# Designing a Shared Workspace for Learning Using Augmented Reality and Social Robots

Christina Pasalidou, cpasalidou@uom.edu.gr

Nikolaos Fachantidis, nfachantidis@uom.edu.gr

University of Macedonia, Greece
Laboratory of Informatics and Robotic Applications in Education and Society, University of Macedonia.

**Abstract.** Augmented Reality (AR) is a novel technology utilized for merging real and virtual elements, enhancing the physical world. Developing AR applications in Robotics has been of interest in recent years. The current paper proposes a shared workspace for learning using Augmented Reality. The objective is to implement this approach using robots, not to execute collaborative robotic tasks but to establish a collaborative learning environment among students and social robots. We use an Augmented Reality application to superimpose virtual objects to the users' real world, aiming to achieve joint attention at a common point of interest among humans and social robots. The social robot perceives what occurs in the augmented environment and interacts (e.g., sharing information, making comments and gestures, giving constructive feedback to the users, etc.), intending to support humans to achieve the learning goals of the activities. The virtual objects are approached through AR with the aims and scopes of educational material in a learning process. The environment that this paper describes will be the testbed for exploring and further researching the proposed approach; handling virtual objects as educational material and aiming to joint attention at a common point of interest among humans and robots in this Augmented Reality shared world. In future studies, research and analysis of the characteristics and effectiveness of this approach will be conducted.

**Keywords:** Augmented Reality · Socially Assistive Robots · Learning environment · Shared workspace

## 1 Introduction

Developing AR applications in Robotics has been of interest in recent years. Up to date, designing a shared workspace where humans and robots interact and collaborate in Augmented Reality [1, 2] has included mobile robots, robotic arms, and aerial robots [3]. The focus has been on; performing collaborative tasks [4], robot programming [5, 6], manipulation of virtual and/or real objects [7], visualization of the robot's path [8], motion planning and teleoperation [9].

Among other technologies, Augmented Reality has been a widely discussed technology in Industry 4.0 [10]. Augmented Reality can be a valuable and effective approach for human-robot collaboration and interaction, providing visual cues through virtual AR elements [4]. Especially for industrial robots, augmented reality technology allows visualization of the robots' motion plan, virtual obstacles, target position and other information that can support Human-Robot Interaction (HRI) [11, 12].

The objective of developing a shared environment with robots is to achieve a high quality human-robot interaction [1]. According to Galin and Meshcheryakov [13], humans and robots collaborating in a shared workspace is a stimulating characteristic of Industry 4.0.

The aim of this study is to draw a parallel with the Industry sector and implement collaborative augmented reality systems in teaching and learning. To be more specific, the physical manipulation using industrial robots, such as robotic arms will be replaced by cognitive manipulation of the virtual objects with the participation of social robots in a shared workspace, where joint attention activities occur. The role of Augmented Reality will be to enrich the information acquisition of the user's real environment [14]. At the same time, the robot can act as a tutor [15], a companion in the learning process [16], or an educational tool [17].

## 2 Related Work

### 2.1 Augmented Reality and Human-Robot Interaction in Shared Workspaces

Human-robot communication enhanced with augmented reality in a shared workspace has already attracted the researchers' interest. In Gao and his colleagues' research [18], visual and spatial information of real objects were fused in a shared workspace through augmented reality technology [18]. Qiu and his fellow researchers [2] proposed a shared augmented reality workspace that establishes active communication between the users and the robots. In their designed AR system, the robot perceives and manipulates the virtual elements, while actively interacting and inferring the utility of the human agent [2]. In the experiment, the physical robot proactively assisted participants to perform a given task successfully in the context of the augmented reality shared environment [2].

Augmented Reality has the potential to show the robots' sensory data, resulting to better understanding the robot's perspective of the world around it [1]. Bolano and his colleagues [19] developed a system utilizing augmented reality to project useful information in the shared workspace, such as the robot's motion intend. Their system was evaluated in various settings. Results indicate that the visualization of information and the display of plan changes achieves a more dynamic and efficient human – robot interaction [19].

An augmented reality-based collaborative workspace was proposed by Materna and fellow researchers [20], using methods such as persona and scenario. In their prototype, users are able to program the robot and perform collaborative tasks effectively. The interaction occurs through an interface projected onto the table [20]. The interface includes various elements to visualize the state of the robot and the task [20].

Effective and substantial human–robot interaction requires bi-directional communication. Chandan and his colleagues [21] introduced a novel Augmented Reality system, called ARROCH, to facilitate collaboration between robots and a human. To be more specific, robots' planned behaviors and state were visualized through Augmented Reality technology for the user to comprehend the robots' intentions. On the other end, robots received feedback from the user, as well [21]. The results from the experiments indicated that humans perform better using the AR system rather than following an approach that does not include augmented reality technology and its potentials [21].

The interaction among humans and robots has been studied not only in the context of industrial robots, such as robotic arms or mobile robots, but also in the field of Social Robotics. Augmented Reality can be utilized to enrich and better study the interaction [22] and support human–robot collaboration [23]. In their study, Bock and his colleagues [24], presented an approach to enable the humanoid robot NAO to play a board game against a human opponent. An AR marker was utilized to help localize the robot and increase the accuracy of the robot behavior [24]. The humanoid NAO robot was also used in Lahemer and Rad's study [14]. The researchers implemented AR technology and vision-based probabilistic landmark-based SLAM for the robot's indoor navigation. The proposed system recognized the location of NAO markers using NAO's camera and displayed the location information to the user's environment through augmented reality technology [14]. Results showed that adaptive augmented ellipsoidal SLAM can improve robot localization and mapping [14].

### 2.2 Socially Assistive Robots and Augmented Reality in Education

Socially Assistive Robots (SARs), such as the NAO robot, have been widely used in Education, being able to improve the educational experience of the students [25].Socially Assistive Robots in educational settings aim to supplement the efforts of educators through engaging children in personalized educational activities [26]. Socially Assistive Robots can be utilized so as to assist teachers in the educational settings, promoting social interaction and improving the quality of education [27].

In addition to social robots' positive outcomes in the field of Education, Augmented Reality technology shows potential in making learning processes more interesting and motivating for students [28]. According to Chang and his colleagues [29], integrating robots into Mixed Reality environments improves students' authentic learning experiences.

In the present study, taking into account the literature, we discovered a gap regarding the use of Socially Assistive Robots in an Augmented Reality shared workspace for learning. Our objective is to achieve joint attention at a common point of interest among humans and social robots, such as the NAO robot. Joint attention (JA) is deemed as an important mechanism of social cognition, where "two persons can jointly attend to an object by one person following another person's gaze toward a given object or possibly a third person" [30]. Responsive joint attention mechanisms evoke higher perceived feelings of social presence of the robot in the context of mutual problem-solving tasks [31]. Both the social NAO robot [32] and Augmented Reality technology [33] have been used to assist students in joint attention activities. Thus, studying the integration of augmented reality and social robots in an educational environment seems to be a promising solution for students' learning, interacting and sharing perception with social robots [16].

## 3 System Design

Based on the review of the literature, we recognized that augmented reality technology is a useful solution for human-robot interaction in an environment where both users and robots share their perception of the world and the events that occur in it. We propose the implementation of an augmented reality system in which a social robot interacts with humans not to execute collaborative robotic tasks, but to facilitate collaborative learning and support the educational process, focusing on the cognitive exploitation of the augmented elements.

The use of augmented reality technology appears to be a solution for human-robot interaction in collaborative workspaces. To achieve that, software and game engines, such as Unity 3D have been utilized for the development of AR applications for smartphone platforms [4]. In our proposed system, an AR application was developed using both Unity 3D and Vuforia software. The designed AR application runs on Android devices.

For the superimposition of the additional virtual objects, the marker-based AR approach was used. Each AR marker represented a different planet. Robots also use markers and landmarks to detect and recognize objects easier [34]. In an Augmented Reality system, markers can be used to render a visualization of an augmented workspace area [4], as well as for localization purposes [24].

In our system the humanoid robot NAO of Softbank Robotics was chosen. The human-like characteristics of socially assistive robots, such as the NAO robot, can enhance positive emotions in young students [35]. The NAO robot used in our study is in version 5.0 with installed software NAOqi, version 2.1.0.19. The robot can connect and communicate through Wi-Fi.

NAO robot's landmarks, called NAOmarks, were used along with the AR markers. They were placed in a table-like surface between the standing robot and the users. Both the robot and the students pointed their attention in the same direction where the markers were placed. The robot prompted students to scan the marker with the mobile device. When the marker was detected, NAO robot shared interesting information, made gestures and provided students feedback in relation to the cognitive objectives of the activities. At the same time, the students observed the animated three-dimensional models of the planets in the mobile device through the AR application, as shown in Fig. 1.

This is a work-in-progress. We are currently examining the connection of the NAO robot with the AR application. The NAO robot is programmed using Python. The robot acts as a server and receives coded actions from the AR application. The AR application communicates with the robot using its IP address and sends messages, correlating the events with the actions we wish NAO to execute in order to interact both with the virtual elements of the AR application and with the users.

**Fig. 1.** Student interacting with the NAO robot, using Augmented Reality in a shared environment

## 4 Discussion and Conclusions

Robotics research has been prevalent in recent years due to technological advances, increased technological accessibility and reliability, as well as commercial availability [36]. Working with robots and understanding their intentions is crucial for human-robot collaboration, especially in the field of Industry [19]. Augmented Reality technology has been studied to supplement the real environment with virtual information and enhance communication between humans and robots [37]. Augmented and Virtual Reality provide users with immersive experiences, visualizing the procedures that occur during human–robot collaboration [38].

An important parameter that needs to be taken into consideration when designing an AR system for human – robot interaction (HRI) is the bi-directional communication, with both users and robots participating actively [2]. This is one of our goals while optimizing our proposed AR system.

Advances inAugmented, Virtual and Mixed Reality are laying the ground work for an alternative solution of mediating human-robot communication [39]. The virtual elements that appear in the real world through Augmented Reality can be used to improve the communication [22] and the interactions between users and robots [40].

Augmented Reality systems may include a robot that aims at manipulating and handling a variety of objects [4]. In our study, we propose the handling of the virtual objects in the AR environment in a cognitive manner, aiming at more engaging learning experiences for students.

Previous studies regarding the utilization of Augmented Reality technology and social robots in educational settings is limited [16]. We are currently in the process of designing and setting all the needed parameters for our AR system for learning with a social robot. The robot has a socially assistive role, setting its attention in a common point of interest with the students. The social robot perceives what occurs in the augmented environment and acts accordingly. The environment that this paper describes will be the testbed for further researching the proposed approach; handling virtual objects as educational material and establishing joint attention in the context of an Augmented Reality shared world. In future studies, research and analysis of the characteristics and effectiveness of this approach will be conducted.

**Acknowledgements.** This work is part of a project that has received funding from the Research Committee of the University of Macedonia under the Basic Research 2020-21 funding programme.

## References

1. Muhammad, F., Hassan, A., Cleaver, A., Sinapov, J.: Creating a shared reality with robots. In: 201914th ACM/IEEE International Conference on Human-Robot Interaction (HRI), pp. 614– 615. IEEE (2019)
2. Qiu,S.,Liu,H.,Zhang,Z.,Zhu,Y.,Zhu,S.C.:Human-robot interaction in a shared augmented reality workspace. In: 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 11413–11418. IEEE (2020)
3. Bassyouni, Z., Elhajj, I.H.: Augmented reality meets artificial intelligence in robotics: asystematic review. Front. Robot. AI **296** (2021)
4. Chacko, S.M., Kapila, V.: Augmented reality as a medium for human-robot collaborative tasks. In: 2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN), pp. 1–8. IEEE (2019)
5. Quintero, C.P., Li, S., Pan, M.K., Chan, W.P., Van der Loos, H.M., Croft, E.: Robot programming through augmented trajectories in augmented reality. In: 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 1838–1844. IEEE (2018)
6. Ong, S.K., Yew, A.W.W., Thanigaivel, N.K., Nee, A.Y.: Augmented reality-assisted robotprogramming system for industrial applications. Robot. Comput.-Integr. Manuf. **61**, 101820 (2020)
7. Ostanin, M., Mikhel, S., Evlampiev, A., Skvortsova, V., Klimchik, A.: Human-robot interaction for robotic manipulator programming in Mixed Reality. In: 2020 IEEE International Conference on Robotics and Automation (ICRA), pp. 2805–2811. IEEE (2020)
8. Cleaver, A., Tang, D., Chen, V., Sinapov, J.: HAVEN: a unity-based virtual robot environmentto showcase HRI-based augmented reality. arXiv preprint arXiv:2011.03464 (2020)
9. Hernández, J.D., Sobti, S., Sciola, A., Moll, M., Kavraki, L.E.: Increasing robot autonomyvia motion planning and an augmented reality interface. IEEE Robot. Autom. Lett. **5**(2), 1017–1023 (2020)
10. Makhataeva, Z., Varol, H.A.: Augmented reality for robotics: a review. Robotics **9**(2), 21 (2020)
11. Fang, H.C., Ong, S.K., Nee, A.Y.C.: Novel AR-based interface for human-robot interactionand visualization. Adv. Manuf. **2**(4), 275–288 (2014). https://doi.org/10.1007/s40436-0140087-9
12. Lambrecht, J., Kruger, J.: Spatial programming for industrial robots based on gestures andaugmented reality. In: IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp. 446–472 (2012)

13. Galin, R., Meshcheryakov, R.: Review on human–robot interaction during collaboration in ashared workspace. In: Ronzhin, A., Rigoll, G., Meshcheryakov, R. (eds.) ICR 2019. LNCS (LNAI), vol. 11659, pp. 63–74. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-26118-4_7
14. Lahemer, E.S., Rad, A.: An adaptive augmented vision-based ellipsoidal SLAM for indoorenvironments. Sensors **19**(12), 2795 (2019)
15. Velentza, A.M., Fachantidis, N., Lefkos, I.: Human or robot university tutor? Future teachers'attitudes and learning outcomes. In: 2021 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN), pp. 236–242. IEEE (2021)
16. Hennerley,J.,Dickinson,M.,Jiang,M.:Augmentedrealityenhancedhumanrobotinteractionfor social robots as e-learning companions. In: Electronic Visualisation and the Arts (EVA 2017), pp. 1–6 (2017)
17. Pasalidou, C., Fachantidis, N.: Distance learning in the era of COVID-19: supporting educational robotics with augmented reality. In: Malvezzi, M., Alimisis, D., Moro, M. (eds.) EDUROBOTICS 2021. SCI, vol. 982, pp. 39–51. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-77022-8_4
18. Gao, P., Reily, B., Paul, S., Zhang, H.: Visual reference of ambiguous objects for augmented reality-powered human-robot communication in a shared workspace. In: Chen, J.Y.C., Fragomeni, G. (eds.) HCII 2020. LNCS, vol. 12190, pp. 550–561. Springer, Cham (2020). https://doi.org/10.1007/978-3-030-49695-1_37
19. Bolano,G.,Juelg,C.,Roennau,A.,Dillmann,R.:Transparentrobotbehaviorusingaugmentedreal ity in close human-robot interaction. In: 2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN) (2019)
20. Materna, Z., etal. :Using persona, scenario, and use case to develop a human-robot augmented reality collaborative workspace. In: Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction, pp. 201–202 (2017)
21. Chandan, K., Kudalkar, V., Li, X., Zhang, S.: ARROCH: augmented reality for robots collaborating with a human. In: 2021 IEEE International Conference on Robotics and Automation (ICRA), pp. 3787–3793. IEEE (2021)
22. Williams, T., Hirshfield, L., Tran, N., Grant, T., Woodward, N.: Using augmented reality to better study human-robot interaction. In: Chen, J.Y.C., Fragomeni, G. (eds.) HCII 2020. LNCS, vol. 12190, pp. 643–654. Springer, Cham (2020). https://doi.org/10.1007/978-3-03049695-1_43
23. Green, S.A., Billinghurst, M., Chen, X., Chase, J.G.: Human-robot collaboration: a literature review and augmented reality approach in design. Int. J. Adv. Rob. Syst. **5**(1), 1 (2008)
24. Bock, S., Klöbl, R., Hackl, T., Aichholzer, O., Steinbauer, G.: Playing Nine Men's Morriswith the humanoid robot nao. In: Proceedings of the Austrian Robotics Workshop, vol. 22, no. 23 (2014)
25. Benitti, F. B. V. :Exploring the educational potential of robotics in schools: a systematic review. Comput. Educ. **58**(3), 978–988 (2012)
26. Clabaugh, C., Ragusa, G., Sha, F., Mataric´, M.: Designing a socially assistive robot forpersonalized number concepts learning in preschool children. In: 2015 Joint IEEE International Conference on Development and Learning and Epigenetic Robotics (ICDL-EpiRob), pp. 314–319. IEEE (2015)
27. Fridin, M. : Storytelling by a kindergarten social assistive robot: a tool for constructive learning in preschool education. Comput. Educ. **70**, 53–64 (2014)
28. Petrov, P.D., Atanasova, T.V.: The effect of augmented reality on students' learning performance in stem education. Information **11**(4), 209 (2020)
29. Chang, C.W., Lee, J.H., Wang, C.Y., Chen, G.D.: Improving the authentic learning experience by integrating robots into the mixed-reality environment. Comput. Educ. **55**(4), 1572–1578 (2010)

30. Jording, M., Hartz, A., Bente, G., Schulte-Rüther, M., Vogeley, K.: The "social gaze space": a taxonomy for gaze-based communication in triadic interactions. Front. Psychol. **9**, 226 (2018)
31. Pereira,A.,Oertel,C.,Fermoselle,L.,Mendelson,J.,Gustafson,J.:Responsivejointattentioninhuman-robotinteraction.In:2019IEEE/RSJInternationalConferenceonIntelligentRobots and Systems (IROS), pp. 1080–1087. IEEE (2019)
32. Cao, H.L., et al.: Robot-assisted joint attention: a comparative study between children with autism spectrum disorder and typically developing children in interaction with NAO. IEEE Access **8**, 223325–223334 (2020)
33. Pérez-Fuster, P., Herrera, G., Kossyvaki, L., Ferrer, A. : Enhancing joint attention skills in children on the autism spectrum through an augmented reality technology-mediated intervention. Children **9**(2), 258 (2022)
34. Figat, J., Kasprzak, W.: NAO-mark vs QR-code recognition by NAO robot vision. In: Szewczyk, R., Zielin´ski, C., Kaliczy´nska, M. (eds.) Progress in Automation, Robotics and Measuring Techniques. AISC, vol. 351, pp. 55–64. Springer, Cham (2015). https://doi.org/10.1007/978-3-319-15847-1_6
35. Subin,E.K.,Hameed,A.,Sudheer,A.P.:Androidbasedaugmentedrealityasasocialinterfacefor low cost social robots. In: Proceedings of the Advances in Robotics, pp. 1–4 (2017)
36. Lambert, A., Norouzi, N., Bruder, G., Welch, G.: A systematic review of ten years of research on human interaction with social robots. Int. J. Hum.-Comput. Interact. **36**(19), 1804–1817 (2020)
37. De Pace, F., Manuri, F., Sanna, A., Fornaro, C.: A systematic review of Augmented Realityinterfaces for collaborative industrial robots. Comput. Ind. Eng. **149**, 106806 (2020)
38. Dianatfar,M.,Latokartano,J.,Lanz,M.:ReviewonexistingVR/ARsolutionsinhuman–robotcollaboration. Procedia CIRP **97**, 407–411 (2021)
39. Williams, T., Szafir, D., Chakraborti, T., Ben Amor, H.: Virtual, augmented, and mixed reality for human-robot interaction. In: Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction, pp. 403–404 (2018)
40. Walker, M., Hedayati, H., Lee, J., Szafir, D.: Communicating robot motion intent with augmented reality. In: Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction, pp. 316–324 (2018)