Emotional Robotics based on iT_Media

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Abstract: Intelligence is thought to be related to interaction rather than a deep but passive thinking. Interactive tangible media "iT_Media" is proposed to explore these issues. Personal robotics is a major area to investigate these ideas. A new design methodology for personal and emotional robotics is proposed. Sciences of the artificial and intelligence have been investigated. A short history of artificial intelligence is presented in terms of logic, heuristic, and mobility; a science of intelligence is presented in terms of imitation and understanding; intelligence issues for robotics and intelligence measures are described. A design methodology for personal robots based on science of emotion is investigated. We investigate three different aspects of design: visceral, behavioral, reflective. We also discuss affect and emotion in robots, robots that sense emotion, robots that induce emotion in people, and implications and ethical issues of emotional robots. Personal robotics for the elderly seems to be a major area in which to explore these ideas.

Keywords: Robot intelligence, visceral design, behavioral design, reflective design, robot emotion, personal robotics

1. INTRODUCTION

Intelligence is thought to be related to interaction rather than a deep but passive thinking. Interactive tangible media "iT_Media" is proposed to explore these issues. Personal robotics is a major area to investigate these ideas. The science of affect and emotion is surveyed and a design methodology for personal robots is investigated [1-3].

Beyond the design of an object, there is a personal component as well. The emotional system is also tightly coupled with behavior, preparing the body to respond appropriately to a given situation. Just as emotions are critical to human behavior, they are equally critical for intelligent machines, especially autonomous machines of the future that will help people in their daily activities. Robots, to be successful, will have to have emotions. The machines and products of the future may be able to sense human emotions and respond accordingly.

Robots are soon to be household objects. These developments will require a coevolutionary process of adaptation for both people and devices. We discuss affect and emotion in robots, robots that sense emotion, robots that induce emotion in people, and implications and ethical issues of emotional robots.

2. SCIENCES OF THE ARTIFICIAL

Sciences of the artificial and intelligence have been investigated. A short history of artificial intelligence is summarized in terms of logic, heuristic, and mobility; a science of intelligence is presented in terms of imitation and understanding; intelligence issues for robotics and intelligence measures are followed.

2.1 Sciences of the artificial [4]

Herbert Simon, a prominent figure in AI and the 1978 Nobel Laureate in Economics, pioneered the study of the artificial. The sciences of the artificial describe objects and phenomena-artifacts-that result from human intervention in the natural world. Much of our daily world is artificial. Aimed at satisfying human purposes, artifacts are not exempt from natural law but are adapted to the environments in which they operate. Conceived in the human activity called design, many are of immense complexity; computers are invaluable in studying natural as well as artificial complexity.

The phrase "artificial intelligence (AI)" was coined at MIT. Research group at Carnegie Mellon University have preferred phrases like "complex information processing" and "simulation of cognitive processes." In some contexts we make a distinction between "artificial" and "synthetic." A gem made of glass colored to resemble sapphire would be called artificial, while a man-made gem chemically indistinguishable from sapphire would be called synthetic. A science of artificial will be closely akin to a science of engineering-but very different from the name of "engineering science." We have identified four indicia that distinguish the artificial from the natural; hence we can set the boundaries for sciences of the artificial:

1) artificial things are synthesized by human beings
2) artificial things may imitate appearance in natural things while lacking the reality of the latter
3) artificial things can be characterized in terms of functions, goals, adaptation
4) artificial things are often discussed in terms of imperatives as well as descriptives.

2.2 A short history of "artificial" intelligence: logic, heuristic, mobility [5, 6]

Some are convinced that intelligent computers must have **mobility** and be able to deal with sensory information; others argue that **logic** is of prime importance, while still others say that rather than power of logic, a computer must comprehend **meaning** before it can exhibit intelligent behavior.

Chess seems a natural for AI: the rules and goals of chess are clear-cut and the moves relatively constrained. In 1954, computer scientist Allen Newell, declared that a chess program would reach Grandmaster status within ten years. In fact, a computer program called "Deep Thought" beat Grandmaster Brent Larson in 1988.

John McCarthy, one of the founders and leading theorists of the AI movement, has been working on the problem: boiling all form of human reasoning down to a system of equations that can be manipulated by a computer. Thinking can be accomplished through the formal language of "first-order predicate calculus," a hybrid of mathematics and English. They often take the equivalent of deductive **logic**: the IF-THEN or the IF-AND-THEN form. Logical operators rely on the computer's ability to search and match symbols.

The prevailing approach of logic proponents is to analyze syntax. The other group, by contrast, believes that syntax is useless and they base their hopes on semantics or meaning. Theorists like Marvin Minsky, one of the four or five principal founders of the AI movement, and Roger Schank contend that the correct strategy consists of discovering and modeling how people think. They believe that machines will grasp meaning before they can display intelligence. Minsky devised the notion of "frames"-elaborate packages of stored knowledge that, like memory associations, are evoked by pattern matches. In semantics proponents' view, computers will need associations and mental images to resolve the ambiguities in language as it is used by people. Roger Schank concluded that people translate what they hear into private concepts, or "mentalese." He invented a computer version of this, known as "conceptual dependency," a simplified language that contains only 11 verbs. The purpose is to create small frame-like structures of expectations to help machine make sense of what it reads. Schank also developed more elaborate knowledge structure called "scripts." Scripts are miniscenario containing slots that outline stereotyped experiences.

A syntax proponent, Nils Nilsson argues that semantics proponents use more or less as hoc schemes that more or less work for particular situations. He thinks that in building intelligent machines, we need to look for fundamental principles to help simplify and build these things.

AI theorists conclude that computers can never really be called intelligent until they **learn to learn**. People learn from observation. This type of inference from observation is called induction, in contrast to the deductions produced by logical operations. Douglas Lenat's program Eurisko steadily improves its knowledge, understanding, and performance through experience. Eurisko can think about its own thinking, employing processes like introspection and stream of consciousness. It runs "thought experiments," employing a stock of general-purpose heuristics to manipulate knowledge frames and slots. On the basis of discoveries, it can add to its stock of heuristics. Lenat sees programs like Eurisko as potential "intelligent amplifiers" to aid people think about complex domains, suggesting new ideas, combining them in various ways, and identifying the most plausible.

Lenat's system, known as Cyc (as in encyclopedia), represents the most ambitious effort ever to create an intelligent machine-a machine that will know everything adult knows and that will be applicable of reasoning with this knowledge in a plausible human-like way.

Conventional AI, which develops a computer system that reasons in a highly ordered, step-by-step fashion, has come up short in area, including recognizing objects, controlling robots, discovering mathematical theories, understanding topics, comprehending speech, and many other aspects of machine intelligence.

Hans Moravec, a prominent roboticist, believes that the route toward Ai is learning to build mobile robots, machine that can get around on their own in real world. **Mobility** forces adaptability and generality. Mobility puts a premium on general talents such as sensory perception, pattern recognition, and learning-talents that humans have in common with lower animals but that turn out to be harder to automate than things that are harder to automate than things that are hard for people, such as playing chess or diagnosing diseases.

Marvin Minsky thinks we'll be lucky to see even a capable household robot inside a hundred years. And John McCarthy thinks artificial intelligence needs 1.7 Einsteins, two Maxwells, five Faradays, and .3 Mahattan Projects. Hans Moravec thinks it's mainly a matter of faster computers to achieve machine intelligence.

2.3 A science of intelligence: imitation and understanding [7]

The Turing test for consciousness shaped the early efforts in the for AI field. Can a machine convince a human being that it, the machine, is human? Perhaps the test is flawed and should be discarded, say Ford and Hayes. The greatest value of AI may lie not in imitating human thinking but in extending it into new realms.

The analogy between artificial intelligence and artificial flight is illuminating. Flying meant imitating a bird. The development of aircraft succeeded only when people stopped trying to imitate birds and instead approached problem in new ways, thinking about airflow and pressure. Wright brothers first work on achieving sufficient lift, then on longitudinal and lateral stability, then on steering and finally on propulsion and engine design, carefully solving each problem in turn.

The traditional view of the goal of AI-to create a machine that can successfully imitate human behavior-is wrong. Rather than limiting the scope of AI to the study of how to mimic human behavior, we can more usefully construe (interpret) it as the study of how computational systems must be organized in order to behave intelligently. A truly humanlike program would be just as useless as a truly pigeonlike aircraft.

The Wright brothers' success was largely attributed to their perception of flight in terms of lift, control and power; similarly, a science of intelligence must isolate particular aspects of thought. Computers are providing the first wind tunnels for thought. Just as the principles of aerodynamic apply equally to any wing, natural or artificial, the computational view of intelligence-or, more broadly, of mentally-applies just as well to natural thinkers as to artificial thinkers.

The scientific aim of AI research is to understand intelligence as computation, and its engineering aim is to build machines that surpass or extend human mental abilities in some useful way. Trying to imitate a human conversation, however "intellectual" it may be, contributes little to either ambition.

2.4 Intelligence issues and intelligence measures

Ruth Aylett looks at what is really necessary to build a successful robot, which include the issues of robot intelligence as 1) intelligence, 2) mobility, 3) sensing, 4) integration: thinking, deciding, & learning, 5) bodies, 6) interaction: the function and desirability of emotions, and the ability to socialize and make friends, and 7) future: fear of robot domination [2].

Aylett further delineates issues we should consider for bring intelligent machines to life. 1) The quest for **intelligence**: creation of a living being, fears about robots, views on intelligence, intelligence test, animal analogies. 2) **Moving** matters, wheels: feet, legs, hopping, swinging, climbing, slither, underwater, wing, robot orangutan Lucy. 3) **Sensing** the world: active or passive sensing, animal behavior, synthetic psychology, grasp of distance, vision, active vision, smells, obstacle avoidance, map, homing, uncontrollable art.

4) **Putting it all together**: reflexes, reactions, & thinking, artificial neural networks, neuro-silicon, learning strategies, watch & imitate, togetherness, swarms, flocks, & formations, work together in teams, planning; cognitive robotics, dancing queen. 5) Shame about the **body**…: robot's body and animal's body, muscles, skin and soft touch, batteries, energizing, size, robot zoo. 6) **Making friends**: emotional intelligence, expressive features of robots, sensing human emotions, how human?, toy robots, helping and guiding, therapeutic robots, creative applications, robot competitions. 7) So **will they take over the world?**: robot culture, reproduction, the state of the art, robot ecosystems, autonomy, self-design, humans rule, making your own robot [2].

How do we measure intelligence?

When the field of AI emerged in the 1950s, **Intelligence Quotient (IQ) tests** were all the rage. A mixture of general knowledge questions and puzzles, these tests claimed to be able to determine a fixed IQ for any individual, which would objectively measure their level of intelligence. As a result, researchers in AI started to build computer programs that could solve the sort of puzzles found in IQ tests [2].

What about the **ability to play chess**? Chess is an example of a closed problem i.e. a problem in the toy world. It has a fixed number of pieces and clear rules of what is allowed, giving the computer the opportunity to consider more moves in a given time than a human. But is living in the real world a closed problem, with finite number of moves? [2]

The **Turing test** was proposed in 1950 by British mathematician Alan M. Turing. In the test, a judge would hold a three-way conversation with a computer and another human. If the judge cannot distinguish between the responses of the human and those of the computer, the machine would pass the test. In 1991, six leading conversation-simulating programs participated in a widely publicized Turing Test competition held in Boston [7].

These ideas of intelligence are all about pure thought, and do not involve any real interaction with the physical world. Intelligence is "doing the right" in the real world. If we think of intelligence as related to **interaction** rather than a deep but passive thinking, then the issue of **mobility** acts as a basic constraint on how intelligent a robot can actually be.

Isaac Asimov was one of the earliest thinkers and science fiction writers to explore the implications of robots as well deigned, fail-safe, autonomous, and intelligent machines that perform to three later four principles. These principles are called the Asimov's Three/Four Laws of Robotics. These three laws dealt with the interaction of robots and people, but as history progressed into more complex situations, Asimov felt compelled to add an even more fundamental law dealing with the robots' relationship to humanity itself. Asimov's laws are an excellent tool for examining just how robots and humans should interact. [3, 8-12]

Asimov's Laws of Robotics (1940/1985)

Handbook of Robotics, 56th Ed., 2058 A.D., "I, Robot," 1940
Revised Laws of Robotics, "Robots and Empire," 1985

Zeroth Law: A robot may not injure humanity, or, through inaction, allow humanity to come to harm.

First Law: A robot may not injure human being, or, through inaction, allow a human being to come to harm, unless this would violate the Zeroth Law of Robotics.

Second Law: A robot must obey the orders given it by human beings, except where such orders would conflict with the Zeroth or the First law.

Third Law: A robot must protect its own existence, as long as such protection does not conflict with the Zeroth, the First, or the Second Law.

The zeroth law could be labeled "humanity" and the first law could be labeled "safety." The second law is about "obeying people," in contrast to the first, which is about protecting them. The third law is about "self-preservation." Asimov detected and investigated the laws' weaknesses.

3. EMOTIONAL DESIGN

Donald Norman says, "In the old days, the focus was on the technology and 'computing,' hence the interest is the interface between humans and machines-us versus them. Not anymore. Design should not be about tasks and their requirements, or applications, or computing-design is really about interaction, with a focus on ubiquity, tangibility, and most of all, shared awareness, intimacy, and emotions." [13]

3.1 Emotional things [3]

Attractive things do work better-their attractiveness produces positive emotions, causing mental processes to be more creative, more tolerant of minority difficulties. The three levels of processing lead to three corresponding forms of design: visceral, behavioral, and reflective. Each plays a critical role in human behavior, each an equally critical role in the design, marketing, and use of products.

Visceral, behavioral, and reflective are three different aspects of design. Visceral design concerns itself with appearance. Behavioral design has to do with the pleasure and effectiveness of use. Reflective design considers the rationalization and intellectualization of a product. Visceral, behavioral, and reflective dimensions are interwoven through any design. But more important, these three components interweave both emotions and cognition.

Just as emotions are critical to human behavior, they are equally critical for intelligent machines, especially autonomous machines of the future that will help people in their daily activities. Robots, to be successful, will have to have emotions. The machines and products of the future may be able to sense human emotions and respond accordingly.

Machines will not be smart and sensible until they have both intelligence and emotions. Emotions enable us to translate intelligence into action. Positive emotions guide us good things in life and negative emotions may keep us from danger. Robots will need something akin to emotion to make complex decisions. Will that walkway hold the robot's weight? Is there some danger lurking behind the post? These decisions require going beyond perceptual information to use experience and general knowledge to make inference about the world and then to use the emotional system to help assess the situation and move toward action.

3.2 Machine emotion and intention [3]

Human emotions have more than a logical, rational component; they are tightly coupled to behavior and feelings. Future machines will need emotions for the same reasons people do. The human emotional system plays an essential role in survival, social interaction and cooperation, and learning. Machines will need a form of emotion-machine emotion-when they must operate continuously without any assistance from people in the complex, ever-changing world where new situations continually arise.

Robots already exist in many forms. As robots become more advanced, they will need only the simplest of emotions, starting with such practical ones as visceral-like fear of heights or concern about bumping into things. Robot pets will have playful, engaging personalities. With time, these robots will come to possess full-fledged emotions: fear and anxiety when in dangerous situations, pleasure when accomplishing a desired goal, pride in the quality of their work, and subservience and obedience to their owners. Because many of these robots will work in the home environment, interacting with people and other household robots, they will need to display their emotions, to have something analogous to facial expressions and body language.

4. EMOTIONAL ROBOTICS

4.1 Emotional robots

Robots are soon to be household objects. The home servant robots, a family of robot appliances in the kitchen, are one of them. Some robots will take care of children by playing with them. Educational toys are already doing this, and the sophisticated robot could act as a powerful tutor. These developments will require a coevolutionary process of adaptation for both people and devices. As robots increase in usefulness, we will ensure their success by minimizing obstacles and eventually, building charging stations, cleaning and maintenance places. We might see robot quarters in homes, that is, specially built niches where the robots can reside, out of way, when they are not active.

What should a robot look like? Form should follow function. Humanoid shape has evolved over eons of interaction with the world to cope efficiently and effectively with it. So, where the demands upon a robot are similar to those upon people, having a similar shape might be sensible. A coffemaker robot should look like a coffeemaker, modified to allow it to connect to the dishwasher and pantry. Appearance of robot vacuum cleaners and lawn mowers is perfectly suited to their tasks: small, squat devices, with wheels. A robot car should look like a car. Some robots will look like an animal or human, because it is the most effective configuration for the task Masahiro Mori, a Japanese roboticist, has argued that we are least accepting of creatures that look very human, but that performed badly, a terrifying nature of zombies and monsters. Even perfect replicas of humans might be problematic, for even if the robot could not distinguished from humans, this lack of distinction could lead to emotional angst which is a theme explored in a scientific fiction novel, Philip K. Dick's "Do Androids Dream of Electric Sheep?" and, in movie version, "Blade Runner." Robots that serve human needs should probably look like living creatures. Thus, an animal or a childlike shape together with appropriate body actions, facial expressions, and sounds will be most effective if the robot is to interact successfully with people.

4.2 Emotion in robots

What emotions will a robot need to have? The answer depends on the sort of robot we are thinking about, the tasks it is to perform, the nature of its environment, and what its social life is like. Does it interact with other robots, animals, machines or people? If so, it will need to express its own emotional state as well as to access the emotions of the people and animals it interacts with.

Servant robots will need to interact with us and with the other robots of the house. For the other robots, they would use wireless communication. They could discuss the jobs they were doing. They could also state when they were running low on supplies and when they sensed difficulties, problems, or errors and call upon another for help. When robots interact with people, robots need some way of issuing commands, some way of clarifying the ambiguities, changing a command in midstream, and dealing with all of the complexities of human language. When should a robot volunteer to help its owners? Robots need to be able to access the emotional state of people. The robot should display its emotional state.

Fake emotion and natural emotion: People in robotics believe that the way to display emotion is to have a robot decide whether it is happy or sad, angry or upset, then display the appropriate face, usually an exaggerated parody of a person in those states. It is fake and it looks fake, as Norman strongly argues. Fake emotions look fake: we are very good at detecting false attempts to manipulate us. If the facial and body expressions reflect the underlying processing, then the emotional displays will seem genuine precisely because they are real. Then we can interpret their state, they can interpret and the communication and interaction will flow ever more smoothly.

The robot should be cautious of heights, wary of hot objects, and sensitive to situations that might lead to hurt or injury. Fear, anxiety, pain, and unhappiness might all be appropriate states for a robot. Similarly, it should have positive states, including pleasure, satisfaction, gratitude, happiness and pride, which would enable it to learn from its actions. Surprise is probably essential. Some states, such as fatigue, pain, or hunger, are simple for they do not require expectations or predictions but simple monitoring of internal sensors. Pain is a surprisingly complex system. Pain serves as a valuable warning system. When motors or joints were strained, this would lead robots to limit their activities automatically, and thus protect themselves against further damage.

Frustration is a useful affect, for when things reach that point, it is time to quit and do something else. This would automatically solve the deadlock. The robot could learn from this experience. Without pride, the robot doesn't care. Pride in doing a good job, in pleasing their owners.

These developments will require a coevolutionary process of adaptation for both people and devices. Norman discusses issues like affect and **emotion in robots**, **robots that sense emotion**, **robots that induce emotion in people**, and **implications and ethical issues of emotional robots**.

4.3 Emotional robotics

One Sony executive said that the 1980s was the decade of the PC, the 90s of the Internet, but he believe the decade just starting will be the decade of the robot. Saffo raised a question, "Do you remember when we have robots with names-like Aibo, Asimo, HelpMate, MindStorm, Minerva, Roomba-to name a few?" Good old industrial robots had names too. But not like the personal robots which bear personal signatures. Robots are not manufactured in industrial electronics division any more. Personal robots are designed and synthesized at the consumer electronics sector. Robots are treated as household appliances, toys, or pets. Beyond the design of an object, there is a personal component as well [3, 14].

Again, Saffo made statement, "In the near future, you will subscribe a car and services provided to driver will be updated according to subscription fees you pay." This will happen for personal robots soon. Personal robots here are robots providing services for persons' needs. Saffo once again said, "The bubble may have burst, but this really is a about media. Not information, not computing, but media." [14-16]

Personal robots should share characters-like objects that evoke memories, feelings of self, personality of products-with interactive media.

Personal robotics for the elderly seems to be a major area in which to explore these ideas. We can start by asking "what are inhumane human conditions to be resolved by technology?" Issues lain robotics for the elderly are described and desirable roles for the robots in such applications are presented. Interdisciplinary science approach is proposed to successfully implement this technology for the elderly [17-21].

There may be many views on the problems of the elderly. Three main issues for the elderly could be summarized as lack of economic affluence, physical health and emotional stability. Research on personal robots for the elderly has to be directed to alleviate these deficiencies and to improve life conditions of the elderly to affluent stage. Desirable roles of robots for the elderly include nursing, abuse prevention, companion, massagist, assistant in professional field, and helpers to household duties [17, 18].

After we explore the issues and areas in which technology can serve for the elderly, next question might be how we can build such a system. Soft engineering methodology based on interactive technology might be good way to implement this system.

Robotics for the elderly requires interdisciplinary efforts, utilized in cognitive science, soft science, and meta science. Eyeball tracking project for the disabled people at the Stanford University portrays such successful efforts. Personal robotics for the elderly could be successful in this way.

Robots for the elderly should carry various functions, human-like intelligence, and psychological characteristics. The issues in artificial intelligence (AI) critical in robotics research have to be resurfacing.

When early AI studies got stuck over the search for the meaning of the intelligence, cognitive science evolved to overcome these difficulties and provide alternatives. Cognitive science is such an interdisciplinary field formed, based on philosophy, psychology, sociology, linguistics, brain neural science, computer engineering [22-25].

Robotics for the elderly also requires these interdisciplinary efforts. These include hard science: robotics, AI, physiology for the elderly; soft science: psychology for the elderly, studies of social welfare, science of nursing; and meta science: philosophy which deals robot ethics or robot axiology, cyber cultures [26-29].

Interactive technology initiative (ITI) is an interdisciplinary research group to search for "interactive technology." Some experimental activities conducted by ITI are introduced, which include 1) an interactive emotional piece "A Stuffed Ox," which interacts with the audience through breathing, touching and eye tracking, as shown in Fig. 1 [30, 31];

Fig. 1 An emotional interaction with a stuffed ox.

2) a design of "A Guide Robot," which interacts with people with a likeable character-an animal or a childlike shape together with appropriate body actions, facial expressions, and sounds, as shown in Fig. 2 [32]; 3) a tangible space "A Room with Sensors," which makes you feel outdoor climate changes and indoor information flow on a sensor chair in the form of vibrations [30, 33]; and 4) an interactive workspace "iT_Workspace," which makes people experience an interactive tangible spatial perceptions based on the calm and ubiquitous iT_Media like robots, tags, pads, and/or boards [34-40].

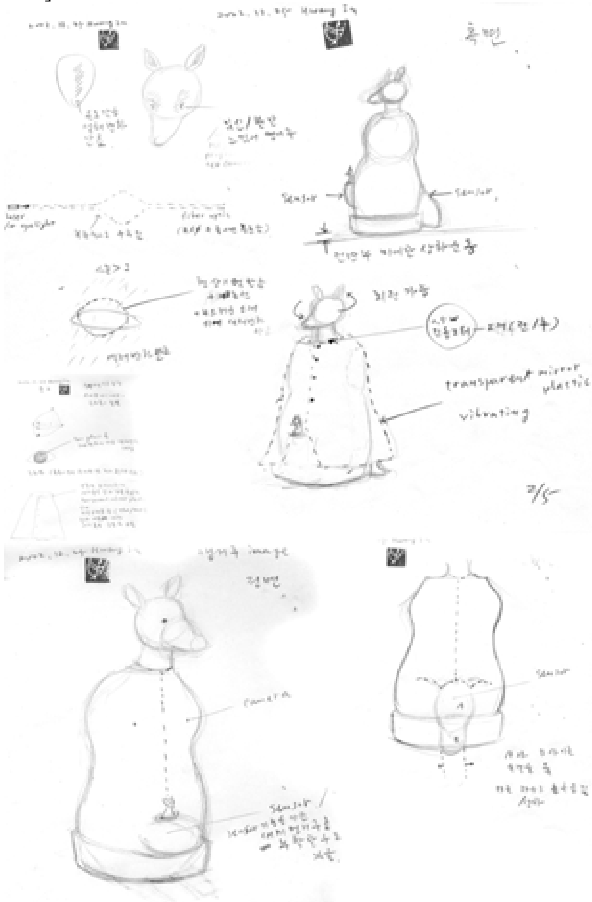

Fig. 2 A design of a guide robot

5. SUMMARY

Intelligence is thought to be related to interaction rather than a deep but passive thinking. Interactive tangible media "iT_Media" is proposed to explore these issues. Personal robotics is a major area to investigate these ideas. A new design methodology for personal and emotional robotics is proposed. Sciences of the artificial and intelligence have been investigated. A short history of artificial intelligence is presented in terms of logic, heuristic, and mobility; a science of intelligence is presented in terms of imitation and understanding; intelligence issues for robotics and intelligence measures are described. A design methodology for personal robots based on science of emotion is investigated. We investigate three different aspects of design: visceral, behavioral, reflective. We also discuss affect and emotion in robots, robots that sense emotion, robots that induce emotion in people, and implications and ethical issues of emotional robots. Personal robotics for the elderly is investigated to explore these ideas.

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REFERENCES

[1] Joongsun Yoon, Myeungsook Yoh, and Hyewon Lee, "Tangible media based on interactive technology: iT_Media," *Proceedings of the International Conference on Control, Automation and Systems (ICCAS 2004)*, CD-Rom, 2004.

[2] Ruth Aylett, *Robots: Bringing Intelligent Machines To Life?*, Barron's, Hauppauge, 2002.

[3] Donald A. Norman, *Emotional Design: Why We Love (or Hate) Everyday Things*, Basic Books, New York, 2004.

[4] Herbert A. Simon, *Sciences of the Artificial*, Third Ed., The MIT Press, Cambridge, 1996.

[5] Tom Alexander, "Artificial intelligence," *Popular Computing*, pp. 66-69, 142-145, May 1985.

[6] David H. Freedman, *Brainmakers: How Scientists Are Moving Beyond Computers To Create A Rival To The Human Brain*, Simon & Schuster, New York, 1994.

[7] Kenneth M. Ford and Patrick J. Hayes, "On computational wings: rethinking the goals of artificial intelligence," *Scientific American*, Vol. 9, No. 4, pp. 78-83, Winter 1998.

[8] Mikell P. Groover, Mitchell Weiss, Roger N. Nagel, and Nicholas G. Odrey, *Industrial Robotics: Technology, Programming, and Applications*, McGraw-Hill Book Company, New York, 1986.

[9] Roger Clarke, "Asimov's laws of robotics: implications for information technology, Part 1" *IEEE Computer*, Vol. 26, No. 12, pp. 53-61, December 1993.

[10] Roger Clarke, "Asimov's laws of robotics: implications for information technology, Part 2" *IEEE Computer*, Vol. 27, No. 1, pp. 57-66, January 1994.

[11] Isaac Asimov, *I, Robot*, Facett Crest Books, New York, 1950.

[12] Isaac Asimov, *Robots and Empire*, Grafton, London, 1985.

[13] Paul Dourish, *Where the Action Is: The Foundations of Embodied Interaction*, The MIT Press, Cambridge, 2001.

[14] Paul Saffo, "It's the media, stupid," *Distinguished Speaker Series of SDForum*, Georgre E. Pake Lab., Palo Alto Research Center(PARC), January 15, 2004.

[15] M. McLuhan and Q. Fiore, *The Medium is the Massage: An Inventory of Effects*, Bantam, New York, 1967.

[16] Paul Levinson, *Digital McLuhan: A Guide to the Information Millennium*, Routledge, London, 1999.

[17] Myeungsook Yoh and Joongsun Yoon, "Personal robotics for the elderly based on interactive technology," *Proceedings of the International Conference on Control, Automation and Systems (ICCAS 2003)*, CD-Rom, Gyeonju, October 22-25, 2003.

[18] Myeungsook Yoh, "Personal robotics for the elderly," *Memoir*, Interactive Technology Initiative (ITI), June 2003 (Korean).

[19] Allison Druin, ed., *The Design of Children's Technology*, Morgan Kaufmann, San Francisco, 1999.

[20] Joongsun Yoon, "Interactive technology: soft engineering," *Proceedings of the 2003 International Conference on Control, Automation and Systems (ICCAS 2003)*, CD-Rom, Gyeongju, October 22-25, 2003.

[21] Daniel Cervone and Walter Mischel, eds., *Advances in Personality Science*, The Gilford Press, New York, 2002.

[22] Michael Posner, ed., *Foundations of Cognitive Science*, The MIT Press, Cambridge, 1993.

[23] Rom Harre, *Cognitive Science: A Philosophical Introduction*, Sage, London, 2002.

[24] William G. Lycan, ed., *Mind and Cognition: An Anthology*, second ed., Blackwell Publishers, Malden, 1999.

[25] William J. Clancey, *Situated Cognition: On Human Knowledge and Computer Representations*, Cambridge University Press, Cambridge, 1997.

[26] Interactive Technology Initiative (ITI) Workshop, Pusan National University, January 2003.

[27] Center For The Study Of Language And Information, http://www-csli.stanford.edu/research/interface.shtml.

[28] Amy Scholder and Jordan Crandall, eds., *Interaction: Artistic Practice in the Network*, Distributed Art Publishers, Inc., New York, 2001.

[29] Vera John-Steiner, *Creative Collaboration*, Oxford University Press, Oxford, 2000.

[30] Joongsun Yoon, Sungho Chang, and In Hwang, "Mom and interactive technology," *Proceedings of the 4th Asia-Pacific Conference on Control and Measurement*, pp. 321-326, Guilin, July 2000.

[31] Joongsun Yoon, In Hwang, and Sungho Chang, "Metatechnology: correspondence of the arts, sciences, technology and humans," *International Journal of the Korean Society of Precision Engineering*, Vol. 1, No. 1, pp. 71-78, June 2000.

[32] Joonsun Yoon, *Evolutionary Robotics based on Interactive Technology*, Phase 2 Report, KOSEF, 2003 (Korean).

[33] Joongsun Yoon and Myeungsook Yoh, "Tangible space and interactive technology," *Proceedings of the International Conference on Control, Automation and Systems (ICCAS 2003)*, CD-Rom, Gyeonju, October 22-25, 2003.

[34] Mark Weiser, "The computer for the 21st century," *Scientific American*, Vol. 23, No. 4, pp. 66-75, September 1991.

[35] Successful Aging, *IEEE Pervasive Computing: Mobile and Ubiquitous Systems*, pp. 12-50, April-June 2004.

[36] Computer and Aging, *IEEE Computer*, pp. 34-49, May 2004.

[37] Celia Pearce, *The Interactive Book: A Guide to the Interactive Revolution*, Macmillan Technical Publishing, Indianapolis, Indiana, 1997.

[38] Mark Pesce, *The Playful World: Interactive Toys and the Future of Imagination, How Technology is Transforming Our Imagination*, Ballantine Books, New York, 2000.

[39] Brad Johnson, Armando Fox, and Terry Winograd, "The Interactive workspace project: experiences with ubiquitous computing rooms," *IEEE Pervasive Computing*, Vol. 1, No. 2, pp. 67-74, April-June 2002.

[40] Adi Ignatius, et al., "Interactive: a skeptic's guide to the innovations that are changing our world," *Time*, June 4, 2001.