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Design to Realize the Harmonious Coexistence of Humans and Robots

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Abstract

In recent years, human-machine interaction (HMI) to realize cooperation and coexistence among humans and machines or robots has been pursued in manufacturing sites and general social scenes targeting consumers owing to various factors including social changes. One of the catch phrases in the 21st century is "the harmonious coexistence of humans and robots". For the harmonious coexistence of humans and robots in society, smooth bidirectional communication between them is required. The means of communication should inevitably be a natural language because robots are a support tool for humans. From the viewpoint of machine safety, a certain level of safety is demanded to ensure that humans are not injured by machines that may be dangerous to humans. Machine safety obtained by optimal design is very important and is realized under conditions of their compromise and coexistence with the society. Machine safety takes four elements into account, i.e., ethics, economy, the social system, and technology. In this paper, we examine 1) the mechanism of communication between humans and robots to realize a harmonious coexistence and 2) the four elements of machine safety to investigate the design required to realize the harmonious coexistence of humans and robots.

Keywords: human-machine interaction, harmonious coexistence, humans and robots, machine safety

1 Introduction

One of the catch phrases in the 21st century is "the harmonious coexistence of humans and robots". In an increasingly complex human society, assistance from robots is indispensable in various fields including safety systems, medicine, nursing care, and education. To realize the harmonious coexistence of humans and robots in society, smooth bidirectional communication between them is required.

When the relationship between humans and robots is considered, we know that Japan has a long history of using industrial robots. In recent years, however, robots have been used not only in factories but also in our living environment and have started providing various services to humans. Japan is a country with high longevity of its citizens, and the roles of robots in the field of welfare are particularly applicable to supporting elderly and disabled people and to prepare for a superaging society. A natural language is required as a means of communication between humans and robots because such robots are different from conventional industrial robots, being tools for providing assistance to humans.

What are some practical and conceivable methods of enabling communication between humans and robots using a natural language, to realize their harmonious coexistence in society? From the technical aspect, one approach to realizing such essential communication is by imitating the developmental process of human communication, which becomes increasingly complicated through learning and experience. To realize this approach, the communicative behavior of humans should be analyzed objectively.

Safety hazards and industrial accidents are caused by risk states due to the coexistence of two elements -humans and machines as a hazard source- in the same space at the same time. Conventional occupational safety has mainly been ensured by the education of employees. However, in recent machine safety based on the risk-based approach, the removal of hazardous sources based on the cause-and-effect relationship has been the point of focus. Therefore, safety has been ensured by the following methods: dangerous machines are enclosed (principle of isolation), the hazard sources and humans are isolated in a Hausdorff space, and devices such as safety interlocks are activated to power off machines in dangerous motion when humans come in contact with them (principle of interruption).

Human-machine interaction (HMI) to realize cooperation and coexistence among humans and machines or robots has been sought in manufacturing sites and general social scenes targeting consumers,

because of various factors, including social change. From the viewpoint of machine safety, a certain level of safety is demanded to ensure that humans are not injured by those machines that may be dangerous to humans. Machine safety obtained by optimally designing machines is very important and is realized under conditions of their compromise and coexistence with society. Machine safety is based on four elements, i.e., ethics, economy, the social system, and technology.

In this paper, we examine 1) the mechanism of communication between humans and robots to realize a harmonious coexistence, and 2) the four elements of machine safety to investigate the design required to realize the harmonious coexistence of humans and robots.

2 Harmonious coexistence of humans and robots

In considering the communicative behavior of humans, the content and mechanism of the instinctive actions of humans should be examined. In general, the following two motives are considered to generate the actions of humans: 1) homeostasis, which is a physiological motive related to life and death, and 2) curiosity, which induces explorative activities. The communication level of humans improves through the development of their senses and physical capabilities. A human recognizes that one's idea is the representation of mind. In this way, a human can distinguish self from others and can think from the perspective of others. Referring to this developmental process of humans, we can construct the mechanism of communication between humans and robots.

The positioning of others in one's mind is important because communication resides in the relationship between oneself and others. Namely, for robots, the positioning of others, i.e., humans, among themselves, will be a key point. What type of interface should be designed for this purpose? In general, the acquisition of a representation method, in addition to homeostasis and curiosity as motives, is considered to be important in the development of communication skills.

Here, homeostasis refers to the function of self-preservation using an autonomous system of living bodies and is related to how to input evaluation criteria into robots to initiate a certain action. Curiosity also follows the evaluation criteria. Therefore, the design of an interface including such an autonomous system should be considered first. The fundamental technology required for the design of the interface is to acquire a representation method, because communicative behavior is induced by representation based on the information of sense and motion.

In addition, to realize essential communication between humans and robots by mutual understanding of the states of mind of both, the following technical issues should be addressed: 1) robots should express their state of mind by themselves, and 2) robots should understand the state of mind of humans.

3 Development and design of robots and related problems

The level, smoothness, and accuracy of communication should be considered to realize constructive communication between humans and robots.

From the viewpoint of the level of communication, the contributions of design engineering and robotics are significant. Research into issues that might arise as a result of the coexistence of humans and robots in the same living space is well under way. In addition, the level of communication skills of robots that are acceptable to humans has become clear. These findings should be used in the development and design of robots in the future.

The accuracy of communication is the level of precise correspondence between the content of communication and the actions of robots, which is closely related to an essential understanding of natural language in human communication. This is the subject of the field of applied linguistics. Recently, the essence of natural language has been dynamically analyzed from the viewpoint of biolinguistics in cooperation with researchers from various fields; this will result in a fruitful outcome in the near future.

On the other hand, while the technology for the development of robots has advanced, the effect of robots on the human society has not been sufficiently discussed. Robotic pets, which have a healing effect for humans, are already commercially available at low cost, and such robots have started to have a psychological effect on humans. The range of applications of these robots includes mental care, relaxation, and functional recovery for the elderly. It is safe to assume that robots of other types, in addition to robotic pets, will enter into and affect the lives of humans in the future.

Now, we must discuss the effect of robots on humans, the environment, and the society more clearly. For example, we must examine 1) the environment in which both humans and robots can coexist harmoniously considering the proliferation of robots in the daily lives of humans, 2) the social system infrastructure, including social rules, and 3) the roles of robots in unusual or special circumstances, such as in times of disaster. By pursuing the solution on the basis of not only engineering but also various fields from psychology to medicine, the future direction of robot development, which is currently based on technology alone, can be provided to contribute to their optimal development.

Humanoid robots are different from machines, such as automobiles, in that the robots can autonomously make decisions and take actions. Therefore, establishing communication with robots as well as establishing ethical, safety, and legal rules required for the coexistence of humans and robots is indispensable. If humanoid robots were to be used without establishing

such rules, our daily lives would be significantly confused.

4 Four elements related to safety

Machine safety is supported by four elements: ethics, technology, economy, and the social system.

4.1 Ethics

Science and technology have significantly increased convenience in our society: however, they have also had adverse effects on society, such as hazards caused by untreated hazard sources, environmental problems, and psychological distress, most of which cause irreversible effects. Such hazards are sometimes uncontrollable. On the basis of the assumption that the designer of machines can manage hazard sources and control the irreversible and negative aspects of such hazards, I believe that many designers will be willing to be involved in such work, which is the ethical basis for engineers.

4.2 Technology

From the conventional concept and methodology of the principles of isolation and interruption, a new principle of HMI should be devised using technology. According to the first law of Isaac Asimov's Three Laws of Robotics, robots are commanded by society not to injure humans. The Three Laws of Robotics are:

1. A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

Therefore, the design of machines to ensure safety against contact and collision is demanded. To this end, essential safety designs should be prioritized; when a sufficient level of risk reduction is not expected to be realized, the development of device technologies, including safety sensors, will be necessary.

No principle for safe HMI has yet been established worldwide. The preparation of the conditions of such a principle is an urgent task.

4.3 Economy

The concept of assurance of safety in Europe is realized by the European Community (Communaute europeenne, CE) marking system, in which the health and safety of humans are secured, trade barriers are removed to promote free trade, and only safe products are transferred to the market; safety is ensured not only by technology. In addition, smooth economic activities in terms of convenience and productivity are considered.

Many countries should participate in establishing systematized international standards on machine safety. To this end, machines do not always use the best technology available but are produced as a result of compromising conditions posed in society. Technology and economic performance are mutually dependent because of their trade-off relationship. An optimal balance between them is required to ensure safety.

4.4 Social system

An appropriate social system considering the laws on the prevention of accidents and on compensation is required regarding the method of use of artificially designed robots (machines) by users, even if the safety factor is ensured in terms of ethics, technology, and economy.

In the case of occupational safety, factory workers who have basic safety education are targeted and the risk is limited. However, in the case of robots providing services to general users, the possibility of accidents is judged on the basis of the level of expectation of users, or subjective criteria of judgement. Therefore, the above four elements should be thoroughly considered in developing an appropriate social system.

For the development of industries and the ongoing improvement of our daily life, the continual creation of new design solutions using innovative skills is necessary. For example, the further downsizing and weight reduction of products, significant reductions in energy consumption, the creation of new energy alternatives such as fuel cells, and the development of new manufacturing strategies are essential.

Therefore, individuals with a thorough knowledge and wisdom regarding related issues should cooperate with each other to achieve innovation.

In addition, designers in companies today tend to have limited knowledge and skillswith respect to safety in particular. The cause of this problem may be inadequate training at technical colleges and companies. Professional education in safety issues at technical colleges and the systematic education of engineers in companies are both required. Since Japan is an advanced country in terms of technology, it should also be a leading country in terms of safety. We believe that it is necessary to correct the current attitudes toward and methods of ensuring safety.

5 Everything done by humans: developing technology, manufacturing and using machines

However advanced technology may be, humans wish to receive care from humans. Humans also desire machines to be tools that support care receivers and givers. I believe that mechanization that leads to the treatment of humans as objects is wrong.

Technology should accommodate itself to humans, rather than humans adjusting themselves to the technology. Each human has both strong and weak points. One of important themes of public welfare is that machines should support the weaknesses of humans in a natural manner. As one becomes older, one may have difficulties in daily life. It is natural that machines would be used to support such people. It is desirable that robots providing support coexist in harmony with the culture and the lifestyles of the people

in society. Limitations arise if designers deal with only the technology.

Technology helps humans make themselves happy. How technology is used should be thoroughly examined considering economic, religious, and cultural aspects of society before manufacturing machines. After all, humans develop technology and manufacture and use machines. The mission of designers is to advance the current culture and civilization as legacies for subsequent generations.

6 Modernity in technology

In a complex society, it is necessary to distinguish between specialists who are capable of prediction, and unprofessional individuals who do not have this ability. For specialists, it is inevitable to require something akin to liability without fault. Design is the act of being conscious of certain meanings within a specific framework. Accordingly, we can say that design involves the discovery of a new nature which shows logical or sensuous understanding of several fields of science, and that design is a technology which cannot be achieved without thoughts on nourishing nature, including human beings.

Machines and structures fulfill specific functions through the combination of various elements within a certain system, and the machines and structures can function synonymously with plans for an artificial nature. In general, functional items required at the design stage consist of those things which can be academically systematized and those things which cannot. To complete a new design under such a broad range of requirements, we need a system or idea that has been integrated by broad recognition, which enables a flexible response not bound by conventional theories.

In particular, technologies treated in the current era tend to be ultralarge or ultrasmall, high speed and highly functional while, simultaneously, they are realized in a form closely related to daily life. Therefore, we are required to achieve a balance between cultural/social sciences and natural sciences, while using natural sciences as the foundation. This implies that the application of science and technology causes problems related to human qualities. In this sense, the fact that a designer's way of thinking and attitude are deeply associated with his/her accomplishments should not be ignored in the evaluation of a design.

For example, in safety design, causes and procedures of human errors are analyzed based on the assumption that humans easily make mistakes. Similarly, with respect to the morality of humans, we should start from the assumption that humans easily ethically deviate. Issues such as the situations in which human behavior becomes deviant, or the level of resistance to deviation, should be empirically examined. People naturally have an interest in other people and a desire to be associated with them. The morality of humans is most naturally exhibited in a face-to-face situation, i.e., in the presence of others. By broadly understating the meaning of technology and assuming that all human acts are technological, the close relationship between virtue and capability becomes more apparent. In addition, if the human spirit consists of rational and irrational parts, in order for the rational nature to function effectively, the rational nature must fully control the irrational nature. Technology is required for such control.

Technology is the wisdom of using dangerous things safely. If we refer to this wisdom as engineering wisdom or design wisdom, then it has such a wide scope that sheds new light on ways to solve the most difficult ethical problems, instead of being limited to the mere handling of hazardous materials or artificial substances. An intellectual act to produce things that do not exist in nature by applying natural laws is creation.

7 Conclusions

To meet the needs of the times, the recent concept of HMI is based on nonlinear elements of science that can coexist with biosystems with minimal energy consumption, rather than the conventional concept based on linear elements of science that clarify and subdue nature. In other words, we aim to establish a society of coexistence in which we can live a safe and secure life with machines.

In an actual society, the number of nonlinear elements is much larger than that of linear elements. In a complex society, we demand to maintain homeostasis while optimally controlling the increase in entropy by various elements to ensure safety. Proceeding with the development, design, and safety design of robots is an effective methodology for realizing this goal.

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