

Environment of Intellect: Considerations for the Future

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SUMMARY This paper describes key design technology issues as general ideas, rather than for specific fields, with a view to realizing better technology for the future. This paper also discusses the scope of the vision we should adopt, the factors we should be conscious of, and how we should design future systems. The key ideas arise from the belief that technology should be designed in the context of the environment with intellect behind it.

key words: environment, future, technology, intellect

1. Introduction

We now live in a technologically rich environment that includes broadband Internet, mobile phones, and high-performance personal computers. However, alongside our high expectations for future technologies and services, fears have recently arisen about the potential for serious problems to occur. For example, there are concerns that we cannot keep up with the rapid changes in our environment and the technologies that underpin our lives, and the flood of unwanted information that threatens to overwhelm us. The key to solving these problems is related to Information and Communication Technology (ICT). Although only 20 years have passed since modern ICT emerged compared with the 150 thousand years of human existence and the 3.8 billion year history of the natural world, it has already penetrated our lives environmentally, economically, industrially, and even psychologically.

The original motives behind technological development were related to achieving a better life, solving various problems, and realizing our dreams. However, our goals have become too economically biased, and have focused on such factors as convenience, efficiency, and functionality. Technologies must be quick and easy for anyone to use anywhere and at any time. We can say that the aim of the 20th century was material wealth. We have been pursuing instant gratification and have been treating our complex and dynamic world in too simple a manner. We have to realize that technology does not function in isolation and is related in various ways to other elements in its surroundings. We need to think about the entire content of our environment.

Figure 1 shows a brief assessment of the benefits and concerns we have in related domains. Today, people are more aware of the international environmental crisis. Albert

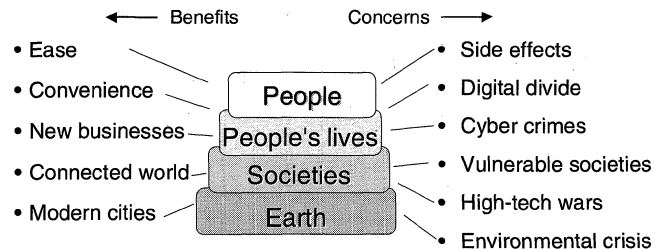


Fig. 1 High-technology: Benefits and concerns.

Gore's movie and book [1] "An Inconvenient Truth" have attracted world attention. However, the environmental crisis is not limited to the climate; it includes social problems such as wars, and even individual human problems. ICT is closely related to these problems as regards various aspects of our environment.

When the 21st century began, we started to notice the many side effects that resulted from an over-emphasis on economy-based goals. We engineers and scientists, who must accept some responsibility for the fate of the world, need to think deeply about potential needs and what we should do now toward achieving a bright future. We must adopt a broader vision in order to minimize crises while retaining benefits.

2. Embracing Factors

The above discussion suggests that there are many things to consider; we need to be more intellectual when designing technology so that intellectually the environment can embrace our society. To achieve this, the first step is to learn about human beings and the environment. Figure 2 shows a rough diagram of factors that surround us to help us picture what is needed in what situation. Man is surrounded by an ambience that consists of human actions, ways of living, and the counterparts to these actions such as nature, other people, society, the cyber-world, and our hopes. Although their power has now waned, fairies and goblins can be understood as symbolic entities that helped people to coexist with nature in earlier times. Manners, customs, ethics, traditions, common sense, rules and laws, handed down over generations, help people cooperate and collaborate with each other. This diagram is simply to provide a general idea about what surrounds us, and it is not intended to provide a complete picture. However, even from this figure, we can see that we are surrounded by many mediating factors. And new factors

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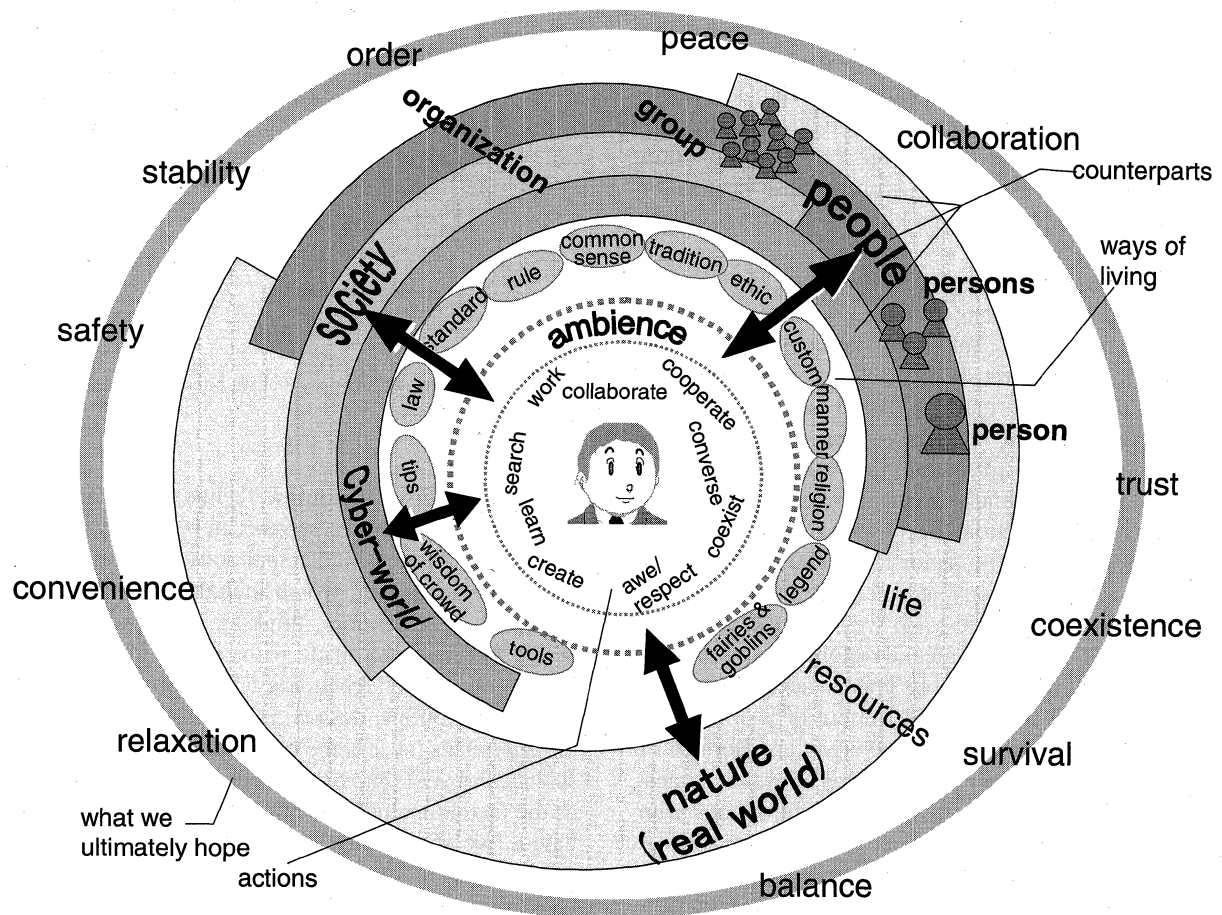


Fig. 2 Environmental factors.

will arise especially in the cyber-world. I hope this diagram will help provide us with a broad enough scope to take various factors into consideration when designing technology.

3. Considerations for the Future

What is truly important when developing a technology? I would like to mention several issues under the heading "Environment of Intellect." This expression implies that we need different kinds of intellect if we are to consider the future from an environmental viewpoint. The issues below are described from three perspectives: scope of vision, consciousness, and system design (Fig. 3).

3.1 Environmental Scope of Vision

(1) Macroscopic

We tend to develop technology in a rather simple and microscopic manner to realize target functions with the hope that they will work exactly as designed. However, there are complex and dynamic relationships between various factors. Unexpected events sometimes occur in unexpected ways in chain reactions. New technology may require the solution of non-technical problems. We need to embrace a macroscopic view of our environment, which is wide in space and long in

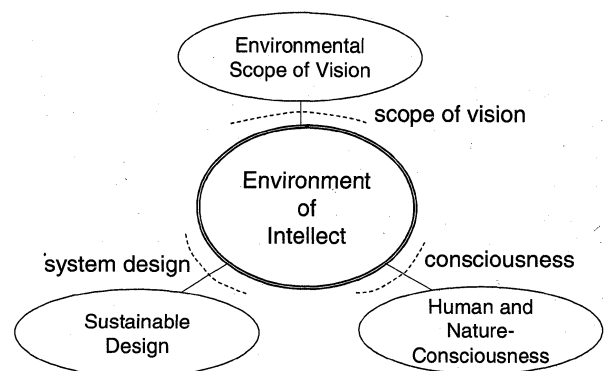


Fig. 3 Perspectives of environment of intellect.

time, as this will allow us to take many related factors into consideration.

For example, when designing a new intelligent car using a new type of energy, and with a sensor-based safety system supported by intelligent information sent to the car, the design scope cannot be limited simply to the car but must extend to road systems, which should be intelligent, and new energy supply systems for widespread use. We should also consider such factors as new road traffic laws, and new car-related facilities. In a sense, entire cities may need to be

redesigned. In fact, the growing demand for bio-fuel made from corn has triggered a worldwide increase in the price of corn for food. This increasing demand for corn has accelerated deforestation in Brazil to create cornfields, and this has led to an increase in CO₂. It is ironic that the production of bio-fuel designed to help the environment has resulted in increased CO₂. We clearly need a vision with global scope.

(2) Harmony in Balance, Range, and Diversity

We have learned many lessons from the environmental problems found in nature. We now know that balance must be maintained in every aspect of nature to avoid catastrophic changes and to keep the earth stable. Loads imposed on nature must be within its resiliency range. We need a diversity of living species to maintain the earth's ecosystem [2]. These conditions, namely balance, range, and diversity, must be kept in good harmony because they are interrelated and the deterioration of one factor has a detrimental effect on the others. This harmony is especially important in a world of large-scale dynamics, and we should keep this in mind with respect to technological development.

For example, in terms of our energy needs, if we depend solely on fossil fuel, we will run out of it in the near future and also accelerate the climate crisis. A shortage of fossil fuel could also trigger international economic chaos. We must have several different well balanced options with respect to energy resources such as solar power, nuclear power, wind power, and water power, to allow us to cope with any type of disaster. For this, we need to develop economically viable technology for its widespread use.

3.2 Human and Nature-Consciousness

The next perspective focuses on human beings and nature. We cannot live ignoring the fact that we are part of nature, which means that we must live in accordance with nature and natural laws. When designing technology, we should also note that we can consider ourselves both users and elements of the ecosystem. We hope that technology will work effectively by making good use of the features of human beings and nature through an essential understanding of them both.

(1) Human-consciousness

We should be more conscious of human beings in nature and the nature of human beings when designing technology. As the relationship between humans and technology includes complex issues of different dimensions, a layered human reference model is introduced here to classify the issues and clarify the essential factors to be considered (Fig. 4).

The biological layer comprises our metabolism, vitality, and reflexes, which we have in common with other creatures. In this layer, careful attention should be paid to prevent the technology from endangering human life or degrading organic functions. Too much assistance may spoil us. The physical layer encompasses the body, arms and legs, and various senses, through which humans interact physi-

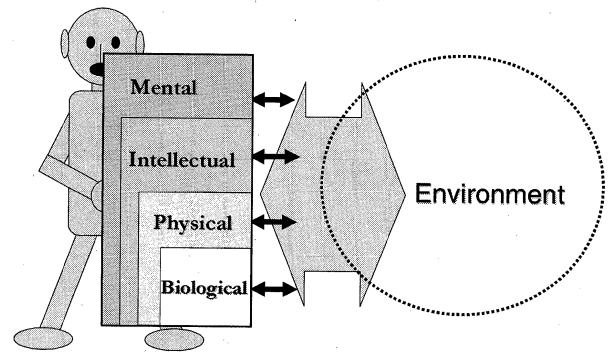


Fig. 4 Layered human reference model.

cally with their surroundings. Technology designed to assist physically handicapped people can be mainly considered in this layer. Various intellectual activities are considered in the intellectual layer, which includes the human ability to use languages, memory, thinking and wisdom. Considerable effort has been made with respect to this layer focusing on information technology. The mental layer comprises feelings, emotions, desires, and states of mind such as fear or relief. This layer is the most difficult to consider because science has yet to provide us with all the answers. However, as the factors included in this layer deeply affect human behavior, we should pay it much more attention. This layer relates to such issues as happiness, peace of mind, and satisfaction, which are important goals when designing future technology. I completely agree with the concept of gross national happiness (GNH), which is said to have been coined by King Jigme Singye Wangchuck of Bhutan in 1976, when he stated at the 5th Conference of the Non-Aligned Countries that "GNH is more important than GDP."

The model shown here is simply a reference for consideration, but it will help us to think about how we should cope with the environment based on the characteristics of related issues. We know that the relationship between human beings and the environment has been distorted by recently developed artifacts and ICT. We need to consider what can be done to alleviate the distortion in any given layer.

(2) Respect for Nature

Too many convenient functional tools blind us to essential solutions. Nowadays, we depend too much on computers even when a simpler solution might exist. We should consider what is really needed and find the appropriate technology. In this sense, it may be good to look back at solutions from less advanced times when there was no access to today's high technology and when people were more respectful of nature. Insightful and sensible ideas can be found in ancestral wisdom accumulated over generations. In some cases science has clarified the secrets behind this ancient wisdom, and we can make use of it based on science. However, there is still much that we cannot fully understand. In particular, we need to pay careful attention to complex systems in nature that involve many nonlinear factors [3]. In

past times, when people encountered an unfamiliar situation, they made full use of their senses and experience to determine how to proceed. In Japan, which was originally an agricultural society, people were sensitive to nature and this has clearly affected Japanese arts, technology and culture. A lot of ancient wisdom has been found in legends, customs, traditions, and religions, and has been handed down from generation to generation.

For example, those involved in agriculture may judge when to sow seed from the shape of the snow remaining on a nearby mountain, or from the arrival of a specific type of breeze. In Kyoto, a type of house design called 'machiya' has been adopted where cooling is provided by natural air ventilation without the need for an air conditioner. There is a river engineering method that reduces the power of a river flood by allowing some of the water to escape instead of trying to control the entire river. There is a famous method called 'shakkei' employed in Japanese garden design, by which the beauty of a garden is enhanced by its background landscape. In the martial arts found in eastern Asia, a fighter makes use of the opponent's power to knock him/her down taking advantage of the human conditioned response mechanism. There are many other examples that could be mentioned. The essence of the ideas common to these examples involves taking advantage of fundamental aspects of nature and natural principles, which leads to the realization of highly efficient solutions. Such episodes force us to think about the meaning of high technology. I think these kinds of wisdom can be found throughout the world, and they are worth examining before they vanish.

We tend to think that computers can make anything possible. However, there may be a more elegant solution that does not employ computers. There used to be a self-winding watch that was powered by human movement. However, today most watches require batteries. In the digital age, many types of media are processed on the same platform in the same manner, which may make us think less about the essential nature of the target task. We need to be careful.

3.3 Sustainable Design

We now depend heavily on technology in many aspects of our daily lives, and it is almost impossible to live without it. Certain systems, especially such lifeline infrastructures as electricity, public transportation, and telecommunications, are expected to continue working without breaking down. The system we need may mirror living things' tolerance for sustainability: fault tolerant, contextual, flexible and adaptable, and distributed and autonomous.

(1) Fault Tolerant

When designing any system, we need to assume various types of disturbance such as malfunctions, abnormal conditions, accidents, and sabotage. The systems must be designed to be fault tolerant in the face of such events.

For the system to be fault tolerant, we need in-built

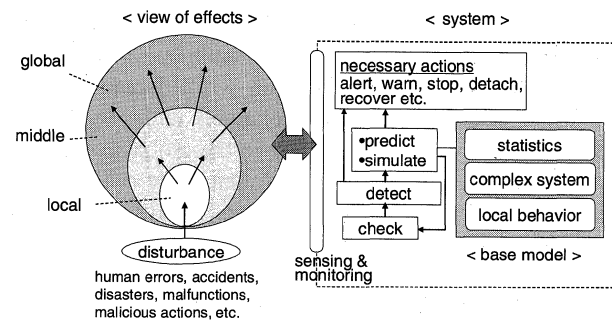


Fig. 5 Technology assessment for fault tolerance.

checks involving the sensing and monitoring of both inter- and intra-systems to allow us to determine the condition of the system and its surroundings as shown in Fig. 5. During that process, when an unusual phenomenon is detected that might induce an accident, action is needed to minimize the effect of the phenomenon. This action may include alerting the system operator, transmitting a warning, stopping the phenomenon from occurring, detaching components that are suspected to be faulty, and undertaking a repair. It is desirable to predict what will happen by using real-time simulations based on behavior models of the target field. The simulation requires a three-level (global, middle, and local) view of the effects of the system. When disturbances occur, such as those resulting from human errors, accidents, disasters, malfunctions, and malicious actions, their effects may be local, widespread, or global. In the simulation, local effects can be calculated based on a local behavior model. Global effects can be assessed with a statistical model, where the balance, range, and diversity mentioned in 3.1 can be checked. We must pay special attention to middle level effects that exhibit complex behavior caused by nonlinearity in related factors. This is described as a complex system and it is not easy to predict what will happen if the initial value changes slightly. In this case, we need to perform a large-scale simulation based on an appropriate complex system model. Complex systems can be found in many fields where there are complex interrelations between factors in the system. Even a small incident could have an unexpectedly large impact as the result of a chain reaction.

Recently, there have been some large-scale incidents in Japan. In the early morning of October 18, 2007, automatic ticket gates malfunctioned almost simultaneously at more than 700 train stations in the Tokyo metropolitan area, which inconvenienced millions of commuters. It was days before it was discovered that the accident had been caused by a program code with just a few incorrect characters. Shortly after the 'Niigataken Chuetsu-oki' earthquake occurred off the coast of Niigata prefecture on July 16, 2007, most of the major car manufacturers stopped production. This was because the earthquake damaged a small factory that produces certain specific car parts and supplies them to these major carmakers. It was pointed out at that time that major carmakers in Japan depended too much on one specific com-

pany. In this case, the inventory control method whereby stock is kept at a minimum, which manufacturers believe be an excellent management technique, worked against them.

The cause and effect were relatively understandable in both cases, but what is happening in the global economy is very complicated with many interrelated and dynamic factors. An economic crisis that originates in one country travels rapidly to other countries in today's net-connected world.

(2) Contextual

Everything has a context. There are various types of context including temporal, spatial, and semantic contexts. For example, for a given object, the temporal context is its history, the spatial context relates to its physical existence, and examples of its semantic context include why it is there, whose it is, or what it is. The context offers clues about how the object is processed.

From the viewpoint of system design, the system should continually keep track of the context by sensing and monitoring related factors so that when necessary it can make quick decisions about what to do and how to proceed. Context allows the system to provide efficient and appropriate processing, especially when there are many complex factors to deal with.

(3) Flexible and Adaptable

One of the main reasons behind the survival of living things on this planet is that they are flexible and adapt to their circumstances. Their organic systems are very well designed biologically, physically, perceptually, and cognitively. There are roughly three ways in which living things adapt to their circumstances; they adjust, develop, and evolve.

Adjustment is a mechanism whereby a living thing adapts itself rather quickly to fit the prevailing conditions with respect to its own flexibility and dynamic range. From an engineering point of view, an automatic control mechanism such as feedback can be used for such adaptation. For example, with the automatic gain control used in many electronic devices, the gain for the input is adjusted to maintain an appropriate output level by feeding back the average output.

Development is a mechanism whereby the capability of a system gradually improves when its loads are mostly heavier than its average capability. Training is a process for development. In signal or information processing, development is realized by machine learning in computers. However, there are no machines that can physically develop themselves.

Evolution is also an adapting mechanism but fundamental improvements occur over generations. With living things, changes in DNA patterns trigger evolution. In engineering, the evolution process is only possible in software.

It remains difficult for us to realize an adaptation mechanism by engineering, which mimics living things. We hope that bioengineering will make it possible to realize not only such adaptation but also self-organization.

(4) Distributed Intelligent Autonomous Systems

Distributed autonomous systems whose functions are not centralized are more tolerant, tough, and scalable than centralized systems. When a part of the system breaks, it can be replaced without the need to stop the entire system. It is also important that the knowledge used in a distributed autonomous system needs to be distributed for each node so that it can work independently of other nodes. As regards distributed knowledge, there is one type that is common to most distributed nodes and local knowledge that is unique to each node. The common knowledge includes, for example, the rules, standards, and information necessary for organizing the entire system. The local knowledge is needed if the local system is to work efficiently considering the local situation.

For the distributed systems to have autonomous intelligent functions as seen in nature or human beings, various kinds of intelligent knowledge are needed. However, knowledge is not usable until it has been explicitly described in some manner. We use a lot of knowledge in our daily lives that is not yet fully usable by computers, such as common sense, expert skills, and what we have learned solely from our experiences. Moreover, there are many examples of implicit knowledge or wisdom of this kind that are very useful but retained within a person, culture, or other unknown host. They must become explicit if they are to be exploited technologically. We should pay more attention to the 'wisdom of the crowd', where superior ideas can be found by aggregating the ideas of individuals [4]. There are phenomena found in animal behavior where the intelligent action of a group of animals is attributed to each individual. There are still many secrets in nature, for example simple behavior can generate complex and intelligent behavior that is seen as chaos, rhythm, and fluctuation. Discovering these secrets and utilizing them is a challenge for distributed autonomous systems because nature is an excellent autonomous intelligent distributed system.

4. Conclusion

I have described several issues from three different perspectives that we should consider by developing sustainable technology based on human beings and nature that incorporates a broader environmental view.

Today technology has a great impact on people, on society, and consequently on the future, and so I believe it is the duty of scientists and engineers to think deeply about the future. In terms of the "Environment of Intellect", I think that distributed autonomous system technology is the right direction to take.

References

- [1] A. Gore, *An Inconvenient Truth*, Bloomsbury Publishing PLC, 2006.
- [2] E.O. Wilson, *The diversity of life*, Harvard University Press, 1999.
- [3] R. Gallagher and T. Appenzeller eds., "Special issue on complex systems," *Science Magazine*, vol.284, no.5411, pp.79-109, April 1999.

- [4] J. Surowiecki, *The Wisdom Of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*, Doubleday, 2004.



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