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Robotic Human Science and Humanoid Robot Development in Japan

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Abstract

We briefly discuss the history and cultural factors within the development of robots focusing on humanoid and service robots in Japan. Robot models for different application domains focusing developmental efforts are being presented. We describe our notion of human robot science and exemplify the approach discussing recent developments from Japan. The challenges and potentials involved in the design of a humanoid robot orchestra are being elaborated upon. Finally we explore how humanoid robots may impact requirements for future communication services and infrastructures.

Brief history of programmable robots

From the Greek myth of Pygmalion to modern science fiction artificial life forms populate literary imagination and challenge designers around the world. Ever since their role model and antagonist has been the human being, whose desires, needs and fears, and whose culture shape their development.

Since the first robots picked up their work in the early 1960ies application fields have been exponentially increasing. 1961 the first digitally operated and programmed robot named Unimate started to lift and stack hot metal pieces from a die casting machine. Unimate performed welding on auto bodies with six programmable axes of movement at a General Motors automobile factory in New Jersey. Briefly after, in 1963, the first artificial robotic arm to be controlled by a computer was designed as a tool for the handicapped and its six joints gave it a sense of the flexibility of a human arm. In these early days robotics was mainly concerned with the design of artificial arms and later, also legs. Within factory hall of automobiles and industrial goods the first commercial models were employed to manufacture cheaper, more accurate and reliable than human worker could. And they did not mind taking on particularly dirty, dangerous or dull jobs. While these tasks could also be performed by humans, in other fields robots show far superior productivity, accuracy, and endurance. Complementing human expertise they finally help to reduce fatigue driven error and risk e.g. in space mission design.

The first mobile robot (named Shakey) controlled by artificial intelligence involved computer vision and natural language processing and was introduced 1970 by Stanford Research Institute International. While Shakey moved on wheels bipedal locomotion soon became a focus of research and development efforts. 1970 Waseda University started to develop the anthropomorphic intelligent WABOT (WAseda roBOT) series, and presented in 1973 WABOT-1, the first full-scale anthropomorphic robot developed in the world. Based on some of the results 1986 Honda begins a robot research program that starts with the premise that the robot “should coexist and cooperate with human beings, by doing what a person cannot do and by cultivating a new dimension in mobility to ultimately benefit society”[1]. Mobility, intelligence, and finally full interactivity became pivotal to the development. Taking robots out of controlled environments such as factory halls with repetitive and predictable tasks into everyday life, and out of fixed into mobile settings, affords new qualities in handling unpredictability, reliable performance and interaction capabilities. Within human-robot interaction the ability of robots to perform certain tasks autonomously is enhanced through human participation in the course of their actions. Human-Robot Interaction (HRI) became a critical component to the success, acceptance, and capability of robot systems. Since the first international conferences on HRI started 1992 in Japan (IEEE International Workshop on Robot and Human Interactive Communication RO-MAN) a research community with journals and conferences has established. Today robots are integrated into the fabrics of production and service industries, and specialized models now spread into domestic environments.

Fig. 1. Asimo at home, Great Robot Exhibition in Tokyo 2008

Nowadays and in the near future robots are supposed to serve in the household, guide visitors through museums, allow for telepresence and mobile videoconferencing, to rescue victims of earthquakes, to set up wireless networks, to support medical or military actions, to sort department stores, to safeguard and clean buildings, even to entertain and to assist in elderly care.

Anthropomorphic robots are laid-out to interact with humans at (respectively slightly below) eye-level. Humanoid robots resembling the human body autonomously adapt to internal and environmental changes and should be able to safely interact and accomplish their task when facing obstacles. Using tools, equipment and vehicles designed for human form they may potentially do everything humans do today. Anthropomorphic robots are being developed in order to support and interact with humans in their culturally grown, anthropomorphic environments, but also as a new access to understanding human motion, emotion, and cognition.

Backed up by government policies Japan is the world leading country in robot research and development. Since academic research started in the 1960ies there is a greater number of humanoid robots and precedent researches in robotics than in any other nation. According to 2008 data from the International Federation of Robotics and the International Labour Japan has more industrial robots than any other country – 10 times the world average and more than 3 times that the US[2] . While most industrial

1 http://world.honda.com/ASIMO/P3

2 http://www.spectrum.ieee.org/robotics/industrial-robots/the-rise-of-the-machines

robots are still fixed along the assembly lines of their automobile antecessors new models move outside the pure industrial into service scenarios. Interestingly especially auto-mobile companies like Toyota, Mitsubishi, and GM have been investing into humanoid social robots.

Top10 Countries by Robot Density

Industrial robots per 10.000 manufacturing workers

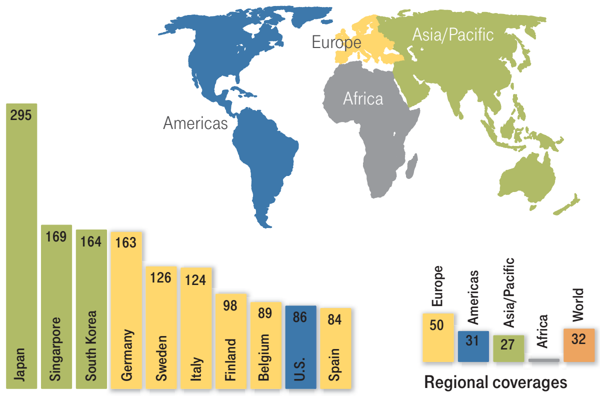


Fig. 2. Illustration: Mike Vella

While personal robots are already popular on the Japanese market, negative images of marauding robots and associations with dystopian science fiction accompany research efforts in Europe. Aesthetic and emotional design based on research on human-robot interaction may increase acceptance and adoption. Anthropomorphic robots operating in corresponding contexts are increasingly presented in appealing ways showing humor or provoking tender emotions in the user audience. They are expected to be found in every Japanese and Korean household within the next 10 years. Japanese and US-Roadmaps "from internet to robotics" have been published[3] [4].

There is nothing sinister or uncanny about a vision of ubiquitous robots in Japan. Cultural factors abet impact the popularity of robotic research and development. The Christian view on humanoid robots as hubris against gods' creation and western dystopias of revolting robots are largely unknown to Japanese researchers and consumers. While westerners tend to look on inorganic robots as immane creations or suspicious tools, in the east they may be viewed as if they were living and naturally afford affection. According to the deep-rooted and prevalent Shintoism almost everything like trees, rivers, mountains, as well as dolls and stuffed animals may be animated. Zoomorphic (or animaloid) robots such as Sony's Aibo or the therapeutic seal robot Paro, developed by AIST may be cute or „kawaii", which in turn is considered to be cultic.

Accordingly robots are not only seen as compensation for a declining workforce, but – supporting functions in household and everyday life – they are intended to support a rapidly aging society. In 2008 robots were more frequently sold for caring than for entertaining purposes for the first time[5] . Humanoid ways of communicating and behaving are particularly demanded in everyday surroundings like offices, households, stores or museums. Therefore cultural factors do not only advocate or obstruct robot development and adoption, but the adequate behavior of social robots autonomously interacting and communicating with humans depends on culture-specific values, rules, norms and standards.

Different types of robots and development trends

2008 forecast predicts worldwide revenue in the personal robotics market at $15 billion by 2015 [6]. Japan Robotics Association even estimated the personal and service robotics market to reach $20 billion in 2010. Since robots are synergetic collections of systems to accomplish a common function, technological developments apply advances from various fields such as sensors (sonar, GPS, light, vision) and object recognition, actuators and mechatronics, network and control software, natural language dialog, or social sciences. And as HRI synthesizes results from various disciplines, it drives innovation in neighboring fields like evolving systems, routing and communication architectures.

Development of humanoid robots is driven by technical challenges particularly with respect to sensing, actuating and controlling, and interacting within different application domains. Proprioceptive sensors measure position, orientation and speed of the robots properties, while exteroceptive sensors yield visual, auditory, and tactile information in order to sense the environment and enable interaction involving different speeds and load volumes. Finally planning and control focus on the detection of obstacles and adaptive path planning allowing the robot to move within and interact with the world.

No standardized classification of robots exists. Differentiating between robots by task some robots substitute currently human labor while others perform tasks better than a humans, increasing productivity, accuracy, and endurance. Telerobots allow remote human operators manipulation at great distances or on a different scale. Microsurgery robots for instance many minimize invasiveness of treatments and shorten recovery time. Nanorobots are being developed to be applied not only in surgery on the cell level, but also for cleaning, manufacturing, and fighting, or even being envisioned as utility fog[7] .

- Since humanoid robots act partially autonomously in unpredictable environments the complexity of their design may only be delimited by knowledge about the task domain and environment. The purpose they serve, their unique specialization, guides their technological development. Application domains may therefore be used to identify the current lines

3 http://www.nedo.go.jp/kankobutsu/pamphlets/kouhou/2008gaiyo_e/25_32.pdf

4 http://www.us-robotics.us/reports/CCC%20Report.pdf

5 http://www.seedplanning.co.jp/press/2008/1224.html

6 http://www.abiresearch.com/products/market_research/Personal_Robotics

7 Internet: http://www.kurzweilai.net/meme/frame.html?main=/articles/art0220.html

of developing humanoid and service robots and central issues in human-robot interaction. We briefly present some examples from some application domains before we proceed to the main challenges in developing humanoid robots and and communication within new infrastructures.
Single task domestic robots save time and effort of their owners, reducing OPEX of household management. Specialized models of "domestic robots" are already being used for household chores. Some perform in activities such as vacuum cleaning (e.g. Roomba, available since 2002, and Scooba by iRobot, Electrolux Trilobite or Robo Maxx), mowing lawns, cleaning pools, ironing clothes or moving objects. Advanced models (domobots) are connected to a WiFi home network. Mobile models can be carried or attached to wheelchairs. Simple forms deliver straight services.

- Search and Rescue Robots master risky areas and awkward grounds. Research by the Tokyo Institute of Technology on rescue robots largely focuses on motion patterns. Souryo II for instances searches for victims in disaster areas by moving in a snake-like manner into the gaps between rubble. Helios IV applies crawling to move on flat lands and elevate itself collecting luggage with two arms. Guard robots have already been put in use. They detect and thwart intruders with sensors and paint guns, and check for fires and water leaks.
- Assistive Robots help. Addressing the needs of an aging society, the development of "assistive robots" is a technological answer to the demographic changes and the increasing needs of eldercare. Robots are intended to either support elderly or handicapped people in their domestic environment allowing them to live independently, or to support caregivers in their work.

Scenario: Assistive Shopping Robot

The TMSUK-4 humanoid shopping robot showcased in Kitakyushu, Japan was being controlled by an elderly lady in her home via an NTT DoCoMo video-capable cell phone. It enabled her to see through the eyes of the robot and presumably control its movements via the keypad. By means of the robot the lady managed to select and purchase a new hat.

Multidisciplinary research results are put to use for automating tasks and assisting people – not only elderly, but also entertaining kids, or assisting astronauts. Advancing from the household chores of commercially available robots to complex tasks reliable interactive systems outside controlled environments are still in an early stage of research. Application scenarios include e carrying things and people, guiding and navigation, monitoring and safety, feeding and dressing support, therapeutic usage. Prototypical developments include:

  - Mobile "Robutler" by German Aerospace (DLR) Institute of Robotics and Mechatronics may perform tasks like opening and closing doors, finding objects, opening bottles, pouring drinks and cleaning up if something gets spilled.
  - Care-O-bot by Fraunhofer IPA is a mobile home care system that moves without colliding and performs fetch-and-carry tasks.
  - Waseda-Leg No.16 is a biped locomotor capable to carry robots or humans up and down stairs at about 1.2 meter height as a walking wheelchair, or to assist humans. It is battery-driven and wireless mobile.
  - Ri-Man is touch-sensitive, capable of face recognition and sound source localization, and differentiates between 8 odors. The Japanese ATR Networked Robot Project develops an open platform for robot collaboration (e.g. watching over aging persons), behavior and environment recognition and context-dependent human-robot interaction integrating various information resources.
  - Paro by Japan's National Institute of Advanced Industrial Science and Technology is supposed to give pleasure and comfort to humans in „robot-assisted therapy". Ifbot (2004) is intended to keep elderly from going senile by means of conversation.
  - Elder-care robot Pearl with moveable facial features is designed to help elderly, and so far already able to guide herself through an area at a pace of up to 50 centimeters a second while avoiding objects in her path.
- Entertainment Robots are not designed for utilitarian use, but for pleasure. They are not only used to create narrative environments in commercial venues like Disneyland's haunted house, but zoomorphic species like Sony's entertainment robot dog Aibo, Segas iDog, the therapeutic companion robot seal Paro, or dancing robot Keepon, developed by NICT (Japan) are evolving to reach consumer markets. Humanoids such as Sony's QRIO and Wow Wee's RoboSapien are capable of features like voice recognition and bipedal walking. Edutainment Robots and Robots in Art may not be considered here.

Human Robot Interaction and Robotic Human Science in Japan

Most big universities and research centers in Japan like Waseda University, the national universities of Tokyo and Osaka, and institutes like ATR and AIST conduct advanced research on service robots with dedicated faculties. Already in the mid-60s, briefly after "Astro Boy", became the orginal, endearing android hero of Japanese popular manga culture, Ichiro Kato, the "father of robotics in Japan", started researching on anthropomorphic robots at

Waseda University. In 1973 WABOT-1 became the first full-scale anthropomorphic robot in the world. It consisted of a limb-control system, a vision and a conversation system and was able to grip and transport objects with hand equipped with tactile sensors. A follow-up project aimed at artistic activity such as playing a keyboard instrument since this requires human-like intelligence and dexterity. The result was WABOT-2's (1984) capable of giving musical performances.

Then WABIAN (WAseda BIpeal HumANoid) was developed in 1996[8]. It can be connected to a network and can walk on its two feet. Its successor, WABIAN-2, developed since 2003, is used as human motion simulator, i.e. for performing exercises with human beings. It integrates information from sensors, shows coordinated actions, and communicates with a human using multimedia such as speech, facial expression and body movement, and propose potential solutions to situated problems.

Human-Robot Interaction

In order to be applied within application fields such as search and rescue, scientific exploration, hospital care and entertainment robots must coordinate their behaviors with the requirements and expectations of human team members. Research results from robotics, cognitive ergonomics, communication sciences, and computing contribute to the understanding, design, implementation and evaluation of HRI. Ethnographic research methods dominate empirical user research with prototypes. Principles and algorithms for interaction and technologies for natural and effective communication (via local area or p2p networks, IR, Bluetooth, context-aware routing) depend on task domains such as industrial production, civil services and support, or entertainment. Teleoperation is needed for search-and-rescue, military and space exploration, and facility management, whereas humanlike communications capabilities and patterns for sociality are necessary for robots operating in everyday settings such as home, office, shopping, and museum environments. Recent key innovations include advances in anthropomorphism, context-aware routing, and a seamless integration of robotics in everyday practices. Interactive robots create a new technological infrastructure. Advanced technology provides for situation awareness and recognition, design of (gestural, natural language, head-mounted or game-control like) controller interfaces, dialog management, and new communication architectures for service delivery. Android science explores natural interaction involving cognitive and behavioral aspects of human interaction with human-like bodies like Robovie.

Robotic Human Science in Japan with examples from Waseda University

Regarding basic research within the field of artificial intelligence, research on robotics has gained interest since the 1980ies due to the notion of embodiment. When cognitive science, trying to model human information processing like a computer program, found its limitations in the decisive impact of embodiment and context, research on robotics as a form of embodied artificial intelligence became an epistemological endeavor. Starting with the development of the pianist robot WABOT-2 at Waseda University by professor Ichiro Kato in 1984, robotic human science is part of this endeavor. Its goal is twofold: on the one hand models of human motor control and psychology should allow creating truly interactive autonomous robots; on the other hand modeling humanoid robots allows for reverse engineering and scientific understanding of human motion, cognition and emotion.

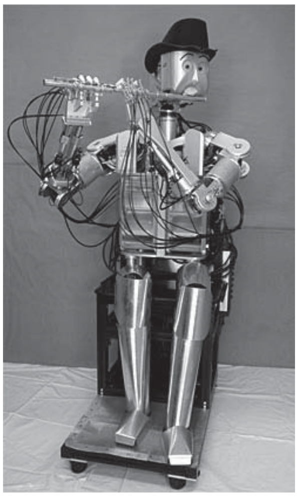


Fig. 3. WF-4RIV: Waseda Flutist Robot

At Waseda University, Takanishi Laboratory, a flute-playing robot has been developed since 1990. The seated robot is essentially made up of two acrylic cylinders and bellows for the lungs, a vibrato mechanism to imitate human vocal cords, an artificial tongue and lips made of a thermoplastic rubber called Septon, two CCD cameras for the eyes, and flexible arms and fingers that can open and close. Together, these organs have 41 degrees of freedom and are driven by complex mechanical systems of motorized belts and pulleys under the control of actuators and a computer. At first a performance index of what constitutes the best flute sounds has been created in collaboration with professional players. These sounds were then translated into mathematical formulations, to which the robot refers. The robot's organs to create a sound have been programmed. Once a sound was produced, the parameters controlling the organs that produced the sound were used as a base and then adjusted those parameters repeatedly until the sound improved and eventually approximated a target sound in the performance index.

Teaching everything from the different positions of the lips and fingers, to the strength of the air pressure turned out to be a slow moving process. In order to speed it up audio feedback control has been added to help the robot make its own adjustments. Additional intelligence allows the robot "read" Musical Instrument Digital Interface (MIDI) data and translate it into the parameter

8 Hun-ok Lim, Atsuo Takanishi (2007)

controls needed to transform the data into flute playing – a video is available online [9].A whole orchestra of robots, and since 2008 an anthropomorphic saxophonist robot is under construction.

The idea of this research is not only to push the borders of robotic capabilities and increasing acceptance of robots by teaching them more entertaining tasks. Robotic Human Science conducts scientific research while designing humanoid robots following an engineering paradigm. How do we walk on two legs, by putting our heel down first, and then pushing off with the ball of our foot to take another step, while keeping the knee straight?
Through demonstration experiments using robots, we endeavor to understand human motion and its mechanism from the robotics point of view.

Even more challenging though inevitable for the design of human-robot interaction is the recognition and expressing of emotion. Humans are fundamentally emotional beings. Their communication and social interaction includes affective or emotive factors. To support the emotional side of human behavior affective interaction and communication between people and robots are being explored. To participate in emotion-based interactions, robots must be able to recognize and interpret affective signals from humans, they must possess their own internal models of emotions (often inspired by psychological theories), and they must be able to communicate this affective state to others.

Emotional affinity in living with robots has been addressed in a joint research with Prof. Hiroshi Kimura from the Waseda University School of Letters, Arts and Sciences, Psychology for over ten years. Several robots have been developed: WE-4RII (Emotion Expression Humanoid Robot Waseda Eye No.4 Refined II) is capable to expressing human emotions like joy, anger, surprise, sadness fear, and disgust, and can be used for modeling and understanding the humans mind; WM-6 (Waseda Mouse #6) is a rat-robot intended for the realization of a symbiotic relationship between rats and robots based on animal psychology, to contribute to the clarification of human psychology; more recently, the whole-body emotion expressing humanoid robot KOBIAN has been developed, by integrating WABIAN-2's body and WE-4RII head and mind.

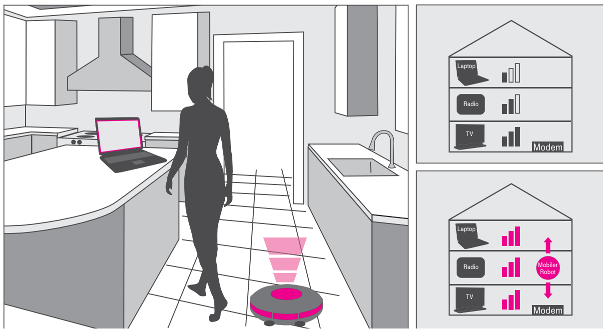
Social (or Sociable) robots are designed to interact with people in a natural, interpersonal manner -- often to achieve social-emotional goals in diverse applications such as education, health, quality of life, entertainment, communication, and collaboration. The long-term goal of creating social robots that are competent and capable partners for people is quite a challenging task. They will need to be able to communicate naturally with people using both verbal and non-verbal signals. They will need to engage us not only on a cognitive level, but on an emotional level as well. They will need a wide range of social-cognitive skills and a theory of other minds to understand human behavior, and to be intuitively understood by people. A deep understanding of human intelligence and behavior across multiple dimensions (i.e., cognitive, affective, physical, social, etc.) is necessary in order to design robots that can successfully play a beneficial role in the daily lives of people. This requires a multidisciplinary approach where the design of social robot technologies and methodologies are informed by robotics, artificial intelligence, psychology, neuroscience, human factors, design, anthropology, and more [10].

9 http://www.ieee.org/netstorage/spectrum/video/flutebot.mp4

The WABOT House

The Japanese WABOT-HOUSE project explores a seamless integration of robots with their social environment, carrying out tasks, interacting, cooperating, and coordinating activities[11] [13]. The concept envisions an urban nuclear family consisting of two parents and a single kid 20 years hence, living in a smart house with various robots. A new middleware platform serves all appliances and devices using a multi-agent peer-to-peer networking paradigm with semantically-rich communication, search, and routing mechanisms. Data from the several hundred sensors is gathered to personalize the environment for the occupants, to save energy by selective switching off of devices, to redirect unused resources and to provide for security.

Swimming robots, tree-climbing robots, rescue robots, wheelchair robots (autonomously navigating using RFID tags embedded in the floor and walls), cargo-hauling robots, and elderly assisting robots are being developed. Human-robot cohabitation is explored with fetching and stationary robots moving seamlessly, recognizing faces, age and gender and mastering variances in furniture. Continuously updated predictive models avoid collisions applying indoor GPS.



Scenario: Robot as Home Gateway

Robots may be utilized as sending and receiving nodes for new telecommunication services, providing a central gateway to home or office infrastructure. As a mobile femtocell they improve capacity and coverage indoors and help to reduce both capital expenditure and operating expenses of the owner. Following its user around it always ensures always the best wireless connectivity.

Research focuses on home server architectures, context-based dynamic routing, and sensor failure detection and prediction. While one building was designed to explore smart home

10 Cynthia Breazeal, Atsuo Takanishi, Tetsunori Kobayashi. (2008). Social Robots that Interact with People.

11 http://www.wabot-house.waseda.ac.jp/html/e-top.htm

technologies to conserve power, reduce waste and emissions, and to explore environment friendly construction materials, within another building a community of robots is intended to interact independently. A third building explores the coexistence of humans and robots in a home.

Remote interaction and impacts on telecommunication

Line-of-sight interaction with robots is often taken as a baseline for modeling remote interaction enabled by high-speed and highly reliable data communication technologies. Taking the variety of multimodal input and output information into account, that may be necessary to reach efficient, effective and enjoyable forms of interactions, robots are heavily impacting and expanding existing communication infrastructures and services.

As artificial participants in everyday interactions they are also predestined as nodes for communication and networking capabilities. Robots as "end user-devices" may become important nodes giving and receiving information within new service networks: At Ilmenau University of Technology (Germany), for example, flying quadcopter robots are being developed. In the event of disaster they can quickly form a self-assembling ad-hoc wireless network providing both mobile phone and WiFi access.

Context-aware routing

This new context-aware routing concept could revolutionize present routing protocols in controlled environments. Instead of using static addressing schemes (IP) devices are being identified based on their current functionality and context.

Differentiators may be: xml-based context definitions, spatial routing, where each location is defined within a context-dependant n-dimensional space. A participating researcher provides the following comment: "Maybe context aware routing is a misnomer in our case, because our idea is quite different from what the term has come to mean. We define the context of a node in terms of its spatial coordinates or location. This spatial information is further complemented by the function that the node is supposed to perform. For example, we are trying to find if messages of the following form can be routed: "This data is to be sent to the temperature controller in the kitchen on the second floor", or "The blinds of the south window in the living room on the first floor are to be closed".

One primary focus of current research is the routing of messages to both mobile and stationary nodes in enclosed environments such as (smart/intelligent) houses, hotels, factories, etc. In such places, it is possible to identify static locations as the examples above show. In the future, such environments are expected to have several hundred active nodes such as sensors, controllers, actuators, audio-visual equipment, robots, kitchen appliances, furniture, etc. The question we ask is, "Is it necessary or even desirable to identify all these nodes using addressing schemes such as IP that do not convey any additional information regarding the node?" Or rather, "Can we eliminate existing addressing schemes, and replace them with a new semantically rich information exchange protocol?"

If such a system is developed, we can imagine the creation of a dynamic set of shared services being provided by the nodes in question. More than just an information search and retrieval protocol, we want to create a complete information communication architecture that provides an adaptive and extensible platform for nodes to share data, coordinate, and collaborate."

Current challenges relate to creating unique contexts and routing algorithms that use multidimensional variable space to identify devices, and also the need for automatic updates when changes in the context occur.

Remote Interaction

Joint research of Scuola Superiore Sant'Anna and Waseda University, starting from the current availability of several mechatronic prototypes in their research laboratories, intends to validate different telecommunication tools for the remote control of mechatronic systems by demonstrating the feasibility and potential benefits deriving from the integration of such technologies.

Remote interaction with robots is essential for operation in environments inaccessible for humans. E.g. for space robotic systems become increasingly to reduce human workload, costs, fatigue driven error and risk. To support human-robot collaboration augmented reality overlaying computer projections onto the real world have been proposed. Augmented reality allows humans to share an ego-centric view with a robot, thus enabling the human and robot to ground their communication and intentions, but also for an exo-centric view of the collaborative workspace affording spatial awareness[12].

Augmented reality may be applied to provide spatial cues permitting users to interact freely with real space and supporting the use of natural spatial dialogue. Automated speech recognition and text to speech synthesis to convert human input into appropriate robot commands and to enable cooperative robots to express their understanding of the situation, to announce their operations, or to propose alternative approaches. Humor and emotion incorporated in such a dialogue system would support a more natural and effective communication. In addition to the audio channel an environmental channel applying real world objects may be used to establish common ground and situational awareness though augmented reality projections. Especially in mobile settings (without mouse and keyboard) physical objects may be used to communicate with a robot. Finally visual cues in AR may be used to support communication through bi-directional transmission of gaze-direction, gestures, facial expressions and body pose[13]. Opportunities for the telecommunication industries arise not only from the continuous transmission of great amounts

12 Green, S.A., Billinghurst, M., Chen, X, and Case, J.G (2008). Human-Robot Collaboration

13 http://www.cs.virginia.edu/~robins/A_Robot_in_Every_Home.pdf

of data, but – even though still in a research stage – also from the service needed to analyze and synthesize data and manage the whole dialogue.

First proofs of concept within simple application scenarios have already been provided: The TMSUK-4 humanoid shopping robot showcased in Kitakyushu, Japan was being controlled by an elderly lady in her home via an NTT DoCoMo video-capable cell phone. It enabled her to see through the eyes of the robot and presumably control its movements via the keypad, and actually selecting and purchasing a new hat.

Conclusion and Potentials

Despite of initial efforts, standards, platforms and design patterns for communication between robots, and between humans and robots of various kinds, are still missing[13]. Telecommunication with autonomous service robots has so far neither been pursued as a major research topic nor as a business opportunity. However, a globally seamless access and reliable communication links are needed for interoperability, for mobile and remote tasks. Mobile communication providers may seek to monetize their frequencies and infrastructures, to provide this missing link and implement SIM-cards as unique gateway into every robotic application. Initial use cases and application scenarios may consider seamless tele-control of an apartment (e.g. security-check or energy control) and learning from interaction (e.g. for self localization, mapping, self-tracking and learning from mistakes). From the technical side frameworks for cell phone based interaction with service robots is missing in order to remote control reactive and autonomous behavior, and to enable close range learning for long distance interaction. Advanced sensors integrated into cell phones will be needed as external sensors of a service robot e.g. for map building. Suitable modalities and handling of multimodality for tele-interaction e.g. applying AR between human and machine still need to be explored.

Robots are becoming part of more aspects in everyday life with an increasing need for integration into everyday practices and new requirements for communication, especially within remote-control and tele-presence scenarios. While western markets for personal communication are saturating, interaction and communication with automobile robots and functionalities may seduce like the next blue ocean. Telecommunication companies have chances to position themselves in this new, emerging infrastructure and business due to the characteristics of robots and the market situation:

- nfrastructure needs to be provided and standardized to achieve highly reliable data connections for m2m and remote human-robot interaction (integrating SIM-cards also allows localization).
- New service will be provided for new tele-presence and remote control applications; existing devices like mobile phones, but also new interface will be applied.
- As physical intermediates robots may add a sense of presence for telecommunication, e.g. functioning as a mobile phone with video transmission capabilities.
- Robots may be utilized as sending and receiving nodes for new telecommunication services, e.g. as a central gateway to home or office infrastructure;
- Utilization of research results and developmental breakthroughs from and for neighboring fields.

While “uncanny androids” in every home may be some years ahead new demands for telecommunication emerge in order to enable a seamless integration of and interaction with travelling and domestic robots. Standardization of operating systems and decreasing prices will increase adoption using existing infrastructures. New business potentials arise in robotics itself, in servicing industries, in the enabling technologies and the telecommunication infrastructures necessary for operation.

About the Authors

ATSUO TAKANISHI is a Professor of the Department of Mechanical Engineering, Waseda University and a concurrent Professor and one of the core members of the Humanoid Robotics Institute, Waseda University. He received the B.S.E degree in 1980, the M.S.E degree in 1982 and the Ph.D. degree in 1988, all in Mechanical Engineering from Waseda University.

His current researches are related to Humanoid Robots and Cyborgs, such as the biped walking robots for modeling human biped walking as bipedal humanoid robots WABIAN (WAseda BIpedal humANoid) series, the biped locomotors for carrying handicapped or elderly as WL (Waseda Leg) series, the mastication robots WJ (Waseda Jaw) series to mechanically simulate human mastication for clarifying the hypothesis in dentistry, the jaw opening - closing trainer robots WY(Waseda Yamanashi) series for patients having difficulties in jaw opening and/or closing, the flute playing robots WF (Waseda Flutist) series, the upper body humanoid robots WE (Waseda Eye) series, the anthropomorphic taking robots WT (Waseda Talker), and other related topics.

He is a member of Robotics Society of Japan (a board member in 1992 and 1993), Japanese Society of Biomechanisms, Japanese Society of Mechanical Engineers, Japanese Society of Instrument and Control Engineers and Society of Mastication Systems (a major board member from 1996 to current), IEEE and other medicine and dentistry related societies in Japan.

He received several awards such as the Best Paper Award from Robotic Society Japan (RSJ) two times in 1998 and in 2005, the Finalist of Best Paper Award two times in the IEEE ICRA in 1999 and in 2006, Best Paper Award and Finalist of Best Biomimetic Paper Award at IEEE ROBIO 2007, the Best of Asia Award from Business Week Magazine in 2001, and so on.

HENNING BREUER investigates human desire in technological environments. He holds a PHD in media and organizational psychology and degrees in law and philosophy. His research and consulting activities in Europe, Chile and Japan focus on form factors and workflows for human-computer interaction, and on new, user-driven methods for innovation marketing. He published on information technology for aging societies, educational technologies, human-robot interaction and strategic user research. At an international business consultancy and as managing partner of "Bovacon - Designing Business Interaction" he worked for clients such as Lafarge, Vodafone, Microsoft, Lufthansa Systems, and the German Aerospace.

In 2003 / 2004 he was Visiting Professor at the Department of Computing Sciences at the University of Chile and worked on interactive learning activities and art. From 2006 to 2009 he was invited three times and spent 10 month as Visiting Researcher at Mitsuji Matsumoto Optical Wireless Laboratory of Waseda University Tokyo, funded by an Award of the National Institute of Information and Communications Technology (NICT Foreign Researcher Invitation Program related to Research and Development in the field of Advanced Communications and Broadcasting). His research dealt with new concepts, system design and evaluation of interactive learning environments involving mobile applications. Since 2006 Henning reports for Technology Radar on emerging technologies especially from Japanese and Korean Research and Development with potential impact and opportunities for the telecommunication industry. He also prepared and conducted several travels of the Telekom Laboratories to Japanese R&D, and helped to set up a first cooperation with KDDI Laboratories.

Further Reading

[1] Anthropomorphic Flutist Robot WF-4RIV Musical Performance (2009). Internet: http://www.ieee.org/netstorage/spectrum/video/flutebot.mp4

[2] Cynthia Breazeal, Atsuo Takanishi, Tetsunori Kobayashi. (2008). Social Robots that Interact with People. Springer Handbook of Robotics 2008; pp. 1349-1369

[3] Gates, Bill. (2007). A Robot in every home. Scientific. American, vol.1, pp.58-65. Internet: http://www.cs.virginia.edu/~robins/A_Robot_in_Every_Home.pdf

[4] Green, S.A., Billinghurst, M., Chen, X, and Case, J.G (2008). Human-Robot Collaboration: A Literature Review and Augmented Reality Approach in Design. International Journal of Advanced Robotic Systems, Vol. 5, No.1, pp 1-18.

[5] Erico Guizzo (2008). The Rise of the Machines. December 2008. Internet: http://www.spectrum.ieee.org/robotics/industrial-robots/the-rise-of-the-machines

[6] Honda. (2009). Asimo. P3 – Prototype 3. Internet: http://world.honda.com/ASIMO/P3

[7] Hun-ok Lim, Atsuo Takanishi (2007). Biped walking robots created at Waseda University: WL and WABIAN family. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 365, issue 1850, pp. 49-64

[8] NEDO (2008). Outline of NEDO (New Energy and industrial Development Organization) 2008-2009. Chapter 2: Machinery Systems Technology. Internet: http://www.nedo.go.jp/kankobutsu/pamphlets/kouhou/2008gaiyo_e/25_32.pdf

[9] Roadmap for US Robotics – From Internet to Robotics. Internet: http://www.us-robotics.us/reports/CCC%20Report.pdf

[10] Personal Robotics. (2007). The Market for Task, Security, Entertainment, and Educational Robots and Major Components. Internet: http://www.abiresearch.com/products/market_research/Personal_Robotics

[11] Seed Planing Press Release (2008). Investigation of market trends in service robotics (source in Japanese only). Internet: http://www.seedplanning.co.jp/press/2008/1224.html

[12] Storrs Hall, J. (1993/2001). Utility Fog: The Stuff that Dreams Are Made Of. Originally published 1993 by J. Storrs Hall. Published on KurzweilAI.net July 5, 2001. Internet: http://www.kurzweilai.net/meme/frame.html?main=/articles/art0220.html

[13] The WABOT-HOUSE project. (2009). Internet: http://www.wabot-house.waseda.ac.jp/html/e-top.htm