Center for robotics
Physics-Mathematics Lyceum 30

Engineering book of
Competition First FTC

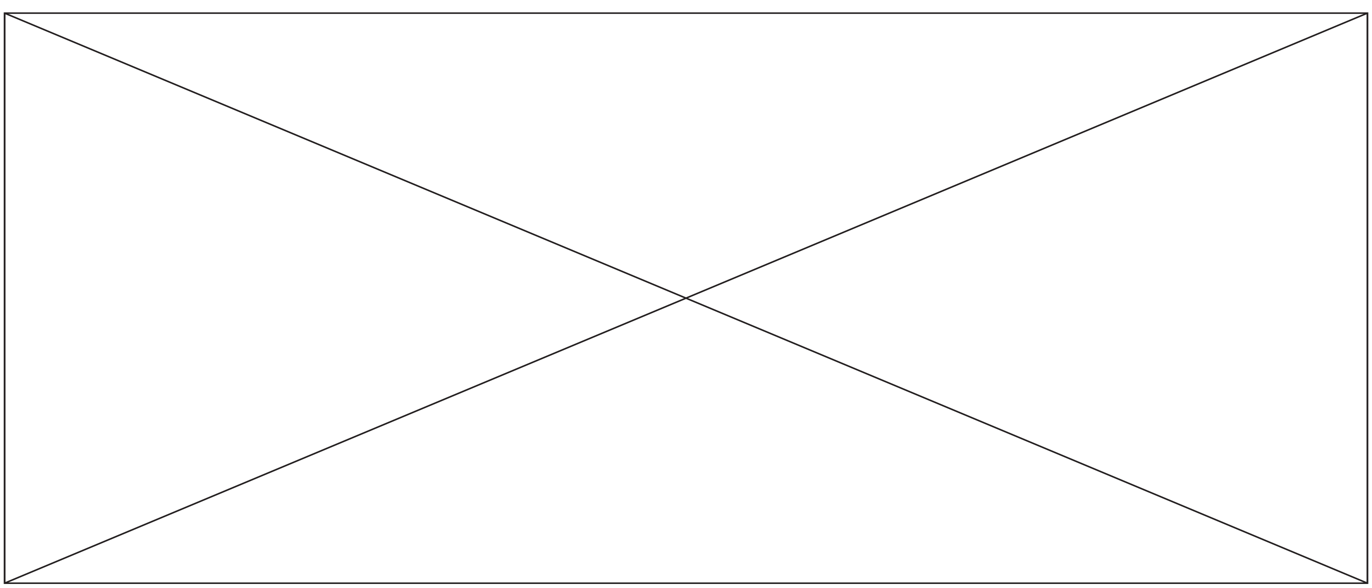
Team PML30 $-Y$

Saint-Petersburg, Russia
2015

Содержание

1 Team PML 30 –Y

Team PML 30 – Y was assembled in September 2014 in the Russian city of St. Petersburg from 3 novices and 2 participants with experience. Tasks and roles were distributed among the participants, and we established safety rules. In the first place the team put spreading principles of gracious professionalism to others. All decisions were made collectively inside team with discussion to find the most optimal solutions. During the year we took part in many events and everywhere we have tried to attract attention to our team and encourage people to take part in FTC. Also we pursued and distributed the principles of honorable professionalism. Talking to the press, we hoped to attract more attention to our team and to the competition in general, as well as attracting sponsors. The latter was important because of the need for funds - purchasing materials and equipment costs a lot. The team took part in the three qualifying competitions and in the regional finals. In all of them we made new contacts, shared experience and provided mutual assistance to other teams. In the first qualifying rounds in Sochi we met Stuy Fission 310 from USA and maintain contact with them to this day. On regional finals, we met with a team from Romania, Auto Vortex, and keep in touch with them through Facebook. Also, there is an active group chat with a large number of Russian teams. You can find the team page in Facebook at the address https://www.facebook.com/pages/FTC-team-PML30-PHI. To increase the efficiency of our team work we used the version control system GitHub, which allows the entire team to work simultaneously on a single projects without losing files and providing easy way to resolve roblems. Also for writing technical books we been used professional typesetting system LaTeX.

[H] 

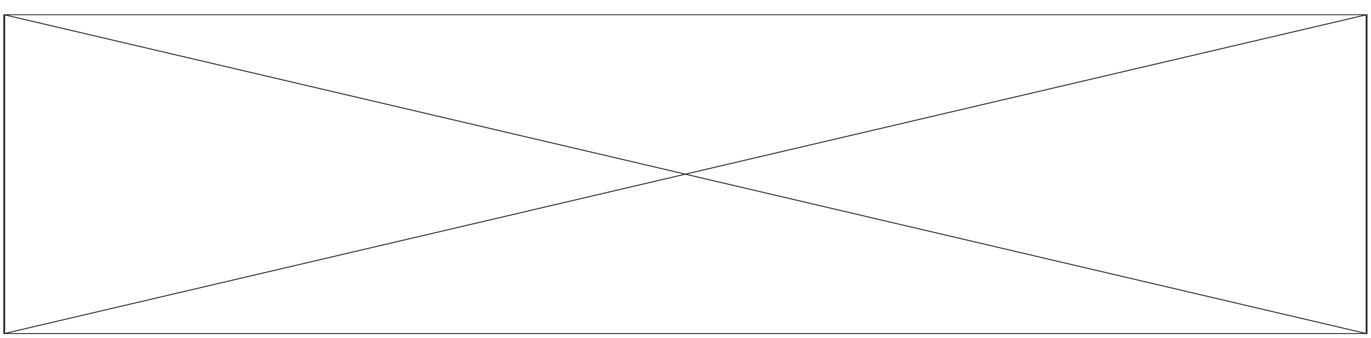
1.0.1 Instructors

Luzin Dmitry
Head of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Main coach of FTC team.
Information: 25 years old, in robotics 5 years, in FTC 3 years.

Luzina Ekaterina
Professor of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Tutor of FTC team.
Information: 25 years old, in robotics 5 years, in FTC 3 years.

Fedotov Anton
Professor of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Tutor of FTC team.
Information: 22 years old, in robotics 4 years, in FTC 3 years.

Krylov Georgii
Professor of Robotics Department in Phys-Math Lyceum 30, Saint-Peterburg, Russia. Tutor of FTC team.
Information: 18 years old, in robotics 4 years, in FTC 4 years.



1.0.2 Team members

Alexandr Iliasov
Role in team: reserve operator-1, decorating robot, Power Design, responsible for the bucket.
Information: 16 years old, in robotics 3 years, in FTC 2 year.
Why I chose FTC: "I choose to partipucate in the FTC, because it requiers many skills in a lot of interesting themes: physics, engineering, programming, geometry. Also, you need to work in team, argument your choise and listen others. You need find problems and solve it. All that skills you can obtain in FTC."

Anton Ponikarovsky
Role in team: captain, communication with other teams and community, reserve operator-2, responsible for the elevator.
Information: 17 years old, in robotics 3 years, in FTC 2 year.
Why I chose FTC: "I decided to join FTC because I believe that this competition is one of the most challenging of those, which are familiar to me. It requires responsibility, capability of working in team, communication with other teams, working on hardware, software and even tecnical documentation. All the experience you accumulate through doing FTC, you can apply in your future profession, if it is technical oriented."

Andrew Nemow
Role in team: operator-1, responsible for the writing of technical book, responsible for debris collecting systems.
Information: 16 years old, in robotics 2 years, in FTC 1 years.
Why I chose FTC: "When I first I attended the event FTC saw hefty metal robots, with enthusiasm and without hesitation decided that I would like to do this."

Gordei Kravzov

Role in team: development strategy in the game, operator-2, responsible for chassis.

Information: 16 years old, in robotics 2 years, in FTC 1 year.

Why I chose FTC:"I enjoy making huge and complicated mechanisms work, that's why I chose FIRST FTC. In my opinion it's a great way to improve your skills and broaden the mind doing something that you love by the whole heart."

2 Thanks and prospects

We enjoyed working on a custom and non-standard project, which, besides its technical aspect, included working with new people who shared our values of friendship and mutual understanding.

Our team is planning to continue doing robotics, setting new goals for ourselves in order to improve. This is our first year taking part in FTC and we will participate next year as well. If we don't realize ourselves this year, we'll look at all our mistakes, correct them, and preform a lot better next year.

In any case, we are ready to learn new things, improve ourselves and expand our skills.

None of us know for sure what we want to do in the future, but we are certain that our experience will be very valuable to us.

Our thanks go to the company FIRST for organizing this competition, which we are very happy to be participating in. We appreciate this wonderful opportunity to test ourselves and learn something new and wish them success and growth in their future endeavors.

Also we thank our sponsors: company PTC and it's Russian representative "Irisoft"and charitable foundation "Finist"for their support. Also we thank Physics-Mathematics Lyceum 30 and it's director Alexey Tretyakov for providing comfortable conditions for preparation to competition.

Team PML 30 φ

3 How to read this book

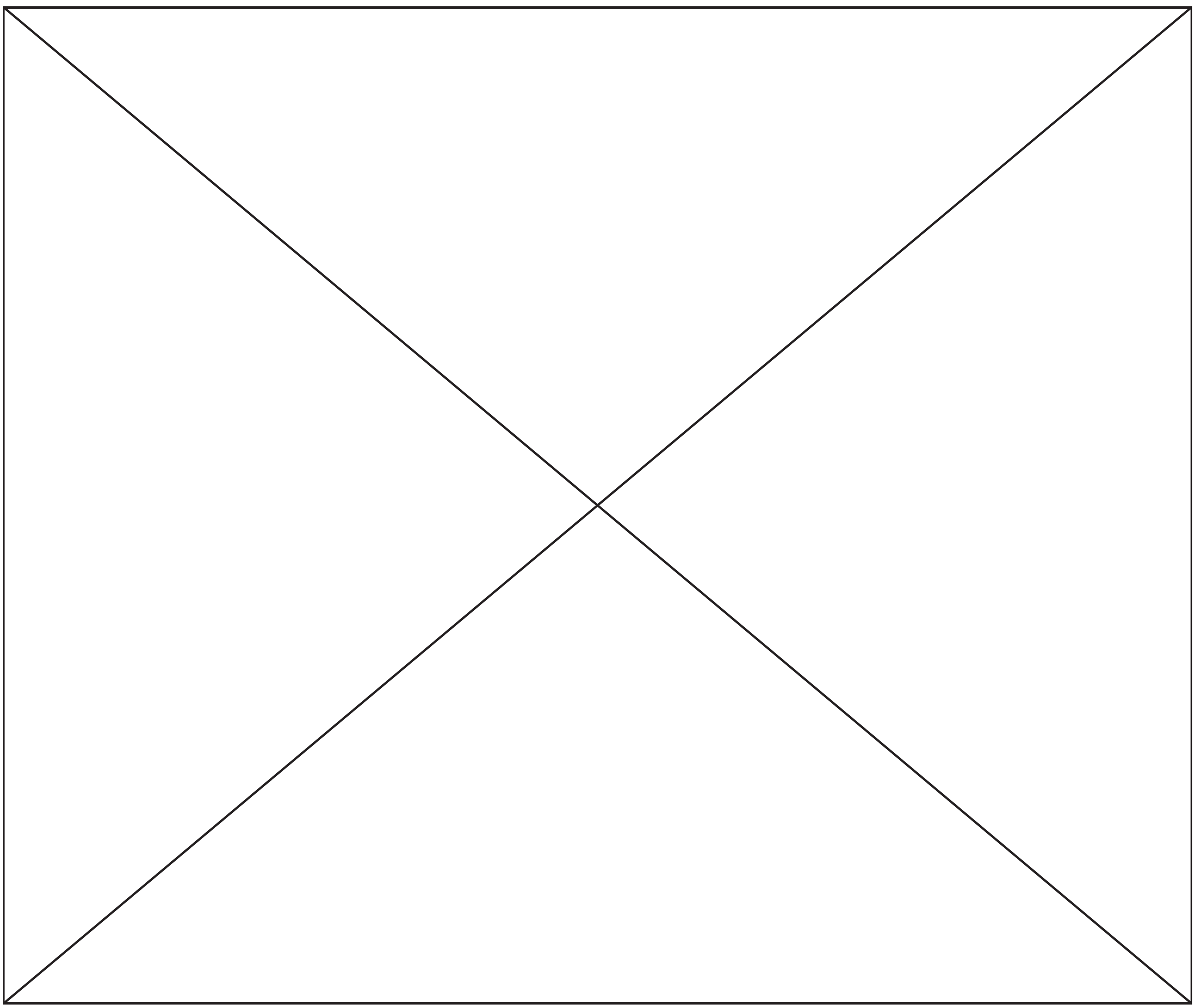
The book consists of 3 chapters.

1. The first is an introduction, here are represented our team, our instructors, our sponsors.

2. The Engineering chapter consists of two parts: consequence of meetings, which show our progress in elaborating and particular documentations for each module and for tele-op and autonomus programs. This approach allows to show the engineering process from two sides: a chronological one and an engineering one.

3. Appendix includes the list of materials applied in our robot.

Here is the detailed structure of Engineering chapter. Sections 1 to 3 show thinking over the project and on-paper calculations and design. Section 4 shows the development of real robot. Sections 5, 6 include specifications for modules and programmes.



3.1 Brainstorming (21.09.2015)

Time frame: 21.09.2015 17:00-21:00
Preview: Since this year FTC rules were published, every member of our team had carefully read them. Today we gathered together to discuss all the aspects of this year gameplay and think of how to get on with the most significant features of the game.

General aspects:

Features	Solutions	Label
Moving to the ramp is essential to achieve high score.	Robot's wheel base should be good at moving on the ramp.	chassis
Space between each two bars in 3-rd zone is wider than the standard TETRIX wheel diameter.	Using tracks or 3-4 wheels from each side of the robot will prevent robot from getting stuck.	chassis
It will take a lot of time to climb to the 3-rd zone of the ramp.	It is possible to deliver debris to the highest goal with elevator standing on the 2-nd zone instead of climbing to the 3-rd.	elevator
Goals for debris have a very little capacity.	It is more preferable to collect cubes than balls. That's why we need mechanism to prevent balls from collecting.	gripper
Pulling up costs 80 points. It's not difficult to realise then.	At least 1 DC motor should be reserved for pulling up. It is possible to grasp the pull-up bar with hook and lift to it by reeling the cable.	pull up
Moving over the inclined plane and pulling up require high moment on motors. However, the number of motors is limited.	Robot should be light enough to decrease the moment required for moiving and, as a result, increase speed of moving.	weight
All the zones of red alliance are the mirror reflection of blue alliance's zones.	Robot should be symmetrical and capable of playing on both sides of field.	concept
Robot can grip 5 debris at once, when the maximal capacity of one bucket is 24 cubes. So, to fill one bucket robot has to repeat collecting and taking cubes to the goal 5 times per 1,5 minutes	Gripper for debris should be at the front side of the robot and extractor for scoring elements - from the back side. It will allow robot to go to the ramp backwards, so it won't need to turn around on the ramp before going down to collect debris. It will save some time.	concept
It's quite unconvenient to exchange ramps with your ally during the game.	We will negotiate with our ally about spheres of influence before each game. Additionally, there should be two autonomus programs for climbing onto both ramps.	strategy
The only main difficulty of this year autonomus period is that both robots in alliance have to fulfil the same tasks at the same place. So, there is a high risk of collisions between them.	A number of different programs for autonomus period are needed for easier adjustment to the ally's strategy.	strategy
It's not restricted to collect debris in autonomus period.	It will be useful to realise automatic collection of 5 cubes in autonomus period. At the conclusion of autonomus period the robot will remain on the ramp with 5 cubes and we will put them to the goal immediately	strategy

Detailed explaination:

1. As we know from our previous FTC seasons experience, there are strict constraints for wheel bases can be used for climbing mountains. Firstly, omni and mechanium wheels are completely not suitable, because mechanium wheels can ride only on plain surface (when 2-nd and 3-rd zones have cross hurdles) and omni wheels have ability of undependable movement on small rollers so they behave very unstable on mountain. Various conbinations of standard and omni wheels can't be used too, as in the 2-nd zone there are obstacles which can cause some wheels lose contact with ground and if the rest of wheels will behave differently, the whole robot would be unstable. In conclusion, we can use only standard wheels or tracks.
   Additionally, wheel base should be symmetrical against central axis for stable climbing to the mountain.
   If we decided to climb 3-rd zone with standard wheels, we will have to put 3-4 wheels at the each side to avoid getting stuck on hurdles (the space between two hurdles is for about 14 cm, when the diameter of big TETRIX wheels is only 10 cm).

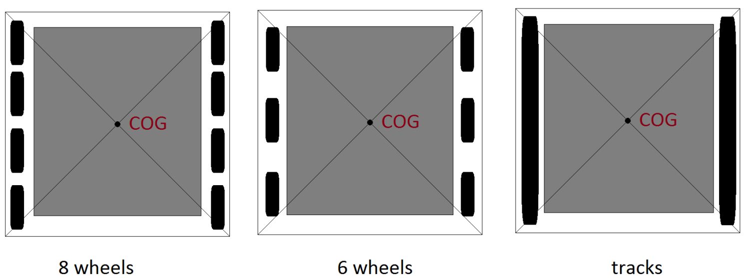


Рис. 1: possible wheel bases

2. To score in high zone goal from 2-nd zone robot should have a mehanism for delivering debris to the distance of 40 cm or more. Shooting debris is entirely unsuitable approach, because it's impossible to realise enough accuracy for stable scoring cubes and especially balls. Another way is elevator. There are three types of lifts which familiar to us: they're crank lift, scissor lift and retractable rails.
   Scissor lift is not suitable for this year competition, because despite it's main advantage - the ability of extracting the longest distances of all - it's too difficult in development.
   Crank lift allows to vary the angle of turning of each segment. However, it requires at least one DC motor of strong servo for every joint.
   Retractable rails can only move along one axis. However, they require the least space and can be equipped by one DC motor (as all the motors are connected to the only reel, which winds the cable).

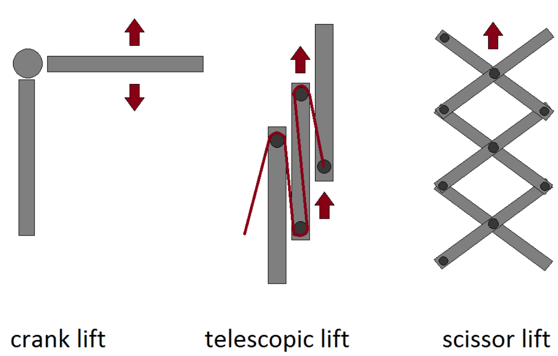


Рис. 2: types of elevators

3. The parameters of the box are $9 \times 5.75 \times 6.25$. So, it can contain at most 24 cubes (4 in length, 2 at width and 3 in depth). As for balls, there can't be scored over approximately 10 of them because of their unconvenient shape and ability of top balls to roll out of the box (especially from the upper box, which is turned on $50°$ from horisontal position).
   This is the reason to implement mechanism for separating debris into cubes and balls. However, there are only 50 cubes on field (12.5 for one robot), so they will run out quickly, so the ability of collecting balls is required as well.
   Additionally, we need to think of how to put cubes into boxes gently so as they will settle down in straight lines. It will allow entire filling boxes with cubes.

4. Solid constructions for pulling up will be too bulky because they have to be strong enough to withstand full weight of the robot. The more reliable and simple solution is steel cable with hook for grasping the bar on it's tail.
   In second case the most difficult objective is to deliver hook to the bar, which can be solved by creating secondary lift for it (the main one is a lift for debris). Mechanism for shooting hook towards the bar is not suitable as it can be dangerous for operators and spectators (if the it will be accidentally activated during the match).

5. The main weight of the robot goes the battery and motors. The weight of the battery is 570g. We have two types of motors: standard TETRIX motor (207g) and "NeveRest 40"motor by AndyMark (334g). The complete control system (phone + controllers + power distributor) weigh about 700g.
   Therefore, total weight of essential components varies from 2926g to 3942g (with 8 motors). With several beams (166g the longest), wheels (117g each) and other construction elements robot will weigh from 6 to 10kg.
   In our primary calculations robot's weight will be accepted as 10kg. However, it is preferable to make robot as light as possible.

6. Wheel bases which are good at climbing mountains are usually less manevrous, than carriages with omni and mechanium wheels. This way, the less robot will turn, the more effective it will compete.
   Accordind to this, it will be more convenient to realise construction that will allow robot to score debris without turning around. Robot can collect debris with gripper on it's front side while moving forward and then go backward to the ramp and score debris with the mechanism on it's back side.
   Furthermore, it will be useful to attach one robot to one ramp in order to prevent them from commiting extra movement. Although it seems that two robots can fill the top goal together two times faster, in fact they will just interfere with each other. So, it will be a good tactical step to negotiate with our ally before the mach which robot will operate with each mountain.

7. This year field is symmetric with respect to the diagonal. It means that all zones of one alliance are the mirror reflection of another. Consequently, the gameplay depends on which alliance you are playing for. So, the robot should be capable of executing equal tasks playing for each alliance. The major unconvenience cause releasing alpinists, as it requires two similar mechanisms from both sides, that will take 2 servos instead of 1. Mechanism For scoring debris should be summetrical to provide filling boxes from both sides of the ramp. Besides, autonomus program should be twoside as well.

Additional comments: For the next meeting we need to think of two issues:

1. which tasks our robot should be able to execute without loss of efficiency
   and
2. to set the priorities of performing tasks during the game.

3.2 Strategy discussing (22.09.2015)

Time frame: 22.09.2015 17:00-21:00
Preview: Today we put the priorities during the building of the robot and performing tasks of the game.

Detailed explaination:

1. The tasks which robot must complete (We assume that robot can do everything. Tasks located in order of priority) :
   - 1.1. Autonomous period:
     - 1.1.1. Push the button and score climbers. It give 60 points (20 - button 10x2 - climbers in autonomous 10x2 - climbers in tele op).
     - 1.1.2. Ride to opposite mountain and collect balls and bricks. It help us to save a time because when start tele op we already have 5 bricks.
     - 1.1.3. Go to middle or high zone of the mountain. It give 40 (or 20) points. Additionally, we start driver control period near the top box. So we can put 5 bricks there immediately.
   - 1.2. Driver control period:
     - 1.2.1. Put elements that we collected in autonomous period to the top box.
     - 1.2.2. Go from the mountain and collect 5 bricks. We decided to collect only bricks because the balls take up much space in the box. So if we collect only bricks we can put more elements to one goal and get more points.
     - 1.2.3. Put 5 bricks to the top box. After that the top box most likely will be full. So we won't be able to put another five bricks.
     - 1.2.4. Collect and put 5 bricks to the middle box.
     - 1.2.5. Start moving to the crossbar and score climbers.
     - 1.2.6. Turn "all clear"signal.
     - 1.2.7. Pull-up.
2. Implementation of robot that can perform following tasks (tasks are in order of priority)
   - 2.1. Stable scoring to the middle box. This task is very simple and give a lot of points.
   - 2.2. Scoring to the high box. This task is more complex but gives more points.
   - 2.3. Releasing the climbers on the rope in driver control period. We can do it very fast and get 60 points but for scoring the top climber we must be able to climb to high zone.
   - 2.4. Scoring climbers in autonomous period. It is very easy task that give 40 points (as 4 bricks in the middle box).
   - 2.5. Riding to the high zone. It can give 40 points in autonomous period and 40 points in tele op.
   - 2.6. Pulling up. This task give the most number of points.
   - 2.7. Turning "all clear"signal. It gives us 20 points and our opponent lose 20 points.
   - 2.8. Pushing button. This task is difficult in terms of programming and gives only 20 points.

Additional comments:Task for the next meeting: to elaborate concept of the robot.

3.3 Concept discussing (24.09 - 02.10)

Description: The main purpose the following number of meetings was to develop a concept of the robot. It is an essential step before creating models and developing construction.

Modules:

Modules	Conclusive solutions	Label
Wheel base	Six standard wheels	wheel base
Lift	Retracktable rails with the bucket on it	lift
Bucket for debris	Bucket mounted on rails that can overturn backwards to put debris into the box	bucket
Gripper	Rotating brush ahead of the bucket	gripper
Scoring autonomous climber and pushing button	F - shaped beam	climbers + button
Scoring climbers in tele op	Retracktable slat	climbers
Pulling up	A hook with the winch	pullup
Push the clear signal	Servo with beam	clear signal

Separation tasks between collaborators:

Collaborator	Modules	Label
Gordei Kravtsov	Wheel base	chassis
Aleksandr Iliasov	Bucket	bucket
Anton Ponikarovskiy	Elevator	elevator
Andrei Nemov	Gripper and slopes	gripper
Timur Babadjanov	Beam for alpinists	alpinists

Days inside section:

3.3.1 24.09.15

Time frame: 17:00 - 21:30
Preview: The main purpose for current meeting was to figure out how the modules of the robot should look and how they will be developed.

Modules:

Modules	Solutions	Label
Wheel base	Six standard wheels with leaf suspension	wheel base
Lift	Scissor lift	lift
Gripper	Rotating brush and bucket	gripper
Scoring autonomous climber and pushing button	F - shaped beam	climbers + button
Scoring climbers in tele op	Retracktable slat	climbers
Pulling	Motor that reel the rope	pullup
Push the clear signal	Servo with beam	clear signal

Detailed explaination:

1. Wheel base will consists of six standard wheels which rotates with help of six DC motors. It allows to climb to low and middle zone fast enough. The leaf suspension ensure stability in the middle zone.

2. We decided to use the lift in our robot. It help us to score elements to high goal from low or middle zone. So we don't need climb to the high zone. We choosed the scissor lift because it is compact and extend to a big height .

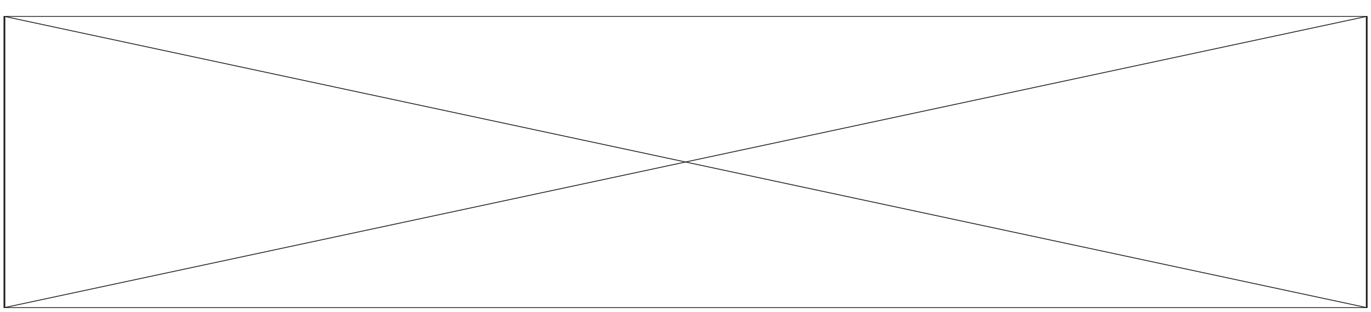
3. The robot will collect elements with help of rotating brush which pull them to the special bucket which connected with the lift. This method is the most simple and fast. After collecting elements the bucket rises by the lift. Then it overturns to the side and elements fall to the box.

4. We decided to make one mechanism for scoring autonomous climbers and pushing the button. It is the F-shaped beam. In the top beam is the bucket for climbers, in the bottom - axle which push button. When we turn this mechanism the axle push the button and in the same time climbers fall to the goal.

5. For scoring climbers in tele op we decided to use horizontal retracktable slat that move to the both sides by the whhel that rotate with help of servo of continuous rotation. When the slat extract it push to the hook that fix zip line.

6. The pulling mechanism is the 2 DC motors that reel the rope which connected with the hook that fixed on the lift. Also this motors rise the lift. When lift is rising the rope is extracting. When the robot pull up rope is reeling and lift is lowering.

7. For pushing clear signal we decided use the servo with beam that fixed on the lift.



3.3.2 26.09.2015

Time frame: 17:00-21:00

Tasks for current meeting: To improve the concept of the robot.

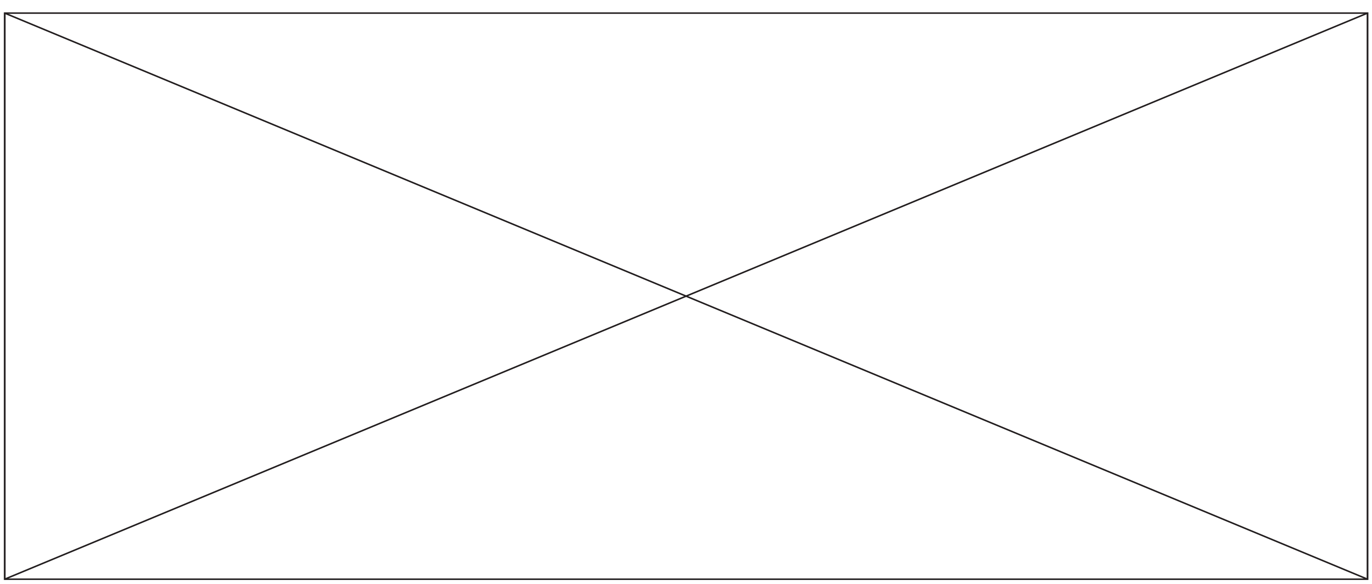
Module	Solutions	Label
Wheel base	6 standard wheels without suspension	wheel base
Lift	Retracktable slats	lift
Scoring elements	Bucket overturns back	gripper

Detailed explaination:

1. We decided to refuse from suspension on wheel base because it is too complex and reduse reliability of the robot.
2. We decided to use lift that consists of retracktable construction profiles. This system is more reliable.
3. We decided to overturn the bucket back and turn the robot because when we overturn it to the side we need ride to the ramp very accurate. In addition when we overurn it to the side we need very long bucket.
4. We decided to score climbers in tele op with help of the servo which turn the beam (one servo on each side of the robot). This mechanism is more compact.
5. Also we thought that for scoring elements and pulling we need different angle of inclination of the lift. So we need the mechanism that turn it.

Additional comments: What to do the next meeting.

1. To think of the mechanism that turn the lift.



3.3.3 30.09.2015

Time frame: 16:00-21:00
Tasks for current meeting: To think about mechanism for turning lift.

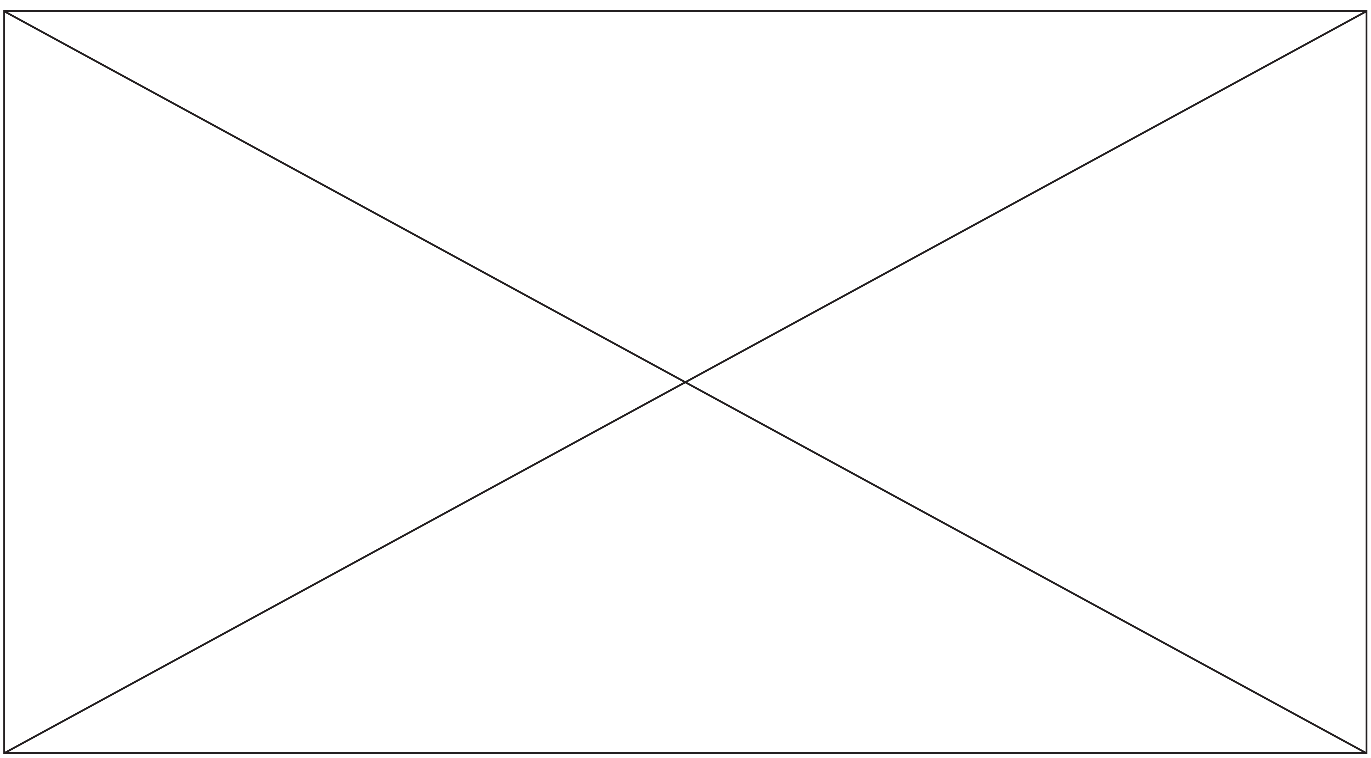
Tasks	Solutions	Label
To elaborate mechanism for turning lift	Servo of continuous rotation with worm gear	robot

Detailed explaination:

1. We made a drawing in GeoGebra where were estimated angles of inclination of the lift for scoring elements and pulling.
2. We looked the variant with DC motor and transmission for power but it take up much space.
3. We decided use the servo of continuous rotation with worm gear. The worm gear esure power and allow to keep position.

Additional comments:
Tasks for the next meeting:

1. To make a schematic model of the robot
2. To devide the robot into modules.
3. To make a technical task for each module and start parallel elaborating models of each module.



3.3.4 02.10.2015

Time frame: 17:00-19:30
Preview: The purpose of this meeting was to divide all construction works into 4 groups (one group for one teammate) to elaborate modules in parallel. After that, we wrote the technical specifications for each group of modules to help collaborators follow the requirements.

Technical specifications for modules:

1. Chassis
   1.1. Carriage consists of two lengthwise beams 41.5cm connected at the back. All other modules will be mounted to this base.
   1.2. Wheel base consists of 3 pairs of standard wheels. All wheels at one side are linked to each other and move together.
   1.3. Wheel base is powered by 4 dc motors (2 at one side).
   1.4. Motors should not interfere with the bucket, which will be placed in the front half of the robot.
   1.5. While the robot is climbing the ramp, no construction elements but the wheels should be touching the surface of the ramp.
2. The mechanism that turns the elevator
   2.1. A continuous rotation servo will turn the worm gear.
   2.2. It should be mounted on the side beam of the base.
3. Elevator
   3.1. Elevator consists of retracktable construction profiles which connected with help of special elements. The shape and size of these elements should be fit with grooves in profiles.
   3.2. It should be mounted on the turning mechanism.
   3.3. Length of the elevator should be enough for scoring debris into high and middle boxes from low zone and starting pullup from the middle zone.
   3.4. A thread and block system will provide lifting of elevator.
   3.5. The servo that turn clear signal should be fixed on the top of the elevator.
   3.6. The hook for pulling the robot up will also be mounted on the top of the elevator.
4. Bucket
   4.1. The bucket will be fixed to a beam turned by a servo on the top of the lift.
   4.2. Free space inside the bucket should be 10-14cm at width, 15-17cm in length and 7cm in height. It should be spacious enough to contain 5 cubes of 3 balls.
   4.3. To prevent gathering more than five cubes at once, the bucket will narrow down to the back (cubes will settle as $2 + 2 + 1$).
   4.4. The bucket's movement should not interfere with debris gripper.
   4.5. The entrance hole of the bucket should have the same height and width as the internal space.
   4.6. Bucket should have a turning flap above the entrance which can prevent balls from scoring not on demand. Additionally, the flap will stop debris from falling out of the bucket when it is be flipped over.
5. Gripper
   5.1. Gripper consists of 2 rotating blades which form a 180° angle.
   5.2. Gripper is powered by 1 or 2 continiously rotating servos.
   5.3. Gripper is placed in front the bucket. Blade width should match the bucket entrance.

5.4. Space between axis and field is enough for unhindered passage of balls.
5.5. Gripper should not pose any obstacle for bucket motion.
5.6. At both sides of the blade's working area placed slopes, which are tapering to the bucket.

6. Scoring autonomous climbers + pushing button

6.1. The mechanism for scoring autonomus alpinists will be placed at the front right side of robot. It's definite position will be determined after discussion of autonomus strategy.
6.2. Mechanism consists of F-shaped beam powered by standard servo.
6.3. At the end of top beam is a bucket for 2 alpinists. The bottom beam pushes the button.
6.4. Module should not interfere with gameplay after the autonomus period ends.

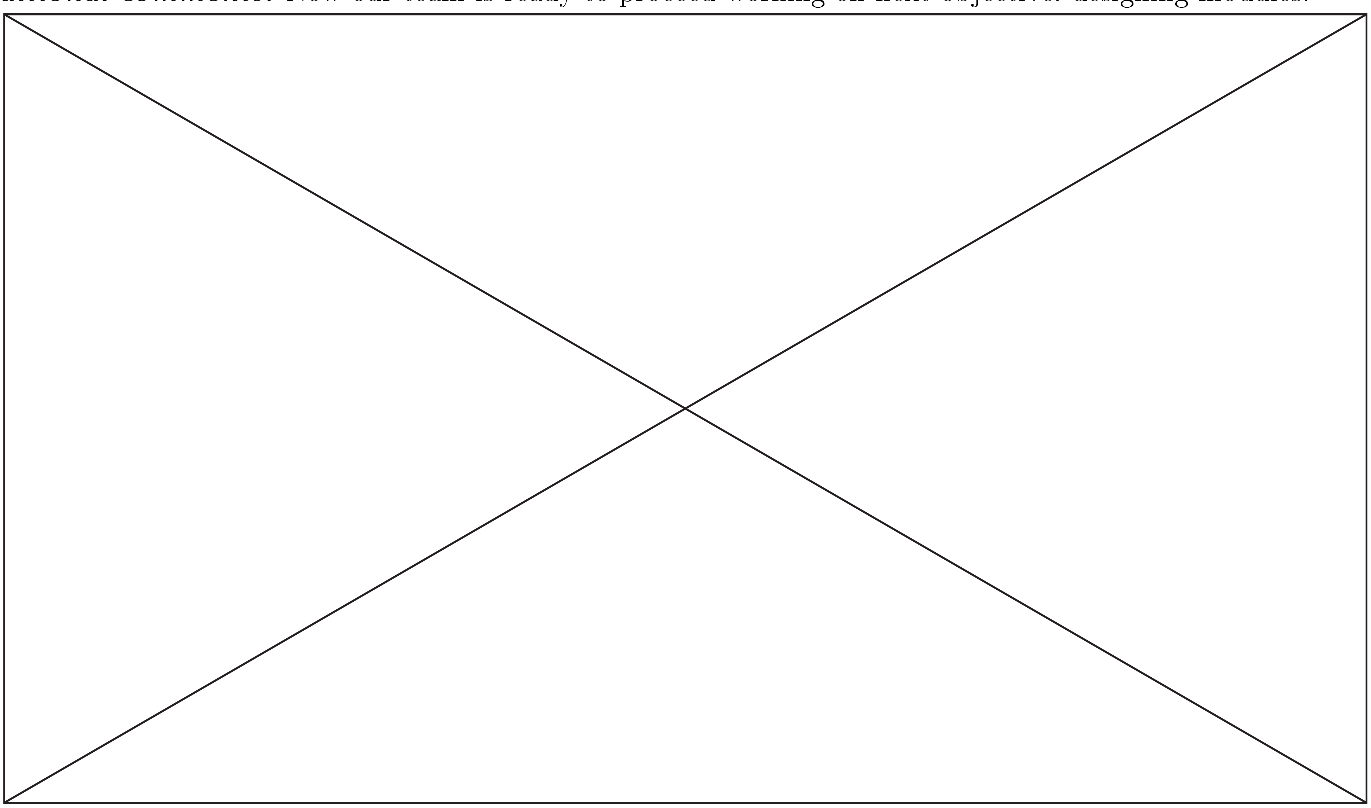
7. Mechanism for extracting lift and pulling

7.1. Two reels that are rotated by 4 DC motors.
7.2. The rope for pulling and line for extracting lift are in different reels. When the line wound the rope unwound and in other way.
7.3. It should be mounted on the back beam of the base.

Responsibilities for each module:

1. Carriage and wheel base - Gordei Kravtsov
2. Bucket - Aleksandr Iliasov
3. Elevator - Anton Ponikarovskiy
4. Gripper with slopes and the mechanism for scoring alpinists - Andrei Nemov

Additional comments: Now our team is ready to proceed working on next objective: designing modules.



3.4 Team meetings (10.11 - 03.12)

Description: The following section contains a consequence of team meetings with short descriptions. The purpose of this is to present the elaboration of the robot in it's progress. You can find the full information about modules and program in sections "specifications for modules"and "specifications for programs"correspondingly.
Days inside section:

3.4.1 10.11.2015

Time frame: 17:00-21:00
This day there were discussed the results of design work. All the models of modules were finished and we were able to start creating the robot.

3.4.2 12.11.2015

Time frame: 17:00-21:30
Today it was created the carriage. There were applied 7 cm standard wheels with gear ratio 2:1 (speed about $2 \times 7 \times 2 \times Pi = 88$cm/sec). Next motors were connected to motor controllers and an NXT brick (as we didn't have new control system) and it was realised a simple program to test the wheel base. Source code is available in the section "specifications for programs". The prototype had no problem with movement on the field. However, it's clearance was too narrow and it couldn't climb to the inclined plane. So, it was decided to rebuild wheel base with 10 cm wheels. It was also created the prototype of the gripper for debris.

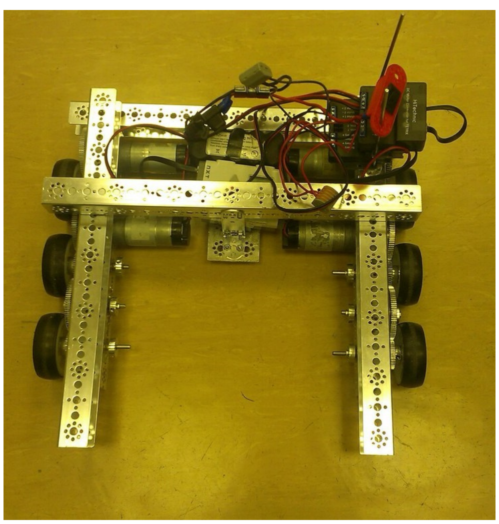


Рис. 3: Prototype of the wheel base

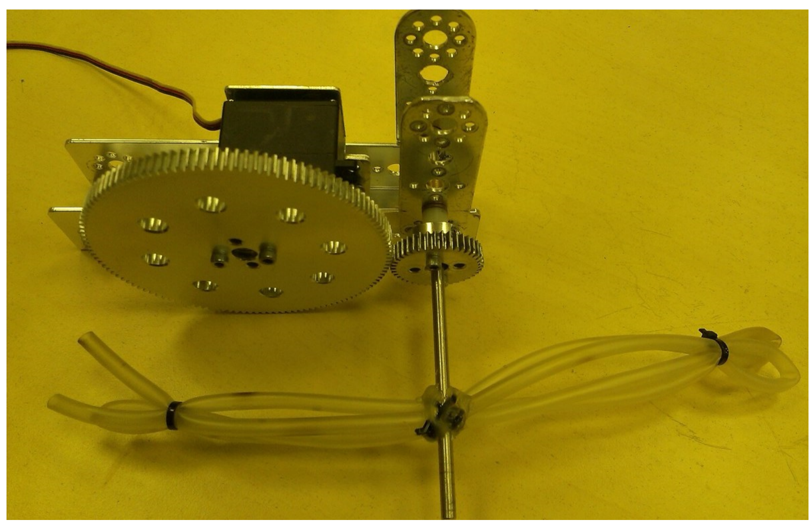


Рис. 4: Prototype of the gripper

3.4.3 14.11.2015

Time frame: 17:00-21:30
This day there was tested the improved version of program. It included movement by left stick, choosing speed with buttons A-D (12%, 24%, 48% or 96%) and accurate turns and straight movement (for alignment) with buttons L1, L2, R1, R2. Source code ia available in the section "specifications for programs".

3.4.4 16.11.2015

Time frame: 17:00-21:30
Today the gripper was mounted to the carriage. Brushes for debris aren't installed yet.

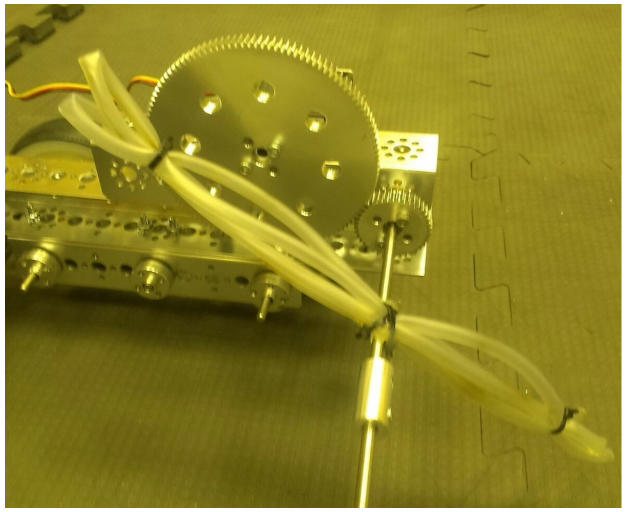


Рис. 5: Gripper on the carriage

3.4.5 17.11.2015

Time frame: 17:00-21:30
It was started the creating of a mechanism for shifting the bucket. This mechanism is used for delivering the bucket to the box at hte horison direction. It was also created a mechanism for scoring alpinists in autonomus period.

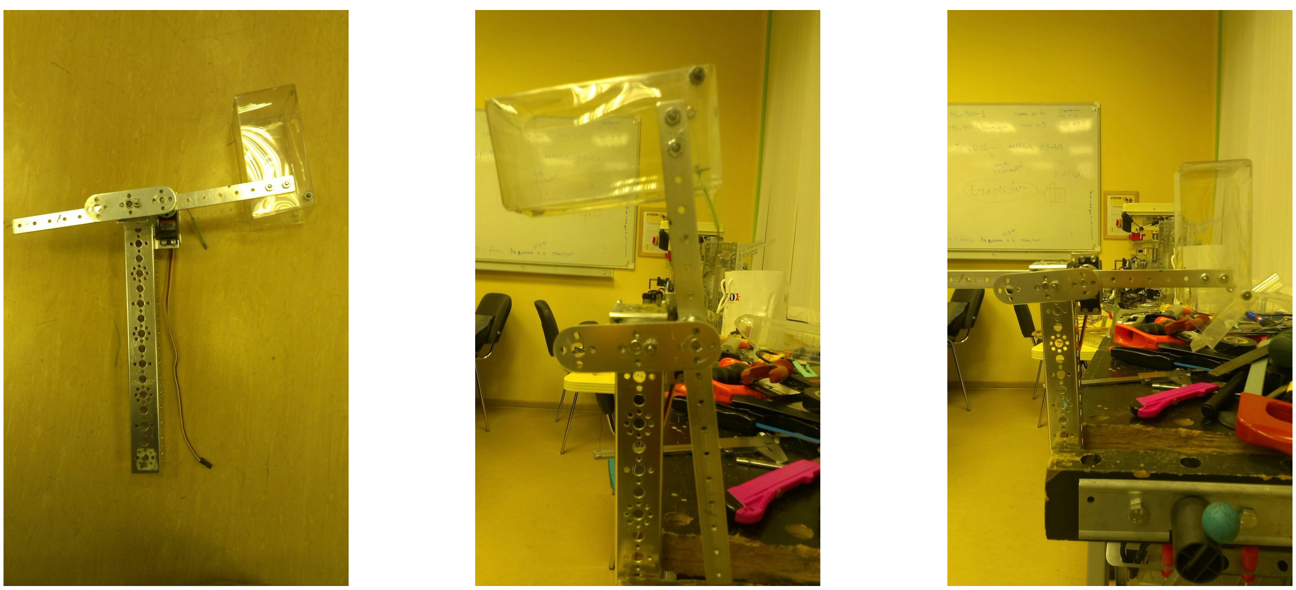


Рис. 6: Mechanism for scoring alpinists

3.4.6 18.11.2015

Time frame: 19:00-21:30
It was started the recreating of the wheel base. The left side was rebuilt with 10 cm wheels (figure 64). The gear ratio was changed to 1:1 (speed about $1 \times 10 \times 2 \times Pi = 63$cm/sec).

3.4.7 19.11.2015

Time frame: 17:00-21:30
The recreating of the wheel base was finished. There was written the new version of the program. An only thing that has been changed since the previous version are the settings of the stick. Operating area of the stick was divided into 6 sectors with one option in each. The previous version had 8 sectors, so it was more difficult to choose the right one by the thumb.

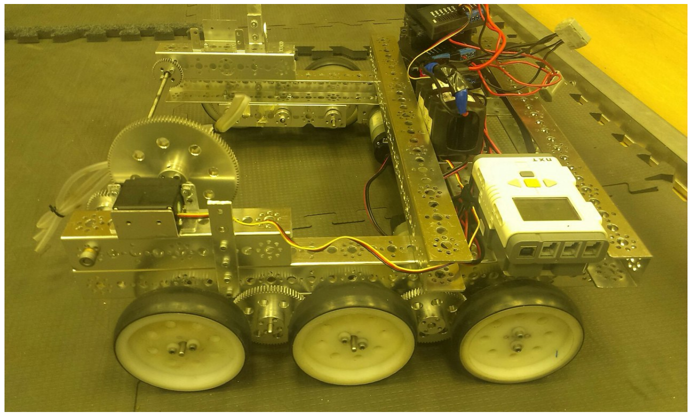


Рис. 7: Wheel base with 10cm wheels

3.4.8 21.11.2015

Time frame: 17:00-21:30
The mechanism for shifting the bucket was finished. The gripper was recreated due to the increasing of the height of the robot after installing 10 cm wheels. The axis was moved to the demanded height. After that there was created the brush. It was made of silicone tubes tied to the axis by plastic clamps. Next, the gripper was tested. The brush was capable of collecting debris. As for continious rotation servo, it was too slow and didn't have enough torque for acceptable collecing of the debris. One more problem was that the gripper was staggering, because it was made of two axes connected by the sleeve. To avoid this, it was decided to install one tetrix tube instead of axes.

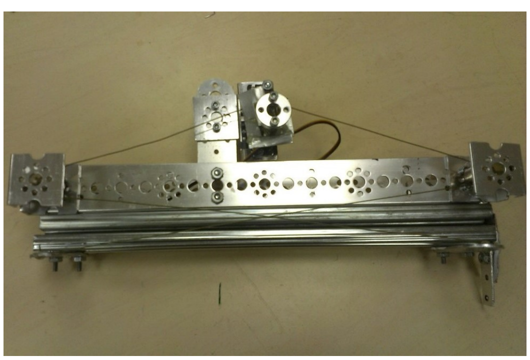


Рис. 8: Mechanism for shifting the bucket

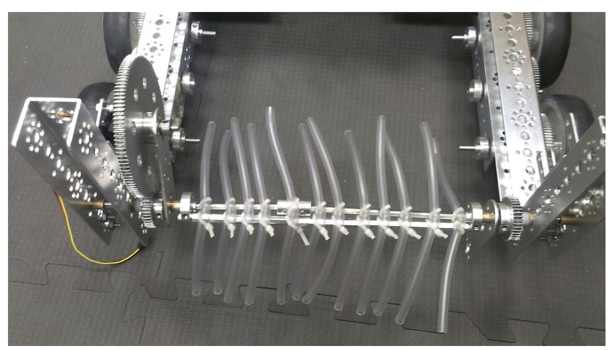


Рис. 9: Gripper with the brush

3.4.9 23.11.2015

Time frame: 17:00-21:30
It was created a prototype of the winch for elevator. This constriction had gear ratio 1:2.

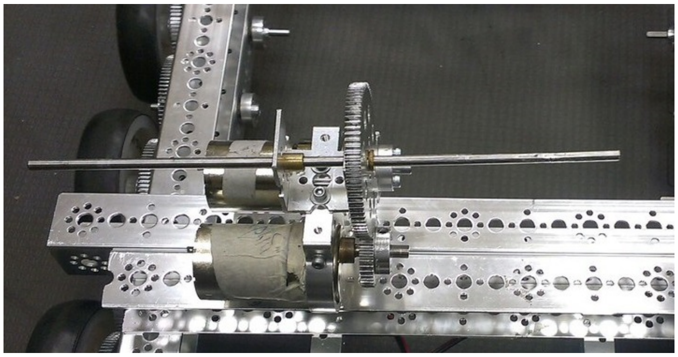


Рис. 10: Prototype of the winch

3.4.10 24.11.2015

Time frame: 17:00-21:30
The mechanism for scoring alpinists was recreated. The beam for countraweight was removed, as the calculations clarified that it is not nessesary. The mechanicm became more compact.

Рис. 11: New version of the mechanism for scoring alpinists

3.4.11 25.11.2015

Time frame: 19:00-21:30
The aluminium profile for the elevator was cut into segments. These segments were prepaired for installation onto the slats.

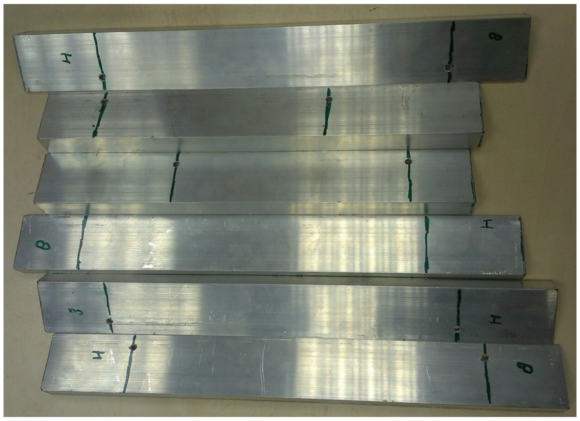


Рис. 12: Aluminium profile was cut

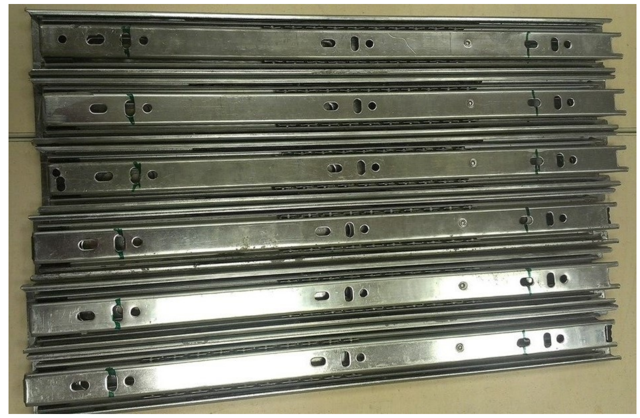


Рис. 13: Furniture rails were marked up

3.4.12 26.11.2015

Time frame: 17:00-21:30
Today we received the parcel with the original field. We started assembling it. The slats were assembled of 3 35cm furniture rails each and installed onto the carriage. The angle between direction of extracting of the rails and the surface amounted to 22.5°

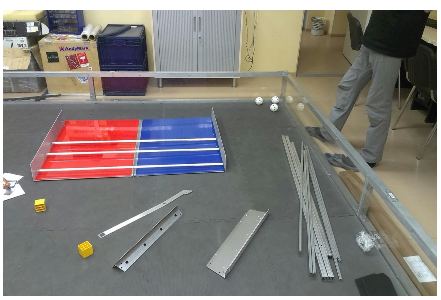


Рис. 14: Assembling of the field

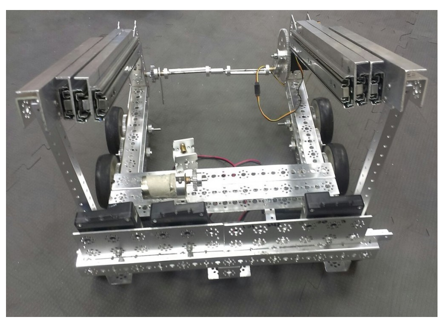


Рис. 15: Elevator installed onto the carriage

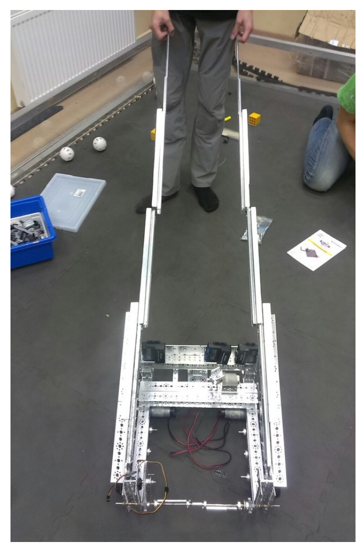


Рис. 16: Length of the slats

3.4.13 27.11.2015

Time frame: 17:00-21:30
The work piece of the bucket for debris was cut out of the pet. It was no time to craft the bucket at this meeting. There were installed angles onto the elevator. These angles will be used for installing blocks.

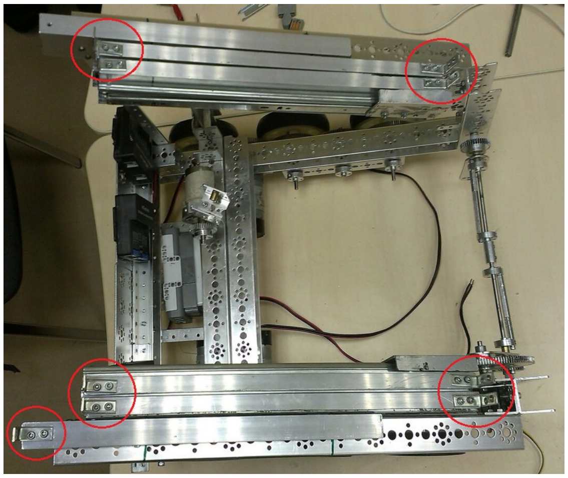


Рис. 17: Angles on the elevator

3.4.14 28.11.2015

Time frame: 17:00-21:30
Blocks were installed onto the angles on the elevator. The concept of the winch was changed. It was decided to apply 3 standard DC motors with gear ratio 1:1. 3 standard TETRIX motors with torque 10 kg/cm and speed 2 r/pm are able to pull up robot of 10 kg with a speed $3 \cdot 2\pi \cdot 2 = 38$ cm/s. Incliding safety coefficient 1.5 the speed will amount to 25 cm/s. Since the overal length of the cable required for pulling up from 1-st zone is about 1m, the robot will be able to pull up in 4 seconds. The time of the full extracting of the elevator would be the same.

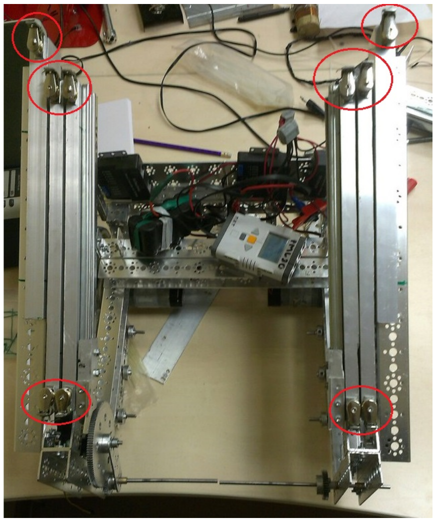


Рис. 18: Blocks on the elevator

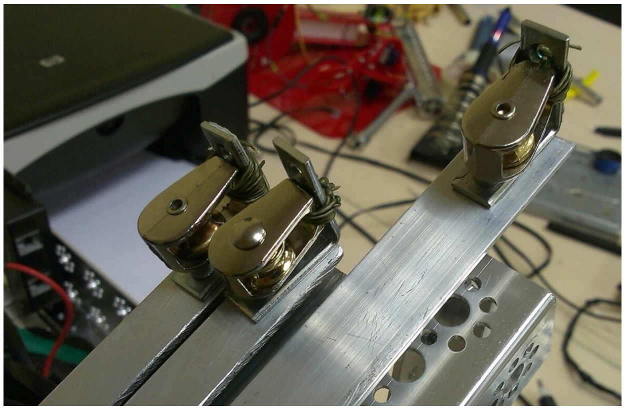


Рис. 19: Blocks

3.4.15 29.11.2015

Time frame: 17:00-22:00
The carriage was reshaped in order to provide more space for installation of the winch.

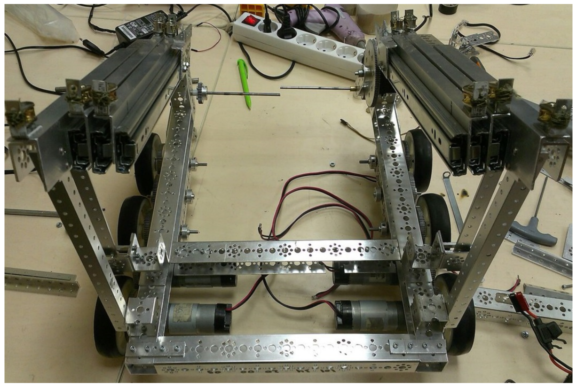


Рис. 20: Carriage reshaped

3.4.16 30.11.2015

Time frame: 17:00-22:00
The winch was assembled.

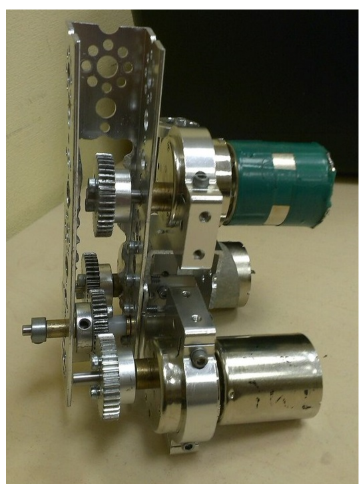


Рис. 21: Winch

3.4.17 01.12.2015

Time frame: 16:00-22:00
The winch was installed onto the robot, in the 8mm axis, that will keep the reels for rope, were drilled all the needed holes for fixing reels. The gripper was reassembled with the tetrix tube. For powering the gripper it was installed a standard DC motor with gear ratio 2:1.

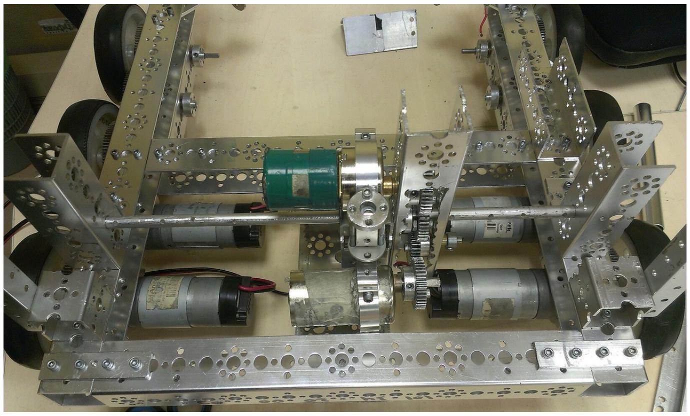


Рис. 22: Winch installed onto the carriage

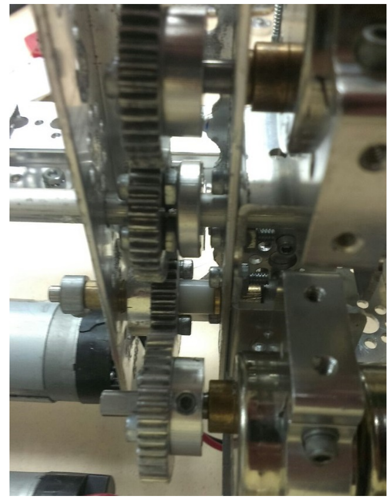


Рис. 23: The construction of the winch

3.4.18 02.12.2015

Time frame: 16:00-22:40
Reels were installed onto the axis connected to the winch. NXT brick, battery and 6 controllers (4 motor controllers, 2 servo controllers) were installed onto the robot

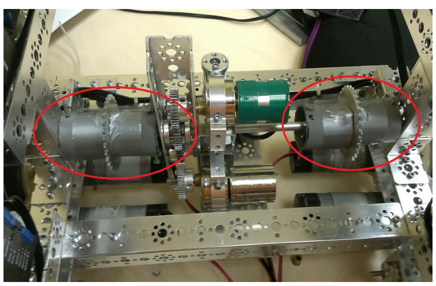


Рис. 24: Reels for the ropes

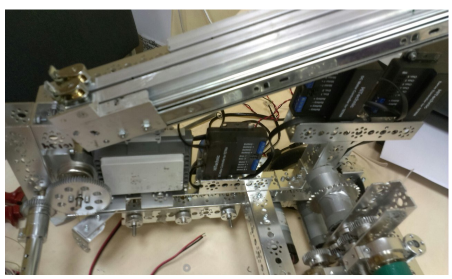


Рис. 25: Controllers and NXT on the right side

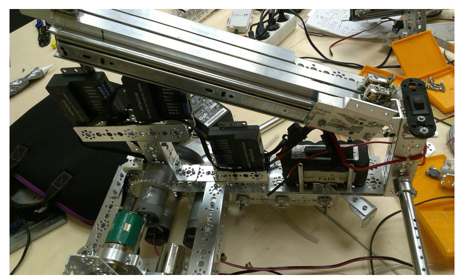


Рис. 26: Controllers and battery on the left side

3.4.19 03.12.2015

Time frame: 17:00-21:30
Today the mechanism for shifting the bucket was installed onto the robot. It was mounted to the top pair of slats. The bucket was installed onto the mechanism for shifting bucket. There were also created brushes for collecting debris on the gripper. To connect servos which are installed on the elevator there were manufactured special wires. They were made of telephone wire by soldering servo connectors. Unfortunately, it was investigated that these wires have too high resistance (9 Ohmes each), so it was impossoble to power standard servos by them. However, continious rotation servos worked with these wires with no problem (possibly because of higher inner resistance).

3.4.20 04.12.2015

Time frame: 16:00-22:00
The winch was installed onto the robot, in the 8mm axis, that will keep the reels for rope, were drilled all the needed holes for fixing reels. The gripper was reassembled with the tetrix tube. For powering the gripper it was installed a standard DC motor with gear ratio 2:1.

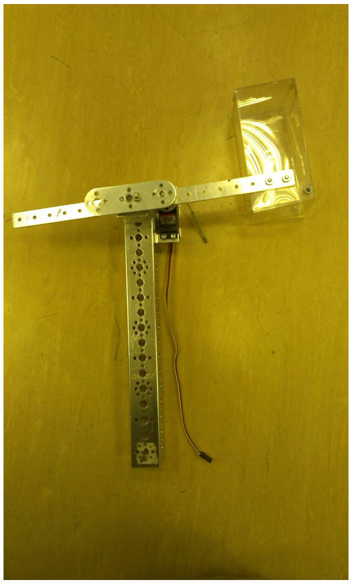


Рис. 27: Winch installed onto the carriage

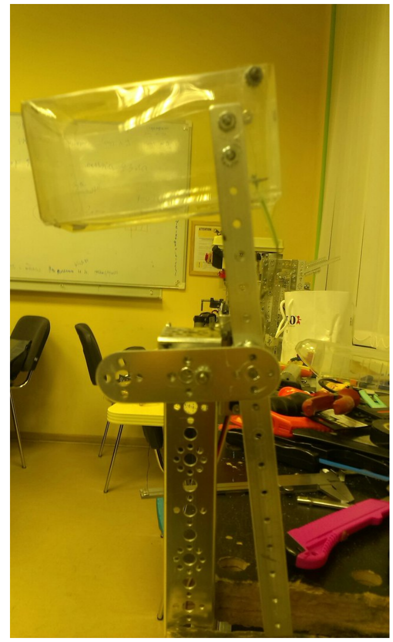


Рис. 28: The construction of the winch

3.4.21 05.12.2015

Time frame: 16:00-22:00
Today there were qualification matches. Our team managed to reach the 2-nd place. After that there were final matches. There were less than 20 teams in the competition, so the final alliances were consisting of 2 teams each. We chose team PML30-x. Due to nice teamwork our alliance won the competition.

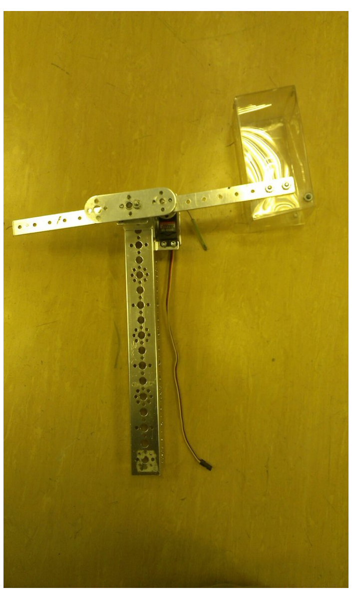


Рис. 29:

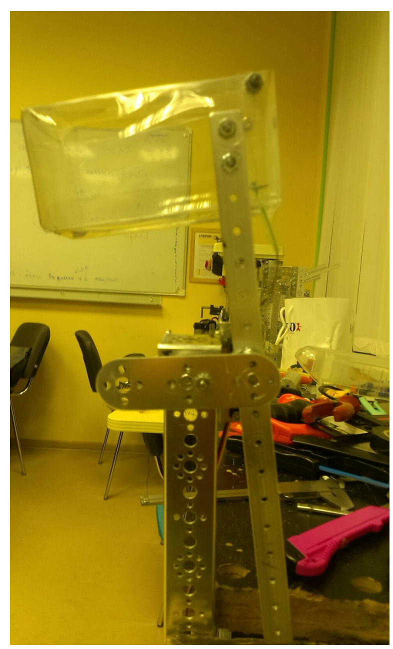


Рис. 30:

3.4.22 08.12.2015

Time frame: 16:00-22:00
Today we were discussing the experience we got at the competition. We thought out what problems does our robot has and how we can improve it.

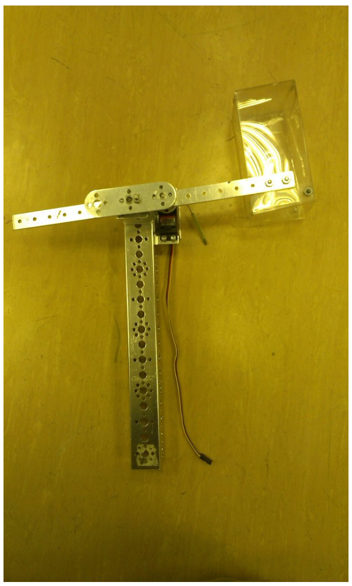


Рис. 31: Winch installed onto the carriage

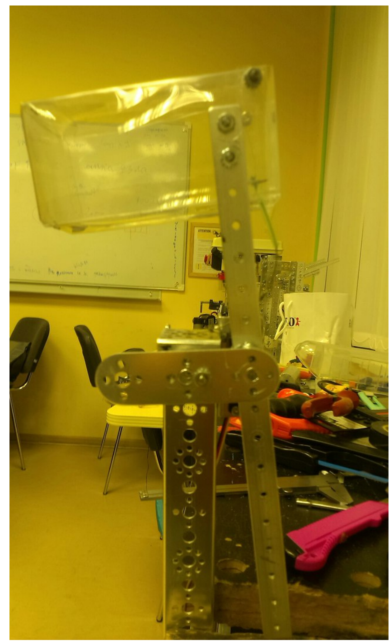


Рис. 32: The construction of the winch

3.4.23 09.12.2015

Time frame: 16:00-22:00
All the electric components were removed. The second elevator was also removed. After that the slats were moved down on 9.6 cm with preserving the former angle of incline.

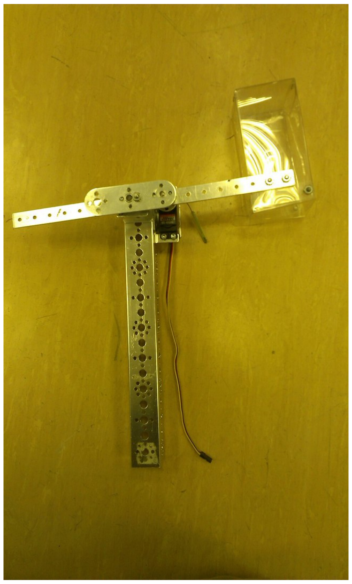


Рис. 33: Winch installed onto the carriage

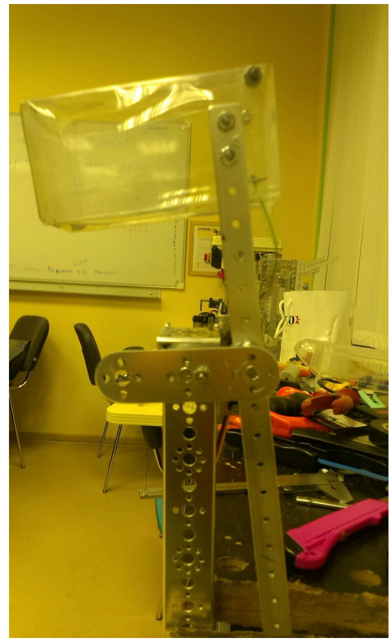


Рис. 34: The construction of the winch

3.4.24 10.12.2015

Time frame: 16:00-22:00
There was installed a motor for the powering the gripper.

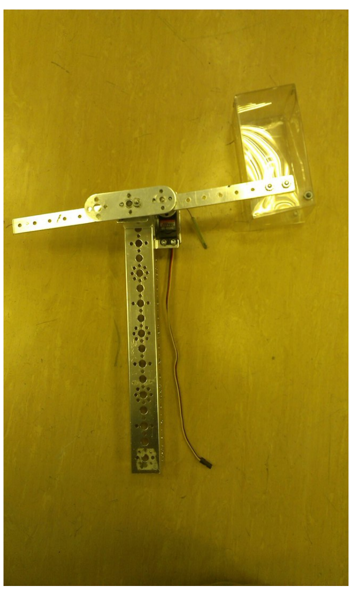


Рис. 35: Winch installed onto the carriage

Рис. 36: The construction of the winch

3.4.25 12.12.2015

Time frame: 16:00-22:00
The opposite pairs of slats on the elevator were connected by the ribs. It strengthened the elevator and made it more stable as from now on both sides will move dependently. In addition, it was started the assembling of

the winch for extracting lift. It will include two distinct reels for two ropes from both sides of the lift. At first, it was an idea to make the reel from two middle-sized gears with screws between them, but this construction was too bulky. So, it was decided to apply wheels from TETRIX caterpillar tracks as reels.

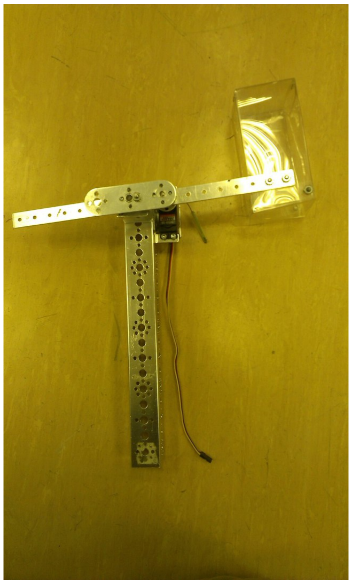


Рис. 37: Winch installed onto the carriage

Рис. 38: The construction of the winch

3.4.26 14.12.2015

Time frame: 16:00-22:00
It was installed the axis of a secondary gripper. The winch for extracting the lift was reliably fixed on the robot's base.

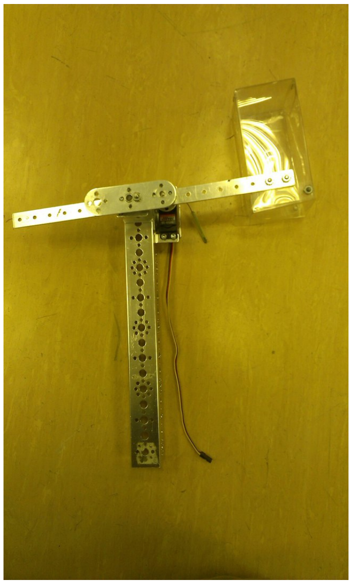


Рис. 39: Winch installed onto the carriage

Рис. 40: The construction of the winch

3.4.27 15.12.2015

Time frame: 16:00-22:00
There were installed a pair of blocks for leading cables from the elevator to the winch. Next, 2 standard TETRIX motors for powering the winch were installed onto the robot.

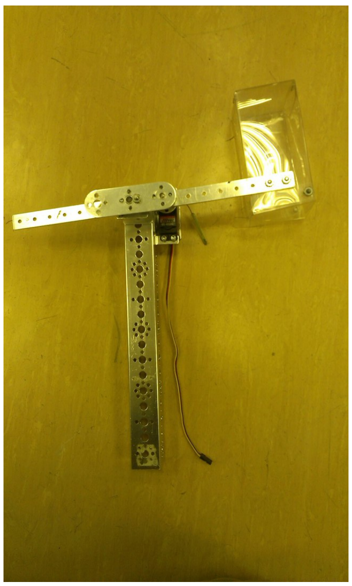


Рис. 41: Winch installed onto the carriage

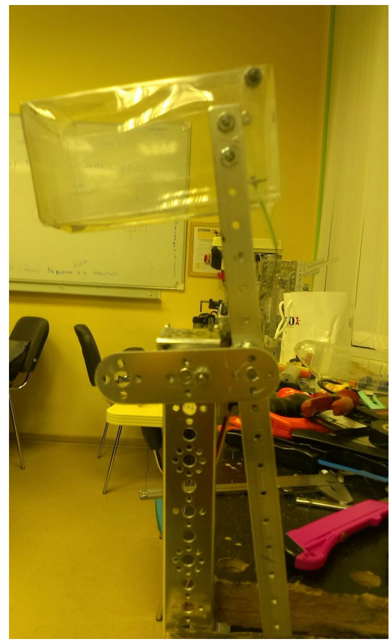


Рис. 42: The construction of the winch

3.4.28 16.12.2015

Time frame: 16:00-22:00
The mechanism for shifting the bucket was recreated with relation to the lastest version. In contrast, in the new version there were applied longer slats (40 cm), that will provide enough offset of the bucket. Also, the mount of the mechanism was made of aluminium profile instead of tetrix parts in order to save weight.

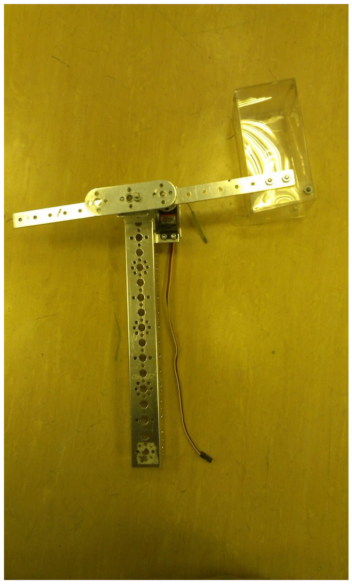


Рис. 43: Winch installed onto the carriage

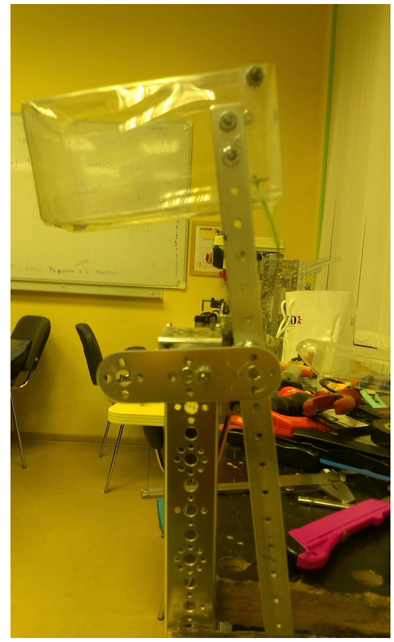


Рис. 44: The construction of the winch

3.4.29 17.12.2015

Time frame: 16:00-22:00
There was installed a servo for powering the mechanism for shifting the bucket. Next, there were held the cables and the mechanism was tested. It worked ok. There was installed a ramp for debris. The brushes were finished. There were installed motor controllers and a servo controller. The wiring wasn't finished yet. The cables for the extracting of the elevator were held.

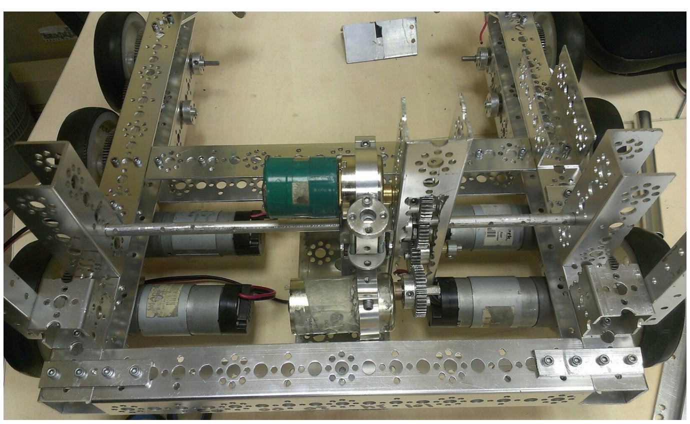


Рис. 45: Winch installed onto the carriage

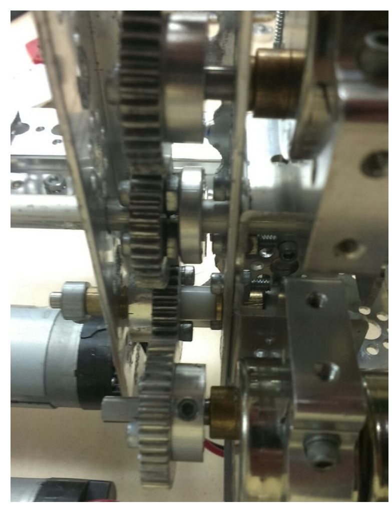


Рис. 46: The construction of the winch

3.4.30 19.12.2015

Time frame: 16:00-22:00
The winch was installed onto the robot, in the 8mm axis, that will keep the reels for rope, were drilled all the needed holes for fixing reels. The gripper was reassembled with the tetrix tube. For powering the gripper it was installed a standard DC motor with gear ratio 2:1.

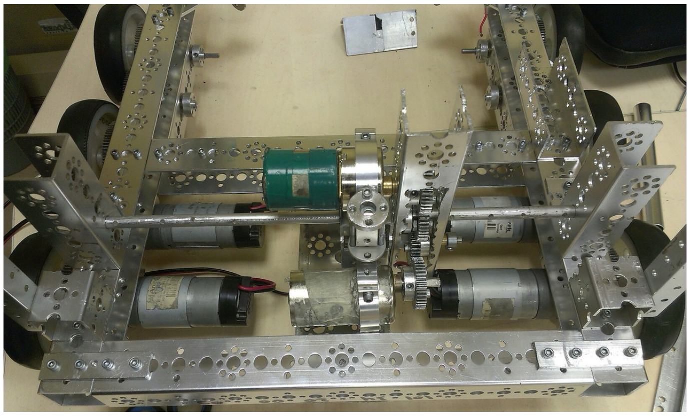


Рис. 47: Winch installed onto the carriage

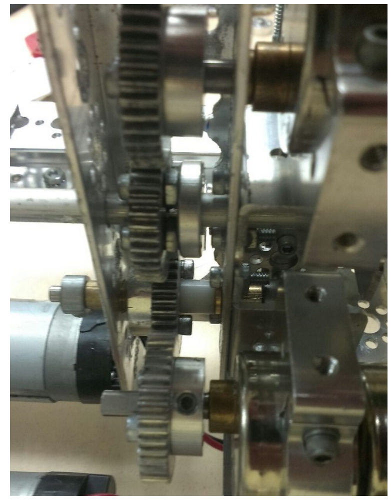


Рис. 48: The construction of the winch

3.4.31 20.12.2015

Time frame: 16:00-22:00
The winch was installed onto the robot, in the 8mm axis, that will keep the reels for rope, were drilled all the needed holes for fixing reels. The gripper was reassembled with the tetrix tube. For powering the gripper it was installed a standard DC motor with gear ratio 2:1.

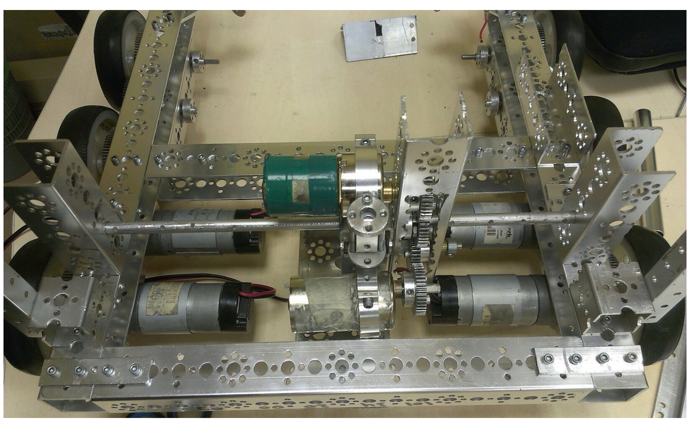


Рис. 49: Winch installed onto the carriage

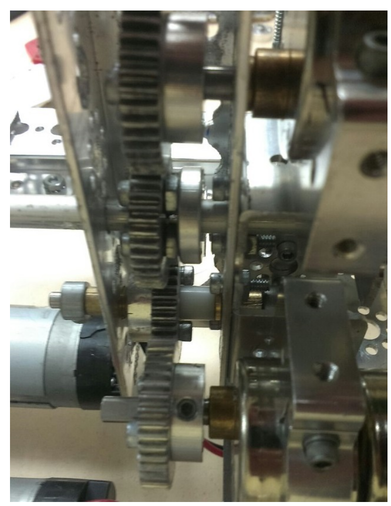


Рис. 50: The construction of the winch

3.4.32 22.12.2015

Time frame: 16:00-22:00
Today it was a consideration on results of the competition. The conclusion of this meeting was a list of tasks:

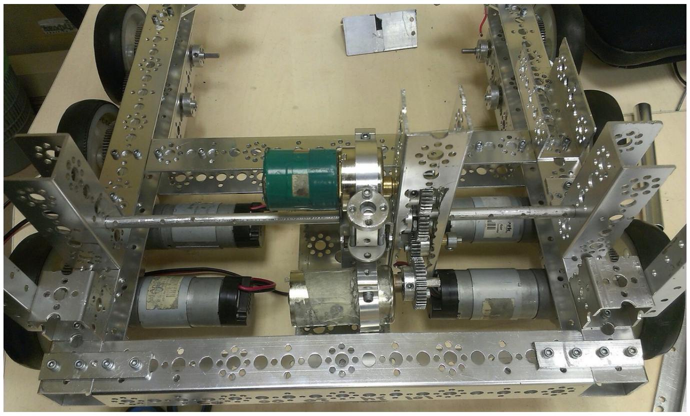


Рис. 51: Winch installed onto the carriage

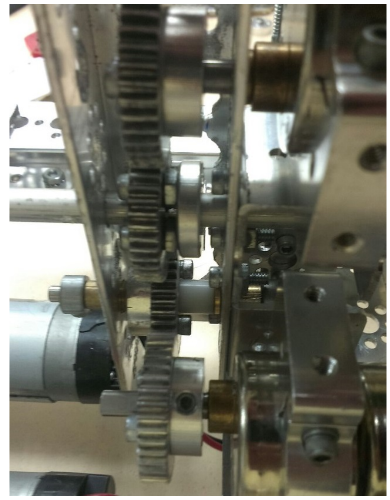


Рис. 52: The construction of the winch

3.4.33 23.12.2015

Time frame: 16:00-22:00
The winch was recreated with a chain. The wiring was held in a more safe way. The mount for battery was installed.

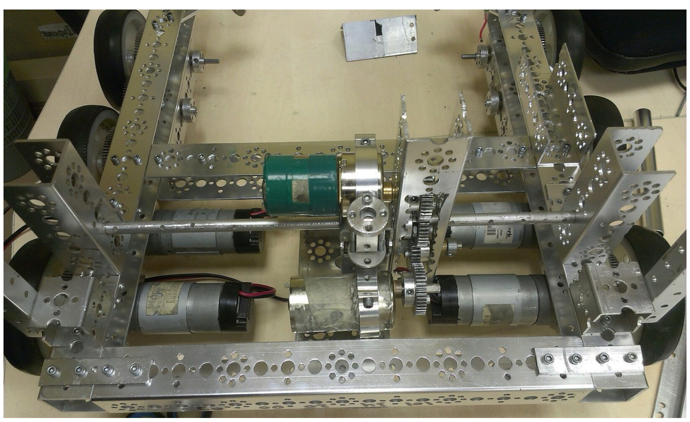


Рис. 53: Winch installed onto the carriage

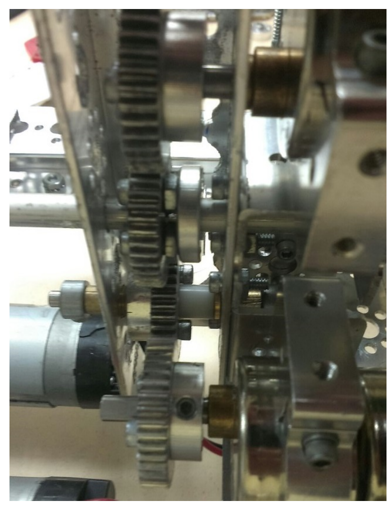


Рис. 54: The construction of the winch

3.4.34 24.12.2015

Time frame: 16:00-22:00
The elevator was tested while the robot was standing on the horisontal surface. It worked ok. The full extraction took 4.5 seconds. The length of cables on the elevator were adjusted so as make the same tension on both of them. It will help to avoid the bend of the elevator while extracting. The wiring to the top section of the elevator (to the bucket and mechanism for shifting the bucket) was held. It was investigated that the beams at the sides, to which the blocks attached, are narrowing because of the tension forse of the cable. To prevent this bending of beams there was installed another beam between them. There were also installed shores for cables that will prevent them from tangling (only for one cable this day).

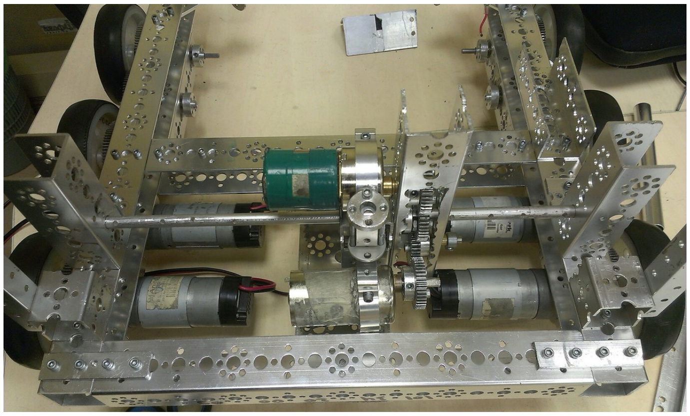


Рис. 55: Winch installed onto the carriage

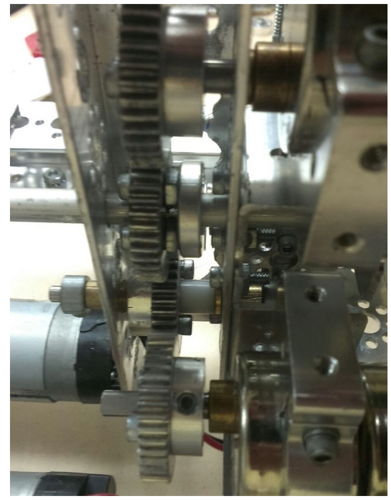


Рис. 56: The construction of the winch

3.4.35 26.12.2015

Time frame: 16:00-22:00
On the ramp for debris there were installed special walls for leading scoring elements to the entrance of the bucket. A second pair of shores for the prevention of the entanglement of the cables on the winch coil was installed. There used to be a problem that slats, on which the bucket is mounted, bend a lot under it's weight. This day it was found a solution to this problem: it is possible to install a special band, that will be fixed on the top slat and slide along the surface to which the bottom slat is attached. This band will rest in the surface and prevent construction from bending. Today it was created a prototype of this module.

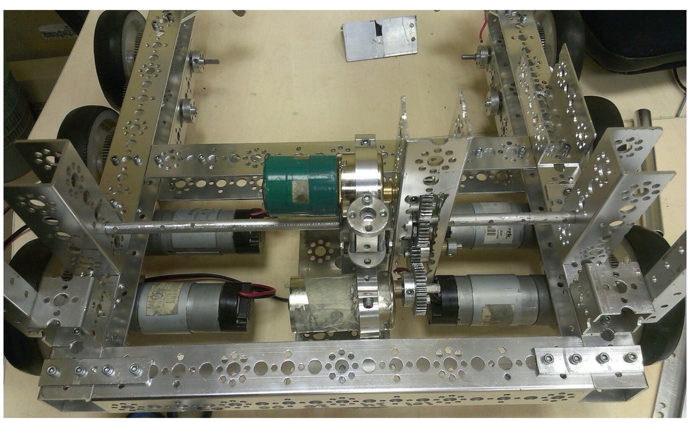


Рис. 57: Winch installed onto the carriage

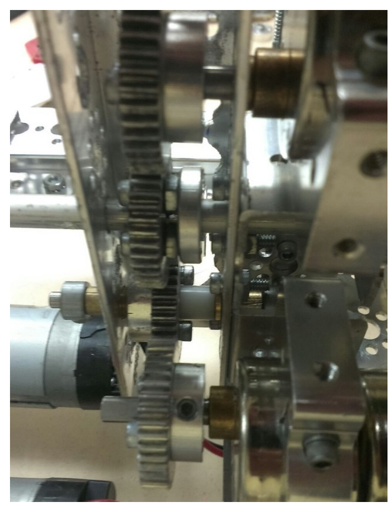


Рис. 58: The construction of the winch

3.4.36 28.12.2015

Time frame: 16:00-22:00
На сложном роботе за сегодня было сделано 1) поднята наклонная плоскость, т. к. она цепляла пол и нельзя было ехать. 2) изменена программа для езды, регулировка скорости и танковый разворот. 3) тестирование подъёмника, откуда выяснилось, что при определённом выдвижение подъёмника можно полностью заехать на горку, но нужно сделать механизм крепления к балке после заезда. Также был сожжён dc-мотор, т.к. мощности двух моторов не хватает для выдвижение подъёмника 4) тестирование

корзины. Механизм выдвижения в бок работает, а также механизмы для открытия корзины и опраки-давоние игровых элементов тоже работают. 5) стало понятно, что надо сделать передачу на нижнюю ось схвата иначе оси будут вращаться в разные стороны

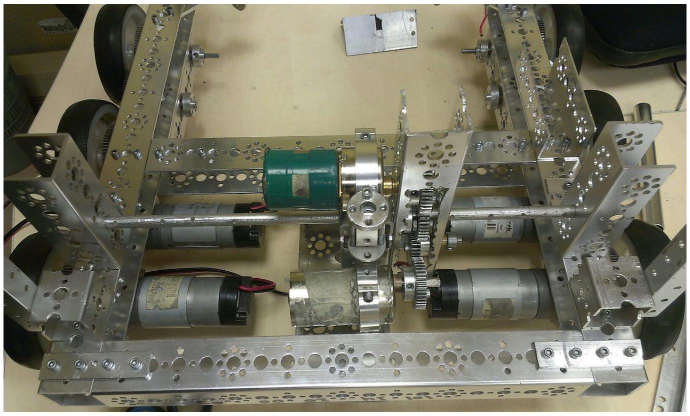


Рис. 59: Winch installed onto the carriage

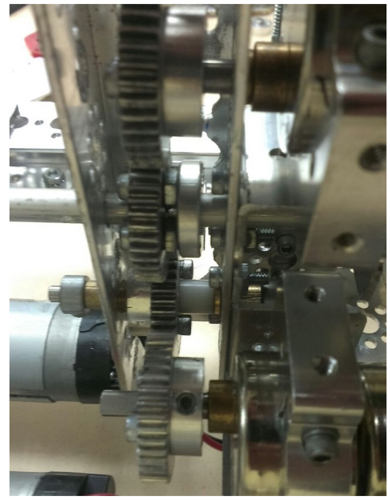


Рис. 60: The construction of the winch

3.4.37 04.01.2016

Time frame: 16:00-22:00
The mechanism for shifting the bucket was recreated. In the new version of this mechanism the shaft of the servo doesn't suffer from bending because the coil that is fixed on it is now attached to the axis at it's other side. This mechanism is not finished yet.

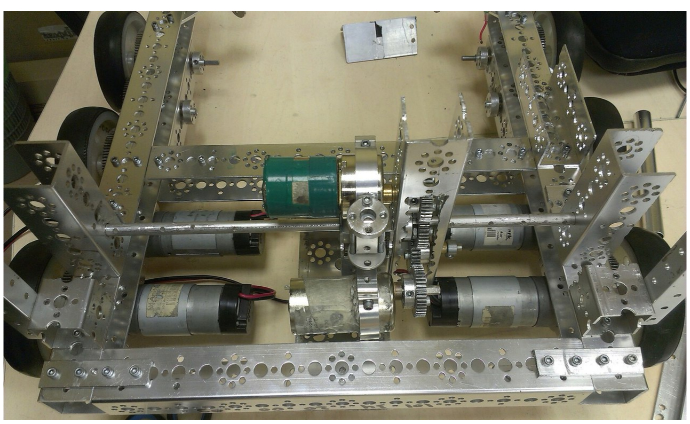


Рис. 61: Winch installed onto the carriage

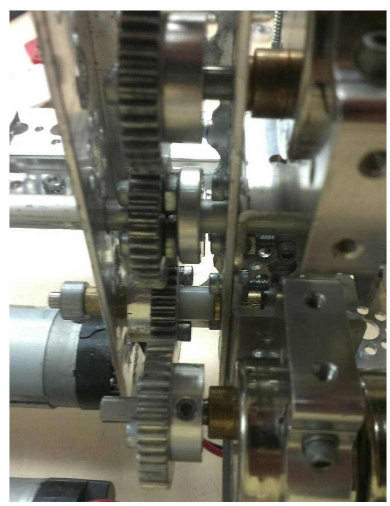


Рис. 62: The construction of the winch

3.4.38 05.01.2016

Time frame: 17:00-21:30
The mechanism for shifting the bucket was finished. The assembling of the new version of the mechanism for scoring autonomus alpinists was started. 2 standard TETRIX motors at the winch were replaced with 3 NeveRest AndyMark motors. Firstly, it 2 times increased torque at the coil (75/40). Secondly, it raised

the reliability of the construction, as the AndyMark motors can cope with stalling for a long time (about 2 minutes), so they will not break down if the movement of the elevator is blocked.

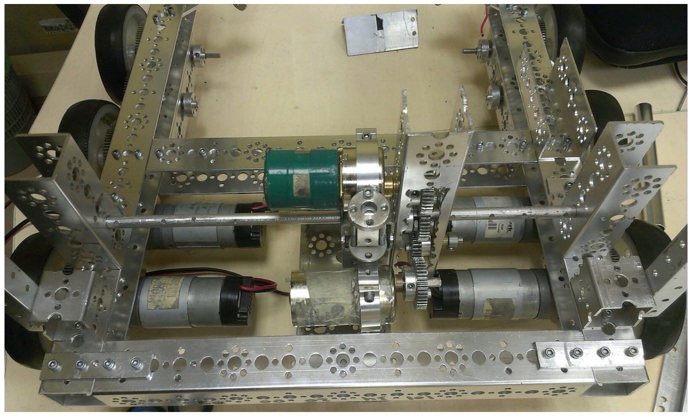


Рис. 63: Wheel base with 10cm wheels

3.4.39 06.01.2016

Time frame: 17:00-21:30
Today it was created the working version of a device for preventing the bending of slats for shifting the bucket. It was tested and it was accepted that the device worked ok. The chain at the winch was installed. The elevator was tested. Firstly, it was found out, that one pair of blocks is fixed not reliable enough. The problem was that due to the cable was not in a plane of the block, it was pulled up by the cable. To compensate this pressure there were installed two plastoc clamps. However, it was a temporary solution.

Secondly, the power of 3 motors still was not enough to extract the elevator to the full. The problem was that the second sectoin (with respect to the bottom) required more power for extraction than the first one and the third section required the most power. So, it was assumed, that the problem caused by overloading the friction of the blocks: in the current system one cable at each side was held through all the blocks and a large part of power was wasted on friction. In this case, to reduce the power that spends on foghtin the friction, it was decided to use another system of helding the cables. The new construction required 3 blocks instead of 5 at a side and the cable from the winch went only through one of them. However, this construction required three times higher torque and three times less length of the cable to reel for extracting. So, the diameter of the coils chould be changed correcpondingly.

Today it was also continued the development or the mechanism for scoring autonomus alpinists. It was created a mechanism for releasing the climbers.

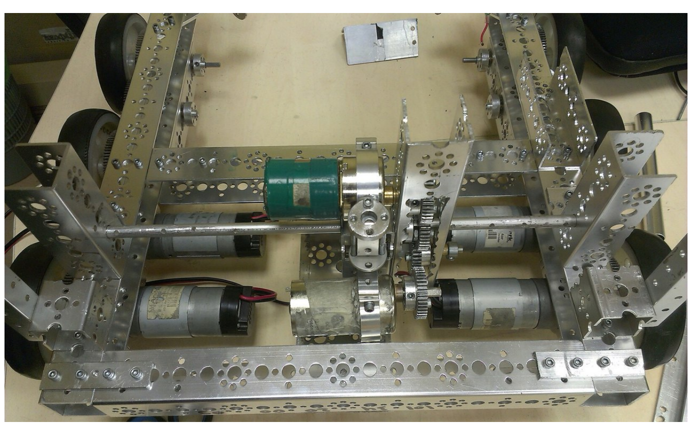


Рис. 64: Wheel base with 10cm wheels

3.4.40 08.01.2016

Time frame: 16:00-22:00
The mechanism for scoring the autonomus alpinists was installed onto the robot. After some tests it was investigatet that it should be moved a but higher and the axis of the servo that turns the module should be strethened.

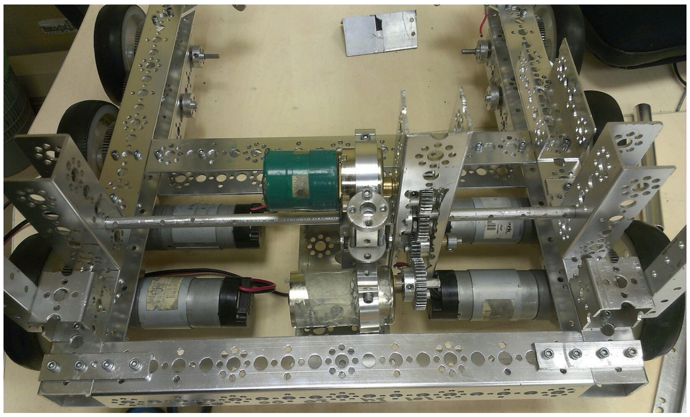


Рис. 65: Winch installed onto the carriage

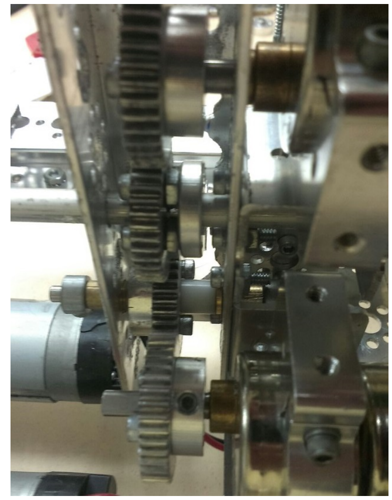


Рис. 66: The construction of the winch

3.4.41 10.01.2016

Time frame: 16:00-22:00
Today the cables at the elevator were held in a new way. As the construction couldn't be tested by motors (the coils weren't recreated yet), it was tried by the arms. There were not noticed any problems.

The bucket was detached from the elevator to provide separate development of the bucket and the elevator.

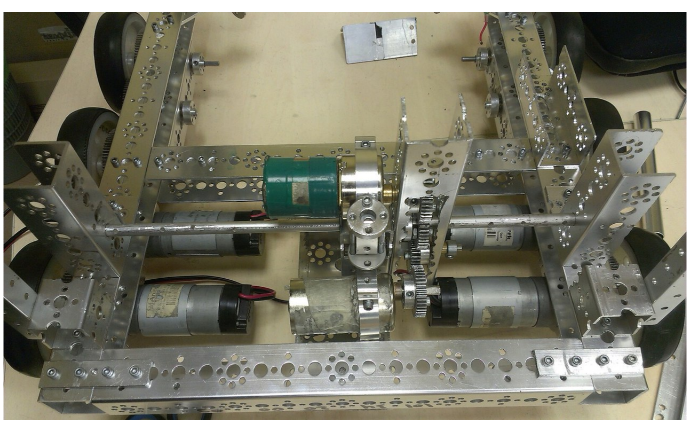


Рис. 67: Winch installed onto the carriage

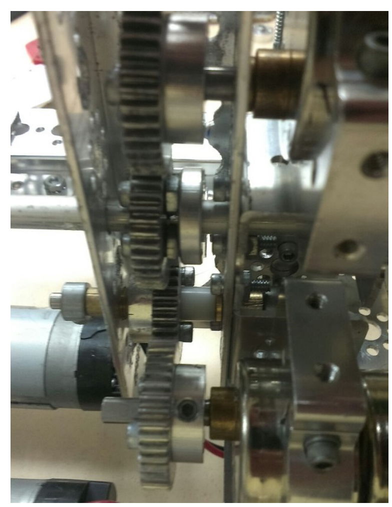


Рис. 68: The construction of the winch

3.4.42 12.01.2016

Time frame: 16:00-22:00
The mechanism for scoring autonomus alpinists was improved.

There were created hooks for grasping the low hurdle of the second zone of the ramp.

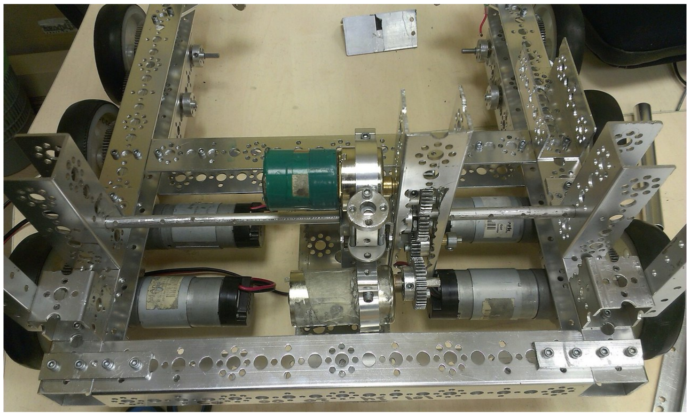


Рис. 69: Winch installed onto the carriage

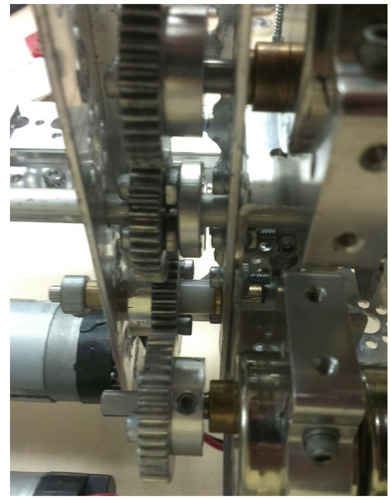


Рис. 70: The construction of the winch

3.4.43 13.01.2016

Time frame: 16:00-22:00
Today the coils were recreated. Their diameter was reduced. Next, the elevator was tested. It worked, but the power was not enough for the full extracting. The reasons of this problem were not found.

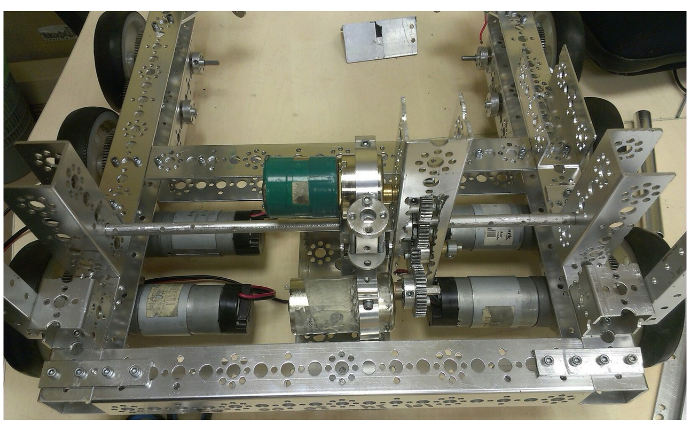


Рис. 71: Winch installed onto the carriage

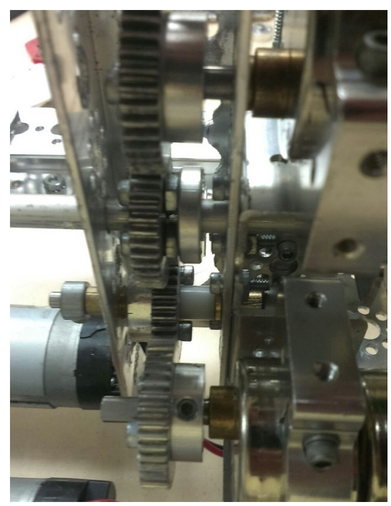


Рис. 72: The construction of the winch

3.4.44 14.01.2016

Time frame: 16:00-22:00
There was found a reason of the problem of the elevator.

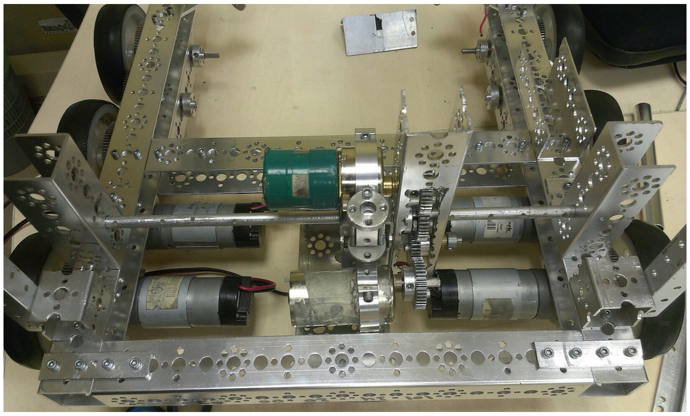


Рис. 73: Winch installed onto the carriage

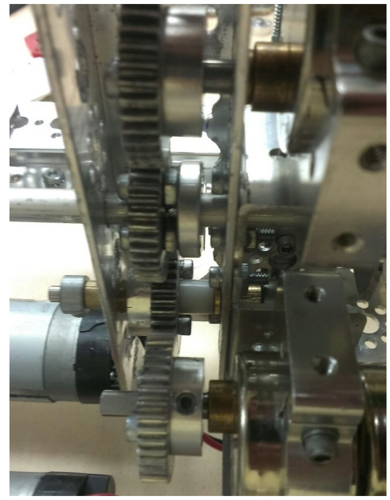


Рис. 74: The construction of the winch

3.4.45 16.01.2016

Time frame: 16:00-22:00
There was created a moving mount for one of the ribs at the elevator.

It was also developed a prototype of a mechanism for grasping the hurdle at the ramp. The construction of the transfer between the servo and the hooks will prevent the servo from breaking down.

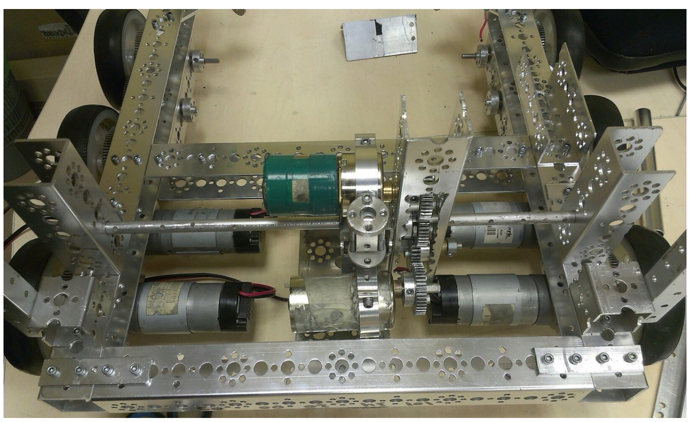


Рис. 75: Winch installed onto the carriage

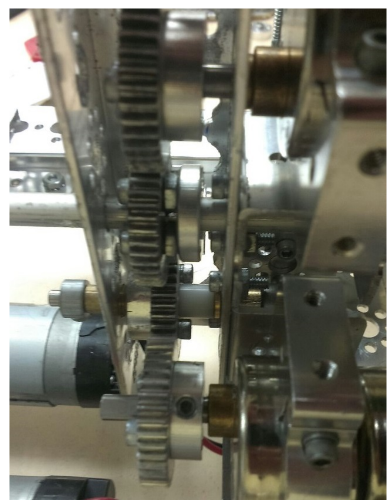
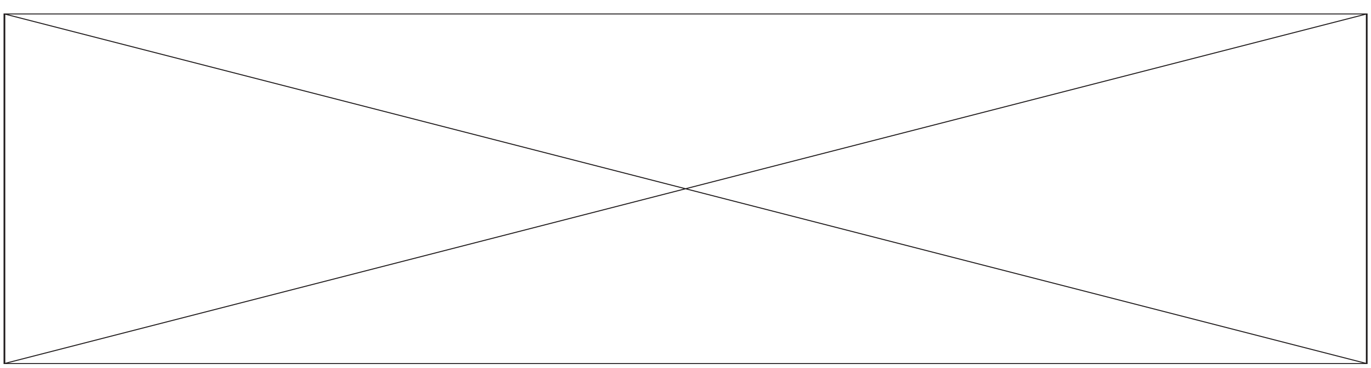


Рис. 76: The construction of the winch



3.5 Specifications for modules

Description: This section contains detailed information the process of elaboration of each module in particular.

3.5.1 Elevator

Engineering tasks included in this module:

1. Lifting mechanism
   1.1. According to the technical plan our team created beforehand, the lifting mechanism was to consist of several construction beams connected to each other with special parts. To create these parts, we first thought through the concept and 3d-modeled them in Creo Parameteric 3.0. These parts are something akin to a brace and will stabilize one beam in relation to another. There are two types of braces: for the central gaps, and side gaps of the beams. Let us consider the simplest way to connect the two beams with these braces. Beam A will be fixed in place to the base of the robot, and beam B will be fixed relative to beam A. Then we can can connect the first three braces to the top of beam A and the second three braces to the bottom of beam B, allowing for maximum freedom of movement for one of the beams against the other. For greater stability we use two groups of three on each end of the beams.
   1.2. We must find such a height and length of the lifting mechanism that there would be an angle of tilt that would allow the robot to throw debris into the highest and middle bucket goals from the low zone, and grab the pull-up bar from the middle zone.
   1.3. Knowing that the individual beams are 350mm long, we calculated that in order to reach this height, we need four beams.
   1.4. Lifting four beams requires a block system - e.g. we need to add blocks with twine that, when reeled in, would lift the system.
   1.5. In order to fasten the braces we need to add caps on the end faces of the beams. I came to the conclusion that I needed to change the caps: drill a hole through their legs, so that the twine could be put through them, and grind off the heads somewhat in order to make a trough, through which to pass the line. This allowed me to avoid adding additional blocks on the beams.
2. Turning mechanism
   2.1. The turning mechanism consists of a servomotor attached to the base of the robot, a worm on the axis, and a gear on the first beam of the lifting mechanism. The servomotor turns the worm, which, in turn, rotates the gear, and the lifting mechanism tilts.
3. Reeling mechanism
   3.1. The reeling mechanism is a system of two coils powered by 2-4 motors. It is both used for extracting elevator and pulling up. The principle of work is folowing: one coil pulls the cable and extracts the elevator when the another coil releases strong cable used for pulling up. When the elevator is fully put forward, so does the pullup cable. Next, when the coil rotates backwards, it pulls the pullup cable and releases elevator's cable causing it to fold back.

3.5.2 Bucket

1. The main requirements for the module were:
   - Maximum capacity: five cubes and three spheres
   - A mechanical limiter on the amount of debris in the bucket
   - A closing mechanism for the bucket

- Delivery mechanism for putting the debris into the goals. содержимое...

2. The first stage of development was creating the general concept of the module, its structure and method of operation. In result, was decided on the following mechanism: The bucket is shifted outside of the robot and turned 90 degrees around an axis parallel to the axis of shift; both movements are done by one servo. This allows to place the bucket opening to be parallel to the ground and increase the accuracy of debris delivery. Movement in two planes at once is accomplished through sloped guide rails, which turn the beams with the bucket during their sideways movement. To prevent premature release of debris from the bucket, the bucket opening will be closed.

3. The next step was developing the closing mechanism. To minimize the load on the servo completing the turning movement, the center of mass of the module has to be situated as close as possible to the mounting point on the lifting mechanism. Thus, the following system was developed:

   - On the beam which is mounted to the lifting mechanism, is installed a reel with twine.
   - The twine is fixed in such a way that when the reel turns in one direction, one of the ends is pulled taut while the other slacks, and vice versa.
   - The twine wraps around several fixed blocks along all the beams which support the bucket.
   - Above the bucket opening there is another axis with another reel identical to the first, and the surface which blocks the opening.

   This allows to open and close the bucket without adding any additional significant load on the servo which turns it. To make sure that such a mechanism for transmitting rotational movement indeed works, a simplified model was assembled. The results of our tests showed that this transmission is operable, but the angle between the extreme positions is slightly more than 135 degrees, rather than 180 degrees, but this is still enough to complete the task.

4. After that the parameters of the guiding rails (slope relative to the vertical direction, maximum height) were calculated depending on where they are mounted: The bucket, mounted on the beams, which in

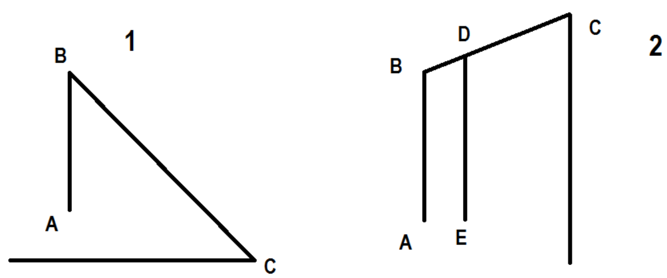


Рис. 77: Side view of beams onto which the bucket is mounted

   turn are mounted on the slats are in point A and move together. CB can rotate around point B. DE is the maximum height of the guiding rails. Position 1: the bucket is lying on the ground and collecting debris. Position 2: the bucket is perpendicular to the ground and can deliver the debris to the goals. The needed ratios can be found from the easily derived formula: $< C = /(DE - BA)$.

5. At the time the above process was completed, the qualification rounds were not far away, and so was decided to temporarily use two servos for shifting and turning the bucket, since the structure of the module would become significantly simpler and would require less time to complete. Were connected two slats in such a way that their uppermost part could move in both directions. After that on one of the ends of the slats were added limiters that depending on their position do not let one of the slats

move. This does not prevent the robot from working properly, as we know our alliance before the match and thus in which direction we need to extend the bucket. This means we can adjust the limiters before the match. (Note: in the figure both limiters are set to the closed position, in which neither slat can

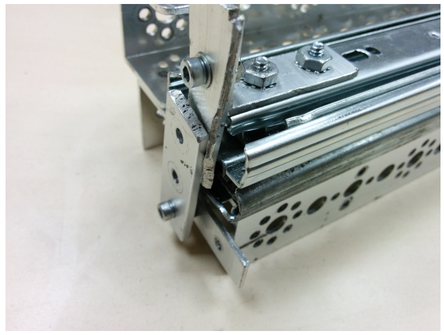


Рис. 78: Structure of limiters

move; during the game itself one of the limiters will be set in the open position).

6. Then the servo with a reel for the twine moving the slats was fixed on. Blocks were attached to the ends of the fixed beams and wound the twine around them; the ends of the twine are tied to the ends of the slats, which allows them to move as needed. The servo direction of rotation defines the direction of movement of the slats and the bucket.

7. After that was come up, tested and made another, less complicated, trapezoidal bucket with the opened part smaller than closed. The construction of the guides on the top of bucket would make debris fall in sequence 2-2-1 from the bottom, that way the scoring goals will hold maximum number of debris. Tests

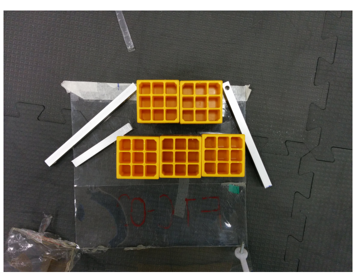


Рис. 79: Structure of guides

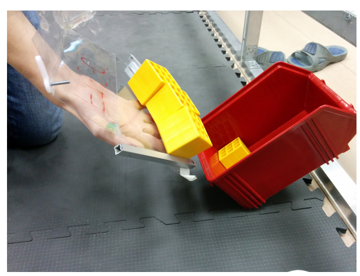


Рис. 80: Process of guides testing

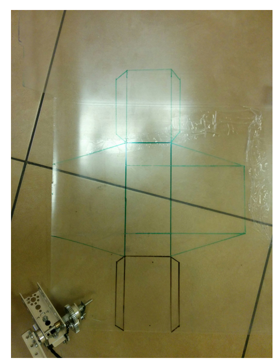


Рис. 81: Marking of bucket

showed that guides work well, so was decided to use them in construction of bucket. The pair of front makes debris fall to the scoring goals more accurately, the assymetric guide slows one debri to make all the debris fall as 2-2-1, not 2-3.

8. After that was streched the line to move the slats. Servos for moving the slats and turning the bucket were placed on the slats.

9. The last done part of module is closing mechanism. The difficalty in it is that axis of servo has to be as close as possible to the front-top edge of bucket.

3.5.3 Elevator

Engineering tasks included in this module:

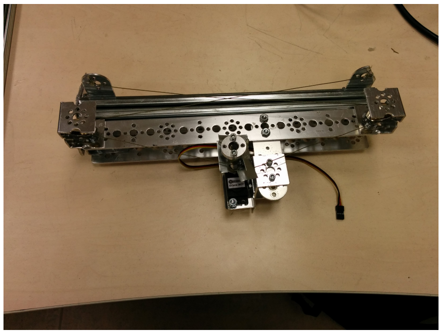


Рис. 82: Construction of line and pulling it servo

Рис. 83: Final construction of the slats

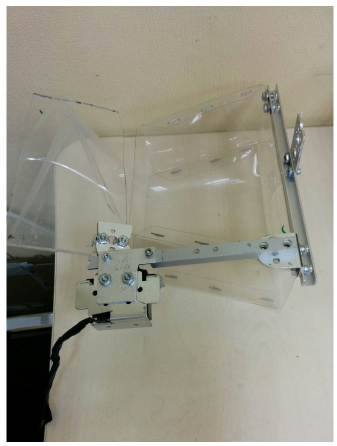


Рис. 84: Final construction of the bucket with closing mechanism

1. Lifting mechanism
   1.1. According to the technical plan our team created beforehand, the lifting mechanism was to consist of several construction beams connected to each other with special parts. To create these parts, we first thought through the concept and 3d-modeled them in Creo Parameteric 3.0. These parts are something akin to a brace and will stabilize one beam in relation to another. There are two types of braces: for the central gaps, and side gaps of the beams. Let us consider the simplest way to connect the two beams with these braces. Beam A will be fixed in place to the base of the robot, and beam B will be fixed relative to beam A. Then we can can connect the first three braces to the top of beam A and the second three braces to the bottom of beam B, allowing for maximum freedom of movement for one of the beams against the other. For greater stability we use two groups of three on each end of the beams.
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   1.3. Knowing that the individual beams are 350mm long, we calculated that in order to reach this height, we need four beams.
   1.4. Lifting four beams requires a block system - e.g. we need to add blocks with twine that, when reeled in, would lift the system.
   1.5. In order to fasten the braces we need to add caps on the end faces of the beams. I came to the

conclusion that I needed to change the caps: drill a hole through their legs, so that the twine could be put through them, and grind off the heads somewhat in order to make a trough, through which to pass the line. This allowed me to avoid adding additional blocks on the beams.

2. Turning mechanism

   2.1. The turning mechanism consists of a servomotor attached to the base of the robot, a worm on the axis, and a gear on the first beam of the lifting mechanism. The servomotor turns the worm, which, in turn, rotates the gear, and the lifting mechanism tilts.

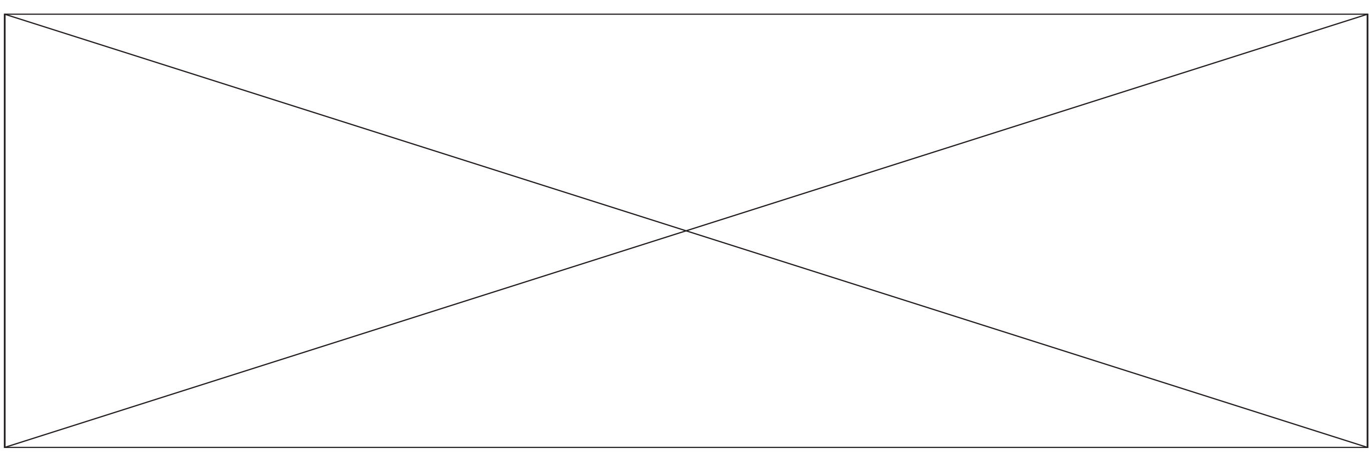
3. Reeling mechanism

   3.1. The reeling mechanism is a system of two coils powered by 2-4 motors. It is both used for extracting elevator and pulling up. The principle of work is folowing: one coil pulls the cable and extracts the elevator when the another coil releases strong cable used for pulling up. When the elevator is fully put forward, so does the pullup cable. Next, when the coil rotates backwards, it pulls the pullup cable and releases elevator's cable causing it to fold back.

3.5.4 Mechanism for scoring alpinists

Engineering tasks included in this module:

1. The first step was find all the sizes of climbers and elements of field that essential for creating module. The size of the box for climbers is the same to the box for debris: 14.6 x 5.75 . The height of the border is about 30 cm. The parameters of the climber 11.6 x 2 x 3 cm. It's weight is approximately 10-20g .
2. After that it was invented the image of the mechanism for scoring climbers into the box. The lever with a container for climbers turns around the axis, which is placed higher than the edge of the border. The container is closed by a cover with a latch, that is tied to the mount of the axis by thread. When the container overturns, the thread stretches and releases the latch. It allows to throw climbers verticallywith high accuracy and prevent them from accidental falling out of the container during the movement.
3. According to this idea it was created the model of the bucket in Creo Parametric. To prevent the servo from breaking down, it was provided a second lever opposite the bucket, that can be charged with contraweight. It was also created a blueprint of a bucket and a cover. These elements will be made of PET.
4. Next, the first version of the module was assembled and tested. The latch for cover was working stable. However, after the implementation in real details it was acknowledged, that the module is quite bulky because of the lever for contraweight. So, there were held calculations of the moment on the servo to investigate whether it can operate without a countraweight or not.



3.6 Specifications for programmes

Description: This section contains detailed information about elaboration of remote-control program and autonomus program.

3.6.1 Driver control program

1. As soon as the first prototype of the wheel base was assembled on November 12**th**, it was elaborated a program for test-drive. It included straight movement and turning around in 4 grades of speed. With this program, there were tested the abilities of the present wheel base.
   Here is the source code of first version:

```
#pragma config(Hubs,  S1, HTMotor,  HTMotor,  none,     none)
#pragma config(Sensor, S1,     ,               sensorI2CMuxController)
#pragma config(Sensor, S2,     TIR,            sensorI2CCustom)
#pragma config(Motor,  mtr_S1_C1_1,     LF,            tmotorTetrix, openLoop, reversed)
#pragma config(Motor,  mtr_S1_C1_2,     LB,            tmotorTetrix, openLoop, reversed)
#pragma config(Motor,  mtr_S1_C2_1,     RF,            tmotorTetrix, openLoop)
#pragma config(Motor,  mtr_S1_C2_2,     RB,            tmotorTetrix, openLoop)
//*!!Code automatically generated by 'ROBOTC' configuration wizard               !!*//

#include "JoystickDriver.c"
int k = 1;
int speed = 12;

void movement()
{
if (joy1Btn(1)) // 1 speed
{
k = 1;
}
if (joy1Btn(2)) // 2 speed
{
k = 2;
}
if (joy1Btn(3)) // 3 speed
{
k = 4;
}
if (joy1Btn(4)) // 4 speed
{
k = 8;
}
if (joystick.joy1_TopHat == 6) // tank turn to left
{
motor[RB] = motor[RF] = speed * k;
motor[LB] = motor[LF] = -speed * k;
}
if (joystick.joy1_TopHat == 2) // tank turn to right
{
motor[RB] = motor[RF] = -speed * k;
motor[LB] = motor[LF] = speed * k;
}
if (joystick.joy1_TopHat == 0) // forward
{
motor[RB] = motor[RF] = speed * k;
```

```
motor[LB] = motor[LF] = speed * k;
}
if (joystick.joy1_TopHat == 4) // backward
{
motor[RB] = motor[RF] = -speed * k;
motor[LB] = motor[LF] = -speed * k;
}
if (joystick.joy1_TopHat == -1) // stop
{
motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = 0;
}
}

task main()
{
while(true)
{
getJoystickSettings(joystick);
movement();
wait1Msec(50);
}
}
```

2. Results of the test drive were analysed so as develop a convenient control system. At first, turning around on high speed is unaccurate. So, the speed of turn was reduced proportionally to speed of straight movement. There also were added extra active buttons for accurate movement. Main drive control was moved from TopHat to a left stick. The operating area of the stick was divided into 8 zones. Zones 3 and 5 are not used because of unconvenience of back semi-turns.
   Here is the source code of second version:

```
#include "JoystickDriver.c"
int k = 2;

int joy_result()
{
int horison_in = joystick.joy1_x1;
int vertical_in = joystick.joy1_y1;

int option = -1;
int sector = 0;

//determining sector
if (vertical_in > 90) sector += 1;
if (vertical_in < -90) sector += 4;
if (horison_in > 100) sector += 2;
if (horison_in < -100) sector += 8;

//set option
if (sector == 1) option = 0;
if (sector == 3) option = 1;
if (sector == 2) option = 2;
if (sector == 6) option = 3;
if (sector == 4) option = 4;
```

```
if (sector == 12) option = 5;
if (sector == 8) option = 6;
if (sector == 9) option = 7;

return option;
}

int setspeed()
{
if (joy1Btn(1)) // 1 speed
{
k = 1;
}
if (joy1Btn(2)) // 2 speed
{
k = 2;
}
if (joy1Btn(3)) // 3 speed
{
k = 4;
}
if (joy1Btn(4)) // 4 speed
{
k = 8;
}

return k;
}

void joy_accomplish()
{
int speed = 12;
int turnspeed = 6;
int option = joy_result();
int k = setspeed();

if (option == 0) // forward
{
motor[RB] = motor[RF] = speed * k;
motor[LB] = motor[LF] = speed * k;
}
if (option == 4) // backward
{
motor[RB] = motor[RF] = -speed * k;
motor[LB] = motor[LF] = -speed * k;
}
if (option == 6) // tank turn to left
{
motor[RB] = motor[RF] = turnspeed * k;
motor[LB] = motor[LF] = -turnspeed * k;
}
if (option == 2) // tank turn to right
{
motor[RB] = motor[RF] = -turnspeed * k;
motor[LB] = motor[LF] = turnspeed * k;
}
```

```
if (option == 7) // semi turn to left
{
motor[RB] = motor[RF] = speed * k;
motor[LB] = motor[LF] = 0;
}
if (option == 1) // semi turn to right
{
motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = speed * k;
}
if (option == -1) // stop
{
motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = 0;
}
}

void accurate_turn()
{
if (joy1Btn(5) || joy1Btn(6) || joy1Btn(7) || joy1Btn(8))
{
int speed = 24;
int turnspeed = 12;
int timeDelay = 100;

if (joy1Btn(8)) // accurate forward
{
motor[RB] = motor[RF] = speed;
motor[LB] = motor[LF] = speed;
wait1Msec(timeDelay);
}
if (joy1Btn(7)) // accurate backward
{
motor[RB] = motor[RF] = -speed;
motor[LB] = motor[LF] = -speed;
wait1Msec(timeDelay);
}
if (joy1Btn(6)) // accurate right
{
motor[RB] = motor[RF] = -turnspeed;
motor[LB] = motor[LF] = turnspeed;
wait1Msec(timeDelay);
}
if (joy1Btn(5)) // accurate left
{
motor[RB] = motor[RF] = turnspeed;
motor[LB] = motor[LF] = -turnspeed;
wait1Msec(timeDelay);
}

motor[RB] = motor[RF] = 0;
motor[LB] = motor[LF] = 0;
wait1Msec(50);

//while (joy1Btn(5) || joy1Btn(6) || joy1Btn(7) || joy1Btn(8)){}
}
```

```
    }

    task main()
    {
    motor[RB] = motor[RF] = 0;
    motor[LB] = motor[LF] = 0;

    while(true)
    {
    getJoystickSettings(joystick);
    accurate_turn();
    joy_accomplish();
    }
    }
```

3. Due to testing it was discovered, that optimal course speed to turn speed proportion varies nonlinearly from one speed mode to another. So, it's more preferable to set speed mode by exact values of both speed parameters instead of common coefficient. In addition, it was decided to reduce the number of sectors on main stick's from 8 to 6 because 2 sectors were not in use .
   Here is the changed fragment of the code:

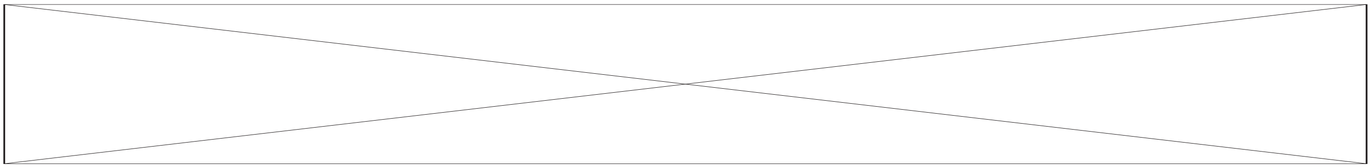
```
        int joy_result()
        {
    int horison_in = joystick.joy1_x1;
    int vertical_in = joystick.joy1_y1;

    int option = -1;
    int sector = 0;

    //determining sector
    if (vertical_in > 10) sector += 1;
    if (vertical_in < -10) sector += 4;
    if (horison_in > 80) sector += 2;
    if (horison_in < -80) sector += 8;

    //set option
    if (sector == 1) option = 0;
    if (sector == 3) option = 1;
    if (sector == 2) option = 3; // sectors 3 & 5 won't be used
    if (sector == 6) option = 2;
    if (sector == 4) option = 4;
    if (sector == 12) option = 6;
    if (sector == 8) option = 5; ////
    if (sector == 9) option = 7;

    return option;
        }
```



4 Appendix

4.1 Supplementary materials which were used in the robot's construction

1. Aluminium axis 1m × 8mm. 1 piece.
2. Aluminium L-shaped profile 2m × 40mm × 40mm × 2mm. 1 piece.
3. Aluminium U-shaped profile 1m × 10mm × 10mm × 1,5mm. 1 piece.
4. Furniture slats 35cm. 6 items.
5. Sheet of PET 1 m × 80 cm. 1 piece.
6. Sheet of plexiglass 3m × 2m (cut). 1 piece.
7. Blocks for rope. 12 items.
8. Steel angles 30mm × 30mm × 10mm. 10 items.
9. Garden hose 20mm × 25m. 1 piece.
10. Plastic clamps.
11. Hot melt adhesive.
12. Tape.