Home applications of Kansei engineering in Japan: An overview

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M. Nagamachi. Home applications of Kansei engineering in Japan: An overview. Gerontechnology 2016;15(4):209-215; doi:10.4017/gt.2016.15.4.005.00 Nagamachi founded kansei engineering in the 1970's, which aimed at a Human-Centered Approach especially as to human emotion, in product design and development, services, and work improvement. Since then, he has developed over 60 kinds of product, generally in response to assignments from client companies. Among them, as part of product development, he has produced many home furniture and systems for promoting healthy home living, among which handrail, door knob, room design, bath tub, toilet, kitchen, and mattress. Artificial intelligence has been applied to some of these. Here, kansei products related to home living systems are described, but these are not aimed at integrating into a complete ergonomics and kansei engineering unit house. The present article describes ergonomics and kansei engineering applied to human home living, including artificial intelligent applications.

Keywords: ergonomics, kansei engineering, healthy living, artificial intelligence

This paper reviews a number of kansei applications in the Japanese home assembled over the years. It describes kansei as a specific kind of ergonomics concentrating on human emotions.

Ergonomics and kansei engineering

Ergonomics aims at realizing good relations between human users and technical systems. An ergonomist endeavors to reach this goal by improvement of the system from the viewpoint of the human body and mind system[1,2]. Kansei engineering was born as a child of ergonomics and it concentrates on the human side much more than ergonomics. Especially it is based on human emotion (kansei) in the relation between human user and technical system and realizes the best of man-machine relation. Thus, kansei engineering is applicable to work improvement and product development as well as to social innovation[3,4].

Kansei engineering is human-centered and tries to optimize human emotions like want, need, comfort, relax, ease of use, beauty, attraction, and good taste. These are called 'kansei'. It looks for the most effective emotion in the situation and the context factor is analyzed from the viewpoint of good relations between human life and living circumstances to find the most comfortable design items. As humans want to have the best home life, there are a lot of applicable situations leading to a comfortable home life for the older people in society.

Home applications

Ergonomics of staircase and handrail

Three decades ago, Japanese houses did not always have a staircase, because the houses are smaller in general. But as the number of senior citizen increases, staircases are needed more often for access to the second floor. Earlier, the Japanese Ministry of Construction recommended a handrail diameter of 40mm. Nagamachi et al.[5] measured palm sizes of 80 people over 65 years old and found that the old females' palm width is relatively small such that they cannot grasp strongly a 40mm handrail in case of falling down. However, when heavy male people happen to fall down, a small-width handrail could break down and they would feel anxious for that. We conducted an experiment concerning what size is most comfortable and easy to grasp without anxiety for old women and men. We arranged several sizes of diameter of handrail every 2,5mm from 32.5 to 45mm and tested eighty old people. 70% of subjects reported that the diameter 35 mm was the most comfortable handrail. Smaller diameters felt as unsafe and scaring as breaking in case of falling down. On the other hand, the bigger ones were reported as 'thick and uncomfortable'[5].

Thus we decided the handrail diameter should be ø35mm, but this size would be unsafe for heavy male persons. After many strength trials of wooden handrail with male subjects, we finally found the strong round plywood made of three layers of wood. Thus we could make the very strong and small diameter handrail depicted in *Figure 1*.

In general, a Japanese small house has a narrow staircase. We tried to create a handrail setting to keep the staircase as wide as possible within the narrow width. After measuring old subjects' palm thickness, we created the small curved support (*Figure 1*). The ø35mm handrail and the small wall support became the Japanese stand-

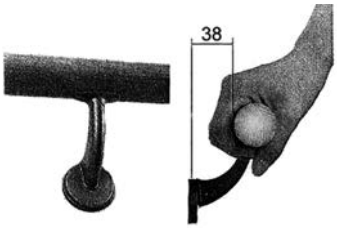

Figure 1. Diameter 35mm hand grip polywood made of three wood plates and the new support

ard. In addition, we measured the ElectroMyoGram (EMG) of legs for old people when going down and up the stairs. The EMG appeared decreased by 40% with handrail as compared to without handrail. So, the new staircase is very useful for safety and for reduction of leg energy when using stairs by old people.

Vertical vs sloped handrail

In Japan when entering a home, one steps up from the floor on a low step after taking off shoes. When going outside, one sits down on the step to put on shoes and then tries to stand up. This action is very hard for old people. It happens similarly when standing up from other situations. We conducted experiments to find out how close a vertical handrail should be positioned to the edge of the step and to compare the effectiveness of vertical versus sloped handrails. We set the vertical handrails just close to the step (*Figure 2*) and then every 10cm from the step to 60 cm. We measured EMG for 3 points of muscles.

The results showed that the vertical handrail is most effective to assist the standing up movement when set at about 30cm distance from the edge of step. The reason is supposedly that the center of body gravity moves forward when standing up by grasping.

Figure 2. The scene of a vertical handrail just at the edge of step

Another experiment comparing vertical and sloped handrails showed the sloped handrail even better than the vertical one. A 60º sloped handrail turned out the best one for standing up. The sloped handrail can also be used for bathtub, bedside, seat and others. We recommend 45°~60°slope depending on the situation[6].

A new toilet seat.

The sloped handrail is more useful for a toilet as well. But we considerd a comfortable toilet seat both for actual use and for standing up. Several factories are making a toilet with a mechanical assist for pushing up toilet seat, but this system costs too much, about 5,000 US$. The high price is also kansei (an emotion), and so we aimed at developing a new cheap toilet seat for older people with an assisting standing up movement. The new toilet needs to apply ergonomic principles.

We collected 7 different available toilets and asked 4 male and 4 female students to assess their feelings on sitting on these. The survey consisted of 5-scaled kansei words like 'comfortable', 'easy to use', 'easy to standing-up', 'joyful', and so forth. Also, we analyzed the various dimensions of toilets like size, width, shape feature, and height. The emotional data and toilet dimensions were analyzed by factor analysis, factor positioning analysis and Partial Least Squares (PLS) analysis. The PLS results showed us the properties for good design specifications.

First, we thought of two armrests to assist the old person's standing-up. And secondly, we designed a new curved toilet seat using the PLS data. The new toilet seat is tilted 3 degrees forward, slopes down under the thigh, and is wider under the hip (*Figure 3*). A new group of old subjects said the new toilet was very comfortable, and they even wished to sit longer on it; also it turned out very easy to stand up using two armrests, as compared with other market toilets. We measured EMG of these subjects' legs and obtained 90% decrement in EMG compared with other toilets. In this case, kansei 'comfortable for sitting' and 'easy standing-up' resulted in the much improved design[4]. A pressure test showed a much more even pressure distribution. Panasonic Electric works is now selling the newly designed toilet with the name of 'TRES'.

The sitting shower

When frail old people take a bath in a nursing home, a hanging robot catches him or her, moves over the bathtub, and deposits him or her into the bathtub. The reason is that it will be unsafe to carry the old person by caregiver's

Figure 3. The new toilet named TRES

hands. This robot carrying system is very expensive, about US$ 20,000. Older persons feel very scared for being carried by such a robot machine. We decided to develop a new instrument that is more friendly to old people. We created a facility with two arms that sticks to the wall (*Figure 4*). A caregiver takes an old client by wheelchair to a bath room and puts the wheelchair to the wall under two arms. The caregiver then pushes a button and the two arms come down, followed by warm water coming out through many small holes (valves) of both arms to make the client's body hot. Next, body soap comes out automatically and the caregiver washes the client's body. Then, warm water comes out again to rinse the client's body. Finally warm air comes out to dry the client's body. So we took off the old people's emotional scaring feeling about the robot and made a more friendly solution. The new shower was named 'The Shower' [4].

Figure 4. The shower

We confirmed that there is no difference in body temperature between using the bathtub and 'The Shower'. This instrument is now very popular in Japan[4] and it is produced by Panasonic Electric Works[6].

A comfortable mattress preventing pressure ulcer

For 50 years, Nagamachi has been involved in research on an ergonomic coil bed which supports human 's sleep. He surveyed sleep Electro-EncephaloGrams (EEG) for 8 hours a night and created a very comfortable bed based on EEG analysis and ergonomic evaluation. Based on this research, the Dream Bed Co. (Hiroshima) is making an excellent bed which is very popular in hotels and private homes. In addition, he started to create a mattress preventing pressure ulcer, because Japan has been the oldest society for a long time and has the big problem of increasing pressure ulcers in clients at hospitals and health care facilities.

He investigated a lot of mattresses utilized at hospitals and found that pressure ulcers were generated by malfunction of mattresses. He started his survey from the viewpoint of ergonomics to find out what function of mattress is able to prevent pressure ulcers to occur and found out that the new material 'Breathair' made by Toyobo will be the best material for this. The material 'Breathair' is shown in *Figure 5* and it is made of polyester fibers that are connected to make a spring function. Each fiber has a hole like a pipe and it is named 'Breathair' because it pushes out air when compressed by a body[4].

He investigated about 80 breathairs with different width and different pipe size and found that special types of breath air materials are the best ones for mattresses.

Thirty university students with 40 to 108 kg body weight joined the kansei engineering experiments using a 5-point scale consisting of the kansei 'comfortable', 'sleep well', 'easy to move on', 'not sink', 'soft-hard', and 'feel well', and they evaluated those kansei (emotions) on 80 test mattresses. At the same time, we measured body pressure for each subject, and we obtained the highest and average pressures in Hg-mm units for each subject on each mattress. From these data we selected best single, two-fold and three-fold combinations. At the same time, we selected 12 different popular mattresses from the market and took the same test. So we obtained a data table of 12 market mattress, in addition to three breathair mattresses.

We applied factor analysis and positioning analysis to this data and obtained *Figure 6*. Af-

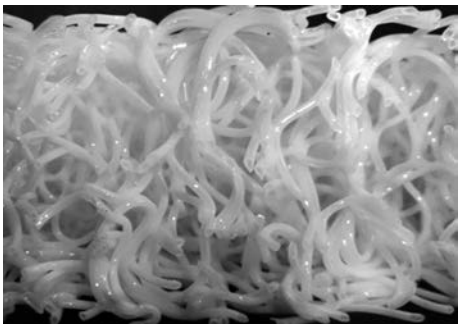

Figure 5. The spring structure of Breathair material

ter calculating factor analysis on kansei words like 'comfortable', 'sleep well', 'easy turning' and so forth, we analyzed by Principal Component Analysis (PCA) 12 popular mattresses from the market plus new three mattresses constructed by Breathair material. The vertical line means softness of mattresses and center of the line means around 32mmHg, which the pressure ulcer international association recommends on pressure. Mattresses above central point on the vertical axis are soft and those below are hard. The central area means fit to the recommendation for prevention of pressure ulcer. The horizontal axes means kansei factors, in which mattresses on the right side of the line mean 'fit to kansei' of 'sleep well' (good sleeping) and so on, but those on the left side mean the opposite kansei, e.g, 'not sleep well' and so on. The arrows indicate kansei directions. Three clusters can be recognized[7].

Cluster I (7 mattresses) are above the center position, which means that those mattress soft and some are satisfied on the pressure test. Cluster II (5 mattresses) are below the central position, which means those are hard mattresses not fit for use. The third cluster right of the center are the three new mattresses which satisfy the association's medical recommendation of 32 mm Hg.

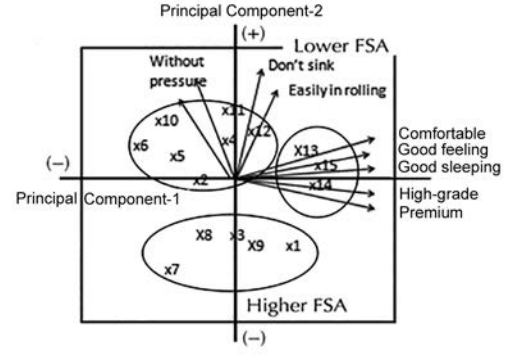

Figure 6. Principal Component Analysis chart for vectors 1 and 2; Codes x1 to x15 indicate the different mattresses tested; FSA=Factor Satisfaction

As we obtained good result of PCA, we imaged from an emotional concept 'sleep well' whether blood on the back streams smoothly or not on the new mattress. We verified the smooth blood stream on the back at each time of 'turning' measured by the blood stream tester.

We donated 10 new mattresses each to 4 national hospitals and asked medical doctors to watch the process of pressure ulcer clients. They reported us that all clients at the hospitals recovered from pressure ulcer completely, after a period from one week through 6 months[7].

AI for kansei kitchen design

We applied an Artificial Intelligent (AI) System to the kansei design kitchen system and started with a survey of people's kitchen styles. We collected 10,000 kitchen designs and classified these designs using cluster analysis. Next, we constructed a 5-point scale of kansei words and conducted kitchen evaluation experiments using women as subjects. Then we constructed a life style survey consisting of 20 questions. We created an AI system that diagnoses a women's life style from the questionnaire. Then we analyzed physical traits of each cluster of kitchen and created another AI system to arrive from the women's life style to the specific kitchen design.

Finally we constructed a two-fold AI system, one side is a kansei kitchen design system based on the kansei data and the other a virtual reality system in which a subject can go through the computer image and can touch any portion of the imaged kitchen design. We name this two-fold Virtual Kansei Kitchen Design System" or ViVA system, because many women visiting Panasonic shouted out: "wonderful, yes this is my wanted image". *Figure 7* shows a diagram of ViVA and Figure 8 shows one of new kitchen images created by the AI system.

A woman customer sits down in front of VivA system and she inputs the number of her family members. And then, the system asks her 20 questions about her life style. Finally, the system asks her about cooking image on the first day when the new kitchen will arrive to her home. After 0.5s from her final response, the new kitchen design image inferred by AI system appears on the screen (*Figure 8*) and then many wives shout out "Wow, wonderful, Yes, I wanted this"[5]. The system is able to display about 100,000 different images on the screen depending on the customer responses[8].

Kansei room atmosphere research

Nagamachi made an experimental miniature room in which all cloth materials of ceiling, wall,

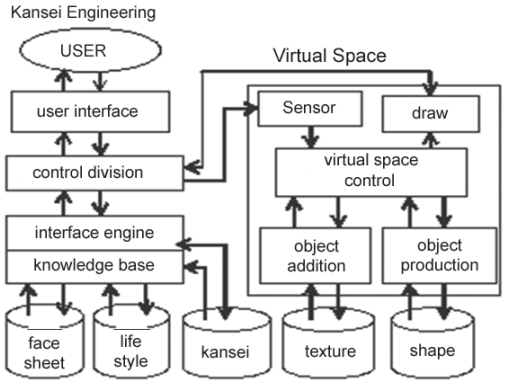

Figure 7. Virtual kansei kitchen design system, ViVA; Left side: Kansei engineering artificial intelligence; Right side: Virtual kitchen system

floor and curtains were changeable due to the experimental design. These materials were arranged with each ten different colors. Twenty male and female students looked inside each experimental room with different combinations of four color materials. The subjects evaluated each room using 5-scale kansei sheet consisting of kansei words like 'beautiful', 'elegant', 'gorgeous', 'comfortable', 'want to do homework', l'ove my wife', 'want to listen to classic music', and so forth.

The evaluated data were analyzed by factor analysis and we found kansei factors. Based on these, we made room atmospheres (*Figure 9*) consisting of each combination of material and color fit to each room emotion and arranged 4 (ceiling, wall, floor and curtain) x50 sets each fit to a different room emotion[4].

A family who wants to refurnish their new rooms sits down in front of a computer screen and each member inputs his or her wanted kansei word into it. Then, the recommended color sets appeared on the screen. For instance, a boy selects a word 'a room where I feel fit to study', then the system selects the kansei room set as if he will have such feeling as to do homework when he comes in. In reality, many customers said their boys worked harder to do study after the new room completed. This computer system is named 'Home Living System' (*Figure 9*).

EEG and AI research on home gardening

All Japanese houses have a small garden in general, because Japanese people like nature very much. A small garden is a kind of nature and consists of trees, a pond, many rocks and a garden lantern. Those are a kind of design elements from the viewpoint of kansei engineering. How these elements are arranged influences people's feelings.

We applied kansei engineering to analyze how to arrange these gardening design elements to fit human kansei such as 'birds come and sing', 'being steady spirit', 'heal our mind', 'feel being inside the forest' and so on[9]. We randomly collected 20 gardens in the Hiroshima area and utilized a 5-point scale survey as well as EEG analysis for the subjects feeling to each sample of 20 gardens[6].

Prof. Yoshida at Hiroshima International University[10] constructed a new model related to the kansei which is able to recognize the feeling on two axes of Comfort-Discomfort and Subsidence- Excitement. He modeled 'Comfortable feeling' surrounded by Comfort and Subsidence, 'Excite feeling' by Comfort and Excitement, 'Boredom feeling' by Subsidence and Discomfort and 'Nervous feeling' by Excitement and Discomfort, by Fourier analysis of frontal EEG. We selected 12 gardens based on the students' evaluation of photos and we visited each of 12 gardens with the Yoshida EEG measurement kit and 3 male and 3 female students joined to the real experiment as subjects.

Figure 8. An example of a new kitchen kansei image produced by ViVA system

Figure 9. An example of Home Living System

Figure 10. Garden scoring high on 'feel inside the forest'

Two typical examples are shown here. The first garden is evaluated as a high score for 'feel inside the forest' in *Figure 10* and the EEG result is shown in *Figure 11*. Subjects reported 'comfortable' for the highly evaluated 'feel inside forest'. This garden is surrounded by a lot of trees.

Another garden example is shown in *Figure 12* which was evaluated highly as 'relaxed'. But the EEG result indicated that 6 subjects felt this garden as 'boring' or 'nervous'. A rock garden makes young people feel as if it is not natural, but artificial.

Based on this kansei research on Japanese gardens, we constructed an AI system on gardening. Following the system, we can have a 3D vision of a virtual reality garden[11-13].

Whole house design by AI system

Nagamachi constructed whole house designing computer system using AI technology[14]. It has data bases of Japanese house construction standard, kansei databases of roof, outer wall, exterior, room interior, and kansei databases of entrance, bathtub, the shower, toilet (TRES), kitchen. It has customer's life style AI system as the same as ViVA system as the reference engine. It has the database of kansei gardening system as well. After a customer answers to the life style questionnaire, s/he inputs his or her family member's emotion (kansei) to each house design item. The system then calculates the data and the inference engine deduces design elements using all databases, and finally the home design system (*Figure 14*) works to draw a blue print and shows room items in detail as images on the screen. The customer can walk through inside the screen. The name of AI system is 'HouseMall'[14] and was completed by the support of research funded by

Figure 12. The second garden example evaluated highly as 'relaxed'

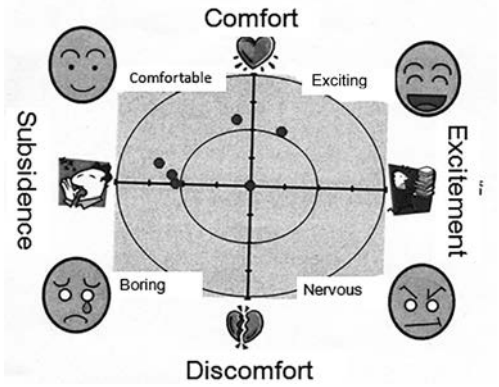

Figure 11. Plot of 6 subjects based on EEG analysis of the garden of Figure 10

Kansai Electric Power Plant House Design Division which utilizes this system. The 'HouseMall' utilizes throughout barrier-free access for old customers.

Conclusion

The articles related to home living systems were selected here from Nagamachi's about 250 articles and 98 books published. The present monograph is restricted to a home living system. Thus this article is a selection only.

Nagamachi has developed more than 60 new products so far using ergonomics and kansei engineering technology. Some of these include products and commodities utilized for house design. Those are top roof, siding, entrance door, room segmentation, interior design (Home Living System), bathtub and sitting shower (The Shower), toilet (TRES), bed or mattress, kitchen. Some of these have been worked out by an AI system. Each of these products was developed independently by the method of kansei engineering[15].

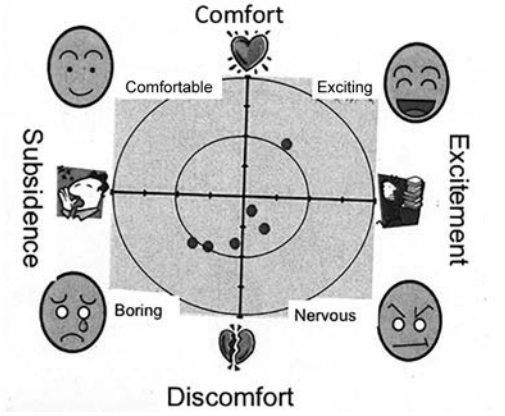

Figure 13. Plot of 6 subjects based on EEG analysis of the garden of Figure 12

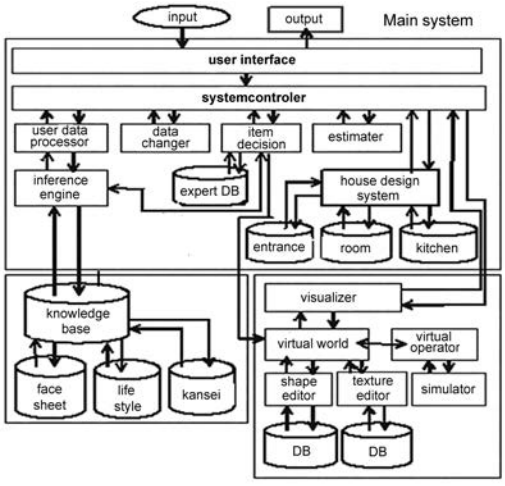

Figure 14. The artificial intelligence system of 'HouseMall'

Kansei engineering aims to develop a new product based on human emotion (kansei) and at the same time, ergonomics is applied to improve product development. In this article, we tried to combine all units as a whole system of house design, and some of them applied AI systems: ViVA (kitchen), gardening system and HouseMall. HouseMall system contains the architectural rules and aims to build a whole house design of room layout, room atmosphere, the Shower and TRES. HouseMall includes the barrier-free design concept for the old people and this system is utilized in Osaka area in Japan.

Asian countries including Japan are ageing faster than the old countries. Thus, many developments have taken place of commodities assisting old people based on kansei engineering research. The most important area is in kansei engineering for finding the comfortable and barrier-free kansei design rules. Nowadays, some of rules are utilized in HousMall, but they are still utilized in a restricted number of design items. And the kansei approach remains concerned with comfort and satisfaction for living in a HouseMall house.

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