# Automatic Stretcher Design

A Major Qualifying Project Report

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# Abstract

The objective of this project is to conceptualize and design an autonomous medial retrieval robot that would be deployed from an ambulance and retrieve a patient. The design of the retrieval robot is modeled to look similar to a modern stretcher. The Automatic Stretcher is able to retrieve an unconscious patient that is 6'-2" and 270 lbs. By using various tubes, motors, and gear systems, the robot is able to easily go under the patient and move them easily and without worry of any additional pain or injuries.

# Introduction

In modern times, automation has allowed many changes to take place, both good and bad. One major upside is that, with the increased output, more of a product can be produced, meaning more individuals have access to these resources. However, one field that is very slow to advance in this way is medical practices. Currently, every doctor and physician are an individual who has had to study their medical field for many years. They know their medical focus inside and out, but this system can cause problems. One issue that can arise was seen in the pandemic of 2020. Due to all doctors and related jobs being operated by a specific, finite set of individuals, doctors and nurses are unable to treat every patient during an influx.

This, however, can be remedied with the use of automation. A system has been devised to create a fully automatic doctor that will be able to see patients and perform whatever needs to be done to them. This system, dubbed the Automatic Physician, would be able to handle all areas of the patient's journey, starting with the revival once they are called in as injured. This project is a portion of the Automatic Physician system as a whole. This project is focused on the conceptualization and designing of an automatic retrieval system. This system would be deployed when a patient is called in and needs to be brought into a hospital. This system is intended to be with an ambulance, meaning it will double as a retrieval system and a temporary stretcher.

# Literature Search

This section explores the method in which a patient is retrieved by medical professionals and the use of other autonomous instruments that are developed and used for medical purposes.

## *Moving a Patient*

Moving a patient is quite an elaborate task despite how it may initially sound. Unlike picking up a friend just by lifting them, an injured or unconscious patient is a far more troubling individual to move. Since an injured person is unable to move themselves or offer too much assistance when moving themselves, the process to lift them must be modified and will greatly depend on the situation. As stated by emt-training.org, in a safe environment and with a stable patient, one should "always suspect a spinal injury" as this will ensure that the patient is always safe and will not have any new injuries added to them during the moving process. With this assumption in mind, an individual should not try to move a patient by themselves as they can inadvertently cause rotation of the patient, potentially making an injury worse. If there is no spinal injury, then a number of methods to lift and move the patient can be employed. This can range from two person carries, either in a cradle position or via their extremities, or one person movements, like a direct carry or a blanket drag (emt-training.org).

Other methods of movement involve the use of various carrying devices, both medical equipment and improvised. This can range from wheeled stretchers, which are located in hospitals and emergency rooms, to having a patient in a chair or a blanket carried or dragged respectively. While these methods of movement will occasionally require some form of special equipment, they are far safer and more recommended (Hopper Institute). These methods are preferred since they will lead to a lower likelihood of injuring the patient or one of the rescuers.

A common trend among both Hopper Institute's training page and emt-training's website, the most important rule to remember is for the rescuer to be safe and not injure themselves trying to help another person. Both pages constantly remind the viewer to be safe and use proper lifting form, ensuring they are not going to slip, and they are not pushing or pulling a stretcher if it's at certain heights. While this reinforcement may seem odd, it is highly important that it is followed by both the emergency service team and any civilian trying to assist. According to FEMA the "average number of emergency medical technicians injured annually between 2008 and 2016 was 23411" (FEMA). An individual trying to help a patient should always be careful and aware of their surrounds and what their body can take, else they risk becoming a second victim. By using portable rolling stretchers this risk decreases as they will be less likely to hurt themselves while moving the patient.

## *Autonomous Systems in Hospitals*

Autonomous vehicles in hospitals were created with the primary goal of transporting patients to various locations without the need for a human to be present. In 2021, an article on springer was published describing the testing of the Connected Driverless Wheelchair. As the name implies, it is a system integrated into motorized wheelchairs that can transport patients reliably, on time, and even across various floors. The Wheelchair is driven using a joystick and two motors, including an environmental sensor and a human-machine interface for real-time information and interactions. As Baltazar explains, the most important aspect is the hospital integration to the system, including elevator controls and patient information. With their system integrated to the hospital, they are able to have the wheelchair automatically go and retrieve a patient and travel anywhere in the hospital with ease. Additionally, the patient also has the option to manually drive the wheelchair.

At the same time, Connected Driverless Wheelchair is not the only system of its kind. A product called Intelligent Wheelchair is a similar device meant for the use of the physically disabled and has many different types of drive systems. These wheelchairs are able to be controlled via voice, hand, face, and head gestures, while maintaining the ability to navigate autonomously as needed. They also are able to connect to not only elevators, but also other service robots and other wheelchairs. This level of interaction allows a wider variety of users to have access to these wheelchairs.

Seeing how both systems are automated driving vehicles for patients inside of hospitals when a staff member cannot be present. Since hospitals are integrating these vehicles into their systems to allow more mobility, it is far to assume that they would also implement a similar system for patient rescue and retrieval if possible.

# Design

The main design of the Autonomous Stretcher is presented in this section. It explains the main goals and objectives the design must achieve, the design itself, and an explanation of the choices made.

## *Objectives:*

The objectives for the design were divided into three main categories, patient requirements, environmental challenges, and robotics.

The patient requirements are what the design should be able to address at a minimum. The requirements are as follows:

1. Height is 6'-2".
2. Weight is 270 lbs.
3. Patient is unconscious.
4. There are no visible injuries to the patient.

The height and weight were chosen for ease of collecting the position and weight requirements. The selected height and weight are well above average for the United States, which currently stands at 5’9” and 180 lbs., respectively.  If the robot is able to move someone in this range, it will be to secure any patient below this range to the stretcher. The requirement for the patient to be unconscious with no visible injuries is solely to eliminate any potential of the patient moving or assisting the robot. This will eliminate other factors such as the patient sitting up or trying to lie on their side. While the latter scenarios are possible in real-life cases, for this design it will not be a factor.

For the next set of requirements shown below, the environmental obstacles were considered. These requirements are focused on the surroundings of the patient and not directly related to their bodies.

1. The environment is well lit.
2. The medical emergency will occur on flat ground with no major obstacles on the path of the stretcher.
3. There are no weather conditions.

Having the environment well-lit will remove any potential problems with nighttime operations or operations being obscured by shadows. While shadows and nighttime operations may be encountered, it will not be considered in this design. Similarly, the ground being mostly flat removes any potential issues related to hills or having to get around some major obstacles. Since there are no weather conditions, like rain or snow, they will not be considered as a factor in the design.

The final set of requirements are around the design itself. These conditions are what the design must incorporate that are not covered in the previous two sets of requirements. The requirements are as follows:

1. Must be able to move in any direction.
2. The bottom edge must reach the same height as fixed stretchers, i.e., 0’-0” to 3’-0” range.
3. Self-contained power source, excluding computation or AI if used.

Requiring the robot to move in any direction allows for the design to not be worried about the way the robot must move to retrieve a patient. This will allow the design to be more focused on retrieval and not as much movement. The bottom edge requirement allows for the robot to lift as high as common stretchers, allowing to place the patient on a separate stretcher or bed as needed. This will allow the users to be more easily able to choose where and on what the patient will be lying on. Lastly, the requirement about the power source is to allow the automatic stretcher the ability to be off the grid, and work in regions with no access to electricity.

## *Automatic Stretcher Design*

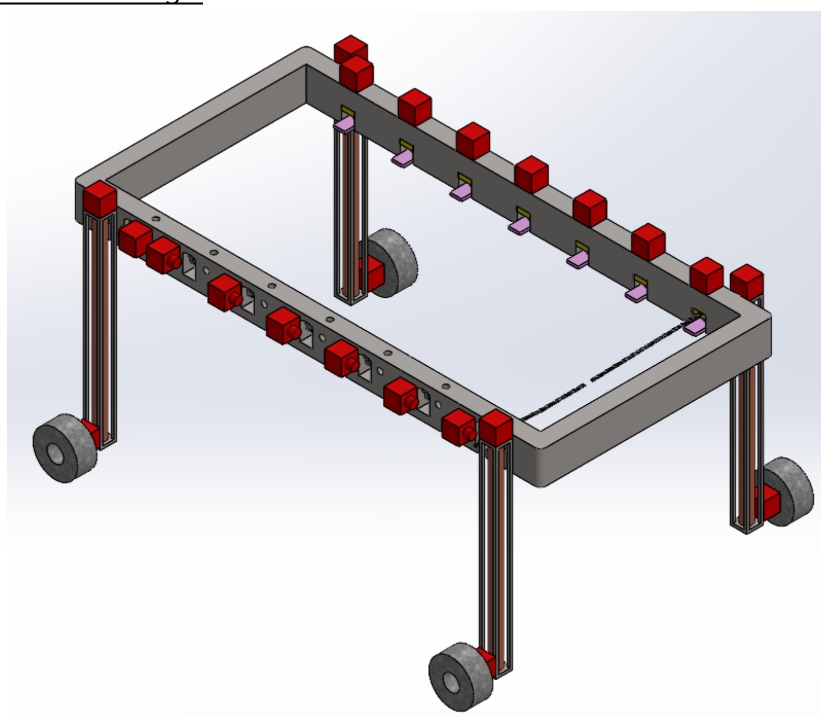

*Figure 1: Automatic Stretcher Full SolidWorks Model*

As shown in the image above, the Automatic Stretcher is designed to be fully electric. Beginning at the bottom, the stretcher will have 4 Omni-wheels, allowing for movement in any direction. While these wheels in the model are not shown as Omni-wheels, they are modeled from of commercially available 8" omni-wheels. Each wheel will have its own high torque low rpm motor. This will allow the robot to move carefully and slowly with a patient.

Each wheel will be attached to a "leg" system to allow the stretcher to change height. It uses a simple worm gear like leg with a motor at the top spinning the gear. While each leg can be spun separately, they will be controlled together and will use higher speed DC motors. This will allow the legs to draw less energy overall and move the bed up and down.

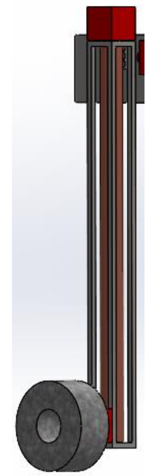

*Figure 2: Wheel and Leg System*

The main frame of the robot is 7' by 3.5', giving an inner bed dimension of 6.5' and 3' respectively. This will allow someone of the specified size of 6 '2 to have some extra room on the bed, giving the robot adequate margin of error. The frame has porthole-like cut outs in the body, where the stretcher would deploy its arms.

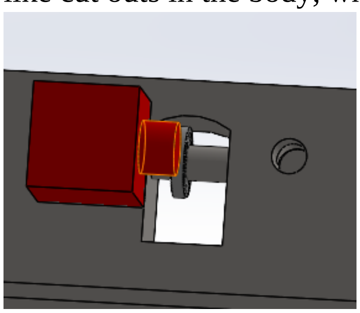

*Figure 3: Flywheel System and CO2 output hole.*

Using a flywheel style feeder, cloth and plastic tubes with metal chain cores are fed through the holes and worm their way under the patient. Once on the other side, a combination of electromagnets and motorized vice clamp down on the other end of the tube ensures a strong connection. Once the tube is secured, $CO_2$ cartridges will be released, inflating the tube to give a more stable platform and create a bed in the stretcher. After the tubes are all inflated, the robot will be able to lift itself and the patient up and maneuver itself to its next location, whether that be a more person friendly stretcher, an ambulance bed, or some other system entirely. The system will be running off of 2 deep cycle marine batteries as that will have enough power across all the systems to function. The entire system will be able to recognize the patient using 4 cameras, each mounted onto the inner corner of the leg frames, and using AI, would be able to identify, recognize, and retrieve the patient as needed. The entire system on the robot will be controlled by sets of micro controllers and motor controllers as necessary.

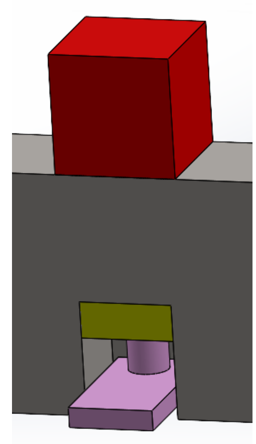

*Figure 4: Vice and Electromagnet System*

## Analysis and Recommended Parts

For this section covers the main analysis of the robot and make recommendations. These recommendations will consist of commercially available parts where appropriate.

### *Wheels*

In its current state, the full system, as shown above, is roughly 1660 lbs. This number is a conservative estimate. It is assuming that under full load with patient and any other parts that are not modeled, the total weight will be roughly 2000 lbs. While this may be a very high estimation, it is safe to assume that there will be some discrepancies between the modeled weight and the actual weight of the system.

Using this assumption, the omni-wheels will need to be able to hold 500 lbs. per wheel. On McMaster-Carr, the 8” Omni-Directional Wheels made of aluminum are rated for that 500 lbs. limit. While these wheels are readily available, they do pose a concern about that 500 lb. limit being exceeded very quickly if there is a small bump or rock, making one wheel take on more weight than the others. For this reason, it is recommended to have stronger omni-wheels that can take more weight imposed on the stretcher.

### *Motors*

As mentioned above, this system will be using various types of motors. Many of the motors serve very different roles, meaning that no singular type of motor can be used. For the driving motors, high torque motors are needed. This is so that the stretcher can always move regardless of the load and will not be moving nearly as fast. A NEMA 34 would be able to accomplish this role, as their holding torques can range from 470 to 2124 in.-oz. Despite this number being a holding torque, this will give adequate torque to the wheels even at a slow rpm. Next is the motorized legs. As stated before, a DC motor will be used for the spinning of the worm gear on the legs. This selection depends far more on the chosen worm gear selection to determine an adequate motor. A DC motor is the most versatile for this role, having many variations and differing specifications. This allows for the worm gear to be selected properly. For the worm gear, McMaster-Carr has many selections for a high strength threaded rod. A strong 36” steel threaded rod will work, but to reduce the electrical requirements from the DC motors, a rod with more threads per inch will be preferred. For the flywheel system to push the chain is not a major concern. A high torque motor is recommended for this application. This will move the roller chain more easily and allow it to push through if it is stuck. This will also allow the robot to pull back on the chain once the other side has been secured in place, creating some tension, and slightly lifting the patient. Lastly, another high torque motor will be needed for the vice clamp system. A high torque motor will allow the vice to tightly grip the tube even when it inflates. For both of these situations, the 12V Round-Face Motor from McMaster-Carr can be used as the 3000-rpm motor operates at 21 in.-oz. of torque. This will allow both the chain to be pushed easily and the vice clamp to hold strongly.

### *Clamping System*

While it may not seem necessary, an electromagnet is used in conjunction with the vice clamp system to hold the chain in place. The electromagnet will be used to hold the chain in place as the vice clamp is being closed on the tubes. Currently, there are commercially available electromagnets that have a pull strength of up to 600 lbs. Currently, the patient, on any given tube, puts at most 120 lbs. onto the tubes, meaning that the more energy efficient 10W, 160 lbs. electromagnet can be used. This also allows the potential to keep the electromagnets on and pulling the tube even with the vice closed, ensuring that if the vice opens for any reason, the tube will not fall.

## Ethical Discussion

Ethics and engineering go hand in hand. If engineering is done without understanding the inherent costs associated with it, a project may end up hurting everyone in the long run, even if it was done with good conscience. This section will touch on how this project is ethically considered. Additionally, while this project is a portion of the fully Automatic Physician system, we will not be going into the ethical costs of the full unit and will only cover the stretcher itself.

The Automatic Stretcher, much like many other automated fields, will displace a number of individuals due to a loss of job. This will affect those individuals whose entire livelihood depends on being first responders. However, while it will affect the lives of the first responders, it will have two major upsides to it. While the system is self-contained, the maintenance of the system is not. This will open new jobs for those first responders, technicians for the stretchers and ensuring they are ready and equipped to take on the next job. Additionally, when paired to a self-driving ambulance system, the Automatic Stretcher will give the opportunity to reach patients in more areas, more specificity, areas where there may not be many first responders. Having a system that can respond to emergencies automatically when no one else may have been before is a very impactful outcome.

Not only can the Automatic Stretcher help many people, but it is also designed with the environment in mind. The stretcher is designed to be fully electric, meaning that it won't be outputting dangerous greenhouse gases directly into the air. On the negative side, while the robot itself may not be putting out emissions directly, the system will still, most likely, be charged up using fossil fuels or slightly cleaner nuclear power. However, this negative can be negated if electricity is made using renewable sources instead of the more common and polluting methods.

## Future Work and Recommendations

The design of the Automatic Stretcher was produced for the purpose of retrieving patients from a situation safely and efficiently, in order to be used in a larger Automatic Physician system. By modeling the stretcher to easily lift and move a patient that is above average in size and weight allows the robot to more easily respond to a large portion of case that may be called in. The Automatic Stretcher is able to move in any direction and easily pick up an injured individual, allowing the patient to be quickly moved to where the patient needs to be. At this stage of the project, the largest recommendation is to begin physical testing, in both small scale and full size, partial prototypes to get a full understanding of the limitations of the system. While a design can work on paper, physical testing and iterations are needed to improve the design. This testing and iteration will allow both the Automatic Stretcher and the Automatic Physician system as a whole to run more efficiently.

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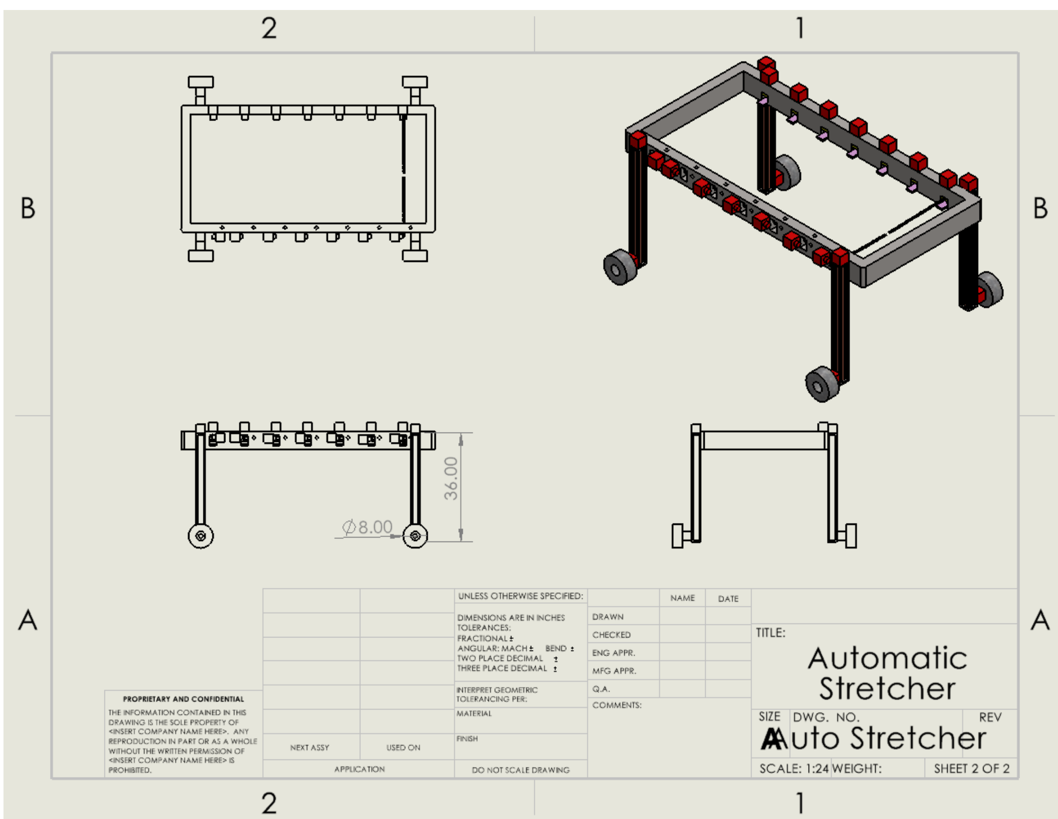
# Appendix

## *Appendix A: CAD Drawing of Model*



*Appendix B: CAD Drawing of Body*