Service Robotics: Technology and Applications

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Introduction

Service robotics is an expanded subfield of robotics dedicated to making robots that can assist people with everyday tasks in human-inhabited environments. In the past, robots were primarily used in factory settings where the environment was fairly constant and the robot had a very specific task that did not require human interaction. For robots to exist in complex human-inhabited environments and perform a variety of tasks in that environment requires new technology and algorithms to be applied. Service robots have potential applications in a variety of environments, some of the most prevalent being in elder care and office spaces. To work effectively in these environments, the robots must be approachable, responsive, and effective at accomplishing their tasks to the specifications of the person. There are many technologies that must come together to make this happen, including speech recognition, sensor and navigation technology, and machine learning algorithms. In this report, we will go through some of these technologies and how they are being used to make service robotics more effective.

Uses

Elder Care

One of the primary anticipated uses for service robotics is elder care. Elderly populations are expected to increase, which will lead to further strains on the caregiving profession. The proportion of elderly in developing regions is expected to grow from 15.3% in developed countries and 5.5% in developing regions in 2005 to 25.9% and 14.6% respectively in 2050, according to Mukhopadhyay et al. Many elderly people want to maintain a sense of independence, even though they may not be fully capable of living on their own anymore. Many families would consider living with their aging parents, getting a caregiver, or sending them to a nursing home, but perhaps assistive robotics could offer a better compromise. The intrusiveness of the service robots being introduced varies. Some can act as full-fledged assistants that can be given tasks by the elderly person, and they will do them, while others, like the one proposed in Mukhopadhyay et al., are minimally invasive and are small robots with a camera and other sensors to detect if the person has fallen or needs assistance.

Offices

Another area for the use of service robots is in office spaces. Workers can ask the robot to deliver things to other people or do tasks like emptying trash cans or cleaning whiteboards. This could save time for people and allow them to do more productive work by avoiding time-consuming, unproductive tasks. The main problem with robots operating in the office space is the aspect of human interaction. Robots must be able to roam the hallways without getting in people's ways and be able to effectively communicate with people in order to know what tasks they have to complete. In the paper by Jean et al., they dive into the necessary functionality of a delivery robot, such as speech recognition and dialogue system, a hand gesture system, sound direction detection system, manipulators, and a wheeled mobile platform. Office spaces are complex and rapidly changing environments, with people and chairs constantly moving to block paths. The robot must be able to adapt to the changes in real time and come up with new navigation plans depending on the obstacles in front of it.

Technology

Navigation

One of the most important aspects of creating an effective service bot is giving it a way to perceive its environment and navigate to locations without hitting any obstacles. One way of doing this is with LiDAR. LiDAR detects objects in the environment by sending out beams of light which hit objects and bounce back to the sensor, allowing it to know where objects in the environment are located. 2D LiDAR uses a single horizontal scanning line, while 3D LiDAR sends beams of light in many different directions. While 3D LiDAR seems like the better sensor type, they are very expensive so often 2D LiDAR sensors are used in conjunction with other, cheaper sensor types (Gatesichapakorn et al.). Depth cameras using point clouds are a cost-effective solution when combined with the 2D LiDAR. All the sensors must be synced up and allowed to communicate with the robot, which is usually done using ROS (Robot Operating System) (Gatesichapakorn et al.). In addition to the sensors to detect objects in real time, the robot must also have a preloaded 2D map to navigate to specific locations and know where it is in relation to goals. ROS provides many different packages to help with localization of the so that the sensor data can help determine where the robot is on the map. In Gatesichapakorn et al., a Python script was used and interfaced with ROS to coordinate with the sensors and mapping to navigate to a goal, updating the current location of the bot on the static map in real time.

Speech Recognition

Speech recognition is necessary for the robot to know what tasks it is supposed to accomplish. Speech recognition can be difficult to implement, especially if there are factors such as noise cancellation for loud rooms or if there isn't a clear method for giving instructions to the robot. An alternative to speech recognition would be using a user interface to give the robot instructions which would make it less error prone. However, successful implementation of speech recognition would make giving the robot tasks faster and more practical. In Wachsmuth et al., the speech model for a robotic arm is trained using human-robot interaction. In this model, there is a teach-in phase where the trainer manually moves the arm to a position and says a word that the robot will associate with that position. Using an offline speech recognition software, the word is transcirbed so that it can be identified in the context of a sentence along with descriptive characteristics relating to the word. In real time, the robot will continuously listen to ambient noise and as soon as a signal word is identified, the on-board computer executes the task that it learned in the teach-in phase. An issue with speech recognition comes from the environment being noisy and reverberant, which may highly degrade the system. In the paper by Cho et al., they use blind source separation, which recovers unobserved sources from several observed mixtures without knowing the mixing systems. This involves taking the short-time Fourier transform of the source signals to separate them and pick out the desired signal, which would be the person talking. With this model, the robot could be addressed from any direction at any time, and it should be able to pick up on the voice and register the command.

Machine Learning

The primary method for service robots to adapt to novel environments is through machine learning. Machine learning algorithms are the basis for the speech recognition and navigation algorithms that we discussed earlier. Reinforcement learning algorithms enable a robot to learn a novel task through repetition, like how a child would learn a task for the first time. Since a service robot may not come preprogrammed with all the knowledge it needs to complete an arbitrary task, it may need to learn through experiences how to do a task properly. In Zhu et al., deep reinforcement learning is used for robot navigation in a variety of scenarios, including obstacle avoidance and multi-robot navigation. The deep neural network used in the deep reinforcement learning process has a loss function which assigns certain values to actions in certain scenarios and in the future will determine which actions produced the least loss in each scenario. This helps the robot develop and optimal set of actions in a scenario to minimize the overall loss. Reinforcement learning algorithms can be applied to many aspects of service robot learning and are an essential part of the process for helping robots learn new tasks.

Conclusion

Service robotics is a rapidly expanding field that could become very commonplace in the coming years. The areas of elderly care and office work are two that could be heavily impacted as service robots could help with basic tasks to free up other people.

The technology involved in service robotics is constantly developing, such as robotic navigation and speech recognition. Sensors like LiDAR and depth cameras are used to help the robots perceive their surroundings and operate in human-inhabited environments. Speech recognition will allow for interaction with humans so that the robot can perform the necessary tasks. Traditionally, robots were used in industrial settings where they have a very specific purpose, and the environment does not change very much. Having service robots that can exist in complex environments and perform a variety of tasks is new and far more challenging, which is why this is such an exciting field. There are many technological and cost barriers to still overcome before service robots become widely used, but there are numerous research efforts making progress and bringing them closer to practical usability.

References

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