ER-Force
Team Description Paper
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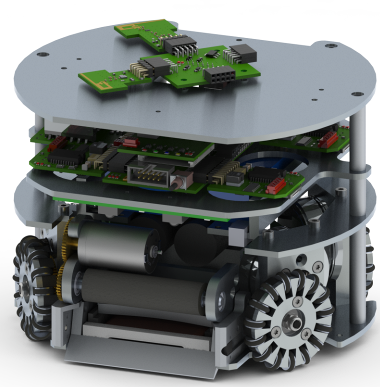
Abstract. This paper presents proceedings of ER-Force, the RoboCup Small Size League team from Erlangen located at Friedrich-Alexander-University Erlangen-Nürnberg, Germany.



1 Introduction

ER-Force has successfully partaken in RoboCup competitions for almost a decade. In this Team Description Paper we present our most recent efforts in improving both our hardware and software. We hope that our remarks support other teams in making Small-Size-League an even faster and more interesting league.

2 Mechanics

Over the last year we observed an increase in mechanical play of the flat-kick plunger in the kick module. As the described sign of wear could interfere with the ability to execute precise passes or shots on the goal, we decided to redesign the flat kick part of our kick module. The flat-kick design used up until now was drafted for RoboCup 2014 and the involved parts were manufactured before RoboCup 2014 and used since then. In this design, described in the 2014's Team Description Paper [1], the flat kick plunger is supported by a single bearing. Conveniently, this bearing surface is the inside of the hole in our flat-kick solenoid, which is made out of polyamide.

In order to improve the durability the guiding function was transferred to the aluminum solenoid mounting blocks. The plunger is guided in the openings of the mounting blocks instead of inside of the solenoid. We use a flat kick plunger and solenoid with rectangular cross sections, which allows us to lower the position of the kick module. This results in a lower center of mass of our robot while avoiding the need to change the rest of the robot. The new design is shown in figure 1.

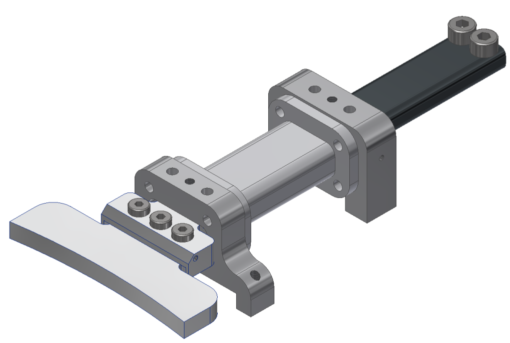


Fig. 1. New Flat-Kick system

3 Electronics

3.1 Adjustments of motor current measurements

Getting correct and precise measurements of motor currents requires synchronization between the motor control and the measurements on the ADC. As our motors are controlled via PWM signals, there will always be periodically arising transients which heavily disturb our measurements, implying an increased effort to trigger the measurement at the right time. To solve this problem the PWM signal as well as the trigger signal for the measurement use the same timer with different offsets. This makes it easier to develop a better motion control.

3.2 Optimizing the kicker board

Since the development of the current robot generation we faced several problems regarding the kicker mechanism: First of all, we use identical circuits for both the linear and the chip kick. While the linear kick worked fine, some parts of the chip circuit broke probably due to not correctly adjusted operating point currents.

Second, the used IGBTs needed too much time to unload their gates after the fire signal falls to the low level again. This is due to the circuit controlling the gate voltage: As there is not enough space to develop a sophisticating circuit for this purpose, we used a simple voltage divider controlled by the output of an optocoupler (which is used as a switch).

On the one hand we tried to choose the resistances of the divider as low as possible to make the unloading time of the gate of the transistor as short as possible, but on the other hand the resistances shouldn't be too small to avoid a huge current through the voltage divider as this will the optocoupler. The chosen compromise isn't good enough yet: The unloading time is still too big.

A problem arising from the big unloading time is that the IGBT stays too long in a semi-conductive state. This causes high thermal power losses of up to 10 kW or more being able to sometimes kill the IGBT. This problem is especially annoying as it is nearly impossible to reproduce the phenomenon in a test environment.

Our first try was to change the IGBT to one that has a low gate capacitance. Although we found some smaller transistors with less gate capacitance they all had other weak points. But since we don't know the actual value of the peak currents they were most of the time not suitable for our circuit.

There are no transistor models with high enough ratings for all criteria (a high maximum rating for V_{DS}, high continuous and peak drain currents and a high maximum power) which fit into the limited space, there was no alternative to just choosing the best one available.

Our goal for this year's RoboCup is to redesign the kicker circuit so that it doesn't exceed the specifications of the IGBTs. This will drastically decrease the amount of time needed for repairs.

4 Motion control

4.1 Rebuild of the old system

Last year we redesigned our complete motion control from scratch as our old system had not been changed for several years. The system was built as simple as possible to ensure that we can complete it to until the last RoboCup. Therefore we used a simple PID–controller implementation which was easy to implement. The created system is shown in figure 2 and figure 3. With a working system as a fall-back, we decided to design a more sophisticated motion control, which will help us for example to implement an anti-slipping regulation.

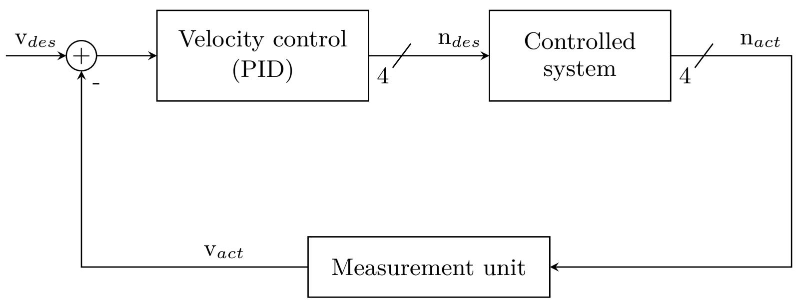


Fig. 2. Flow chart of our current motion control on the main board

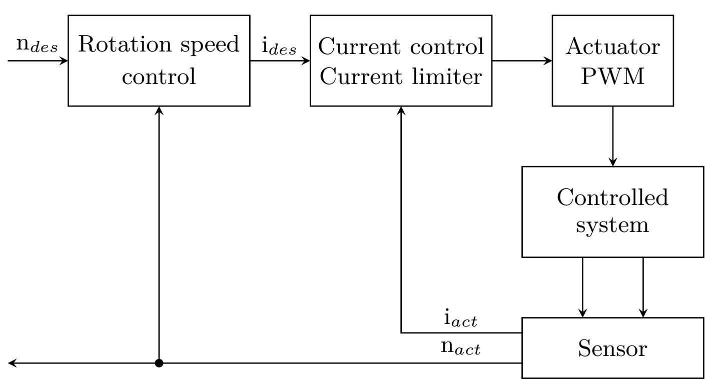


Fig. 3. Flow chart of our current motion control on the motor boards

4.2 New control system

Current controller The current controller is basically an observer based state controller with two degrees of freedom. The first is the feedforward, shown in figure 4 as the G_{AW}–block. This feedforward ensures a fast reaction time by creating a control signal which already fits the optimal control signal quite good without a need of measurement, so only a relatively small error has to be compensated by the controller. This feedforward is quite good due to a lot of work in validating and verifying the mathematical model of the electrical machine. The second degree of freedom of the current control is the feedback. First the measured values are filtered due to a high noise in the measurement. The error, calculated by difference between the desired output signal and the measured signal, stimulates an observer and an error model for constant errors. The observer estimates four values, which describe the states of the modeled system. The output of the error model for constant errors and the observer are used as base values for the feedback, so they are multiplied by factors which were calculated with the Ackermann formula, summed up and added to the signal from the feedforward. As the feedforward ensures a short reaction time of the whole system to changes in the desired current, the feedback ensures stationary precision. This system is already built and working.

Speed controller The new speed controller is not yet implemented, but is the goal of our current working and we want to finish this part till the RoboCup in Japan. It will also consist of an observer based state controller with the same structure as the current controller. The difference between both controllers is the complexity of the model. As a mathematical model for an electrical machine is a quite easy and linear equation, the modeling of the mechanics of the robot is more difficult, as a compromise has to be found between a good enough model and an amount of equations which the used microprocessor is able to calculate in a high frequency.

Observer for the subwheels Furthermore we want to use a second observer, which observes the disturbance caused by the subwheels. They lead to high dependencies of the physical dynamics from the actual position of the wheel. Knowledge about the position of the subwheels in relation to the ground could allow us to compensate this variation in dynamics in the controller which could lead to a smoother behavior of the wheel and thus a movement of the whole robot.

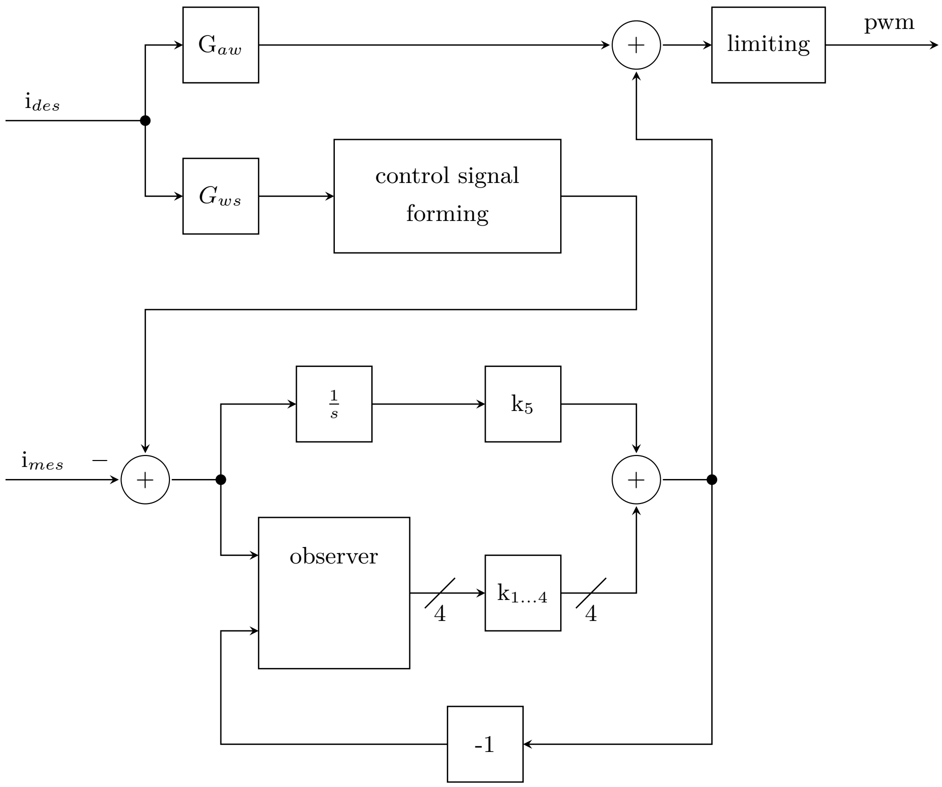


Fig. 4. Flow chart of our future current motion control on the motor boards

5 Defensive Game

In preparation for the RoboCup 2016 we completely reworked our defense. Throughout the whole competition, we only received two goals, one each from the current champion MRL and the runner-up CMDragons. In the following chapters the general concepts and ideas will be described.

5.1 Components

Our defense consists of three main tasks:

1. The duel task is responsible for contesting the ball while impeding direct goal shots.
2. The manmark task tries to prevent an opponent from scoring a goal by actively following him across the field.
3. The center-back is the most defensive one and usually moves in close proximity to the defense area.

Duel The first line of a good defense is the duelling behavior. Duel means that at least one robot of each team tries to obtain possession of the ball. For the RoboCup 2016 we implemented a very defensive duelling approach. Our main objective is to always prevent a direct goal shot. Therefore, we don't drive directly towards the ball but rather try to block the line between the ball and our goal as fast as possible. Once we reach the line, we head for the ball. This behavior not only limits the time window for the opponent to shoot a goal but also favors clutch saves.

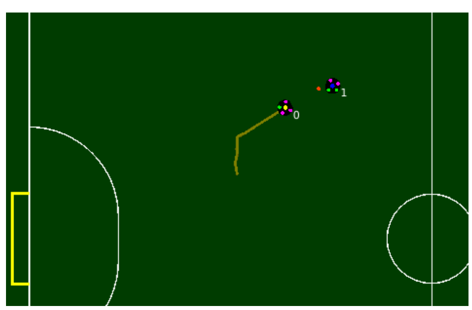


Fig. 5. Duel movement

Manmark Blocking direct goal shots is by far the most important task of the defense. However, good teams also pass the ball to teammates way faster than a defender can react. Therefore, the defending team always has to anticipate the next move of the opponents. At the time of writing this paper, our strategy only considers passes as possible attack maneuvers (besides goal shots of course). To estimate which robot is most likely to receive a pass, we compute a dangerousness value for each opponent. This value consists of criteria such as

- the distance to our goal
- the angle ball-opponent-goal to estimate the probability of a volley shot
- the angle ball-goal-opponent to rate the distance the defenders as well as the keeper has to travel when the ball is passed to the opponent

Our defense coordination always tries to assign manmarkers to the most dangerous opponent.

Because the defenders have to react to the other team's movement, they are always at least one system delay behind their adversary. Therefore, staying close to the opponent is not very helpful if the other team is able to play fast passes. To ensure that our defense doesn't get outplayed, we keep at least half a meter distance to the marked robot. As far as the movement is concerned, the manmarkers use the same line-first approach as the duel task.

Center back The center-backs are the backbone of our defense. A center-back can defend against any type of object by blocking the line between the current position of the target and our goal while staying at a fixed distance to the defense area. Usually this target is a predicted ball. If dangerous opponents get close to our defense area, the manmarkers also adopt the center-back positioning to not interfere with other defenders.

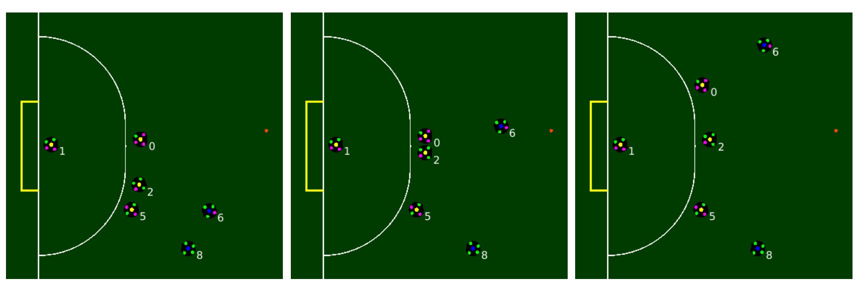


Fig. 6. center-back coordination

The defenders have to be capable of reacting to any type of movement in a coordinated way. Therefore, all targets are collected and dynamically reassigned. Figure 6 shows an example of this behavior. Here, a blue robot moves in front of the ball and the previously assigned defender 2 exchanges the target with robot 0.

5.2 Composition

Depending on the current state of the game, the number of defenders changes accordingly.

game state	number of center-backs	number of manmarkers
offensive corner kick	1	0
offensive throw-in	1	0
offensive goal kick	1	0
dynamic game	1	1 or 2
stop	4	0
defensive goal-kick	1	3
defensive throw-in	1	3
defensive corner kick	1	4

Fig. 7. Number of defenders

In Stop, we move back all of our robots except one. The reason behind this is that we don't know which referee state comes next. If it's a freekick for the opposing team, they can execute it immediately without us having a chance to react. Therefore, it's best to expect the worst.

6 Conclusion

In this paper, we described the small changes made to our hardware in section 2. Section 4 described the current state and future plans of our motion control system. Section 5 provided insights into the structure and concepts of our defense coordination. We hope that these topics represent valuable input for teams working in these fields.

Some topics have been developed further based on previous Team Description Papers. Likewise, we look forward to hearing other teams' comments.

References

1. Bayerlein, H., Danzer, A., Eischer, M., Hauck, A., Hoffmann, M., Kallwies, P., Lieret, M.: Team Description Paper for RoboCup 2014 (2014)