LETTERS

edited by Etta Kavanagh

An Intelligent Crow Beats a Lab

I READ WITH INTEREST THE PROFILE OF NICOLA CLAYTON AND HER WORK ON COGNITION IN birds ("Nicky and the jays," News Focus, V. Morell, 23 Feb., p. 1074). As an amusing aside to bird intelligence and food hiding, I contribute this photograph taken in 1955. My father owned a seafood market on the central Oregon coast and was very fond of crows as pets, which he valued highly for their intelligence. The attached picture represents a regular ritual of food hiding and searching between our labrador retriever and pet crow.

After the crow ate his fill, he would hide surplus food in the market's backyard, which afforded many niches under wood chips and other detritus. Our dog, Jocko, was always interested in an extral morsel and would scour the yard using his nose as his prime detector. The crow followed alongside him and when Jocko came too close to the concealed prize, Jimmy the crow would hop ahead of him, knock the wood chips aside, grab his food, and move it to another location. The crow relied on his memory of his stashed food to beat the dog to the prize nearly every time.

Jocko the labrador and Jimmy the crow

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Prototype Resilient, Self-Modeling Robots

THE MAIN CONTRIBUTION DESCRIBED IN THE Report "Resilient machines through continuous self-modeling" (J. Bongard *et al.*, 17 Nov. 2006, p. 1118, and the accompanying Perspective, "What do robots dream of?", C. Adami, p. 1093) is a robot that can autonomously recover from certain types of unexpected damage, through an adaptive self-model derived from actuation-sensation relationships, used to generate forward locomotion.

Neither the Report nor the Perspective mention that the first resilient, self-modeling machines of this type were built by Alexander Gloye-Förster *et al.*, who won the 2004 RoboCup in the very fast, small-size league (where human adversaries with a joystick have no chance). Gloye-Förster *et al.* equipped the RoboCup robots with self-models based on artificial neural networks, to model current properties of their four-wheel omni-directional drives. They showed that when a robot gets damaged and is no longer able to execute a precise driving pattern, it can heal itself by quickly adapting its model of the relation between motor commands and sensory inputs, and using the modified model to plan and optimize future driving trajectories (*1*, *2*).

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1. A. Gloye, F. Wiesel, O. Tenchio, M. Simon, *IT Information Technol.* **47** (no. 5), 250 (2005).
2. See also www.idsia.ch/~juergen/resilientmachines.html.

Response

INDEED, MANY EXISTING APPROACHES SUCH as robust control (*1*, *2*) and reinforcement learning (*3*) allow artificial systems to sustain functionality despite variation and uncertainty in their internal structure, by adjusting controllers and estimating model parameters from data. Our self-modeling approach differs from these approaches in two key aspects, concerning both the way the data are collected and the properties of the resulting model.

First, our approach actively determines which data to collect in order to improve the model. This is in contrast to Gloye *et al.* (*4*), whose learning algorithm requires driving the robot through all possible combinations of driving situations "to cover all the regions of the input space" of the predefined neural network (*5*). Such an exhaustive approach does not scale to complex situations with many sensors, actuators, and complex environments, while the active learning method we use scales more favorably (*6*).

Second, our self-models are explicit body schemas useful in scenarios other than those they were trained in. This is in contrast to Gloye *et al.* (*4*), whose model implicitly maps inputs to outputs but has little predictive ability outside its training scenario [e.g., bumping into an obstacle would require retraining (*5*)]. Our robot could use the same explicit internal body schema to determine how to balance on an inclined plane or tackle an obstacle. The ability of a self-model to be useful beyond its training scope is critical to scaling the cognitive ability of machines and may underlay humans' remarkable ability to perform reasonably well in new and unforeseen situations.

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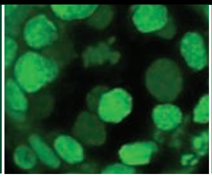
5. S. Behnke, A. Egorova, A. Gloye, R. Rojas, M. Simon, *Predicting Away Robot Control Latency*, RoboCup '03 Symposium (2003), pp. 12–19.
6. J. Bongard, H. Lipson, *J. Machine Learn. Res.* **6**, 1651 (2005).



Watching embryos move
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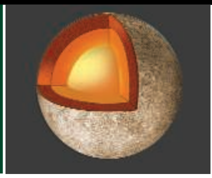

Mercury's molten interior
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Can a Nuclear Weapon Really Be "Safer"?

IN HIS ARTICLE ON THE COMPETITION SPONsored by the U.S. Department of Energy to design a Reliable Replacement Warhead (RRW) ("Livermore Lab dips into the past to win weapons design contest," News of the Week, 9 Mar., p. 1348), Eli Kintisch includes the following sentence: "Although the focus is reliability, RRW is also intended to create safer, more secure, and greener weapons." I can understand more secure, even though I would argue that the best security would be universal elimination, an achievable target if the will is there. But, although I sympathize with the author's need to cover the new armaments program in real-world terms, there is something distinctly Orwellian about the use without comment of the words "safer" and "greener" to describe atomic bombs. At the very least, a phrase like "relatively speaking" would be in order, to remind us of what we are really talking about. Or is it 1984 already?

MICHAEL NEUSCHATZ

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Using Radiocarbon Dating in Jerusalem

THE ARTICLE "JUDGING JERUSALEM" (A. Lawler, News Focus, 2 Feb., p. 588) presents the diverse points of view of many archaeologists on the chronological and political implications of the findings from the City of David excavation. Most of these archaeologists agree that the relative chronology based on ceramic typology cannot determine the age of this site in relation to other sites. There is almost a consensus that radiocarbon dating is the only way to solve this problem. I would have expected the article to provide an evaluation of whether radiocarbon dating can solve this problem by consulting with experts in the field, rather than publishing a quote by an archaeologist comparing radiocarbon dating to a prostitute.

The problem translates into whether two events that occurred within a century can be differentiated. Bearing in mind the analytical uncertainty (±30 years) and that the calibration can sometimes significantly increase the probable range of the date, such precise dating is a major scientific challenge.

With Ilan Sharon (Hebrew University), Ayelet Gilboa (Haifa University), and Tim Jull (Arizona University), I addressed this issue by dating the transition from Iron Age I to Iron Age II. We compared samples prepared in three laboratories (Weizmann Institute of Science, University of Arizona, and the University of Groningen). No bias was detected, disproving

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misconceptions that radiocarbon labs have specific agendas besides doing scientific research (*1*, *2*). We paid careful attention to the archaeological contexts of all samples, characterized their states of preservation, and analyzed more than 150 samples. The radiocarbon dates mentioned in the article by Eilat Mazar were performed by me on samples that were chosen after careful discussion with her. Radiocarbon analysis is not a routine technical operation.

Our Iron Age study proves that two events can be differentiated within a century. Much depends upon the reliability of the archaeological context from which the sample is taken and upon a deep understanding of the science involved with radiocarbon dating.

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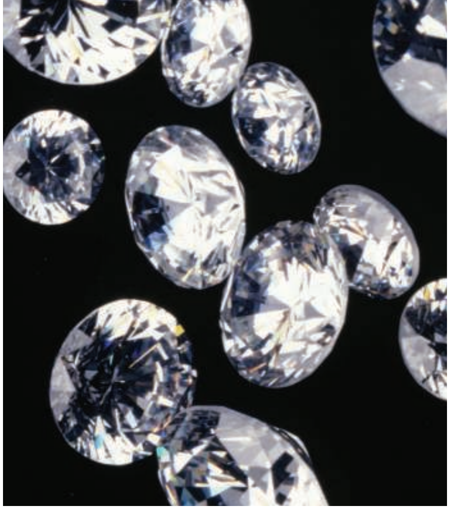
Oops, That's Not Really a Diamond

THE ILLUSTRATION FOR THE INTERESTING Editors' Choice item "Diamond diversity" (23 Mar., p. 1638) appears, even to this biologist, not to be of diamonds at all. Rather than being rough and tetrahedral in form as diamond crystals typically present, these crystals are hexagonal, very clean surfaced, and optically clear, just as certain quartz crystals can be.

Furthermore, they appear to be doubly terminated, suggesting that they formed free-floating in a fluid-filled cavity rather than attached to a mineral matrix. They appear to be Herkimer diamonds, named for the town in upstate New York where they are found in cavities, or vugs, in the surrounding stoney matrix. They are very attractive, and it is entertaining to spend a Saturday picking these



"diamonds" from cavities in the rock, but they are not true diamonds, which are of course not crystrallized silica but crystalline carbon.

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Editor's Note: The letter writer is correct. The image that was chosen by *Science* staff to run with this item was not a diamond. The image shown here is diamonds.

Coal's Future: Clearing the Air

AS REPORTED BY ELI KINTISCH ("REPORT backs more projects to sequester CO_2 from coal," News of the Week, 16 Mar., p. 1481), the recent Massachusetts Institute of Technology (MIT) study (*1*) on the future of coal stresses the need for reducing the carbon intensity of coal use. More than two coal-fired power plants are projected to be built each week over the next 25 years, adding 1800 GW of electricity production (*2*) and at least doubling current coal-based CO_2 emissions unless CO_2 mitigation technologies are rapidly deployed. Although these technologies are still in the R&D phase, the report's authors rightly caution that we "not fall into the trap of picking a technology winner." Paradoxically, the report then goes on to discuss in great detail the capture and geologic storage of molecular CO_2 (CCS), to the exclusion of other options.

Current mitigation alternatives include the postcombustion chemical or biological uptake of CO_2 from waste streams or from air [e.g., (*3–5*)], often converting CO_2 into stable, benign chemical forms that need not be stored deep within the Earth. In certain settings, such approaches could avoid potential obstacles to widespread CCS use (*1*), including (i) the energy cost of capturing, concentrating, and compressing CO_2; (ii) risks associated with transporting and storing CO_2 under high pressure; and (iii) the inability to cost-effectively mitigate existing conventional coal-fired plants. Alternative technologies that can address this last point are critical since, according to the report, CCS only appears practical for new coal combustion technologies that will take decades to penetrate the power industry, time that we can ill afford.

As in the case of CCS, much work is needed to determine the safety, economics, capacity, and timeliness of these alternative CO_2 mitigation approaches. Yet this will never happen if industry and government decision-makers and R&D funders continue to treat conventional CCS as "the only game in town." At this early stage, it is imperative that our CO_2 mitigation strategy be broad in scope, acknowledging that multiple technologies are likely to be needed and that they may bear little resemblance to those currently favored. Given the magnitude and urgency of the CO_2/energy problem, it is unwise to plan the fate of both coal and our environment based on an unnecessarily narrow vision of the future.

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5. USCCTP, *U.S. Climate Change Technology Program Strategic Plan* (U.S. Climate Change Technology Program, Washington, DC, 2006) (see www.climatetechnology.gov/stratplan/final/index.htm).

CORRECTIONS AND CLARIFICATIONS

ScienceScope: "Bignami back in orbit" by F. De Prestis (23 Mar., p. 1649). Giovanni Bignami has been nominated as president, not director, of Italy's space agency, ASI. He is no longer chair of the Space Science Advisory Committee of the European Space Agency, as was reported. Bignami says he left his position as scientific director of ASI in 2002 when his contract expired, and that his departure was not connected to uncertainty at that time over government support for an Italian radar instrument on a NASA mission to Mars, as the ScienceScope item implied.

Perspectives: "Water from first principles" by A. J. Stone (2 Mar., p. 1228). The dotted lines indicating the hydrogen bonds between the water molecules were inadvertently removed from the top configuration.

Reports: "Water catalysis of a radical-molecule gas-phase reaction" by E. Vöhringer-Martinez *et al.* (26 Jan., p. 497). The third author is identified incorrectly; the correct name is H. Hernandez-Soto.

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