Quality of Life Technology

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Guest Editor

We define quality of life technology (QoLT) as intelligent systems that augment body and mind functions for self-determination for older adults and people with disabilities. QoLT systems can take many forms: they could be a device that a person carries or wears, a mobile system that accompanies a person, or a technology-embedded environment in which a person lives. While QoLT aims at intelligent systems, it is a fundamental departure from traditional "autonomous" robotics. Traditional robotics systems, with industrial production, space exploration, hazardous environment, and military engagement as the main application domains, has had an implicit premise of reducing human involvement. In contrast, QoLT systems must work in daily environments with a person and for the person. They are a person-system symbiosis in which the person and the artifact components are mutually dependent and work together.

QoLT responds to societal needs, specifically a large and growing segment of our population—people with reduced functional capabilities due to aging or disability. The number and percentages of people in need of QoLT increase every year. About 50 million Americans have a disability that affects one or more of their major life activities; among them are over 6 million children who use special education services. Perceptive, cognitive, and musculoskeletal diseases that impair motor skills dramatically increase with age. By 2030, over 20% of the U.S. population will be over 65 years of age, with one in two working adults serving as informal caregivers. The situations are more severe in some countries, notably in Japan. Globally, the number of people older than 65 years is anticipated to double between 1997 and 2025. The economics are staggering; it is estimated that well over $1 billion will be saved in the United States annually if all seniors' entry into assisted living facilities can be delayed by a single month.

This Special Issue is a collection of papers that represent current research on various aspects of quality of life technologies including systems that help people in their daily lives.

In 2006, Carnegie Mellon University established the Quality of Life Technology Center, jointly with the University of Pittsburgh, and funded by the National Science Foundation's Engineering Research Center Program. The basic tenet of QoLT systems that appropriately make up for diminished human capabilities is

$$\text{QoLT compensation} = \text{person's intention} - \text{person's capability}$$

with delta plus or minus. With delta plus, the systems extend a little convenience to the user, and with delta minus, the systems present a little challenge to the user promoting her maintenance or rehabilitation of capabilities.

This Special Issue is a collection of papers that represent current research on various aspects of QoLT, heavily drawn from activities within the Quality of Life Technology Center. For developing systems that help people in daily lives, QoLT research is inherently interdisciplinary. It spans a broad range of aspects, from sensor and interpretation, to mechanisms and manipulation, to human interaction and modeling, to rehabilitation and health science, and to communication and distributed systems. In addition, personal and socioeconomic considerations, such as user acceptance and privacy issues, must be brought to the forefront of advanced technology research. As such, one may notice that the authors of papers in this Special Issue include not only technologists, but also gerontologists, sociologists, psychologists, clinicians, and health scientists.

The Special Issue starts with a paper titled "Designing and evaluating quality of life technologies: An interdisciplinary approach" by Schulz *et al.* It provides a roadmap for design, development, and evaluation of QoLT system development by defining quality of life and identifying key attributes of QoLT. The central theme is that successful QoLT development is highly dependent on collaborative interdisciplinary teams involving social scientists, clinicians, engineers, and computer scientists.

Digital Object Identifier: 10.1109/JPROC.2012.2200555

The next four papers present examples of cutting-edge research on robotics planning, manipulation, and sensing for QoLT. The paper "HERB 2.0: Lessons learned from developing a mobile manipulator for the home" by Srinivasa *et al.* describes the hardware design, software architecture, and core algorithms of a bimanual mobile manipulator developed for performing useful tasks for and with people in human environments. The paper "Home assistant robot for an aging society" by Yamazaki *et al.* presents a life-sized humanoid robot performing various daily chores, including kitchen tasks, clothes handling, and sweeping. Then, in the paper "First person vision," Kanade and Hebert propose a new vision paradigm for achieving person and environment awareness. For the purpose of understanding the behavior, intent, and environment of a person, instead of installing cameras in the environment, first-person vision senses the surroundings and the user's activities from a wearable sensor so that images are taken from her view points and interpreted together with readily available information about her head motion and gaze through eye tracking. The final paper in this group is "Cognition-enabled autonomous robot control for the realization of home chore task intelligence" by Beetz *et al.* It gives an overview of a home chore service robot, whose feature is the artificial inference mechanism that decomposes a higher level task specification into primitive tasks with flexible decision making for reliability.

The next two papers are about intelligent devices and instrumented environments that sense, observe, and assist people. In the paper "Architecture and applications of virtual coaches," Siewiorek *et al.* present the design and development of a new generation of always-attentive individually personalized cognitive aids, called virtual coaches, which continuously monitors its users activities and surroundings, detects situations where intervention would be desirable, and offers prompt assistance. In the paper "Toward an ecosystem for developing and programming assistive environments," Helal *et al.* present their experience in building assistive environments for older adults, and argue the importance, beyond technology prototyping, of commercial proliferation and creating a vibrant industry around assistive environment technology.

The following three papers present research, development, and evaluation of rehabilitation and therapeutic systems. The paper "Personal mobility and manipulation appliance—Design, development, and initial testing" by Cooper *et al.* describes the development and testing of a system that assists with mobility and manipulation together, the most critical activities necessary to live at home and participate in one's community, for people with severe disabilities involving both the upper and lower extremities. The paper "Using socially assistive human–robot interaction to motivate physical exercise for older adults" by Fasola and Matarić presents a socially assistive robot designed to engage elderly users in physical exercise. Its user study indicates a strong user preference for the relational over the nonrelational robot for an effective exercise coach. The final paper in this group, "Therapeutic seal robot as biofeedback medical device: Qualitative and quantitative evaluations of robot therapy in dementia care" by Shibata, presents evaluation results of robot therapy by PARO, one of the most successful robotic animals being used in hospitals and care facilities in approximately 30 countries. From his neurological study, the author suggests that PARO has the potential to change moods and behaviors of the elderly with dementia as a nonpharmacological approach.

The final paper in the Special Issue on Quality of Life Technology is "Universal design for quality of life technologies" by Steinfeld and Smith. The authors, experts on universal design, present arguments and discussions on why and how the inclusive design approach by universal design is needed in order to ensure that anyone is able to benefit from a QoLT system regardless of their functional challenges.

As the editor of this Special Issue, I thank the authors for their outstanding contributions and the reviewers whose help improved the quality of the papers. Also, I would like to express my appreciation to J. Calder, Managing Editor, and J. Sun, Publications Editor, of the Proceedings of the IEEE, for their help, support, and patience throughout the preparation. ■

ABOUT THE GUEST EDITOR

Takeo Kanade (Fellow, IEEE) received the Ph.D. degree in electrical engineering from Kyoto University, Kyoto, Japan, in 1974.

He is the U. A. and Helen Whitaker University Professor of Computer Science and Robotics and the founding director of Quality of Life Technology Center at Carnegie Mellon University, Pittsburgh, PA. After holding a faculty position in the Department of Information Science, Kyoto University, he joined Carnegie Mellon University in 1980. He was the Director of the Robotics Institute from 1992 to 2001. He also founded the Digital Human Research Center in Tokyo and served as the founding director from 2001 to 2010. He works in multiple areas of robotics: computer vision, multimedia, manipulators, autonomous mobile robots, medical robotics, and sensors. He has written more than 350 technical papers and reports in these areas, and holds more than 20 patents. He has been the principal investigator of more than a dozen major vision and robotics projects at Carnegie Mellon University.

Dr. Kanade has been elected to the National Academy of Engineering and the American Academy of Arts and Sciences. He is a Fellow of the Association for Computing Machinery (ACM), a Founding Fellow of the American Association of Artificial Intelligence (AAAI), and the former and founding editor of the *International Journal of Computer Vision*. Awards he received include: the Franklin Institute Bower Prize, the ACM/AAAI Allen Newell Award, the Okawa Award, the C&C Award, the Tateishi Grand Prize, the Joseph Engelberger Award, the IEEE Robotics and Automation Society Pioneer Award, and the IEEE PAMI-TC Azriel Rosenfeld Lifetime Accomplishment Award.