KAUNAS UNIVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

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RESEARCH OF THE VEHICLE FOR CARRYING DISABLED PERSON ON THE STAIRS

Final Master's Degree Project

Supervisor
Prof. Hab. Dr. Vytautas Ostaševičius

KAUNAS, 2016

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DEPARTMENT OF MANUFACTURING ENGINEERING

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Mechatronics (code M5096M21)

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Mechatronics (code M5096M21)
(Title and code of study programme)

"Title" of final project

DECLARATION OF ACADEMIC HONESTY

1 June 2016
Kaunas

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Study area and field: Production and Manufacturing Engineering, Technological Sciences

Key words: machine, security, wheelchair, microcontroller, mechanical system, stairs

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SUMMARY

The final Master‘s project examines manufactured prototype of stair climbing wheelchair. Real time tests were performed to evaluate wheelchair performance. Test shown that technical issues such as frame rigidity, seat repositioning, safety and control should be solved. New design for the frame was created. Simulations were performed to evaluate rigidity of a new frame design. Together with new frame design more comfortable and safer chair was suggested. New control system (Arduino Uno R3) and safety sensors (ultrasonic sensor) were implemented to create smoother and safer ride.

Vytautas, Kizys. Vežimėlio skirto vežti neįgalųjį ant laiptų tyrimas. Magistro baigiamasis projektas / vadovas prof. habil. dr. Vytautas Ostaševičius; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas, Gamybos katedra.

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Reikšminiai žodžiai: mašina, saugumas, mikrovaldiklis, neįgaliųjų vežimėlis, laiptai

Kaunas, 2016.

SANTRAUKA

Galutinis magistro darbas nagrinėja pagamintą laiptais lipantį vežimėlio prototipą. Realūs bandymai buvo atliekami siekiant įvertinti vežimėlio galimybes. Bandymai parodė, kad reikia išspresti šias technines problemas: rėmo standumą, sėdynės padėtį, valdymą ir saugos sitemą. Naujas rėmo dizainas buvo sukurtas. Naujo rėmo konstrukcijai buvo atlikti įtempių modeliavimas naudojant „Solidworks“ programą. Nauja valdymo sistema (Arduino Uno R3) ir saugos jutikliai (ultragarsinis jutiklis) buvo įdiegti siekiant sukurti sklandesnį važiavimą.

KAUNO TECHNOLOGIJOS UNIVERSITETAS
MECHANIKOS INŽINERIJOS IR DIZAINO FAKULTETAS

Tvirtinu:

Gamybos inžinerijos katedros vedėjas ____________________ *(parašas, data)*

Kazimieras Juzėnas
(vardas, pavardė)

MAGISTRANTŪROS STUDIJŲ BAIGIAMOJO PROJEKTO UŽDUOTIS
Studijų programa MECHATRONIKA

Magistrantūros studijų, kurias baigus įgyjamas magistro kvalifikacinis laipsnis, baigiamasis projektas yra mokslinio tiriamojo ar taikomojo pobūdžio darbas, kuriam atlikti ir apginti skiriama 30 kreditų. Šiuo projektu studentas turi parodyti, kad yra pagilinęs ir papildęs pagrindinėse studijose įgytas žinias, yra įgijęs pakankamai gebėjimų formuluoti ir spręsti aktualią problemą, turėdamas ribotą ir (arba) prieštaringą informaciją, savarankiškai atlikti mokslinius ar taikomuosius tyrimus ir tinkamai interpretuoti duomenis. Baigiamuoju projektu bei jo gynimu studentas turi parodyti savo kūrybingumą, gebėjimą taikyti fundamentines mokslo žinias, socialinės bei komercinės aplinkos, teisės aktų ir finansinių galimybių išmanymą, informacijos šaltinių paieškos ir kvalifikuotos jų analizės įgūdžius, skaičiuojamųjų metodų ir specializuotos programinės įrangos bei bendrosios paskirties informacinių technologijų naudojimo įgūdžius, taisyklingos kalbos vartosenos įgūdžius, gebėjimą tinkamai formuluoti išvadas.

1. Projekto tema Laiptais vežančio roboto prototipo tyrimai / Research of stair carrying robot
Patvirtinta 2016 m. gegužės mėn. 3 d. dekano įsakymu Nr. V25-11-7

2. Projekto tikslas atlikti tyrimus laiptais vežančio roboto prototipui ir pateikti pasiūlymus tobulinimui
3. Projekto struktūra konstrukcijos tobulinimas, saugumo sistemos įdiegimas, roboto automatizavimas, pirštų sistemos valdymo pakeitimas iš mechaninio į elektromechaninį
4. Reikalavimai ir sąlygos robote užtikrinti keleivio saugumą, sugebėjimą užlipti laiptais ar šaligatviais. Sukurti lengvą roboto valdymo sistemą.

5. Projekto pateikimo terminas 20__m. ______ mėn. __ d.

6. Ši užduotis yra neatskiriama baigiamojo projekto dalis

Išduota studentui Vytautui Kiziui

Užduotį gavau Vytautas Kizys __________
(studento vardas, pavardė) (parašas, data)

Vadovas Prof. Hab. Dr. Vytautas Ostaševičius __________
(pareigos, vardas, pavardė) (parašas, data)

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INTRODUCTION

One specific area of need is that of providing increased freedom in terms of mobility for the elderly or disabled. The main reason is to provide decent quality of life for the disabled or elderly.

For most people getting older means that health will be worse, one of issues is to get up and down the stairs or total loss of capability to walk. That means that person will be running of options. The options depend how disabled person is. It ranges from moving a one floor house or just living in first floor, or installing adaptations, such as rails or a stair lift also independent stair climbing machines. Option to use just first floor can be not suitable because of lack of space in first floor and moving to another place it can mean that it will be harder to reach loved ones and allow it is expensive. So, only two potential solutions are left: rails or a stair lift and independent stair climbing machine. These two solutions can be used together one for outside another for inside or independent stair climbing machines for both.

This Master's project is focuses on stair climbing machine for the elderly and disabled people that can safely carry people outside and inside home and that can pass obstacles such as stairs.

Aim of Master work:

- Investigate stair carrying wheelchair prototype and make proposals for improve.

Objectives:

- Improve design.
- Calculate stresses of the frame using "Solidworks".
- Create control system for wheelchair.
- Create safety system.

Software:

- Microsoft Office 2010
- Adobe Photoshop
- SolidWorks
- Arduino
- Fritzing
- AutoCAD

1. REVIEW OF EXISTING STAIR CLIMBER

Any of disability is very prevalent because of advantages of technology. As technology developed more machines are created that increase life quality of impaired peoples. One of aria that are emerging is wheel chair that can help peoples with hoe can walk. It includes old peoples that are losing capability to walk.

1.1 Track based stair-climbers

Track based system is more suited to overcome rough terrain. It uses more energy than standard wheel system to run. One of solution is to use double system that transform from wheel chair system to track system.

Advantages:

- Can be used at some indoor stairs and at almost all outdoor stairs.
- Simple construction and operation.
- Autonomous stair-climbing capabilities.
- Ability to carry standard wheelchair up the stairs.

Disadvantages:

- For climb stairs it must ride backwards while climbing.
- Unsafe because it can be unstable on indoor and some outdoor stairs, because not enough space.
- Some of mechanism needs additional systems that can change from straight drawing to angular while stair-climb.
- Weight of machine (because of additional systems for stair-climbing capabilities).
- Non slide system have to be implemented (on tacks can be implemented knobs or bums that prevents sliding)

Some existing track based stair-climbers are analysed.

Stairmax

Person that uses wheelchair day to day and need freedom of mobility to overcome stairs, the Stairmax is helpful supplement.

Stairmax a stair lift is stair lift that doesn't need any rails. It is cost saving machine which is compatible with standard wheelchair and has unique stair climbing system. To drive up and down straight stairs it uses electrical system of Stairmax that eliminates need of building expensive lift for persons with needs.

Fig. 1.1 Stairmax [1]

Main features of such stair lift are mobility, independence, simple handling and robustness. Simple construction of this mechanism insures that it won't malfunction and that increases safety of driver and easy maintenance of this stair lift.

Stairmax is tracked stair climber which is capable to ride just up to 35 degrees slope and steps which length no less than 220 mm.

Characteristics [1]:

- Dimensions - 1473x635mm
- Dead weight - 54 kg
- Motor – 12 V
- Speed upwords – 6,5 m/min
- Speed downwords – 7,7 m/min

TopChair

TopChair is powerful wheelchairs with capabilities of going up and down the stairs. This wheelchair is two in one, by transforming between track driving mechanism and wheel driving mechanism. The wheelchair climbs stairs by using loop track belts (Fig. 1.2).

Fig. 1.2 TopChair (modelis) [2]

And on strait tarmac it uses standard four-wheel system with two drive wheels. To switch between riding on straight surface and stairs all wheels has to be pulled up until track system touches ground. And like in most wheelchairs chair, the seat has to tilt when riding on stairs to get horizontal sitting position.

Fig. 1.3 TopChair (model S) [3]

Characteristics [3]:

- Overall length with footrest – 115 cm
- Total height - 128 cm
- Width – 69 cm
- Empty weight of TopChair – 145 kg
- Maximum user weight – 110 kg
- Maximum speed on wheels - 9,2 km/h
- Maximum speed on tracks 0,7 km/h
- Distance of travel – 35 to 48 km

The Tankchair:

Tankchair is big and very stable wheelchair, so for driver it gives sense of safety and security. But one off the worst characteristic of this machine is size. Because of its size it is impossible ride inside the house and the driver has to have another wheel chair which is fitted riding inside the house. Another side of size is capability to go through very ruff surrounding like rubble, in to hills and also on outside stairs. Wide tracks give capability to ride over the snow so it is usable at winter like most anthers isn't.

Fig. 1.4 Tankchair [4]

Most chairs are custom made so they slightly different, but they still are built on same chassis.

Characteristic:

- Parameters: wide - 164 cm, high – 147 cm, length 140 cm
- Chassis weight – 250 kg

1.2 Stepping wheelchair

Stepping wheel chairs is difficult in design but is easy to control for driver. Peoples that have difficult time to control all of theirs bodies can drive this wheelchair with ease.

Abilities:

- It is very stable.
- It can overcome high curb.
- It has high mobility inside and outside.
- It is easy to control.

Disadvantages

- It has large turning circle
- Heavy (weight depends from applied drive system)
- Some existing stepping wheelchairs are analysed.

Manus wheelchair:

Manus is quite old mechanism that was design to climb stairs. It uses little fingers that can fold in to wheel and unfold. When it is folded in to the wheel it looks like rubberized wheel (Fig.). When it is unfolded, fingers expand from the wheel that are fixed on springs. Fingers hook on the stair tip and little by little machine go up the stairs. This prototype did not used batteries because they were very heavy instead it was powered directly through wire. But it concept started innovations in to climbing machines that can carry peoples up and down stairs. [5]

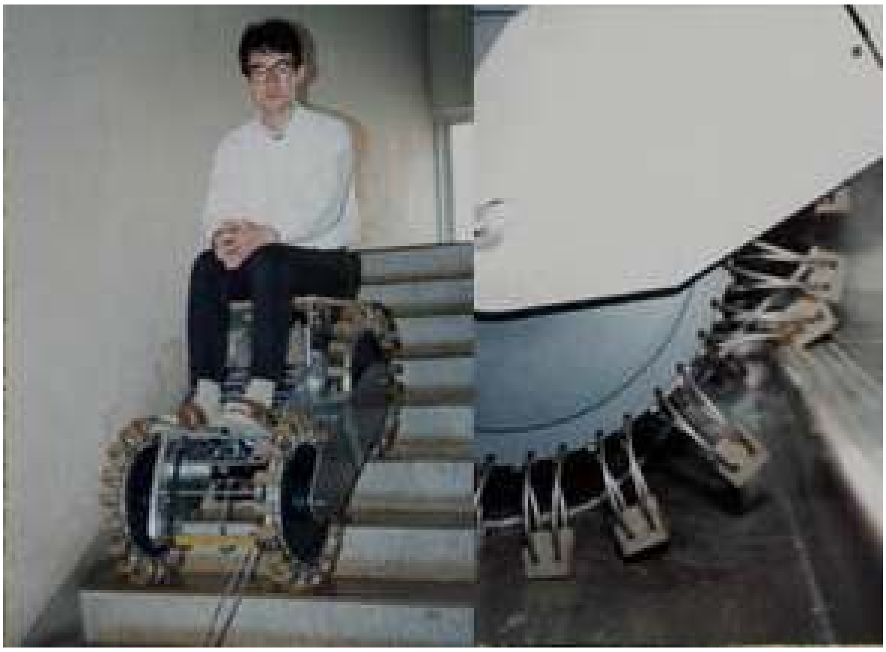


Fig. 1.5 Manus [5]

Galileo Mobility Wheelchair:

This wheelchair combines two systems of stair climbers, track and wheel drive system. This (Fig. 1.6) prototype wheelchair takes best from two drive systems, from wheel it takes speed and from track system it takes capability to ride up and down the stairs.

Galileo mobility wheelchair is very similar to Manus climbing system. Then track is folded in it becomes regular wheel same as in Manus machine. Another similarity is that when it unfolded it uses grooves in track to hang to the stairs edge (Fig. 1.6).

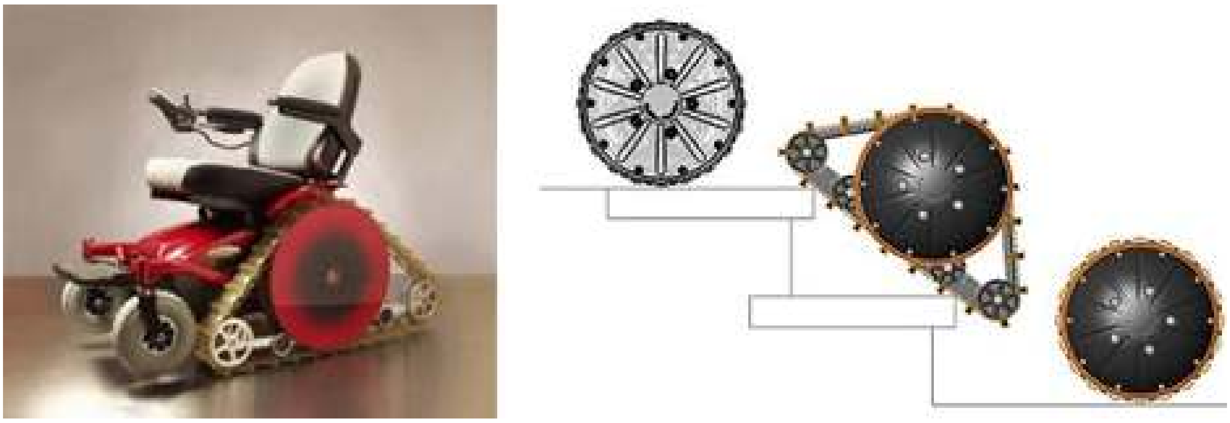


Fig. 1.6 Galileo Mobility Wheelchair [6]

1.3 Multiple wheels, stair-climbers

Multiple wheels combination is simple system. This kind of system is widely by delivery company to transport packages to the apartments that does not have lift. This system wheelchair uses three or more wheels to climb the stair. Most common system is using three-star wheel configuration (Fig 1.7).

Fig. 1.7 Three-star system [7]

Advantages:

- Capable to overcome almost all stairs (depends from stairs and wheels dimensions).
- Ability to climb stairs.

- Lightweight
- Compact
- Easy construction

Disadvantages

- Ride can by uncomfortable.
- It can require some assistance from another person.
- Battery powered stair-climbing wheelchair

Battery powered stair-climbing wheelchair:

This wheelchair uses similar system as three-star wheel cart. But it does not require the extra men power as standard three-star car, and also it can carry person. However, it still needs some help to guide machine when climbing up stairs. When it rides on straight tarmac the ride is very smooth and easily controlled.

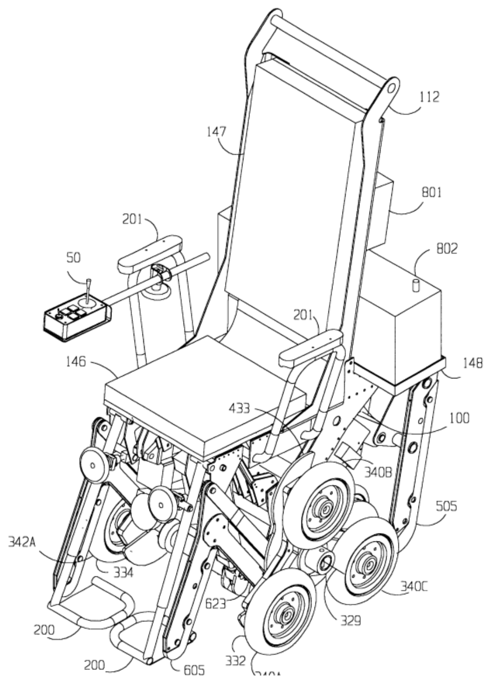


Fig. 1.8 Battery powered stair-climbing wheelchair with tri-star wheel configuration [8]

1.4 COG multiple wheels, stair-climbers

Advantages:

- It can run as stair climber or general purpose powered wheelchair.
- Capable to run in different environments as gravel, sand uneven surface and ride to slope or 25 degrees.
- Suited to climb almost all stairs.
- Compact.
- Light.

Disadvantages

- Have to climb stairs backwards.
- Expensive.
- Need assistance.
- Hard to control when climbing stairs.
- Balancing this machine on two wheels can be unsafe.

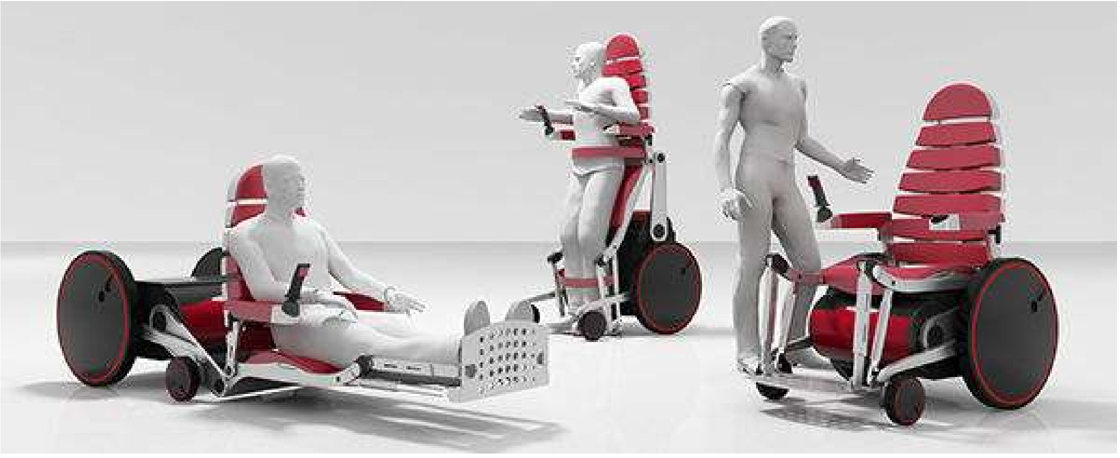


Fig. 1.9 Convenient Convertible Wheelchairs [9]

This wheelchair conception has many advantages but it still in designing phase. Unlike the conventional assistive seat on wheels, this can lower person or put him to standing. Then it puts person in standing position belts holds in the place driver. This mobility of chair gives person with disabilities the aid to reach things that in standard wheelchair will be impossible reach.

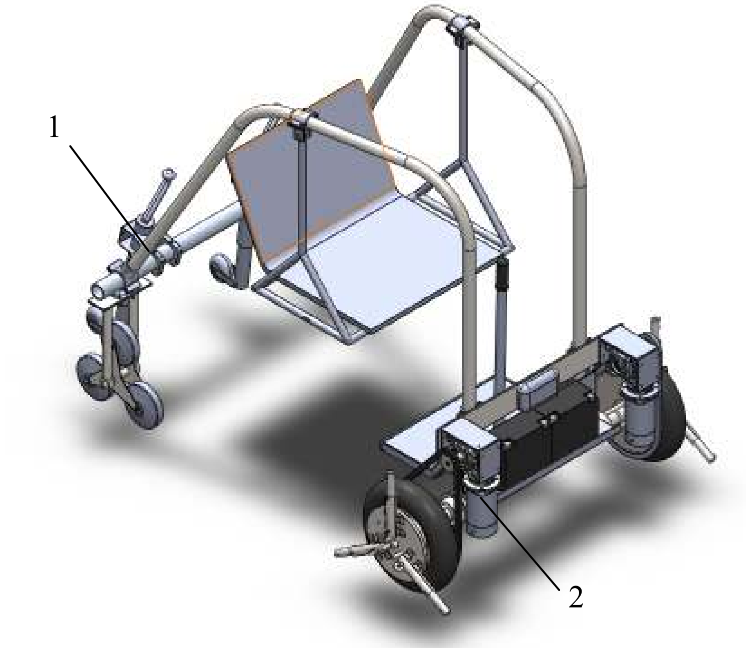
2. DESIGNING STAIR CLIMBER MACHINE

2.1 Development of a design

Initial concept of machine was designed for testing. First test was conducted by using “Solidworks” simulation. This test showed problem that the seat was too low and it had to be lifted up. Flaw was eliminated and first design was born. It was very primitive in design but it worked. It can be seen in Fig 1.1. The machine consists of four main elements rear bridge 1, front axis 2, frame 3 and driving and control block 4. Front wheels are the driving wheels. Both front wheels are driven by separate electric motors. Motors, control centre and platform for person are fixed on the frame.

Fig. 2.1 Initial wheelchair

of flaws was detected. Fixing those flaws meant that initial design will change. Main changes of designs include finger system control, placement of engines and including motoreducers, placement of rear bridge changes 1, battery's and control block 2 (Fig. 2.2).



a)

b)

Fig. 2.2 Prototype wheelchairs

The initial test proved that concept works but prototype still needs improvement. Main flaw of the machine was steadiness of the frame. The frame didn't have problem with plastic strains but it had problem with elastic strains along frame. To overcome this problem additional segment of the frame was added 1 (Fig. 2.3). Mechanical leaver which realised fingers for deployment and it was changed to electromechanical linear gear 2 (Fig. 2.3). Changes and be seen in Fig 2.3.

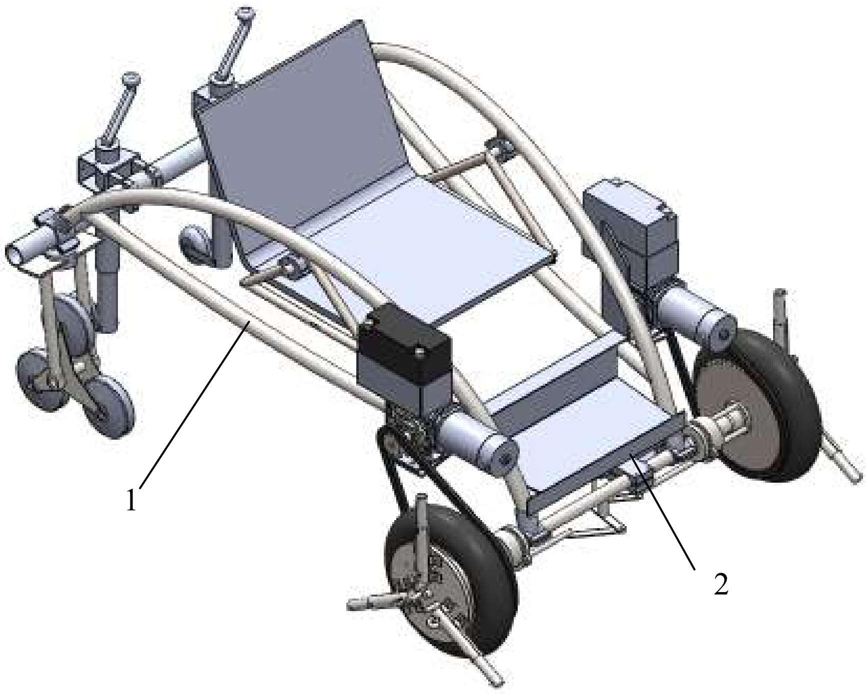


Fig. 2.3 Wheelchairs

2.2 Front axle

Frontal axle consists of stair climbing mechanism, wheels and drive gear. Frame is directly connected to axle with clamps. On ends of axle wheels are mounted. Wheels are standard inflating wheel of 33cm in diameter because they have to be bigger than climbing system. If wheel diameter will be smaller by 4 cm climbing system will be disrupting ride.

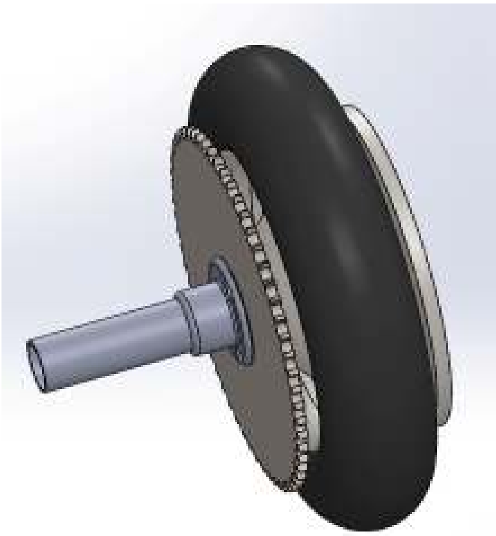


Fig. 2.4 Wheel

Fig. 2.5 Front axle

In Fig 1.6 it is used linear actuator for controlling fingers reenlistment.

Electrak 10 models incorporate a ball bearing screw drive system for applications requiring maximum load capacity. A specially designed anti-back driving brake holds tension or compression loads in position when the actuator is not in use. This holding brake activates automatically when the actuator is turned off and will continue to hold the load in position without power consumption, until the actuator is started.

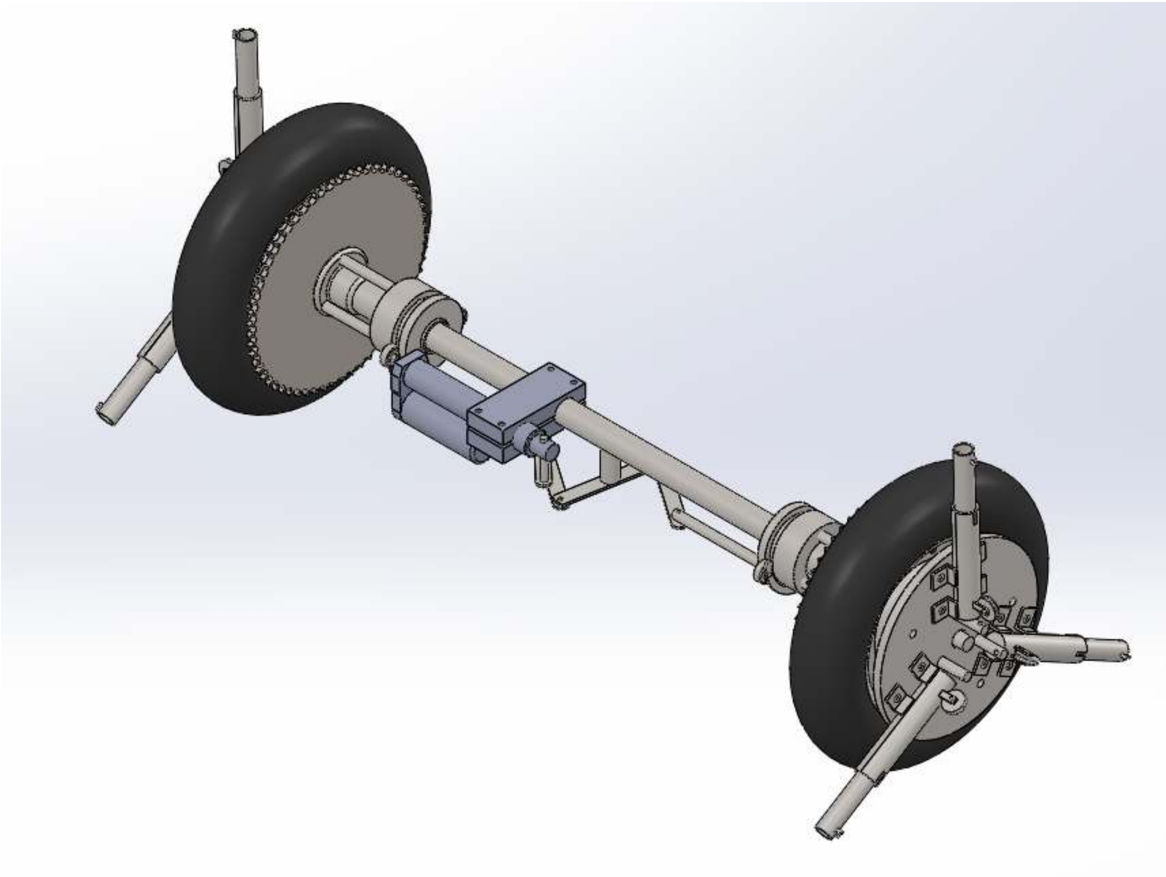


Fig. 2.6 Front axle, electronica switch

Calculations were done for frontal axle to find how much load it can hold. Because axle have sections of different diameter ant length, calculations were done for all sections.

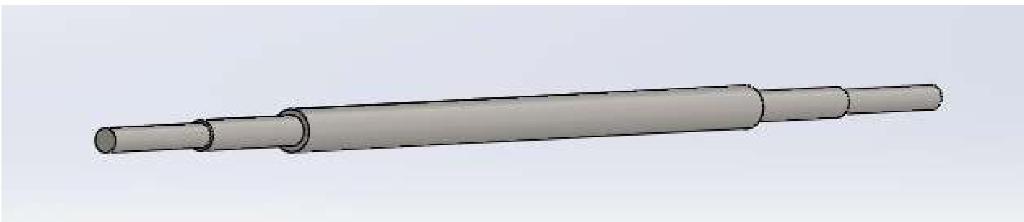


Fig. 2.7 Axle

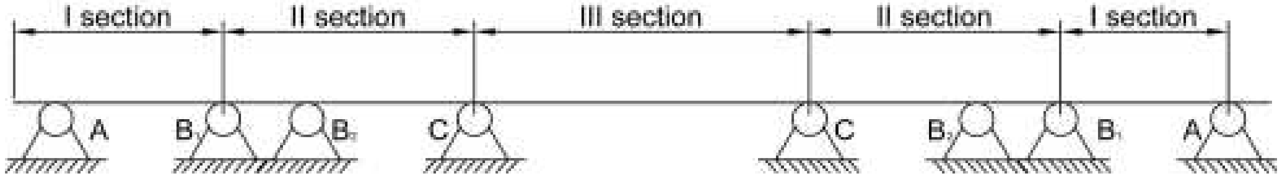


Fig. 2.8

Diameter of shaft in sections:

16 mm

20 mm

28 mm

It has three different sections with different diameters. To find allowable stresses calculations had been done for each segment. It was founded that in segment I is weakest. And allowable stresses is 9.65 kN.

2.3 Finger system

In isometric figure (Fig. 2.9) it is sown in finger relays system. Finger system consists of finger and spring. At the end of finger there is fixed cable which controls compression of a spring. While driving on a flat surface spring is compressed and machine is moving use rubber wheel. When stair is approached, driver use leaver to release cable holding finger and spring push him out letting machine to climb stairs. The main purpose of a spring is to compress the angle and load to the finger is exceeds limitation and prevent machine of moving forward. [9]

Fig. 2.9 Finger

Spring takes all inner volume of shell part and finger. Spring is fastened to the beginning of a shell and end of a finger. Because spring need to compress by 70mm its length has to be at through all system. If spring would be fastened to the beginning of shell and the beginning of a finger its compression distance would be to low and ride would be a lot of bumpier. [9]

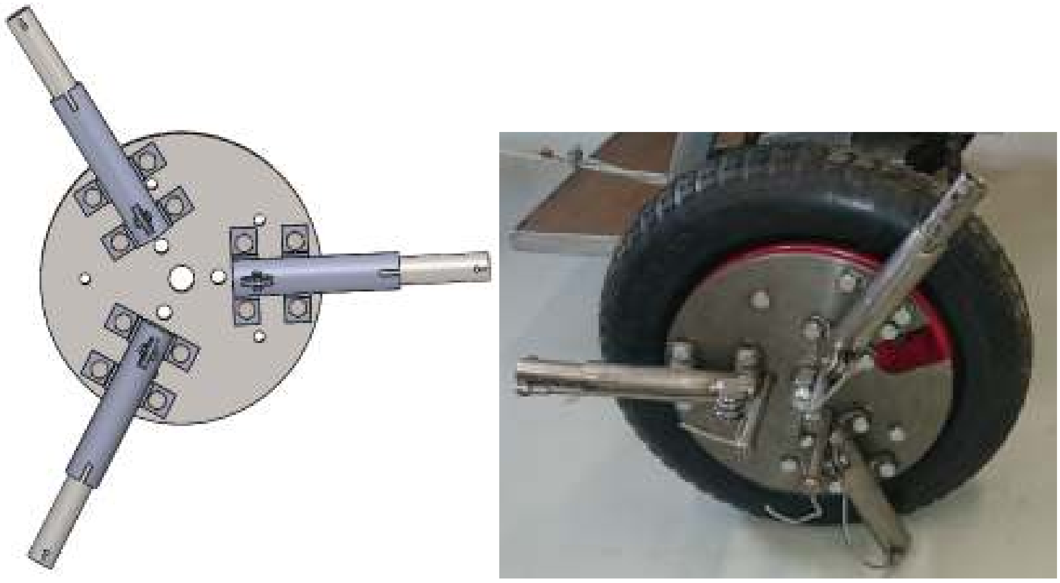


Fig. 2.10 Finger holder

On external wheel flange three fingers systems are mounted the angle between fingers systems is 120°. The calculations were made for standard stairs. In account was taken angle of the stairs high and length of stairs. And we got that that we need put three fingers in 120° intervals. If stair angle is bigger than 40° in account was taken wheel spin. [9]

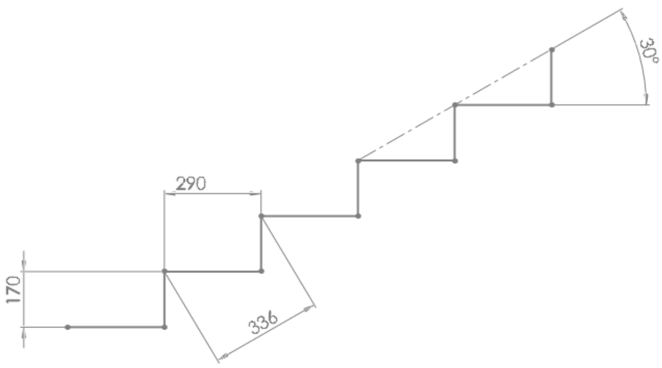


Fig. 2.11 Stairs

In testing phase was discovered that fingers can make damage to the surface on which it is riding. Damage to the surface accrues then sharp tip is in contact with surface. One of solutions is to cover in rubber end of finger for perverting damage to surfaces (2.12).

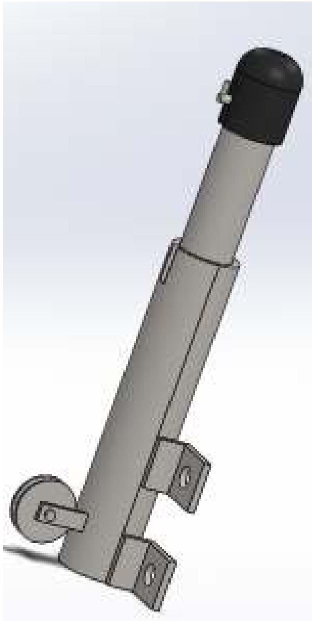


Fig. 2.12 Rubber coated finger

Calculations were made to check if finger dos not fail and if spring has enough energy to eject finger.

Materials for finger was chosen carbon steel S235JRH and calculations shown that finger can hold 259kg. So taking in account the one finger can hold 259kg and it always rest on two fingers, so total weight it can hold is 518kg.

Also calculations have been done to check what maximum allowable cutting force it can withhold. Calculations shown that finger can withhold 264kg weight. And because machine weights around 100kg so person who weighs less than 100kg can softly ride it.

Further calculations were done using Hooke's law to find stiffness of spring that can extend finger. Minimum stiffness of spring was needed 3714 N/m.

2.4 Rear bridge

Rear consists from three main components climbing wheels, rear axle and raiding wheels. Solution for climbing wheels is very simple it uses simple technology it is used in various delivery trolleys. Type that is used on this project it can be seen in Fig 2.13. It is three wheels arranged in triangle configuration, diameter of wheels is 130mm. This type of climbing wheels is cold tri-star 1 (Fig. 2.13) configuration. To overcome obstacle in every step of stair or side walk curbs, all tri-star rotates about its main axis. Thus free wheel lands on a next step. These two tri-star wheel configurations are connected with crossbar.

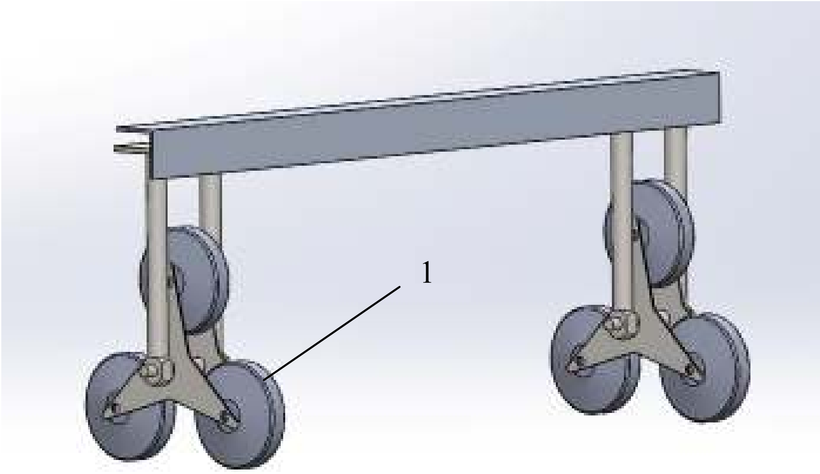


Fig. 2.13 Initial rear bridge

At the concept phase angle iron was used as rear bridge and tri-star wheel system. On angle iron frame was welded. Because tri-star wheel can rotate 360 degrees around main axis and they are fixed on rear axle. Taking in account that it isn`t any easy way to control them it was added additional two wheels that can be lifted manually (Fig 2.14). After Additional two wheels lifts rear bridge and tri-star system doesn't touch ground, because of that they are welded and positional parallel to drive wheals. Tri-star wheel system is use just for climbing. Additional two wheels 1 system is use for riding and turning (Fig 2.14).

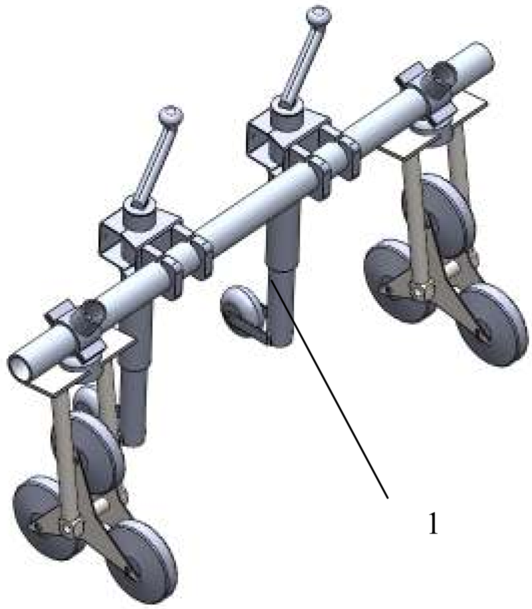


Fig. 2.14 Rear bridge

2.5 Driving system

The mechanism is powered by two 12 Volt batteries. Batteries are connected in series and it combines voltage of 24 Volts. Drive motors used for mechanism is two DC 24 Volt, 240 Watt, 20amp, 3700 r.p.m. electric motors. These kinds of motors are used in commercial wheel chairs.

In initial design motors was placed in mounts and mounts was fix on tick plate which was secured to frame. Extended drive shafts were fastened to the motors and shaft placed in two bearing units with eccentric collar locking. At the end of shaft there is chain wheel DIN 8192 B13Z 08B-1. Power is transmitted to wheels by chain.

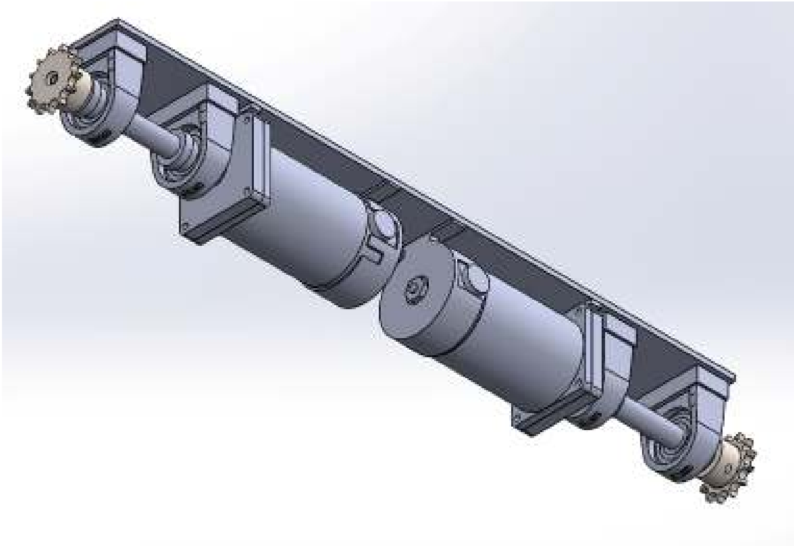


Fig. 2.15 Engines

Testing shown that moment of engines was low for climbing the stair so motoreducers 1 (Fig 2.16) was used. Because driving shafts of motor reducers and motor rotates around different axis place and mounting had to be changed. Motors 2 from horizontal position had to be mounted vertically (Fig 2.16).

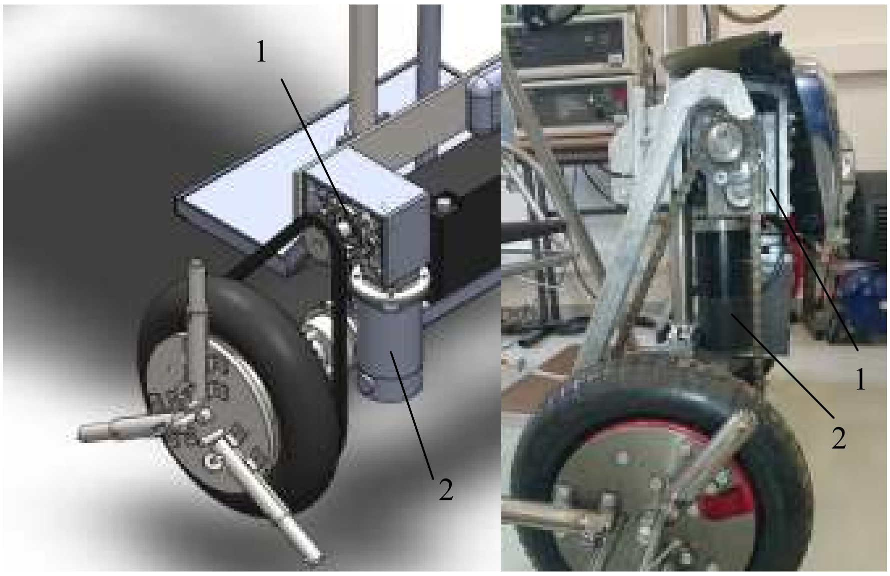


Fig. 2.16 Front engine mounting

After some more testing flaws in frame construction was found. Frame was not rigged enough to be safe for riding. So frame was changed and motors placement had to be changed also. Motors were placed to the outer side of the frames. Batteries were placed on the top of motors shocked.

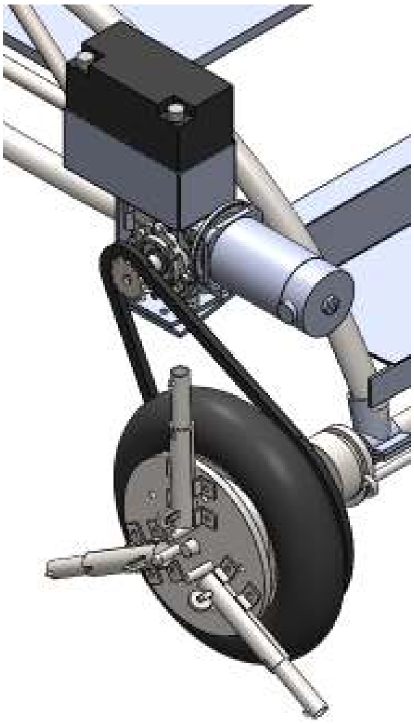


Fig. 2.17 Engine mounting

2.6 Frame

Initial concept of the frame had two big arcs on which were fixed to the rear axle and front axle. Chair moves like swings but it angle of chair is controlled (Fig 2.18).

Fig. 2.18 Initial frame

Climbing test revealed flows in design, frame had too much of flexibility and it wasn't info rigged to be safe to climbing stairs. That problem was fix bay changing frame in to sturdier frame construction. Now frame construction is made from two pipes bended into arch form. Arcs are welded facing each other bay inner radius of arch and it looks like needle eye. Another plus was that easier access can be installed. For easier axes to seat of machine was cleared front and step was added.

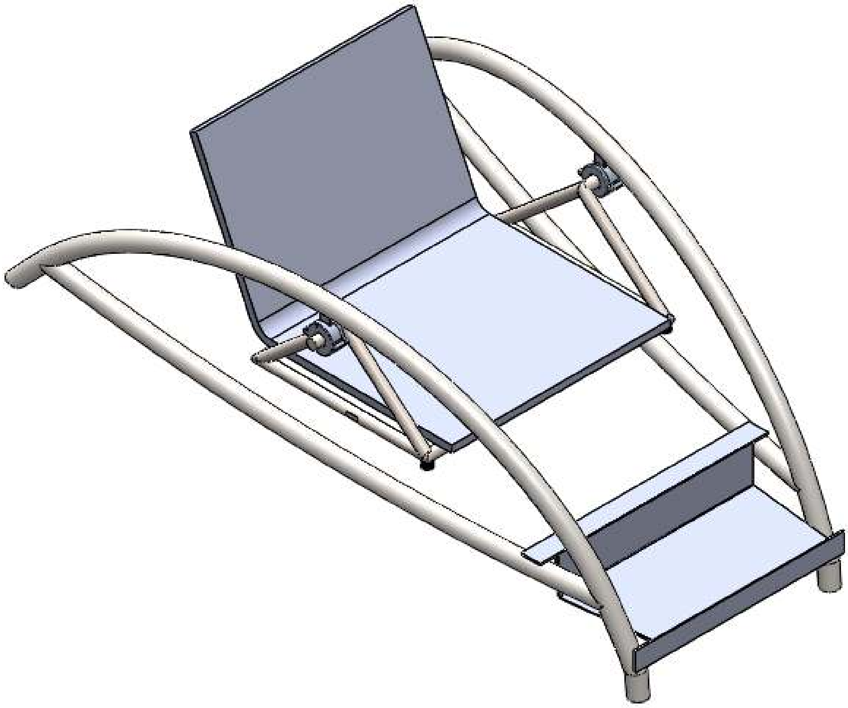


Fig. 2.19 wo arch frame

Calculations for the frames where done using "Solidworks" software which simulates and calculates bending stresses and displacements. Materials used for carbon steel grade S235JRH which consist of:

Table 2.1 Chemical composition

Chemical composition % of grade S235JRH				
C	Mn	P	S	N
Max 0.2	Max 1.4	Max 0.04	Max 0.04	Max 0.009

According to "Inžinieriaus mechaniko žinynas"(Vilniuas: Mokslas 1988, prepared: Balys Dragūnas, Kęstutis Pilkauskas, Antanas Stasiūnas, Raimundas Stasiūnas) best metal for frame construction is low carbon or medium carbon steel. For frames was pick low carbon steel because of its cost.

Frames are made of pipe with dimensions D=33.7mm d=27.7mm. Such diameter and thickness of pipes was used for all frames on which calculations was done.

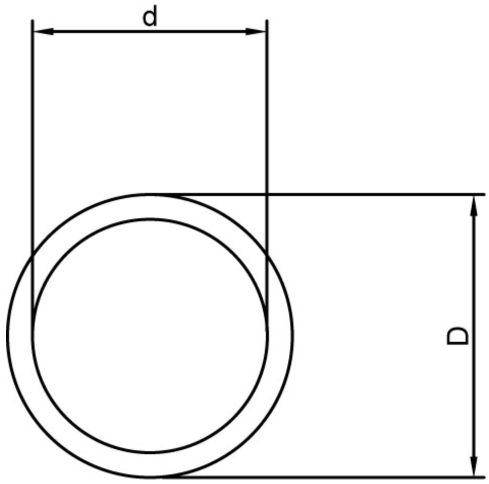


Fig. 2.20 Pipe

It is important to calculate stresses to check if frame will info strong. To be sure that frame wont brake or bend permanently in real model, simulation has been done in “Solidworks” program. Frame will be exposed op to 1200 N. Because it consist of two identical pieces of frame load is divided in two. So both sides are loaded with 600 N

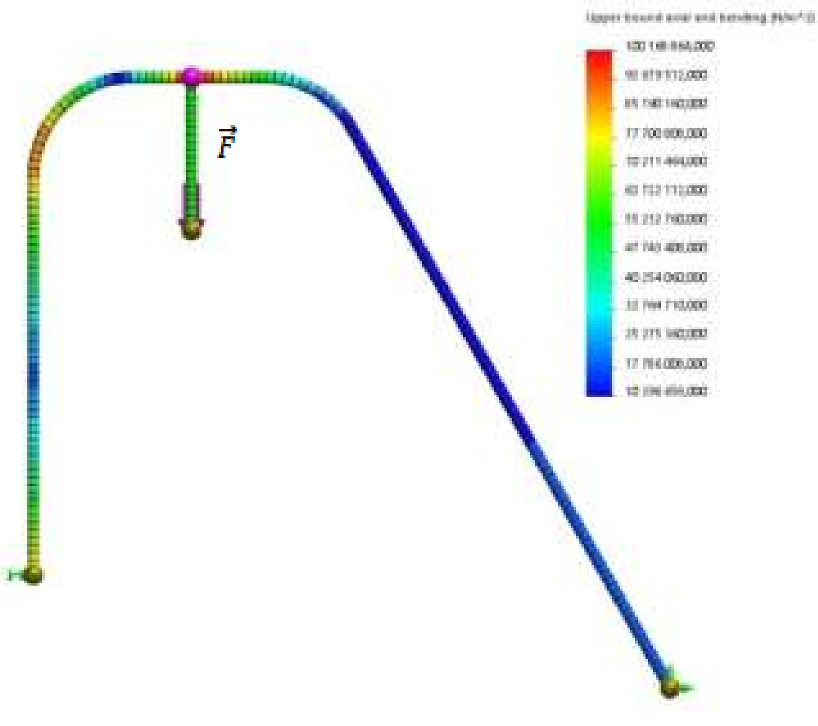


Fig. 2.21 Stress forces

For initial frame calculations was done for the stress to check if it can hold and it shown that it did. However in account was taken just plastic deformation and it wasn’t shown that was a problem. Also elastic deformation was dismissed because it was very low 3,5mm. And it was vital mistake because frame was too flexible.

In Fig can be seen how stress forces are acting. Stress forces action on the frame shown bay collar. Red is where stresses are biggest and blue shows where stresses are lowest. A maximum stress that appears on frame is 100 MP when 600N is applied.

In Fig 2.22 is shown displacement of a frame and it is 3.5mm. Displacement of frame in Fig 2.22 greatly exaggerated but sill this small displacement was flow that made machine unstable. But for testing climbing system it didn't have influence.

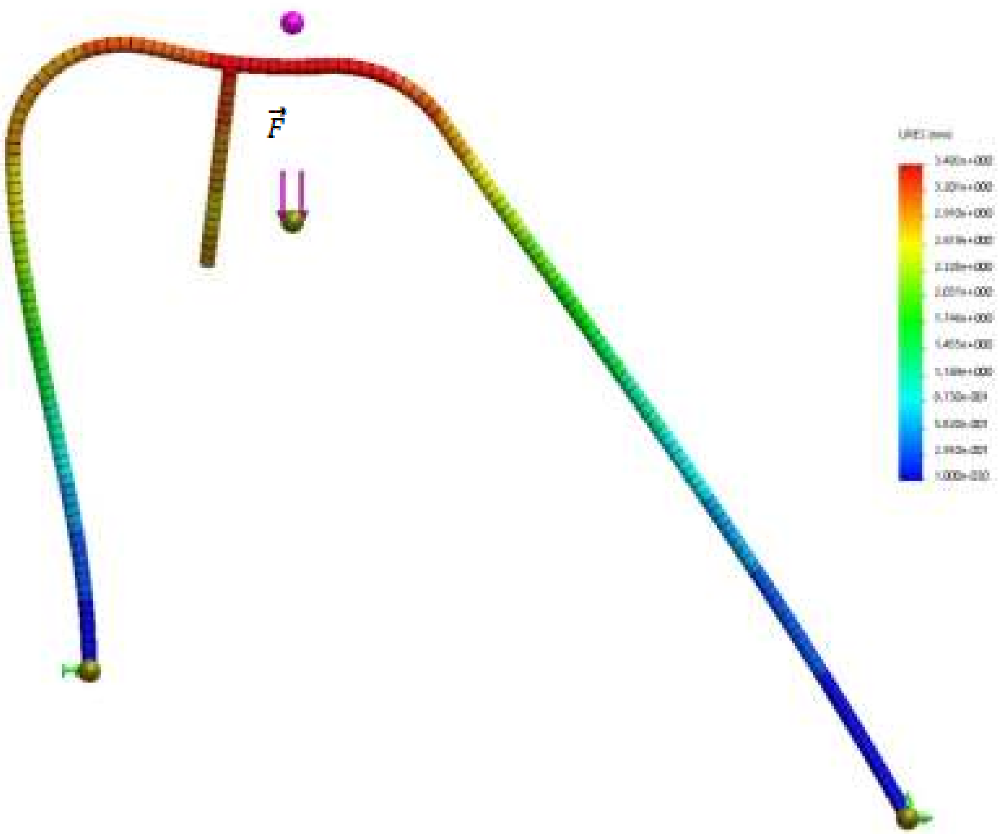


Fig. 2.22 Displacements

Taking in account that elastic deformation of frame was vital flow now frame concept was developed. And calculations were done using "Solidworks" simulation. Just for this frame construction force was increased from 1200N to 1400 N. Farce was increased for safety factor.

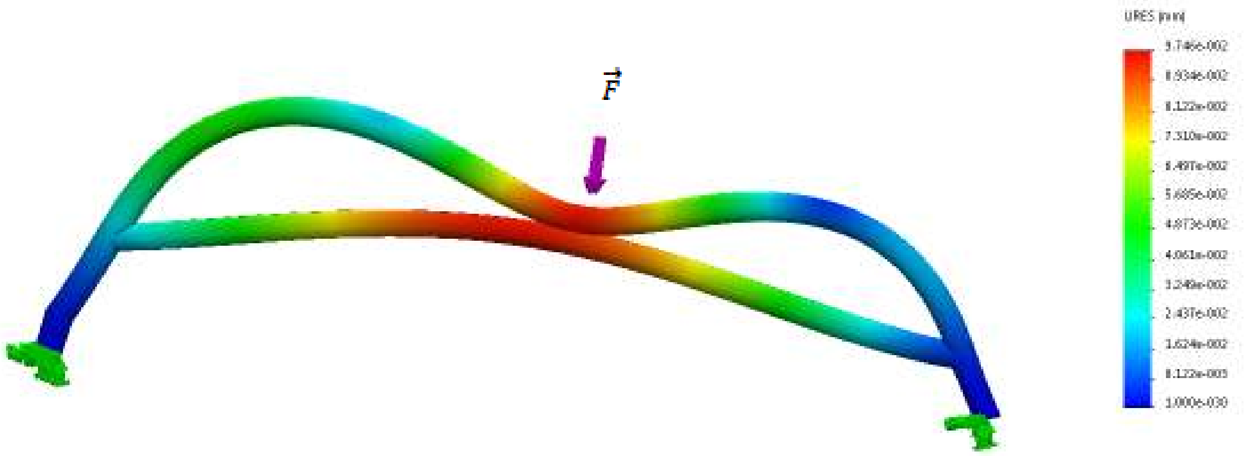


Fig. 2.23 Displacements

After changing shape of a frame and adding reinforcement, displacement decrease significantly and can be seen in Fig 2.23. Where in initial frame displacement reached 3.5 mm and in now frame displacement is just 0.01mm. Displacement decreased by 350%. Also taken in account that force on the frame increased by 100N.

2.7 Safety of driver

To increase safety for wheelchair seat with safety seatbelt was designed (Fig 2.24). Seat is made from ultra-high-molecular-weight polyethylene (UHMWPE). To make it more comfortable paddings are added for head, back and bottom. Adding rounded edges of chairs hugs driver and it increase safety and comfort.

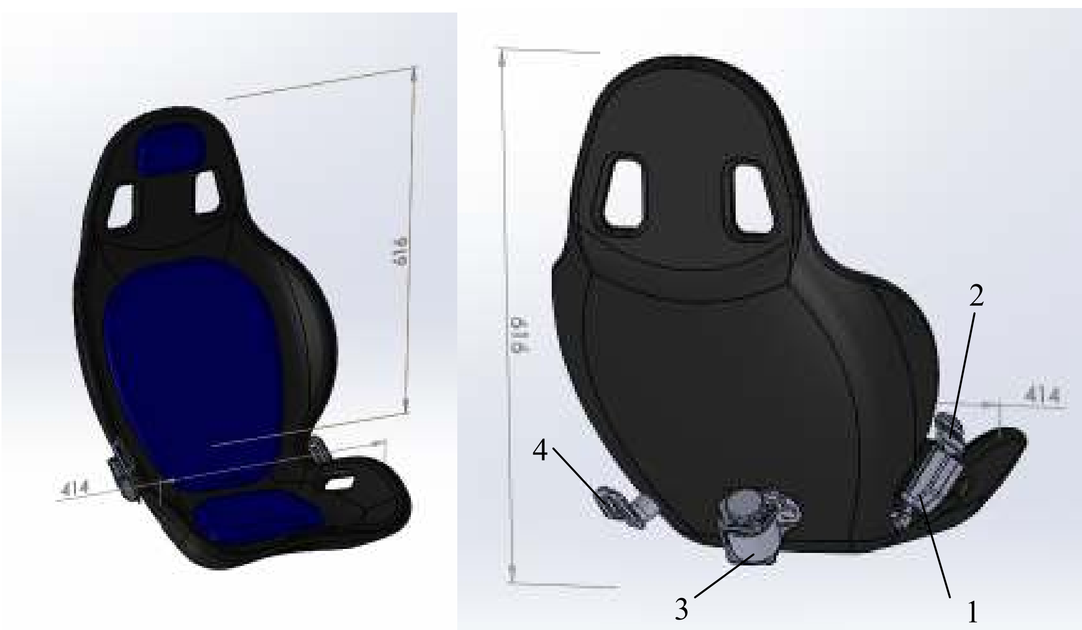


Fig. 2.24 Now design of seat

Additional safety future is safety belts same as in standard car. Belt goes over driver waist. Belt mechanism consists of parts lock 1, pin 2, spool 3 and guide 4 (Fig 2.24). To fix all parts implants are added when manufacturing seat (Fig 1.25). In this example can be seen that in middle of the X thread sleeve is welded. Wings of X can be folded in needed shape according to the curves of the seat and then imbedded in to the seat. Implant size different for every part of the safety harness system.

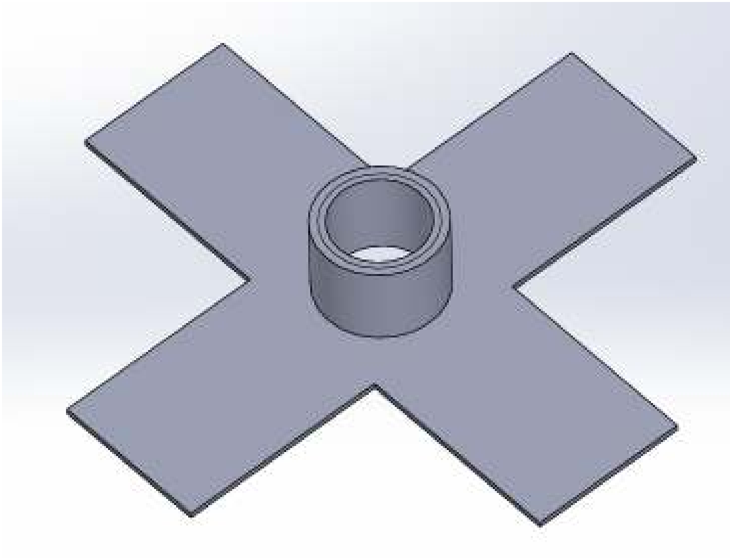


Fig. 2.25 Implant for bolts

Ultra-high-molecular-weight material was picked because of its price and superior qualities which includes [10]:

- High quality abrasion resistance
- Low friction coefficient
- Good impact strength
- Strong chemical resistance
- High-quality dispersion traits
- Exceptional mechanical strength
- Superior heat and water resistance

3. CONTROL OF WHEELCHAIR

3.1 Software

Software for controlling wheelchair electronica system was chosen Arduino. Main reasons it was chosen because it is open source, easy to use and it is free. Arduino software is based on processing and programing on wiring. Arduino can run more few operating systems. It runs on Linux Windows, and Macintosh OSX.

3.2 Control board

For controlling this project electronic sensors and components it is used microcontroller which is programed to control distance measuring system and driving system. Driving system is controlled through microcontroller by input from analogic joystick.

In order to ensure control of wheelchair be fluent, a microcontroller is chosen with enough analog and digital pins and capability of running all of needed components for functional wheelchair. The microcontroller board chosen for machine controls is Uno R3 Arduino (Fig 3.1).

Fig. 3.1 Uno R3 Arduino (11)

Table 3.1 Uno R3 Arduino summary (11)

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB
Processor	16 MHz

This microcontroller has USB port for inputting code or it can be powered thro it also external power connector that can be connected to external power source.

3.3 Distance measuring

A most important priority of wheelchair is safety. To increase safety it can be incorporated sensors that can detect obstacle. Obstacle can be peoples that get in a way of machine and can lead to injure of driver and person. Also it can use to detect obstacles of terrain that can't be overcome without using climbing system. For detecting obstacles ultrasonic sensors are used. After detection it can send signals to stop or just send signal to driver.

For detection object was selected ultrasonic ranging module HC - SR04. It was selected for his range detection capabilities; its range is from 2cm – 400cm.

Fig. 3.2 Ultrasonic range module HC - SR04 (12)

Table 3.2 Ultrasonic ranging module HC - SR04 summary(12)

Working Voltage	DC 5 V
Working Current	15mA
Working Frequency	40Hz
Max Range	4m
Min Range	2cm
Measuring Angle	15 degree
Trigger Input Signal	10uS TTL pulse
Echo Output Signal	Input TTL lever signal and the range in proportion
Dimension	45*20*15mm

As shown in timing diagram Fig 2.3. Supplying short burst of 10 uS pulse by microcontroller board to trigger input to start the running. Then it star running it sends 8 cycle burst of ultrasound at 40 kHz and raise its echo. Distance calculation of obstacle through the time interval between sending trigger signal and receiving echo signal [13].

$$S = \frac{t \cdot v_{sound}}{2} \quad (1)$$

S – Distance between object and sensor.

t – Time between when an ultrasonic wave is emitted and when it is received.

v_{sound} - Speed of sound 340 m/s

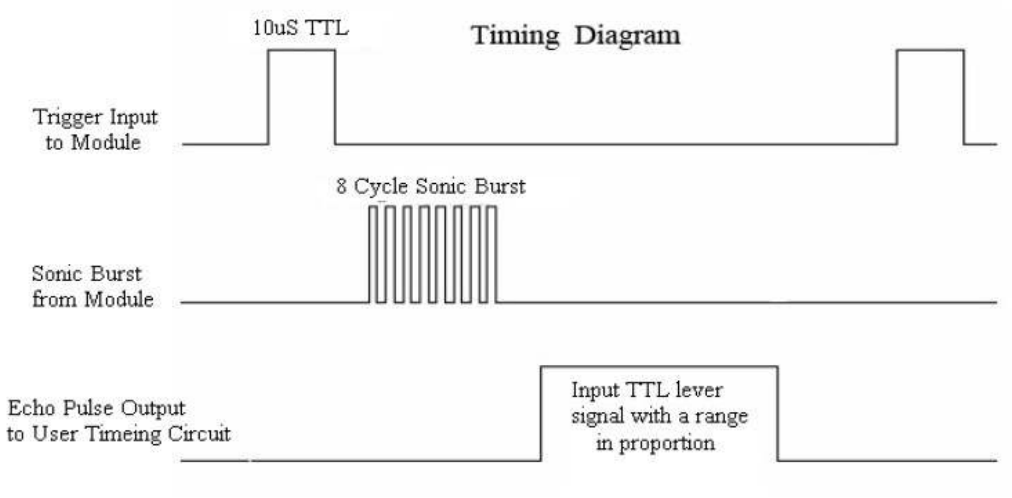


Fig. 3.3 Timing diagram(12)

Schematic and blueprint of microcontroller board and sensor was done using ‘’Fritzing’’ software. Blueprint can be seen in Fig 3.3. Blueprint is drawn for tracking how much each of components uses digital pins and analog pins because it has limited amount (Table 3.1). Ultrasonic ranging module HC - SR04 uses two digital input pins one for echo and another for trigger. Trigger uses red wire, echo black wire

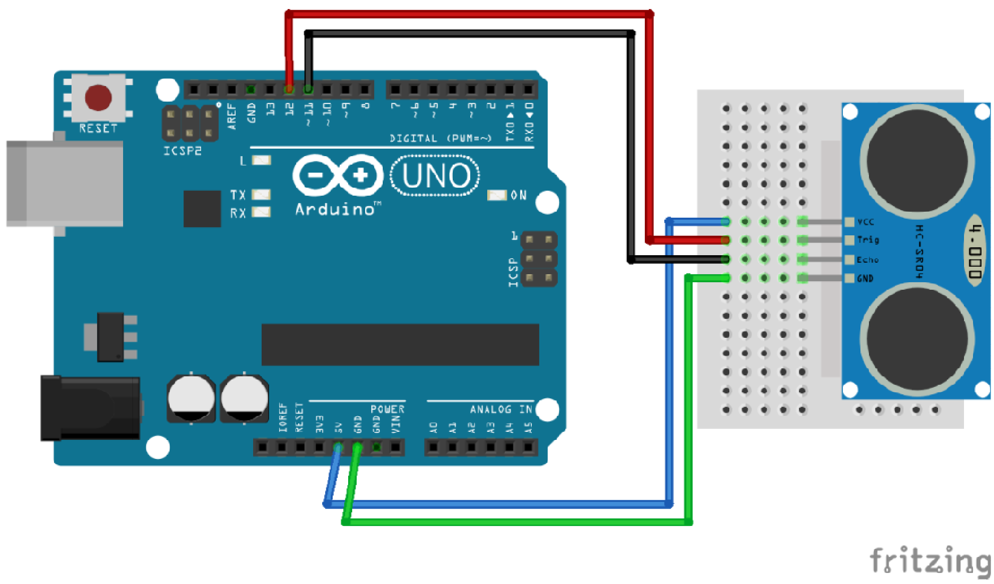


Fig. 3.4 Ultrasonic ranging module HC - SR04 blueprint

After connection of the boards and encoding it was tested if it works. Test shown positive results and that meant that it can be integrated in to machine for safety. In Fig 2.4 can be seen distances of obstacles detected bay ultrasonic ranging module.

3.4 Controls of machine electromotor

3.4.1 Analogic joystick

Control wheelchair movement it is used joystick (Fig 3.5) with two axes analogical output and one digital switch. To get analogic output from, it uses two independent potentiometers that separately adjust voltage. Such adjustment provides deferent voltage when joystick stick is turned. Those differences in voltage are as analogical input by microcontroller [12].

Fig. 3.5 Analogic joystick (14)

Table 3.3 Analogic joystick summary (14)

Power capability	0.01W; 10 VDC maximum working voltage
Interface	Dual 10 kΩ potentiometers with common ground
Dimensions:	41.67 mm H x 35.56 mm L x 27.94 mm W

Using Arduino hardware, software code was written to read output of two analogical inputs from joystick and input from digital input from the switch. In Fig 3.6 can be seen how joystick is connected to micro microcontroller board, yellow and green vires are two analogical inputs, black is connected to digital switch. Test shown that program works and from all three inputs signal are received. Taking in account that test was successful next step was programing output to DC motors.

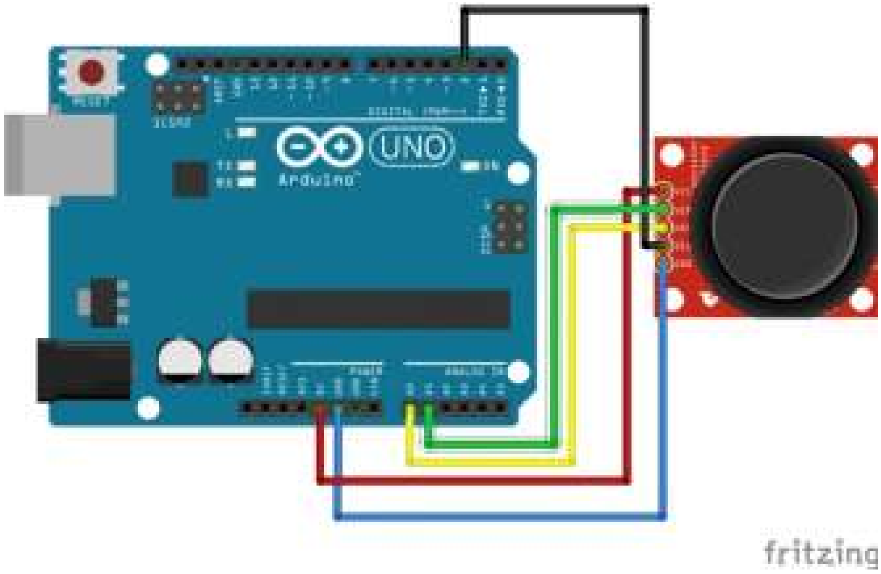


Fig. 3.6 Analogic joystick blueprint

3.4.2 DC control with analogic joystick

Two DC 5 volts motors were connected to micro controller. DC motors was connected to pins with pulse-with outputs for purpose to control speed and direction of motors. X and Y axes was used to control movement forwards and backwards. For turning on or off engines was used joystick switch.

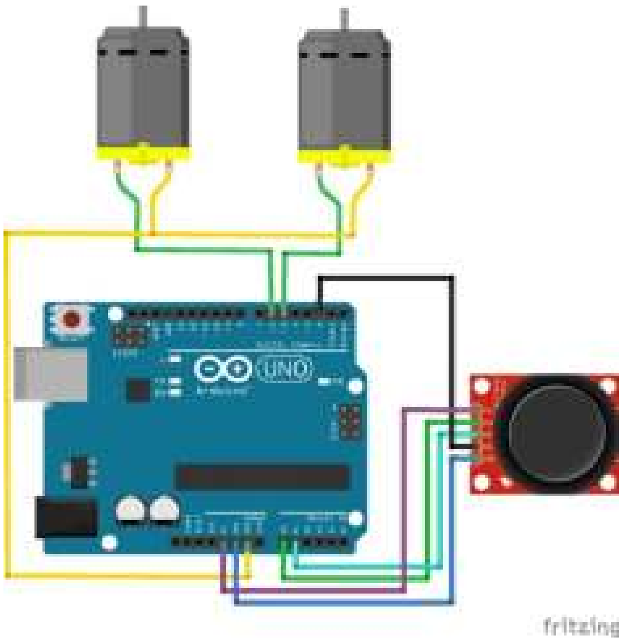


Fig. 3.7 Two DC 5 volts

3.4.3 Electromotors control

Electromotors is running on 24 volts and Arduino Uno microcontroller runs from 7 volts to 12 volts. Because electromotors need different currents then microcontroller additional component is needed. For controlling motors L298N driver module is integrated in to the control system.

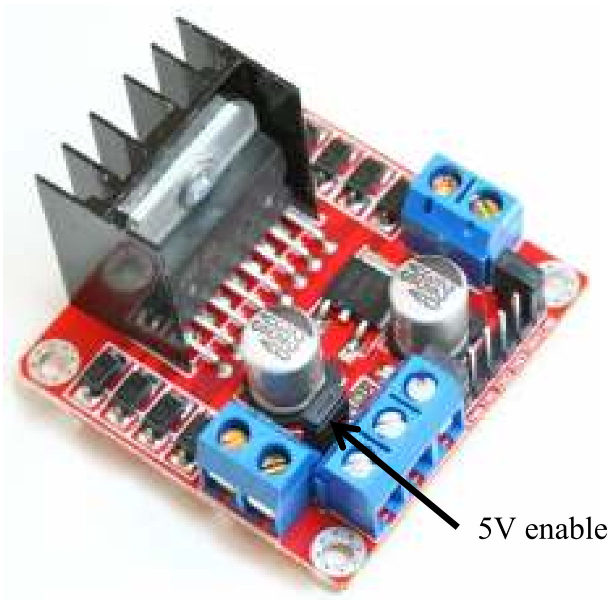


Fig. 3.8 L298N driver module (15)

Table 3.4 L298N driver module summary (15)

Supply to terminal driven parts	5-35V
Circuit of driver chip	L298 integrated monolithic circuit
Drive board dimensions	55x49x33mm
Output to logical parts	4,5-5,5V
The control signal input	4,5-5,5V

L298N module is powered by external powers supply. It can directly supply for from 3 volts to 35 volts to two DC motors, it fits perfectly for this project need because motors of wheelchair runs on 24 volts. Also it can supply 5 volts power for mower board. But it needs external power supply of 12 volts or more to be able to supply power to microcontroller if it is lower than 12 volts additional power supply is needed to power microcontroller board. Also pin has to be unplugged for enabling 5 volt power supplied (Fig 3.8).

Blueprint (Fig 3.9) shows control system of two 5 volts DC motors using L298N driver module. Because for testing if program works was used 5 volts DC motors and input was lower than 12 volts two power supplies was used. Arduino Uno was powered by USB cable and DC motors by external battery.

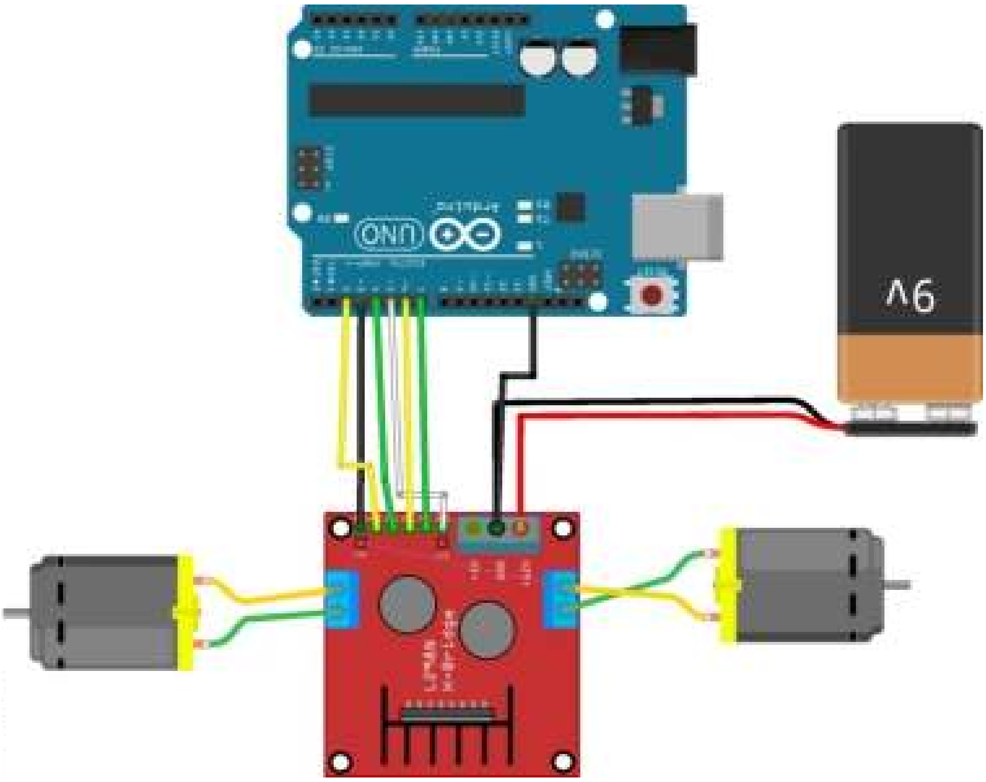


Fig. 3.9 System of two 5 volts DC motors

Motors in this case are controlled by writing code for direction to which it has to rotate (appendix). Microcontroller encodes input signal for driver module and it inputs thro pins that can transmit pulse-with modulation. In this case pins that can transmit pulse-with modulation are connected by white and black wire. Input for DC motors spinning direction is throw green and yellow wires.

3.5 Finger control system

For controlling finger system from mechanical leaver was changed to the electro mechanical linear actuators. It was changed for clearing space in front for easier entrance for person. Also it eliminated requirement of rider using his muscles. It is important if person hands are week because riders cadent use climbing system. Linear Actuators was picked to change mechanical leaver (Fig 3.10).

Fig. 3.10 Electrak 10 (16)

Table 3.5 Electrak 10 summary (17)

Input	24v
Stroke length	101.6 mm
Current	20A
Load capacities	226 kg

For controlling linear actuators was needed to add relays that can handle 24 vats. Two was added to control direction of stroke. Direction is control bay to buttons. And linear actuators shown as 5 volts DC motor.

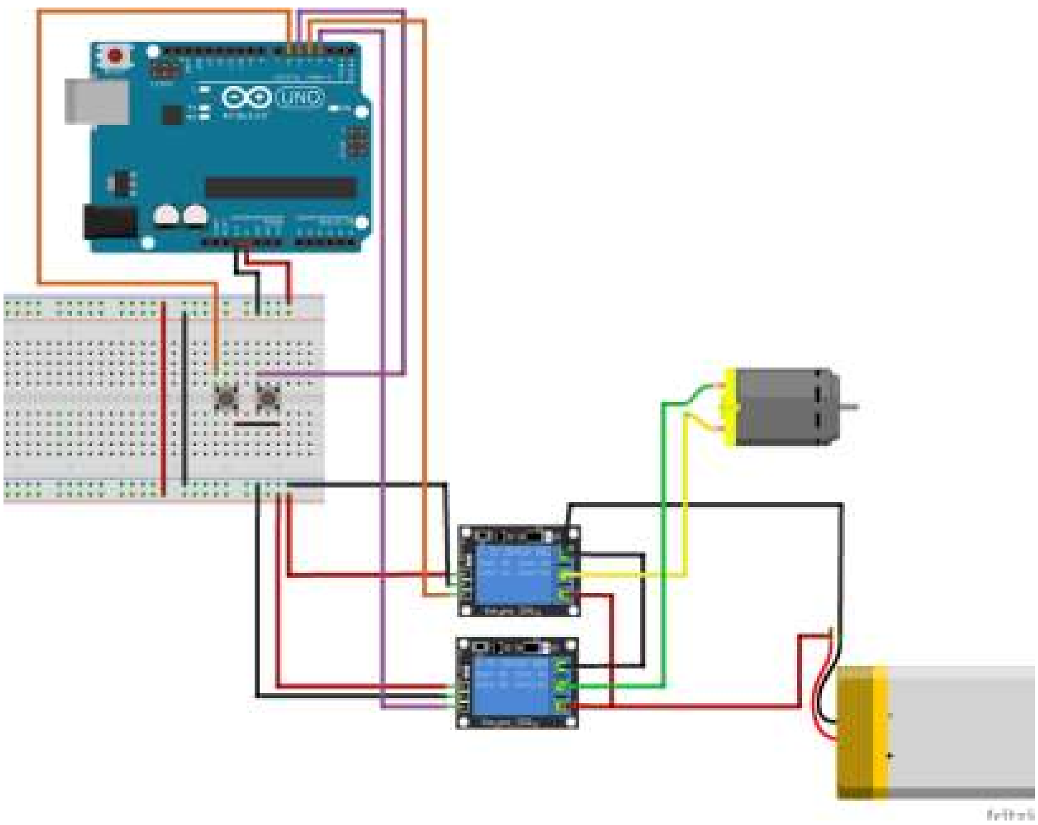


Fig. 3.11 Blueprint of Electrak 10 control system

3.6 Control block

After testing all different modules system it was connected in one system to control wheelchair. In blueprint can be seen analogical joystick that controls two DC motors. Also it shows distance measuring system and finger control system.

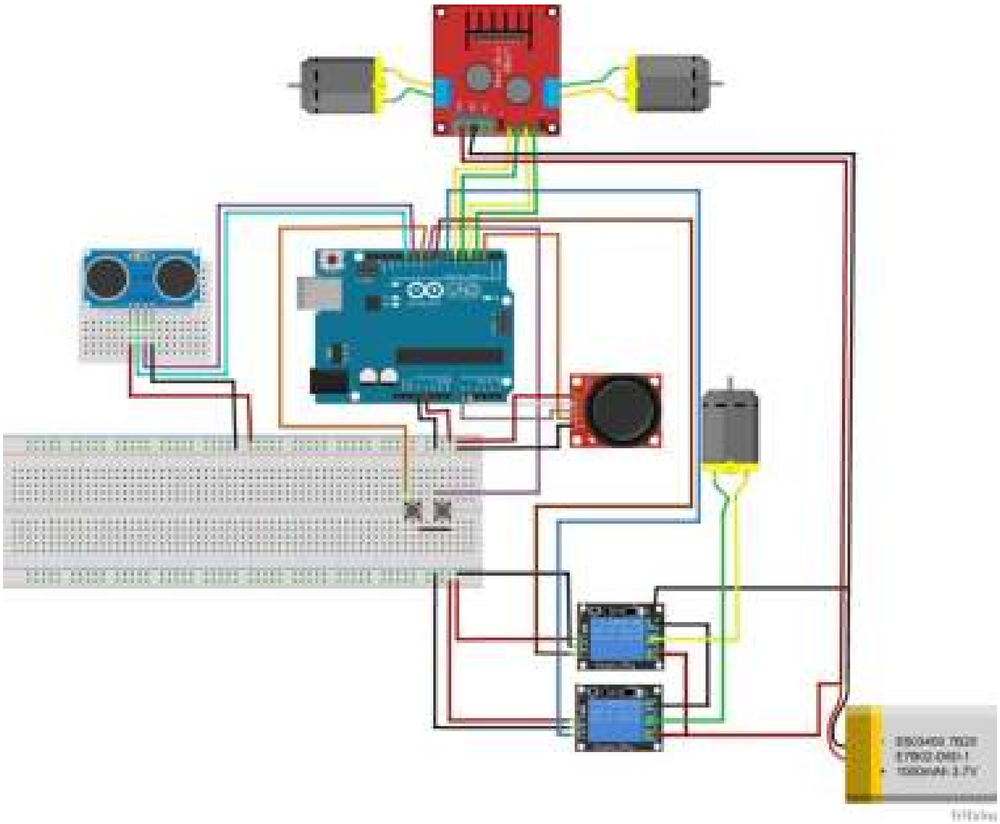


Fig. 3.12 Control block

3.7 Housing of controls

Housing of controls of machine is divided in three main parts firs one control unit. In it is microcontroller Uno R3 Arduino 1 which controls all of medullas. Also two coils 2 for controlling linear actuators and last component L298N driver module 3 (Fig. 3.13). Bock is placed under the step 1 (Fig. 3.15).

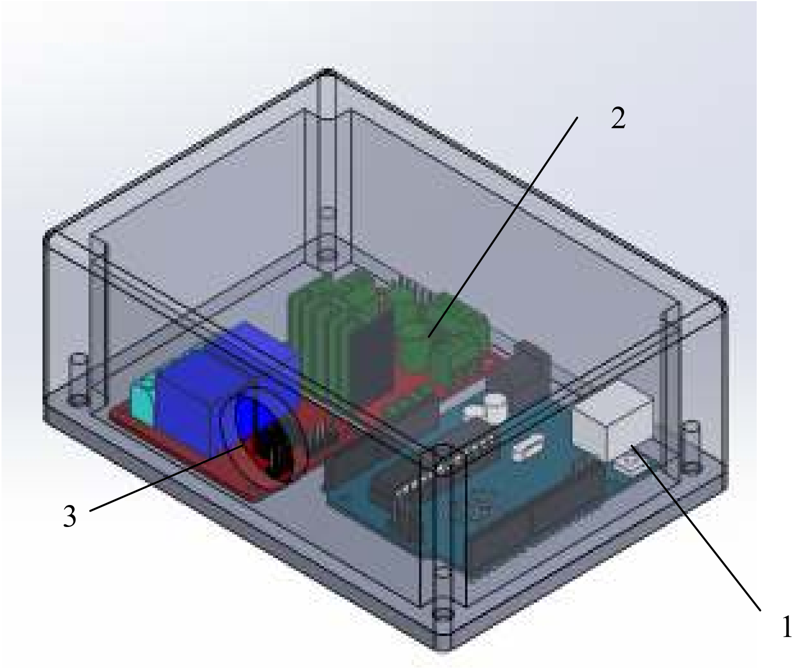


Fig. 3.13 Control block

In controller (Fig. 3.13) is mounted analogic joystick 1 for front engines control and two battens 2 that are mounted in the sides of controller box. Controller is mounted to the chair 2 (Fig. 3.14).

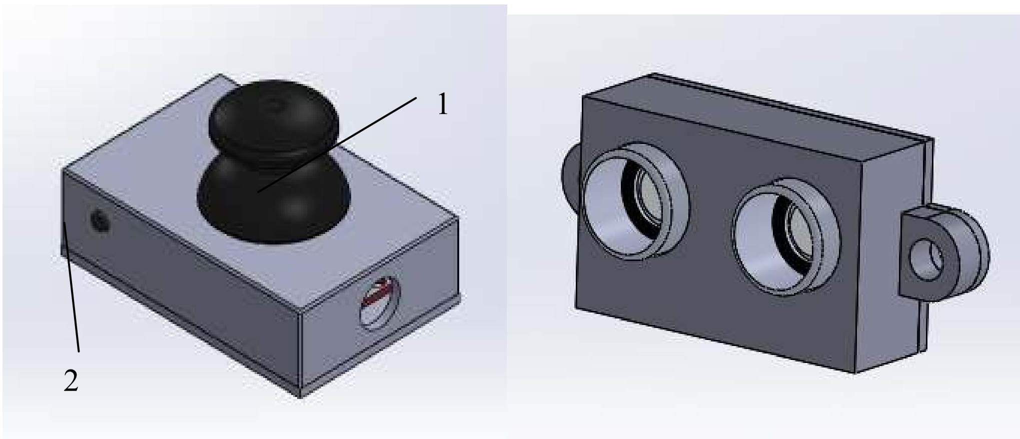


Fig. 3.14 Controller block

A lest bock is Ultrasonic ranging module HC - SR04 and it amounted on the front of the machine 3 (Fig. 3.15).

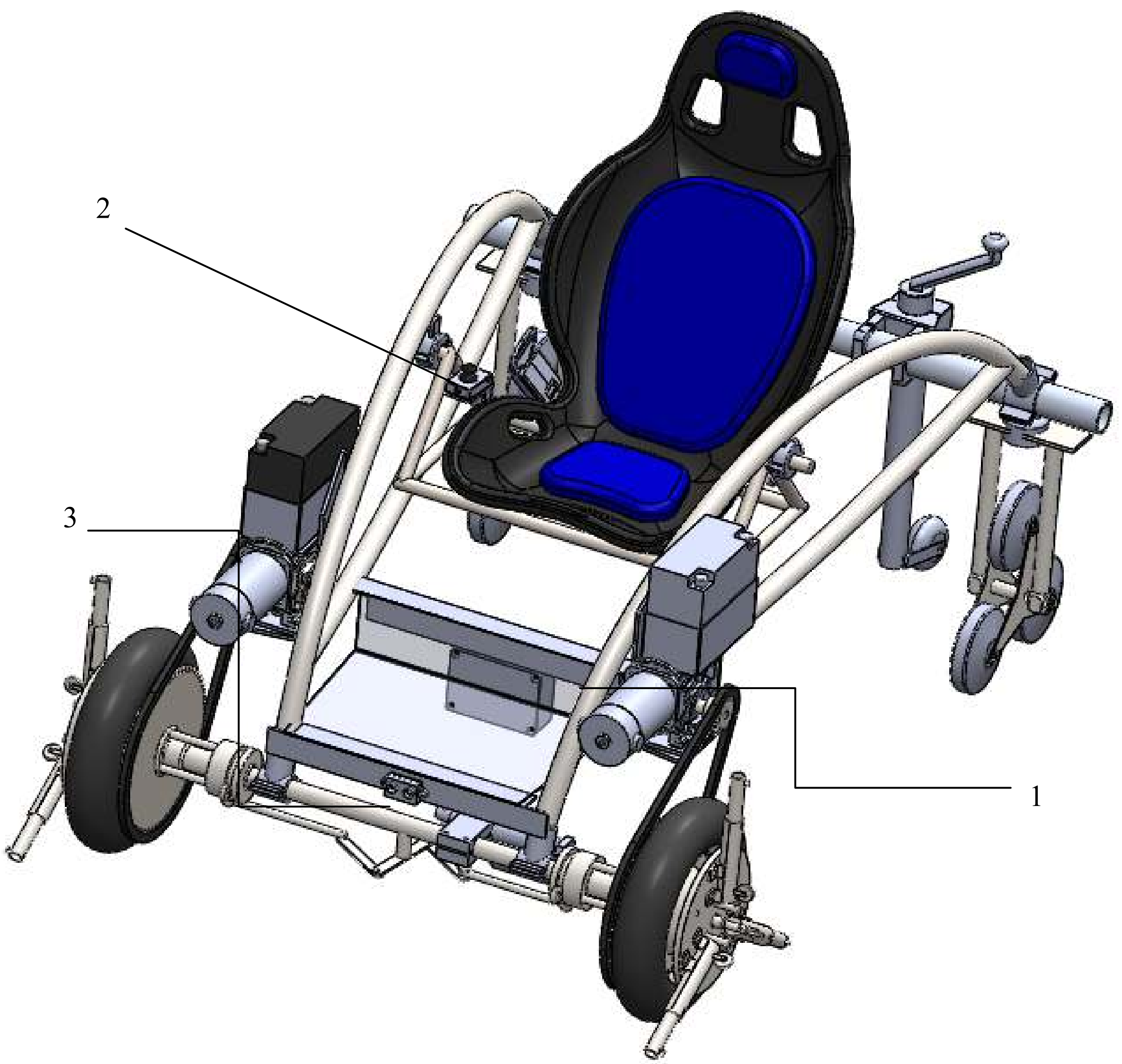


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Fig. 3.15 Control block placement

3.8 Additional features for control system, lock-unlock system

To integrate lock-unlock system it needs more pins. And because of additional pins another micro controller is needed. To fit need of additional pins Arduino mega R3 2560 is used to replace Arduino uno R3. This Lock-unlock system issues safety of the machine.

Fig. 3.16 Arduino mega R3 2560 [18]

Table 3.6 Arduino mega R3 2560 summary [18]

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage	7-12V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
Flash Memory	256 KB of which 8 KB used by bootloader

In this blueprint is shown system of lock unlock system which uses RC522 module. RC522 module is radio-frequency identification (RFID). And it used instead of key. Sound is emitted and led lights up if card fits.

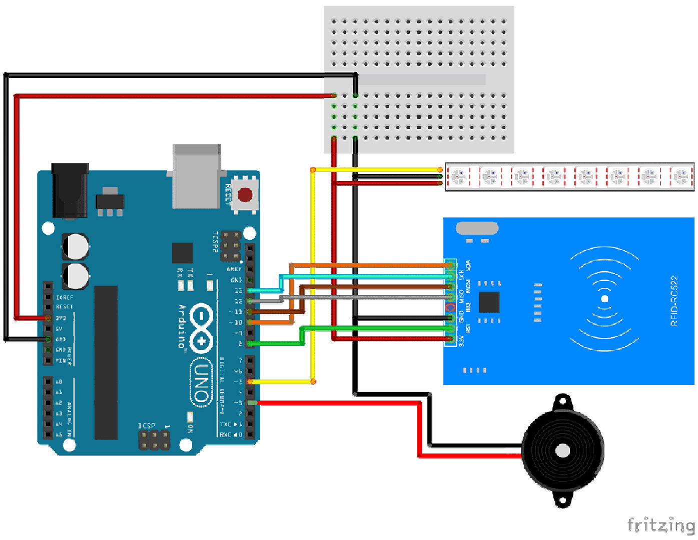

Fig. 3.17 Blueprint of lock-unlock system

CONCLUSIONS

- New design of the wheelchair was created. Frame was changed to much slimmer and strength of the frame was increased. More comfortable and safer seat was designed. Also easier approach to chair was implemented by making access point from axel.
- New calculations were carried out for frame because of changes in frame design. Simulation shown that new frame will withhold load that will appear.
- For controlling wheelchair electronic sensors and components is used: microcontroller Arduino uno R3 which is programed to control safety system and driving system. Driving system is controlled through microcontroller by input from analogic joystick.
- Safety system was implemented to make wheelchair more safer machine. Safety belts was added, and ultrasonic sensors was implemented which detect obstacles that machine can’t pass.

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