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Social Aware Navigation Based on Proxemic Interaction for an Autonomous Wheelchair

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Abstract. Social robotics is an increasing area that has boosted the integration of robots and people in common environments. Thus, new human-robot interaction (HRI) techniques have emerged to make robots behave in acceptable and social ways. Proxemic interaction is one of these new techniques, that dictates the interaction between people and devices based on distance, which in turn defines proxemic zones. In this sense, robots must respect the proxemic zones of people around them, while navigating in the shared spaces. In this work, we propose a social aware navigation system based on proxemic that responds to voice commands integrated with a chatbot to define path planning for a wheelchair, in around a crowded environment. This social navigation system is integrated into GProxemic Navigation, a system that automatically provides the robot location and decides the proxemic zones of people that robots (an autonomous wheelchair, for this work) must not transverse during their navigation, according to the environment characteristics. With this implementation, the autonomous wheelchair can be driven to make the most efficient path respecting the social constraints of the environment

Keywords. Navigation System, Proxemics Interaction, ROS, Autonomous wheelchair

1. Introduction

Social robotics is becoming more and more present in people's daily lives [1,2,3]. Nowadays, there is an increasing research interest to incorporate social robots into crowded environments for providing services to people in areas such as hospitals, museums, malls, education centers [4,5,6]. Service robots have expanded its performance from autonomous works in traditional manufactures until performing basic human tasks in social

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environments to offer services. In this context, new approaches to improve human-robot interaction (HRI) are demanded, in particular to make robots be aware to social interactions. As a result, several adaptations to new environments are necessary, which can make robots more complex and with new capabilities. In addition, it is important that robots understand human behavior and the characteristics of environments, using different tools, such as GProxemic Navigation [7], which delimits the proxemic zone according to the characteristics of the environment, and Dialogflow, which works with natural language processing. These particularities improve the HRI, as they provide the ability to analyze speech, being able to obey voice commands, such as in [8,9,10], and the capacity of respecting social constraints during robots' navigation (i.e., social navigation).

Interaction based in proxemics is defined according to the distance between people and the digital devices to interact with [11,12,13,14]. In robotics, proxemics is becoming commonly used to improve HRI and to implement social navigation [15], in terms of the four proxemic zones defined by the distance: intimate (defined by a distance of 0-50 cm), personal (when people proximity is 0.5-1m), social (if distance is 1-4 m), and public (with distance $>$ 4m).

Social navigation for robots means to consider the proxemic zones of people to respect social constraints and thus avoiding a disruptive attitude of humans towards the robots [16,17]. The way a robot moves reflects its intelligence and delineates its social acceptance, in terms of the perceived safety, comfort, and legibility. Thus, researchers are focusing on making robots to act naturally, by considering people and trying to generate some feeling, recognizing emotions, showing implicit and explicit social patterns, and considering social places and its characteristics [18,19,20,7]. In this context, we propose a proxemic aware social navigation system for an autonomous wheelchair to respond to voice commands that indicate a new location in the environment. This social navigation system is integrated into GProxemic Navigation system [7], which is able to identify the robot's localization (the autonomous wheelchair, for this work) and respect the people proxemic zones according to the environment characteristics.

From a human perspective, the integration of a proxemic aware social navigation system into an autonomous wheelchair could greatly improve the wheelchair user's experience in crowded environments. By considering the social constraints and proxemic zones of people in the environment, the wheelchair can navigate in a more natural and socially acceptable way, providing a sense of safety and comfort for both the user and those around them. The use of voice commands and natural language processing also allows for more intuitive and seamless control of the wheelchair, enhancing the user's autonomy and independence. Overall, this work presents a promising approach to improve HRI and enable more inclusive and accessible environments for all.

2. Related Work

Currently, there exist many studies proposing service robots in several sectors, such as in restaurants, taking the customers orders to their tables and also being responsible for the payment [21,22]; in hospitals, carrying medical equipment among the departments, streamlining the process, and being able to save lives in addition to reduce surgical operations costs [23,24]; in the tourist sector, social robots are highlighting themselves in taking the tourists to their goal in different places [25] or exploring an archaeological site [26]. For robots to make these tasks, it is necessary they navigate into the environment with no collisions. For this purpose, robots are equipped with sensors that gather different types of information from the environment to be processed by them [27]. Computer vision is one of the popular techniques used for processing such information; for example, to read the characteristics of the images in static environments, or even in dynamic environments, where the goal and the objects move over time.

However, when people are sharing with robots the same environments, it is important to consider new robots capacities to make their behaviors more socially compatible.

Social robotics emerges from this need fostering research beyond people detection and considering other aspects of people, such as emotion recognition [28] and proxemic interactions [15,29,30,31,32], to improve HRI and facilitates the navigation process.

Due to the complexity and necessity of robots to supply more and more complex services, the integration of several techniques and approaches appears as more efficient solutions. Authors in [33] explain how the integration of different frameworks are important for robotics. Tools like auto-localization, combined with IoT and computer vision techniques, are useful for rescue robots [34] or robots assisting in agriculture [35].

The work presented in [7], proposes GProxemic, a proxemic navigation system that receives an IP address and is able to define the localization and the environment the robot is as well as the correct proxemic zones to be respected.

However, despite the recent research advances, there is a mismatch in the development of applications for social robots. Thus, there exist still needs to facilitate the HRI processes with neurocognitive mechanisms to recognize the critic insights of the interaction, for example considering voice processing for HRI, as described in [6].

The proposal in [36] allows the robot to understand the request sent through voice recognition, measuring the distance to reach the object and get it. Also, in [37], using voice command, the navigation replace the traditional buttons, making the vehicle moves.

In this work, the main contribution is to integrate three different systems to implement a social aware navigation system in a service robot (an autonomous wheelchair): (i) a voice detection system to identify commands to make the robot move, using a chatbot, (ii) a geolocation system to determinethe proxemic zone in different environments; and (iii) a proxemic navigation algorithm, that considers the social constraints according to proxemic zones.

3. Social Aware Navigation System: Our Proposal

To insert the service robots in social environments, it is necessary the use of several techniques that support HRI, as well as autonomous navigation respecting social constraints. To do so, we propose a proxemic based navigation system, roughly composed by three subsystems: (i) the voice recognition system (chatbot) [8]; (ii) the GProxemic Navigation system [7]; and (iii) the social navigation algorithm [15]. In the following, we detail each component.

A chatbot implements the voice recognition system; to do so, we use the Erika architecture [8,38], which is based on the reliable Dialogflow technology, developed by Google LCC. The integration of the Erika architecture for the Chatbot in our system, allows a user to indicate the location in the environment where he/she wants to go (for example, bathroom). In the current version of our system, we do not exploit all the features of this technology; the chatbot is limited to only indicate places; however, it can be extended to implement a richer HRI, for example, to establish a conversation with the robot.

The GProxemic Navigation system [7] maintains automatic location maps with semantic annotations. That is, this system uses the Mapbox API that requests the geographic coordinates of a satellite, then these data are converted into annotations and published in ROS. With this information, the robot can define three different proxemic zones to respect: the personal zone, the social zone, and the public zone. The choice of these zones depends on the characteristics of an environment. For example, in an office the robot must obey the personal zone, because it is an environment that needs more agile activities. However, in a restaurant the robot must obey the social zone, because it can intimidate people.

The social navigation algorithm is based in the proposal presented in [15], which combines Social Momentum and A* to perform an autonomous proxemic navigation in a known map. This social navigation algorithm takes into account proxemic zones of people, and even of other robots sharing the space, to define the path from its current location to the target new location. To be able to perform the autonomous navigation, the robot must know the environment. To do so, the robot can apply a traditional Simultaneous Location and Mapping (SLAM) algorithm to previously know the map of the environment. In this version, we use an Adaptive Monte Carlo Localization (AMCL), based on a filter of particles to track back the position of a robot during its navigation, while it builds the map. Thus, from the GProxemic Navigatin system, the social navigation algorithm receives its current location in the world and, through the characteristics of this environment, the proxemic zone is defined in which the robotic prototype must respect in its trajectory.

The integration of these three systems to conform the social aware navigation system is summarized in Algorithm 1, Firstly, if the robot does not know the environment, it has to apply a SLAM algorithm to generated it (line 1). The robot receives a signal from the satellite indicating its current geographic point (line 2) and the proxemic zones it must configure (line 3), both from the GProxemic system. At this moment, the system load the correct proxemic zones among three different ones: personal, social, and public (the intimate zone will not be approach in any environment), according to the environment the robot is located. The chatbot is driven by voice commands to indicate a place in the environment (line 4). Since the robot knows the environment map, it can match the voice command to a specific location in the map, and start the autonomous navigation (lines 5). In this step, it must be chosen a specific place in the map and start the autonomous navigation considering social constraints (lines 6).

Algorithm 1. Chatbot, GProxemic, and Proxemic Autonomous Navigation Integration

```
1: If (unknown map) then Generate Maps with SLAM
2: Receive signal for Satellite from GProxemic
3: Identify Environment with proxemic zone from Gproxemic
4: Identify voice command (chatbot)
5: Receive a goal from chatbot
6: Make Social Navigation
```

4. Implementation and Results in an Autonomous Wheelchair

The actual wheelchair prototype was simulated as shown in Figure 1. We implement the proposed social navigation system in a simulated autonomous wheelchair, as shown in Figure 2. The implementation was tested in a simulated environment using ROS Melodic, that afford libraries and tools to help in the development of robotic applications. The simulated wheelchair is equipped with a Lidar sensor, responsible for catching the environment data and, through ROS, communicates itself with Gazebo and Rviz (to perform SLAM) and MATLAB software (the social navigation algorithm).

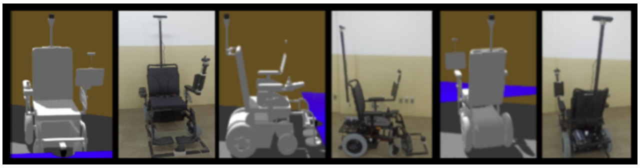

Figure 1. Simulated and real model

Gazebo was used to allow the wheelchair to create the map of the environment; the AMCL SLAM algorithm was implemented based on the `gmapping` package in ROS and the `Laserscan` of the wheelchair to the viability of the navigation planners. In Rviz, we control the global and local planners to capture and manage the sensor data about the map built. The proxemic navigation system was implemented in MATLAB. GProxemic and the chatbot systems communicate themselves with the wheelchair through `ROSLibJs` library, that creates specific topics to each system and sends messages to MATLAB (the proxemic navigation system), reading and incorporating the data and the functionalities to the navigation execution.

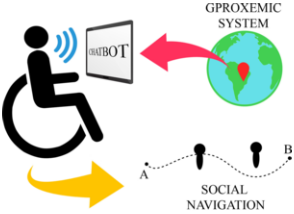

Figure 2. General architecture of the social aware navigation system

The simulated environment was a museum, divided into different sections, as shown is Figure 3: section 1, represents the museum entrance; section 2 represents the museum guide; section 3 is a room to find initial information of the museum; section 4 is an office; section 5 is a hallway with posters; section 6 is the entrance to the bathroom; section 7 is the central room of museum; and section 8 represents the farewell poster room.

Algorithm 2 shows the steps to social aware navigation based on proxemic interaction, implemented in an autonomous wheelchair and simulated in ROS/Gazebo. Firstly, the wheelchair draws the museum map (line 1). It receives a signal from satellite indicating its geographic location from GProxemic (line 2). Thereafter, this information is converted to semantic annotation and published in a topic in ROS (lines 3-5). At this moment, the system loads the correct proxemic zones among three different ones (per-

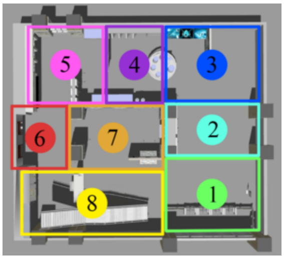

Figure 3. Representation of the different sections of the museum

sonal, social, and public), according to the environment the wheelchair is located (lines 6-12). The chatbot is driven by voice commands and sends a semantic annotation to another topic in ROS (line 13). In this step, it must be chosen a specific place in map from the navigation must start running (lines 14-25). Lastly, the wheelchair position (line 26), the obstacle matrix from ROS (line 27), the final goal to where the prototype must navigate (line 28) are received to perform the autonomous navigation considering social constraints (line 29).

Algorithm 2. Chatbot, GProxemic, and Proxemic Autonomous Navigation Integration: study case

```
1:  If (unknown map) then Generate Maps with AMCL SLAM
2:  Receive signal for Satellite from GProxemic
3:  Send Data String for ROS
4:  Publish a topic with local data:
5:  $proxemic\_topic \leftarrow local$
6:  switch $proxemic\_topic$ do
7:      case $office, home, industry$
8:          Define personal proxemic zone
9:      case $restaurant, hospital, museum, etc.$
10:         Define social proxemic zone
11:     case $shopping, airport, square, etc.$
12:         Define public proxemic zone
13: $dialogflow\_topic \leftarrow goal$
14: switch $dialogflow\_topic$ do
15:     case $entrance$
16:         Define goal to the Entrance
17:     case $museum\_center$
18:         Define goal to the Museum Center
19:     case $bathroom$
20:         Define goal to the Bathroom
21:     case $Other\_Environment..$
22:     ..
23:     ..
24:     ..
25:     ..
26: Receive robot position from GProxemic
27: Receive obstacles from ROS
28: Receive a goal from Chatbot
29: Make Social Navigation
```

The RViz was used to prove the real trajectory done by the autonomous wheelchair around the map, and the Matlab to show the theoretical trajectory. In the experiments, the GProxemic sends a semantic annotation to the wheelchair indicating that it needs to obey the social zone, because it is in the museum. The user activates the wheelchair by a voice command, and the chatbot indicates that he wants to go to the Entrance (section 1, in Figure 3). The wheelchair navigates to this area considering social restrictions, theoretically in Matlab, as shown in Figure 4; the concentric circles represent the proxemic zones of people in the museum, five people in total, but only two people are in the navigation path, unfortunately this autonomous navigation model does not yet support people in motion. The limitation of our system is because the map we generate is static, and the algorithms used cannot change the navigation route if there are moving objects. To solve this limitation, we are studying dynamic SLAM techniques and computer vision algorithms that allow autonomous navigation with moving objects.

Metrics describing the navigation path can be seen in [7] . Practical navigation in RViz is shown in Figure 5.

Figure 4. Wheelchair trajectory respecting the social restrictions theoretically in Matlab, in a museum and with objective the entrance

Figure 5. Wheelchair trajectory respecting the social restrictions practically in RViz, in a museum and with objective the entrance

Figure 6 and Figure 7 show the trajectory theoretically made in the Matlab and the practical trajectory in RViz, when the voice command is changed to museum center (section 7 in Figure 3). In this case, only two persons are simulated that are in the path of the navigation (see Figure 6).The autonomous wheelchair recognizes the environment where it is inserted and defines the social proxemic zone to be respected, with the support of the GProxemic system.

These results make it explicit that the objective is reached. The chatbot can send the final objective of the trajectory to the wheelchair, which can be activated by voice commands. The GProxemic sends the geographic point, so the wheelchair recognizes the environment and the proxemic zone it must respect.

Figure 6. Wheelchair trajectory respecting the social restrictions theoretically in Matlab, in a museum and with objective the central museum

Figure 7. Wheelchair trajectory respecting the social restrictions practically in RViz, in an office and with objective the central museum

In relation to the navigation with social constraints, it is significant that the theoretical trajectory represented by Matlab in Figure 4 and in Figure 6 is so similar with the trajectory in practice represented by RViz in Figure 5 and in Figure 7.

The simulation has been optimized for better performance. At Figure 7, for example, we observe the trajectory made in RViz, when the wheelchair has its frontal orientation contrary to its objective, it needs to rotate around its own axis to reach the final target; that is, the robot needs to turn, and for that it needs to move, generating this circumference when starting the path. In this case, we have a different trajectory from the one theoretically imagined in Matlab in Figure 6, approaching the proxemics that it needs to respect, but also approaching the path that a real wheelchair would take. In other cases, shown in Figure 4, Figure 5, and Figure 6, there is no such problem, as the forward orientation of the chair is directed to the goal.

The simulations were made using a museum as an example of social environment. However, whether the place is a coffee shop, a mall, restaurant, or another social environment, we can note that the system is able to adapt itself to these new scenes. This adaptability works in the integration with GProxemic, because it aims to catch the main characteristics of the place, molding the proxemic and the autonomous navigation to the localization where the robot is. The simulation with results can be seen at: https://www.youtube.com/watch?v=NeLJSbi74QY&t=242s&ab_channel=Gipar-IFBA

5. Conclusion

Through the integration of GProxemic Navigation system (a geo-location system), a chatbot, and a social navigation algorithm it was possible to develop an autonomous navigation system that considers proxemic zones. The autonomous navigation system was implemented in an autonomous wheelchair, as the study case. The GProxemic Navigation system allows the wheelchair to follow the route by respecting the concepts of social restrictions, adapting to other environments, cultures, or social places. The chatbot enriches the HRI by providing greater accessibility to the use of the navigation system.

We are currently developing a real prototype, in which we can operate the chair remotely, read the sensor data through the web system we created. The objective is to migrate all the simulation technology to the real prototype. Check out the video of the tests done in the laboratory: https://youtu.be/4nd0rR2BamE

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References

[1] Naneva S, Sarda Gou M, Webb TL, Prescott TJ. A systematic review of attitudes, anxiety, acceptance, and trust towards social robots. International Journal of Social Robotics. 2020;12(6):1179-201.

[2] Severinson-Eklundh K, Green A, Hüttenrauch H. Social and collaborative aspects of interaction with a service robot. Robotics and Autonomous systems. 2003;42(3-4):223-34.

[3] Shukla M, Shukla AN. Growth of robotics industry early in 21st century. International Journal of Computational Engineering Research. 2012;2(5):1554-8.

[4] Belpaeme T, Kennedy J, Ramachandran A, Scassellati B, Tanaka F. Social robots for education: A review. Science robotics. 2018;3(21):eaat5954.

[5] González-González CS, Violant-Holz V, Gil-Iranzo RM. Social robots in hospitals: a systematic review. Applied Sciences. 2021;11(13):5976.

[6] Henschel A, Hortensius R, Cross ES. Social cognition in the age of human–robot interaction. Trends in Neurosciences. 2020;43(6):373-84.

[7] Vilasboas JP, Sampaio MSC, Moreira GF, Souza AB, Diaz-Amado J, Barrios-Aranibar D, et al. Application of social constraints for dynamic navigation considering semantic annotations on geo-referenced maps. In: 47th Annual Conference of the IEEE Industrial Electronics Society; 2021. p. 1-7.

[8] Correia E, Leite A, Fernandes G, Vilasboas J, Sampaio M, Bastos A, et al. An Architecture for Social-aware Navigation based on a Chatbot Interaction. In: SENTIRobot Workshop at 18th International Conference on Intelligent Environments. IOS Press; 2022. .

[9] Valipour S, Perez C, Jagersand M. Incremental learning for robot perception through HRI. In: 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS); 2017. p. 2772-7.

[10] Sergiyenko OY, Tyrsa VV. 3D optical machine vision sensors with intelligent data management for robotic swarm navigation improvement. IEEE Sensors Journal. 2020;21(10):11262-74.

[11] Ballendat T, Marquardt N, Saul G. Proxemic interaction: designing for a proximity and orientation-aware environment. In: Proc. of Internat. Conf. on Interactive Tabletops and Surfaces, Saarbrücken, Germany, 7–10 November; 2010. p. 121-30.

[12] Greenberg S, Marquardt N, Ballendat T, Diaz-Marino R, Wang M. Proxemic interactions: the new ubicomp? interactions. 2011;18(1):42-50.

[13] Hall E. The hidden dimension. An anthropologist examines man's use of space in public and private. New York: Anchor Books; Doubleday & Company, Inc. 1969.

[14] Wolf K, Abdelrahman Y, Kubitza T, Schmidt A. Proxemic zones of exhibits and their manipulation using floor projection. In: Internat. Symposium on Pervasive Displays,; 2016. p. 33-7.

[15] Daza M, Barrios-Aranibar D, Diaz-Amado J, Cardinale Y, Vilasboas J. An approach of social navigation based on proxemics for crowded environments of humans and robots. Micromachines. 2021;12(2):193.

[16] Mead R, Matarić MJ. Perceptual models of human-robot proxemics. In: Experimental Robotics. Springer, Berlin, Germany; 2016. p. 261-76.

[17] Redondo MEL. Comfortability Detection for Adaptive Human-Robot Interactions. In: 8th Internat Conf on Affective Computing and Intelligent Interaction Workshops and Demos. IEEE; 2019. p. 35-9.

[18] Breazeal C, Dautenhahn K, Kanda T. Social robotics. Springer handbook of robotics. 2016:1935-72.

[19] Kanda T, Ishiguro H. Human-robot interaction in social robotics. CRC Press; 2017.

[20] Sheridan TB. A review of recent research in social robotics. Current opinion in psychology. 2020;36:7-12.

[21] Akhund TMNU, Siddik MAB, Hossain MR, Rahman MM, Newaz NT, Saifuzzaman M. IoT Waiter Bot: a low cost IoT based multi functioned robot for restaurants. In: 18th Internat Conf on Reliability, Infocom Technologies and Optimization (Trends and Future Directions). IEEE; 2020. p. 1174-8.

[22] Qing-xiao Y, Can Y, Zhuang F, Yan-zheng Z. Research of the localization of restaurant service robot. International Journal of Advanced Robotic Systems. 2010;7(3):18.

[23] Kuo CM, Chen LC, Tseng CY. Investigating an innovative service with hospitality robots. International Journal of Contemporary Hospitality Management. 2017.

[24] Takahashi M, Suzuki T, Shitamoto H, Moriguchi T, Yoshida K. Developing a mobile robot for transport applications in the hospital domain. Robotics and Autonomous Systems. 2010;58(7):889-99.

[25] Alexis P. R-Tourism: Introducing the Potential Impact of Robotics and Service Automation in Tourism. Ovidius University Annals, Series Economic Sciences. 2017;17(1).

[26] Coad MM, Blumenschein LH, Cutler S, Zepeda JAR, Naclerio ND, El-Hussieny H, et al. Vine robots: Design, teleoperation, and deployment for navigation and exploration. IEEE Robotics & Automation Magazine. 2019;27(3):120-32.

[27] Bettencourt R, Lima PU. Multimodal navigation for autonomous service robots. In: IEEE International Conference on Autonomous Robot Systems and Competitions. IEEE; 2021. p. 25-30.

[28] Fiorini L, Mancioppi G, Semeraro F, Fujita H, Cavallo F. Unsupervised emotional state classification through physiological parameters for social robotics applications. Knowledge-Based Systems. 2020;190:105217.

[29] Banisetty SB, Williams T. Implicit communication through social distancing: Can social navigation communicate social norms? In: Companion of the ACM/IEEE International Conference on Human-Robot Interaction; 2021. p. 499-504.

[30] Ginés J, Martín F, Vargas D, Rodríguez FJ, Matellán V. Social navigation in a cognitive architecture using dynamic proxemic zones. Sensors. 2019;19(23):5189.

[31] Mavrogiannis C, Hutchinson AM, Macdonald J, Alves-Oliveira P, Knepper RA. Effects of distinct robot navigation strategies on human behavior in a crowded environment. In: 14th ACM/IEEE International Conference on Human-Robot Interaction. IEEE; 2019. p. 421-30.

[32] Narayanan V, Manoghar BM, Dorbala VS, Manocha D, Bera A. Proxemo: Gait-based emotion learning and multi-view proxemic fusion for socially-aware robot navigation. In: 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). IEEE; 2020. p. 8200-7.

[33] Lee MH, Ahn HS, Wang K, MacDonald B. Design of an API for integrating robotic software frameworks. In: Australasian Conference on Robotics and Automation. vol. 2. Citeseer; 2014. p. 1.

[34] Imteaj A, Chowdhury MIJ, Farshid M, Shahid AR. RoboFI: autonomous path follower robot for human body detection and geolocalization for search and rescue missions using computer vision and IoT. In: 1st Internat Conf on Advances in Science, Engineering and Robotics Technology. IEEE; 2019. p. 1-6.

[35] Aguiar AS, dos Santos FN, Cunha JB, Sobreira H, Sousa AJ. Localization and mapping for robots in agriculture and forestry: A survey. Robotics. 2020;9(4):97.

[36] U K J, V I, Ananthakrishnan KJ, Amith K, Reddy PS, S P. Voice Controlled Personal Assistant Robot for Elderly People. In: 5th Internat Conf on Communication and Electronics Systems; 2020. p. 269-74.

[37] Saravanan M, Selvababu B, Jayan A, Anand A, Raj A. Arduino Based Voice Controlled Robot Vehicle. In: IOP Conf Series: Materials Science and Engineering. vol. 993. IOP Publishing; 2020. p. 012125.

[38] Correa J, Viana D, Teles A. Desenvolvendo ChatBots com o Dialogflow. Sociedade Brasileira de Computação. 2021.