Immortals Open Source Project

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Abstract. *This document contains the description of Immortals open source RoboCup Small-Size-League project. We explain both the philosophy behind our contribution to the league, and some technical details of the project.*

Keywords: RoboCup, AI, SSL, Robotics, open-source

1 Introduction

Immortals is a RoboCup soccer Small-Size-League team consisting of Sharif, Tehran, and Amirkabir university students. The small size project started in summer 2007 and simple-structured robots were made by summer 2008 and have continually improved since then. After participating RoboCup 2009 Graz and RoboCup 2010 Singapore competitions, it was decided to gear up for the next competitions with revising the whole Mechanical system and equipping the robot with a sophisticated electronic system to extract the maximum efficiency and maneuverability from the robots. Inheriting all preceding robots strengths while decreasing their weaknesses, a brand new generation of robots was set to participate in the RoboCup 2011 competitions. Those robots were granted the 2nd place at RoboCup 2011 Turkey.

2 Philosophy

The entrance barrier of the Small-Size-League is too high for the new teams, and newcomers simply could not compete with the top-performing teams; thus blocking their further research and commitment to the big-picture vision of the league. So we believe by sharing our designs and frameworks, exactly the ones we are using in the competitions, we could give them a better head-start, opening greater possibilities for their research.

We also believe that sharing the research and experiences with top-performing teams, could benefit the league as a whole; since the RoboCup has never been just about competing, and the main focus should be on the research that will eventually make the vision possible.

These are the different parts of our project that we have published:

- Mechanics: `https://github.com/lordhippo/ImmortalsMechanics`
- Main electronics: `https://github.com/lordhippo/ImmortalsMainPCB`
- Robot embedded firmware: `https://github.com/lordhippo/ImmortalsFirmware`
- Wireless embedded firmware: `https://github.com/lordhippo/ImmortalsSender`
- Main software: `https://github.com/lordhippo/ImmortalsSSL`
- Debugger software: `https://github.com/lordhippo/ImmortalsDBG`
- Communication library: `https://github.com/lordhippo/ImmortalsCom`
- Shared protocols: `https://github.com/lordhippo/ImmortalsProtos`

3 Hardware

3.1 Mechanics

The mechanical design of Immortals robots, with the exception of some minor improvements, was done for RoboCup 2010, and the robots showed their great performance since then. The main chassis consists of a 5mm hard anodized 7075 aluminum alloy plate on which motors, batteries, encoders, capacitors, and kicker systems are mounted. Robots are covered by a carbon-fiber compound that is light as it is solid. In order to mechanically stabilize the robot movement and kicking, the altitude of the center of mass is lowered by arranging rather heavy parts on the plate, that level first in the whole robot structure. The overall height of the robot is 148mm and its diameter is 178mm.

Since the mechanical manufacturing and research are too expensive, many new teams could not reach a sophisticated design. By the way, the main focus of the Small-Size-League has never been the mechanical research, and in the past years most of the top-performing teams have been using a somehow identical mechanical design. So we believe that new teams could just get away with the provided design, and focus their efforts on the other domains.

Wheels Robots are designed omni-directional by using four omni-wheels. Each wheel is 61mm in diameters and has 18 rollers covered by double seal O-rings for better grip. Both wheels and rollers are made of 7075 aluminum alloy. As the field size has been increased, higher speeds are inevitable; so the gear ratio is optimized to 45:12 and 50 Watts Maxon EC-45 brushless motors are used to overcome the max-speed/max-acceleration trade off. The gearbox is merged into wheels to minimize the volume occupied by driving system. Its design is unique so that the gear used for transition is carved into the wheel itself.

One of the major issues in the robots was inaccurate low-level navigation. After many experiments, measurements and inspections on the control system, it came out that non-identical mechanical properties of each gear are the biggest issue, which was caused by manufacturing inaccuracies. To have smoother and more accurate movement, gear module is redesigned with smaller module size this year. Also there are a little change in sub wheels design and tolerance to reduce unsteadiness and to stick better to the field during fast accelerations.

Casing Although safe navigation has been a must for years in the league, highly dynamic nature of the SSL causes unavoidable collisions that lead to damages ranging from minor to severe. To avoid damages to internal parts, especially electronics which are fragile, making a robust, solid casing that can efficiently damp impacts is a necessity. Thus, a case made up of 2mm thick carbon-fiber compound is made which is as solid as it is light to cover the whole body but kicking devices and the dribbler.

Kicking and Dribbling System To account for the increase in field size, the kicking system is redesigned and to have more power and accuracy in booth chip and direct shoots. Also because of some high voltage short circuit caused by magnet solenoids, in our new version whole kick system is isolated from body and there isn't any direct metal to metal contact by using resin as an isolation material.

Our kicking system has suspension which works as a shield in hard contacts with other robots and this shield damps the impact and prevent the boards from taking damage. Similar to wheels, small changes in tolerances of dimensions in parts like chip and direct kick solenoid cores, achieved better results.

3.2 Electronics

The main electronics of the robots is responsible for receiving commands from the main computer through wireless link, driving the robots motors, applying control loop on the motors, doing some local sensing, and sending some feedback data to the main computer.

From an electrical point of view, the PCB is designed in a multi-layer fashion (4-layer). This is because of the FPGA requirements, and the very high current drawn by the BLDC motors (230 amperes!).

Embedded Firmware The firmware of the FPGA is developed using Altium Designer. It allows developing both logic design and embedded software for the soft processor in one tool. The embedded software is written in C, and the logic design is done using a combination of schematics, Verilog and VHDL.

4 Software

The overall software architecture is to take information of the field from SSL-Vision over network, filter this information and pass them to the AI. The AI calculates a target for each robot, and finally transmits the processed data to the robots, in each frame.

To start working on small size soccer robots, a team must initially work on solving basic problems like noise filtering, sensor fusion, prediction, navigation, multi-agent cooperation, etc. Immortals has been working on these areas since 2008, and our current software could be used as a solid framework for the new teams, allowing them to focus on further researches and innovations.

4.1 Calculating World State

Kalman filter is used for reducing noises, and predicting the future state. There are two types of input for the filter. For our robots, we use the data that is sent to the robots in previous frames, and for the ball and opponent robots, vision-calculated data is used.

4.2 Decision Making

The main method for this part is STP[7], developed by CMDragons[2] and is tested since 2003, and the results show the success of this method. STP consists of Skills for executing the low-level actions that make up robot behavior and tactics for determining which skills to execute, and Plays for coordinating synchronized activity amongst team members. In our system, skills and tactics are script files, and plays are generated by either script files or the visual Strategy Maker software.

4.3 Safe Navigation

In order to achieve safe navigation, we use a combination of a custom probabilistic positional planner, Safety Biased-Rapidly-exploring Random Trees (SBRRT), and a dynamic planner, Dynamic Safety Search (DSS).

Safety Biased-Rapidly-exploring Random Trees Sampling based motion planners leave no comment on safety of the planned path. This method suggests biasing the Rapidly-exploring Random Trees (RRTs)[5], with the outcome of a safety evaluation, which affects the probability of choosing a random point in the sampling phase of the RRT algorithm, to increase the chance of safer outcomes.

Dynamic Safety Search Dynamic Safety Search (DSS)[6], an improvement over the well-known Dynamic Window method, is a multi-agent sampling-based dynamic path planning method. In contrast to positional planners (e.g. ERRT) it considers each agent kinematic parameters and current velocities in planning.

4.4 Strategy Maker

Since it is harder to develop soccer-like strategies using text-based scripting, we developed a custom visual scripting tool for defining the high-level strategies, making it easy for everyone to propose strategies. The AI software use these strategies in every free kick to assign roles to the robots.

Using this tool we can choose when the robot can start the play and the other robots role. In each situation, the AI selects one of the strategies depending on their probability which is assigned manually, and change based on the previous result of each strategy. The final roles in this software can choose between the wait for pass on the position, wait for pass in best position, attract the defenders, run away, go to position, shoot directly to goal, etc.

5 Conclusion

We, the Immortals team, are setting free what we have done with great love and passion[1], open-sourcing all of our mechanical and electronics designs, as well as our embedded and off-board software. We hope our contribution could find its way to the 2050 match, and make that dream come true.

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