Center for robotics
Physics-Mathematics Lyceum 30

Engineering book of
Competition First FTC

Team PML30 –*Y*

Saint-Petersburg, Russia
2015

0.1 Specifications for modules

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

0.1.1 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 (winch)
   - 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.

At the 25$^{\text{th}}$ December it was decided to stop the development of the current construction of elevator. The reason was that the first competition was taking place in a week, and nothing was ready yet. Firstly, the plastic details for connecting the profiles to each other were not created in material as there was nowhere to make them. Secondly, this system was never made before, so it could have some latent problems.

It was decided to use the furniture rails instead of construction profiles because our team had used them in 2 previous FTC seasons and we have an experience in developing the elevator with furniture slats.

0.1.2 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

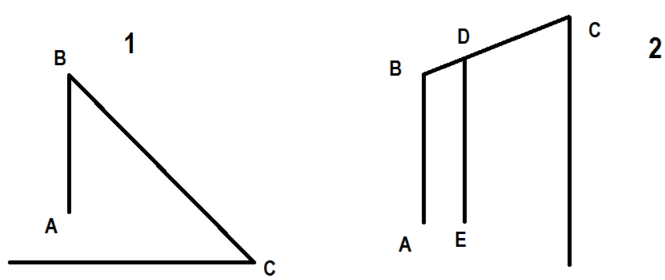


Рис. 1: Side view of beams onto which the bucket is mounted

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

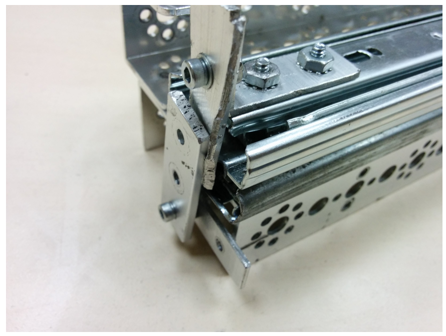


Рис. 2: Structure of limiters

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.

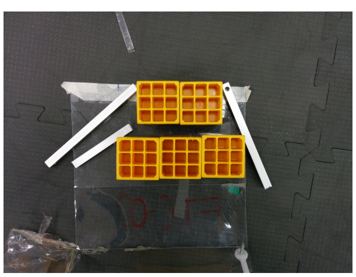


Рис. 3: Structure of guides

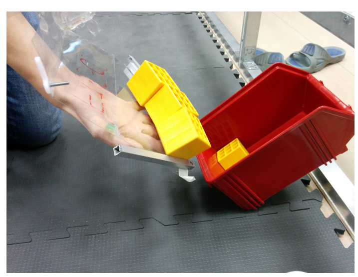


Рис. 4: Process of guides testing

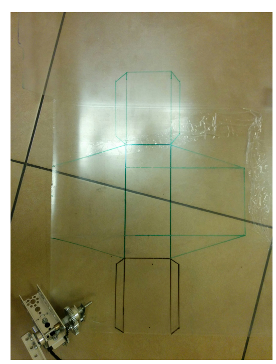


Рис. 5: Marking of bucket

   Tests 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.

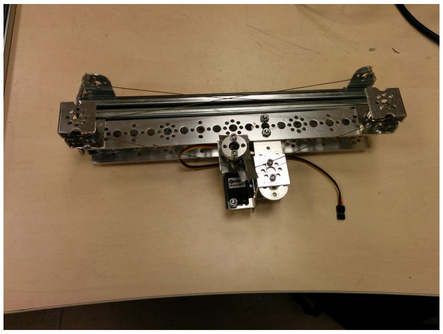


Рис. 6: Construction of line and pulling it servo

Рис. 7: Final construction of the slats

9. Next 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.

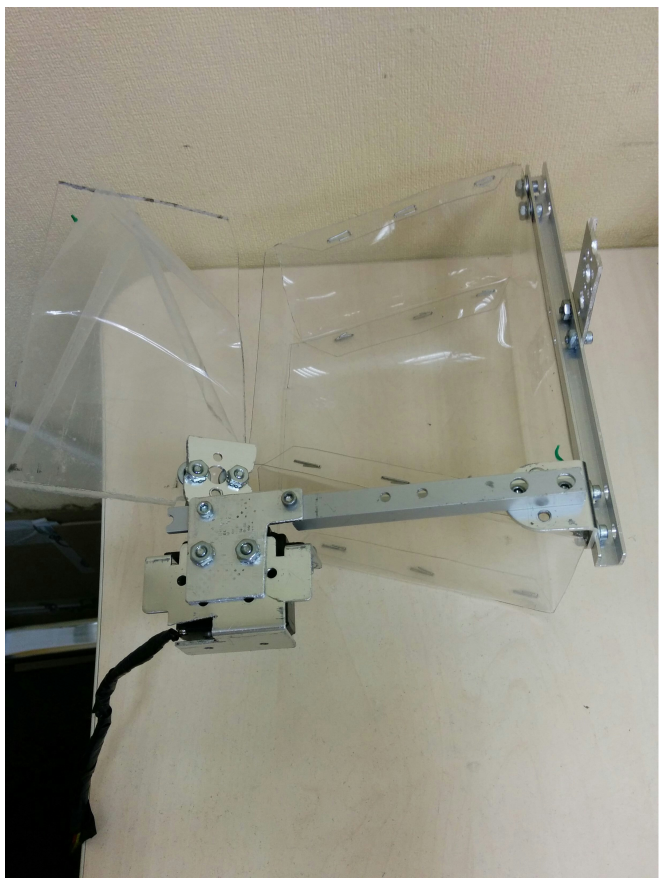


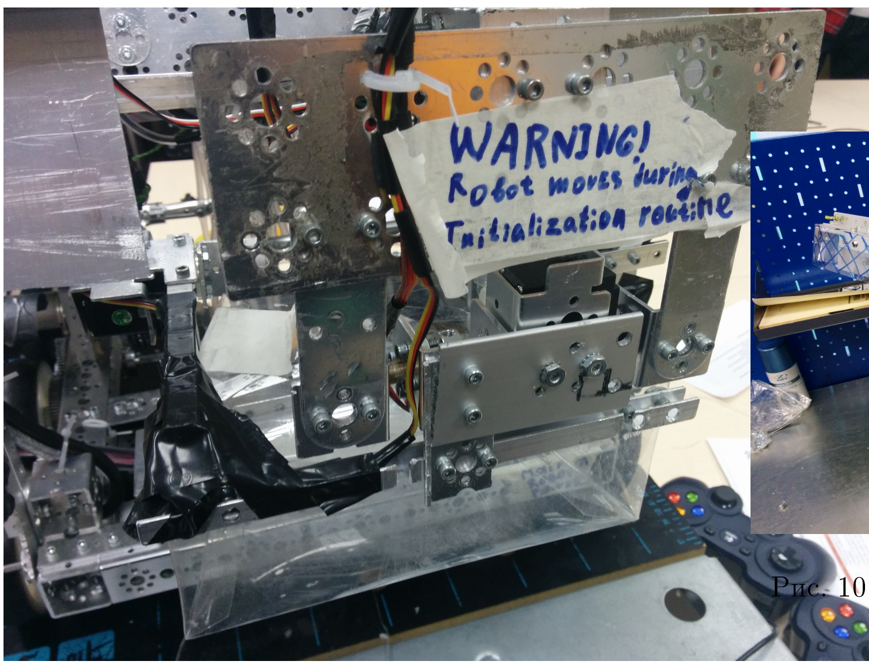
Рис. 8: Final construction of the bucket with closing mechanism

10. After that bucket was installed on bracings on the slats. Then all the module was mounted on the lifting mechanism. It was done in the way to make the bucket turning axis as low as possible. It would make the volume, used by bucket less, because with that place of the bucket it was necessary to turn it while lifting because otherwise bucket intersected with other parts of robot while lifting. So the lower axis made the radius of bucket turning less and reduced the capacity on the servo by shortening the

shoulder of buckets weight. By the time it was done, the first competitions had almost started so the slats weren't mounted on the lift because of time troubles.

11. After the end of competitions slats were replaced by longer ones (40 cm instead of 35) to make bucket shifting completely out of robot teoreticaly possible. Also the shifting servo was changed to faster and more powerful servo in order to make bucket shifting faster and more reliability. Then possible work process of bucket was estimated and it turned that fast lifting was impossible. It was so because the bucket was to be turned in case not to intersect with other parts of robot to be lifted. And generally bucket was close to catch parts of robot while moving from front of robot to its end during the lifting. To solve these problems was decided to place the bucket int end of the robot above two beams. It would make lifting easier because bucket would move inside robots projection much less time than before, also it is easier to transport debris throw the robot than to transport the bucket.

12. Then the slats were mounted on this lift in the way to place bucket in the end of robot. The next problem was not much space so the beam, on which the bucket was mounted intersected with lifts slats while shifting. So the mount of the bucket was changed. With that construction servo was turning with the bucket. It made the non-intersection beam possible. After that bucket was mounted on the sift mechanism without any intersections, so the problem was solved.



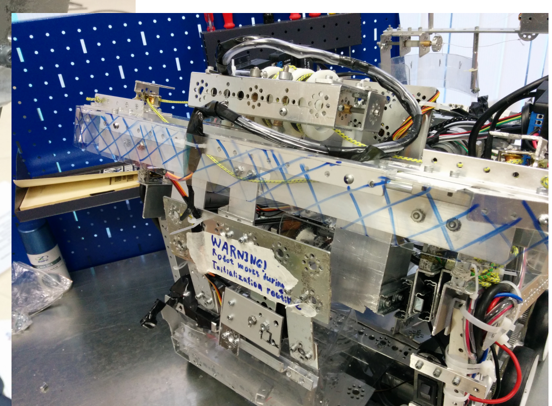


Рис. 10: The bucket mounted on robot

Рис. 9: Construction of bucket

13. The next step was testing bucket and the whole robot. In the process of it was found two problems: the closing mechanism was able to work only when the bucked was a bit lifted and bucket couldn't hold 5 cubes, caught by grab mechanism. First problem was solved by cutting sides of partition, closing bucket. The second problem weren't solved by adding guides to move first cube sideways (grab couldn't move the cube so). Because of it was decided to change the shape of bucket.

14. After that the new shape was devised.

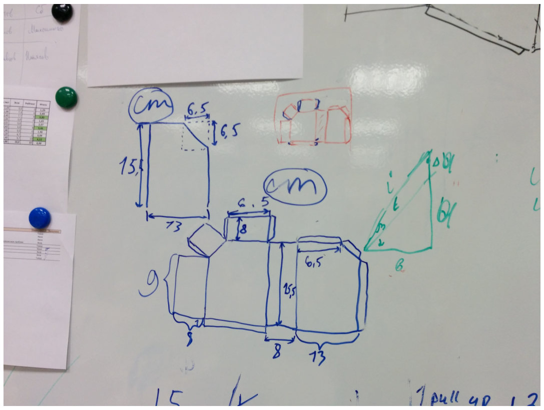


Рис. 11: Shape and scan of the bucket

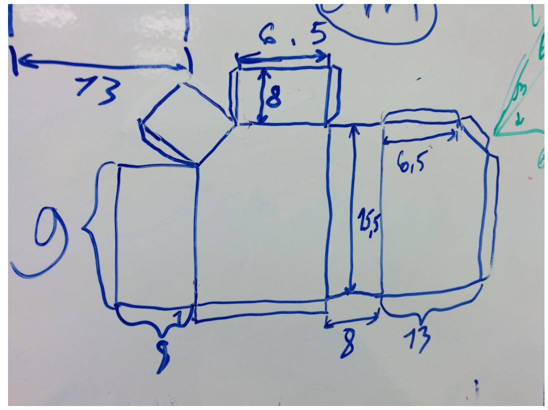


Рис. 12: Closer view of the scan

This shape was chosen because:

- It was easier to fill by the grab mechanism
- It was big enough to hold 5 cubes
- It was not enough spacious for 6 cubes
- It has output hole with width of 2 cubes and that made cube falling vore direct and allows to score cubes.

15. Then the new bucket was marked and cut from a sheet of plastic (the same was used for the first bucket). Next, bucket was assembled and tested (not on robot). Tests showed that bucket was able to hold 5 cubes and score them directly to the high scoring bucket.

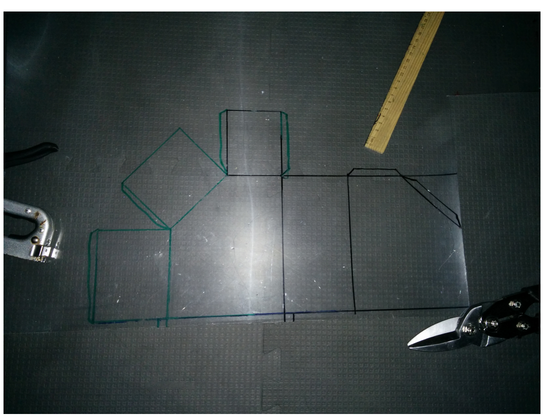


Рис. 13: Marking of bucket on the plastic sheet

Рис. 14: Fully assembled bucket with cubes inside

16. After that was made protection for wires that could get into slats and break there. Also was made protection for rope of shifting mechanism that could catch on parts of robot because of which shifting stopped. Both protections are plastic strips.

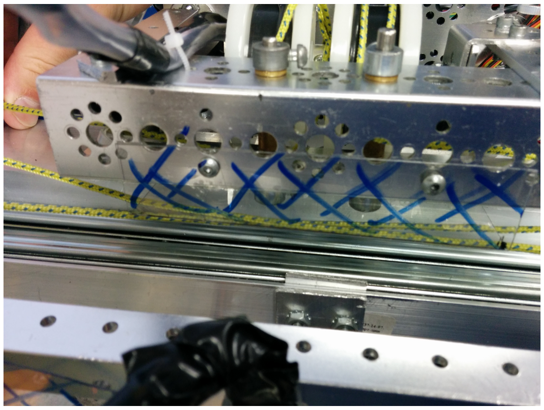


Рис. 15: Protection of rope

Рис. 16: Test of new bucket