ROBOCON 2015 - Robominton

A 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. Designs of the assembled robots were prepared and the modules were assembled.

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Appendix I: Robocon – A Brief Description

1. Introduction

ABU Robocon is an annual Asia-Pacific robotics contest. Robocon 2015 – Robominton required the teams to build 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 is 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 is essential to facilitate simultaneous development of all aspects of the robots. Hence, different modules for varying functions are 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.

2. Modules

2.1 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 isn'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. However, 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 Fig. 1).

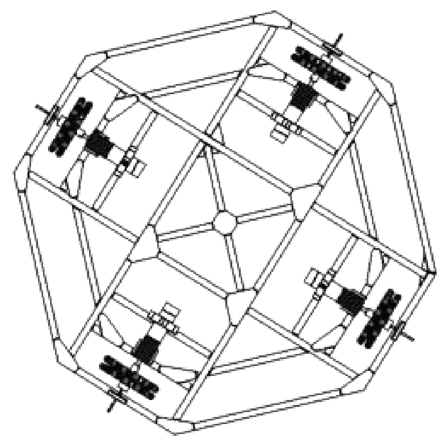


Fig. 1: Octagonal Chassis

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 has been 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, Fig. 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.

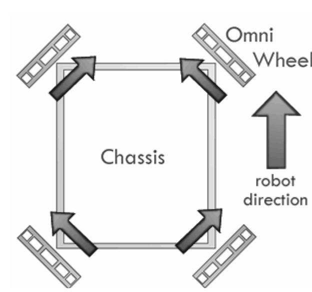


Fig. 2: Holonomic Drive

The chassis has been 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 have been cut and welded together to form the arrangement.

2.2 Service Mechanism

As mentioned before, the accuracy of service is 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 are 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, a DC motor (1000 RPM) has been used.

The module is 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 is 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 in Fig. 3.

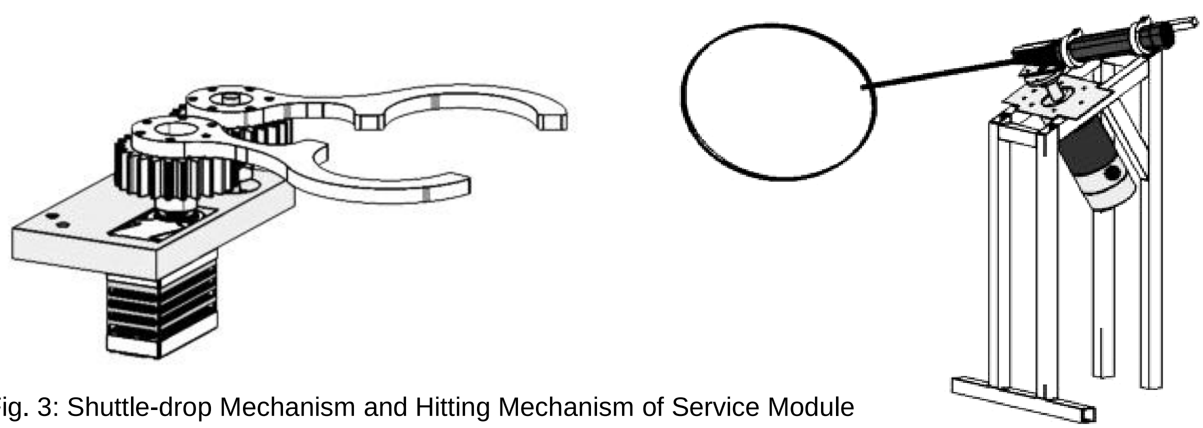


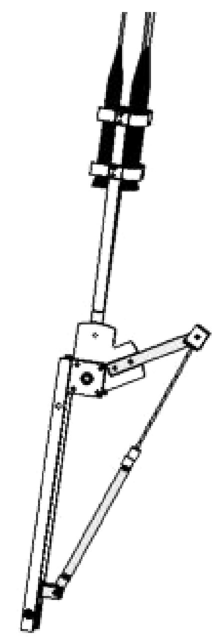
Fig. 3: Shuttle-drop Mechanism and Hitting Mechanism of Service Module

Basic machine-shop operations such as cutting, drilling, and lathe have been used for constructing the frame using aluminium extrusions. The housing for servo motor and gripper in dropping mechanism are 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 is also made of aluminium.

2.3 Double-actuation Hitting Mechanism

One robot has been 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 has been 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 is used. One link is grounded, the pneumatic piston is the second link and the third link is connected to the racket.



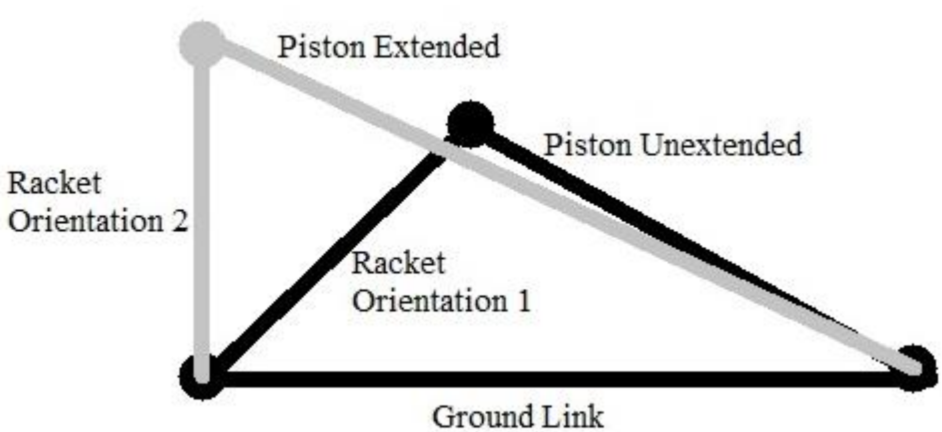


Fig. 4: 3R linkage for conversion of linear motion to rotation

The mechanism in Fig. 4 works similar to the human wrist. The human wrist carries out this motion relative to 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 in Fig. 5.

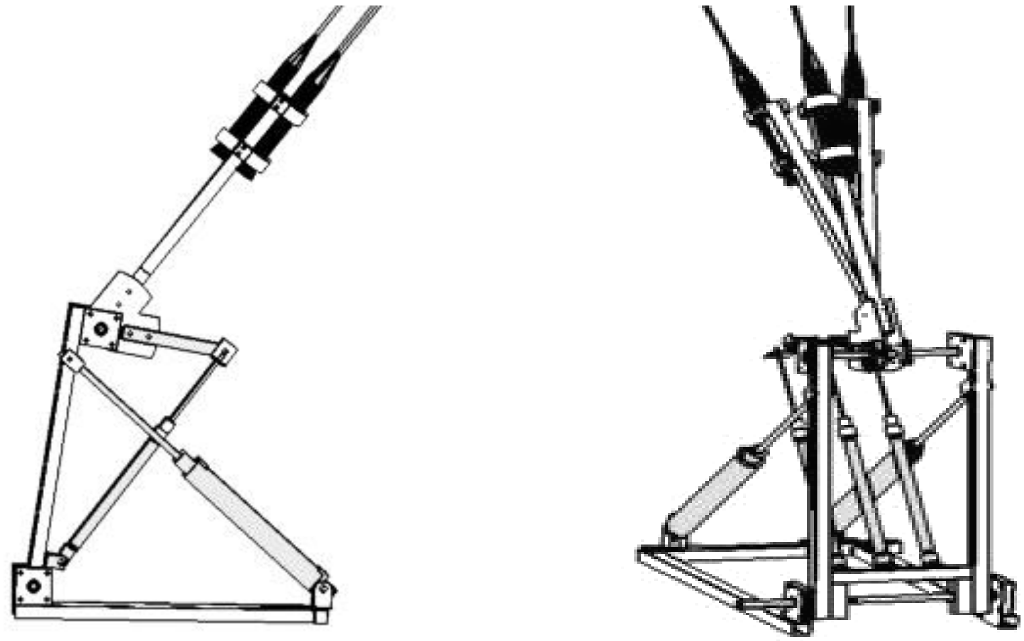


Fig. 5: Double-actuation module

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

To replicate 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 has been found that the maximum range is achieved when the actuation of smaller pistons started when the larger pistons have been half extended. This relation is purely experimental as the variation in the trajectory of incoming shuttle is 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.

2.4 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 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 Fig. 6.

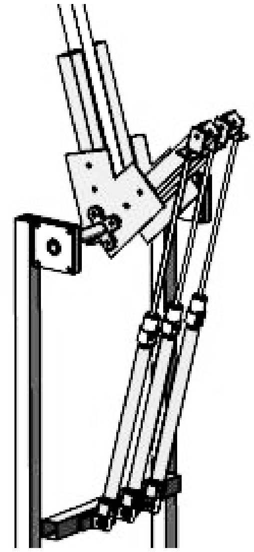


Fig. 6: Overhead Mechanism

2.5 Underarm Hitting Mechanism

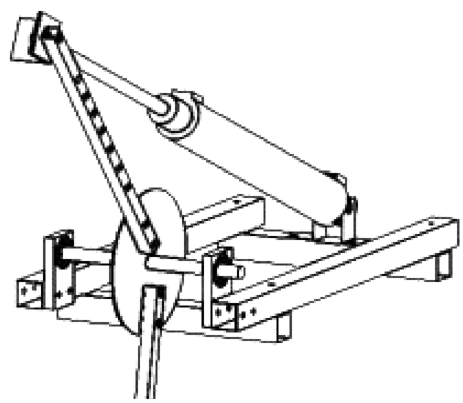


Fig. 7: Underarm Mechanism

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

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

3. Final Assembly

The modules are designed, fabricated and tested independently and then the final CAD design has been made to ensure that there is no interference between any of the modules. The designs are depicted in Fig. 8 and Fig. 9.

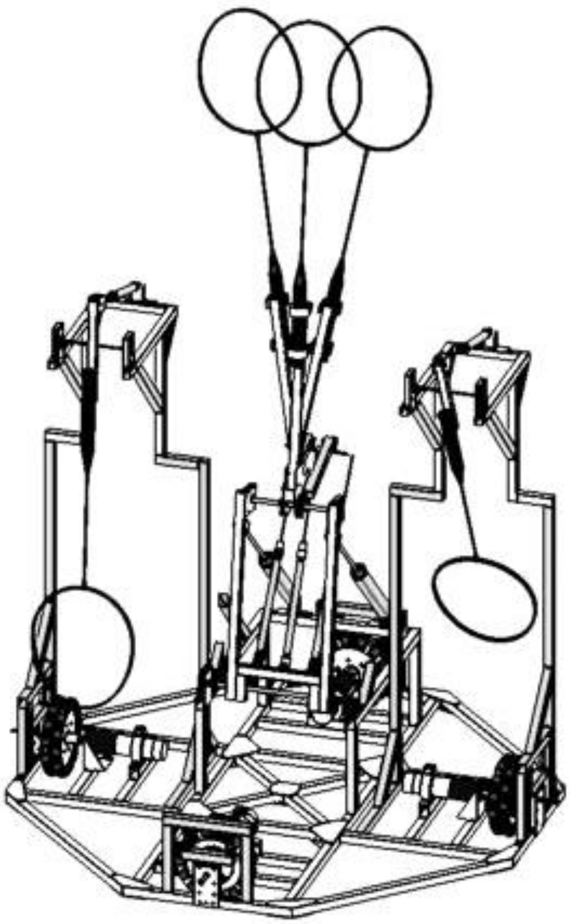


Fig 8: Robot specialized for hitting

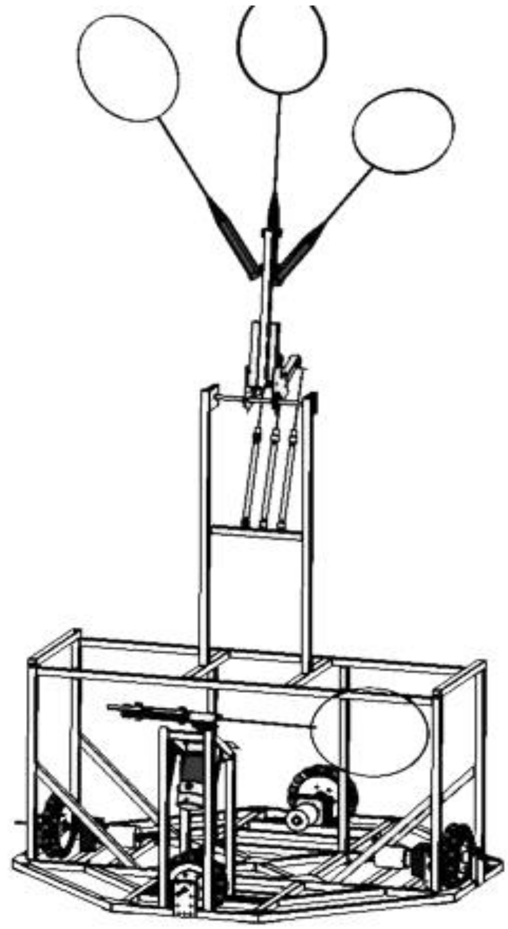


Fig 9: Robot specialized for service

4. Conclusion

Holonomic drive using Omni wheels was successfully implemented. The Service-module, both the hitting mechanism and shuttle-dropping mechanism were designed with optimum parameters and fabricated. The rest three hitting mechanisms were also designed and fabricated and were actuated using pneumatic pistons. Finally, the modules were distributed among the two robots according to their functions and were assembled on the chassis.

The team participated in National ROBOCON India 2015 in Pune and finished eleventh in eighty-five teams from all over the country.

Appendix I: Robocon-A Brief Description

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.

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.

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.

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.