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The Role of 3D-Technologies in Humanoid Robotics

A Systematic Review for 3D-Printing in Modern Social Robots

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Abstract. The novelty of Three Dimensional (3D) technologies for modeling and printing robotics parts are increasingly popular. In order to use 3D technologies in designing modern social humanoid robots and to draw convincing concluding remarks for other researchers' references, we need to critically incorporate various latest works available in the field of 3D printing and humanoid robotics. The basic principle behind 3D-printing is that it permits the creation of complex artefacts in the simplest possible way. Thus, the aim of this study is to critically evaluate the role of 3D-technologies for developing modern social robots in humanoid robotics. The research methodology is systematic review the relevant literatures on Web of Science and Scopus. Two large literature databases were screened to get the latest 3D print research and applications in modern social robots. As a result, 61 articles were analyzed, discussed and reviewed. We investigated and compared the use of 3D printing for various purposes such as humanoid robots, social robot models, hybrid robot projects and social robot auxiliaries. The finding leads to the design principles that contribute to the home-built 3D printed humanoid robot by adding all the dimensions together, following the principles of social robotics. Future research will revolve around these definitions for the applied role of 3D technology in modern social robotics and to develop a low-cost proto-type of 3D printed humanoid robot, which will be reported in another paper.

Keywords: 3D Printing low cost, 3D Printing low cost robot, 3D Printing robot, 3D Printing Efficient robot, Robot Hospitality, Social Robotics.

1 Introduction

1.1 The definition & characteristics of 3D-printing in modern social robots

The basic concept behind 3D-printing is that it helps in developing complex things in simplest ways as possible. For using 3D-printing in modern social robots, we have to combine different researches that are currently available in the field of humanoid robotics to reach at a proper conclusion. We adopted various research strategies in terms of search, study selection and quality assessment. We discussed the history of the use of 3D-printing in modern social robots and the taxonomy for humanoid robotics through the lens of 3D-printing i.e., literature review summary for 3D-printing & humanoid robots from 3 studies, 3D-printing & social robot models from 16 studies, 3D-printing & hybrid robot projects from 6 studies and 3D-printing social robot auxiliaries from 36 studies. In total, we have critically analyzed 61 articles to reach proper convincing conclusions and recommendations that can provide helpful references to other robotics researchers and practitioners in building modern social robots with 3D technologies.

1.2 Research Methodology

Two major literature databases, Web of Science and Scopus were selected for screening literatures of 3D printing in modern social robots. Each index term was searched over both databases using the flow of research methodology represented in below Figure 1. First, we have searched the respective index term aligned with the objective, i.e. to evaluate the role of available 3D-technologies for developing modern social robots in humanoid robotics. After that we have excluded total results with less relevance databases/disciplines, less relevance document types and finally results are sorted out by relevance for further analysis and inclusion.

Fig. 1. Flow Diagram of the Research Methodology.

. Search Technique
We searched the literature using Scopus and Web of Science databases/disciplines. A combination of relevant index terms was used to collect articles. Our search involves relevant printing till Jan., 2020. Above Figure 1, represents our total strategy of search and for reference organization, we used Mendeley developed by Elsevier.

. Research Criteria
Less relevance databases/disciplines were removed then, the name and extract of all publication were taken into consideration to get the desired criteria for incorporation. The criteria for incorporation are:

- *Articles: less relevance document types were excluded from the review, i.e., only articles are considered.*
- *Materiality: papers need to show primarily on the basis of search of index term that evaluates the importance accordingly.*
- *Communication: papers that are written or converted in English medium are considered for review.*

Where the results of the reviewed articles conflicted, rational for exclusion/inclusion was considered and for the justification of the materiality of article's, research methods and opening statements of paper's was evaluated. For all the included articles agreement on acceptability was attained. Using the corresponding inclusion criteria, included articles undergo a full text evaluation and for relevance cited reference in the review was also assessed.

. Standard evaluation
Above Figure 1 shows the flow of research methodology that we have used to reach at relevant conclusions which also acts as a basis for quality evaluation. First, we started by searching the relevant index terms that aligns with the research problem. After that we have excluded the less relevance databases/disciplines and document types from the total results to get proper study base. Finally, we consolidated the papers by relevance for further analysis and inclusion based on the study criteria defined above. Figure 2 depicts the overview of taxonomy of the systematic review.

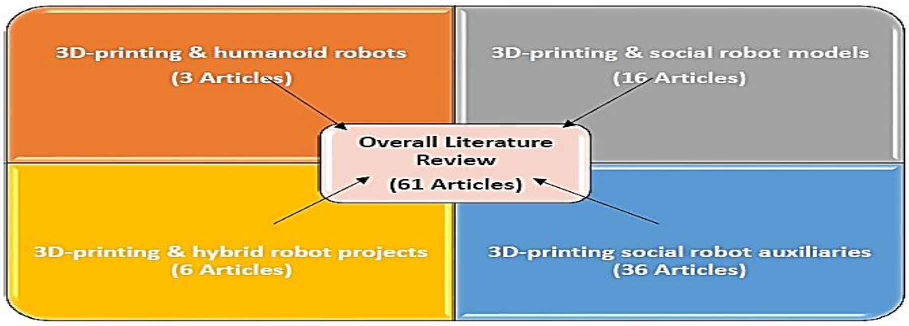

Fig. 2. The Taxonomy of the Systematic Literature Review.

2 The history of the use of 3D-printing in modern social robots

2.1 3D-printing & humanoid robots

Fig. 3. Synopsis of the literature review for 3D-printing & humanoid robots from 3 studies.

In building a person i.e., human like robot, personhood criteria or thresholds that robotic agents must possess should be considered (Barresi, 2019). There is also a robot known as Reachy which assist in the study, design and evaluation of novel control mechanisms and interfaces on a human robot (Mick et al., 2019). All these foster a critical theoretical ethical approach to social robotics "synthetic ethics" which aimed at motivating people to use social robots for two main purposes i.e., self-knowledge and moral growth (Damiano and Dumouchel, 2018).

2.2 3D-printing & social robot models

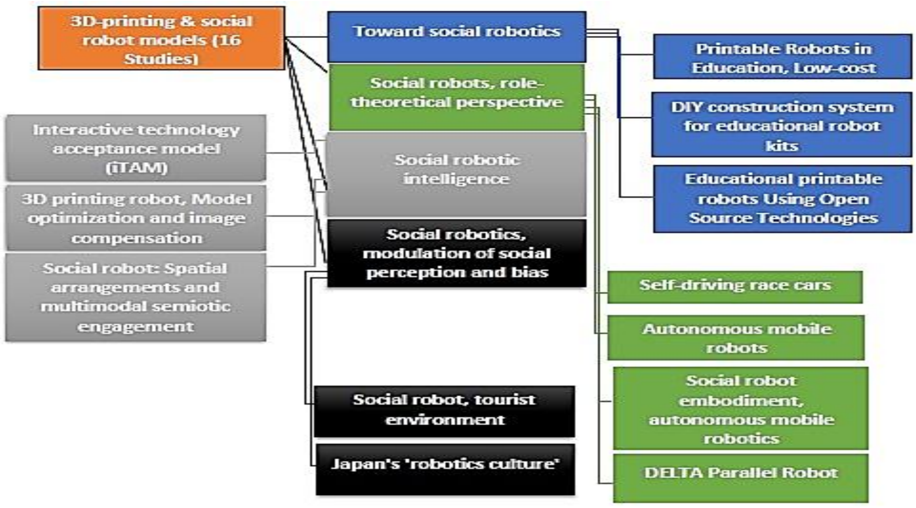

Fig. 4. Synopsis of the literature review for 3D-printing & social robot models from 16 studies.

Wider availability of 3D printing has allowed small printable robots i.e., print bots to be directly integrated into the engineering courses. Print bots can be used in many ways to build lifelong learning skills, improve communication and promote cooperation and teamwork (Armesto, Fuentes-Durá and Perry, 2016). There are technologies that combines motion controller integration with image recognition in an opto-mechatronic system (Lin, Luo and Lin, 2015) and various frameworks that offer fundamental bases for future studies on what impacts market acceptance on AI robots as an emerging technology that can be applied to empirical experiments and analysis to include long-term approaches and practical tips for implementing and managing a variety of tasks (Go, Kang and Suh, 2020). In 3D printing, there is a multi-step correction algorithm based on model optimization and image correction by investigating the cause for colour distortion (Chen et al., 2012) and there are various points to the relevance of spatial organization and coordination between the robot and the humans who interact with it (Alač, Movellan and Tanaka, 2011). There is an environment that centered on using robotics as a social dimension and as a tourism intermediary i.e., social robot Karotz (Nieto et al., 2014). Some authors sketched briefly the basics of a role-based approach to socio-technical innovation, and including examples of why a role-based approach could be useful for observation and interaction in social robotics (Meister and Schulz-Schaeffer, 2016) while some authors on the other hand examined how robots co-construct Japan's history (Šabanović, 2014). In a real-world social robot model offers the social metaphors of personality, character, desires, and responsibilities that are interpreted and applied to promote the achievement of specific social goals (Duffy, 2004). There are helpful ways to develop an interdisciplinary and multi-theoretical approach to promote robotic architecture (Wiltshire et al., 2017) and a type of robot-mediated communication that continues in the absence of potentially biased signs of identity-and explain how this social robotics technology can be used to illuminate implicit bias in social cognition and inform new strategies for bias reduction (Skewes, Amodio and Seibt, 2019). There is a self-reference pairing of self-organizing processes as architectural basis for the autonomous collaborative systems as well (Sekiyama and Fukuda, 1999).

2.3 3D-printing & hybrid robot projects

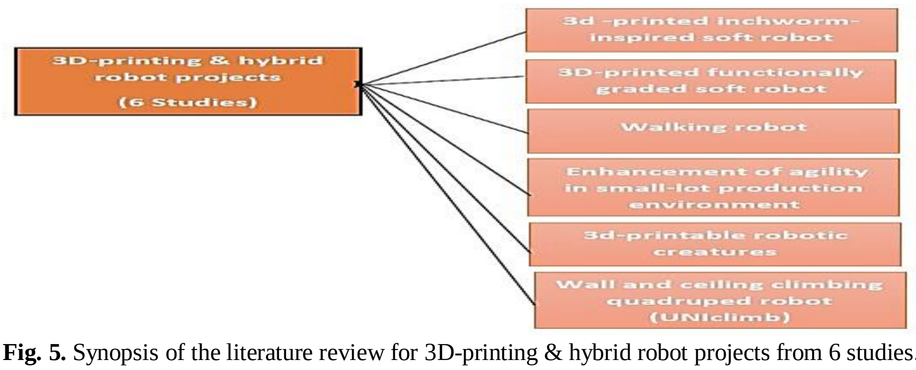

Fig. 5. Synopsis of the literature review for 3D-printing & hybrid robot projects from 6 studies.

3D manufacturing using stereolithographic projection assisted by magnetic field technique (Joyee and Pan, 2019) and effective optimization-based approach, producing stable, randomly defined motions for legged robots.

The relation between morphological features and the resulting motions (Megaro et al., 2015) i.e., the 3D printer, industrial robot, and computer vision combined to create a mobile prototype production line (Hu et al., 2016). A scale walking robot (Chavdarov, 2016), quadrupled robot (Ko, Yi and Jeong, 2017) and flexible or partially flexible robot bodies which are capable of being more stable and adaptable to human activity and safer than traditional or rigid robots (Bartlett et al., 2015).

2.4 3D-printing social robot auxiliaries

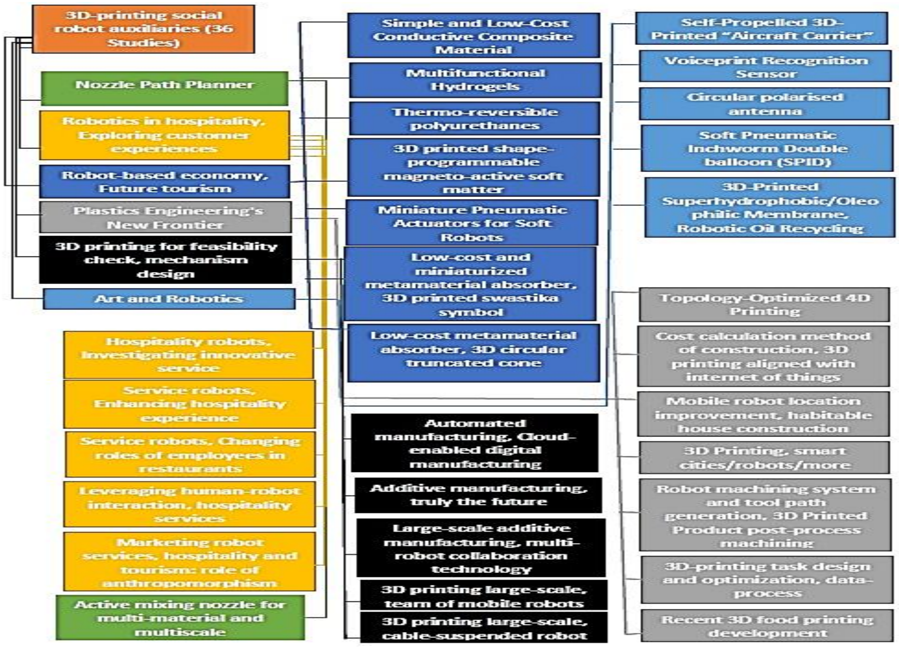

Fig. 6. Synopsis of the literature review for 3D-printing social robot auxiliaries from 36 studies.

A computationally efficient heuristic search algorithm for finding fast routes and overheads in the printing process (Fok et al., 2019) combined with cloud systems and cloud-enabled databases which would allow the production of large quantities of virtual products (Huang, 2015). For the systematic and efficient customization of material formulation and different processing parameters using digital light processing-based 3D printing (Zhang et al., 2019), a new concept of micromotors carried by small millimeter-sized engines for long distance crossing, and a wide variety of applications (Kong et al., 2019) was developed. Topology optimization along with four-dimensional printing is an important digital method that can be used to achieve optimum internal architecture for efficient porous soft actuators output (Zolfagharian et al., 2019). Balloons provide anchorage into the colonic wall for a bio-inspired inchworm locomotion (Manfredi et al., 2019) and 3D printing process based on carbomer rheology limiter for quick ink writing of different useful hydrogels. In addition, this process unlocks new paths with its unparalleled versatility for the manufacturing of bioprinting and engineered hydrogel products (Chen et al., 2019). The combination of 3D printing technology with shape memory apps enables smart devices with extremely complex 3D structures to be created, enabling an arbitrary transition between permanent and temporary 3D forms (Zhang et al., 2019). Not only does one-step manufacturing shorten the production cycle but it also narrows tool differences and enables large-scale production (Guo et al., 2020). The form organizing plan that give a coherent method to completely exploit the ability i.e., to evolve a broad scale of actuators that are soft and useful for bionics, soft robotics and curative supervision (Qi et al., 2020). The metamaterial absorber combined with 3D printing technology i.e., assisted by a swastika symbol to minimize footprint size (Kim et al., 2019) is also helpful and the same goes to truncated spherical cone structure as well (Yoon et al., 2018).

The growing use of 3D printing has opened the door to low cost goods produced by individual consumers (Winkless, 2015) which helps in creating the flexibility and low cost that allow for a fast turnaround (Romeo, 2019). It facilitates the development of a low cost, 3D patch antenna printing equipment (Jun et al., 2017) in that calculation of construction costs in terms of both the production property and goods on-site and offsite was also helpful (Yang et al., 2018), even the 'carbomorph' can be used to print electronic sensors capable of sensing mechanical flexing and ability changes (Leigh et al., 2012). The properties of food printing and food ingredient materials which can be used to design the 3D food matrix for developing a food production system (Yang, Zhang and Bhandari, 2017) with the combination of a single, multi-scale, 3D printing technique based on multi-material nozzle, combining electrohydrodynamic jet printing with active multi-material mixing nozzles (Lan, 2017) would be very helpful. Even the manufacturing theory (Subrin et al., 2018) and topics like gadgets that help you track missing objects, clever downside cities and soldiers mix together with their robots (Hong and Baker, 2014) will increase the demand for 3d printing as well. There are various examples like a robot machining tool to machine 3D printed objects like five degree-free serial robot arms were attached to the spindle frame (Shim et al., 2019).

In a large-scale 3D printing system, that consists of many collaborative robots (Shen, Pan and Qian, 2019), a rapid prototyping method, which can generate scaled prototypes for experimental validations from the early stages of robot creation (Cafolla et al., 2016) was very helpful. Optimization steps in the printing cycle (Qian et al., 2013) that uses lots of mobile robots (Zhang et al., 2018) which utilizes a 6 ° liberty wire draped robot for arranging, accompanied by polyurethane foam as the item matter and shaving foam as the hold-up matter (Barnett and Gosselin, 2015) was also helpful. Somehow it contributes to the management of hospitality and tourism (Tung and Au, 2018) and introducing ever broader front-of-house restaurant service automation systems that requires a cross-cultural study of employee positions in the context of robotic operation (Tuomi, Tussyadiah and Stienmetz, 2020). The effect of service robot features on client hospitality experience has been examined widely in literature from a relationship building perspective (Qiu et al., 2019) but there are various other factors that drive the development of service robots and applied a strategic perspective to the hotel industry regarding service innovation (Kuo, Chen and Tseng, 2017). By using social robots in hospitality, the facilities are conceptualized and empirically evaluated through structural equation modelling and semi-structured manager interviews (de Kervenoael et al., 2020). In the last part, it helps in developing the tourism or hospitality consequences of robonomics i.e., the positive and negative impacts of robots on tourism and vice versa (Webster and Ivanov, 2019) which helps in fostering robot capabilities that influence anthropomorphism (Murphy, Gretzel and Pesonen, 2019). Finally, the importance of pioneering inventions i.e., 3D printers and their impact on society and culture to the field of robotics science (St-Onge, 2019) are indeed novel.

3 Conclusion

We have reached at the relevant insights by analyzing 61 studies in four different dimensions of taxonomy for humanoid robotics through the lens of 3D-printing. We analyzed all these four dimensions and divided them into 4 different spheres of studies aligned to the research problem i.e., to evaluate the role of available 3D-technologies for developing modern social robots in humanoid robotics. The first dimension, i.e., 3D-printing & humanoid robots, we find out that for building a person we need to follow specific measures which includes other researches like human robotic arm and Anthropomorphism. In the second dimension, i.e., 3D-printing & social robot models, we find out that there are four approaches to deal with social robot models with 3D-printing, first is toward social robotics, second is social robots – role theoretical perspective, third is social robotic intelligence and fourth is social robotics – modulation of social perception and bias. Within these four broad approaches we have defined various social robot models (Figure 4). In the third dimension, i.e., 3D-printing & hybrid robot projects, we have discussed six projects - 3d printed inchworm inspired soft robot, 3d printed functionally graded soft robot, walking robot, enhancement of agility in small lot production environment, 3D printable robotic creatures and wall and ceiling climbing quadruped robot. In the fourth dimension, i.e., 3D-printing social robot auxiliaries, we find out that there are six approaches to deal with social robot auxiliaries with 3D-printing, first is nozzle path planner, second is robotics in hospitality – exploring customer experiences, robot - based economy: future tourism, Plastics Engineering's New Frontier, 3D printing for feasibility check - mechanism design and Art & Robotics. Within these six broad approaches we have defined various social robot auxiliaries (Figure 6). By combining all these dimensions together, we will be able to make our own complete 3D printed humanoid robot that follows the principles of social robotics. Future research will revolve around these definitions for the applied role of 3D technology in modern social robotics and to develop a low-cost prototype of 3D printed humanoid robot, which will be reported in another paper.

References

1. Alač, M., Movellan, J. and Tanaka, F. (2011) 'When a robot is social: Spatial arrangements and multimodal semiotic engagement in the practice of social robotics', Social Studies of Science, 41(6), pp. 893–926. doi: 10.1177/0306312711420565.

2. Armesto, L., Fuentes-Durá, P. and Perry, D. (2016) ‘Low-cost Printable Robots in Education’, Journal of Intelligent & Robotic Systems. Springer Science and Business Media LLC, 81(1), pp. 5–24. doi: 10.1007/s10846-015-0199-x.
3. Barnett, E. and Gosselin, C. (2015) ‘Large-scale 3D printing with a cable-suspended robot’, Additive Manufacturing. Elsevier B.V., 7, pp. 27–44. doi: 10.1016/j.addma.2015.05.001.
4. Barresi, J. (2019) ‘On building a person: benchmarks for robotic personhood’, Journal of Experimental and Theoretical Artificial Intelligence. Taylor and Francis Ltd. doi: 10.1080/0952813X.2019.1653386.
5. Bartlett, N. W. et al. (2015) ‘A 3D-printed, functionally graded soft robot powered by combustion’, Science. American Association for the Advancement of Science, 349(6244), pp. 161–165. doi: 10.1126/science.aab0129.
6. Cafolla, D. et al. (2016) ‘3D printing for feasibility check of mechanism design’, International Journal of Mechanics and Control. Levrotto and Bella, 17(1), pp. 3–12.
7. Chavdarov, I. N. (2016) ‘Walking robot realized through 3D printing’, Comptes Rendus de L’Academie Bulgare des Sciences. Academic Publishing House, 69(8), pp. 1057–1064.
8. Chen, X. et al. (2012) ‘3D printing robot: Model optimization and image compensation’, Journal of Control Theory and Applications, 10(3), pp. 273–279. doi: 10.1007/s11768-012-1122-7.
9. Chen, Z. et al. (2019) ‘3D Printing of Multifunctional Hydrogels’, Advanced Functional Materials. Wiley-VCH Verlag, 29(20). doi: 10.1002/adfm.201900971.
10. Damiano, L. and Dumouchel, P. (2018) ‘Anthropomorphism in human-robot co-evolution’, Frontiers in Psychology. Frontiers Media S.A., 9(MAR). doi: 10.3389/fpsyg.2018.00468.
11. de Kervenoael, R. et al. (2020) ‘Leveraging human-robot interaction in hospitality services: Incorporating the role of perceived value, empathy, and information sharing into visitors’ intentions to use social robots’, Tourism Management. Elsevier Ltd, 78. doi: 10.1016/j.tourman.2019.104042.
12. Duffy, B. (2004) ‘Robots social embodiment in autonomous mobile robotics’, International Journal of Advanced Robotic Systems, 1(1), pp. 155–170. doi: 10.5772/5632.
13. Fok, K. Y. et al. (2019) ‘A Nozzle Path Planner for 3D Printing Applications’, IEEE Transactions on Industrial Informatics. IEEE Computer Society. doi: 10.1109/TII.2019.2962241.
14. Go, H., Kang, M. and Suh, S. B. C. (2020) ‘Machine learning of robots in tourism and hospitality: interactive technology acceptance model (iTAM) – cutting edge’, Tourism Review. Emerald Group Publishing Ltd. doi: 10.1108/TR-02-2019-0062.
15. Guo, R. et al. (2020) ‘A Voiceprint Recognition Sensor Based on a Fully 3D-Printed Triboelectric Nanogenerator via a One-Step Molding Route’, Advanced Engineering Materials. Wiley-VCH Verlag. doi: 10.1002/adem.201901560.
16. Hong, J. and Baker, M. (2014) ‘3D Printing, smart cities, robots, and more’, IEEE Pervasive Computing. Institute of Electrical and Electronics Engineers Inc., 13(1), pp. 6–9. doi: 10.1109/MPRV.2014.1.
17. Hu, F. et al. (2016) ‘Enhancement of agility in small-lot production environment using 3D printer, industrial robot and machine vision’, International Journal of Simulation: Systems, Science and Technology. UK Simulation Society, 17(43), pp. 32.1-32.6. doi: 10.5013/IJSSST.a.17.43.32.
18. Huang, C. H. (2015) ‘Continued evolution of automated manufacturing - Cloud-enabled digital manufacturing’, International Journal of Automation and Smart Technology. Chinese Institute of Automation Engineers, 5(1), pp. 2–5. doi: 10.5875/ausmt.v5i1.861.
19. Joyee, E. B. and Pan, Y. (2019) ‘A fully three-dimensional printed inchworm-inspired soft robot with magnetic actuation’, Soft Robotics. Mary Ann Liebert Inc., 6(3), pp. 333–345. doi: 10.1089/soro.2018.0082.
20. Jun, S. et al. (2017) ‘Circular polarised antenna fabricated with low-cost 3D and inkjet printing equipment’, Electronics Letters. Institution of Engineering and Technology, 53(6), pp. 370–371. doi: 10.1049/el.2016.4605.
21. Karaman, S. et al. (2017) ‘Project-based, collaborative, algorithmic robotics for high school students: Programming self-driving race cars at MIT’, in ISEC 2017 - Proceedings of the 7th IEEE Integrated STEM Education Conference. Institute of Electrical and Electronics Engineers Inc., pp. 195–203. doi: 10.1109/ISECon.2017.7910242.
22. Kim, M. et al. (2019) ‘Low-cost and miniaturized metamaterial absorber using 3D printed swastika symbol’, Microwave and Optical Technology Letters. John Wiley and Sons Inc. doi: 10.1002/mop.32221.
23. Ko, H., Yi, H. and Jeong, H. E. (2017) ‘Wall and ceiling climbing quadruped robot with superior water repellency manufactured using 3D printing (UNIclimb)’, International Journal of Precision Engineering and Manufacturing - Green Technology. Korean Society for Precision Engineering, 4(3), pp. 273–280. doi: 10.1007/s40684-017-0033-y.
24. Kong, L. et al. (2019) ‘Self-Propelled 3D-Printed “Aircraft Carrier” of Light-Powered Smart Micromachines for Large-Volume Nitroaromatic Explosives Removal’, Advanced Functional Materials. Wiley-VCH Verlag, 29(39). doi: 10.1002/adfm.201903872.
25. Kuo, C. M., Chen, L. C. and Tseng, C. Y. (2017) ‘Investigating an innovative service with hospitality robots’, International Journal of Contemporary Hospitality Management. Emerald Group Publishing Ltd., 29(5), pp. 1305–1321. doi: 10.1108/IJCHM-08-2015-0414.
26. Lan, H. (2017) ‘Active mixing nozzle for multimaterial and multiscale three-dimensional printing’, Journal of Micro and Nano-Manufacturing. American Society of Mechanical Engineers (ASME), 5(4). doi: 10.1115/1.4037831.
27. Leigh, S. J. et al. (2012) ‘A Simple, Low-Cost Conductive Composite Material for 3D Printing of Electronic Sensors’, PLoS ONE, 7(11). doi: 10.1371/journal.pone.0049365.
28. Li, G. et al. (2019) ‘All 3D-Printed Superhydrophobic/Oleophilic Membrane for Robotic Oil Recycling’, Advanced Materials Interfaces. Wiley-VCH Verlag, 6(18). doi: 10.1002/admi.201900874.
29. Lin, J., Luo, C. H. and Lin, K. H. (2015) ‘Design and Implementation of a New DELTA Parallel Robot in Robotics Competitions’, International Journal of Advanced Robotic Systems. SAGE Publications Inc., 12(10). doi: 10.5772/61744.
30. Manfredi, L. et al. (2019) ‘A Soft Pneumatic Inchworm Double balloon (SPID) for colonoscopy’, Scientific Reports. Nature Publishing Group, 9(1). doi: 10.1038/s41598-019-47320-3.
31. Megaro, V. et al. (2015) ‘Interactive design of 3d-printable robotic creatures’, in ACM Transactions on Graphics. Association for Computing Machinery. doi: 10.1145/2816795.2818137.

32. Meister, M. and Schulz-Schaeffer, I. (2016) 'Investigating and designing social robots from a role-theoretical perspective: Response to "Social interaction with robots—three questions". In Gesa Lindemann (this volume)', AI and Society. Springer-Verlag London Ltd, 31(4), pp. 581–585. doi: 10.1007/s00146-015-0635-2.
33. Mick, S. et al. (2019) 'Reachy, a 3D-printed human-like robotic arm as a testbed for human-robot control strategies', Frontiers in Neurorobotics. Frontiers Media S.A., 13. doi: 10.3389/fnbot.2019.00065.
34. Murphy, J., Gretzel, U. and Pesonen, J. (2019) 'Marketing robot services in hospitality and tourism: the role of anthropomorphism', Journal of Travel and Tourism Marketing. Routledge, 36(7), pp. 784–795. doi: 10.1080/10548408.2019.1571983.
35. Nieto, D. et al. (2014) 'A social robot in a tourist environment', Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). Springer Verlag, 8867, pp. 21–24. doi: 10.1007/978-3-319-13102-3_5.
36. Pérula-Martínez, R. et al. (2016) 'Developing Educational Printable Robots to Motivate University Students Using Open Source Technologies', Journal of Intelligent & Robotic Systems. Springer Science and Business Media LLC, 81(1), pp. 25–39. doi: 10.1007/s10846-015-0205-3.
37. Qi, S. et al. (2020) '3D printed shape-programmable magneto-active soft matter for biomimetic applications', Composites Science and Technology. Elsevier Ltd, 188. doi: 10.1016/j.compscitech.2019.107973.
38. Qian, H. et al. (2013) 'Design and optimization of 3D-printing task based on data-process for printing robot', Jiqiren/Robot, 35(6), pp. 678–685. doi: 10.3724/SP.J.1218.2013.00678.
39. Qiu, H. et al. (2019) 'Enhancing hospitality experience with service robots: the mediating role of rapport building', Journal of Hospitality Marketing and Management. Routledge. doi: 10.1080/19368623.2019.1645073.
40. Romeo, J. (2019) 'Plastics Engineering's New Frontier: Embracing the Brave New World of 3D Printing', Plastics Engineering. Wiley-Blackwell, 75(1), pp. 22–27. doi: 10.1002/peng.20055.
41. Šabanović, S. (2014) 'Inventing Japan's "robotics culture": The repeated assembly of science, technology, and culture in social robotics', Social Studies of Science. SAGE Publications Ltd, 44(3), pp. 342–367. doi: 10.1177/0306312713509704.
42. Sekiyama, K. and Fukuda, T. (1999) 'Toward social robotics', Applied Artificial Intelligence, 13(3), pp. 213–238. doi: 10.1080/088395199117405.
43. Shen, H., Pan, L. and Qian, J. (2019) 'Research on large-scale additive manufacturing based on multi-robot collaboration technology', Additive Manufacturing. Elsevier B.V., 30. doi: 10.1016/j.addma.2019.100906.
44. Shim, J. et al. (2019) 'Design of A robot machining system and tool path generation for post-process machining of 3D Printed Product', Transactions of the Korean Society of Mechanical Engineers, A. Korean Society of Mechanical Engineers, 43(5), pp. 359–364. doi: 10.3795/KSME-A.2019.43.5.359.
45. Skewes, J., Amodio, D. M. and Seibt, J. (2019) 'Social robotics and the modulation of social perception and bias', Philosophical Transactions of the Royal Society B: Biological Sciences. Royal Society Publishing, 374(1771). doi: 10.1098/rstb.2018.0037.
46. St-Onge, D. (2019) 'Robotic Art Comes to the Engineering Community [Art and Robotics]', IEEE Robotics and Automation Magazine. Institute of Electrical and Electronics Engineers Inc., 26(3), pp. 103–104. doi: 10.1109/MRA.2019.2927198.
47. Subrin, K. et al. (2018) 'Improvement of the mobile robot location dedicated for habitable house construction by 3D printing', IFAC-PapersOnLine. Elsevier B.V., 51(11), pp. 716–721. doi: 10.1016/j.ifacol.2018.08.403.
48. Teo, J. et al. (2015) 'Evolutionary robotics + 3D printing = rapid & low-cost deployment of autonomous mobile robots', ARPN Journal of Engineering and Applied Sciences. Asian Research Publishing Network, 10(18), pp. 8372–8378.
49. Tung, V. W. S. and Au, N. (2018) 'Exploring customer experiences with robotics in hospitality', International Journal of Contemporary Hospitality Management. Emerald Group Publishing Ltd., 30(7), pp. 2680–2697. doi: 10.1108/IJCHM-06-2017-0322.
50. Tuomi, A., Tussyadiah, I. and Stienmetz, J. (2020) 'Service robots and the changing roles of employees in restaurants: A cross cultural study', e-Review of Tourism Research. Texas A and M University, 17(5), pp. 662–673.
51. Vandevelde, C. et al. (2016) 'Design and evaluation of a DIY construction system for educational robot kits', International Journal of Technology and Design Education. Springer Netherlands, 26(4), pp. 521–540. doi: 10.1007/s10798-015-9324-1.
52. Webster, C. and Ivanov, S. (2019) 'Future tourism in a robot-based economy: a perspective article', Tourism Review. Emerald Group Publishing Ltd. doi: 10.1108/TR-05-2019-0172.
53. Wiltshire, T. J. et al. (2017) 'Enabling robotic social intelligence by engineering human social-cognitive mechanisms', Cognitive Systems Research. Elsevier B.V., 43, pp. 190–207. doi: 10.1016/j.cogsys.2016.09.005.
54. Winkless, L. (2015) 'Is additive manufacturing truly the future?', Metal Powder Report. Elsevier Ltd, 70(5), pp. 229–232. doi: 10.1016/j.mprp.2015.05.003.
55. Yang, F., Zhang, M. and Bhandari, B. (2017) 'Recent development in 3D food printing', Critical Reviews in Food Science and Nutrition. Taylor and Francis Inc., 57(14), pp. 3145–3153. doi: 10.1080/10408398.2015.1094732.
56. Yang, H. et al. (2018) 'The cost calculation method of construction 3D printing aligned with internet of things', Eurasip Journal on Wireless Communications and Networking. Springer International Publishing, 2018(1). doi: 10.1186/s13638-018-1163-9.
57. Yoon, Y. et al. (2018) 'Low-cost metamaterial absorber using three-dimensional circular truncated cone', Microwave and Optical Technology Letters. John Wiley and Sons Inc., 60(7), pp. 1622–1630. doi: 10.1002/mop.31211.
58. Zhang, X. et al. (2018) 'Large-scale 3D printing by a team of mobile robots', Automation in Construction. Elsevier B.V., 95, pp. 98–106. doi: 10.1016/j.autcon.2018.08.004.
59. Zhang, Y. et al. (2019) '3D printing of thermoreversible polyurethanes with targeted shape memory and precise in situ self-healing properties', Journal of Materials Chemistry A. Royal Society of Chemistry, 7(12), pp. 6972–6984. doi: 10.1039/c8ta12428k.
60. Zhang, Y. F. et al. (2019) 'Miniature Pneumatic Actuators for Soft Robots by High-Resolution Multimaterial 3D Printing', Advanced Materials Technologies. Wiley-Blackwell, 4(10). doi: 10.1002/admt.201900427.
61. Zolfagharian, A. et al. (2019) 'Topology-Optimized 4D Printing of a Soft Actuator', Acta Mechanica Solida Sinica. Springer International Publishing. doi: 10.1007/s10338-019-00137-z.