STOX's Team Description Paper 2018*

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Abstract—In this paper we present the current state of STOX's team to participate in LARC/CBR Small Size Robot League competition 2018, in João Pessoa, Brazil. Initially, we show the structure of our team in terms of mechanics and hardware. Next, we describe the operation of our robots at lower level. Then, we present our new approach to a smarter strategy for tactic selection and dynamic role assignment, based on hierarchical finite-state machines. Finally, we believe that LARC/CBR Small Size League competition is an adequate event to validate our new approach, with the help of other teams of recognized research groups in robotics at the regional level.

I. INTRODUCTION

The STOX's team from Universidad Santo Tomás has participated in several editions of RoboCup Small Size Robot League. Our soccer team has been developed inside the research group GED (Group of Studies and robotics Development, by its initials in Spanish), which belongs to the Faculty of Electronic Engineering at Bogotá, Colombia. The STOX's team was established in 2010 by two students, founders of our team, which were part of the Electronic Engineering undergraduate program at Universidad Santo Tomás [1]. The STOX's team attended to the Latin American Open RoboCup in 2010 with the first generation of robots, where it placed 2nd. Later, the team participated in the RoboCup Small Size world championship 6 times in a row since 2012 to 2017, outstanding the 4th place achieved in Heifei 2015, as their classification among the top 8 during 2013, 2014 and 2017. Although the STOX's team has a great experience participating in RoboCup tournaments, the GED research group is currently training new researches. Therefore, we consider the Latin American and Brazilian Robotics Competition 2018 as the best scenario to achieve better knowledge about intelligent and multi-agent robotics.

Our robots are currently the third generation. Its mechanical structure was presented in the TDP for RoboCup World Championship 2014. We would like too remark that this generation attended to the RoboCup World Championship last year, 2017 [2]. However, both the trajectory and obstacle avoidance tracking systems, as well as the tactics strategies have completely different developments than the ones used

in previously contests. On this occasion, the strategies will be based on hierarchical finite-state machines for the selection of tactics and behaviors, as well for the role assignment task in an architecture with global perception and centralized control, as exposed in [3].

In the following sections we describe the general information of the current STOX's team that is going to participate in Latin American Open RoboCup 2018. This document is divided as follows: in section II we show the mechanical structure of our robots. Section III describes their hardware and electronic designs. Finally, in section IV we present a new proposal for tactics strategy and its current progress.

II. MECHANICAL STRUCTURE

Fig. 1. 3D render of STOX's small size robots

We are working with the third generation of STOX's robots, which are completely described in [4]. Fig. 1 shows a 3D render of the current mechanical structure of our robots. Their *chassis* is based on the model used by Skuba team [5], incrementing its thickness from 3mm to 5mm in order to achieve higher sturdiness. The chassis was made with aluminum 7075, using a CNC machinery. The traction of our robots is omni-directional, conformed by four wheels with 55mm diameter and 20 rollers each one, with the purpose of having better contact between the wheels and the field.

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The wheels have double flange bearing and are connected to the brushless motors "Maxon EC45- Flat 50 Watt" through a gearbox of 20:72.

The *dribbling system* allows to move or shoot the ball on the playing field while the robot moves. It is composed of a Maxon EC-16 30W brushless motor coupled with a cylindrical rod covered in rubber of 10mm diameter, providing a maximum rotation of 12000 rpm. The design features a damping system that improves the ball reception and dribbling. In addition, the *flat kicker* is a custom solenoid with a core of Bakelite, wrapped with 6 layers (400 turns approximately) of 24AWG enameled wire. The plunger is made with a magnetic part and other non-magnetic. This configuration provides the robots with a maximum kick speed of 10m/s. Nonetheless, it was reduced to 8m/s to fulfill the rules book of the Latin American Open RoboCup 2018. Finally, the *parabolic kick system* is also based on Skuba's designs. It achieves a 4m of ball kick distance with the same solenoid as the flat kicker.

III. ELECTRONICS

The electronics of our robots is the same used in [1]. The electronic design covers the *main board*, responsible for the emission of signals to carry out control actions and actuators activation. Furthermore, the main board contains first the motor drivers, implemented as a tri-phase inverters, second the sensor acquisition and signal conditioning circuit and third, a visualization module for debugging purposes. Our robots have a set of sensors, such as quadrature encoder for speed measurement, an IR sensor to detect the ball presence and a SD-788 gyroscope to improve motion. Fig. 2 presents the block diagram of our traction system. It can be noticed that the PI controller uses as input the measurement of the encoder and outputs a PWM signal to control the tri-phase bridge of each motor.

Fig. 2. Block diagram of the traction control system for the motors

The kickers circuit consist of two elementary sections. First, a DC boost converter that charges four capacitors of $1200\mu F$ from 0V to 200V. Second, two IGBTs that switches the energy from the capacitors to the corresponding solenoid. The PWM signal used to control each IGBT allows to modulate the intensity of the shot. As ball detector, IR emitter-receptor pair sensor is used. Their signals are

Fig. 3. Low-level Software Architecture of STOX's

amplified and digitized to be analyzed by the decision-making or AI system.

The robot's power supply is a Li-Po battery with a nominal voltage of 14.8V and a nominal capacity of 2000mAh. This features provides to each robot 30 minutes of game autonomy.

The communication system consist of a RF server and a communication module within each robot. The server receives all commands given by the control system and transmits the information to every robot, through a dedicated Tx channel. Likewise, the RF server receives the data from each robot through a different Rx channel. The communication module within each robot is based on a nRF24L01 chip, which is configured for transmission or reception according to its function. Each robots periodically reports its current features, such as ID, battery level and ball possession. The communication module works in the range of 2.4GHz to 2.5GHz and the air data rate is 250Kbps at 0dBm.

IV. SOFTWARE DESIGN

For the RoboCup Small Size League, the STOX's team presents the architecture shown in Fig. 3. The SSL artificial vision system provides information about players and ball to the decision-making system. This last, defines the tactics and game strategy. As result for each strategy, the robots receive coordinates of their destination points on field. The shortest path that the robot has to follow to reach its destination, is given by the trajectory tracking algorithm. Subsequently, the generated path is divided into intervals by the path discretizer. Each interval represents intermediate coordinates (x,y) that the robot must follow. They are used as input for

digital PIDs to control the linear velocities that each robot must apply, according to its current position on field.

Additionally, an angular position control is implemented for allowing robots to always face either the ball or a specific position in field, which is determined by the decision-making system. The angular position control is achieved with a PID controller, that takes as input the angular error, calculated between the reference and the current angular position of the robot. The controller outputs the angular velocity.

Both linear and angular velocities are inputs for the Omnidirectional Motor Control block, which is based on the reverse kinematic model [6]. This module outputs the velocity needed by the four motors of each robot player. This information is encoded in a package and transmitted by the communication system. Every robot receives the message, decodes it, and applies the corresponding PWM signal to perform the speed and direction control of each wheel.

A. Work in Progress

Currently, we are working in the design and implementation of a new decision-making module, which is going to dictate the strategy according to the state of the game. We have found that, for planning purposes, several works are based on finite-state machines. For instance, in [3] and [7] hierarchical finite-state machines are proposed for the dynamic selection of tactics, role assignment and behaviors selection in architectures with global observation and centralized control.

In this occasion, for RoboCup Small Size League, STOX's team is working on the architecture shown in Fig. 4. A unique strategy is proposed with defense and attack tactics. They will be selected depending on whether the ball is in the defensive zone (Ev1) or offensive zone (Ev2) of the field. Free kicks, penalty kick and corner kick will be programmed independently of attack and defense tactics.

Fig. 4. Upper-level Software Architecture for Tactics Selection

Fig. 5 shows that, once the tactic has been selected, the roles are dynamically assigned. Nevertheless, they take into account the position in the field, the distance to the ball and the position of opponent players. Once the roles are assigned, the decision-making system selects a specific behavior for each role from a second layer of state machines, which depends on the dynamic conditions of the game. Finally, each behavior determines positions in the field where the robot must move, continuing with the architecture presented in Fig. 3.

Fig. 5. Layer of role assignment and selection behavior

Of the 6 players, the only one who will have a constant role will be the goalkeeper, whose behavior diagram is presented in the Fig. 6. Basically, this player follows the ball in reference with the goal line, without leaving the defense area. The other roles will be organized between two defenders, a midfielder and two strikers. The role assignment will be performed each time a new selection of tactics is made, focusing mainly on the position of the players on field and their distance to the ball.

Fig. 6. Goalkeeper behaviors

We propose the following role assignment for both tactics:

Roles in Defense Tactics

Central defender:

player closest to the ball. He must intercept the ball and send it to the offensive zone.

Full-back defender:

second player closest to the ball. He must block the opponent closest to the ball, in order to avoid scoring or passing.

Midfield:

third player closest to the ball. He must block the second opponent closest to the ball in order to avoid passing.

Winger:

fourth player closest to the ball. He stays in the midfield, waiting for passes to make counter-attack.

Main striker:

fifth player closest to the ball. He is in the offensive zone, in order to wait for passes to counter-attack.

Roles in Offensive Tactics

Main striker:

player closest to the ball. He must intercept the ball to try to score goals or make a pass to the winger.

Winger:

second player closest to the ball. He must join the main striker from the other side of the field, in order to receive his pass. Also, the winger has to try to intercept the ball for regaining possession.

Midfield:

third player closest to the ball. He is in the middle of the field, endeavoring to break up the opposition's attacking play by regaining possession of the ball.

Full-back defender:

fourth player closest to the ball. He is located in the defensive zone, where an opponent must go to mark him.

Central defender:

fifth player closest to the ball. He is located in the defensive zone, where a second opponent of the central defender must go to mark him.

Fig. 7. Behavior selection using synchronization function in finite-state machine.

In the case of offensive tactics, the main striker and winger roles will change depending on which player is closest to the ball. For both players, we propose the use of a synchronization function, as presented in Fig. 7. This function is used to synchronize collaborative behavior between two players. For instance, player with role r_n activates its behavior k when condition $St2k$ is met. On the other hand, role r_n can switch to behavior 1 only if condition $St1k$ is presented and agent with role r_m has behavior k and triggers $fm_n(Stk1)$ function.

Moreover, for the offensive tactics we proposed that when the main striker has possession of the ball, the decision-

making system reviews the possible trajectories to score a goal. If the trajectory is blocked by a player other than the goalkeeper, the main striker must make a pass to the winger; otherwise, he must shoot at the opponent's goal.

Fig. 8 shows the behavior diagrams for the main striker and the winger. They present the sequence of behaviors that both roles must execute. Notice that each behavior depends on changes in game conditions, due to the influence of previous ones. For the main striker, the decision-making system must confirm that he is the player closest to the ball, unless, he must assume the winger role. If the main striker role is viable, this player must intercept the ball to regain possession. The decision-making system must evaluate if there are opposing players, other than the goalkeeper, in the path to the goal afterwards. In case there is a blockage in the goal path, the main striker activates the synchronization function and kicks the ball to the winger. When the ball is close to a winger, he will assume the role of main striker. The new winger must go to the opposite side of the main striker and follow the ball in lateral line, in order to support the main striker in case he loses possession of the ball.

We present in Fig. 9 an example of behavior synchronization between the main striker and the winger, including a change in roles. In Fig. 9(a), player 2 (main striker) detects that an opponent blocks the trajectory of the ball to the goal, while player 1 (winger) accompanies. Therefor, in Fig. 9(b) player 2 activates the synchronization function and kicks the ball to player 1. In this case, new roles are assigned, in which player 2 becomes winger and player 1 assumes the main striker role. Finally, Fig. 9(c) shows player 1 endeavor to score a goal, meanwhile player 2 supports.

V. CONCLUSIONS

We present an overview about the STOX's team, belonging to the Group of Studies and robotics Development GED of Universidad Santo Tomás. A review of the electronic and mechanical design of the robots has been presented. The main contribution, with respect to the work of previous years, is the design of a new decision-making system, based on hierarchical finite-state machines, for the selection of tactics, behaviors and dynamic role assignment depending on the game conditions. We propose, as well, the usage of synchronization functions for the selection of behaviors, in order to promote coordination and cooperation between team's players. Lastly, we expected to validate our game strategy during the Latin American and Brazilian Robotics Competition, against other participating teams in the Small Size League.

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Fig. 8. Behavior diagrams for main striker and winger in offensive tactic

Fig. 9. Example when an opponent player blocks the goal with synchronization function.

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