TEAM ROBOCON IIT KANPUR

IIT KANPUR
Indian Institute of Technology, Kanpur

ROBOCON 2015 - Robominton

Description of the Mechanical Aspects of the Robots Developed by Team IIT Kanpur

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Acknowledgement

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Abstract

Team Robocon IIT Kanpur participated in ABU ROBOCON 2015 – Robominton which required the students to build two robots to play badminton doubles game on an actual-size court. The mechanical aspects of this project included the design, fabrication and testing of robots. Different modules performing different functions were developed independently and assembled together. The chassis was made octagonal which maximised the area covered by the robot while maintaining the feasibility of its fabrication. Holonomic drive system was used to achieve motion in all directions and rotation. The rules of the game asked for highly accurate service of shuttle. Hence, for ensuring consistency and invariability of the mechanism a DC motor was chosen as the actuator over pneumatic pistons and springs. The design parameters for both hitting and shuttle dropping mechanism were determined experimentally. Also, three types of hitting modules were developed to cater to the myriad possibilities of the shuttle trajectory coming from the opponent's side. All these systems were actuated by pneumatic pistons. The double-actuation system replicated the motion of the wrist and elbow system in humans. It was the most powerful and versatile mechanism among the three built. The rest two mechanisms were simple linkages to convert the linear motion of pistons to rotation of racket. This conversion mechanism was a three-link (three revolute pairs) linkage with one link grounded, one link attached to the racket and the third link was the piston itself. This linkage was used in double-actuation module as well. Finally, these modules were distributed among the two robots according to the decided game strategy. CAD designs of the assembled robots were prepared and the modules were assembled.

Table of Contents

1. Robocon-A Brief Description

1.1 ABU Robocon

ABU Robocon is an annual Asia-Pacific robotics contest organized by the Asia-Pacific Broadcasting Union. Founded in 2002, the competition aims to help in advancement of engineering and broadcasting technologies in participating countries. The event is broadcast in many countries through ABU member broadcasters. Since its inception, following countries have hosted Robocon at least once – Japan, Thailand, South Korea, China, Malaysia, Vietnam, India, Egypt and Hong Kong.

Each year the contest has a different theme. The participant teams build robots for completion of a specified task in the most effective manner. To build the robots, contestants, who are restricted to be undergraduate students, must possess rich knowledge in programming, mechanical design and electronic circuit design.
Each participating country has its national rounds and the winners represent their nation in the international rounds.

1.2 Robocon 2015 – Robominton

ABU Robocon 2015 was organised by Televisi Republik Indonesia (TVRI) in Yogyakarta, Indonesia . The contest theme was "Robominton-Badminton RoboGame". In the contest, the two teams had to play the game of badminton against each other. Each team made two robots to play a normal doubles badminton game. The rulebook is included as Appendix.

1.3 Robocon India 2015

Doordarshan organised National Robocon India 2015 in Shree Shiv Chhatrapati Sports Complex, Balewadi, Pune. Eighty-five educational institutions participated in the event.

1.4 Team Robocon IIT Kanpur

IIT Kanpur introduced Robocon in India in 2002 and has been participating since then. The team operates under Centre for Mechatronics, IIT Kanpur headed by Dr. Bhaskar Dasgupta, Department of Mechanical Engineering, IIT Kanpur. The team works in the 4i Laboratory (Innovation) and has access to other facilities as well (including the Central Workshop and Tinkering Laboratory).
The team recently bagged the “Best Innovative Design” award in Robocon 2014 and secured eleventh position in Robocon 2015.

2. Introduction

The contest required two robots to play a badminton doubles match. The rules of the game specified that a serve would be considered valid only if either the shuttle drops in a small region marked in the opponent's side of the court or the shuttle touches the opponent's robot before falling on the ground. Thus, an accurate service mechanism was fundamental to the project. Also, the availability of relatively powerful drive motors was limited. Hence, the game strategy decided by the team required one of the robots to specialize in 'Service of shuttle' whereas the other had to be swift and capable of implementing different badminton racket strokes. With severe time constraints and a strict deadline, it was essential to facilitate simultaneous development of all aspects of the robots. Hence, different modules for varying functions were designed, optimized and fabricated independently and later assembled on the chassis of robots along with the drive mechanisms.

The general scheme of operations performed for development of any module was:

1. Design of mechanism to render desired function as well as accommodate electronic and other requirements
2. Optimization of design along with considering feasibility of design
3. Fabrication of child parts using machine-shop operations and advanced machining techniques in some instances and their assembly
4. Final assembly on the robot/robot chassis

This report deals with the mechanical aspects of the Robocon 2015 project. Descriptions of all the modules for specialized functions such as implementation of different racket strokes, service and drive are provided. The descriptions will also be accompanied by a brief account on the procedures of their designing and fabrication.

3. Modules

3.1 Chassis with drive mechanism

The maximum dimensions of the robots specified in the official rulebook stated that the robot (fully extended) must fit into a cylinder of diameter 1.2 metres and a height of 1.5 metres (excluding the rackets). Also, with limited motor speed, a chassis made to maximum dimensions would ensure maximum coverage and least distance to be travelled to approach a shuttle. The maximum area is achieved through a circular chassis but its fabrication wasn't feasible. Also, fitment of other modules and motors on a circular chassis would also be troublesome. Now, a circle can be seen as a regular polygon with infinite vertices, all vertices on the circumscribing circle. Hence, decrementing the number of vertices lying on the circumscribing circle would regularly decrease the area covered. The octagon was the most suitable shape for chassis. An octagon was feasible and also allowed easy fitment of drive motors and wheels in desired directions. But, a large chassis meant large weight too. Hence, only the outline of the chassis was kept octagonal. The perimeter was supported by many trusses (shown in figure 1).

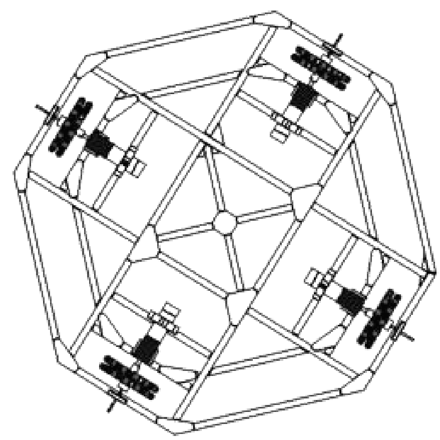
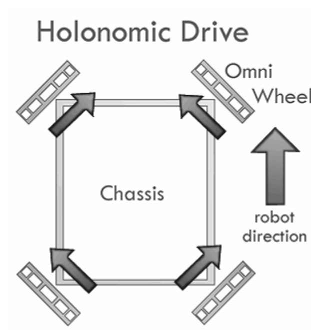


Fig 1: Octagonal Chassis

The drive mechanism should allow for movement in all directions from any orientation of the robot. Hence, a special four-wheel drive with omni wheels was implemented. This drive is called holonomic drive and is popularly known as X-drive. The direction and magnitude of motor speed can be controlled independently of each other to cause a specified amount of rotation of chassis and movement of chassis in a particular direction. This can be easily computed using vector algebra. As an example, figure 2 on right shows the forward movement of chassis and the corresponding rotation of wheels. This drive requires the wheels to slide in the direction perpendicular to the direction of rotation of wheels. Omni wheels are capable to do this. Omni wheels are wheels with small discs around their circumference which are perpendicular to the turning direction. The effect is that the wheel can be driven with full force, but will also slide laterally with great ease.

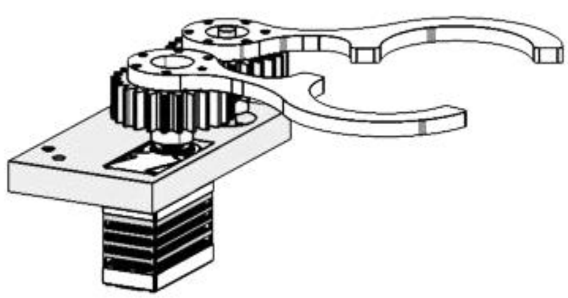


The chassis was constructed using aluminium hollow square extrusions to keep it light. However, wooden pieces were inserted to avoid their bending by weight of other modules. After designing, the extrusions of desired dimensions were cut and welded together to form the arrangement.

3.2 Service Mechanism

As mentioned before, the accuracy of service was critical to the game. The repeatability should be good, i.e. the variation should be minimum. Thus the actuation used for service should provide the same force and velocity with each use during the game. There were three actuators available- DC motors, pneumatic pistons and spring-cam arrangement. The change in spring stiffness with usage and lack of controllability proved that the spring-cam arrangement was inconsistent and not useful. Pneumatic actuation also depended upon the air pressure stored. The air pressure regularly dropped with each use and hence pneumatic pistons also proved to be unreliable for service mechanism. The DC motors always gave the same output and the voltage drop per use was negligible. Hence, an DC motor (1000 RPM) was used.

The module was designed to achieve the desired range and height for the projectile, the shuttle. However, the trajectory followed by a badminton shuttle is not a simple parabola. This difference in trajectory hindered the calculation of range and height achieved for a particular set of parameters. Thus, the angle of inclination of the plane of rotation of the racket, the distance of racket hitting-face from the shaft of motor, the height from which the shuttle was dropped, the time of shuttle drop, the initial configuration of racket and the speed of the motor were varied experimentally with respect to the position of robot to achieve accuracy and precision in service. The shuttle was held via a gripper actuated by a servo motor. The servo motor was coded to time the drop of shuttle during service. Thus, the service module consisted of a hitting mechanism and a shuttle drop mechanism. The schematic drawing of the final service module is shown below.



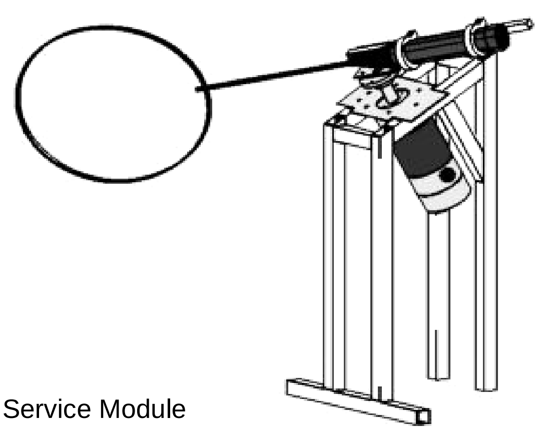


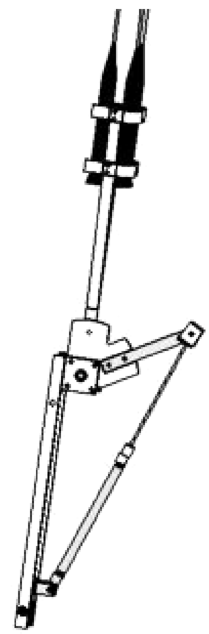
Fig 3: Shuttle-drop Mechanism and Hitting Mechanism of Service Module

Basic machine-shop operations such as cutting, drilling, lathe were used for constructing the frame using aluminium extrusions. The housing for servo motor and gripper in dropping mechanism were made of acrylic sheet and fabricated through Laser Cutting. The plate connecting the high-speed motor to the frame in hitting mechanism should be precisely fabricated and hence was first designed and then cut using Abrasive Water Jet Machining. This plate was also made of aluminium.

3.3 Double-actuation Hitting Mechanism

One robot had to be equipped with varied hitting techniques catering to different types of strikes from the opponent. Some types of strokes from the opponent include shuttle dropping just near the net, shuttle moving almost horizontally at considerable height relative to the robot and shuttle dropping almost vertically on the robot. The possibilities are innumerable. Also, power-hitting would be beneficial to achieve high range and great shuttle velocity to reduce the reaction time available to the opponents. A mechanism inspired by the human forearm and wrist was developed to match these requirements.

To convert the linear motion of pneumatic piston to the motion of racket in a circle, a three-link (3R) mechanism was used. One link was grounded, the pneumatic piston was the second link and the third link is connected to the racket.



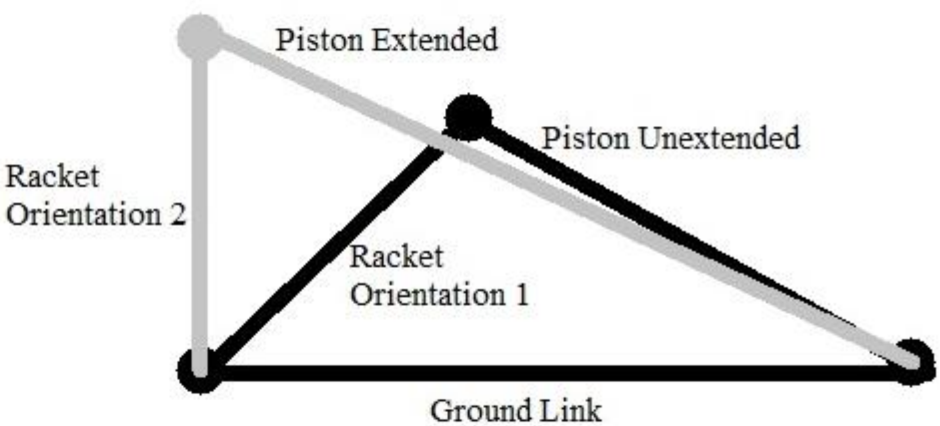


Fig 4: 3R linkage for conversion of linear motion to rotation

The above shown mechanism works similar to the human wrist. The human wrist carries out this motion relative to the the rotation of forearm about the elbow. Hence, while playing a stroke, the velocity of forearm (due to its rotation about the elbow) is added to the relative velocity of racket moved by the wrist muscles. To implement this, the mechanism shown in figure (top-right) is mounted on another similar mechanism. The system representing the forearm-elbow combination is actuated using pistons with greater bore (greater bore results into greater force/torque). The overall mechanism is shown below.

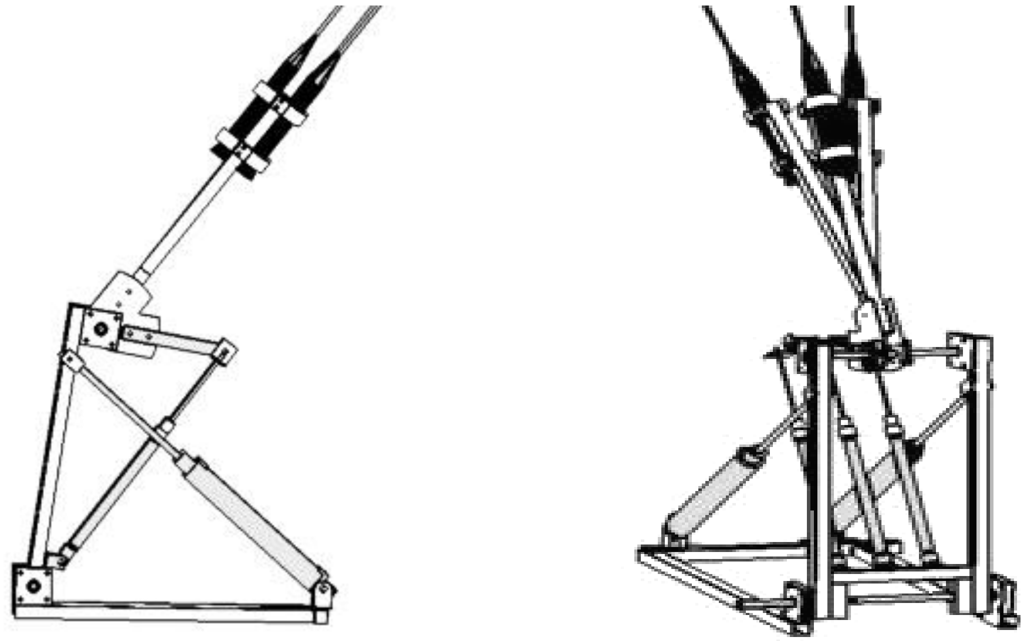


Fig 5: Double-actuation module

Number of rackets was increased to increase hitting area and hence improving the chances of a successful hit. But, increasing the number of rackets to three meant that the torque requirement also increased three times. Therefore, three pistons were connected in parallel to get three times the torque and the velocity remains the same.

To replicate the the motion of the human hand, the actuation of smaller pistons (or the wrist system) should happen during the extension of larger pistons. After several trials, it was found out that the maximum range was achieved when the actuation of smaller pistons started when the larger pistons were half extended. This relation was purely experimental as the variation in the trajectory of incoming shuttle was highly uncertain yet highly critical for the performance of any hitting mechanism.

Further, this mechanism also gave the choice of using single actuation as well. Hence, three kinds of strokes could be implemented- double actuation, actuation of only larger pistons or actuation of only smaller pistons.

3.4 Overhead Hitting Mechanism

The double-actuation module, along with the large number of pressurised air-bottles it needs, required a large amount of space on the chassis. Also, the service module involved the rotation of a racket in a plane nearly parallel to the ground and thus required huge area too. Therefore, both these modules cannot be assembled on a single robot. This created a need for a hitting mechanism catering to the most probable kind of shuttle trajectories coming from the opponent's side. It is was observed that in any badminton game, the overhead technique is used the most.

Its implementation essentially required the same mechanism as used for the implementation of wrist-like motion in the double actuation module mentioned before. The module is shown in figure 6.

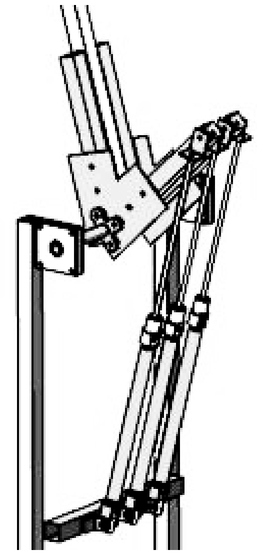


Fig 6: Overhead Mechanism

3.5 Underarm Hitting Mechanism

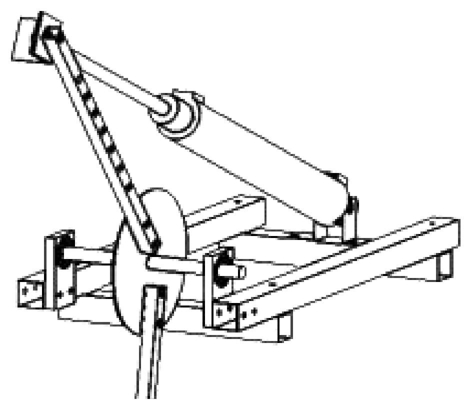


Fig 7: Underarm Mechanism

The underarm technique is widely used in real badminton games. Shuttles just above the net height and dropping near the short-service line were relatively difficult to play using the overarm technique or the double-actuation module. The underarm technique was a good solution to this problem. The conversion of linear motion of piston to rotation of racket was achieved using a similar mechanism as in overhead hitting. Considering the link connected to racket as a lever, the only structural difference was the position of fulcrum. In overhead mechanism, the fulcrum was at one end of the lever, the piston was connected in the middle and the racket was at the other end. Whereas, in underarm module, the fulcrum is in the middle, the piston is connected at one end and the racket at the other end. The module is shown in figure 7.

The above three pneumatically-actuated hitting mechanisms - the double-actuation hitting mechanism, the overhead hitting mechanism and the underarm hitting mechanism, all were constructed using aluminium square extrusions and sheets, nylon sheets and stainless steel shafts. Nylon sheets were used to create housing for bearings and hence these housings were fabricated using AWJM to ensure that the shaft is straight. The shafts had to endure sudden torsions applied via pneumatic actuation and hence, they were made of stainless steel. The joining of different parts was done through either rivets or bolt and nuts.

4. Final Assembly

The modules were designed, fabricated and tested independently and then the final CAD design was made to ensure that there was no interference between any of the modules. The designs are depicted below.

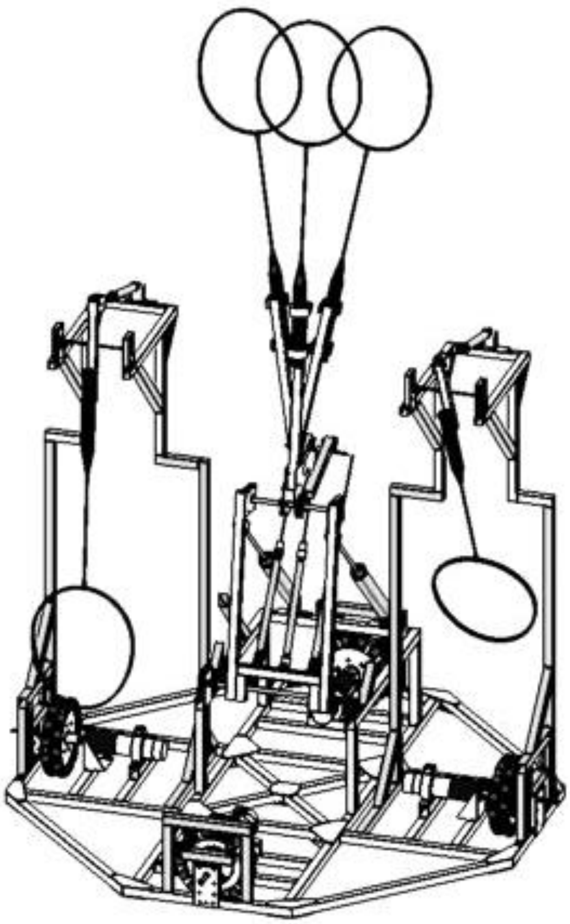


Fig 8: Robot specialized for hitting

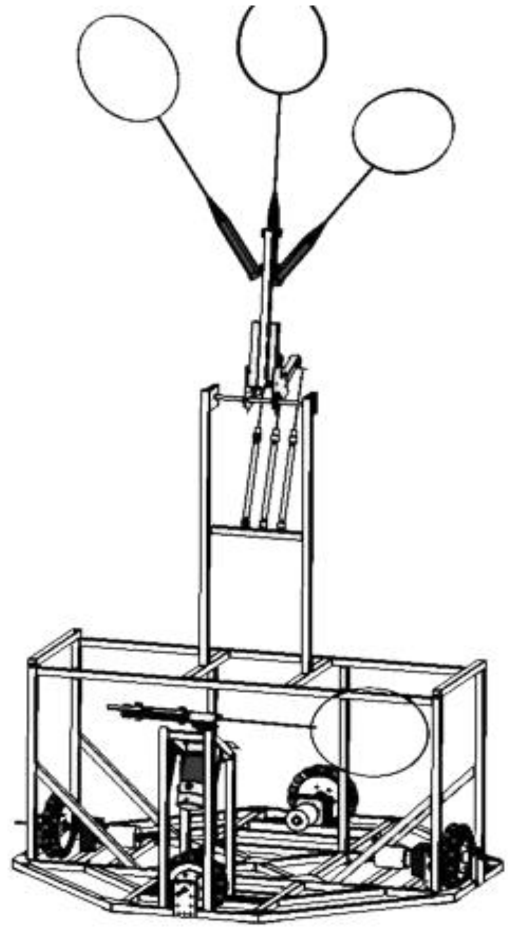


Fig 9: Robot specialized for service

Appendix

"ROBOMINTON: BADMINTON ROBO-GAME"

THEME AND RULES

The motif of this contest theme is badminton's doubles game. The highlight of this game is how the two robots hit and hit back shuttle by collaborating each other. The longer the rally continues the more exciting the game becomes. The robot with unique way of hitting shuttle can be entertaining. The audience will be enthralled if the robot made an eye-opening jumping smash. We are looking forward to witnessing exciting matches of unique robots built by the young budding engineers in Yogyakarta, Indonesia.

TEAM MEMBERS

1. Each team comprises of four members consisting of three students, one instructor and pit crews, all from the same university, polytechnic or college.

2. Team members and pit crews must be enrolled in their university, polytechnic, college at the time of the international contest. Postgraduate students are not eligible to participate in the contest.

3. All the robots that will participate in the contest must be designed and constructed by the team members and pit crews.

4. Only three student team members are permitted to participate in the contest.

FLOW OF THE GAME

1. The first server will be decided by a lottery before the game.

2. Each team must preload six shuttles that will be provided by the referee. Teams can decide how many shuttles to preload to each robot.

3. Setting time

3.1. With the referee's sign, teams will be given a minute of setting time before the game.

3.2. The power source of the drive system of the robots must be switched off until the setting time begins.

3.3. Teams can set their robots anywhere in their side of the field.

3.4. During the setting time, maximum of three team members and three pit crews are allowed to prepare for the game.

3.5. The team will be given 6 shuttles. The shuttles must be loaded to the robots during the setting time, within 15 seconds from the previous points are confirmed to the next service is delivered. The team can decide how many shuttles to load to robot(s).

4. Service

4.1. Service will be delivered by both teams taking turns.

4.2. Service must be delivered within five seconds from the referee's whistle.

4.3. Service can be delivered by any of the two robots.

4.4. When delivering a service, a part of the robot must be in contact with the right side of the service area (including the border line) of its own zone.

4.5. When delivering a service, the robot must drop the shuttle vertically using free-fall. The position to drop the shuttle must be in the space above of right side of the service area (including the border line) of its own zone.
4.6. The robot that delivers a service must hit the base of the dropped shuttle with a racket.
4.7. At the moment when the robot delivers a service, the area from shaft to head of the racket must be facing downward lower than horizontal.
4.8. The racket and the shuttle can come in contact only once per service.
4.9. The shuttle that has been hit must travel over the net (without touching the net) and land on the opponent team's serve drop zone. However it doesn't apply if the opponent team hits back the shuttle or the shuttle should come into contact with the opponent's robot (if operated by cables, including the cable and its operator).
4.10. The robot(s) that will receive service must stand behind the short service line until the robot receives the service.
4.11. The robot shouldn't come in contact with the short service line.
4.12. The robot shouldn't enter the space above the net side.
5. Scores
5.1. When the conditions mentioned under '4.4.1-4.4.12 Service' are achieved and the shuttle lands on the serve drop zone (including border line) of the opponent team or if the shuttle should come into contact with the opponent's robot (if operated by cable, including cable and its operator), the team will gain score.
5.2. If the team failed to achieve the conditions mentioned under '4.4.1-4.4.12 Service', the service ends in failure and opponent team will gain score.
5.3. Excluding service, if the shuttle hit by the racket lands in the opponent's court (including border line, refer to Fig.5) or comes into contact with the opponent's robot (if operated by cable, including cable and its operator) the team will gain score
5.4. If the shuttle hit by the racket doesn't land on the opponent's court, (including borderline) opponent team will gain score.
5.5. If the same robot hit the shuttle twice, opponent team will gain score.
5.6. If the A robot and B robot of the same team hit the shuttle consecutively, opponent team will gain score.
5.7. The opponent team will gain score if the team cannot set the robot to deliver next service within 15 seconds from the referee blows the whistle after the previous score has been confirmed. In this 15 seconds, team members are allowed to enter the contest field and touch their robots including to maintain the preload shuttle(s) that should be loaded.
5.8. If the team should committed act of violations mentioned in the rulebook, opponent team will gain score.
6. Win and loss of the game
6.1. The team which gains 5 points first will win the game.
6.2. If the score reached draw of 4-4, the team which scores 2 points first will win the game.
6.3. If the score reached draw of 6-6, the winner will be decided by the following order;

6.3.1. The team which hit greater number of shuttle when the team gained score.
6.3.2. The team with higher successful rate of services.
6.3.3. The team with less number of warnings.
6.3.4. To be decided by the judge panel.
7. Timeout
7.1. Each team can take 1 timeout per game.
7.2. The duration of timeout is 30 seconds.
7.3. Teams cannot take time out while the service is being delivered and point is yet to confirm.
7.4. Timeout can be taken only if the team said to referee ‘Timeout’ and the referee grants it.
7.5. During timeout, both teams are allowed to enter the field and touch their robots including maintaining the preload shuttle(s) that should be loaded.
7.6. After timeout is finished and referee blows whistle, the team must deliver a service within 5 seconds.

CONTEST FIELD

1. The contest field is rectangle of 8,500mm×16,400mm and it is surrounded by a wooden fence. Inside the field, badminton doubles court will be laid.
2. The height of the net from the surface of the court is 1,524mm in the middle, 1,550mm on the side-line of the doubles court.
3. The same net and support pole used in badminton game will be used.

ROBOT

1. Each team must make two robots.
2. Robots can be manual or automatic.
3. Robots cannot be separated.
4. Operation of the robots
4.1. Team must operate their robots from outside of the contest field.
4.2. The maximum number of robot operator is two.
4.3. The robots can be operated by wire or wireless. But only one robot can be operated via cable.
5. Wireless communication
5.1. The method of wireless communication is limited to following;
5.1.1. Bluetooth (IEEE802.15.1x After Ver2.0x No indication of class),
5.1.2. IR ray,
5.1.3. sound, sonic wave,
5.1.4. visible radiation.
5.2. Basic rules for wireless communication
5.2.1. Please follow the guidelines of the Contest Committee
5.2.2. The use of wireless/radio wave device which will affect on other teams and run of the contest is prohibited.
5.2.3. The use of wireless communication systems other than under ‘6.5.1’ is prohibited.

5.2.4. Please use wireless devices that comply with the law of the participating country and host country.
5.3. The two robots of the team are allowed to communicate. However the method of communication must be mentioned under 6.5.1.
5.4. Wireless control could cause troubles in actual use. Please take necessary measures against interference to promote smooth run of the contest.
6. The maximum dimension of a robot when fully extended excluding the racket must fit in a cylindrical tube with diameter of 1,200mm and height of 1,500mm.
7. The weight of each robot must be under 25kgs. However, if the robot is controlled by cable, the weight of the cable and controller will be included in the total weight.
8. There is no limit in the number of rackets that each robot can hold.
9. Robot must not jump using propellers.
10. The two robots must fit in the robot box with dimension of 1,600mmW X 1,000mmD X 1,400mmH for shipping.
11. The voltage source used in the robot must not exceed 24 volts.
12. It is allowed to operate robot using compressed air filled in PET bottle and so on. However it must be under 6 bar of compressed air.
13. It is strictly prohibited to use dangerous energy source such as high pressure gas and explosives.
14. When using a laser beam, it must be less than Class 2 laser and used in a way that will not harm anyone in the venue, equipments and contest field.
15. Robots must be designed in the way that the rubber (or similar) bumper surroundings come in contact first with the object in case of a crash.

VIOLATIONS AND DISQUALIFICATION

1. The following actions will be regarded as violations and 1 point will be given to the opponent team.
1.1. Team member or robot (including racket) to enter opponent’s field
(including its space above) after the service is delivered and before
the point is fixed.
1.2. Team member and robot (including racket) to touch opponent’s robot.
1.3. Robot (including racket) to touch net or its support pole.
2. The following action will lead to disqualification and the opponent team will win with score of 5-nil.
2.1. Repeating the act in 9.1.1 twice.
2.2. Racket is detached from the robot.
2.3. Damaging the contest field.
2.4. Team or someone related to the team to omitting interference radio wave.
2.5. Changing the shape of the shuttle intentionally