Robots – ready to work with and for humans?

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The last decade has seen a sudden growth in interest and funding allocated to robotics. Focus is on robots that can be smart and become good proxy of humans in both their behavior and their understanding of the world. Progresses are steady and robots are becoming smarter every day. They are still very far from matching humans, but they are endowed with this ability that is unique to our species: they can *learn.* This enables them to acquire new skills on the go. Robots can learn either from observing humans or from trying the task on their own. Robots are hence no longer these machines that, once programmed, can only replicate what they had been programmed for when getting out of factory. Robots can progress. They can adapt to their environment and hence become increasingly more flexible. This opens the door for introducing robots in our daily environment. Robots may soon work side by side with humans in factory, drive cars and carry deliveries.

While these progresses lead some to dreams of more profit and of a better world with safer roads, for others they generate all sorts of fears: from the fear to loose ones' job to a robot to the fear of being killed by robots. These fears are not to be underestimated. Yet, robots are far from replacing humans and are more likely to improve the quality of our lives than the converse. Next, I review current and expected trends in *robot manipulation*, an area close to my research.

Robots for factories in the 21st century

Dexterous manipulation of objects is robotics 21st century primary goal and a cornerstone of industry 4.0. It envisions robots capable of sorting objects and packaging them, of chopping vegetables and folding clothes. It also requires robots to be human aware. Robots should work side by side with humans, offering their strength to carry heavy loads, while presenting no danger to humans should they inadvertently touch them. The past decade has made a leap forward endowing robots with new levels of dexterity. These progresses benefitted from breakthroughs in mechanics with new sensors for perceiving touch all along the robot's body and new mechanics for soft actuation to offer compliance. Most importantly, it leverages the immense progresses in machine learning to encapsulate models of uncertainty and to support further advances on adaptive and robust control. Recent years have therefore witnessed a significant turn toward data-driven methods and use of simulators for data generating. Still, grasping and dexterous manipulation require level of reality in, for example, contact modeling for soft contact situations that existing simulators are not yet able to deliver. Learning to manipulate in the real-world is costly both in time and hardware. Two roads are hence pursued. The first one takes inspiration on the way humans acquire skills and has robots learn skills from observing humans performing complex manipulation. This allows robots to acquire manipulation in just a few trials. But, it is not clear how one can generalize the knowledge so acquired to actions different from those demonstrated. The second road constructs databases of real object manipulation, as to better inform the physics of the simulator. Yet, achieving realistic simulation of friction and material deformation from real textures may not be possible and real experimentation will be unavoidable for manipulating deformable objects.

One main challenge to achieve human dexterity is the hardware – both in terms of hand design and accompanying sensing. Human hands are flexible with a dexterous thumb whose unique range of motion still eludes robotics. Compliance is a pre-requisite for dexterity, to conform to the object's shape, to absorb unexpected forces at contact and to compensate for load change during manipulation. Hence, recent efforts build on new solutions from 3D manufacturing and material science, and create *soft* hands.

On par with hardware, perception is a major challenge to dexterous and fluid manipulation. Human manipulation uses haptics, primarily perception of touch and force. Advances in robot perception for manipulation privileges hence multi-modal information processing, combining visual and haptic information in preparation phase to infer information about texture, shapes and orientation. Once the object is in hand, other physical properties, such as rigidity, mass and mass distribution, not readily observable can be inferred through touch and force measurement. Sound has also recently received attention as a mean to infer the object's content when invisible and for monitoring change in content.

Robotics is now particularly interested in dynamic manipulation, such as when manipulating objects *in-hand*, e.g. twisting a pen across fingers. Manipulation does not stop to simply controlling the hand, it requires control of the arm, torso and ultimately the entire body. The challenges listed above only increase in scale when one wishes to enable a full humanoid robot to manipulate objects, as one must take care of not setting the robot off balance.

To some researchers, learning has become a solution to many of the problems faced by robotics. Learning methods are, indeed, particularly suited to embed the dynamic nature of manipulating objects. It allows to model the dynamics of complex non-rigid objects that cannot be described analytically. Manipulation actions that generate changes on the object (cutting, crushing) are particularly difficult as they require a model of the deformation and advanced perception to monitor these deformations. They also require to vary the forces applied by the hand, such as controlling the reduction of the friction as one unscrews a bottle cap, or the increase in viscosity as one digs in a melon. Modeling friction and viscosity properties of object is an intricate task and learning these seem more appropriate.

Outlook

Open questions remain on how to enable robots to deal with the most unpredictable agent of all, the human. With industry 4.0, the fences that used to separate humans from robots will disappear and robots will be engaged in collaborative tasks where they jointly manipulate objects. One challenge to achieve this is to enable robots with advanced interaction capabilities so as to become a smooth partner that synchronize its motion to that of the human. This requires advances beyond simple object interaction. Robots will need better understanding of how humans interact and achieve joint goals through planning and direct physical interaction. There is also a need to develop robots that are safe by design, putting focus toward soft and lightweight structures as well as control and planning methodologies that are based on multisensory feedback. Human way of acting will continue to serve as an inspiration to build future robot systems and robots will serve as a tool for understanding humans better.

Ethical concerns:

This talk cannot be closed without discussing some of the current and open ethical issues related to the use and dangers arising from industry 4.0 robots.

Dexterous robots will ultimately take over jobs currently performed by unskilled workers, leaving these jobless. New jobs will be created but will require different sets of skills. It becomes an issue of public policy to determine the right tradeoff between benefits and harms brought by these robots. Unskilled workers may stand a chance to keep their job and to improve their working condition, if they are trained for more skilled works. We can hope that employers may see a benefit to offer such training to their employees. We can also reach out to governments and advocate need for coaching programs to those working in areas most at risk.