENT-HISTORY/.