INTEGRATING SOFT COMPUTING AND ACTIVE LEARNING STRATEGIES IN UNIVERSITY-LEVEL ROBOTICS EDUCATION INTEGRANDO COMPUTAÇÃO SOFT E ESTRATÉGIAS DE APRENDIZAGEM ATIVA

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ABSTRACT: This study presents the implementation of robotics instruction within the undergraduate Mechatronics Engineering program at the Federal University of Technology – Paraná (UTFPR), Brazil, emphasizing the integration of intelligent computational systems and active learning methodologies. The proposed approach emerged as a response to the pedagogical challenges posed by the COVID-19 pandemic. While no comprehensive statistical analysis of student satisfaction was conducted, qualitative observations suggest a high level of student engagement and interest. This is evidenced by the initiation of several undergraduate thesis projects that originated from seminar discussions within the course. The methodology adopted focuses on problem-based learning, supported by the presentation and explanation of computational models, which students then applied in their own experiments. It is important to note that the application of intelligent systems was not mandated for all problems discussed, allowing for methodological flexibility. Individual results and reflections are explored throughout the paper. The article concludes with final considerations and directions for future work.
KEYWORDS: Robotics, intelligent computer systems, project-based learning.

NO ENSINO DE ROBÓTICA DE NÍVEL UNIVERSITÁRIO INTEGRANDO COMPUTAÇÃO SOFT E ESTRATÉGIAS DE APRENDIZAGEM ATIVA

RESUMO: Este estudo apresenta a implementação do ensino de robótica no curso de Engenharia Mecatrônica da Universidade Tecnológica Federal do Paraná (UTFPR), Brasil, destacando a integração de sistemas computacionais inteligentes e metodologias ativas de aprendizagem. A abordagem proposta surgiu como uma resposta aos desafios pedagógicos impostos pela pandemia da COVID-19. Embora nenhuma análise estatística abrangente da satisfação dos alunos tenha sido conduzida, observações qualitativas sugerem um alto nível de engajamento e interesse dos alunos. Isso é evidenciado pelo início de vários projetos de tese de graduação que se originaram de discussões em seminários dentro do curso. A metodologia adotada concentra-se na aprendizagem baseada em problemas, apoiada pela apresentação e explicação de modelos computacionais, que os alunos então aplicaram em seus próprios experimentos. É importante notar que a aplicação de sistemas inteligentes não foi obrigatória para todos os problemas discutidos, permitindo flexibilidade metodológica.

Resultados e reflexões individuais são explorados ao longo do artigo. O artigo conclui com considerações finais e direções para trabalhos futuros.
PALAVRAS-CHAVE: Robótica, sistemas de computadores inteligentes, aprendizagem baseada em projetos.

INTRODUCTION

Due to several applications using robotics, it is possible to find plentiful research on the subject, such as industrial production, space exploration, manufacturing in the industry, construction of houses, and even medicine—the motivation of the research in the development of engineering areas related to robotics. Among the related areas, a possible contribution of this research is through active methodologies, mainly based on projects, to use other areas as intelligent computational systems to solve classic robotics problems (Siciliano; Khatib, 2016).

In this context, the evolution of science and technology has brought the sophistication of the notion of robots. We can define robots as agents that can feel and act in the environment to complete their goals, and for that, they perform manipulations in the physical world, equipped with effectors such as legs, wheels, joints, and claws (Maja, 2008).

The application of intelligent computer systems and expanding and stimulating the horizon of solutions for students reinforces the importance of this discipline that, among other areas such as the Internet of Things (IoT), Big Data has brought.

Improvements in production processes include quality, precision, and standardization. For example, with the help of artificial intelligence technology, big data technology, 5G, and other new technologies will soon shift from connecting people-oriented to connecting to the IoT (Zhang, 2021).

This work describes the results obtained in an exploratory study developed with a group of young digital natives while interacting in games connected to the Internet. The concept of digital natives was coined by educator and researcher Marc Prensky to describe the generation of young people born from the availability of fast and accessible information on the extensive computer network – the Web (Prensky, 2001).

To mitigate the situation described above, the authors used active methodologies in teaching robotics through problems, projects, games, among others, aiming to make students capable of building conceptual, procedural, and attitudinal learning through proposed issues that expose them to situations motivators, preparing students to the labor market.

This research uses in the Mechatronics Engineering course at a Federal University in Brazil, in which classic problems of the robotics discipline were presented solutions using intelligent computational systems, e.g., Artificial Neural Networks (ANNs) and Genetic Algorithms (GA) in the inverse kinematics solution; ANNs for camera calibration, and fuzzy logic in solving the problem of an autonomous mobile robot. Students are expected to be motivated by the correlation and multidisciplinary approach between the two areas. However, problem-solving modes make the course non-trivial to students. The results obtained indicate that improvement in teaching practice is necessary.

This work is divided as follows. Chapter 2 makes a brief foundation of multi-disciplinarity and some similar techniques. Chapter 3, on the other hand, addresses the problem of autonomous robotics and some of its foundations and results. It also addresses the calibration of cameras and the solution of inverse kinematics. Chapter 4 discusses and analyzes the results and methodologies used. Finally, the authors present the conclusion and address future works.

MULTI-DISCIPLINARITY FUNDAMENTALS AND CONCEPTS

Transformations in society cause significant impacts on schools and the teaching-learning relationship. Such modifications require changes that allow quick and effective responses to the demands of students, who live in an increasingly competitive environment, with the intensification of unpredictability in the business world and with technological evolution. A new configuration of university students, formed by a generation whose information is presented through various tools and in an exaggerated volume, arrives at higher education institutions to prepare for the professional market they wish to work in. It is a digital generation, in which it develops individuals who existed born between the beginning of the 80's and the end of the 90's, whose growth paralleled the evolution of the digital world.

For educator and researcher Marc Prensky, these young people are used to obtaining information quickly and tend to first resort to digital sources and the Web before looking in books or print media. Because of these behaviors and attitudes and because they understand digital technology as a language, Prensky describes them as Digital Natives since they "speak" the digital language from birth (Prensky, 2001).

The purpose and motivation of this work are to use active methodologies to motivate and learn basic concepts such as inverse kinematics, camera calibration, and the first version of an autonomous valet, robotics concepts, and fundamentals through solutions by intelligent computational systems.

It is well known that inter and transdisciplinary research has three essential functions; to create the original idea and to solve problems whose solutions are beyond the scope of a single discipline or field of research practice (Brammer, 2012). However, documents and Related reports speak of several terms such as disciplinary, interdisciplinary, transdisciplinary, so the consensus of these terms often depends on theoretical and cultural contexts (Pohl, 2011).

In the present paper, multidisciplinary is the concept that most suits the robotics teaching proposal. Dua, according to the concept of multidisciplinary, information from several subjects is used to study a specific element without the concern of interconnecting the topics. Thus, each subject contributed with the information detailed to its field of knowledge without considering an integration between them. This relationship between disciplines is deemed ineffective for knowledge transfer since it prevents a connection between the various abilities.

Another relevant area, more specifically in education, can be cited in work *(*Ros *et al., 2020)*, which included technology and circumscribed cooperative methodologies and motivated this present research. Figure 1 shows the main areas of knowledge used in the robotics teaching proposal of this article.

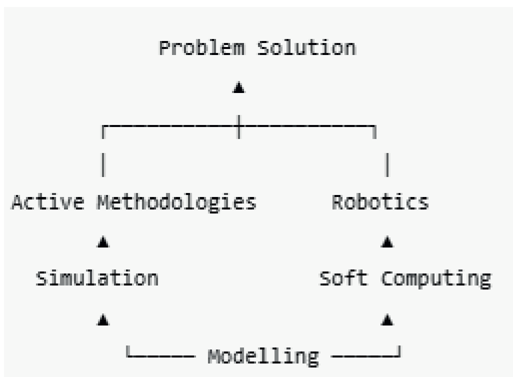

Figure 1: Multidisciplinary of the present research.

Source: Authors (2025).

In general, an active methodology is used to conceptualize the solution form. The robotics discipline has some problems, preferably classic ones, to be solved by soft computing. However, the model and simulation are not yet necessary to at least validate the difficulties. The most relevant areas of knowledge are the application area of the robotics discipline: Intelligent Computational Systems, Active Methodologies, Modeling, and Simulation to validate the solution of the proposed problem. These concepts are worked on in the domain of teaching, how they complement and connect each other. However, electronics also added to an Arduino in a course conclusion work.

APPLICATION OF EXPERIMENTS

The concepts addressed in the set of interconnected disciplines advance beyond foundational topics, delving into more complex domains such as robotic vision and the inclusion of path planning algorithms, among others. Despite this increased depth, the approach can still be considered **multidisciplinary**, as the themes remain situated within the broad domain of computer systems. A notable example of *transdisciplinary* practice was identified in a project conducted by another university laboratory, which developed a dancing robot inspired by the intersection of arts and musical cultures. This initiative integrated engineering with humanistic disciplines, crossing the boundaries of traditional academic silos.

These cases are significant because they serve as references for enhancing multidisciplinarity in engineering education, which is one of the central aims of this scientific investigation. Ultimately, such initiatives often culminate in undergraduate thesis projects or are disseminated through scientific publications and presentations, many of which are derived from the research efforts of the **Advanced Automation and Robotics Laboratory (AARLab)** at the Federal University of Technology – Paraná (UTFPR-CP).

Among the intelligent computational models explored in this context, **Dynamic-Fuzzy Cognitive Maps (D-FCMs)** stand out. These models synthesize the adaptive capabilities of **Artificial Neural Networks (ANNs)** with the interpretability of **Fuzzy Logic** *(*Mendonça *et al., 2020)* e (Mendonça et al., 2019), offering a promising alternative for addressing challenges in autonomous robotics. While the full breadth of techniques within Artificial Intelligence is beyond the scope of this paper, a conceptual overview of D-FCMs is provided as a foundational element for application development.

Fuzzy Cognitive Maps (FCMs) are characterized by their flexibility and low computational complexity (Souza et al., 2017), making them applicable to various fields, including control systems, robotics, and even social modelling (Papageorgiou, 2017). However, a significant limitation of traditional FCMs is their static nature — they assume that all causal relationships occur simultaneously, without accounting for the temporal evolution of states. This limitation has spurred extensive research into dynamic extensions of the model, leading to the development of **Dynamic-Fuzzy Cognitive Maps (D-FCMs)**.

The specific D-FCM model proposed in this work enhances traditional FCMs by dynamically updating the weight matrix based on real-time sensor inputs and the robot's current behavioural state (Mendonça *et al.*, 2019). In essence, the system adapts its internal structure in response to environmental stimuli, enabling more nuanced and context-sensitive behaviour. This dynamic updating process follows the principle described by ***Mendonça*, Arruda, and Neves-Jr (2011)**, where the evolution of the robot's internal state is driven by sensor-derived events, as illustrated in Figure 2.

- (1) RS (Right Sensor)
  - Influence:
    - $W_{14} \rightarrow$ (4) **W_D**
    - $W_{15} \rightarrow$ (4) **W_D**
- (2) FS (Front Sensor)
  - Influence:
    - $W_{24} \rightarrow$ (4) **W_D**
    - $W_{25} \rightarrow$ (5) **W_E**
- (3) LS (Left Sensor)
  - Influence:
    - $W_{34} \rightarrow$ (5) **W_E**
    - $W_{35} \rightarrow$ (5) **W_E**

Figure 2: D-FCM for mobile robot coordination.

Source: Authors (2025).

The concepts of input and output are similar to the original proposal (Kosko, 1986). However, this initial version of the D-FCM for this problem has variable and non-fixed cause and effect relationships as in the classic version. A priori simulations were performed until all landmarks were collected, as shown in Figure 3.

In this Figure, it is noteworthy that there was no collision, and in three different scenarios, the objective was achieved without human intervention (Russel; Norvig, 2009), which suggests that the robot or mobile agent was autonomous. This prototype uses ultrasound sensors combined with a time-of-flight laser and a color sensor underneath for target location.

[Initial] → [Enhanced Exploration] → [Final Optimization]

Path 1 Path 2 Path 3

Random trajectories Active sensors and chaos Efficient paths

Figure 3: Simulations in 3 environments (paths).

Source: Authors (2025).

In the context of multi-disciplinarity, some problems were treated with non-traditional methods and, in some cases, compared with traditional methods, such as the inverse kinematics problem.

Forward kinematics is relatively more straightforward with a vector of angles it is possible to find the position of the actuator.

However, in practice, the important thing is the opposite: to find a vector of angles that determines the final position of the actuator. Therefore, the proposed solution of this investigation is not optimal but plausible. For example, in a course completion project, an autonomous arm had an accuracy of a few millimeters.

Indeed, this would not be a necessary precision for a surgical arm; for example, for industrial applications such as manipulating objects, the use of Genetic Algorithms or artificial neural networks, as will be addressed in this research, would be a good solution.

To solve inverse kinematics, algebraic, geometric, and iterative methods are commonly applied in literature. However, when referring to handlers, the use of these methods becomes inappropriate due to the complex algebraic solution. An alternative approach is the application of ANN. This method is effective in dealing with a manipulator by being able to learn through training and being flexible (Haykin, 2009).

Generally, to achieve the necessary precision for specific tasks. Thus, a handler with a degree of freedom (DOF) number more significant than required to perform a task is used (Xiao; Zhang, 2014). A robotic manipulator with 3 DOF is used to reach specific points in this work, and the environment is a two-dimensional space (2D).

Related work is presented in (Tian; Collins, 2004), which proposed a genetic methodology for trajectory planning. Algorithms also plan the trajectories of a manipulator in a workspace with obstacles. The goal is to find an optimal solution in the workspace. The trajectory is represented by polynomials that have their formulas written for internal points interpolated with parameters of the GA.

By defining the original position of a manipulator at one of its ends represented by O and the desired position at the other end of the manipulator represented by P, there can be several solutions that satisfy the joint angle configuration. In other words, there are multiple solutions in the inverse kinematics resolution related to redundant solutions, as shown in Figure 4; for simplistic manipulators of 2 DOF, we can already observe two different solutions that grow exponentially according to the number of DOF (Dalmedico *et al.*, 2004).

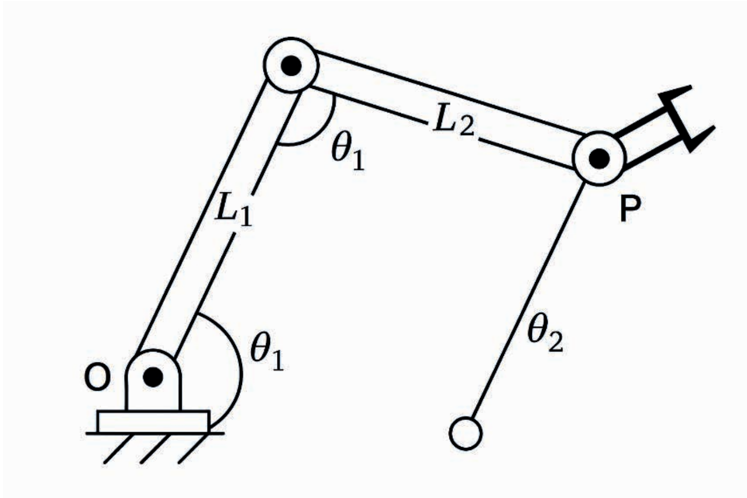

Figure 4: Two possible trajectory solutions for a robotic arm.

Source: Authors (2025).

Figure 5 shows a workspace generated with a mass of points for ANN learning and some test points. As for the GA, the most important thing is to try to use an initial population close to the problem's solution for faster convergence and possibly a good result. In the case of GA, it is not easy to make any statement due to the stochastic nature of part of the algorithm. In this problem, a canonical version with real values was used, with five elements and a population between 20 and 40 fixed with less than 5% low mutation.

In this work, the ANNs are multi-layer perceptron's with one or two hidden layers with the Levenberg-Marquardt training algorithm. In this case, some parameters were relaxed to find adequate solutions to the proposed problems and for students to understand how to work with this tool by varying parameters and analyzing the best possible results, remembering that the solutions cannot be defined as optimal (Haykin, 2009).

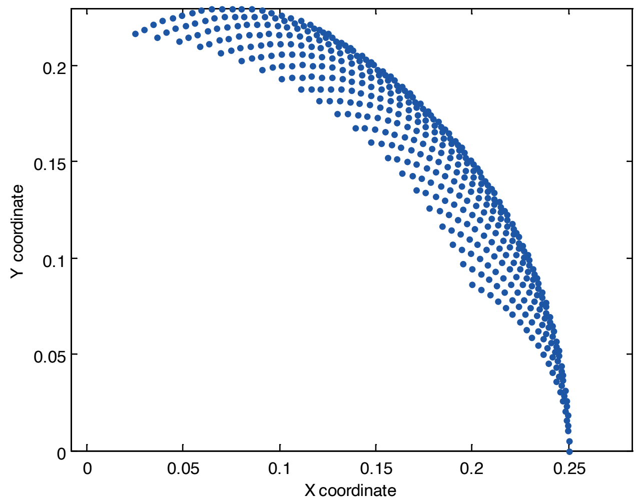

Figure 5: Robotic arm workspace representation.

Source: Authors (2025).

In this experiment, 40 ANNs were compared, and the results of the best solution are shown in Table 1 and Figure 6.

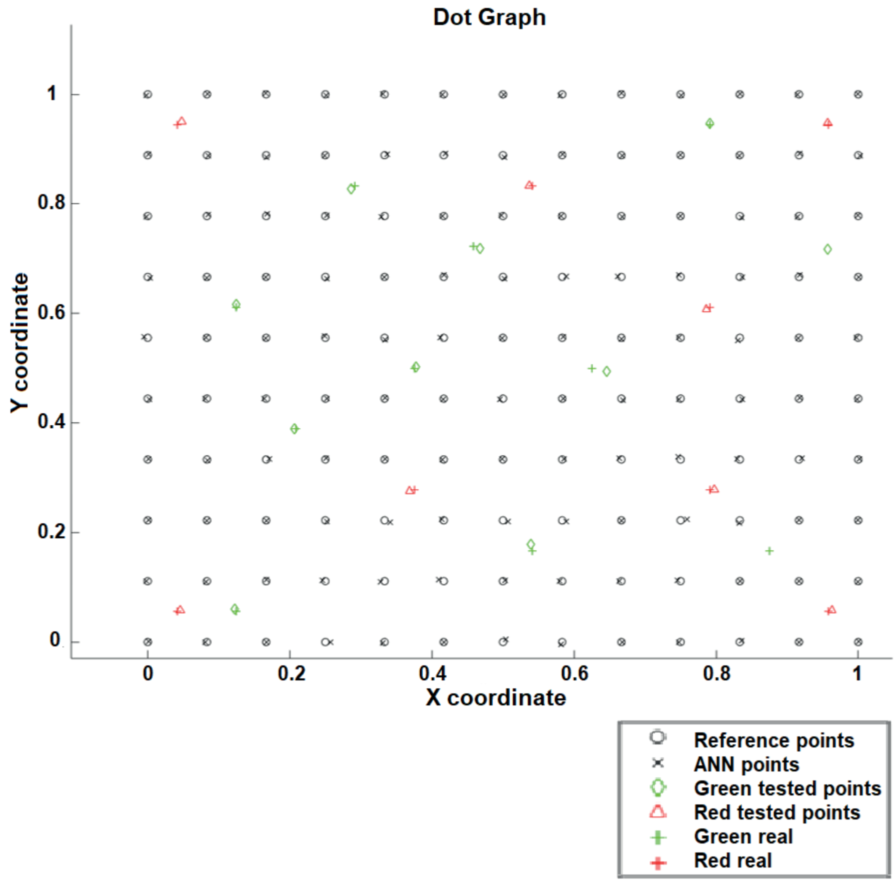

Figure 6: ANN results.

Source: Authors (2025).

The results of the GA approach can be seen in Table 2. The ANN have 20 neurons in the hidden layer and 2 output neurons (angle of both arms), finishing the simulation with 4239 epochs, with a stopping criterion of 10-6 mean squared error. The GA used a single tournament of 5 individuals, with the same stop criterion of the ANN.

Target values (+)		**Obtained values (squares)**		**Absolute Error**		**MSE**
x	**y**	**x**	**y**	**x**	**y**	
0.0417	0.0556	0.0459	0.0577	-0.0042	-0.0022	0.0048
0.9583	0.0556	0.9629	0.0575	-0.0046	-0.0019	0.005
0.375	0.2778	0.3685	0.2754	0.0065	0.0023	0.0069
0.7917	0.2778	0.7977	0.2786	-0.006	-0.0008	0.006
0.7917	0.6111	0.7863	0.6069	0.0053	0.0042	0.0068

Table 1. ANN results.

Another application of this work is to apply in-camera calibration. Computer vision is related to how a computer, or any machine can see through the environment. Therefore, computer vision science approaches image processing technologies to extract and process important characteristics from objects and their environments. For example, the usual information that can be easily extracted is the position of a given object, expressed as global coordinates, in a reference system centered in the camera (Gonzalez; Woods, 2017).

Target values		***Obtained values***		***Absolute Error***		***MSE***
x	***y***	***x***	***y***	***x***	***y***	
0.125	0.0556	0.1224	0.0601	0.0026	-0.0046	0.0052
0.5417	0.1667	0.5389	0.1782	0.0027	-0.0115	0.0118
0.2083	0.3889	0.2068	0.39	0.0015	-0.0011	0.0019
0.375	0.5	0.3774	0.5021	-0.0024	-0.0021	0.0032
0.625	0.5	0.6456	0.494	-0.0206	0.006	0.0214
0.125	0.6111	0.1243	0.616	0.0007	-0.0049	0.005
0.4583	0.7222	0.4675	0.7183	-0.0092	0.0039	0.01
0.875	0.1667	0.9566	0.7172	-0.0816	-0.5505	0.5565
0.2917	0.8333	0.2863	0.8272	0.0053	0.0062	0.0081
0.7917	0.9444	0.7913	0.9468	0.0003	-0.0024	0.0024

Table 2. GA results.

In robotic vision, an essential task is to explore unknown areas. In this context, a guided system that uses computer vision to detect and recognize obstacles/or targets visually can be used to allow safe navigation. It can be developed using data information from display objects.

Besides, apply techniques cited in this work teaching Robotics. For example, another active methodology is used in the discipline, such as game-based learning in autonomous car strategy concepts using the state machine (Mendonça *et al.*, 2021).

CONCLUSION

The projects developed showed satisfactory qualitative results according to students' feedback, indicating the potential of active methodologies in robotics education. Although a formal statistical analysis was not conducted, it is estimated that approximately 90% of students evaluated the project-based activities positively, reinforcing the effectiveness of this approach for educational purposes.

Although the outcomes involving intelligent systems were not outstanding, they are considered consistent with the training objectives of the program, which focuses on industrial applications related to product manipulation.

For future work, it is proposed to carry out more rigorous quantitative analyses regarding student satisfaction, as well as to expand practical applications. The continued use of Artificial Intelligence techniques is also planned, especially by comparing the performance of Artificial Neural Networks (ANN) and Deep Learning in robotic arms with 3D simulations, considering the complexity and volume of training data involved.

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REFERENCES

BRAMMER, G. B.; VAN DOKKUM, P. G.; FRANX, M.; FUMAGALLI, M.; PATEL, S.; SKELTON, R. E.; MOMCHEVA, I. G.; NELSON, E. J.; WHITAKER, K. E.; LEJA, J.; LABBÉ, I. 3D-HST: **A Wide-Field Grism Spectroscopic Survey with the Hubble Space Telescope.** The Astrophysical Journal Supplement Series, v. 200, n. 2, p. 13, 2012. DOI: 10.1088/0067-0049/200/2/13.

DALMEDICO, J. F.; MENDONÇA, M.; SOUZA, L. B. de; BARROS, R. V. P. D.; CHRUN, I. R. **Artificial Neural Networks Applied in the Solution of the Inverse Kinematics Problem of a 3D Manipulator Arm**. In: Proceedings of the International Joint Conference on Neural Networks, 2018. p. 1–6. DOI: 10.1109/IJCNN.2018.8489532.

GONZALEZ, R. C.; WOODS, R. E. **Digital Image Processing**. 4. ed. Upper Saddle River, NJ, USA: Pearson Prentice Hall, 2017.

HAYKIN, S. S. **Neural Networks and Learning Machines**. 3. ed. Upper Saddle River: Pearson Prentice Hall, 2009. DOI: 10987654321.

KOSKO, B. Fuzzy cognitive maps. **International Journal of Man-Machine Studies**, v. 24, n. 1, p. 65–75, 1986. DOI: 10.1016/S0020-7373(86)80040-2.

MATARIC, Maja J. **The Robotics Primer**. v. 45, n. 06, 2008. DOI: 10.5860/CHOICE.45-3222.

MENDONÇA, M.; KONDO, H. S.; SOUZA, L. B. de; PALÁCIOS, R. H. C.; ALMEIDA, J. P. L. S. de. **Semi-Unknown Environments Exploration Inspired by Swarm Robotics using Fuzzy Cognitive Maps**. In: 2019 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), 2019. p. 1–7.

MENDONÇA, M.; PALÁCIOS, R. H. C.; PAPAGEORGIOU, E. I.; SOUZA, L. B. de. **Multi-robot exploration using Dynamic Fuzzy Cognitive Maps and Ant Colony Optimization.** In: 2020 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), 2020. p. 1–8.

MENDONÇA, M.; PALÁCIOS, R. H. C.; CHRUN, I. R.; MELLO, D. E.; AGONILHA, H. C.; PAPAGEORGIOU, E.; PAPAGEORGIOU, K. **Initial Experiments using Game-based Learning Applied in a Classical Knowledge Robotics in In-Person and Distance Learning Classroom.** Advances in Science, Technology and Engineering Systems Journal, v. 6, n. 4, p. 212–222, 2021. DOI: 10.25046/aj060425.

PAPAGEORGIOU, E. I. (Ed.). **Fuzzy Cognitive Maps for Applied Sciences and Engineering.** Heidelberg: Springer-Verlag Berlin Heidelberg, 2014. DOI: 10.1007/978-3-642-39739-4.

POHL, C. **What is progress in transdisciplinary research?.** Futures, v. 43, n. 6, p. 618–626, 2011. DOI: 10.1016/j.futures.2011.03.001.

PRENSKY, M**. Digital Game-Based Learning.** 1. ed. New York, USA: McGraw-Hill, 2001.

ROS, I.; FERNÁNDEZ, J.; SAENZ, M. **Active methodologies and the use of technology at the UPV/EHU: proposal for the inclusion of technology for the development of active and cooperative methodologies in Higher Education**. In: 2020 X International Conference on Virtual Campus (JICV), 2020. p. 1–4. DOI: 10.1109/JICV51605.2020.9375667.

RUSSELL, S.; NORVIG, P. **Artificial Intelligence: A Modern Approach**. 3. ed. Upper Saddle River, USA: Prentice Hall, 2009. DOI: 10.1017/S0269888900007724.

SICILIANO, B.; KHATIB, O. (Eds.). **Springer Handbook of Robotics.** 2. ed. Heidelberg: Springer-Verlag Berlin Heidelberg, 2016.

TIAN, L.; COLLINS, C. **An effective robot trajectory planning method using a genetic algorithm.** Mechatronics, v. 14, n. 5, p. 455–470, 2004.

XIAO, L.; ZHANG, Y. **A new performance index for the repetitive motion of mobile manipulators**. IEEE Transactions on Cybernetics, v. 44, n. 2, p. 280–292, 2014. DOI: 10.1109/TCYB.2013.2253461.

ZHANG, C. **Intelligent Internet of Things service based on artificial intelligence technology**. In: 2021 IEEE 2nd International Conference on Big Data, Artificial Intelligence and Internet of Things Engineering (ICBAIE), 2021. p. 731–734. DOI: 10.1109/ICBAIE52039.2021.9390061.

SOUZA, L. B. de; SOARES, P. P.; BARROS, R. V. P. D.; MENDONÇA, M.; PAPAGEORGIOU, E. I. **Dynamic Fuzzy Cognitive Maps and Fuzzy Logic Controllers Applied in Industrial Mixer.** International Journal on Advances in Systems and Measurements, v. 10, n. 3, p. 222–233, 2017.