Falcons Team Description Paper 2019

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Abstract. The Falcons are a robotic soccer team participating in the RoboCup Middle Size League (MSL). Over the course of the last year, several significant improvements and investigations have been performed. This paper describes the most notable developments done in order to qualify for RoboCup 2019. These developments include the introduction of a novel mirrorless vision system, a redesign of the mechanical layout of the robot, the integration of new motor electronics allowing for improved motion control and the adaptation of the robot software to use Real-Time Database (RtDB).

1 Introduction

The Falcons are a robotic soccer team from Veldhoven, The Netherlands, who participate in the RoboCup MSL. The team consists of around 30 ASML employees who share the same passion and vision: to work with robots as a hobby and become champions in the RoboCup MSL league in the foreseeable future.

The Falcons team was formed in November 2013 and forms a voluntary activity outside working hours, actively encouraged and sponsored by ASML. We share a passion for robotics, technical innovation and teamwork. Together we try to maximize and expand the capabilities of our robots on software, hardware and strategy. Key values for us are: sharing information, knowledge and having fun. By sharing knowledge, we want to push forward the boundaries of the MSL towards the main goal of robocup.

An important aspect of the team is to teach and inspire children and students for a technical career. To this end, the Falcons participate in several events in the Eindhoven area for technical promotion, such as the Dutch Technology Week, presentations and classroom training at secondary schools. Furthermore we also provide opportunities for our members to improve their professional skills. This can range from deepening the knowledge in their own field of expertise, to learning new technical or soft skills. In this way, team members can prepare themselves for new challenges within ASML, and/or practice learnings in their professional or day to day life.

This paper gives a brief overview of the status of our soccer robots and describes the most significant investigations and improvements for 2019. In section 2, an introduction to the hardware and software of our current robot platform is given. Section 3 presents the novel mirror-less vision system that was developed over the course of 2018. The ongoing effort to adapt the robot software to RtDB is described in section 4, while section 5 elaborates on the design of a new electronics platform to improve the motion control of the robots. Finally, the changes in mechanical layout of the robots are presented in section 6.

2 Robot Platform Overview

The Falcons MSL robots are based on the Turtle 5K design. Five years ago we started working on improving the reliability and predictability of the robots. This phase is successfully finished, playing most games with 5 robots in the field and having a minimum of unexpected behavior/rogue robots.

Since then, the focus shifted to optimizing the software and tactics of the team; improving the control loops for faster moving and more accurate passing next to better anticipation on the competitor. The team has defined a technical roadmap which will constantly enrich the functionality of the existing robots and improve parts which are fully utilized or end of life. The novelty for 2018/2019 was a mirror-less camera system, with the use of 4 cameras looking forward, each covering 90 degrees. This concept was well received by our peers.

Items on the roadmap are a lighter kicker design, new control electronics, and improved ball handlers. At the 2017 world championship, the robots were at the maximum weight limit of 40Kg. A weight reduction is needed to enable hardware additions in the future. A weight plan of all components was created and the base plate is changed from steel into aluminum. First steps are taken to redesign the internal structure of the robot and change the shooting height mechanism. Together those groups contribute for half the robots weight. The battery packs are now of the NiMh type, and the idea was to go to a LiPo system, but this was abandoned because of Air Traffic regulations and technical complexity.

3 Mirror-less MSL Vision System

The multiCam is a novel, multi-camera setup to achieve robot omni-vision, without the use of a parabolic mirror as was present in the original Turtle 5K design. The system consists of an assembly of four Raspberry Pi v2.1 cameras (Sony IMX 219) each connected to their own Raspberry Pi model 3 B+, a network switch (Netgear GS108) and several power supplies, and is connected to the main Central Processing Unit (CPU) (Intel i7-6700) in the robot. A mechanical overview of the multiCam setup is depicted in Figure 1.

The multiCam system was introduced on the robots mainly because the range of the previous vision system proved too limited. The decision was made to choose for multiple cameras instead of a single camera, mirror-based setup, for various reasons.

For instance, when using front-facing cameras, the mounting can be adjusted such that the main part of the camera image is used to register details that are relatively far away from the robot. In contrast, when using a parabolic mirror, one has to use the image reflected towards the edges of the mirror where distortion is most prominent. Also the number of available pixels is increased.

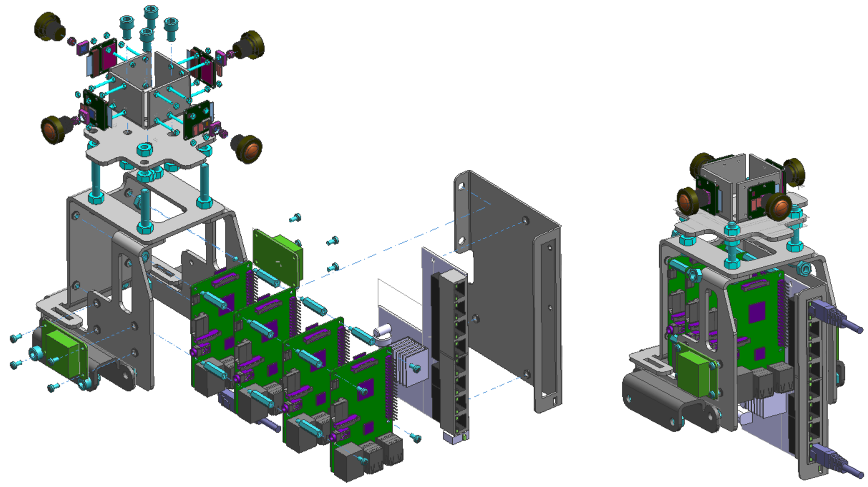

Fig. 1: Multi-camera setup for omnivision

Another advantage of the multiCam setup is that the cameras are positioned radially on the robot. This not only allows for registering objects on the ground, but also those flying in the air. For this reason, airborne balls can be almost continuously detected, leading to strategic advantages and more accurate ball tracking.

Finally the potential for applying parallelism in the detection algorithms is increased when using multiple cameras, as processing of the image feeds can easily be distributed over multiple processors or even different computation platforms. This also implies that the concept is inherently scalable.

The images that are captured by each camera are first acquired and filtered by the Raspberry Pi. At this stage the camera hardware control, color conversion (RGB to HSV) and detection, and detection of objects with similar colors (e.g. lines) takes place. Vector data of these objects is then forwarded to the main CPU. The multiCam software on the CPU then tries to determine the position of the robot on the field and to identify balls and obstacles.

In order to improve the portion of the field that can be seen by the cameras, the viewing angle of the cameras has been increased by replacing the default lenses that are supplied with the Raspberry Pi cameras with fisheye lenses. Furthermore, the cameras are rotated by 90 degrees such that the wide angle is in the vertical plane.

The lenses themselves have been adjusted such that the camera maintains infinity focus, where the center of the camera is directed at the horizon. The selection of the lenses has been such that the robot is able to see the ball near its base and cover a full 360 degrees of vision, with each camera overlapping for about 5 degrees. An example of an image captured by one of the cameras of a 18 by 12 meter field is displayed in Figure 2.

Fig. 2: Raw vision image from a single camera

4 RtDB Transition in Robot Software

Up to this year, the Inter-Process Communication (IPC) on the robots was governed by the Robot Operating System (ROS) and the inter-robot communication was supported by a self-built UDP messaging protocol. Although functional, this setup had several disadvantages. For instance the messaging framework, as well as the facilities provided by ROS have high resource usage, adding latency to the robot performance and development cycle. Furthermore, our WiFi bandwidth usage during RoboCup 2018 was very high.

In order to simplify and speedup both the IPC and inter-robot communication, while leveraging the work that has been done by CAMBADA [1], we are adopting the RtDB2 library. This has the added benefit that it can replace custom-made software facilities (such as data logging, sync protocols), and enable new improvements (such as (wifi) data compression, simulation). This has turned out to be a major software redesign activity, yet the investment is still found to be worth the effort.

4.1 Changes in Execution Architecture

The software architecture in the robot consists of a number of software components that each take input data and convert it into output data. For example, the Teamplay component takes the world state as input data and makes a decision on which action the robot should take, which is Teamplay's output data. Subsequently, MotionPlanning takes the output data of Teamplay and uses it to define setpoints for PathPlanning, ShootPlanning and BallHandling. Our complete software architecture is designed in such a cascading flow of software components that convert specific input data into output data.

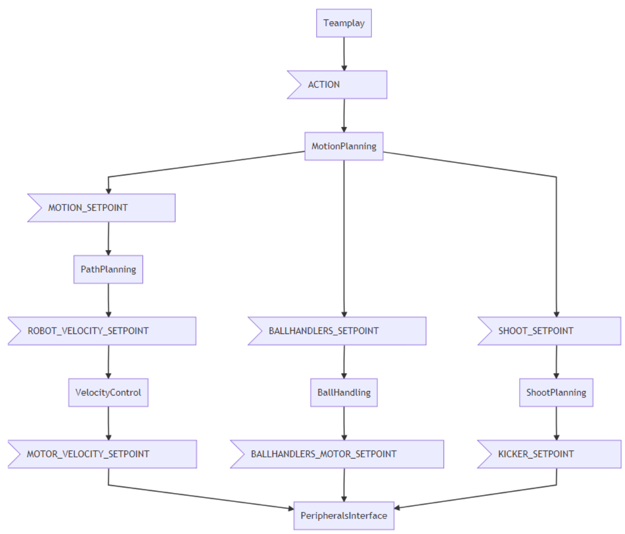

Fig. 3: Software Control Flow using RtDB

ROS offers a facility to put a software component to sleep, and wake up as soon as new data is available. This design introduces less latency compared to a design where every software component sleeps and wakes up after a fixed time interval.

With the transition from ROS to RtDB, the facility to wake up a software component when new data is available was no longer available. For this reason, RtDB was extended with an interface named *wait_for_put* during the 2018 MSL Workshop in Aveiro, Portugal. Figure 3 shows the different RtDB data elements which trigger the software component to wake up using *wait_for_put*.

4.2 Logging

A facility was written to write RTDB frames as binary into a file. Here, a frame is a sequence of key/value pairs specific to one robot, as used by the comm process. The visualizer can read data from such files and browse through it. This logging functionality will be proposed as extension to the Cambada RtDB2 package.

Additionally, this logging facility allows us to apply a new kind of component testing. Each software components typically takes an input data stream and produces an output stream. Given a log file, any component under test can be put under test and will create a new output log file. This proves to be very valuable for regression and progression testing.

4.3 Comm2

The comm utility is in need of improvement. For instance, it turns out the data sub-sampling option is not yet implemented. Furthermore its code quality could be improved as well. We are considering to use comm2 to sync timestamps between robots, taking over the responsibility of ntp. At the time of writing, we are still working on defining and implementing comm2. Once finished, it will be proposed as improvement to the Cambada RtDB2 package.

5 Motion Control Electronics Platform

The electronic controller boards present in the robots over the last years were part of the original Turtle 5K design. Unfortunately, these existing controller boards are not good in terms of reliability. After repeated improvement effort in hardware and software, the serial and USB communication between the CPU and the controller boards still suffers from sudden resets, hickups and connectivity issues.

Furthermore, the control system is limited in functionality. The motor controllers are for instance not able to actively monitor or limit the current, which has resulted in several burned motors. The lack of torque feedback and the low sampling rate (100Hz) limits the controllability of the system and the type of control algorithms that can be applied. Finally the controllers do not allow for brushless motors and software upgrades can only be applied manually.

In order to attain faster and more precise controlled motion and improved ball handling and shooting accuracy, it is key that these problems are resolved. For that reason effort has been put in the design of a new motion electronics platform, which is depicted in figure 4.

The platform is centered around a so-called Motion Control Board (MCB), which will govern the active motion feedback control of the robot. In practice this MCB is implemented as BeagleBone Black (BBB) to which all the peripheral hardware on the robot is connected. The three driving motors and encoders, as well as the ballhandler motors, tachos and angular sensors, are connected via Maxon EPOS4 (Compact 50/15) positioning controllers over EtherCAT to the MCB. All devices previously connected to the Input-Output board, i.e. the kicker height adjustment, capacitor charging, kicker solenoid and switches on the robot, are rerouted to the MCB as well. In addition a Inertial Measurement Unit (IMU) is connected directly to the board. As such, the board serves as general hardware interface module towards the CPU.

The MCB will mainly be used to orchestrate the motion control of the robots and the ball handling. By using communication over EtherCAT a sample rate towards the motor controllers of 1000 Hz can easily be achieved. The control loop and logging can therefore also be applied at 1kHz, which will add to the diagnosability and controllability of the robot. By deploying this part of the robot control on a dedicated board, the CPU can run on the frequency dictated by the acquisition of vision, while the MCB can run on the higher frequency necessary for motion control.

Additionally, by introducing the IMU to the system, the motion control need not only rely on the odometry data that is sourced from the motor. Instead, sensor data from the motor encoders and IMU can be fused, allowing for more accurate position or velocity control at a low level.

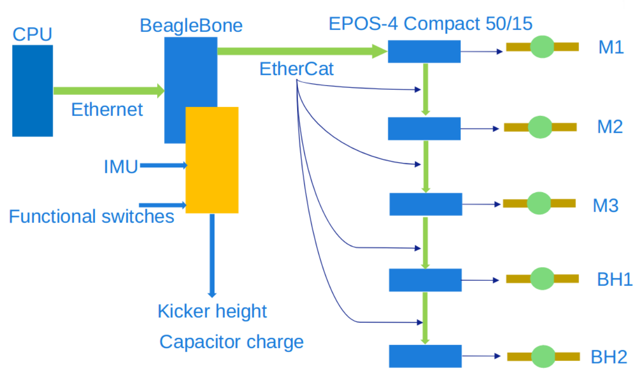

Fig. 4: Motor Control Platform using EtherCAT

6 Mechanical Robot Layout Redesign

The mechanical layout of both the keeper and the field players has been redesigned, and are shown in Figures 5a and 5b. This was primarily done to incorporate the new motion control electronics and attain weight reduction. Next to that the frame bottom plate has been upgraded, as an earlier attempt to reduce its weight of left the structure prone to unwanted deformation during games and transport. In the Team Description Paper of 2018 [2] the development of the moving keeper frame was discussed, yet it proved difficult to integrate the hardware for the moving keeper frame in the existing Turtle 5K hardware. In this year's updated keeper design, the integration of the moving keeper frame and its actuators has been explicitly taken into consideration.

References

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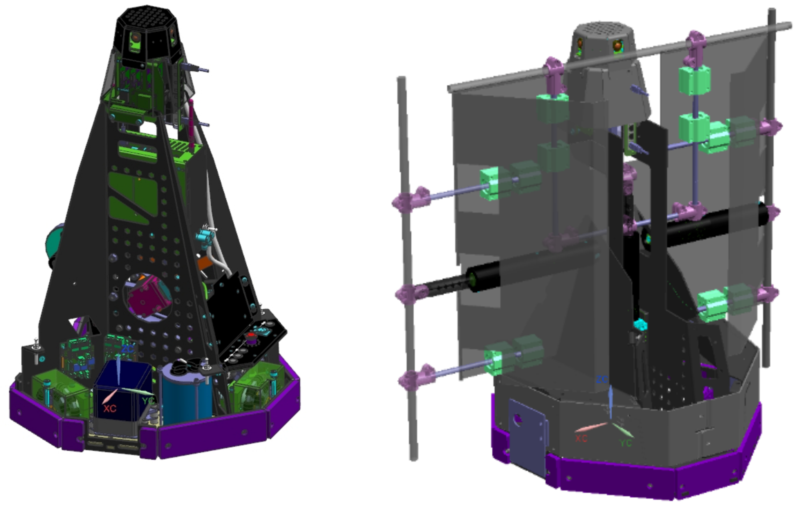

(a) Field player design (b) Keeper design

Fig. 5: Mechanical robot architecture

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