

Enhancing Child Safety in Vehicles: Advanced Solutions for Mitigating Injury and Saving Lives

By Jonathan Z. Li

Author Biography

Jonathan Li is a freshman at McLean High School, where he has a passion for coding, science, and math. He dedicates much of his time to researching potential issues related to vehicle safety. Beyond academics, he thrives as the 1st chair cellist in the school orchestra, an avid artist and photographer, he finds joy in expressing himself creatively through various mediums.

Abstract

Despite significant advancements in vehicle safety technology, motor vehicle crashes continue to pose a significant risk to child passengers. This paper addresses the persisting issue of inadequate child safety measures in vehicles by proposing innovative solutions to mitigate injuries and save lives. Drawing upon original research and a comprehensive review of existing literature and safety data, this study explores the implementation of adaptive airbag systems tailored to the unique needs of child passengers.

The research methodology involves developing a video-based camera that accurately identifies infants, toddlers, and children within vehicles. Experiments and testing regimens determine optimal airbag deployment angles and forces based on passenger height and weight. Additionally, the paper discusses the integration of a system to adjust airbag deployment angles in real time, ensuring maximum protection for child occupants.

Consumer insights are essential, prompting a survey to gauge public opinion on current child safety measures and proposed solutions. The survey results highlight widespread concern among respondents regarding the effectiveness of existing safety precautions, particularly airbag systems.

Ultimately, this paper presents a holistic approach to enhancing child safety in vehicles, combining original research efforts with insights from existing literature to propose practical solutions. By implementing adaptive airbag systems tailored to the unique needs of child passengers, this study aims to significantly reduce the incidence of injuries and fatalities in motor vehicle crashes, safeguarding the well-being of young passengers for generations to come.

Keywords: Engineering Mechanics; Ground Vehicle Systems; Vehicle safety; Adaptive airbags; Vehicle collision protection

Introduction

After many decades of engineering efforts to improve vehicle safety, it has come to a point where the implements added have severely decreased the severity of collision car crashes for humans, helping save countless lives¹. However, there is an age group that is still heavily impacted by these accidents: children. According to the Centers for Disease Control (CDC)², 607 child passengers ages 12 and younger were killed in motor vehicle crashes in the United States, and more than 63,000 were injured in 2020; 711 child passengers ages 12 and younger were killed in 2021². These data indicated that children still need better protection against motor vehicle crashes. Additionally, safety procedures fail to prevent the irresponsible/dangerous actions (e.g. not wearing seat belts, crawling out of the seat belt, etc.) these unaware children do, also resulting in these young children being harmed.

We need to fix this problem quickly. This is for these children who, when faced with an unfortunate incident, are still able to see the light of tomorrow. Several design solutions can be implemented in modern vehicles to solve the problem. First, one option is setting up a sensor inside the seatbelt to detect if it was buckled on. From the information on [iihs.org](https://www.iihs.org)⁶, I learned that in current vehicles, we have sensors that detect if a seat belt isn't on⁷; however, that only applies to the front row. This implementation in the back can ensure that the safety belt is on, a step forward to increase the safety of toddlers/children. Second, the airbag deployment could be at a different angle based on the child's height. Due to children's short height compared to teenagers/adults, airbags do not deploy in the right position to help children in car crashes. Due to this, they receive the impact full force, along with potential injuries from the airbag itself. So, by reading about how airbags deploy from the Canadian National Transportation Agency (<https://tc.canada.ca/>)³, we can angle the deployment of the airbag depending on the child's height, which provides them with full protection from collisions in the future.

However, it is important to obtain consumer insights and preferences before more resources can be allocated to such research and development. Therefore, this study aims to collect consumer opinions on these two solutions and explore other possible solutions to minimize the fatality rate for children.

Method

Survey

To start, I will conduct a survey online by creating a Google Form to gather the opinions of several adults throughout nearby Virginia communities. I will ask the question "Do you think the safety precautions in the backseat of a car can protect children?" to which they will then answer "yes" or "no". After this, a follow-up question, asking them why they chose their answer. This will show what the majority think about current child safety practices and whether this research is crucial to conduct.

Airbags - Research

To initiate the research, the primary step involves developing a video-based camera system to differentiate between infants, toddlers, and children. Utilizing advanced computer vision technology, we will craft an algorithm capable of effectively identifying an individual's height and age. This information will enable the system to dynamically adjust the airbag within the vehicle to an angle where the head, shoulder, and chest are maximally protected. Moreover, the system will be able to discern supplementary elements, particularly those pertinent to child safety. Notably, this pertains to infants and young children in car seats. Once the camera identifies the presence of these supplementary extensions, it will proceed to validate their usage and subsequently factor in these external sources.

In addition to height, the video-based camera system will also incorporate a methodology to calculate the child's weight. The camera will be able to consider the subject's structural characteristics and height to assess and estimate the passenger's potential weight further accurately. This information will then be stored in the car's Electronic Control Unit (ECU) for further use.

Furthermore, a critical aspect of a child's safety within the system is their orientation and posture. To ensure the system functions effectively, the child must be facing forward and maintaining an upright sitting posture. To enforce this safety requirement, a dedicated camera system will continuously monitor children's posture in the vehicle's rear. If the camera detects any deviation from

the optimal position, it will transmit a signal to the car's control system, alerting the driver to the issue and prompting corrective action.

After developing this system to collect data from the passenger, our priority will shift to the derivation of a formula that computes the optimal release angle of the airbags concerning the height and weight provided by the video-based camera system. This endeavor will need a testing regimen involving a diverse collection of children and infant dummies with varying heights and weights to compute this relationship. Through simulated collisions and subsequent airbag deployments, we will record the impact points of three types of dummies: infant, toddler, and child. In these experimental trials, our primary focus will center on the impact points of the shoulder, head, and chest on the rear airbags. In these trials, our objective is to pinpoint the optimal positions for these body parts to ensure safe contact with the airbags and determine the precise angle at which these positions should be implemented to achieve maximum safety and effectiveness.

Furthermore, our research will examine the interplay between a passenger's height and weight during collision events. This analysis will then be used for us to create an equation that constantly calculates the optimal angle at which the airbag is positioned for a specific height.

Afterward, the insights gained from these experiments will then be gathered and examined to formulate an equation that consistently aligns the passenger's impact location with the optimal region of the airbag.

We will also acknowledge the significance of the force exerted by the airbag upon deployment. To attain an optimal balance in force exertion, we will continue our experimental efforts, concentrating this time on establishing a relationship between height, weight, and exerted force. Through systematic testing involving child and infant dummies of diverse weights and heights, we will collect data encompassing the impact of both the airbag deployment and the subsequent collision force between the dummy and the airbag. This data will then be accumulated to find the relationship between the 3 factors to find the optimal force needed to be exerted.

Airbag- Implementation

Following the completion of our research phase, our attention will shift toward the development of a system designed to adjust the angle of airbag deployment relative to the passengers' height and weight.

To achieve this objective, our focus will be an investigation into the dynamics of airbag deployment. This investigation will include emphasizing the triggers of deployment, the chemical processes in airbags, and the diverse systems of airbag configurations. We will then locate an area in the airbag system where our A.I. technology can be integrated successfully.

With this foundation established, we will then go through a series of rigorous innovation tests. The tests will involve the same child and infant dummies in the cars but with our adaptive system implemented to be tested with them. A series of trials will commence, enabling us to assess the fatality rates with our system in a car. If any areas of our project need refinement, we will then focus on fixing the flaws and further enhancing the efficacy of our system.

Results and Discussion

Survey:

From the 250 survey responses by Google Forms, around 76% think that the current safety precautions do NOT protect children from harm, while others think it does. Their reason for this answer all direct to one specific safety precaution: airbags. As stated by one of the respondents, "The airbag system especially concerns me. I don't feel safe for my children when acknowledging that airbags are the only safety precaution available for collisions."

According to the results, many people around the communities of Virginia does not believe in children being safe in the backseats and that the safety procedures don't protect the children entirely.

Video-based Camera System:

The camera that we will use is a pinhole camera. It can keep hidden in the car and efficiently give us the necessary information for the program to work. The video-based system will then revolve around the coordinate system.

Height:

The camera implemented will lay out an x-axis, y-axis, and z-axis on the ground and coordinate the following places: feet, knee, waist, chest, shoulder, and head. We will then use these key points and the distance formula ($\sqrt{x^2 + y^2 + z^2}$) to estimate the child/infant's height.

If there is any external material that lifts a child/infant's height, it will be thoroughly estimated from the width of the seat using image processing techniques. In these cases, the implemented coordinate system will only focus on where the bottom of the seat is and the layer where the child is sitting. Subsequently, we will use the distance formula to calculate the width and proceed to add the calculated value to the height of the passenger present.

Lastly, we will round to the nearest tenths and store the information in the database for further usage

Weight:

To estimate a passenger's weight, we first need to know their gender. Using the camera implemented before, it can then identify certain types of characteristics that can tell the gender of a passenger. After this step, the average weight per height for males and females can be estimated from the following tables [4].

Table 1 Females: *Height vs Weight* [4]

Height	Weight
33.7"	26.5 lb
37.0"	31.5 lb
39.5"	34.0 lb
42.5"	39.5 lb
45.5"	44.0 lb
47.7"	49.5 lb

50.5"	57.0 lb
52.5"	62.0 lb
54.5"	70.5 lb
56.7"	81.5 lb
59.0"	91.5 lb

Table 2 Males: *Height vs Weight* [4]

Height	Weight
34.2"	27.5 lb
37.5"	31.0 lb
40.3"	36.0 lb
43.0"	40.5 lb
45.5"	45.5 lb
48.0"	50.5 lb
50.4"	56.6 lb
52.5"	63.0 lb
54.5"	70.5 lb
56.6"	78.5 lb
58.7"	88.0 lb

Using these two tables, we are then able to determine the average weight corresponding to a passenger's height.

However, it's important to note that many, either underweight or overweight, might fall outside the typical weight range for their height. To address this, we can use the same coordinate system used to find height. By using the same methodology, we can derive the passenger's body width. If an individual has a broader and thicker body composition, the system will add an appropriate number of pounds to the average weight. Conversely, if a passenger has a leaner and slimmer physique, the system will subtract a certain number of pounds from the average weight. These adjustments are necessary to approximate the actual weight of the passenger better, increasing their safety during collision.

Posture and Orientation Check:

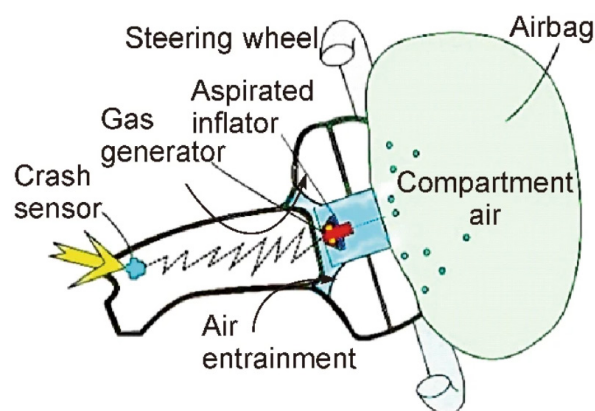
To assess a child's posture accurately, the video-based camera system will identify where the passenger's head and shoulders are. If the head and shoulder locations are relatively perpendicular to the

ground, then they are in the right position. If not, a signal will be sent to the car's control system to alert the driver of the corrective measures needed to be taken.

In addition to monitoring posture, the camera system will also gauge the child's orientation by tracking the direction of where their nose is pointing towards. The child faces the correct direction if their nose is oriented toward the camera. If not, a signal will also be sent to the car's control system to alert the driver of the corrective measures needed to be taken.

Airbag – Implementation

To implement this system, the part of the airbag system that we will modify is the part between the aspirated inflator and gas generator in the diagram below.



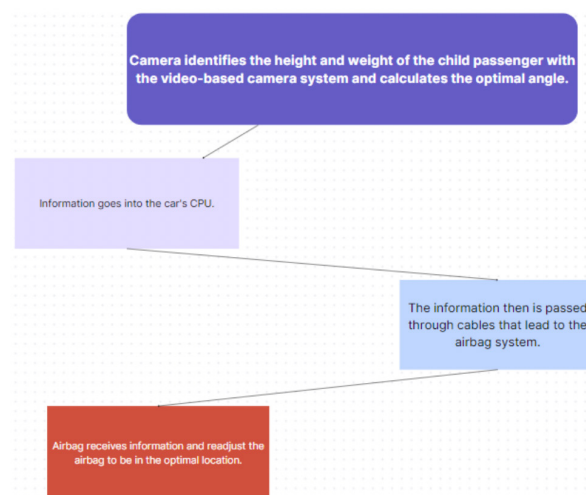
Figure/Image_X_Airbag Aspirated Inflator Operation [5]

In this section, we will create a designated surface for the aspirated inflator and its surrounding cushion to rest on. This surface will provide a stable foundation for the mechanisms already present in this design. We will then add a motor mechanism that will be affixed to this surface. This extension allows the surface to move up and down without problems.

A cable system will be established to connect the car's Electronic Control Unit (ECU) to facilitate the motor's movement based on the passenger's information. This cable system will serve as the passageway for crucial data, including the calculated adjustment angle and the force required to be applied. This entire process will be initiated once the passenger

enters the car, enduring that the airbag is positioned intelligently to provide the optimal safety measures in the event of an incident, as shown in the following diagram.

Image 1: Flow Chart of our Intelligent Airbag system



Conclusion

Across the nation, a distressing number of children are suffering severe injuries in car crashes, often due to inadequate safety measures. Despite the presence of various safety features within vehicles, these measures are predominantly targeted towards only teenagers and adults, leaving children unprotected. This issue is considered to be a problem by over 76% of citizens of a large community, as revealed in my survey.

Fortunately, my research proposes a solution that can change this forever. By integrating advanced video-based camera systems, we can accurately measure children/infant's height and weight. Subsequently, it will allow the airbag system to rotate to an optimal angle for the child. Furthermore, the airbag will then be programmed to exert a certain amount of force that will protect and not harm the child. This approach holds the potential to substantially reduce the likelihood of child injuries and, most importantly, save their lives.

With this project set in motion, it creates better safety for children/toddlers across the nation and puts them at less risk of losing their lives in accidents. This project improves the safety of everyone, which is a good step in the direction of car safety.

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References

NCHS Data Brief (No. 400, March 2021), Motor Vehicle Traffic Death Rates, by Sex, Age Group, and Road User Type: United States, 1999–2019, <https://www.cdc.gov/nchs/products/databriefs/db400.htm>

Child Passenger Safety: Get the Facts, Transportation Safety, Centers for Disease Control and Prevention, https://www.cdc.gov/transportationsafety/child_passenger_safety/cps-factsheet.html

Canada, T. (2013, December 10). How Air Bags Work. Transport Canada. <https://tc.canada.ca/en/road-transportation/publications/air-bag-deactivation/how-air-bags-work#:~:text=Air%20bags%20inflate%20when%20a>

Children's Wisconsin. "Normal Growth Rates for Kids | Children's Wisconsin." Childrenswi.org, 2022, <https://childrenswi.org/medical-care/adolescent-health-and-medicine/issues-and%20concerns/adolescent-growth-and-development/normal-growth>

Design of the Airbag Inflation System Applicable to Conventional and Autonomous Vehicles, Automotive Innovation, Volume 4, pages 390–399, (2021), <https://link.springer.com/article/10.1007/s42154-021-00156-y>

IIHS. (2015). Airbags. IIHS-HLDI Crash Testing and Highway Safety. <https://www.iihs.org/topics/airbags>

Occupant Detection for Seat Belt Reminders. (n.d.). IEE Smart Sensing Solutions. March 26, 2023, <https://iee-sensing.com/automotive/safety-and-comfort/seat-belt-reminder/>