# STOx's 2017 Team Description Paper

Saith Rodríguez, Eyberth Rojas, Katherín Pérez, Carlos Quintero, Oswaldo Peña, Andrés Reyes, and Juan Calderón

Faculty of Electronics Engineering
Universidad Santo Tomás
Bogotá, Colombia
{saithrodriguez,eyberthrojas,kathyperez,carlosquintero,
oswaldopena,andresreyesf,juancalderon}@stoxs.org
http://www.stoxs.org

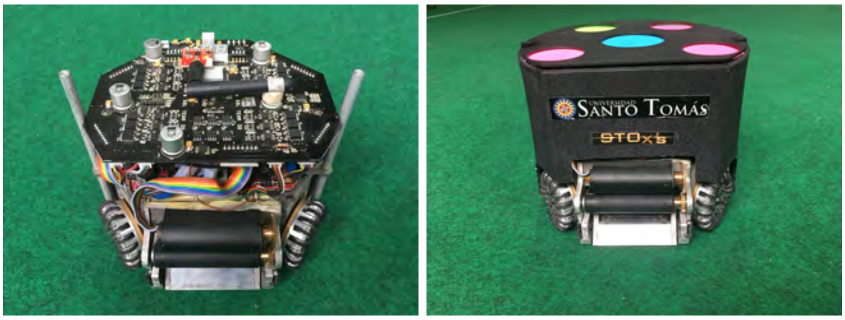
**Abstract.** In this paper we show the current state of the STOx's team after its *6th* participation in the RoboCup world competitions. Initially, we show a description of the latest contributions made by the teams in the league during the last years as well as the proposals made by the STOx's team, especially in data processing, tracking and prediction algorithms in order to facilitate the higher-level decision making processes. We also show the performance of our chip predictor algorithm in the games of RoboCup 2016. Finally, we show the defensive strategy implemented by our team, specifically, the *optimal markers assignment*, which optimally assigns defender markers to opponent attackers minimizing therobot's traveled distance.

## 1 Introduction

The STOx's team from University of Santo Tomás has attended the RoboCup world championship 6 times in a row since their first participation in Istambul 2011 and their latest in Leipzig 2016. Our best performance was achieved in Hefei 2015 where we placed *4th* and 2013-2014 where we were ranked in the top 8.

Our robots have dramatically evolved during these years, going from the first generation developed in 2010 to participate in the latin-american competition held in Brasil, to the current $3^{rd}$ generation manufactured for the 2014 RoboCup world championship in Joao Pessoa. Since then, we have updated the main electronic board to improve the motor drivers performance, some minor enhancements to the communication modules and the addition of a special protection for the dribble motors [1]. For 2017, the robots will not suffer any hardware or mechanic modifications. In Figure 1 we show the current state of one of our robots.

In terms of strategy, the team has also evolved as well as many other teams in the league from sets of fixed gameplays and static strategies that were used based on simple game conditions, to more autonomous and dynamic strategies where the system not only decides the gameplay that should be played next from




(a) (b)

Fig. 1: Pictures of the current robots of the STOx's team

a set of prefabricated options, but it creates plays on the fly that usually depend on the game situation [1, 7, 10]. For these strategies to be possible, efficient and functional, it is highly important to propose, implement and integrate appropriate computational concepts and algorithms that allow for automatic and optimal decision making during the game. For example, algorithms to accurately determine the ball and robot positions in the presence of overlapping cameras [4, 6] and models to predict the position and velocities for the ball [2] have been proposed. Also, proposals to optimally intercept the ball [3] to help the robot transition from defense to offense have been made.

Note that these data processing and modeling techniques are of paramount importance to aid other decision making processes in regular games. One important concept that uses these advance ball and robot models is one that aims at synchronizing passer and receiver robots [5], also known as non-reactive offense strategies [11]. The general idea consists on not showing the opponent team the specific plans to be carried out ahead of time in order to avoid being marked by the defenders. This strategy requires fine-tuned synchronization and accurate ball modeling to ensure successful passes. Finally, zone-based strategies [11] and score-based optimal locations [8, 1] have been proposed for the creation of offensive strategies.

In this paper we briefly summarize the current state of our team going over the performance of specific concepts during the games of the previous RoboCup tournament. Finally, we present the approach followed by our team to assign defender robots to opponent attackers.

## 2 Current State of STOx's

After 6 contiguous participations in the RoboCup world tournaments the STOx's team has gone through many experiences and also through many stages. Initially, we experienced many troubles with the mechanic and electronic design of our robots starting with the 1*st* generation in 2011, then our 2*nd* generation in 2012 and 2013 and finally our last $3^{rd}$ generation since 2014. Our robots are currently highly competitive, realiable and robust requiring simple maintenance between games. They are built in aluminium 7075 using CNC machinery, with omnidirectional custom wheels with 20 small rollers each and a gearbox of 20 : 72. Each robot is equipped with 4 Maxon EC45-Flat 50 Watt motors for driving and one Maxon EC16 30 Watt brushless motor for dribbling the ball at a top speed of 12.000 rpm. The kickers (flat and chip) are custom made solenoids with bakelite core and wrapped with 6 layers of 24 AWG enameled wire. The main electronic board contains the robot's main processing unit (FPGA with embedded soft 32-bit microprocessor) as well as visualization module, motor drivers and RF communication interphase. Our robots also have secondary boards that contain the power source and the kicker controllers. All of these components have shown to work effectively during the last RoboCup competitions and little changes have been made. For specific references to our general robot design see [12, 6].

In terms of software development and game strategy our team has put a lot of efforts in improving the general team behavior aiming for more intelligent, dynamic and coordinated game style. In this context, we performed a code refactoring for the RoboCup competition of 2015 to prepare our software for future changes, especially for changing from a fixed set of gameplays to dynamically created plays. For this change to be possible, we have proposed, implemented and integrated different data processing and tracking algorithms into our software framework that aims at supporting the high level decision making processes that are required to achieve intelligent and autonomous games. In 2015, we presented our data processing chain framework that includes a preprocessing step to create one unique representation of the elements within the field based on the information provided by the four cameras as well as a *predictor* module in charge of predicting and simulating the behavior of every object inside the field. This framework has allowed our team to be less fragile to noise in the vision system. The information related to these techniques and experiments showing their performance can be found in [6].

More recent proposals include the development of a tool that automatically identifies and reconstructs chip kicks during games. The tool is based on an automatic classifier model that uses support vector machines fed with a set of features and observations that allows it to decide with little amount of frames whether a shot is a chip kick or not. After that, we have implemented a method previously proposed in [14] to reconstruct the parabolic path followed by the ball in order to accurately predict the ball's landing position. This tool has turned out to be an extremely useful tool to aid our defensive strategies to block dangerous passes and also to perform more accurate passes when building offensive plays. In Table 1 we show the performance of our SVM-based chip predictor during the RoboCup 2016 games. Also, the percentage of chips correctly classified was 79.48%, while the number of "not chips" correctly classified was 83%. The general classification accuracy is 81.52%

Finally, in 2016 we also presented an algorithm that dynamically selects locations within the field where passes can be made with high chances of scoring. Our

Table 1: Confusion matrix for our SVM-based chip kick predictor

| | **Predicted as chip** | **Predicted as not chip** |
|---|---|---|
| **Actual chips** | 33,69% | 8,69% |
| **Actual not chips** | 9,78% | 47,82% |

algorithm is modeled as an optimization problem with many simplifications that allows us to find a set of solutions that finally creates offensive plays on the fly and in very short time. For more information about our chip kick reconstructor and dynamic ofensive plays creator, see [1].

## 3 Defensive Strategies

The importance of the team's defense strategies has increased in recent years, especially, with the enlargement of the field size. Currently, there is significantly more space for the robots to perform a wider variety of plays, making more difficult the task of defense. Moreover, the recent creation of fast and dynamically created offensive gameplays in many teams further complicates the task and leaves out the possiblity of covering all possible cases during a game. Only a few teams have shared part of their defensive strategy and in most cases they are based on the threat level of the opponent robots [11, 5].

Our general defense strategy consists of man-to-man marking, where each defender is assigned one unique attacker to mark rather than covering a specific area. The strategy consists of 4 main steps as described below:

1. **Opponent Attackers selection:** The initial step of our general defense system decides which attacker robots are possible threats (set $A$) and hence need to be marked. The number of possible threats is $|A| = K < 6$. In general, this decision depends on several features of the game, such as the opponent aggressiveness and the current score among others.
2. **Markers selection:** The system chooses a set $M$ of marker robots that will be used to mark the opponent attackers. In general, the number of markers equal the number of previously identified threats, i.e., $|M| = K$. This step is usually carried out in a hierarchical manner, initially selecting first our attackers, then, the midfielder and finally the defenders. The idea is that if there are few threats that need to be marked, our defenders will remain in *general defend position*, blocking possible shots to our goal.
3. **Marker-attacker assignment:** In this step, the system decides which attacker $a_i \in A$ is assigned to which defender $m_j \in M$. See detailed description below.
4. **Marking procedures:** Finally, each marker performs the man-to-man marking procedure by moving and staying closer to the assigned attacker. Usually,

the marking distance is proportional to the distance between the attacker and our goal line, i.e., the closer is the attacker to our goal line, the closer is the marker to its correspondent attacker.

In the following section, we will show our approach for the *Marker-attacker assignment problem.*

### 3.1 Optimal Markers Assignment

During this phase of the STOx's defensive strategy, we are given a set of attacker robots $A$ that need to be marked and a set of marker robots $M$, both of the same size $|A| = |M| = K$. The problem consists on assigning exactly one attacker $a_i \in A$ to one defender $m_j \in M$ in a way that the distance traveled by our marker robots remains as short as possible.

This problem can be modeled as an optimization program where there is a cost $C(i,j)$ related to assigning marker $m_i$ to mark attacker $a_j$. In our framework, this cost is the distance that needs to be traveled by the robots to perform the marking procedure. Our proposal is to encourage an assignment of markers and robots that result in minimal distance traveled by our robots. One option could be to find the assignment that minimizes the total distance traveled by the robots. However, this formulation may be problematic for this specific scenario since it could generate solutions with many short distances and one or two extremely large. Usually, these type of assignments may cause that one or more robots require to change sides within the field and go through several obstacles during their travels. In contrast, our formulation proposes to find the assignment that minimizes the maximum distance traveled by the marker robots. This strategy aims at minimizing all traveled distances and generally avoids problematic paths.

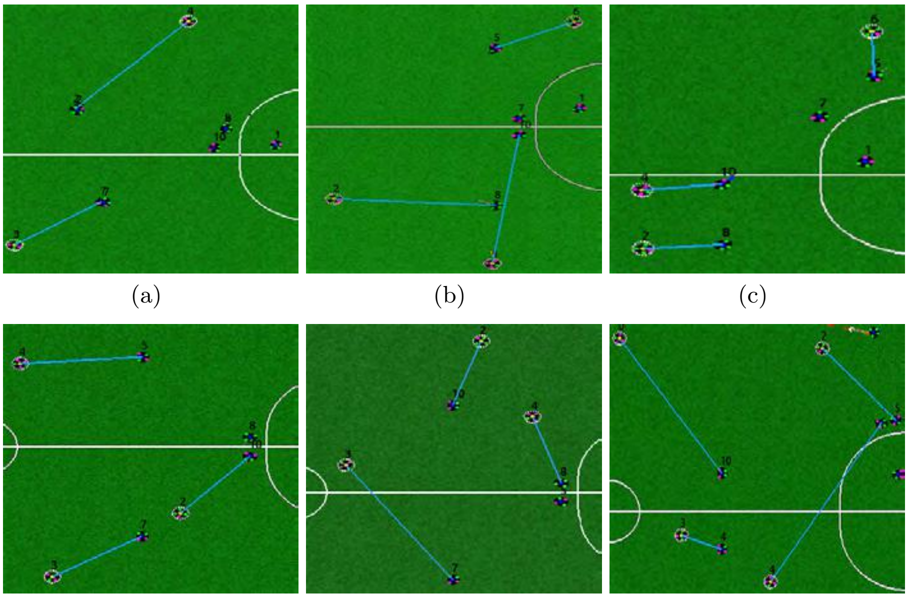
The mathematical program solved by our system is as follows:

$$\begin{gathered}\min z = \max\nolimits_{i,j} \{x_{ij} C(i,j)\} \\ \text{subject to} \\ \textstyle\sum_{a_j \in A} x_{ij} = 1, \forall m_i \in M \\ \textstyle\sum_{m_i \in M} x_{ij} = 1, \forall a_j \in A \\ x_{ij} \geq 0, \forall a_j \in A, m_j \in M\end{gathered}$$

where $x_{ij}$ is a binary variable that takes the value of 1 if marker $m_i$ should mark attacker $a_j$ and 0 otherwise.

This problem is an integer (binary) constrained nonlinear program and is widely known in optimization as the *minimax assignment problem.* It has been demonstrated that it can be efficiently solved in computers if $|A| = K < 10$ by using the method of exhaustion [13]. The idea is to compare all objective functions of feasible solutions directly or indirectly. The feasible solutions are created by arranging $K$ "1" and $K^2 - K$ "0" of a $K \times K$ $0-1$-matrix, where all 1 are located in different rows and columns of the matrix.

In Fig. 2 we show the result of our marker-assignment algorithm during several real games in RoboCup 2016. It is noteworthy that in most cases the algorithm creates assignments where defenders are required to mark attackers without changing sides. For example, in figures 2(a), 2(c) and 2(d) we see simple assignments where the algorithm find simple solutions where each defender is assigned its closest attacker robot or the attacker closest to its defend area. In figures 2(b), 2(e) and 2(f), more complex assignments are shown always ensuring the shortest traveled distance of the marker robots.



(a) (b) (c)

(d) (e) (f)

Fig. 2: Examples of our optimal marker assignment algorithm in several games of RoboCup 2016. In all cases, STOx's is the blue team and the straight blue lines show the results of the assignment algorithm, i.e., which opponent attacker is assigned which defender. a) Output of our Optimal Marker Assignment algorithm in presence of two threatening attackers. b-e) Output of our Optimal Marker Assignment algorithm in presence of three threatening attackers. f) Output of our Optimal Marker Assignment algorithm in presence of four threatening attackers.

## 4 Conclusions

In this paper we have shown the current state of the STOx's team from University of Santo Tomás by going through our more important proposals in the last years. Our team has achieved a maturity in terms of hardware development that has allowed us to focus more on mid-level strategy development and data processing algorithms. In this paper we also show our algorithm to optimally assign opponent attackers to our defenders. Our strategy makes such assignments in a way where the maximum distance traveled by all of our defenders is minimized. The problem is modeled as a *minimax assignment problem* and solved in real time during games in RoboCup 2016. Currently, we are working in more high level algorithms and team coordination strategies that allow us to fully exploit our team's potential.

## References

1. S. Rodríguez, E. Rojas, K. Pérez, C. Quintero, H. Báez, O. Peña, J.M. Calderón. STOx's 2016 Extended Team Description Paper. Leipzig, Germany 2016. Available for download in http://wiki.robocup.org/images/0/0d/Small_Size_League_-_RoboCup_2016_-_TDP_STOx%27s.pdf
2. C. Lobmeier, P. Blank, J. Buehlmeyer, D. Burk, M. Eischer, A. Hauck, M. Hoffmann, S. Kronberger, M. Lieret and M.B. Eskofier. ER-Force Extended Team Description Paper RoboCup 2016. Available for download in http://wiki.robocup.org/images/0/07/Small_Size_League_-_RoboCup_2016_-_TDP_ER-Force.pdf
3. R. De Iaco, S. Johnson, F. Kalla, L.k. Lu, M. MacDougall, K. Muthukuda, J. Petrie, M. Ragoonath, W.Y. Su, V. Tang, T. Tsu, B. Wang, G. Whyte, C. Xi, K. Yu, E. Zhang and K. Zhang. 2016 Team Description Paper: UBC Thunderbots. Available for download in http://wiki.robocup.org/images/f/f8/Small_Size_League_-_RoboCup_2016_-_TDP_UBC_Thunderbots_-_Review.pdf
4. S. Aoki, T. Degawa, K. Fujihara, Y. Notsu, T. Beppu. MCT Susano Logics 2016 Team Description. Available for download in http://wiki.robocup.org/images/2/27/Small_Size_League_-_RoboCup_2016_-_TDP_MCT_Susano_Logics.pdf
5. A.G. Poudeh, M. Sobhani, A. HosseniKia, A. Karimpour, S. Mosayeb, H. Mahmudi, S. Esmaeelpourfard, M.K. Naeini and A. Adhami-Mirhosseini. MRL Extended Team Description Paper 2016. Available for download in http://wiki.robocup.org/images/8/8d/Small_Size_League_-_RoboCup_2016_-_TDP_MRL.pdf
6. S. Rodríguez, E. Rojas, K. Pérez, J. López, C. Quintero, O. Peña, J. Giraldo and J.M. Calderón. STOx's 2015 Extended Team Description Paper. Hefei, China 2015. Available for download in http://wiki.robocup.org/wiki/File:Small_Size_League_-_RoboCup_2015_-_ETDP_STOx%E2%80%99s.pdf
7. L. Jin, L. Chen, X. Chen, Y. Li, W. Hu and R. Xiong. ZJUNlict Extended Team Description Paper for RoboCup 2016. Leipzig 2016. Available for download in http://wiki.robocup.org/images/6/60/Small_Size_League_-_RoboCup_2016_-_TDP_ZJUNlict.pdf

8. T. Sakaguchi, K. Ohno, T. Mimura, N. Tanaka, K. Satoh, Y. Yamauchi, Y. Nagasaka, M. Watanabe and T. Sugiura. Leipzig 2016. Available for download in http://wiki.robocup.org/images/2/20/Small_Size_League_-_RoboCup_2016_-_TDP_KIKS.pdf
9. Y. Adachi, H. Kusakabe, N. Tsuzuki, H. Hayama, D. Yamaguchi, M. Ito and T. Naruse. RoboDragons 2016 Extended Team Description Paper. Available for download in http://wiki.robocup.org/images/5/51/Small_Size_League_-_RoboCup_2016_-_TDP_RoboDragons.pdf
10. J.P. Mendoza, J. Biswas, D. Zhu, R. Wang, P. Cooksey, S. Klee, and M. Veloso. CMDragons 2015: Coordinated offense and defense of the SSL champions. In Proceedings of the International RoboCup Symposium, to appear 2016.
11. J.P. Mendoza, J. Biswas, D. Zhu, R. Wang, P. Cooksey, S. Klee, and M. Veloso. CMDragons 2016 Extended Team Description Paper. Available for download in http://wiki.robocup.org/images/d/dc/Small_Size_League_-_RoboCup_2016_-_TDP_CMDragons.pdf
12. S. Rodríguez, E. Rojas, K. Pérez, J. López, C. Quintero, and J.M. Calderón. STOx's 2014 Extended Team Description Paper. Joao Pessoa, Brazil 2014. Available for download in http://robocupssl.cpe.ku.ac.th/_media/robocup2014:etdp:stoxs_2014_etdp.pdf
13. L. Yang, M. Nie, Z. Wu and Y. Nie. Modeling and Solution for Assignment Problem. International Journal of Mathematical Models and Methods in Applied Sciences. Issue 2, Volume 2, 2008.
14. R. Rojas, M. Simon and O. Tenchio. Parabolic Flight Reconstruction from Multiple Images from a Single Camera in General Position. In Chapter RoboCup 2006: Robot World Cup X. Vol 4434 of the series Lecture Notes in Computer Science pp 183–193, 2007.