Computer Science 773

Robotics and Real-time Control

COMPLIANCE

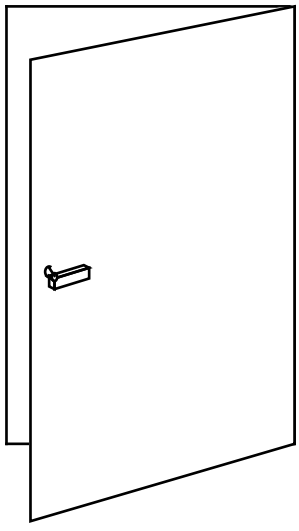
Even when we can perfectly control a robot's position and the forces it applies, we cannot immediately write programmes to make the machines do what we want them to. That's because they have to fit in with the world around them in many ways, so until we know where the world is and what's in it we don't have enough information.

Further, even when we have perfect sensors and can interpret the information they give to produce a complete, detailed, and accurate world view, we still have to know what to do with the objects in the world. Some of this is obvious : we want our robots to avoid hitting things, not fall down stairs, and refrain from trying to move through themselves. These are comparatively easy to manage (given the perfect knowledge and abilities we're assuming). But we also want them to pick things up, and manipulate things, and otherwise interact in fairly specific ways with the world, and this is where it can get tricky.

That's because the world contains things that can break. Under most circumstances we don't want our robots to break the things around them, and that means that we must make them handle the world carefully. This almost always means that they must adapt their motions to take into account the positions of the objects they deal with, and perhaps also the way in which they move. This adaptation of behaviour to the world outside is called *compliance*. People do it all the time without even thinking, but robots don't, and programming them to operate with compliance can be quite hard.

EXAMPLE : OPENING A DOOR.

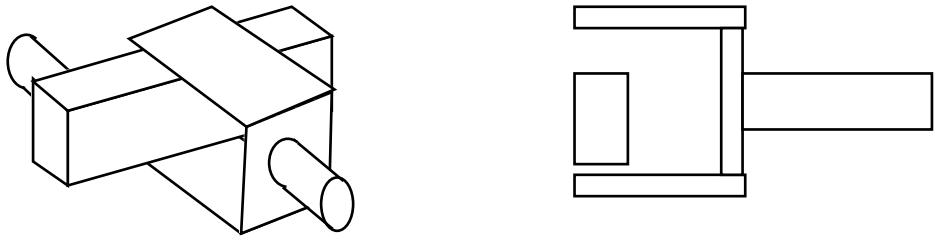
Opening a door is easy : you just grasp the handle, turn it, and pull. But you're not a robot. The robot can move itself to a position close to the door without difficulty, but then the difficult stuff starts. Here's the door :



Grasp the handle.

The vision system can see the handle, and work out where it is relative to the robot; the robot can then move its gripper close to the handle by straightforward motion control, and manage fine adjustment with some form of position control - perhaps the vision is good enough to get a reliable measure of the distance between gripper and handle so that we can guarantee to get the gripper around the handle.

But once the gripper gets very close it is likely that the vision system can't see the handle any more. Two views (free impressions) of the gripper and handle :



Now if the robot simply closes its gripper while keeping the horizontal effector carrying the gripper still, it could tear the handle off the door. It would be much better if it noticed when the bottom "finger" touched the handle, and adapted by moving the horizontal effector downwards while continuing to close the gripper until both "fingers" made contact. That's compliant motion.

Turn it.

Turning the gripper is easy, but there are two sorts of compliance which must be programmed : as the gripper turns, it must move downwards in a short circular arc, following the circular motion of the point of contact round the handle's spindle; then it must stop moving when the handle reaches the limit of its motion, and the applied force increases.

Pull.

Further compliant motion is required as the door opens; this time the robot must be able to follow the motion of the door as a whole around the door hinge. This is likely to involve changes in all the robot's joint angles.

HOW TO DO IT.

Clearly, control of compliance must depend on sensory information, and in the case illustrated the appropriate sensors must detect the forces experienced by the gripper "fingers" and the robot joints. In compliant motion, it is usual that one motion must happen while motion in other directions must be left free, with the balance determined by some constraint on permissible sensory readings.

In the first example, the gripper must continue to close with free vertical motion of the gripper as a whole subject to the constraint that the imbalance between the forces experienced by the two "fingers" must not exceed a certain small limit. The gripper stops closing when both "fingers" experience a stronger force.

The other cases are more complicated, but the principle is the same.

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