Research Statutes and Prospects of AI in Domestic Robot Manufacturing

Linhao Fan[1*] and Siyi Ruan[2]

[1] Garden International School Kuala Lumpur, Kuala Lumpur, 50480, Malaysia
[2] Wuhan Britain-China School, Wuhan, 430000, China
*205609@gardenschool.edu.my

Abstract. In the past few years, the field of artificial intelligence (AI) has experienced explosive growth. Large language models (LLM) such as some AI developed for chat and information generation have drawn massive attention from the public, and more robots for commercial uses are implemented with them. However, from recent research reports, the development of domestic robots seems to be relatively slow, and the achievements are insignificant. The most common domestic robot in households is still the sweeping robot, which lacks an AI system inside. Therefore, this paper discusses the current developments of domestic robots, the principle of deep learning, the applications of AI in domestic robots as well as their benefits. This paper summarizes the existing development of domestic robots, the principle and applications of AI inside domestic robots, pointing out a possible direction of utilizing AI with deep learning for future domestic robots' development. With the ability to think independently, future domestic robots will be able to carry out complex moves and logical thinking, enabling them to not only complete complex household chores with ease, but also provide linguistic interactions and many other functions.

Keywords: Domestic robot, AI, Deep learning.

1 Introduction

To save efforts from busy daily routines, humans demand a type of machine that can replace themselves to do some house chores. One successful innovation of such a machine is known as the sweeping robot, which replaces humans to clean the floor. Though unable to achieve people's wishes of doing all kinds of chores, sweeping robots marked an initiation for autonomous robots in household applications. Most of the existing domestic robots are based on sensor technologies and datasets. For example, some sweeping robots utilize laser simultaneous localization and mapping (SLAM) algorithm to obtain data from surrounding environments [1], so that the robots can move freely and prevent unnecessary collisions with other objects like walls. Some other domestic robots, which have computer vision, employ datasets when trying to recognize objects. An available benchmark dataset called object detection for sweeping robots in home scenes provides a huge number of images and

Y. Yue (ed.), *Proceedings of the 2024 International Conference on Mechanics, Electronics Engineering and Automation (ICMEEA 2024)*, Advances in Engineering Research 240,
https://doi.org/10.2991/978-94-6463-518-8_67

instances for domestic robots [2], enabling them to scan and detect objects that are similar or almost identical to those stored in the datasets. Except for the previous two methods, there are more ways of making domestic robots more intelligent. Such as accessing online open-source image searching engines, so that the robots, instead of using datasets, can obtain more object recognition results from clouds [3]. However, all previous methodologies have limitations. For instance, If the robots access existing datasets stored locally or datasets from clouds, the amount of extant data always has a limit, meaning the domestic robots are unable to identify objects that are recently invented or never stored in datasets. To make such robots' visions remain functional when encountering new objects, datasets, stored inside them or datasets in clouds must be constantly updated. To overcome the limitation, a new technology becomes the best choice: AI (AI) with deep learning. Before handing the robots to customers, deep learning, a subset of machine learning, learns the appearances of a variety of objects, human languages, and many other things via neural networks. Later in the households, the domestic robots utilize their learned data, making them able to identify more objects regardless of how the appearances of those objects change. Not only that, households may instruct domestic robots to learn to do household chores, which also can be easily done with deep learning. Compared to the dataset methodology, deep learning AI is more efficient, more accurate, and more cost-effective since numerous datasets are no longer needed.

This paper reviews the current development of domestic robots, the mechanism of deep learning, how can AI be applied to domestic robots as well as its benefits. With the advancement of deep learning, it is possible to invent domestic robots that are just like humans: Not only able to learn and complete household chores with ease, but also provide communication and entertainment for households. By the time, with possibly more functions added, such robots will greatly improve the convenience of people's lives, and it will be a milestone of the development of autonomous robots.

2 Progress in Domestic Robot

2.1 Definition of Domestic Robot

Domestic robot is a type of autonomous robot aimed to do household chores and provide services for people and may also be applied for education and entertainment [4]. From their initial appearance in public, domestic robots' responsibilities have rapidly expanded: From simply delivering food and drink through set routes to combining AI which made the domestic robots able to perform tasks with complexity. Modern domestic robots can communicate with humans. For one purpose, as previously mentioned, provides service to humans as they are instructed. For another purpose, reacts to humans in a conversation which would build up intimacy and trust with households [5]. Thus, the development of domestic robots' trends to be intelligent, meaning they can fulfill multiple obligations: Including but not limited to completing household chores, bringing a sense of happiness to households, and many other functions.

2.2 Recent Developments in Domestic Robots

The latest development of a domestic robot can be considered to be the Mobile Aloha developed by Fu et al.: A domestic robot that has its learning assisted by data collected from a whole-body teleoperation system [6]. The robot is initially manipulated by humans manually using the teleoperation system, to collect data about the surrounding environment, to conduct some tasks. Throughout this process, the robot gathers important data into its dataset so that it can familiarize itself with the physical surroundings and geographical locations. With data being successfully collected and identified, completing complex tasks with autonomous manipulations is made possible

There are other household robots developed recently, though they are not as multifunctional as the Mobile Aloha robot. Amazon announced its domestic robot product 'Astro' in September 2021 [7]. The 'Astro' is a wheeled robot with an interactable touchscreen, as well as built-in sensors and some carriage capacity. Unlike the previous example, 'Astro' is a fully developed robot model mainly focused on interaction and alert purposes. With the ability to connect with Amazon's smart AI assistance 'Alexa' [8], 'Astro' provides entertainment such as streaming music and video [8]. In addition, the built-in camera enables 'Astro' to continuously update real-time conditions inside the house [8].

Though the domestic robot is not a fresh new concept, most of them are only designed for completing simple tasks such as mowing lawns, cleaning floors, and interacting with humans [4]. With the rapid development of AI technology, multifunctional domestic robots like the Mobile Aloha may see their innovations widespread in the future

3 AI Applications in Domestic Robot

3.1 Principles of AI in Domestic Robots

AI with deep learning and machine learning are undeniably the pioneers in revolutionizing the domestic robot industry [9]. With AI algorithms implanted into robots' computing systems, domestic robots become more intelligent in doing household chores: They gain the ability to logically thinking, making their actions fast and efficient. In addition, with high precision and more accurate calculation, they can execute complicated chores with lower safety risk and considerable quality of completion. Machine learning is a branch of computational algorithms that imitates the human brain to learn from the surrounding environment [10]. Deep learning, a subset of machine learning, is widely applied in building an AI with functionalities such as speech recognition, visual object recognition, and object detection, etc. [11]. Thus, deep learning and its learning model: neural networks, are to be discussed further in this part.

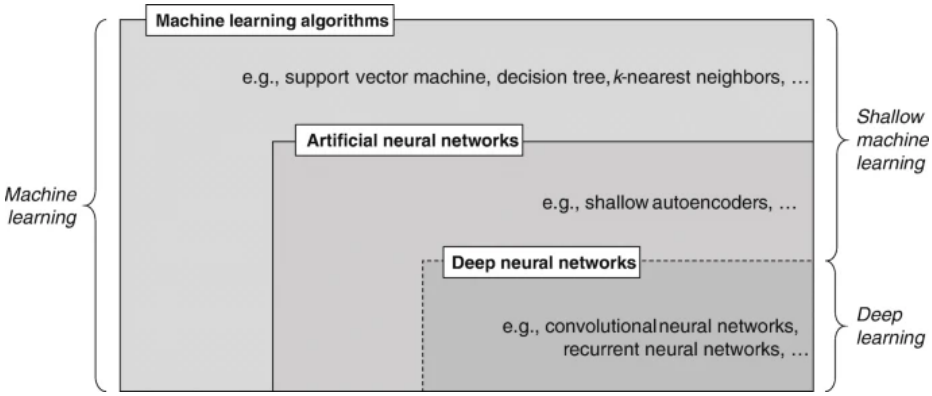

Fig. 1. Venn diagram of machine learning [12].

Fig. 1 illustrates a Venn diagram of machine learning and deep learning. Neural networks are what provide the ability to learn in the process of deep learning. They have excellent features, for instance, high accuracy [12], which makes them the most pivotal component of deep learning. There are two common types of networks: Convolutional neural networks and recurrent neural networks [13, 14].

Convolutional neural networks (CNN) provide AI with essential functions, namely computer vision, image recognition, and speech recognition [15], carried out by convolution operation [16]. Different from human eyes, the computer recognizes images as pixels in binary code arranged in a sequence.

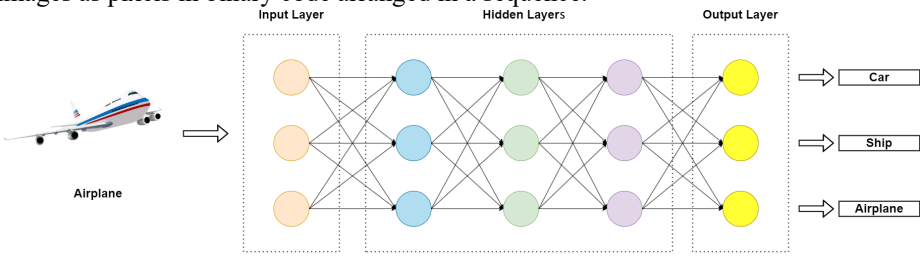

Fig. 2. Simplified model of a CNN. (Picture credit: Original)

Fig. 2 illustrates a simplified model of convolutional neural networks. CNN consists of three sections: Input layer, Hidden layers, and Output layer. In the section of the input layer, the computer is fed with an image of an object. Then the image passes through the hidden layers, which contain multiple filters. These filters also considered layers, each extract features from the image [16] and then transfer them to the next layer. When the processing reaches its final section, the output layer determines possibility distributions for every option [16] (e.g., car, ship, and airplane) Eventually, the option with the highest possibility is considered as the result.

Another neural network, the recurrent neural network (RNN) works in a slightly different way. CNN can analyze images with great accuracy; however, it is only able to process static images. The reason is that the CNN is feed-forward [17], meaning

the process is only conducted once from the input layer to the output layer. In recurrent neural networks, as its name suggests, the process recurs itself.

Take a very simple example here: A football is shown in Fig. 3. In CNN, the output of vision recognition will be a football, but it is not possible to determine which direction of the football's motion.

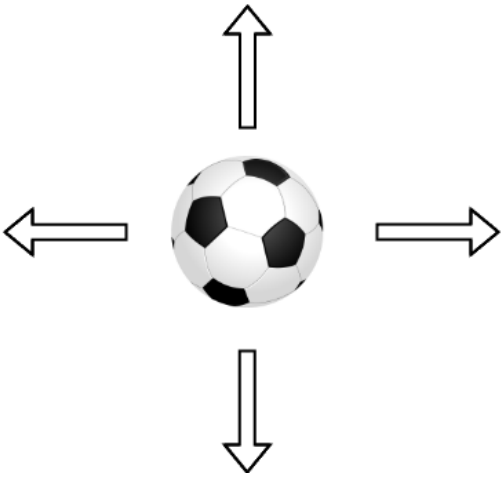

Fig. 3. A football. (Picture credit: Original)

In the hidden layers of RNN, recurrence happens between certain layers. Fig. 4 represents a motion of a football moving both to the right and upward. Fig. 5 demonstrates how the motion in Fig. 4 is computed in a simplified RNN model.

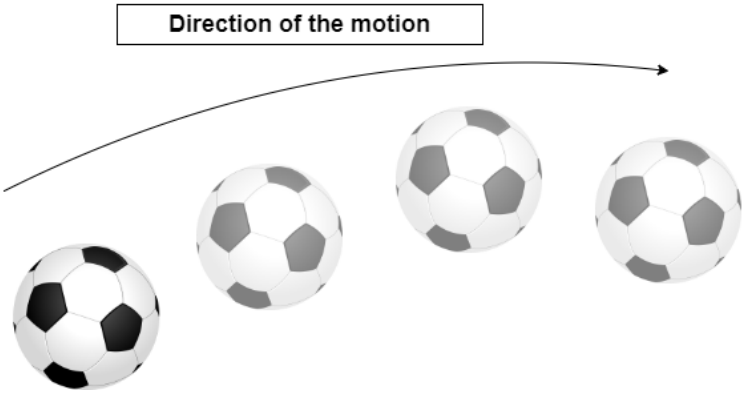

Fig. 4. A football in motion. (Picture credit: Original)

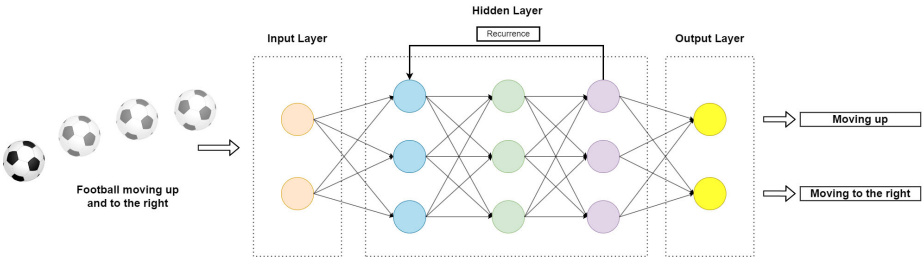

Fig. 5. Simplified model of an RNN. (Picture credit: Original)

As Fig. 5 shows, after data reaches the last hidden layer, it is transferred back to the first hidden layer. Then the data continues its path forward (to the right) toward the last hidden layer, completing a loop inside the RNN model. By doing the iteration, the input data will be processed multiple times, resulting in any detection of the change of position of the football.

By utilizing CNN or RNN, deep learning can be extremely efficient. Before the robots are sent to households, AI (with deep learning ability) inside the systems learns a variety of objects, sounds, and terrains, making them able to recognize and distinguish objects in houses with great accuracy [12]. Such accuracy is crucial in guaranteeing safety and efficiency when executing household chores, no matter if it is a simple task or a task with great complexity.

3.2 Current applications of AI in domestic robots

Objects and Speech Recognition. AI can help domestic robots recognize both objects and speech. For the example of how AI recognizes the object, the domestic robots first catch the figures or images with their camera. Then, the images and figures are sent to preprocess such as adjusting the size, the data is then sent to extract the features including textures, colors edges, etc. Adding these features that were analyzed to deep learning algorithms, for instance, as the CNN and RNN mentioned above, could give some help in training the deep learning algorithms. To be more specific, CNN is more useful than RNN in the recognition of objects due to the reason that CNN is able to capture the spatial features of images better. Once the deep learning model has been trained, the domestic robots can recognize the object through their camera, so that the domestic robots are able to detect whether there is a specific object in their sights. The domestic robots may collect the recognition results and give out feedback or optimize the algorithm, these could actively demonstrate that deep learning can improve the efficiency and accuracy of recognizing objects.

For recognizing the speaker and the information, there are few differences compared to the recognition of objects. However, the features detected by domestic robots may change to Mel-Frequency Cepstral Coefficients. This can help detect the age of users and identify the identity of the user in a family according to analysis [18]. The data are then sent to the well-trained acoustic model, as an illustration, a hybrid model of the Hidden Markov/Radial Basis Function Neural Network (HMM/RBF)

[19]. According to the recent research by Wu X and Zhang Q, by combining the HMM model with dynamic timing modeling capabilities and the RBF model with classification decision-making ability, domestic robots can recognize the users' emotions with higher correctness and efficiency. The output of the hybrid model is decoded into an understandable sequence of text. Natural Language Processing aims to make further processes to determine the user's intent and translate the decoded intent into executable commands for domestic robots. In that way, the domestic robots could understand the instructions from their users better and give out more useful help even including soothing their users.

Route Navigation. Route navigation is one of the competencies that can be executed by AI in domestic robots as well. By combining a variety of sensors with different functions, the domestic robots are able to perceive their surrounding environment and construct relevant maps. The AI algorithms can help domestic robots to plan the optimal path and avoid obstacles. Moreover, the AI algorithms can make the domestic robots adapt to the environment such as redecoration of the house, and help with the decision making, for the sake of clarity, AI algorithms assist domestic robots make a choice like whether to avoid or move the obstacle. When the battery is low, the AI algorithms can guide the robot to go to the right place to charge.

Sensors Utilization. The AI in domestic robots can utilize different sensors to perceive the environment and control intelligent devices such as air conditioners, luminaires, and so on. It can also detect unusual situations such as the broken water pipe and the inferno. To illustrate the example of the detection and alarming the inferno, the fire sensors, heat sensors, distributed optical fiber heat detectors, thermos resistance sensors, miscellaneous heat detectors, gas sensors, metal oxide semiconductor gas sensors, optical gas sensors, acoustic gas sensors, miscellaneous gas sensors, flame sensors, smoke sensors and multifarious sensors [20], work together and send these data to a well-trained algorithm, combining these sensors can also lead to higher successful rate of fire detection. According to the recent research by M. Ajith and M. Martínez-Ramón, the algorithm called Markov Random Fields distinguishes fire, smoke, and background with a high accuracy and correctness of 95.39% [21]. By learning normal household activities, algorithms can recognize abnormal situations such as the abnormal operation of electrical appliances, which might be the premonitory of the electrical fire. The algorithm can predict the potential fire risks and remind the users to maintain the devices by analyzing the data from these sensors. Once the algorithm detects that there is a fire, it can activate the relevant measures such as cutting off the power supply and the algorithm can also provide the optimal evacuation routes that could increase the survival rates of residents in the fire.

3.3 Benefits of AI Applications and Future Improvements in Domestic Robot

First of all, AI that is applied to domestic robots may have a lower cost. To be specific, once an AI system is developed, it can apply to multiple occasions and a variety number of domestic robots, therefore, the users do not need too much maintenance, which outweighs the expenditure of exploitation and development. Second, AI has higher efficiency and accuracy. To be exact, the algorithms keep improving all the time, which means the household robots can perform better as time passes. It could also improve workflows and improve the decisions that humans make, and AI makes controlling and sending out instructions easier. Third, the AI algorithms can give users a more personalized service. The algorithms can learn from the users' behaviors, hobbies, and preferences, consequently, the domestic robots could give out advice that is more in line with their users' own.

Moving forward, AI must be improved to give better experiences to users. To begin with, develop more advanced algorithms and increase the robustness. This can lead the domestic robots to a more stable operation while facing situations like drastic collisions and increase the accuracy of the operation results. Furthermore, establishes and unifies the standards of the domestic robot industry. Therefore, the interactions between different domestic robots can get better. Additionally, protecting the privacy of users is significant. To be more specific, encrypting data and restricting access are some of the useful measures.

4 Conclusion

To sum up, everything that has been stated, having delved deeply into the subject of domestic robots in this paper, it becomes clear how AI algorithms such as CNN and RNN cooperate with the domestic robots and help to make better decisions, to be more specific, RNN can deal with the dynamic images more efficiently. The recent development of domestic robots and applications in domestic robots have contributed to the understanding of the principle of operating domestic robots. These technologies help domestic robots progress and develop at a rapid speed, the domestic robots may not be only a single tool in the future, but also could integrate into the family and be a part of a family. The remarkable developments in the AI models and AI algorithms of domestic robots make them more intelligent and react to better interaction while communicating with their users.

The value of this paper lies in its ability to introduce the current development in domestic robots, illustrate the main algorithms of deep learning that are applied in the domestic robots, and enumerate examples of detecting and recognizing speech and objects, navigating the routes, and utilizing the sensors with different functions. Furthermore, this paper also writes about the benefits of AI algorithms and models in domestic robots, which gave a deep potential in the development of the industry of domestic robots. The future of domestic robots is hopeful due to the core of AI, they can even provide entertainment in the forward years.

In addition, to give the users a better experience while using domestic robots, developing more advanced AI algorithms and models is truly significant in the

development of domestic robots. This could help them become more reliable and easier to control. Strengthening the domestic robots' robustness which can operate more stable while facing abnormal situations thereby improves the accuracy of their output. The privacy of their users is also an important part of the use of domestic robots, this can prevent the users from some attacks. Thus, the protection of users' privacy has to be strengthened in the future.

Ultimately, according to the sustainable development of technology, the living standards of citizens are keeping increasing. People pay more attention to themselves rather than spending spare time in the household, and the demand for domestic robots might have a huge increase in the time of a few years. The domestic robots still have a large amount of space for improvements.

Authors Contribution

All the authors contributed equally, and their names were listed in alphabetical order.

References

1. Pan, S., Xie, Z, Jiang, Y.: Sweeping Robot Based on Laser SLAM. Procedia Computer Science **199**, 1205–1212 (2022)
2. Lv, Y., Fang, Y., Chi, W., Chen, G., Sun, L.: Object Detection for Sweeping Robots in Home Scenes (ODSR-IHS): A Novel Benchmark Dataset. EEE Access **9**, 17820–17828 (2021)
3. Kehoe, B., Matsukawa, A., Candido, S., Kuffner, J., Goldberg, K.: Cloud-based robot grasping with the google object recognition engine. In: 2013 IEEE International Conference on Robotics and Automation, pp. 4263–4270. Karlsruhe, Germany (2013)
4. Domestic robot. Wikipedia, https://en.wikipedia.org/wiki/Domestic_robot, last accessed 2024/05/12
5. Caudwell, C., Lacey, C.: What do home robots want? The ambivalent power of cuteness in robotic relationships. Convergence **26**(4), 956–968 (2020)
6. Fu, Z., Zhao, T. Z., Finn, C.: Mobile aloha: Learning bimanual mobile manipulation with low-cost whole-body teleoperation. arXiv preprint arXiv:2401.02117 (2024)
7. Guerrero Peño, E.: How the TAII Framework Could Influence the Amazon´ s Astro Home Robot Development. Available at SSRN 4015317 (2022)
8. Amazon Astro, https://www.amazon.com/astro, last accessed 2024/05/24
9. Mohsen, S., Behrooz, A., Roza, D.: AI, Machine Learning and Deep Learning in Advanced Robotics, A Review. Cognitive Robotics **3**, 57–70 (2023)
10. EI Naqa, I., Murphy, M.J.: Machine Learning in Radiation Oncology. 1st edn. Springer Cham, Switzerland (2015)
11. LeCun, Y., Bengio, Y., Hinton, G.: Deep learning. Nature **521**, 436–444 (2015)
12. Janiesch, C., Zschech, P. and Heinrich, K.: Machine learning and deep learning. Electron Markets **31**, 685–695 (2021)
13. Sze, V., Chen, Y. H., Yang, T. J., Emer, J. S.: Proceedings of the IEEE. Efficient Processing of Deep Neural Networks: A Tutorial and Survey. **105**(12), 2295-2329 (2017)

14. Vulpi, F. Milella, A. Marani, R. Reina, G.: Recurrent and convolutional neural networks for deep terrain classification by autonomous robots. Journal of Terramechanics **96**, 119-131 (2021)
15. Krichen, M.: Convolutional neural networks: A survey. Computers **12**(8), 151 (2023)
16. Zhang, X., Zhang, X., Wang, W.: Convolutional Neural Network. Intelligent Information Processing with Matlab. Springer, Singapore (2023)
17. Ketkar, N., Moolayil, J.: Feed-Forward Neural Networks. Deep Learning with Python. Apress, Berkeley, CA (2021)
18. Meng, Z., Liu, H., Ma, A. C.: Optimizing Voice Recognition Informatic Robots for Effective Communication in Outpatient Settings. Cureus **15**(9), e44848 (2023)
19. Wu, X., and Zhang, Q.: Design of aging smart home products based on radial basis function speech emotion recognition. Frontiers in Psychology, **13**, 882709 (2022)
20. Khan, F., Xu, Z., Sun, J., Khan, F.M., Ahmed, A., Zhao, Y.: Recent advances in sensors for fire detection. Sensors **22**(9), 3310 (2022)
21. Ajith, M., Martínez-Ramón, M.: Unsupervised segmentation of fire and smoke from infrared videos. IEEE Access **7**, 182381—182394 (2019)