A DELICATE

Robotics specialists observe nature carefully and try to recreate the complex motions performed by people and animals with ease. Locomotion and the ability to manipulate flexible objects are especially challenging, but progress is being made.

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We use our hands to handle hundreds of different objects every day. We can hold a pen in our fingers and skillfully maneuver it to write down our thoughts or sketch out a research article. We can hand someone a cup of tea or shake their hand. Sometimes we manipulate flexible items such as wires or a hair tie, which deform when touched and exert some force on our hands. Experience helps us predict how such an object will behave. We learn all of this in early childhood, and later we simply know how to grab and handle an object intuitively, without having to think about it at all. However, the complexity of such seemingly simple actions becomes starkly apparent when trying to teach machines to replicate them. Determining how such everyday actions could be performed by a robot is the subject of a grant funded by the Polish Center for Research and Development, as part of the Leader VII program. Our goal is to build a robot capable of perceiving flexible objects, processing the available visual and tactile information,

TOUCH

then developing and executing a plan to manipulate such an object. In the first year of the project, we focused on constructing a new robotic hand.

Step one

Building a mechanical hand that is an accurate replica of a human hand is an extremely difficult task that roboticists have been grappling with for years. Every prototype has its advantages and disadvantages, and it will take a very long time before scientists and engineers are able to construct a hand that has all the manipulating skills of a human one. The materials and motors are the biggest problem. Most mechanical hands use electric motors to move the fingers, which are completely different from human muscles. There have been attempts to build devices that work very similarly, known as the McKibben Artificial Muscle, but they require constant access to compressed air, and this is not always possible. The human hand is covered with soft skin with numerous nerve endings. Roboticists usually build mechanical fingers out of aluminum and other hard plastics. Although some are made of silicone, none of these solutions have anything similar to the nerves that provide humans with large amounts of information about the object being touched. The only option roboticists have, then, is to gauge the forces acting on the fingertips. But when handling objects, humans can also use their sense of sight, and this is the second area of research we want to work on this year.

Currently we are working on the visual perception of deformable objects. We would like the robot to be able to determine what material an object is made of and what forces are acting on it, and on this basis predict its deformation. We have managed to improve some previous achievements in this area, but we are still working on establishing the physical parameters of interaction. Image processing is an extremely rapidly developing field, above all thanks to the latest achievements in machine learning. We are harnessing these advances in our work by utilizing deep neural networks and other techniques to identify data patterns.

Step two

In the second year of the project, once our hand has been constructed and we have developed the algo-

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rithms allowing us to obtain visual information about the deformation of elastic objects, we want to focus on developing perception algorithms using the sense of touch. For this purpose we intend to use data from force sensors placed in the fingertips and to machine learning methods to relate them to the physical parameters of the object. The tactile information will then be used to plan the robot's hand and arm movements so that it can properly deform the elastic object and perform a task, such as placing a gasket in a groove.

Another issue is the use of visual information to determine the behavior of long, flexible objects such as wires, hoses, tubes and gaskets. In a camera image such objects often have a width of just several pixels, and due to camera imperfections, they may even appear to be discontinuous.

Step three

In the third year we intend to combine tactile information with visual information and develop an algorithm that, based on visual information, will allow us to predict tactile sensations, such as where and how an object will deform. This is necessary for devices that are intended to manipulate objects based on visual information. Ultimately, we want to develop a system in which a robot can insert plugs into electrical sockets. This is a complex operation, because usually initially the plug is resistant, while pushing it in requires less strength. The robot must master this movement and modulate the strength with which it interacts with the plug, so as not to damage it, and designing such an algorithm is not an easy task.

The Leader program prioritizes projects with high implementation potential, and our project meets this criterion. These flexible wires, hoses, tubes and gaskets suggest possible applications. We would like our mechanical hand to be used to assemble electronic devices, which usually consist of a printed circuit board and outgoing wires. These wires must be properly placed in the casing and then attached to the plugs. In addition to the electronics industry, we also want to contact household appliance manufacturers (note that Poland is one of the largest producers of household appliances in Europe). Lastly, we envision our solutions being used in the manufacture of electronic medical devices, where having robots take the place of humans could be beneficial in terms of preserving sterility, for example.

Out on a limb

In addition to robots capable of manipulating flexible objects, my research interests also include "legged" robots, capable of walking. The abilities of humans and animals in this area have yet to be mastered by machines. Although the challenges of manipulating objects and walking seem to pose very different problems, in some respects they are similar. The limbs of a walking robot try to "grip" the ground and move across it, but when we turn it upside down, its action will essentially resemble the fingers of a robotic hand. Another similarity between these two actions is the method of analyzing the physical parameters of objects with which the robot interacts. For the walking robot, tactile information about the nature of the ground, its flexibility and friction is important, as is the information reaching the fingers of an artificial hand.

Our Institute has recently received an international grant for studying such physical aspects of walking robot interactions with various types of surfaces. Its aim is to develop methods of perception, navigation, movement planning and controlling a moving robot, with the view of using it to inspect the underground corridors of mines or urban subterranean passages. This robot will be able to run and jump, and such dynamic behavior requires a lot of fast calculations because the force distribution and torque change rapidly as a result of the interaction of the robot with the ground. Any calculation error and improperly planned movement may lead to a fall, which is why correct terrain perception is so important. Just like in the case of the robotic hand, we want to integrate visual and tactile information and, on this basis, create the right control algorithms that will allow the robot to interact with various types of surfaces.

Based on our previous experience we are convinced that one of the key factors necessary to improve robots is developing perceptual and control algorithms, which take into account the physical parameters of objects with which the robot interacts. Both visual and tactile information can be used to estimate these parameters. We would also like the robots to be able to predict the consequences of their actions, such as take into account the impact of gravity on a stack of objects if they pull out an object from the bottom.

The grants we have obtained enable us to be optimistic about the future, and at this time our only limitation is our creativity.

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Photography by Jakub Ostałowski

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