Cleaning Up With Second Hand Sensing

David P. Miller*
MITRE Corp.
7525 Colshire Drive, M.S. Z459
McLean, VA 22102, USA
dmiller@starbase.mitre.org

Abstract

Second-hand sensing is the process of using beacons, labels, markers, and other pre-compiled sensing cues. When using second-hand sensing, a cashier does not have to identify what the product is, and then look up the price, that information has been pre-compiled into the UPC code. In the same way, *robo-vac's* job can be greatly simplified by thoughtful placement of sensible cues in the household environment. This paper discusses this process.

Motivation for Discount Sensing

For robots to become widely used in American households, they must be, above all else, cheap. As we all know, sensing is a very expensive habit. There are three things that make sensing expensive: the sensor, the interface between the sensor and the computer, and the algorithm to make sense of the sensor's data. In general, the cost in all three of these categories rises very quickly with the general utility of the information provided by the sensor.

For example, a contact sensor provides provides reliable information that the sensor is in contact with something at the location of the sensor. A stereo camera system can provide range data at several hundred points in front of the sensor, but at $-cost several thousand times greater, and an algorithmic complexity hundreds of thousands of times greater—not to mention a more challenging bit of wiring.

The goal of second-hand sensing is to get the utility of the more complex sensor while only paying for the simple sensor. This can be accomplished if the scope of the problem is sufficiently limited and the environment can be littered appropriately with sensible cues, detectable by the simple sensor.

Second-Hand Sensing

People use second-hand sensing all the time. All road-signs, especially warning signs such as *Slippery When Wet* are forms of second-hand sensing. It is very difficult for a driver to tell if the road ahead is slippery, or whether the road ahead is a tight S-curve, or which road the next highway exit leads to. These problems are compounded by the time constraints in highway driving. Fortunately, individuals without those constraints have been able to examine these conditions in a leisurely fashion, and pre-compile the pixels to predicate process. All that is left for the driver is the relatively simple OCR process to get all of that information available to them.

The same sort of thing can and should be done for household robots. A coded IR beacon on the charging stand reduces an image processing problem to a phase-lock-loop. Bar codes can obviate the need for model-based vision. A password can eliminate the need for a face recognizer. Even for robots, finding and reading a sign is easier than scene interpretation.

There is a tendency in the AI community to look negatively at systems that use artificial markers. There is a greater tendency among people outside of the AI community to look negatively at computers and robots that are unable to perform tasks that trained cockroaches can do.

Using artificial cues is not cheating, its just not as desirable as getting along without them. However, using artificial cues is much more desirable than not being able to solve the problem, or having a solution that is more expensive than the problem it is designed to solve.

Sucking-Up to Your Second-Hand Sensor

Second-Hand sensing is the major sensing modality of Fudd-bot (it hunts dust-bunnies) a demonstration robot being developed at the KISS Institute. Fudd-bot is a small wheeled robot that carries a battery operated hand-vac. Its domain is to operate on hard smooth floor and suck up the fur-balls and dust-bunnies that typically inhabit that sort of environment.

The strategy for picking up hair and fur-balls is straightforward. Fur tends to collect along baseboards and in corners. By sweeping the perimeter of the

*This work was supported in part by MITRE MSR funds.

room (a trivial wall-following task) the majority of the offending detrius can be taken in. Dust-bunnies are another matter. Dust-bunnies are free-roaming, highly reactive, and quite resourceful. The sidewash from the hand-vac is often enough to alert the dust-bunnies of the approaching vacuum, and send them scurrying across the room for cover. It turns out that the best strategy for catching dust-bunnies is to ignore them. Sudden deviations towards a dust-bunny usually just spook them, and send them running. But like a deer caught in the headlights of a car, if the robot never deviates from its course, it will probably just run right into them. For this reason, Fudd-bot requires no dust-bunny sensor.

The sensors (in addition to the wall following sensors) that it does need, are sensors that can guide it back to its charging stand, and sensors that can help it explore most of the room in which it finds itself.

Fudd-bot uses a set of three beacons to navigate about in a room. The primary beacon is a coded infrared beacon. The code in the beacon gives the room ID (if Fudd-bot is operating over several rooms). This allows the robot to know which room it is in and how it should divide its time over the rooms.

The other two beacons in a room are simple night-lights placed near the opposite side of the room. All three beacons are placed a few inches above the floor, at standard wall-outlet height.

The robot can determine its relative location and orientation uniquely, anywhere in the room where all three beacons can be seen. A single beacon can be used for tracking curved and straight paths.

The behavior of the robot is as follows:

1. The robot starts at the main beacon
2. The robot follows the right-hand wall around the room. This succeeds if the robot comes across the main beacon again while following the wall. This fails if the robot goes more than its maximum allowable perimeter distance without coming across the beacon a second time. In the event of a failure, the robot searches and tries to get to the main beacon. If it succeeds (while traveling less than its perimeter distance, it tries a left-hand perimeter. If this fails, it goes to the first beacon it sees and starts its cross-room cleaning. If it sees no beacon of any sort, it send up a flare and waits for help to arrive.
3. Fudd-bot does cross-room cleaning by placing itself near one beacon, facing towards another beacon, and then moving so that it always keeps the first beacon at a constant heading. This heading is incremented each cross-room sweep.
4. A cross-room cleaning run continues until Fudd-bot runs into an obstacle. Fudd-bot then follows the perimeter of the obstacle for a couple feet. If it goes back on heading, then it continues the sweep. If not it then moves to a beacon and repeats the process. If it never had completed the perimeter cleaning, and it comes across the main beacon again, it picks up that task.

The resulting behavior is that the robot goes around the room, and then starts a cross room pattern that resembles a very slow moire pattern screen saver. A large portion of the room is covered. When the batteries start to run low, the robot returns to its charging stand the next time it spies the primary beacon.

This is not an efficient algorithm for the robot to do carpet cleaning. But it is adequate for getting dust-bunnies. This design shows that second-hand sensing is a viable way of solving a realistic robot problem.

Final Thoughts

Sensing is easy, it is understanding that is difficult. Too often, researchers working on "practical" robots get caught up in totally impractical sensing systems. Often, the majority of the sensing complexity can be eliminated by giving the robot a simple clue about how the world operates, or where something is. We call this second-hand sensing; the process of condensing information about the world into a an easily sensible (but not necessarily naturally occurring) cue.

Methods of doing second-hand sensing are not new. Beacons have been used by a variety of robot systems for decades. The problems with second-hand sensing are not technical, but attitudinal. Many AI researchers believe that second-hand sensing is cheating. I believe that the rules of AI are way to ill-defined for anything to be considered cheating. Most of what separates humanity from other organisms is second-hand sensing. Written and spoken communications is second-hand sensing. Signs and Drawings are second-hand sensing. They all relate complex world experiences and involved mental processes to other individuals in bite sized pre-digested chunks of data. To rely strictly on first-hand, direct, sensory information, of all experiences throws away our history and culture and denies are very humanity. Its also a bitch to automate.