Overview

The goal of the proposed project is to provide an algorithm that will provide robots with enhanced grasping capabilities. Through the use of machine learning and simulation, the algorithm will take in object features including material strength, temperature, center of gravity, and friction coefficients as well as a robot arm configuration to generate a series of potential grasping positions that will allow a robot to safely and properly grasp and move the given object. Initial research and testing will be conducted using OpenRAVE simulation software with its grasping module, and the algorithm will be tested using Willow Garage's PR2 robot. As this project focuses on improving the dexterity and manipulation of robots, it falls under the subtopic RH2, Robotic Applications.

Intellectual Merit

This Small Business Innovation Research Phase 1 project addresses the current issue of robotic grasping. As it stands now, something as simple as a coffee cup proves a challenge for robots. By using grasping algorithms of today, material properties of the cup are lost. The liquid inside the cup is not factored into the decision, and the fragility of the cup does not play a deciding factor either. This yields grasping positions that may include sticking the robotic arm inside the mug into the liquid, grabbing the handle and tipping the cup over, or squeezing the cup too hard causing it to shatter.

In the proposed approach, once the robot identifies the object in question is a cup, it will look at precomputed grasping positions that the intelligent algorithm calculated. These grasping positions will take into account a typical mug's material, acknowledge that a mug usually contains liquid and the interior cannot be used for grasping, and understand that gripping by the handle may not be best due to the center of gravity.

This project assumes that the object properties (center of gravity, coefficient of friction, surfaces that are off limits for grasping) are already determined and provided to the algorithm. The main focus of the project is to predict the best grasping position given this data. The two largest hurdles to overcome will be understanding how all this data interacts as well as how to generalize a solution to a variety of different complex objects.

The project will begin with extending OpenRAVE's grasping module to work with complex objects in a physics free environment. After that the research will be focused on using the supplied datapoints to generalize a solution for any object. This algorithm will then be used to extend the grasping module. Once tested in simulation, tests will begin using the PR2.

Broader Impact

The success of this project will aid in the advancement of human-robot interaction. Commercially, this technology will provide one piece of the puzzle in the development and production of robots that can take care of the sick and elderly. The basic task of grasping is essential for the long term goals of having robots in the household, and this algorithm will bring roboticists one step closer to making this dream a reality.

Project Summary Revised | Joshua Shapiro | 26 September 2016 | Senior Design

The goal of the proposed project is to provide an algorithm that will provide robots with enhanced grasping capabilities. The algorithm will take in object features including material strength, temperature, center of gravity, and friction coefficients as well as a robotics arm configuration. Through the use of machine learning and simulation, a series of potential grasping positions will be generated that will allow a robot to safely and properly grasp and move the given object. Initial research and testing will be conducted using OpenRAVE simulation software with its grasping module, and the algorithm will be tested using Willow Garage's PR2 robot. As this project focuses on improving the dexterity and manipulation of robots, it falls under the subtopic RH2, Robotic Applications. Keywords released to the proposal include machine learning, OpenRAVE, robotic grasping, and human-robot interaction.

This Small Business Innovation Research Phase 1 project addresses the current issue of robotic grasping. As it stands now, objects as simple as a coffee cup prove challenging for robots. By using grasping algorithms of today, material properties of objects are lost. Grip strength has to be guessed and tested instead of calculated based on center of gravity and coefficients of friction. Whether the objects contain liquids or are made of fragile materials does not affect the grip output. When handling a coffee cup for example, the robot has no understanding that gripping the cup on its interior surfaces would contaminate an individual's coffee.

In the proposed approach, once the robot detects the object in question, it will look at precomputed grasping positions that the intelligent algorithm calculated. These grasping positions will take into account the object's material, acknowledge there may be surfaces that cannot be grasped (such as the inside of a mug), and understand the best grip positions factoring in center of gravity and friction.

This project assumes that the object properties (center of gravity, coefficient of friction, surfaces that are off limits for grasping) are already determined and provided to the algorithm. The main focus of the project is to predict the best grasping position given this data, not fetching this data in the first place . The two largest hurdles to overcome will be understanding how all this data interacts as well as how to generalize a solution to a variety of different complex objects.

The project will begin with extending OpenRAVE's grasping module to work with complex objects in a physics free environment. After that the research will be focused on using the supplied datapoints to generalize a solution for any object. This algorithm will then be used to extend the grasping module. Once the algorithm has been run through a number of simulations, it will be tested using the PR2.

The success of this project will aid in the advancement of human-robot interaction. In the past 5 years, there has been great success with bringing robots into the home. Machines like the Roomba and Amazon Echo demonstrate the progress made in speech recognition and robot navigation. The last part of the puzzle needed for complete human-robot interaction in the home is the ability for a robot to interact with objects in its surroundings. By creating a grasping algorithm that takes into account the variables that come up in a typical home, this problem will become partially solved.

Commercially, this technology will provide the basis for the development and production of robots that can take care of the sick and elderly, help clean houses, and even take care of young children. The impacts of grasping are far reaching, and this technology will bring true human-robot interaction closer to the masses.

Elevator Pitch | Joshua Shapiro | 26 September 2016 | Senior Design

In the past 5 years, there has been great success with bringing robots into the home. Devices like Amazon Echo and Roomba illustrate the advances that have been made in natural language processing and indoor navigation. However, one piece of the puzzle is still absent before we can have true human-robot interaction in the home. That piece is grasping. The current algorithms for grasping don't work well for dynamic environments and typically don't take into account material properties of the objects being grasped. This works fine for factory robots that work in a human-free environment manipulating the same object in the same way daily, but for robots to exist in the home a better solution must be found.

This proposed project aims to create that solution. By taking in material properties such as center of gravity, friction coefficients, and surface material, the proposed algorithm will be able to more intelligently suggest grasping positions for robots. This results in robots that could pick up coffee cups without spilling, handle tv remotes without accidentally pressing buttons, and moving cooking utensils while being cognizant of hot areas.

By creating an algorithm that enables robots to process not just objects but the context in which they exist, we will be one step closer to true robot assistants in the home. The elderly would be able to live at home with their independence longer. Those that are sick would still be able to have a proper home-cooked meal. While grasping seems like a small insignificant problem, its solution will provide immensely beneficial in the future of robotics.

Commercial Opportunity

In the United States there are over 12 million individuals who live in some form of assisted living. These people have lost their independence due to old age or chronic illness. Though not physically able, a large percentage of these individuals are completely mentally aware, and crave for the independent life they once had. They wither away in assisted living facilities, burdening family members with the high financial costs of care. Additionally, the care provided at these facilities varies drastically, and numerous reports of elderly abuse populate the news every year. It is sickening to realize individuals with their full mental faculties are being cast away and abused in costly nursing homes simply because of physical disabilities or age.

The problems that face adults in assisted living facilities also affect young children. 21 million people in the United States are under the age of 5. These children are incapable of taking care of themselves, and must be supervised throughout the day. For some families, this care takes the form of expensive nannies that sit at home with the child beckoning to his or her every whim. For others, child care consists of daycares that suffer from similar problems as nursing homes. These facilities are typically over priced and understaffed, and in some cases employ unqualified workers that abuse the children. Even so, for other families daycare is simply too expensive and young children are left at home and neglected as the parents are forced to go to work. None of these situations are perfect, and these experiences in a child's formative years will shape the child for the rest of his or her life.

For both children and the physically disabled, there is an apparent need for robotic assistants. While the technology is at least 5 years out, it is not unreasonable to replace human care in both of these situations with robots. For the elderly and physically handicapped, a robot in the home could give back the independence that they once had. For children, a robot could provide the one on one attention that is not possible in a daycare setting. And for both of these groups, robots would be far cheaper in the long run than the other options and would provide more standardized non abusive care for all individuals.

Though robots will solve the various problems that plague the child-care and assisted-care industries, there are a handful of issues that keep this technology 5 years away. The current cost of a robot with the sensors necessary to navigate a home environment and interact with it is over $400,000. Given enough time, this cost will drop substantially, and research has been conducted in manufacturing parts in a far cheaper way. If a robot is to traverse an individual's home, it is imperative that it has the ability to navigate without GPS and can identify stairs and other obstacles that it cannot traverse. While this navigational skill is definitely a barrier to entry, devices like the Roomba show that it is possible to implement interior navigational capability in production. Most importantly, if a robot is to interact with humans it must be safe. There should be no way the robot can injure individuals or pets, and it is assumed the robot will not destroy its environment. Most factory robots work in controlled settings where humans are not present, so this is one area of research that will need to be expanded over the next 5 years. Finally, if a robot is to help those in need, it must have the capability to fetch objects and bring them to the user. This grasping capability is the focus of this NSF proposal.

Currently, basic grasping algorithms do exist. It is possible to objectively compute the "best" grasping positions given an object, however these algorithms do not take into effect the object's material properties. This type of algorithm works fine when robots are picking up screws and bolts to assemble cars, but falls short when a robot needs to fetch a tv remote or glass of water. In both of these circumstances it is imperative the robot knows more about the object than its shape. For the tv remote, the robot must not press buttons when picking it up. For the glass of water, the robot needs to understand that the glass may shatter if squeezed to hard, the interior of the glass is not a good place to pick it up, and the orientation must remain upright so as to not spill the water when moving. The proposed algorithm handles these situations. By taking in human input for the material properties of objects, a database is created that can be shared across multiple robots. Once a robot identifies an object, it can look in the database for the material properties and then generate a grasp with these new attributes in mind. Once completed, this algorithm will revolutionize human-robot interaction.

As stated above, it will take an estimated 5 years before a robot can replace humans in assisted living situations. A large part of this time is due to the stringent safety testing that would need to be conducted before a robot could be put into production. If this device were also responsible for administering medicine to patients, other tests would be required that could set back production by at least another 3 years. However, the grasping algorithm is no more than 1 year away from complete development. Since the fundamentals of grasping have already been completed and the code is being used today, the updated grasping algorithm simply requires extending the pre-existing code base. While some of the code will have to be modified and rewritten, the majority of the work will involve using object attributes to create a subset of the object. This subset can then be run through the original algorithm to generate possible grasps. The cost of grasping development will not be high, though the expenses for safety testing will be substantial.

While production of the robot will be expensive, the demand for the product ensures that a profit will be made. By just looking at the two customer segments mentioned in the beginning, 10% of the United States population can use this product. If the cost of the robot is $20,000, this will net a revenue of $660,000,000,000. Insurance could subsidize a large portion of cost allowing a greater market reach. Then, software updates and repairs ensure that there will be a continuous cash flow after the initial sale. Even will high cost of testing, the revenue is promising. Over time, newer versions can be developed causing increase in sales, and eventually the market can expand to the wealthy who are simply lazy and have no true need for a robot assistant.

Overall, this product can revolutionize the world. Robots can give independence back to those who lost it too early in their lives. They can give children the individual attention needed at such a young age. Robots can solve some of the biggest problems in the assisted living industry, and by financing this algorithm we will be one step closer to this robot reality.

Societal Impact

As mentioned above, 33 million people in the United States are dependent on another human being for the most basic tasks. If left alone, these individuals would sadly perish in a matter of days. These individuals currently receive expensive and subpar care, and are in dire need of an alternative. The creation of robotic assistants can drastically reduce the cost of care while substantially increasing the attention given. Elderly individuals would no longer need to be put in nursing homes, and could keep their independence and live in their own houses. Children would no longer need to be taken to and from daycare, and could simply stay at home with the added safety of a robot. Just looking at these two customer segments, 10% of the United States population can be positively affected by the production of robot assistants.

In addition to those who truly need this technology, robot assistants could quickly expand to wealthy homes and to the workplace. The wealthy who hire butlers and maids could easily replace these individuals with robots that cost less and perform better. Workplaces could begin to replace some of the repetitive monotonous tasks with robots as well. Currently at Carnegie Mellon University there is a fleet of 6 robots that deliver mail and packages between classrooms. In a similar vein, offices could use robots to pick up mail, fetch copies from printers, and get coffee for the workers. This would yield higher productivity from the workforce as less time would have to be spent doing repetitive monotonous tasks and more time could be spent solving the creative challenging problems humans are good at solving.

Unfortunately, safety is a large concern regarding putting robotic assistants in production. The obvious fear is that robots may accidentally cause injury to humans or pets when navigating through home environments. While thousands of hours of safety testing will be performed on these devices before they are put in production, there are no clear laws or regulation that dictate how to test robots for human-robot interaction. Similar to the self-driving car problem, new rules would have to be created, and that is a time consuming process surrounded by rolls of bureaucratic red tape. Even with the laws in place and stringent safety tests performed, there is always the miniscule chance that something goes wrong. And when that eventually happens, the blame must be placed on someone. When a human makes a mistake at a nursing home or a daycare, it is evident who should take the blame. When a robot makes the mistake, is it the company’s fault, or is it no one's fault at all? This question is one of many that need to be decided by lawmakers, and must be done before robots can be present in homes and the workforce.

On a broader scale, the addition of robots in the workforce would unfortunately force a large number of individuals out of their jobs. Those working in healthcare taking care of the elderly and physically disabled will be partially if not fully replaced by robots. Those running daycares will no longer be need either as children could stay at home with their robot. While the future may be grim for both of these professions, the transition will not be immediate and most likely will take decades to fully occur. Additionally, the medical profession will still need specialists to handle the most severe assisted living situations, and robots may not be best for all children. Though a large amount of jobs will inevitably be destroyed, a new industry will be created for manufacturing, servicing, and selling the robots. In the past similar problems have been faced when dealing with innovation. The advent of the car put thousands of horses and carriage drivers out of business, and automated farm equipment put thousands of day laborers out of work. Few would argue that it would be better to not implement the new technology and keep the old jobs. It is important to ease the transition to new innovations as much as possible, but job loss should never prevent innovation from occurring in the first place.

There are unfortunately some severe downsides to robotic assistants, however the good that can come of them far outweighs their negative impact. 33 million people's lives would be dramatically improved, and the amount of elder abuse and child abuse would plummet. Individuals would be able to live independently at home longer, and the number of people withering away in nursing homes would plummet. People would be happier, healthier, and safer, and this positive impact makes the development of robotic assistants worth it in the long run.