Internet tools, such as search engines, recommender systems, and Web site aggregators.

One consequence of trying to build complete agents is the realization that the previously isolated subfields of AI might need to be reorganized somewhat when their results are to be tied together. In particular, it is now widely appreciated that sensory systems (vision, sonar, speech recognition, etc.) cannot deliver perfectly reliable information about the environment. Hence, reasoning and planning systems must be able to handle uncertainty. A second major consequence of the agent perspective is that AI has been drawn into much closer contact with other fields, such as control theory and economics, that also deal with agents. Recent progress in the control of robotic cars has derived from a mixture of approaches ranging from better sensors, control-theoretic integration of sensing, localization and mapping, as well as a degree of high-level planning.

Despite these successes, some influential founders of AI, including John McCarthy (2007), Marvin Minsky (2007), Nils Nilsson (1995, 2005) and Patrick Winston (Beal and Winston, 2009), have expressed discontent with the progress of AI. They think that AI should put less emphasis on creating ever-improved versions of applications that are good at a specific task, such as driving a car, playing chess, or recognizing speech. Instead, they believe AI should return to its roots of striving for, in Simon's words, "machines that think, that learn and that create." They call the effort **human-level AI** or HLAI; their first symposium was in 2004 (Minsky *et al.*, 2004). The effort will require very large knowledge bases; Hendler *et al.* (1995) discuss where these knowledge bases might come from.

HUMAN-LEVEL AI

ARTIFICIAL GENERAL INTELLIGENCE

A related idea is the subfield of **Artificial General Intelligence** or AGI (Goertzel and Pennachin, 2007), which held its first conference and organized the *Journal of Artificial General Intelligence* in 2008. AGI looks for a universal algorithm for learning and acting in any environment, and has its roots in the work of Ray Solomonoff (1964), one of the attendees of the original 1956 Dartmouth conference. Guaranteeing that what we create is really **Friendly AI** is also a concern (Yudkowsky, 2008; Omohundro, 2008), one we will return to in Chapter 26.

FRIENDLY AI

1.3.10 The availability of very large data sets (2001–present)

Throughout the 60-year history of computer science, the emphasis has been on the *algorithm* as the main subject of study. But some recent work in AI suggests that for many problems, it makes more sense to worry about the *data* and be less picky about what algorithm to apply. This is true because of the increasing availability of very large data sources: for example, trillions of words of English and billions of images from the Web (Kilgarriff and Grefenstette, 2006); or billions of base pairs of genomic sequences (Collins *et al.*, 2003).

One influential paper in this line was Yarowsky's (1995) work on word-sense disambiguation: given the use of the word "plant" in a sentence, does that refer to flora or factory? Previous approaches to the problem had relied on human-labeled examples combined with machine learning algorithms. Yarowsky showed that the task can be done, with accuracy above 96%, with no labeled examples at all. Instead, given a very large corpus of unannotated text and just the dictionary definitions of the two senses—"works, industrial plant" and "flora, plant life"—one can label examples in the corpus, and from there **bootstrap** to learn