0.1 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).

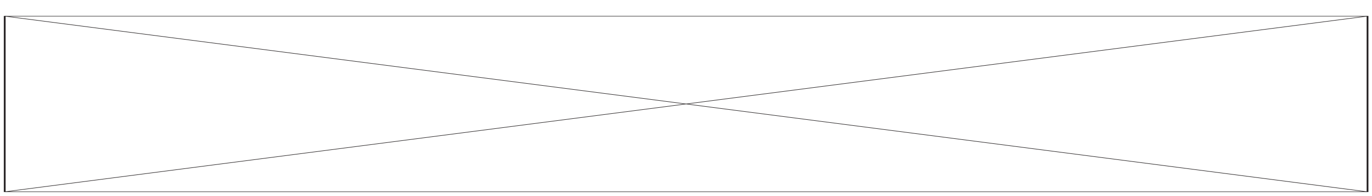
5. The main weight of the robot goes the battery and motors. The weight of the battery is 570g. We have two types of motors: standard TETRIX motor (207g) and "NeveRest 40"motor by AndyMark (334g). The complete control system (phone + controllers + power distributor) weigh about 700g.
   Therefore, total 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.



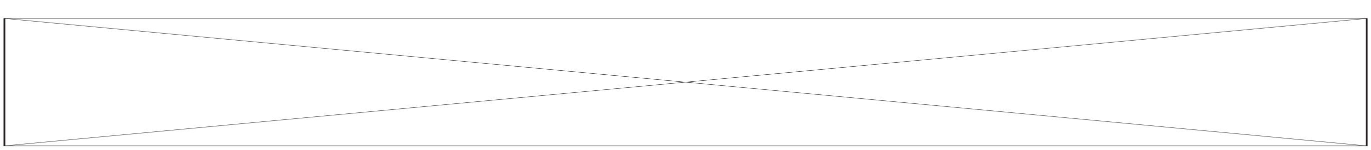
0.2 Strategy discussing (22.09.2015)

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.



0.3 Concept discussing (24.09.2015 - 03.10.2015)

Time frame: 24.09.2015 - 03.10.2015
Preview: Objectives for current section are developing the concept of the robot and division engineering works by modules.
Conclusive solutions for modules:

Module	Solution	Label
Carriage	U-shaped construstion opened from the front side.	chassis
Wheel base	6 standard wheels with 6 DC motors. The center of gravity is between second pair of wheels; corner wheels are equidistant from the center of gravity.	chassis
Elevator for debris	Crank elevator with one degree of freedom.	elevator
Bucket for debris		bucket
Separator for debris		bucket
Rotating blades		gripper
Slopes for collecting debris	Slopes on both sides of the bucket will increase the collecting area	gripper
Beam for scoring autonomus alpinists	L-shaped beam turning by servo. Alpinists placed in small bucket on the remote side of the beam.	alpinists

Separation tasks between collaborators:

Collaborator	Modules	Label
Wheel base		chassis
Elevator and bucket		elevator bucket
Gripper and slopes		gripper
Beam for alpinists		alpinists

Days inside section:

0.3.1 24.09.2015

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 work.

Modules:

Module	Solution	Label
Wheel base	6 standard wheels with 6 DC motors. The center of gravity is between second pair of wheels; corner wheels are equidistant from the center of gravity.	chassis
Heaviness	Robot should be as light as possible to afford gear ratio for speed 2:1 on drive motors.	chassis
Elevator for debris	Crank elevator with one degree of freedom.	elevator
Bucket for debris	Bucket with turning cover which will close entry inside the bucket to prevent scoring elements from accidental falling out	bucket
Slopes for collecting debris	To increase collecting area on both sides of the bucket will be placed slopes	gripper
Separator for debris	Turnable beam before the bucket, which prevents balls from getting into the bucket in it's lower position (5cm from floor).	gripper
Beam for scoring autonomus alpinists	L-shaped beam turning by servo. Alpinists placed in small bucket on the remote side of the beam.	alpinists

Detailed explaination:

1. Wheel base includes 3 pairs of wheels. The middle pair of wheels provides better rotation, because the their direction corresponds with tangent of the circle of rotation.
   The center of gravity should be on the crossing of lines which link opposite wheels. wheels on one side should be placed on one line. In this construction each wheel will obtain $\frac{1}{6}$ of robot's weight and moments on all wheels will be the same.

Рис. 3:

2. Both standard TETRIX and "NeveRest 1:40"motors have moments around 10 kg/cm. The diameter of standard wheels is 10 cm. So, the moment on wheels will be $\frac{10\text{kg}\cdot\text{cm}}{5\text{cm}} \cdot n = 2n\text{kg}$ (n - number of motors). Moment required for climbing to the ramp is $10\text{kg} \cdot sin30° = 5\text{kg}$. Consequently, 3 motors will be enough for driving robot of 10kg to the 1 zone of the ramp. It's possible to use 6 motors with gear ratio 2:1.
3. The crank elevator is the most reliable construction. One rotating beam requires 1 DC motor.
   The moment of DC motor should be enough for moving bucket with 5 scoring elements at a lever of about 40-50 cm. Moment of 5 cubes (250g) is $0.25\text{kg} \cdot 50\text{cm} = 12.5\text{kg} \cdot \text{cm}$. Moment of bucket will be about 10kg as well. So, it was decided to use gear ratio 1:3 (it will increase motor's moment to 30kg*cm).

Рис. 4:

4. Bucket will be made of PET. PET is the best variant because of it's little weight (weigt of $100 \times 100 \times$

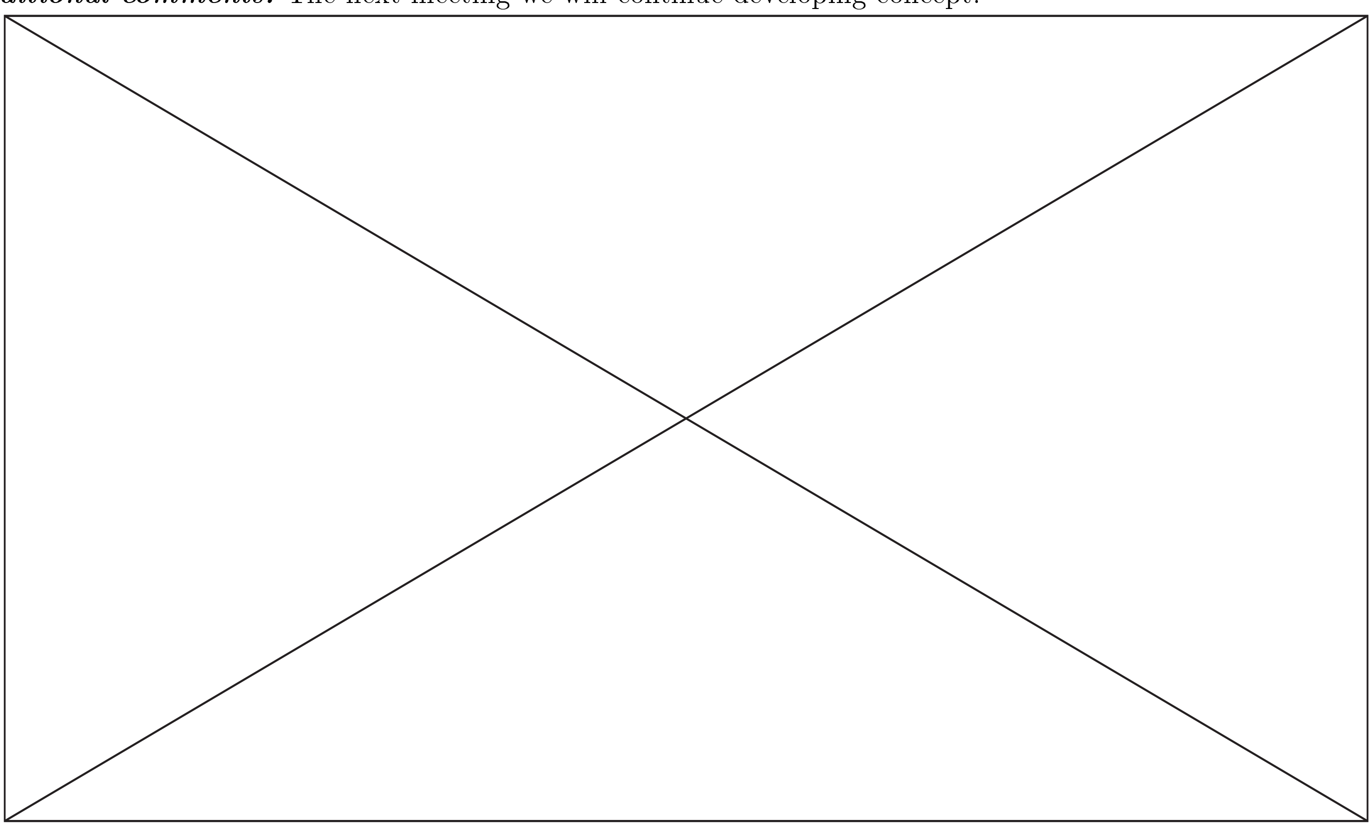
0.5mm sheet is 7g) and flexibility. This plastic is limpid, so it will be possible to watch how much debris inside it.
Bucket will have special cover for retaining deebris in the bucket during turning of beam with bucket towards the goal.

Рис. 5:

5. Slopes will be mounted to the carriage. They will be placed on both sides of the bucket entrance and will lead debris from corners of capturing area to the center. Additionall, they will protect wheels from debris (wheels can get stuck on debris).

Рис. 6:

Additional comments: The next meeting we will continue developing concept.



0.3.2 26.09.2015

Time frame: 16:00-21:30
Preview: The purpose for current meeting was to develop ideas were invented last meeting.

Modules:

Module	Solution	Label
Bucket for debris	The shape of bucket should form one stage.	bucket
Debris separator and lock for bucket	Flap above the enter.	bucket
Crank elevator	There were calculated basic parameters.	elevator
Gripper for debris	Axis with 2 rotating blades ahead of the bucket for grabbing debris.	gripper

Detailed explaination:

1. Today was held a research on how to score debris into boxes in with maximal efficiency. Due to experiment it was revealed, that scoring cubes one-by-one won't allow to score a lot of elements because they will settle down randomly. It was discovered, that the best solution is to put 4 stages with 5 cubes in each one. Cubes in stage should be placed as 2+2+1 (fig. 1). According to this researches, the shape of the bucket for debris should form one stage.

Рис. 7:

2. Today was invevted one possible construction of separator for debris. It consists of axis with a flap above the bucket's enter, which can narrow it's height so as prevent balls from scoring. It will also prevent debris from falling out of the bucket while it's overturnded. This way, current mechanism will be a separator and a lock at one time.

Рис. 8:

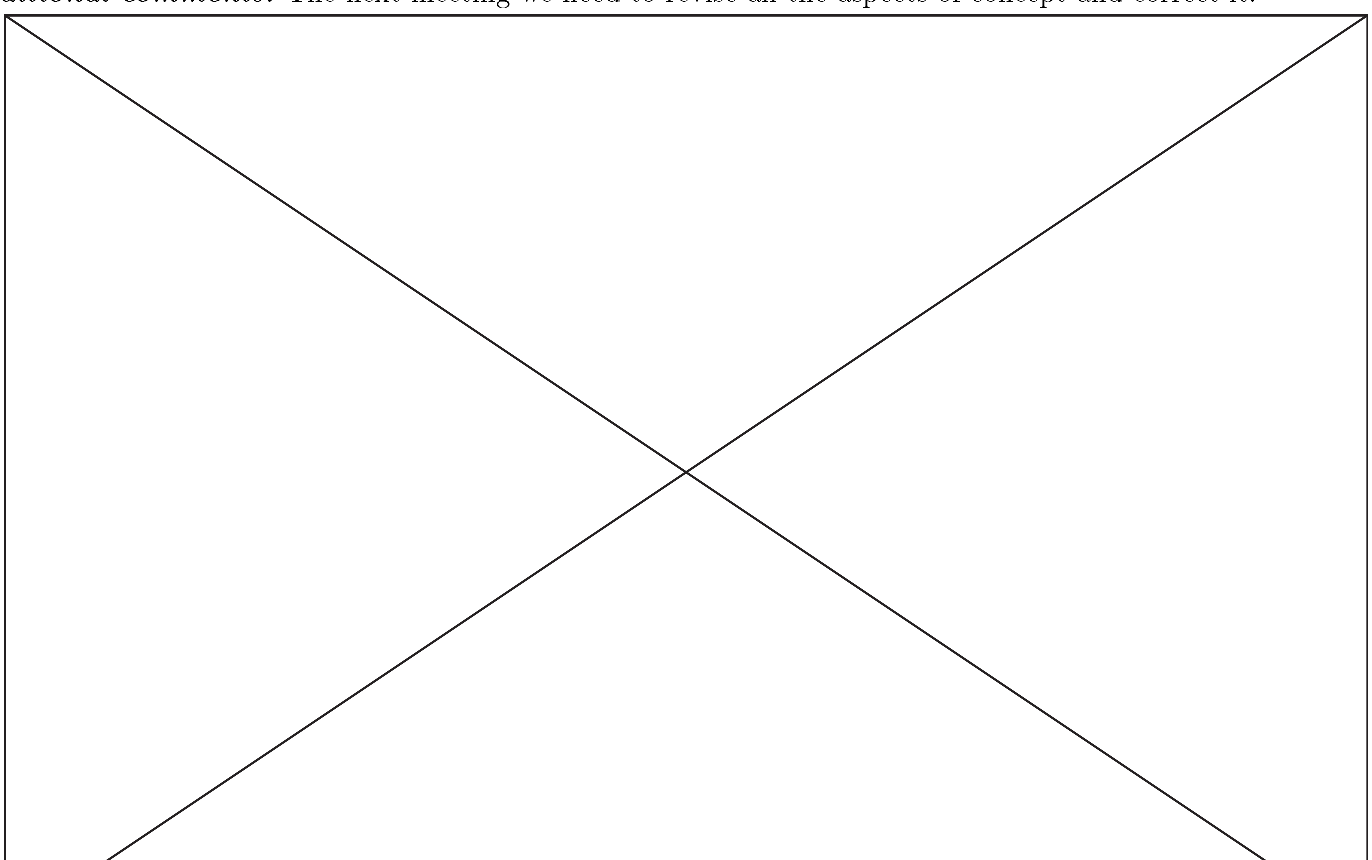
3. Today there were calculated parameters of crank elevator, that required for scoring debris into the top goal from the second zone.

Рис. 9:

4. Gripper is a rotating brush for collecting debris. It will be used for faster collecting of the debris and also for retaining it in bucket (without gripper debris can freely escape the bucket when the robot moves backward). Gripper should be powered by 1 DC motor or 1-2 powerful servos to be fast and powerful enough. Using 2 blades at an angle of 180° is the most convenient solution as it's simple to realise and it requires less space than construction with 3 blades at an angle 120°.

Рис. 10:

Additional comments: The next meeting we need to revise all the aspects of concept and correct it.



0.3.3 28.09.2015

Time frame: 17:00-21:30
Preview: The purpose for current meeting was to revise all our previous ideas and reveal weaknesses. Then correct concept.

Weak points

Weak point	Solution	Label
Gear ratio 2:1 on wheels can be not enough for climbing	It will be installed gear ratio 1:1 at first. If tests of gear 2:1 will be successful, it will be installed on the robot.	chassis
Shape of the bucket		bucket
Shape of the beam for scoring alpinists		alpinists

Detailed explaination:

1. It's difficult to predict if the gear ratio 2:1 will provide robot with enough power for climbing to a second zone of a mountain before the test drive. That's why at first wheel base should be realised with gear ratio 1:1. A test model with gear ratio 2:1 should be assembled and tested independently. In case the testing of 2:1 model will be successfull, this gear ratio will be installed onto the main robot.

Рис. 11:

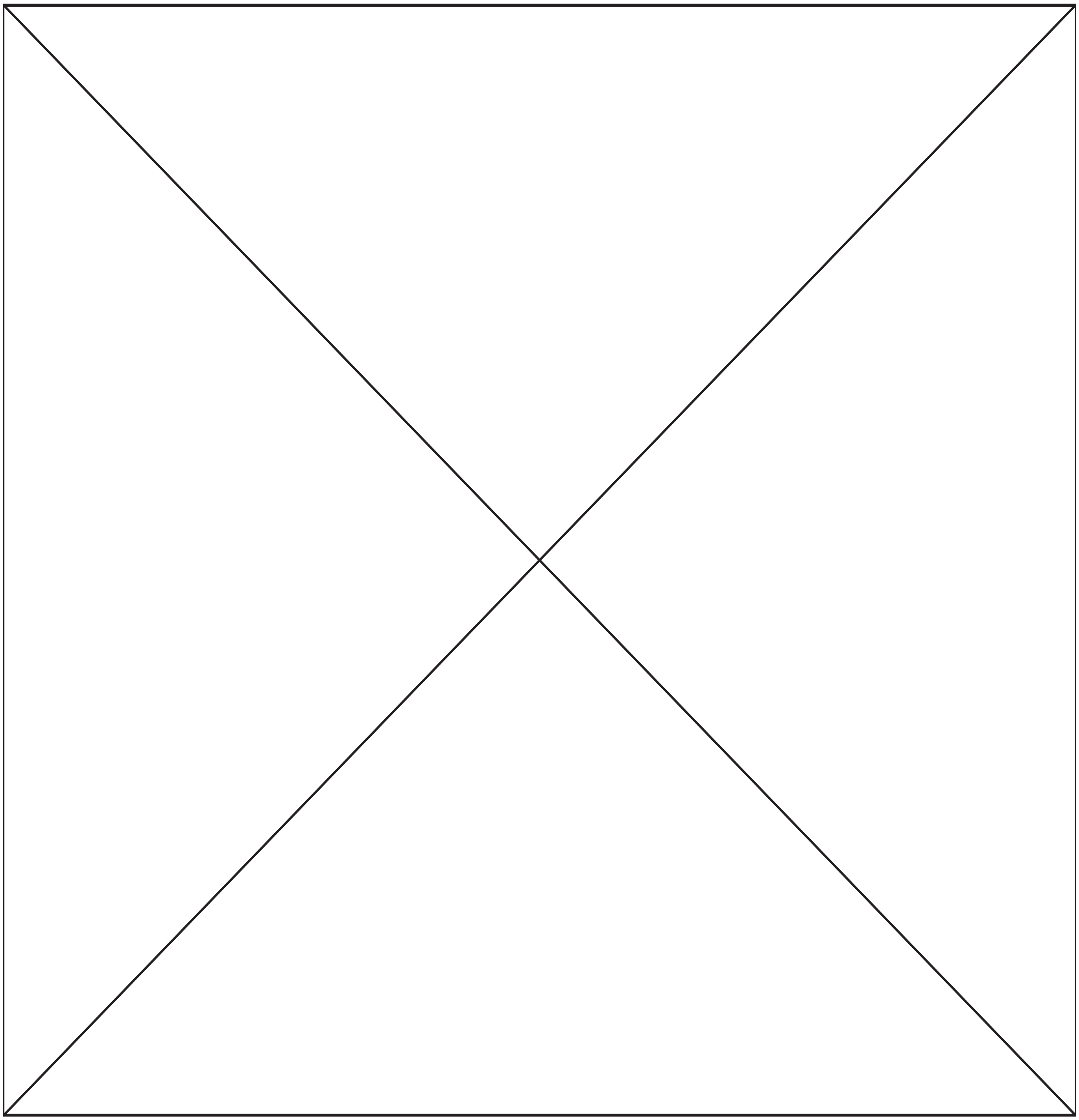
2. If the bucket would be a size of 5 cubes, it could keep no more 2 balls at once. That's not good enough as when cubes run out our robot becomes uneffective. So, the bucket's capacity should be improved. The possible solution is to improve the length with saving the prior width. For example, bucket with parameters 13 × 21 cm is enough for containing 5 balls.

Рис. 12:

3. Shelter for autonomus alpinists is only 5.75 inches in length, so the most accurate way to score climbers is to throw them vertically. To provide this, the axis of rotation should be placed higher than the resque beacon (fig. 1).

Рис. 13:

Additional comments: The next meeting we will structure ideas into a system.



0.3.4 01.10.2015

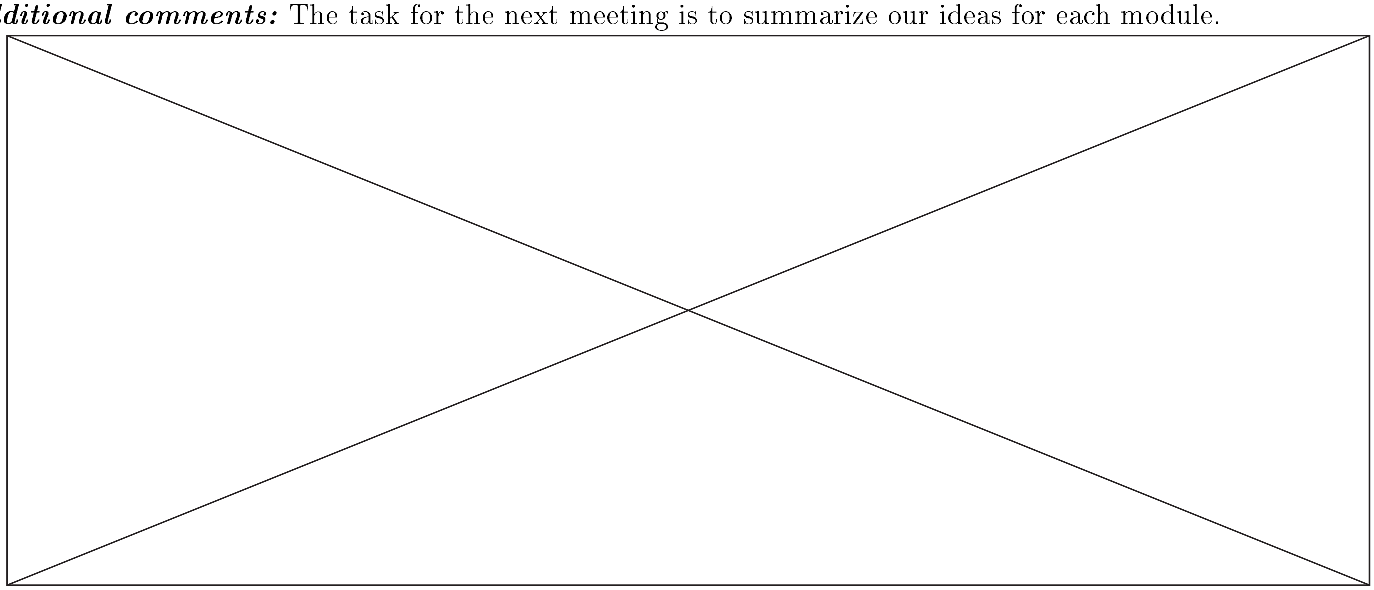
Time frame: 17:00-21:30
Preview: The purpose for current meeting was creating structural layout of the robot in CAD Creo Parametric 3.0.

Detailed explaination:

1. We made a structural model of the robot. The whole construction was divided into particular modules. They are:
   1.1. Chassis - carrying base and wheels mounted on it.
   1.2. Bucket - container for debris.
   1.3. Elevator - mechanism for lifting bucket.
   1.4. Gripper - mechanism for collecting debris.
   1.5. MSA - mechanism for scoring autonomus alpinists.

Рис. 14: Structural model of the robot

Additional comments: The task for the next meeting is to summarize our ideas for each module.



0.3.5 03.10.2015

Time frame: 16:00-21:30
Preview: The purpose for current meeting was to divide all construction works into 4 groups (one group for one teammate) to provide elaborating modules in parallel. After that, we wrote technical specification for each group of modules to help collaborators follow the requirements.

Technical specifications for modules:

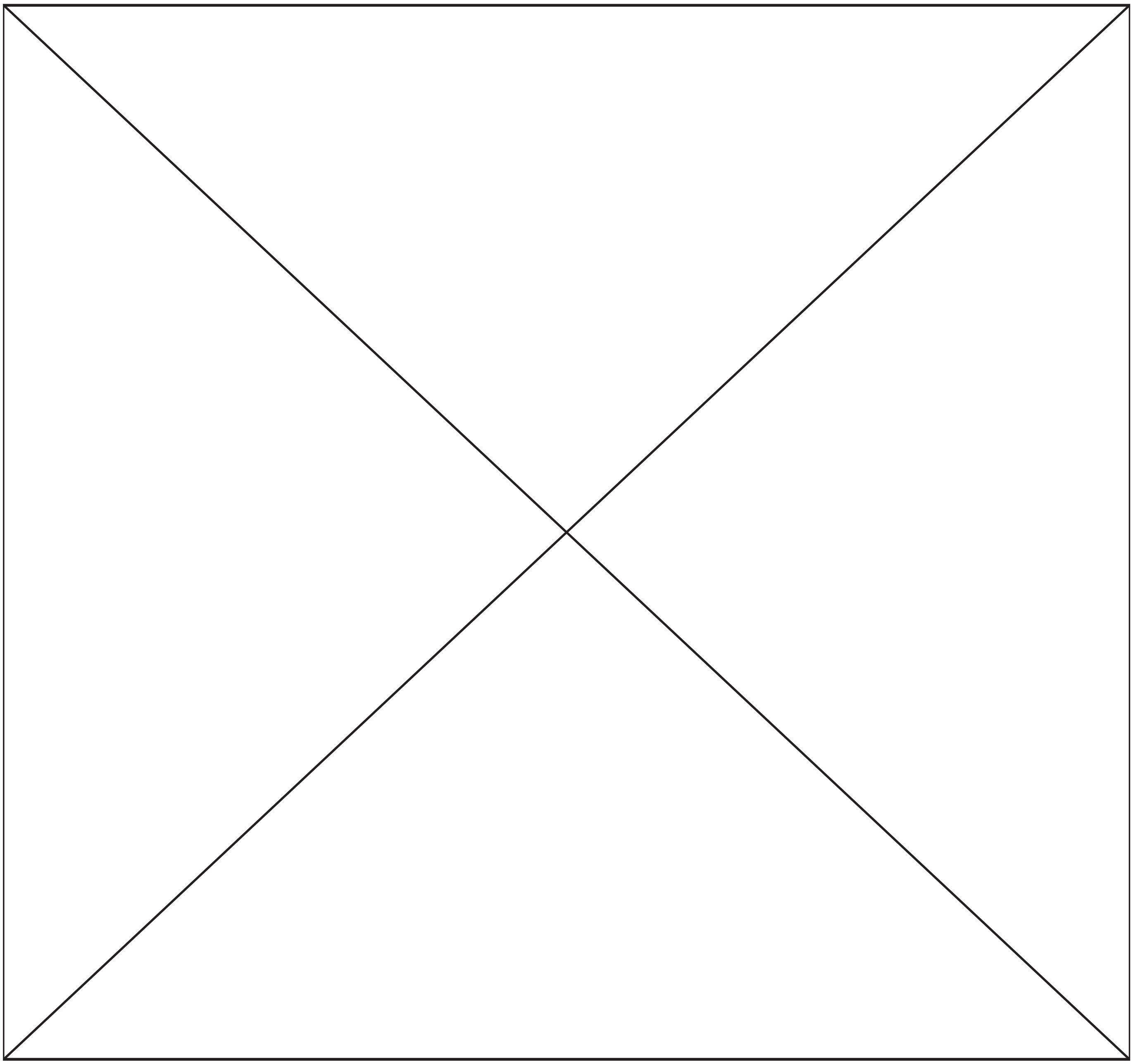
1. Chassis
   1.1. Carriage consists of two lengthwise beams 41.5cm connected at the back side. All other modules will be mounted to this base.
   1.2. Wheel base consists of 3 pairs of standard wheels. All wheels at one side are linked to each other and move dependently.
   1.3. Wheel base is powered by 6 dc motors (3 at one side).
   1.4. Motors should not interfere with bucket which will be placed in the forward half of the robot.
   1.5. There should be no construction elements except wheels that can touch the surface while climbing the ramp.
2. Elevator
   2.1. Elevator consists of 2 static beams fixed on the base and one pivoting with bucket on it.
   2.2. Turnable beam rotates around the axis on top of the static beams. It's rotation powered by 1 dc motor with gear ratio 1:3.
   2.3. Length of the elevator should be enough for scoring debris into all boxes without climbing to the 3-rd zone.
3. Bucket
   3.1. Bucket should be fixed to the turning beam of elevator stationary.
   3.2. Free space inside the bucket should be 10-14cm at width, 15-17cm in length and 7cm in height. It should be capacious enough for containing 5 cubes of 3 balls.
   3.3. The back side of the bucket can be narrower to prevent collecting more than 5 cubes at once (cubes will settle as $2 + 2 + 1$).
   3.4. Bucket's movement should not interfere with gripper for debris.
   3.5. Entrance hole of the bucket should have the same height and width, as the internal space.
   3.6. Bucket should have a turning flap above the entrance which can prevent balls from scoring on demand. Additionally, the flap will stop debris from falling out of the bucket when it will be overturned.
4. Gripper
   4.1. Gripper consists of 2 rotating blades, mounted to axis at an angle 180° to each other.
   4.2. Gripper is powered by 1 or 2 continious rotating servos.
   4.3. Gripper is placed ahead the bucket. Width of blades should match with the entrance of the bucket.
   4.4. Space between axis and field enough for unhindered passage of balls.
   4.5. Gripper should not make any obstacles for bucket's moving.
   4.6. At both sides of the blade's working area placed slopes, which are tapering to the bucket.
5. Alpinists
   5.1. Mechanism for scoring autonomus alpinists will be placed at the forward side of robot. It's definite position will be determined after discussion of autonomus strategy.

5.2. Mechanism consists of L-shaped beam powered by standard servo.
5.3. At the end of beam placed a bucket for 2 alpinists.
5.4. Module should not interfere with gameplay after the autonomus period ends.

Responsibilities for each module:

1. Carriage and wheel base - Victoria Loseva
2. Bucket and elevator - Evgeniy Maksimychev
3. Gripper with slopes - Ivan Afanasiev
4. Mechanism for scoring alpinists - Nikita Safronov

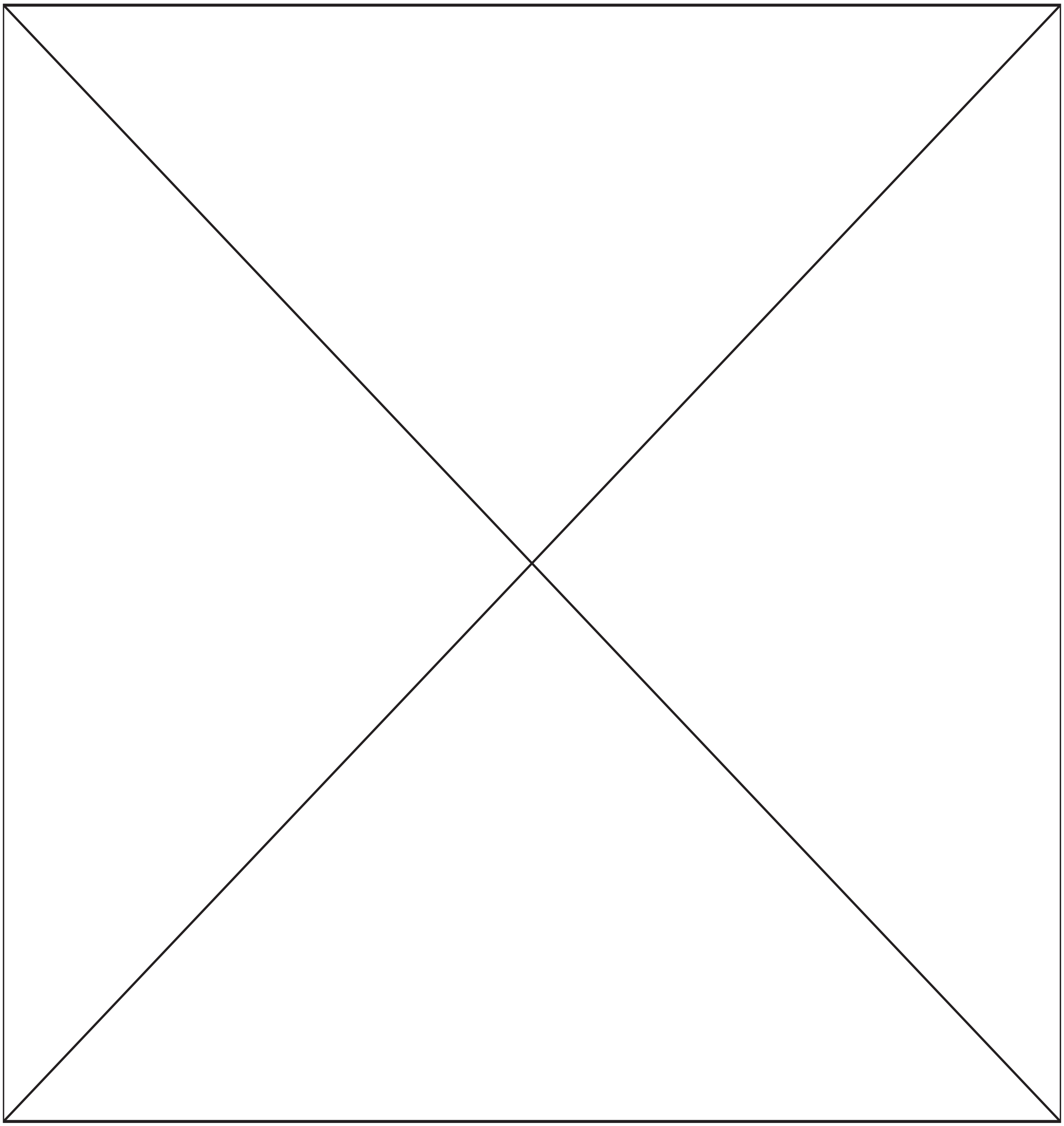
Additional comments: Now our team is ready to proceed to the next objective: designing modules.



0.4 Designing modules (03.10 - 09.11)

Description: During this period there were pondered the main aspects in implementation of each module and were developed primary CAD models of modules. In the following section there are mentioned only results of this work. Further clarifications about the process of engineering are available in section "specifications for modules".

0.4.1 Wheel base



0.5 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 of modules"and "specifications of programs"correspondingly.
Days inside section:

0.5.1 10.11.2015

Time frame: 16:00-21:00
Description: The main purposes for current meeting were making robot and writing program...

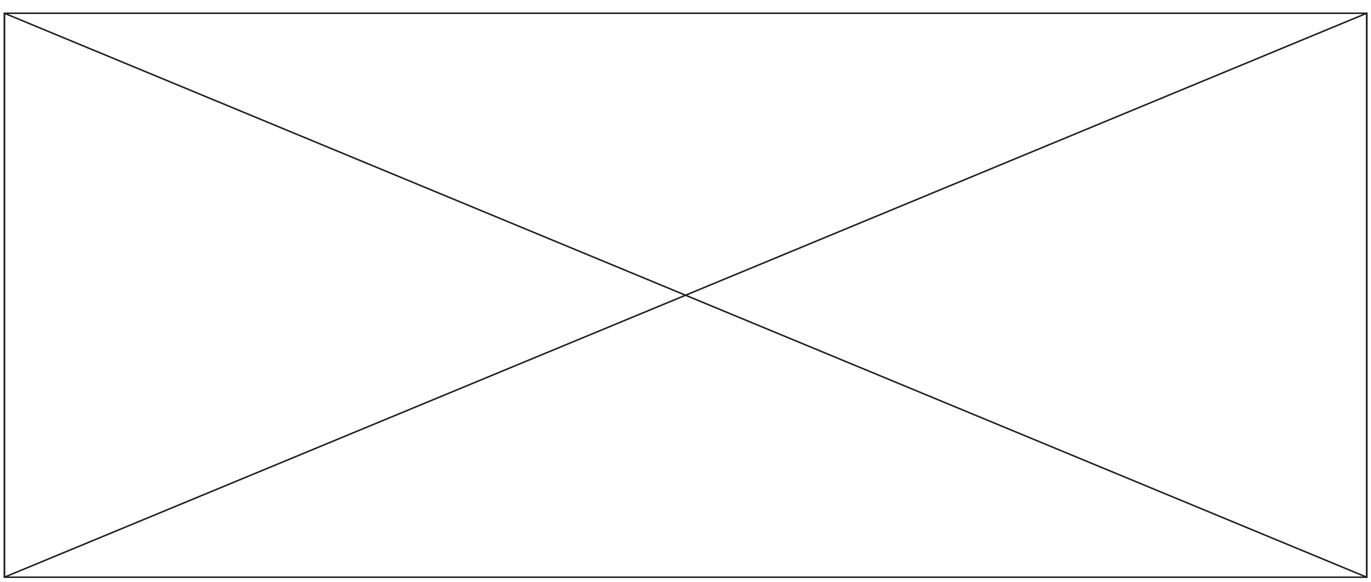
Detailed explaination:

1. Detailed explaination of robot...

Рис. 15: robot

2. Detailed explaination of program...

Рис. 16: robot



0.6 Specifications for modules

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

0.7 Lift and bucket for debris

0.7.1 Lift

The lift consists of two beams. One beam is stationar and it is fixed vertically on the back part of the robot. The second beam turns by DC motor that mounted at the top of stationar beam. The length of beams must allow to score debris to the high goal from the middle zone and to middle goal from low zone.
For estimating optimal length of beams it was made drawing in GeoGebra.

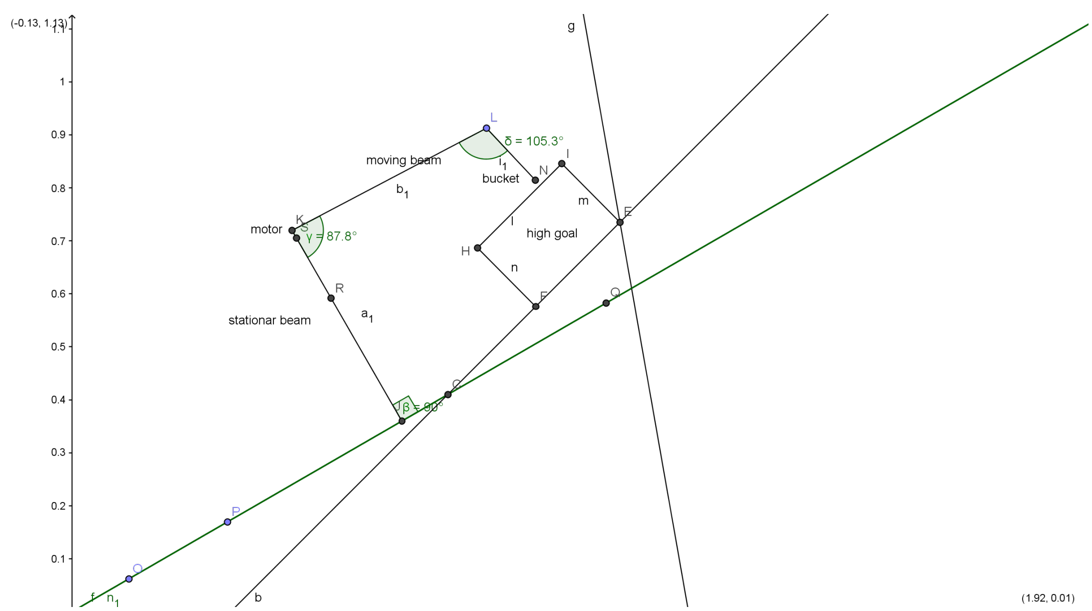


Рис. 17: Drawing of the lift

0.7.2 Bucket

The bucket's size allow to fit 3 cubes and 2 balls. So we can collect 5 cubes (because size of cube is smaller than size of ball) or 3-4 balls. It is enough for us because we want to concentrate on collecting cubes.
For estimating optimal size and form it was made drawing in GeoGebra. During designing model of the bucket for all sizes were made dimention tolerances 2cm.

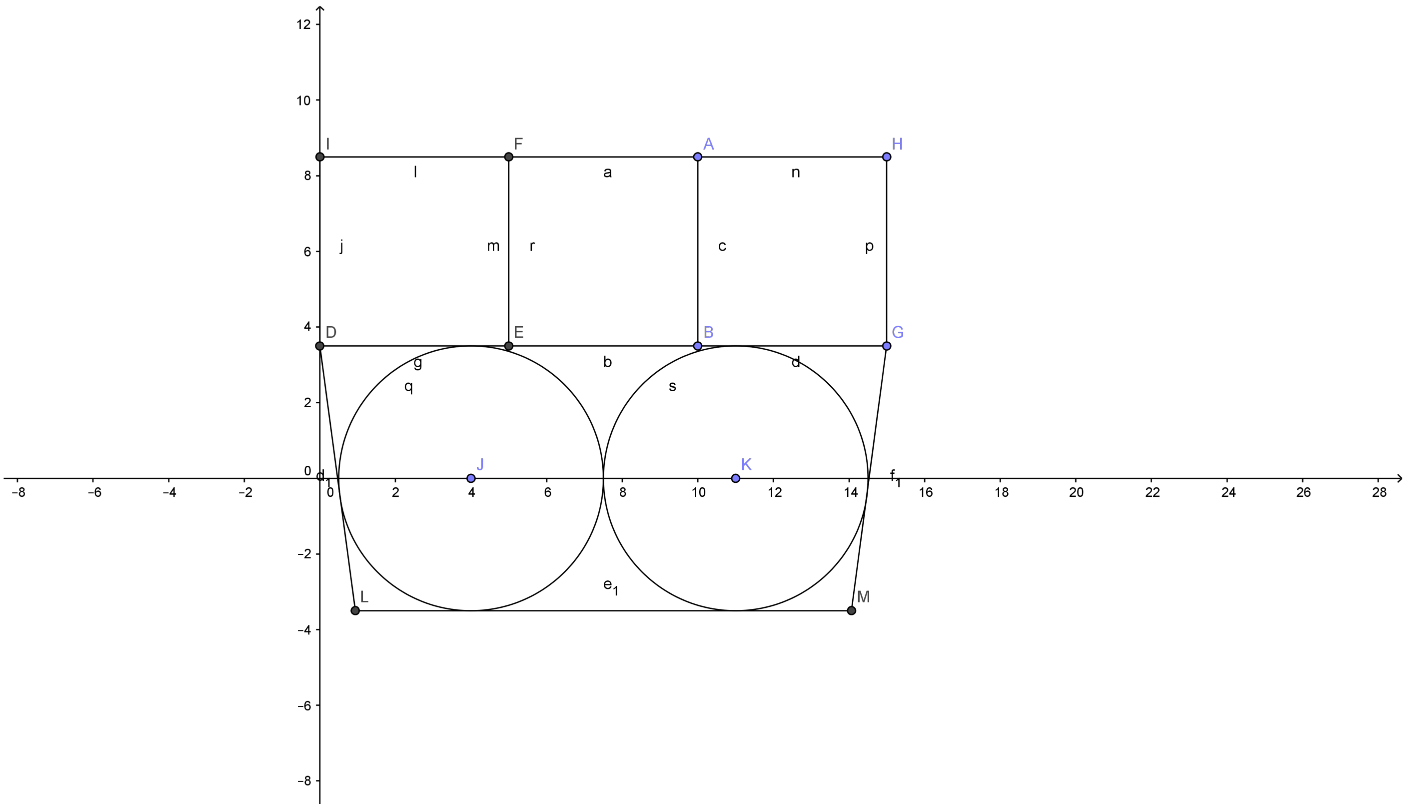


Рис. 18: Drawing of the bucket

But after that it was decided to change size of the bucket. The width entrance hole and width of the scoring box should be the same. It ensure maximal accuracy of scoring debris. It was decided to make bucket that can fit 5 cubes or 3 balls.

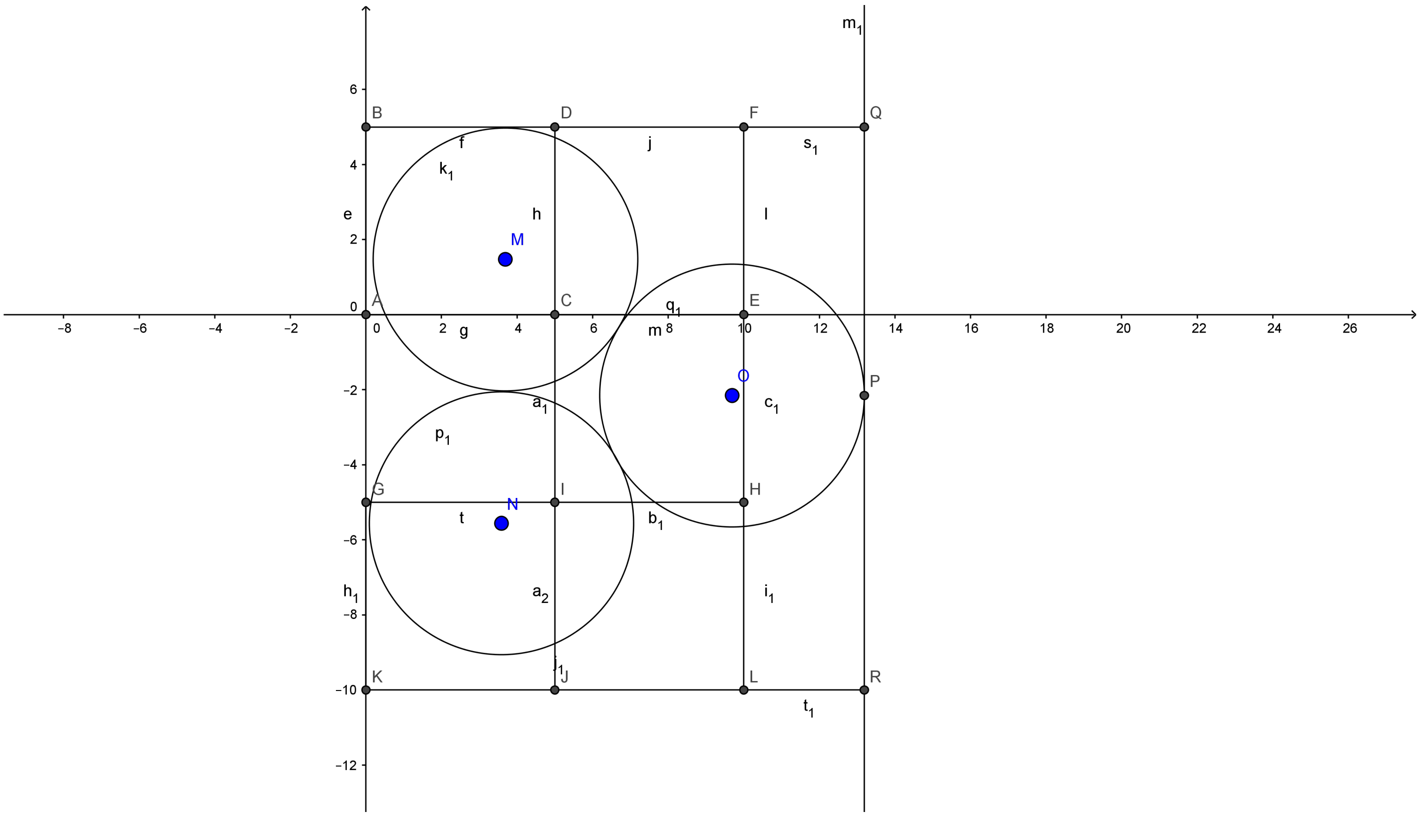
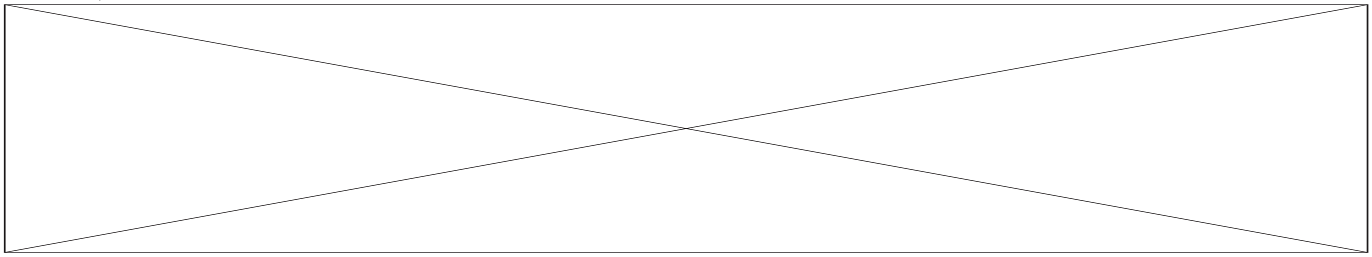


Рис. 19: Changed bucket

For building bucket it was decided use plastic PET 0.5mm. It is easy to cut it, it light, cheap and clear that allow us to see how much elements are incide the bucket.

The bucket mounts to beam that turns by the servo which fixed on the lift. It need because else we have to make detail that fix bucket to the elevator on the defined angle. It require high accuracy. So it will be difficult to make this detail. In addition the mount with servo extend operational window of the lift.

The bucket equped by the cover that turn by the servo and close entrance hole of the bucket. It prevent to falling debris out it during turning of the moving beam of lift. Also it can to prevent balls get into the bucket when we collect only cubes. When it closed not fully (so that distance between bottom edge of cover and floor is about 6cm) the cube can get into the bucket but the ball is not. When we open cover the balls can get to the bucket.
The cover fix on 14cm beam that turn by the servo. It was decided use so long beam as the most optimal variant when cover move vertically because otherwise it can to prevent rotating gripper for debris. When it turn around the circle with big radius trajectory of cover's moving is close to vertical.
Also they were calculated moments of force that acts to servos (for servo that turn bucket and for servo that move cover).



0.8 Specifications for programmes

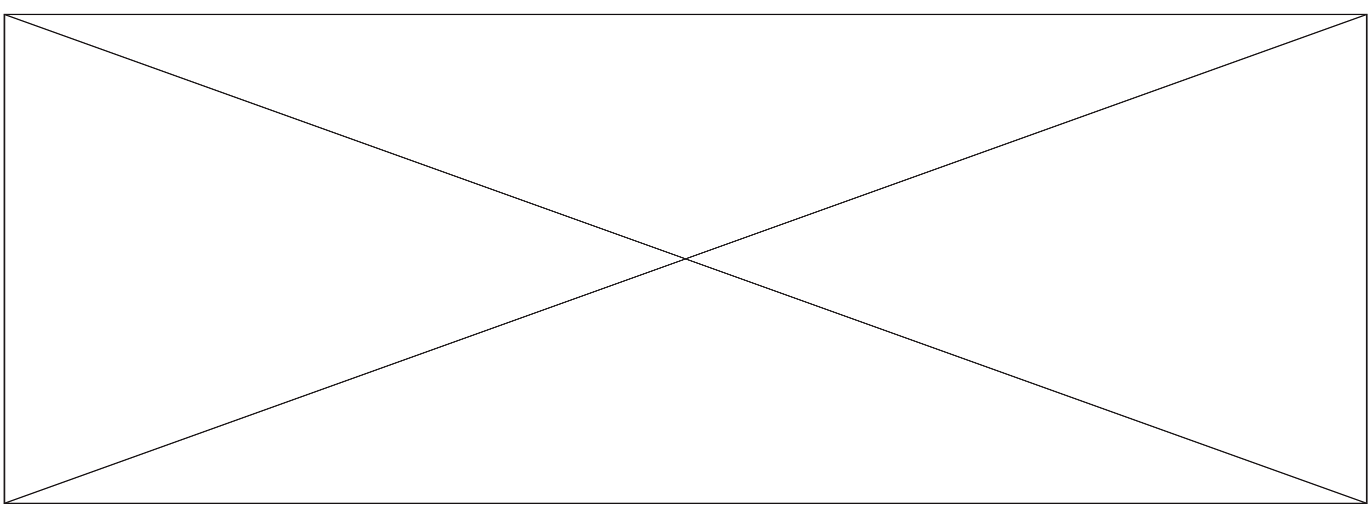
Description: This section contains detailed information about elaboration of remote-control program and autonomus program.

0.8.1 Driver control program

As soon as the first prototype of the wheel base was assembled on November $12^{\mathbf{th}}$, 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. 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 (fig. 1) are not used because of unconvenience of back semi-turns. Here is the source code of second version. 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 (fig. 2). Here is the source code of third version.

Рис. 20: robot

Рис. 21: robot



0.8.2 Autonomus program

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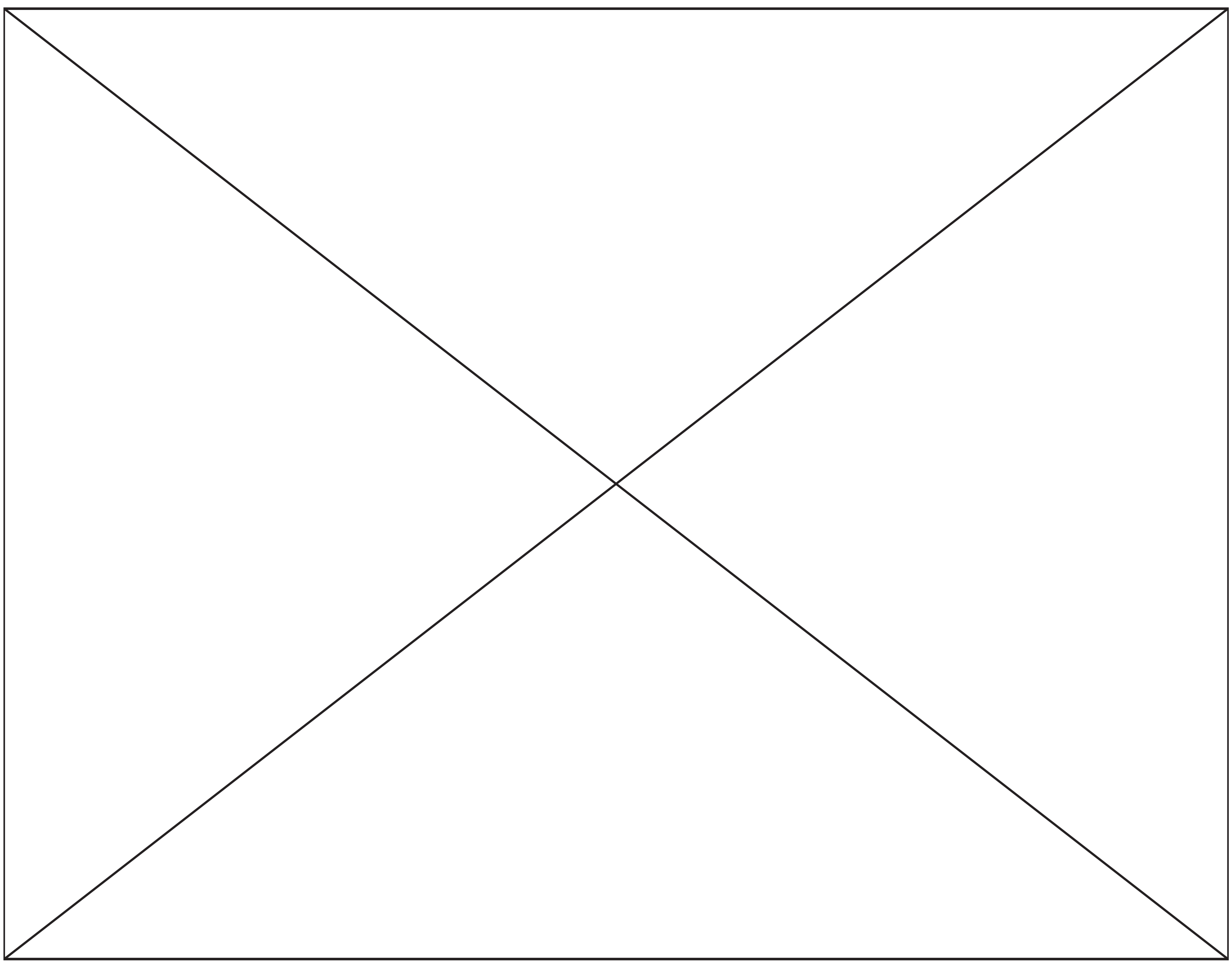
Рис. 22: robot

Рис. 23: robot



0.9 Key summary

Description: Here are marked the tactical and technical characteristics of the final version of the robot.