INSTITUTO TECNOLÓGICO DE AERONÁUTICA
CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTÍFICO E TECNOLÓGICO - CNPq

CNPq
CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTÍFICO E TECNOLÓGICO

PROGRAMA INSTITUCIONAL DE BOLSAS DE INICIAÇÃO CIENTÍFICA - PIBIC

Projeto de Modelagem de Mecanismo de Roda de Geneva para Chute Angulado de Robô Small Size

Francisco Arthur Bonfim Azevedo

RELATÓRIO FINAL DE ATIVIDADES

Orientadora: Emilia Villani
Coorientadora: Daniela Vacarini de Faria

08 / 2019

INSTITUTO TECNOLÓGICO DE AERONÁUTICA
CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTÍFICO E TECNOLÓGICO - CNPq

CNPq
CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTÍFICO E TECNOLÓGICO

PROGRAMA INSTITUCIONAL DE BOLSAS DE INICIAÇÃO CIENTÍFICA - PIBIC

Final de Atividades

Projeto de Modelagem de Mecanismo de Roda de Geneva para Chute Angulado de Robô Small Size

São José dos Campos, 06/08/ 2019

Nome do aluno	Francisco Arthur Bonfim Azevedo
Assinatura do aluno	Francisco Arthur Bonfim Azevedo

Nome do orientador	Emilia Villani
Assinatura do orientador	

INSTITUTO TECNOLÓGICO DE AERONÁUTICA

PROGRAMA INSTITUCIONAL DE BOLSAS DE INICIAÇÃO CIENTÍFICA - PIBIC

Formulário de Aprovação de Relatório pelo Orientador

Relatório: ☐ Rel. Parcial ☒ Rel. Final

1- CONSIDERO O RELATÓRIO APROVADO COM BASE NOS SEGUINTES ASPECTOS

2- APRECIAÇÕES DO ORIENTADOR SOBRE O DESEMPENHO DO BOLSISTA NA EXECUÇÃO DO TRABALHO DE INICIAÇÃO CIENTÍFICA

Local e data:

Assinatura do Orientador:

Sumário

1 Resumo do Plano Inicial

O principal intuito dessa pesquisa é projetar e validar um sistema de chute angulado para o robô Small Size da equipe ITAndroids, grupo de robótica do ITA. O projeto é voltado para competições de futebol de robôs, RoboCup (Competição Internacional de Robótica) e LARC (Latin American and Brazilian Robotics Competition). O projeto se limita às condições impostas pelos regulamentos das competições que serão mais detalhadas na Seção 3. Além disso, existem as limitações de manufatura da equipe. A partir disso, foram levantados os seguintes requisitos para o projeto:

1. Ser fabricável considerando as capacidades de fabricação da equipe ITAndroids;
2. Ser de baixo custo;
3. Ser possível de ser manufaturado com os recursos disponíveis para a equipe ITAndroids;
4. Mecanismo juntamente com o robô deve ser capaz de realizar gols olímpicos no campo da Divisão B (Small Size League Technical Committee, 2018) da competição, que é a Divisão com campos menores e a qual a equipe participa atualmente.

Faz parte do seu estudo determinar o que o mecanismo precisa atender para realizar o requisito 4.

A categoria Small Size da ITAndroids estreou na competição LARC em 2017. Dessa forma, ela ainda está em seus estágios iniciais, partindo para a segunda versão do robô em 2019, com ajustes baseados na experiência da competição de 2018. Em 2017, que foi a primeira participação, o projeto não chegou a funcionar, pois o seu desenvolvimento não havia sido terminado. A versão de 2019 foi a primeira a receber algumas modificações já visando a implementação do chute angular no futuro: subiu-se as rodas, encurtou-se o mecanismo de chute do robô e ajustou-se outros parâmetros para que o chute não perdesse sua força com a mudança do mecanismo, para facilitar o mecanismo giratório que será inserido nele. Na Figura 1 é possível ver a primeira versão do robô feito pela equipe.

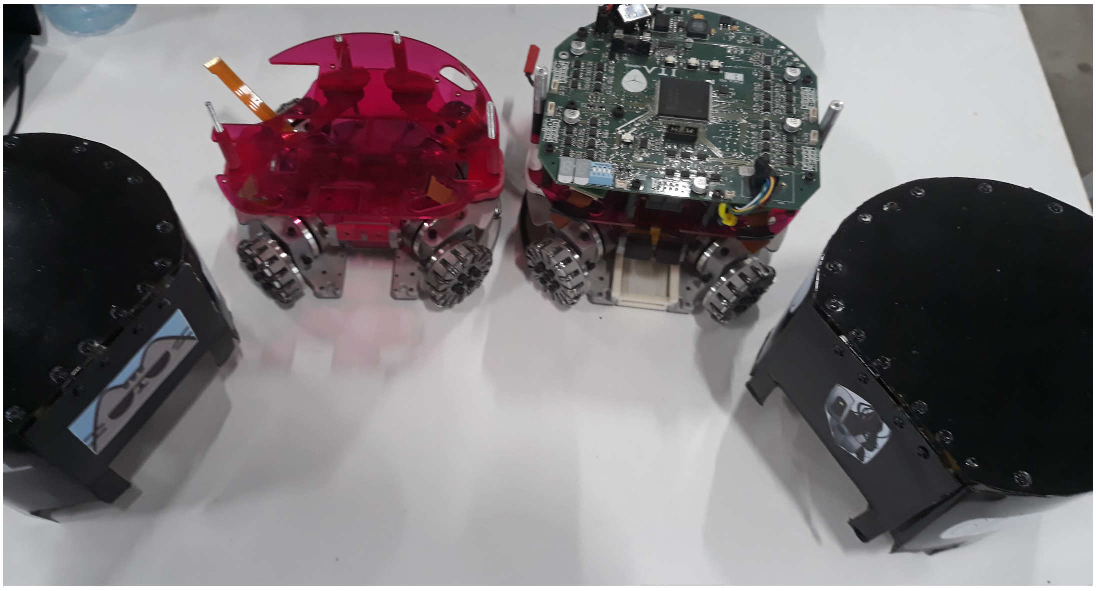


Figura 1: Dois robôs da versão 2018 durante a competição. A capa que protege os robôs foi retirada para melhor visualização dos seus sistemas interiores.

Definidos os requisitos do projeto, decidiu-se que primeiramente seria feito um estudo sobre dados históricos de outros times que projetaram o chute angular para o robô, a partir disso seria escolhido o melhor mecanismo, estimaria-se, através de modelagens, os parâmetros de projeto para o mecanismo escolhido. Então a partir disso, será feito o design do mecanismo completo em CAD. Com isso, partiu-se então para a manufatura do primeiro protótipo, eventuais iterações e por fim a validação do projeto.

2 Summary of Activities Performed

The main advantage of the angled kick device is that it makes the kick less predictable, so teams that consider that the robot kicks is aligned with the robots front hardly will predict where the robot is aiming, misleading the opponent. Also, using it combined with the dribbler, it is possible to make curved kicks, that is extremely difficult to predict, since the curve that defines the trajectory of the ball is a solution of a non linear ODE, that depends of the velocity of the kick, angular slope of the robot and velocity of ball's rotation on the field applied by the dribbler. In addiction, since this mechanism is very recent in the competition, and the majority of the teams use only the straight kick, the most of the teams on the competition do not consider it on the strategy algorithm, making it almost uncounterable.

Also, to contour a adversary usually it is used the chip kicker. But in situations that the opponent is too close, it is ineffective, since the is a minimum height needed by the chip kicker to be effective. As shown in Fig. 2, to overcome that, may be used the curved kick to make a pass, as we call curved pass. The curved kick situation may be seen in Fig. 3 and one of the most impressive use of the curved kick may be seen in the Fig. 4, as we call the Olympic goal.

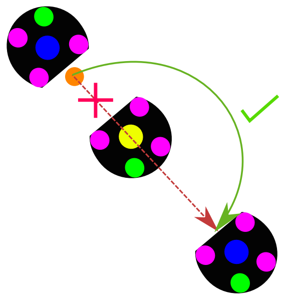


Figura 2: Curved pass. Straight pass trajectory in red and curved pass trajectory in green.

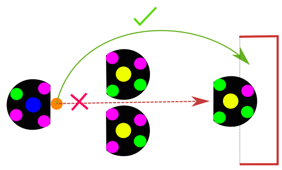


Figura 3: Curved kick. Straight kick trajectory in red and curved kick trajectory in green.

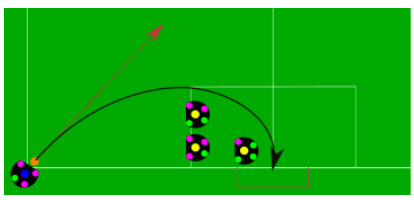


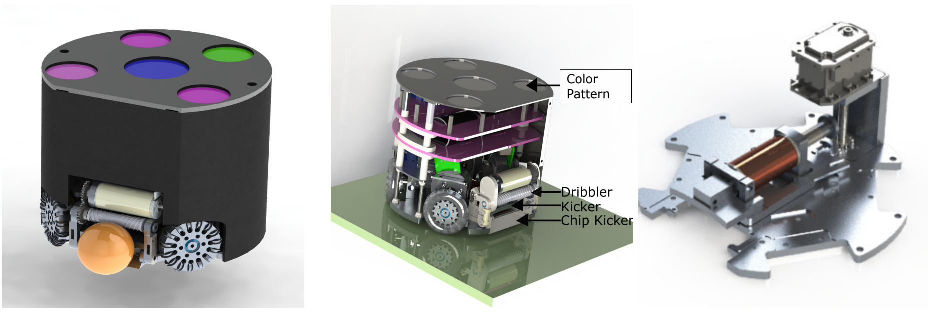
Figura 4: Olympic goal. Curved kick trajectory in black.

As said before and will be shown, the trajectory of the ball is a solution of complex nonlinear ODEs that are solved numerically. But the solution of that problem give the position on the Cartesian's plan given the velocity of the kick, the slope and angular velocity of the dribbler, but, if it was need the opposite? To make the precise kick, it is needed to aim in some point of the plan, than apply the velocity, slope and angular velocity that is needed, for example, to make a curved pass aiming in a ally. Obtain that is far from simple, requiring the inverse solution of the problem, making it even more complex and costly computationally. To solve this problem, was used a shallow neural network Goodfellow et al. (2016) that was trained with cases of the parameters of the kick and the position the ball reached. It prevents from needing a mathematical model of the inverse problem and make the results quicker for the robot, what is very important since the algorithm runs in real time during the match. The numerical solution of the equations, the neural network and the simulation was made on the software MATLAB.

3 Description of the problem

The Small Size League (SSL) is a robot soccer competition of omnidirectional robots with matches of two teams of 6 robots, for the division B, or 8 robots, for the case of division A Small Size League Technical Committee (2018). The rules establish that the robots must fit in a cylinder of 180 mm diameter and 150 mm height. Generally, the robots have 4 wheels, with several little rollers, that allows the omnidirectional movements of the robot. The vision system is made of cameras positioned on the ceiling of the field and vision algorithms capable of identify every robot because of a color pattern on the top of the robots, measuring its position and angular orientation. The most of the processing, like decision making and path planning algorithms, occur in a central computer that communicates with the robots via radio. The robot have two kicker systems, with a high kick, called chip kicker, and a low kick, called kicker. These devices are largely responsible for the robot's passes and shoots. Other important device of the robot is the dribbler, based on the rotation of a roller, that rotates the ball to high speeds in order to keep it close to the robot's body while it is moving, thus allowing the robot to effectively dribble.

An important characteristic of the robot is the ability of make straights pass and kicks using the chip kicker and the kicker devices. This paper documents the project of a neural network for the ITAndroids team to decide the kicking parameters for a curved kick, like velocity of the kick, angular slope of the robot and velocity of ball's rotation on the field applied by the dribbler. The mechanism that allow the curved kick was designed by the team based on the device of the team Op-AmP Yoshimoto et al. (2017). ITAndroids is the robotics competition group from Instituto Tecnológico de Aeronáutica (ITA). The group also has experience with other robotics competitions, namely RoboCup's Soccer 2D, Soccer 3D and Humanoid Kid-Size leagues. The team's Small Size robot may be seen in the Fig 5a, its kicker and chipper devices in the Fig 5b and the curved kicking device designed by the team may be seen in the Fig 5c.



(a) General vision of the robot. (b) Systems of the robot. (c) Designed mechanism for the curved kick.

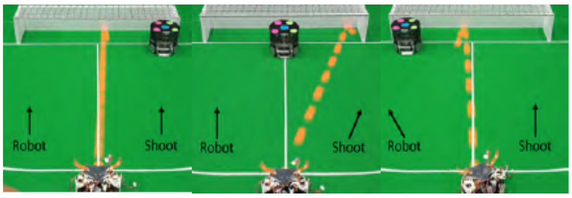
Figura 5: Small Size robot of the ITAndroids team.

The kicker and chip kicker devices are based on a ferromagnetic part being expelled by a solenoid subtly by the discharge of a capacitor. This ferromagnetic part hits the ball, transferring linear momentum, accelerating the ball. The main difference from the low kick to the high kick is the slope of the hit. The curved kicker device uses a Geneva drive to, rotating the kicker, make the ball be launched in a angled trajectory, as may be seen in the Fig. 6, that show tests on the robot's kicker of the Op-AmP team Yoshimoto et al. (2017). Combining that with the dribbler, it is possible to the ball to make a parabola-like trajectory.

4 Results

4.1 THE NEURAL NETWORK

To choose what neural network would be the most appropriate to solve the problem, we first considered the kind of problem that we wanna solve: to establish a simply correlation between two group of parameters, $V_{kick}, \omega_{dribbler}, \theta$ and x_{target}, y_{target}, being x_{target} and y_{target} the coordinates of the target that we wanna to hit with the ball. For a



(a) straight kick. (b) Diagonal kick 1. (c) Diagonal kick 2.

Figura 6: Results of the angled kick of the Op-AmP team.

problem like that, was choose the Shallow Neural Network Goodfellow et al. (2016), that is less complex than a Deep Neural Network and can easily solve the problem.

With the neural network chosen, we created the data that will be used to train the network. Using the MATLAB's function ODE45, was solve for a large number of combinations of $V_{kick}, \omega_{dribbler}, \theta$, obtaining the respective positions that the ball hit.

To take the coordinates from the simulation a simplification was made: we considerate that the robot is always on the origin of the coordinate system and the target is laying on the x axis, ergo, the y_{target} from the simplified system will always be zero. This reduces the number of variables on the coordinate system from four, considering x and y from the position of the robot and the x_{target} and y_{target}, to one, x'_{target}. Obviously, that is a consideration that would make the curved pass and curved kick to be extremely imprecise. The strategy to use it was: all the data was trained on the simplified system, and for the result, we take the real position, make a translation and a rotation on the coordinates, obtain the position on the simplified system, and use it on the neural network, obtaining the values of $V_{kick}, \omega_{dribbler}, \theta$ that is independent of the position of the robot, and then apply that values to the real coordinate system. The Fig. 7 illustrates that procedure.

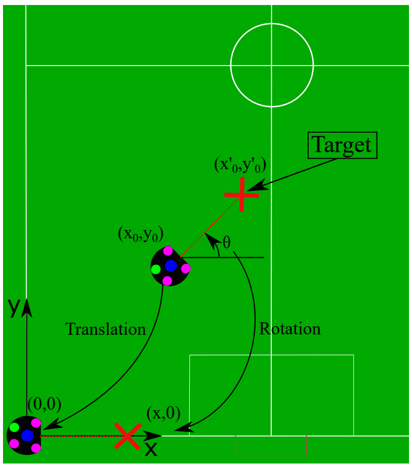


Figura 7: Coordinate system transformation between real system and simplified system.

Then, a matrix to train the neural network was made, with a large number of data of $V_{kick}, \omega_{dribbler}, \theta$ and x'_{target}, the target position on the simplified system.

Summarizing, the neural network used was a SNN (Shallow Neural Network), with a two-layer feed-forward network. The network has one hidden layer with 30 neurons. The input of the network is the position of the target on the simplified coordinate system x'_{target} and the outputs the parameters of the kick $V_{kick}, \omega_{dribbler}, \theta$. The diagram provided by the training of the network on MATLAB with the indicated inputs and outputs may be seen in the Fig. 8

With the matrix of train and the neural network set, the simulations of the results was made.

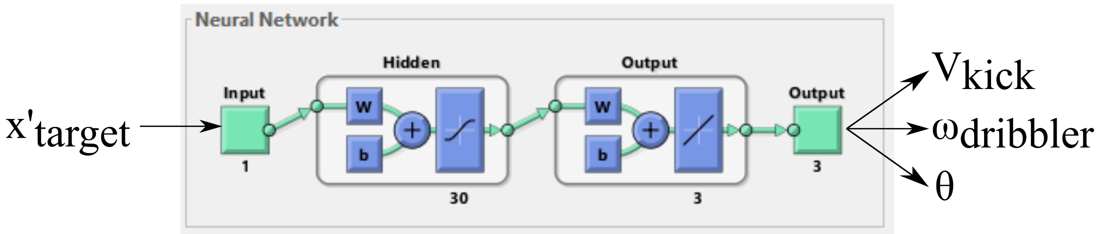


Figura 8: SNN diagram on MATLAB with the inputs and outputs.

4.2 SIMULATION RESULTS

A simulation with the field of the competition was made on MATLAB to a visual feedback of the results. The black circle represents the robots, the circle inside the black circle represents thee team of the robot, blue for ally and yellow for adversary, the orange circle represents the ball, the blue line the trajectory of the ball, the black lines and circles are the field marks, the blue point is the target of the kick and the dotted circle is the admissible region for the fourth requirement. The Fig. 9 shows the legend for the elements of the simulation. Fig. 10 and 11 show results for the case of the Olympic goal, Fig. 12 and 13 show results for the case of the curved pass and Fig 14 and 15 show results for the case of the curved kick.

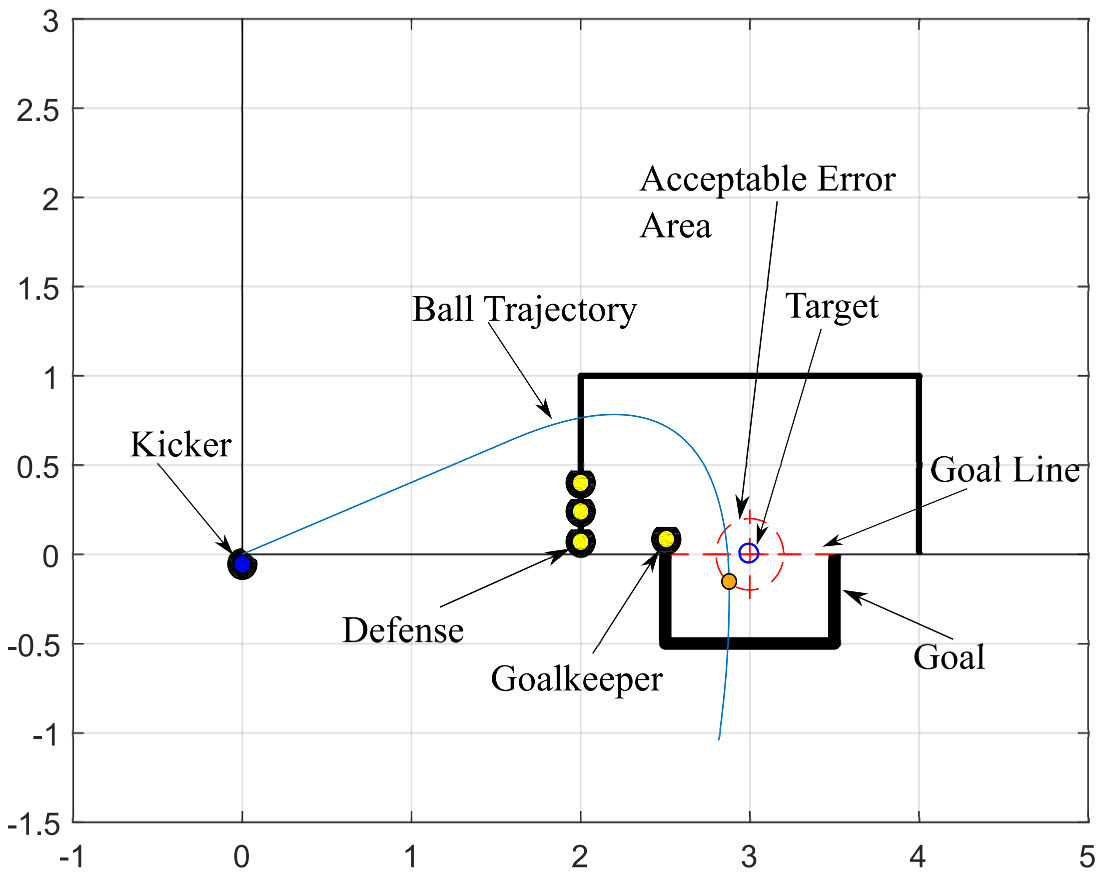


Figura 9: Elements in the simulation.

As may be seen in the results of the simulation, the results converged with the required precision and all the requirements was fulfilled.

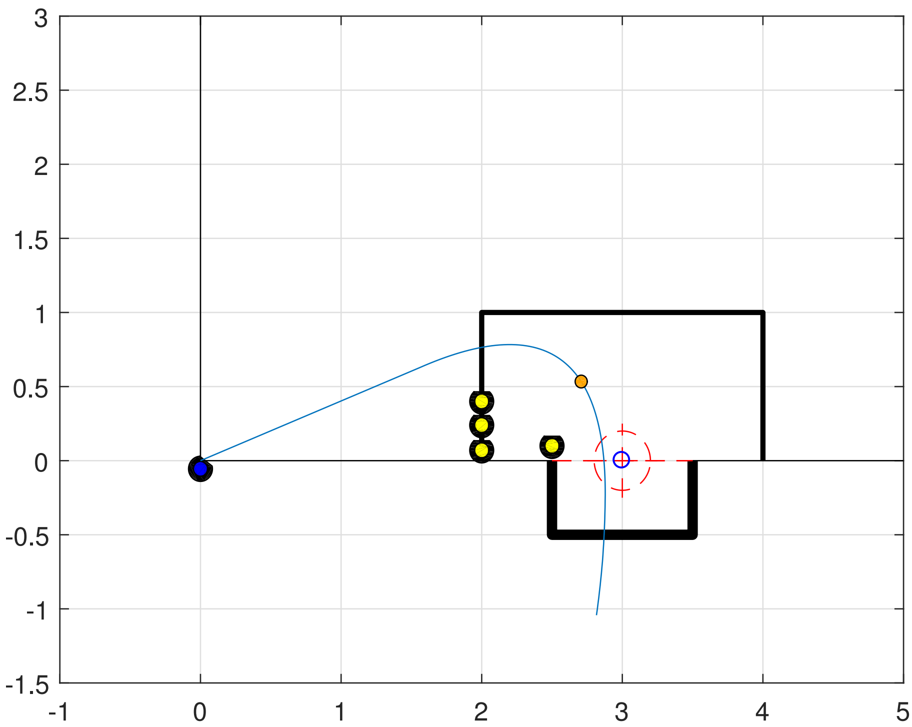


Figura 10: Olympic goal with robot in origin and target point $(3, 0)$.

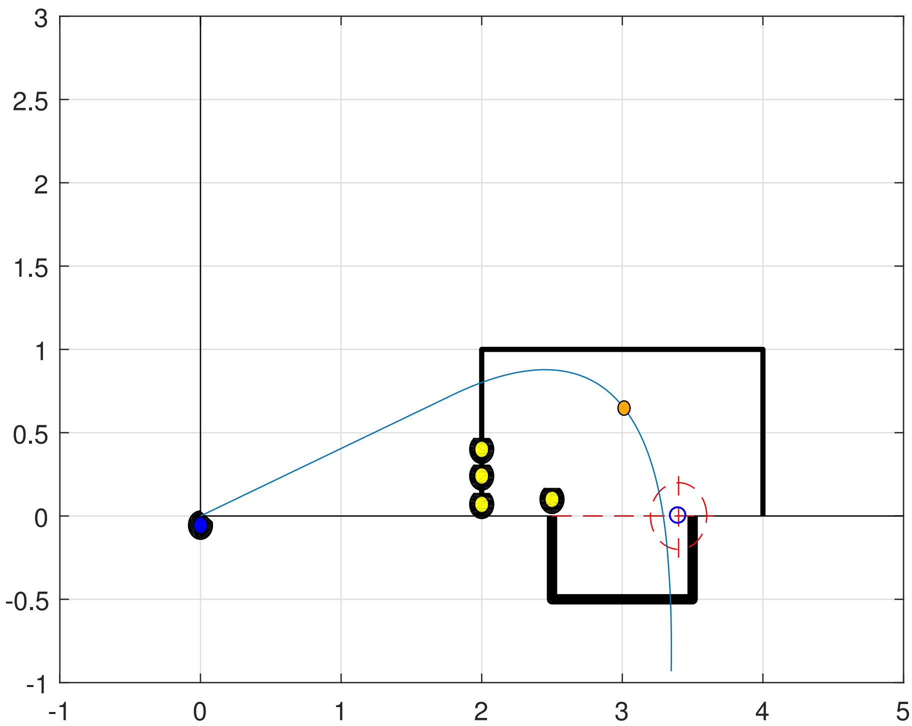


Figura 11: Olympic goal with robot in origin and target point $(3.4, 0)$.

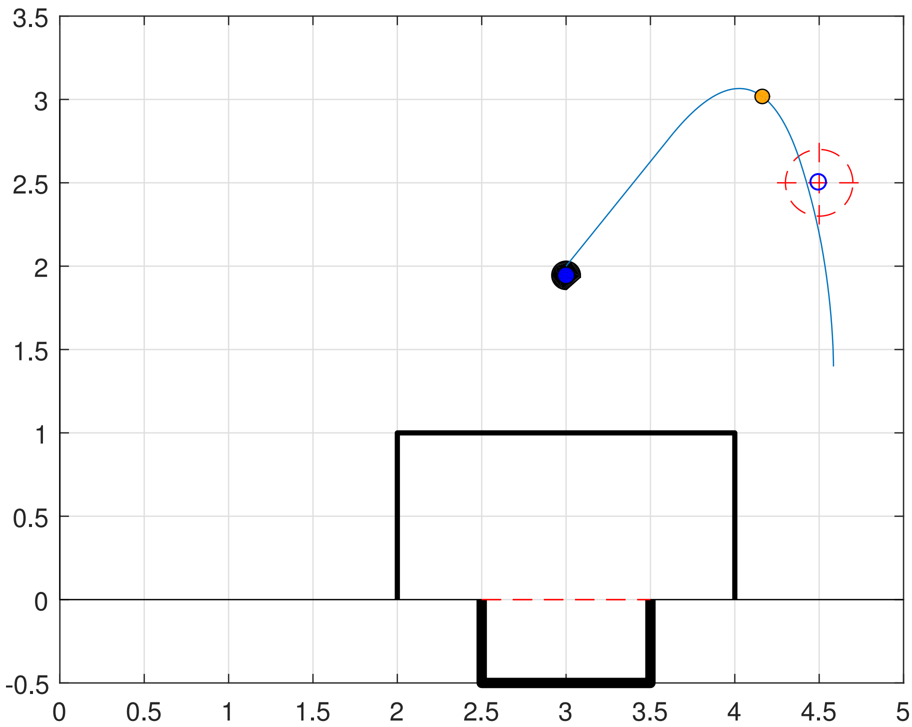


Figura 12: Curved pass with target point $(4.5, 2.5)$ and robot in $(3, 2)$.

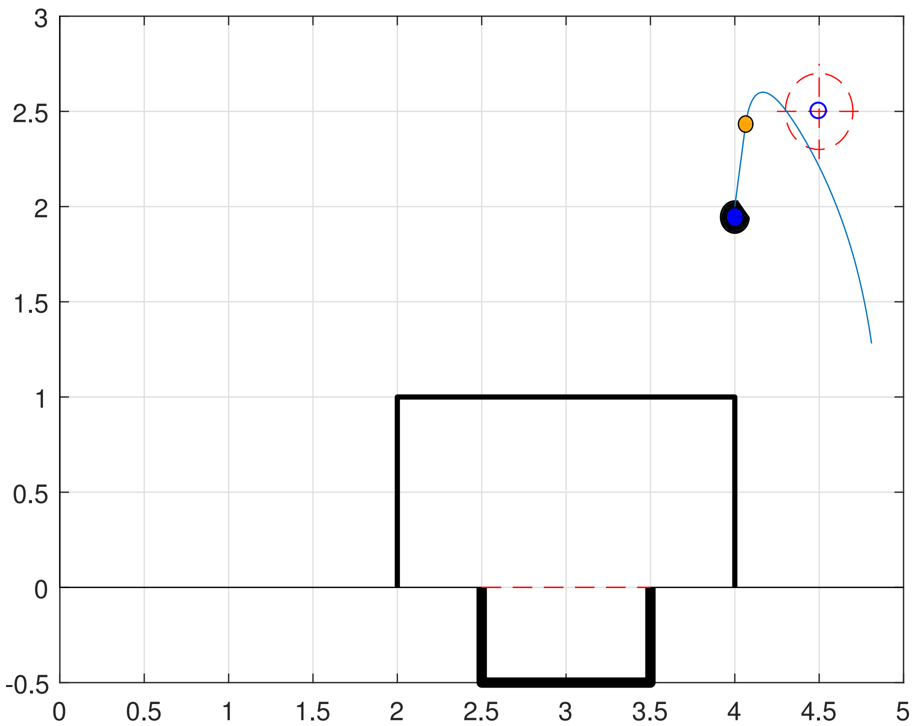


Figura 13: Curved pass with target point $(4.5, 2.5)$ and robot in $(4, 2)$.

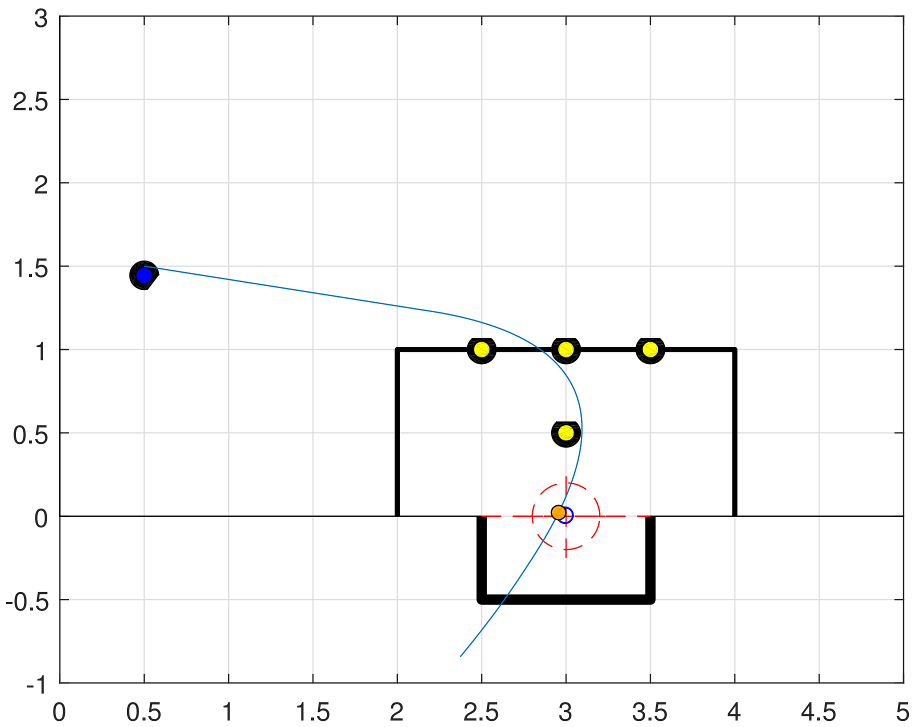


Figura 14: Curved kick with robot in $(0.5, 1.5)$.

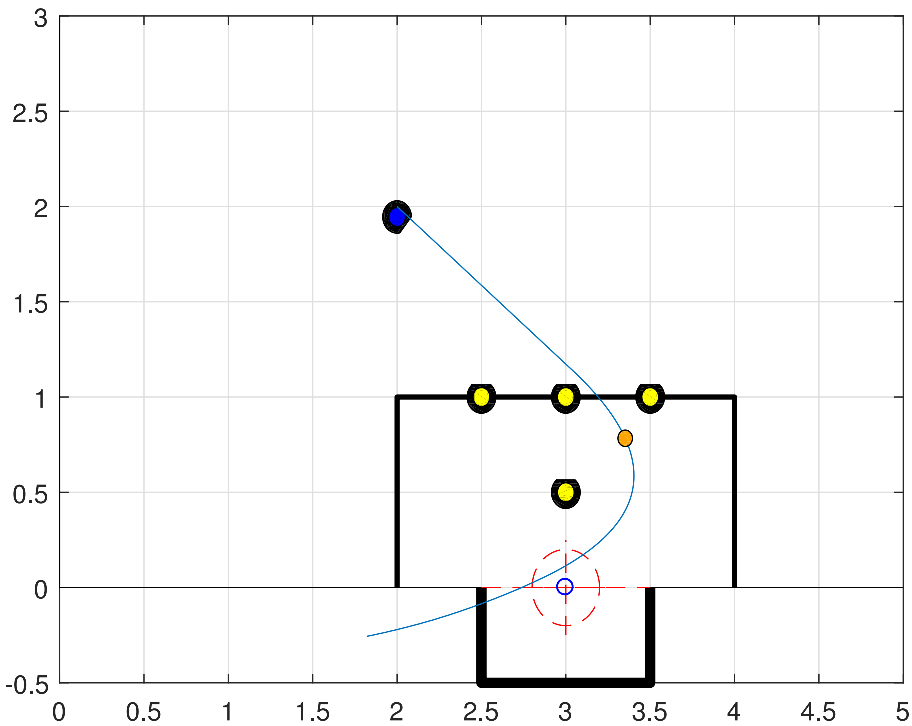


Figura 15: Curved kick with robot in $(2, 2)$.

5 Conclusion

As shown in this work, the neural network worked very well with the problem of the curved kick. The results of the simulation shown that the solution converged for a robot that was capable of, autonomously decide the parameters for a kick that hits the desired target.

As a future research direction, we are looking to optimize the code and implement on the real robot, testing it, obtaining new data to train the neural network, making the real robot more precise. For the simulation, it is intended to make it more robust and precise, training it with more data for better results.

6 Agradecimentos

Gostaria de agradecer ao CNPQ (Conselho Nacional de Desenvolvimento Científico e Tecnológico) por conceder a bolsa de iniciação científica que permitiu realizar essa pesquisa, à professora orientadora Emilia Villani por me acompanhar e guiar nesse processo, à coorientadora Daniela Vacarini de Faria por acompanhar e ajudar a guiar esse projeto, ao coorientador e atual presidente da ITAndroids professor Marcos Ricardo Omena de Albuquerque Máximo por todo seu trabalho em conjunto com a equipe e pelo apoio ao projeto, ao membro da ITAndroids e atual líder da categoria Small Size da ITAndroids Eric Pereira Queiroz Moreira pela ajuda ao longo deste trabalho e à Victória Geisa Brito de Oliveira por ter sempre me apoiado e estado ao meu lado. Por fim quero agradecer a toda a equipe ITAndroids por ter ajudado em muitas etapas, à ITAex por financiar a iniciativa e tornar a compra de boa parte do material possível e ao ITA por disponibilizar laboratórios de alto nível que foram de alta valia para o projeto e por ter comprado os servos MX-28AT para o projeto e a empresa Polimold, patrocinadora da equipe ITAndroids, que usinou as peças do robô Small Size da equipe.

Referências

Small Size League Technical Committee, Laws of the RoboCup Small Size League 2018, RoboCup 2018 (2018).

I. Goodfellow, Y. Bengio, A. Courville, Deep learning, 2016.

T. Yoshimoto, T. Horii, S. Mizutani, Y. Iwauchi, Y. Yamada, K. Baba, S. Zenji, OP-AmP 2017 Team Discription Paper, Technical Report, 2017.