

Kicking the Sensing Habit

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Sensor abuse often starts innocently. Perhaps a robot has to make a decision based on information about the state of a task. One possibility is to introduce a sensor to supply the information. Some roboticists do not stop to consider the other possible sources of information. Let us try to identify all the sources of information that might affect a robot's decision. One source is sensor data. Another source is the robot's memory of past actions—*motor history*. Yet another source is communication that the robot might be receiving from other agents, possibly including humans. Finally, there is a huge amount of inborn information, either in the form of explicit data structures or information implicitly embedded in the design of the robot and its software. For the purposes of this article, we neglect communication with other

agents, leaving three basic sources of information: sensation, inborn, and motor history.

Generally, a robot's knowledge of the task domain and the task state includes information from all three sources. One important class of information is *expectation*, which includes inborn information, sensor history, and motor history but excludes current sensor data. Thus, an estimate of the current task state can be viewed as a combination of sensory data and expectation. The estimate of a future state, resulting from a hypothetical action, would be pure expectation.

Victims of sensor abuse sometimes forget all about expectation and become obsessed with immediate sensory data. This obsession might be the result of excessive introspection as well as the subjective impression that the human sensorium instantly provides a directly useful representation of the task. Another possible cause is the widespread misunderstanding of the capabilities and limitations of expectation.

The Sensor-Dependency Quiz

What are the signs of sensor abuse? If your answer to any of these questions is yes, your robot might be suffering from sensor dependency.

Is your robot slow? Underuse of expectation prevents decisions from being made offline. Online decision making takes time. You should get some help checking for this symptom. Because you know what your robot is thinking, you might fail to notice when your robot is not doing anything.

Is your robot limited to simple tasks? The neglect of expectation, combined with the pressure of demonstrating robot perfor-

mance, creates an atmosphere where roboticians naturally settle into simple domains. Does your robot roll around in your lab but never actually touch anything? Are there measurable performance criteria?

Is your robot hypersensitive to environmental changes? Sensing, used in proper moderation, can make a robot more robust with respect to task-domain variations. Overuse can have the opposite effect. Sensors are devices, too, and carry their own assumptions about task conditions. Did your robot stop working when your lab went from 100-watt bulbs to 80-watt bulbs? Does your robot respect blue denim but roll right over anyone wearing something else (not necessarily a bad thing)?

Is your robot only a dream? Some robots exist only on paper or proceed only as far as the simulation stage. Simulated sensing is easy; real sensing is hard.

Just Say “Know”

If you are involved in robotics research, chances are you have already been exposed to a sensor pusher without realizing it. What are the common ploys used by sensor pushers? Here are some of the standard tricks of the trade and some defenses you can try.

“Let the world be its own model.” This homily contains a kernel of truth: “Do not compute that which can be sensed more economically.” However, the opposite is equally true: “Do not sense that which can be predicted more economically.” Some sensor pushers assert that expectation is always more expensive than sensing. When pressed, they even store information in the external world so that they can use their sensors rather than the robot’s memory, as when Hansel and Gretel used a trail of bread crumbs to record the path home. This technique really changes nothing; it is just a different implementation of the memory that holds the expectation. Nonetheless, a comparison (table 1) is illuminating.

“Sensing is free.” If a sensor is already installed and carefully engineered to give the desired information with a minimum of processing, then it is true that sensing is cheap. In other words, once you pay the price, sensing is free.

“Uncertainty requires sensing.” The first weapon against uncertainty is to ignore it; most of the task state information is irrelevant. The second weapon is to finesse the uncertainty: Actively pursue actions that are

	Crumbs ¹	Chips ²
<i>Read-Write Time</i>	1 sec	10 ⁻⁷ sec
<i>Problems</i>	Birds	Bugs
<i>Price</i>	\$10 ⁻⁵ /bit	\$10 ⁻⁶ /bit

¹Crumbs: Nickel’s Lite White at \$1.04/pound. I assume 1 gram/crumb and 19 bits/crumb (enough to encode any of 360 different headings and a distance as great as 1000 paces). The information content might be considerably less, such as when used at a fork in the woods.

²Chips: 41256 256K x 1 DRAM priced at \$1.95 in units of 1 (Advertisement, *Electronic Engineering Times*, 8 July 1991).

Table 1. Sometimes, It Is Better to Know Than to Look.

immune to the uncertainty. The third weapon is information: Actually reduce the uncertainty by improving the inborn information, making better use of motor history, or sensing.

“An intelligent robot has to have sensors.” A robot without sensors might never vary in its performance of a task. Such dogged repetition doesn’t look intelligent, at least to a behaviorist. Looking inside the machine reveals a different story: The decision-making processes are equally intelligent whether the information comes from sensing or expectation. The main difference is that the use of expectation might allow a decision to be made offline. However, this difference is good. Do not let appearances prevent your robot from doing the smart thing. If a behaviorist is watching, a few random actions, combined with several long delays, never fail to convey an aura of intelligence.

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