

# Human-Product Communication

Shuichi Fukuda

**Abstract** Communication between humans and products is increasing its importance. The environments and situations change very frequently and extensively and engineers cannot foresee the operating conditions anymore. Only users on site can understand what are happening now. Thus, machines or products that communicate with the user and provide the necessary information for them to judge and to make adequate decisions are called for. Such communicating machines or products will also satisfy customers much more because they will learn through communication what the user is expecting and they can feed it back to the producer. Users' expectations vary from user to user because their lifestyles are different. This is why today's customer requirements are so diversified. To cope with today's diversified requirements, engineers have to know how the machine or the product is being used. Therefore, without such feedbacks, engineers cannot do anything. In other words, yesterday's engineering is an open-loop system, but today we have to change it to a closed-loop system. Therefore, communicating machines or products are now our necessity of life.

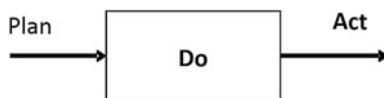
## 1 Introduction

It is pointed out in Chap. “[Age of Subjective Engineering](#)” that engineering is moving from the traditional objective way toward subjective and individual-oriented direction. And instead of the current way of satisfying today's customer wants, how we can satisfy customer expectations becomes more important. In other words, the traditional engineering is based on the past, but the engineering tomorrow should really look into the future and take into account what people expect from engineers and to consider how we can satisfy these expectations. These expectations are

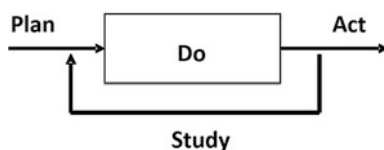
---

S. Fukuda (✉)

System Design and Management, Keio University, 4-4-1 Hiyoshi, Kohoku-ku,  
Yokohama 223-8526, Japan  
e-mail: shufukuda@gmail.com



**Fig. 1** Open loop system



**Fig. 2** Closed loop system

people's dreams and increasingly important role of engineering now is to make their dreams come true, rather than to meet their needs for today.

In fact, this is what engineering is for. Why humans are called *Homo Faber*? We make tools to realize our dreams. Engineering started to make our dreams come true. But with the progress of technology, we are stuck with the technological tools and we forgot this starting point and we are now focusing our attention to produce better products, forgetting why we developed such technologies. This will be discussed from another viewpoint in Chap. "[Human Centered Industry](#)".

But to understand what a customer is dreaming about is very difficult. Our traditional engineering is one way, from producer to user and it is an open-loop system (Fig. 1). Producers have their models of production and their models are fixed. What producers are paying attention to is to how effectively they can work on this model.

In order to understand the dreams of customers, producers have to understand what a customer is thinking and how he or she is living. Producers need continuous feedback from their customers. Thus, engineering tomorrow will be a closed-loop system and how we can get feedback from our customers become crucially important (Fig. 2).

To achieve this goal, a product has to sense what a user is expecting and how he or she is using it. To sense appropriately, a product has to communicate with a user all the time. Communication is not only important for producers, but also for users, too. As situations change very frequently and extensively, users have to make an adequate judgment all the time. To do it, they need adequate information. Products that can communicate with users can provide such information necessary for users.

This chapter describes the importance of communication and how products and users can communicate will be discussed.

## **2 The Importance of Human Role in System Operations: Lessons Learned from United Airlines Flight 232**

The more technology advanced, the more complex and complicated mechanical products became and it sometimes went beyond the human capabilities to operate them. Therefore, engineers moved toward automating the entire system and eliminate the unpredictable and unreliable humans as much as possible. Thus, when they considered humans in their designs, it is nothing other than the mechanical elements because their roles are only to perform as they expect.

The famous accident of United Airlines Flight 232 in 1989 reminds us, however, how important human role is in operating a system and how wise humans can be in making a decision when some unexpected events happen.

This plane suffered engine failures when flying over Iowa and in spite of the loss of flight control, the crew managed to control the remaining, but failing engines and succeeded to land the plane, although 111 died out of 296 on board.

This accident is well known as a very successful example of crew resource management [1]. The captain Alfred C. Haynes told later that he and his crew were really upset when they found out almost all engines went out. But the crew regained their composure because the air traffic controller responded in a very unperturbed and composed manner. Then, he realized that they were not flying over the mountains, but they were flying over the flatland of Iowa. Runways were everywhere. He thought he could find some ways to bring the plane back to the ground. This shows how emotion is important in making decisions when some critical events happen.

What this accident teaches us is the following. Designers cannot foresee or cannot take every precaution against accidents. They have to leave the final decision to humans when something unexpected happens. Thus, they have to design a system that leaves ample allowance for such human interventions.

What Haynes and his crew did was not taught or not trained. But they managed to control the engines independently and brought the plane back on the ground. Such operational management was possible because the plane was DC-10 and was not so complicated and complex as the ones today. The engines could be managed independently. Thus, there were still ample allowances where humans could intervene, although engineers did not design that way intentionally. We have to learn that making things complex or advancing technology far ahead does not necessarily solve the solution. Sometimes, simplicity provides the key to success. In this sense, we have to look back into the future. It is interesting to note that Boeing is designing their planes today with allowance to human interventions or to human decision making.

### 3 Machines That Will Listen

This accident reminds us of the importance of the machines that listen, listen to the operators or the users on site. No matter how smart designers or engineers may be, they cannot foresee all the situations and they cannot prepare countermeasures for all events.

What engineers have been doing up to now is how we can develop machines that will speak. Our technology up to now is focused on speaking. Especially mechanical engineers have been trying to build up the world of the artificial. If workers do not work as they expect, mechanical engineers introduced robots to replace them. And if the room humidity affects welding, they introduced air conditioning in a factory. Mechanical products are artificial and mechanical engineers have been trying to keep their operating conditions as artificial as possible. What mechanical engineers have on their minds is how they can achieve the highest quality. They often forget that we are living in nature, and their mechanical products are operated by humans. Humans do not act as they are told. They would like to do everything their way. And nature is unpredictable.

Interestingly enough, although it is called by the same name of engineering, civil engineers work in a very different manner. Most of their structures are very few in number or only one. And these structures are built and used in nature. Further, they cannot be produced and assembled in a factory. Components may be produced in factories, but final structures have to be assembled on site, in a complete natural world.

Thus, civil engineers do not simply pursue the highest level as mechanical engineers, but rather they try to secure the acceptable bottom level, because many unpredictable events happen when the structure is being constructed on site in natural environment. Of course, they also pursue to achieve the highest, but they know sometimes they have to compromise. Thus, civil engineers' model is adaptive, while mechanical engineers' is fixed.

Stewart Brand, known for his words, "Stay Hungry and Stay Foolish" and as the editor of the Whole Earth Catalog [2], published an interesting book "How Buildings Learn" [3]. Brand points out that structures designed by smart architects do not live long, but those which were designed by less smart ones do live long, because these building *learn* how to adapt to the changes. In other words, buildings that only speak do not live long, while buildings that listen to the changes live much and much longer.

Mechanical engineers have been too smart and have been trying to make the world as artificial as much as possible, but we are living in a natural world. We have to learn how to adapt to the changes in order to survive. Mechanical engineers' approach has been successful up to now because our lifestyles were not so much different from person to person and besides the areas we were living in were very much limited and small. So the changes were very small and slow. But with the rapid progress of technology, our world is expanding very quickly and our lifestyles are diversifying extensively. Further, there are frequent and extensive changes

in situations and in environments. So their traditional approach of making things artificial and uniform does not work anymore.

In other words, machines that only speak are no more effective. Mechanical engineers have to change their way of thinking from speaking to listening. They have to listen to what the human users are thinking or what decisions they are making to cope with these changes. In fact, only users know what is happening now. Therefore, mechanical engineers have to quit designing smart machines. Instead, they have to make machines more adaptable to the situations, just as Brand pointed out with respect to buildings.

## **4 Listen for the Next Action**

Why do machines have to listen? It is not to listen to orders or instructions, but to make the next action more appropriate. Machines have to communicate with the users to help them come up with better decisions. Traditional machines worked in the open-loop environment. In an open-loop system, machines did not listen.

But to cope with the frequent and extensive situational changes, machines have to work in a closed loop environment. They need to interact with humans and with the outer world to cope with the changes.

## **5 Communicating Machines**

To put this in another way, this is to attach capabilities of communication to machines and to add the memory functions. The current design of machines is based on speaking technology. Machines work in the same way, no matter how the situations change. Reproducibility has been regarded most important in machine design. If machines work the same way, no matter how the situations may change, its functions were thought to be robust. Robustness is the ability of a system to resist change without adapting its initial stable configuration. This philosophy is very much hardware oriented. In fact, robust originated from the Latin word “robustus,” which means “strength, hard timber or oak.” But if the wind blows very hard, oak trees fall, but willows will survive. This is because willows communicate with the wind and adapt to its changes.

Thus, communication becomes increasingly important in the age of frequent, extensive, and great changes. To design a machine that will resist all these changes is extremely difficult and will cost very much, even if it may be possible. But if we note how willows survive the strong winds, we will realize it is much better and far easier to change our goal from developing a robust machine to designing a machine that is flexible enough to adapt to the changes.

## 6 Soft Materials

Such changes from oak tree robustness to willow adaptation can be observed elsewhere. Haptics is now getting wide attention and is being applied extensively. This is because the number of soft materials is quickly increasing. In robotics, tele-grasping cannot be discussed without haptics, because the target object is getting softer and softer and the traditional method using vision alone does not work anymore.

Up to now, we could identify what the target is by vision alone, because the target material is hard and does not deform when we grasp it at a distance. But when the target material becomes soft, it changes its shape when we grasp. Thus, vision alone does not work and we have to study what it is by touching and by observing how it changes its shape. Thus, we have to communicate to identify.

## 7 Changing Constraints

This change of material attributes calls for the change in our design of mechanical products. Up to now, they were designed based on a speaking technology basis. i.e., Designers have their models and the machines were operated based on this fixed model. And users or operators were supposed to do what machines (designers) expect them to do.

In these days, materials themselves were hard. So most of the constraints were hard at the time of design and it remains the same during operations. Thus hard constraints remained hard all the way throughout its product lifecycle. And designers preferred to introduce hard constraints as much as possible because it is far easier to design machines that way.

But the frequent and extensive situational changes and diversifying environments has made such an approach ineffective. Machines have to adapt to the changes immediately. So instead of designing on a fixed model, we have to introduce an adaptive model approach. To be adaptive, we have to communicate and learn what is happening now.

As the materials are changing from hard to soft, the machine parts have to communicate with each other. When the materials are hard, they fit in because each part wears away (this is another communication). But if the materials are soft, communication mechanisms must be taken in from the first. Otherwise, parts cannot work together well.

## 8 From Fixed Model to Adaptive Model

In the days of a fixed model, emotion was considered to be noise. It fluctuates and cannot be controlled easily. It gets in the way to build up a fixed model. Thus, emotion was thrown out of consideration. And decisions were not important

because once the model is fixed, any more decisions are not needed. So decision is one time and early decisions were encouraged.

But to be adaptive, what becomes most important is to judge what is happening now and to make a right decision for the next step. We have to make decisions for every step forward. So decision making becomes multi-step and each decision making becomes critically important. Therefore, consideration about humans, especially about their decision-making, becomes increasingly important in mechanical design.

## **9 Emotion Prioritizes Jobs**

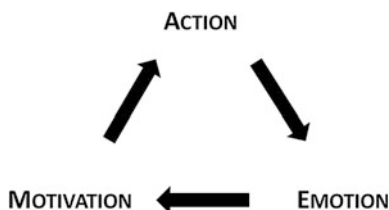
Emotion may be considered as a gift from heaven to us to adapt to the changes in order to survive. In fact, some brain psychologists reveal that anger, for example, restricts our brain activities to concentrate on a particular action. This is the same as we do in computer programming, known as an “interrupt”. By interrupting, computers can prioritize their jobs and do the job with highest priority first. Therefore, emotion may be regarded as a tool to recognize an event that needs immediate attention and prioritize our actions. So it plays a very important role in our decision making.

## **10 Memory**

To recognize such an event that needs immediate attention, memory plays a very important role. As mechanical products used to be made of hardware alone, it was not easy to memorize the past events, although hardware can memorize, too. But their capabilities are very much limited. But now majority of mechanical products are combination of hardware and software. Or in some cases, software occupies the major portion of the product. Thus, it is no more difficult to remember what has happened in the past. Further, software enables mechanical products to learn from other cases. They can memorize these cases and when something unexpected happens, machines can communicate with the user and help them to come up with the best decision.

What designers have to do now is not to foresee the operating conditions as they did in the past, but to provide machines with communication capabilities to provide such memorizing functions.

Currently, designers are trying to respond to the quickly diversifying users' requirements by widening a variety of products as much as possible. But this does not make any sense, because what is diversifying is the operating or use conditions. So designers should focus their attention on the issues of operations. To cope truly with diversification is how we can make our mechanical products work best in



**Fig. 3** Motivation-action-emotion cycle

diverse working conditions. This is not a one time delivery problem. This is not the problem in space, but the problem in time.

To cope with such problems of operations or uses, engineers have to understand emotional aspects of their users. Emotion is not just a feeling. It is an important factor in decision making. Emotion originates from the Latin word “*movere*” and motivation or motive comes from the same Latin word “*movere*”. Thus, motivation-action-emotion constitutes a cycle as shown in Fig. 3.

In old days when changes were small, we did not have to consider such reflective cycle, because once the model is finalized, it goes all the way to the end. But today, in order to respond to rapid changes, we have to repeat this cycle all through the operations. Software serves a great deal for practicing such a reflective approach.

## 11 Experience

Experience and memories are closely related. But experience contains not only knowledge, but also skills and it goes with involvement in the event. Memories, on the other hand, do not necessary call for direct involvement in the event.

It is interesting to note that experience comes from the Latin word *experiential*, which means trial. So it means to try and to learn. In this sense, it is nothing other than experiment. Thus, experience is also very much associated with decision making. We make decisions and experience what follows. Thus, we learn from experience.

Software added mechanical products can learn from experience. They can memorize what actions they took and what results followed. Thus, they can adapt to the current situation and work better. In the traditional mechanical design, which is primarily based on mechanics, the interaction means if you push the wall, the same force comes back from it. In other words, it meant nothing other than a physical law (Fig. 4). But interaction here means communication. Feedbacks vary from case to case (Fig. 5).

**Fig. 4** Action-reaction**Fig. 5** Communication

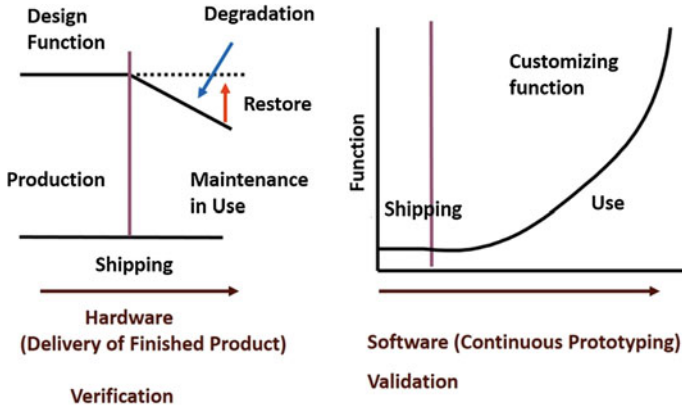
## 12 Hardware and Software

### 12.1 System Development

As hardware products cannot change its attributes, once they are developed (this situation is quickly changing as describe in Chap. “[Age of Subjective Engineering](#)”, hardware is developed with fixed functions.

Software used to be developed in the same way. But we soon realized that software and hardware are completely different. So software introduced the development style called continuous prototyping (Fig. 6).

Software developers provide the basic functions first and as users get used to the system, get confident and calls for higher functions, they provide little higher functions. Thus, functions grow with time and software systems are customized.



**Fig. 6** Hardware and software developments

The growing curve is nothing other than a learning curve and it is more appropriate to call the curve an adapting curve. It not only grows on the same track, but it adapts to the changes and to the situations as the version goes up. As we learn more, we become more confident. So, continuous prototyping serves for increasing users' confidence. And when we are confident, we put trust in the system. Thus, continuous prototyping works both ways, to increase users' confidence and to increase trust in the product.

## ***12.2 Their Benefits: Utilize Them Properly as Needed***

The addition of software to mechanical products is more than just adding flexibility. What is more important is it adds the capability of learning and increases adaptability. Since situations cannot be foreseen any more due to their frequent and extensive changes, it is important is to have enough adaptability to cope with the unexpected events.

If the machines can share their experience with the user, the user can make better decisions. Even if the user may be using the machine for a long time, he or she may not be able to recall what happened in the past and may not be looking into the appropriate search space. Software reinforced mechanical products can help the user to look at the problem in the right perspective and to search for a better solution in the right search space. Thus, emotional communication between machines and humans is increasing its importance very rapidly.

### ***12.3 Hardware Is Tangible***

We have to be aware that hardware is physical and software is nonphysical. So hardware deteriorates and has end of life, but software does not. Software may be outdated, but it never deteriorates and does not have a physical end of life, although their service life may expire. And what is more important is hardware is tangible.

Touching is a real-time communication. So it is directly related to experience. And it is a direct means of human-product communication we have had for a long time in history, before software was invented. Thus, as touching is direct communication with the outer world or with the physical world, it facilitates us to memorize experiences.

As described later, the fact that excellent mirror finishing of the outer case of Apple iPod drove many people to select Apple among many choices demonstrates, people feel attached to the product, if it holds good in their hands. Direct communication provides the endowment effect in behavioral economics.

### ***12.4 Change and Motion: The Essence of This World***

Most of us are obsessed with the idea that mechanical products are machines, i.e., they move. Although such products as bottles, cans, clothes, etc. are not called mechanical products, they are mechanical, in the sense that mechanics play an important role in these products.

For example, to drink from a bottle, we have to grasp it and carry it to our mouth. This involves motion. And if it is a can and it has a tab on top, we have to design how a tab can be easily pulled out. This is mechanics. And how well we feel when we wear clothes is also another problem of mechanics. Thus, all physical products are more or less mechanical in this sense. And even static products, even a still picture is also mechanical, because Stark [4] clarified that our eyes are moving very quickly around the boundaries of an object to identify what it is, although in the conventional image processing edge detection does not relate to mechanics and from outsiders, our eyes are focused on the object. Thus, it is no exaggeration to say that all things on earth are related to mechanics or it would be better to say they involve motion and change. We have to remember the words of Johann Wolfgang von Goethe “All things are only transitory” and what German physicist, physician and philosopher Hermann von Helmholtz pointed out in his speech “The Fact of Perception” [5].

### ***12.5 Motion and Emotion***

As pointed out earlier, emotion is related with motivation and with motion or action. It is of fundamental importance to recognize that motions are involved even

in our daily things. Mechanical design is not only designing machines, but it also includes these daily things. Again, motion and change characterizes mechanical design.

We drink from a bottle or open a can in astonishingly diverse ways. Some would like to drink in one gulp. Others would like to drink sip by sip. These differences are deeply associated with emotion. If you are very thirsty (motivation), then you would drink in one gulp, although usually you may drink little by little. Then, you would feel very happy. The bottle is the same, but its effect is very much different.

Thus, the value of a bottle varies by what motivates you to drink and by how you drink. Thus, we should note that products are not evaluated at the time of delivery, but how it is used affects product value. Engineers have been discussing hardware product value at the time of delivery. How good final product qualities are their main concern. But users evaluate our product when they use.

Before diversification comes on top of everyone's mouth, our products, especially daily products, are used in a wide variety of ways. We should focus more on operations. Such uses of daily goods are not called operations, but the essence is the same. There is no difference between a commercial airliner and our daily goods. Users are humans and humans act as they like. We have to keep a close watch on operations and we would find out how much emotion is associated with and we have to characterize them to design products best fit for our customers.

## ***12.6 Tangibility and Emotion***

What differentiates hardware from software is tangibility. As product materials are getting softer and softer, haptics is increasing its importance. We cannot predict how the product will behave until we touch it, if the material is soft. But what is more important from the standpoint of emotional engineering is once we touch something, we have a feeling something like attachment. This effect is very much associated with the effect called the endowment effect in behavioral economics. iPod is a good example. Although many other companies provided the same kind of products with almost equal quality of functions, customers preferred iPod. It is well known that the touching feeling played a very important role. When the customers take up iPod and hold it, they feel it fits into their hand perfectly. Other companies thought a case is a case and if it can accommodate the parts and can be held, then it is OK. Apple thought in a different way. If a customer holds it and feels that it perfectly fits into his or her hand, then he or she feels it is his or her product. iPod introduced titanium for a case and although titanium is difficult to grind, Japanese small companies succeeded to finish it like mirror. This served to generate a feeling on the part of a customer that it is his or her product when he or she holds it.

Touching is of course motion, but engineers did not realize until then that touching constitutes a great portion of product value and such factors have not been counted in as functions. This may not be technical functions, but this is certainly an important factor in product value.

Touching enables real time communication with the outer world, while other senses cannot. Thus, a good feeling of touch implies that we can communicate with the product directly in real time. The feeling that we can communicate better with the product enhances product value. This is nothing other than emotional value.

Thus, touching is more often than not more important than vision or sound, because customers can directly communicate with the product. Thus, touching is very important for marketing.

In the same sense, touching is important in other products such as clothes. If we feel that they fit us well, then we will evaluate them very highly. This is because we can communicate with the product better. We have to remember that communication between products and users start after products are put into use.

## 13 User Experience

User Experience (UX) is getting wide attention these days. But most of them do not discuss the issue of operations or use. Experience is gained through interaction or it would be better to call it communication between the product and the user. So it is the problem of how a user uses a product. But UX is discussed more loosely and such research focusing on the issue of operations which vary from person to person is not explored yet, or if there are any, very few.

If we can successfully categorize them in terms of the motivation-action-emotion cycle, then, we could drastically reduce the number of variety of products and we could design and produce mechanical products (in the broad sense as discussed above) which would fit our customers far better and give them the highest satisfaction.

## 14 Fulfillment

Customer satisfaction and diversification are hot words today. But when products were difficult to get, people are satisfied if the products they want are produced and delivered. But today what our customers want is mental fulfillment, rather than simple satisfaction that they receive the product. Satisfaction conveys an impression of one time event. But fulfillment is more associated with time.

As discussed in Chap. “[Age of Subjective Engineering](#)”, *Expectation Satisfaction* is an issue over time and it is different from one time satisfaction. And feeling of fulfillment is associated with *Expectation Satisfaction*. The current customer satisfaction considers only short term one, while fulfillment is long term.

Customers’ expectations are fulfilled when our products serve them as they expect or as they wish. Thus, fulfillment is more related with the issue of operations or use. UX is getting wide attention because it is considered to add value to

products. But to really evaluate how UX adds value, we have to study how customers' expectations are fulfilled. This is a very important and challenging issue of emotional engineering.

## 15 Room for Growth

To express it in other words, what Brand pointed out is that the buildings which had ample room for growth lived long. And buildings, which had little room for growth, did not, although they are designed in a very smart and sophisticated way.

As discussed in Chap. “[Age of Subjective Engineering](#)”, *Item Response Theory* (IRT), or *Latent Trait Theory* is getting wide attention these days. Traditional evaluations in *Classical Test Theory*, achievements were evaluated objectively based on scores. But IRT pays attention to latent trait or room for growth. If the examinee grows to the maximum range of his or her room for growth, his or her achievement is 100 %, no matter the reached level of growth might be lower than those of others.

Thus, the examinee obtains the feeling of accomplishment or the feeling of fulfillment because he or she can extend his or her ability to the maximum. The higher level in the range he or she can grow up to, the happier he or she feels and is filled with satisfaction that he or she can meet his or her expectation or he or she can overcome the challenge.

This satisfaction is very much subjective and individual. It depends largely on to what level he or she sets his or her goal and how much room for growth he or she has. The feeling of accomplishment or fulfillment is nothing to do with the achievements of others. It solely depends on how much extent he or she can achieve in comparison with his or her capabilities or room for growth.

## 16 Age of Judgment

Although importance of decision making has been emphasized in the above, we have to remember that decision is made after judgment and judgment is more important than decision making in the age of big changes, because right decisions can be made if the right choices are presented.

In the traditional mechanical design, designers presented choices so users had no other choice but to make decisions based on them. But the frequent and extensive situational changes invalidate these pre-arranged choices. Users have to find out what choices are available by judging the situations.

Communicating products are called for to help users to find out the appropriate options. Thus, if users can find appropriate options and can make an appropriate decision, then they feel happy, because they know their judgments and decisions are adequate and their sense of achievements is fulfilled. The word “satisfaction”

hints that the producer's action affects the customer's feeling, while the word "fulfillment" is more associated with the customer's judgments and actions.

If we consider the origin of the word "emotion", fulfillment or the feeling of accomplishment would be better to describe the happiness of the user. Thus, good communicating products will facilitate better judgment, thereby bringing the good results and the feeling of accomplishment. Such emotional value will increase its importance as the situational changes will be more frequent and more extensive.

## References

1. <http://www.crewresourcemanagement.net>
2. [http://en.wikipedia.org/wiki/Whole\\_Earth\\_Catalog](http://en.wikipedia.org/wiki/Whole_Earth_Catalog)
3. Brand S (1995) How buildings learn: what happens after they're built. Penguin Books, New York
4. [http://en.wikipedia.org/wiki/Lawrence\\_Stark](http://en.wikipedia.org/wiki/Lawrence_Stark)
5. Helmholtz H (author), Kahl R (editor) (1971) Selected writings of Hermann von Helmholtz. Wesleyan, Indiana (translated from German)

Emotional Engineering (Vol. 3)

Fukuda, S. (Ed.)

2015, VII, 116 p. 64 illus., 45 illus. in color., Hardcover

ISBN: 978-3-319-11554-2