MECATEAM F-180: A MULTI-ROBOT SYSTEM FOR ROBOCUP F-180 SMALL SIZE LEAGUE

Augusto Loureiro da Costa*, Andrea Peixoto Bitencourt*, Cristiane Corrêa Paim†, Jés de Jesus Fiais Cerqueira†, Tiago Nascimento†

*Programa de Pós-graduação em Mecatrônica
Universidade Federal da Bahia
Salvador, Bahia, Brasil

†Programa de pós-graduação em Engenharia Elétrica
Universidade Federal da Bahia
Salvador, Bahia, Brasil

Emails: augusto.loureiro@ufba.br, andreab@ufba.br, cpaim@ufba.br, jes@ufba.br, tiagopn@ieee.org

Abstract— The MecaTeam F-180, a multi-robot system for the RoboCup Small Size League challenge is presented in this paper. The multi-robot system consists in a set of six fully autonomous omni-directional mobile robots, these robots are called AxeBot. The AxeBot robot uses three omni-directional wheels for movement and be equipped with a shooting device for shooting the ball in different directions. Once the AxeBot robot is a fully autonomous mobile robot all the sensors, engines, servos, batteries, wireless network, and the computer system, are embedded on. The AxeBot robot brings up a new chassis concept for three wheels omni-directional robot, also present a new shooting device that allow the robot to kick the ball in an desired direction with out robot re-orientation, also presents a embedded computer network responsible for perception, decision make, control, communication and action and, finally present a distributed approach to control a multi-robot system based on a mult-agent system.

Keywords— Mobile Robot, Omni-directional Mobile Robot, Autonomous Robots.

1 Intoduction

The RoboCup Initiative is an international research group whose aims are to promote the fields of Robotics and Artificial Intelligence. A standard challenge, a soocer match performed by autonomous robot teams, was proposed in 1996 (Kitano, 1997). Initially with three different league 2D Robot Soccer Simulation league, Small Size Robot league, and Middle Size Robot league. Todays these leagues have been increased up to: Four-Legged League, Humanoid League, Middle Size League, RoboCupJunior Soccer, Small Size League, Soccer Simulation,Standard Robot League. Also, another challenge, the RoboCupRescue was proposed in 1999 to show that the result from the robot soccer reseach could be directally applied on a real world problem like a disaster rescue made by robots. Through the integration of technology and advanced computer algorithms, the goal of RoboCup is to build a team of humanoid robots that can beat the current World Cup champions by the year 2050.

Our research group starts with the 2D Robot Soccer Simulated League of RoboCup Federation where a Mult-Agent System, called MecaTeam 2006, where implemented as a distributed control strategy for a robot team. The MecaTeam 2006 has its roots on UFSC-Team'98 (Costa and Bittencourt, 1999b) and on the Concurrent Autonomous Agent (Costa and Bittencourt, 1999a).The MecaTeam 2006 took part on RoboCup Brazil 2006 achieving the second place among six team from differents Brazilian Universities (Vieira Jr, 2006). Looking forward to support some research and dissertations unter the Mechatronics Master Program and Electrical Engineering Master Program at Federal University of Bahia (UFBA), the AxeBot projet was created to build fully autonomous mobile robot, called AxeBot, for the RoboCup Small Size league.

The MecaTeam F-180 multi-robot system consists in a set of six AxeBot robots contolled by a multi-agent system. Then the MecaTeam F-180 presentation is organized in the following way.Section 2 presents the AxeBot robot point to some mechanical aspect like the chassis concept, the shooting device, and the omni-directional wheels. Section 3 presents the embedded computer network responsible for the robot perception, the decision making, the mobile robot control, and the communication among another robots. Section 4 presents the multi-agent system responsible for MecaTeam F-180 multi-robot system control. Finally, section 5 presents some conclusions and future works.

2 The AxeBot Robot

The AxeBot robot is an open architecture proposes, designed to support researches involving fully autonomous omni-directional mobile robots and multi-robot system and can be freely used for academic proposes. The Axebot robot have been used to support some research and dissertations unter the Mechatronics Master Program and Electrical Engineering Master Program at Federal University of Bahia (UFBA), since 2004, two master dissertation were presented and another four dissertation have been developed involving some subjects related to the AxeBot project.

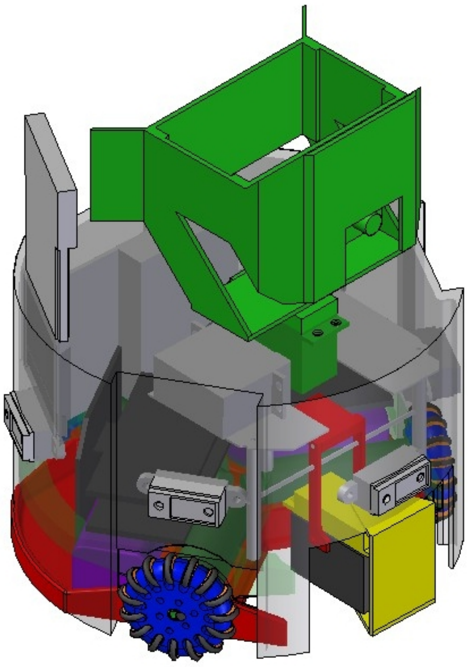

Figure 1: The AxeBot Robot

The AxeBot uses three omni-directional wheels, positioned on a circle with an angle of 120° among each wheel, to move in different directions. Three Maxxon A-22 motors are used to drive omni-directional wheel, one motor per wheel. These motors are controlled two BrainSterm Moto 1.0 and cascade controller made the robot trajectory control (da C. S. Franco, 2007). The AxeBot also holds a shooting device to kick the ball in different directions, a Vision System with a CMUCam Plus and GP202 Infra-red sensor (OLIVEIRA et al., 2005), a embedded Computer System based on StrongArm, called StarGate Kit and a IEEE 802.11 wireless network card.

The mechanical project to enclose these equipament into an fully autonomous omni-directional robot called AxeBot. The complete AxeBot dynamic and kinematics model can be found in (Franco and Costa, 2006), this model was used to specify some mechanical parameter, like the wheel diameter.

2.1 The Chassis

The chassis of the robot is the frame to which all other components can be attached, directly or indirectly. Therefore the chassis must be strong enough to carry the weight of all parts when the robot is in rest. The chassis has to withstand

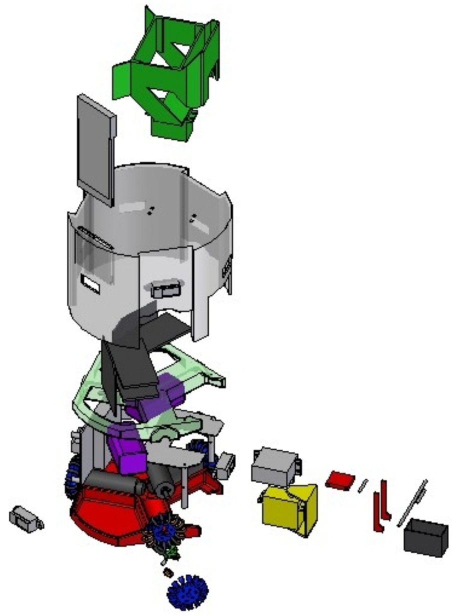

Figure 2: The AxeBot exploded view

the forces on it, caused by the acceleration of the robot as well. Another important requirement of the chassis is that it fixes all components in a stiff way, so that there will be small relative displacements of the components within the robot, during acceleration and deceleration. This is particular important for the three driving motors, which are positioned on the ground plane with an angle of 120° between each motor. The performance of the control of the robot is dependent on a precise and stiff fixation of the motors. The chassis has to be strong enough also to withstand a collision of the robot against the wall or against another robot, with the highest possible impact velocity that can occur. Finally the chassis has to be built with the smallest amount of material. In the first place to minimalise the costs and in the second place to minimalise the total weight of the robot. Less weight requires less power to accelerate. So with the same motors, less weight gives you more acceleration. This is of course only true, when all the power generated by the motors can be transferred, via the wheels, to the ground. In other words, the wheels must have enough traction that there will be no slip between the wheels and the ground.

Therefore a groundplate with 3 slots for the motors is modeled. At the front side each motor can be attached to the chassis. At the rim of the groundplate an edge is attached to give the chassis more torsional stiffness. This edge can also be used for attaching other components of the robot, like the covering shell. Also there is a

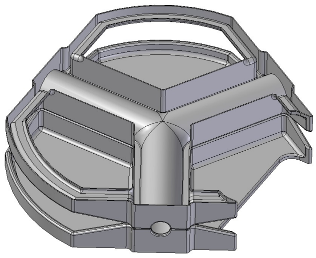

Figure 3: Upper and lower chassis attached to each other

cutout to create space for the shooting device of the robot. However no final design will be presented and therefore we stick with this assumption that the shooting device needs these cutouts. All edges are rounded, because this will make the construction of the part easier.

To get a stiffer and stronger chassis, a second chassis part, the upper chassis, is modeled. This is almost an exact copy of the first part, only now there are 3 cutouts that provide more space for placing the components of the robot. These cutouts also save some material and therefore weight. The both parts are attached to each other as shown in the picture below. This sandwich-construction gives the whole chassis more stiffness, and so the total thickness of both the chassis can probably be lower than using one chassis part.

Fiberglass shall be used to build the chassis. This choice is purely financial, because the material is cheap (although it is strong) and there is no need to hire a professional constructor. The building of all the chassis (six in total) can be done by the team members themselves. Only the moulds have to be built by a professional. The upper and lower chassis can be made using one mould that can be adjusted to produce the different chassis.

2.2 Wheels

The wheels are based on an existing design of an omni-directional wheel from the Cornell Robot 2003. Figure 2.2 shows an exploded view the final version of a wheel.

The two shells are connected to each other by screws and hold every part on the right place. The hub is also attached to the shells by screws. The hub is mounted on the output axle of a motor by a screw to transfer the rotational output of a motor to the wheel. The rings of the rollers have contact with the floor. A roller can rotate around its roller axle.

As mentioned above, the wheel has to enable two translations (x and y, see figure) without rotating around its z-axis. The total wheel ensures one translation by rotating around the output shaft of the motors. The rollers ensure the

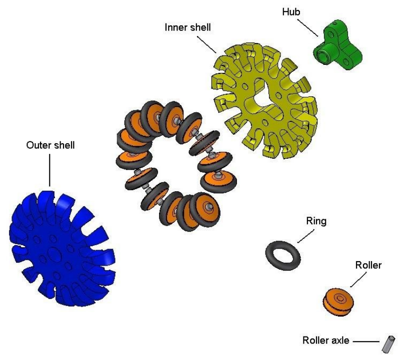

Figure 4: Explode view of the wheel

other translation. Combining these translations on a proper way a robot can move anywhere in a plane and make rotation ?.

2.3 Shooting Device

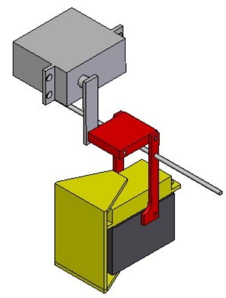

Figure 5: The AxeBot shooting device

This design consists of a vertical arm (the kick arm), that can swing around an axle which is fixed to the robot. This movement will be actuated by one of the two servos, the kicking servo, that is also fixed to the robot. The other servo, the directional servo, is attached to the bottom of the kick arm (the servosocket). A pendulum-like system is formed in this way, because a large mass is concentrated in the lower part of a rotating arm. The kicking servo has a kicking plate attached to it which can rotate and thereby makes it possible to shoot in different directions. The kicking plate can be positioned very accurately since servos are designed for these kinds of tasks. The kicking plate is also connected to the servosocket. In this way the collision force between the ball and the kicking plate will be guided to and divided by these two connection points. There will be less bending in the kicking plate then with one connection point and smaller reaction forces will act on the connection points.

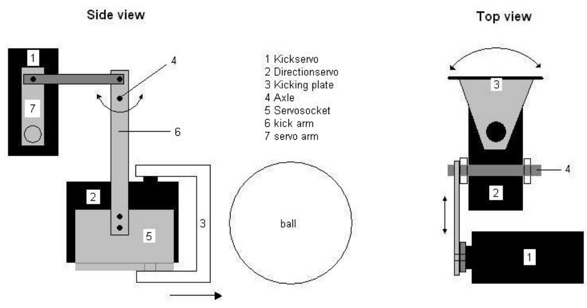

Figure 6: The AxeBot shooting device

2.4 AxeBot assembly

The shell is the cover of the total robot. It will be made from fiberglass as well, for the same reasons as stated in the section about the chassis. In the figure below the design of the shell is shown. There are cutouts to make room for the wheels as well as for the shooting device. The diameter of the shell is 178 mm. Because the maximum allowable diameter is 180 mm, a margin of 2 mm is created.

The robot consists of an upper and lower chassis. Three motors with three omni-directional wheels are attached to it. On the bottom of the robot, the two battery packs are placed, because these parts have the largest mass. The three motor processors are attached to two general processors. Also the overall processor with the data-transfer-unit is assembled. The latter parts are assembled in a way that is most compact. With this assembly it is possible for all parts to fit in a shell with height of 100 mm.

On top of the shell a vision system is mounted. For the sake of compactness of the robot the height should be as small as possible, with all the parts fitting in. To assemble the robot the most important demand is to obtain a total center of gravity that has the lowest possible position in the robot. This will give the robot positive driving habililties. Another demand is of course that all the parts fits in the maximum height of 150 mm.

3 Embedded Computer Network

A Embedded Computer Network was built inside the AxeBot robot. This computer network uses the IIC bus to allow communication among the network nodes. The network nodes are: one CMUCam Plus, two BrainSterm Moto 1.0, a embedded Computer System based on StrongArm, called StarGate Kit, a circuit board based on PIC microcontroller designed to data acquisition from eight GP202 as is shown in figure 3. The StarGate Computer System also has a IEEE 802.11 wireless network PCMCIA card, connected to inter-robots communication.

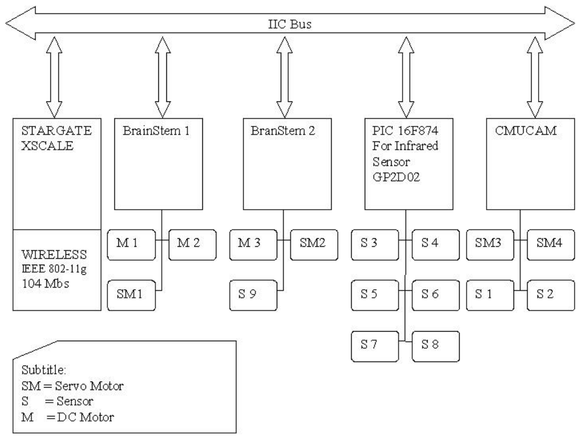

Figure 7: The AxeBot Embedded Computer Network

The CMUCam Plus and the acquired from the GP202 are used to implement a local vision system that uses a Support Vector Machine to identify the object, their distances and directions and a Fuzzy System used to the sensor fusion. This vision system is responsible to generate a knowledge representation called framework that describes the robot visual field informing which object are inside their distances, directions and speeds (OLIVEIRA et al., 2005). Two servos allows the CMUCam pan and tilt moving.

The BrainSterm Moto 1.0 are responsible for the DC motor speed control. Each BrainSterm Moto 1.0 has two speed controllers then two BrainSterm Moto 1.0 are used to control the three DC motors. These DC motors controllers and cascade a controller, running on the embedded Computer System based on StrongArm, called StarGate, made the robot trajectory control (da C. S. Franco, 2007).

Finally an autonomous agent is running embedded Computer System which is responsible by whole robot control giving the fully autonomy for the AxeBot robot. This autonomous agent encapsulates the trajectory generation and control as one behavior and implements the environment mapping, planing, navegation, etc. this autonomous agent also allows the AxeBot robot to interact with another robots to integrate a mult-robot system.

4 The Multi-Robot System

The MecaTeam F-180 Multi-Robot System presents a mult-agent system approach for a multi-robot system distributed control unter the RoboCup Soccer Small Size League. This multi-agent system uses The Concurrent Autonomous

Agent Architecture (?; ?) where the reactive level encapsulates the trajectory generation and control as one behavior, and the framework generated by the vision system is used by instinctive decision level. Also here the three process for the three decision levels concurrent architecture was replaced by a multi-thread approach.

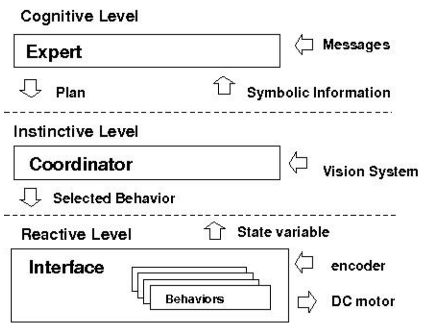

Figure 8: The MecaTeam F-180 Autonomous Agent.

The Reactive level encapsulates the trajectory generation and control as behaviors. The behavior accept four parameters defined by the instinctive level which define the tracetory will be tracked by the cascade trajectory controller.

The Instinctive level encapsulates a Knowledge-Based System with a one cycle Inference Engine, a rule base and a fact base. The Fact Base stores the framework sent by local vision system and the state variable used by the cascade controller. The Rule base is organized into a finite number of rule sets. Each plan is associated with a different rule set. This rule set contains the knowledge to identify the current environment state and to choose the best behavior to satisfy the current plan. In the case that the chosen behavior is different from the currently active behavior in the Reactive Level, a message is sent to the Reactive Level informing the new parameters for cascade trajectory controller. The Instinctive level is also responsible by the generation of symbolic information that is sent to Cognitive level.

The Cognitive level also encapsulates a knowledge-based system, but one with a multiple cycle inference engine, that also includes a fact base, a local rule base, a social rule base and a Plan Set base. The local rule base is responsible for handling the symbolic information sent by the Instinctive level, building with it a logical model about the environment. Using this logic model, it chooses a local goal; verifies whether the current plan is still valid; chooses the most appropriate plan and sends it to the instinctive level. The social rules contain the knowledge needed by the agent to take part in a cooperation process. For this cooperation process Dynamic Social Knowledge cooperation strategy (Costa and Bittencourt, 2000), (Costa and Bittencourt, 2002), is used by the agents who control the robot to form the multi-robot system.

5 Conclusion

The MecaTeam F-180, a multi-robot system for the RoboCup Small Size League challenge is presented in this paper. The multi-robot system consists in a set of six fully autonomous omni-directional mobile robots, these robots are called AxeBot. The AxeBot robot uses three omni-directional wheels for movement and be equipped with a shooting device for shooting the ball in different directions. Once the AxeBot robot is a fully autonomous mobile robot all the sensors, engines, servos, batteries, wireless network, and the computer system, are embedded on. The AxeBot robot brings up a new chassis concept for three wheels omni-directional robot, also present a new shooting device that allow the robot to kick the ball in an desired direction with out robot re-orientation, also presents a embedded computer network responsible for perception, decision make, control, communication and action and, finally present a distributed approach to control a multi-robot system based on a mult-agent system. The Multi-Robot System presented here was concept for academical proposes, using the robot soccer as a laboratory to research in Autonomous Mobile Robots, Artificial Intelligence and related areas. Looking forward, the MecaTeam F-180 will support our research and dissertations unter the Mechatronics Master Program and Electrical Engineering Master Program at Federal University of Bahia (UFBA).

References

Costa, A. L. d. and Bittencourt, G. (1999a). From a concurrent architecture to a concurrent autonomous agents architecture., *IJCAI'99, Third International Workshop in RoboCup* pp. 85–90. Springer, Lecture Notes in Artificial Inteligence.

Costa, A. L. d. and Bittencourt, G. (1999b). Ufsc-team: A cognitive multi-agent approach to the robocup'98 simulator league., *RoboCup98 Workshop - Team description* pp. 371, 377. Springer, Lecture Notes in Artificial Inteligence, vol.1694.

Costa, A. L. d. and Bittencourt, G. (2000). Dynamic social knowledge: A comparative evaluation., *Intenational Join Conference IBREAMIA'2000 / SBIA'2000.* pp. 176–185. Springer, Lecture Notes in Artificial Inteligence, vol. 1952 - Best Paper Track Award.

Costa, A. L. d. and Bittencourt, G. (2002). Dynamic social knowledge: The timming evaluation., *XVI Brazilian Symposium on Artificial Intelligence - SBIA'02* pp. 175, 184. Springer, Lecture Notes in Artificial Inteligence, vol.

da C. S. Franco, A. (2007). *Geração e controle de trajetória de robôs móveis omni-direcionais*, Master's thesis, Universidade Federal da Bahia / Programa de Pós-Graduação em Mecatrônica, Salvador, Bahia, Brasil.

Franco, A. C. and Costa, A. L. (2006). Modelagem e simulação do robô omni-direcional axebot, *XVI CBA Congresso Brasileiro de Automação*, p. Artigo submetido.

Kitano, H. (1997). Robocup: The robot world cup initiative, *in Proc. of The First International Conference on Autonomous Agent (Agents-97))* . Marina del Ray, The ACM Press.

OLIVEIRA, L. R. d., COSTA, A. L. d., SCHNITMAN, L. and Souza, J. F., k. (2005). An architecture of sensor fusion for spatial location of objects in mobile robotics, *Encontro Português de Inteligência Artificial, EPIA'2005, 2005, Covilhã. EPIA 2005 LNAI 3808. Berlin Heidelberg : Springer-Verlag*, pp. 462–473.

Vieira Jr, O.and Rocha, J. P. L. M. C. A. L. (2006). Mecateam: Um sistema multiagente para o futebol de robôs simulado baseado no agente autônomo concorrente, *XXVI Congresso da Sociedade Brasileira de Computação, Encontro de Robótica Inteligente - EnRI2006*.